species into the Lower Valais, while others of later origin were principally introduced by human agency.

During these changes the Mont Blanc district and the country between the Alps and the Jura were still ice-bound, and seeds carried by the wind from the south and west would fall on snow or sterile moraines. And when in their turn these districts were released, their opportunity of being stocked by the flora fast disappearing from the lower levels had gone. The asylums which were earliest opened were most richly supplied and have remained so.

M. De Candolle considers that a potent cause of the extermination of this flora has been the destruction of the forests which has rendered the climate south of the Alps hotter and drier in summer, and colder in winter.

The rare plants of the Italian Alps are the remains therefore of an ancient flora like that of St. Helena on its last legs. The climate of Europe tends to become drier, and M. De Candolle thinks it probable that in the course of centuries the centre of Switzerland may in turn become relatively rich in rare species, while the southern slopes of the Alps become poor. In the Lebanon and the Pyrenees this reversal of conditions has actually taken place, and their southern face—once rich probably in species remigrating northwards—is now actually poorer than the northern. The Caucasus and the Himalaya are, however, at present comparable with the Alps. T. D.

DEEP-SEA TELEGRAPH CABLES: HOW THEY ARE TESTED

THE "testing" of a telegraph cable, whether long or short, proceeds upon the principle that the materials offer to the electrical current a certain resistance: the testing of a cable is the measurement of this resistance. In any cable there are two kinds of these resistance measurements; one of the resistance which opposes the current in its progress along the conducting wire, the other of that which opposes its lateral dispersion. The conductor-resistance is technically termed the copper-resistance, and is extremely small compared with the other resistance. The lateral resistance to the escape of the current opposed by the insulating substance which surrounds the copper-conductor is technically termed the insulation-resistance. Where the resistance to the direct propagation of the electric current through a conducting wire is represented in units, the resistance to lateral dispersion through the insulator will be represented by hundreds, or even thousands of millions, of these units. A third property is that known as the electro-static, or inductive capacity, or simply "charge"[1] of the cable; in other words, that measured quantity of electricity which the given cable will take up in a given time. So much for the necessary explanation of technical terms.

The copper-resistance (1), the insulation-resistance (2), and the "capacity" (3) are the three points to be ascertained in the testing of a cable; and it is useful to inquire why these are the points to be ascertained.

The chief commercial requisite in any cable, and upon which depends its value to its owners, is the speed with which signals can be transmitted. Speed depends directly upon two of the foregoing points (that is upon the copper resistance and "capacity"), and indirectly upon the insulation-resistance. Popular assumption is very much given to the idea that the electrical worth of a cable increases with its insulation-resistance; as usual with popular notions this is only half-truth. That the cost of a cable follows the ratio may or may not be, but it is certain that above a definite limit the thickness of the insulating coating has no effect upon the practical working condition of the cable. It may be that minor indirect benefits arise, but with these, under the present consideration of the practical testing of a cable, we have nothing to do. A certain standard of insulation-resistance attained, there remain the two points, first, of the resistance offered by the copper wire; secondly, of the charge. Now it is collaterally to be understood that, as there can be obtained through a pipe a greater flow of liquid when the pipe offers little resistance to the flow, so through the conductor of a cable can a greater flow be obtained when the conductor has low resistance. With most of the Atlantic cables each nautical mile of the conductor has a resistance equal to that of three to four of the arbitrary units selected by the profession for comparison. There are in use two units of electrical resistance, namely, that determined by a committee of the British Association and the Siemens unit. These units are very nearly of the same value, one Siemens' mercury unit (the resistance offered by a column of pure mercury of one metre length and one square millimetre section at 0° C.) being equal to 0·9536 of an Ohm, the technical term for a British Association unit. There is, then, to be considered an electrical length as well as an absolute (or ordinary) length; the proportion that one bears to the other being known, the measures are convertible. Vague as may appear to the reader this idea of electrical resistance, when he knows that of a copper wire of given diameter or weight two lengths offer twice the resistance of one, he is as learned as the most skilled electrician who virtually knows no more.

The consideration of the electrical capacity of a cable is more difficult. While the two other points relate to mass, the question of capacity involves that of surface, and of a property of the insulating material of the cable known as its "specific inductive capacity." The material with which long telegraph cables are insulated is gutta-percha. Two different cables may be insulated with this material to precisely the same dimensions, both as regards the thickness of the insulator and the thickness of the copper wire, but the "charge" taken by these cables may be very different, and the difference will be due to difference in the specific facilities offered by the two gutta-perchas to induction. This difference between various kinds of gutta-percha is as inherent as is the difference between resistances to conduction offered by different metallic alloys, and is probably very often due to want of homogeneity of the substance. It is by judicious selection and careful manipulation that the cable manufacturer is enabled to maintain a certain standard for any particular cable in question. Capacity, however, not only varies with the insulating material, but it also varies with the amount of surface of the conductor. It is different with different thicknesses of insulating material, but in this respect, after a certain limit has been passed, the decrease in capacity is very small for very large increase in the thickness of the insulating material.

High charge is incompatible with high speed. That cable will, other conditions the same, have the greatest speed in which the charge, or the fraction of the charge to be altered at each signal, is least. Professional necessity has given rise to a unit of quantity of electricity termed a "farad," of which the "micro-farad" is the millionth part. The capacity of a telegraph-cable generally ranges from three to four-tenths of a micro-farad per nautical mile.

The object of testing a cable is, then, to ascertain whether the insulation reaches the amount specified, and whether the conductor-resistance and the charge are of the required minimum. As these tests are each applied separately to the cable, their consideration will fall under the several heads. It would clearly be impossible within the limits of this paper to describe the many methods which have from time to time been proposed and in use for the testing of telegraph cables. The first methods of testing submarine lines are undoubtedly due to Dr. Werner

[1] "Capacity" and "charge" are not equivalent terms, although they are so considered in this article to prevent confusion, by the general reader, with the ordinary meaning of the word "capacity." The capacity of a cable remains constant, while the charge varies with the battery power employed.

Siemens and Dr. C. William Siemens, who early in the history of submarine telegraphy communicated their researches on the subject to the British Association at the Oxford meeting of 1860. The principle of these early methods still remains the principle of the methods employed by Sir W. Thomson in his testing of the Direct United States Cable at Ballinskelligs Bay Station in September, 1875, and upon which he has reported to the manufacturers of the cable, Messrs. Siemens Brothers. It is the purport of this paper to describe these tests and the results obtained.

To those who may be unacquainted with the route of the Direct United States cable, it will be necessary to explain that the course taken is from Ballinskelligs Bay, on the west coast of Ireland, to Torbay, in Nova Scotia, whence it again passes to Rye Beach, in New Hampshire, America.

The construction of the cable, which was decided upon by the company acting under the advice of Dr. William Siemens, their scientific consultant, is as follows :—The cable from Ireland to Nova Scotia consists of a conductor formed of a strand of twelve copper wires weighing 400 lbs. per nautical mile. This conductor is surrounded with four coatings of gutta-percha and gutta-percha-compound weighing 360 lbs. per nautical mile, so that the total weight of the "core," as it is technically termed, is 760 lbs. per knot. It was specified that the core should have an insulation resistance per nautical mile equal to 160 millions of mercury units; tests, however, checked and taken under the direction of Mr. von Chauvin, the manager and electrician to the Company, show that no length of core was passed that did not insulate to nearly double this extent, or to 300 million units per knot, the tests being taken after twenty-four hours' immersion of the core in water at 75° F. The "core" is "served" or enveloped in jute yarn, and is then sheathed or covered with iron wires of a diameter best suited to the position of the cable. Thus for the deep-sea, 1,630 knots of the cable are sheathed with ten strands of wire and hemp, each strand consisting of a homogeneous iron wire surrounded with five strands of Manilla hemp, each strand being passed through a compound of pitch, tar, and india-rubber. Each of the iron wires has an average breaking strain of 53 tons per square inch, and is of 0·099 inch diameter. The cable termed medium cable is sheathed with fifteen wires of 0·148 inch diameter with proper sewings of yarn, while for the shore ends, where there is considered to be more friction or wear, this medium cable is again surrounded with iron sheathings of twelve strands of iron wires, each strand consisting of three iron wires of 0·230 of an inch diameter.

The cable from Nova Scotia to New Hampshire consists of a strand conductor of seven copper wires weighing 107 lbs. per knot, covered with three coatings of gutta-percha and compound weighing 150 lbs. per knot, and is also sheathed with iron wires.

The non-electrical reader who may choose to wade through detail that must be somewhat technical will perhaps find help in considering the conducting wire as representing a line of flow or force, such that if two of these lines be directed into a galvanometer or current-measurer in opposite directions, that having the greatest head or greatest force will preponderate, while no indication will be found on the instrument when the forces are equal; also that from a known force giving through a known resistance a certain instrumental measure, any unknown resistance may be reduced when its instrumental measure is ascertained.

Testing the Resistance of the Copper Conductor.—Electrical measurements upon a long submerged cable differ from measurements made in the laboratory as described in text-books in one very important particular—that of earth-currents. Earth-currents are the *bête-noir* of the electrician, who not infrequently finds them so far masters of the field that his chance of obtaining accurate measures is a poor one. Fortunately, earth-currents do not have so much influence upon the working of a cable as they have upon the testing, and more fortunately still these currents do not always exist, so it is possible to obtain measures during a tranquil period. On the Direct United States' Cable, Sir William Thomson found these currents to be equal in value at a period of greatest strength to that from about eighteen cells of the testing-battery—the Irish end being positive generally to the Nova Scotian end. Under such conditions, Sir W. Thomson employed the simple deflection-method of measuring the conductor-resistance, which he takes to be "the only proper method for measuring copper-resistance in a submerged cable." In the following description of the method and its results, it will be seen that the method consists in applying together with a measuring instrument an electric force which yields a certain measure through the unknown resistance of the cable; a known resistance (7,300 units) is then substituted for the resistance of the cable, and the latter determined by proportion. The principle of this method is applicable not only to the measurement of the copper-resistance, but is that also of the ordinary method of measuring insulation-resistance, a higher known resistance being used in order more readily to effect comparison with the unknown and much greater insulation-resistance. The actual operation during the period of testing is thus described :—

"The insulation-galvanometer quickened three- or four-fold by a magnetic adjustment, and, with a shunt of twenty Siemens' units on its coil, was put in circuit between line, battery, and earth, and the deflection was observed and recorded every ten seconds. As was to be expected, large and rapid variations of the deflections were continually taking place on account of earth-currents. The direction of the earth-current was from east to west the whole time, as was shown by the 'copper' current being always greater, and the 'zinc' current less, than the true mean concluded from the observations. It increased gradually (but with some slight backward pulsation) from the beginning—when its amount was that due to a difference of potentials between the Ballinskelligs and Torbay earths equal to 1·7 of a cell—till the end, when it was more than five times as strong, and corresponded to nine cells; the Irish earth positive relatively to the Nova Scotian earth the whole time. To measure the copper-resistance a time of comparative tranquillity was chosen, a reading taken, and then as quickly as possible the galvanometer short-circuited, the battery reversed, the galvanometer circuit reopened, and a fresh reading taken. Half the space travelled by the spot of light from the first reading to the second is taken, as being the deflection which would be produced by the battery applied in either direction were there no earth-currents. This was done seven times, and the half ranges were as follows :—235, 231, 229½, 234½, 231, 235, 230—mean 232·3. I found that the same battery applied in the two directions through the galvanometer, and 7,300 Siemens' units gave 232 divisions on one side of zero, and 233 on the other—mean 232·5. Hence the copper-resistance to be inferred from the observations is—

$$7300 \times \frac{232{\cdot}5}{232{\cdot}3}, \text{ or } 7306 \text{ Siemens' units."}$$

As the cable in question is 2,420 nautical miles in length, we have $\frac{7306}{2420} = 3{\cdot}02$ Siemens' units per knot.

Insulation Test.—The ordinary method of testing the insulation-resistance of a cable consists, as has been said, in obtaining upon the galvanometer or measuring instrument a certain measure with a known resistance, and a measure with the unknown resistance, the electric force being constant during the two measurements. From these two measures the unknown resistance is determined.

If, for instance, it is known that with a certain battery power and a resistance of 100,000 units we have a deflection-measure of 100, it is deduced, when with an unknown resistance and the same battery power the deflection of 50 is obtained, that the resistance must be twice as great (namely, 200,000), since the observed effect is halved. This system is that generally pursued, but, like the other measurements upon submerged cables, comes under the effect of earth-currents; and to meet this contingency Sir William Thomson has arranged a new method, bearing upon the principle that the insulation of a cable may be determined from the proportion of loss (during a given time) of electric power that has been imparted to it. In the following description it will be seen that this loss is measured by the deflection due to the current entering the cable to make up the loss, and this deflection is compared with another deflection obtained by altering suddenly by a small quantity the battery power employed. The latter deflection being a measure of a known force or potential, the other measure for lost potential is determined, and consequently the loss of potential known.

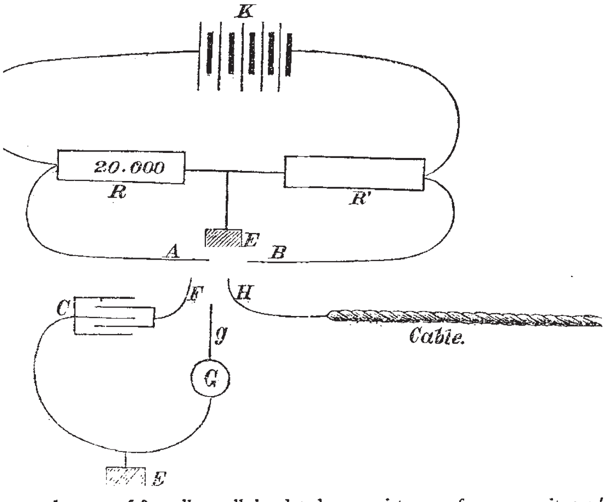
"The cable being offered to me again from midnight till 2 A.M. on the 17th, I made," says Sir W. Thomson, "another series of tests at that time for the main object of measuring the insulation-resistance. I found the line in a much less disturbed state, and was able to make a perfectly satisfactory insulation test by the ordinary galvanometer method. I applied, however, also a new method which (no electrometer being available) I had planned to meet the contingency of the line being disturbed by earth-currents so much as to render the ordinary test unsatisfactory, but not so much as to vitiate an electrometer-test. This method, which I think may be found generally useful for testing submerged cables when an electrometer is not available, is as follows:—1. Apply the ordinary test by battery and galvanometer for a certain time. 2. Insulate the cable for a certain time and then shunt the galvanometer to prepare for No. 3 (unless you have conveniently available a second galvanometer suitable for discharges). 3. Instantaneously reapply the battery, through the insulation galvanometer properly shunted (or a special discharge galvanometer), to the cable, and observe the maximum of the sudden deflection produced. 4. Go on repeating Nos. 1, 2, and 3 as long as you think proper, according to circumstances. 5. To determine the proper ballistic constant of the galvanometer for utilising the observed result of No. 3, find the maximum of the sudden deflection which takes place when a sudden change of electrification is produced by instantaneously changing by a small measured difference the potential of one electrode of the galvanometer, the other electrode being in connection with the cable. 6. The change of potential which, in the operation of No. 5, would give the same deflection as that observed in No. 3, is equal to the change of potential which the conductor of the cable has experienced during the time when it was left insulated according to No. 2. Hence calculate the insulation-resistance in ohms or megohms as in the ordinary electrometer method when the electrostatic capacity of the cable is known."

In carrying out this test, the 20-cell insulation battery (with its poles joined through 20,000 Siemens' units) was applied, zinc to cable, through the insulation galvanometer with a shunt of 5,000 Siemens' units on it. Then, the galvanometer indication was read and recorded every ten seconds for three and a half minutes, when the cable was insulated during a minute according to No. 2 of the directions above, and a shunt of 30 substituted for the 5,000. At the end of the minute the battery was instantaneously reapplied, the throw of the galvanometer observed according to No. 3 and the shunt of 30 removed, and 5,000 reapplied. The cable was again insulated for a minute, the galvanometer shunted with 50 (instead of 30 used the first time), and the operation of No. 3 repeated. The proper ballistic constant of the galvanometer was determined by applying alternately full power and $\frac{48}{50}$ of full power of the insulation battery; the change from one power to the other being made in each case as instantaneously as possible. Twelve galvanometer readings taken at ten seconds' intervals during the second and third minutes of the electrification gave for mean deflection 127, and the readings taken from the fourth to the twenty-fourth minutes gave for mean deflection 82·1. The sensibility of the galvanometer in the condition in which it was used for these readings was such that a deflection of 290 would have been given by the actual battery, with a resistance of 1,000,000 Siemens' units. Hence the insulation-resistances proved by the mean observed deflections were for the deflection, 127 from the second and third minutes 2,280,000 Siemens units, and for the mean deflection 82·1 from the fourth to twenty-fourth minutes 3,540,000 units. The new method described gave, as the mean of the observed ballistic deflections or "throws," the number 89·8, or say 90. The ballistic deflection due to instantaneously changing the potential by $\frac{1}{40}$ of that of the insulation battery, in accordance with the rule of one to five above, was found to be 112 divisions. This is $1\frac{1}{4}$ time the preceding mean throw (90), which therefore showed a change of potential equal to $\frac{1}{50}$ of that of the battery. Hence the mean fall of potential was $\frac{1}{40}$ during the minute, or at the rate of $\frac{1}{3000}$ per second. The capacity of the cable (measured in the way presently described) had been found to be 991 microfarads. Hence the insulation-resistance is $\frac{3000}{991}$, or 3·027 megohms, or 3,170,000 Siemens' units, corresponding to the 3,540,000 units given by the ordinary method. With copper to line, a fresh series of tests gave 3,520,000 megohms, or 3,690,000 Siemens' units.

In the reduction of the insulation-resistance of the whole cable to its insulation-resistance per knot, it has to be observed that as the insulation of the cable is inversely as its length, one knot of the cable will give an insulation resistance equal to that of the whole cable multiplied by the number of knots' length in the whole cable.

Measurement of "Capacity."—Just as the chemist has his vessels for measuring out quantities of liquid, so has the electrician his special arrangements for measuring out quantities of electricity; but there the analogy ends, for while the measure of the liquid is direct and visible, the electrician infers his measured quantity generally by the mechanical work effected on the index of the measuring instrument, or by the absence of such work. The apparatus used in practice for measuring quantities of electricity is termed a "condenser." "Condensers" are constructed having any required capacity, and if such a condenser of which the capacity is known is charged from a battery, then discharged through the measuring instrument, and the deflection produced noted, it is only required to charge from the same battery the cable or any other condenser of which the capacity is to be measured, then to note this discharge deflection, and by proportion to deduce the unknown capacity. On short lengths of cable this procedure is actually adopted, but on long lengths it becomes liable to error, chiefly from the fact that as with long lengths some perceptible time is required to discharge the cable, the ballistic throw or sudden deflection produced upon the measuring instrument by the rush of electricity from the cable does not measure all that passes out. It is consequently necessary to devise some method like the following used by Sir W. Thomson, in which the charge from the cable (communicated thereto by a different battery power to that charging the condenser, but the relative powers being known) is neutralised by a charge of opposite electricity from the condenser, and the neutralisation declared by the non-production of movement in the measuring instrument.

The following diagram, which is not, however, taken from the report, will explain the method :—



K, battery of 80 cells, well insulated; R resistance of 20,000 units; R', variable resistance; C, condenser of 80 microfarads' capacity; G, shunted galvanometer; E, earth.

The condenser is electrified by bringing F and A into contact, and the cable by making contact between H and B, for sufficiently long time to fully charge the cable. These contacts are then broken, and instantly after contact made between F and H. This contact is maintained for five to ten seconds, when the additional contact with *g* is made. The variable resistance is adjusted till this last contact produces no movement on the measuring instrument.

It was found that when the cable and condenser were charged to opposite potentials in the proportion of 1,615 to 20,000 no throw occurred, whence the deduction that the capacity of the cable was

$$\frac{20000}{1615} \times 80 \text{ microfarads, or}$$

991 microfarads, and the length of the cable being 2,420 knots, this was equal to 0·409 of a microfarad per knot.

In concluding the report upon the electrical conditions of the Direct United States Cable, Sir William Thomson remarks: "I am glad to be able to say that my tests proved the cable to be in perfect condition as to insulation, and showed its electrostatic capacity and copper resistance to be so small as to give it a power of transmitting messages, which, for a transatlantic cable of so great a length, is a very remarkable as well as valuable achievement." This article would be exceeding its purpose if it were to include inquiry into the present position of Atlantic Telegraphy; but it is a mark of great progress in electrical engineering and cable manufacture that a cable of such length as 2,420 miles can be delivered up to the company working it in a *perfect* electrical condition. This has not been the case in earlier transatlantic attempts; and some idea may be formed by the general reader of the care required to bring about this end, when it is known that a small hole, smaller in size than the finest pin-hole, in any portion of the two thousand miles length of gutta-percha covering would render the electrical conditions of the cable imperfect.

THE CLIMATIC CHARACTERISTICS OF WINDS AS DEPENDENT ON THEIR ORIGIN[1]

OF the climatic characteristics of winds the most important are, primarily, their temperature, and, secondarily, their moisture. The general occurrence of certain characteristics, especially when more strongly marked, with particular directions of the wind, experience soon forces on our attention, and much labour has been bestowed, particularly by Dove, in grouping the winds simply according to their directions, and calculating the mean atmospheric pressure, temperature, humidity, cloud, and rainfall, for each of the directions. Interesting and to some extent valuable results have been obtained from these inquiries; results, it must, however, be added, far from being commensurate with the enormous labour expended in arriving at them. But in extending this line of research into such regions as Western Norway, Faiö, Iceland, Newfoundland, and the Azores, its unsatisfactoriness soon becomes evident; and the further consideration that the climatic qualities of a particular wind repeatedly differ widely from its general character, makes it evident that a climatic inquiry which groups the winds merely according to their direction does not proceed from a scientific basis.

A striking case, showing a great deviation from the general qualities of a wind, occurred during the great Edinburgh hurricane of the 24th of January, 1868, on which occasion the wind remained persistently in the south for several hours, and possessed a coldness and a dryness which were truly polar. The qualities of this south wind are readily explained by the limited area of high pressure, which lay immediately to the south-eastward of Scotland at the time, out of which this wind blew. As the barometer continued to fall, the wind ultimately veered to S.W. and W., and the temperature presented the unusual phenomenon of rapidly rising with a change of the wind into westward. The point to be noted here is, that as long as the wind was connected immediately with the circumscribed area of high pressure it was cold and dry, but when it was involved in the area of low pressure it became mild and moist. This relation between the climatic qualities of a wind and the state of the pressure is a vital point in atmospheric physics, and to Dr. Köppen belongs the merit of applying the principle in inaugurating a new method of inquiring into the climatic characteristics of the different winds by referring each wind-observation to the system of atmospheric pressure with which it is at the moment immediately connected.

If we examine weather-charts representing a large portion of the earth's surface, such as those published in the *Journal of the Scottish Meteorological Society*, vol. ii. p. 198, two distinct systems of pressure are seen, which change their position and form from day to day, one indicated by isobars inclosing spaces of low pressure, into which the winds all round blow vorticosely in the northern hemisphere in a direction contrary to that of the hands of a watch, and the other by isobars inclosing areas of high pressure, out of which the winds blow on all sides, but in opposite directions to those assumed in blowing inwards upon a space of low pressure. The former are usually called cyclones, and the latter anticyclones. Not only do the direction of the winds within the areas of cyclones and anticyclones respectively differ from each other, but the temperature and humidity of the winds connected with each have certain well-marked characteristics. A south-east wind at St. Petersburg, for instance, blowing in immediate connection with a cyclone, comes from the south and south-west, that is, from the south-west of Russia or from Germany; whereas a south-east wind in immediate connection with an anticyclone comes from the east, that is, either from the east of Russia or from the White Sea, and consequently these two south-east winds are markedly different in their climatic qualities from each other.

Dr. Köppen has compared the temperature, humidity, and other weather conditions at St. Petersburg each day for 1872 and 1873 with daily weather-charts constructed for the whole of Europe, and separated each of the eight winds (N., N.E., E., &c.) and calms into the following

[1] Ueber die Abhängigkeit des Klimatischen Charakters der Winde von ihrem Ursprunge. Von Dr. W. Köppen. (St. Petersburg, 1874.)