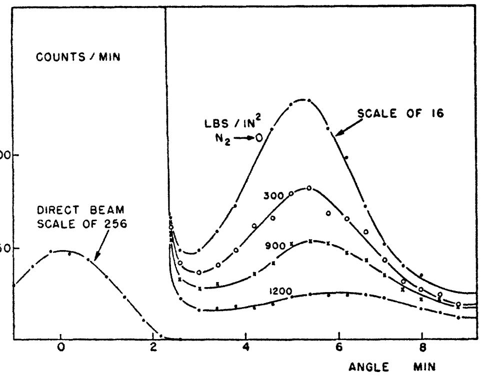

FIG. 1. Thermal neutron beam incident at about 2.5-min angle on vanadium-nitrogen interface and reflected beam at various pressures of N_2.

corrected for background and for scattering in the gas, as a function of pressure. The reflected beam contains all neutrons of wavelength

$$\lambda > \lambda_c = \theta/(2\pi^{\frac{1}{2}})^{\frac{1}{2}}(n_0\sigma_0^{\frac{1}{2}} - n\sigma^{\frac{1}{2}})^{\frac{1}{2}}$$

in the long wavelength portion of the pile flux, $N(\lambda)d\lambda \approx d\lambda/\lambda^5 \times$constant; n and n_0 are nuclei/cc in the gas and mirror, respectively; θ is the incident angle, and λ_c is the critical wavelength. It follows that the reflected intensity, I, varies as $(I/I_0)^{\frac{1}{2}} = 1 - P/P_0$, where P = pressure and P_0 = pressure at which the indexes of refraction are equal. Then we obtain

$$\sigma_0 \text{ (mirror)} = [n(P_0)/n_0]^2\sigma \text{ (gas)}.$$

From the intercept P_0 in Fig. 2, we have

$$\sigma_{coh} \text{ (vanadium)} = 0.028b \pm 0.005 \text{ (positive phase)}.$$

On the basis of the above result for σ_{coh} Hamermesh's calculations[2] need be modified only to the extent of adjusting the potential scattering radius, R, from $0.508b^{\frac{1}{2}} (b = 10^{-24}\text{ cm}^2)$ to $R = 0.602b^{\frac{1}{2}}$. We may further add that if the resonance at 2700 ev accounts for the entire thermal absorption cross section ($\sigma_{abs} = 4.8b$ at 0.025 ev), then from

$$\sigma_{abs}{}^{th} = \pi g \lambda\!\!\!^{-}{}_0{}^2 \Gamma_n \Gamma_\gamma [40E_0 \text{ (ev)}]^{\frac{1}{2}}/E_0{}^2 = 4.8b,$$

$$\sigma_0{}^{abs} = 4\pi \lambda\!\!\!^{-}{}_0{}^2 g \Gamma_\gamma/\Gamma_h = \text{absorption cross section at resonance},$$

we obtain $\Gamma_\gamma = 1.3$ ev and $\sigma_0{}^{abs} = 0.7b$.

Spectrographic analysis of the vanadium gives V = 99.7 percent, Fe = 0.22 percent, Mn = 0.006 percent, Ti = 0.001 percent, C = 0.09 percent. The iron contributes ~0.001 barn to the coherent cross section. The presence of $\frac{1}{4}$ percent of V^{50} likewise has negligible effect.

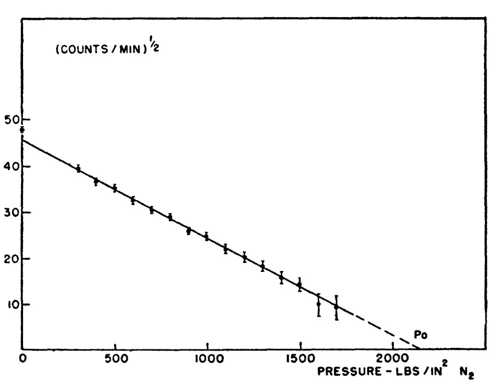

FIG. 2. Total intensity of a thermal neutron beam reflected from a vanadium-nitrogen interface as a function of nitrogen pressure. The intercept (P_0 = 2130 lb/in.²) is the pressure at which the index of refraction of nitrogen equals the index of refraction of vanadium.

We wish to thank Dr. P. Bendt for the use of the vanadium.

* Research carried out under contract with AEC.
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[2] M. Hamermesh and C. O. Muehlhause, Phys. Rev. **78**, 175 (1950).
[3] Recent work of S. P. Harris [Phys. Rev. **83**, 235(A) (1951)] indicates a resonance at 3100 ev. None of the results of this paper are significantly affected by this.
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Gravitational Acceleration of Neutrons*

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SINCE the acceleration of gravity is observed to be a universal constant for all matter, including nuclei which are aggregates of nucleons, it is reasonable to assume that a neutron, free of nuclear forces but in a gravitational field, is subject to the same acceleration. The high neutron flux from a reactor makes possible a direct check of this otherwise unsupported assumption.

Acceleration was determined by measurement of the drop of a highly collimated beam of thermal neutrons from the Brookhaven reactor in 12 meters of path, or more specifically the difference in drop of neutrons of different velocity but defined by the same collimating system. Boron carbide and Lucite slits 0.075-cm high ×5 cm wide, spaced 150-cm apart in the shield, defined the beam. Its position at 11.6-m range was measured by vertical scanning of a 0.9-cm wide slit in front of a BF_3 proportional counter. A 25-cm filter of BeO was then interposed between the reactor and first slit and the beam position determined by a second scanning. The first beam contains the entire thermal distribution $N(E)dE = Ee^{-E/kT}dE$ with peak at about 0.07 ev, 1A wavelength, or velocity 3.95×10^5 cm/sec. The filtered beam contains only that small part of the distribution with wavelengths greater than the BeO cut-off of 4.4A or 9.00×10^4 cm/sec. In Fig. 1 is shown a typical plot of the two beams, adjusted to the same peak height, indicating a downward shift of the slower neutron beam of about 1.2 mm in 12-m path.

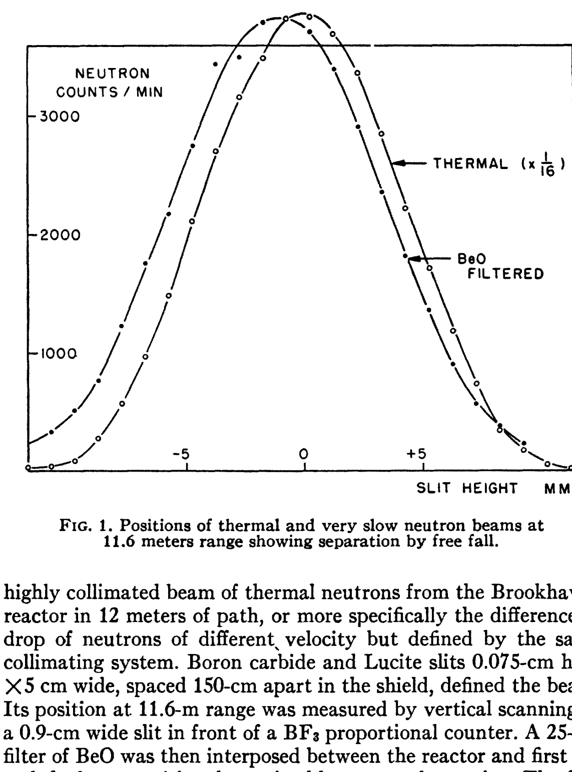

FIG. 1. Positions of thermal and very slow neutron beams at 11.6 meters range showing separation by free fall.

A value of g for neutrons can be calculated from the separation of the centers of gravity of the two beams, the geometry of the collimator and scanning slits, and velocity distributions in the two

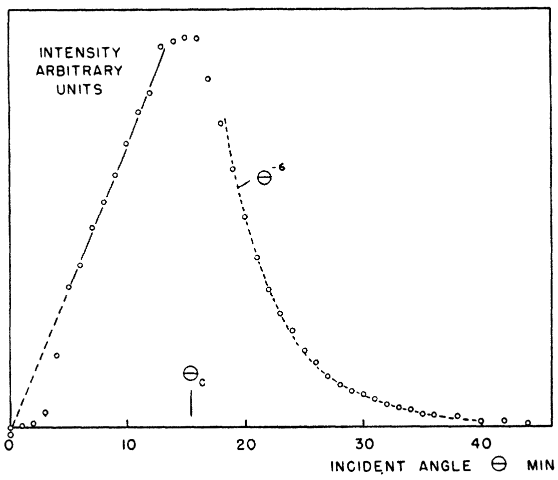

FIG. 2. Intensity of entire reflected beam from glass mirror; incident beam filtered through 25 cm BeO.

beams. The drop d of a neutron of velocity v passing through slits at 0, l_1, and l_2 is given by

$$d=(g/2v^2)(l_2^2-l_1l_2).$$

Therefore, the separation of two beams of velocity distributions v_1, v_2 is

$$\Delta=d_2-d_1=\tfrac{1}{2}g(l_2^2-l_1l_2)[\langle v_1^{-2}\rangle_{Av}-\langle v_2^{-2}\rangle_{Av}].$$

For the thermal beam the average over the maxwellian distribution is $\langle v_1^{-2}\rangle_{Av}=v_{max}^{-2}$. The velocity distribution of the filtered beam was not truly maxwellian, because inelastic scattering in the filter is greater for longer wavelengths. It was therefore measured by reflected intensity from a glass mirror *vs* incidence angle, as shown in Fig. 2. If the flux

$$N(v)dv\propto v^n dv$$

(where $n=3$ for a maxwellian distribution), then reflected intensity beyond the critical angle for 4.4A neutrons should vary as $1/\theta^n$. It was determined from plots of $n=5$ and $n=6$, as seen in Fig. 2, that $n=5.5\pm0.5$. An average over the velocity range 0 to 9.00×10^4 cm/sec (∞ to 4.4A) then gives

$$\langle v_2^{-2}\rangle_{Av}=n+1/n-1(9.00\times10^4)^2=6.5/4.5(9.00\times10^4)^2.$$

These velocity values, together with the average $\Delta=1.22\pm0.06$ mm, from a number of measurements, give

$$g=935\pm70 \text{ cm/sec}^2$$

in agreement, within the experimental error, with the usual value 980.

* Research carried out under contract with AEC.

High Altitude Measurements of the Penetrating Component Intensity of Cosmic Radiation Near the Geomagnetic Equator

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THE vertical intensity of cosmic radiation penetrating 10 cm of lead absorber at high altitudes was measured by the authors near the geomagnetic equator (Bangalore 3°N mag.) using free balloon ascents during 1950–1951. The measurements were made with quadruple coincidence GM counter telescopes whose vertical half angles were 13.5° and 24.5°. The most inclined ray recorded by the telescope had a path length only 10 percent greater than that of a vertical ray. The temperature inside the gondola which contained the apparatus was maintained above 10°C throughout the flight using the "greenhouse effect." Quadruple coincidences, together with atmospheric pressure and temperature inside the gondola were transmitted continuously over a single ultra-high frequency radio carrier to the ground receiving apparatus which recorded the information automatically on a moving paper tape.

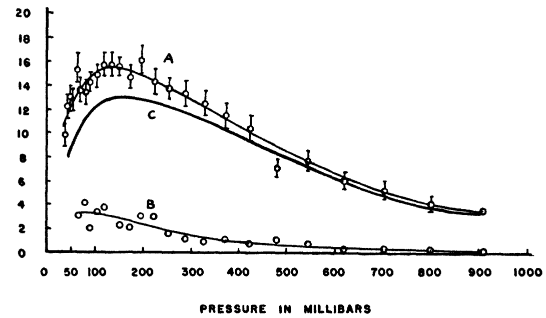

FIG. 1. Vertical intensity of cosmic radiation penetrating 10 cm Pb at Bangalore 3°N mag. A: Composite curve of flights made on 11/21/50, 11/24/50, 2/1/51, 2/8/51, 2/26/51, and 3/8/51. B: Shower intensity curve. C: Difference curve between A and B.

The telescopes were tested on the ground for many hours before they were sent up. Their performance was also checked at the highest altitudes reached to insure that they were working satisfactorily during the flight in the following manner. The apparatus always floats for several hours at or near the minimum pressure reached, and a χ^2 test could therefore be applied to the statistical fluctuation of counts recorded in small equal intervals of time during the floating period. It is interesting to note that for the curves in which the scatter of the points was rather large during ascent, the χ^2 fit for the floating region was also poor. This was taken to indicate a possibly defective performance of the equipment, and the entire data of such flights was therefore rejected.

A composite curve of six good flights made at Bangalore is given in Fig. 1, with the root mean square deviation marked for each point. From the composite curve given in the figure and the individual curves, which are not shown here, it is seen that the vertical intensity of cosmic radiation penetrating 10 cm of lead absorber at Bangalore 3°N (mag.) rises continuously down to a pressure of about 120 millibars, and then falls gradually down to the lowest pressures reached by the apparatus. This is contrary to the observations of most of the previous workers,[1–4] who made their measurements at higher magnetic latitudes and observed a montonic rise of penetrating intensity up to the greatest heights reached. The hard component intensity curve was corrected for side showers and accidentals by making separate flights with identical telescopes, but with the second counter tray of the quadruple coincidence telescope displaced sideways so that at least two particles are necessary to make a coincidence. The shower and accidental intensity curve and the difference curve, which represents the penetrating component intensity, are also given in the same figure. Although the correction due to side showers and accidentals is rather appreciable at pressures below 200 millibars, it is nevertheless obvious that this does not affect the shape of the penetrating component intensity curve which reaches a maximum at about 120 millibars and then falls with decreasing pressure.

A detailed paper on the results and the experimental technique will be published soon elsewhere.

We are greatly indebted to Professor H. J. Bhabha for his valuable guidance of this work.

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