Conductivity and Insulation of Telegraph Lines.

It is often supposed the size of the wire conductor or its conductivity is a measure of its working capacity. When the insulation is unvarying or a constant the strength of current is approximately in proportion to the size of the wire; and, on the other hand, when the conductivity is a constant, the strength of current is increased by increasing the insulation.

The working capacity of a circuit is measured more by the margin or difference between the conductor and its insulation, both being considered as conductors.

Strength of current or strength of signals is not so desirable as action, that is free from interference or counteracting effects. In a mechanical sense, force is less desirable than celerity and regularity of movement, conditions incompatible with a low degree of insulation.

In practice the working capacity of a circuit is dependent more upon its degree of insulation than the low resistance of its conductor. For example, a circuit of one hundred miles, with a No. 5 gauge wire for conductor, with poor insulation, has not the capacity of a No. 11 wire with perfect insulation, or the large wire in hard rain has not the capacity of the small wire in dry, cold weather, both being insulated with the common insulators of the country. The margin between the insulation and the conductor in the conditions of the smaller wire is immensely greater than in the conditions with the larger wire.

Leaving out of question the article manufactured by the proprietor, there is a very great difference in the insulators in use throughout the world as regards their insulating properties in unfavorable weather. In 1867, while on a tour in Europe, standard sets of insulators were procured as specimens from eleven nationalities. In England four sets were obtained, representing the kinds in use by the telegraph companies. During the past eight years these insulators have been used for comparative galvanometrical tests, and the records preserved. Highest among these stands the Prussian, as manufactured in Paris of French porcelain, and the lowest are the English. The highest English is lower than the Swiss glass insulator, which is the lowest of those used on the continent. The best English is more than twenty times below the Prussian. That the standard of insulation in England is very low there is other evidence than these recorded measurements.

Mr. Culley, in his Hand Book, fifth edition, gives the insulation resistance of two circuits, "better situated as regards insulation," Belfast to Dublin as 131,300 units each per mile in rain and "working well." Never have I seen so poor an insulation in this country, except for short portions in cities. With the insulators used in England it would appear almost impossible to avoid such a state of affairs in rain. To lessen these difficulties they are obliged to use very large wire conductors—No. 4, Birmingham gauge—on all the main circuits, being employed, and in some instances No. 3; weight per mile 775 and 909 pounds, respectively.

Another means is the use of ground wires upon the posts, to carry the leaking current to the earth and prevent "confusion of signals."

Further, the use of a separate and independent battery for each circuit. In the London office alone there were in 1873 forty thousand cells employed.

With such an amount of leakage they must necessarily operate on the open circuit system, and this involves the use of a battery wherever transmission is performed. This system has some advantages, but is not economical.

In France and Prussia a different state of affairs exists. Reference is made to these nationalities because their circuits are longer, consequent upon covering a larger territory.

In these countries the large conductors are five millimetres in diameter. The weight of these wires are about 525 pounds per mile, and are called the international lines because they are worked direct from capital to capital, distances more than twice the length of the longer circuits in England.

Upon these circuits the Hughes printer is employed. The capacity of these instruments is about twice that of the *Morse*, or is so rated by the officials of England, France, Prussia and Belgium. Two operators perform with these instruments with one wire as much as four operators in this country with one wire, using the double transmission system.

For the ordinary circuits in France a wire of three millimetres is used; weight, per mile, about two hundred pounds.

In Prussia the ordinary lines are two and a half millimetres in diameter; weight, about 150 pounds.

The officials of these countries, Prussia and France, state they have no difficulty in operating these wires in rain with the Hughes printer at its full speed and capacity. These instruments are used on all the important circuits. In the main office, Paris, seventy-five of these instruments are employed. In London fifteen, and those on the shortest circuits. The reason given for not using them on the longer circuits in England was that they were unable to operate them in unfavorable weather.

The minimum price of a dispatch in France and Prussia is about half a franc. It was raised temporarily in France as a means of revenue to provide for the debt incurred in the late war with Prussia. In England the minimum is one shilling, or about two and a half times greater.

There is a commendable ambition in each of these countries to bring the use of the Telegraph within the means of all the people—to cheapen the rates. Can any one give a reason why it is so much more expensive in England, except on account of the poor insulation in that country? The wires in England are more than twice as large as those of the former countries; they cost fully double; it requires twice as many wires and operators to perform the same amount of service. In each of those countries the Telegraphs are maintained as a public convenience, and not as a source of revenue; but if we are to believe the statements circulated in this country the administration of the Telegraph in Great Britain is attended with a very heavy deficit, notwithstanding these greater rates charged for transmission.

In an article recently published by Mr. Culley, Chief Engineer of the British Telegraphs, he refers to the use of wires of large diameter as follows:

"The most decided effect of substituting wire of $\frac{24}{100}$th of an "inch for that of $\frac{17}{100}$ of an inch (the latter being more extensively "used) is the absence of the inconveniences resulting from defective "insulation. This advantage has been actually demonstrated many "times in practice. Comparing two wires put up between the same "cities and equally well insulated, it has been discovered that by "means of the large diameter wire the signals are reproduced dis-"tinctly and that the communication is perfect, while in using the "wire of small diameter the transmission is more difficult on account "of the weakness of the current. The correctness of Ohm's law "has been thoroughly confirmed by these experiences."

$\frac{24}{100}$ths

Ohm's law may be thoroughly confirmed by these experiences, but it is also a more striking demonstration of the expense of poor insulation, a $\frac{17}{100}$th of an inch diameter galvanized wire weighs 800 pounds per mile, a $\frac{24}{100}$th of an inch diameter wire about 400, or half as much as the former.

$\frac{17}{100}$

In the same paper he states "the longest circuits are from London "to Cork and from London to Aberdeen, which is from four hundred "and thirty to five hundred and sixty miles respectively."

The longest circuit of this country, from San Francisco to Ogden, one thousand miles, has a No. 9 wire, but portions running over the mountains are of No. 11 steel. So far as resistance of conductors are concerned, the advantages are in favor of the London Aberdeen line, in the proportion probably of 5 to 1. In England about twenty posts are used to the mile. On the San Francisco Ogden line, twenty-five; say there are twice as many insulators on the latter; as regards number of insulators, this circumstance is in favor of the English line in the proportion of 2 to 1.

We now come to the quality of the insulation. Mr. Culley says on the long circuits the double bell insulator is used. In 1868 a set of these double bells, with Ebonite covered stalks, were placed side by side for galvanometrical tests and comparison with a set of the insulators taken from those furnished for the San Francisco Ogden line. The comparative tests in rain in favor of the latter for the past six years, are more than 1,000 to 1. Nor has this San Francisco Ogden circuit during this time been in the least affected by rain. It is in the direct line from San Francisco to New York, and commercially one of the most important circuits in the country.

The defective character of the insulation in England is admitted by every person connected with the Telegraph, but the cause is often stated to be their peculiar climate; very humid and smoky. The rains are very frequent, but they are light rains, the air is seldom fully saturated and the rains are of short duration compared to the rain storms of this country. Ordinary insulators in this country in rain are affected proportionately as the air becomes charged with moisture. In the winter months this often occurs and is notably the case when the ground is covered with melting snow, and the rain is from the South. North-East storms begin with the wind from the North-East. Usually the wind changes to the East and South and finally clears up with the wind from West or North-West. During the portion of the storm when the wind is from the South-East and South, the air is charged to its full capacity, or total saturation. It is during this time that the ordinary glass insulator is most affected. When the storm is accompanied by the wind changing in the other direction, that is from North-East to North, and finally to North-West, then the insulation is much less affected because the atmosphere is seldom charged to over 80 per cent. of full saturation.

With the English insulator the case is different. Five minutes of moderate rain brings it down to its minimum of resistance, a point at which it remains until the weather clears.

All the later and improved methods and processes, such as automatic and double transmission, require the better degree of insulation.

The English labor under the disadvantage of a smoky atmosphere, and in that respect have more to contend with than we do. On the other hand in cities their wires are under ground and out of the influence of such causes. The Belfast and Dublin lines in Ireland are less affected by such causes than the majority of lines in this country. In this country the insulation in the cities is most affected. In Philadelphia the atmosphere is quite clear for a city, especially so, when we take into consideration the large extent of its manufactures. The reason of this is the coal used here is the anthracite. It gives very little smoke, but a gas arises from its combustion that produces its effects upon insulators. In this localiiy an ordinary glass insulator in rain shows a resistance of from four to six million units when measured with a battery of ten cells. In the country, outside of the city, the same insulators in corresponding weather will show a resistance of from sixty to one hundred millions; its insulation appears at least tenfold better. In the city in this locality the glass insulators are clean from exposure to rain; but if we take an insulator from the neighborhood of the gas works—one that is coated with soot—its resistance in rain is less than a million. While such an insulator is much worse than one that is apparently clean yet the latter are seriously affected. The gases from combustion unite with the moisture of the atmosphere and form an acid solution, and it is a solution of this nature upon the insulator which conducts in an immense degree compared to the pure rain of the country. The great difference in the resistance of the pure rain water of the country and that collected in the cities is a measurer of the impurities contained in the latter. These impurities in some instances increase its conductivity hundreds of times.

In Pittsburgh, two miles of line, about sixty common glass insulators, in rain gave an insulation resistance of less than a million units per insulator. These insulators were up not two years and were coated with soot.

The patent insulator is not affected by these conditions. It is as repellent of acids as of moisture. It can be used to immense advantage for the insulation of wires in cities. To simply insulate the wires in the cities in this country will raise the total insulation of the lines a hundred per cent. or more.

It is about seven years since the present insulator was introduced. There have been more than a hundred certificates given of its performance and not a single complaint of its insulating qualities. But its merits are not rested upon the opinions of those who have used them. If they do not fully and completely protect the good working of lines from the effects of humidity, rain, smoke, &c., in any climate or country, there will be no charge for their use.

I may have those wrong in the copy but you when I referred to the automatic—please see—

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