ELECTRIC TELEGRAPH CONDUCTORS.

CHAPTER XXXVII.

Composition of Telegraph Circuits—Conductibility of Metals and Fluids—Conducting Power of different sizes of Copper Wire—Conducting Powers of Telegraph Wires—Advantages of Zinc-Coated Wires—Conductors composing a Voltaic Circuit—Strength of Telegraph Wires—Scale and Weight of Telegraph Wire.

COMPOSITION OF TELEGRAPH CIRCUITS.

In the present chapter will be considered electric telegraph conductors. There are but two questions necessary to be discussed; first, the conductibility of the metals and other materials composing the voltaic circuits; and, second, the strength and durability of the metallic substances employed as component parts of the circuit.

A telegraphic circuit is composed of iron wire, copper wire, mercury, brass, tin, platina, zinc, acidulated water, and nitric acid. This arrangement contemplates the use of the Grove battery. The Smee, Daniell, Bunson, and other batteries, are sufficiently near the same organization, as to conducting elements, to be considered as equivalents. In regard to the conductibility of metals there seems to be some difference of opinion. Different experiments have produced different results.

CONDUCTIBILITY OF METALS AND FLUIDS.

Some experiments instituted by M. Becquerel produced the results indicated in the following table. The conductibility of each metal is given respectively.

Copper wire	100	Platinum wire	16.4
Gold "	93.6	Iron "	15.5
Silver "	73.6	Lead "	8.3
Zinc "	28.5		

The following is the result of some experiments mentioned in the German works.

Silver	136	Platinum	22
Gold	113	Iron	17
Copper	103	Mercury	2.6
Zinc	28		

This table is to be understood thus: a copper wire 100 feet in length, offers as great a resistance in the transmission of an electric current, as silver wire, of equal thickness, 136 feet long; of gold 113 feet long; of iron 17 feet long, and so on with the other metals.

Mr. Moses G. Farmer, of Boston, instituted thorough experiments, and the following were found to be the relative conductibility of the respective metals and fluids. The specific resistance to the transmission of electric currents, compared with chemically pure copper at ordinary temperatures, was, of

Copper wire	1.00	Tin wire	6.80
Silver "	.98	Zinc "	3.70
Gold "	1.13	Brass "	3.88
Iron "	5.63	German Silver wire	11.30
Lead "	10.76	Nickel "	7.70
Mercury	50.00	Cadmium "	2.61
Palladium wire	5.50	Aluminum "	1.75
Platinum "	6.78		

His experiments with fluids produced the following results:

Pure rain water,	40,653,723.00
Water twelve parts and Sulphuric Acid one,	1,305,467.00
Sulphate Copper one pound per gallon,	18,450,000.00
Saturated Solution of Common Salt,	3,173,000.00
Saturated Solution of Sulphate of Zinc,	17,330,000.00
Nitric Acid 30° B.,	1,606,000.00

CONDUCTING POWER OF DIFFERENT SIZES OF COPPER WIRE.

Experiments showing the relative resistance of Nos. 18 *and* 16 *copper wire, insulated by double covering of gutta-percha, and submerged in the Regent's Canal, London.*

No 18 gauge copper wire, covered with gutta-percha to gauge No. 7.

No. 16 gauge copper wire, covered with gutta-percha to gauge No. 4.

An ordinary single needle instrument was employed—connected to earth, as usual in practice.

100 miles.	No. 18.	No. 16.	
With 3 pairs of plates	29°	39°	deflection of needle
" 6 "	50°	59°	"

The same instrument employed, but the needle slightly weighted:

Battery of 72 pairs plates.	No. 18.	No. 16.
100 miles	23°	30°
90 "	25°	
80 "	26½°	
70 "	28½°	
65 "	30°	

Battery of 144 pairs plates:	No. 18.	No. 16.
100 miles	35°	41°
90 "	37°	
80 "	38½°	
70 "	40°	
65 "	41°	

Battery of plates:	No. 18.	No. 16.
100 miles 72 pr. plates	23°	30°
100 " 84	26°	
100 " 96	28½°	
100 " 102	30°	

According to the above experiments a wire, No. 18, has capacity to conduct a given voltaic current 65 miles, and No. 16, 100 miles. Suppose the conductibility of iron wire, Nos. 8 and 10, have equal powers as Nos. 16 and 18 of copper, respectively; on a line of 300 miles No. 8, iron wire, can be worked successfully, but the No. 10 could be worked but 195 miles; or, if No. 10 wire can work maximum 300 miles, No. 8 could be worked 461 miles. These facts clearly prove a very great advantage in the use of the larger size wire for telegraphic purposes. This is an important matter, and it is worthy of being very gravely considered by companies having lines on long routes, where long circuits are required. For example, suppose a line to be 900 miles long, using No. 10 wire, a size common on American lines, the practical circuits would be about 300 miles each. If the wire be No. 8, a circuit of 461 miles can be as effectually operated, with a battery of a little more *intensity* than that employed for the 300 miles circuit, and, therefore, the line of 900 miles can be operated in two circuits of 450 miles each. In the use of the larger wire there will be economy, resulting from its increased strength. There will also be a saving of expenses in three years, by the lessening of repeating stations, sufficient to pay for the additional cost of No. 8 wire for the 900 miles of line.

CONDUCTING POWER OF TELEGRAPH WIRES.

Considering the above-mentioned facts, and others observed in my experience, I am convinced that the larger conductor is the best for telegraphic purposes, pecuniarily and electrically considered. On the Bengal lines, No. 1 iron rods are used for conductors, and those lines are successfully worked in long circuits. The philosophy establishing the surface as the part, on or through which the current moves, adds further proof in favor of the larger wire. In practical telegraphing we have had many proofs establishing the advantage of full metallic surface. In Pittsburg, and many other cities, where great quantities of coal are daily burned, the sulphurous vapors arising from such fuel, in a very short time, corrodes the iron wire, leaving but very small metallic substance to serve as a conductor. These corroded wires have frequently been replaced by new ones, and the increased facility in telegraphing at once realized. To remedy their rapid decay, zinc coated wires have been adopted, and their durability is greatly extended; nevertheless, in time, they too yield to the devouring elements; the sulphurous vapors, passing over the oxyde of zinc covering, convert it into sulphate of zinc, which being soluble in water, is immediately dissolved by the rain and drops off. The wire being thus deprived of its insoluble armor, rapidly corrodes.

ADVANTAGES OF ZINC-COATED WIRES.

Many of the American lines have in use zinc-coated wires—commonly but improperly called "galvanized"—and their use has given great satisfaction. The advantages realized from the use of the zinc-coated wires, in the perfection of the joints, are sufficient to compensate for their general adoption. The economy to any company resulting from this one point of consideration is more than can be estimated by comparative values. Besides this, the wire for the whole line is preserved in its full metallic surface, and its conductibility is made even and continuous. On a line of 300 miles, if one mile of the line wire be reduced in size from that of the other 299 miles, the one mile of faulty wire will be a continual retardation to the flow of the current on the 299 miles of good wire. The trials given zinc-coated wire have established, beyond doubt, very great advantages in favor of its use for telegraphic purposes.

Objections have been made to the use of zinc-coated wire, in the Southwest, especially across prairies, where there are no trees to serve as auxiliaries in conducting the atmospheric electricity to the earth. A telegraph wire traversing forests can not be disturbed by atmospheric electricity, while on the other hand, when it traverses open fields, or prairies, it is very liable to serious interruption from that source. The use of the zinc coated wire, across these open plains, affords a greater metallic surface for the atmospheric electricity. If the iron wire was of equal size without the zinc, the result would be in proportion to the conductibility of iron and zinc. It is *not* the zinc that induces the atmospheric electricity to localize upon the line wire. The conductibility of zinc is $3\frac{7}{10}$ and that of iron is $5\frac{6}{10}$ The zinc, it is true, has a great surface or circumference, but that additional surface does not give it an equal power with the iron. It cannot be maintained, therefore, that the zinc is at fault in the premises. If the wire was copper, the interference would be much greater than with the iron and zinc. From these facts it may be said, that the better the conductor, the greater the interruption. Such a conclusion may be very true, but the cause and effect must be considered philosophically. In Sardinia, the lines have been constructed to meet the case. To each pole is attached a paratonnerre or lightning rod, which conducts to the earth the atmospheric electricity, and they have no interruption to retard the successful working of the lines. It is reasonable to believe, that if earth-wires were run from the tops of the poles into the moist earth, the working of the line wires would not be disturbed by atmospheric electricity. Such an arrangement throughout the line would be expensive, and most likely never will be tried in America, although it would be strictly conformable to established philosophy. From the facts above cited, it will be seen that the use of zinc-coated wires is promotive of the durability and working of the lines, and in no case injurious to successful telegraphing.

Some telegraphers may insist upon the truth of the questionable theory that the brightness of the zinc tends to attract atmospheric electricity. The use of a cheap paint would remedy that objection, and at the same time add to the protection and preservation of the wire. On making the joints, however, care should be taken to remove the paint so as to cause a perfect metallic contact. I am not prepared to believe, however, that the paint would be of any advantage. Dry paint serves as a non-conductor, and when the wire is covered with a film, the whole becomes a Leyden jar. The wire inside is charged and the dry paint acts as the glass of the Leyden jar, and on the exterior is collected the negative electricity from the atmosphere. The presence of this negative influence retards the interior or positive current, and thus the telegraph is disturbed to the extent of the retardation. On ordinary wires, covered with dry oxyde, the same philosophy must be considered. These philosophical considerations are worthy of attention, though, perhaps, their importance may not seem appreciable in practical telegraphing.

CONDUCTORS COMPOSING A VOLTAIC CIRCUIT.

The conductors common to a telegraphic circuit may be considered as 1st, iron; 2d, copper; 3d, brass; 4th, zinc; 5th, tin; 6th, platina; 7th, nitric acid; 8th, water, pure and acidulated; and, 9th, the earth.

1. The principal conductor used by the telegraph is iron. The size of this conductor should be commensurate with the length of the circuits desired.

2. The copper wire used, is confined to the interior of the station, and they should be fully equal in size to the relative conductibility of the iron wire; thus, a copper wire may be $5\frac{63}{100}$ less in circumference than the line iron-wire.

3. The brass connections should be full, so as to form a contact with the copper wire sufficient to secure an equal conducting capacity with the iron. Usually the connections with the apparatuses through the brass binding screws or posts are greatly at fault, not having as much metallic contact as necessary.

4. The zinc metal in the circuit is confined to the battery, and that part of the circuit is seldom at fault.

5. Tin is used for solder, and though a better conductor than iron, yet the amount of contact is very often inferior, and far more at fault than any other part of the circuit. By studying the table given by Mr. Farmer, the telegrapher can readily determine to what extent he should make the metallic contact with the solder, especially in the battery.

6. The platina strips used in the battery, and in the key, should be sufficiently large to give its full ratio of conductibility in the circuit; and, also, to present surface sufficient to afford contact with the acid, so as to meet the lesser conductibility of the nitric acid held in the porous cup.

7. The nitric acid is placed in porous cells, through which it penetrates. It is necessary to form a contact with the platina, sufficient to give conducting medium equal to the other component parts of the circuit. It will be observed that the conducting power of nitric acid is about 260,000 times less than iron, and the metallic contact with the fluid should be commensurate with that law.

8. The water employed in the battery cells should be acidulated. I have known some operators to collect pure rain-water and use it unacidulated. Of course, as soon as the nitric acid passed through the porous cups, its conducting power was increased. Some telegraphers have supposed that the pure distilled water was the best for conducting purposes and for generating electricity. Many such errors have been practised to the detriment of the working of the telegraph. The acidulated water, in which the zinc is immersed, has about 216,000 times less conducting power than iron, and its contact with the zinc should be equal to the line wire.

9. The earth serves as a half of the circuit. The connection between the earth and the line should be equal to the conducting power of the wire. The earth wire should be attached to copper plates, or sheets, to afford the required surface. Iron

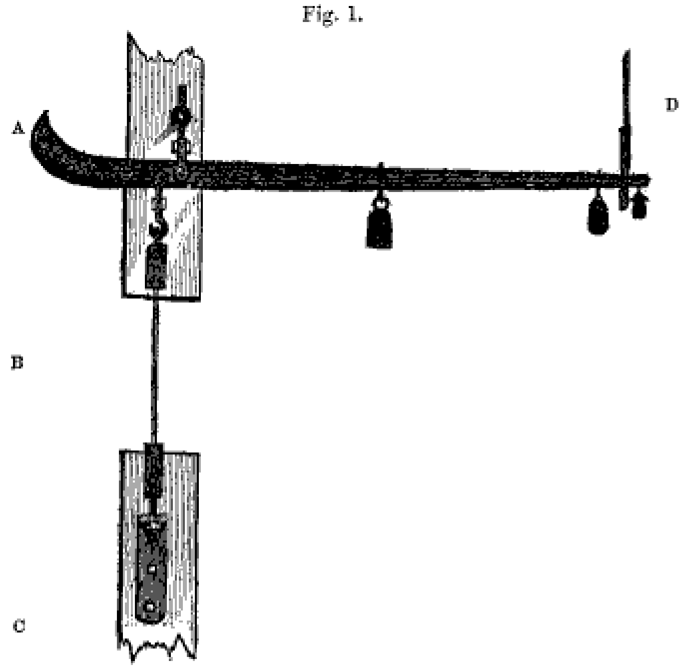
plates would answer if it did not so quickly decay. Sheet iron electro-plated with zinc or copper would answer fully the purpose required. The earth plate, of whatever metal it may be, should be buried in moist earth, and the greater the moisture the better will be the circuit. The iron wire next to and in the earth, ought to be coated with tin or zinc to prevent its decay.

I have, in the foregoing, briefly considered the component parts of the electric circuit; and the practical telegrapher can readily see that he cannot too well understand the philosophy of the media, composing the conductors of the voltaic circuit. A uniformity of the conducting powers will always prove of the greatest value in the attainment of telegraphic success.

STRENGTH OF TELEGRAPH WIRES.

During the winter of 1858–'9 I instituted a series of experiments testing the strength of various sizes and qualities of iron wires. In these I was most liberally aided by Messrs. Ichabod Washburn & Co., wire manufacturers at Worcester, Massachusetts. This old established firm provided the various qualities of wire and the necessary appliances and help to enable me to effect the most thorough investigation. The average results of

Fig. 1.



the trials, as to the strength of the wires, are given in the accompanying tables. To test the wire, an ordinary steelyard was employed, as represented by fig. 1: A is a suspended timber, to which was swung the steelyard; B is the wire undergoing the test; C is an upright timber; D is an iron rod fastened to the joist. At the lower end of the rod D is an opening through which the beam is passed. This opening is scaled to limit the movement of the beam within a foot. Whenever the wire stretches and lets the beam descend to the lower end of the opening, the screws at C can re-adjust the scale so as to allow the weight to again bring down the lever beam to its limit. The wire frequently broke within the clamps, and could not be counted. Only the breaks that occurred at B were recorded. The averages of these trials are given in the table. Table 6 shows some tests of wire not as strong as the wire of the other trials. The wire of each kind, viz.: Swedish and American, was from the same qualities and the same lot of iron. The difference in the strength, is owing to the manner of drawing. Messrs. Washburn & Co. have attained this superiority of strength by many years of careful experiment. Most of the telegraph wire used in America is manufactured by these gentlemen, and the peculiar wants of the enterprise have been carefully studied and accommodated by special arrangements. It is important for telegraphers to consider the peculiar wants of their line, and to have the wire manufactured to meet every contingency. Mr. P. L. Moen, of the above-named firm, informs me that the toughness of the wire depends as much upon the drawing, as upon the quality of the metal. I have frequently visited their establishment, and have been highly gratified to see the great care exercised to attain the greatest degree of perfection in the manufacture of the wire to meet the especial wants of the telegraph. The telegraphic enterprise has reason to rejoice that these gentlemen have done so much and are continuing their attentions, regardless of expense, toward the accomplishment of every consideration, having in view the perfection of the art of telegraphing, so far as can be attained in their specialty.

The earlier lines of telegraph were constructed with *annealed* wire. No builder would use *un*-annealed wire, nor would any company have any other kind employed. It was required to be *well* annealed, and the more pliable it was, the more acceptable. The experiments given in Table 4 show how great was the folly of the earlier ideas relative to the use of annealed wire. It cannot be denied, however, but what the wire should be slightly annealed, so that the joints can be made with rea sonable facility. The coating of the wire with zinc accomplishes this desideratum, and slightly anneals it. The difference in the strength, between the annealed plain wire, as table 4, as practically required some twelve years ago, and the zinc coated annealed wire, given in the other tables, will be seen to be very considerable.

The trials, given in the following tables, were made with much care, all under my own direction and observation. They are worthy of the telegrapher's careful study:

Table 1.

SWEDISH IRON WIRE.

No.	Plain Iron broke at	Zinc-Coated broke at	No.	Plain Iron broke at	Zinc-Coated broke at
6	2,490	2,300	10	1,430	1,270
7	2,370	2,176	11	1,185	1,030
8	2,925	1,993	12	1,020	921
9	1,748	1,495	13	770	665

Table 2.

ENGLISH IRON WIRE.

No.	Plain Iron broke at	Zinc-Coated broke at	No.	Plain Iron broke at	Zinc-Coated broke at
6	2,050	1,945	10	960	935
7	1,670	1,500	11	740	725
8	1,580	1,365	12	635	670
9	1,270	1,055	13	550	445

Table 3.

AMERICAN IRON WIRE.

No.	Plain Iron broke at	Zinc-Coated broke at	No.	Plain Iron broke at	Zinc-Coated broke at
6	2,390	2,300	10	1,385	1,270
7	2,210	2,010	11	1,155	1,043
8	1,985	1,820	12	992	832
9	1,665	1,520	13	885	641

Table 4.

The following table shows the result of the trials of the strength of some annealed wire, taken from the lot of the English wire:

No. 7 broke at	1,173	No. 11 broke at	618
" 8 "	1,030	" 12 "	410
" 9 "	815		

Table 5.

In 1853 I instituted some experiments at the same establishment, and the following were the average results:

No. 10, zinc coated,		broke at....	925 lbs.
" "	annealed	"	875 "
" Plain	"	"	1,050 "
" "	not annealed	"	1,300 "

Table 6.

In January, 1859, I tested, at the same establishment, some wire manufactured for commercial purposes from the same quality of bars, from which were drawn the samples tested in the experiments of January and February, 1859. It will be found to be of much less strength than the wire manufactured for telegraphic purposes.

	American.	Swedish.
No. 6	1,940	2,020
7	1,675	1,640
8	1,550	1,430

SCALE AND WEIGHT OF TELEGRAPH WIRE.

The mode of measuring wire has not been uniform or based upon any fixed standard. The two leading rules are the Birmingham gauge of England, and the Washburn gauge of America. The former measures the wire by passing it through a fixed opening, between parallel lines; the latter, by passing the wire between steel bars, fixed at an acute angle resembling a very elongated v. The wire descends the opening until its diameter rests against the sides forming the isosceles triangle, and the points marked upon the sides, gives exactly the size of the wire. This gauge is a great improvement over all other forms, because the fractionals can be given. If the wire is $10\frac{1}{2}$ or $10\frac{1}{4}$ or $10\frac{1}{8}$, the Washburn measure can indicate it exactly.

This novel improvement in measuring the diameter of any sized wire is the recognized gauge of America, and is known as the "Washburn gauge." The weight of the wire according to this scale is given in the following table:

Table 7.

WEIGHT OF IRON WIRE PER TWENTY FEET, BY WASHBURN GAUGE.

No. 1 weight	4 lb. 2 oz.	No. 8 weight	1 lb. 7 oz.
2 "	3 " 8 "	9 "	1 " 2 "
3 "	2 " 15 "	10 "	14 "
4 "	2 " 8 "	11 "	10 "
5 "	2 " 5 "	12 "	9 "
6 "	1 " 14 "	13 "	6 "
7 "	1 " 10 "		

No. 7 weight of iron wire per mile	430 lbs.
8 " "	375
9 " "	320
10 " "	250
12 weight of copper wire per mile	176
16 " "	63
18 "	38

Table 8.

WEIGHT AND MEASUREMENT OF ENGLISH WIRE.

No.	No. of feet per lb. Ft.	in.	Birmingham Gauge.	Yards per cwt. about	
No. 1	4	3	$\frac{5}{16}$	140	galvanized.
2	5		$\frac{9}{32}$	170	"
3	6		$\frac{1}{4}$	210	"
4	7		$\frac{15}{64}$	240	"
5	8		$\frac{14}{64}$	275	"
6	9	6	$\frac{13}{64}$	320	"
7	12		$\frac{3}{16}$	400	"
8	13	6	$\frac{11}{64}$	450	"
9	16	6	$\frac{10}{64}$	550	"
10	21	6	$\frac{9}{64}$	730	"
11	28		$\frac{1}{8}$	950	"
12	33		$\frac{9}{80}$	1,150	"
13	41		$\frac{1}{10}$	1,420	"
14	55		$\frac{7}{80}$	1,900	"
15	66		$\frac{6}{80}$	2,300	"
16	90		$\frac{1}{16}$	3,100	"
17	17	7		4,000	"
18	16	2		5,200	"
19	22	2		7,000	"
20	33	1		10,500	"