fuel which could just as well be used as a propellant.

Among the problems facing a large manned orbiting laboratory (MOL) is atmospheric drag, a major source of orbit degradation. For a 20 000-lb MOL with a 7-m^2 cross section at a 100-mile altitude, it is estimated that the drag would dissipate power at a 7-kilowatt rate, lowering the orbit ~15 km/day. To compensate this drag we propose flying the "kite," but with a power source aboard MOL to drive the current backward, thereby gaining the 5-10 kilowatt of power required to neutralize the drag loss and to maintain the altitude of MOL with a small increase of total weight in orbit; higher power levels could also be utilized to make MOL sail to higher altitudes (possibly for the purpose of storing electrical energy).

We may speculate on this kind of mechanism as a propulsion engine for flight to further reaches of space. For interplanetary travel typical parameters are $\vec{B}_0 \sim 10^{-5}$ gauss and densities $\sim 10^{-23}$ g/cm^3, leading to Alfvén speeds of $v_a = 10$ km/sec. We are in the Alfvén regime if $\omega < \Omega_i \sim 10^{-1}$ cps, corresponding to a "kite" dimension of $L \sim 100$ km. With $v_c \sim v_a$, the maximum generated power is $P \sim \frac{1}{8}$ kilowatt.

The conversion of energy from gravitational attraction near another planet to electrical energy is also a possibility if both a reasonable magnetic field and ionospheric plasma are present.

Finally, note that the phenomenon discussed in this paper can be used to determine ionic mass densities in regions of known magnetic field strength, as both the Alfvén field strength and the power dissipation are proportional to $\rho_i^{1/2}$.

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[1]Satellite Environment Handbook, edited by Francis S. Johnson (Stanford University Press, Stanford, California, 1961).

[2]The change in direction of the charge flow away from the conductor due to $\vec{h}$ leads to a displacement no larger than the transverse dimension of the Alfvén wave at a distance of about one wavelength away from the conductor in the direction of $\vec{B}_0$. This is a rough sufficiency criterion for the neglect of higher order terms in computing current flows, power radiated, and drag on the satellite.

[3]A detailed account of this work has been submitted to J. Geophys. Res., and is presently available as a preprint from the Institute for Defense Analyses, 400 Army-Navy Drive, Arlington, Virginia.

[4]R. Jastrow and C. A. Pearse, J. Geophys. Res. 62, 413 (1957); I. I. Shapiro and H. M. Jones, Science 132, 1485 (1960).

[5]K. L. Bowles, Advances in Electronic and Electron Physics (Academic Press, Inc., New York, 1964), Vol. 19, p. 55; K. L. Bowles, G. R. Ochs, and J. L. Grenn, J. Res. Nat. Bur. Std. 66D, 395 (1962).

[6]M. Tiuri and J. D. Kraus, J. Geophys. Res. 68, 5371 (1963). We thank Dr. Allen M. Peterson for informative discussions on this point.

REMARK ON THE HYDROXYL ION SYSTEM IN ALKALI HALIDES*

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A recent contribution of Känzig, Hart, and Roberts[1] submitted to this journal reported on an experiment which measured the dielectric constant, ϵ, of OH^- in KCl. The striking observation was made that ϵ had a maximum at temperatures T_{max} which increased with concentration according to a law

$$T_{max} \simeq 0.05 N_d \,^\circ\mathrm{K},$$

where N_d = concentration of dipoles in units of 10^{18} cm^{-3}. The height of the maximum is rather insensitive to concentration varying between $\epsilon = 4$ and $\epsilon = 6$. Here ϵ refers to the OH^- system alone. The width of the peak varies more rapidly with N_d and is not inconsistent with a law proportional to N_d^2.

These data were interpreted by Känzig, Hart, and Roberts in terms of an ordered ferroelectric phase. It is the purpose of this Letter to point out the existence of a more likely interpretation in terms of a random antiferroelectric array. The system in question is reminiscent of the dilute magnetic system Mn in Cu treated by Klein and the author[2] and other such systems treated by Klein.[3] In these systems the interaction between two spins was the Ruderman-Kittel oscillatory potential, falling off like r^{-3}, r being the distance between two spins. The dipole-dipole interaction falls off like r^{-3} and varies in sign according to angle. The ground state of a system of random dipoles should then not be entirely dissimilar to that of the Mn spins in Cu.

To be more explicit, consider the state of minimum energy of a pair of dipoles in two instances: (a) The vector distance $\vec{r}$ between dipole 1 and 2 is along the direction of dipole 1; (b) $\vec{r}$ is perpendicular to the direction of dipole 1. In case (a) the state of lowest energy gives rise to a parallel configuration, and in case (b) to an antiparallel configuration. Between these extremes, intermediate configurations will be realized. Since the spatial configuration of dipoles is random, it is then clear that there will not be a completely ordered parallel (i.e., ferroelectric) configuration of dipoles at $T = 0$. Rather, as the temperature is lowered, the dipoles will freeze into a configuration of random orientation characterized by local order whose range is R_c, where $R_c \sim N_d^{-1/3}$. This latter result is based on analogy with the spin system treated in reference 2 where identical considerations were brought to bear. From the above argument, it is clear that the Clausius-Mosotti catastrophe of reference 1 is spurious resulting from the neglect of the all-important correlations of dipoles within a distance R_c one of the other. The maximum in the dielectric constant occurs through the competition between breakup of local order and the T^{-1} Curie law just as in reference 2.

Short of a precise statistical theory we will simply take over the result of reference 2 for T_{max}. One must realize that the averaging process will be different for the dipole-dipole interaction as compared to the exchange interaction so that our calculation is for an order of magnitude only. Using reference 2, Eq. (5.5), one finds

$$kT_{max} = (p_0^2/\epsilon_0)/\gamma R_c^3, \qquad (1)$$

where R_c is the correlation distance

$$R_c \simeq 0.5d/c^{1/3}; \qquad (2)$$

d = lattice distance, c = atomic fraction, and $\gamma = 0.3$. The numbers 0.5 and γ in Eqs. (1) and (2) are consequences of the details of the averaging process and will change in the present problem as compared to the Ruderman-Kittel exchange case. p_0 is the dipole moment of $OH^- = 1.8 \times 10^{-18}$ cgs units, and ϵ_0 is the dielectric constant of KCl = 4.5. Equation (1) gives

$$T_{max} \simeq 0.12 N_d. \qquad (3)$$

It is to be hoped that a more adequate statistical analysis would rectify this result to bring about agreement with experiment; the result is quite sensitive to details of calculation. Thus an increase in R_c of 30% would set things right. One should also note that the correlation zone will not be a sphere and could easily bulge out by this much in directions perpendicular to the central dipole.

The indicated experiments to check this idea are the following: (a) Probe the ferroelectric structure to see whether or not long-range order exists; (b) measure the specific heat for $T \ll T_{max}$. According to the above interpretation, at low T, C_v due to the hydroxyls will be linear in T and independent of N_d. At very low temperatures a spectroscopic experiment might be possible to determine the distribution of local field.

I am most grateful to Professor Werner Känzig for discussing his exciting experiment with me and to the IBM Research Laboratories, Zürich, for their hospitality.

Note added in proof. – Dr. Michael Klein has kindly informed the author that R_c in the dipole system should be increased by a factor of $3^{1/3}$ over R_c in an Ising model owing to the fact that there are six instead of two positions. Only $\frac{1}{3}$ of these positions are effective in screening. This would bring our estimate of T_{max} into very close agreement with the experimental value. It is our hope to have a reliable theory of these effects quite shortly.

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[2]M. Klein and R. Brout, Phys. Rev. 132, 2412 (1963).
[3]M. Klein, Phys. Rev. Letters 11, 408 (1963).