23. Telegraphy

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CHAPTER I

TELEGRAPH LINE

Circuit.—A telegraph circuit between two stations consists of the telegraph apparatus at both stations, the insulated line of wire connecting the two sets of apparatus, and a return connection either by a second wire, or by means of the conductivity of the earth. The former would be known as a "metallic" circuit, the latter as a "single" wire, or circuit with earth return.

Line Wire.—The most suitable materials for the line wire are iron, copper, and phosphor-bronze; the first because of its cheapness, copper and bronze on account of their higher conductivity and durability as compared with iron, more especially in chemical manufacturing districts, and in large towns where acid impurities in the air vigorously attack iron wire and shorten its life. For short circuits and those long circuits not requiring a high speed of working, galvanized-iron wire or bronze wire is used—the latter where the life of iron wire would be less than, say, five years, i.e. would be comparatively short. Copper wire is employed for long circuits equipped with fast-speed automatic or quadruplex apparatus.

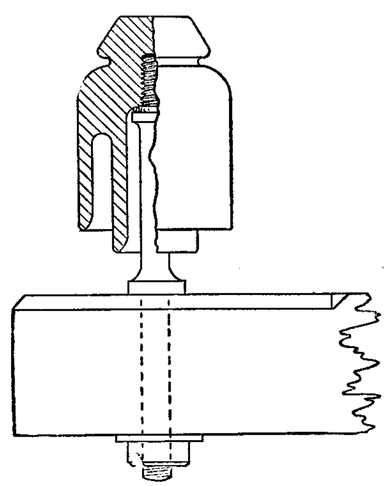

Fig. 1.—Insulator and Bolt

The tables on p. 2 give details of the wires in common use.

Insulator and Spindle.—The line wire is supported by being bound to porcelain insulators screwed on to steel spindles (fig. 1). At the base of the thread on the spindle an india-rubber or felt washer is placed to prevent injury to the brittle thread of the insulator when the latter is screwed firmly down. Iron wires are bound to the insulator by small-gauge galvanized-iron wire (60 lbs. per mile). Copper

Iron Wire

Weight per mile in lbs.	Approximate S.W.G.	Diameter in inches.	Resistance in Ohms per mile at 60° F.	Minimum Breaking Stress in lbs.
400	7.5	.171	13.32	1240
200	10.5	.121	26.64	620
60	16	.066	88.8	...
Hard-drawn Copper Wire				
800	4.5	.224	1.098	2400
600	6	.194	1.464	1800
400	8	.158	2.195	1250
300	9.5	.137	2.928	950
200	11.5	.112	4.391	650
150	13	.097	5.855	490
100	14	.079	8.782	330
181	7/19	...	4.86	630
112	3/18	...	7.87	350
Bronze Wire				
150	13	.097	12.14	730
70	16	.066	26.00	345
40	18	.05	45.50	197

and bronze wires are first wrapped with a tape of copper or bronze respectively, to prevent the insulator from chafing the "skin" of the wire (which is characteristic of hard-drawn wire and in which its strength chiefly lies), and a binder is then applied. This is of copper (or bronze) wire, approximately the same gauge as the line wire, and flattened at both ends. The centre, i.e. the cylindrical part, is placed in the neck of the insulator on the side opposite to that on which the line wire rests, and the ends are then wrapped tightly in reverse directions round the taped line wire. The tapes are 17 to 23 inches long, according to the gauge of the line wire, and the binders 15 to 18 inches. Experience over many years has proved this method of binding to be most efficient.

Arms.—Well-seasoned oak—British or Russian—which has been open-stacked for three months after being planked, is preferred for arms. After being cut the arms are treated with creosote: the process is dealt with in the paragraph on "Poles". The scantling varies from 2½ inches square to 3½ by 3 inches, depending on the length of the arm, the number and gauge of the wires to be carried. Holes for the insulator spindles are bored 3 inches from the end, and if the arm carries more than two wires the inner holes are spaced at 12-inch or 9-inch centres from the outer ones, the 12-inch spacing being used for main lines with heavy-gauge wires, and the 9-inch for lines consisting of light-gauge copper or bronze wires.

Arms carrying more than two wires are provided with an earth wire, which is stapled along and also encircles the arm between every two insulators. At the centre where the arm is bolted to the pole the earth wire is put in metallic connection with the pole earth wire (see "Pole Fittings") by being clamped beneath the washer of the arm bolt. This arm earth wire is for preventing leakage from one wire to another.

Poles.—Red fir from Norway, Sweden, and Russia is most generally employed for telegraph poles. Home-grown larch is used to a small extent. The trees should be hard-grown (indicated by closely pitched annular rings), sound, free from large or dead knots, and be felled when the sap is low, during the months November to February inclusive. The natural butt of the tree must be left on. After the outer and under bark have been stripped off, the timber is cross-stacked in the open until thoroughly seasoned. It is then usually subjected to a preservative process to eradicate germs in the pores liable to bring about early decay. Various processes are used—burnetizing, consisting of the injection of zinc chloride solution into the poles; boucherizing, in which green timber is soaked in a solution of copper sulphate; and kyanizing, used to some extent in foreign countries, consisting of treatment with corrosive sublimate. But none of these has been found so effective as creosoting for preserving poles subjected to the varying conditions of climate in the United Kingdom. The poles, when well-seasoned and perfectly dry, are placed in cylinders, which are then closed at the ends and made air-tight. Air is withdrawn and creosote pumped in until the pressure of the latter is from 100 to 150 lbs. per square inch, and 10 to 12 lbs. of creosote per cubic foot of timber has been absorbed. A recent modification, known as the Ruping process, provides for the subsequent extraction of half the creosote, leaving 6 lbs. per cubic foot; the sap-wood being well impregnated is rendered aseptic, harmful bacteria are destroyed, but the excess creosote is recovered, which in the older process oozed gradually out of the poles after they had been erected, and was lost.

Poles for telegraphs range from 16 to 80 feet in length. They are classed as light, medium, and stout, according to the diameter (*a*) at top, and (*b*) 5 feet from the butt.

Length.	Light.		Medium.		Stout.	
	At top.	5 ft. from butt.	At top.	5 ft. from butt.	At top.	5 ft. from butt.
Feet.	Inches.	Inches.	Inches.	Inches.	Inches.	Inches.
16–20	5	6	—	—	—	—
24	5	6.5	5.5	6.75	—	—
28	5	7	5.75	8.5	—	—
30	5	7.25	6	8.75	7.5	10.75
40	5	8	6	9.75	7.5	12
50	5.25	9.5	6.5	11.5	7.75	13.75
60	5.5	11	7	13.25	8	15.5
70	6.5	13	7	14.75	8	17
80	—	—	7	16.25	8	18.75

The length and class of poles to be used on a route are determined by (*a*) the number of wires that will be carried ultimately, (*b*) the character of the road, its configuration and exposure to gales, and (*c*) providing a factor of safety of 8 to 10. The latter is governed by the weight of the wires acting vertically downwards, the lateral stresses at angles in the line, which vary as the wires contract and expand under changes of temperature, and the wind pressure on poles and wires, usually taken as 17 lbs. per square foot of effective area. The latter is calculated for telegraph purposes as 0.66 × diameter × length of wire, although for general purposes it is frequently taken as 0.5 × diameter × length.

Pole Fittings.—Before poles are erected, the arms and other fittings are put in position. The top of the pole is protected by being cut to shape and having a roof of galvanized iron nailed on it. When a wire has to be carried on the top, the insulator spindle is fixed on a special form of bracket known as a saddle (fig. 2). At an angle in the line the saddle is strengthened by a stay consisting of a strip of hoop iron fitted as shown in fig. 3.

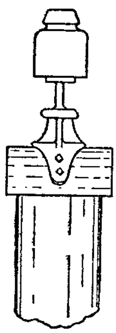

Fig. 2.—Saddle Bracket

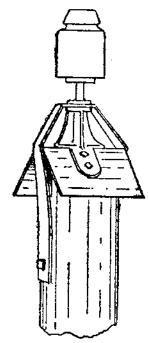

Fig. 3.—Saddle Bracket with Stay

An earth wire is provided, consisting of a No. 8 S.W.G. galvanized-iron wire, which is coiled in a flat spiral of three or four turns stapled to the bottom of the butt, and then run up and stapled to the pole, looped to encircle each arm bolt, so as to connect with the earth wires on the arms, and ending 3 inches above (but not touching) the roof of the pole. This wire acts as a lightning conductor, and also as a path to earth for currents that leak off the circuits at the insulators. In very wet weather these leakage currents would otherwise cause partial contacts between the circuits, the disturbance increasing with the length of the circuits, so that the longest circuits, which are invariably worked at high speed, and must be kept in a high state of efficiency to maintain the speed of working, would be seriously affected.

Slots $1\frac{1}{2}$ inches deep, spaced at 12-inch centres, are cut for the arms and painted thickly with creosote and tar. The arms are bolted to the pole by means of $\frac{1}{2}$-inch galvanized-iron bolts, or by $\frac{5}{8}$-inch bolts for arms carrying more than four wires when fitted on single poles.

Between the bottom arm and a point approximately 24 feet from the ground, galvanized-iron pole-steps held firmly by coach-screws are fitted 15 inches apart on alternate sides of the pole, so that repairs may be carried out without the aid of long ladders.

Stays.—At angles in the route, where a pole cannot itself withstand the lateral stress, it may be strengthened by a stay or a strut (figs. 4 and 5).

The stay-wires in common use are of four or of eight No. 8 S.W.G. galvanized-iron wires stranded, having breaking weights of 53 cwts. and 90 cwts. respectively. The stranded wire is taken twice round the pole, and just above the ground line is attached to an adjustable stay-tightener and iron rod. The top end of the latter passes through the bottom of the tightener, and has a thread and nut for tightening the stay-wire as required, and the bottom end is bolted through a creosoted wood block (10 inches by 5 inches; 2 feet to 3 feet 6 inches long) buried at least 4 feet in the earth.

In addition to stays for lateral stresses, longitudinal stays, i.e. stays fitted in the plane of the wires, are provided on main lines. Their utility comes into play when a tree falls, or a storm completely severs the line, allowing the total stress of all the wires to act directly on an otherwise unsupported pole, which would give way and allow the stress to run back along the line from pole to pole, probably wrecking a great number of

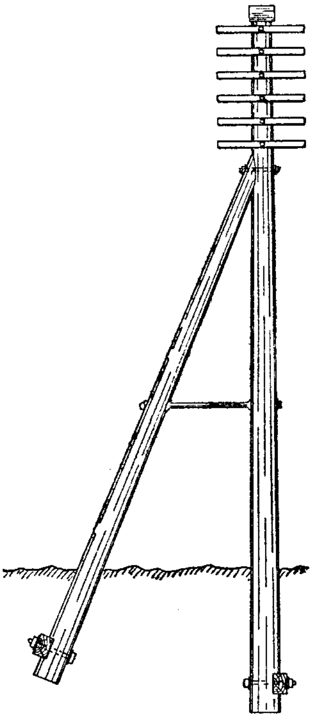

Fig. 4.—Pole with Strut

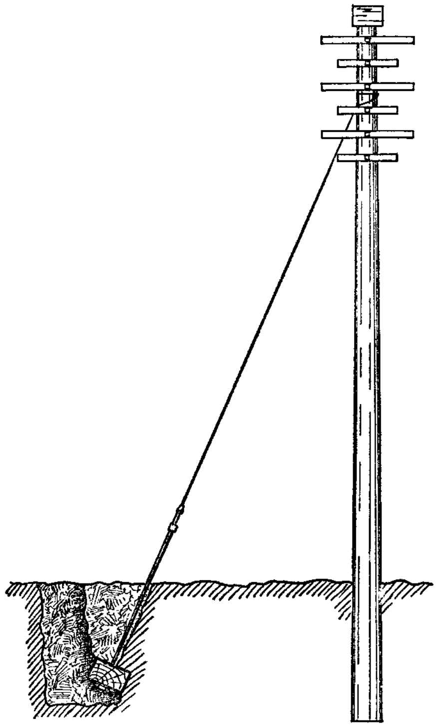

Fig. 5.—Pole with Stay

them. Two longitudinal stays, one on each side of poles at quarter-mile intervals, are always fixed, or alternatively one at each side of a convenient road or railway crossing.

Struts.—A somewhat lighter pole than the one to be supported may be used for a strut. The top is shaped to fit the pole, and is bolted to it with a $\frac{5}{8}$-inch bolt. The pole should not be notched or cut at the junction. Half-way between the apex of the triangle and the ground line the pole and strut are braced by a $\frac{3}{4}$-inch tie-bolt. This is enclosed between the pole and strut in a 1-inch galvanized iron tube, with large washers at each end which prevent the ends of the tube breaking into the fibre of the wood when the structure is strained, and the system is thus prevented from buckling. A stay-block is bolted with $\frac{5}{8}$-inch bolts to the foot of the pole, and one to the bottom of the strut to guard against the pole lifting or the strut driving into the earth. Failure to observe this point has been known to result in extensive damage during storms.

"A" Poles.—When a stay or a strut cannot be applied, two poles arranged as shown in fig. 6 may be employed. The two poles are scarfed (not more than one-third of the diameter of each at the top being cut away) with a scarf at least 6 feet long, to form an isosceles triangle. Two $\frac{5}{8}$-inch bolts hold the scarf, assisted by the arms, each of which is bolted with a $\frac{1}{2}$-inch bolt to each pole. A $\frac{3}{4}$-inch tie-bolt with 1-inch tube, as in the case of the strut, braces the structure midway between the bottom of the scarf and the ground line, and a creosoted wood brace, 6 or 8 feet long and 8 inches square, is sunk into notches 6 inches deep just above the butt of each pole, and bolted firmly with $\frac{3}{4}$-inch galvanized-iron bolts. This structure is capable of withstanding the stress on a heavy line at an acute angle in the line, without risk of buckling or giving way laterally.

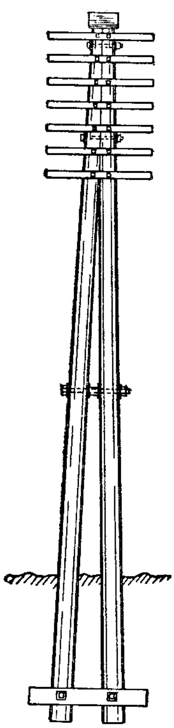

Fig. 6.—"A" Pole

"H" Poles.—Main routes built to carry sixty or more wires of the heavier gauges for long-distance circuits are frequently built of "H" poles (fig. 7). The two poles are put together with a system of trussing giving the equivalent of a lattice girder. They are laid parallel, with 18 inches clearance, braced at the butts with a pole-brace, as in the case of "A" poles, and from this brace two $\frac{3}{4}$-inch brace rods, 7 feet long, pass upwards to the lowest tie-bolt, just above the ground line. Two additional, or in tall poles three tie-bolts, spaced 8 feet apart, are put in, fitted with the usual tubes and large washers, and the trussing in each of the rectangular spaces so formed consists of four $\frac{3}{4}$-inch truss rods, 4 feet long, united in the centre of the rectangle by a steel truss ring of channel section. The arms complete the structure. Many miles of route built of "H" poles are to be seen on the backbone lines of the United Kingdom.

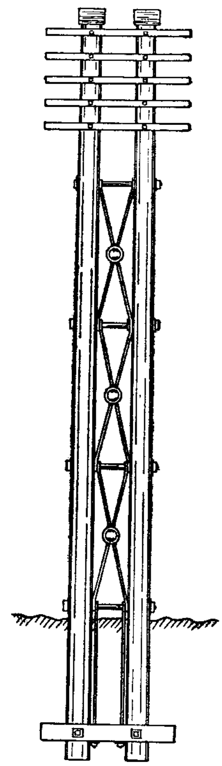

Fig. 7.—"H" Pole

Erection of Poles and Wires.—Poles are planted 4 to 6 feet deep, according to their length and the nature of the soil. A common rule is to put poles up to 40 feet in length one-sixth of their length in the ground. Longer poles are put 6 feet deep: greater depth is rarely necessary. The hole should be dug in the direction of the wires—not across the line—and should be little wider than the diameter of the pole, so that the lateral stresses which give most trouble shall be resisted by the firm undisturbed ground.

In erecting the wires sufficient stress is applied to draw them up tight enough to prevent contacts, while at the same time allowing a satisfactory factor of safety. This is the figure by which the stress to which the wire is drawn up must be multiplied to give the breaking weight of the wire itself. Iron and copper wires are drawn up to a quarter of their breaking weight at low winter temperature (22° F.), but in very exposed positions this margin may be increased by 50 per cent for copper wires. Bronze wires are given a factor of safety of 3, while on lines carrying both copper and bronze, factors of 3 and 4 respectively are employed. Under these conditions the wires hang practically in a parabolic curve, and the dip (or sag) is given by the expression $d = l^2 w/8 s$ where l is the length of span, w is the weight of unit length of the wire (a foot if l is taken in feet), and s the stress to which the wire is drawn up. The dip is the length of the perpendicular drawn from the lowest point in the curve to the horizontal plane through the insulators.

As the wires lengthen with rise of temperature the stress will diminish;

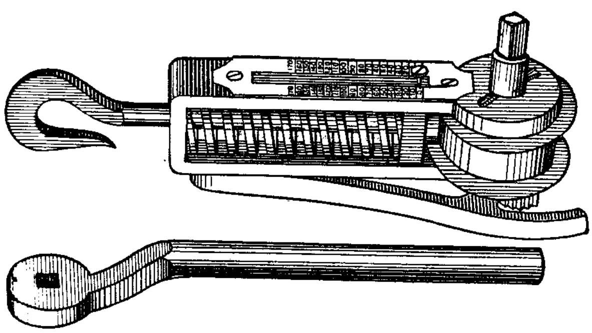

Fig. 8.—Tension Ratchet

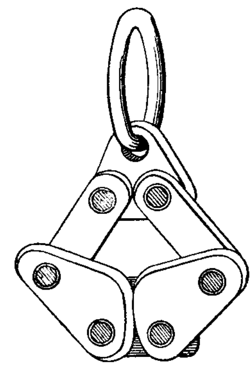

Fig. 9.—Draw Vice

the tension therefore varies not only with the load, i.e. the weight of the wire, but also with the temperature. When the first wire is erected on a line the foreman should be supplied with a schedule showing the stress for a given length of span and temperature, and have a thermometer and tension ratchets for carrying out the work. Tension ratchets (fig. 8) consist of a spring balance with a drum and ratchet for straining the wire; the scale showing at top of the figure is graduated in pounds. The hook is wired to the pole-arm, a length of wire is wound on the drum and the free end attached to the ring of the vice (fig. 9), and the jaws of the latter clutch the line wire. The drum is then wound till the appropriate stress has been applied. Additional wires of the same material, whether of the same gauge or different gauge, erected subsequently will always have the correct tension if regulated to the curve of the first wire. This regulation can always be effected by observation from the ground, and the employment of thermometers and reference to a schedule of stress become unnecessary in subsequent work on the line.

Joints.—Joints in the heavier gauge wires are made in the form known as the "Britannia" joint (fig. 10) as follows: The two ends to be jointed are cleaned and laid side by side for 3 inches, or slightly less, depending on the size of the wire, and are then bound with annealed wire of galvanized iron (60 lbs. to the mile) in the case of iron wire, and of tinned copper (50 lbs. to the mile) in the case of copper and bronze wires. The whole is then soldered, making a solid joint. Where the line wire is large a piece of binding wire is laid in the groove each side of the section to be jointed to facilitate and economize soldering. Light-gauge copper and bronze wires are jointed by twisted sleeve joints. The ends of the wire are thrust through a copper sleeve, which is then grasped firmly at one end in a clamp. Close up to the latter a second clamp is applied, with which the sleeve is given five or six complete twists, thus forming a firm mechanical joint.

Underground Wires.—Many cases occur in which overhead lines

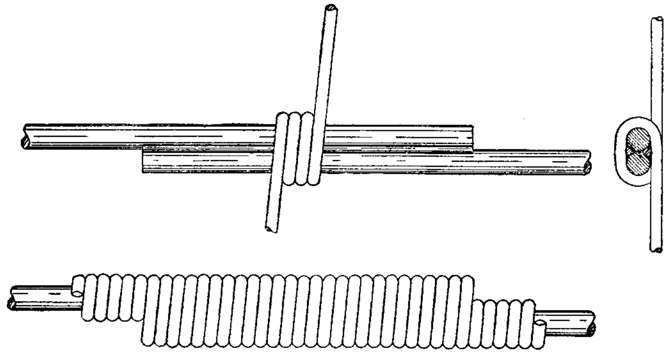

Fig. 10.—Britannia Joint

cannot be erected, and the wires have to be placed underground. Moreover, the large towns in the United Kingdom are nearly all linked up by underground cables to ensure a stable service unaffected by storms. In addition to the higher capital cost there is the serious disadvantage that, in efficiency, underground circuits compare unfavourably with overhead lines, the former being quite unsuitable for long-distance circuits that have to maintain a high speed of working.

The earliest type of underground cable consisted of 40 lbs. copper wire covered with gutta-percha to an over-all gauge of No. 7 S.W.G. In recent practice this type has been displaced by paper-core lead-covered cables. The conductors in the latter are of annealed high-conductivity copper, ranging from 6½ lbs. to 300 lbs. per mile, wrapped loosely with paper as insulation, applied in strips either longitudinally or wound spirally round the wire and held in position by a binding thread. The wires thus insulated are twisted (or twinned) in pairs with a length of lay depending on the gauge of wire, varying from a 2-inch lay for 10-lbs. conductors to 20 inches for 200 lbs., and also with a different length of lay for pairs of the same gauge which will lie adjacent in the finished cable. Inductive interference between adjacent circuits is thus reduced to a minimum. If the wires are to be used as single-wire (i.e. earth-return) circuits they are