The Earth's Electric Charge

BY W. F. G. SWANN[1]

OUR earth is not a neutral body. It is coated with a layer of negative electricity of such amount that, at the surface, there is an electrical potential gradient of the order of 150 volts per meter. This potential gradient diminishes with altitude until, at an altitude of 10 kilometers, it becomes insignificant compared with its value at the surface. The potential gradient, and so the negative charge on the earth's surface, goes through fairly regular variations throughout the day and throughout the year; variations amounting to 50 per cent or more of its value.

The atmosphere is a very feeble conductor of electricity, so that there is a continual conduction of negative electricity from the earth's surface on account of the field. The conductivity of the atmosphere is extremely small. A column of air an inch long, at the earth's surface, offers as much resistance to the flow of the electric current as would a copper cable of equal cross-section extending from here to the star Arturus and back, twenty times over. Nevertheless, this small conductivity is sufficient to insure that 90 per cent of the earth's charge would disappear in 10 minutes if there were no means of replenishing the loss. The nature of this replenishment is the greatest of the outstanding problems of atmospheric electricity.

Many years ago it was suggested that the earth's charge might arise from negatively charged particles, or electrons, shot into our earth from the sun. The difficulty attending this explanation lies in the very great penetrating power which the corpuscles would have to possess in order to pass through our atmosphere, which is comparable, in absorbing power, with a column of mercury 76 cm. high.

For many years we have had information pointing to the existence of a very penetrating radiation of a hard ray type, which enters our atmosphere from outside and breaks up some of its molecules into positive and negative charges. The source of this radiation, is one of the most interesting speculations of cosmical physics today. By means of this radiation, it is possible to visualize one method by which the earth's charge may be maintained, for we know that when such rays eject electrons from atoms, they hurl them out in the directions of their own line of flight. The cosmic rays are like bullets fired downwards from a lot of guns in space, and the electrons which are knocked out of the atoms by these "bullets" continue their downward flight. Those electrons which are ejected from the upper regions of the atmosphere will be absorbed by the layers of air below; nevertheless, the earth will receive electrons from those layers of air which are, as it were, within striking distance of it. The farther the electrons are able to travel through the air without absorption, the greater the thickness of the atmosphere from which electrons will be fired into the earth. As a result of calculation, it appears that the replenishment of the earth's charge could be accounted for satisfactorily by supposing that each cubic centimeter of the atmosphere supplied three electrons per cu. cm. per sec. and that these electrons were of such speed that they could travel a distance of 9 meters in air without absorption. The emission of only one electron per cu. cm. per sec. would be sufficient, providing we were willing to assume for the electrons, a range of 27 meters, and such an assumption is not unreasonable. Two primary difficulties confront any attempt to explain the earth's charge through the agency of high-speed electrons shot into it. For we should expect such electrons to be capable of charging an insulated mass of metal exposed to their entry, but no such charging effects have been observed. A careful survey of the situation shows, however, that this difficulty is not insurmountable.

The second difficulty inherent in attempts to explain the earth's charge by high-speed electrons comes from the disruptive action which these corpuscles might be expected to produce in the air through which they pass. If these electrons should behave in a manner similar to that of such electrons as we meet in the laboratory, a stream of them strong enough to maintain the earth's charge, on passing through the atmosphere, would produce 10,000 times as much disruption therein as our measurements of atmospheric conductivity show to occur. A closer scrutiny of this matter, however, shows us how we may relieve ourselves of the difficulty. For it appears that electrons which travel with a velocity very nearly equal to that of light,—that is to say, very nearly 186,000 mi. per sec.,—would have properties vastly different from those of electrons of slightly less speed. The electromagnetic theory teaches us that if a swiftly moving electron should disrupt an atom as it passes, it would have to pay a sort of tax in the shape of energy radiated, and this tax would be greater the greater the velocity of the electron. To put the matter in a way which appears to endow the electron with characteristics perhaps too humanistic, but which, nevertheless, have their counterpart in the cold criteria of mathematical theory, the electron knows the tax which it will be expected to pay, and if its velocity is high enough, that tax will be too great and the electron will know how to avoid disrupting the atom at all. It turns out that the velocity which an

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electron would have to attain in order that it could avoid disrupting the atoms of air through which it passes is only 45 meters per sec. less than the velocity of light. This happens to be just the velocity which Birkeland calculated many years ago as the velocity which electrons entering our atmosphere would have to have if they could account satisfactorily for the Aurora Borealis.

It is possible to adopt an entirely different view as to the origin of the earth's charge. Modern theory teaches us that the structure of matter is electrical; and a cubic centimeter of the earth contains so much positive and negative electricity that if these amounts could be separated and concentrated at two points one centimeter apart, they would attract each other with a force of a hundred million, million, million tons. A very, very slow but continual death of the positive electricity would leave a surplus of negative sufficient to provide for the atmospheric electric current. As a matter of fact, to account for the atmospheric electric current, it would be sufficient to assume a rate of death which was so slow that only one-half of one per cent of the earth's mass would disappear in a hundred million, million, million years. To merely postulate such a state of affairs without regard to the other facts of natural philosophy would be to run the danger which one would incur in things politic were he to alter one of the nation's laws without considering its bearing on everything else. It has been possible, however, to incorporate this idea of a slow death of electric charge as a result of the earth's rotation into a consistent scheme of electrodynamics, and at the same time to secure that the rotation shall provide an explanation for that other mystery, the earth's magnetic field. Moreover, it is possible to make this remolding of our physical laws so as to conform to the right ratio of the magnetic field of the earth to that of the sun. Further, the theory suggests a possible origin of the known magnetic fields of sun spots, magnetic fields 5000 times as great as that of the earth. Indeed, according to one interpretation of the theory the velocity of matter in the sun spots need be no greater than about 80 kilometers per sec. in order to provide for the magnetic activity which they exhibit. The planet Jupiter presents us with another heavenly body of interest for comparison for its diameter is eleven times as great and its angular velocity more than twice as great as that of the earth. The theory predicts for its magnetic field primarily two possibilities, a field twenty times that of the earth, or a field a hundred thousand times as great as the earth's field. The latter possibility, while speculative, suggests interesting possibilities as regards the kind of aurora which Jupiter might be expected to show and it is not inconceivable that the light of such an aurora may play a part in explaining certain peculiarities of the light which appears to be reflected from Jupiter's surface.

Ideals of the Engineer[1]

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IN receiving this great honor, I do so with feelings of deep gratitude and not without a sense of humility, for I realize that the brain of the individual has its limits as a storehouse, and that with knowledge continually increasing, any one mind can take in only a small portion of the rapidly accumulating body of engineering information. In these days, intellectual specialization is absolutely necessary, and whatever I have been able to accomplish is the result of specialization and the cooperation of many individuals.

In order to be of use to society, the ideas of the engineer, in every department,—transportation, communication, architecture,—must first be embodied in physical form, and because of this, he has achieved such a mastery over material things that he is regarded as preeminently the exponent of a material age. The great utility and economy resulting from his activities are so sensational as to conceal from view the ideals which form the basis of his creative work.

If seeking the truth and applying the truth to the affairs of man is a spiritual thing, then the engineer must be absolved from the charge of materialism. He is an advocate for truth; his works must be tried in the inexorable court of Nature, where no errors are committed and no exceptions granted. The work of the engineer is dedicated to the use of mankind, and the pecuniary compensation which he himself obtains is slight compared with the great benefits received by society. He finds inspiration and reward in achievement, and his real compensation is the good which others derive from what he has done.

Let us consider briefly the ideals of the engineer and the nature of his functions in the light of modern theories of evolution.

We are told that man has come from lowly origin, and that during ages of time incalculably long, he has advanced to his present position at the head of the animal kingdom. It has been supposed that in man, himself, this evolutionary process is still at work, and that therefore in the course of the ages, he will evolve into a superlative type and then, perhaps, all will go well.

Inasmuch as this evolutionary process in man himself is said to have taken vast periods of time, it is not

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