No. 154

The Institution Post Office Electrical Engineers

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By

W. H. BRENT, B.Sc. (Hons.), A.M.I.E.E.

Read before the London Centre of the Institution on the 12th December, 1933, and before the South Wales Centre on the 8th January, 1934

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Synopsis.

The paper aims at giving a comprehensive survey of the subject, including the structure and strength of a pole, its " birth " from the forest tree, its " life " in service, its " death " whether from disease, fatal accident or exposure to blizzards and, finally, a proposal for securing longer life and better construction by a scheme termed " precutting."

The structure of coniferous and hardwood timber is compared. Scots pine is the ideal wood and experience with home-grown timbers, such as larch and spruce, and Imperial timbers, such as Ironbark and Wallaba, is being obtained.

The strength of a taper pole is shown not to depend on the diameter at the ground line in all cases, but possibly on that at a point well above the ground. Tests of poles to determine the fibre strength of the material are discussed.

Consideration is given to foundation strengths and depth of setting is shown to depend not on the length of pole, but upon the diameter at the ground line. The use of mechanical aids for excavation of holes and the erection and extraction of poles is described.

The life history of a pole up to the time of erection comprises growth in the forest, felling, shipping to pole depôts, dressing and seasoning. The interval between ordering and issue to work may be up to 3 years. A preservative treatment is of value in prolonging life and preventing accidents or interruptions. Creosote is of unrivalled efficiency when the impregnation of poles is done by pressure methods such as the Rüping process.

The average life of a creosoted pole is approximately 30 years and service may be terminated by decay, damage by road traffic, attacks by birds or insects, by lightning strokes, or by blizzards. Particular reference is made to the snow storm of February, 1933, typical loads due to snow accumulations are deduced and typical fractures illustrated. The importance of efficient staying is commented upon. An analysis of the condition of the broken poles is given and decay shown to be present as often in the top of a pole as in the part near the ground line.

A scheme for securing an unbroken layer of creosoted wood throughout is described. In this, arm slots are not used, but a flat surface at the top of the pole and the roof slopes are prepared before the pole is creosoted. To hold arms square with the pole, arm braces are required and a strong fixture is obtained.

1. Introduction.

Wood poles were used in the construction of the first telegraphic lines nearly a century ago (1836) by the private companies and railways, who used larch and Scots pine poles chiefly of home-grown origin and, more often than not, without preservative treatment.

They have been used by the British Post Office ever since the nationalisation of the telegraph services in 1870 and it is of interest to note that some of the poles then purchased are still standing to-day as monuments to the engineer who made the decision that creosote and not copper sulphate should be employed for preserving the timber.

For many years creosoting by the " full cell " process was standard practice, but 1908 saw the first trials of the Rüping or " empty cell " process of which details are given later in this paper, and in 1913 this process was adopted as standard. In the following year the war period commenced and as the supply of timber normally came from abroad, difficult times were experienced. The effects of this lasted until about 1920 and soon after, the light steel girder which had been introduced, was discontinued. In the S. Midland District some of these were this year (1933) replaced by wood poles, the storm of February having bent them badly.

From time to time tubular iron poles with cast iron bases have been used in deference to the wishes of local bodies, but, apart from their extra cost, they are less reliable and their doom was sealed in 1915 when a line of 11 poles of this type collapsed in Ditchling Road, Brighton, (14)* the spread of the trouble being arrested at the first wood pole.

At the present time, as a result of the experience gained since 1870, supplies of wood telegraph poles are of a very satisfactory standard. As proof of their continued importance in plant provision it is only necessary to mention that the issues of all sizes amounted to no less than 100,000 poles during the last financial year and that at the last survey (made in 1929) there were over 2 million poles carrying the Department's overhead wires.

2. Marking of Poles.

Detailed records covering every pole issued and recovered are not kept and indeed the number of poles renders this impracticable. A system of marking poles has, however, been in operation for many years so that if anything unusual occurs a history of the pole can be deduced. Localities of special trials are recorded and from time to time the poles are examined and reports made.

At a point ten feet from the butt of the pole the following marks are to be found scribed on the surface of the wood. First, there is the G.P.O. inscription and below this the length of the pole and class. Below this again are the last two digits of the year of creosoting and beneath the date appear any letter or letters to indicate special features regarding the method of preservation or type of timber. Table

* See Bibliography.

I gives the interpretation of the various letters which may appear.

TABLE I.

Distinguishing Marks on Poles at 10 ft. from Butt.

Letter.	*Indication.*
A	Russian red fir (Archangel).
B	Preserved with Wolman Salts.
BX	,, ,, ,, and Fuel Oil.
B/B	Creosoted by " Quick " process.
E	Larch, Summer felled.
H	Spruce, ,, ,,
IP or IC	Ironbark.
K	Creosoted by Rüping process. (Mark discontinued in 1931).
L	Larch, Winter felled.
M	Canadian Red Cedar.
N	Creosoted by " China " process.
Q	,, ,, " Quick " process.
R	Russian red fir (Riga).
T	Larch, seasoned with bark on.
W	Weymouth Pine.

At five feet from the butt is marked the cubic contents of the pole. This is for transport purposes only, for which 48 cubic feet to the ton is allowed. The figure is based on the length of the pole and the circumference at the centre, *i.e.,* it is a " string measurement " weight.

On the butt itself are additional markings (*a*) 1, 2 or 3 crowns indicating light, medium or stout class, (*b*) the length in feet, (*c*) two letters which are the initials of the Inspecting Officer and (*d*) two letters, the first of which indicates the depôt (thus " O " poles are from Southampton) and the second the shipper's code letter.

3. Timber.

(*a*) *Structure.* (1)*

Wood cannot be regarded as a homogeneous material. It is made up of different types of hollow elements, these varying considerably in size and bore. The substance of the cell walls is mainly cellulose, but this undergoes changes in constitution during growth termed " lignification," to which process the wood owes its strength.

Fig. 1 (1)* is a diagram of a portion of coniferous timber magnified to show the general structure. A are the medullary rays which run radially from the circumference towards the centre of the tree and which serve to distribute food and water to the cambium or growth-producing layer beneath the bark or to store food. They are minute and numerous in Scots pine, but in oak they are larger and spaced more widely and may be easily seen in the quarter-sawn surface as the decorative figuring. D shows their cross section on a tangential face. The elements running vertically are the " tracheids " and these constitute the main substance of the timber. They are elongated, tapering cells which not only provide the strength of the tree or pole but serve to conduct the solutions, which pass up and down by travelling from one tracheid to the next *via* the " bordered pits " or membranous holes, which give communication between the cells. B are the spring tracheids and have a large bore but thin walls, thus easing the flow of the sap; whilst C are the thicker-walled and smaller-bored summer tracheids which give most strength to the timber. When the cross section is viewed the summer wood stands out in concentric rings of reddish wood (the annual rings), whilst the spring wood provides a field of white and softer material.

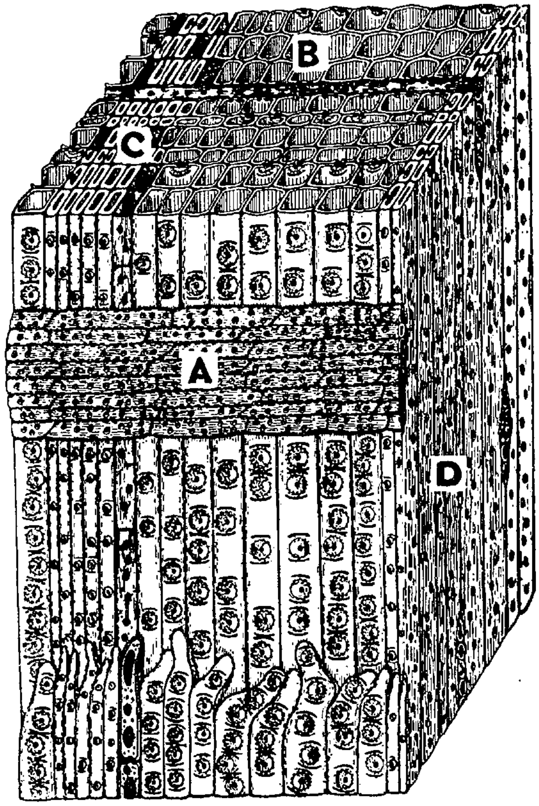


FIG. 1.

It is interesting to note the difference between the " softwoods " (*gymnosperms*) and the " hardwoods " (*angiosperms*), although we are almost entirely concerned here with the former. The classification " softwoods " refers to coniferous trees which have needle-shaped leaves and the term " hardwood " to broad-leaved trees, but there are other differences besides that of leaves, for instead of one type of cell, the tracheid, performing a double duty, there are, in hardwoods, two types of cells each carrying out a particular function. Thus there are " fibres " which provide the strength and stiffness of the timber and the spring and summer " vessels " which are responsible for the conduction

* See Bibliography.

of fluids in the tree. In Fig. **2** (1),* C represents a fibre of oak and D and E the spring and summer vessel segments of oak. The segments connect together, as minute self-aligning ducts, to form continuous tubes. F is a parenchyma cell, which serves to store food and G is a portion of a medullary ray of oak. Some conifers carry resin passages in spaces formed by the separation of the elements. In this figure, A and B are the spring and summer tracheids of Scots pine.

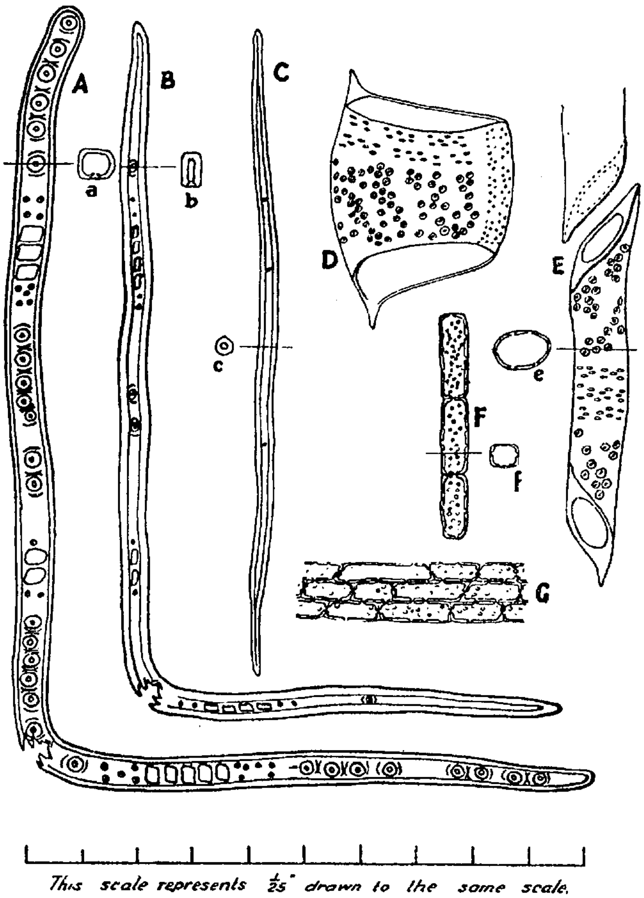


FIG. 2.—TYPES OF CELLS. MAGNIFIED 159 TIMES.

To show the different formation more clearly, Fig. **3** (1)* is a comparison between ash (*Fraxinus excelsior*), a hardwood of ring-porous type (as distinct from a diffuse-porous wood such as beech, in which the vessels are all much the same size and equally distributed) and Scots pine (*Pinus sylvestris*) a coniferous timber, in which the vessels are absent. This figure also illustrates a difference arising from the rate of growth. Generally speaking, a ring-porous wood is stronger if it is quickly grown as there is then a greater preponderance of dense summer wood and fibre cells; whilst in the coniferous timber the opposite is the case and the slower the tree has grown, the stronger will be the wood. In the case of Scots pine, the strength is good and uniform if the growth is more than nine annual rings to the inch; usually the imported Norwegian Scots pine has roughly 25 rings to the inch.

With every specification which accompanies the invitations to tender for the supply of timber a photograph of a representative butt section of pole is associated; this is shown in Fig. **4**. The tree for this 40 ft. stout pole took approximately 170 years to reach the diameter shown. Markings as described earlier are to be seen.

The trees grow by producing tissue in the "cambium." This is beneath the "bast" or inner-bark, which conducts food material down from the leaves. The exterior bark is a protective corky layer. The bark, bast and cambium are all removed before the logs are stacked for seasoning. As the living cells in the sapwood are covered by fresh layers, they gradually pass over into the inner region of heartwood, where they are in a dead condition, in that they are more or less blocked up by growths within the cells -resins, gums, etc.—a condition which effectively obstructs the passage of creosote or other preservative solutions even under considerable pressure. It is, therefore, undesirable to have too much heartwood, but on the other hand too much sapwood might reduce the strength of the pole unduly. The ideal proportions of sapwood and heartwood are shown in the photograph in which the sapwood extends for roughly $\frac{1}{3}$ of the radial depth.

(*b*) *Varieties in use and on trial.*

Although Scots pine is the standard timber for telegraph poles in the United Kingdom a number of other species of timber have been put on trial from time to time.

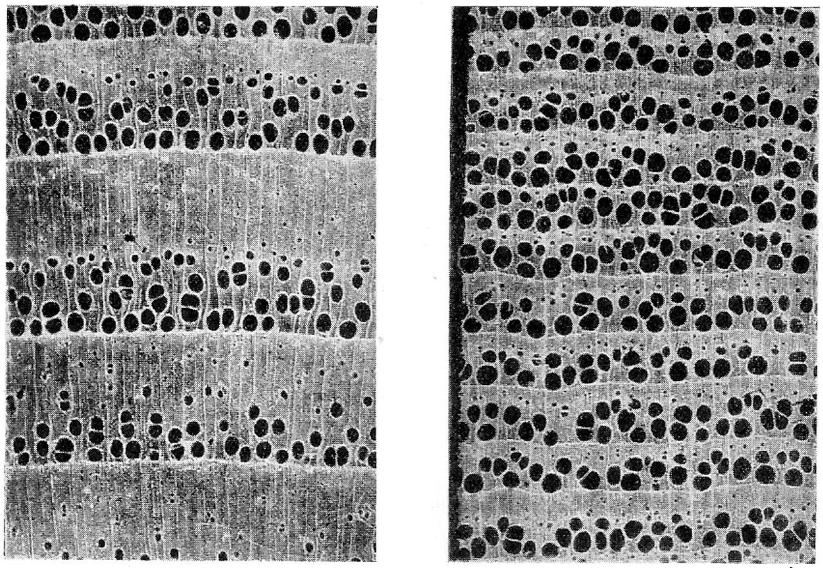
Scots pine (*pinus sylvestris* L.) also known as redwood, is the timber almost exclusively used by the British Post Office. It is the ideal timber for conductor supports. It is readily available in quantities; it is reliable in quality. The strength is adequate and the weight is moderate, a point of importance when transport is considered.

The majority of the Scots pine is obtained from Sweden, Norway and Finland, but every effort is made to obtain supplies of the timber from the forests of Scotland and England and preferential treatment is given to the home-growers in a number of ways (15).* For example, the contractor is not tied down to specific quantities of definite sizes and the standard of examination is relaxed although not so as to decrease safety margins. Advice is also given on standing trees and inspections are made at the place of felling to eliminate ineffective transport. In 1930 and 1931 the poles received from home-growers amounted to 3,500 in each year and in 1932 to over 27,000.

Generally throughout this paper, when no mention is otherwise made, Scots pine is the timber referred to.

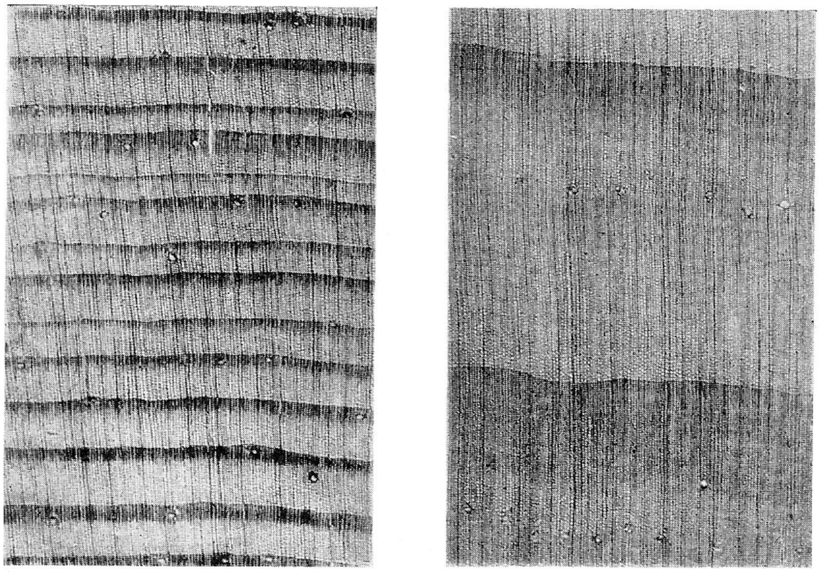
Pitch pine (*Pinus palustris* Mill.), a strong timber, was used in many cases for terminal poles prior to 1913 (when the Rüping process of creosoting was introduced), but such poles were very expensive. As

* See Bibliography.



Quick-grown and strong. Slow-grown and weak.

Ash, *Fraxinus excelsior, Linn.*



Slow-grown and strong. Quick-grown and weak.

Scots Pine, *Pinus sylvestris, Linn.*

Fig. 3.—Cross Sections of Slow- Grown and Quick-Grown Timber.

this timber was used untreated, but painted, the G.P. leads on the pole were not liable to deterioration by creosote. The poles were of square section. Although this type of pole is no longer purchased, there are still a number in existence.

Corsican pine (*Pinus nigra* Arnold) was used to a certain extent during the war. The small amount of heartwood is a characteristic of this timber, the heart being often less than one-third of the total diameter. This tends to give a pole which is less stiff and the large amount of sapwood to be creosoted means that the cost of preservation is higher.

Yellow pine (*Pinus strobus* L.), or Weymouth pine, is another pine which has been introduced into England—of the conifers only Scots pine is a native of this country—but, although apparently suitable for poles, supplies have not been forthcoming. Five poles were Rüpingised in 1920 and erected in South Wales; the condition of these is still satisfactory.

European spruce (*Picea abies* Arst.), or Baltic

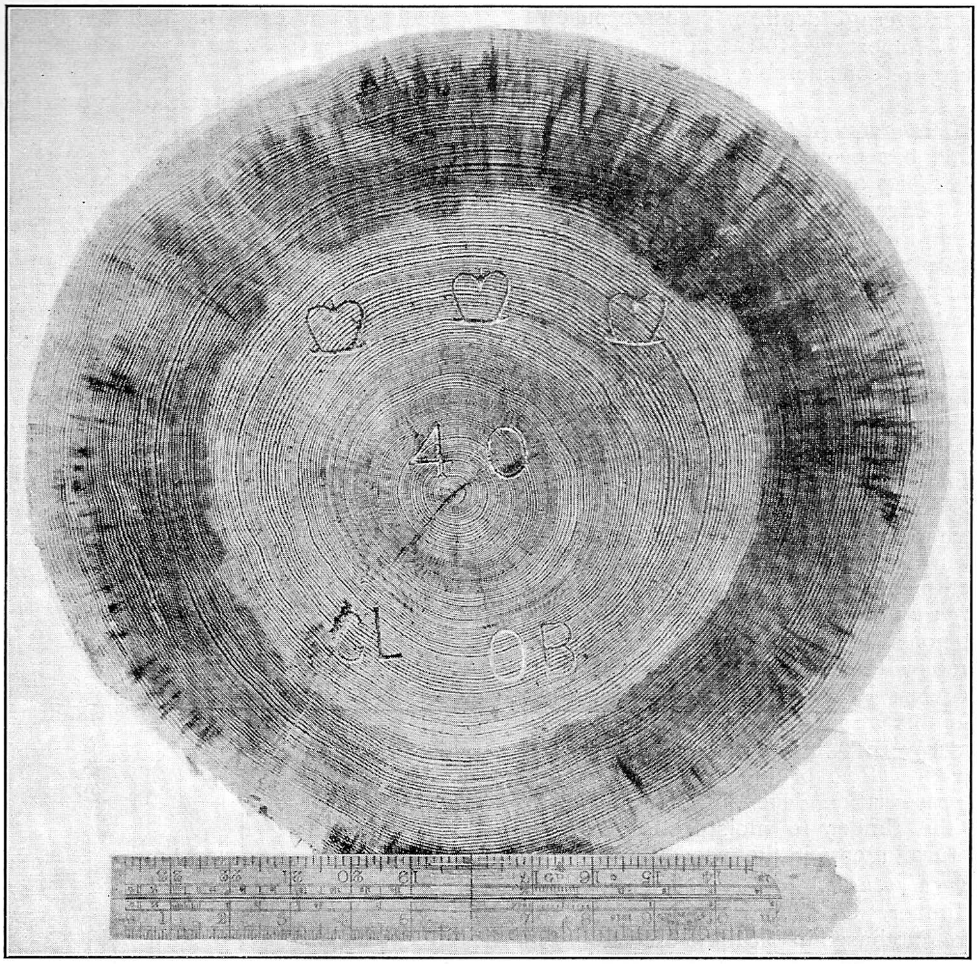


Fig. 4.

whitewood, has been put on trial, a parcel of 600 being taken in 1920, but they are likely to have a limited life due to the difficulty of introducing creosote. Further experiments with this and Sitka spruce (*Picea sitchensis*) are being carried out at the Forest Products Research Laboratory with a view to overcoming their disabilities.

European larch (*Larix europea*) was used by the National Telephone Company and by the Post Office before and during the war (about 38,000 poles of this type were obtained through the Timber Supply Department of the Board of Trade during the period from May, 1917, to January, 1921), but purchase was discontinued in 1921, mainly on grounds of safety. The timber is about 30% stronger than Scots pine, but it develops bad seasoning checks in service, all the shrinkage tending to open the wood at one or two large cracks instead of a large number of fine shakes round the circumference. The wide shakes are bad for two reasons—they open the untreated heartwood to the action of fungus spores in the atmosphere and they are a trap for an unwary lineman when using the standard type of spiked climbing iron. Cases have occurred also of pole steps giving way under a climber when a crack has coincided with the coach screws. An additional characteristic of the timber is that of twisting as the pole seasons in position if the tree has grown with spiral grain. A twist of 15° in the arms is not exceptional in such poles; nor are cracks having a maximum width of $\frac{5}{8}$th inch and up to 5 inches depth.

With larch, the sapwood does not extend more than $\frac{1}{2}$ inch to an inch from the surface and consequently there is only a relatively thin layer of creosoted wood in a treated pole, easily penetrated by the deep checks referred to. Although untreated larch is much more resistant to decay than untreated Scots pine, the treated poles have not been as satisfactory.

A method of incising larch poles before seasoning and creosoting has now been developed by the Forest Products Research Laboratory (2)* to overcome these defects. This consists of making incisions $\frac{3}{4}$ inch deep, spaced $1\frac{1}{2}$ inches round the circumference and 4 inches longitudinally. The result is to encourage a greater number of smaller seasoning checks and to

* See Bibliography.

obtain a greater average depth of creosote penetration. This is of importance to the home growers of timber, as there are considerable sources of larch in Great Britain.

Douglas fir (*Pseudotsuga taxifolia* Brit), or British Columbian pine, has been used occasionally in the past for square poles as an alternative to pitch pine and for poles of exceptional length which were very difficult to obtain in Scots pine. It is a wood which is very difficult to treat with creosote, and when used by railway companies as sleepers, it is the practice now to apply an incising method to obtain effective penetration.

From time to time consideration has been directed to timbers from Empire sources and poles have been given practical trials.

Western red cedar (*Thuja plicata*) is a Canadian timber. A small number were Rüpingised and erected in 1923 and are still in sound condition. This wood, like larch, allows little depth of penetration for creosote; and in America, where it is often used for poles, butt treatment only is normally arranged.

Wallaba (*Eperua falcata*) is a timber from British Guiana. Two poles were presented to the Post Office from the Wembley Exhibition in 1926 and stand at Dollis Hill Wireless Research Station. These have developed a number of shakes. A further two poles were erected at Liverpool in 1931, the sapwood being entirely removed. None of the poles was treated in any way, preservation depending on the imperviousness of the timber to moisture and on the presence of natural agents in the wood.

Ironbark (*Eucalyptus paniculato and E. crebra*) is an Australian timber. One hundred Queensland ironbark poles were purchased in 1931 and erected in four districts for trial. The intention is that these should compete in the untreated state with the standard creosoted Scots pine pole and the majority were erected in this state, but a few of the batch were butt-treated with creosote before erection. This wood is extremely hard and resistant to decay—the sapwood is normally entirely removed—so that a life of 12 to 20 years is expected in Australia. It is interesting to learn that the Australian authorities are seriously considering the use of creosote with the retention of the sapwood, as a white ant preventative is necessary and the caustic soda-arsenic preparation at present used for this purpose has no fungicidal properties.

The timber is very heavy, weighing 73 lbs. to the cubic foot as against 37 lbs. per cubic foot for Scots pine (uncreosoted) and consequently transport charges and erection costs are considerably increased. The hardness of the wood precludes the use of the Post Office climbing irons and additional pole steps require to be fitted. Furthermore, more time is required for slotting and boring the poles for fitting arms.

It seems unlikely that ironbark will be able to compete with European timbers in price.

The Australian administration recognises 25 different varieties of Eucalyptus in its pole specification, other types being known as black butt, tallow wood, etc., but the strengths of these are intermediate between Scots pine and ironbark, the latter being twice the strength of the former.

4. Strength of Wood Poles.

(*a*) *Strength.*

A pole carrying conductors is required in particular to withstand the stresses imposed by storms and it is necessary to know not only what these stresses are likely to be, but also the resistance of the poles. The latter is the more easily and accurately determinable.

Normally, the vertical load on the pole due to the weight of conductors, even when coated with ice, is negligible, although at an angle in the line where the stay has been given only a short spread the downward force tending to buckle the pole may become considerable and contribute to failure. The least resistant condition to be considered, however, is that of an unstayed pole in a straight pole line and, for the purpose of ascertaining the strength available, such a pole can be regarded as a cantilever set rigidly in the ground and loaded at the resultant of the wires, usually assumed to be at a point 2 ft. from the top, with a force acting at right angles to the pole and the wires.

Thus, in Fig. 5, AB represents a pole of length L inches, set to a depth b inches in the ground and

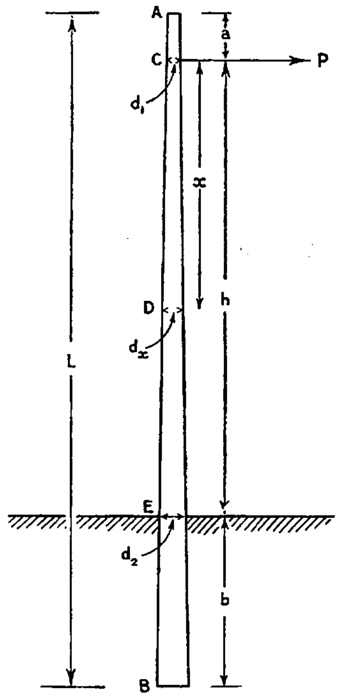


Fig. 5.

carrying a load P lbs., at a point C, distant h inches above the ground level. At any point, D, the bending moment will be $P \times x$, where x is the distance from C to D. The bending moment is greatest at the ground line where it becomes $P \times h$ inch-lbs.

The bending moment is resisted by the tension and compression of the wood fibres across the section and if f is the fibre stress and Z the modulus of section we have, at the ground line,

$$\text{bending moment}, = Ph = fZ \quad \ldots\ldots(1)$$

$$= f\ \frac{\pi d_2^3}{32} \quad \ldots\ldots(2)$$

If f is regarded as the apparent ultimate breaking stress (modulus of rupture) obtainable by tests to destruction, P becomes the breaking load and this can be calculated for any pole of normal taper.

The taper on a long pole, particularly of the stout class, may cause the weakest section to be not at the ground line but higher up. If the diameter at the load point is d_1 and the taper is t inches per inch length the diameter, d_x, at D is given by

$$d_x = d_1 + xt \quad \ldots\ldots(3)$$

the bending moment formula is

$$Px = f\ \frac{\pi d_x^3}{32} \quad \ldots\ldots(4)$$

$$= f\ \frac{\pi}{32}\ (d_1 + xt)^3 \quad \ldots\ldots(5)$$

and, rearranging the above, the maximum fibre stress for a given load will vary along the length of the pole as follows :

$$f = \frac{32P\ x}{\pi(d_1 + xt)^3} \quad \ldots\ldots(6)$$

To illustrate the effect of this, the stress curves of Fig. **6** have been calculated for a 50 ft. stout pole of minimum and maximum allowable top diameters. In the case of the former, the maximum stress in the extreme fibres occurs at a point 11 ft. above the ground, but as the stress curve varies little in value between a point 20 feet above the ground and the ground line the actual break would probably occur at a defect in this section such as at a pronounced knot or ring of knots.

By differentiating (6) and equating to zero, the maximum stress is shown to be where

$$x = \frac{d_1}{2t} \quad \ldots\ldots(7)$$

or, putting this value in (3), where

$$d_x = \frac{3d_1}{2} \quad \ldots\ldots(8)$$

This provides the simple rule that the weakest part of a tapering pole is where the diameter is $1\frac{1}{2}$ times the diameter at the load point, *i.e.*, very nearly, the diameter at the tip. The breaking load of the pole is then from (4), (7) and (8),

$$P = f\,\frac{\pi 27 d_1^2 t}{128} \quad \ldots\ldots(9)$$

or, taking the taper in inches per foot of length for convenience,

$$P = 0.0552\, f\, d_1^2 t \quad \ldots\ldots(10)$$

Assuming a modulus of rupture of 7800 lbs. per square inch, the theoretical breaking loads which standard poles will support have been calculated and are given in Table II. The dimensions have been taken from the Post Office Specification.

(*b*) *Pole Tests.*

The value of 7800 lbs. per square inch for the ultimate stress in the extreme fibres is based upon the results of tests carried out in 1885 at the Gloucester Road Factory by Messrs. Andrew Bell and James Gavey. (13)* It is quoted by the Electricity Com-

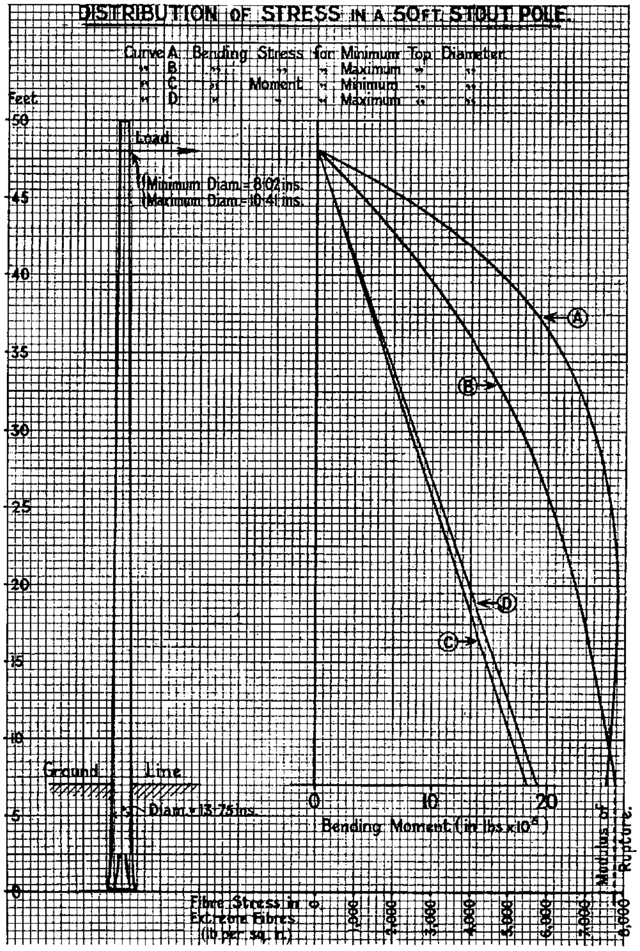


Fig. 6.

missioners in connection with power transmission lines on wood poles and is used in tables of wood pole strengths published by Messrs. Richard Wade, Sons & Co.

Further tests on record in the Post Office are described by Mr. F. L. Henley in a paper read before the International Telegraph and Telephone Conference at Paris in 1910. In these, as in the earlier tests, the poles were supported horizontally on a wooden structure with the butt firmly clamped between the two halves of a split iron cylinder so that the greatest bending moment was at the ground line

* See Bibliography.

Table II.

THEORETICAL BREAKING LOADS OF STANDARD SCOTS PINE POLES.

NOTE (1) The load is assumed to be applied 2 ft. from the top.

(2) In the case of poles of maximum top diameter the point of maximum stress or theoretical breaking point, is at the ground line except for 70 and 75 ft. Stouts.

(3) In the case of poles of minimum top diameter the theoretical breaking point is on the average 30 feet below the point of application of the load.

Length. ft.	Assumed Depth of Setting. ft.	Minimum Diameter 5 ft. from Butt. ins.	Minimum Top Diameter. ins.	Theoretical Breaking Load. lb.	Height of Breaking Point. ft.	Maximum Top Diameter. ins.	Theoretical Breaking Load. lb.
Light.					Ground		
20	4	6	5	1020	Line	5¾	1020
22	4	6¼	5	1010	,,	5¾	1010
24	4	6½	5	1010	,,	5¾	1010
26	4½	6¾	5	1020	,,	6	1020
28	5	7	5	1040	,,	6	1040
30	5	7¼	5	1060	,,	6	1060
32	5	7¼	5	970	,,	6¼	970
34	5	7½	5	1000	,,	6¼	1000
36	5½	7¾	5	1020	,,	6½	1020
40	6	8	5	990	1.6	6½	990
Medium.					Ground		
24	5	8	5½	1920	Line	6¾	1920
26	5	8¼	5¾	1890	,,	7	1890
28	5	8½	5¾	1870	,,	7	1870
30	5½	8¾	6	1870	,,	7¼	1870
32	5½	9	6	1870	,,	7¼	1870
34	6	9¼	6	1870	,,	7½	1870
36	6	9½	6	1890	0.5	7½	1890
40	6	9¾	6	1780	3.0	7½	1790
45	6½	10¾	6½	2060	4.7	8	2070
50	7	11½	6½	2170	10.8	8¼	2230
55	7	12½	7	2470	13.2	8¾	2570
60	7	13¼	7	2570	19.3	8¾	2760
Stout.					Ground		
28	5½	10½	7½	3530	Line	9½	3530
30	6	10¾	7½	3470	,,	9½	3470
32	6	11	7½	3420	,,	9¾	3420
34	6	11¼	7½	3370	,,	9¾	3370
36	6½	11½	7½	3350	,,	9¾	3350
40	6½	12	7½	3330	1.3	9¾	3330
45	7	13	7¾	3640	5.5	10	3670
50	7	13¾	7¾	3700	11.0	10¼	3810
55	7	14¾	8	3980	16.0	10½	4200
60	7½	15½	8	4020	20.2	10½	4400
65	8	16¼	8	4050	24.8	10½	4600
70	8	17	8	4090	30.0	10½	4840
75	8	17¾	8	4110	35.2	10½	5050

of the pole when in service. Fig. 7 illustrates the arrangement adopted. The load was applied at the unsupported end by adding successively one cwt. weights to a suspended wood platform. Due allowance was made for the overhanging weight of the pole itself.

The results of these tests may be summarised as follows :

Mean of 9 recovered poles between 20 and 38 years old	6,690 lbs. per sq. inch.
Mean of 2 new creosoted poles	6,950 lbs. ,, ,, ,,
Mean of 2 new uncreosoted poles	7,625 lbs. ,, ,, ,,

In order to verify these figures some further tests were made at the Hume Pipe and Concrete Construction Company's Works, at Grays, in 1929. The poles were clamped in heavy concrete blocks for a length of 6 feet and the load applied horizontally by means of a steam crane *via* a dynamometer.

Three new creosoted poles from stock were broken, failure being indicated by the appearance of a line on the compression side with longitudinal splitting on the tension side, and the mean result was an ultimate fibre stress of 7,360 lbs. per square inch.

The British Electrical and Allied Industries Research Association has carried out some valuable work upon the strength of poles, both single and

* See Bibliography.

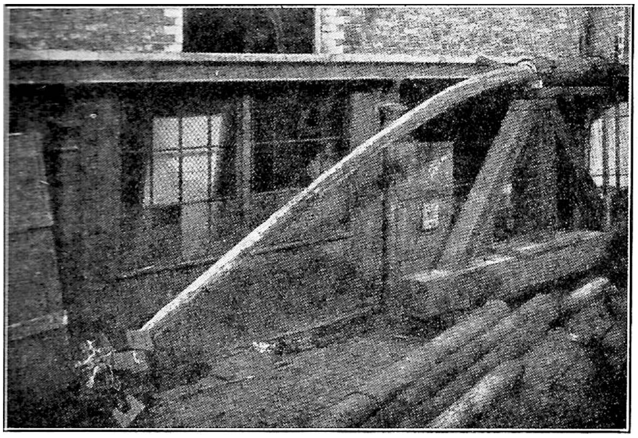


FIG. 7.

composite. The Association's Report (3)* shows that the single poles had fibre stresses averaging 4,724 lbs. per sq. inch (3 poles) when fracture occurred. The tests were of a practical character, the poles being in this instance buried vertically in the ground as in service and pulled over by a steam crane until failure occurred. In each case failure of the pole was preceded by a large displacement of the pole in the ground.

The Forest Products Research Laboratory at Princes Risborough, using a 100,000 lb. Denison Universal Testing Machine (2)* are able to make tests in which the load is applied steadily and at a predetermined rate (800 lb. per sq. inch per minute in the extreme fibres), thus exercising control over an important factor in tests upon wood. The pole is supported at each end on the weighing platform, which is extended in order to take the extra length, and a load is applied, by hydraulic ram at a point four feet from the butt support. Fig. **8** is a photo-

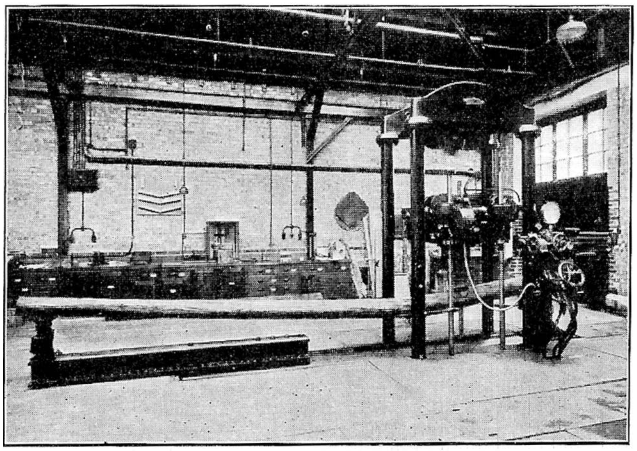


FIG. 8.

graph of this machine and shows a typical failure. Tests on some creosoted Scots pine poles (5 poles) of 23% moisture content and rate of growth averaging 20 rings per inch gave a fibre stress at maximum load of 8,590 lbs. per square inch (2)*.

The varying values for Scots pine obtained by different authorities are no doubt due in part to the differing methods of test, and in part to the fact that no allowance can now be applied for moisture content or the rate of loading or for the rate of growth of the timber and also to the varying characteristics of the timber itself. The Post Office figure of 7,800 lbs. per sq. inch for the maximum fibre stress is, however, substantially confirmed by the more recent tests which have been made.

The Forest Products Research Laboratory have also carried out similar tests on Australian timber and on home-grown larch poles, and the values of ultimate fibre stress given in Table III have been obtained.

TABLE III.

Ironbark	16,600 lbs./sq. in.
Tallowwood	15,300 ,,
Larch, creosoted, unincised (air dry) (2)*	11,560 ,,
Larch, creosoted, incised (air dry) (2)*	10,500 ,,
Creosoted Scots pine (P.O. value)	7,800 ,,

It is apparent from these figures that, with equal diameters at the ground line, a larch pole is approximately 30% stronger than a Scots pine and an ironbark pole twice the strength. For practical purposes, however, it is better to take as a basis of comparison that of carrying equal loads, for the strength of a pole depends more upon its diameter than upon the material, and varies as the cube of the former, as will be seen by reference to Section 4 (*a*).

For example, an ironbark pole of strength equal to a 32 ft. stout Scots pine pole (11 inches diameter) would have a diameter at the ground line of $8\frac{1}{2}$ inches, *i.e.*, a reduction of only 22%, and in view of the density of the timber (approximately 73 lbs. per cubic foot) the ironbark pole would be actually slightly heavier. It would also be less stiff than the larger diameter Scots pine pole.

5. Foundations.

Correct design of a pole line implies proper attention to the foundations. Too often, however, this aspect is neglected through lack of knowledge and indeed in view of the variable character of soils—more variable even than the timber of the poles—some excuse may be accepted for this. By applying some mathematical considerations it is possible, however, to reduce the range of error.

It will be assumed that the earth pressure increases proportionately to the increase in depth following a law represented by

$$p = kx \qquad \text{...(1)}$$

* See Bibliography.

where k is a constant and p the pressure in lbs. per sq. inch at a depth of x inches. This is probably most true for large movements in a soil of a sandy type; the tendency in clay is more for the soil to flow round the object and so vary with the extent of the movement rather than in respect of depth.

Fig. **9** represents this variation of pressure for a pole carrying a load P lbs. and buried to a depth of b inches. Under the action of the force, the pole pivots about a point O at a depth of c inches. As the pole does not move bodily the sum of the earth pressures above O must be equal to the sum of the earth pressures below O together with P; thus we have, d being the diameter at the ground line and neglecting taper of the pole,

$$\int_0^c k \cdot d \cdot x \cdot dx = \mathrm{P} + \int_c^b k \cdot d \cdot x \cdot dx \quad \text{.............(2)}$$

and from this, $c = \frac{b}{\sqrt{2}}\left\{1 + \frac{\mathrm{P}}{kdb^2}\right\}$ ....(3)

As the expression in the bracket is approximately 1.02, the point O is therefore at about 0.72 of the depth of setting.

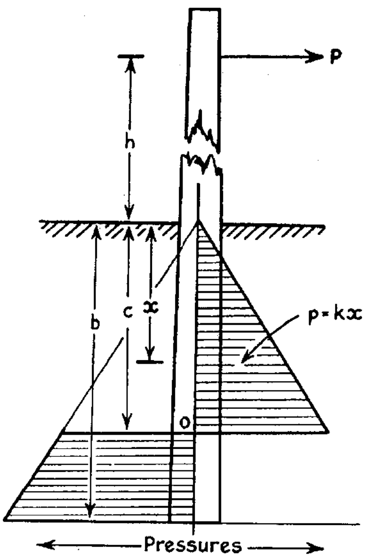


FIG. **9**.

Considering next the moments of the earth resistances about the point O, which vary in the manner shown graphically in Fig. **10**, we have

$$\int_0^c k \cdot d \cdot x \cdot (c-x)\,dx + \int_c^b k \cdot d \cdot x \cdot (x-c)\,dx = \mathrm{P}(h+c) \quad \text{...............(4)}$$

from which is obtained

$$\frac{kd}{6}\{2b^3 + 2c^3 - 3b^2c\} = \mathrm{P}(h + c) \quad \text{.........(5)}$$

or taking $c = 0.72\,b$ and a ratio of b/h equal to 1/5

$$0.59\,kdb^3 = 6\,\mathrm{P}h\left(1 + \frac{0.72}{5}\right) \quad \text{...............(6)}$$

i.e.,

$$b^3 = \frac{11.6\,\mathrm{P}h}{kd} \quad \text{..................................(7)}$$

and since $\mathrm{P}h = 7800\frac{\pi d^3}{32}$ (from Section 4)

at the breaking load on the pole thus we have

$$b^3 = \frac{11.6 \times 765\,d^3}{kd} \quad \text{..............................(8)}$$

or

$$b = \frac{20.7}{\sqrt[3]{k}}\,d^{\frac{2}{3}} \quad \text{....................................(9)}$$

Thus it is deduced that the depth of setting is proportional to the two-third power of the diameter at the ground line and a more reliable criterion of the depth at which a pole should be set is obtained. It is often quoted that the depth should be a certain proportion, such as one sixth, of the length of the pole, but more correctly we find it as a function of the diameter. Departing however from theory, a practical assumption is that a 36 foot stout pole ($11\frac{1}{2}$ inches diameter) should normally be set at a depth

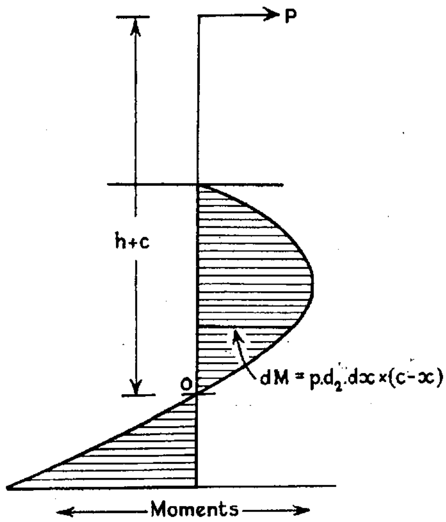


FIG. **10**.

of 6 feet or in very poor soil at 18 inches extra depth. (From (7) it will be observed that this amount of extra depth doubles the resistance in the same soil). From these assumptions the curves of Fig. **11** have been prepared so that corresponding depths for poles of differing diameters can be read and for convenience of reference, the length and class of representative poles have been added. It can also be derived from the assumption and from formula (7) that $k = 0.76$ lbs. per sq. in. per inch of depth at the safe load on the pole (837 lbs. at a factor of safety of 4); at 6 feet deep, this corresponds to 8,000 lbs. per square foot.

Actually, there is only one true way of determining with certainty that the proper foundation strength is given and that is by driving a standard size of pile into the ground in question and ascertaining the load it will stand for a certain deflection. The correct

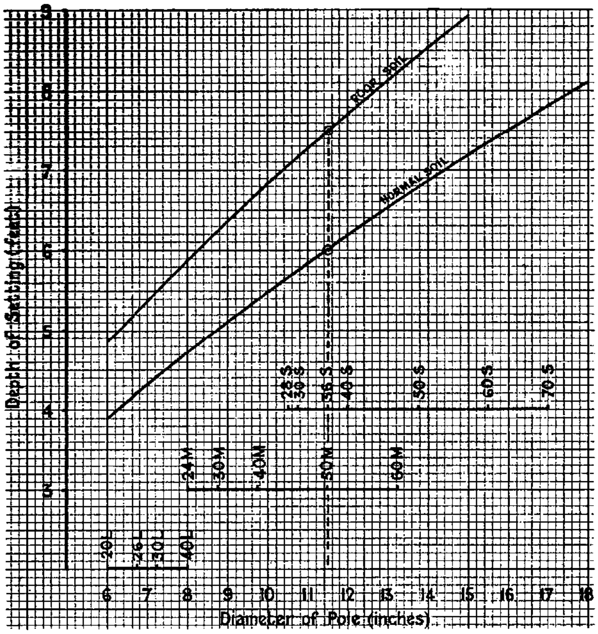


FIG. 11.

depth of setting can then be deduced with reasonable accuracy. Simple apparatus for doing this would be required, however, for the method to be of practical use.

Reference to Fig. **10** illustrates very well the best position at which blocks should be placed so as to secure the greatest moment of resistance. It is evident that the bottom block should be at the very lowest point whilst the upper block should be half way between ground level and point O, being thus roughly at one third of the depth. Further, by reference to Fig. **9**, as the intensity of the pressure on the lower block is three times that of the pressure on the upper, the area of the lower one may be only one-third of the upper to give equal effect, allowance being made for the portion of pole covered by the blocks. By using a light stay-block below in conjunction with a medium or heavy block above, excavation work can be saved.

6. Erection, Recovery and Shifting.

The requisite depth for the foundation may be obtained by digging the well known "stepped" form of pole hole. This is necessary if the pole to be erected is of considerable size, *i.e.*, one which is not easily lifted to a vertical position so that it can be dropped into a circular hole. For light and medium poles up to 30 ft., it is the practice to excavate the cylindrical hole using a bar and spoon combination for loosening and scooping out the soil, or, in anything but gravel or stony soil, to employ a 10-inch earth auger which is operated by hand and quickly removes the soil. Power-driven earth borers have been tried but in view of the limitations imposed by heavy soils and of the generally discontinuous character of pole erection work their introduction is not justifiable. Ingersoll-Rand or Reavall compressors are, however, used for drilling rock for the blasting of pole holes.

For the erection of poles by hand, ladders are often used, and pole-lifters, *i.e.*, stout staves, each topped with two sharp prongs, are of great convenience. A special jib crane mounted on a lorry is available for use when a number of poles are to be dealt with. (Fig. **12**). It can be used for heavy poles with

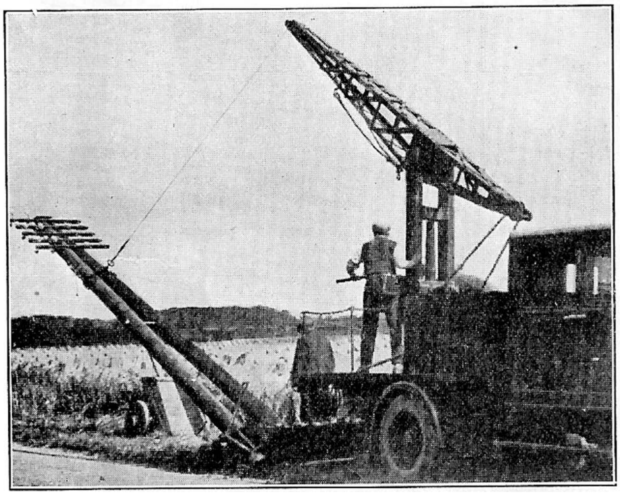


FIG. 12.

marked safety to the men, as compared with hand erection methods, and, in addition, savings are effected as excavation is reduced to a minimum.

An alternative method is being investigated which at least posseses the merit of low cost per individual equipment. The apparatus is a form of sheer legs having two members attachable to a 3-ton lorry and a third (vertical) strut to take the downward thrust. The arrangement is shown in Fig. **13**. As a winch is normally fitted to this type of lorry, all that is required are the three struts and the block and the means for readily attaching the apparatus to the lorry. In contrast to the crane lorry already described, the usefulness of the standard lorry for other work is not impaired by permanent fixtures, but on the other hand the movement is not so flexible and the sheer legs will be mainly an aid to hand erection, enabling heavy stout poles to be erected by a gang of four to six men with ease and security.

For the recovery of poles the pole jack has proved invaluable. It will extract a pole from heavy soil and save completely the time of excavation. It is often overworked, however, and in many cases a pair of jacks is desirable with one positioned on each side of the pole to distribute the load.

Road widening work sometimes renders it necessary to shift poles back from the road and, using one jack, a pole may easily be pushed or "kicked" a number of yards either along a trench dug between the old and new position, or, more economically, by kicking the pole along the surface of the ground to the hole dug to receive it, where it is lowered using

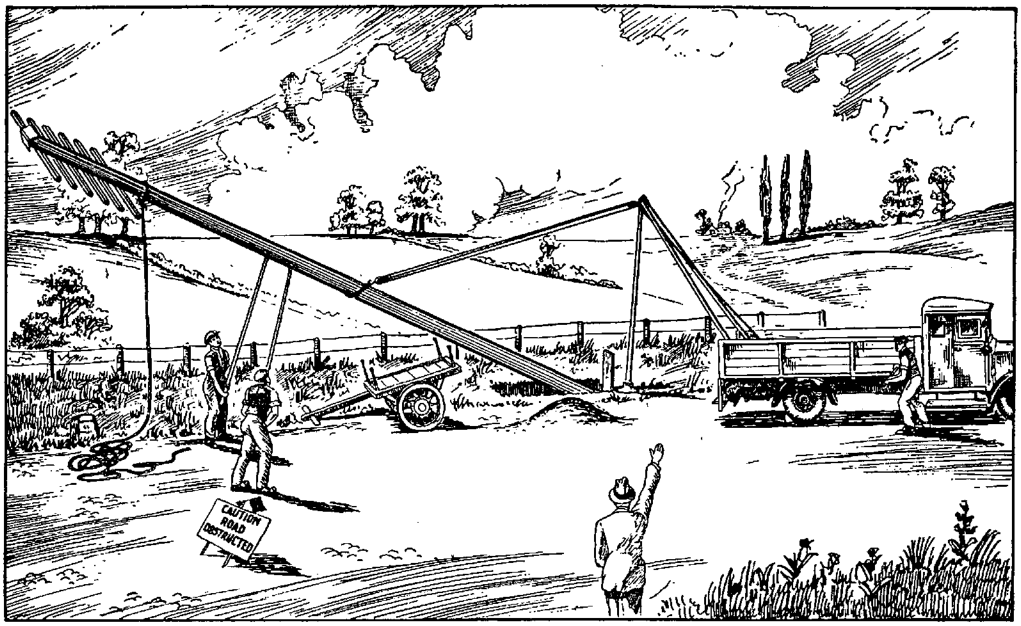


FIG. 13.—ERECTION OF POLES.

two jacks. In this work the head of the pole is held longitudinally by the wires and transversely by temporary guy lines.

7. Design of Pole Lines.

In order to arrive at some conclusion regarding the permissible load which can be placed on a pole line, it is necessary to decide two things—the magnitude of the storm stresses which may be expected, and the factor of safety.

Generous allowance is made for storm stresses but only a liberality of design devoid of all economic considerations would prevent an interruption when snow accumulations reach an abnormal amount and a heavy gale supervenes. It is the practice to allow for the occurrence of a gale of 80 miles per hour unaccompanied by snow or ice, but, in considering special cases, such as aerial cable loads, a coating of ice of $\frac{1}{4}$ inch radial thickness, accompanied by a wind of 50 miles per hour, is often taken. The latter corresponds to the design of electrical transmission lines, for which a radial ice thickness of 3/16 inch (L.T. lines) or $\frac{3}{8}$ inch (H.T. lines) with a 50 m.p.h. wind is specified by the Electricity Commissioners.

The factor of safety adopted by the Post Office for wood poles is 4 under the higher wind conditions.

The British Electrical and Allied Industries Research Association has investigated extensively in the field of wind pressures on poles and cables (3).* Theoretically and practically it can be shown that the pressure coefficient (K^1) of similar objects has a constant value depending upon the product of the velocity (V) and a dimension, such as the diameter (D), and this has been determined for both wires and poles over a range of diameters and of wind velocities. For wires, the coefficient at 80 m.p.h. varies from 0.0025 for 40 lb per mile bronze wire to 0.0029 for 600 lb per mile copper wire. For poles, curiously enough, the coefficient is found to fall off considerably and at 80 m.p.h. K^1 varies from 0.0003 for a 4-inch diameter pole to 0.0011 for an 8-inch diameter pole.

This coefficient, when multiplied by the square of the velocity, gives the pressure, (P) in lb. per square foot of projected surface, thus—

$$P = K^1V^2 \quad \ldots\ldots\ldots\ldots \quad (1)$$

The velocity of a wind also varies with the height above ground, being, at 2 ft. above open grass land, roughly half that at 32 feet. Table 14 of the Association's report (3)* makes allowance for this variation in calculating the equivalent force due to the wind at a point of 2 ft. from the top of the pole. This table has been referred to in the preparation of Table IV, which applies to representative standard sizes of pole used by the Post Office, Column (3) is obtained by dividing the theoretical breaking load by the factor of safety, taken as 4, and the safe working load in column (5) by deducting the wind load from the figure obtained. The pressures per 60 yard span of 40-lb. cadmium copper and 150-lb. copper wire are taken from (1) above which gives 12 lbs. and 26 lbs., respectively; and the number of wires which the working load permits is thereby deduced.

In the last two columns, average carrying capacities for light, medium and stout poles of 18, 35 and 61 40-lb. wires or 9, 16 and 29 150-lb. wires, respectively are arrived at.

These figures are somewhat higher than those obtained from instructions now in force; this is on account of the more accurate values, now available, for wind load on large diameter cylinders being, on

* See Bibliography.

TABLE IV.

CARRYING CAPACITY OF STANDARD POLE LINES. WIND VELOCITY 80 MILES PER HOUR.

NOTE Number of wires marked * impracticable with standard arms and clearance above road margin.

Length of Pole (ft.)	Minimum Breaking Weight.	Safe Load.	Wind Load on Pole.	Working Load.	Number of wires 60-yd. span.	
					40 lb. wire.	150 lb. wire.
Light.	lb.	lb.	lb.	lb.		
20	1020	255	15	240	20*	9
24	1010	252	16	236	20*	9
28	1040	260	18	242	20	9
32	970	243	24	219	18	8
36	1020	255	32	223	19	9
40	990	248	51	197	16	8
Medium.						
24	1920	480	18	462	38*	18
26	1890	473	23	450	37	17
28	1870	467	29	438	36	17
30	1870	467	33	434	36	17
40	1780	445	65	380	32	15
50	2170	542	143	399	33	15
Stout.						
28	3530	882	50	832	69*	32
30	3470	868	60	808	67	31
34	3370	842	82	760	63	29
40	3330	833	122	711	59	27
50	3700	925	240	685	57	26
60	4020	1005	600	405	34	16

calculation, somewhat less than the approximate determinations based on a uniform pressure of 8 lb. per square foot of projected surface. There is, moreover, a sharp falling off for tall poles owing to the pressure rising above this earlier equivalent, and it will be seen that the permissible loading on a 60 ft. stout pole is considerably below that of poles of shorter lengths.

For spans other than 60 yards it is necessary to increase or decrease the number of wires inversely as the span length. When the route is sheltered so that an 80 m.p.h. wind is never likely to be experienced, more wires can be carried with equal safety.

8. Composite Poles.

It is not intended to make other than a brief reference to the use of composite poles, as H-poles are now definitely discouraged, and few new pole lines requiring A-poles are built.

There are occasions when the introduction of A-poles into a line may be of value; for example, when the load is likely to be more than that suitable for a single pole line, A-poles to the extent of 1 in 5 are inserted at important points, or, when there is no room for stays or struts at angles in a line. Two important points, however, require attention..

In 1907 Mr. C. Wade and Professor J. Goodman (4)* showed by their experiments that an A-pole, if properly constructed and having a spread of 1 in 8, should have a breaking strength approximately 4½ times the strength of the component poles used singly. These tests were carried out by holding the brace and butts of the A-pole rigidly in a framework and thus give an estimation of the strength which is available. More recent tests carried out by the British Electrical and Allied Industries Research Association (3),* however, make it clear that this strength cannot be developed unless the foundations are properly designed, as in those tests the poles overturned in the soil under load without breaking. Kicking blocks across the ends of the brace are essential. Both series of tests showed the importance of careful construction. As soon as any deformation of the structure occurs—and this may be either in the scarfed joint or in the brace fitting—the state of pure compression in one leg and tension in the other is lost. The bending stresses introduced by the deformation will cause the A-pole to break at much less than the theoretical load. Unless, therefore, the foundations are good and the construction sound, the benefit of using composite poles is greatly discounted and one is led to the conclusion that a transversely stayed single pole (given room for spreads of stays equal to ½ the height) would be often equal to if not better than a composite pole. It is certainly a much cheaper form of construction.

9. Felling, Shipping and Seasoning.

It is interesting to trace the history of a pole up to the time it leaves the creosoting yard. Firstly, the tree is selected in the forest, which may be either a plantation specially grown by silviculturists, or a virgin one in which the pines have grown naturally close together, as is usually the case in the northern forests of Europe. The result of growing very close together is to produce straight trees and the lack of light and free air causes the lower branches to die and fall off in early life. If the interior of a pole is examined, it is found that at intervals of about 18 inches there is a series of five knots overgrown by many annual rings. This is brought about by the upward growing main stem sending forth five side shoots each year. The trees shown in Fig. 14 are typical Scots pine, suitable for use as telegraph poles.

In felling the tree as much of the natural butt as possible is retained, no timber whatever being removed from the butt, thus giving the maximum bearing surface against settlement of the pole in service. The tree is sawn off square close to the ground as shown in Fig. 14, and, with the top branches trimmed, the log is drawn out to a clearing where the work of stripping the bark proceeds. In this condition the logs are drawn by chains on to pole wagons and taken to the pole depôt.

Poles obtained from abroad may be transported by floating the logs down convenient rivers to the seaport, from which they are shipped to one of the ten depôts situated around the coast of Great Britain.

* See Bibliography.

FIG. 14.

These are at Leven, Grangemouth, Northumberland Dock (R. Tyne), Staddlethorpe (Hull), Boston (Lincs), Charlton, Grays, Southampton, Newport (Mon.), and Ellesmere Port.

Felling of the trees takes place during the winter season whilst the sap is down and must in no case be earlier than the 1st November or later than the 1st of March. Shipping of the poles can commence as soon as practicable, but owing to the ice in the Baltic and Northern ports the first ship loads may not arrive until April or even May. They are delivered at the wharf of the creosoting contractor or loaded into trucks or timber wagons provided by the creosoters. Following a thorough examination by an Inspector of the P.O. Stores Department, the poles are dressed either by hand or in a machine. The latter, illustrated in Fig. **15**, neatly trims off the outer surface by means of two rotary cutters, meanwhile feeding the pole through with a sharp toothed wheel set at an angle. This wheel gives rise to the spiral series of marks often seen on a pole.

For seasoning, the poles are cross-stacked in open formation according to their lengths and classes. Suitable dunnage keeps the lowest tier of each stack well clear of the ground, at least 5 inches being specified. Each full tier of poles is separated by poles placed at the middle and ends as shown in Fig. **16**.

The time required for seasoning may vary from about 6 months for a short light pole up to 3 years for a long stout pole. Estimates of pole requirements are called for annually in July so that contracts may be placed and felling commenced on the 1st of November, and thus from the date of estimating to the date of the supply of the poles for use, a period of from 18 months to 4 years may elapse. If unfavourable weather is encountered, such as in 1932, and the normal period is not sufficient, difficulties in meeting demands are liable to occur.

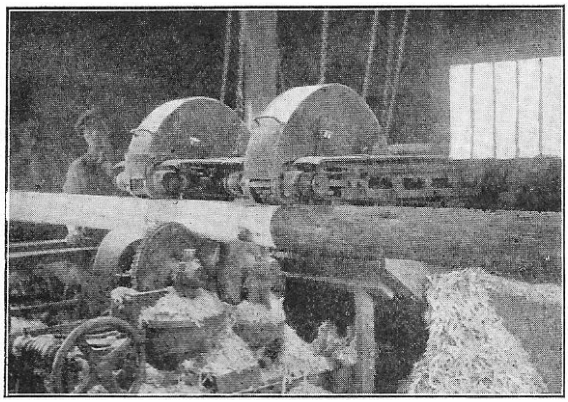


FIG. 15.

In addition, it is the practice to hold sufficient stocks in hand to enable the creosoted surface to weather somewhat before use so as to be less slippery and less objectionable to handle during erection and better capable of taking paint if circumstances demand this.

Correct seasoning is very important for wood which has to be treated with creosote under pressure, as any moisture in the cells above fibre saturation point will tend to prevent the proper access of the creosote to the sapwood. When timber is felled, there is usually over 100% of moisture present as measured by the loss in weight of a given volume of wood when it is dried in an oven at 105°C until there is no further loss, compared with its final oven dry weight. The moisture is partly in the spaces in and between the wood cells; and partly in the substance

FIG. 16.

of the wood; when, in seasoning, the cell spaces have been freed of moisture, "fibre saturation point" (25 to 30% moisture content for Scots pine) is reached and this is desirable. In addition, the wood checks, *i.e.,* splits or shakes, and the preservative will enter the pole more deeply at these points and thus protect it where it is likely to open up under stresses due to abnormally hot weather.

10. Preservative Treatment.

(*a*) *General.*

In the untreated state, wood is subject to the natural forces of decay, which, in course of time, lead to the material losing the mechanical properties upon which its value in structural work depends. In the construction of buildings, the main contributory condition, *i.e.,* dampness, can be guarded against by care in design and it is not often that precautionary treatments are adopted, but when the timber is used externally, for example as telegraph poles, railway sleepers, hop poles or fence posts, the conditions (particularly near the surface of the earth) are such that fungoid growths can easily propagate themselves and insect life will flourish. Different timbers resist in varying degree the forces of decay, and *pinus sylvestris*—which in many ways is the most useful of timbers—is unfortunately one of the least resistant. Also, with this wood as with others, the exposed sapwood is much less resistant than the heartwood. Thus, untreated, a life of only 4 to 5 years can be expected of a Scots pine pole; rather more, say 7 to 10 years at the most, for an untreated larch pole; and, for the " desapped " ironbark poles, possibly no more than 15-20 years can be anticipated.

Charring and tarring of the butts of larch poles has been done in the past but this is so much a surface treatment that it is found to be scarcely better than leaving the pole untreated.

The advantage of using some form of preservative is obvious and such processes date from the dawn of history. The preservative value of certain oils and bitumens was known to the Greeks and Romans and there is little doubt that the Egyptians applied the knowledge gained in the art of embalming to more material objects. From time to time many substances have been advocated. Amongst these are copper sulphate and zinc chloride, and numerous organic antiseptics, often mixed together, which have been marketed under various trade names. But with the advent of coal-gas production on a large scale and the distillation and use of the by-products, it soon became evident that in coal-tar creosote a most efficient preservative had been found. This is at the present time the standard preservative for wood poles used by the Post Office.

Not only is this preservative treatment economical —for the extension of the useful life is thereby secured at less cost than that which would be incurred if untreated poles were used and replaced as required during the equivalent period,—but the reliability of the service is considerably improved and the possibility of accidents and interruptions is reduced. Moreover, a lower factor of safety in loading can be permitted.

(*b*) *Creosote Methods.*

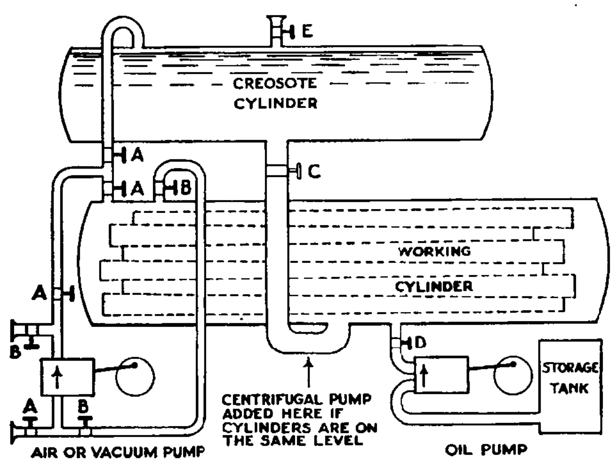
Coal-tar creosote contains a variety of chemical substances so that it is difficult to say which is responsible for the beneficial effects and this has led to wide discussion. Some have maintained that it is the tar acids, principally carbolic, which are the antiseptic agents and that the albumen in the wood is thereby coagulated. But when poles are examined after prolonged exposure it is found that practically all the tar acids have disappeared from the wood. Again, the napthalene is held by some to play an important part, but certain " napthalised " poles erected by the Department did not give 10 years life. It seems, therefore, that a large part is played by the heavy oil constituents, such as cryptidine, anthracene, and acridine, which are valuable antiseptics and, as the boiling points of these are high, they are probably the most permanent substances introduced into the wood. The British Standard Specification (No. 144) for creosote ensures this by specifying that no more than 40% shall distil at 230°C (446°F) and not more than 78% at 315°C (599°F) thus ensuring a proper proportion of the heavier oils.

There are a number of ways of introducing the creosote into poles, the principal ones used by the British Post Office being the " full cell " or Bethel process and the " empty cell " or Rüping process. Proper seasoning of the timber is essential for efficient treatment in these and the majority of the other methods described below. The object of this is primarily to allow room for the preservative to enter the cells of the wood to the fullest extent.

Full cell process. John Bethel brought out his patent in 1838. In this he describes the method of placing the articles to be impregnated in an airtight vessel, of exhausting the container with an air pump in order to remove air from the pores of the articles to be preserved and introducing the heated preservative, and of replacing the vacuum by pressure until the material refuses to take up any more oil. Up to 20 lbs. of creosote per cubic foot of pole can be absorbed, the minimum specified in the (now obsolete) Post Office Specification for creosoting Scots pine poles being 12 lbs. per cubic foot. Until 1913 this process was standard for Post Office poles.

Empty cell process. Rüping developed his process in Germany and it was used in that country from 1904 onwards. In this Country it was adopted at first for all except main line poles in 1912 and then for all poles in 1913. The advantages over " full cell " poles were considered to be as follows (*a*) the poles are easier and cleaner to handle and require less weathering before erection; (*b*) they are more pleasing in appearance; (*c*) contamination of water and damage to clothing becomes practically negligible; (*d*) there is a direct saving in creosoting cost; (*e*) the weight is reduced for handling and transport, and (*f*) they can be painted more satisfactorily than " full cell " poles. Further, if there was any doubt about their life compared with " full cell " poles, the latter generally were so lasting that very frequently they were replaced for other reasons and therefore a shorter life was perhaps permissible: Rüpingised poles have not (in 1933) been in use long enough, however, to settle this point.

Briefly, the process is the converse of the Bethel process in that air pressure is applied to drive more air into the pores of the wood, and after the creosote has been forced in, a vacuum is applied in order to withdraw as much oil as possible. The poles, the cubical contents of which are ascertained, are loaded up on trucks and wheeled into a cylinder, the end of which is then bolted on. The cylinder may take poles up to 85 ft. in length. Fig. 17 illustrates in detail



1. Apply air pressure to both cylinders through valves A.
2. Flood working cylinder through valve C; air passing over *via* A-A.
3. Close valves A & C. Pump additional creosote from storage tank through D.
4. Release all pressure through valves C & E. Surplus oil is returned to creosote cylinder.
5. Close valve C, and apply vacuum through valves B.

Fig. 17.—Rüping Process.

the operations which follow. The compressor applies a pressure of about 60 lb. per square inch to the air in the working cylinder, the pressure being increased gradually to this amount during about 20 minutes. Then, without reducing the air pressure, the valves from the creosote container are opened and the hot creosote is transferred to the working cylinder until it is full. Next, the pressure is increased by means of an oil pump until the scale which measures the oil pumped from the auxiliary creosote tank indicates that the requisite amount of oil has been introduced. This is checked by the Inspector who estimates the amount on the basis of 12 lbs. of creosote for each cubic foot of timber comprising the charge. The time for this operation and the actual pressure used vary considerably according to the timber and it may be necessary to reach a pressure of 150 lbs. per square inch, occupying an hour in the process. It is the practice to load up with timber of similar characteristics in order to avoid inequalities. The pressure is released when the sapwood has thus been fully impregnated, all free oil is drained off and a vacuum is applied to remove as much creosote as practicable. Usually a 26 inch vacuum is maintained for 30 minutes, leaving 4 to 5 lbs. of oil per cubic foot of pole. The Inspector confirms the efficiency of the impregnation by weighing a number of test poles before and after the charge and satisfies himself that the whole of the sapwood has been impregnated by taking borings at random. The poles are taken out at the other end of the cylinder and, as shown in Fig. 18, a crane gathers them up to take them to

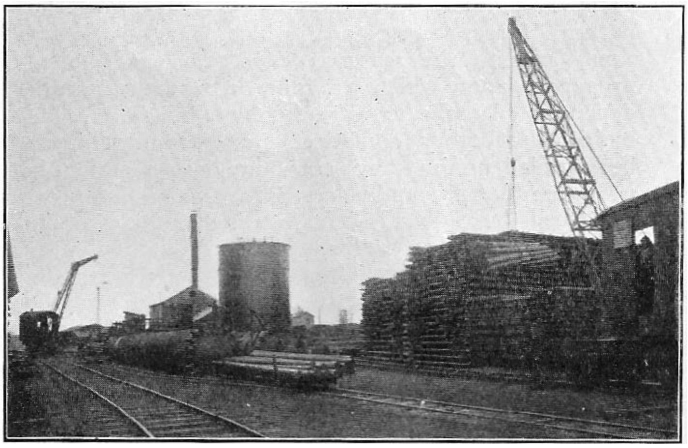


Fig. 18.

pole stacks where they are sorted into sizes and classes ready for despatch in due course. This photograph shows a charge in the cylinder, and a truck load being prepared at the other end. It will be observed that the "black" poles are close-stacked as distinct from the open-stacking of "white" poles shown in Fig. 16.

Lowrie process. This process, favoured by American creosoters, is intermediate in effect between the Bethel and Rüping processes. The creosote is introduced under pressure and recovered under vacuum. As the recovery depends only upon the elasticity of the initial air in the wood, more creosote is left in than in a Rüpingised pole—about 7 lbs. per cubic foot.

Boulton (16)* *or "Quick" process.* The process patented by Sir Samuel Boulton in 1879 is suitable for unseasoned or waterlogged timber. The excess moisture is removed by immersing the timber in creosote the temperature of which is raised to 200°F; the moisture is drawn off as steam and condensed. Under reduced pressure, a vacuum of 25 ins. being usual, this is continued for a number of hours until sufficient water has been removed. After this, either the Bethel or Rüping operations may follow.

China process. As a means of economising creosote Captain China invented a special colloidal mill for emulsifying creosote with water to which a stabilising compound has been added. A number of

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* See Bibliography.

poles treated in this way have been on trial since 1923.

Brush and Butt Treatments with Creosote. In the U.S.A. where several naturally resistant timbers, such as Western red cedar, Northern white cedar or chestnut, are available, it is often the practice to treat the pole partially. Brush treatment has been shown to be of little use in prolonging the life but the successive immersion of the butts in hot and cold creosote baths has been found to be effective. For example, untreated chestnut poles on the Omaha-Denver Line of the American T. & T. Co. have given an effective life of 12.3 years; with brush treatment, 2 coats, 13.7 years was obtained and it is estimated that a serviceable life of 20 years will be given by the butt treated poles (6).*

The value of butt treatment in an open tank is evident when transport to pressure plant renders the cost of the pressure process prohibitive and when the cost of the creosote itself is high.

(c) *Other Methods.*

Boucherising. Copper sulphate is normally used for this process, but the method of introducing the preservative is the main feature. The poles are laid out horizontally soon after felling and the solution is applied under slight pressure to the butts. This is maintained—usually for 10 to 12 days—until tests show that the solution has arrived at the tip after having replaced the sap in the wood. This process is still largely used in France, Switzerland and Denmark, a partial treatment of creosote being often given to the butt to supplement the copper sulphate. As the wood structure of spruce resists impregnation by creosote, this is the best means of preserving such a timber, and it is contended by advocates of the timber that the resistance to pressure impregnation also prevents water dissolving out the copper sulphate during service.

Burnettising. The use of a specific "Burnettizine" comprised of zinc chloride and other salts was patented by Sir William Burnett in 1838 and was largely used up to 1913 in the London and Home Counties area when painted poles were required. The solution was injected into the wood in pressure tanks. A distinct factor influencing the life of these poles was the paint applied to the surface and without this aid to the retention of the preservative in the wood, the life would have been much less.

In both this and the previous method, and indeed in all processes in which a water soluble salt is the agent, there is a tendency for the chemical to leach out of the wood in the course of time, so that in the end its concentration is so low that decay is not prevented.

Wolman Salts. The chief constituents of this preservative mixture are sodium dinitrophenate and sodium fluoride, the former being the most active fungicide. A 2.0% aqueous solution is injected into the timber by pressure in the usual way. It is claimed that the method is more economical than creosoting and that an adequate life for the treated wood is obtained. The treated wood can also be painted without difficulty when dry.

As the salts are soluble in water it is probable that the salts will leach out in course of time, although it is asserted that fixation takes place in the wood fibres by chemical action. In addition, during dry weather, the wood will dry out quicker than will a creosoted pole so that excessive cracking might be expected. A trial consignment was erected in 1929; part of the consignment was treated with Wolman's salts (Triolith) alone, and part was treated with a mixture of the salts with a cheap oil (fuel oil) with the object of preventing any leaching. These poles are still all in sound condition, although the fuel oil is leaving the wood and thus may be regarded as failing in its purpose.

The salt has its recommendations where creosote is objectionable, *i.e.*, particularly in building work, and one type, the Minolith, is also a fire retardant. The latter is intended primarily for pit props which are not normally creosoted on account of fire danger and of the smell masking the presence of gas.

"Cobra" process. This is an ingenious method whereby the material in the form of a paste is injected with a special tool. The hand tool for treating poles in situ is a heavy hammer having a large hollow "inoculating" needle thereon. After driving this needle into the wood up to 2½ inches deep, a lever is operated in order to force the poisonous ingredients into the puncture as the needle is withdrawn. Hence the characteristic name.

The paste is said to spread gradually throughout the sapwood, but to apply the paste to a complete pole is not an economical method, and it would appear that its use is limited to cases where application of the preservative at the ground line only is considered sufficient.

Haskinising. The invention of Col. Haskins is of interest only. The process consisted in subjecting timber simultaneously to a considerable air pressure varying from 150 lbs. to 200 lbs. per square inch and to a temperature of about 250°F. Briefly, the intention was to vulcanise the wood and it was said that the effect on the wood would be similar to charring but extend farther into the pole. To investigate the merits of Haskinising a number of poles were so treated in 1901 but 27 were damaged by an explosion in the cylinder whilst out of 70 erected only 7 remained 5 years later.

Impregnation of Standing Timber. Several patents have been filed for methods of treating the living tree before felling. The feature of these is generally that an easily diffusible substance is introduced into the sap stream at the foot of the tree via bore holes or a trough cut in the bark and added until the leaves wither and the tree is killed. Thus the impregnating agent is thoroughly disseminated throughout the trunk and the tree can be used as a pole within a short time of its treatment. One such process (7)* incorporates the use of arsenic compounds, as being readily conveyed by the sap; and

* See Bibliography.

mixtures of 3 parts arsenic acid to 1 part sodium fluoride, or sodium arsenite and benzoate in equal parts, are specified.

11. Life.

(*a*) *Statistics.*

As mentioned on page 3, detailed records covering the history of every pole erected are not kept. It is therefore difficult to obtain an exact figure for the average life of a telephone pole. Indeed an upper limit for the life of a creosoted pole in the service of the Post Office has not yet been settled for the reason that there are still standing a number of poles which were erected in 1870. One of these was inspected this year (1933) and the timber found to be quite sound. Such poles are, therefore, 63 years old, and there are also many between 50 and 60 years of age in excellent condition.

In 1912, particulars of poles recovered owing to decay, during the previous 2½ years were obtained for valuation purposes and these are shown in tabular form below.

TABLE V.

Type of pole.	No. of poles recovered owing to decay,	Average effective life.
Creosoted (full cell)	10,662	28.75 years
Burnettised	473	13 ,,
Pitch pine	73	20.5 ,,

This does not give a true idea of the ultimate life of the poles generally as an allowance would have to be made for the sound poles with, at that time, up to 41 years life remaining in the line. It is evident that if a creosoted pole remains in position a life of over 30 years can be expected.

For financial studies it is desired to know what is the overall life taking into account all factors, including among other things, replacement of poles due to increasing loads which call for stronger or higher timber, and also the reissue of some of these poles on works. From a knowledge of the total number in existence and the issues of the Post Office Stores Department from year to year an overall life of 28 years has been estimated. In view of the different conditions appertaining to main telephone and telegraph pole lines, as distinct from subscribers pole lines which are frequently disturbed by underground development schemes, main line and local line poles are considered separately, and economic lines of 40 years and 20 years, respectively, are recognised.

After a pole has withstood successfully a period of, say, 20 years, it is considered that it will have experienced sufficient extremes of temperature and moisture to determine the full development of seasoning checks. If these are not at all pronounced, the untreated heartwood will be properly protected and a continuance of the pole in service can be confidently looked for whether the pole remains in one position or is removed to a new duty. Even if there are pronounced checks and the pole has not commenced to decay, it is probable that the creosote penetration was good and that the checks have not pierced the layer of creosoted wood. Thus, even if a pole is 40 or 60 years old, its age is no criterion of an early termination of its usefulness and its condition alone is a guide.

The benefit of an unbroken thickness of creosoted wood will again be referred to in this paper when a scheme is described for ensuring this by the preparation of the pole for the reception of the arms and roof before creosoting is done.

The life of a pole is, however, affected by a number of factors. Apart from decay, damage is sustained by road traffic, fire, attacks of insects and birds, lightning, and storms or blizzards. These are referred to briefly in the following paragraphs :—

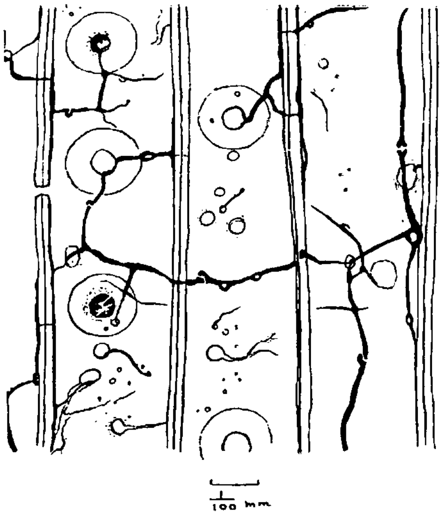
(*b*) *Decay* (8) & (9).*

Unprotected felled timber is liable to attack by fungi or, as it is usually termed, " Dry Rot." The chief varieties of this which are met with are *merulius lacrymans* and *fomes annosus*.

The living trees are also liable to attack by fungus diseases (Wet Rot) such as *trametes radiciperda* which attacks the tree beneath the bark or *agaricus melleus,* both of which spread to the tree, *via* the roots, from the soil. Among others there is *polyporous sulphureus* which enters a wound in the bark or at a broken branch and when full grown produces the well known horizontal brackets on diseased tree trunks. The presence of any such disease is readily detected by inspection in the pole depots and should not concern engineers.

All fungus growths are very similar in their behaviour. Corresponding to the seeds of normal plant life, reproduction is carried on by the production of " spores " from a fruiting body or "sporophore." This may be of the toadstool type as in the case of agaricus or of the bracket type as evinced by the polyporii. The spores are produced in countless myriads and are carried about by the wind or by animals and insects or even rain and, when deposited on the damp surface of timber where the conditions are favourable, they germinate, sending their germinal filaments or " hyphae " into the tracheides or wood cells to decompose the wood substance with the fluids emitted in their growth. As they extend and multiply a matted mass is formed called the mycelium, which in *merulius lacrymans* is a grey colour with patches of lemon yellow and tinges of violet. The timber develops fine cracks and loses its strength, turning brown and splitting up into small cubical pieces. Fig. **19**, prepared by the Forest Products Research Laboratory, shows in a much enlarged diagram the hyphae of *lentinus ledipus* in the tracheids of spruce. When fully developed the mycelium sends forth a fructification, which continues the cycle by liberating more spores into the atmosphere. A typical bracket type which occurred on a pole is shown in the photograph (Fig.

* See Bibliography.



Note bore holes made by fungus.

Fig. 19.

20) which also shows the tape-like mycelium running vertically in what was a pronounced crack.

The conditions in which the fungus growths flourish, are, a certain amount of moisture, a moderate temperature, the presence of air and in most cases the presence of an alkali, such as ammonia. Generally, in the absence of any one of these conditions the spores will not germinate. In the case of

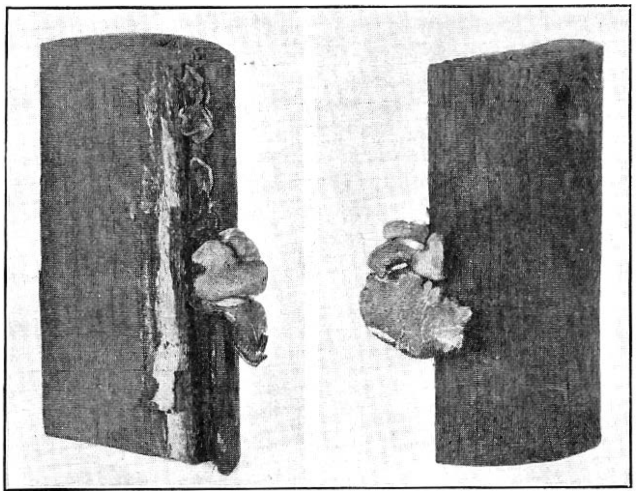


Fig. 20.

telegraph poles the majority of these conditions occur near the ground line (between 2 ft. below and 2 ft. above) or in cracks, such as seasoning checks or in the crevices at arm slots. The mineral poisons and acids of the creosote, however, effectively prevent the germination of the spores and decay cannot proceed unless the protective layer is pierced or broken. It is for this reason that it is so important to paint thoroughly with a creosote and tar mixture any cut surfaces of a pole.

One of the difficulties of detecting decay is the fact that the creosoted exterior may remain to give the superficial appearance of a sound pole. A ready test, given an ear accustomed to the sound, is to strike the pole with a hammer, but a more certain test is to make a boring of the wood with a Timber Tester. This is a hollow auger, which extracts a specimen of the timber about $\frac{1}{8}$ inch in diameter, showing clearly the condition inside the pole. The hole is then stopped with a creosoted wood plug.

The correct stacking of poles to allow a free ventilation of air around them is important and a clear space of 9 inches between any pole and the ground with an absence of vegetation is to be desired. The leaving of a pole or poles direct on the grass margin of a road for any appreciable length of time should not be permitted.

(c) *Damage by road traffic.*

In the great majority of cases, telephone poles in this country are situated on the road-side and from time to time accidents will happen, however much care is taken to choose the most suitable positions or to render the pole conspicuous to motor drivers by means of reflectors or aluminium paint. It is not the intention to discuss law or procedure relating to damage of this type but to refer to it as an instance of the termination of a pole's service.

The damaging force is of necessity a sudden blow, —a force of impact—and, as distinct from a storm load, it is applied at a point near the foot of the pole. If the blow is a glancing one the result, as far as the pole is concerned, may only be the removal of a splinter of wood but if on the other hand the vehicle hits the pole squarely at high speed the pole may easily be fractured at the point of impact, or at some weaker point by the whipping of the pole under the shock. An example of this occurred at Ashford in Middlesex last March (1933) when a 16 h.p. Humber car collided with a pole on the off side of the road. The pole was moved 3 or 4 inches at the ground line and the head fractured at a stay fixing and snapped off below the bottom arm so that the top carrying the arms and wires swung over the carriageway. A similar case occurred some years ago at Golders Green, when an omnibus caused the unusual condition of the wires supporting the arms instead of the arms supporting the wires and the circuits were not put out of order.

(d) *Damage by insects and birds.*

Although it is claimed by some that birds in causing damage are looking for insects, the ravages of birds and insects are not invariably related. Indeed, insects are probably more closely associated with decay fungus, for wood boring beetles are known to carry fungus spores into the cracks or bore holes in order that the wood shall be softened by decay or that the larvæ shall feed upon the fungus. Creosote is, however, a deterrent to insects as well as to fungus growth.

Damage due to the activities of the green woodpecker is considerable in some forest localities, and creosote is certainly no deterrent to the birds, for both new and old poles alike are attacked. It is not always evident that the birds have been seeking insects although in some cases colonies of wood lice or the cocoons of the leaf-cutting bee have been found in the vicinity of the attacks. On the other hand, it is seldom that the shape of the hole indicates that the birds had in view the formation of a nest so that, although one of the reasons referred to is generally regarded as the probable explanation, it appears that there is scope for the naturalist to suggest some other objective.

In one locality alone repairs recently cost nearly £500.

A pole may have as many as 12 holes made in it between the top and about 6 ft. from the foot. Generally, the hole is 2 to 4 inches in diameter, somewhat oval in shape and extending some 3 inches into the pole, *i.e.*, it is mainly in the softer sapwood. There are exceptions to this, however, and occasionally sound heartwood is penetrated and in some cases a hole right through the pole may be found.

As a deterrent many devices have been tried, but small mesh wire netting covering the region of the activities has proved the most successful and, of course, creosote and tar mixture has to be applied to prevent decay setting in.

(e) *Damage by lightning.*

Occasionally poles sustain damage during thunderstorms and have to be replaced. The effect is generally as though a charge of explosive had been detonated within the pole and in all probability depends upon the degree of wetness; a rain-soaked pole carrying the current on the surface with less damage than one struck before the rain comes. The high intensity of the current finding some internal path will cause the conversion to steam of the moisture which is always present in the wood cells or cell walls and may cause its decomposition into gaseous hydrogen and oxygen of several thousand times the original volume. (10).* The sudden generation of pressure is sufficient to account for the result, which may vary from the production of long splits to complete demolition of the pole with large pieces flung 50 yards from the site.

The vagaries of lightning are many and often it is difficult to find an explanation of the way in which damage has occurred. Poles have been struck although almost surrounded with taller trees and thus not conspicuous or isolated in any way.

The earth-wiring of poles is effective in obviating damage by a direct stroke, but of little use unless all poles are wired which is not justified economically in this Country.

Pole earth-wires may be of use at intervals along a pole line as a means of reducing noise caused by induced charges, but it is doubtful if these charges, having less than one-millionth of the energy of a direct stroke (11)*, can injure poles.

A suggestion has recently been put forward by the American T. & T. Co. that the shattering of poles by lightning can be mitigated or obviated by a wire extending from the top of the pole to a point just below the lowest arm and terminated there (12)*, care being taken to have no staples or other sharp points entering the pole near the lower end as these tend to lead the discharge into the pole. At first sight, a wire which is not earthed might appear to be of little use, but it is interesting to learn that there is some basis for the suggestion both in laboratory tests with a lightning surge generator and in field tests on exposed lines. This suggests that old pole earth wires which have corroded away at the ground line are still of use as lightning protectors.

(f) *Damage by storms.*

The effect of storm damage upon the average life of poles is small, partly because the number broken is such a small percentage of the whole and partly because the poles will generally have had a reasonably long life. For example, in the storm of February, 1933, the percentage of breakages amounted to about 0.06% of the poles in use by the Department and the average of 250 broken poles, having recognisable dates, in the Cardiff and Swansea area was 24 years. This does not mean, however, that storm damage is not important; rather the opposite is the case and, in view of the expense involved in the work of repair, some remarks upon the character of storm damage, with special reference to the last occasion and some lessons gained from the experience, are possibly of value.

As already pointed out in Section 7, the design of a pole line is such that there is a good margin of safety against the effect of a high wind. When, however, as on the 23rd February, 1933, there occur heavy falls of snow or sleet at approximately the melting point of ice, *i.e.*, 30-34°F, accumulations of the sticky snow will form on the wires and it is not uncommon for such accumulations to attain a diameter of 3 or 4 inches. Comparison of the snow-covered wires with the arms and insulators on the pole in Fig. **21**—a photograph taken in Cowbridge

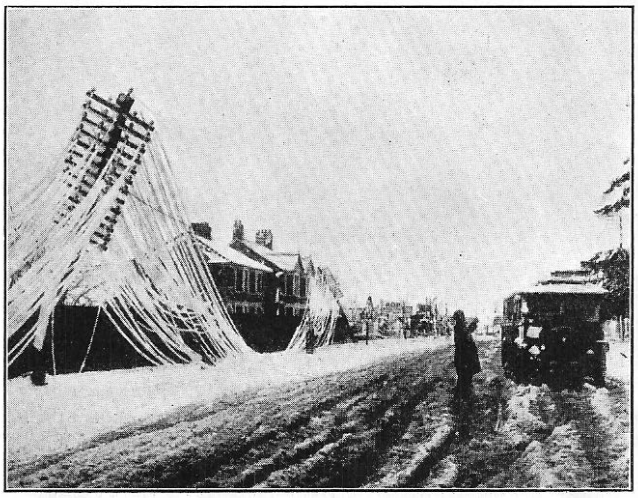


Fig. **21**.

* See Bibliography.

Road, Cardiff, after the storm had ceased—indicates a full 2-inch thickness of snow.

An estimate of the actual loads imposed on a line of stout poles carrying 48 150-lb. wires at 60-yd. spans is as follows: The total tension in the conductors under ordinary conditions is 2.25 tons which is normally balanced on either side of a straight line pole or at an angle the resultant is held by a stay. With a deposit of 1 inch diameter of snow, this is increased to 5.9 tons in still air, and should the deposit grow so as to cause each wire to be at its breaking point (490 lb.) the total tension would become 10.5 tons. Under these conditions an insufficiently stayed angle or terminal pole might fail or, if some of the wires break in a span leaving the remainder to bear the tension, the bed of wires might break one by one until the pole, which cannot stand more than 2 tons, gives way. If, moreover, a transverse wind of say 50 m.p.h. acts on the 1-in. diameter wires, a side pressure of 2.3 tons is added and this in itself would break an unstayed pole.

The sleet conditions experienced last February were such that heavy and light gauge conductors alike accumulated the snow and the general result was that trunk line poles became loaded to breaking point before the wires; whilst in the majority of cases of local line plant failures the poles remained standing with the wires broken due to the inability of the latter to withstand the additional weight.

It was observed that the majority of breaks were such that the poles must have broken under longitudinal stress in the line and it could be deduced how damage had travelled along the line away from a certain point. This is evident in Fig. **22**, which shows a typical break on the Bristol-Bridgewater line where the pole has broken away from some more distant point. The far side of the fracture showed the parting of the fibres under tension, splinters about 2 ft. long being left on the stump. In some cases, however, a long sliver of wood was left extending to what was the bottom arm slot, generally of shell formation caused by shear between the annual rings. The near side of the fracture illustrated failure in compression and the effect of shear stress has caused the fracture to fall in planes at roughly 45° to the horizontal, *i.e.*, in V-formation. Failure in compression normally occurs earlier than failure on the tension side and lines of compression appear on the surface of a pole which has approached breaking point. In one case the lines occurred at intervals of 18 inches between the ground line and the actual break at a height of 6 feet, these intervals coinciding with the interval between the knots of the yearly growth stages of the tree. The presence of these "kinked" fibres on a deflected pole is a good guide for determining whether it should or should not be replaced.

At Bridgewater a line of 50 ft. stout poles suffered damage. When the break occurred the damage spread to a line of poles close to a row of council houses. The presence of arm slots 2 to 3 inches deep on the tension side caused the tops of the poles to snap off and be deposited in the gardens of the houses, leaving the stumps standing. This was fortunate as damage to the houses might otherwise have been considerable. Indeed, on the whole, damage to property was remarkably small and the only life lost was that of a cow electrocuted owing to the telegraph wires, which she encountered, being in contact with a power circuit at another point.

The breakages at Bridgewater condemn the practice of cutting the lower arm slots deeper than normal in an endeavour to position the arms vertically one above the other, and provide an argument in favour of any method which reduces the depth to which wood is removed at these points.

The presence of efficient stays is an important factor in reducing the amount of damage incurred under storm conditions and too much attention to stays cannot be given when building lines.

Fig. **22**.

The beneficial effect of line stays in preventing the spread of damage was very apparent, but several were observed where the wire of line stays had pulled out under tension and also where line-stayed poles had deflected badly, although the stays had held. It is rarely that a spread at least equal to the height cannot be given to a line stay, and if this is done the structure is made stronger and movement of the pole reduced. The force due to the bed of loaded wires is so enormous that line stays rendered inefficient by short spread are apt to be like the proverbial reed which fails in the time of need.

Regarding the effect of angle stays, it was noticed that very often when a pole had broken at a height of 12 to 15 feet above ground level it was fitted with these and this pointed to buckling of the pole under a heavy compressive stress being a contributory cause. This is easily understood if the stay has a short spread, for if the spread is $\frac{1}{X}$ times the height then the downward force on the pole is X times the resultant of the wire tensions. For example, if the height of the stay is 24 feet and the spread 6 feet, the pole has to support a vertical load of 4 tons for every ton acting horizontally at the top. In the same way the stay wire itself cannot support so great a load on the pole if the spread is reduced.

Fig. **23** shows a high break due to a buckling load, photographed in the Swansea area. The stay wire has not broken, but the stay crutch has bent completely out of shape.

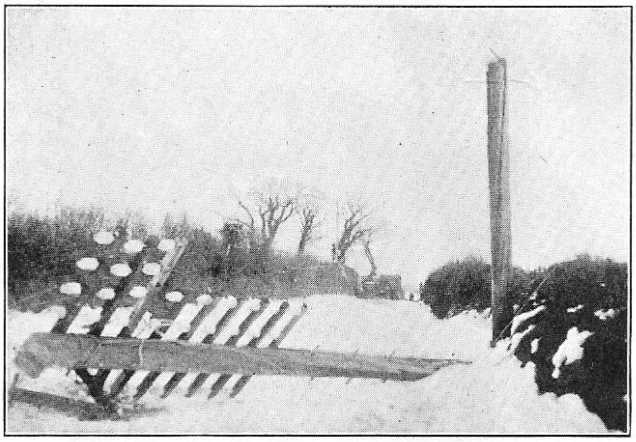


Fig. 23.

I am only repeating what has been said many times before in saying that, where the proper stay position requires the negotiation of a private consent, the effort of obtaining this is well worth while. Nevertheless, it is evident that full use is not always made of the space available on public property or even when a wayleave has been obtained.

It was apparent from a brief tour of the South Western and South Wales areas that the condition of poles, as evidenced by the type of break, was exceptionally good and that failures due to decay were very few. A record was made in the Cardiff and Swansea Sections of brief particulars relating to each broken pole. A summary of the notes relating to condition is as follows, the position of the break being taken as an indication of the location of the decay :—

Table VI.

Number of broken poles examined ...	336
Sound condition	80.4%
Fair ,, ...	12.2%
Decayed at top	3.5%
,, ,, bottom	3.9%

A special examination of the poles on the Cardiff-Newport main line, where the majority of the poles were overturned in the weak soil rather than broken, was made by a pole inspector of the Stores Department in order to determine how many should be used again. In view of the object of the examination it was no doubt more rigorous in the detection of decay than that of the broken poles referred to above in which the condition at the break only was noted.

An analysis of his report is also of interest.

	P.O. line.	*Acquired line.*
Number of poles examined...	391	208
Fit for re-issue	48.3%	30%
Broken	18.6%	31%
Sprung	1.5%	1.9%
Decayed in arm slots ...	15.1%	16.0%
,, elsewhere	10.7%	15.4%
Woodpecker attack, larch poles, etc.	1.3%	—
Needing further examination	4.3%	5.8%

These summaries establish that the occurrence of decay in the top of the pole is almost of as much frequency as decay elsewhere and there are three main reasons for this: firstly, the creosote in the timber tends to soak down the pole, giving additional protection to the butt and less to the top; secondly, wood is removed at the top of the pole to form arm slots or roof slopes, exposing unprotected wood which is not always painted over; and thirdly, during line inspections more attention is given to the conditions at the base of the pole.

12. Precutting of Poles.

Considerable thought has been given to a scheme whereby all the necessary cutting and boring of a pole would be carried out in the pole depôt before issue instead of being done on the site at the time of erection or later under more unfavourable conditions. Power transmission authorities often specify this and with the fixed number of small attachments which they employ it is readily possible.

The advantages of cutting away the wood before creosoting are manifest, but until recently several disabilities prevented its adoption.

There is no question but that a greater life of the poles thus treated would be secured and depreciation charges reduced. Sufficient has been said regarding the action of decay, which is purely the work of fungus growths, to show that the retention of an unbroken creosoted layer over the whole surface of the pole, should, apart from damage causes, provide a pole with an exceptionally long life which will meet all practical requirements.

In addition, there should be a saving in cost by having the work done on a mass production basis by men (or machinery) continually employed in the operation, as against work in the field; and undoubtedly a saving in the cost and maintenance of tools (saws, augers, arm gauges, planes, adzes, etc.) would be effected. If A-poles were constructed in the depôt and issued in parts marked ready for assembly a definite saving should be obtained, for this certainly is a difficult job for the roadside.

Against these considerations are (1) the possibility of damage to the slots in transport, (2) the elimination of choice for the " set " of a pole which is not straight and (3) the use of $2\frac{1}{2}$ and 3 inch arms.

The details of the scheme as visualised originally were :—

(*a*) The cutting of all arm slots $2\frac{1}{2}$ inches in width —as 96% of the arms issued are of this size. For 3-inch arms a $\frac{1}{4}$-inch portion of wood required removal top and bottom of the slot.
(*b*) The boring of a bolt hole centrally in the slot.
(*c*) The cutting of the slots on the concave side of slightly curved poles so that the curve would not be seen when viewed along the line and would be on the correct side of terminal poles.
(*d*) The cutting of the roof slopes.

This is, however, a more or less straightforward application of the idea to existing methods of construction and unfortunately it broke down for three main reasons. Firstly, the existence of variations in the size of arms from the nominal $2\frac{1}{2}$-inch depth, brought about by seasoning of the wood between the time of planing and of erection—by gauging the width of slot from the arm itself a good fit is obtained, but this could not be guaranteed with slots cut beforehand. Incidentally, the attention directed to this point has led to the specification of longer seasoning periods for arms and consequently better arms should be obtainable in future than during the past years; secondly, the need for filling the slots for protection increased the cost so that it approximates to the present cost of doing the work *in situ*; and thirdly, a number of slots cut in the depôt would not be required immediately the pole is erected, if at all, thus representing deferred or wasted capital. For these reasons the scheme was not adopted.

A suggestion was then made by the Engineer-in-Chief that arm braces be used as was the R.E. practice during the Great War. This has been developed on lines which will be described and it is evident that the object will not only be achieved, but that a distinct improvement in the standard of construction will be obtained, for arms cannot become diverted from the right angle position as they are liable to be at present, particularly when extension brackets are fitted to one end only of a four-wire arm.

The work to be done in the pole or arm contractor's yard under the revised arrangement will be—

(*a*) The cutting of a flat surface of sufficient length from the top of the pole to accommodate 4, 6 and 8 arms on light, medium and stout poles, respectively. The " flat " is to be obtained by removing a minimum of $\frac{1}{2}$ inch of wood at the centre of the width and if the pole is not exactly straight, this is to be cut on the concave side.
(*b*) The boring of the holes for the arm bolts at 12-inch centres in a straight line centrally along the flat surface.
(*c*) The cutting of the roof slopes.
(*d*) The boring of two bolt holes in all single-pole arms at 12-inch centres from the arm bolt hole.

The arm braces have two holes at 1 ft. 5 inch centres, so that when they are bolted to a 4-way arm at the holes referred to above and are secured to the bolt of the arm immediately below (Fig. **24**), the

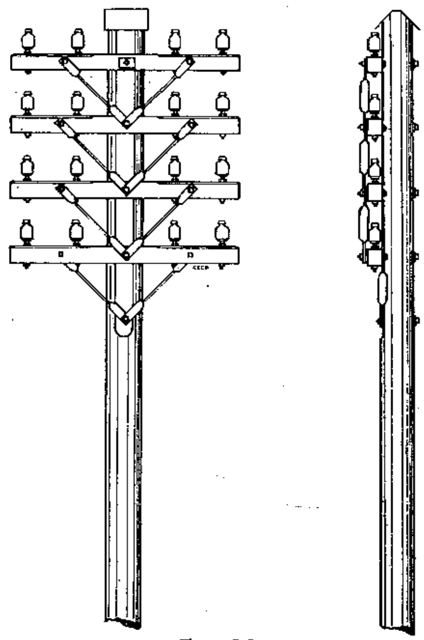


Fig. **24**.

arms are at right angles to the pole and the braces at an angle of 45° with the pole and the arm. In this way a satisfactory clearance is obtained between the arm braces and the line wires nearest the pole. In the case of 6-way and 8-way arms, the braces are used in conjunction with the standard combiners and are fitted only to the top and bottom arms, the lower pair being bolted to the pole 12 inches below the bolt of the lowest arm. An alternative for 4-way arms is to use one brace on each arm so as to leave more room for climbing. The unsupported side is then no weaker than when the arm is slotted into the pole, but the arm bolt is subjected to greater shear. Alternatively, to give more room for climbing where two braces per arm are used the point of fixing the brace to the arm can be brought in towards the pole and yet retain greater support than an arm slot gives. Preliminary trials have been made in several Engineering Districts and Fig. **25** is a photograph of a pole fitted with 8-way arms braced in this fashion.

As approximately $\frac{1}{2}$ inch of wood is removed the strength of the pole is not reduced to anything like the extent caused by arm slots $1\frac{1}{2}$ inches deep, or, as mentioned in an earlier section, even greater depths. Other points in favour of the new method are that arms can be fitted almost as easily on a standing pole as on the ground and thus, when renewing poles, the operation can be simplified by

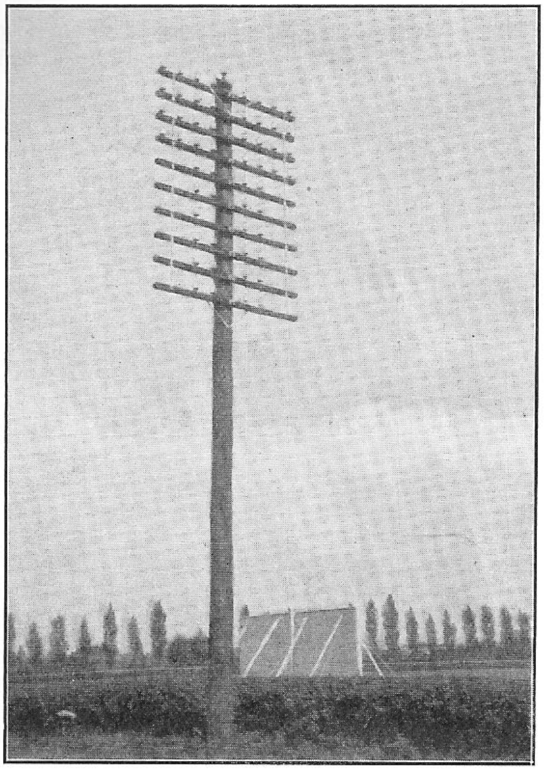


FIG. 25.

raising the pole as brought from the stack, through the bed of wires unhindered by the presence of arms, the arms and roof being fitted afterwards.

13. Acknowledgments and Bibliography.

In conclusion, I desire to record my appreciation of the encouragement and advice of Mr. P. J. Ridd in the preparation of the paper and of the assistance of Mr. R. G. Bennett of the P.O. Stores Department. To Messrs. Burt, Boulton and Haywood, I am indebted for a photograph of their creosoting plant; and to the Forest Products Research Laboratory for a photograph of their testing machine and diagrams of wood structure. I am also indebted to Dr. C. C. Forsaith, of the New York State College of Forestry, for permission to reproduce Fig. 1 and to H.M. Stationery Office for permission to reproduce Figs. 2 and 3. In order to indicate my acknowledgment of other sources of information and to supplement this somewhat general survey of the subject, references are given in the folowing short bibliography :—

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(3) " Overhead Electric Lines." W. B. Woodhouse. (J.I.E.E., 1929, Vol. 67, p. 217).
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(5) British Standard Specification No. 144, " Creosote for the Preservation of Timber."
(6) " Service Records of Treated and Untreated Poles." R. M. Wirka. (Electrical World —July 29, 1933).
(7) " Arsenimprägnierung von lebendem Holz für Telegraphenmasten." Max Knopff. (T.F.T., July, 1933).
(8) " Timber and some of its diseases." H. Marshall Ward. (Nature Series).
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(10) " Code for Protection against Lightning." Bureau of Standards (U.S.A.) Handbook No. 17 (p. 78).
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(14) " The Collapse of Iron Poles at Brighton." (J.P.O.E.E., Vol. 8, p. 302, Jan., 1916).
(15) " Home - Grown Telegraph Poles." G. Morgan. (J.P.O.E.E., Vol. 9, p. 45, Apr., 1916).
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(17) British Standard Specification No. 513, " European Larch Poles for Transmission Lines."

SOME NOTES OF THE DISCUSSION.

MR. P. J. RIDD :

I have searched the records of this Institution and find that we have not had a paper on this subject within the last 20 years and the references in the *P.O.E.E. Journal* are very few indeed. There is, however, one article, contributed by Mr. G. Morgan, Controller, Stores Department, and published in Vol. IX, Part I, 1916 (15),* which might, I suggest, be added to the bibliography. Mr. Morgan's article deals very fully with the history to that date of the efforts made to encourage home supplies of telegraph poles, and describes the results which had been achieved. There are difficulties, arising from the location of the home-grown supplies, which are not always apparent to the growers. In the Journal of 1916 previously mentioned, there is, in fact, an article by a grower who stated that it would be possible to grow, in Strathspey and Deeside alone, all the poles required by the Post Office. The writer, however, forgot the fact that, with poles as with men, Scotland is unable to absorb all its native stock. We cannot make use of many thousands of poles in Scotland alone and it would not be economical to pay carriage for delivery all over England. It should, however, be stated that the home supplies in recent years have increased to about 20,000 per annum or about 20% on the total demand. Mr. Brent deals with some of the troubles which have arisen in connection with home supplies and in particular with a method which has been devised to prevent the development of deep checks in home-grown larch. This process has now been incorporated in the British Standard Specification No. 513 (17),* which specification might also, I suggest, be added to the bibliography.

Mr. Brent has made out a very strong case for the continued employment of creosoted soft timber and there seems to be no prospect of its displacement by hard Dominion timbers. It needs to be borne in mind that on account of the reduced diameter of the hardwood pole a deeper setting would be necessary and consequently a longer pole would be required.

I am very much interested in the development of the equation which states that the weakest part of a tapered pole is at the point at which the diameter is $1\frac{1}{2}$ times the diameter at the point of application of the load. I do not remember that this has been published previously. It provides an explanation of breakages frequently brought to notice and particularly in the breakdown of February, 1933.

In dealing with the depth of setting of a pole Mr. Brent has provided us with an equation which is perhaps not so completely satisfying. He has, in fact, found the same difficulty in making allowance for the characteristics of the soil as was experienced by the compilers of Technical Instruction XIII. The present instructions relative to the depth of setting certainly leave much to be determined by experience and Mr. Brent's equation is clearly a step forward.

On the question of " A " poles, we have varied the spread between 1 ft. and 3 ft. at the ground level and are now back to about 2 ft. It seems very doubtful, having regard to the experiments of W. B. Woodhouse (Journal I.E.E., Vol. 67, p. 217), that the spread can give a 4 :1 strength ratio of a single pole. The difficulty, of course, is that very frequently it is quite impossible to increase the spread without creating an obstruction. I am inclined to think that in the majority of cases a stayed pole is as effective a structure.

The question of protection against damage by lightning has been given a good deal of consideration recently. The Post Office practice has been modified from time to time and now requires earth-wiring to be provided on every 10th pole on main lines, on all distribution poles, and on other poles in exposed situations. Doubt has been felt whether the earth-wiring does, in fact, afford protection to the pole, particularly at a date some years after installation, but experience of recent storm damage has shown that the earth-wire does serve its purpose in the protection of the pole. The method adopted in America described by Mr. Brent in which the earth-wire is not continued below the ground line has been investigated by the P.O. Engineering Research Section by means of the high voltage impulse generator, but the results so far obtained have not confirmed the results recorded in American experience.

MR. H. FERGUSSON :

Mr. Brent has mentioned the question of Australian hardwood and the fact that the poles were generally sent in stripped of the sapwood. I have seen poles out there, where the sapwood had not been stripped off and no preservative used except some butt treatment. The sapwood was stripping itself off, or rather the grub or beetle had been very effective. Of course, it may be that even the heartwood would not stand other insects, but the sapwood is nearly as strong as the heartwood and, if properly preserved, would last longer than the heartwood. It must cost almost as much to strip off the sapwood as to preserve it. The poles I particularly refer to were blue gum. I think the Australian Post Office uses very many blackbutts.

In the matter of creosote, I am still a believer in the full-cell process, although I think, as Mr. Brent has shown, the other poles have lasted up to the present, more or less, and their life history is not yet completed. In many cases it is true to-day that we have had a useful life of 30 years, so that the Rüping process may be taken as economical for the treatment of poles where a shorter life is sufficient.

I should like to ask Mr. Brent if, in his experience, he has noticed the difference between a full-cell pole and a Rüping pole.

As regards the quality of creosote, the fact that the constituents mentioned do not occur in an old pole does not show that they have not played a certain part. Possibly they may have acted as sterilisers, and under the action of light and oxygen heavier and more solid substances may have been formed fairly quickly. Heavy-tar acids play their

* See Bibliography.

part and are changed, when they will no longer be antiseptic, so that it is certain that other basic bodies and hydro-carbons are acting as the antiseptics and also as the waterproofers.

Mr. C. Wade :

I believe it is quite true that after a pole treated by the full cell process has been erected for a few years, most of the oil has drained out at the bottom and there is very little more left than with the Rüping process. Of course the Rüping process poles have not been up so long as the others and you cannot tell how long they are going to last. One appears to crack more easily than the other.

Mr. Ridd mentioned the strength of an A-pole. I think this was originally settled by the tests carried out by Professor Goodman and myself in 1907, in which we took a span, *i.e.,* spread of $\frac{1}{8}$ of the length. The generally accepted figures was, I think, a strength of $4\frac{1}{2}$ times the single pole, but that, of course, was apart from the " give " in the foundation.

More recently, in the tests carried out for B.E. and A.I.R.A. we found it was very often the foundation which gave way, and not the pole. I think our figures of many years ago agree fairly closely with Mr. Brent's, but he takes his point of breakage rather differently and allows extra strength for a pole with a bigger top, which we never did. In recent tests we found that a pole broke slightly above the ground line. As regards the foundation, we recommend kicking-blocks, but of course I am speaking more from the power engineer's point of view. I think the tables we got out are fairly accurate and are generally used by the power engineers as a basis for power lines.

I am rather interested in the woodpecker, and think I am right in saying that if you fill up a hole with concrete he will pick it out again.

Mr. Brent has given information about a great many different kinds of timber, but the one universally adopted is creosoted redwood, a great deal of which comes from abroad. I dare say that in time the whole lot will be supplied in this Country, but I do not think it will be in my time.

Capt. Cave-Browne-Cave :

The point was made by Mr. Gomersall, concerning poles treated by the Rüping process, that they save members of the public from getting their coats damaged; but the biggest advantage to my mind is to the men who have to handle the poles. It has been an advantage to our ganghands to have these much drier poles to raise and carry.

The reason, I think, that poles have been comparatively little written about is that the Engineering Department has no say at all in the inspection or testing of these poles, and it would be interesting to be told, in such an extremely instructive paper, why the Engineering Department and the Test Section are not responsible for approving poles. We may perhaps be informed whether poles are being tested at all. They must be, I take it, but if they are, where can we get the figures? Of course bulk testing of poles is a difficult matter, apart from its expense, because you may damage poles which are perfectly sound.

I should like to mention a very simple bulk test for arms. It is merely a drop arrangement which falls on to the arm, whereby the depth of penetration is measured. By this means it has been found uniformly possible to give a very close approximation to the strain under which the arm will break. Perhaps a similar penetration test could be devised for a pole. If it were possible it would be extremely valuable.

Mr. Brent showed us a slide showing the top of a pole slung in the air on the wires. Only last evening there was a case outside Chelmsford of a stayed A-pole, one leg of which had been broken away from the ground line to a point two feet below the bottom arm by a lorry, and the structure did not seem much the worse for it !

In another case a lorry charged into a pole, which penetrated right into the cab. It was not possible to shift the lorry at all till the top of the pole, complete with wires, was cut off and separately suspended. It would be interesting if Mr. Brent would show some similar cases of sturdy poles.

Mr. Brent might possibly have made a reference to the channel iron pole extensions that can be fitted at the top of poles to give us an extra few feet of height without having to renew the pole. Such extensions are of special use where power wires cross our routes and it is practically impossible to get clearance in any other way.

With regard to Mr. Brent's arm braces, I have been considering what could be done in the case of existing arms which become loose. If they are wedged it often happens that after a hot summer most of the wedges fal out. The question is whether arm braces could not be used to better effect, but I think it would be a pity to have to bore uncreosoted horizontal holes in rather a delicate part of the arm. I wondered whether an arm brace could not be devised that would slide under the arm and wedge up against or fix under one of the spindles.

Finally, there is the question of pole renewals. I would suggest that it would be worth while considering the keeping of a special record of poles that are proved to be dangerously rotten, and of the dates of issue of the poles concerned. Imagine you are a field officer who has to decide whether or not a pole has to be renewed at once because of decay. It is not a simple thing to do, and a schedule of all renewals elsewhere of rotten poles would be a useful guide.

In rare cases, where the only serious visible defect in a pole is a very wide crack, does Mr. Brent consider it would be possible to find some compound with which the crack could be filled, and which would prevent ingress of damp and consequent further damage? For climbing and other reasons the compound would have to be about the hardness of the pole, and possibly a wood solution would be suitable.

Mr. J. Latham :

By virtue of my duties at the Forest Products Research Laboratory I am particularly interested in the strength of poles. During the last few years we have made a large number of tests of poles of different species, and Mr. Brent has mentioned an investigation of the creosoting qualities and strength characteristics of poles of home-grown Corsican pine, Sitka spruce and Norway spruce now in progress. In connection with the substitution of poles of these species for red fir poles strength tests are of great importance. The red fir pole, by virtue of the high structural strength of the timber combined with comparative mildness and ease of working, is a really excellent pole and has permitted a very high standard to be attained by the Post Office engineers.

Fair comparison of pole strength can only be made by exercising the correct technique in testing. Frequently the principal claim made for a timber test is that it is a " practical " test. Too often, however, one finds that this word " practical " merely covers extreme crudeness in conditions of testing, which affect the result of the test very considerably.

A number of factors affect the strength of a pole under test. The method of supporting the pole must be such as not to submit it to strain which cannot be accounted for in the result. In bending, a pole is reduced in length on the compression side and stretched on the tension side, and the apparent strength is considerably affected if there is restraint at the point of support. The method and rate at which the load is applied can also affect the result. The most important factor influencing the strength of timber is the moisture content of the wood at the time of the test. Mr. Brent had a note in his paper, explaining the way in which moisture is present in the wood. As a rule at least half the weight of a freshly felled log consists of water so that in a 200 lb. log there is about 100 lbs. of water and 100 lbs. of wood. As the water comes out of the wood there is no shrinkage and no change in strength until the water content is about 25 lbs., *i.e.*, about 25%, based on the weight of the wood. With further reduction in moisture content most strength properties increase progressively, the exception being that the timber becomes less tough, *i.e.*, more brittle, and the timber shrinks. The bending strength of a pole is thus not a fixed quantity but is much higher when the pole is well seasoned than when it is green. It is therefore of fundamental importance to quote along with the strength of the pole the moisture content at the time of test. During the winter, which is the critical season so far as poles are concerned, the wood will be saturated with water up to fibre saturation point and the strength will correspond to that of green timber. For this reason calculation of pole strengths should be based on the strength of green timber.

Mr. J. W. Atkinson :

I should like the author to say precisely what evidence there is that some of the poles recovered recently were erected in 1870; I have seen poles in different parts of the country that were alleged to date from 1870, and in some instances it was easy to prove that they were of later date.

In regard to larch, unless it proves possible to dress these poles in the same manner as red fir, I hope they will not find their way into use for suburban telephone work. I would like to do everything possible to encourage home-grown larch; but I have always been very disappointed when comparing even the best specimens with red fir, and I am not in the least optimistic that the larch pole will be suitable for suburban use.

The position as regards the Rüping process of creosoting is that it was a matter of trying to weigh up known facts and possible effects in the future. We had to chance something as we found that the creosoting contractors were unable to work the two processes side by side, and we plumped for the Rüping process. I have looked very carefully for any evidence that the latter process is economically unsound for our use and I feel that the decision was right. There is undoubtedly a great deal of practical information in the experience of our workmen which it is difficult to extract and value, *e.g.*, some 30 years ago a large parcel of Russian fir was purchased, and shipped from Riga, many of the poles being 40′ stout : we tried to get a comparison between it and the Norwegian variety, but although there was a general impression that the Russian timber was inferior, we could not get any quantitative value at all. The same feature seems to come into operation in the matter of creosoting; you will find many workmen who will tell you that you cannot expect the same life from a Rüping as from a " full cell " creosoted pole. I do not know whether opinion is of any value, but there it is; the men feel that the Rüping process is not so good.

On the question of strength, I feel that there is still ground for further tests to determine whether poles deteriorate after, say, 20 years. I incline strongly to the view, in the light of cases of damage, that there is a loss of strength due to some ageing factor—what one might call brittleness; such a pole broken by traffic or storm usually presents a different form of fracture from that of a new pole broken in the same way.

I am very interested in the experiment of " flatting " a pole at the top, in order to obviate arm slots and particularly to see whether we can keep the arms as well set as with slots.

Mr. R. G. Bennett :

As a member of the P.O. Stores Department, which is responsible for the examination and treatment of poles, I think the author has very fairly described the work we do up to the point at which the poles are issued to the engineering staff.

One or two fears have been expressed that the high standard of poles in this country, which is the envy of the world, is not being maintained, but I can assure you—and I think those in the Engineer-in-Chief's Construction Section will bear me out—that there is close co-operation between the Stores Department and the Engineer-in-Chief, and so long as this lasts there need be no fears. In these days there is also very close co-operation with the people at Princes Risborough. A very good instance of that was the production of the new arm-testing machine a short time ago.

Many things have been said which interested me, and one remark in particular suggested that there was a difference between the chemical analysis of the creosote injected into a pole treated by the full cell process and of that left in a pole treated by the Rüping process. By the old full cell process 12 lbs. of oil per cu. ft. at least is pushed into the wood. After about four years the amount of oil remaining is not more than 4 lbs. per cubic foot which is about the same as that left in a pole treated by the Rüping process. Eight has run out. A good deal is in the soil at the foot of the pole, where it does very beneficial work. It is believed that the 8 lbs. which has run out includes all the volatile elements and, possibly, what is left behind is far more valuable as a toxic agent detrimental to fungus than the 4 lbs. left in at the completion of the empty-cell process. There is perhaps a higher percentage of those volatile elements in an empty-cell pole than in the creosote which remains in a full-cell pole. What ingredient of creosote actually does preserve the wood, nobody knows. Very active investigation is being made into the matter at the present time and towards the end of the session a paper is going to be read to the British Wood Preserving Association on the value of creosote as a wood preservative. Sections of poles creosoted many years ago by the full-cell process are being macerated, the oil extracted and measured. Some are found to have less than 2 lbs. per cu. ft. in the butt end of the pole. Analysis of the extracted oil is being made, the results so far revealing in a remarkable way the absence of the tar acids and low volatile elements and the richness of the heavy oils which are what one would expect to have remained in for all these years.

I have said a great deal about creosote, but it is astonishing what a lot might be said about the other points which have been raised.

Before the Post Office took over the Telegraphs in 1870 most of the private companies used larch poles; some of them charred and tarred the butts, and it was found, from information obtained from the staffs who came over at the transfer, that the life of such poles was between 10 and 15 years. The life of untreated larch was about 7 years.

The Post Office, in 1910, erected in four or five localities composite lines of larch, creosoted and uncreosoted, and Scots pine creosoted, and the durability figures were remarkable confirmation of those given by the transferred staffs. There are one or two instances of remarkable life of larch poles. The National Telephone Co. had several in London of which two, standing in Spital Square, had 23 years' life. In addition to creosote oil, copper sulphate was used, before the transfer, as a preservative (the Boucherie process) and the first tenders invited by the Post Office included pole timber which could be treated by that process, but it was not adopted. A little later, bichloride of mercury (Kyanising) was used at Plymouth, but the experiment was not repeated. The use of zinc chloride (Burnettizing process) was persisted in for a great many years as its use enabled poles to be painted; it was discontinued in 1913. Burnettized poles had a very unreliable life, but there is amongst the exhibits on view a section from a pole which has stood since 1902. Whereas all these other preservatives gave most unreliable results, creosote seems to give consistently very good results. Whether the Rüping process is going to be as good as the full-cell process of course only time will tell. At the rapid rate at which telephone construction is developing, the Rüping process will probably be found to do the job quite well enough.

Col. H. Carter (*communicated*):

On page 10, in Table II, Mr. Brent shows that the pole failing under load does not always break at the ground line. This fact is of course well known, but it is interesting to see a mathematical proof. I cannot, however, agree that Mr. Brent's application of the theory to the telegraph pole is a practical proposition. In the first place, Table II gives the maximum and minimum top diameters of the poles, but only gives one butt diameter, *i.e.*, the minimum. This is, of course, in accordance with the B.S.I. Specification for telegraph poles, but it surely cannot be claimed that the same butt diameter applies to both top diameters, so that calculations made on this assumption must be open to criticism. In addition to this, under present conditions we are rarely concerned with medium poles over 40′ or stout poles over 45′. Taking the figures shown in Table II at their face value I find that in the case of a 40′ medium pole, the error made by assuming breakage at the ground line is negligible. In the case of a 45′ stout pole, the error would be of the order of 3%. It is only in the case of the very long poles, which are practically speaking now never used for telephone purposes, that the point dealt with on these pages becomes of practical value. I therefore claim that having regard to the uncertainty which exists as to the maximum fibre stress of any particular pole, it is not worth while complicating matters by taking account of the fact that under certain conditions a pole will not fail at the ground line in the practical design work of the Post Office Overhead Telephone System.

In Section 5, Mr. Brent deals with the question of foundations. Having seen many efforts to treat the subject both theoretically and experimentally, without achieving any reliable or satisfactory result, I am very sceptical of the possibility of reducing this problem to exact terms.

On page 14, the design of pole lines is dealt with. In this connection it would perhaps have been interesting to have explained that the reason why no ice accumulation is assumed in considering calculations for open wire lines is the fact that ice accumulates equally rapidly on wires of all gauges.

Had ice accumulations been allowed for it would have been necessary to arrange for different regulation of the wires of various gauges. This is of course an impossibility on mixed lines. At first sight, Table IV appears to propose somewhat alarming increases of the maximum allowable loads on pole lines. I would point out, however, that this increase is more apparent than real since the table assumes a uniform 60 yd. span, whereas the Tables in T.I.XIII assume 70 yds. for light poles and 65 yds. for medium poles; some of this apparent increased loading allowance is therefore due to the span difference. Actually increases of 18%, 24% and 15% on light, medium and stout pole lines respectively represents the summary of the proposal if we take averages throughout for those sizes which are tall enough to be fully loaded. I should strongly deprecate the issue in official Instructions of a table of this kind. It is much too complicated and would not be observed. I think there is no doubt that average values are quite sufficiently near the mark, again remembering the point mentioned previously that the maximum fibre stress is by no means a fixed quantity. Incidentally there is no need to encourage an increase in the loading of light pole lines. It will be found that in many cases there is far too great a tendency to overload these lines. It should perhaps have been made clear that Table IV refers to an exposed, unstayed pole line. From the practical point of view, the safe load of every line varies depending upon the degree of exposure and the staying facilities available. I hold that any efforts which could be made to secure a better appreciation by engineers of these factors would be of more value than an adjustment of the theoretical safe loads of lines.

On page 25, the fitting of arm braces is said to be an R.E. practice. I think it would be much more correct to call it an American practice. Certainly, during four years' experience with R.E. Signals in France, I never saw or heard of the use of arm braces, although of course I do not deny that some formations may have used them to some extent.

I am very glad to see from the references on page 25 to the new method of fitting arms, that the question of pre-slotting, of which I have always been a strong opponent, appears to be dead. I think I could secure a large measure of support for the view that this must always lead to unsatisfactory work. I am not quite sure whether the flat which it is proposed to cut on the face of the pole is intended to be parallel with the axis of the pole or not, and I should be grateful for information on this point.

Mr. W. H. Brent (*in reply*):

Several speakers have referred to the question of the full-cell poles versus Rüping poles, and I have been glad to have the remarks of Mr. Atkinson, who had so much to do with the introduction of the latter process. It is evident that this is going to give a good life to the pole, but when we have got precutting in addition, so that we have an unbroken protective layer, in my opinion we shall get an extra life out of the pole, which will then give as much life as a full-cell process pole which has had the slots and roof cut in it after creosoting.

Again, with regard to the question of "full-cell" poles or Rüping poles, I can assure you we shall never go back to "full-cell" poles for the reasons I have stated in the paper. Mr. Fergusson and also Mr. Wade implied that an empty cell pole was more liable to develop shakes, but after a few years the amount of creosote per cubic foot of timber above ground becomes substantially the same for the two processes and there should therefore be little difference in this respect; it would depend more upon the timber.

With regard to larch, although there is now a method of incising larch poles which greatly improves them in connection with creosote penetration and distribution of the seasoning "checks," I can say that at present we have not decided to extend our trials of this timber. It is not comparable with sound creosoted red wood and I would not recommend its adoption on the same terms.

The evidence that certain poles have been in position since 1870 is of course the date which is to be found branded on them. A doubt exists, however, as the practice of dating poles commenced, as far as I am aware, in 1890 when the poles *in situ* at the time were branded by linemen who were relied upon for their local knowledge. Similarly, in 1904, men went round branding the letters G.P.O. on the Department's poles in the line as a sign of ownership. Regarding Mr. Atkinson's remarks in this connection, possibly he has in mind the very early practice—before zinc labels were used for the purpose of branding the pole number on poles in the line in sequence.

With regard to the strength tests referred to by Mr. Gomersall probably those of Preece in 1885 were the earliest ones. I believe they were made in a similar fashion to those tests of Henley in 1910. The butts of the poles were clamped in a concrete or cast iron cylinder and well rammed in, so that they were tightly fixed. The effect of that is perhaps uncertain, but it seems to me that it is a rather different case from that of the pole in service, where the wood fibres have an opportunity of sliding relative to one another in the pole hole. No doubt we shall obtain some useful data from the tests which the Forests Products Research Laboratory are going to make for us as a result of the Forestry Commission encouraging the extended use of home-grown timber. The Post Office has always tried to take home-grown timber, but the efforts have not been well rewarded, although the Stores Department every year send out tenders to all the home-growers and advertises well. I think, as Mr. Christopher Wade does, that it will be many years before the Department takes all its supplies from home-grown sources.

I can assure Capt. Cave-Browne-Cave that there is close co-operation between the Construction Section of the Engineer-in-Chief's Office and the Stores Department regarding the strength of timber. Not only is the testing of poles to destruction expensive in wasted materials, but the proper apparatus for the work is costly to install. If it were proved that one pole in a batch of say 100 poles were satisfactory it would be no guarantee that the 99 poles were also satisfactory without an expert examination of the timber for sound growth and freedom from defects. It is upon this inspection by experienced men that we chiefly rely in order to ensure that the strength given by poles of equivalent quality and obtained by occasional tests, is being maintained.

With reference to wide cracks the chief danger is to men using climbers and it would be difficult to find a compound which would hold the climbing spike and key into the crack to take a man's weight. In continued damp weather the cracks close up (preventing to a large extent the entrance of fungus pores from the atmosphere in the autumn). This opening and closing might very well render it necessary to refill the cracks each year and if so the expense would not justify the advantage to be gained.

The ageing of poles has been considered not only by Preece in his tests, but several other investigators since. In the tests made by Mr. Henley in 1910 a difference of only 4% was obtained.

Col. Carter, from his experience on overhead line work with the Department and with the B.E. and A.I.R.A., is a worthy critic. I can only say, regarding the strengths, that by basing the calculation on the minimum top and minimum butt diameters (at 5 ft.) instead of the butt diameter alone the very minimum strength will be obtained and for general purposes this is all that should be taken as available for a class of pole. For special cases I maintain that account should be taken of the taper and the appropriate formula used. The number of stout poles of 50 ft. and over used by the Department (last year it was 130) is possibly not large, but there will be many in existence. It is perhaps more of interest that this reduction of strength for tall poles, combined with an increased calculated wind pressure on them, more than halves the available strength (safe load) of a 60 ft. stout pole (see Table IV).

I agree with Col. Carter regarding the impossibility of reducing foundation strengths to exact terms. Indeed my attempts at a short cut to a simple solution appear to have given rise to doubts in Mr. Ridd's enquiring mind as to the validity of the deductions; however, I will not now attempt to improve upon what has already been put before the meeting.

The flat surface of a pre-cut pole is intended to be parallel with the surface of the pole, but the main point is that it will be flat. The somewhat similar practice already referred to of cutting the lower arm slots deeper so as to have the arms in a vertical plane, will be avoided.

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