gesting a mean rate of ice movement on the order of 285 ± 155 meters per year. Variations in Antarctic sea-ice distribution between 7° and 92°W longitude were discussed by J. A. Heap (Michigan), who said that evidence from 62 years of study at Laurie Island suggests a repeated shorter-term variation with about a 4-year period, and one longer-term (1923–32) variation with prolonged severe ice conditions. The superabundance of ice in the 4-year cycle may be due initially to a persistent cyclonic cell over the Weddell Sea; the prolonged period was linked with low air temperatures which prevailed less strongly north of the Antarctic Convergence. In the Ross Sea area of Antarctica, L. K. Lepley (Texas A&M) believes the submarine morphological features are directly related to the continental ice sheet. He attributes the great depth of the outer shelf to isostatic depression by the continental ice when the ice was more extensive, and the origin of Sulzberger Bay possibly to erosion by a locally accelerated "ice stream" during glacial maxima. He considers longitudinal and transverse submarine ridges as moraines. An interesting laboratory study (L. D. Taylor and J. Gliozzi, Ohio State), using a Coulter counter as a tool in stratigraphic studies of Antarctic firn, concerns a quantitative analysis of solid matter (1 to 3 microns in diameter) contained in firn cores. One result of this study indicates a possible 2-year cyclic variation in particulate distribution with depth.

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The Ionosphere and Radio Propagation in the Lower Frequencies

Recent results of investigations of the ionosphere, with particular emphasis on radio propagation in the lower frequencies, were presented at a session of the third western national meeting of the American Geophysical Union in Boulder, Colorado, 27 December 1963. The papers dealt with seven topics: "Schumann' resonances of the earth-ionosphere cavity; measurement of the phase velocity of very low frequency waves in the earth-ionosphere cavity considered as a waveguide; chemionization in the ionosphere; F-region theory; evidence that certain magnetic micropulsations may be excited by slow electrons trapped in the magnetosphere; statistics of occurrence of very low frequency emissions, including comparison of magnetically conjugate locations; and theory of the interaction of very low frequency waves with fast trapped electrons.

Simultaneous measurements made in the frequency range 0.2 to 5.0 cycle per second at several low-latitude stations were presented by Lee Tepley, (Lockheed Missiles and Space Co., Palo Alto, Calif.). A number of simultaneous records at magnetically conjugate stations, Kauai and Tongatapu, showed similar patterns of periodically enhanced pulsations with a period of about 2 minutes, but out of phase by 180 degrees. At Canton Island, near the magnetic equator in the same magnetic meridian, the pattern appeared to be a superposition of those at Kauai and Tongatapu. Such an alternation of enhancements in opposite hemispheres was predicted by the theory of Jacobs and Watanabe, who supposed that hydromagnetic waves would be generated by slow electrons trapped in the magnetosphere.

J. R. Wait (National Bureau of Standards, Boulder, Colo.) extended the theory of resonances of the earth-ionosphere cavity, initially published by W. O. Schumann in a series of papers beginning in 1952. The resonant frequencies are roughly related to the reciprocal of the time taken by an electromagnetic signal to go around the earth (1/7 second). The problem is treated generally in terms of a contour integral, and specific solutions were obtained which facilitate the interpretation of experimental data.

Charles Polk (University of Rhode Island, Kingston) reviewed the evidence for enhancement of noise generated by thunderstorms at the Schumann resonant frequencies. The data seemed to show reasonable correlation with thunderstorm activity, but less well-marked correlation with solar flare activity and sunspot numbers.

Speaking on phase velocity at very low frequencies and the height of the lower ionosphere, F. K. Steele (National Bureau of Standards, Boulder) gave an account of phase and amplitude measurements of 18-kc/sec waves transmitted simultaneously at Jim Creek, Washington, and at Balboa, Canal Zone. Measurements of relative phase of the two signals at Boulder (Colorado), College (Alaska), Maui (Hawaii), and Tucuman (Argentina), permitted the phase velocity to be calculated, and from this, by the theory of propagation in the earth-ionosphere waveguide, it was possible to deduce the effective height of the bottom of the ionosphere. The results, 70 km in daytime and 95 km at night, are in good agreement with other data.

R. D. Cadle (National Center for Atmospheric Research, Boulder) presented data and arguments to show that important amounts of ionization in the ionosphere are contributed directly by certain chemical reactions. Laboratory studies of chemionization reactions suggest rate constants comparable to those for neutral gas-phase reactions; this together with available information about the concentrations of reacting constituents suggest that the following reaction is likely to be important in the E and F regions:

$$N(^2P) + O(^3P) \rightarrow NO^+ + e.$$

In the D region, the chemionization reaction of sodium with atomic oxygen appears to be the important one:

$$Na + O + O \rightarrow Na^+ + O_2 + e.$$

The theory of the F-region is extremely difficult because effective recombination times tend to be comparable to the length of the day; diffusion is strong and is complicated by the earth's magnetic field; and transport of ionization by winds and electrodynamic forces tend to be important. T. Shimazaki (National Bureau of Standards, Boulder) reported some results of a systematic theoretical analysis of night-time variations of the F-region electron density over Puerto Rico. Two approaches were made. In one the temperature was assumed to remain constant, and vertical drift was invoked. The remarkable result is that the phase of the drift oscillation, required to make the theoretical time variation agree with observation, is almost exactly that of the current system for the geomagnetic quiet-day (S_q) current system. In the other approach, drift was assumed to be absent, and the night-time temperature decrease (about 15 percent) required for agreement of the theoretical electron density variation with the observed variation is quite reasonable. Further analysis is required to determine the proportion in which the two effects are present in nature.

Hiroshi Kamiyama (AVCO Corp.,

Wilmington, Mass.) discussed the special case of the winter night-time F-region in polar regions. Anomalously high electron densities are maintained in spite of the long duration of the arctic night (6 months at the pole at winter solstice). Theory and data were presented which suggested that photoionization formed high above the usual ionospheric heights and its subsequent diffusion downward along the magnetic field could account for the observed F-region densities.

Besides whistlers, which have their origin in lightning flashes in the troposphere, there are other very low frequency "sounds," called "VLF emissions," which appear to be generated in the magnetosphere. R. M. Gallet (National Bureau of Standards, Boulder) presented statistics of the diurnal, seasonal, and longer term variations of rate of occurrence of very low frequency emissions at a number of high and middle latitude stations, including geomagnetic conjugate pairs, gathered in collaboration with J. Koch (same laboratory). An unexpected long-term negative correlation was found with 10-cm solar flux, but there was a positive correlation with magnetic activity. All stations showed strong seasonal variations (greater activity in local winter) and a tendency for greater activity at night than during the day. Diurnal variations at conjugate locations were strikingly similar. A calculation of the absorption incurred in traversing the D region of the ionosphere in daytime indicated that this might amount to as much as 30 decibels at 4 kc/sec, which could account for much of the observed diurnal, seasonal, and solar cycle trends.

The phase velocity of very low frequency waves traveling in the magnetosphere is less than the free space velocity and may easily be in the range of velocities of fast electrons. Waves and electrons traveling in the same direction with approximately the same speed will interact and exchange energy. J. M. Cornwall (Aerospace Corp., El Segundo, Calif.) showed that the regions of the magnetosphere where this condition is met depend strongly on L, the parameter which defines a shell in which a trapped electron is confined. He suggested that changes in the mirroring levels of energetic trapped electrons brought about by interaction with very low frequency waves in the preferred L shells could cause their precipitation at corresponding preferred magnetic latitudes. C. S. Roberts (Bell Telephone Laboratories, Murray Hill, N.J.) discussed the implications of an exact solution of the non-relativistic equation of motion of a charged particle in a constant magnetic field in the presence of electromagnetic waves propagating in the "whistler mode" (phase velocity less than that in free space). One important effect is that, at resonance, the kinetic energy of the particle does not increase without limit (assuming unlimited energy in the wave) but is oscillatory instead. This result would lead to the conclusion that the Mev electrons in the Van Allen belts could not result from interaction of slower electrons with very low frequency waves, except in a random-walk fashion.

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Bioastronautics: Fundamental and Practical Problems

Fundamental problems of space biology and some of the important practical considerations necessary to space exploration were reviewed and discussed at a special astronautics symposium held at the AAAS annual meeting in Cleveland, Ohio, on 30 December 1963.

In his introductory remarks the program chairman reminded the audience that, although rockets were developed about A.D. 1100, manned, powered flight observed only its 60th anniversary in 1964. For centuries space travel and exploration has stimulated the imagination of scientists and engineers, as well as writers, but it is less than 45 years since Goddard proposed that it was theoretically possible to send a rocket to the moon and observe its impact there. Goddard's work did not receive favorable publicity and the attitudes of many observers have not changed. Space flights of recent years have been heralded as either man's greatest accomplishments or scientifically useless adventuring. But, in space, it will be possible to validate theory and perform biological research that cannot be accomplished in any earthly laboratory. This symposium was concerned with biological problems to which only experimentation in space can give answers, and with the limitations biology itself imposes on space exploration. A great deal of the work accomplished to date has been an effort to apply the knowledge of terrestrial human physiology in order to protect the man from the extraterrestrial stresses (or absence of stress) imposed by space flight. Space experimentation is a cooperative effort of many fields of science and engineering, and financially supported entirely by government funds. It is subject to costs that almost exceed man's imagination. Thus serious consideration must be given to the value received from experimentation. Because of these conditions unique to any space probe, the topics of the meeting ranged from strictly applied problems of selection and protecting crews, through speculative areas concerning weightlessness, biological rhythms, and extraterrestrial life, to congressional attitudes on space research.

William L. Whitson (president, American Astronautical Society, and president, Clarkson College of Technology) in officially opening the meeting remarked that even though the man in the space program has received a great deal of attention, the original appropriation of funds for space exploration made no provision for biological research. Engineering considerations continue to dominate the program.

L. D. Carlson (Kentucky) reviewed some of the biological problems to which definitive answers can be gained only through experimentation in space and proposed, where man's tolerance is concerned, that the periods of experimentation (space flight) must be gradually increased to determine safely man's limits. Carlson felt that present programming is adequate and reasonable but stressed the necessity for continuing critical evaluation of goals and a soundly based program beginning with experiments in earth laboratories and then progressing to animal experimentation in space and on to critical measurements made during manned flight.

Weightlessness, a condition which can occur for physiologically significant periods only in space flight, and its possible physiological effects were discussed by Michael McCally (Yale). Conclusions based on studies of bedrest, water immersion and immobilization indicate that physiological deconditioning (mainly cardiovascular) appears to be the primary cause for concern. This will manifest itself during the stress of reentry and the return of the astronaut to the normal upright, 1g condition on earth. These conclusions are supported to a degree by ob-