of seasonal mullet, sea trout, saithe, flounders and occasional plaice.

In spring 1944, Kyle Scotnish was stocked with eggs of plaice, cod, haddock and witch, which were obtained by stripping ripe fish on board fishing boats in Loch Fyne. Some young plaice caught in the summer and autumn of 1944 showed very promising growth, and flounders more than one year old showed in the pattern of their otoliths that they had grown better in 1944 than in 1943. But the numbers of fish caught were very small.

In the spring of 1945 between one and two million plaice eggs and fry, produced in a hatchery erected in the neighbourhood at Carsaig Bay, were released in Scotnish, and samples of fish obtained throughout the summer and autumn.

By the autumn of 1945, plaice of age-group 0 (as determined by otolith examination) attained a mean size of 13·2 cm.–25 gm. which corresponds to approximately five times the normal weight increment. At the same time Group I plaice reached a mean size of 20·4 cm.–100 gm. Compared with a good growth to 15 cm. on normal grounds, they had put on approximately three times more weight.

Group 0 flounders grew to a mean size of 9·5 cm.–10 gm., which is an improvement by about 400 per cent in weight over their growth on normal grounds. Group I flounders attained a size of 21·6 cm.–116 gm., approaching the best growth observed in Loch Craiglin[1].

There is, however, good evidence that the mean sizes are not true indices of growth-rate, but rather under-estimate the improvement in growth under conditions of fertilization. Examination of the otoliths and analysis of size distribution of successive catches indicated an appreciable immigration of fish into Kyle Scotnish, causing an extremely wide range of size in fish of the same age. For example, 135 Group I flounders, caught in June, ranged from 7 to 23 cm. Moreover, in the summer some of the large one-and-a-half year old specimens—old inhabitants of Scotnish—moved out of the fertilized loch following their habit of offshore migration. Hence the range narrowed down and the increase in the mean size during that period was largely due to the growth of the recent immigrants.

No data on the growth-rate of round fish could be obtained as both cod and saithe stay in Kyle Scotnish only during the first summer of their life.

## Conclusions

The migratory habits of the fish set a limit to any further exploration of Loch Sween for the furtherance of marine fish cultivation. To this must be added the fact that in our experience heavy stocking with the aid of hatcheries is not practicable owing to the low survival-rate of fry. It is estimated that in 1945 only about 2,000 plaice survived until the summer, that is, only about 1–2 out of every 1,000 fry released from the hatchery.

Therefore any future experiment or development of marine fertilization will have to be done in an area with a natural rich fish population and an area which contains those habitats to which flatfish tend to move in their offshore migration, that is, waters of greater depth. This implies an experiment on a rather large scale which alone could lead to an assessment of the economics of fertilizer distribution in the sea.

The investigations at Loch Sween were begun in 1942 in the hope that application of fertilizers to enclosed areas of the sea would lead to an increased yield of fish and thus contribute to the stores of home-grown food during the War[3]. The original aim has been supplanted by the more attractive prospect of increasing productivity in the open waters. Taken over all, the results so far obtained have given evidence of the beneficial effect of fertilizers on plankton, bottom fauna and fish growth, in an open as well as an enclosed sea loch—evidence as consistent as could be reasonably expected considering the complexity of the factors involved. A good deal of research remains to be done which cannot be done at Loch Sween. But, though the goal, that is, increased food production from the sea, has not yet been reached, no fact or factor has emerged which would suggest that fertilizer application has been a wrong approach to marine cultivation.

It is obvious, however, that in the sea, fertilizer application does not lend itself to private commercial development. There is no private ownership of the waters of the sea, and any raising of the fish crop would have to be done on a national and, at a later stage, even on an international basis[4]. Two weighty reasons may be advanced why the work, initiated at Loch Sween, should be continued in a suitable area under Government auspices. (1) In view of the world shortage of food the application of readily available industrial products—ammonium sulphate and superphosphate—for the raising of the fish crop would, if proved to be economical, be ideally suited to present-day conditions as it would not involve greatly increased demands in labour. (2) Russell[5] and Graham[6], discussing the overfishing problem, have recently emphasized that sea fisheries under present conditions have reached, if not over-reached, the limits of profitable yield. A large-scale test of the effect of fertilizers on a natural feeding ground would show if fisheries have not at the same time reached a threshold from which a new and enhanced level of productivity might be attained by the addition of plant nutrients.

[1] Gross, F., Raymont, J. E. G., Marshall, S. M., and Orr, A. P., *Nature*, **153**, 483 (1944), also separate papers by the same authors in *Proc. Roy. Soc. Edin.*, B (in the press).
[2] Fleming, R. H., *J. du Cons.*, **14**, 210 (1939).
[3] Gross, F., *Nature*, **148**, 71 (1941).
[4] Ritchie, J., *Nature*, **154**, 275 (1944) and **154**, 832 (1944).
[5] Russell, E. S., "The Overfishing Problem" (1942).
[6] Graham, M., "The Fish Gate" (1944).

H21.

# GEOPHYSICS OF THE IONOSPHERE

A GEOPHYSICAL Discussion dealing with the ionosphere was held in the rooms of the Royal Astronomical Society on May 31, with Prof. S. Chapman in the chair.

Opening the discussion, Sir Edward Appleton (Department of Scientific and Industrial Research) pointed out that the literature of the ionosphere has now become very extensive. Information about the ionosphere can be derived from (*a*) radio sounding, a method of direct exploration now being conducted by upwards of forty stations all over the world, (*b*) changes in the geomagnetic field, and (*c*) auroral manifestations. Soon it should also be possible to use rockets. The general structure of the ionosphere, with its *D*-, *E*- and *F*-layers, has been known for some twenty years. The ionization densities of the *E* and *F* layers have been measured at Slough since 1931, and it is known that there is a considerable sunspot cycle variation. Since 1935 Mr. Piggott and he studied $D$ layer ionization indirectly by measuring absorption. A similar sunspot cycle variation of about 60 per cent was found, which is the same as the corresponding change in the geomagnetic currents. From this we can conclude that the geomagnetic currents, required by Balfour Stewart's theory, flow in the lower part of the ionosphere.

Although the $E$ and $F_1$ layers behave regularly and much as one would expect according to simple theory, the $F_2$-layer is anomalous. Ionization is, for example, greater in winter than in summer, and there is a difference between the northern and southern hemispheres. Pre-war studies by Berkner and Wells, and by Eckersley, sought to explain these anomalies. But the extended observations now available render earlier work suspect in that a considerable dependence on longitude, or perhaps a magnetic dip, has been identified, as shown in a recent communication in *Nature*. Sir Edward suggested as a tentative theory that the anomalies should be attributed, not to an annual variation of solar radiation, but to variations of the atmosphere with situation and season.

Another anomaly has been found to occur in connexion with radio fadeouts for, whereas McNish found a 60 per cent enhancement of the magnetic diurnal effect, Mr. Piggott and Sir Edward found an increase in $D$-layer attenuation of a much greater order of magnitude.

Certain outstanding ionospheric problems still remain: for example, (*a*) the physics of the multi-layer formation; (*b*) the explanation of the $F_2$-layer morphology; (*c*) the identification of the level of the geomagnetic currents; and (*d*) the elucidation of ionospheric storm phenomena.

Mr. A. H. Mumford (General Post Office) spoke about reciprocity in long-distance transmission. Tests made by the G.P.O. in collaboration with the American Telephone and Telegraph Company were intended to discover whether the vertical angles of transmitted and received rays are equal. Vertical angles were measured on transmissions from Rugby received at Holmdel with 'Musa' equipment. In the reverse direction, a pulse transmitter at Deal, N.J., was received at Baldock. A transmitting aerial with a null in the vertical diagram was used, the direction of the null being swept. The time of disappearance of a particular echo then showed the vertical angle at which it had been transmitted. It was found that in undisturbed conditions the angles were stable and equal at both ends to $\pm 1°$ for hours at a time, and a beam width of 3° in the vertical plane could be usefully steered. During disturbed conditions, however, the beam width needed would be widened from 3° to 8°.

Mr. H. L. Kirke (British Broadcasting Corporation) described experiments on lateral deviation on the route from Daventry to New Delhi using a similar sweeping null in the horizontal plane. The variations in direction were within 1°–2° at almost all times. It is thought they would be greater on longer routes such as to Australia or New Zealand. Some progress has also been made on the effects of the ionosphere on medium waves, where it is merely a nuisance to broadcasters. He hoped there would be more study of attenuation on long routes. He also suggested that studies of the influence of the gyromagnetic frequency on interaction in the ionosphere would be well worth while.

Mr. J. W. Cox (Marconi's Wireless Telegraph Co.) described the large amount of routine application of ionosphere knowledge for communications planning and other uses that was carried out during the War by the Interservice Ionospheric Bureau. This was an extension into war-time of the propagation work led by Mr. T. L. Eckersley in the Marconi Company's Research Division, which formed the technical nucleus of the Interservice Ionospheric Bureau. All types of communication problems were dealt with, including a service which gave warnings of the likelihood of ionosphere disturbances. The war-time advances were more in matters of detail than in understanding; and particularly in regard to the $F_2$-layer, a theory permitting calculation is badly needed by engineers as well as by geophysicists.

Measurements of the variation of the reflexion coefficient of region $E_S$ with frequency showed that it often has a thickness between 50 m. and 500 m., with an average of 150 m.

Measurements of attenuation show a winter anomaly in region $D$. In summer, the attenuation varies from day to day by perhaps $\pm 15$ per cent, but in winter, though a number of days have low attenuation, there are some which show values all day up to twice as much as are attained in summer. These days have a 27-day recurrence tendency, but are not associated with magnetic disturbance. Apart from the appearance of reflexions from 80 km. height (which may also occur at other times without attenuation) it has not been possible to correlate them with any other phenomenon. There is also no definite correlation between attenuation and magnetic disturbance at Baddow (51° 40′ N., 0° 30′ E.).

Mr. J. S. Hey spoke of the noise associated with solar disturbances. This is not measurable at wave-lengths less than 1 metre, but above 1½ metres it increases rapidly with wave-length and at 5 metres it is about $10^6$ times that which would be expected as thermal noise from the sun radiating as a black body at 6,000° K. With receiving aerials giving a power gain of 100 at 5 metres, the noise is $10^4$ times the thermal noise in the receiver. On waves longer than 15 m. the noise drops off, presumably because the longer waves cannot penetrate the ionosphere.

Scatter bursts at heights around 95 km. have been investigated with directional aerials on about 60 Mc./s. It has been found possible to correlate some of them with visible meteors. Experiments in which three widely spaced equipments were directed at the same patch of sky at 100 km. height showed little correlation between reception at the three places. The diurnal curve of frequency of occurrence of bursts is quite definite at each place and is found to depend on the direction of observation. This is taken as further evidence that the bursts are caused by meteors, as there is a diurnal variation in the predominant azimuth of meteors, and it is to be expected that the reflecting power of a meteor train will depend on direction.

Prof. H. S. W. Massey spoke of fundamental processes of recombination and attachment in the ionosphere. The main difficulty is lack of precise knowledge of the absorption of ultra-violet light in oxygen, nitrogen and possibly sodium. It is also necessary to remember that the region of maximum ion production may not be the region of maximum density. The distribution of the various gases is also not known, but it is fairly certain that there will be enough atomic oxygen above 100 km. to absorb all ultra-violet radiation with energy greater than 13·5 volts. This may account for the $F_1$-layer, but the $E$- and $D$-layers must be produced by something else. The ionization potential of $O_2$ is 12·5 volts, but its absorption is difficult to calculate and experiments suggest that it is not strong.

The difficulty with regard to the loss of electrons is to account for the observed high recombination rate of $10^{-8}$. The reaction

$$O^+ + e \rightarrow O' + h\nu$$

would give a rate of $10^{-12}$.

A possibility is

$$O + e \rightarrow O^- + h\nu,$$

which could be fast as there is so much atomic oxygen present. It would need

$$O^- + O^+ \rightarrow O' + O''$$

to give the final equilibrium, and to get the correct recombination-rate would need a high probability of at least $10^{-6}$ for this reaction, whereas it can scarcely be above $10^{-7}$.

Thus only

$$O_2^+ + e \rightarrow O' + O''$$

is left, and it is difficult to be precise about this as the details will also involve the behaviour of molecular nitrogen. It is therefore not yet possible to come to any very definite conclusions, and further advance needs both the computation of theoretical rates, and also improvement in the very difficult experimental technique of measurement.

Sir Edward Appleton, summing up, said that the discussion showed that in spite of the War, and even because of it, it had been possible to make notable scientific progress. Prof. Chapman, from the chair, commented that most of the war-time material remained difficult of access, and he hoped it would be published in as much detail as possible. He instanced the detailed publications of meteorological stations in which the availability of a large amount of information had often proved quite unexpectedly useful, and hoped that some similar publication could be made of ionospheric information.

J. W. Cox

# NEWS and VIEWS

## Mechanical Engineering at the Imperial College: Prof. C. H. Lander, C.B.E.

Prof. C. H. Lander, who is retiring from the chair of mechanical engineering at the City and Guilds Engineering College, University of London, has played an outstanding part for a long period in research and education in engineering, particularly in relation to the utilization of fuel. He obtained varied practical experience in engineering over several years, first with the Manchester Ship Canal Company, then as assistant to Mr. Charles Hopkinson and later with Heenan and Froude, Ltd. As a result he had acquired an excellent background before taking the course in engineering at the University of Manchester, where he graduated in 1905 with first-class honours and was awarded the Fairbairn Prize. He was demonstrator and later lecturer in engineering in the University of Manchester during 1906–16, in which year he was awarded the degree of D.Sc. for a series of original investigations on heat flow, surface friction, and allied subjects. During this period he was also part-time engineer to the Home Office in charge of experimental work on heating and ventilation; this work was the basis of provisions in the Factory Acts. During the First World War Dr. Lander served as an officer in the R.N.V.R., and his important service was recognized by one of the awards to inventors for secret war inventions.

Soon after the establishment of the fuel research organisation of the Department of Scientific and Industrial Research, Dr. Lander was appointed assistant to the Director of Fuel Research (the late Sir George Beilby), and he was rapidly promoted to deputy director in 1922 and director in 1923. In 1928 he was awarded the C.B.E. It was in 1931 that he returned to academic life as professor of mechanical engineering at the City and Guilds College, where he has advanced education not only in mechanical but also in chemical engineering, and has inspired post-graduate research. Prof. Lander's ability and experience were invaluable during the Second World War. He played a prominent part in the development of flame-throwers, gas turbines and jet propulsion, and petrol burners (F.I.D.O.) for dispersion of fog over airfields. For many years he was vice-chairman of the British National Committee of the World Power Conference, to mention only one of the many organisations assisted by his knowledge and advice. Perhaps the work in which he has been most interested is that in relation to heat transfer, on which he has led teams of investigators for more than twenty-five years. Though he has reached retiring age, Prof. Lander will not be idle. He is president-elect of the Institute of Fuel; a year ago this Institute awarded him the Melchett Medal for his distinguished work.

## Dr. O. A. Saunders

Dr. O. A. Saunders, who has just been appointed to the University of London chair of mechanical engineering at the Imperial College of Science and Technology, is a graduate of London and Cambridge and was a senior scholar at Trinity College, Cambridge, during 1926–29. After leaving the University he was trained at the Fuel Research Station under Dr. C. H. Lander and Eng.-Capt. J. Fraser Shaw, after which he specialized on the thermodynamical side of fuel and power appliances. His work on industrial heat transmission is well known, and in 1921 he published in collaboration with Dr. Fishenden a standard book on heat transmission. In 1932 he took up the post of lecturer in applied mathematical physics in the Mechanical Engineering Department at Imperial College, and in 1937 became the first Clothworkers' reader in applied thermodynamics. During the War his services were seconded to the Ministry of Aircraft Production for special investigations on internal combustion engines, and later he joined the Directorate of Turbine Engine Research, in which he was in charge of research on jet propulsion and gas turbines.

Dr. Saunders has published numerous original papers including fundamental investigations of heat transfer by convection in gases and liquids, radiation and the phenomenon of exhaust gas discharge from