Thunderstorms and Globular Lightning.

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THERE is no real boundary between pure science and applied science, and it is inconceivable that any one whose life's work is the practical application of electricity should not be interested in all things electrical. One might, therefore, expect an electrical engineer to show at least a dilettante interest in atmospheric electricity, but one is surprised—although equally gratified—to find that the president of the Institution of Electrical Engineers devoted a large part of his inaugural address on October 18 to the discussion of the electrical potential gradient in the atmosphere and the mechanism of thunderstorms. There has been a great deal of work done on these subjects in recent years, but it cannot be said that the results have yet reached far beyond the small band of workers who are actually engaged in making the investigations. Dr. Alexander Russell has, therefore, done a good service to his fellow engineers in summarising for their benefit our present knowledge and indicating problems still unsolved.

Dr. Russell accepts the breaking drop theory for the origin of electricity in thunderstorms, but he appears unable to give up entirely the old idea that free electrons form nuclei for condensation in the atmosphere. There are certain ideas which once they have appeared in scientific literature cannot be eradicated no matter how conclusively they are shown to be wrong. C. T. R. Wilson in his classical work on the condensation of water on to ions showed two things: first, with great supersaturation water will condense, in the absence of other nuclei, on positive and negative ions; and secondly, that no condensation takes place on even the negative ions until fourfold supersaturation has been reached. This latter point is nearly always forgotten, and until some one has shown that fourfold supersaturation does exist in the atmosphere, meteorologists cannot recognise that ions play any rôle in the processes of atmospheric precipitation.

The breaking drop theory of thunderstorms has met with very wide acceptance; for it gives such a simple and complete account of the origin of the electricity and explains so many of the observed facts, such as the part played by ascending air currents, why the lightning flashes are mainly between the base and the top of the cloud, and why the rain carries sometimes a positive and sometimes a negative charge with the former preponderating.

The physical basis of the theory has been examined in great detail by Lenard in Germany and McClelland and Nolan in Dublin, and there can now be no doubt that the breaking of drops does produce a separation of electricity. There was, therefore, every justification for Dr. Russell to give the breaking of drops as the chief source of electricity in thunderstorms, but this is only a part of the complete theory of thunderstorms, which takes into account the part played by hail and explains also those winter thunderstorms in which there appears to be no drop formation.

The breaking drop theory was put forward as the result of work during the monsoon in India, and in the original paper it was said that there had been no opportunity to examine the electrical phenomena connected with ordinary rain or with snowstorms. That opportunity has since occurred, and has given the data for rounding off the theory so that it can now be applied to all kinds of atmospheric precipitation.

The separation of electricity on the violent disruption of a body is not confined to liquids, but occurs, probably more strongly, when solids are rapidly separated. Rudge's work on the electrification of dust clouds threw much light on this subject. When dust is blown up into the air, the dust particles are found to be highly charged. This is not an effect of frictional electricity as usually understood, because two different substances do not come into contact; for example, highly charged particles are obtained when sand consisting of pure silica is used to make a dust cloud. The effect appears to be exactly the same as in the case of the breaking drops; a violent separation of parts takes place, the substance obtains one kind of electricity while the other kind passes into the air probably in the form of large ions.

Rudge's work was undertaken to explain the high potential gradient observed in tropical regions during dust storms, but similar electrical effects are observed during blizzards in polar climates. There is physically no difference between a dust storm and a blizzard accompanied by much driven snow, and in both cases the particles of solid matter become charged in consequence of their frequent collisions. This is then the origin of electricity in snowstorms. One difficulty, however, must be faced. If the electrification takes place by collision, how does a sufficient separation of electricity take place to give a lightning flash, for this can only occur after some process has widely separated the electricity set free by the collisions? The answer is that so long as the cloud contains only snow which settles very slowly through the air, there is no thunderstorm; it is only when soft hail accompanies a snowstorm that thunder and lightning occur. As the soft hail falls through the snow flakes, electrification takes place on each collision and the falling hail carries away with it large charges of electricity. Thus the fall of the hail effects the separation of electricity which gives rise to the large electrical fields necessary for a thunderstorm. Compared with the electrical effects of a tropical thunderstorm with its heavy rainfall, the electrical effects of a snowstorm are almost insignificant, and during the polar winter, when there is no soft hail associated with the snowfall, thunder and lightning do not accompany the most violent snowstorms.

Dr. Russell in his address also gave considerable time to discussing globular or ball lightning. He came to the conclusion, which is now very generally held, that this is a real natural phenomenon with an objective existence. The chief characteristic of ball lightning may be summed up as follows:

(1) The body or ball itself, which is able to retain its individuality as it moves through the air, appears to be composed of gas or matter in some novel luminous condition.

(2) The balls appear to exist independently of any large electrical intensity, for they have been observed within closed rooms where large electrical fields are impossible, and have also

been observed to pass in and out of parallel telegraph wires.

(3) They appear to be associated directly or indirectly with large quantities of energy, for they have been observed to explode with violence, and have also been seen to fuse the overhead wire of an electrical tramway.

No satisfactory explanation of ball lightning has been offered. Dr. Russell says: "Globular lightning seems to be a brush discharge taking place at the end of a column of air of higher conductivity than the neighbouring air." He then points out some of the difficulties of this explanation, to which others can be added; in fact, there is really nothing very similar between a brush discharge and the ball of glowing gas so frequently described. The only physical phenomena yet produced in a laboratory at all approaching ball lightning is the active nitrogen studied by Lord Rayleigh. In this case we have a mass of nitrogen subjected to an electrical discharge which continues to glow for some time after it has been removed from the field. Lord Rayleigh, however, is unable to accept this explanation of ball lightning, and all that we are able to say is that active nitrogen is the nearest physical phenomenon to ball lightning yet produced in our laboratories. Ball lightning appears always to be associated with a thunderstorm, and it is possible that the intense discharge of a lightning flash can produce some atomic change in the air or rain through which the discharge passes. If this is so, the glowing matter of ball lightning may be in a state otherwise not met with in Nature.

Unusual Forms of Crystallisation of Cementite in Steel.

CEMENTITE, the carbide of iron, which confers on iron the properties of steel, exists in three principal forms in hypereutectoid steels, (1) the pseudo-dendritic form, (2) the cellular or intergranular form, and (3) the intragranular form which gives rise to the Widmannstätten structure. Pseudo-dendritic distribution arises directly from the irregular concentration of the solid solution which results on solidification. The cellular variety occurs between the grains, *i.e.* in the network of the grain junctions, while the Widmannstätten structure is caused by the precipitation of cementite in the interior of the grains themselves and shows evidence of the directive influence of the crystalline network of each grain.

A. M. Portevin has examined a sample of steel which has enabled him to make certain new observations in regard to these forms of cementite. These results were presented at the autumn meeting of the Iron and Steel Institute held recently in Italy. The sample was found in the hearth of a blast-furnace, and its exterior presented the characteristic concave facets peculiar to intergranular fracture. The grains of which it was composed were exceedingly well developed, their size being of the order of 1 cm. in transverse thickness and several centimetres in length. The specimen contained 1·22 per cent. of carbon, 1·35 of silicon, and 0·17 of phosphorus. It was, therefore, very distinctly hypereutectoid and corresponds, so far as carbon percentage is concerned, to a fairly hard cutting tool. An examination of the microstructure of this sample revealed the presence of the cellular and Widmannstätten modes of distribution of cementite, but the pseudo-dendritic form was absent.

INTRAGRANULAR CEMENTITE.

A micrographic section usually shows the cementite in needles arranged along three or four directions in each grain. This corresponds spacially with lamellæ parallel with the faces of the octahedron, and has the appearance which cementite assumes more particularly in case-hardened samples very high in carbon. In the sample examined by Portevin a different orientation of the intragranular cementite was observed. The constituent was present, not in the usual isolated rectilinear needles, but in the form of bundles of numerous very small needles, or of groups of elements crowded together. These were apparently elongated prisms analogous to the prismoids of Belaiew, grouped in masses. This is apparently the first time that intragranular cementite has been noticed with these morphological characteristics. It can, however, also be produced in steel which has been strongly case-hardened at a very high temperature and very slowly cooled. Inclusions and notably bubbles constituted centres of crystallisation around which the bundles of needles were grouped.

INTERGRANULAR CEMENTITE.

This is customarily described and represented as enveloping the grains and appearing in a section as continuous ribbon-like filaments which do not display any characteristic shape or orientation. Howe and Levy, however, have directed attention to the needle points which impinge from the cementite network into the interior of the grains, and have raised the question as to whether these take their direction in obedience to the crystallisation orientation of the adjacent grain or of that of the network itself. They have suggested that both influences manifest themselves, and that sometimes one and sometimes the other predominates. In the present sample there is no continuous network of cementite surrounding the grains. There is a grouping of this constituent along the confines of the grain joints, the variable orientation of which can sometimes be attributed to that of the intragranular elements of cementite dispersed within each grain and sometimes appears distinctly different. In other words, the two influences remarked by Howe and Levy manifest themselves. Fig. 1 represents the appearance obtained after oil-quenching at 950° C. followed by annealing at 550° C., a treatment which causes the great bulk of the pro-eutectoid cementite, and more especially the Widmannstäten cementite, to disappear. The photograph has been taken at the junction of three grains. The needles which compose the network have in one instance different directions in regard to each grain, giving the junction the appearance of the barbs of a feather, while in the two other junctions they have an almost uniform orientation. It appears that the structural elements of the network have distributed themselves along a mean direction or have assumed a direction of their own, the influences of the orientation of each grain conflicting with each other in the neighbourhood of the junction. The needles are