tic properties are not particularly so, and these latter are the principal concern of this Letter.

A lucid colloquium by Dr. Peter J. Wojtowicz stimulated the author's interest in these problems.

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ALBEDO NEUTRON SOURCE FOR HIGH-ENERGY PROTONS TRAPPED IN THE GEOMAGNETIC FIELD*

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An absolute intensity measurement of cosmic-ray neutrons in the atmosphere, in the energy range from thermal to 20 MeV, leads to a value of 0.36 ± 0.06 neutron cm^{-2} sec^{-1} for the albedo neutron leakage flux at 42° geomagnetic latitude near solar minimum. The significance of this value for evaluating the contribution of the cosmic-ray albedo-neutron-decay source for the high-energy protons in the inner radiation belt is discussed.

While cosmic-ray albedo neutron decay (CRAND) is probably a source for some of the protons of the inner radiation zone, the measurements reported here, confirming earlier estimates by Boella et al.,[1] indicate that if the theoretical calculations of Dragt, Austin, and White[2] are correct, CRAND is too small by a factor of 50 to account for the high-energy ($E_p \geq 20$ MeV) inner-zone protons.

The measurements were made in an experiment in which boron plastic-ZnS(Ag) scintillation detectors were flown on balloons to obtain the neutron counting rate from sea level (1030 g cm^{-2}) to 4 g cm^{-2} at 42° geomagnetic latitude near solar minimum. The detection unit was similar to that described by Boella et al.[1]: Two detectors, one enriched in B^{10} and one unenriched, were flown back to back and the neutron counting rate was obtained by the difference technique. The detection unit was small and lightweight to minimize local neutron production, and it responded to energies from 0.025 eV to 20 MeV.

The measurements carried out enabled two estimates of the CRAND source strength to be made. First, the neutron flux measured closest to the top of the atmosphere near solar minimum was 0.58 neutrons cm^{-2} sec^{-1} at 4 g cm^{-2}. Since the flux decreases with increasing altitude near the top of the atmosphere, this measured flux must be an upper limit to the neutron flux at 0 g cm^{-2}.

Second, the measured neutron flux within the atmosphere can be extrapolated to 0 g cm^{-2}. A simple linear extrapolation of the data overestimates the leakage flux. The most meaningful extrapolation is made by normalizing the data to a theoretically calculated solution to the Boltzmann transport equation for neutrons in the atmosphere and to use the renormalized flux value of the 0 g cm^{-2} intercept of this curve as the correct value of the albedo neutron flux. The two theoretically calculated solutions (by Lingenfelter,[3] using the diffusion approximation, and by Newkirk,[4] using the S_n approximation to the transport equation) agree at 0 g cm^{-2}. Following this procedure gives an extrapolated experimental value of 0.36 ± 0.06 neutrons cm^{-2} sec^{-1} for the albedo neutron flux at 42° geomagnetic latitude near solar minimum.

The measured values reported here can be used to calculate the albedo neutron leakage flux for specific energy ranges, utilizing Lingenfelter's spectra[3] (calculated from primary cosmic-ray intensities). Table I summarizes the albedo neutron flux at 42° geomagnetic latitude for several pertinent energy intervals as based on these measurements.

Dragt, Austin, and White[2] estimated the strength of the CRAND source required to balance atmospheric loss for protons in the inner radiation zone. Comparing the required source strength with the theoretically calculated albedo neutron leakage flux of Lingenfelter,[5] they conclude that the CRAND source is a factor of 50 too low to account for these higher energy protons. The intensity of the measured neutron flux reported here agrees with that calculated by Lingenfelter, and confirms the previously measured value found by Boella et al.[1] Therefore, if the theoretical calculations of the atmospheric loss of Dragt, Austin, and White[2] are correct, these measurements show that the CRAND source is in fact a factor of 50 too low to account for the high-energy protons in the inner radiation belt.

However, CRAND at present is the only tractable source for these higher energy protons. Furthermore, recent measurements[6] show that for $E_\alpha, E_p \geq 0.52$ MeV per nuecleon, the ratio of intensity of alpha particles to protons is 1.1×10^{-3}, for $1.8 < L < 2.2$. This ratio is much smaller than would be expected if the solar wind were the sole source of these inner radiation zone particles. Therefore, the calculations of radiation belt source and loss mechanisms should be carefully scrutinized. Accurate representations of the atmospheric density and of the geomagnetic field are crucial for an evaluation of the atmospheric neutron intensity required for an adequate CRAND source. At present, there is much uncertainty as to the accuracy of the various models employed. More accurate calculations, preferably based on detailed measurements, are needed.

Table I. Albedo neutron flux at 42° geomagnetic latitude for several pertinent energy intervals, based on our measurements at solar minimum.

Neutron energy range (MeV)	Albedo neutron flux (neutrons cm^{-2} sec^{-1})
0-1	0.23
1-4	0.32×10^{-1}
4-10	0.72×10^{-2}
10-20	0.11×10^{-2}
20-35	0.05×10^{-2}
35-45	0.02×10^{-2}
45-55	0.08×10^{-3}
>55	0.08×10^{-3}

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