conductor; D' = outer diameter of the insulating coat ; I=specific inductive capacity of the gutta percha or other substance consti­tuting the insulating coat. Then

C= I/(2 log*e* D'∕D).

In the case of a single wire of circular section, diameter D, un­disturbed by the presence of others, and supported at a constant height *h* above the earth by poles so far apart as not to influence its capacity sensibly— ∣

θ ~ 2 logβ 4Λ∕D'

Example 1. In a submarine cable in which D'= 1 centimètre ; D = 0’4 centimètre ; and 1=3’2—

I \_3·2x·4343\_ yκ c~21ogeD'∕D~ 2χ∙3979

Example 2. In a land line in which D = 0,6 centimètre and A=600 centimètres— ∣ ∙4343 1

C = 2 log, 4Ä/D = 7∙204 = 16τ6-

The capacity, therefore, is in this case less than one-twenty-ninth of that of the submarine cable of example 1 for the same length.

*Telegraph Testing.*

*Standards of Measurement.—*A brief consideration of the standards according to which the electrical qualities referred to in the last section are measured, and the measurements to be described in this section are made, will render the statements of those qualities and quantities more definite. A complete and universally comparable system of standards for physical measurements can be obtained by adopting arbitrarily as fundamental units those of length, mass, and time, and expressing in terms of these in a properly defined manner the units of all the other quantities. The units now adopted all over the world for electrical measurements take the centimètre as the unit of length, the gramme as the unit of mass, and the mean solar second as the unit of time. There are two systems in use, the electrostatic and the electromagnetic. In the former the mutual forces exerted by two bodies, each charged with static electricity, are taken as the starting-point, and in the latter the mutual forces exerted between a current of electricity and a magnet. The units according to these two systems are definitely related ; but as we deal in the present article with the electromagnetic system we give the following brief account of it only.

The *dyne* or *unit force* is that force which, acting on a gramme of matter, free to move, imparts to it a velocity of 1 centimètre per second. *Unit qτιantity of magnetism* or *unit magnetic pole* is that quantity of magnetism which, when placed at a distance of 1 centi­mètre from an equal and similar quantity of magnetism or a magnetic pole, repels it with unit force. *Unit magnetic field* is a field which, when a unit quantity of magnetism or a unit magnetic pole is placed in it, is acted on by unit force. *Unit current* is a current which, when made to flow round a circle of unit radius, produces a magnetic field of 2π units’ intensity at the centre of the circle, or acts on a unit quantity of magnetism placed at the centre of the circle with 2π units of force. *Unit quantity of electricity* is the quantity conveyed by the unit current in one second. *Unit difference of potential* is the difference of potential between the ends of a conductor of unit length when it is placed with its length at right angles to the direction of force in a unit magnetic field and kept moving with a velocity of 1 centimètre per second in the direction at right angles to its own length and to the direction of the magnetic force. *Unit electromotive force* is produced in a closed circuit if any unit of its length is held in the manner, and moved in the direction and with the velocity, described in the last section. *Unit resistance* is the resistance which, when acted on by unit electromotive force, transmits unit current. *Unit capacity* is the capacity of a body which requires unit quantity of electricity to raise its potential by unity. The units above specified are generally referred to as the absolute C.G.S. electromagnetic units of the differ­ent quantities. In practice their magnitudes were found incon­venient, and certain multiples and submultiples of them have been adopted as the practical units of measurement : thus the *ohm* is equal to 109 C.G.S. units of resistance; the *volt* is equal to 108 C.G.S. units of electromotive force ; the *ampere* is equal to 10-1 C.G.S. units of current ; the *coulomb* is equal to 10-1 C.G.S. units of quantity ; the *farad* is the capacity which is charged to a volt by a coulomb, and is equal to 10-9 C.G.S. units of capacity ; the *microfarad* is the millionth part of the farad, and is equal to 10-15 C.G.S. units of capacity.

We are here chiefly concerned with the units of electromotive force, resistance, and capacity. No universally recognized standard of electromotive force has yet been established, but the want has been to a great extent supplied by the potential galvanometers, electrostatic voltmeters, standard cells, and other instruments devised by Sir W. Thomson and others. The work of Lord Rayleigh, Dr. Fleming, and other experimenters on the Clark and Daniell standard cells has shown conclusively that an electromotive force can be reproduced with certainty within one-tenth per cent. of accuracy by means of either of these cells. Specimens of the standard unit of resistance, or ohm, made of an alloy of platinum and silver, or of platinum and iridium, have been constructed, and can be relied on, if properly taken care of, to remain very nearly accurate from year to year. Similar specimens of the standard unit of capacity or microfarad which remain very nearly constant have been successfully produced. For a fuller treatment of this subject and of the methods of determining the different units, see Elec­tricity, vol. viii. p. 40 *sq.@@1*

Telegraph line testing consists mostly of comparisons of the re­sistance of the conductor and the insulator with sets of standard resistances, and of comparisons of the inductive capacity of the line or cable with standard condensers of known capacity. When, as is sometimes the case, the strength of the current flowing through the line or through a particular instrument is to be determined, it is measured by an electrodynamometer, or by a current galva­nometer, properly constructed for indicating currents in absolute measure. In the absence of such an instrument it may be obtained accurately by the use of a standard galvanometer in a known or determined magnetic field, or, taking advantage of Faraday’s dis­covery of the electro-chemical equivalents, by measuring the amount of silver or of copper deposited by the current when it is made to pass through an electrolytic cell ; or the electromotive force per unit resistance of the circuit may be determined by the use of standard resistances and a standard cell. Space does not allow us to do more than simply refer to these methods, the first two at least of which involve accurate and somewhat difficult experimental work.@@2

*Measurement of Wire Resistance.—*(1) By *Wheatstone's bridge.@@3* Let *l* (fig. 8) be the line with its distant end connected with the earth, *a* and *b* known resistances, *x* a resistance which can be varied, G a galvanometer, K a single lever key, K1 a reversing key, and B a battery. Put the zinc pole of the battery to the line and adjust the resistance *x* until the gal­vanometer G shows no deflexion when K1 is depressed. We then have, assuming no electromotive force in the line, *l=ax1/b.* Next put the copper pole to the line and repeat the test, and suppose in this case *l = ax2/b* ; if these two values of *l* nearly agree the true value may be taken as *2ax1x2*/*b*(*x1* + *x*2). The effect of an electromotive force in the line itself is nearly eliminated by reversing the battery.

(2) Let the battery B (fig. 9) be connected through the keys K1 and K and the galvanometer G with the line *l,* which has its distant end to the earth as before ; shunt the galvanometer by a shunt *s* until a convenient deflexion is obtained, and then take as quickly as possible a series of readings with zinc and copper alternately to the line. Next substitute for *l* a set of resistance coils and vary the resistance until the same series of readings is obtained. The resistance introduced for the reproduction of each reading indicates the apparent resistance of the line when that reading was taken. The readings will generally differ because of the existence of a vari­able electromotive force in the line. If, however, the difference is not very great, the harmonic mean of the arithmetic mean of the

@@@1 For the development of this important part of electrical science, see Weber, “ Messungen galvanischer Leitungswiderstände nach einem absoluten Maasse,” in *Poggendorffs Annalen,* March 1851; Thomson, “Mechanical Theory of Electrolysis,” “ Application of the Principle of Mechanical Effect to the Measure­ment of Electromotive Force, and of Galvanic Resistances in Absolute Units,” and “ Transient Electric Currents,” in *Phil. Mag.,* 1851 and 1852 ; Weber, *Electrodynamische Maassbestimmungen, insbesondere Zurückführung der Strom­intensitätsmessungen auf mechanischen Maass,* Leipsic, 1856 ; Thomson, “ On the Electric Conductivity of Commercial Copper," “Synthetical and Analytical Attempts" on the same subject, and "Measurement of the Electrostatic Force between the Poles of a Daniell’s Battery, and Measurement of the Electrostatic Force required to produce a Spark in Air,” *Proc. Roy. Soc.,* 1857 and 1860; reprint of *Reports* of Brit. Assoc. Committee on Electr. Stand., &c., edited by Prof. F. Jenkin ; Thomson, *Electrical Units of Measurement,* a lecture delivered at Institution of Civil Engineers, 1883 ; *Reports* of the International Conference for the Determination of the Electrical Units, held at Paris in 1882 and 1884 ; A. Gray, *Absolute Measurements in Electricity and Magnetism,* London, 1884.

@@@2 See A. Gray, *Absolute Measurements in Electricity and Magnetism,* pp. 27, 74; also T. Gray, *Phil. Mag.,* November 1886. The following quotation from the art. Telegraph in the 8th ed. of the *Ency. Brit.* shows how comparatively recent is the introduction of anything like absolute measurement in telegraph testing The ordinary test for insulation consists in applying a galvanic battery, with one pole to earth and the other through a galvanometer coil, to the line of telegraph of which the remote end is kept insulated. If the insula­tion of the whole line were perfect, the galvanometer needle would stand at zero ; but, when looked for with a battery of suitable power and a galvanometer of suitable sensibility, indications of a current are always found, unless it is a very short length of very perfectly insulated line that is tested. The absolute measure of the strength of this current divided by the absolute measure of the electromotive force of the battery gives an absolute measure for the insulation of the cable. No telegraphic testing ought in future to be accepted in any de­partment of telegraphic business which has not this definite character, although it is only within the last year that convenient instruments for working in absolute measure have been introduced at all, and the whole system of absolute measure­ment is still almost unknown to practical electricians.” It was put in practice systematically for the first time in 1859, in experiments by Prof. F. Jenkin.

@@@3 For this theory, see Electricity, voL viii. p. 44.