TRANSMISSION
LINE CONSTRUCTION

Published by the
McGraw-Hill Book Company
New York

Successors to the Book Departments of the
McGraw Publishing Company Hill Publishing Company

Publishers of Books for
Electrical World The Engineering and Mining Journal
Engineering Record American Machinist
Electric Railway Journal Coal Age
Metallurgical and Chemical Engineering Power

TRANSMISSION LINE CONSTRUCTION

METHODS AND COSTS

BY

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McGRAW-HILL BOOK COMPANY
239 WEST 39TH STREET, NEW YORK
6 BOUVERIE STREET, LONDON, E. C.
1912

THE • MAPLE • PRESS • YORK • PA

PREFACE

There is, at present, no book treating adequately of the practical methods employed in modern high-tension line construction. The writer's aim in this book has been to supply material of value to the man actively engaged in this kind of work, and to set forth the respective merits of the various types of line construction, together with the methods commonly employed in their building. No attempt has been made to cover the electrical and mechanical calculations involved. The book treats the subject from the standpoint of the construction man rather than that of the office engineer.

Considerable attention has been given to cost data. In handling this material, the aim has been to note as far as possible all conditions which might affect costs, and to make these data as definite, useful and reliable as possible.

The writer wishes to acknowledge the assistance of Mr. E. J. Le Blond, Minneapolis, Minn., Mr. W. K. Archbold, President of the Archbold-Brady Co., Syracuse, N. Y., and Mr. Charles E. Brooks, Minneapolis, Minn., in securing much valuable information.

He also desires to express his appreciation of illustrative matter provided by the Locke Insulator Mfg. Co., The Ohio Brass Co., The Archbold-Brady Co., the Electrical World, the Franklin Steel Co., the Bowie Switch Co., the Pacific Elec. & Mfg. Co., the Railway & Industrial Eng. Co., W. N. Matthews & Bro., and others.

R. A. LUNDQUIST.

MINNEAPOLIS, MINN.,
July, 1912.

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TRANSMISSION LINE CONSTRUCTION METHODS AND COSTS

CHAPTER I

Preliminary Work

In this discussion of the engineering methods employed in the laying out and building of a transmission line, it is assumed that the work is of sufficient magnitude to warrant the study and investigations to be described; where work of lesser importance is to be carried out, the point to which the same procedure can be applied economically must be left to the judgment of the engineer. From the writer's personal observations, however, he is led to believe that in most cases not enough rather than too much attention is given to details in the engineering of transmission lines.

The first step preparatory to the construction of any kind of a line is the making of a general map. The main points between which the line is to be built will have already been determined upon and the map of the intervening territory should now be laid out to such a scale that it will be convenient to handle in making the preliminary investigations in the field, but still be large enough to show clearly for office study, all division lines, towns, villages, roads, streams, railroads, bridges, etc.; and to allow for the laying out on it with accuracy, of all existing telephone, telegraph and transmission lines. The territory to be included in this general map will necessarily be determined by the possible diversity of the lines and the judgment of the engineer, based upon his knowledge of conditions. In the making of it, county plat books will be found very useful and though such books are not generally very accurate as to recent changes in roads, etc., they will be sufficiently so for all preliminary work. Discrepancies can be noted as this work progresses, and changes can be made accordingly.

In addition to the map just described, topographic maps or atlas sheets, as published by the United States Geological Survey, should be secured if they are available for the section of the country to be traversed. These atlas sheets, about 16 1/2 in. × 20 in., usually taking in quadrangles of 7 1/2 or 15 minutes of latitude and longitude on a side, give contour lines, bench marks and many reference points and details that will help greatly in studying the topography of any section of the country. As yet, however, only a small percentage of the area of the states has been mapped in this way, so that it may not be possible to obtain them; in that event, much information can be gleaned by a careful study of the courses of streams and the lay of roads on the general map. While, of course, relative elevations cannot be determined to any extent, the rough and hilly sections will be easily located and other general knowledge of the topography of the country secured.

As he studies the geographical features of the territory and familiarizes himself with the general lay of the land, the engineer should also look into the statistics of the towns and villages throughout the country traversed, noting their population, wealth, industrial plants, existing light and power plants, electric railways, shipping facilities, future prospects, and all other points that will determine whether any business might later on be developed in them that would have a bearing on the location of the line. It very often happens that cases are noted where lines of moderate capacity and voltage have been built merely as a connection between two points in total disregard of all possible opportunities for load that might be developed at any of the small villages in the country passed through, where not only would the average revenue per kilowatt-hour be much higher, but the conditions for continuity of service would not be so exacting. Against this, the argument is made that under these conditions the construction costs and operating charges are too high for small high-voltage plants, that the growth is limited and that it involves risks to the service, in that trouble in any one of the smaller sub-stations or lines connecting them to the main line will interrupt the service of the heavier customers on the trunk lines direct. This argument may be true if the proper arrangements, now usually not considered difficult, be not made; but with modern well-tried high-voltage apparatus, proper segregation of trouble can ordinarily be made automatically with very little voltage disturbance.

The possibilities for revenue from small communities in the territory to be traversed should certainly be considered, especially in the case of moderate capacity lines; and, profiting by the experience of the past, these possibilities are beginning to be noted even to the degree of extending lines from large central steam stations.

In studying the towns and villages, note should be made of the roads radiating from them and their general lay. This information will be of great value in determining the accessibility for construction and maintenance of the different tentative routes laid out in the preliminary study. Then taking into consideration with his geographical and statistical data as noted in the foregoing, the possible use of the public highways or the paralleling of them, the following of section lines or the right-of-way of a railroad, as discussed below, the engineer is prepared to sketch in tentative routes on his maps for further study in the field.

Naturally, from the standpoint of first cost, he must work to secure the shortest line practicable, but he must also consider the probable right-of-way costs, and from the latter angle alone, he will often discover that "the shortest way across is the longest way around," and that he can well afford to make detours and avail himself of roads, section lines, etc. The paralleling of highways, or the use of them where not already occupied by heavy telephone leads, results in a transmission line that is very accessible both for construction and maintenance, and that naturally lends itself to the quick location of cases of line trouble. A point advanced against the use of highways for high-tension lines is that they are liable to damage from external influences. However, it has been the writer's experience that when high-tension lines are located along a road where there are even a few scattered farm-houses, the fear of detection usually deters persons from attempting to bring injury to the line. While on the subject, it may be well to state that the best insurance against anything of this nature is for the company to adhere strictly to a policy of absolute fair dealing in all its right-of-way and damage transactions, not striving to drive too sharp a bargain, and thus avoid all possibilities of incurring the enmity of its neighbors along the line. Cultivating the acquaintance of these people pays well in the good will they will evidence toward the company at all times, and the friendly assistance that they will render in times of trouble on the line.

With his maps and data the engineer is now prepared to make a reconnaissance of the routes he has laid out on paper, driving or riding through the country. He will note the general character of the land and its soil, the streams and their banks at points of crossing, ravines and erosions, timber, exposed slopes and ridges, houses and buildings near by, all telegraph, telephone and transmission lines and railroads with the possible methods of making crossings. His investigations should be electrical as well as mechanical. He should be on the lookout for evidences of prevalent lightning conditions in the shape of blasted trees or split telegraph and telephone poles. In connection with the last point, interviews with the repairmen and "trouble shooters" of companies who are operating lines in that vicinity will be of great value in determining the zones subject to severe lightning disturbances. Where it is proposed to utilize the highways if feasible, careful note should be made of all shade trees which would interfere with the line, with special reference as to height and kind, number and location, distance from house or buildings, with names of owners. As a rule, shade trees involve much expense, not always on account of their intrinsic value, but of the sentiment attached to them. Very frequently it is hard to secure proper trimming clearance at any price. Then again, trees like cottonwood and poplar with their easily breaking branches are often of such height that it is necessary to purchase the right of cutting or trimming them when they are at a comparatively great distance from the line.

Where the line is to pass through well-settled country with rich farms and prosperous-looking homes, it is a wise policy, in addition to utilizing roads where available or paralleling them, to seek a route that will follow natural division lines of the land, such as section lines, as far as possible. Under these conditions the right-of-way for a line of poles or towers, especially the former, will be very much cheaper and more easily secured. A line of poles set closely into a fence, and one usually finds fences along section lines, will not materially interfere with the working of the land. It is likewise apparent that a line of towers which parallels closely the line fence of a field will not prove the inconvenience or effect the permanent injury to it, that a line which runs through the middle of the field will. This will apply whether the right-of-way is secured by title or by easement. In the latter case where only the right to the tower location is included, with rights of access when needed, and the towers are located in a field of growing grain, it is obvious that every time a patrolman finds it necessary to go closely up to a structure so situated, it makes a vast difference to the owner whether the tower is in the middle or at the edge of his field. To appreciate these points thoroughly, one has only to spend a little time with the right-of-way men at their work.

Having covered the country thoroughly and studied the conditions met with along his various tentative routes, the engineer can lay out a preliminary line that will fulfill conditions most satisfactorily. In general, these conditions are that the line should be as direct as possible with due consideration to possibilities for load in the territory between its terminals; that it should avoid as much as practicable the crossing of isolated hills and ridges, swamps and bottom lands and to lessen its exposure to storm as noted in practice, it should also avoid western slopes; that it should skirt around sections known to be subject to severe lightning; that as far as is practicable, it should avail itself within the limits of sound construction of the cheaper right-of-way, of natural division lines of the land and of public highways, and that it should be of the greatest possible accessibility for construction and maintenance. Naturally, many of these conditions are antagonistic, as met with in any engineering work, and the choice rests upon the knowledge and experience of the engineer, and his preliminary line as laid out on the map should be the result of careful consideration and study of the various conflicting conditions. With the paper location of the proposed route completed, a thorough investigation of it should be made either, if in rough country and the importance of the line warrants it, by a stadia survey or merely by the engineers riding or walking over the ground in territory where it is possible to pick up landmarks and follow the paper location closely in the field. Of course, this is very easily done in well-settled country, but it is another matter where the roads are practically nothing but trails and are changed at the whim of travelers.

Where a survey is to be made, a party of two or three equipped with a stadia instrument and a 14-ft. stadia board will handle the work readily, excepting where thick underbrush or much timber is encountered, where it will be found good economy to hire an axeman. Ordinarily a crew of the foregoing size will make a survey of this character and get all the data necessary for transmission line work at a cost of from $5 to $10 per mile. It should run 1 mile to 4 miles a day, depending upon the character and topography of the country. The surveying party should be carefully instructed by the engineer as to data to be secured, and the work should be carried out under his general supervision. In addition to the line and levels, the crew should make detailed notes of the topography, describing the character of the ground, kind and size of timber, slopes, all swamps, streams and bottom land closely contiguous to the proposed line as well as actually on it, noting generally the character of the country for a short distance on either side of the line of survey, and they should describe, illustrating with sketches, all highway, river, telegraph, telephone, transmission line and railroad crossings that are to be made, noting for the lines, the spans, height of poles, number of wires carried, etc., with possible locations and foundations for the proposed line structures.

These refinements are not generally observed in average line work and are often scoffed at. Yet they require little additional time and are very valuable in deciding upon the type of construction best suited to conditions and in preparing estimates therefor; furthermore, if it should be necessary on account of right-of-way difficulties, etc., to make any slight changes in the line, sufficient data are available to determine upon their feasibility without the necessity of a special trip to the spot. From the notes and data of the survey a profile is prepared; the preparation and use of this is described in the next chapter. Where an instrument survey is deemed unnecessary, the engineer or an assistant, by walking over the line and making detailed notes as previously outlined, can make a study of the route which will be sufficient for all practical purposes.

As he is now provided with all the necessary field data to supplement his statistical information, including probable right-of-way costs for pole and tower construction, secured by investigation of land values and by inquiry among representative farmers, the engineer is prepared to decide upon the type of construction that is best suited to the conditions. He has available, wood, steel and, with limitations, concrete poles and steel towers and while, under existing financial conditions, it has often happened that steel construction has never been considered owing to its repute for high first cost, there has been in recent years a decided change in sentiment, especially with companies that have used both steel and wood, and that have found that the lower priced labor which is possible with steel construction frequently makes the cost per mile of the completed steel tower line compare very favorably with that of wood. In some instances, the cost of a steel line has actually been less than that of wood. Of course, this condition is more true in the higher voltages but with the semi-flexible systems and the patented types of poles which are now being used to an increasing extent, it is often possible, even in the lower voltages, to obtain a first cost equal to that of wooden construction.

It is apparent, therefore, that all practicable forms of construction should be considered and estimates made of the cost under the conditions existing. This is another point that, queer as it may seem, is frequently overlooked. We have estimates made up of the comparative costs of different types of construction where no attempt is made to ascertain local conditions and their relative influence on the construction costs of these different types. Only the costs of material at the given point are investigated, and the labor items assumed on an equal basis. The fallacy of such a method of preparing estimates for comparison is clearly apparent when we take actual relative labor costs of, say, wooden pole and steel tower construction on good dry ground and compare them with those for the same types in soft bottom land. In the latter case, the poles can often be "worked in" at only little more than the cost of setting in dry ground, whereas extensive cribbing or sheathing must be employed to permit the proper setting of the tower anchors, thus necessitating a great increase over normal for this part of the work. The assembling and erection costs would also be greater under the latter conditions.

With his knowledge of the route and any possible changes that might be made to the advantage of one type of construction or another, of the varying influences of local conditions on the labor costs, of the probable costs of right-of-way per pole or tower for the different types, of the transportation, of field expenses, etc., in addition to his data regarding the material required, the conditions of voltage, size of conductors, number of circuits, necessary heights of poles and towers, spans, etc., imposed, the engineer will be able to prepare comparative estimates of first cost for the different types of construction in which due advantage can be taken for each type, of all the possible conditions favorable to its particular method of handling.

Then, with his first costs before him, he must weigh against each other for the different systems, their depreciation, reliability, maintenance cost and accessibility for repairs and maintenance.

The life of a steel tower or pole is estimated at from twenty-five to forty years. With proper original construction and careful maintenance, however, there is no reason why it should not exceed these figures. As noted in Chapter VI, the size of the tower members, the quality of their protection, the climate and the care with which the assembling and erection of the structures were effected are the prime factors that go to determine the life of a steel structure.

The durability of a reinforced concrete pole is not as yet established satisfactorily; claims are made for almost eternal life, but it will be interesting to note the long-continued effects of frost and the elements upon them. Another feature that appears to influence the durability of such poles is the effect of the whipping and vibratory action which is produced by the action of the wind on the line conductors; the results of an investigation of this latter effect in the case of reinforced poles is given in the chapter on Reinforced Concrete Poles. As far as can be learned, concrete poles that have been in service for five to six years appear to be in first class condition and show no visible depreciation.

The life of wooden poles varies with the kind of timber, with climatic conditions and with the particular locations in which they are set. Most engineers assume a life of about ten to twelve years for white cedar, which is the most common pole timber. Treated poles of various kinds will average twenty years. In preparing estimates for a particular locality, the life of the kind of timber it is proposed to use should be ascertained by an examination of existing telephone, telegraph and transmission lines, supplemented, wherever possible, with careful investigation of the construction records of the different companies.

As far as can be ascertained from the meager data available, concrete is the cheapest form of construction to maintain, and steel structures come next; but, as will be discussed later, the quality of the steel and the character of the protection which is given to it make the cost of maintenance a variable factor for this type of construction. Wooden construction, of course, requires considerable attention after the first few years of service, varying with the care with which the original construction work was carried out, the climatic conditions and the loads to which the poles are subjected. Cross-arm maintenance must be considered with wooden construction and also with steel and concrete structures employing wooden arms. This factor may be great or small depending upon the safety factor of the insulator and the climatic conditions. For instance, the salt fogs frequently encountered in certain parts of the West often increase the leakage current sufficiently to destroy the arms.

The insulation maintenance for a type of construction which employs the longer spans is naturally lowered with the decrease in the total number of points of support. Nevertheless, the question may arise as to whether or not insulators which work under a heavier mechanical strain where long spans are used are any more susceptible to electrical failure than those where short spans are supported, even though the load in both cases is well within the limits of the insulator. However, nothing that would indicate such a condition has ever come to the attention of the writer, although it is very apparent in strain insulators. Where the same insulator is used to carry, say a 250,000 or 300,000 circ. mil copper cable in 250-ft. and 500-ft. spans respectively, the relative failure would in all probability be greater on the long span line.

As to reliability we must place steel first, and concrete, based upon its performance up to the present time, next. Steel is not injured by the direct stroke of lightning and is immune from damage by grass fires, birds, insects, etc. These conditions may also be said to apply to concrete, although there is a question in the writer's mind as to the effect of a direct stroke of lightning upon a wet concrete pole. It would appear that there is great liability that the concrete outside of the steel reinforcement will spall off under these circumstances, but in the concrete transmission line work of the Marseilles (Ill.) Land & Water Company, this has occurred in but one instance and then to a slight extent at the top and the ground line only. Wooden pole construction is easily damaged by lightning, although this trouble is decreased to a great extent by the installation of ground wires, which could also probably be used to advantage in concrete pole work. Annoying damage and interruption to the service with wooden construction are caused very frequently by grass fires, especially where the line is built along a road or parallel to a railroad right-of-way.

As far as accessibility is concerned, the question lies in the form of the structure and not the material. Poles can often be used to gain this advantage where the room required by a tower would prohibit its use. Sometimes, however, as in the case of utilizing the public highways, either longer poles or shorter spans than would be necessary on a private right-of-way may have to be used in order to maintain safe overhead clearances. Hence the limits in this regard must be taken into consideration.

In conclusion, it may be said that, leaving concrete out of the discussion for a complete line at the present time, owing to its untried possibilities and to the fact that it generally requires that the company manufacture its own poles, steel construction of some kind, as a straight business proposition, will usually be found preferable for high-tension transmission work, excepting in a few isolated cases where the existing financial considerations demand the lowest possible first cost, regardless of quality, depreciation and maintenance, or where the location is such that pole timber is available at such a low figure as to offset these items. Even then the question of reliability must be carefully considered.

Concrete may prove itself a factor in the situation in the near future for with the interest now being shown, its possibilities will no doubt be developed in the next few years.

CHAPTER II

LOCATION OF LINE—SURVEYS AND ENGINEERING

With the route of the line and the type of construction settled to his satisfaction, the engineer is ready to make his location or staking-out survey. This may be either a stadia or chain survey, depending upon the type of construction to be employed and the character of the country. If the line be through rough, hilly country, the stadia will usually be preferable, but in well-settled districts, chaining will generally be found the more rapid and economical, especially in short span construction. A party of from two to four will be large enough to do the work efficiently, where it is possible to pick up an extra man as axeman when heavy brush or timber is encountered, though of course this practice will be impossible in remote regions, where, if the going is likely to be heavy at times, it will be well to carry an extra man, but as in this case it will very likely be necessary to carry a light camping outfit, the extra man can also help to take care of the camp when he is not required in the field. Generally a line surveying party will be able to secure accommodations along its route in most sections of the country, and will not be obliged to maintain much of a camp. It is not, however, within the scope of this book to discuss details of a survey other than those affecting its purpose as a step in transmission line work, and the reader is referred, therefore, to some one of the many good works on surveying practice for more extended information as to the handling and maintenance of a field party.

The surveying crew should be equipped with a light transit, which, if stadia work is to be done, should have either a vertical arc or a full vertical circle and stadia cross-hairs. Depending upon the kind of survey, the men will be provided also with chains, tapes, two or three 8-ft. flag-poles, level rod, stadia board, preferably about 14 ft. long, axes, etc.

In making the staking-out survey, there are three general ways of carrying out the work: First, where a preliminary survey of the route has been made and a profile prepared, the towers or poles are located on this in the office and the field party stakes them out on the ground with the profile as a guide; second, where no preliminary survey has been made, in which case the crew runs out the line in 100-ft. stations and carries the levels the same as for a railroad survey, though not as a rule carrying the work on to the same degree of accuracy, sometimes reading only the elevations to the nearest 1/2 ft., though they should be taken to the nearest tenth to make possible better checks with bench marks; third, where no preliminary survey has been made and the party locates the structures as it goes, recording lengths of spans, etc., and taking elevations at the points of locations and also at enough intermediate points to give data for a relatively accurate profile in cases of higher or lower intervening ground or of abrupt changes in slope. By relatively accurate is meant the securing of close readings at the locations of structures to allow of their heights for proper grading being determined, and then enough intermediate elevations taken so that the clearance of the low point of the spans to ground can be closely ascertained.

The first method is probably the one most generally used for heavy tower line construction. The work of the party in the field consists merely of taking its data from the profile, measuring off the spans as called for and driving stakes in accordance with the numbers indicated on the profile; this method is open to the objection that what appears to be the most favorable point of location on paper may be the poorest one for the economical construction in the field. Unless one of the party is conversant with good line construction and can be relied upon to make advantageous changes from the lay-out on the profile where it appears desirable, it is likely to result in a high first cost with poorer construction, possibly, in addition. Following this method of staking out, especially for tower lines, the work can be carried on very rapidly and economically with a stadia instrument. Where the locations are made on paper in the office, it is a wise plan to check clearances to ground in the field in places where there is a rise of ground or abrupt change of slope between towers, where the line passes up or down steep side hills; also if it is built on or along steep slopes where the line of the survey may show ample clearance for conductors at the center line indicated on the profile, whereas actually the uphill conductors may be dangerously close to ground.

In carrying out the work as outlined in the second method, which is best adapted to wooden pole work and cases where no preliminary survey has been made, the crew makes no attempt to locate any of the structures, merely running out the line in 100-ft. stations, taking the levels and noting the general topography and the ground conditions, leaving to the construction foreman the responsibility for the actual pole or tower location and the proper lining-in, the profile furnishing the foreman with the necessary data as to pole heights and spans. In staking out, the foreman will have the station stakes to refer to for line and general distances.

Following the third method, the surveying party is given the paper location of the line, as decided upon after investigation on the ground. It stakes out the center locations of the structures at points most suitable under the conditions as determined in the field, adhering of course to a standard spacing as closely as is practicable, and at the same time taking levels at stations and such intermediate points as may be necessary to give all data needed in determining heights of structures both for clearance and for horizontal grading of the line. With this method, as well as with the first, it is essential that one of the party be a man experienced in practical line construction, capable of deciding any question that may arise as to spans, angles, foundations, etc.

In staking out tower locations, it has been usual in light moderate-span construction to set only a center stake as in wooden pole work. This practice has also been followed in some heavy work. It is evident, however, that with the long spans employed in tower work, this method of staking cannot result in very good alignment. To make a good workmanlike job possible, a reference or lining stake should be set. This stake should be located a short distance outside of the anchors and, with the center hub, it will give the setting foreman a reference line by means of which he can bring his templet into the proper position. In some instances two lining stakes, one on each side of the center stake, have been used, but one stake will give the same results.

In connection with the staking out, it is proper to consider here some of the features that determine the location of line supports in first-class construction practice, with special reference to those that frequently will have to be settled in the field.

The first question is that of the maximum allowable angle or "corner" that the surveying crew may assume to carry on one structure; in the past, in wooden pole construction, it has been the custom to carry on one pole a maximum corner of 15 degrees, splitting the angle up between two or more, where it exceeded this limit. However, with the advent of steel structures and better insulators and pins, one now often sees angles up to 60 degrees, and sometimes right angles, carried on one specially designed structure which is provided with a number of insulators proportionate to the strain developed by the angle and spans on either side; with the strain type of suspension insulators at angles, the handling of corners is greatly simplified, and with special designs of structures almost any problem in this line can be solved. Under ordinary circumstances, however, it is well to limit the angle on any one structure to a maximum of about 45 degrees and to use one standard angle tower for the whole construction. This will avoid the relatively great expense, both in material and labor, of special structures of varying design. Excepting possibly where right-of-way difficulties are encountered, a maximum angle of 45 degrees need not be exceeded. Where an angle greater than 45 degrees appears necessary, it should be made the subject of careful study before approval. In some instances in high-tension work, buck-arms have been used in wooden pole construction, but this is not standard construction for high voltages and it should not be employed where any other solution is possible; for any heavy corner two structures are better than one because with failure of either one of them the other will at least prevent the whole construction from coming down.

It is in building a line along or closely parallel to a highway, that the ingenuity of the engineer is taxed to the utmost in overcoming "corner" difficulties as introduced by the turns and twists of the road and at the same time the lack of guy room.

Where deflections of more than 10 degrees occur, the strain should be minimized by shortening up the spans on either side of the corner, making them about three-fourths the standard length for angles of from 10 degrees to 20 degrees and down to two-thirds or three-fifths of the normal for angles greater than that; at dead-ends also the last span should be only about three-fifths of the standard.

Another point on which the men should be instructed is the location, within reasonable limits, of the structures so as to assist in the grading of the line as much as possible; often the moving of a pole or tower relatively a few feet one way or another, will make it possible to use a standard structure where otherwise one of an odd size would have been called for to maintain the horizontal grade. Where bad ground is encountered attention should be given to seeking the best foundation under the circumstances. In cases of long spans it is better to increase a span a trifle than to locate the towers on costly foundations.

The crew should also use particular care in marking plainly and setting solidly the location and reference stakes for the structures so that in carrying out the construction work later on, the material distribution and erection crews will be able to do their work accurately. The surveying party should also be cautioned against any unnecessary axing or other damage to property. It should seek to carry on its work in a gentlemanly manner, without arousing any enmity through careless or unnecessary trespass.

All surveys should be tied in with section corners and salient topographical features so that they can, if necessary, be put on record, as well as platted accurately, regardless of whether or not the line is to be built on private right-of-way, under leased rights or on public highways. While the location work is being carried on in the field, an accurate map of the complete system, in sections as desired, should be made. For this map the writer has found a scale of 2 in. to the mile to be very satisfactory, since this scale is generally employed in county plat books and permits the transferring of details without change of scale. The holdings of the various property owners along the entire length of the line should be indicated and marked on this map. In this way, the map will be useful not only for the right-of-way men, but also for giving the construction foremen reference points in directing the work. The map will also show all other features included on a map of that size, locating accurately the various farm-houses and buildings, streams, roads, bridges, railroads, fords, etc. It should indicate all crossings of the transmission line with existing power, telegraph or telephone lines. The transmission line route as finally located should be laid out with all details as to deflections, etc., together with numerous reference points on tangent; further, the insertion of the station numbers on either side of such division line as streams, railroads and high ridges will assist the distribution foreman in directing that part of the work.

A profile of the line is made upon the completion of the survey, unless it has already been prepared as will be the case if the first method of laying out a line has been followed. Usually this profile is made to the same scale as railroad profiles on standard cross-section paper, platting 400 ft. to the inch horizontal and 20 ft. to the inch vertical. The transit line should be shown on the bottom of the sheet as is customary in railroad work. Angles and all road, stream, railway and line crossings should be laid out with any necessary data referring to same, and the profile should show height out of ground of all poles carrying lines to be crossed with data as to the number of cross-arms and wires on the same.

The next act is the location on this profile of the structures or at least the determination of their heights, etc., where the second or third survey methods have been followed. If the first method has been employed, this will have been done before the staking-out party took the field. With the second method, the profile as laid out in 100-ft. stations is taken and, with the standard height of structure, the standard span and the minimum clearance to ground as a basis, the locations of the poles or towers and their heights (as made necessary to give a good even grade free from unusual vertical strains on the insulators) are drawn in. Where poles are to be used, only the height out of the ground should be shown, as indicated on the typical profile, Fig. 1. Towers, however, are always bought on the basis of the clearance of the lowest conductor to ground, and are generally so rated when the height is mentioned.

Where the third method of laying out a line is followed, the centers of the structures will have already been located in the field. The office work then consists in determining their heights and type for the conditions of load encountered.

For finding the clearance to ground of the low conductor, where the points of support are at approximately the same elevation, the air line between the pin tops can be drawn in and, deducting the maximum sag, the clearance of the low point of the sag curve to ground can be determined. A preferable way is to use a templet of the sag curve laid out to scale on a piece of tracing cloth or celluloid, for in this way a check can be secured on the clearance to all intermediate points in the span. As the clearance to ground need not usually be checked where the line is built through level or gently rolling country, where a straight-line method would give the information satisfactorily, it is apparent that if a check is required by the contour of the ground, it should cover all the points intermediate between the two towers.

A curve templet is the only thing that will give these last data accurately. Where, as in rough country, the points of support of the conductors are at an appreciable difference in elevation, so that the low point of the sag will not come at the middle of the span, the clearances should certainly be checked closely.

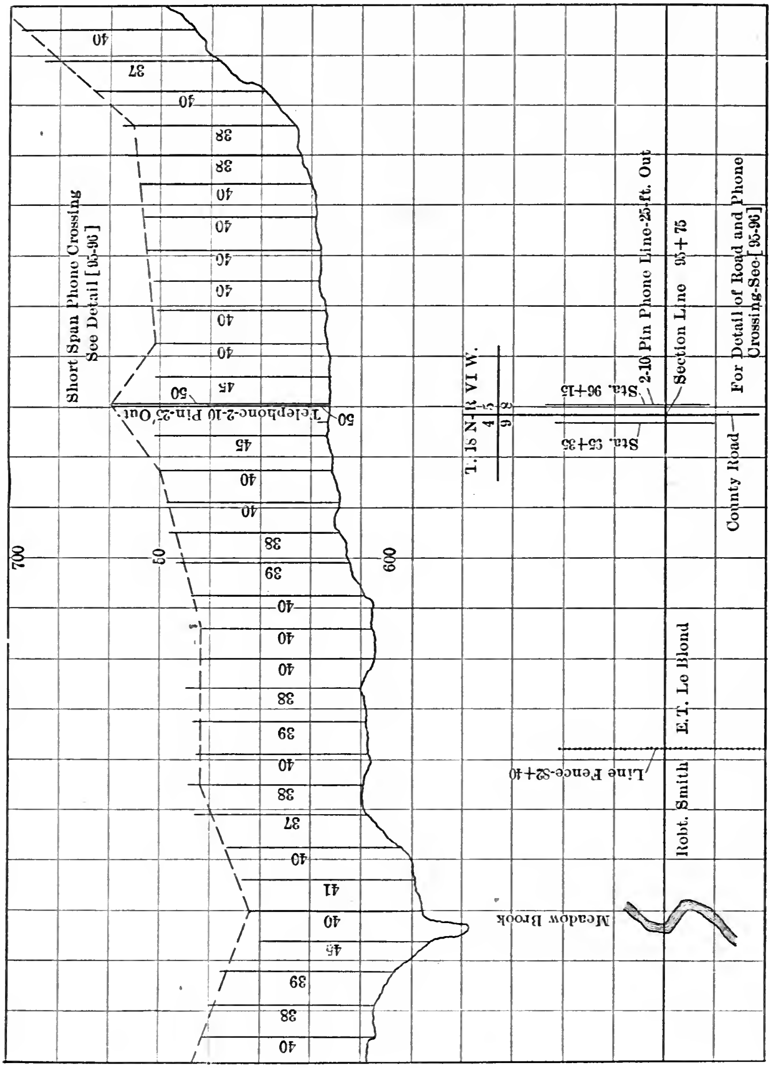


FIG. 1.—Profile, 40-ft. wooden pole-line.

For the foregoing work and for the location of structures on a profile to give a required clearance, the method of making a universal templet on celluloid to cover the probable range of span lengths, as used by T. Holmgren in the transmission line work of the Trolhattan project, is very good. This method can be employed to solve any problem involving location and clearance of structures on a profile. It was described by Mr. Holmgren in the *Teknisk Tidskrift, Elektroteknik,* No. 3, 1910, and by J. S. Viehe in the *Electrical World* for June 15, 1911.

In laying out the line on the profile, there is another point that must be taken into consideration—namely, the condition that may arise where a line is built along or parallel with a steep slope. Here the profile may indicate that the low conductor has ample clearance to ground. The profile, however, shows the same for the center line of the towers. It is apparent from this that where a conductor is out 10 ft. or 12 ft. to the side of this center line the clearance of the conductors on the uphill side of the structures may easily be reduced to a dangerous point. In such cases a little general information as to the topography of the ground on either side of the line of survey, as noted in the discussion of surveying methods, will be of value.

With the completion of the laying out of the line on the profile and map, begins the work of making up the bill of material required. For this the profile sheets are the "plans" of the construction. From them are determined the number of the various standard line structures needed, and the angle, transposition, dead-end and other special types required; from these data also the list of insulators, pins, cross-arms, hardware, etc., as may be called for by the type of construction, together with ties, insulator clamps, etc., is made up. From the data on the profile, the amount of wire, with an allowance of from 2 per cent. to 5 per cent. for sag and waste, is also determined.

In making up estimates of material it must be borne in mind that contingencies such as slight changes in spacing or detours due to right-of-way demands, accidents in the course of construction, etc., must be allowed for and amounts ordered accordingly. A contingency allowance of 1 per cent. to 3 per cent., depending upon the magnitude of the work, will be a good insurance against delay in the construction; much of this material will be required for stock in taking care of the repairs and maintenance upon beginning operation, so that the amounts need not be cut to a minimum. All estimates should be made up by two persons independently and checked against each other to avoid possibility of errors.

Next follows the matter of shipment, that is, to say, the amounts of material which are to be delivered at the various shipping points serving the territory traversed should be listed. If necessary, portions of the total of an item may be shifted from one point to another, so as to bring all of the shipments into car-load lots. From his knowledge of the various roads radiating from the different towns, the engineer will be able so to arrange his shipping schedule as to take advantage of the possibilities of a cheaper long haul on a good road over that of a costlier shorter one on a bad road. Consideration should also be given to the teaming facilities at the different stations. In small communities, especially in winter, it is often possible to secure a man and team to haul poles or towers for as low as $3.50 a day, where in larger towns the same service will cost from $4 to $5. It is also good policy to make general inquiries regarding the number of teams that will be available for use in the distribution of material at the season of the year that they will be needed. Another feature that is very relevant to the matter of shipping instructions is the question of unloading and storage facilities for delivered material. Poles or towers require ample space along a side track where they can be unloaded and arranged systematically for ease and economy in hauling out for distribution; insulators should be under cover where they will be safe from breakage, or at least they should be stored where they will not be too subject to the careless investigation of the curious public. Copper wire, so subject to mysterious disappearance, should be kept under lock and key.

With all these considerations in mind, a shipping schedule can be made up for the suitable points of shipment and proposals can be asked for, f.o.b. these points, thus putting all bidders on the same basis. If the weights assumed in making up the material estimates and shipping information, differ from those proposed, they will require checking to see that the carloading will be satisfactory. It often happens that proposals are invited before the estimates are complete. Then the request is for bids on the various materials based upon approximate amounts, the bids to give the unit price of each delivered in car-load lots at the several specified stations. With the completed estimates and the data of the bids, detail shipping instructions are then made out.

The right-of-way problem is always the most annoying step in line construction. The first matter to be settled is whether the right-of-way is to be bought outright or acquired under easement. It is not very often, except in cases of important undertakings maintaining a private road along their lines, that title is acquired to a transmission line right-of-way, because under ordinary circumstances it is a good deal cheaper and as satisfactory to secure the right to locate and maintain structures on a piece of property under easement. This applies to the first cost as well as to the operation of the line. Where a strip of land is bought outright the cost is always relatively high, the land is subject to taxes and other assessments, and fences are generally required along each side of the right-of-way line. In many cases it may be that the outright purchase of the right-of-way may prove economical, especially in sparsely settled districts, but the method that is now generally followed in good transmission line practice, is to pay so much per structure for the perpetual right and easement—sometimes this is for a limited term of years, with provisions for renewal at expiration—to erect and maintain a line of poles or towers and wires upon the described property in accordance with the survey, allowing for necessary guys and braces, with full right to remove for a given distance on either side all trees which are dangerous to the operation of the line.

To meet the demands of the contracting parties, special clauses, such as a provision to reimburse the property owner for possible damage to his growing crops in the construction of the line, will often have to be incorporated. In all cases, no matter how worthless a piece of property or how obscure the highway traversed, right-of-way contracts should be secured for every pole or anchor set, for not only does the actual right-of-way cost itself increase wonderfully after construction sets in, but the delay in the work and the cost of coming back to clean up skipped work will be found very annoying and expensive. Some companies do not pay as much attention as they should, to the securing of rights to set along highways, as they assume that their state charter or township authorization, is all that is necessary. Ordinarily this authorization is sufficient for the setting of the poles but it cannot include any rights to trim trees and set anchors inside of fences, etc., which are the main features in a highway right-of-way contract.

A form of contract for the acquirement of right-of-way under easement is given below. This form has been found satisfactory by several companies in the Middle West. Contracts should be recorded in the same manner as any other agreement.

FORM 1.

....

part........of the first part in consideration of..Dollars ($..................................) to..........................paid by Western Water Power Co., a Wisconsin corporation, authorized to do business in Wisconsin, receipt of which is hereby acknowledged, do............hereby convey and warrant unto said Western Water Power Co., second party, its successors and assigns, the perpetual right and easement to erect and maintain a line of poles and wires with all necessary anchors, guys and braces over and across land owned by first part............in Township of.. County of..State of Wisconsin, described as follows, to-wit:..

....

....

....

....

....

....

The route to be taken by said pole line across said land being more specifically described as follows:..

....

....

....

....

Together with the right to enter upon said premises for the purpose of erecting such poles and supports and stringing said wires and repairing or removing the same, and the right to trim or remove such trees as interfere with said line.

WITNESS the hand and seal of part........of the first part this.......................day of..A. D., 190..........

In presence of

....L. S.

....L. S.

STATE OF WISCONSIN, } SS.
County of .... } On this .... day of
.... A. D. 190........, before me, a Notary Public in and
for said County, personally appeared ....
.... to me known to be the same person ....
described in and who executed the within instrument who ....
acknowledged same to be .... free act and deed.

....
Notary Public.

My commission expires ....

The way the work of securing the right-of-way is carried on and the personality of the man who represents the company, has much to do with determining the future sentiment shown toward the company. It is poor business to pay more for a privilege than it is worth, but it is even poorer policy to get the better of the bargains through sharp practices and so leave behind a trail of dissatisfied property owners. A few dollars extra spent in purchasing right-of-way will be more than repaid in the good-will obtained. Anyone who bears the responsibility for continuity of operation of a high tension line can testify to the inestimable value of the friendship of the people along the line.

The cost of right-of-way naturally varies with the character of the country; on highways in the Middle West for a high tension line built in 1908–09, the cost per pole varied from 50 cents to $5 depending upon the amount of tree trimming and clearing necessary; along section lines the cost ran from 50 cents to $2 per pole, and where the line ran diagonally through fields or at some distance in from fences, from $2 to $10 per pole. The averages under the three different conditions were, for the first about 75 cents, for the second $1, and for the third about $5. This line ran through a well-settled community where, however the land value would not average over $50 to $60 per acre. The prices given are for a perpetual right and easement to erect and maintain the line, and they include all cutting and trimming privileges for a distance of 25 ft. on each side of the line. In special cases separate purchase was made of such tall trees outside of the 25 ft. limit as were deemed dangerous.

The right-of-way under easement for a tower line built through sparsely settled territory in the Middle West was about $9 per tower, and where it passed through well-settled country about

$20. Another tower line in the same locality, but passing through well-settled country, averaged $26.50 per tower for right-of-way.

In making final preparations for the beginning of the construction work much assistance can be given the line foreman by furnishing him with his general data worked up in compact form. One handy little kink that the writer has used is a small typewritten book made up as shown in Fig. 2. This book gives the length of pole or height of tower required at each location and notes all special construction, corners, lengths of span; further, where a structure location is at or near some land-mark or close by a farm-house, it is indicated so as to give the construction men numerous points of reference in doing the work. The foreman should also have copies of all shipping instructions and, supplementary to them, definite distribution instructions to direct him concerning the various roads to be used in hauling out the material for the different sections, for instance "from No 235 to No. 307 use the main road running due north from Aville," etc. Duplicates of all right-of-way contracts should also be furnished to the general foreman together with the property map of the route on which is shown the name of every property owner with whom dealings have been had in securing location privileges. These contracts will state in detail the number and location of the structures to be set, the

470–40 ft.
71–40 ft.
Xing Le Blond farm road.
72–43 ft.
73–42 ft.—Due east Le Blond house.
74–40 ft.
475–45 ft.
76–50 ft.
———From here on haul from Nedford———
77–35 ft.
100 ft. span.
78–40 ft.—A 8 deg. R—Dbl. Arm.
100 ft. span.—8 ft. top for 78
79–40 ft.

FIG. 2.—Data book for construction foremen.

guying that is to be done and the trimming and cutting of trees and shrubbery that has been agreed upon. It will also give explicit authorization to the foreman of the rights acquired under that particular agreement.

All data and instructions to be furnished line foremen should be as simple and explicit as possible.

CHAPTER III

TYPES OF CONSTRUCTION

The wooden pole is to-day most widely employed for the support of transmission lines, but with the increase in the cost of good pole timber and the advent of cheaper and more scientific steel construction, not to mention the pioneer work with reinforced concrete, it is only a question of a few years when it will be superseded for transmission lines of any importance at all. Furthermore, power consumers are exacting continuity of service, so that the line, always the part of the power system most susceptible to damage and hardest to repair, must utilize the construction that will give it the greatest reliability. This insistance upon uninterrupted service, combined with the high maintenance and increasing first cost of wooden construction, will hasten the departure of the wooden pole line.

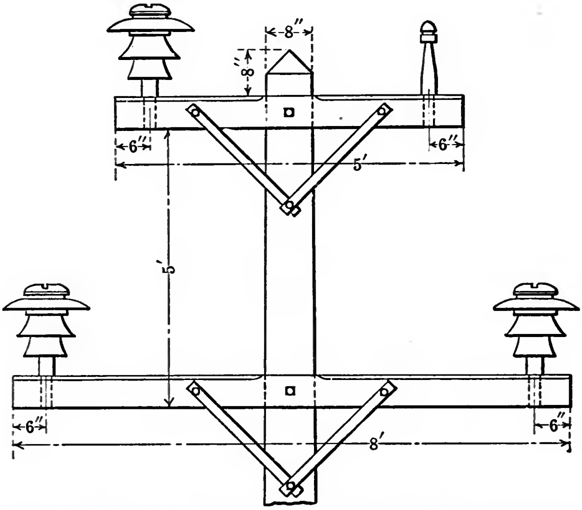


FIG. 3.—Commonwealth Power Co.'s standard pole top construction 40,000- and 60,000-volt transmission.

Wooden poles, as generally used in lengths of from 25 to 75 ft., are spaced from 100 to 200 ft. apart. The length of span most used varies from 125 ft. to 130 ft., which gives a high factor of safety with the comparatively few wires ordinarily installed. This condition obtains only during the first few years of service because the pole rapidly decreases in strength from the day it is set. A pole less than 35 ft. long is rarely used as standard owing to the clearance required by high-tension circuits. Legal requirements for heights above roads, etc., usually call for clearances that demand a pole at least 30 ft. long. The size of the top varies with the loading. The average good construction in this country may be said to employ 35-ft. or 40-ft. poles with 7-in. or 8-in. tops as the standard.

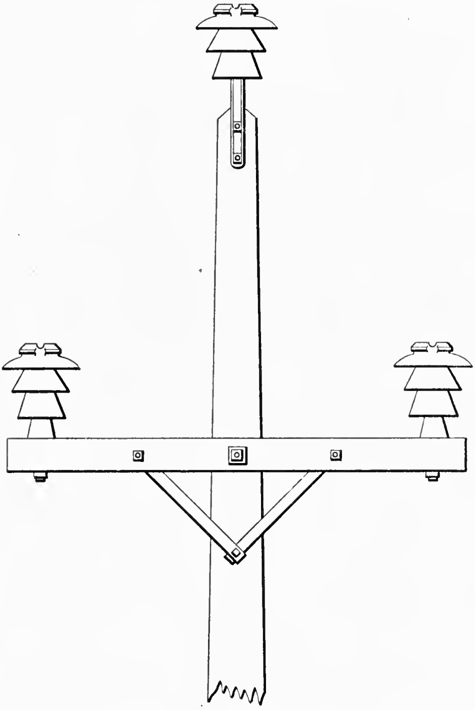


FIG. 4.—Typical single circuit pole top where no ground wire is carried.

A good example of Eastern and Middle Western pin-type construction with ground wire is shown in Fig. 3. This is the pole top used by the Commonwealth Power Company and several other companies for 50,000-volt and 60,000-volt lines.

As originally used in Michigan, the line was built with 7-in. top, 35-ft. northern cedars as standard set in 125 ft. spans. Similar construction in Wisconsin employed 40 ft. cypress in 125-ft. spans, three No. 2 equivalent copper strand conductors, a ground wire, cross-arms of 5 in. × 7-in. yellow pine, a 5-ft. top arm and an 8-ft. bottom arm, 5 ft. below.

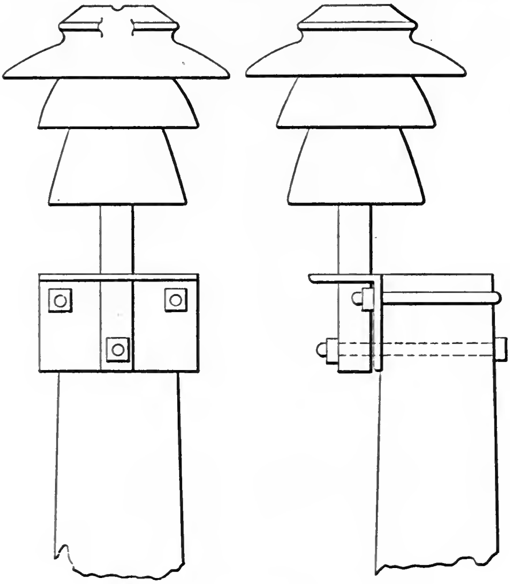


Fig. 5.—Pole top, using pipe pins.

Fig. 6.—Ridge pin.

Figure 4 shows a typical arrangement where no ground wire is carried. The only point in which the construction with different companies varies much is in the manner of attaching the top pin. Some early lines have used a wooden pin which was set into a hole bored into the top of the pole and fastened with a 3/8-in. through-bolt. Others have designed an angle arrangement for holding the top pin as shown in Fig. 5 to enable the same type of pipe pin to be used at the top as on the arms, which is a valuable feature where the whole pin is in one piece and cemented into the insulators. In late years a ridge pin such as the one shown in Fig. 6 has been used much for the lower voltages, while a type similar to that illustrated in Fig. 7 (*a*, *b*, *c*) has been employed for high voltages. In other details, the pole tops for a single circuit without ground wire have been carried out in practically the same way.

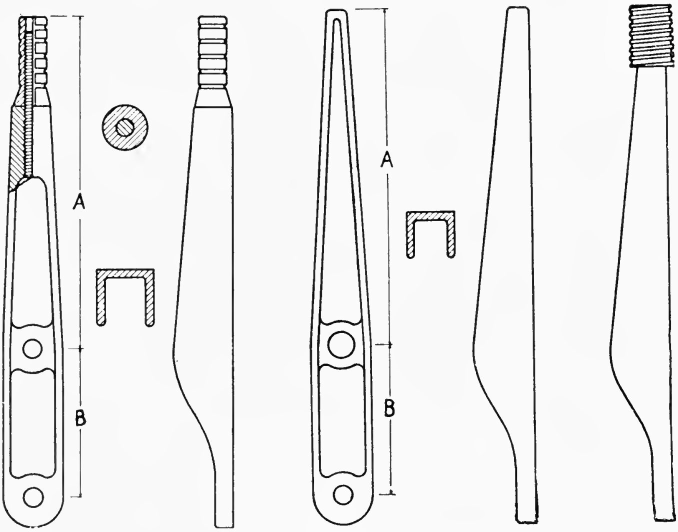


Fig. 7 (*a*, *b*, *c*.)—Pole top pins.

In the Southern Power Company's construction, the ground wire is carried on a pipe extension through-bolted at its lower end to the pole and braced against and by a special pole top casting which also supports the top insulator. This type is shown in Fig. 8. It represents a very ingenious method of placing the ground wire above the line conductors without sacrificing pole height in order to secure proper clearance and with the offsetting of the top insulator gives a balanced loading of the pole. Another clever pole top arrangement is that of the Consumers Power Company, as designed by H. M. Byllesby & Co. This construction, which is illustrated in Fig. 9, has been termed the "wishbone" arm arrangement. The arm equipment and the ground-

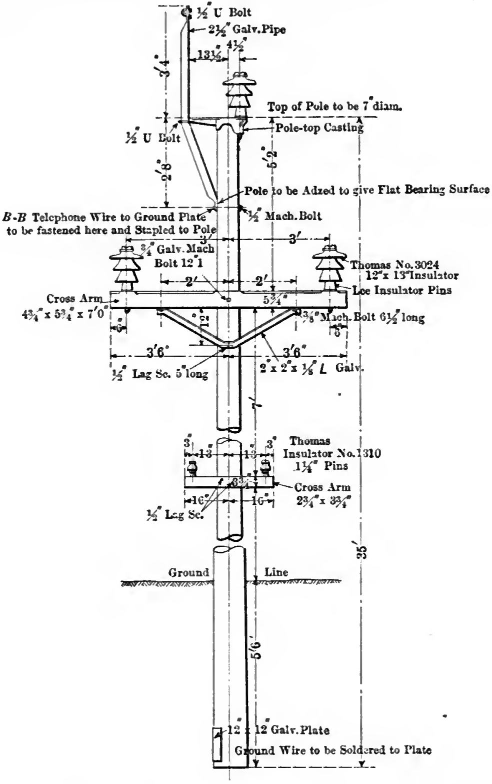


FIG. 8.—Southern Power Company's standard wooden pole construction.

wire bayonet are of 3 1/2 in.×3 1/2 in.×5/16-in. angle iron. The arrangement brings the top insulator above the roof of the pole, and requires less room on a support than any other construction yet devised to carry a ground wire above the line conductors. While this pole top design is very efficient, the use of steel on a wooden structure is incongruous. The cost of the construction with the spans employed, about 125 ft., must be very close to that of steel pole or steel tower work in economical spans.

Single-circuit construction is always preferable where it is possible to build two separate lines situated from 30 ft. to 50 ft. apart instead of carrying both circuits on one pole. The best method of all is to bring the two single circuits in by as widely diverging routes as practicable, but in this case it is not possible to use cut-over switches to gain the fullest advantage from sectionalizing switches if they are installed.

Where double-circuit lines are to be built, the arrangement of the pole top for most cases is that shown in Fig. 10 or Fig. 11. In Fig. 10 it will be noted that the long arm is at the top, whereas in Fig. 11 it is at the bottom. Where the long arm is above, repairs may be made with greater safety because more clearance is provided for a man to work on the dead circuit while the other one is alive; on the other hand, with four wires at the top, the pole is subjected to somewhat greater strain. However, the balance of advantage favors the installation of the long cross-arm above. These arrangements are good only up to about

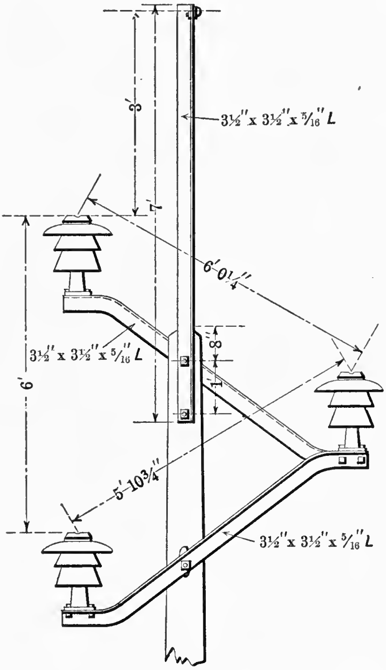


Fig. 9.—"Wish-bone" cross-arm arrangement.

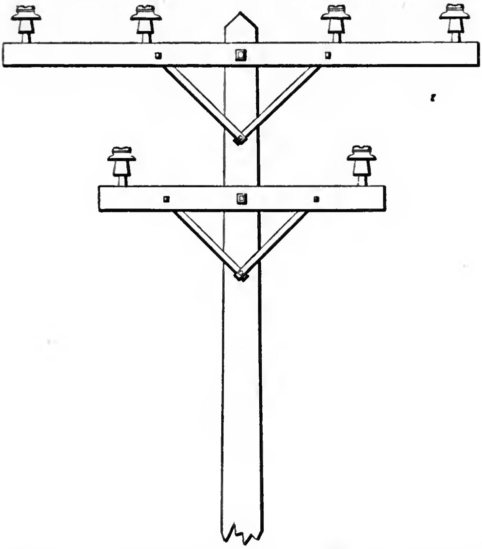


Fig. 10.—Double circuit pole top for voltages up to 44,000 volts.

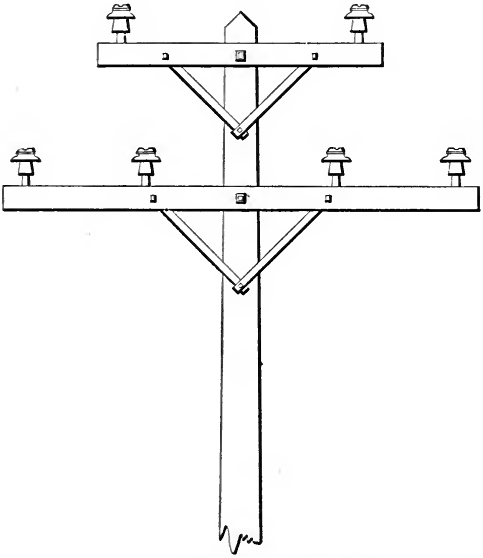


Fig. 11.—Double circuit pole top for voltages up to 44,000 volts.

40,000 volts on account of the long arm required for voltages higher than that.

Another design that is mechanically better than either of the foregoing, and one that is used in carrying double-circuit lines at the higher voltages, is the triple cross-arm scheme shown in Fig. 12. This type of pole top is open to the objection that it does not give as safe clearance for a man working on one circuit with the other alive, as the two-arm construction does.

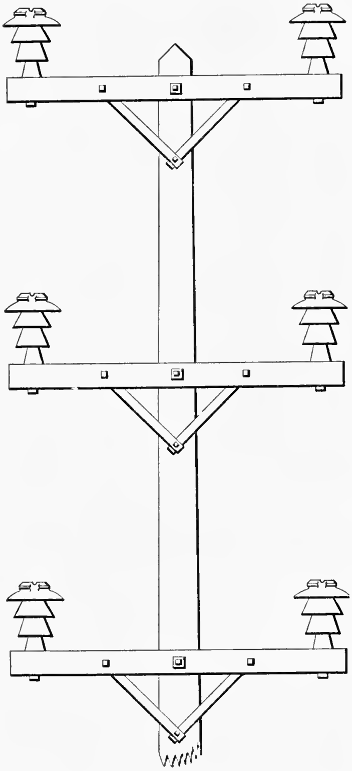


Fig. 12.—Double circuit pole top, —voltages over 44,000 volts.

The spans for double-circuit lines are generally about the same as those for single-circuit construction up to where the line conductors are No. 1 or so; from there on the spans are cut down as may be dictated by the size of the conductors, by climatic conditions and very often by financial circumstances.

While it has been the standard Eastern and Middle Western practice to build with the spans hereinbefore noted, the Western lines, especially near the Pacific Coast have used wooden poles to carry much longer sections. Thus Mr. Baum mentioned in his paper on "Transmission Economics" in the 1907 *Transactions* American Institute of Electrical Engineers that the California Gas & Electric Corporation has used single wooden poles with single arm and insulator construction to carry spans up to 500 ft. on straight line; also that the same line equipped with double arm and plate construction, but with only one insulator per phase, has been used for spans ranging from 500 ft. to 700 ft., and with two insulators per wire, for 700 ft. to 900 ft. Of course, these spans are carried on comparatively short poles located on high points in hilly country where it is possible safely to give the conductors the heavy sag required because of the natural clearance due to the contour of the ground. Again, with the short poles in service, the moment of the transverse stresses is correspondingly reduced. Clearance between conductors is provided by a spacing of 7 ft. for spans up to 500 ft., 9 ft. for 500-ft. to 700-ft. sections, and 11 ft. for 700-ft. to 900-ft. spans. Besides this particular installation, there are several other notable lines on the Pacific Coast where the spacing has been much greater than it would be in the East. The absence of sleet in the Far West, except in a few isolated sections, is naturally responsible for the good showing made by this long-span construction.

Fig. 13.—Madison River Power Company's long span wooden pole line.

A recent example of medium long-span work on wooden poles, is that of the Madison River Power Company, whose line has been in service since November, 1910, with a very clear operating record. This line is built with a standard span of 300 ft. using 8-in. top, 45-ft. and 50-ft. Idaho cedars. The pole top layout is shown in Fig. 13. The maximum span with standard construction is 834 ft., with many in the neighborhood of 500 ft. The line wires are medium hard drawn copper strand made up of three No. 8 B. & S., with a three-strand Siemens-Martin ground wire of about the same weight as the line conductors. The insulators are of the suspension type with three units, operating under 50,000 volts. On this line, the height of the pole alone for the long spans carried, gives the necessary clearance to ground. While this type of construction lacks the high initial factor of safety of the ordinary wooden pole line, it has been very satisfactory. In the writer's opinion, steel or possibly concrete poles, with medium length spans of say from 250 ft. to 350 ft., will be much used in the future.

Throughout the continent, where added strength or rigidity is necessary, as at river crossings, in swamp and bottom land construction, and also for a standard in medium or long-span work, we find much utilized the A- or H-frame construction, which is shown respectively in Figs. 14 and 15. These frames are made up of two poles arranged in the shape of the letter from which they derive their name. The A-frame as generally proportioned, has the strength of two poles along the line and about four across the line. In addition to its advantage in strength over single poles, the A-frame makes a very good, rigid structure in soft ground, where by doubling the length of the spans from, say 125 ft. to 250 ft., it gives a very economical fixture. However, it requires much more room than a single pole line. This last fact, in connection with the higher labor cost of framing and setting, does not compensate enough for the increase in strength over ordinary single pole construction, to make the use of A-frames generally justifiable as a standard type of construction. Wooden A-frame construction was used to quite an extent in some of the Ontario Power Company's work, and for several other installations.

H-frames are used under about the same circumstances as A-frames. Several lines have been built with this type of structure set from 250 ft. to 300 ft. apart. Without extra braces, however, they are not as rigid as A-frames. H-frames have been used quite extensively on one system in Utah, the one long arm being far enough down from the top of the poles to allow clearance for two ground wires, one at the peak of each pole.

For special purposes, there has been employed a great variety of wooden pole structures such as double A-frames and H-frames, three-pole structures, etc.

Steel poles are now being used to a greatly increasing extent. For the average voltages and conductor sizes, they give a more economical construction than straight tower lines, due to the lower right-of-way and labor costs possible. In Europe the use of steel poles not only for transmission work, but even for telegraph and telephone work is very common, and steel construction is also somewhat used for distribution work in many cities. In America, wooden pole construction has in the past had the advantage of a much lower first cost, and on this account has been widely used in developments where the main consideration of the promoters was for something cheap. Now, however, steel construction is rapidly coming into its own in consideration of its fair cost, greater reliability and much lower maintenance charges.

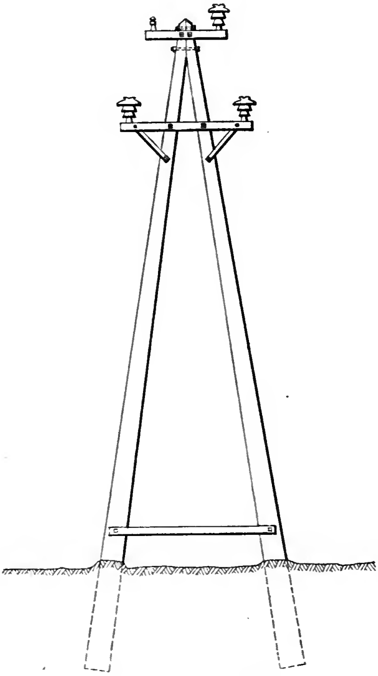


Fig. 14.—A-frame.

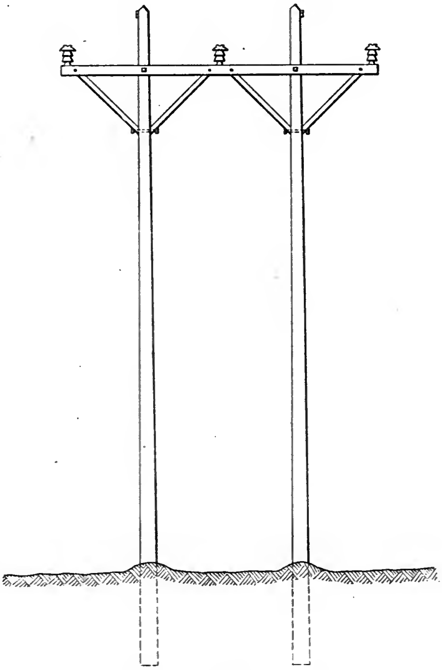


Fig. 15.—H-frame.

The latticed riveted type of pole structure is probably the one

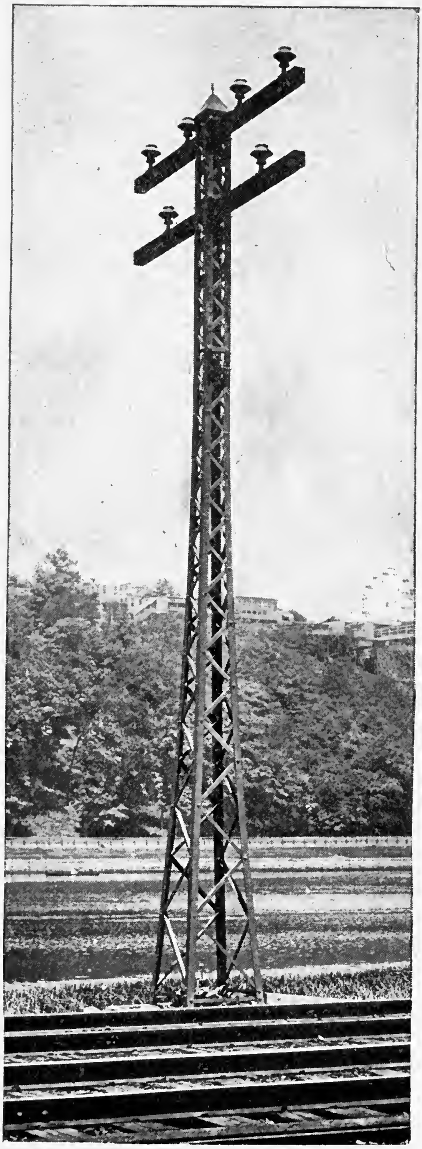


FIG. 16.—Steel pole used by New York Central & Hudson River Railroad.

that has been used to the greatest extent, particularly abroad. It is ordinarily built up of four main angle-iron corner members, laced with angle iron or flat bars, the whole being assembled and riveted in the shop in one piece for ordinary lengths, and in two or more sections for the field splicing of high poles. The section usually is square with a uniform taper from top to bottom, as may be demanded by conditions of loading. In ordinary work

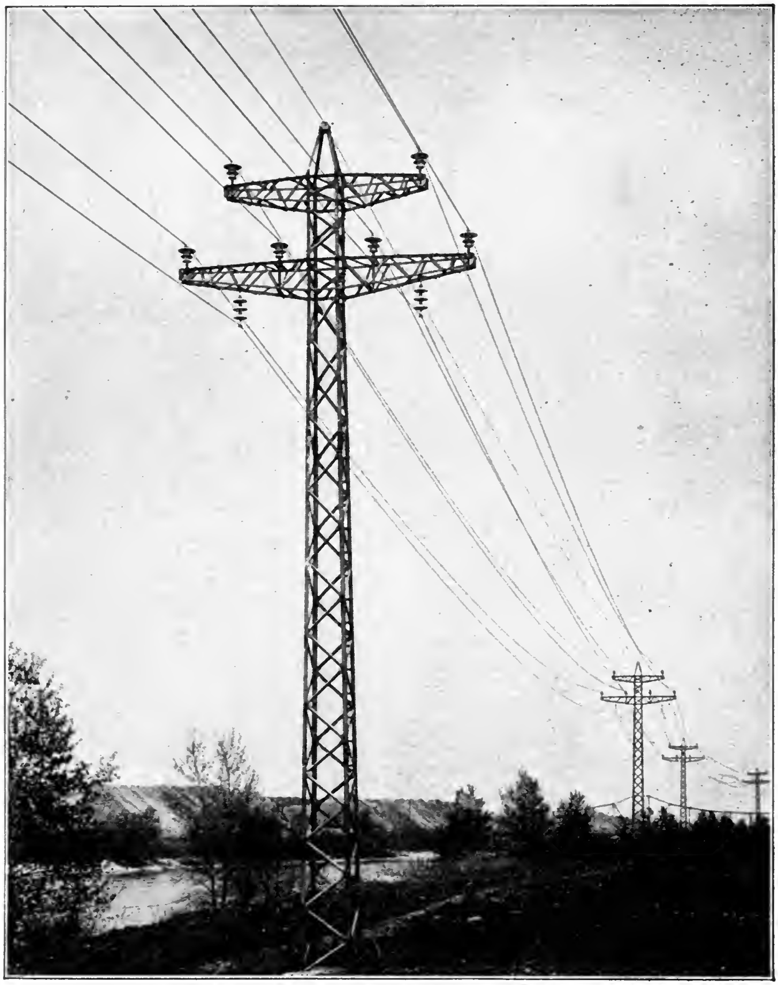
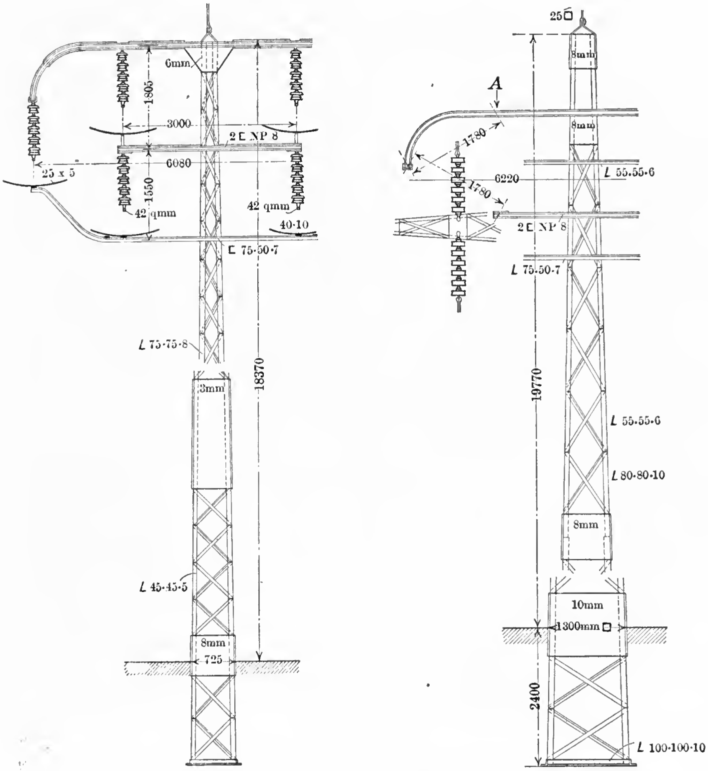


Fig. 17.—Sanitary district—steel-pole construction.

single lacing is ample. The cross-arms are generally of steel although wooden arms have sometimes been used.

While latticed riveted poles have not been used so widely in the United States as in Europe, there are a few good examples of this kind of construction in this country. Among them are the New York Central & Hudson River Railroad's electric zone, the Long Island Railroad, and the Sanitary District lines, with many isolated cases where short stretches of line have been built with latticed poles. The first-mentioned line, shown in Fig. 16, used wooden cross-arms and the last named, illustrated in Fig. 17, has built-up steel arms.



Figs. 18 and 19.—Lauckhammer steel poles.

Europe has many great systems using latticed steel poles. In the earlier work straight four-post riveted poles, much like those just described, were used throughout the entire line. More recently, the lines have been constructed on the flexible system. In a typical example, the 200- ft. or 300-ft. spans have light poles built up of two channel posts laced with light angle iron, with heavy four-post latticed angle poles at uniform intervals. The general tendency in Europe has been to use a bracket support instead of cross-arms for the insulators. Each bracket holds one insulator. It is also noted in many instances that where arms are used, the conductors are so arranged that the bottom of the equilateral triangle formed is not horizontal. It also appears to be the practice to carry more than one circuit on a pole.

In the north of Italy, under the guidance of Mr. Semenza, in Switzerland and in Germany, a great deal of latticed pole construction has been built. Fig. 18 shows the anchor, and Fig. 19 the intermediate poles for the recent Lauckhammer line in Germany the first in Europe to operate at 110,000 volts. The design of its structures is typical of those employed in Europe for latticed pole construction, except that cross-arms have not been employed to as great an extent as in America.

While the latticed pole has been much favored for transmission work, tubular poles and various patented types have also been put forth. Of the latter designs the diamond and the tripartite are the most prominent.

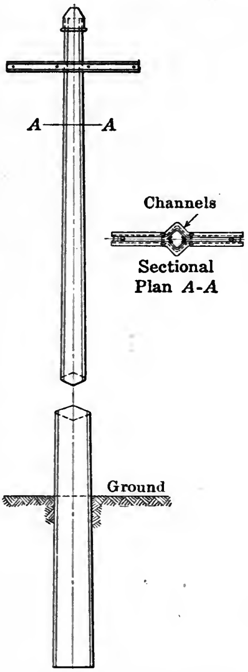


Fig. 20.—Diamond pole.

The tubular pole is not economical for transmission work. It has not been used much for that purpose in this country, although it has been given more favorable consideration in Europe.

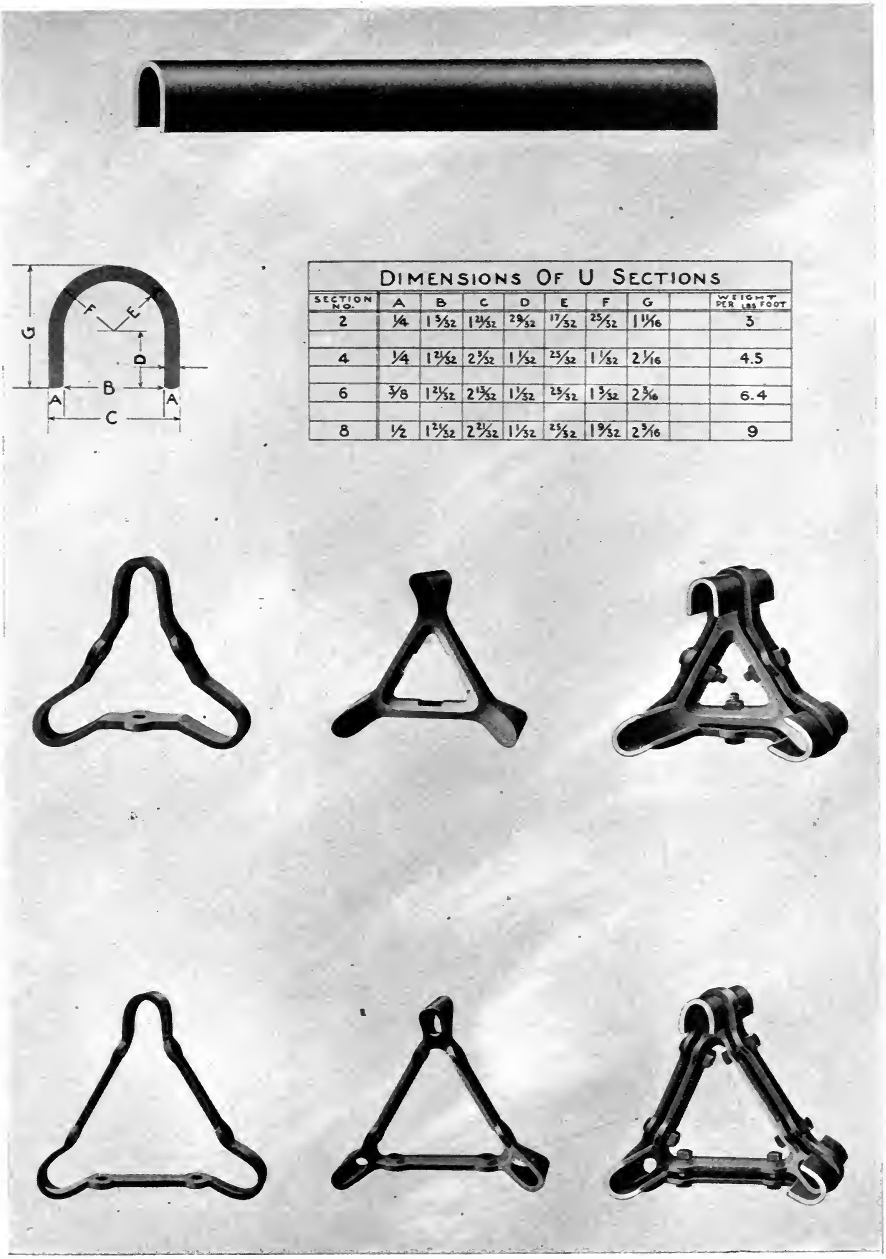
The diamond type pole, which like the tubular is best adapted to electric railway trolley work, is made of two sheet steel V-shaped troughs with flanged edges, driven one within the other longitudinally, as shown in Fig. 20, which also shows a typical cross-arm with method of attachment. The taper of the pole and the thickness of the metal vary with the conditions of loading imposed. The pole is set so that the line of strain is taken on the diagonal passing through its joints. Strength and stiffness are added by the extra metal at the joints. This type of pole is lighter than the tubular pole, but it has the same great disadvantage, namely, that it is impossible to get at and protect all of the surface most subject to corrosion.

The other patented pole, the tripartite, is practically a structural pole with bolted connections. It is composed of three U-section members arranged in the shape of an equilateral triangle, and bound together with malleable iron clamps, called collars and spreaders. A typical line built with this pole is shown in Fig. 21. Fig. 22 shows the constructional features of the design.

Fig. 21.—Tripartite steel pole line.

The number of collars and spreaders used, as well as the taper given the pole, varies with the conditions of loading. Thus almost any desired combination can be made up with a few different weights of U-bar and a line of collars and spreaders of various dimensions. The material of the U-bars is bessemer steel with a tensile strength of 100,000 lb. per square inch.

In general for transmission line or any other purposes, a pole that is accessible for protection from corrosion is preferable from a mechanical standpoint. Structural poles of the three or four-



DIMENSIONS OF U SECTIONS									
SECTION NO.	A	B	C	D	E	F	G		WEIGHT PER LBS FOOT
2	1/4	1 5/32	1 21/32	29/32	17/32	25/32	1 11/16		3
4	1/4	1 21/32	2 5/32	1 1/32	25/32	1 1/32	2 1/16		4.5
6	3/8	1 21/32	2 13/32	1 1/32	25/32	1 5/32	2 3/16		6.4
8	1/2	1 21/32	2 21/32	1 1/32	25/32	1 9/32	2 5/16		9

Fig. 22.—Details—tripartite pole.

post riveted types or similar designs such as the tripartite, will be the most favored.

In connection with the use of steel poles for transmission line work, it will be of interest to quote the following from an editorial in the *Electrical World* for March 30, 1911: "We have always had a fondness for the steel pole of moderate height in transmission line construction. It is going to be used in the

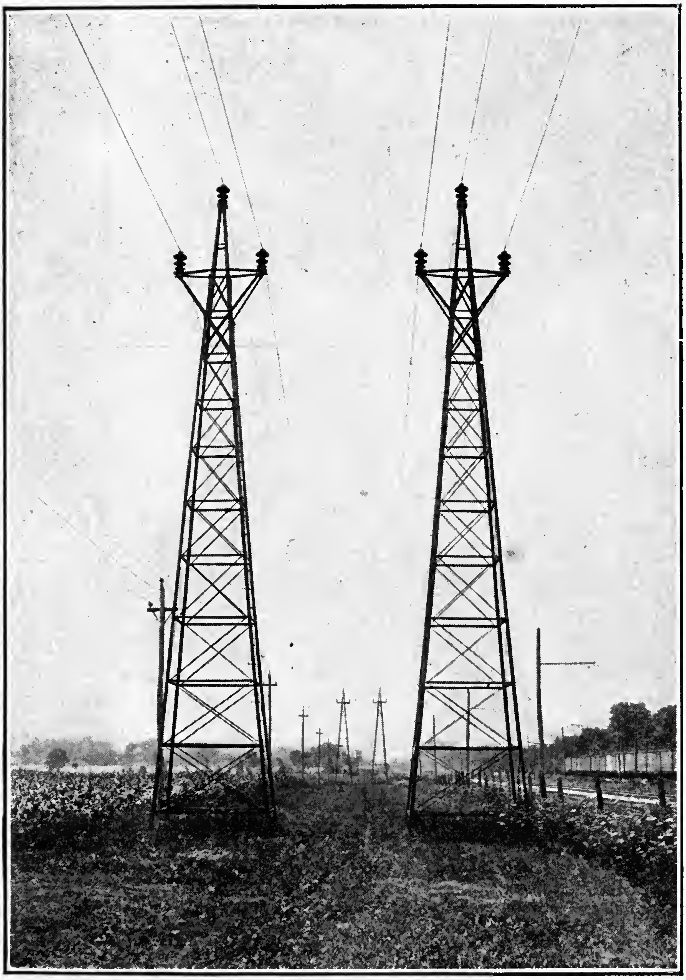


FIG. 23.—Niagara-Syracuse towers.

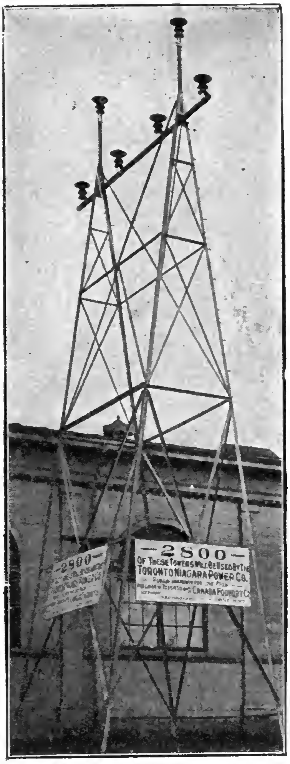


FIG. 24.—La Crosse Water Power Co.'s tower.

FIG. 25.—Toronto-Niagara Power Co 's tower

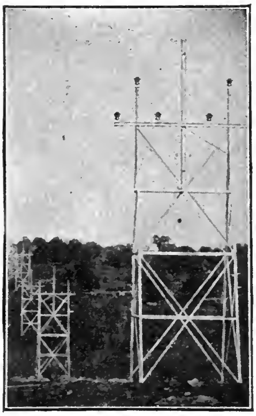


FIG. 26.—Connecticut River Power Co.'s tower.

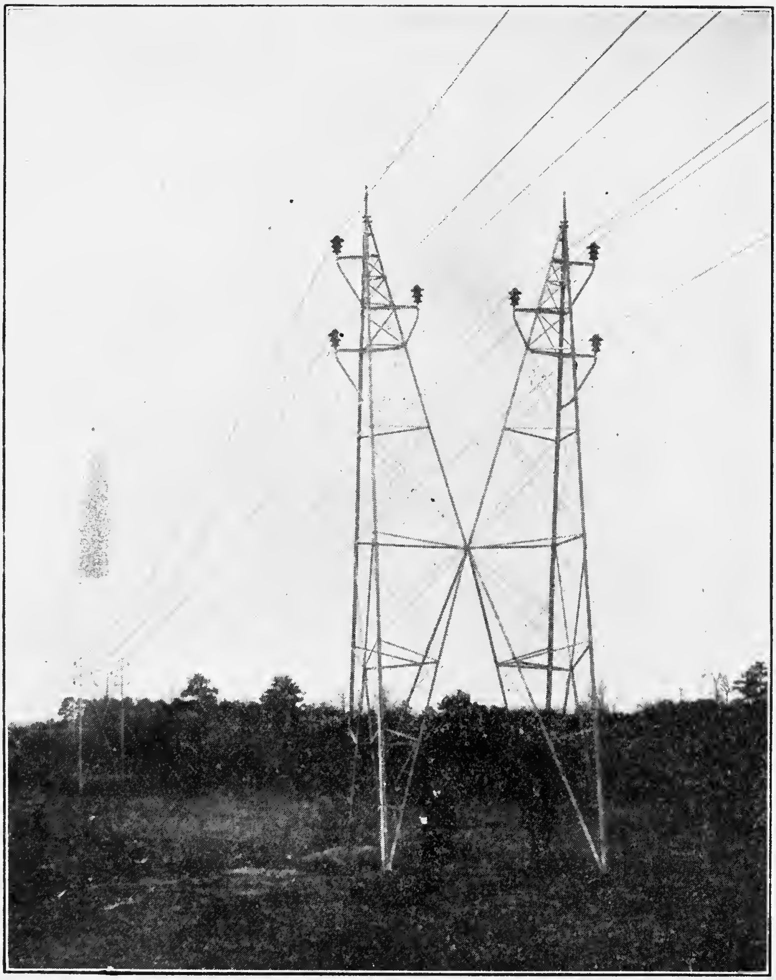


Fig. 27.—Southern Power Co.—twin circuit tower.

future a great deal more than it has been in the past . . . ." The writer believes that this prophesy will come true and that, following the lead of European practice in this regard, poles, in preference to towers, will be employed more and more for general work; and that they will show greater economy than tower construction, especially where right-of-way cost is any appreciable part of the total.

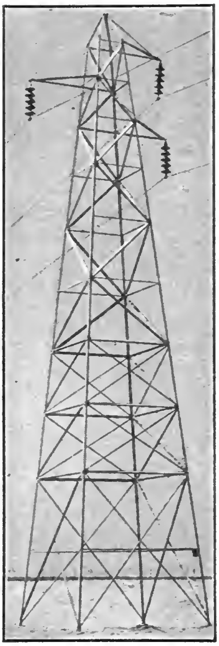


FIG. 28.—Sierra-San Francisco Power Co.'s tower.

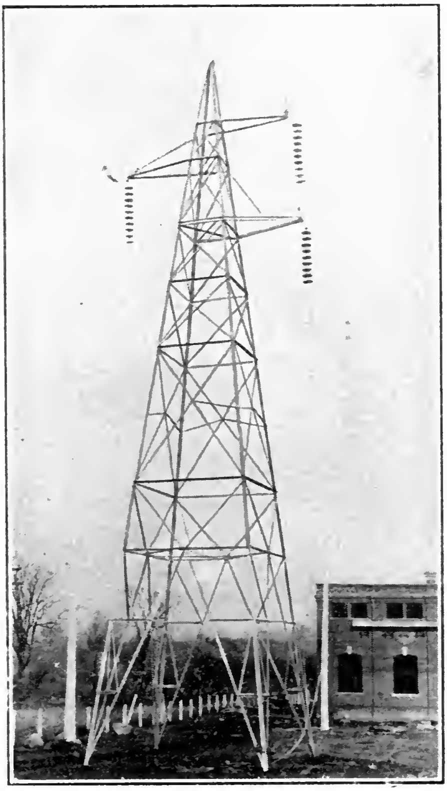


FIG. 29.—Single-circuit tower used by the Ontario Hydro-electric Power Commission.

Steel tower construction embraces an almost innumerable variety of designs in the two fundamental systems of using either structures of equal strength throughout which are designed to carry considerable horizontally-applied loads in any direction, or of providing heavy anchor towers which are located usually at mile intervals with intermediate two-post A- or H-frame steel structures to resist heavy strains transverse to the line but with only nominal strength in a longitudinal direction. These two methods may be designated as "rigid" and "flexible," and both have a strong following among engineers. The flexible or elastic system is used to a very great extent in Europe. To the writer's mind it appears that the flexible system is a reaction from the practice followed in many installations of specifying that the strength of a tower shall be sufficient to stand the unbalanced strain due to the severance of all the conductors on one side of the structure or similar severe assumptions. A tower built to such specifications was necessarily high priced, and the search for a means of reducing line costs has led to the other extreme. However, with anchor towers at close enough intervals and with sufficiently heavy ground wires, there is no reason why the flexible system will not work out satisfactorily.

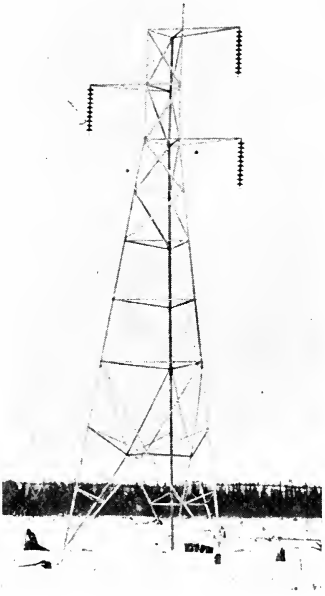


Fig. 30.—Standard tower used on 140,000 volt line of Au Sable Power Co.

The typical tower for single-circuit rigid construction, which is illustrated in Fig. 23, has no ground wire, is 49 ft. from lowest conductor to ground and carries the line in 550-ft. spans, standard spacing. An example of a single-circuit tower with provision for a ground wire is shown in Fig. 24. This structure is built to carry three No. 2 copper strand conductors, one ground wire of similar weight, and two No. 5 B. & S. hard-drawn copper telephone wires in 480-ft. spans or eleven per mile.

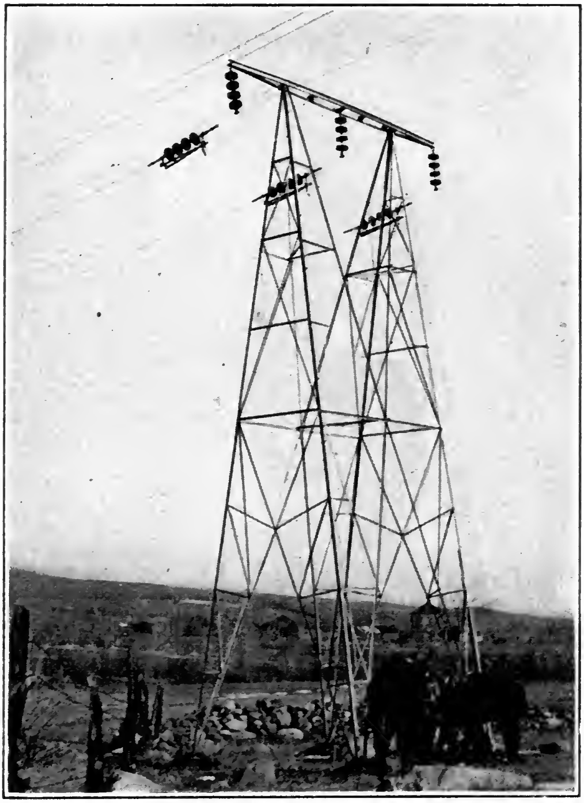


Fig. 31.—Type of tower used by Central Colorado Power Co.

Figure 25 illustrates a good example of a tower which is designed to carry two circuits without ground wire, while Fig. 26 shows a similar two-circuit structure with a ground-wire support provided. These two types have been widely used with uniform success. A type of double-circuit structure, however, that isolates the two circuits to a greater extent, is that shown in

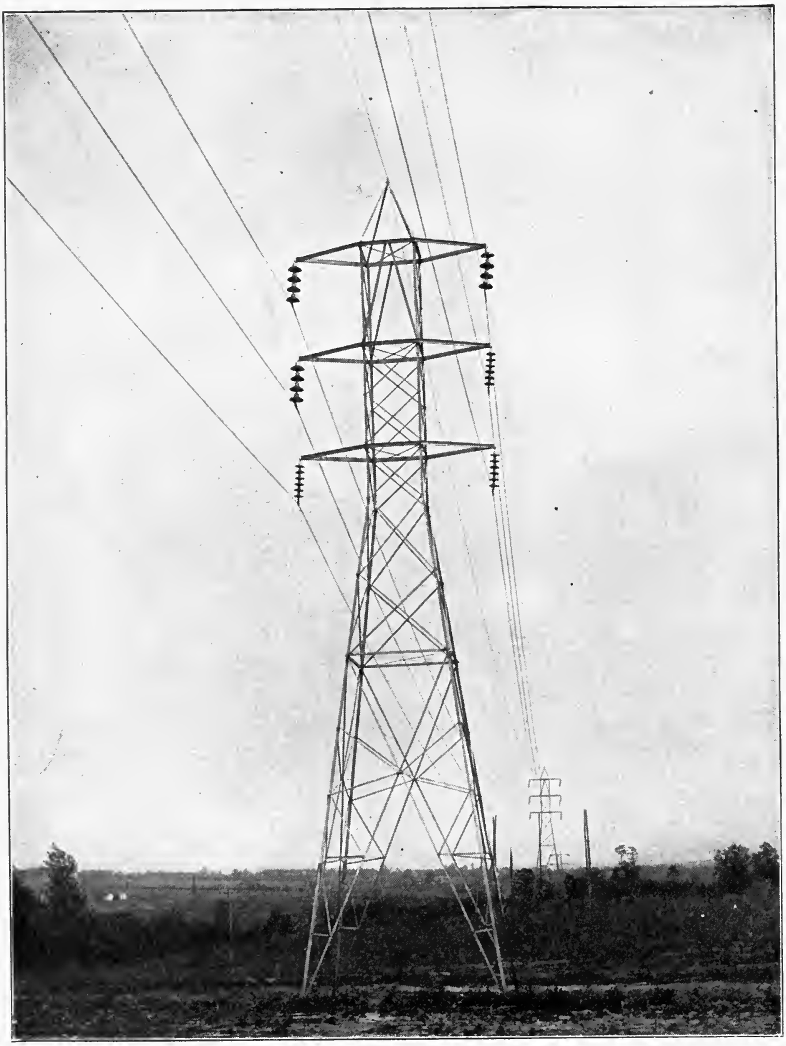


FIG. 32.—Southern Power Co.—100,000-volt double-circuit construction.

Fig. 27. While this tower may not have much greater actual clearance between the two separate circuits than may be provided for in the two designs previously noted, the separation is more effective so that repairs can be made with greater safety. When the patrolmen have a greater sense of security, they can make repairs in less time, thus minimizing the time of shut-down. From a mechanical standpoint, however, the design in Fig. 27 does not appear to be as economical or as strong as the preceding structures. It will be noted that the last type of tower carries two ground wires, one at the peak of each side.

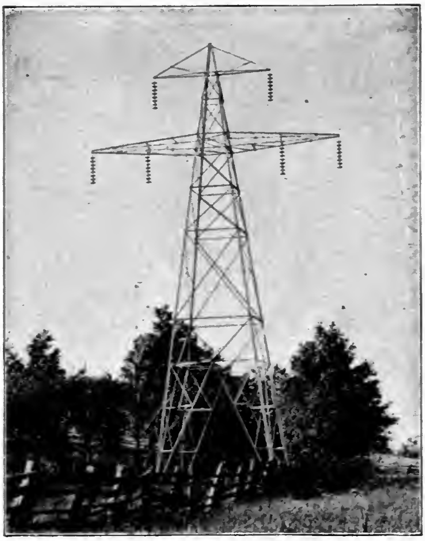


Fig. 33.—Ontario Hydro-electric Power Co. standard double-circuit tower.

The designs so far discussed have been arranged for pin-type insulators but the same main structures, with cross-arms and supports adapted to the suspension type, are used in either case. Designs followed out in good practice are shown in Figs. 28, 29 and 30. The type of cross-arm used in the single-circuit tower in Fig. 28, etc., is the one employed in most cases, although several lines have been built where the conductors are carried in a horizontal plane from one long arm as shown in Fig. 31.

Two general methods of supporting two circuits on suspension type insulators are shown in Figs. 32 and 33. The first design has often been preferred, however, for voltages of 100,000 volts and more, because of the long cross-arming that is required to carry four conductors in the same plane and to give them proper electrical clearance; also the great torsional moment exerted with the long arm calls for a heavier structure, although this is offset by the greater height of tower which is necessary where the conductors are arranged vertically on each side.

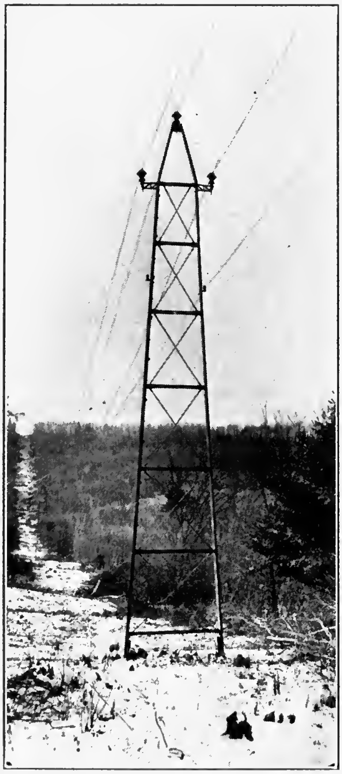


FIG. 34*a*.

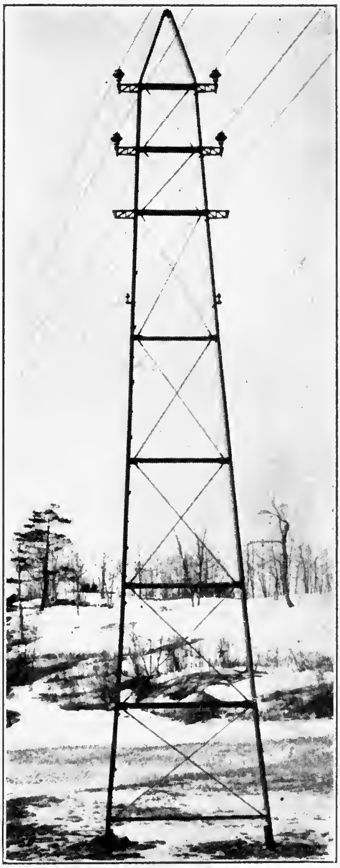


FIG. 34*b*.

Flexible intermediate towers.

In the flexible system the anchor towers are of the same general types as those that have been described, proportioned, of course, to meet the greater demands. The intermediate structure designs are a reversion to the A- and H-frame types used in wooden pole construction. A good example of an A-frame intermediate tower is that shown in Fig. 34. Its main members are heavy channel iron with angle-iron girts and round rod diagonal bracing, giving a structure which can resist heavy strains in a direction across the line but which has only slight strength in the opposite direction. This construction has economy in tower weight, but the greatest saving over that of a straight rigid construction is in its lower assembling and erection labor costs. A first cost very close to that of wood is claimed for it.

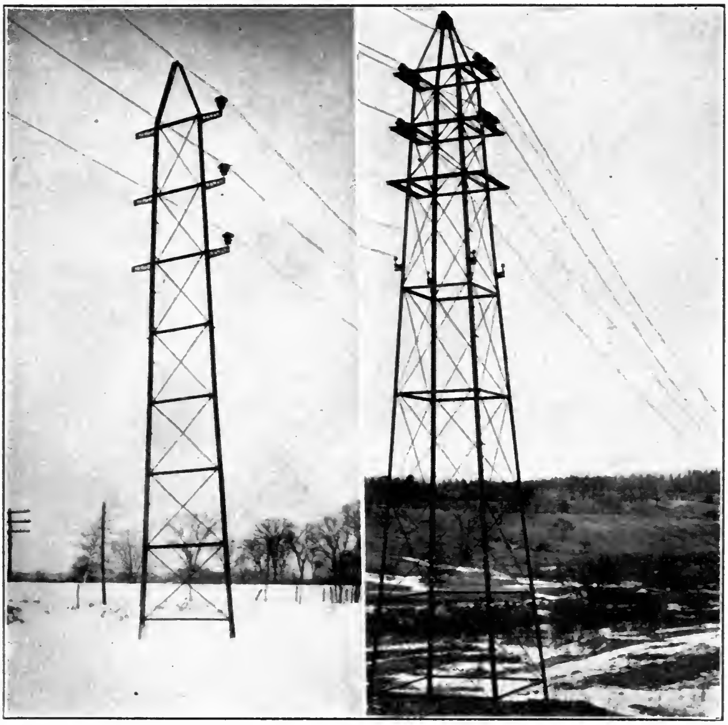


Fig. 34*c*. Fig. 34*d*.
Intermediate and anchor towers used in flexible tower work.

The H-frame has not been much used commercially for flexible line work, the A-frame lending itself more readily to the usual arrangement of conductors.

In this system of construction the anchor towers are usually specified at 1-mile intervals; also at all corners and all road, telephone, telegraph, transmission line and railroad crossings.

In reinforced concrete we have a new material for line supports for which much has been claimed. As yet, however, excepting for a few isolated cases of light construction, its use has been confined mainly to trolley, telegraph, telephone and city distribution work, which as a rule do not demand the same type of structure as a transmission line.

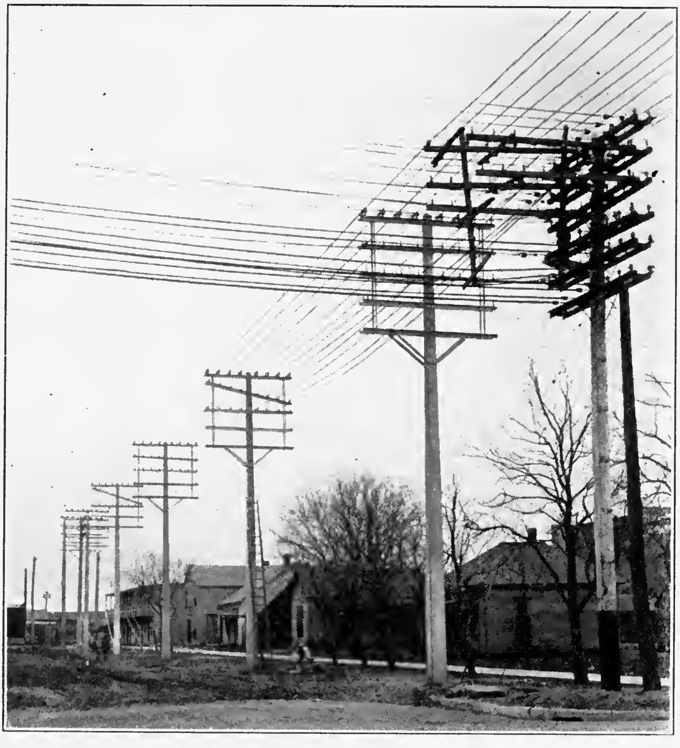


Fig. 35.—Concrete poles of Oklahoma Gas & Electric Co.

There are two general classifications of concrete poles—those molded horizontally in a yard or near the pole location, and those cast vertically in place like the column of a building. The former method is the only practicable one for transmission line work. The ordinary practice in this country has been to use a trough form, casting the poles by hand. This has worked out well, but is necessarily slow. The Germans, however, have developed a process of forming hollow poles of circular section, by centrifugal

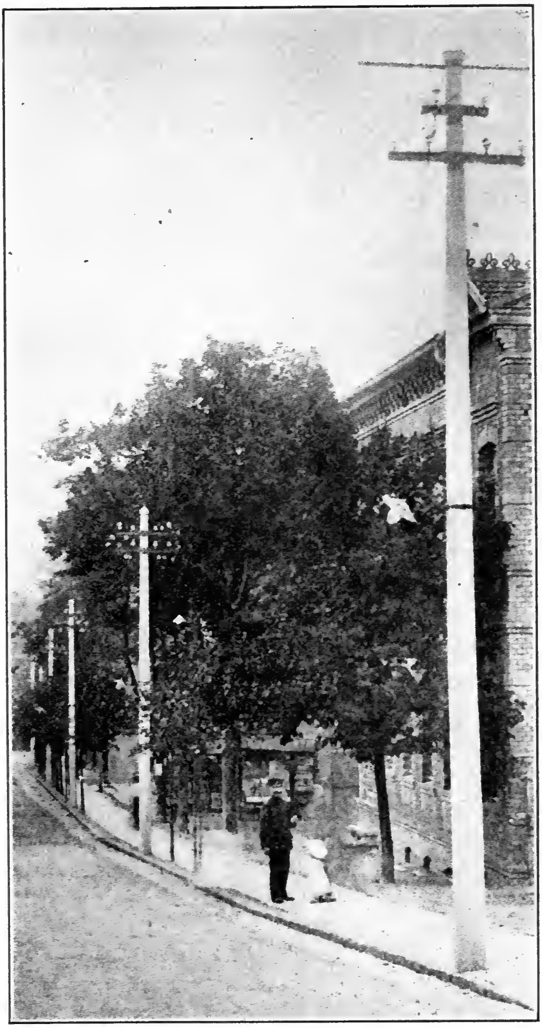


Fig. 36.—Hollow centrifugal type concrete poles.

action. Their form, consisting of a closed cylinder of the length and taper of the pole desired, is revolved in a lathe-like machine for from 10 to 15 minutes, varying with the character of the pole. This method of manufacturing concrete poles has proved successful and is now being introduced into this country. A plastering machine method known as the Siegwart process has also been developed abroad.

Figure 35 shows a line using a typical horizontally molded pole, and Fig. 36 illustrates a line employing the hollow centrifugal type for city distribution work. The neat appearance presented by a concrete pole is a notable feature of this class of construction.

The cross-arm arrangements with concrete construction are the same as those of standard wooden pole line work, excepting as to material. Wooden arms have been used to quite an extent but generally angle iron is specified. Concrete arms have been experimented with to some extent but so far as known have not been used commercially.

CHAPTER IV

WOODEN POLE CONSTRUCTION

A wooden pole has been said by a steel pole man to be "A tree trunk converted into a pole at the buyer's expense," and naturally we find almost as many varieties of pole timbers as there are species of trees. Cedar, however, is the most extensively used, with chestnut ranking next; pine, juniper, cypress, oak, tamarack, douglas fir, locust, catalpa, red-wood and a few others are used also in varying amounts, the first three being the most important.

Cedar is the most durable of all pole timbers, its useful life varying with the section of the country where it is used, from ten to thirty years, and its lasting qualities, in addition to its strength and lightness, have made it enormously in demand. Chestnut does not have the long life of white cedar and is much heavier, but it is used to a very great extent throughout the East, especially the upper half of the Atlantic Coast States where the supply of cedar and northern pine is nearly exhausted and the freight rates on northern and western poles runs into big figures; chestnut is also used to quite an extent throughout the eastern and middle section of the central group of states. Yellow pine, untreated with some good preservative, is subject to extremely rapid decay, having a life of only four or five years, and it is therefore usually given some preservative treatment before being used; oak, in common with all hardwoods, does not last well, is expensive and heavy; cypress in its native localities is quite satisfactory, but in one or two particular instances, installations in the North Central States have shown poor life, in one case lasting less than five years, even with unusually heavy poles as standard.

In general, it may be stated that the best and most durable pole timbers are coniferous woods of slow growth in heavy stands, so that good pole trees will be found in heavy timber land at fairly high altitudes and where the soil is poor.

The time of cutting is an important factor in the subsequent life of a pole. Careful study and investigation have shown that pole timber felled when the tree carries the least amount of sap invariably has longer life than timber cut at any other time; the sap is naturally lowest in the winter time and the best time for cutting pole timber is therefore from November to April. Excepting for the large consumers, few companies make any note whatever in their specifications limiting the time of cutting, whereas it is really as important as a clause specifying the permissible amount of butt rot. The pole should be trimmed, cut to length and peeled immediately after being felled. It should then be rolled up on skids in separate layers and allowed to season for from six months to a year.

The proper seasoning of poles has also not been given the recognition that it should have. Tests by the Government Forest Service have demonstrated that the durability of a timber in itself is increased by thorough seasoning, and, where the brush or open-tank methods of impregnation are to be used, it is imperative for securing good results, that poles be in an air-dry condition, owing to the low absorption of the compound by unseasoned woods. Where the pressure system of applying the preservative is to be employed, unseasoned timber can be used, but a great saving in the time of application of the treatment can be made if the timber is air dry. A direct saving in transportation charges is also effected by purchasing poles that are well seasoned, the reduction in weight being from 16 per cent. to 30 per cent. and even more for some species, according to government investigations.

To season poles properly, they should be laid out in single layers on sound high skids and all underbrush, weeds, etc., cut away so that they will not be in contact with any vegetation, and especially so that there will be free air circulation all about them. Skidding poles in solid piles should be avoided where at all possible, as not only is the seasoning retarded, but the timber is more susceptible to decay and to injury by wood-boring insects. Below in Table I are given results of an investigation by the Government Forest Service of the time required for proper seasoning of various species of poles cut at different seasons of the year. It will be noted that, except in the case of northern cedar, spring and summer-cut poles dry out more rapidly than the fall- and winter-cut. The data are taken from *Forest Service Bulletin* No. 84.

TABLE I.—TIME REQUIRED FOR POLES CUT AT DIFFERENT PERIODS OF THE YEAR TO SEASON TO APPROXIMATELY AIR-DRY WEIGHT

Species	Location of test	Time required for seasoning			
		Spring-cut	Summer-cut	Autumn-cut	Winter-cut
		Months	Months	Months	Months
Chestnut	Parkton, Md	5	4	8	7
Southern white cedar	Wilmington, N. C.	3	3	8	5
Northern white cedar	Escanaba, Mich	12	9	7	6
Western red cedar	Wilmington, Cal	[a][b]4	[a]5	[a]3	[a]3
		[c](3)	[c](6)	[c](7)	[c](4)
Western yellow pine	Madera County, Cal.	5	3	9	6

[a] Period of seasoning computated from time poles arrived at Wilmington three to seven months after cutting.

[b] Weight of spring-cut poles at termination of test, 28 lb. per cubic foot.

[c] Period in storage and in transit, during which time little seasoning took place.

Too rapid seasoning, however, may result in injurious checking of the timber which not only increases the area presented for the entrance of fungi and insects, etc., but in all probability the torn wood fibers at checks are more susceptible to deterioration than the exterior of the pole.

The life of untreated poles of the different species varies within wide limits, depending upon the locality where they are used; the National Electric Light Association gives for the average of the figures secured by a canvass of members, the following for the country:

Cedar	13.5 years
Chestnut	12.0 years
Cypress	9.0 years
Pine	6.5 years
Juniper	8.5 years.

Decay is given as the cause of the destruction of 95 per cent. of all poles, with insects 4 per cent. and mechanical abrasion 1 per cent.; in straight transmission line work, the last-mentioned cause will practically disappear and the percentage of damage through insects and birds may be increased a per cent. or two. In some sections of the country much trouble has been experienced with wood-boring insects, and in others woodpeckers have destroyed many poles.

According to the statistics compiled by the Government

Census Bureau, while the total number of poles purchased by all pole users in the last four years has shown a steady increase and while more cedars have been used than all others combined, the proportion of cedars to the total is diminishing yearly: in 1907 the percentage of cedars to the total was 64.2 per cent.; in 1908, 67.7 per cent.; in 1909, 65.3 per cent. and in 1910, 62.8 per cent. Of the total number of poles used by electric railways and light and power companies in 1910, almost 30 per cent. was given some sort of preservative treatment. From the statistics we may draw the conclusion that with the increase in the cost of cedars, not to consider the exhaustion of the supply, we are finding it more economical to buy a pole of lower inherent life and to increase its period of usefulness by applying to it some preservative process.

Decay in timber consists in the destruction of the wood tissues by low forms of plant life, fungi, requiring heat and moisture for development; to prevent fungous growth in poles which are set in contact with the soil or with hot, damp air, the wood cells, as far as is possible, are rendered antiseptic by the application of various oils or chemical solutions.

There are a variety of preservative processes that have been used in an effort to stay the progress of decay, some of the best known being creosoting, kyanizing, burnetizing, copper sulphate solutions and tarring. Kyanizing consists in the use of mercuric chloride solutions and burnetizing, of zinc chloride solutions. There are also a number of preservative compounds on the market sold under various trade names, most of which have more or less of the characteristics of creosote; these have been used mainly in giving brush treatments and have, when applied with judgment, given results amply justifying their use. In general practice in this country the use of creosote has taken precedence over that of mineral salts, and it is considered the most efficient and economical, the longer service of creosoted poles offsetting the greater first cost of the treatment. Mineral salts show a tendency to leach out, although this characteristic is reduced to some extent when proper seasoning or aging follows the treatment. The use of mineral salts, especially copper sulphate, appears to be preferred in some parts of Europe.

The Government Forest Service has carried out extensive investigations of the various processes of timber preservation under widely varying conditions and with different species of timber, seeking the method that appeared to give a maximum efficiency with a minimum relative cost; the published reports to date favor coal-tar creosote as the preservative most nearly fulfilling these requirements for pole use, preferably applied by the two-bath open tank process, or the pressure tank method, depending upon local conditions.

There are three general methods of applying creosote treatment—the first usually termed the brush method, the second, the open tank, and the third, the pressure process; the latter two methods are not necessarily confined to the use of creosote as the preservative, being also employed with variations as necessary, for mineral salts.

The brush method consists in painting the butt of the pole, usually from a point about 2 ft. up to a point about 8 ft. up—though often only a narrow belt 1 ft. above and 1 ft. below the ground line is covered—with two coats of coal-tar creosote at about 200° to 220° F. As a general thing two coats applied twenty-four hours apart have been most satisfactory though in some cases only one, and in others three, coats have been tried. For the brush method several of the proprietary compounds, those containing a large percentage of the heavier oils, have given very good results, often better than the regular creosote as used for treatment in general.

Only poles that are well air seasoned should be treated and the work should not be carried on following after a rain storm, until the poles are thoroughly dried out again; it is also obvious that efficient work cannot very well be done in cold weather. Great care should be taken to remove all bits of the inner bark adhering to the surface of the pole as they will prevent the absorption of the preservative by the timber itself and besides that, they will drop off later, and so expose portions of a supposedly treated surface to the attack of decay. Another point to be especially noted in applying the brush treatment is that of carefully working the preservative into all season checks, scars, etc.

The brush method is the cheapest process for the application of creosote as a preservative, the work being easily carried on with the poles on skids in the yard. It involves only the use of a small quantity of the oil, and requires no investment for a treating plant.

The penetration obtained varies, of course, with the kind of timber, government experiments showing for two-coat applications on well-seasoned poles, 1/16 in. as an average for northern white cedar, 1/8 in. for western red cedar, 1/8 in. for western yellow pine and about 1/16 in. for chestnut; the northern cedar poles were treated in cold weather and the penetration is lower than it would probably have been under more favorable conditions; the penetration for chestnut given above is calculated from data giving the total absorption, the information not being given direct.

One of the large telegraph companies has adopted a method of pouring the oil over the surface of the pole from specially shaped vessels, instead of applying it with brushes, owing to the rapid destruction of brushes from the action of the oil. This method has the advantage of working or carrying the oil into the checks in better shape but is is doubtful if as good penetration can be secured in this manner and the leakage and spillage is very likely to be greater. The spraying method, which has been experimented with appears also to be subject to these disadvantages.

In general, we may say for the brush method of applying creosote or some of the kindred patented preservatives, that it is the simplest for use where only a small number of poles are to be treated. Butt treatment made in this way affords sufficient protection to warrant the expenditure as a good business policy. The weak point of this process is in its penetration being so slight that bruises or abrasions cut through the treated wood and lay bare the unprotected portions.

The Forest Service estimates that the increase in life of poles treated in this manner with creosote is from two to three years, and results attained in some localities tend to show that the addition to their serviceable life will be even higher than this, probably three to four years.

The cost of a two-coat brush treatment with creosote as given by the Forest Service is from 15 cents to 20 cents per pole in the East and from 20 cents to 30 cents in the West, based upon tests on 7-in. top, 30-ft. poles mainly, with the application extending from the 2-ft. to the 8-ft. points on the butt, a space of 6 ft. being covered. Where the oil is purchased in small quantities also, the cost per pole may exceed that given above; from 1/2 gallon to 1 gallon per pole will be required for the treatment of a 30-ft. pole as outlined, depending upon the kind of timber and its degree of seasoning.

However, where any great number of poles is to be treated, the use of either the open tank or the pressure method is advisable, the preferable one depending upon climatic conditions and timber species.

The open tank method of creosoting consists in subjecting the poles first to a hot bath of oil for from three to six hours and then to a cold one for from two to four hours; the temperature of the hot bath is maintained at about 215° to 220° F., and that of the cold one at about 110° to 150° F., the most suitable temperatures and the length of time required for the treatment varying greatly with the condition of the timber.

The theory of the open tank method is that in the hot bath the heat of the oil "boils out" the moisture and the air in the wood cells and in the walls of the wood cells, expanding such air and moisture as is not driven off, then, when the bath cools or the hot bath is replaced by a cold bath, this remaining air and moisture contracts and condenses and tends to produce a vacuum, drawing the preservative into the wood cells; the penetration is also assisted by capillary action. The main function of the hot bath therefore is to prepare the timber for absorption of the preservative, and the actual penetration of the oil takes place when the hot bath cools or a cold bath is introduced.

There are three general methods of applying the open tank process with reference to the way in which the two baths are handled; the temperature of the oil may be maintained at the "hot" temperature for the required number of hours and then the heating may be discontinued and the oil allowed to cool as it is, using the same batch of oil for both baths, or the poles may be moved from the hot-bath tank to another containing cool oil, or again, the hot bath may be drained off and the cool bath pumped in. The first method requires too much time for commercial treating, but can be used economically where a small company wishes to treat its own poles in small batches at intermittent periods; the second method involves too much handling of the poles with an accompanying loss of the preservative through dripping, but allows a lower investment in plant; the third is the most economical and satisfactory method where the plant can be properly arranged.

The depth of penetration obtained by the use of the open tank method varies of course with the timber, its species, rate of growing, seasoning, etc., the following being average results obtained in the Forest Service experiments: Chestnut 0.3 in., northern white cedar 0.5 in., western red cedar 0.8 in., western yellow pine 3.1 in., and lodgepole pine 1.0 in. In the open tank method it will be noted that the penetration is very much greater than with the brush method, but that it does not extend much beyond the depth of the sap-wood.

In the experimental use of the open tank method by the Forest Service, a shallow tank with a sloping bottom was first used, the angle of the slope and the depth of the tank being such that about 7 ft. or 8 ft. of the butts of the poles were submerged without having to raise the top of the poles more than a relatively small distance in the air; the tank was sunk into the ground so that the top was but a little above ground level, with arrangements made for a fire underneath. The poles were snaked with a team up alongside of the tank, then rolled into position over the edge, and the butts immersed by raising the tops with a pair of blocks and suspending them with a sling from a timber rack overhead. While this makes a cheap outfit where only a small number of poles is to be treated, the method involves the use of a large quantity of oil in proportion to the number of poles treated, it is slow and the loss of the oil by evaporation is high, owing to the broad surface exposed; as in this method the cold bath is obtained by allowing the hot bath to cool, usually only one charge a day can be treated.

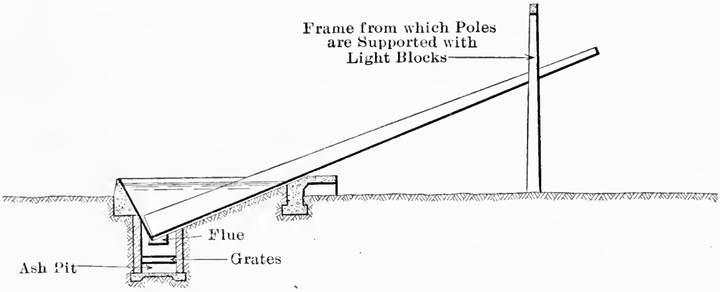


Fig. 37.—Small open tank treating plant.

As roughly outlined in Fig. 37, a plant of this type with a capacity of about twelve to fifteen 7-in. top, 40-ft. poles, butt-treated to a height of about 8 ft., can be built for about $600 to $700, not including rigging and tackle for handling the poles; and the cost of treating with creosote, a 40-ft. pole as described above, is estimated to be from $1.15 to $1.35, including fixed charges on plant and oil stock, labor, fuel and oil costs, but not any charges for holding poles for seasoning either before or after treatment.

In its experimental work the Government later on used an

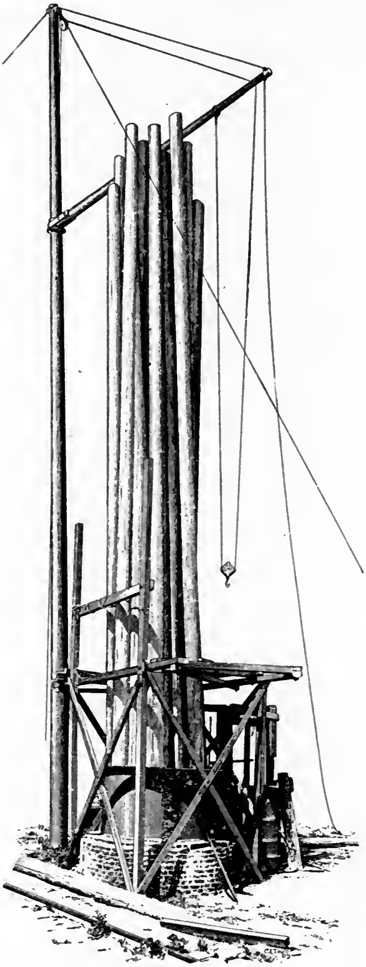


Fig. 38.—Open tank and ginpole used in experimental pole treatments.

upright cylindrical tank, 7 ft. in diameter and 8 ft. deep built of 1/4-in. plate, the creosote being heated by means of an oil burner located underneath the tank, and the poles being handled with a derrick; a cut of this tank is shown in Fig. 38. For commercial purposes, the Forest Service estimates that for from $1000 to $1200, a plant along similar lines, equipped with a steam boiler for heating and for operating a steam pump, electric hoist for derrick, steam pump for changing oil baths and an oil-storage tank of one car-load capacity, may be installed. The capacity of the treating tank is twenty poles per charge, based upon 8-in.

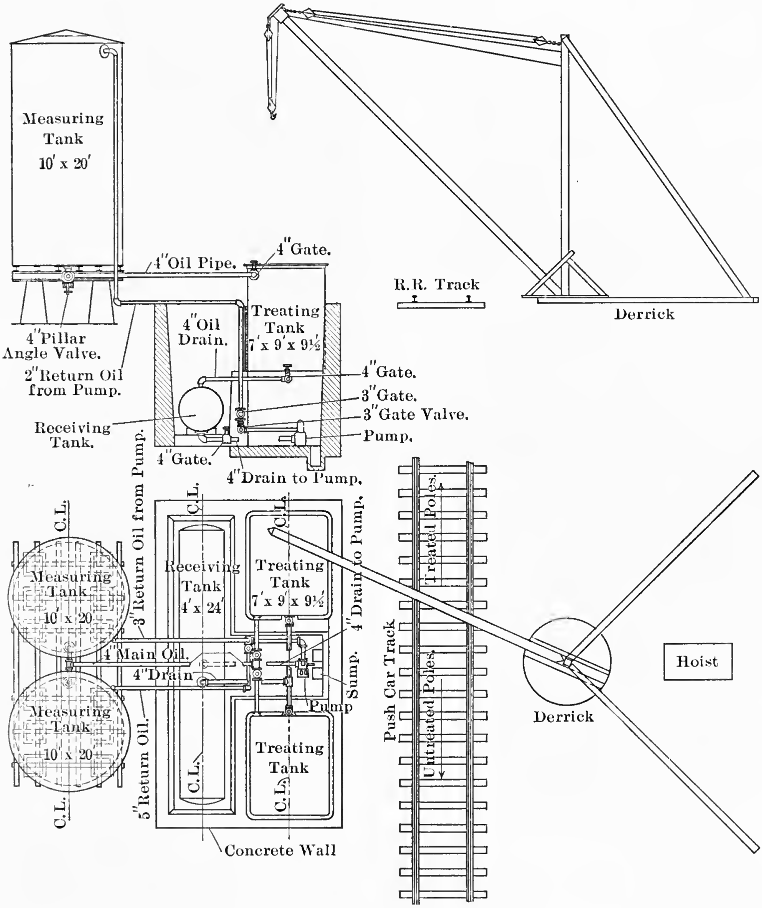


FIG. 39.—Commercial—open tank treating plant.

top, 40-ft. western red cedars and yellow pine poles and, being equipped for applying the cold bath by change of oil, two charges a day can be treated.

For economical operation as a commercial plant, however, the

Forest Service has designed the plant shown in Fig. 39. This plant is equipped with two treating tanks, each 7 ft. × 9 ft. × 9 1/2 ft. deep with an estimated capacity each of thirty 8-in. top, 40-ft. western cedar or yellow pine poles, or, figuring on two charges per tank a day, a total capacity of 120 poles per operating day. Arranged as it is, with two storage and measuring tanks and a receiving tank, the cost of the handling and the heating of the oil can be reduced to a minimum, as well as the time required for the cycle of operations; a 50-h.p. boiler will be required for power and heating.

The cost of this tank is estimated to be between $4000 and $5000 complete erected, and the cost of treatment per pole, including all labor, fuel and fixed charges of the plant, but not the preservative itself, is estimated at $0.422, basing the estimate upon a yearly plant output of 30,000 poles; the detail figures of this estimate are given below.

Labor per Diem			
1 Yard foreman	$4.00		
1 Plant engineer	4.00		
1 Stationary engineer	4.00		
2 Firemen at $2.50	5.00		
5 Laborers at $2.00	10.00		
Total		$27.00	
Labor charge per pole			$0.225
Fuel per Diem			
2 Tons of coal at $4.00	$8.00		
Total		$8.00	
Fuel charge per pole			$0.067
Maintenance per Annum			
Depreciation and repairs	$500.00		
Interest on investment in plant and oil	400.00		
Total		$900.00	
Maintenance charges per pole			$0.030
Interest charges per pole, seasoning			$0.100
Total treatment cost, not including preservative			$0.422

It will be noted that the labor charge is a little more than half of the total cost of treatment, and also that the wage scale is higher than will ordinarily obtain outside of large cities and in the Far West; furthermore, the duties of the plant engineer could be assumed by the stationary engineer in addition to his regular duties, and where the plant is operated in connection with a pole yard, as appears to be the assumption in the case above where no charge is noted for the loading and unloading of poles from cars, only part of the plant foreman's time need be given to the routine operation of the treating plant, so that it is probable that a substantial reduction in labor cost can be made. Also, if the pole yard be located so as to be able to purchase steam and use an electric hoist and a motor-driven pump, not only can a large reduction in cost be made, but a further decrease in labor charge can be attained as well.

Based upon the estimate of $0.422 or, as it is used in round numbers, 45 cents per pole for butt treatment, the total cost of applying the treatment to poles of different species is given below in Table II, which is the average of the results obtained in the government tests in conjunction with the estimates noted; the same is discussed in detail in *Forest Service Bulletin* No. 84.

TABLE II.—COST OF CREOSOTE BUTT TREATMENT BY OPEN TANK METHOD

Species	Size of pole		Amount of creosote applied		Cost of treatment		
	Top diam. in.	Length ft.	Lb. per cu. ft.	Lb. per pole	Preservative	Operation	Total cost
Chestnut	7	30	....	25	$0.30	$0.45	$0.75
Northern white cedar	7	30	....	50	.60	.45	1.05
Western yellow pine	8	40	6	37.5	.90	.45	1.35
Western yellow pine	8	40	10	62.5	1.45	.45	1.90
Western red cedar	8	40	6	39	.90	.45	1.35
Lodgepole pine	7	35	....	35	.80	.45	1.25

The increase in the life of pole resultant upon the use of creosote in this manner is as yet not very definitely established, but from all data available and taking into consideration the life of treated ties, the butt will very likely outlast the top, and so the ultimate life of the pole will be the serviceable life of its upper portion. The Forest Service believes that conservative estimates for the total useful life of butt-treated poles of the different species are as follows: Chestnut, twenty years; western cedar, twenty years; northern white cedar, twenty-two years; and in the drier western climate, pine, twenty years. These figures, especially in the case of northern white cedar, will very likely be exceeded, as many cases are known of such pole tops that have been in service for twenty-five to thirty years; furthermore, it is very probable that in untreated poles, the rot in the butt will infect the whole pole, and with this eliminated to a great extent with a treated butt, better life for the upper portion of the pole may be expected. The occurrence of infected soil and its effect on pole timber was clearly established in Europe, in experiments on the use of copper sulphate as a preservative for pine, spruce and larch poles; the effect of a decaying butt on the upper part of a pole is analogous to the above.

In localities in the South, where the upper portion of a pole decays almost as rapidly as the butt, the whole pole is subjected to treatment. The open tank method may be employed for this, as well as for butt treatment alone, using a horizontal cylindrical tank with doors at each end, through which the charge, loaded upon low trucks, is handled. However, as the open tank method is not adapted to the treatment of woods which are difficult to impregnate, or of unseasoned or partly seasoned poles, and furthermore is subject to a heavy loss of oil by volatilization from the exposed surface of the treating tank, and as no great uniformity in the absorption of the preservative can be attained, the pressure method is recommended where it is necessary to treat the entire pole. The cost of a low-pressure plant over that of an open tank plant for complete treatment is not great, and considering the better results obtained, is advisable as a business proposition.

In the application of the pressure treatment, we have the full cell and the partial cell methods of impregnating timber, the former consisting in general, in displacing the contents of the wood cells with the oil, and the latter, in coating the cell walls. In this country the full cell method has been used mostly for poles, but in some of the European countries, the partial cell treatment by the Reuping or similar processes, has been more favored. A good discussion of the various pressure processes employed in the treatment of timber with creosote is given in the *Engineering News* for Oct. 14, 1909, and only a general outline of the method, as used for the pressure treatment of pole timber by one of the largest telephone systems, will be given here.

The process used is what is known as the full cell method, and the first step consists in steaming or heating the poles in the treating vessel, which is a horizontal cylindrical tank like that for the treatment of the entire pole by the open tank method, except that it is arranged for sealing so as to stand a pressure of about 75 lb. per square inch. (For a description of the plant required for the application of the pressure treatment to poles, the reader is referred to *Forest Service Bulletin* No. 84.) If the poles be wet or green they are steamed for from five to eight hours, with the steam maintained at a pressure of from 12 lb. to 17 lb., and if partially seasoned, for from three to five hours at from 15 lb. to 20 lb. pressure; seasoned poles are not steamed but are subjected to heat at 150° F., maintained for from one to two hours by means of steam coils. Then, if the poles being treated are green, wet, or partially seasoned, a vacuum of at least 24 in. at sea level, and proportionate for higher elevations, is maintained for from one to two hours, with the temperature in the cylinder kept at a little above the boiling-point during the time the vacuum is on; if the poles be seasoned, the exhaustion part of the process is omitted. The final step in the treatment consists in filling the cylinder as rapidly as possible with creosote at a temperature of not less than 140° and not more than 175° F. and applying pressure sufficient to secure the absorption desired. The absorption is determined by measurement of the oil, which is withdrawn from the measuring tank, with due temperature corrections.

The only objection to this process is the liability of the creosote to exude and appear upon the surface of the pole, making necessary the protection of the pole butt from contact by passersby where the poles are located along the streets in a city; in transmission line work, of course, this objection will not often obtain, but nevertheless it is a question whether or not the application of a vacuum for a short period following the pressure stage of the treatment would not extract the surplus oil in the sap-wood without diminishing the value of the treatment or withdrawing any oil at all from the heart-wood, compromising slightly between the full cell and the partial cell processes.

The cost of treating the entire length of the pole with creosote, either by the open tank or the pressure methods, as estimated by the Forest Service is $1.10 for a 5-in. top, 25-ft. loblolly-pine pole and $2.45 for a 6-in. top, 35-ft. pole of the same species; the cost is based upon an absorption of 10 lb. per cubic foot.

As given in the *Electrical World* for June 1, 1911, the cost f.o.b. Birmingham, Ala., for southern pine poles with a 12-lb. creosote treatment of the entire pole is as follows:

30 ft. 8-in. tops	$ 6.95
30 ft. 10-in. tops	8.30
30 ft. 13-in. tops	11.35
35 ft. 8-in. tops	7.85
35 ft. 10-in. tops	9.90

The cost of these poles is about double that of the untreated poles, and this ratio appears to hold good generally over the country.

In the *Electrical World* for Sept. 30, 1911, a description is given of a machine that has been developed for the application of creosote under pressure to a narrow belt at the ground line, in this case for a space of 3 ft. The machine is portable, about 19 ft. long and 6 ft. wide, and is easily handled by one team; it is self-contained and includes a steam boiler, an air compressor and storage tank, a closed oil tank containing steam coils for heating the oil, an air-tight canvas band which encases the pole at the zone to be treated, and the necessary gearing and mechanism to pass this band about the pole and tighten it to resist pressure. The pole is rolled onto the machine and the canvas band brought around it, made fast and clamped at the ends; then the hot oil, by means of air pressure in the oil tank, is forced under this band, and the pressure maintained for from ten to fifteen minutes ordinarily; suitable arrangements are provided for catching drips and leakage and returning them to the oil tank. A 35-ft. northern cedar pole with a ten-minute treatment under 5 lb. pressure, showed a penetration of 3/16-in. with an absorption of about 1 gallon or approximately 8 1/2 lb. in the 3-ft. belt. The capacity of the machine is said to be fifty poles a day, and it will handle any diameter from 7 in. to 24 in.

While no attempt has been made to describe the various methods of preservation by the use of metallic salts, such as zinc chloride, mercuric chloride, copper sulphate, etc., the applications of which, however, do not differ greatly from the tank methods described for creosote, it will be interesting to note the value of the various methods in fulfilling their purposes. Below is given the average life of poles as determined from statistics of the

Telegraph Department of the German Government covering a period of more than fifty years. In comparing these figures due consideration must be given to the fact that mineral salt treatments are somewhat cheaper than creosote; also the cost of making replacements here and there along the length of a line enters into any comparisons of the relative efficiencies of preservatives with especial force when the poles are to be used for transmission line work.

The average life of poles treated as below is as follows:

Copper sulphate	11.7 years.
Zinc chloride	11.9 years.
Mercuric chloride	13.7 years.
Creosote (coal tar)	20.6 years.
Untreated	7.7 years.

The same statistics as noted in the report of the National Electric Light Association committee on the subject show that almost 90 per cent. of the poles observed were treated with copper sulphate, 5.5 per cent. with mercuric chloride and only about 3 per cent. with creosote.

While the matter of applying creosote treatment to timber appears on the surface to be a simple proposition, much trouble has been experienced in securing the results called for; there is so much opportunity for poor work, through inferior creosote, misjudgment in the application and deliberate attempts to defraud, that specifications should be closely drawn for every detail and provision made for competent inspection at the plant. Much variety is apparent in the specifications for the creosote itself, and many cases have been recorded, especially in the treatment of piling, where creosote with a high percentage of the lighter oils has volatilized in a very short time. From the investigation of the Forest Service it appears that the heavy oils, containing a high proportion of anthracene oil, remain in the timber indefinitely, the naphthalene oils for an extended period, but the tar acids, which have been credited as of great value, appear to work out of the timber in a short time; therefore it seems that the most effective creosote (dead oil of coal tar) is that which contains a fairly large proportion of high-boiling constituents. The specifications for creosote as called for by one of the large telephone companies, are given in the appendix.

In general in the United States, it is only within the past few years that much attention has been given to the possibilities of timber preservation as applied to poles; the abundant supply and the lower demand of a few years ago resulted in prices that, with the slight attention given to the subject, did not appear to display any opportunities for saving. The reversal of conditions brought the matter up sharply and, following the lead of the larger telegraph and telephone companies, power companies are now rapidly adopting some one of the various preservative methods.

Whether or not the use of a preservative will be warranted under any particular set of conditions, will have to be made a subject of study under the particular conditions obtaining; it is open to mathematical determination from a comparison of the annual costs of the different poles as outlined below. The pole timbers available in the particular locality, both untreated and with preservatives applied, are listed with their respective costs per pole in place in the line and with their estimated serviceable life in years; then, using this initial cost and the life in each case, and allowing the usual local interest chrge in the calculation, the annual cost of each of the different kinds of poles can be obtained, giving a direct comparison between them. It is very seldom that the application of a preservative will not show a saving.

For transmission line work as ordinarily constructed (as tall poles are not generally required as they are for city distribution lines), the standard height of pole adopted is usually 35 ft. or 40 ft. for spans up to say, 150 ft.; the top diameter for straight-line work is either 7 in. or 8 in. Horizontal grading of the line will call for some poles shorter and some longer than the standard, the minimum height of pole being naturally determined by the vertical clearance required under the conditions and the maximum by economy and safety, and for average 35-ft. and 40-ft. lines it is good policy to work with 60-ft. or 65-ft. poles as the maximum allowed, and at that, employing them only where a change in spacing, use of long span with heavier construction, etc., cannot be substituted.

In buying poles many companies consider the top diameter only, specifying for instance, "so many 7-in. top, 35-ft. cedar poles in accordance with Northwestern Cedarmen's Association Specifications," no mention being made of the butt; this method of purchasing is akin to calling for a 9-in. I-beam, 16 ft. long, without specifying its weight per foot. This "scientific" method of buying poles is not confined altogether to small companies either, and one often wonders if the computation of the strain on a pole is not so simple that engineers oftentimes prefer to guess at it, rather than stop to figure out what their special conditions call for. In general, for one or two circuits of from No. 6 to No. 1 B. & S. conductors, poles fulfilling the specifications given in Table III will be used; for lines carrying conductors of from No. 1 to No. 0000 in size, heavier ones as given in Table IV will be called for; it will be noted, however, that these figures are for average conditions and for average spans, about 125 ft. to 150 ft. for the lighter lines and from 110 ft.to 125 ft. for the heavier lines, and that local weather conditions such as heavy sleet and high winds, etc., must always be taken into consideration and allowed for.

TABLE III

Northern cedar			White chestnut			Juniper		
Length, ft.	Top, in.	6 ft. up from butt, in.	Length, ft.	Top, in.	6 ft. up from butt, in.	Length, ft.	Top, in.	6 ft. up from butt, in.
30	22	36	30	22	32	30	22	33
35	22	38	35	22	36	35	22	36
40	22	43	40	22	40	40	22	40
45	22	47	45	22	43	45	22	45
50	22	50	50	22	47	50	22	47
55	22	53	55	22	50	55	22	50
60	22	56	60	22	53	60	22	56

Top and butt measurements for poles are for circumferences.

TABLE IV

Northern cedar			White chestnut			Juniper		
Length, ft.	Top, in.	6 ft. up from butt, in.	Length, ft.	Top, in.	6 ft. up from butt, in.	Length, ft.	Top, in.	6 ft. up from butt, in.
30	25	41	30	25	36	30	25	36
35	25	44	35	25	40	35	25	40
40	25	48	40	25	43	40	25	44
45	25	51	45	25	47	45	25	48
50	25	54	50	25	50	50	25	51
55	25	57	55	25	53	55	25	53
60	25	60	60	25	56	60	25	57

The cost of wooden poles has varied considerably in the last few years, but the figures below give current prices for 1911–12, on northern and western cedar.

NORTHERN CEDAR F.O.B. MINNEAPOLIS, MINN.

30-ft. pole, circumference top, 22-in., butt, 6 ft. up, 36 in.	$4.60
35-ft. pole, circumference top, 22-in., butt, 6 ft. up, 38 in.	6.70
35-ft. pole, circumference top, 24-in., butt, 6 ft. up, 40 in.	6.95
40-ft. pole, circumference top, 22-in., butt, 6 ft. up, 43 in.	7.50
45-ft. pole, circumference top, 22-in., butt, 6 ft. up, 47 in.	10.25
50-ft. pole, circumference top, 22-in., butt, 6 ft. up, 50 in.	11.90
55-ft. pole, circumference top, 22-in., butt, 6 ft. up, 53 in.	15.10
60-ft. pole, circumference top, 22-in., butt, 6 ft. up, 56 in.	22.50
65-ft. pole, circumference top, 22-in., butt, 6 ft. up, 59 in.	29.00

WESTERN CEDAR POLES F.O.B. SPOKANE, WASH.

Note.—No butt measurements given; taper is approximately 1 in. to every 8 ft. of the length.

30-ft. pole, 6-in. top	$ 1.75
30-ft. pole, 7-in. top	2.50
30-ft. pole, 8-in. top	2.85
35-ft. pole, 6-in. top	2.75
35-ft. pole, 7-in. top	3.25
35-ft. pole, 8-in. top	3.75
40-ft. pole, 7-in. top	3.75
40-ft. pole, 8-in. top	4.25
45-ft. pole, 7-in. top	4.25
45-ft. pole, 8-in. top	5.00
50-ft. pole, 7-in. top	5.00
50-ft. pole, 8-in. top	5.50
55-ft. pole, 7-in. top	5.50
55-ft. pole, 8-in. top	6.00
60-ft. pole, 8-in. top	7.00
65-ft. pole, 8-in. top	8.50
70-ft. pole, 8-in. top	10.00

In western cedars, the 6-in. tops must measure 18½ in. in circumference, the 7-in. tops, 22 in., and the 8-in. tops, 25 in.

The loading of poles for shipment varies with different railroad companies; for instance, one road sets 24,000 lb. as the minimum load for poles up to and including 30-ft. lengths while for poles 35 ft. and more in length the minimum is 30,000 lb.; another road sets the minimum car-load at 30,000 lb. for poles up to 34 ft. in length and for all poles over that, 34,000 lb. Below in Table V are given shipping data for northern cedar poles as furnished by various pole companies.

TABLE V.—NORTHERN CEDAR, WEIGHTS AND CAR LOADING

Length, ft.	Circumference. Top, in.	Circumference. 6 ft. up from butt, in.	Weight of each, lb.	Number per load
30	22	36	450	55 to 95 single car.
30	24	41	550	45 to 80 single car.
35	22	38	600	50 to 70 single car.
35	24	44	730	40 to 60 single car.
40	22	43	800	40 to 55 single car.
40	24	48	975	30 to 45 single car.
45	22	47	1,000	60 to 70 double car.
45	24	51	1,150	52 to 58 double car.
50	22	50	1,250	48 to 55 double car.
50	24	54	1,350	44 to 48 double car.
55	22	53	1,550	39 to 42 double car.
55	24	57	1,750	34 to 37 double car.
60	22	56	2,000	30 to 33 double car.
65	22	59	2,700	23 to 25 double car.

In this Table V of shipping weights and loading for northern cedars, it will be noted that all lengths up to and including 65 ft. are listed; as a matter of fact, 60-ft. and 65-ft. poles are practically unobtainable and 8-in. tops in poles over 40 ft. in length are very hard to get; western cedar is still obtainable in any top and length commercially used, at prices in the Middle West that compete with northern cedar, but the length of time required for delivery is a great drawback and bars them from consideration in many cases.

Western cedar runs lighter than northern cedar for the same size top and length on account of its slimmer taper, averaging about 80 per cent. to 85 per cent. the weight of the northern; chestnut is heavy compared with cedar, running from 60 per cent. to 100 per cent. greater in weight for the same average sizes; cypress is also much heavier than cedar; juniper or southern white cedar is slightly heavier than the northern cedar; pine runs from 40 per cent. to 50 per cent. heavier than northern cedar.

The unloading of car-loads of poles is a simple matter; many companies continue the old practice of cutting off the stakes and letting them roll off, often at the expense of accidents and of cracked poles; the safer and better method is to use ropes fastened underneath the car on the unloading side, passed over the top of the poles and snubbed on the far side; then the stakes and wire may be cut and the poles snubbed down on to the skids in safety and under control. As noted earlier in the chapter, poles should be skidded in single layers if possible, laid out either on other poles blocked up off the ground, or on old sound timbers, and all decaying rubbish and all weeds that can grow up into contact with the poles or so as to impede the circulation of air underneath them should be removed. Where it is not practicable to store all the poles in single layers, the following courses should be laid out with poles in between them in the same manner as the skids at the bottom are arranged.

The cost per pole for unloading and skidding, varies naturally with the size and kind of pole and with the track conditions; the figures given below are based upon the handling of the average run of northern cedar poles of 7-in. top, with foreman at $3.50 to $4, linemen at $2.75 and groundmen at $1.75 to $2 a day.

Unloading 30-ft. poles costs from	5 to 8	cents each.
Unloading 35-ft. poles costs from	8 to 12	cents each.
Unloading 40-ft. poles costs from	12 to 15	cents each.
Unloading 45-ft. poles costs from	15 to 18	cents each.
Unloading 50-ft. poles costs from	20 to 25	cents each.
Unloading 55-ft. poles costs from	25 to 30	cents each.
Unloading 60-ft. poles costs from	30 to 35	cents each.

These figures are based upon average conditions met with in the construction of high-tension transmission lines in the Middle West; the laying of skid poles is included and poles are unloaded in single layers; where the unloading is done in restricted quarters, the cost will be higher. For poles other than cedar, the cost is closely proportional to the respective car loadings.

For the handling of poles for distribution, a little attention to systematizing the arrangement of the poles in the yards will not only cut down the cost of distribution but will allow greater progress in the work. In the first place the poles should be laid out so that teams will have easy access to them; then all poles of the same nominal length and diameter of top should be skidded together in separate piles; ordinarily there will probably be only two or three sizes in which any number of poles will have been ordered and the few extra length poles can be placed together. Where close attention is to be given to the grading of the line it will be well to go through the piles and measure up poles that run a little above or below the standard length, chalking the actual measurement on the butt of the pole, as it is apparent that these odd lengths can be used to very good advantage in grading. It is a good plan at least to mark all extra length poles, with the top diameter and length measurements, so that in loading up teams no time need be taken to check up dimensions and also that the chances of incorrect lengths being sent out, may be minimized.

In loading poles upon wagons for hauling out, a gin pole set facing the skidway a sufficient distance away so that the wagons can be driven in between it and the poles, is a great time-saver, and with teams at from $3.50 to $5 a day this is an important item. The gin pole is rigged with a pair of double blocks, reeved with a rope long enough to permit a long extension of the blocks and yet leave enough fall line to pass down through a snatch block hooked in a sling at the butt of the gin pole, so that a team can be used for the pulling; where the amount of work is considerable, a crab may be rigged to take the place of the team. Where the company is in possession of a gin wagon used for setting poles, this can be utilized very nicely for the loading and is somewhat better than a gin pole in that it can be moved about more readily.

In distributing poles or for that matter any line material, difficulty is often experienced in getting teamsters to take out full loads, and a competent and "non-bluffable" loading boss can materially influence the distribution cost. The loading boss or yard foreman will have as his guide in supervising the pole distribution, a copy of the data book described in Chapter II and illustrated in Fig. 2, giving pole heights, etc., corresponding to the numbered survey stakes, from which in connection with the map of the line and the routing instructions, he will be able to direct the teamsters as to the best roads, etc., to use. Teams should be sent out in threes or fours so that they can help each other out if bad spots in the road or steep hills be encountered. Poles as loaded at the yard will be numbered in accordance with their location, so that the only discretion that need be exercised on the part of teamsters is to unload their poles at the stakes bearing the same numbers; the care and accuracy shown in carrying this out will be checked by the general foreman in the field. It is a good policy to keep a record of the pole numbers hauled out by the various teamsters as oftentimes some of the company's poles will be found unloaded at some little distance from their proper location, especially if there be some hard work involved in the getting of them to their proper place and, in the absence of record, no one will be found to have hauled those particular poles.

The cost of handling and transporting a pole from the yard to its location out on the line varies in any one locality for a certain size pole, with the time of the year in which the work is carried on, upon the weather conditions prevailing and, of course, upon the average length of haul; in different localities it will, in addition to the above, vary with the character of the country traversed and the prevailing labor conditions.

For 9-in. top, 40-ft. and 50-ft. cypress hauled out in winter time on wagons, on account of poor sledding, with teams at $3.50 a day and an average haul of 4 to 4 1/2 miles, the cost was from 40 cents to 50 cents per pole; these poles were wet and heavy and consequently the number of poles to a load was small, though the roads were generally good and fairly level; also their weight combined with large flaring butts made them awkward to unload at their destination. The cost given does not include any charge for general superintendence or general expense, but does include all yard labor.

For a line in Minnesota using 7-in. top, 35-ft. northern cedar poles, the cost for distribution of the poles was about 25 cents each; the average length of haul was about 3 miles and the work was carried on in the early fall over fair country roads through rolling country; teams cost $4 a day; this line was built along the highway for most of the way and the poles were dry and easily handled. The figure includes all yard and team labor but no charge for general superintendence or general expense.

In the West where lines are built through rough mountainous country and through unsettled regions in many cases, the cost of distributing the line material is very high and the cost per pole, in one instance under such conditions, was estimated by the company in the absence of segregated costs, at 90 cents for 7-in. top, 35-ft. western cedars; the average haul was about 8 miles to 9 miles.

Another western operating company which recently built about 85 miles of pole line using 8-in. top, 45-ft. western cedars in 300-ft. spans, gives the average cost per pole for hauling at $1.50; this appears to include the distribution of cross-arms and hardware and allowing the high figure of 20 cents per pole for this, the distribution cost per pole for the poles alone was about $1.30 each.

The framing of poles for transmission line work is in most cases done in the field, though sometimes the work is carried on in the pole yard. The framing of 9-in. top, 40-ft. and 50-ft. cypress poles, including roofing, cutting two gains for 5-in. × 7-in. arms boring two 3/4-in. holes, averaged about 45 cents, three men averaging about twenty-two poles a day, working in the yards. On a job using 7-in. top, 35-ft. northern cedars, three men, one at $2.50 and two at $2 for a ten-hour day, framed and attached a patent steel cross-arm for single-circuit 60,000-volt construction to an average of about thirty poles a day, or at a cost of about 22 cents each, not including proportion of foreman's time, general superintendence or expense; this construction required no sawing except at the roof, the rest being only facing-off with a hand-ax. The cost of framing for a line of 8-in. top, 45-ft. and 50-ft. western cedars, with two gains for 4-in. × 5-in. arms and one for a telephone arm below is given at $1 per pole; this work was done under unfavorable conditions with high-priced labor and includes the attachment of the arms. Where the framing is done in the field as is usually the case, a saving over the system of carrying this on in the pole yard is effected, in that the work of cutting gains, boring, etc., is merged with that of attaching the arms and braces; also it is more convenient where the grading of the line may call for the sawing off of poles. In general for 7-in. and 8-in. top cedar poles 35 ft. to 40-ft. long, the cost of roofing will run about 10 cents and the cutting of gains about 10 cents to 15 cents per gain, based upon average arms such as 4 in. × 5 in. and larger, as will be used in high-tension work. The cost of fitting cross-arms in the foregoing cases will run from 8 cents to 15 cents when the work is done on the ground, and from 15 cents to 25 cents when done in the air after setting; the great variation is due to the fact that the cost per arm where only one arm per pole is carried is higher than where several arms are to be fitted with one climb or one move; average length of arm assumed at about 6 ft.

The cost of digging holes for setting poles is even more variable than that of most of the other steps in the work, depending upon the character of the soil, the time of the year, the local weather conditions and naturally upon the size and length of the poles. The depths to which poles should be set in average soil are given in Table VI, which represents the general practice in America; where the setting is in solid rock, the depth of holes is usually 2 ft. less than the tabular figures and for corner poles in average soil, 1 ft. more; for soft ground the depth is increased about 1 ft. In digging on hillsides the measurement is taken from the low side of the hole and in the case of steep slopes, the depth of set is increased as may be deemed necessary.

TABLE VI.—DEPTH OF SETTING FOR WOODEN POLES IN AVERAGE GROUND

30-ft. pole	set 5 ft.
35-ft. pole	set 5½ ft.
40-ft. pole	set 6 ft.
45-ft. pole	set 6½ ft.
50-ft. pole	set 7 ft.
55-ft. pole	set 7½ ft.
60-ft. pole	set 8 ft.
65-ft. pole	set 8½ ft.
70-ft. pole	set 9 ft.

Holes should be dug so as to leave about a 3-in. tamping space all around the pole, and should be cut full to the bottom so as to allow of easy lining in and tamping.

Holes for the greater part of a line of 9-in. top, 40-ft. cypress poles with a standard setting of 6 ft. were dug at the average rate of about eight holes per nine-hour day per man with men at $1.75 per diem; with board allowance and part time of foreman and team proportionately charged, the cost per pole was about 35 cents. The soil was sandy and damp enough to hold up well so that the digging was easy, though the flaring butts of the poles required holes of large diameter; in cases where water was encountered as in bottom land, the cost per hole varied from 75 cents to $2 each. The latter figure is for holes where much tough blue clay and quicksand were encountered and where, with no sand-pump available, the sand and water had to be scooped out with pails and sand barrels. These figures include all labor and field expense but not general superintendence, locating, or general expense.

In digging for a line of 7-in. top, 35-ft. northern cedars in medium clay ground built in early fall, one man working ten hours would dig from three to five holes 5 1/2 ft. in depth; diggers were paid $2 a day and the average cost per hole, including foreman and team time, was about 62 cents.

In another case where the work was carried on under high-priced labor conditions in isolated regions, the cost of digging holes for a line of 8-in. top, 45-ft. and 50-ft. poles is given at $2.60; much rock was encountered and the poles are set in about 300-ft. spans.

In *Contracting Engineering* for Feb. 5, 1908, the cost of digging for a line of 32-ft. poles is given as about $1 per pole; this involved only a short piece of line, with few men, the charge being foreman 23 cents and groundmen 75 cents or a total of $0.98 per hole actual; the soil was a red sandy clay and judging from the figures one man must have dug only an average of two holes per diem, as the wage scale is $1.50 a day with no reference to board allowance. In the same journal for March 4, 1908, an interesting summary of the digging cost for about 600 trolley poles is given; the work was carried on from February to July with diggers at $1.50 and a foreman at $3 per ten-hour day, and for 320 holes averaging about 6 3/4 ft. deep and 3 1/2 ft. in diameter, the cost was $1.33 each; sixty-four holes 6 ft. deep and about 2 ft. in diameter cost 79 cents each; the first lot of holes were dug in cinder and slag fill where much trouble was experienced from caving-in, while the last sixty-four mentioned were dug in original ground.

In *Contracting-Engineering* for May 27, 1908, figures are given for a small city construction job where the cost of digging 5 1/2-ft. holes is noted as averaging $0.47½ each.

Digging in wet ground where muck and quicksand are encountered, and blasting pole-holes in rock, are expensive operations. In the first case the holes will have to be sheathed in some way, either by the use of ordinary stave packing barrels, horizontal plank cribbing, vertical plank shoring, or steel plate sand barrels. The first three methods are the same as may be used in any excavation work. The sand barrel is a cylinder of about 1/4-in. boiler plate, made of the length and diameter called for by the maximum size of pole to be set in the particular case, and constructed in halves split vertically and arranged with bands by means of which the two halves are pinned together in the manner of a hinge, the bands also acting to stiffen the cylinder; these are driven down as the excavation proceeds and where much wet digging, especially with quicksand, is encountered, they will pay for themselves. After raising the pole, the pins of the barrel are drawn, and by means of a pair of blocks rigged from the pole and hooked into an eye on the barrel, each half is pulled out separately. For isolated wet holes, a couple of ordinary barrels will answer, and 2-in. × 6-in. or 2-in. × 8-in. shoring is also very satisfactory, especially where the poles are set with a gin wagon.

Rock holes are the most expensive of all excavation for pole setting, the average for 35-ft. and 40-ft. poles running from $2.50 to $3.50 per hole; where very hard rock is encountered in isolated stretches, the cost may exceed the maximum figure; in one case where holes were blasted in hard trap rock, the cost for a 40-ft. line ran from $4 to $4.50 each; two men averaged one-half day per hole and the cost of drill-sharpening was about $1 per hole.

In ordinary digging work each member of the crew should be equipped with a D-handle No. 2 round-point shovel, a long-handled (about 8 ft.) No. 2 round-point, and a spoon or scoop, with about an 8-ft. handle, in addition to which digging-bars and pick-axes are provided as required; usually in ordinary digging a pick-axe and a digging-bar to each two men will be all that is needed. Under general conditions a man will line out his hole around the stake and work down 2 ft., 3 ft., or even 4 ft., as far as the diameter of the hole will permit, with the short-handled No. 2, and will not have to use the spoon at all in this distance; then for the remainder of the hole, the long-handled shovel and the spoon are employed in the usual manner. Where poles with a large butt diameter are to be set, the holes can often be dug for the entire distance with a short-handled shovel, the digger often preferring to get into the hole and do it this way rather than to use a spoon, and it is a good policy to make this manner of digging a rule, where conditions will allow its use, as it is better and more rapid.

In setting poles, or to be more exact, in raising them, the usual method employed is piking, though on long lines through fairly level country, and especially along highways, a gin-wagon will often do the work more cheaply. The number of men required for piking-in average cedar poles is given in Table VII as follows:

TABLE VII.—CREWS REQUIRED FOR RAISING POLES WITH PIKES

Pole length 30 ft., 4 pikers, 1 jinny-man, 1 man at butt.
Pole length 35 ft., 5 pikers, 1 jinny-man, 1 man at butt.
Pole length 40 ft., 6 pikers, 1 jinny-man, 1 man at butt.
Pole length 45 ft., 8 pikers, 1 jinny-man, 1 man at butt.
Pole length 50 ft., 8 pikers, 1 jinny-man, 1 man at butt.
Pole length 55 ft., 9 pikers, 1 jinny-man, 2 men at butt.
Pole length 60 ft., 10 pikers, 1 jinny-man, 2 men at butt.

While data are given for poles up to 60 ft. it is not very often that lines, using poles over 40 ft. as standard, employ piking to raise their poles. The number of men given in Table VI is that which has been found to give the most economical results, though a man more or less in the crew will frequently be encountered; the figures given represent general practice, based upon cedar poles and good pikers; as piking is heavy work, the men should be selected with this point in mind and the cost per pole for raising will often be reflected by the judgment exercised in selecting the crew. In piking, the raising and setting costs of a pole are merged and costs are usually given for the whole operation; in gin-wagon work, the two steps can be more readily separated.

The cost of raising and setting 7-in. top, 35-ft. northern cedars for a typical line in the Middle West, built in late summer and early fall, averaged about 39 cents per pole; the crew of five pikers at $2, a jinnyman at $2, a buttman at $2 and a foreman at $4 per ten-hour day, working at setting about three-quarters of the time and helping the diggers the rest of the day, erected on an average thirty-five poles per day; these poles were set with cross-arms on and the pikers were ordinary unskilled laborers; the soil was a sandy clay and all holes were trenched about 1 ft.

In *Engineering-Contracting* for Feb. 5, 1908, figures are given for the building of a short line (74 poles set) of 30-ft. to 33-ft. chestnut poles with 5-in. to 9-in. tops; seven groundmen at $1.50, one lineman at $2.50, and a foreman at $3 per ten-hour day were used in raising and setting, and the cost per pole for the same was 76 cents, distributed as follows: Foreman 14 cents, groundmen, 50 cents, and lineman 12 cents, no charge for teaming being noted. This cost is somewhat higher than usual, probably due to the small amount of work done.

A 3-mile stretch of heavy 9-in. top, 40-ft. cypress poles set in 125-ft. spans in sandy loam was piked in at an average cost of about 95 cents each; these poles were set without cross-arms, and the work was carried on in early springtime.

Under average conditions such as will be encountered in work involving 25 miles to 50 miles of line, in the Middle West with sandy loam, light clay, or black soil, 7-in. top, 35-ft. cedar poles can be set with pikes at an average cost for labor of 45 cents; 8-in. top, 35-ft., at 50 cents, 7-in. top, 40-ft., at 50 cents; 8-in. top, 40-ft., at 55 cents, and 7-in. top, 45-ft. poles at about 65 cents. These figures are based upon results obtained in practice with men at $2 per ten-hour day and foreman at $3.50 to $4 per diem, for work through fairly well-settled country, where the men can be boarded not more than a mile or two, on an average, from the location of the work. For heavy clay soil the costs will be about 10 to 30 per cent. higher, and if the construction work be carried on in the winter time or the early spring months, the average cost per pole will be from 10 to 25 per cent. greater, depending upon the latitude.

Where the line is built on or closely parallel to a highway, or through fairly level or rolling country without a great number of fences, and in construction where tall heavy poles are employed, such as 8-in. top, 45-ft. or 50-ft. poles in the cedars, and shorter in the case of cypress and chestnut, a gin wagon is usually the more economical method of erecting poles.

A gin wagon as usually built, consists of a 6-in. top, 30-ft. to 35-ft. cedar pole, mounted upon a trunnion on the bed of a stone wagon or on a frame arranged to be mounted on the running gear of an ordinary heavy lumber or farm wagon, in place of the box, one of the latter type being shown in Fig. 40; where the amount of work under construction warrants the purchase of a complete outfit, wagon and all, a stone wagon or similar rig with underslung bed is preferable; the gin pole itself is arranged for raising and lowering with blocks or a small crab, and space is left at the head end for stowing ballast; guy ropes are also usually arranged for in cases where the lift may be heavier than will be taken care of by the ballast. The use of a gasoline engine-driven crab has been suggested for the raising of the poles, but this is generally done by unhooking the hauling team and using them for that purpose.

In Fig. 41, *a, b, c, d,* is illustrated a patented gin wagon that seems to embody most of the features desirable in a gin wagon; it will be noted that it is arranged with an A-frame mast, if it may be called that, provided with extension legs, so that most of the thrust is transmitted to the ground directly instead of through the wheels, securing better leverage and at the same time ensuring much greater transverse stability than in an ordinary wagon; this apparatus is arranged to fit on any ordinary farm or work wagon, and is designed so that it may be readily dismantled for shipment from place to place. This outfit is quoted at about $175 however, whereas the one shown in Fig. 40 cost only about $60.

Cost data for raising poles with a gin wagon are not very abundant; many companies that employ them not having segregated their costs, or having let the work by contract, know only the total costs. A line of about 20 miles of 9-in. top, 40-ft. cypress poles, set partly on public highways and partly among line fences in well-settled rolling country, was erected with a gin wagon at an average of forty poles a day, with a maximum of eighty-seven in one nine-hour day, the latter record being made on a stretch where the line was built at the side of a straight level road; a gin wagon with a 28-ft. gin mounted on a

Fig. 40.—Erecting poles with gin wagon.

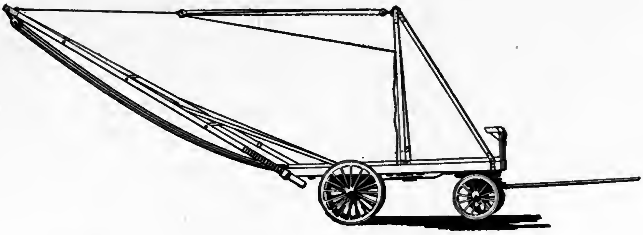


FIG. 41*a*.—Gin wagon.

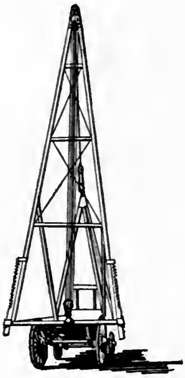


FIG. 41*b*.

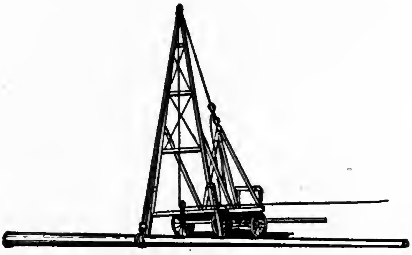


FIG. 41*c*.

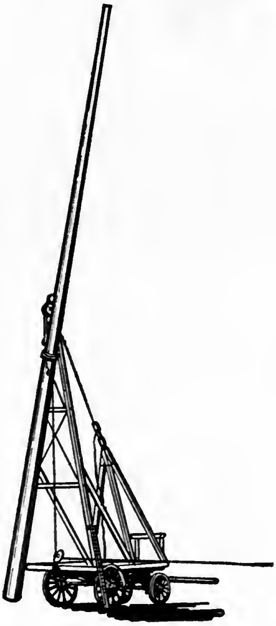


FIG. 41*d*.

frame set on the running gear of an ordinary wagon was used. With this rig, which required guys, four groundmen at $2 a day, one lineman at $2.75, besides team and teamster, who also provided the running gear of the wagon, at $4 a day, the labor cost per pole erected but not set, on a basis of forty poles per day, was 37 cents.

With the Matthews pole erector, shown in Fig. 41, the manufacturers claim that an average of from forty to fifty poles, any length up to 50 ft. can be set in one day, with a crew of two linemen and a teamster; in a test cited, the wagon was stationed 125 ft. away from a hole with the rig headed away from it, and the gin wagon was brought into place and the pole dropped into the hole in six minutes. From the writer's experience with gin-wagon setting, where the conditions are such that this method of raising poles would be adopted, an average of forty to fifty poles a day can be maintained with a wagon of a type similar to the Matthews; the saving of an erection wagon varies with the amount of labor required to handle it, and the design that will be the most economical in this regard will generally be the most efficient.

Assuming an average of forty-five poles, say 8-in. top, 40-ft. cedars, set per day with a gin wagon requiring a crew of two linemen at $2.75 a day with team and teamster at $4, the labor cost per pole for raising will be about 21 cents; the cost per pole for setting in sand, sandy loam, or black soil, with a crew consisting of a foreman at $3.50 and five groundmen at $2 a day, will be about 30 cents, making a total labor cost of 51 cents for the poles raised and set. With heavy poles of greater length, the saving over piking will be more marked.

In the *Electrical World* for Aug. 1, 1908, figures are given for the raising of a line of 45-ft. poles with a gin wagon, a maximum of eighty-six poles being raised in a ten-hour day with a crew of one groundman and the teamster handling the wagon; it must be assumed in this case that the groundman was able to remove the sling from the pole by climbing the gin pole, as this part of the work is where a lineman is usually employed. The wagon used in this work was very good, amounting practically to a stiff-leg derrick erected on an underslung wagon-bed; it was long-coupled, using a long bed, and carried ten bags of gravel for ballast, this being used in place of the ordinary pig iron, etc., for ease in shifting when it was desired to handle the load from the side of the wagon.

In general, as has been noted before, the gin wagon can show great economy over piking where the poles are tall and heavy and merits greater use than it is given in general line construction work; even where light poles, such as 7-in. top, 35-ft. poles are used, a saving can often be effected where conditions are such that the wagon can be hauled along easily and without too much delay on account of fences, steep slopes, detours in crossing creeks, ravines, etc.; along roads, where too many trees are not encountered, there is no reason why a good gin-wagon outfit cannot average sixty poles raised in a ten-hour day, especially if a bonus system of payment be put into effect.

In setting poles, that is, the straightening-up, lining-in and back-filling work after the pole has been raised, four groundmen with about 16-ft. pikes, one groundman with cant-hooks on the butt and the foreman, are all that will be required for an ordinary 35-ft. or 40-ft. line; where taller poles are to be set, one or two extra men will be required; where it is desired to speed up the setting work, this gang after lining-in the pole and filling and tamping in enough dirt to hold it solid, can leave it for a crew of four men to complete. In lining-in poles, an experienced eye in directing this part of the work is essential to give the line the trim, clean appearance that always goes hand in hand with good workmanship; a line that may be set with the poles a trifle out of line will have the tops pulled over as soon as the wire is strung and will not only present an untidy appearance, but will start out under a handicap of unbalanced strains. Again, where the alignment of the line is good but where the tamping has been poorly done, the line is liable to be raked over by a heavy wind and likewise appear in a poor light; the old rule of using "one lazy shoveler to three good tampers" is still good.

In all line construction, extraordinary conditions are met with which must have special treatment, such as right-angle turns, branch taps, transpositions, etc.; this matter is discussed in detail in Chapter VIII, but mention may be made here with particular reference to general considerations that should be taken into account in deciding upon any special construction.

As a rule, any special work that may be required in wooden pole work can be built more economically of wood than of steel;

the reason is that in the first place the pound cost and transportation charges on any special structures of which only a few are required, will be exceedingly high, and in the second place the work of assembling and erecting them will devolve, in all probability, upon a crew unaccustomed to this class of work, and the ultimate cost of the structures in place will usually greatly exceed that of wooden structures. In the case of long river crossings, etc., where much special material for even the wooden structures would have to be ordered, steel towers may be more economical, and there often will arise cases where only steel structures can be used. The point to be emphasized, however, is this: Wherever it is possible to make use of the standard line material, such as poles, cross-arms, pins, etc., at about the same cost as the material for steel or concrete construction, the labor cost of erecting wooden structures will, as a general thing, be so much less than that of erecting isolated steel towers that the lower first cost, in view of the remainder of the construction being of wood, will offset the advantages of permanency and reliability possessed by the steel construction.

CHAPTER V

STEEL POLE CONSTRUCTION

With the great increase in transmission line building in the past few years, there has been an insistent demand for supports of greater permanency, of lesser liability to damage or destruction, and of greater possibilities for economy in the higher voltages than wooden poles, but which still would not require the extensive field work nor demand the right-of-way space of structural towers. For the long, heavy, extra high-voltage lines of great capacity, where heavy expenditures for private right-of-way, private patrol roads, etc., may be warranted by the general magnitude of the whole undertaking, the steel tower line has the field practically to itself, but for lines of medium capacity operating under potentials up to 50,000 or 60,000 volts, poles of either steel or reinforced concrete in 250-ft. to 350-ft. spans, will show great possibilities and, when due consideration is given to the comparative right-of-way costs, field expenses and ultimate life, will usually be found more economical than the light tower construction that would be required for the same conditions.

In the line of steel poles, we have various structural designs of the latticed girder type, tubular poles and several patented designs, such as the diamond and the tripartite, previously described in Chapter III. Of these four general types, the tubular and the diamond have each points of weakness in that they do not have the weight efficiency of a structural pole, and that they are totally enclosed, making it impossible to maintain the protection of the inner surfaces; to the best knowledge of the writer there are no regular transmission lines utilizing either of these types in the United States, and they will not be discussed further as a factor in steel pole construction for high-tension lines; in Europe, and also somewhat in Canada, the tubular pole has been used to some extent in transmission work, but as a general thing its employment has been limited to trolley construction.

What little steel pole line has been built in this country has employed either a three- or a four-post (in most cases the latter) angle-iron latticed riveted structure, or a pole of the tripartite design. Though there have been many instances where short stretches of line have been built in connection with other types of construction, as at city ends of transmission lines, etc., the development of the possibilities of steel pole construction in America is far behind that in Europe.

The best-known installations of latticed pole construction in this country are the lines of the Sanitary District of Chicago, the New York Central & Hudson River Railroad and the Long Island Railroad.

The Sanitary District poles are 60 ft. long overall, set 6 ft. deep in concrete, and carry two three-phase circuits of nineteen-strand aluminum cable equivalent to No. 000 copper, operating at 44,000 volts, on standard pin-type insulators; as shown in Fig. 42, the poles are arranged with two arms, a top arm 12 ft. long and a bottom arm 18 ft. long, for two circuits normally, but recently another circuit was added by the use of two suspension-type insulators swung one on each side of the bottom arm, midway between the original conductor supports, in connection with a pin-type insulator attached at the peak of the pole in place of the ground wire clamp. At the top these poles are 14 in. square and at the base 42 in. on a side; they weigh complete about 4000 lb. and are designed to carry a load of 5000 lb. applied at the top; normally they are spaced about 350 ft. apart. As will be noted they are of angle-iron construction, riveted and assembled with two field splices, making the sections about 20 ft. long; the structures are galvanized throughout.

The New York Central poles, illustrated in Fig. 43, are built with the top straight for about 7 1/2 ft. and then the corner posts follow a parabolic curve from that point to the base; the standard height of the pole above the concrete base is 29 ft. 1 in. As given by the *Engineering News* for June 14, 1906, they are built up of four 3-in.×3-in.×5/16-in. angles, single laced with 2 1/4-in.×1 1/2-in.×3/16-in. angles and weigh about 1340 lb. each; the standard pole measures 14 in. square at the top and 2 ft. 10 in. at the base; wooden arms are used and two three-phase 11,000-volt circuits are carried; the standard spacing on tangent is 150 ft.

These poles were not galvanized, but in assembling them in

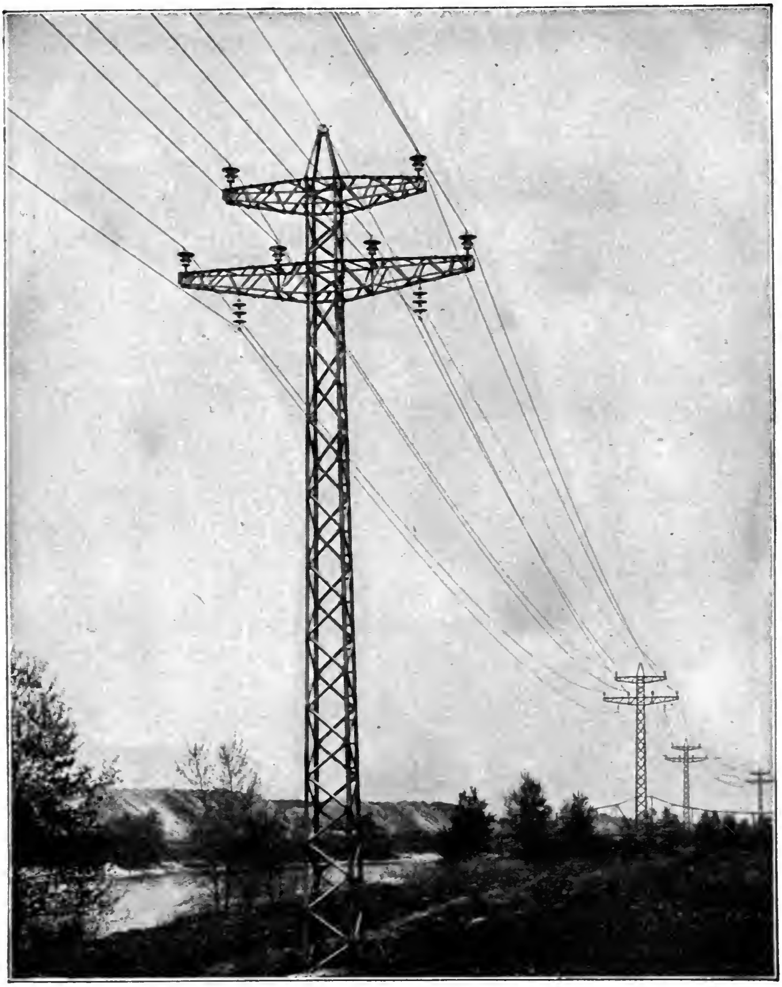


FIG. 42.—Sanitary district—steel pole construction.

the shops, all contact surfaces were painted with New York Central red lead paint, and upon completion of the shopwork they were given one coat of the same; in the field they were given two heavy coats of black asphaltum varnish.

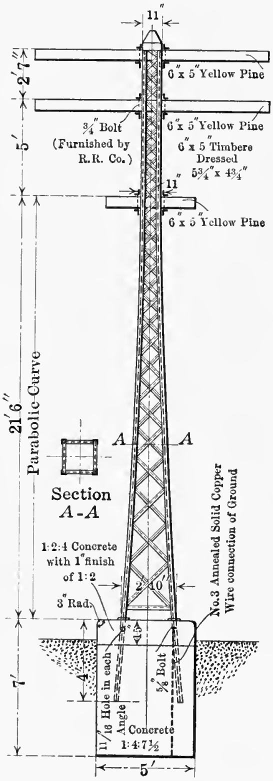


Fig. 43.—New York Central pole.

The Long Island Railroad poles, shown in Fig. 44, are somewhat similar in design to those of the New York Central, excepting that the corner posts, or main members, are not curved and the top is rectangular instead of square; the top of this design measures 6 in. × 11 in. and the base about 3 ft. 4 in. square; the poles are about 39 ft. 4 in. in height above the base to which they are bolted, which is of concrete about 4 1/2 ft. to 5 ft. square and 8 ft. deep. As given by the *Street Railway Journal* for June 9, 1906, these poles are designed to carry twenty-four 250,000 circ. mil cables at the top, with eight 500,000 circ. mil feeders lower down, in 150-ft. spans on tangent; in making the calculations the maximum wind pressure was assumed as 13.5 lb. per square foot of the projected area of the cable. The standard poles were built with 3-in. × 3-in. × 3/8-in. angles for the main members, and for angles, and other heavy work, poles with 3-in. × 3-in.- × 7/16-in. posts were used; the poles were single laced with angles and were painted instead of galvanized.

In this design as in that of the New York Central, wooden arms were used. They were attached to the poles by passing them through the pole and clamping them down on two angles, one on each side of the pole, by means of U-bolts over the top; with the clamp pin designed by W. N. Smith for this work, in connection with this method of attaching cross-arms, no boring of the arms at all was required.

In construction utilizing the tripartite steel pole, the lines of the United States Reclamation Service in connection with the

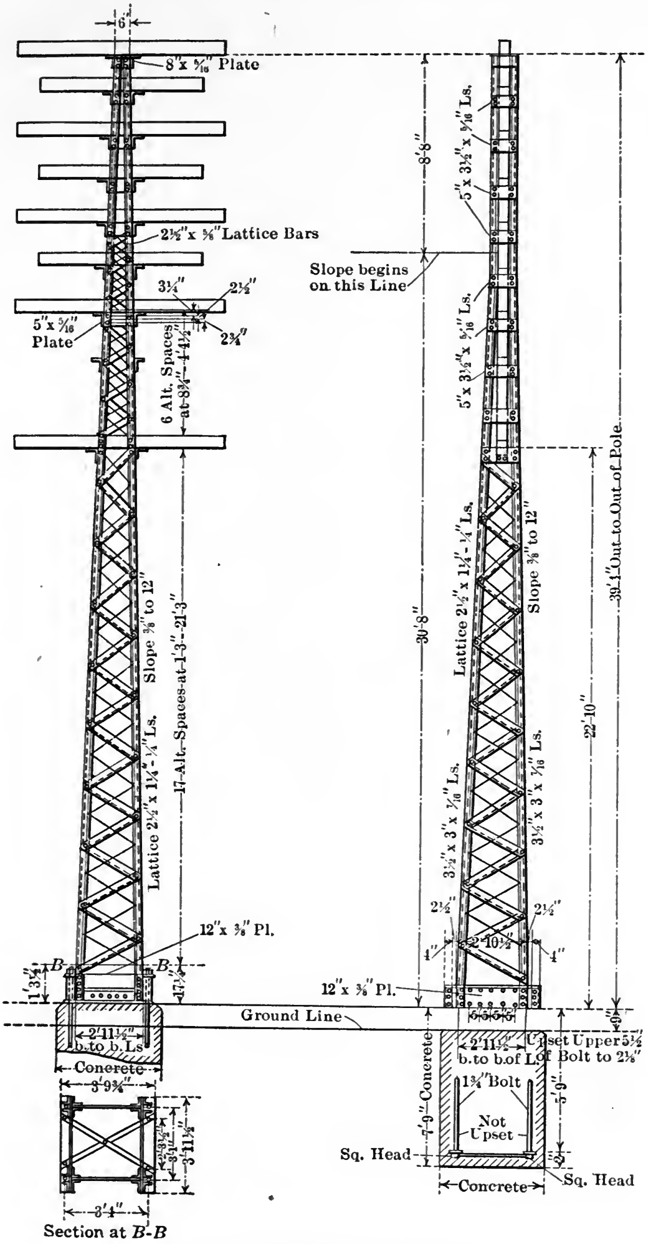


Fig. 44.—Long Island R. R. poles.

distribution of power from the Roosevelt Dam development in Arizona, and the Pueblo line of the Anglo-Mexican Hydro-Electric Company of Mexico City, Mexico, are typical.

The poles used in the original Reclamation Service work came in three lengths with three different weights in each length, the data on the various designs being as follows:

Length, ft.	Weight, lb.	Diameter top, in.	Diameter butt, in.
40	1100	7.5	18.5
40	1183	7.5	22.0
40	1230	7.5	28.0
45	1230	7.5	18.5
45	1310	7.5	23.0
45	1400	7.5	30.0
50	1370	7.5	19.0
50	1520	7.5	23.0
50	1680	7.5	32.5

These weights are for the bare pole; the cross-arming for the single circuit construction weighed 130 lb. in addition to the above, and the same for carrying a double circuit, 450 lb. The poles are all built up of a special U-section bar, 2 13/32 in. wide ×2 3/16 in. deep×3/8 in. thick, weighing 6.4 lb. per lineal foot, arranged in the form of an equilateral triangle and bound together with malleable iron collars and spreaders. The double-circuit line, shown in Fig. 45, built with the above-mentioned poles set in concrete to a depth of 4 ft., 4 1/2 ft. and 5 ft. respectively for the 40-ft., 45-ft. and 50-ft. poles, carries the two three-phase circuits of 83,000 cir. mil copper cable in spans of from 300 ft. to 400 ft. The cross-arm construction of this installation is unusual in that U-bars, 1/4 in. thick, are used instead of the ordinary angle-iron section. This is one of the largest individual installations of steel poles in the United States, a total of 2700 poles being reported to have been installed in connection with same, in both low- and high-tension work.

The line of the Anglo-Mexican Hydro-Electric Company was built with poles 43 ft. 7 in. long from cap to butt, and provided with a ground-wire support, formed by the prolongation of one of the main U-members, extending about 6 ft. above the top of the pole; the diameter of the top of this design is 7 1/2 in. and

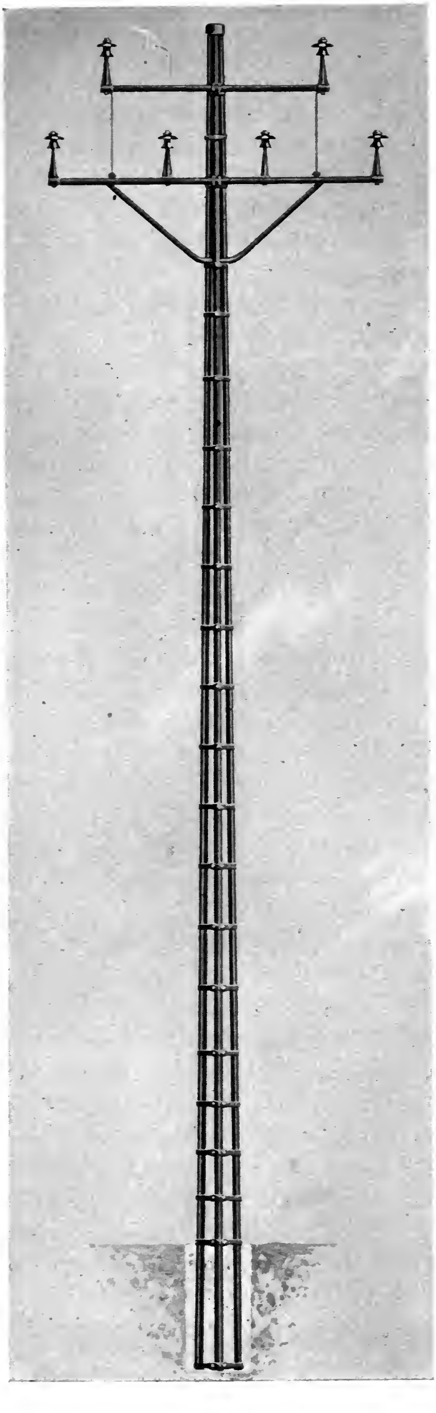


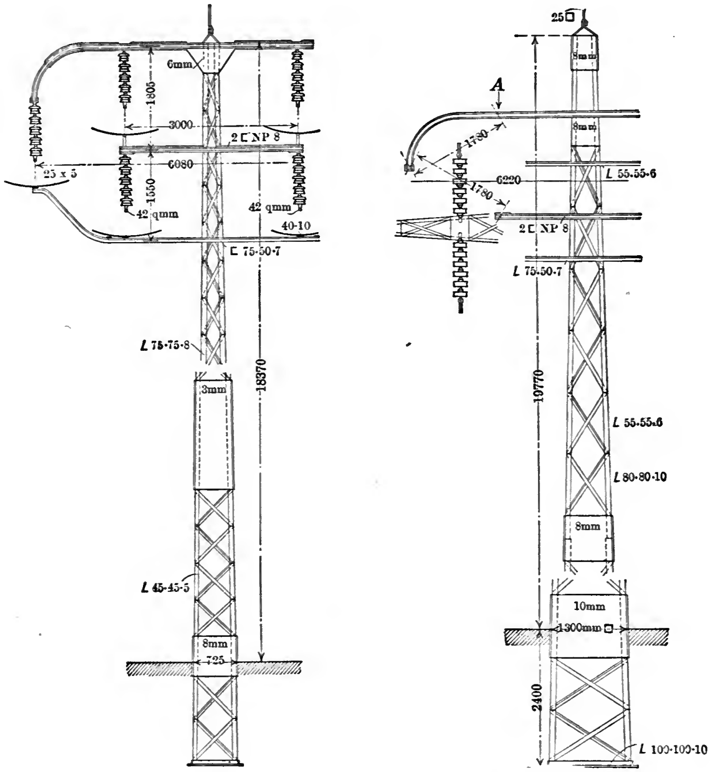
FIG. 45.—Tripartite pole.

that of the butt, about 18 in. The conductors are arranged in a 48-in. triangle with three malleable-iron bracket-arms, and a telephone circuit is carried on malleable-iron brackets below. The main U-members of the pole are 2 5/32 in. wide×2 1/16 in. deep×1/4 in. thick; the pole complete with equipment weighs about 1050 lb., and set to a depth of 5 ft. in concrete bases carries three No. 1 copper line conductors and two No. 8 telephone wires in 285-ft. to 350-ft. spans.

In Europe, especially in Italy, Switzerland and Germany, steel pole construction has been developed to a much greater extent than in this country. The general practice in Europe, however, appears to tend to the use of lighter supports placed more closely together than here; the structures themselves are generally of a latticed type, though I-beam sections, tubular poles, and a design somewhat similar to the tripartite, are also used. There the practice has also been to build the lines on the elastic or flexible system, with anchor structures at quite close intervals, whereas here one design is used throughout, with the possible exception of cases where heavy angles are to be turned.

One of the late European installations, the Lauckhammer line, notable in that it is the first 110,000-volt transmission to be constructed in Europe, employs a type of structure that may well be classed as a pole, though on account of the high voltage, heavier poles and longer spans are used than in ordinary practice. As described in the *Electrical World* for Oct. 28, 1911, the structures, illustrated in Figs. 46 and 47, are 60 ft. to 65 ft. in height above the ground, and are built of four angle-iron main members with a lacing of lighter angles; the line is constructed on the flexible system with intermediate poles about 28.5 in. on a side at the ground line and anchor structures about 51.2 in. The poles are spaced from 500 ft. to 650 ft. apart, and carry two three-phase circuits of 83,000 circ. mil seven-strand copper, with a 100,000 circ. mil steel ground wire at the top. As will be noted from the illustrations, a novel cross-arrangement was devised, reducing the torsional moment on the structure; a grounding scheme is also provided for in the shape of an extra arm arranged to catch and ground a conductor should an insulator break. The spacing between conductors is only 5 ft. 9 in., with a distance between circuits of about 9 ft. 10 in., whereas the general American practice for this voltage and span has been to provide a conductor clearance of from 8 ft. to 10 ft.; it is likely, however, that climatic and mechanical considerations determined this as the most suitable.

Another German line, built from Homburg to Crefeld and other points, will be of interest as showing general Continental practice more closely; as described in the *Electrotechnische Zeitschrift* for Dec. 14, 1911, this line, which is constructed on the flexible system, uses intermediate poles built up of two latticed channels, and strain poles of four-post latticed-angle construction. These poles were bolted to concrete bases, in a manner similar to the Long Island Railroad poles, instead of being set into them, as is the method most usually employed. The poles are a little less than 37 ft. long, and carry two three-phase 20,000-volt circuits in spans of 40 meters to 80 meters.



Figs. 46 and 47.—Lauckhammer steel poles.

This type of construction appeals to the writer as a natural combination of the good features of both steel tower and wooden pole construction with an elimination of many of the undesirable ones. The moderate length of span allows the use of fairly short structures, and with voltages below 50,000 to 60,000 volts, moderate spans ought to work out very economically. One drawback to the use of steel poles in this country has been the lack of proper judgment as to the load for which poles should be designed; the same people who will erect wooden lines with almost any kind of a pole will make all sorts of extraordinary assumptions when they come to figure what they should require their steel poles to carry. According to Mr. Semenza, as noted in his paper in the 1904 *Transactions of the American Institute of Electrical Engineers,* the same condition prevailed in Europe in the early development of steel pole structures there; this characteristic, moreover, is not confined to steel pole design, but as discussed under Steel Tower Design in a later chapter, is also a condition that prevails in other types of construction.

As far as the present development of steel pole construction in this country and abroad is concerned, the general overall lengths of poles usually employed as standard, appear to be from 35 ft. to 45 ft.; the poles are usually assembled complete in one length in the shop, except in special cases; the weights for average high-tension service in these lengths will run from 800 lb. to 2500 lb., varying much for the same service, with the climatic conditions in different parts of the country.

The cost of riveted latticed poles, with one shop coat of paint, will run from 3 1/2 cents to 5 1/2 cents per pound, depending upon the size of the order and the particular design, together with condition of the steel market; tubular poles will run from 2 3/4 cents to 3 1/4 cents, and tripartite poles from 2 3/4 cents to 4 cents per pound. All prices are f.o.b. the shops.

As steel poles are generally assembled complete, with the exception of cross-arms, in the shops, they call for about the same loading for shipment as do wooden poles; as in the case of the latter, poles over 40 ft. in length require double car loading; the minimum car-load weight for steel poles is, however, usually a little greater than that for wooden poles.

The handling of steel poles requires the exercise of a little more care and discretion than in the case of wood in order not to scrape off paint or galvanizing, and to avoid kinking or buckling any of the members; the unloading of a shipment of steel poles can be handled very easily by using a light 25-ft. or 30-ft. cedar pole as a gin pole, or in the case of a load of long poles, two gin poles, erected on the side of the car opposite to which the unloading is to take place and raked so as to bring their tops fairly near to the center line of the car; skids are then built up to the side of the car so that after a pole is raised clear of the balance of the load, it can be pulled over and lowered to the skids by means of a tag line, at the same time slacking off on the gin-pole blocks; the poles may then be worked along this unloading skid-way to their proper position in the yard. No data are available as to the unloading costs on any particular steel pole for transmission work, but from personal experience in unloading other types in the above manner, the writer believes that for a 40-ft. pole weighing from 1500 lb. to 2000 lb., the cost per pole for unloading should not exceed 30 cents to 35 cents.

The arrangement and the system of handling of poles in the yard should be the same for steel poles as for wooden, and they will be loaded for distribution by means of a gin pole or derrick; in unloading in the field they cannot be "snaked off" as easily as a heavy wooden pole, but by exercising a little care and ingenuity, they can be unloaded without any trouble; with very heavy poles it may be necessary, and will probably be good economy in the case of lighter ones also, to rig up a light tripod or to employ a gin wagon in the field to unload the wagons. The distribution costs cannot be estimated with any degree of accuracy without knowing the characteristics of the particular design of pole used. No figures are available for the distribution costs per pole where steel poles have been hauled out by team under conditions that ordinarily prevail in transmission line construction, but, basing an estimate upon ordinary four-post latticed-angle poles, 40 ft. long and weighing about 1500 lb. each, an ordinary team can easily haul three of these over average country roads and make two 10-mile round trips, or a total daily mileage of 20 miles. With teams at $4 a day, a yard foreman at $3 and a helper at $2 per ten-hour day, and a man in the field to help unload at $2 a day, the cost for distribution under these conditions with six or eight teams working ought not to exceed 75 cents or 85 cents per pole. Where a long stretch of the line is to be served from one distribution point, a man should be stationed at both the near and the far ends, and the teams sent out alternately on long hauls and short hauls; it is obvious that the more teams employed, up to a certain point, the lower the yard and field expenses per pole delivered.

Steel poles are generally set in concrete bases, and the usual practice is to make the depth of set one-tenth the overall length of the pole, for transmission work; the Sanitary District poles which are 60 ft. overall, are set 6 ft. deep, and the Franklin Steel Company also uses this ratio in its work; the minimum depth of set in any case is usually 4 ft. The size of the concrete base naturally depends upon the dimensions of the butt of the pole and upon the character of the soil in which the poles are to be set, and is usually specified by the manufacturer. Where poor setting is encountered, it is well to calculate the bearing area required at the base, when the pole is under maximum load, and to make sure that sufficient base width is provided.

The holes for setting steel poles are usually dug with more care than in wooden pole work, and to a specified size, as in most cases the sides of the holes are the forms for the concrete, and where the digging is not closely observed, more concrete than is needed will be required. For the bases, a 1:3:6 or a 1:3 1/2 :7 mixture of cement, sand, and coarse gravel or crushed stone will be satisfactory and should be placed fairly sloppy; the concrete base is usually brought up 6 in. or so above the ground level and the top sloped a little so as to shed water.

The cost of digging holes for steel pole construction will run the same as that for wooden pole work, under the various conditions, except in so far as the necessity for cleaner cut holes may slow down the work a little.

Steel poles are set in the same manner as wooden poles, by means of pikes, gin wagon or gin pole; for average poles, weighing up to 2500 lb. or so, an ordinary gin wagon rigged as for wooden pole work is very satisfactory; for heavier poles a special heavy rigged gin wagon or a gin pole will be required; light- and medium-weight poles can be piked in very readily, using a pike provided with a U- or V-shaped point instead of a spike, in connection with a regular jinny adapted to the section of the pole to be raised. Where a gin wagon can be used it is generally the most rapid and economical method of raising poles, excepting in the case of light ones; the gin-wagon or gin-pole methods of erecting have in many cases an important advantage over piking, in that there is no danger of gouging-out or caving-in the walls of the holes in setting, and so increasing the subsequent cost of concreting.

After raising, the poles must be braced or guyed in position for lining-in and after being set in alignment, must be left with the braces or guys in place until the poles have been concreted and the concrete has set sufficiently to allow their removal; in the setting of the tripartite poles used in the Salt River Reclamation work, as described in the *Electrical World* for March 30, 1911, four guys were attached to a pole, and after its erection, it was straightened up by means of these, and lined-in with plumb-bobs located over reference stakes set by the surveying party for that purpose; after being lined-in the pole was held in place by pulling up the four guys with a pair of light blocks, fastening them to steel stakes, and then leaving them for the concreting gang.

The lining-in of poles set in long spans can possibly be done very easily by the use of reference stakes, but this requires a location survey, and for lines employing moderate spans, there is no reason why steel poles cannot be lined-in by sighting back to the poles previously set, as in wooden construction.

For tall poles, guys will probably always have to be used to hold the poles in position during the concreting of the bases and until they are hard enough to hold, but where short poles are employed, it may often be possible to block the poles at the ground line with stones or wedges, leaving enough room to pour the concrete, and bring the concrete up around them, thus saving the labor of going back and removing guys after the concrete has set.

The concreting of the bases should be carried on immediately after the poles are set; general information as to mixture and consistency of the concrete has already been noted; the work can be done by a crew of two men with team and teamster, equipped with a light sheet-metal mixing "board" or a small hand-turned machine mixer. In pouring the concrete, care should be taken not to get any dirt mixed with it, and a trough or chute should be provided for this purpose; the concrete should be tamped so as to work it well around the pole. The material for the bases will be carried along in the wagon, with another team on the road hauling from the base of supplies and replenishing the same as needed.

As to the crew required for the erection and setting of steel poles, its average daily progress on the work depends naturally upon the weight, length and design of the pole in question; for average work through farming country with sandy, sandy-loam, light gravel, or black soil, the digging, raising and setting, namely, the erection of the structures complete, for a line of 40-ft. latticed poles weighing about 1800 lb., will require a crew consisting of about the following: one general foreman, four diggers, one sub-foreman, five groundmen with gin wagon, one team and man for same, two men with team and teamster for the concrete work, and one man with team and teamster removing guys from previous day's work and hauling material for concrete work; this crew ought to average from ten to twenty poles erected a day. On this basis for conditions obtaining in the Middle West, where foremen will cost $3.50 to $4, sub-foremen, $2.50 to $3, groundmen $2 and teams with teamster, $4 per ten-hour day, the labor cost per pole erected will run from $2.10 to $4.20.

On the Salt River Reclamation Service work, with the labor and climatic conditions prevailing in Arizona, from eight to twelve poles were set each day with a crew of twenty-two men. On a line of steel poles built in Colorado, the poles varying in overall length from 25 ft. to 45 ft., with a 35-ft. pole weighing about 510 lb. as standard, the contract price for erecting the poles was $6.50 per pole; the poles were set about 4 1/2 ft., in concrete, the material for which was furnished by the contractor.

On the Sanitary District work, the cost of setting the 60-ft. poles weighing about 4000 lb. each is given at $55 average; in this work 18 miles of the total 30-mile length, was rock setting.

The general mile cost of steel pole construction will, as a rule, not be much greater than that of wooden pole line; in many cases it is less and where the comparison is made with treated poles there is very little difference in the Middle West between the first costs of the two types of construction. In connection with hydro-electric work of moderate capacity, steel pole line will undoubtedly in the near future take the place of wooden pole lines just as concrete dams are superseding wooden dams. With the development of transmission systems radiating from a large central town to the smaller towns and villages surrounding, where the capacity and operating voltages of the lines will be moderate, the steel pole has another great field.

CHAPTER VI

STEEL TOWER CONSTRUCTION

Steel towers are the unquestioned standard for trunk lines of any great capacity operating under the higher voltages, and in the past few years they have been utilized in practically all suhc installations of any magnitude. With the development of steel tower work, two distinct types or systems of construction have been evolved, the rigid and the flexible or elastic.

As previously noted, the former consists in proportioning all line towers, excepting those at angle points, long-span crossings, etc., to resist the same strains in all directions, while in the flexible system, two kinds of line structures are used, classed as anchor or strain towers, and intermediate towers, the former designed for heavy strains both longitudinally and transversely and the latter, built with only two posts or main members, arranged to resist the same transverse strain as the anchor towers but with practically no strength in a direction parallel to the line, and designed to allow considerable distortion or deflection due to unbalanced conductor pull, without any permanent set.

There is a variation from each of the foregoing general types of tower construction; in the rigid construction, while it is the general practice to use all towers on tangent of the same strength, several lines of a capacity demanding heavy conductors have employed structures of a design much heavier than standard, at 1-mile or 2-mile intervals, to serve the same purpose as storm-guyed poles, that is, to prevent cumulative failure of structures on a long tangent; these towers have been designed to carry the dead-end pull of all conductors, with sometimes a heavy wind in addition. In the flexible system, likewise, we have a variation from the design of a light structure acting as a prop under the conductors, in the type which is known as semi-flexible construction; a semi-flexible structure, as its name implies, is a tower of greater strength in the direction of the line than that of the type first brought out. The flexible system is primarily the result of an attempt to lower the total cost of structures for a line, and in principle amounts to providing props to keep in the air, a line that is anchored solidly at each end of long stretches with plenty of slack in between, the props being braced against transverse strains and held in place longitudinally by a heavy ground wire and the conductors themselves, transmitting longitudinal strains to the anchor towers at intervals of a mile or so.

The flexible system is based upon the fact that with equal spans on both sides of a structure, the longitudinal strains are ordinarily balanced; if a conductor breaks, the tower, under the influence of the unbalanced pull of this conductor, assuming that it is tied-in or clamped solidly so as to be the same as dead-ended, is distorted and pulls around at the top until the decreasing tension in the broken conductor, say in the case of a single-circuit structure, is balanced by the pull of the ground wire and the other two conductors transmitted from the anchor tower theoretically, though the resistance of the intermediate supports helps also. As a small increase in the length of wire in a span reduces the tension materially, it is apparent that the deflection at the top need not be considerable to effect a balance; ordinarily it is not more than 6 in. or 8 in., and as the structures are usually designed for a safe distortion of two or three times this, there is no permanent deformation. This type of construction has worked out very satisfactorily in Europe, and with attention to the balancing of the spans, the employment of a heavy ground wire, and with the use of moderate span lengths, there is no reason why it should not meet with the same approval here. Proper use of head-guys at intervals as needed, in between the anchor structures, ought also to allow the employment of unequal spans to take advantage of favorable topographical conditions without dire results from unbalanced pull under varying temperature conditions, where this variation in the construction may be permissible.

The structures for flexible construction are as a general thing made up complete and riveted in the shop, and shipped assembled with the exception of the cross-arms; they have therefore the advantage of lower field costs than towers of the rigid type in the elimination of the assembling work, and as usually constructed with the main members of channel-iron, are also much simpler to erect. They possess another feature that gives them an advantage over light-tower construction, in that the section of their members is greater and they have a minimum of small section members at the best, so that the effect of corrosion in a moderate degree is not so serious a matter to them as it is to a light-built rigid tower.

In the general matter of the design of any type of tower, for a given size and number of conductors, and length of spans, under similar topographical and climatological conditions, there is a great difference in opinion among engineers as to what strains the tower and its attachments shall be designed to resist, and to some extent as to what factor of safety shall be allowed. One engineer will often specify test loads or make assumptions of conditions to be met, that another engineer will declare absurd; the fact of the matter is, that the difference in opinion is often due to the point of view that each takes in the light of his past experience in other parts of the country, and so we sometimes find sleet-proof construction in localities where sleet has never been known to occur, and light construction through a territory where sleet is a regular occurrence.

Again, outside of assumptions as to what weather conditions may be encountered, which latter can usually be quite clearly determined by referring to the Government climatological records of the particular locality for a period of thirty to fifty years back, comes the question as to what condition of loading due to the line conductors should be combined with the strains set up by sleet and high winds, etc. Some engineers will want a tower that will stand, say, for a single-circuit structure, the wind and sleet load as noted, in combination with the dead-end pull produced by the breakage of any two of the conductors, while others will figure that for a single-circuit tower, the unbalanced loading due to the severing of only one conductor will need to be reckoned with; still others will require a tower to stand only the maximum wind and sleet load, without the combination of unbalanced strains due to broken conductors, each engineer backing his own personal opinion.

In commenting upon this feature of tower design, D. R. Scholes of the Aermotor Company says in his article on tower design, *Transactions American Institute of Electrical Engineers* for 1907, page 1257, "Each engineer seems to have a different set of natural conditions to meet. The severity of his assumptions seems to depend, generally, on how much money his company can afford to spend on towers." From the inconsistency displayed in the specifications under which tower structures are purchased, it certainly does seem that engineers have no inclination to trifle with nature if they can possibly "play safe."

In general, following the recommendations of the engineering societies, it is now the practice in localities where sleet is known to occur, to assume a 1/2-in. coating of sleet all around a conductor with a wind pressure of 8 lb. per square foot on the projected area of the sleet-covered conductor, and a wind pressure on the surface of the tower structure of 13 lb. per square foot; then in combination with the foregoing weight and wind load, the structure is designed to withstand the unbalanced pull due to one or more broken conductors.

The allowance for broken conductors, it appears to the writer, should depend somewhat upon the generating capacity of the system; in the case of lines with a small generating capacity that could not hold up a heavy current on short circuit for any length of time, there is not so much danger of burning off conductors upon the breaking down of the insulation as where the station capacity is relatively great, and from the writer's experience, a line wire is burned off very seldom where the total capacity of the system is only a few thousand kilowatts. Furthermore, when a conductor does burn or break off, the unbalanced pull will often slip it through the tie or, in the case of a suspension-type insulator, will pull that over and throw slack into the adjacent spans, materially reducing the pull and shock also, and this feature should be taken into consideration.

The manner of drawing up specifications for tower structures varies, in that some engineers give ultimate test loads and others give the working loads and specify a certain safety factor; the latter method is certainly preferable. The factor of safety called for is usually two or three for the structure as a whole, under the maximum conditions of load, and for the fittings, either three or four; with the assumptions as to what the maximum load is to be, as severe as they usually are, a safety factor of two for the structure and of three for the fittings is in the estimation of the writer ample. Where no sleet is assumed, as on the Pacific coast, and where very high winds are encountered, the higher safety factors may be assumed.

In the design of towers for a flexible system, the intermediates are built to stand the same loading and conditions, as outlined in the foregoing, but only in a direction transverse to the line;

in a longitudinal direction, their strength is generally determined by the size of the members necessarily provided to take care of the transverse load; the anchor towers, located usually at 1-mile intervals, are designed to resist the wind and weight load resultant in combination with the dead-end pull if all the conductors should be severed; the factors of safety should be the same as for other types.

The height of structure that is required for a given circuit and size of conductors in average level country depends upon the number of towers used per mile, the minimum allowable clearance to ground, the material of which the conductors are composed, and the natural conditions as to sleet, temperature, etc., imposed by the particular locality in which the line is to be built.

As a general thing, from seven to twelve towers per mile has been the standard American practice, the longer span construction naturally being employed in the higher-voltage lines; based upon the height of the lowest conductor above ground, as is the standard in rating structures of this type in America, and using copper wire, 45-ft. to 50-ft. towers have been used generally for the longer spans, 40-ft. to 45-ft. for the medium, and 35-ft. to 40-ft. for lines employing eleven or twelve structures per mile. Under similar conditions as to temperature range, etc., aluminum conductors will require a higher structure for the same minimum clearance to ground than copper, and steel-strand a lower one.

The weights and prices of towers vary naturally with the conditions imposed and the design, but for a single-circuit 60,000-volt line up to say No. 00 copper conductors, 40-ft. towers will weigh from 1600 lb. to 2500 lb.; 50-ft., from 1800 lb. to 3000 lb. and 60-ft., from 2200 lb. to 3500 lb.; 40-ft. double-circuit towers for the same general conditions will weigh from 2200 lb. to 3500 lb.; 50-ft., from 2600 lb. to 4200 lb. and 60-ft., from 3200 lb. to 5000 lb.; the price per pound for towers will vary with the market, the design, and the size of the order, from 3 1/4 cents to 4 1/4 cents f.o.b. shops, for galvanized structures, with prices dropping below the foregoing minimum at times; painted structures will cost from 1/2 cent to 1 cent less per pound than the above.

There has been much discussion in the past as to the comparative values of galvanizing and painting in the protection of a tower from corrosion, but it is now the general practice to specify galvanizing irrespective of the relative values of the two methods, in order to avoid the trouble and operating difficulties incident to repainting. If galvanizing is properly done, especially by the sherardizing process, it is of unquestioned value, but many cases of inferior work are encountered and even where the original protection is satisfactory, its value may be greatly reduced by careless field work, as for instance in the assembling of a tower, where drifting is required, the galvanizing at the bolt holes is destroyed, and in the case of light members, rusting at these points will soon reduce the strength of the section to an unsafe value. In the case of tower designs that do not involve the use of a great number of small members, so that the cost of repainting will be prohibitive, there is still a field for paint as a protection; this applies particularly to the heavy-section structures used in flexible tower work.

While discussing protection, it will be well to take note of the matter of minimum thickness of metal for the various members of a structure; many light towers have been built with the main members only 1/8 in. thick, which in the writer's estimation does not give sufficient lee-way against the effects of corrosion and a thickness of not less than 3/16 in. and preferably 1/4 in. ought to be specified for main members, with 1/8 in. to 3/16 in. for minor members.

In the consideration of the various proposed designs of structures for a line, they should not only be studied from the standpoint of cost, loading, and material, but also as to the rapidity and economy with which the field work on them can be carried out. There is a marked difference in the cost of assembling and raising a tower built on a simple girt and diagonal plan over that of a type involving the use of many small truss angles, and where the conditions of loading will allow the use of either at about the same price, the former will give more satisfactory results in place.

Any tower should be so designed that the parts can be tied up into convenient bundles of similar members weighing not more than about 100 lb. each, for ease in shipping and in handling in the field; all small parts that cannot be readily bundled should be boxed with the bolts. All bundles should be securely wired together and tagged with the erection number or letter for those particular parts and with the size and type of structure for which they are intended; it is also a good policy to call for the stenciling of this information on one or two of the pieces in each bundle of similar parts; boxes or kegs containing bolts, etc., should be marked with the list of parts contained and the tower height to which they belong.

As tower shipments come in, they cannot usually be unloaded for distribution directly from the cars and it is necessary to provide a systematic means of unloading and arranging the material, so as to avoid delay and confusion when the teams are to be loaded in hauling-out for distribution later on. The most satisfactory method usually is to seek a level place along a sidetrack, where teams can come in easily, and lay out spaces for each kind of tower, large enough to accommodate segregated piles of the various bundles making up the parts of each size of structure in a group; then series of two or three stakes, extending 4 ft. to 6 ft. out of the ground should be driven so as to form pens into which the bundles of similar members may be piled, leaving all the parts of a certain size of structure laid out so as to be readily accessible, and the material for the different kinds of towers isolated in groups. This is similar to the method used in storing steel for reinforced concrete building construction, and works out well; the stakes between the piles will be marked with the erection mark for the parts enclosed. The bundles should be laid out endwise to the driveway, and if the groups can be arranged on either side of a lane through which the team may drive, this will be of assistance in loading.

In distributing, the wagons should be provided with ordinary boxes or, preferably, racks with full bottoms so that there will be no possibility of the smaller bundles working through. In construction through agricultural country where it will be necessary to use teams from the small towns along the line as well as those of farmers living in the territory traversed, close supervision will usually be required to get the right tower to the right stake. In average medium voltage and capacity line work, under conditions obtaining in the Middle West, two towers per load can be hauled over ordinary country roads.

As each teamster is loaded and is ready to start, the yard foreman will give him a slip naming the individual stakes to which the towers comprising his load are to go, checking-out against him by name on a progress sheet or time book, the numbers he is to haul to, in order to identify him in case of poor delivery. It is also a good policy to place a man in the field to assist in the unloading, but primarily to see that the towers go where they are supposed to go and that the full number of bundles is delivered at each location; where a man is so used in the field to check the distribution, each teamster should be required to return to the yard foreman for checking on his tally sheet, the hauling slip previously mentioned, duly O. K.'d by the field man, giving a definite progress report on the distribution work. A foreman at $2 to $2.25, who will also do all the timekeeping for the distribution work, besides checking material on to the loads and directing the teamster, with two men at $1.75 or $2 a day, can take care of the yard work.

Based upon hauling two towers per load an average distance of 5 miles or 6 miles per trip, with teams at $4 a day, a yard crew as already noted and a man in the field at $2 a day, the labor cost for distribution will run from $2 to $2.50 per tower; these figures of course will not apply to the heavier structures, but are based upon the fact that on average country roads a fair team can haul 4000 lb. to 6000 lb. as a load and make two round trips of 10 miles or 12 miles each per diem. As noted under the topic of distribution for wooden poles, the teams should be sent out in twos or threes, so as to assist each other in case of accident or of bad roads, hills, etc.

Actual cost figures on a short line of double-circuit tower construction for a line about 4.2 miles long, give the cost of distributing the steel for these 4400-lb. structures as $2.25 per tower average, with teams at 56 1/4 cents and unskilled labor at 28 cents per hour; in the *Electrical World* for Sept. 9, 1911, the cost of hauling towers for the Amherst Power Company line is given at $4.28 each, with 16 cents as the cost of delivering the anchors for each structure.

In most cases the anchors for towers are a channel-iron or similar plate attached to the end of a 6-ft. or 7-ft. stub of angle iron, for the lighter structures, or in the case of tall, heavy towers a built-up grillage of steel is used, bolted to an angle-iron leg in the same way as in the lighter work; in many cases concrete foundations are placed for the line structures also, but in most instances they are used only at points of unusual strain.

A typical anchorage of the grillage type, showing the method on installing the same is illustrated in Fig. 48; a typical concrete foundation, consisting in anchor bolts embedded in concrete footings, in the same manner as for a piece of machinery, is shown in Fig. 49. These anchors are the standards used in the

Ontario Hydro-Electric Power Commission work, the earth setting being used ordinarily and the concrete foundation in the case of angle, dead-end, high towers, etc.

In most tower work, the anchor stubs are shipped in advance of the main structures and are set before the rest of the material arrives. The method of setting anchors, practically universal now, is to employ a light, but rigid, angle-iron templet to which the anchor stubs may be bolted and rigidly held at the correct level, spacing and slope.

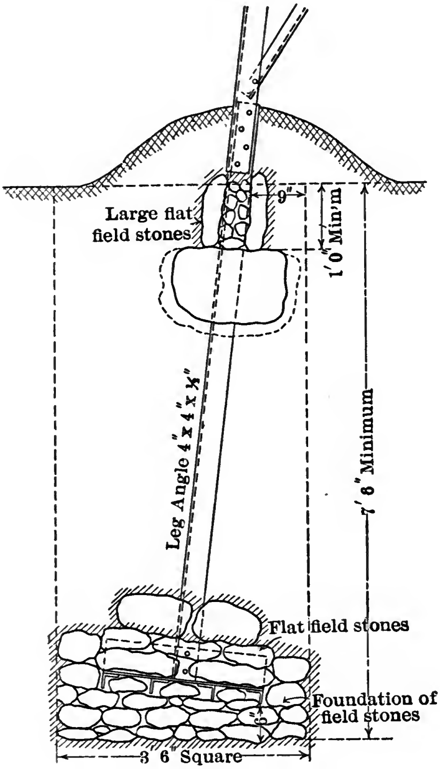


Fig. 48.—Standard earth setting of anchors—Ontario Hydro-Electric Power Commission work.

The towers are, or should be, staked out, as described in a previous chapter, with a hub-stake for locating the center of the tower and a lining or reference stake 10 ft. or 15 ft. ahead on line, by means of which the anchors can be set square with the line, though very often only the center stake is located and the anchors are lined-in by means of the adjacent location stakes; this latter method is fairly accurate where the towers are quite close together, but does not ensure the workmanlike job that the first method does.

The general system often employed in anchor setting in earth is as follows, where the soil is sand, sandy loam, light gravel, or similar average digging, and where the work is being carried on in the summer time. Two crews are used, the first one consisting of a sub-foreman and three men, provided with a "dummy" templet of wood and digging tools, and the second crew, of the digging foreman and, for average conditions as described, about eight men, equipped with the setting templet, shovels and tamping tools

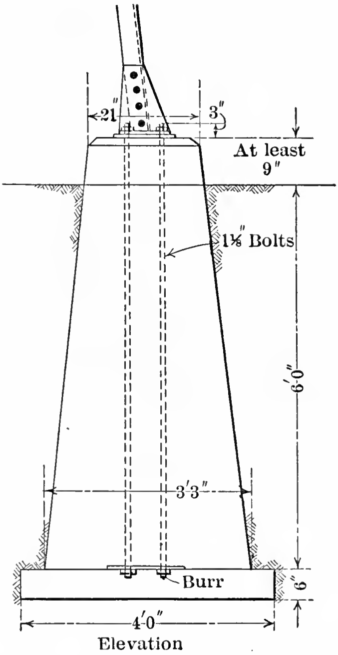


Fig. 49.—Concrete anchors—Ontario Hydro-Electric Power Commission work.

The first crew with the "dummy" or digging templet, made up with light 1-in. × 4-in. or 6-in. stuff, as shown in Fig. 50, locates the tower corner points by centering the templet over the hub by means of the hole in the center, and then lining-in the mark or tack at "A," with the center-hole and the reference or lining stake set by the surveying crew a short distance ahead on line; with the stub positions located, the templet is removed and each man blocks out a hole and digs to the required dimensions.

In digging for towers set on gentle slopes, the low holes should be dug full depth and the others to the same level; where steep slopes are encountered, a "cut" and "crib-fill" arrangement may have to be used. Anchor holes should be dug so that the bottom of the anchor plate will rest on undisturbed earth as far as is possible and should always be deep enough so that the ground joint can be covered by banking the dirt a little around the corner posts, and where towers are set in tilled fields it is a good policy even to bring the ground joint partly below the original ground level, as in the working of the land, especially where the tower design is such that there is room to drive through the tower and the space beneath the structure is under active cultivation, any banking will soon be leveled.

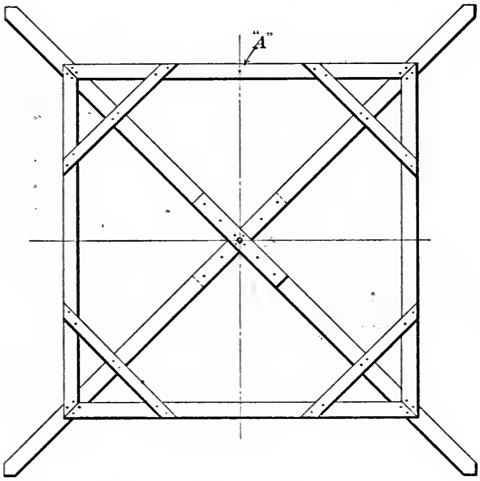


FIG. 50.—Digging templet.

In digging these holes a man can ordinarily work in the hole with a 2-ft. D-handle No. 2 shovel, though sometimes it is necessary to use a shovel with a shorter grip in order to handle it well in the size pit required; there is a marked increase in the output of a digger working in the hole, over that of one working on top of the ground, using a No. 2 as far as possible and finishing up with a spoon. For most towers, the size of the holes demanded for the proper setting of the anchors is sufficient to allow a man to work in them, and if it is not, they may often be economically dug a little larger than necessary so as to make the same possible, as the difference in the amount of excavation will be more than compensated for by the increase in the amount of work done. In throwing out the dirt from the hole, the same should always be cast outside of the area enclosed by the tower and preferably in a pile in line with the diagonals of the base produced; in this way the spoil will not be in the way of the men of the second crew in handling the templet, and will allow three tampers and a shoveler to work at the hole conveniently in backfilling.

FIG. 51.—Setting anchors.

The second crew, carrying the setting templet, places it roughly in position over the holes, assembles the anchors, and bolts them in place on the templet; the templet is then centered over the tower-hub and squared with reference to the line by means of marks on the templet and the lining stake as previously described; where the templet is so constructed that the center cannot be closely located, marks at the middle of the opposite sides of the templet will be lined-in with the hub and reference stakes. As the templet is lined in it is also leveled up all around, a 24-in. carpenter's level being very satisfactory for this purpose, and then blocked securely in position; typical views of anchor-setting showing templets will be noted in Figs. 51 and 52.

Before back-filling is commenced, the templet should be checked by measuring the diagonal distances, to detect and correct any tendency to rack into a diamond shape; with the heavy riveted templets, or the elaborate trussed types, this may not be very necessary, but with the light bolted kind provided with rod-diagonals, this check should be taken.

With the anchors in their correct position, two men at each corner commence filling-in and tamping carefully, working the dirt solidly under the anchor plates until all four anchors are solidly backed up with tamped dirt, the holes being filled and tamped evenly all over the bottom in so doing. With all four anchors properly bedded, the templet should be tried for level and, everything O. K., the crew will split into two gangs composed each of three tampers and a shoveler, each gang taking an anchor on the same side of the line and back-filling the hole complete and then repeating the operation on the other side. The tamping should be thorough and where, especially in the case of structures that will be subjected to line strains a short time after their erection, it may be deemed necessary, water should be used to wet down the back-fill when dry soil is encountered.

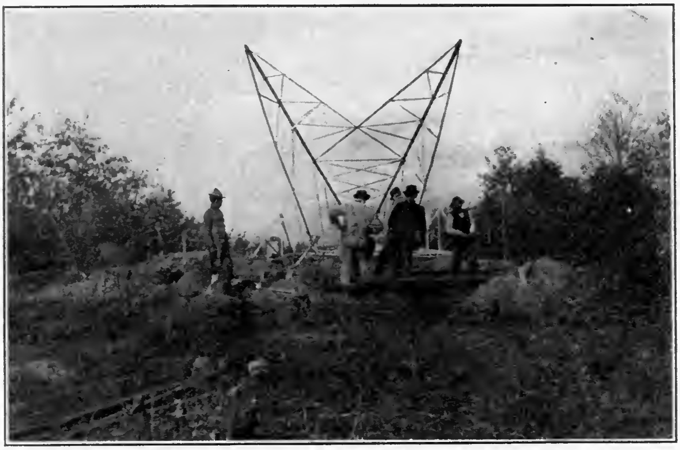


Fig. 52.—Setting anchors.

Where the digging is slow, owing to the kind of soil or to frost, if the work be carried on at times of the year when it may be encountered, an extra crew of two or four diggers each may be required to follow up Crew No. 1, and Crew No. 2 may be increased in size as may be required, though the use of too many men to one setting templet should be avoided; where the total crew is increased in this way, Crew No. 1 would be reduced probably to two men only with the digging templet and they would merely block out the holes to a few inches in depth, leaving the excavation to be done by the intermediate crews; this would probably also call for an extra man as sub-foreman in general charge of the digging, acting under the direction of the setting foreman.

In the work of the Ontario Hydro-Electric Power Commission, the system followed in setting anchors was somewhat similar to the above, two men with the digging templet comprising the leading crew, following which came the diggers, with the setting gang of twelve men and a foreman bringing up the rear.

In the work just mentioned the anchors required a hole 7 ft. 6 in. deep and 3 ft. 6 in. square, and under favorable conditions five sets of anchors could be set each day; the labor cost on standard footings set in dry or damp soil was from $15 to $25; it will be noted that the depth of these holes is about 1 1/2 ft. greater than is required for towers used in most installations; and that the anchors were blocked around with field stones; water was also carried to wet down the back-fill.

On a job in the Middle West where digging was easy, the soil being a sandy loam, the labor cost of setting anchors about 6 ft. deep for a line of light 40-ft. and 50-ft. towers ran from $4 to $6 per tower; for setting in earth, with a little concrete work in places, the anchors for a line of 40-ft. single-circuit towers, the *Electrical World* for Sept. 9, 1911, gives a cost of $3.38 per tower, with excavation at $6.91 per tower; these are contractors costs and no information is given as to wage scale, or character of soil.

The cost of setting concrete foundations for a line of double-circuit 40-ft. standard towers, weighing about 2650 lb. each, is given as $11 per set for the standard line structures and $81 for angle towers; this line was built in the Middle West, where labor costs about $2 to $2.25 per ten-hour day. In the West, where the cost of labor is very high, the following costs of concrete tower footings for a 4.2-mile line of double-circuit towers weighing about 4400 lb., will be of interest; these are contractors costs and do not include his profit; the excavation for the anchors averaged $12 per tower and the concrete, $31 or about $6.45 per cubic yard, making a total labor and concrete cost per set of anchors of $43. The first half of the line was built through rocky ground, but for the remainder of the work sandy soil was encountered; the unskilled labor received 28 cents, linemen and mechanics, 45 cents, foremen, 50 cents and teams, 56 1/4 cents per hour.

In general there has been little consistency shown in the labor costs of setting anchors as compared for instance with those for setting poles, and the inference is that much of the difference is due to a greater familiarity on the part of the construction men with the latter work.

The assembling of towers in the field is a phase of line construction that provides many opportunities for the development of a "system" of handling the work. Usually each line job is a study by itself as far as this matter is concerned, as the tower designs not only differ, but the skill and intelligence of the workmen is a variable quantity.

The method of carrying on the work of assembling that appears to give the most satisfactory result is that of splitting up the crew into small gangs, each with its own particular part of the work to perform; for instance in the case of a line of 40-ft. towers with a crew of fourteen to sixteen men and a foreman, two men will be sent ahead to break out bundles, open bolt-boxes, etc., and then roughly lay out in place the members for the bottom face of the tower, with those for the other three sides arranged systematically in their relative places, then four or five men and a subforeman will follow and assemble say the upper half of the structure, bolting everything pertaining to this part of the structure in place, but not necessarily drawing the bolts up tight, then the next crew of about the same number of men will arrive and complete the assembling, after which two men will go over the entire structure and draw-up tight all bolts and fastenings, leaving the structure ready to erect. This system of carrying on the work allows each set of men to become more familiar with a certain part of the work which naturally increases their efficiency, and again the men are not so liable to be in each other's way, etc., as when one big gang goes to work to assemble a tower by itself, complete. By adjusting the crews or the amount of work to be done by each gang, so that one gang will naturally complete its work in a little less time than the other gang can its own, a

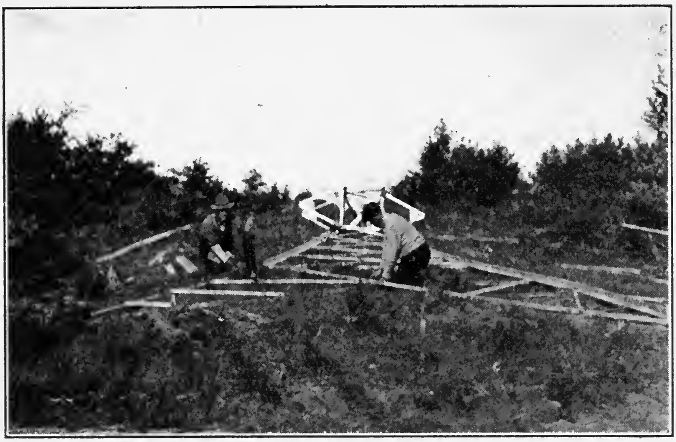


Fig. 53.

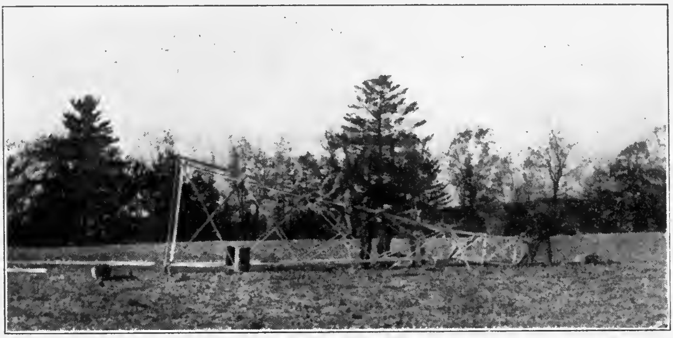


Fig. 54.

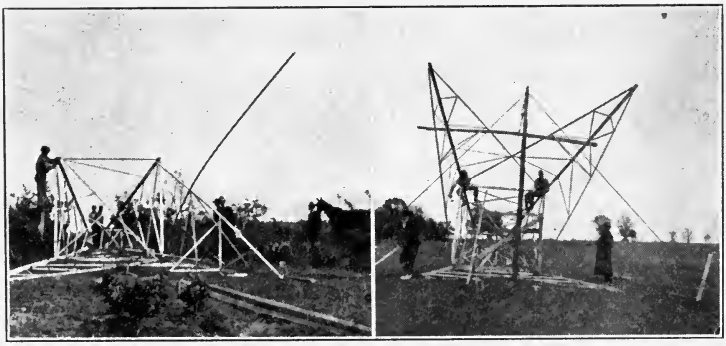


Fig. 55. Fig. 56.

Views showing the assembling of tower illustrated in Fig. 57.

spirit of rivalry may be worked up that will make its effect apparent on the progress report. While the use of two men to follow up the assembling gang and go over and tighten up all bolts, may possibly lead to a little carelessness on the part of the main gangs, which however can easily be located by noting the part of the tower where it occurs, it insures a good, final inspection of the work and the saving of time to the main gangs though not having to delay each other in finishing the setting up of a nut in a hard place, more than offsets the cost of the extra men.

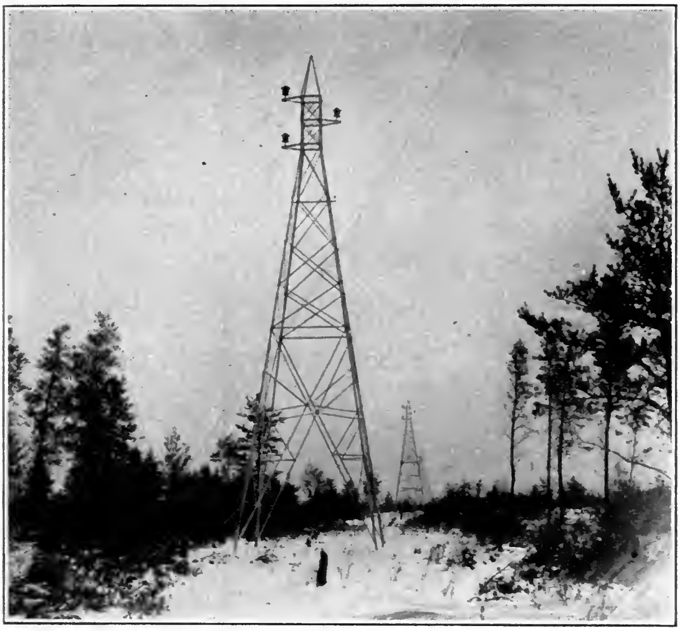


Fig. 57.

After setting up the nut on a bolt, some companies will batter the threads so as to prevent the nuts from working loose; this is a good idea.

In Figs. 53, 54, 55 and 56 are shown typical views of the assembling of the tower illustrated in Fig. 57; this structure was usually assembled in three steps, the head, then the section down as far as the long diagonals at the bottom, and then the bottom; in Fig. 56 will be noted the light gin pole used to support the top members until the side members were all attached, and also the horse used in working on the top face. For ordinary assembling work, 10-in. or 12-in. monkey wrenches, a few ball-pien hammers, drift-pins, center-punches, one or two axes, 5/8-in. rope and a set of light blocks, and track wrenches are all the tools that will be required, with such equipment in the way of light ladders, horses and a light gin pole arrangement, etc., as may be called for by the particular design to be assembled; of these, the only one that may not be generally familiar is the track wrench, which consists merely in a combination of an open-end wrench and a drift pin, the jaws of the wrench being made narrow and thick and the shank forged into a drift pin.

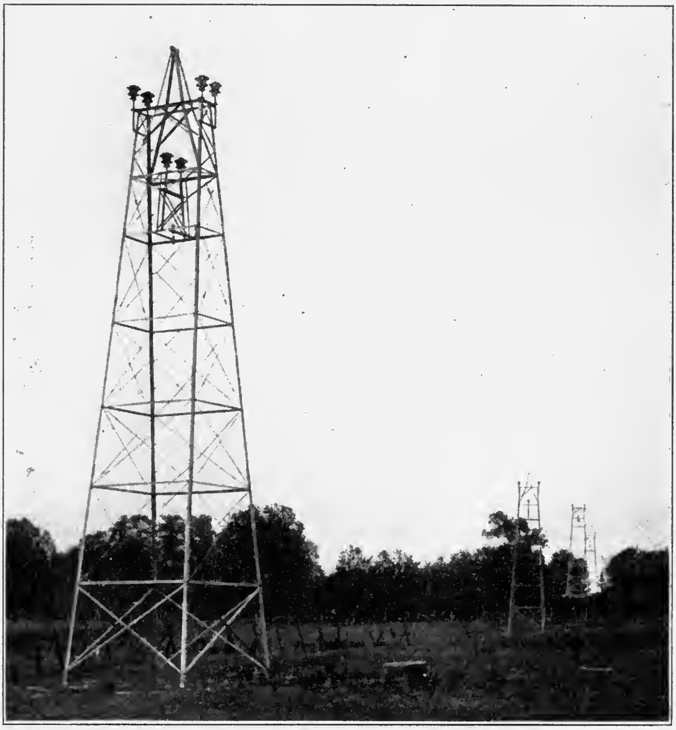


Fig. 58.—Amherst Power Co.'s tower.

The labor cost for assembling towers on a line using as standard a 50-ft. tower with 16-ft. base spread of the design shown in Fig. 57, was about $7.50 each; this work was carried on in late summer and fall under unfavorable circumstances; the men were quartered in camps and unskilled labor cost about $2.50 a day; the length of the line was about 42 miles. The assembling cost of the towers for another line of single-circuit structures is given in the *Electrical World* for Sept. 9, 1911, as $8.20; a cut of this tower line is given in Fig. 58, and it may be noted that it was only 8.5 miles long; no data is given as to wage scale. The single-circuit tower shown in Fig. 58 is a 42-ft. structure, about 52 ft. overall, with a base spread of 12 ft. The average cost of assembling the single-circuit towers of the Ontario Hydro-Electric Power Commission, shown in Fig. 59, the work being carried on in the summer time, is given at $7.35 each.

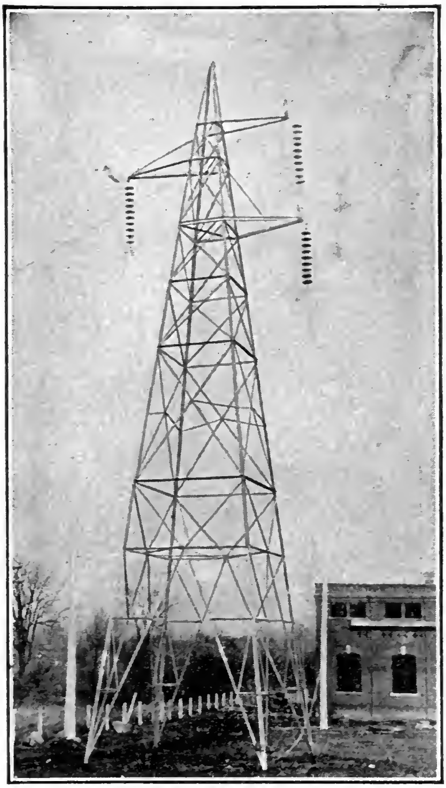


Fig. 59.—Single-circuit tower used by the Ontario Hydro-electric Power Commission.

In double-circuit work, the average cost per tower for the assembling in the Ontario Hydro-Electric construction, is given as \$10, with a maximum cost in winter of \$24 and a minimum in summer of \$6.25; this tower as well as the single-circuit structure

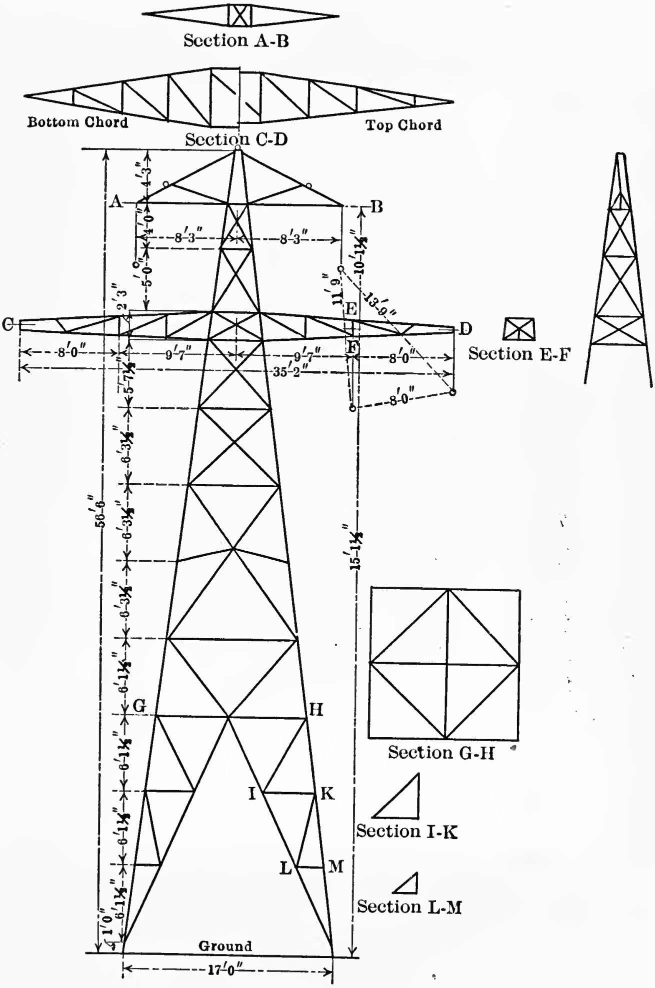


FIG. 60.—Double circuit tower used by the Ontario Hydro-Electric Power Commission.

previously mentioned, is designed for a clearance to ground of the lowest suspension, of 45 ft., with an overall height of about 64 ft. 6 in.; the base spread of the double-circuit structure is 17 ft. and that of the single-circuit, 16 ft.; an outline of the design of the double-circuit structure and a view of the same in the line, are shown in Figs. 60 and 61, respectively.

The contractor's cost for the assembling of towers for a 4.2-mile stretch of 45-ft. double-circuit construction built in the West under high-priced labor conditions, is given as $19.70 per tower; unskilled labor received 28 cents and linemen and mechanics 45 cents per hour; the labor conditions prevailing did not allow the use of common labor to replace mechanics, where feasible, as would be the case in the Middle West.

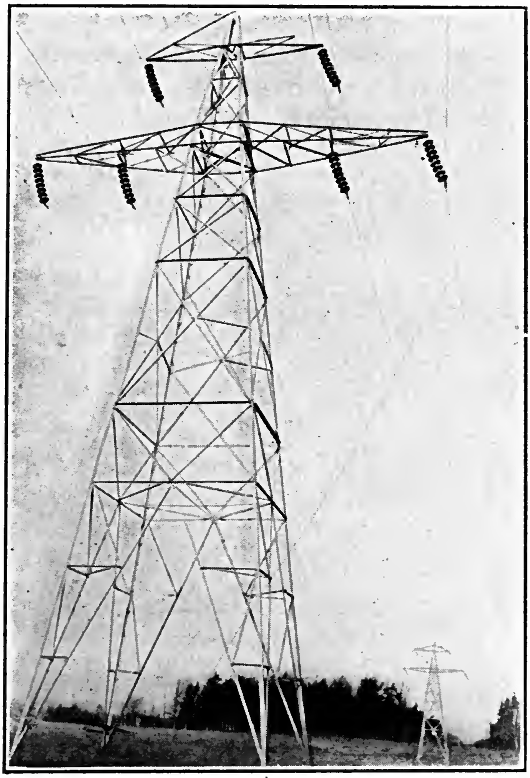


Fig. 61.—Double circuit tower shown in Fig. 60.

The raising or erection of towers is ordinarily, comparatively simple, dependent in cost and progress upon the skill and ingenuity of the foreman in charge, and his aptitude for "rigging."

Several different methods of raising towers have been employed by different construction men, such as using a tall gin pole with blocks at the top, a two-gin-pole arrangement, shear legs, and a variation from straight shear legs, where an A-frame or a shear pole with a 6-in. or 8-in. sheave at the top was used.

High gin poles with the raising blocks attached at the top, and the fall-line reeved through a snatch block at the butt, have been used in the construction of many important lines, as have tall A-frames similarly rigged; arrangements of this kind, however, are heavy to place in position for work and to transport, though by the use of trucks permanently attached to A-frames, they may be made quite convenient in this latter respect. A typical view of a tower being raised by means of a high gin pole is shown in Fig. 62; where such a pole is used as shown, it must be set outside of the line of the anchors, it requires considerable time to erect and guy, and must be quite carefully handled in lowering after the tower is raised. This method of raising is being supplanted by the shear-pole rig.

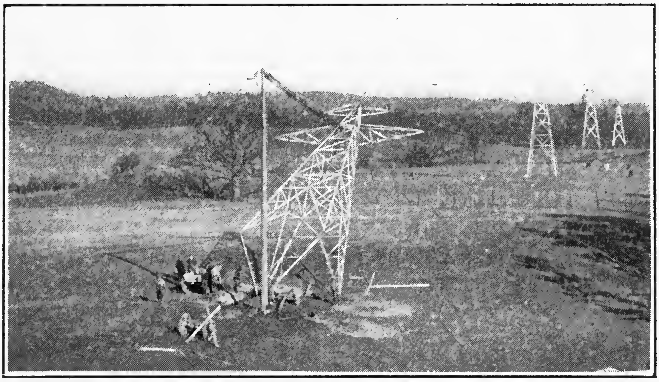


Fig. 62.—Raising tower with tall gin pole.

An arrangement using two gin poles, one on each side of the tower and practically lifting it, is shown in Figs. 63 and 64; this method involves the use of two fairly tall gins with their guying and attachment of the blocks to the structure, and their two fall lines; while it may work out very well for certain types of structures, it is not to be preferred over that of using one gin pole, and certainly not over that of employing a shear rig.

For all-around purposes, the writer believes that shear legs, or a shear or gin pole provided with a sheave at the top, provide the best rig for raising towers; where the straight shear method is used, the shear legs are inclined ahead at such an angle that, traveling backward as the raising cable is pulled up, it will take the thrust until the tower top has risen far enough to bring the raising pull in a straight line from the tower to the stakes to which the blocks are attached; where a sheave instead of a groove is provided at the top of the frame or pole, the pole is inclined slightly ahead of the vertical and maintained there until the raising line is just clearing, by means of a pair of light blocks hooked into the tower structure at some convenient point. In Fig. 65 is shown a type of shear legs recommended by one of the tower manufacturing companies for raising towers up to 3000 lb. in weight and about 80 ft. in overall height, and in Fig. 66 is illustrated a shear pole as often used, provided with a 6-in. or 8-in. sheave at the top; in lieu of this latter, the writer has often used an ordinary 6-in. top, 30-ft. cedar pole with a 6-in. snatch-block hooked in a guy-strand sling at the top, with a through bolt at the top to prevent slipping; in using this improvised rig care must be taken to see that the pole does not turn or twist so as to foul the sling and prevent it from pulling off clear, when the raising line ceases to bear.

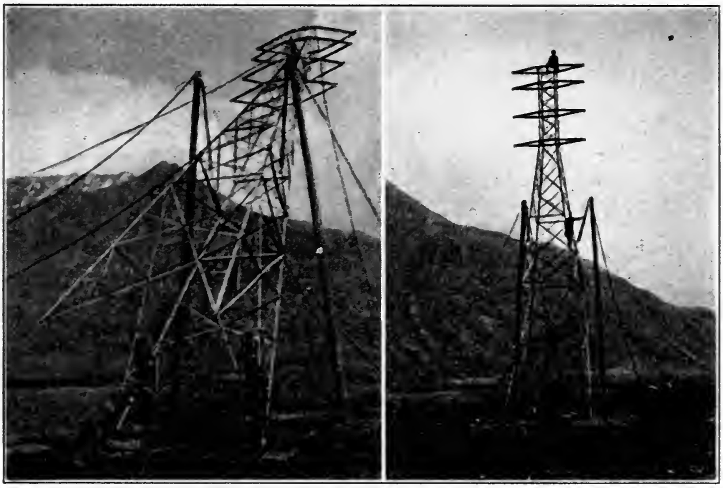


Fig. 63. Fig. 64.

Raising tower—two gin pole method.

An A-frame made up of 3-in. pipe suitably braced and provided with a sheave at the top, and arranged so that its width at the base was the same as that of the tower, has been used with very satisfactory results by bolting the frame to the bottom main members of the tower and leaving the lower ends of the A-frame to project and by the thrust of the cable in raising, dig into the ground and take care of the horizontal thrust of the structure as it is being erected; the objection to any kind of an A-frame, however, is that it cannot be handled as easily or as roughly from place to place, as a simple pole can.

The height of any kind of shear fixture need not be more than 30 ft. to 35 ft. for towers up to 70 ft. or 80 ft. in overall length, and a 6-in. top cedar pole will handle all ordinary work. To prevent the butt of the fixture or pole from slipping, it may be shod with a 6-in. or 8-in. spike, it may have the lower end sharpened, or as has worked out very well in the case of a single pole, it may be set into a shallow hole, 8 in. or 10 in. deep.

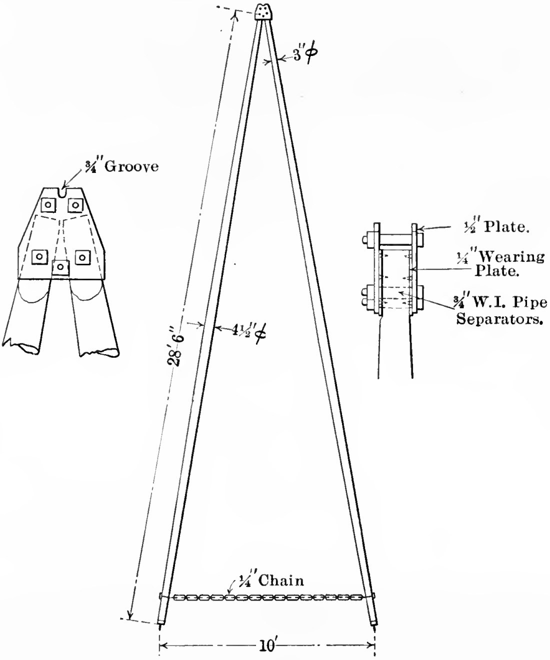


Fig. 65.—A-frame for raising towers.

To take up the horizontal thrust in raising, the bottom of the tower must be secured in some way, which in addition to per-forming that function also facilitates its rotation about the ends of the bottom legs as its comes up; this is usually done by the use of some form of trunnion, varying from an elaborate set, in which each leg is bolted to a separate roller provided with two bearing blocks each, equipped with stake chains for anchoring, to a field-made device consisting of a "borrowed" section of cedar pole, about 6 in. or 8 in. in minimum diameter and about 4 ft. or so longer than the width of the base of the tower, to which the ends of the main members are bolted; in the case of the section of old pole, the ground provided the bearing and the stake chains were pieces of rope, snubbed back to stakes.

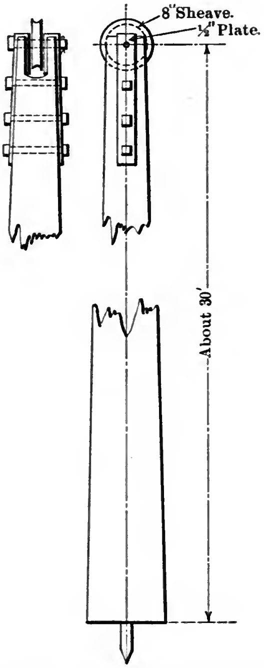


FIG. 66.—Shear pole for raising towers.

Either a long 6-in. or 8-in. diameter roller, similar to the improvised rig just described, provided with bands (inside of which the roller can turn easily) to which stake chains are attached to hold the trunnion against the raising thrust, such as is shown in Fig. 67, or the two-roller method with bearing blocks as described will give satisfactory results; the use of the pipe

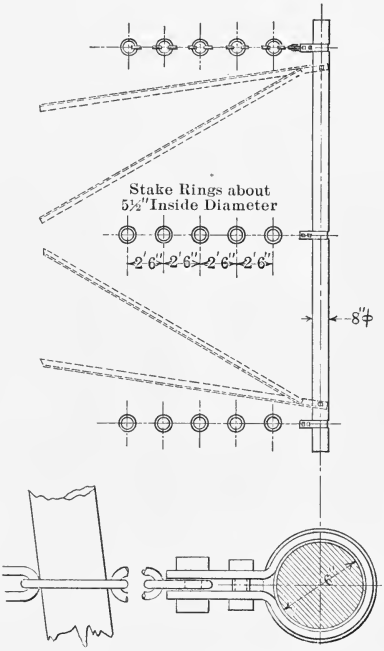


Fig. 67.—Raising trunnion.

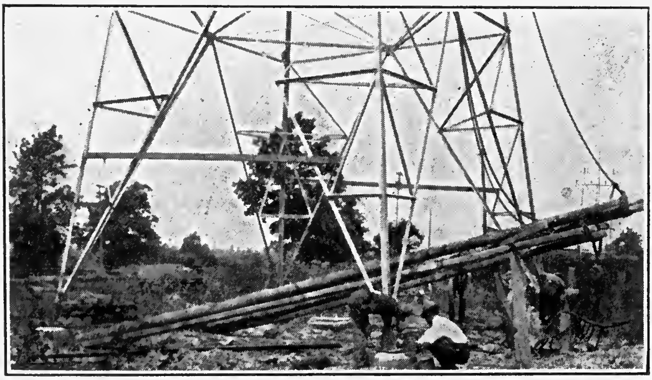


Fig. 68.—Raising struts—used to reinforce tower against strain of erection.

A-frame, doing away with any special arrangement, is also satisfactory in solid ground; the writer's personal experience causes him to favor the long single-roller method, except probably in the case of heavy towers.

In the raising of many types of towers, they must be braced at the bottom in order to withstand the strains produced in the erection; this is usually specified in the manufacturer's proposals; ordinarily 3-in. ×3-in. or 4-in. ×4-in. stuff will be ample and in the course of most jobs, the bottom bracing is secured as needed along the right-of-way. Fig. 68 shows the application of this reinforcement.

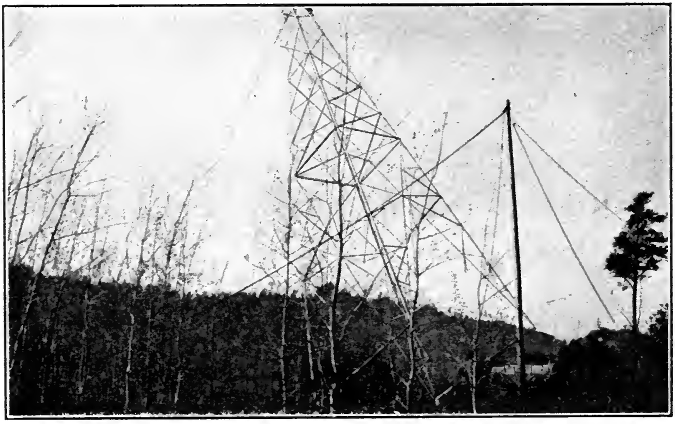


FIG. 69.—Raising tower with shear pole.

Figure 69 shows the raising of a tower with a shear pole provided with a sheave at the top; in this case it will be noted that a fairly high pole is used, and that it is set outside of the line of anchors and is not dropped when the tower-raising line clears.

Figures 70, 71, 72, 73 and 74 show the steps in raising a tower with the shear pole set at about the center of the space enclosed by the anchors and the series is self-explanatory; it will be noted that the work is being done with the improvised rig described earlier in the chapter.

In general, for the raising of a structure by almost any method, the actual time required for the erection itself is only a small part of the average time consumed, and so the efficiency of the methods, when compared with each other, will depend in each case upon the ease and rapidity with which the rigging can be taken down, transported to the next tower location, and set up again.

Fig. 70. Fig. 71.

Fig. 72. Fig. 73.

Raising tower with short shear pole.

Where a shear-pole method of raising is used, the general routine of raising a tower will require a crew consisting of a foreman, six men, and a team and teamster; and equipment and rigging of one 6-in. top, 30-ft. to 35-ft. pole with a 6-in.

or 8-in. sheave mounted at the top, one long roller-trunnion, about 6 in. or 8 in. in diameter and of the length called for, two 4-in. × 4-in. raising struts as may be required for the particular tower, one 3/4-in. flexible plough-steel raising cable about 200 ft. to 250 ft. long, provided with a half dozen or so Crosby clamps, one team chain, two special stake chains (chains made up with rings about 4 1/2 in. or 5 in. inside diameter, to receive stakes about 3 1/2 in. to 4 in. in diameter, spaced 2 ft. or 3 ft. apart throughout their length), a set of three-sheave 8-in. blocks reeved with 3/4-in. or 7/8-in. rope to extend 75 ft. or 80 ft., one pair double-sheave 6-in. blocks with 5/8-in. line to extend about 50 ft., one pair 4-in. double-sheave blocks with 5/8-in. line to extend about 50 ft., three 50-ft. 3/4-in. lines for guying shear pole, two 3/4-in. lines about 100 ft. long for tower side guys where they may be needed, twenty or twenty-five 4-ft. stakes about 4 in. in diameter, and a few post-mauls, shovels, wrenches and axes. The rigging will be loaded into a wagon

FIG. 74.—Raising tower with short shear pole.

with the gin pole dragging behind in moving from tower to tower, as also may the raising cable if desired, or the whole outfit can be carried; if they are snaked along, the time of coiling and uncoiling the cable will be saved.

Upon arriving at the tower to be raised, one man will scoop out a shallow hole for the butt of the gin pole if it is not shod, four of the men will carry the gin pole into position, lay out the guys and 4-in. blocks and drive guy stakes, etc., while the other man and the teamster will unload the rigging from the wagon. Then two men will set the tower back-guy stakes, two men the pulling stakes, and the other two will carry the raising line up in place and fasten it to the tower at about the lower cross-arm by means of the team-chain used as a sling; this done, the 6-in. back-line blocks will be laid out and hooked on and the 8-in. raising blocks extended; then the raising cable will be placed in the sheave of the shear pole, and the pole raised into place by means of the 4-in. blocks pulling from a sling fastened to one of the bottom members of the upper face of the tower, the men helping in this by lifting at the start; if raising struts are required they should preferably be placed before the pole is raised. The shear-pole guys are then snubbed to their stakes, and the trunnion or roller placed in position, bolted in place, blocked level where necessary, or all around where the ground is soft, and the thrust stakes driven; if the tower is lying a little at an angle to the line, enough slack may be left in one of the trunnion chains as may be necessary to correct this by letting the tower swing into its proper position as the strain comes on, but care should be taken that none of the stakes will interfere with the cross-bracing of the tower as it comes ahead, or for that matter, that the bracing will not foul the tops of the stakes as the tower raises up.

With the placing of the trunnion everything is ready for the erection, and the raising blocks are hooked into the cable with the fall line pulling away from the tower; to prevent the blocks from twisting, a weight of some kind, such as a post-maul, is fastened to the head raising block; the team is hooked to the fall line and one man stays with the teamster, one goes to the tower back guy, one to the shear-pole blocks to keep the pole in position until the cable clears it, one watches the trunnion, and the other two watch side guys and stand ready with drift pins, wrenches and bolts.

As the team starts, the tower takes the slack out of the trunnion chain and comes up nicely—usually—the team going slowly and evenly; as the line clears the shear pole, this is dropped back and the men with tools watch as the tower is slowly pulled into a vertical position and signal for the team to stop as the ends of the corner posts come within a short distance of the tops of the anchors, and with the team holding their slack, the tower is worked into position by the man at the back guy, with such shifting of the trunnion, which may have to be loosened, as may be required; as the ends of the corner posts slip over the anchors, they are caught in position with a drift pin and bolts loosely inserted; with the forward legs fastened, the tower is pulled over a little so as to remove the strain from the trunnions, the back guy following up, and the trunnion is removed, the tower let back and the legs bolted in place; the bolts are then set up all around and the erection is completed.

The erection of a flexible structure is carried out along the same lines, with the exception that in most cases the design is such that no trunnion is required, the ends of the main members being connected with one bolt on each side and serving the purpose; the raising of one of the riveted type of flexible towers with heavy channel main members, it is apparent, therefore, is very easy, and as the same methods apply in either case no special mention need be made of the same.

The number of towers that can be raised a day by a crew such as described above, will vary with the design of the tower, its weight, the weather, the location, the condition of the ground, the crew itself and the "luck" they have.

On a job in the Middle West, with a crew as above outlined, the cost of raising 50-ft. single-circuit towers weighing about 1900 lb. each, averaged about $3 per tower, with the crew raising about eight towers daily; the work was carried on in the late fall and early winter and the men were quartered in camps; shear poles and A-frames, with sheave at the top, were used for erecting. On another job, as noted in the *Electrical World* for Sept. 9, 1911, the cost of erecting 45-ft. single-circuit towers of medium weight was $6.10 each, using twelve men with gin-pole rigging; a maximum of fourteen towers was erected in one day; it will be noted that this line is only about 8.5 miles long. In the line work in connection with the Roosevelt Dam Reclamation project, where light 35-ft. to 40-ft. double-circuit towers were used, a crew of six men would average about ten towers erected each day; no wage scale is given.

The cost of erecting the single-circuit towers of the Ontario Hydro-Electric Power Commission system, 45-ft. standard and weighing 3200 lb. averaged $3.50 each, the work being done in the summer and early fall; the raising cost of the 45-ft. 3995-lb. double-circuit towers on the same system was $4.75 each, with a minimum of $2.45. During the summer time the crew of five or six men, foreman, and team, could, with "good going," raise eight towers every day. It may be noted that on this work gin poles, A-frames and shear legs were all used, the most satisfactory results being obtained with the latter.

On the 4.2-mile line built in the West, with the high-priced labor conditions, the cost of erecting 4400-lb., 45-ft. towers by the two-gin-pole method shown in Fig. 63, is given as $9.80 per tower.

The labor costs on steel construction have in general been higher than would appear necessary, this being due, in many cases at least, to the fact that the work being line construction, it has been assumed that linemen must be employed, regardless of whether or not the same work could be done as well by ordinary labor; of course there are places where common labor will not do and likewise localities where labor organizations call for certain classes of mechanics for certain parts of the work, and a skilled-labor price may have to be paid for unskilled-labor work.

The influence of this feature on the cost of steel construction is conclusively proven in the case of two similar lines of about the same length, one of cedar pole and the other of steel tower construction, built by the same operating company under about the same conditions, where the steel tower line was built at a substantially lower first cost than that of the wood, as noted in Chapter XII. The company cites as the reason for the difference the fact that the tower line work, wire stringing and all, was done with common labor.

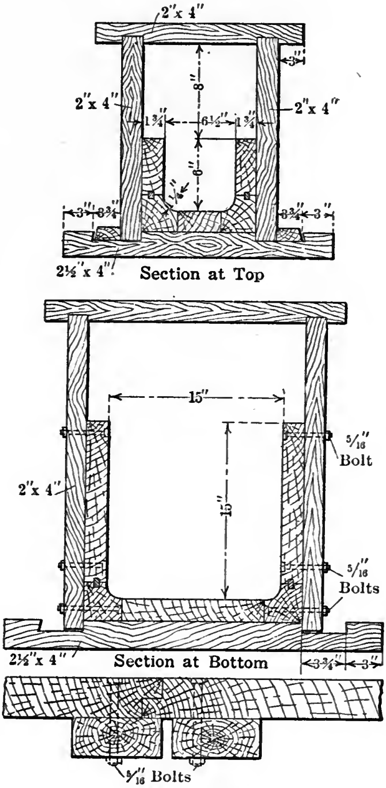
With systematic plans for carrying on the work and with judicious selection of labor and equipment, there is no reason why the present average labor cost of steel tower construction cannot be reduced.

CHAPTER VII

Reinforced Concrete Construction

Reinforced concrete poles are divided into two general classes, the solid and the hollow types; the latter include such as are built with the major portion hollow and the rest solid.

The solid type is the one that has been used in a great deal of the construction of this character in the United States, probably the main reason being that isolated companies have all built their own poles, and the work being to a great extent a preliminary investigation as to the possibilities of concrete in line construction, have not cared to go to any great expense for forms or appliances, such as would be required for molding hollow poles. In the casting of solid poles most companies have employed horizontal forms, though there have been several instances of poles of great size where it was deemed expedient on account of their weight, to build vertical forms at the pole locations and cast them in place, so that upon the removal of the forms the poles would be ready for service, after seasoning a reasonable length of time.



Section at Top

Section at Bottom

Detail of Splice

Fig. 75.—Forms—Marseilles Land and Water Co.'s concrete pole.

The forms for poles consist of tapered troughs of usually square or hexagonal section, made of wood throughout, or of wood sheathed with galvanized iron, so constructed that the sides can be readily removed after the concrete has set for a day or so; where poles of square section are used, they are generally made with the corners rounded off or beveled, not only adding to the appearance of the poles, but making them easier to handle.

The general requirements of a form for pole work are the same as for any kind of concrete work where the forms are to be used over and over again; the material should be such that there will be no warping, and the construction should be such that there will be no leakage in using sloppy concrete, no distortion or bulging of the sides when filled, and that it be sufficiently rigid to retain its shape with ordinary handling. A sheet-metal form properly braced, probably combines these qualities to the greatest extent and should be superior to wood, though cypress has been used with very satisfactory results.

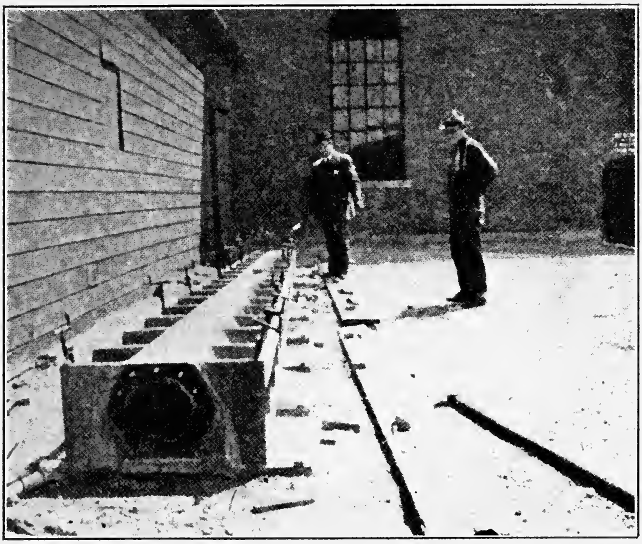


Fig. 76.—Forms used for Oklahoma Gas & Electric Co.'s hollow concrete poles.

The steel for reinforcement has in most cases been some type of bar with a mechanical bond and in many cases has been provided with a spiral wrapping of wire similar to a Considere column, or with bands fastened to the longitudinal rods; it appears, however, that the use of this spiral or band reinforcement in many cases is due more to the necessity for a means of tying the steel together for handling, than it is to a knowledge of the increased strength resultant upon its employment.

As an example of what is probably the largest installation of solid concrete poles for purely transmission purposes in the United States to-day, a description of the pole used by the Marseilles Land & Water Company of Marseilles, Ill., will be of interest; the total length of this concrete pole line is about 30 miles. The standard pole length is 30 ft. with a 6-in. square top and a 9-in. butt; the reinforcement, as shown in section at ground in Fig. 77, consists of six 1/2-in. square high carbon rods located 1 1/2 in. from the face of the pole and running the length of the pole, with two 1/2-in. rods similarly located, extending only 7 ft. up from the butt; as described in the *Engineering Record* for May 21, 1910, the full length steel is distributed so as to take care of the heaviest strain in the direction of the line instead of transverse to it. The poles are designed for two three-phase circuits of No. 4 B. & S. copper carried in 125-ft. spans.

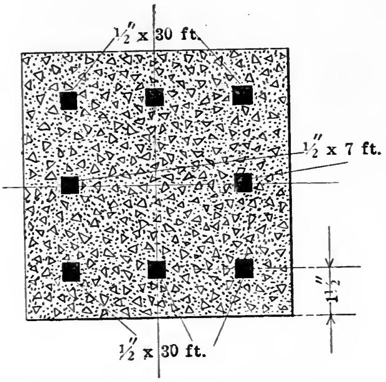


FIG. 77.

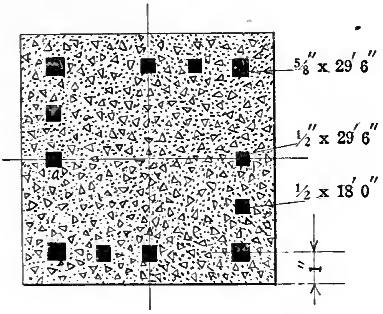


FIG. 78.

The poles were molded in wooden forms, sectional views of which are shown in Fig. 75, a mixture consisting of 1 part cement to 5 parts gravel being used; the gravel graded from fine sand up to stones from 1/2 in. to 3/4 in. in diameter. The sides of the forms were removed in twenty-four hours and then after curing for two days longer, the pole was turned on its side and the bottom removed, after which the pole was allowed to season from two to three weeks or longer before being considered ready to set. This design of pole in the 30-ft. length weighed about 1700 lb.

The Welland Canal concrete pole line is probably one of the next largest of this type of construction used for transmission purposes, not including poles used in city distribution work, being about 12 miles long with 35-ft. poles as standard. As described in the *Electrical World* for Nov. 3, 1906, this line is designed to carry two three-phase circuits in 220-ft. spans, the poles being figured for a horizontal pull at the top of 2000 lb.; with the 35-ft. length as standard, the pole heights vary from that up to 75 ft.

Quite extensive use of solid concrete poles has also been made for electric railway work, by the Fort Wayne & Wabash Valley Traction Company, the Syracuse Rapid Transit Company, and the Cleveland Railway Company. The poles for this class of work have been about 30 ft. in length and of square section, and in the case of the first-mentioned company, eight 1/2-in. square twisted bars were used the full length of the pole, a bar being placed at each corner and at the middle of each face, the steel being located 1 in. in from the face of the pole; no hooping or transverse reinforcement of any kind was used. In molding these poles the method of procedure was as follows: About 1 in. of concrete was placed over the entire bottom of the form, on which were laid the three bars for the lower face, then the form was poured half full and the two bars for the middle of the side faces placed, after which the concrete was filled in to within 1 in. of the top, the three bars for the top face placed, and the concrete poured in to complete the pole and trowelled smooth. In the casting of this pole no tamping at all was done, reliance being placed upon trowelling and spading to secure a homogeneous structure; it is apparent that it would not be feasible to subject a structure of this kind with loosely placed bars to indiscriminative tamping, and it is questionable if very uniform results can be obtained without having the steel held in place or fabricated in some way, so that this may be done.

Both the Syracuse Rapid Transit Company and the Cleveland Railway Company have also constructed their poles along similar lines without fabricated reinforcement, and details of the Syracuse pole as described in the *Engineering Record* for Oct. 1, 1910, are given below.

This pole is made with 6-in. top and 11-in. butt, is f30 t. long and square in section, with a 2-in. bevel on corners above the ground line; it is more heavily reinforced than the Fort Wayne pole just described. In each corner, as shown in Fig. 78, a 5/8-in. twisted bar was used, running the full length of the pole, with a similar full-length 1/2-in. bar in the middle of each face, then in each face midway between the two full-length bars was placed an 18-ft. 1/2-in. bar, as extra reinforcement for the lower portion of the pole. The steel was all laid in as in the case of the Fort Wayne pole and the concrete was proportioned as follows: 1 cement, 2 sand, and 2 crushed stone, a mix that is quite a bit richer than is ordinarily used in pole work.

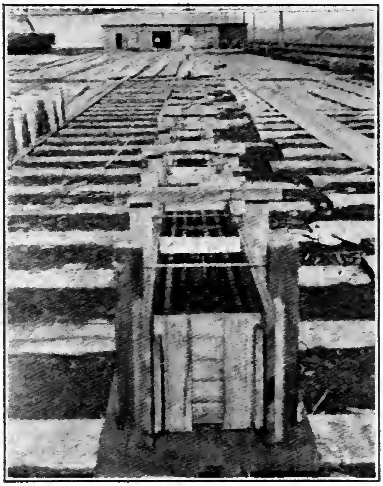


Fig. 79.—Forms and reinforcing steel—Pennsylvania R. R. concrete poles.

Probably the heaviest solid concrete pole line in commercial use for the support of wires of any kind, is the telegraph and telephone lead of the Pennsylvania Railroad built across a 5-mile stretch of swamp land on the Meadows Division between Newark and Bergen Hill to carry ultimately sixty open wires and two forty-pair cables in average spans of 120 ft., described in the *Electrical World* for Sept. 2, 1911. The design which was made by R. D. Coombs, is based upon a maximum load of 6000 lb. applied at a point 6.5 ft. below the top. The poles are of square section with chamfered corners and the steel is fabricated, mechanical bond bars tied together with horizontal bands, being used, as will be noted in Fig. 79. The mix was 1:2:4,

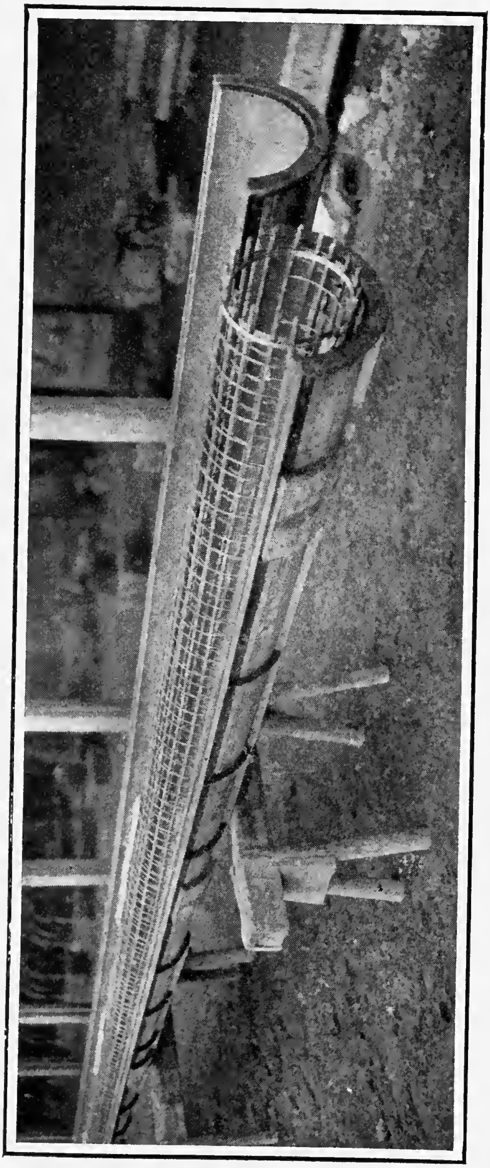


FIG. 80.—Form and reinforcing steel—centrifugal type concrete pole.

well tamped and the steel was located 1 in. in from the face of the pole; the overall lengths of the poles varied from 35 ft. to 65 ft.

While the solid design of pole has been used in the greater number of installations in this country, the commercial development of the hollow type has been given the most attention in Europe, and in this country there is one very notable exception to the general rule.

In Europe the commercial manufacture of poles of hollow design is practised on quite an extensive scale, two machine processes being used, one of which applies the concrete quite wet and the other comparatively dry. The first method is the centrifugal process of Otto & Schlosser of Eisen, Saxony, in Germany, and is described in detail in the *Cement Age* for March, 1911.

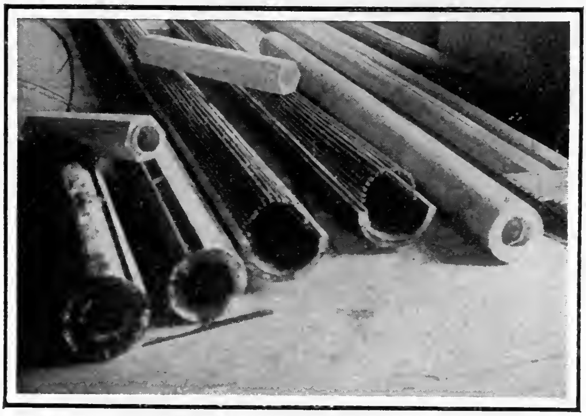


FIG. 81.

The process consists in placing in a tubular form of the desired dimensions, fabricated reinforcement consisting of various numbers of longitudinal bars held in place by an inner and an outer spiral of wire, as is well shown in Figs. 80 and 81, then filling the mold with as much wet concrete as may be required to give the desired wall thickness, and then revolving this shell or form at a high speed in a lathe-like machine, the centrifugal action packing the concrete in a homogeneous layer on the inside walls of the form.

Going a little more into detail, the forms are built up of longitudinal strips or staves of wood, lined with sheet iron, giving the pole a smooth exterior finish, and they are split in halves longitudinally. The reinforcing steel is held rigidly in position by means of small concrete spacing blocks wired to the fabricated unit at different points. In a typical pole 29.5 ft. long, 5.9 in. in diameter at the top and 9.5 in. at the butt, sixteen 1/4-in. rods 29.5 ft. long and fifteen 1/4-in. rods about 19.7 ft. long were used for longitudinal reinforcement, with an outer and inner spiral of No. 11 wire with a screw pitch of 6 in. to 8 in., tying the same together.

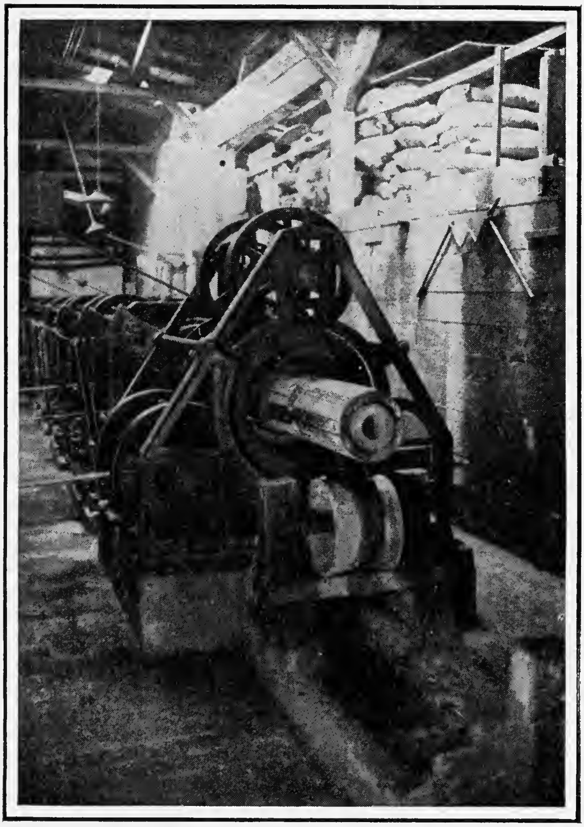


Fig. 82.—Machine used in molding centrifugal type concrete poles.

In the manufacture of this pole, the concrete tends to separate into layers of its individual components upon subjection to centrifugal action, owing to their different specific gravities, and it is found necessary to introduce a binding material to counteract this; disintegrated asbestos fiber is used for this purpose, and tends to mat the concrete and to prevent the sand from being forced to the outside; the addition of the asbestos does not seem to depreciate the strength of the concrete; the mixture used for these poles appears to be about 1 part cement to 6 or 7 parts sand, no information being given as to the percentage of asbestos fiber used.

The lathe or machine developed for the manufacture of these poles is shown in Fig. 82. It consists of a series of units, similar to the one in the foreground of the illustration, provided with suitable clamps and adjustable rollers; in between the rollers are self-centering screw clamps similar to those used on a lathe, and these serve as pulleys for the belting; a line shaft, driven by electric motor, runs the length of the installation of machines and the units are belted directly to this. The speed varies from 500 r.p.m. to 1000 r.p.m., depending upon circumstances. Varying with the thickness of the walls of the pole, the length of time required for the proper formation and compacting of the concrete in the forms, runs from ten to fifteen minutes.

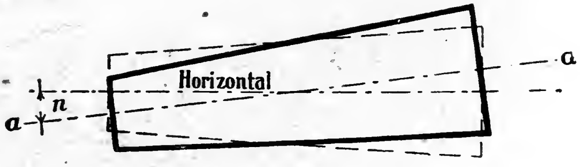


FIG. 83.

By inclining the axis of the form as in Fig. 83, the thickness of the walls of the pole may be varied from top to bottom as desired; for a straight cylindrical pole, the horizontal position of the form will give walls of uniform thickness, but for a pole tapering in diameter, the small end will have to be lowered to secure the same result; the amount of inclination required depends upon the speed of the form and the amount of its taper, and must be determined by experiment.

Upon completion of the formation of the pole, the machine is stopped and a train of rollers such as that shown at the end of the unit in the foreground of Fig. 82, is raised into bearing with the form and it is withdrawn; the pole is allowed to remain in the form for ten to twelve hours after which it is removed and seasoned in damp sand until thoroughly hardened. In Fig. 84 is shown a view of the factory with poles skidded in the foreground much like a stock of wooden poles, and in Fig. 85 an installation of this type of poles in a German city, is illustrated.

The other machine process developed in Europe is the Siegwart; in this an interior form or mandrel is used instead of an exterior shell as in the centrifugal process, and after fitting on this the steel reinforcement, a fairly dry mixture of concrete is mechanically plastered, as it were, on the revolving mandrel in a narrow continuous belt, by means of a combination of conveyor and wrapping of canvas under tension, wound spirally the length of the pole. Both this type and the centrifugal, have given very satisfactory results in Europe.

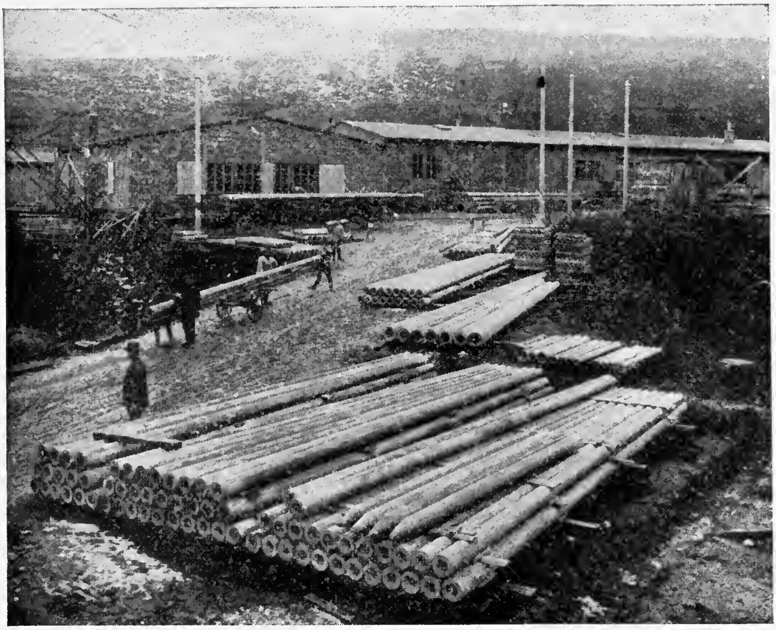


Fig. 84.

In the United States, to the best knowledge of the writer, there is at the present time no installation of machine-made hollow poles, but the Oklahoma Gas & Electric Company of

Oklahoma City has developed a hand-molded pole of hollow design that has been very satisfactory and it now has about 40 miles of line carried on this type of pole, mainly for city distribution work, though some transmission line is included. It has some poles that have been in service for five years that show no apparent depreciation.

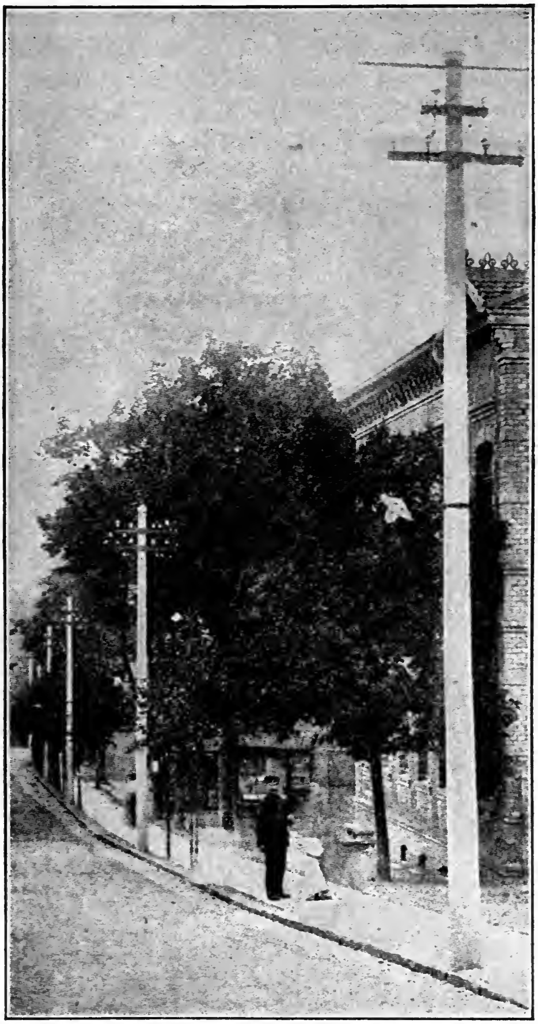


Fig. 85.—Centrifugal type concrete poles.

As described in the *Electrical World* for May 25, 1911, most of the poles are 35 ft. in length and the standard dimensions for this size are 7 in. at the top, and 16 in. at the butt, with walls approximately 2 3/4 in. thick; these poles are hexagonal in section and are reinforced with twelve 1/4-in. twisted or mechanical bond bars, an unusual departure from other processes being to maintain these rods under considerable tension during the casting of the pole and until the concrete has set sufficiently hard to support the strain itself.

Fig. 86.—Oklahoma Gas & Electric Co.'s concrete poles.

The external form for this pole, shown in Fig. 76, is made of 1/4-in. galvanized iron, braced with transverse ribs, and is made in sections; the internal form is made to telescope or collapse within itself and is removed as soon as the concrete will bear its own weight; a mixture of 1 part cement to 2 parts sand and 3 parts crushed stone, is used.

This type of pole has been developed, and several of its features patented, by F. H. Tidnam, general manager of the Oklahoma

Gas & Electric Company and has been adopted by that company as standard for the construction of all principal lines. Fig. 86 shows a line of these poles used for city distribution work; as will be noted these poles are not stepped as is the case in many installations, extension ladders being used by the linemen in substitute thereof.

Load tests of concrete poles of various designs have been very gratifying, though naturally there is great variation in results obtained, as would be expected from the different methods of applying the reinforcing steel and the variety of concrete mixes employed. The pole built by the Syracuse Rapid Transit Company for trolley purposes was given a thorough test as noted in the *Engineering Record* for Oct. 1, 1910. This pole was 30 ft. long with 6-in. top and 11-in. butt reinforced as previously described and set 6 ft. in the ground; load was applied at a point 3 ft. down from the top, and under a strain of 1100 lb. the deflection was 3 in., and with 1250-lb. load, this increased to 3 3/4 in.; the pole failed at 3300 lb. The failure occurred at the ground line and from a study of the illustration of the broken section, accompanying the article in the *Engineering Record,* it appears that the spalling off of the concrete from the buckling of the rods on the compression side caused the failure to occur at a lower load than would have been the case if the reinforcement had been provided with transverse ties or a spiral web reinforcement.

A solid 30-ft. pole with 7-in. top and 12-in. butt, tests of which are given by W. M. Bailey of Richmond, Ind. in an article in *Concrete Engineering* for March, 1909, showed better results as far as ultimate strength is concerned, than the Syracuse pole. This pole was reinforced with four 5/8-in. high carbon twisted rods "thoroughly bound together with No. 9 binding wire" to quote the original article, no data being given as to pitch of spiral. The pole mentioned in the test was set 5 ft. in the ground and showed the following characteristics under load:

840 lb. applied at top in a horizontal direction........ 6-in. deflection.
1780 lb. applied at top in a horizontal direction........ 17-in. deflection.
2800 lb. applied at top in a horizontal direction........ 30-in. deflection.
(Slight cracking noted.)
3640 lb. applied at top in a horizontal direction........ 36-in. deflection.
(Crushing at ground line.)
7200 lb. applied at top in a horizontal direction........ 60-in. deflection.
(Crushing badly at ground line.)

The pole deflected over 6 ft. before falling; the rods did not break, the failure being due to the crushing of the concrete. It will be noted that this pole, containing considerably less steel longitudinally, though of somewhat greater cross-section than the Syracuse pole, showed an ultimate strength of more than two times that of the same; in the case of the Syracuse pole a dynamometer was used to measure the load, while no information was given as to the means of determining the load used in the Richmond test.

As a rough comparison, tests of single poles are of interest, but in structures built under the conditions that these are, the average result obtained from similar tests of at least four or six poles is preferable, and is the only fair means by which their relative merits can be determined.

In the *Cement Age* for Aug., 1907, comparative tests of concrete and cedar poles are noted, in which the concrete poles showed quite uniform results; in this case, however, only two concrete poles were tested and even they were of slightly different design. One of these poles was octagonal in section and the other was square, both being hollow for two-thirds of the total length, the top section being solid; the thickness of the walls of the lower two-thirds varied from 1 3/4 in. to 3 in. These poles were both designed for a load of about 1000 lb. applied horizontally at the top, and were figured with a safety factor of 3; the octogonal pole was 8 in. in diameter at the top and 14 in. at the butt, while the square pole was 7 in. at the top and 13 in. at the butt; both poles were 30 ft. overall and were reinforced with four 3/4-in. and four 5/8-in. round rods 24 ft. long.

With the poles set 5 ft. deep in concrete bases and load applied 10 in. down from the top, the octagonal poles showed a deflection of 3 3/4 in. at the top when under a load of 1830 lb. and broke at the ground line at 3150 lb. after having stood 3430 lb.; the square section pole showed a deflection of 2 1/2 in. under a load of 1830 lb. and failed at 3690 lb. It is interesting to note that the two cedar poles tested in comparison with the concrete, both white cedar of 8-in. top and 14-in. butt, 30 ft. long, failed, respectively, at 2530 lb. and 3490 lb. at a point about 7 ft. above the ground line; the wooden poles were set to the same depth and had the load applied at the same point as the concrete poles.

Many tests of machine-cast poles are recorded, among them a series on some of the centrifugal type conducted by the Royal Mechanical and Technical Institute of Dresden, Germany, as noted in *Cement Age* for March, 1911. Three poles of the following dimensions were tested: length, 29 ft. 6 in.; top diameter, inside 3.75 in., outside 5.9 in.; butt diameter, 5.5 in. inside and 9.5 in. outside; the materials used per pole were 70 lb. cement, 539 lb. sand, 160 lb. water, sixteen 1/4-in. steel rods 29 ft. 6 in. long, and fifteen 1/4-in. rods 19 ft. 8 in. long, the rods being held in position by an inner and outer spiral of No. 11 wire with a screw pitch of from 6 in. to 8 in.

The first pole tested, was placed horizontally and gripped 5.9 ft. from the butt and a load giving a deflection of 3.6 in. was applied and removed repeatedly without showing material permanent set; poles Nos. 2 and 3 were set vertically to a depth of 5.9 ft. and were tested with horizontally applied loads, the first breaking at 1195 lb. with the maximum deflection recorded of 45 1/8 in. at a load of 1175 lb., and the second at 1115 lb. with a deflection of about 42 1/2 in. at 1110 lb.

These tests show a greater uniformity than those of solid hand-cast construction without fabricated reinforcement, as might only be expected from a consideration of the respective methods of manufacture.

In the *Engineering Record* for Nov. 19, 1910, a test of a Siegwart process pole is noted. This pole was 26.24 ft. long, 7.5 in. in outside diameter at the top and 10 in. at the butt, with walls about 1.2 in. thick, reinforced with thirty-two 1/4-in. rods. It was tested horizontally, being gripped 4 ft. from the butt; with 550-lb. load the deflection was 2.2 in. with a permanent set of 0.16 in., with 1320-lb. load the deflection was 9.5 in. with a permanent set of 1.9 in., with 1690-lb. load the deflection was 17.9 in. and the permanent set 8.3 in., the pole failed finally at about 1960 lb.

The hollow hexagonal 7-in. top, 16-in. butt, 35-ft. poles used by the Oklahoma Gas & Electric Company, from tests made on line poles in place, are assumed to be safe for a horizontal strain of 1500 lb. applied at the cross-arm.

Owing to the great weight of the solid type of concrete poles, as used in most installations in this country, the tendency has been to use them in the shorter lengths, generally from 30 ft. to 35 ft., with a few exceptions; with the development of several simple practical methods of casting a hollow pole, it is very likely that poles of greater lengths will be available on a commercial basis for the construction of cross-country lines.

The 6-in. top, 9-in. butt, 30-ft. solid poles used by the Marseilles Land & Water Company weighed about 1700 lb. and the 60-ft. poles used on the same job, which were constructed with about the same taper, weighed 8500 lb.; the Meadows Division, Pennsylvania Railroad poles weighed about 5300 lb. for the 35-ft. lengths aud 17,300 lb. for the 65-ft. lengths; the 35-ft. Welland Canal poles weighed about 5000 lb. and the 50-ft. poles, 10,000 lb. each. In the poles used for trolley work, in 6-in. top, 11-in. butt, 30-ft. solid pole used by the Syracuse Rapid Transit Company weighed about 2550 lb. each.

In the hollow design, the weights of the poles are materially reduced and do not present the difficulties of erection that the solid poles do. The standard 35-ft. 7-in. top, 16-in. butt, hexagonal section hollow pole of the Oklahoma Gas & Electric Company weighs only about 2000 lb., 550 lb. less than the 6-in. top, 11-in. butt, 30-ft. pole of the solid type built by the Syracuse Rapid Transit Company. In the centrifugal type of pole much data are available on various sizes and loadings of poles, due to the fact that this type as well as the Siegwart, has been manufactured in commercial competition with wood and steel for some years past and naturally many different standard designs have been developed. Below are given specifications and price list, covering sizes and loadings for a few typical poles such as would be required in transmission line work in this country, the data given being selected from the specification list of the standard line of designs manufactured by Otto & Schlosser in Germany, as given in the article by C. H. Furst in *Cement Age* for March, 1911.

It will be noted that these poles are rated with a factor of safety of 5, whereas 4 is usually considered ample in this country, and the completeness of the whole data shows that a closer study of the practical considerations involved in the design of this class of structure has been made in Europe, than has been the case with the builders of poles in this country. Except in a few isolated cases, little attention has been given here to the working out of an economical design for a stated loading with a set factor of safety, the usual aim of the builders being directed to the production of a substitute for an existing type of construction by cut and try methods. This accounts for the paucity of reliable data as to assumptions and computations made for various designs; in the matter of costs, however, information is more definite.

Length, ft. in.	Outside diameter, in.		Thickness of walls, in.		Working load. Safety factor of 5, lb.	Weight, lb.	Cost
	Top	Butt	Top	Butt			
32 10	7.5	13.4	1.97	3.15	1100	2310	$15.76
39 4	7.5	14.6	2.36	3.15	1100	3190	18.58
42 8	6.9	14.6	2.36	3.15	1100	3465	21.74
46 0	6.3	14.6	2.36	3.15	1100	3740	24.86
32 10	7.5	13.4	1.97	3.15	1540	2530	20.00
39 4	7.5	14.6	2.36	3.15	1540	3696	22.82
42 8	6.9	14.6	2.36	3.15	1540	3850	27.16
46 0	6.3	14.6	2.36	3.15	1540	4180	31.26
37 9	8.0	14.6	2.36	3.15	1760	3630	22.50
32 10	8.7	14.6	2.36	3.54	2420	3360	22.18

In the solid type, the 30-ft. poles of the Fort Wayne & Wabash Valley Traction Company were made under a contract price of $7.50 each, while the 6-in. top, 11-in. butt, 30-ft. poles of the Syracuse Rapid Transit Company were built by the company for $10.39 each; it may be noted, however, that the latter poles were more heavily reinforced than the former, about 125 lb. more steel being used. The manufacturing cost of the Oklahoma Gas & Electric Company design of hexagonal hollow pole is given as $6 for the 25-ft. size, and $8.50 for the 7-in. top, 16-in. butt, 35-ft. size; compared with the centrifugal type of about the same characteristics (see *Cement Age* for March 1911, page 146), it appears that this hand-cast pole can be built at a cost closely approximating that of machine-molded types. There is a great difference in manufacturing output, however, between the two processes; with a set of forms costing $45 each and an equipment of fourteen sets, with seven cores, a gang of five men can turn out from seven to eight poles of the 35-ft. Oklahoma City type each day, while in the German factory where the centrifugal type of pole is manufactured, a crew consisting of one foreman, eight men, and four boys, operating one machine, will turn out about 25 poles per day. From this comparison it is evident that with the same amount of labor, the machine method is considerably more rapid, but the increase in output is offset by the greater fixed charges of the machine plant equipment, and the expense for power, maintenance, etc.

The cost of handling any type of concrete pole is a serious handicap to its use in transmission line work, especially in a rough country and in isolated regions, and it may be safely said that its use for country work, at the best will be limited to some form of the hollow type. Concrete poles, if manufactured at a central point, could be shipped as easily as structural steel poles as the same facilities would be required in either case, and they could be unloaded and stored just as well, derricks being used for all handling; in weight, however, they will run about two or three times as heavy as the same length of steel poles for equal safe load rating.

The transportation and handling of the poles for distribution is the most serious feature and it would seem that some form of long-coupled wagon equipped with rollers at the points of support for the poles, or an ordinary wagon, with a gin wagon stationed in the field to unload the poles, will have to be used; in many cases it is possible that poles can be molded at the pole locations more economically than in a yard, but the conditions are so much better for uniformity where the poles are all cast in central yards, that the advantage may be negative.

No general cost data are available for the delivery of poles in the field under average transmission line conditions, but for such as would obtain in the Middle West with fair dirt roads and an average haul of 5 miles or 6 miles, the distribution cost per pole on the basis of 35-ft. poles weighing about 2000 lb. will be about $3 to $5 each; as noted in the *Engineering Record* for Oct. 1, 1910, the cost for the distribution of the 30-ft. poles used by the Fort Wayne & Wabash Valley Traction Company from yard to pole location, ready for erection, was $2 each; it is probable that these poles were hauled out on flat cars, rigged for the economical unloading of the poles at their sites. In general, where concrete poles are used in their natural field for transmission work, that is, for lines with 35-ft. or 40-ft. poles in 200-ft. or 300-ft. spans as standard, with the line built along highways or through fairly level country, the matter of distribution can be worked out satisfactorily.

With the favorable conditions for distribution and setting that obtain with them, electric railways will probably find the use of concrete poles for combination trolley and transmission work to be economical and it will probably be in this line that such poles will find their greatest development; it will be noted that the two foremost examples of transmission lines utilizing concrete construction, are those built where the natural conditions especially lent themselves to the cheap handling and erection of this type of work. In the case of the Marseilles, Ill. line with nearly 30 miles of 33,000-volt construction, the poles were cast in a yard adjacent to a canal, loaded with the yard derrick directly to a barge, floated on this to their locations, and set, in most cases, by means of a derrick erected on the barge; the crew consisted of a foreman and eight men and normally about twenty poles per day were set, the spacing being about 125 ft. The conditions at the Welland Canal also were favorable to the handling of heavy poles, though not allowing the methods followed out at Marseilles.

Where 30-ft. to 40-ft. poles have been set under average conditions, a gin wagon, such as is used for the erection of wooden poles and with about the same crew, has been used. The cost of setting 30-ft. poles of the solid type, in 100-ft. to 125-ft. spans, is given by the Fort Wayne & Wabash Valley Traction Company as $1.62 each, a gin pole or a gin wagon being used; the Oklahoma Gas & Electric Company gives the cost of building, hauling and setting, including cost of steel cross-arms and pins, of its standard 35-ft. poles, at $18 each, estimating that the cost of its concrete construction is about 50 per cent. greater than that of wood. Typical views of the setting of an Oklahoma City pole, secured through the courtesy of J. M. Brown, superintendent of lines for the Oklahoma Gas & Electric Company, are shown in Fig. 87, *a*, *b*, *c*, *d*, *e*, *f*, *g*, *h*.

Concrete poles, properly constructed and adapted to the proper conditions, will undoubtedly be used to an increasing extent; early doubts as to their ability to withstand the ravages of frost and the elements, appear to have been somewhat removed, as they have shown practically no discernible depreciation where they have been in service for several years. In one instance that has been brought to the attention of the writer, poles reinforced with a mechanical bond bar, that had been in service for a few years were cut off at the butt for examination and revealed the fact that the concrete surrounding the bars was crumbled and powdered, leaving the steel loose, but on the other hand, the experience of the Oklahoma Gas & Electric Company,

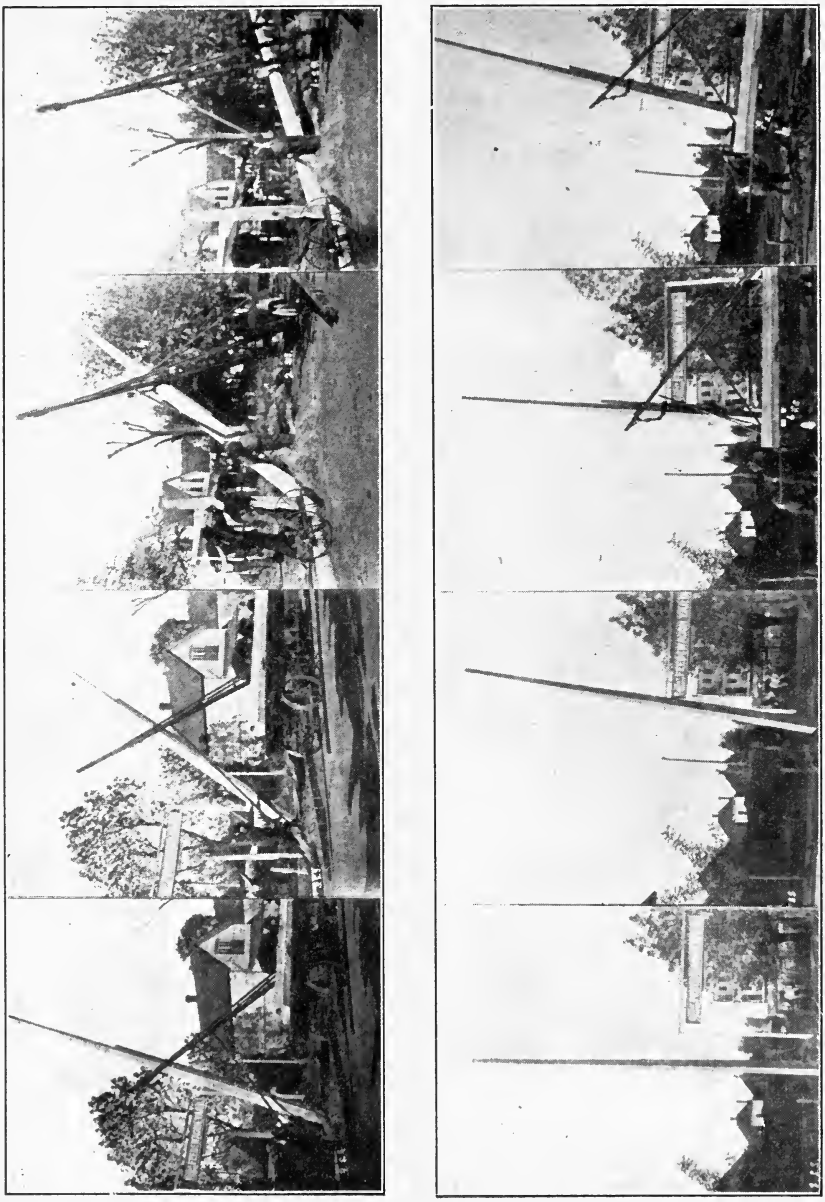


Fig. 87.—Setting concrete poles.

from examination of several of its early poles that were taken down for that purpose, is that the interior of the pole was dry and the steel unchanged; these conflicting experiences may be due to poor concrete in the first case, but this feature merits further investigation. The effect of lightning on concrete poles has not in the actual cases noted up to this time, been serious, though spalling off of the concrete from the bars from this cause has been noted.

Taking all things into consideration, the pioneer work in concrete construction has so far been satisfactory, but with the high average cost of these poles in place, bearing in mind also the uncertainty as to their ultimate life, they can hardly yet be treated as on a par with other types of construction for work of any magnitude.

CHAPTER VIII

SPECIAL STRUCTURES

In almost any transmission line project conditions are encountered for which the standard type of structure is not suitable and cannot well be used; this applies for all materials, wood, concrete and steel, and either special combinations of the standard materials are developed or entirely new designs are worked out to meet with the demands of the extraordinary conditions that arise.

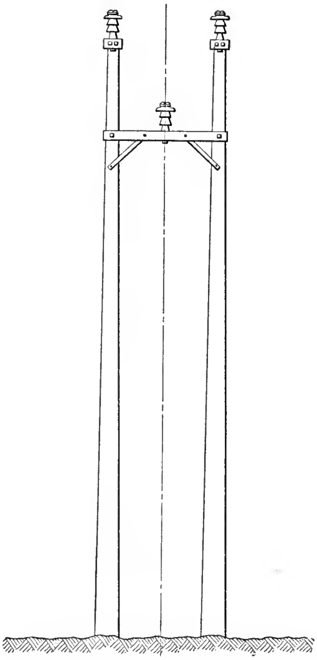


FIG. 88.—Transposition fixture—wooden pole work.

The transposition of the conductors of high-tension lines is generally effected by the use of a special structure, though in the case of lines built with good conductor clearance, transpositions are sometimes made without any change from the standard

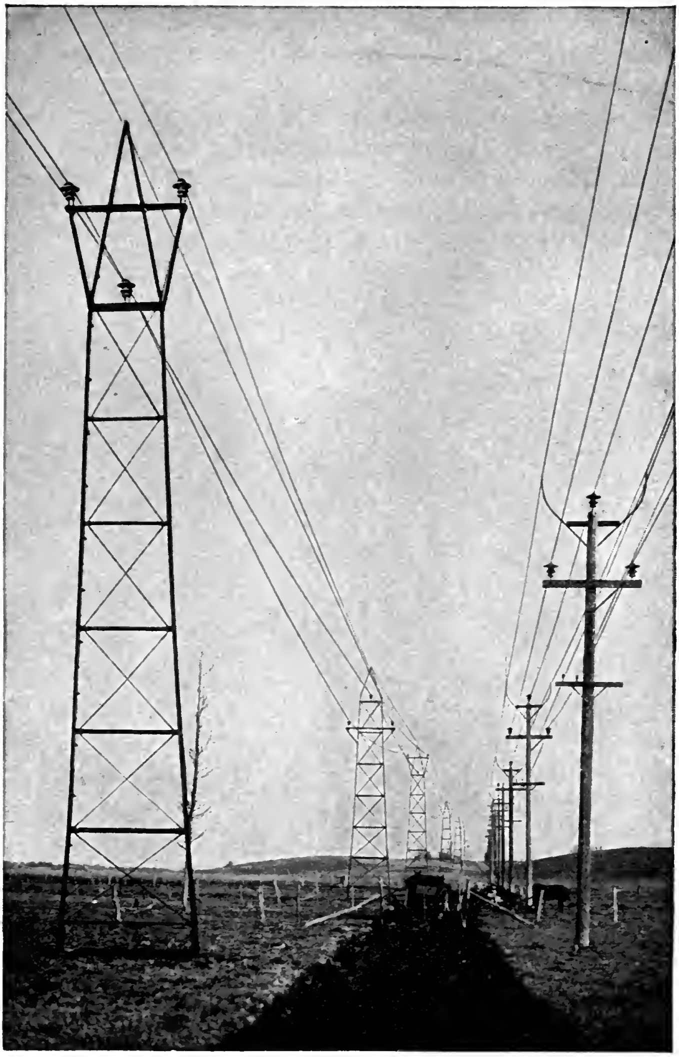


FIG. 89.—Transposition tower—single circuit construction.

construction. A form of special structure used in wooden pole work is shown in Fig. 88; in this structure two standard poles and standard fittings all the way through are used; a fixture of this kind has often been set with the spans on either side only about half the standard length, though in many cases there is no reason why the regular spacing cannot be used, as for instance in the ordinary short-span construction where the conductor spacing is relatively great. The disadvantage of a two-pole structure is that it cannot ordinarily be used where lines are built on public highways and for that reason transpositions in wooden pole line work are often made without any special provisions.

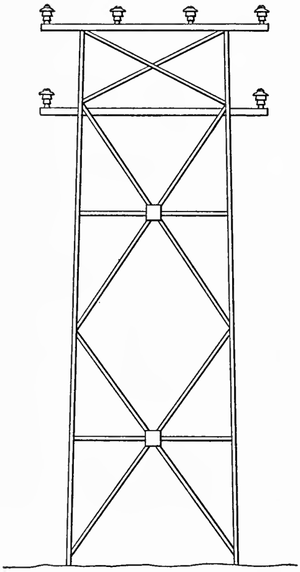


FIG. 90.—Transposition tower—double circuit construction.

In steel tower work special structures are generally employed and are set midway between two standard line towers; Figs. 89 and 90 show typical arrangements followed out in single-circuit and double-circuit construction; as will be noted, the principle of revolving the delta 60 degrees is the same as used in wooden pole work. In Fig. 91 is shown a method of transposition that is somewhat akin to methods employed in telephone work; a standard anchor tower, excepting for the middle cross-arm, is used and the conductors are dead-ended to the regular strain insulators, the jumpers instead of bridging the insulators as in straight construction, crossing over to make the transposition as shown in the illustration. This type of transposition has the advantage of requiring only a standard strain tower with a slight modification and there is no crossing of conductors in mid-span as occurs where transpositions are made in the ordinary way.

In wooden pole work the cost of a two-pole fixture as described, complete in place, will average about twice the cost of a standard line pole of the same height erected in the course of the regular work. In steel tower work the cost of transposition structures along the line of those illustrated will cost from 10 per cent. to 20 per cent. more than a standard straight-line tower, except in the case of the tap transposition, where the structure, with the slight changes necessary, ought not to be more expensive than the regular strain or anchor design.

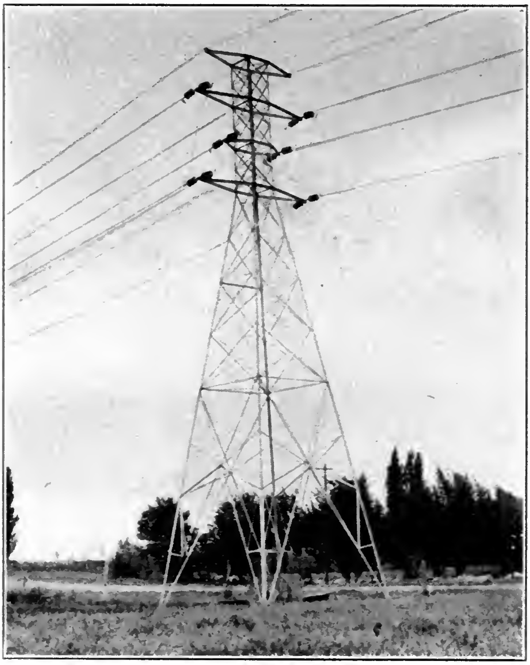


Fig. 91.—Transposition—dead-end and jumper type.

The crossing of rivers, bays, etc., in long spans calls for special

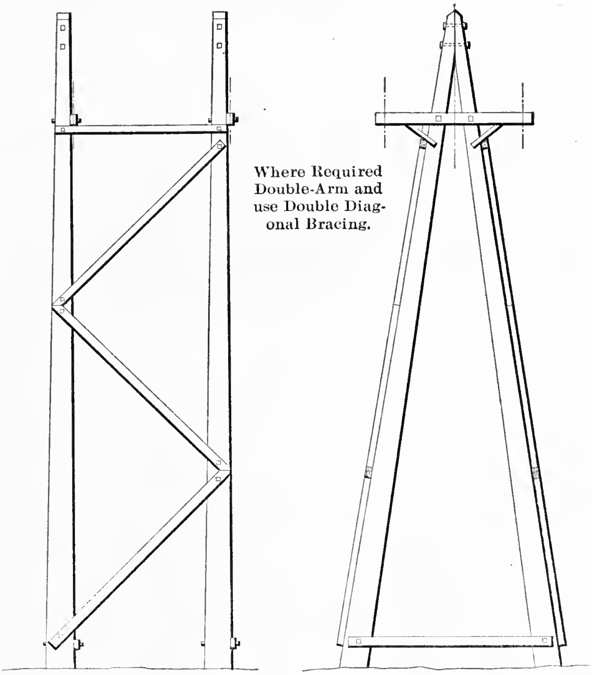


Fig. 92.—Double A-frame structure.

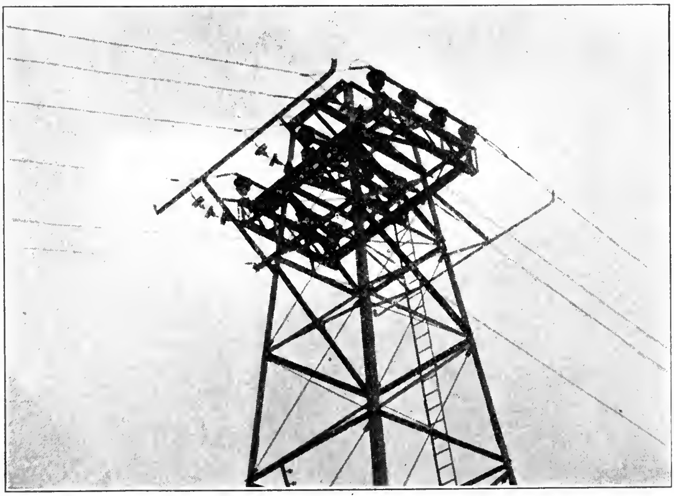


Fig. 93.—River crossing tower.

construction of great strength, conditions being most severe where navigable water courses must be crossed.

In wooden pole work, structures built up of standard poles of the required length will be generally satisfactory except in cases of unusually long spans where the sag required will necessitate the use of a greater length of pole than economical, or where a navigable clearance demands a structure of comparatively great height; for average long-span work, a tower built up of four poles set vertically and provided with suitable cross-arming and bracing has been used much, but a combination of two A-

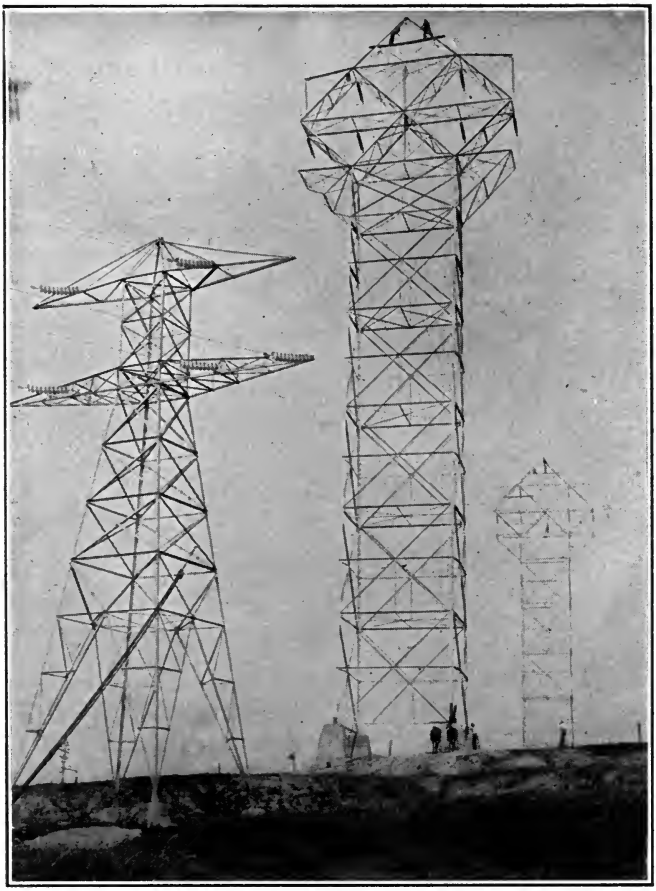


Fig 94.—Welland Canal crossing—Ontario Hydro-Electric Power Commission.

fixtures set either as shown in Fig. 92 or at right angles thereto, gives a better arrangement; where there is a combination of low banks and a quite long span, or where a navigable stream is to be crossed, a steel structure will usually be required.

FIG. 95.—River crossing structure.

In Fig. 93 is shown the top arrangement of a steel tower used to carry three 1/2-in. Siemens-Martin cables in a 1200-ft. span; these towers were 60 ft. high and have a base spread of 18 ft.; the cost of one river tower in place is given as $1375 and that of the complete river span, $3258, including all labor and material. In Fig. 94 are shown the special towers used by the Ontario Hydro-Electric Power Commission in crossing the Welland Canal; these towers were designed to give 150 ft. clearance for vessels and weighed about 50,000 lb. each; they were erected on reinforced concrete foundations.

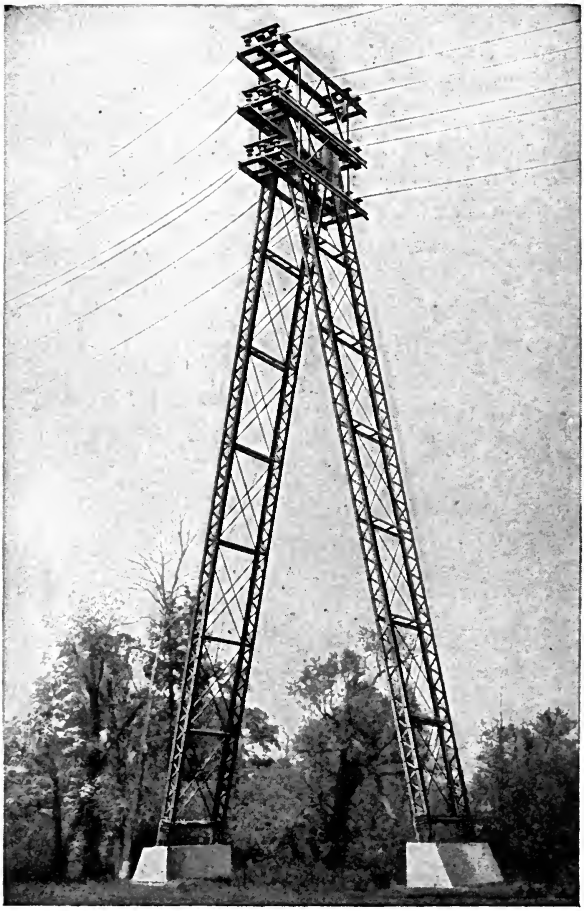


Fig. 96.—River crossing structure.

In Figs. 95 and 96 are shown a type of long-span river-crossing structures that have been developed by the Archbold-Brady Company, Syracuse, N. Y., the first-mentioned being made up with rolled sections for the main members and the latter with built-up sections for these parts; the tower shown in Fig. 95 carries two three-phase 25,000-volt circuits of 5/8-in. nineteen-strand special plough-steel cable in crossing the Susquehanna River near Berwick, Pa., with a span of about 2200 ft.; the towers for this crossing were designed for a working load of 12,000 lb. per conductor. The structure shown in Fig. 96 is 70 ft. high, from the top of the tower to the top of the concrete base and carries a 1000-ft. span of two three-phase circuits of 1/2-in. high strength steel strand, with a maximum strain of 8500 lb. per cable allowed for. The advantage of the type of structures just described is that they are easy to erect and the field expense is very low compared with that for other types.

Fi :. 97.—Disconnecting switch structure.

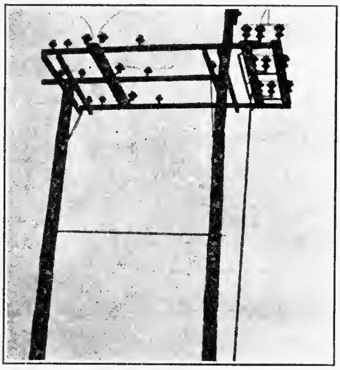


Fig. 98.—Burke switch mounting

In the past few years another kind of special structures has been demanded in transmission line work—towers for the mounting of high-tension line switches. The main considerations in the design of a switch tower are those of operating clearances between opposite phases and the mechanical conditions imposed are, as a rule, simple; the clearance required will depend upon whether the switch is to be operated dead or alive, and if it is to be used for live circuits, whether it is to open a loaded circuit or only the charged line.

Where the switches are more a line disconnecting switch, intended mainly to be opened dead or with very little line current on, a regular vertical breaking hinged switch, mounted as shown in Fig. 97, is often used; the supporting structure here consists merely of two double-armed standard poles, with the arms on which the switches are mounted, arranged between them. Where line current of any magnitude or a loaded circuit is to be opened, switches with either a horizontal or vertical break, provided with horns should be used; for the support of this kind of a switch considerable clearance must be provided between center lines since the arc on breaking the circuit is necessarily heavy. The designs of the various types of switches of this character will be discussed later.

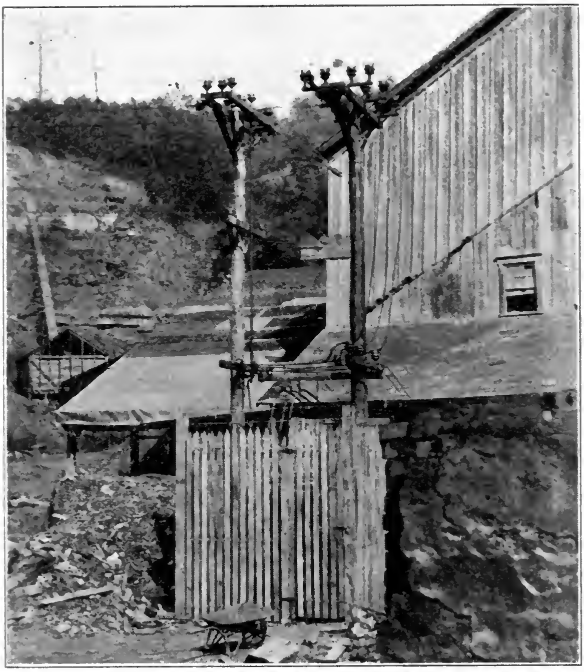


Fig. 99.—Burke switch mounting.

Figs. 98 and 99 show typical wooden pole mountings of a Burke outdoor switch, the first named for 22,000 volts and including a high-tension fuse; the latter for 11,000 volts and including fuse, choke coils, and arrester gaps for an outdoor sub-station; Fig. 100 shows the framing for a Pacific Electric & Manufacturing Company Baum type switch as generally used for disconnecting purposes on 60,000-volt lines; the three insulators comprising each switch unit are now mounted on steel, as shown in Fig. 105, instead of on a wooden arm and where the load is to be interrupted, the spacing between switches is increased about 30 per cent. and horns are provided, as shown in the cut.

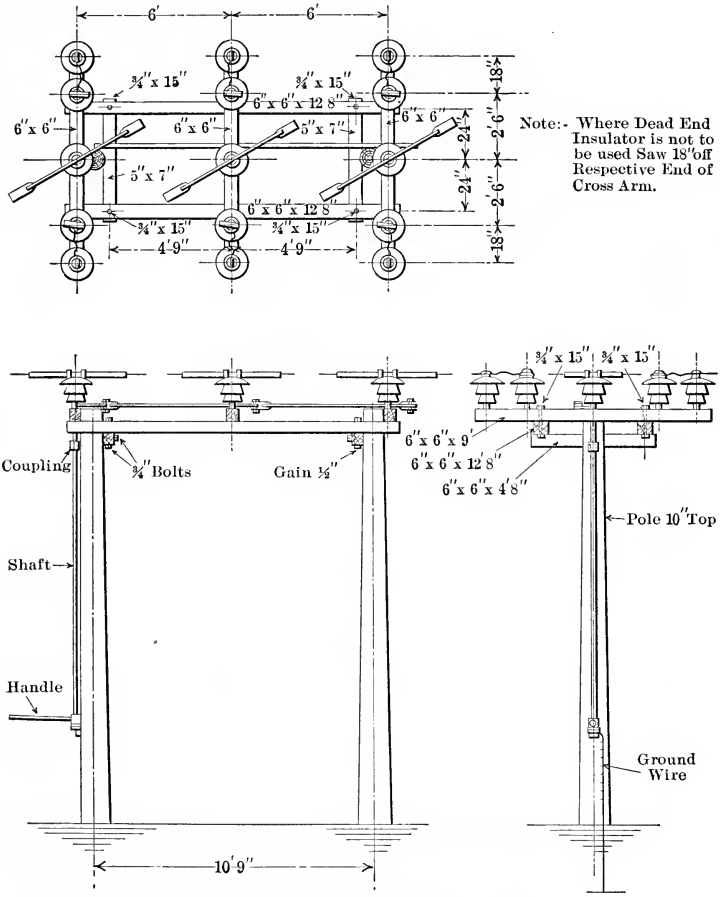


Fig. 100.—Baum switch mounting.

The steel disconnecting switch structure shown in Fig. 101 is practically a standard strain tower for the line in question arranged for the mounting of the switches; Figs. 102 and 103 show the disconnecting switch structures with suspension insulators, used on the Central Colorado Power Co's. system; in Fig. 104 is illustrated the type of structure used for the support of "Kilarc" switches.

As previously noted, switches for the opening of a heavy charging current or a loaded circuit should be arranged not only to rupture the arc safely, but to prevent its re-formation after being once broken; this is accomplished in all the outdoor air-break switches by means of horns to which the arc is transferred upon breaking the contact at the clips; the operation of the horn gaps being the same as in the case of lightning arresters. Outside of the common use of horns, the mechanical features of the different switches vary considerably.

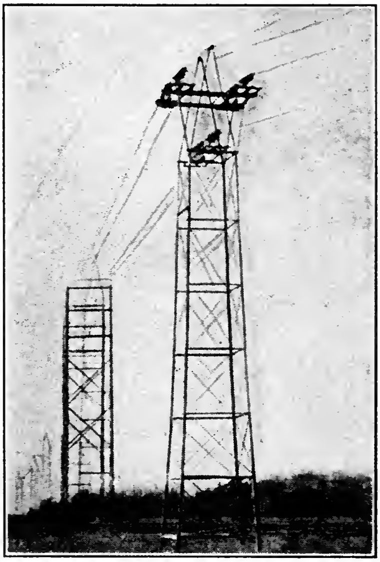


Fig. 101.—Disconnecting switch tower.

In the Burke switch, shown in open and closed positions in Figs. 105 and 106, a single horizontal break is made with a two-insulator rotating unit; this is noteworthy in that there is no torsional strain between the pin and the insulator as occurs where one insulator is used under such conditions, and the alignment of the blade can be maintained in better shape also. The Baum switch shown in Figs. 107 and 108, employs a double horizontal break, the latter design, provided with a special contact mechanism, being used for 100,000-volt service; this special contact mechanism consists of an arrangement for withdrawing the contact blades from the clips in a direction parallel to the line by means of short levers working on a 6-in. radius; after this system of levers has reached the end of its travel, the main arm is engaged and swung around; this method of withdrawing the blades from the clips obviates trouble due to the "sticking" of switches which have been closed for some time. The "Kilarc" switch, which is shown in Fig. 109, *a, b, c,* opens vertically, transferring the arcs to the horns; this switch has been developed with a view to the handling of loads of great capacity, one of the types being rated at 20,000 k.w. for 110,000-volt service. Fig. 109, *a,* shows a standard hand-operated

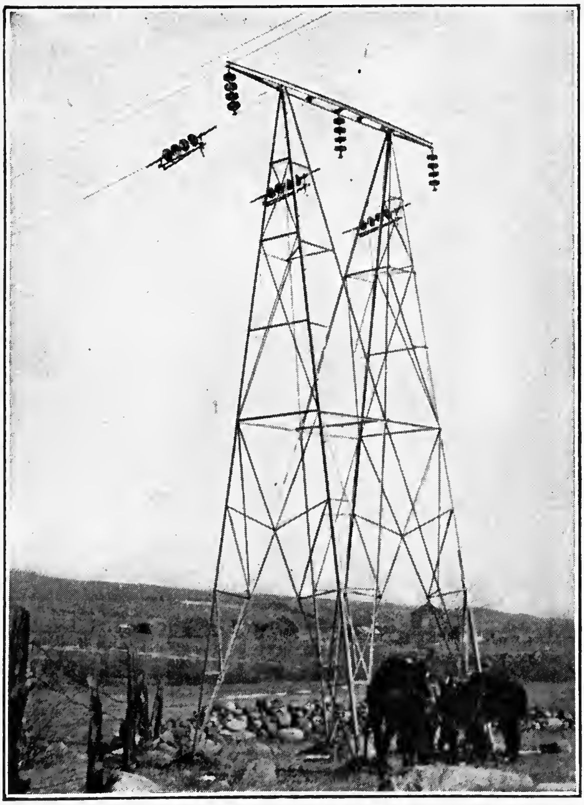


FIG. 102.—Disconnecting switch tower.

60,000-volt switch; 109, *b*, an overload automatic circuit-breaker, and 109, *c*, an insulator for a 150,000-volt switch in course of construction (May, 1912).

All of the switches described are arranged for the simultaneous opening of all three phases by a system of levers and rods or chains operated from a platform or from the ground.

In the foregoing paragraphs note has only been made of switch structures as would be used in sectionalizing lines, etc. (simple isolated tower structures), but, as a matter of fact, there are many installations of outdoor switching and junction stations where the structural framing for the mounting of the appliances is larger than most stations and which cost thousands of dollars where the simple switch will cost. hundreds. A typical structure of this class is shown in Fig. 110.

FIG. 103.—Dead-end switch tower with insulated platform.

The framing for a one-pole switch support erected complete will cost ordinarily about one and one-half times, and a two-pole support, about three times the cost of a standard line pole of the same size in place; a steel tower will cost about 25 per cent.

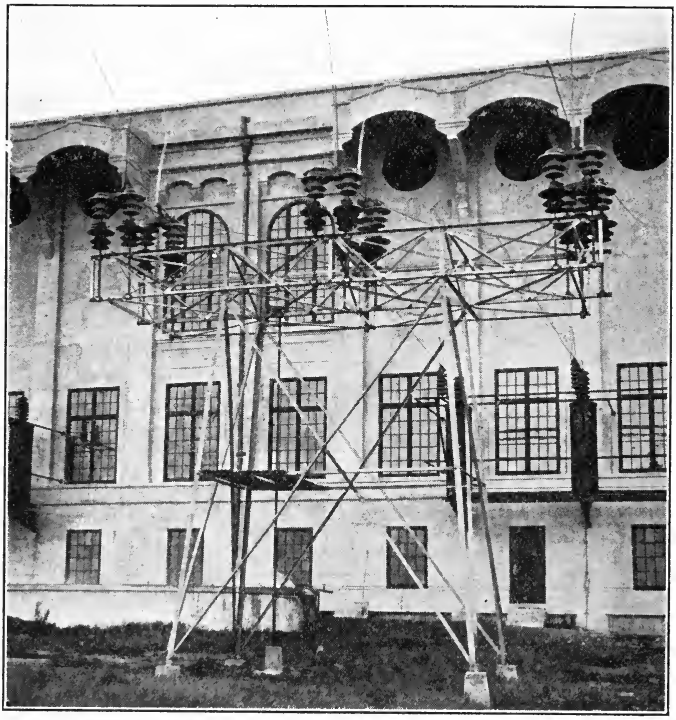


FIG. 104.—Kilarc switch mounting.

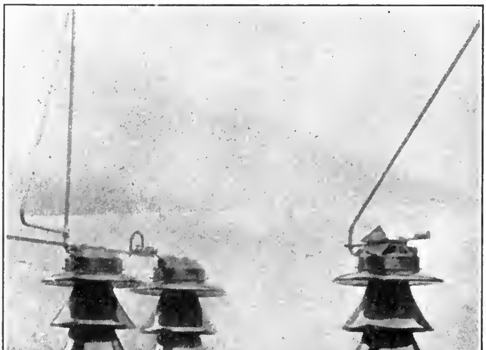


FIG. 105.—Burke switch—open.

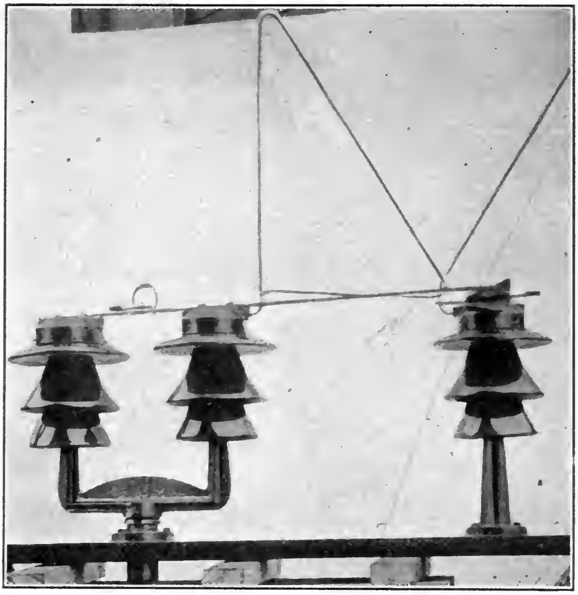


Fig. 106.—Burke switch—closed.

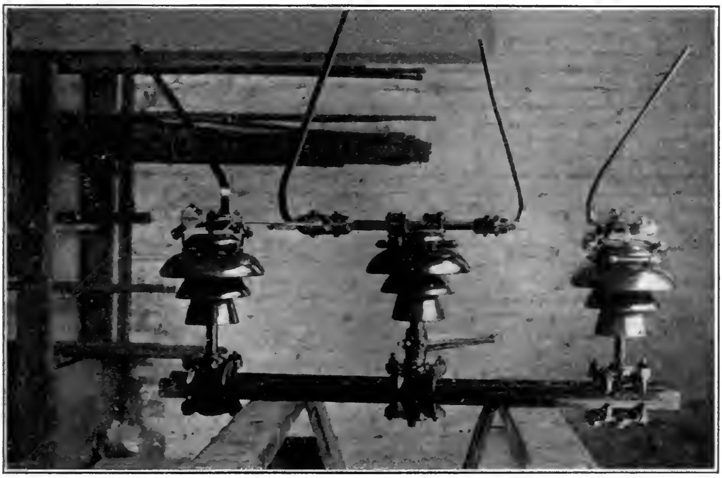


Fig. 107.—Baum switch.

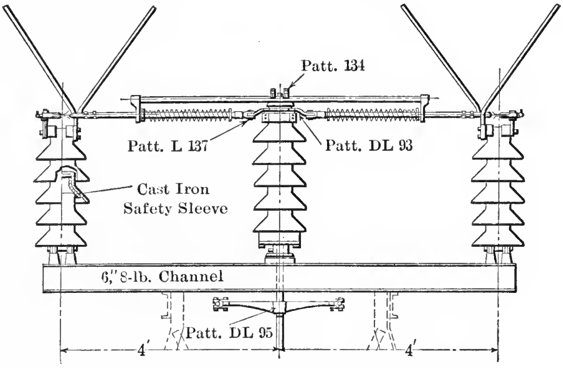


Fig. 108.—Baum 100,000-volt switch.

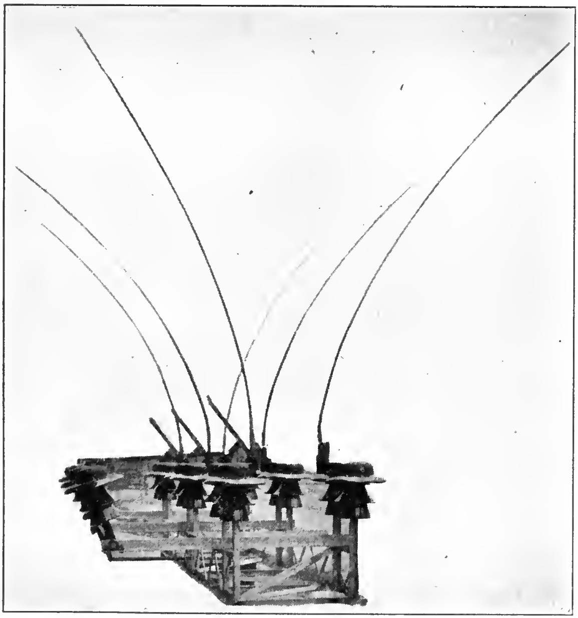


Fig. 109*a*.—Kilarc switch.

to 75 per cent. more than a standard line tower of the same height, depending upon the amount of special framing required by the switch itself.

The cost of the switches themselves will vary considerably for the same service with the different makers; one of the standard types will cost about $80 for a three-phase 45,000-volt unit and about $350 for 100,000 volts, f.o.b. factory, complete with insulators.

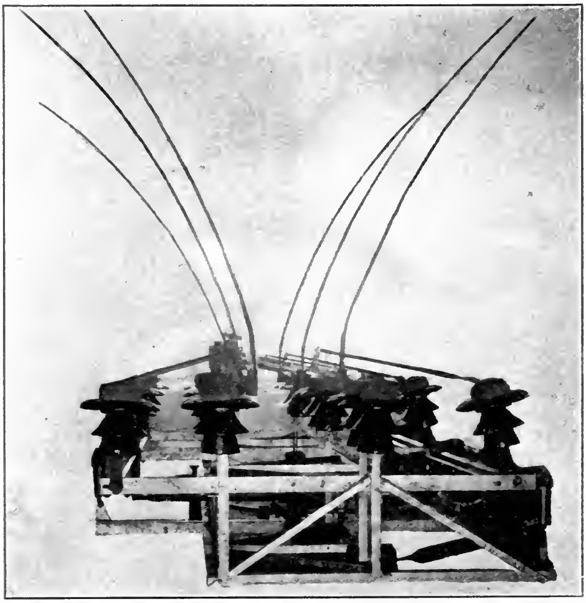


Fig. 109*b*.—Kilarc automatic circuit breaker.

For tapping-off branch lines, splitting circuits, etc., special junction towers are employed. In wooden pole work without switches a four-post structure such as those illustrated in Figs. 111 and 112 is generally used; in steel construction, junction towers will be found in all types, ranging from two standard line towers set close together with a little special cross-arm framing in between, to elaborate structures of great size such as shown in Fig. 110. Fig. 113 shows the method of bringing the 140,000-volt line of the Au Sable Electric Company into its Zilwaukee sub-station, using two dead-end towers and swinging to a third structure.

FIG. 109*c*.—Insulation for 150,000 volt Kilarc switch.

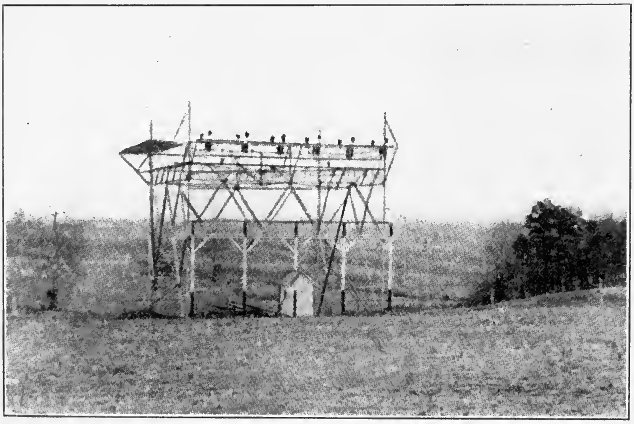


FIG. 110.—Out-door switching station.

Dead-end towers to take the terminal strain at stations, etc., are similar to line anchor towers ordinarily, except that where bought specially for certain locations, they may be designed to handle strains from a specified direction only. Dead-ends in wooden construction are usually made on a four-post structure similar to the junction towers illustrated, suitable arming and bracing being provided according to the span and size of conductor, or on a double A-frame as shown in Fig. 92.

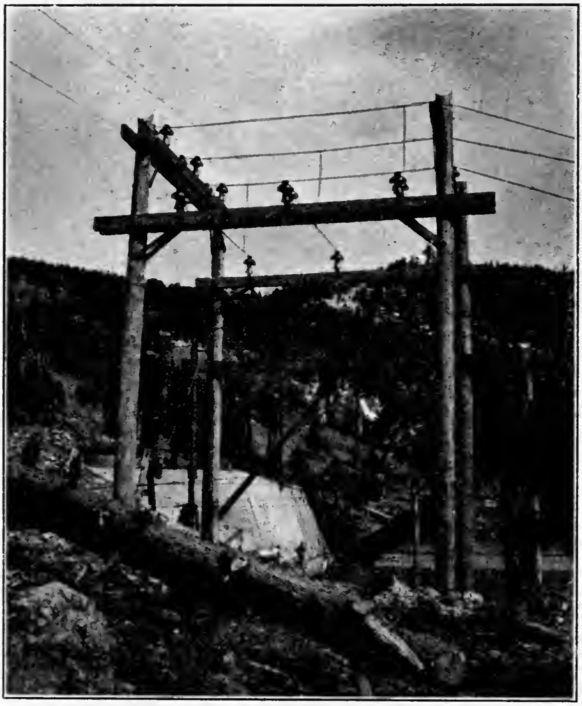


Fig. 111.—Wood pole junction or dead-end structure.

In the crossing of railroad rights-of-way, special construction is usually called for; there is, however, a great lack of uniformity in the requirements of the different roads so that the same transmission system may have two or three different types of crossing construction, depending upon the number of railroad systems crossed. In the past a basket or cradle construction supported beneath the line conductors so as to catch a broken high-tension wire as it fell, has been often demanded by the railroad authorities; after observing the operation of this as a protective device, especially in the winter time when it was liable to be dangerously loaded with sleet and snow, its value has been questioned and it has now come to be regarded as a doubtful means of protection.

Several disconnecting devices have been offered as a solution for this problem, in which the conductor is dead-ended to a lug that is held safely in contact with a clip or casting clamped to the insulators, as long as the strain in the crossing span is maintained, but which, upon the failure of this strain, as would occur when a wire breaks, drops out and with the broken section of wire falls to the ground; in one of these types, the lug drops out by the force of gravity and in another it is expelled by a spring. These test out very well but have been objected to by railroads in localities where sleet occurs, on the ground that the lugs might be frozen in and fail to clear. Several schemes for grounding broken conductors have also been tried out but have not been satisfactory.

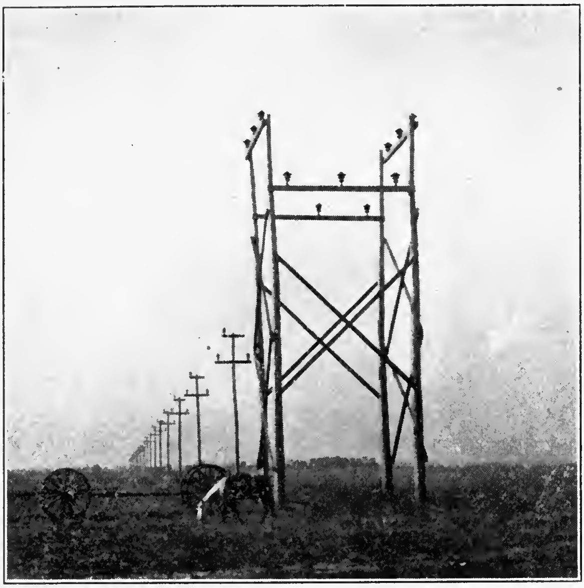


Fig. 112.—Wood pole junction or dead-end structure.

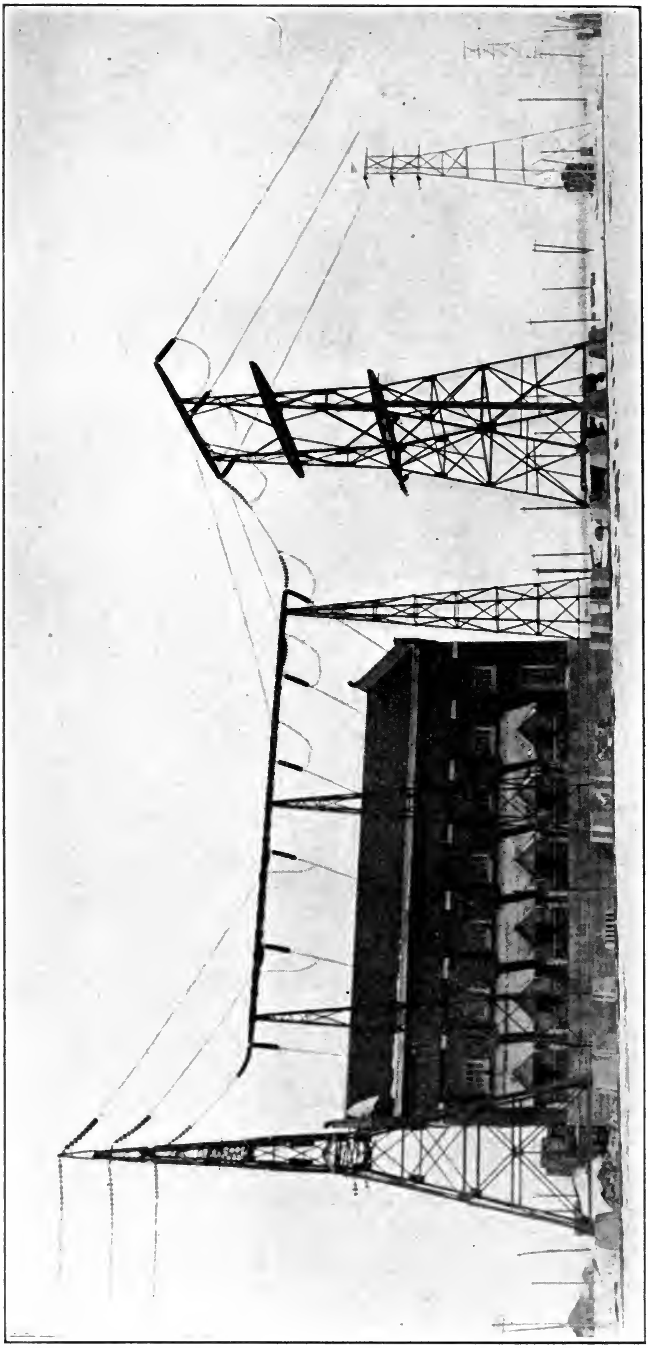


FIG. 113.—Top to Zilwaukee sub-station—140,000 volt line of Au Sable Power Co.

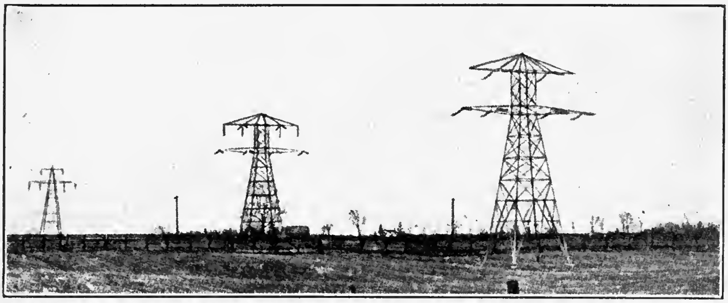


FIG. 114.—Railroad crossing—Ontario Hydro-Electric Power Commission lines.

FIG. 115.—Joint tower at crossing of two high-tension lines.

The method of making a crossing that is now beginning to be regarded as the most practicable is for the transmission company to build the work in as short a span as possible and as well as possible without any attempt to catch broken conductors or to disconnect them in case of trouble, in other words, to figure that there are to be no broken wires.

Along these lines specifications have been drawn, limiting the size of line wires in one case to No. 0 for copper and No. 00 for aluminum, calling for double insulators, arcing sleeves or serving of No. 6 wire for 24 in. on either side of insulators, and requiring structures of a certain factor of safety for the different materials and designed to give a clearance of 25 ft. to 35 ft. from the top of the rail to the lowest wire at a certain maximum temperature.

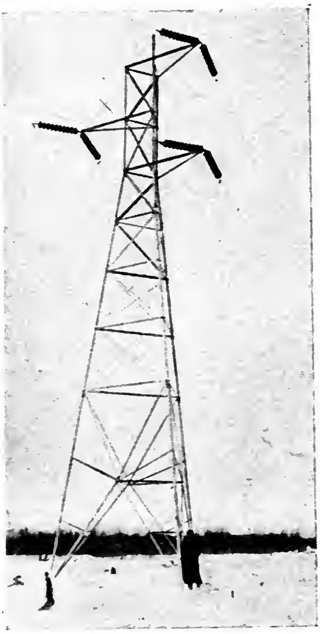


FIG. 116.—Corner tower—140,000 volt line of Au Sable Power Co.

In Fig. 114 is shown a typical railroad crossing on the Ontario Hydro-Electric Power Commission system; the towers are the standard anchor structures and the equipment the same as at regular strain tower installations.

In the crossing of telephone, telegraph, or other lines, the same general conditions as to the character of the construction necessarily hold good. It often occurs, however, that better means present themselves; in the case of a wooden pole line crossing a telephone line, for instance, a line pole can be set on either side close up to the telephone line and make what is known as a short-span crossing, wherein the height of the line poles and the length of the span are such that if a wire breaks it will be too short to reach down to the telephone wires; with a crossing of this type it will require the failure of both supports for the high-tension wires to come in contact with the telephone line; horns should be provided at the ends of the cross-arms to catch a conductor in the event of the failure of the ties on both poles.

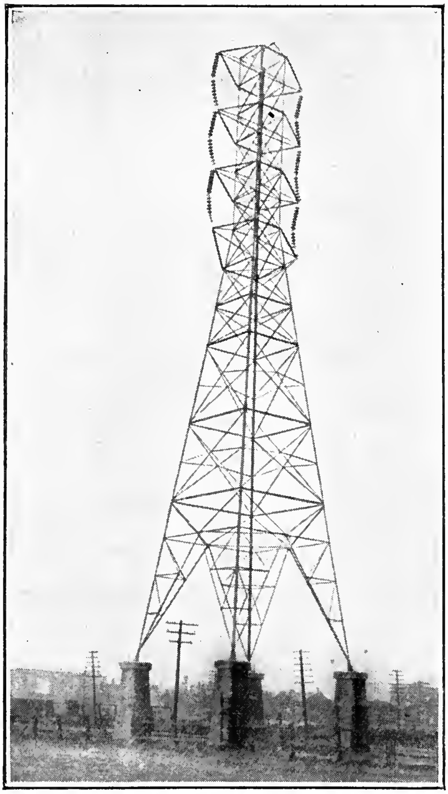


FIG. 117.—Corner construction—Ontario Hydro-Electric Power Commission lines.

In long-span tower work, it is obvious that the foregoing method of crossing protection will be found very expensive, and is not resorted to; an arrangement that has been used in several cases has been to set a line tower so as to "straddle" the telephone line and carry the same through the structure on cross-arms bolted to convenient braces, providing suitable projecting arms on each side of the tower to catch and ground a falling conductor. This method has been objected to in some instances but with good construction ought to be satisfactory.

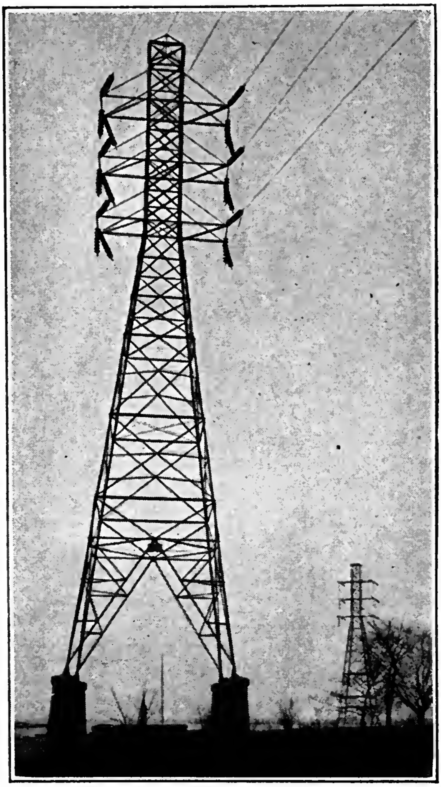


Fig. 118.—Corner construction—Ontario Hydro-Electric Power Commission lines.

In considering both railroad and line crossings, it will be well to note the stringent requirements which must be fulfilled in Europe in this line; in cases noted by the writer, the protection amounted practically to the building of an aerial tunnel for either the telephone and telegraph line, or for the high-tension conductors; in the description of the Lauckhammer 110,000-volt line, already noted as the first line of that voltage in Europe, the *Elektrotechnische Zeitschrift* for Aug. 31, 1911, illustrates the structure used for the protection of a railroad crossing, which is typical of what appears to be often demanded.

FIG. 119.—Special heavy-angle tower—Hoosac Tunnel electrification.

The crossing of one high-tension line by another is a problem in line construction that has been encountered in very few instances and only in the past few years. The method of short-spanning may be used, or a joint structure may be provided at the crossing point arranged to carry the two lines so that either will be safely accessible while the other is alive. In Fig. 115 is shown the crossing of two western lines where special crossarming was fitted to a standard tower of the line first built.

Corner towers as ordinarily used for angles encountered in transmission work are hardly what would be called special structures, being generally of the same design as the line towers except that they are heavier and in the case of pin-type insulators, arranged for the use of two or more insulators per conductor; it is only where extraordinary conditions are met with that other designs are called for.

Figures 116, 117 and 118 show typical standard angle towers, the first-mentioned being the "Aermotor" tower used for the 140,000-volt construction of the Au Sable Electric Company, and the other two being respectively the small angle and the regular corner arrangement on the Ontario Hydro-Electric Power Commission system. Fig. 119 shows an Archbold-Brady special corner structure used on the transmission line for the Hoosac Tunnel electrification of the Boston & Maine Railroad.

CHAPTER IX

CROSS-ARMS, HARDWARE, PINS AND INSULATORS

Cross-arms as used in wooden pole line work are usually long-leaf yellow pine, Washington fir, short-leaf yellow pine or Norway pine, though other woods, such as oak, spruce, cedar, white pine and cypress, have also been used to a limited extent; in some few instances steel, naturally almost always used in steel pole, steel tower or concrete pole work, has been employed in wooden pole construction, angle sections being used in most cases.

For transmission line work exceeding about 5000 volts, there is no standard size of cross-arms, but for light construction in voltages up to 22,000 volts or so, a regular electric light arm of the pin size required to give adequate conductor spacing, has often been used; the section of standard electric light arms, 3 1/4 in. × 4 1/4 in., is heavy enough for this class of work as a usual thing. In the heavier construction at the higher voltages, almost every individual line builder has had his own ideas as to the most suitable proportions for the section of wooden arms, and we find them 4 in. × 5 in., 4 in. × 6 in., 5 in. × 6 in., 5 in. × 7 in., and in all the possible fractional combinations intermediate; the conductor spacing demanded by the voltage, and the size and number of the line wires, naturally determine the length and section of a cross-arm, but in the case of lines built under identical conditions, great variations in this feature, especially as to the section of the arms, are often noted.

Long-leaf yellow pine and Washington fir are the most favored of all timbers for high-class construction, being of good strength and moderate weight, and possessing good lasting qualities; the National Electric Light Association gives the average life of pine as 8.7 years, and that of fir as 11.0 years, for untreated arms.

In the past no attempt was made to protect arms against deterioration except by the application of a coat of mineral paint, which applied to unseasoned woods in most cases was worse than nothing at all. In the last few years with the attention given to increasing the useful life of the poles, the preservation of cross-arms against decay has been given serious consideration, and they are now frequently subjected to treatments by the same processes as the poles. Many companies, however, that do butt-treat their poles do not use treated arms, figuring that the expense is not warranted and that if arms are carefully seasoned under cover for six months or a year and then given a good coat of mineral paint, the resultant life is more economical than that of a treated arm. There are many localities, however, where the climatic conditions do make the preservation of cross-arms an economical matter and in such places creosoted or kyanized arms have been employed with satisfactory results. *Forest Service Bulletin* No. 151 gives interesting details of government investigations of the application of creosote to cross-arms by the pressure process. The cost of creosoting will run from 2 cents to 3 cents per foot board measure. The Government recommends an absorption of about 6 lb. of oil per cubic foot for Class A timber (75 per cent. or over heart-wood), 10 lb. per cubic foot for Class B (75 per cent. or over sap-wood), and 8 lb. per cubic foot for Class C, intermediate between A and B. Arms of the above classes should be treated separately and all timber should preferably be held until it is in an air-dry condition before being treated.

Cross-arm timber should be first-class, sound, live, straight-grained and free from pine knots, pitch, seams, splits or shakes; knots 3/4 in. or less in diameter may and usually are allowed if they are solid and do not reduce the strength of the arm to any appreciable extent. The arms should be surfaced four sides with a 3/8-in. or 1/2-in. bevel along the top edges and all holes should be bored clean and to dimension. In some cases the tops of arms have been rounded off, but with the type of pins now generally used in high-tension work, a flat-topped arm is required.

The prices of cross-arms vary somewhat with the market, and with the length and boring called for, but the following prices are representative for long-leaf yellow pine arms delivered in the Middle West in 1911–12:

3¼ in. × 4¼ in., per lineal foot	$0.0375
4 in. × 4 in., per lineal foot	.055
4 in. × 5 in., per lineal foot	.075
4 in. × 6 in., per lineal foot	.0825
4½ in. × 5¾ in., per lineal foot	.089
5 in. × 7 in., per lineal foot	.12

Fir cross-arms will run from 5 per cent. to 15 per cent. higher in price than the yellow pine.

Steel cross-arms are seldom used in straight wooden pole construction except where some unusual arrangement of the pole top, such as that shown in Fig. 9 in Chapter III, is followed; the angle-iron section is the one that is generally employed, of the dimension and unit weight demanded by conditions; the channel section has been used a little. Generally steel arms have been employed painted, and the cost of them drilled complete and with one shop coat, runs from 2 1/2 cents to 3 cents per pound. The use of reinforced concrete cross-arms in connection with concrete poles has been suggested and experimented with, but to the best knowledge of the writer, has not been given a commercial test; the cross-arming of concrete poles is generally of steel, though wood has been used quite a bit also.

Cross-arms should in all cases be snugly fitted into a 3/4-in. gain and attached to the pole by means of a single through bolt, usually 3/4 in. or 7/8 in. in diameter, 2 1/4-in.×2 1/4-in.×3/16-in. or 3-in.×3-in.×1/4-in. washers being used under the head and nut; through bolts, with nuts and washers, should be galvanized, preferably by the sherardizing process, after all threading is completed. In purchasing through bolts, they should be specified to have a 3-in. or 4-in. length of threading, with the threads rolled.

Cross-arm braces may be either flat-bar or light angle iron; in transmission line work, the flat-bar braces, one to each side of the arm, are generally used, though in many installations only one side of the arm has been braced; in many of the older lines and in some quite recent ones where two-pole fixtures have been used, oak or maple braces have been employed. The standard section of steel-bar braces is 1/4 in.×1 1/4 in. with lengths running from 20 in. to 32 in.; for transmission work these braces are often not considered heavy enough and larger section bars are specified, depending upon the length of the arms and the size of the conductors. Braces of this type are through-bolted to the cross-arm with a 1/2-in. carriage bolt usually, and are attached to the pole with 5/8-in.×6-in. or 7-in. lag screws; the pole ends of braces are sometimes fastened with a through bolt in place of a lag, and a machine bolt instead of a carriage bolt, used for the cross-arm end; where a machine bolt is employed to attach the brace to the cross-arm, it is possible to drive the bolt through the arm from the brace side so that should the nut work off, the bolt will tend to hold the brace in position whereas if the nut be on the brace side and drops off, there is nothing but the short protruding length of bolt to depend upon; the use of a machine bolt at the arm end of a brace is therefore preferable, but in the writer's experience nothing is gained by substituting a through bolt for a lag bolt at the pole end.

Where a lag bolt is used for the heel or toe bolt, as the pole fastening of a brace is termed, it is often specified that it shall be driven in for not more than 1 in. and turned in with a wrench the rest of the way; common practice, however, is to drive heel bolts in for about the length of the thread and turn them in the balance of their length, and the writer has never found anything to indicate unsatisfactory results from this method. A washer should be used under the head of the heel bolt to assist in setting it up tight.

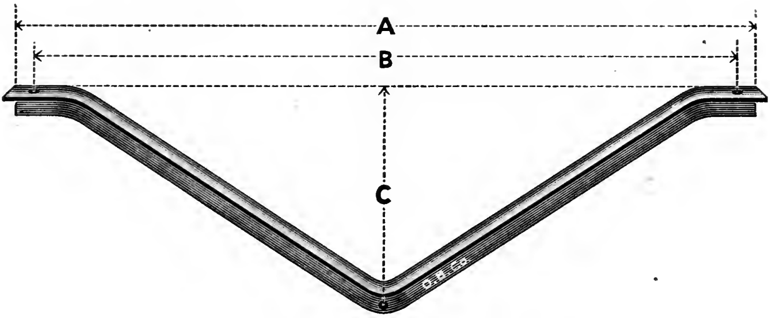


FIG. 120.—Angle iron cross-arm brace.

Angle-iron braces in one piece, as shown in Fig. 120, have been used to some extent in wooden pole work, but their cost is necessarily higher; the section of the angle is usually 1 1/2 in.×1 1/2 in.×3/16 in. or 1 3/4 in.×1 3/4 in.×3/16 in. As will be noted from the illustration these braces are fitted to the bottom of the arm instead of the side as with the flat-bar type.

All pole hardware should be galvanized, excepting possibly the heel bolt, and as noted previously, the threads should be rolled, and all operations concluded before galvanizing is done, so that the entire surface will be protected.

Bolts, lags, braces and washers should be shipped in unit packages and bundles, the bolts and washers in kegs, stenciled with number contained and size, and the braces in bundles well wired together and tagged; as a usual thing braces come in bundles of twenty making a convenient weight and size to handle. All hardware should be stored under cover as it comes in, and if possible, for obvious reasons, under lock and key; the material should be arranged systematically by size so that there need be no confusion in loading up for distribution and so that the stock on hand at any time can be readily checked.

As cross-arms come in, usually in box cars, they should be piled on blocking or skids clear of the ground, in a place convenient for the loading of teams, and if they are to be held for any length of time, in such a manner that there will be as free air circulation through the pile as possible. To allow for checking over of stock, they should be arranged systematically in piles of a certain number.

The distribution of cross-arms, braces and bolts is usually carried on just in advance of the setting work, though sometimes where poles are set without arms, the work coincides with the distribution of insulators. In distributing arms and hardware, teams should be loaded up with the requisite amount of material for a certain stretch of poles and the teamster directed to begin distributing at a certain number stake and leave one complete set of fittings, as per a standard list provided him, at each pole location from there on to the end of the stretch covered by his load, except at such locations as are otherwise specified on his slip. The work of distribution is often directed by the foreman of the crew in the field but the better way is to place the responsibility for distributing and keeping record of all material in the hands of a stock or material man, as discussed in Chapter XIII. Braces should be bolted to the arms before loading for distribution, and in the case of certain types of pins, they may also be fitted in the yard, which can be done usually by the material man in between times; it is well, especially in the winter time, to require that the arms shall be set leaning up against the pole with the bolts laid on top; washers should be slipped on the bolts; material should preferably be hauled out only sufficient for each day's progress.

Insulator pins for wooden construction should preferably be iron, though for the lower voltages, up to 20,000 volts or better, wooden pins are much employed; in older construction wooden pins have been used for potentials up to 60,000 or 70,000 volts.

The objections to wooden pins are both mechanical and electrical, and naturally are most apparent in the higher voltages where taller insulators are required and where the electrical conditions are more severe. Wooden pins are weaker than steel and being of greater diameter require a larger hole in the arm, not only weakening it from the start, but offering a greater opportunity for decay; then for voltages above 25,000 volts to 30,000 volts under certain climatic conditions, and above 50,000 volts generally, the digesting or carbonizing of wooden pins from leakage is a serious drawback to their use.

Locust, oak and maple have been the most extensively used pin timbers; as a rule pins outlast the arms, having an average life of eleven years, according to the National Electric Light Association, unless conditions are such that they are subject to digestion.

Wooden pins are made with the shank or part fitting into the cross-arm slightly tapered, and the holes in the arms should be bored so that the pin will fit snugly when driven in; in low-tension work, the pins are then set up by driving a six-penny nail through the arm and pin, and in higher voltage work, by means of a 3/8-in. through bolt passing through the arm and pin. In most cases where wooden pins have been used in high-tension work, they have been either creosoted or boiled in linseed oil or paraffine; the method of treating pins with paraffine is akin to the open tank process for the impregnation of timber with creosote, described in Chapter IV. They are placed in a tank of hot paraffine, maintained at as high a temperature as practicable without danger of flashing, and kept there for four to six hours, after which the bath is allowed to cool; after the paraffine has solidified, the pins are removed by reheating the tank until the wax is fluid.

The timber for pins should be sound, live, straight-grained, and generally free from sap-wood, knots and checks, with the grain running fairly true with the axis of the pin; small solid, sound knots, not more than 1/4 in. in diameter, are permissible as well as a small amount of sap-wood, if they be above the shoulder of the pin. Pins should be seasoned thoroughly before being turned, should be close to the dimensions called for, should have clean-cut uniform threads and a reasonably smooth finish.

Iron pins, as they are generally classed, may be of steel, malleable iron, cast iron or cast steel, or combinations of two of them.

The earlier type of iron pins was an adaptation of the forms of wooden pins, extra heavy pipe, usually 2-in., being swaged to fit and be cemented into the insulators, the whole being mounted on the cross-arm in the same manner as a wooden pin; made a little longer with the shank flattened and drilled with two holes for through bolts, or with a regular pin mounted in the manner illustrated in Fig. 5, Chapter III, this type of

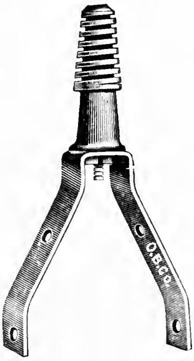


Fig. 121.—Ridge pin.

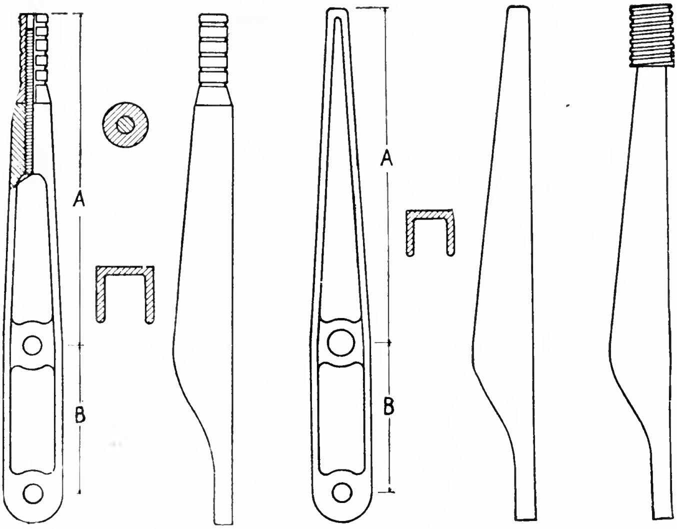


Fig. 122 (*a*, *b*, *c*.)—Pole top pins.

pin was adapted for use at the top of a pole, and was a great improvement over the method previously followed, of setting the top pin into a hole bored into the pole roof, not only making a better job mechanically, but lessening the danger of rot.

With the beginning of the use of metal pins, and with the development of porcelain insulators, better designs of pins were worked out and now for low-tension work, that is for potentials up to about 25,000 volts, either a ridge pin such as is shown in Fig. 121, or a malleable pole-top pin such as is illustrated in Fig. 122, *b* or *c*, is used, while for the higher voltages the type with separable thimble, shown in Fig. 122, *a*, is generally employed. Fig. 122, *c*, is the same as 122, *b*, except that the former is provided with a threaded lead thimble, cast on the end, whereas the latter is cemented into the insulator. With the separable type of pin, the thimble is usually cemented into the insulator at the factory.

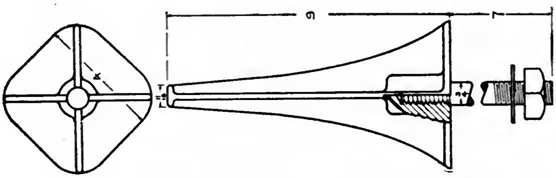


Fig. 123.—Cross-arm pin.

For cross-arm work the defect of a pin requiring a large hole in the cross-arm was early realized, and pins of the type shown in Fig. 123 were offered, consisting of a cast-iron base cemented into the insulator, and held to the arm by a stud bolt screwed into the base. Cemented into an insulator, this latter type of pin was hard to install on a pole in the larger sizes, especially where an insulator was to be replaced in a hurry, and on this account and also to avoid the necessity of carrying a heavy cemented unit, a lead thimble, cast on the end and threaded, is preferable. This gives the installation flexibility of a wooden pin, and in medium voltages works out quite well.

For general transmission line work, however, pins with separable thimbles, such as are illustrated in Figs. 124 and 125, are the best; in these a threaded cast-iron thimble is cemented into the insulator pin hole, preferably at the insulator factory, and the balance of the pin installed permanently on the arm, the insulators being readily placed in position or changed by screwing on, or unscrewing the thimble, to or from the projecting end of the stud bolt. In Fig. 124, it will be noted that the base is itself threaded at the top and that the pin bolt is screwed through the threaded neck so as to project the required distance above the top of the cone casting; in Fig. 125, a flat nut is used in place of a threaded section in the base, and this is turned down into position and the base slipped on, or *vice versa*. When the separable top pin was first introduced, there was no way of installing them on a cross-arm without an insulator in place, the use of threading at the neck of the base or of

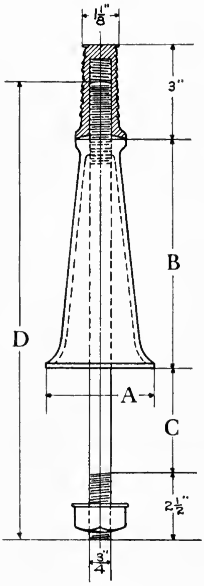


Fig. 124.—Separable type cross-arm pin.

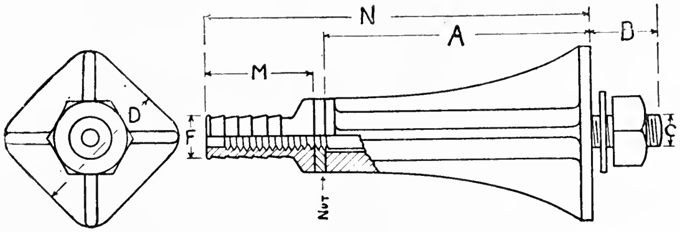


Fig. 125.—Separable type cross-arm pin.

a nut, not having been developed. This pin bolt was therefore screwed into the insulator thimble and the base slipped over the pin, the whole then being held and the end of the bolt introduced in the hole in the arm; where 66,000-volt insulators, weighing about 35 lb. with pins weighing 12 lb. to 15 lb., were to be installed in wooden pole work, this type of pin was not exactly a thing of joy for the linemen.

Besides the all-metal pin for the range of voltages, we have porcelain base pins with lead or wood thimbles and steel pin bolts, which require no cementing, the insulator pin hole being threaded as with plain wooden pins; and for the lower voltages, we have a wooden-base pin with a steel through bolt.

In general for pins we may say that an all-metal pin should be used always in steel construction, and in wooden pole work for potentials above 44,000 volts; below this pressure, a porcelain base pin may be used, though an all-metal pin is preferable for all voltages exceeding about 22,000 volts; an all-wooden pin should not be used for pressures above 22,000 volts for first-class line construction. Where metal pins or part metal pins are used, these should be galvanized throughout and, for potentials higher than about 44,000 volts, the pins should preferably be of the separable type, arranged for permanent installation on the arms.

For the insulation of transmission lines we have offered, porcelain, glass, and patented compounds.

The proprietary compounds possess very good mechanical characteristics and excel porcelain or glass in this regard, but it is doubtful if any insulator of this kind of material can for any length of time withstand the ravages of weather, combined with the electric strains obtaining in high-voltage work; insulators of this type have not as yet been used commercially to any great extent.

Glass is the oldest commercial insulating material for line work and possesses good insulating qualities, is cheap, and allows the detection of flaws, etc., by visual inspection, but is mechanically weak, and subject to surface deterioration; glass insulators of any size will often fail from unequal temperature strains alone.

Porcelain with its superior mechanical strength and its dialectric strength, though of greater cost than glass, is, even in the very low voltages, accordingly used generally as the material for insulators. Porcelain, for insulator purposes, should have a fine uniform grain, free from blow-holes, cracks or strata; an insulator broken, should show a clean even fracture and the fractured surface should be neither chalky nor too glossy, the former indicating under- and the latter, overfiring; drops of red ink placed upon the fractured surface should not spread nor be absorbed. Exposed surfaces of an insulator should be evenly glazed, preferably a brown color, and should be smooth and glossy, without pits, ridges, hollows or anything that will catch and retain dirt; the glazing should show no crazing or hair cracks. It is very probable that a great many insulator failures have been due to a combination of underfired porcelain and crazed glazing, and that what has been termed fatigue of insulators is merely the depreciation of the insulation through absorption of moisture in such cases.

For the support of conductors we have two distinct types of insulators in the pin and the suspension designs, the former being made for all voltages up to 88,000 volts, and the latter in units rated at 11,000 volts to 25,000 volts, the number of units required depending upon the line voltage. The unit type of insulator is finding great favor for all voltages above 33,000 volts, but for pressures up to 50,000 volts or 60,000 volts the pin type is still holding its own.

In America the pin-type insulators for the higher voltages are made up of three or four parts cemented together with neat portland cement, the same being preferably done at the factory, but sometimes carried on in the field; medium voltage insulators are made up in two parts.

In the selection of an insulator of the pin type to operate under a certain pressure, consideration must be given not only to the internal electrical conditions of the system, but also to the mechanical features involved, and to the climatic conditions met with, such as the prevalence of dust and salt storms, fogs and long rainy seasons, heavy lightning storms, etc. The design of an insulator is not usually within the province of a transmission line engineer or at least should not be; while experience will teach him undesirable features, it requires long and careful experimental work to determine those that will give the most economical and efficient designs, and it is usually best to specify performance, and rely upon the designs submitted by well-known manufacturers.

Specifications for pin-type insulators should in addition to the quality of the material and details of finish, etc., list the tests for performance and specify in detail the manner of applying them; generally a dry flash-over test of from two and one-half to three times the rated line voltage, and a wet flash-over of at least one and one-half to two times the rated line voltage, are called for, depending upon the line conditions; a puncture test at the full, or at least 75 per cent. of the full, rated line voltage, applied to any shell separately, is also usually specified. Doctor Steinmetz has suggested that specifications for insulators also call for a series of electrical tests to be made upon samples that have been immersed in water for a week or ten days; this kind of a test will assist in weeding out the kind of insulators that might be subject to "fatigue" later on, as previously noted.

While in this country the practice has been to design insulators with multiple parts to secure the required leakage distance, the same result is obtained in Europe by molding petticoats on the shells and using probably two-part designs where we use three or four. One-piece insulators up to 12 in. in diameter, of the design shown in Fig. 126, *a*, have been successfully manufactured in Germany. Figs. 126, *b* and *c*, show two other typical German insulators of the pin type. For a study of European insulators the reader is referred to a series of papers in the *Elektrotechnische Zeitschrift* for Jan. 13, 20, and 27, 1910; also in the *Electrical World* for May 19, 1910, A. S. Watts gives an interesting comparison of American and European insulator designs.

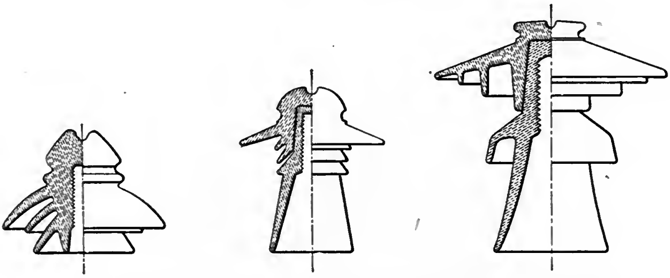


FIG. 126*a*, *b*, *c*.—Typical European pin-type insulators.

In Figs. 127, 128, 129, 130 and 131 are shown typical designs of American pin-type insulators for, respectively, 13,000, 23,000, 35,000, 44,000 and 66,000 volts. The cost of pin-type insulators for a certain voltage varies of course with the factor of safety called for; for pressures up to and including 33,000 volts, a factor of safety of 3 for dry flash-over and 2 for wet test can be readily secured, but above that point, insulators with those rated safety factors will be expensive.

FIG. 127.—13,000-volt insulator.

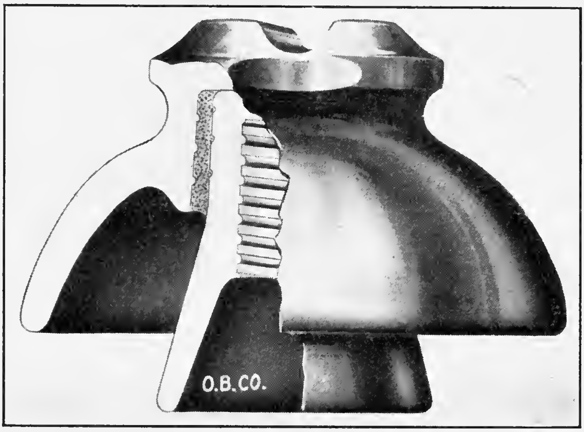


FIG. 128.—23,000-volt insulator.

Pin-type insulators above 66,000 volts are very heavy and expensive and on account of the height of pin required subject

Fig. 129.—35,000-volt insulator.

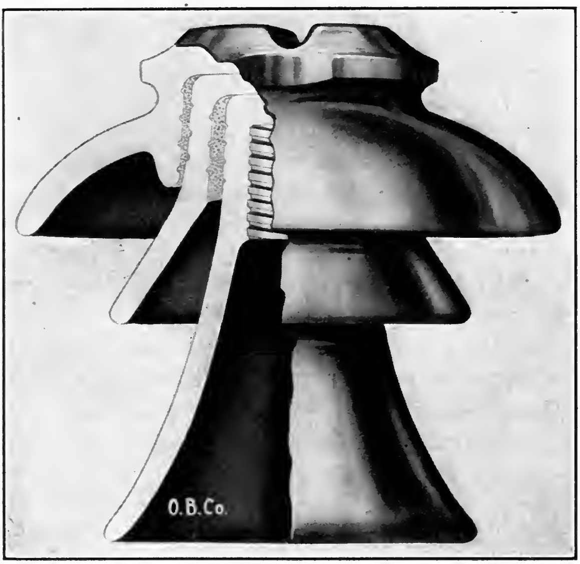


Fig. 130.—44,000-volt insulator.

the cross-arms to a heavy torsional strain. The cost of securing a suitable safety factor together with the mechanical considerations involved led the insulator manufacturers to seek new methods.

With the reincarnation of the suspension-type insulator, used in the early days of telegraph line construction and abandoned on account of its clearance requirements, the problem of insulating lines for pressures above 60,000 volts or 70,000 volts, and especially above 100,000 volts, was greatly simplified. So rapidly has the suspension insulator come into favor, that it is being used in many instances where economical considerations would tend to prove the pin type preferable.

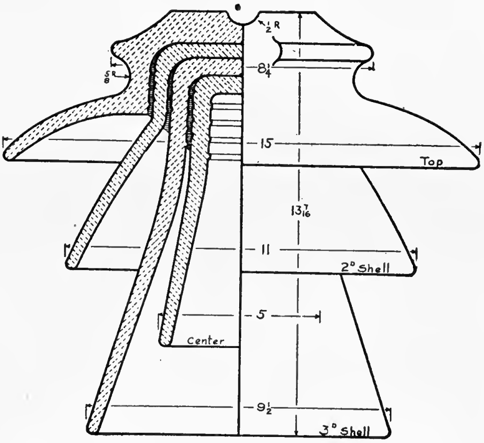


Fig. 131.—66,000-volt insulator.

The advantage of a suspension-type insulator over a pin type lies in the fact that it is electrically more efficient and mechanically stronger, not only in itself but in the lesser strain that it exerts upon the cross-arms, and commercially a better business proposition in that the voltage of transmission can be raised by the addition of extra units without scrapping or sacrificing the former insulators, as would be the case with the pin type. Again in the case of an insulator failure, where multiple units are used, the damage is usually confined to one unit, which can be replaced at a correspondingly low cost.

The specifications for suspension-type insulators are the same as for the pin type as far as workmanship and material are concerned, but in specifying performance, tests not only of separate units should be called for, but dry and wet flash-over tests of the standard string of units, with regular interconnection and spacing between them, and with a stated mechanical load applied, should be made. Recent tests of series of units under both wet and dry conditions demonstrate that the effective voltage per unit drops off very fast as the number of units is increased, and the assembled tests under line conditions should be made to determine the actual safety factor. The units in series also do not carry the same insulation "load," the one connected to the line being under greater voltage strain than the one farther along, and the second under greater strain than the third and so on;

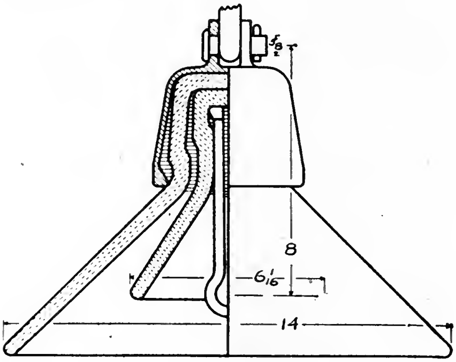


Fig. 132.—Two part cemented suspension type unit.

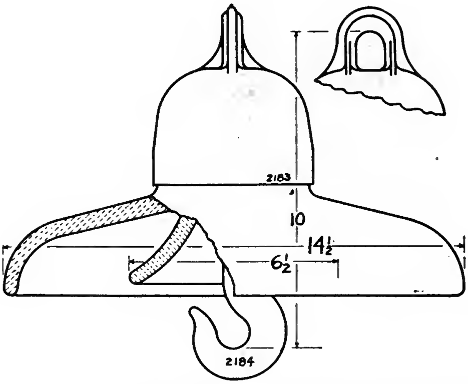


Fig. 133.—Two part cemented suspension type unit.

when a long series of units is to be used it appears that some means of lowering this potential gradient either by spacing or by a variation in the dimension of the units can be worked out so as to increase the assembled working pressure of the series, though the practicability of any such arrangement is questionable.

Different designs of suspension-type insulators are offered by the various insulator manufacturing companies, some a two-part cemented unit as illustrated in Figs. 132 and 133, others a one-piece cemented unit as shown in Fig. 134, and still others of the all-porcelain interlinking type shown in Fig. 135. There has been some discussion as to the relative constructional merits of the cemented and the interlinking types, many engineers having favored the latter because of the mechanical interconnecting feature between units, in the event of the shattering of the porcelain body, and the argument advanced by adherents of the cemented type has been that the connections of a broken unit would not as a general thing be pulled into good contact and often into no contact at all so that the arc between the

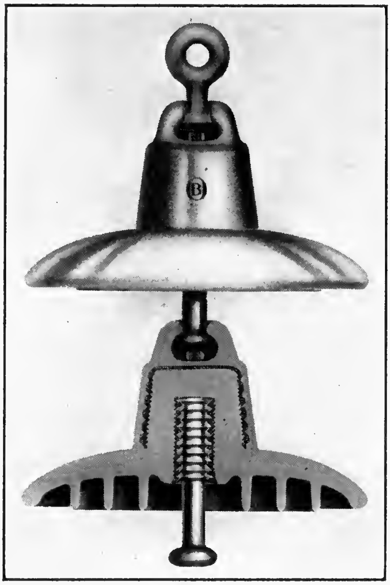


Fig. 134.—One piece suspension type unit.

interlinking parts would destroy the loops and drop the wire. The point has also been advanced, that with the type of interconnection used for the cemented type it is possible to subject every unit to mechanical test, while with the interlinking designs, the strength of the series depends upon the care exercised in the erection work. In repair work, the replacing of a unit of the cemented type can be effected more easily and quickly than that of an interlinking type; also where a long series of units is used for the higher-voltage work, the possibility of maintaining a more closely uniform spacing between units as desired, is a great point in favor of the cemented type.

Fig. 135.—Interlinking type suspension unit.

There has been much important work where each type of insulator has been employed, but as a rule it appears that engineers favor the cemented type; between the relative merits of the one-piece and the two-piece cemented types there is much discussion, the question being whether it is better to use, say for 100,000-volt service, four units of the larger diameter two-piece type, or six units of the smaller diameter one-piece design. The following comparison of the two types, each with units for 100,000-volt line pressure, as made by A. O. Austin in his paper before the 1911 convention of the American Institute of Electrical Engineers, gives a concise summary of their respective merits, as well as interesting information as to details of insulators for 100,000-volt service.

	One-piece type	Two-piece type
Number of sections	6	4
Number of shells per section	1	2
Diameter	10 in.	14½ in.
Length of insulator	34½ in.	41 in.
Mechanical strength	10,000 lb.	8,000 lb.
Weight of porcelain	30 lb.	62 lb.
Total weight	50 lb.	90 lb.
Number of cemented joints	12	12
Formation of arc—dry	Through air	Over surface
Formation of arc—wet	Through air	Over surface
Total tested dialectric strength	540 kv.	440 kv.
Wet flash-over	265 kv.	235 kv.
Depreciation due to loss of one section	16⅔ per cent.	25 per cent.

In passing, the factors of safety shown in the above comparative tests will be noted as being far greater than those of the pin type as generally rated.

In Europe the development of the suspension-type insulator has been along the same lines generally as in this country; they have, however, been of the one-piece type with turned petticoats on the same order as the pin-type designs previously commented on; they have been made both with cemented and interlinked connections. Figs. 136 and 137, *a*, *b*, show the insulators used for the Lauckhammer 110,000-volt work, see Figs. 46 and 47, the suspension unit in Fig. 136 being used five in series and the regular strain insulator, Fig. 137, *a*, six in a string; the design shown in Fig. 137, *b*, was employed in the long span over the River Elbe and seven insulators per string were used, arranged with the strain yoke shown. The suspension unit here is only 8.86 in. in diameter with 6.69 in. between centers, somewhat

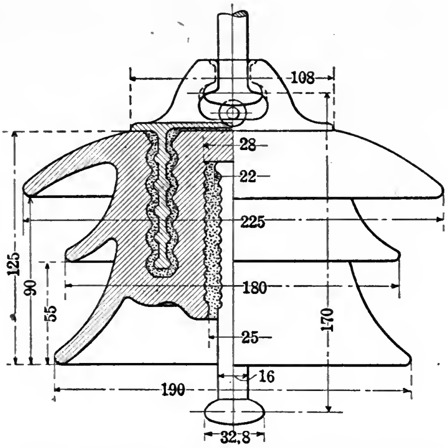
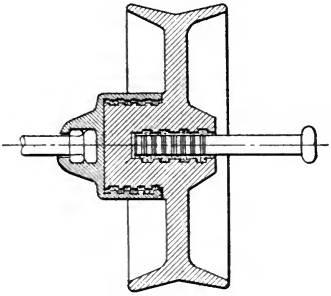


FIG. 136.—Lauckhammer insulator unit.



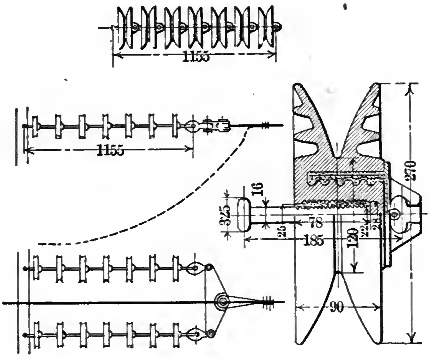
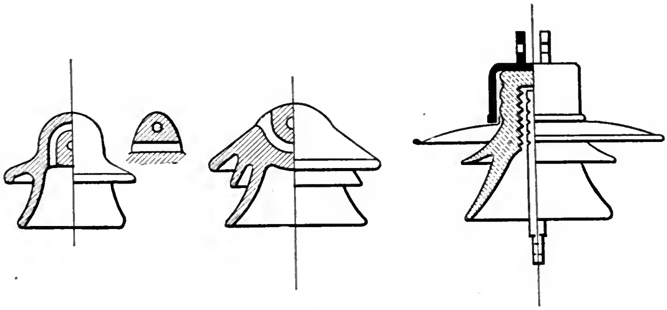


FIG. 137*a*. FIG. 137*b*.

Lauckhammer strain insulator units.



a *b* *c*

FIG. 138.—Typical European suspension insulator units.

smaller than the units generally adopted in this country. Fig. 138, *a*, *b*, *c*, shows other typical European designs which it will be noted are one-piece, though somewhat similar in design to the two-piece units manufactured here.

The costs of suspension-type insulators is greater than that of the pin type for the voltages at which they are generally listed, even including pins in the case of that type and suspension attachments for the unit type. Costs for a line of typical insulators not, however, including pins or fittings in this case, are shown in Fig. 139, as given by A. O. Austin of the Ohio Brass Company, in a paper read before the Central Electric Railway Association. As a comparison, for 66,000-volt service, a pin-type insulator will cost from $1.75 to $2 and a suspension-type insulator from $2.50 to $2.80, for insulators alone with a safety factor of about 2 at wet flash-over.

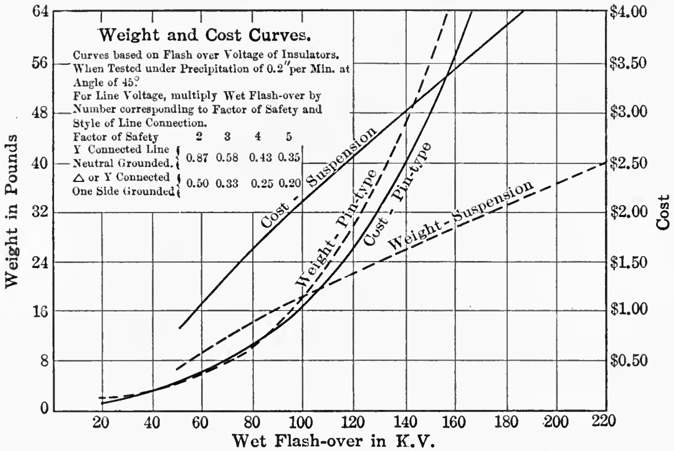


FIG. 139.—Weight and cost curves—pin and suspension type insulators.

For shipment, insulators should always preferably be completely assembled and cemented at the factory, including thimbles for pins, where the separable type of pin is used. For convenience and safety in distribution, large pin-type insulators are shipped three in a crate; in this regard, it may be said that no harm will be done by incorporating in the specifications a clause covering the quality of the material and workmanship employed in crating; smaller insulators are generally shipped in barrels.

In the unloading of a car of insulators, a competent man should be in charge to inspect and check over the shipment, not only for the purpose of establishing claim for insulators broken in shipment, but to keep the rejected ones separate from the good ones to avoid the possibility of defective insulators being hauled out on the line for distribution. Care should be taken where insulators are piled in the open, to see that they are arranged so that no part of them will retain water which upon freezing may burst them. Insulators not under cover are subject to the curiosity of the local inhabitants, who, turning a crate over for inspection, neglect to replace it, so that it is well to keep a close watch over the stock in freezing weather.

The distribution of insulators should be kept apace with the work and only enough laid out ahead for each day's work; a team with a hay-rack is convenient for handling crated or barreled insulators, and one man besides the teamster can handle the work nicely. The cost of this work varies of course with the size of the insulators, length of haul from storage yard, and length of spans, but for pressures from 40,000 volts to 60,000 volts, average hauls of 4 miles through Middle West farming country, with spans about 125 ft., the cost will be from 3 cents to 5 cents per insulator, man and team figured at $4 a day and an extra man at $2; where long-span tower construction is employed the cost is greater and through rough country may be double the figures given.

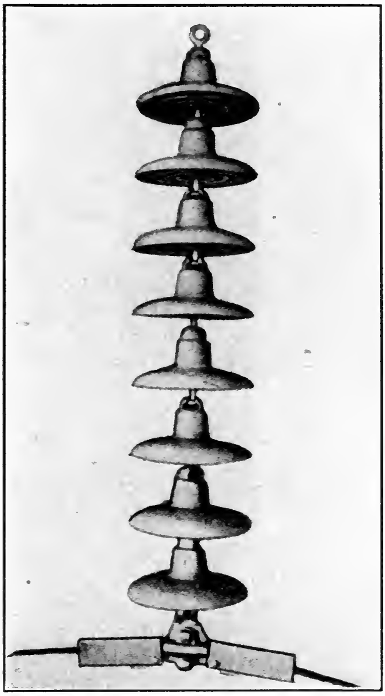


FIG. 140.—110,000 volt insulator string.

The system followed in the erection of cross-arms and insulators varies; in steel tower work the cross-arms are of course

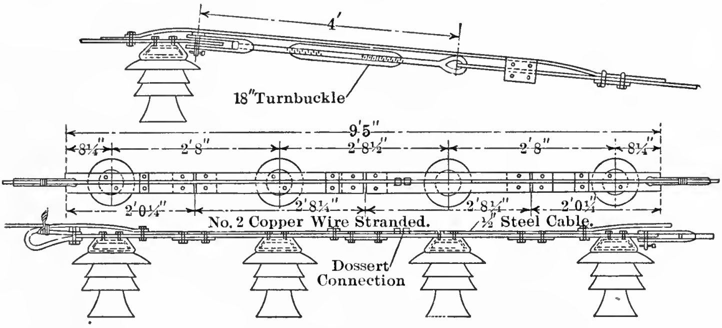


FIG. 141.—Dead-end insulator arrangement.

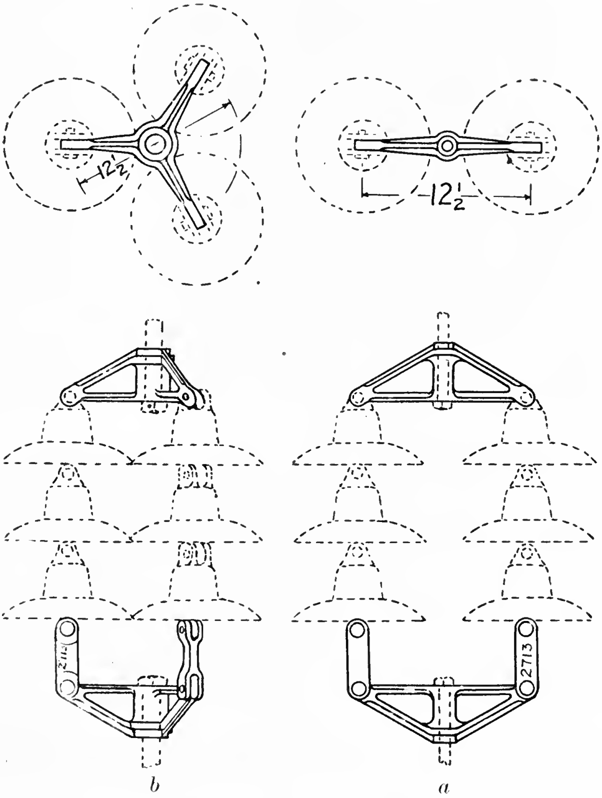


FIG. 142.—Strain yokes.

integral with the tower structure, in steel pole work this is also generally the case, while in wooden pole work, the arms, though usually put on before setting, may in the case of high heavy poles, be left off and installed later.

The labor cost of putting on high-tension arms, from 4 in. × 5 in. to 5 in. × 7 in. in size and 6 ft. to 8 ft. long, averages from 8 cents to 15 cents when done on the ground and 15 cents to 25 cents when done in the air.

Pin-type insulators are as a rule placed on towers before raising, but seldom on poles on account of the greater liability of breakage in the latter case; the suspension type must necessarily be installed after the structures are erected. The cost of installing 66,000-volt insulators of the pin type ran about 3 cents to 4 cents each for tower work and 6 cents to 8 cents each for wooden pole construction where they were put on after setting, single-circuit work in each case. Suspension-type insulators for the voltages to which they are generally applied can be installed, it appears, more cheaply than the pin type of equal voltage placed after setting. It is interesting to note that in the 110,000-volt construction of the Ontario Hydro-Electric Power Commis-

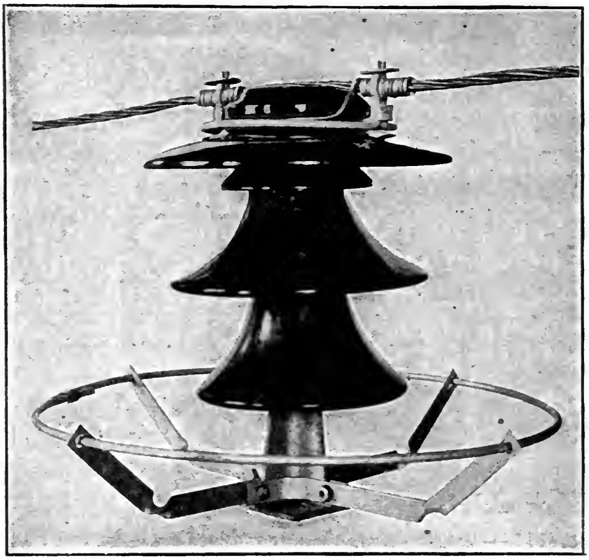


FIG. 143.—Arcing rings.

sion, a foreman with three men installed in one day under favorable circumstances, as high as 120 insulators—forty single-circuit towers spaced about 500 ft. apart. These insulators are made up of eight 10-in. units with an overall length of about 5 ft. and weighing about 100 lb.; a cut of this insulator is shown in Fig. 140. Figuring the foreman at $4 and the three men at an average of $2.50 a day, the total labor cost for erection will be $11.50 or about 10 cents per insulator.

For handling dead-end strains on pin-type insulators, several of them are usually placed in series or multiple-series; Fig. 141, showing a typical arrangement, with the tops clamped to a longitudinal equalizing-bar; in suspension insulator work, where the strains are too heavy for one insulator a yoke arrangement for two or three sets of units, as shown in Fig. 142, *a*, *b*, is used.

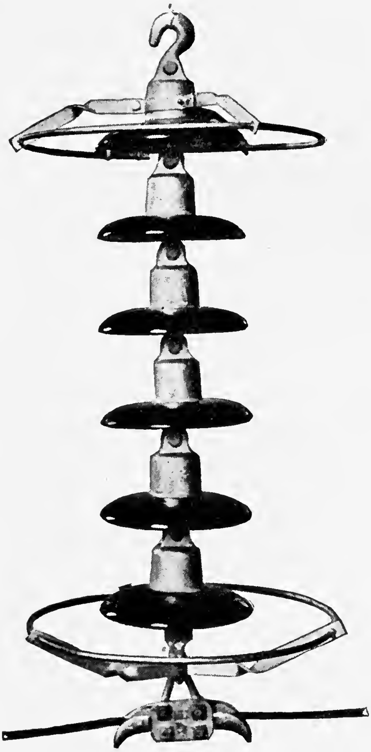


Fig. 144.—Arcing rings.

In the case of lines of great capacity where the dynamic arc following the flash-over of an insulator or a failure is of enormous value, it is necessary to protect the line conductor from burning and also the insulator itself from being destroyed by the heat of the arc. For this end, arcing rings as illustrated in Figs. 143 and 144, have been developed. In many cases also, the conductor has been protected merely with a serving of wire or with a sleeve of sheet metal, or a protection like that shown on the clamp of the Ontario Hydro-Electric Power Commission in Fig. 140, has been applied.

CHAPTER X

GUYING

The character of the guying of a line as a rule reflects the character of the whole construction; if it be poorly and cheaply done, it is generally the case that there is neither quality nor finished workmanship in the remainder of the construction, and *vice versa.*

Guying is the general term used to cover that phase of transmission line work that has to do with the external reinforcement of line structures to help resist unusual strains; these strains may be permanent, due to angles in the route of the line, or as they are known to construction men, "corners," to "dead-ends," to taps for branch circuits, etc., or may be transient, such as would be set up by extreme weather conditions, broken conductors, etc. To resist the first we have the straight "line guying" as it is known, and to provide against the second, what is termed "storm guying"; in line guying, either wire guys or push braces may be used, in storm guying, which is not employed in transmission line work to as great an extent as it is in telephone toll line work, the wire guy is generally employed.

In the early days of transmission line construction, there was more or less prejudice in favor of push braces for high-tension work instead of wire guys, with their metallic connection to ground carried up on the pole, along the same lines as where wooden cross-arm braces, cross-arms set through a slot in the pole and keyed with wooden pins, etc., have been used, and wire guys were not employed very freely. With better knowledge of the work, and more especially with better line insulators, and possibly somewhat on account of the cost of good pole timber, this condition has been reversed. In general, it may be said that where either may be used, about the only advantages possessed by a push brace are that it cannot be so easily damaged maliciously, can be arranged to take both tension and compression, and adds somewhat to the strength of the line in a longitudinal direction; on the other hand, brace poles cannot be adapted to varying conditions, are expensive in the larger sizes, and are liable to destruction from grass fires and lightning. Wire guys, on account of their greater flexibility, cheapness under general conditions, and ease of installation, are now used practically altogether for the external reinforcement of line supports.

Typical methods of setting single and double push braces, used in general pole line work, are shown in Figs. 145 and 146; to increase the bearing area of the brace where the ground end is of smaller diameter than is safe under the soil conditions, it will be noted that two pieces of plank are placed under the butt; a large flat stone, say 18 in. to 24 in. on a side, may be used very well in place of the plank, and where the brace thrusts into hard ground or a rock ledge, of course nothing will be required. Where a combination push and pull brace is desired, the brace pole should be set deeper, as shown in Fig. 147, and have a slug or deadman, a piece of sound pole 5 ft. to 6 ft. long and 10 in. to 12 in. in diameter, bolted to its butt as shown.

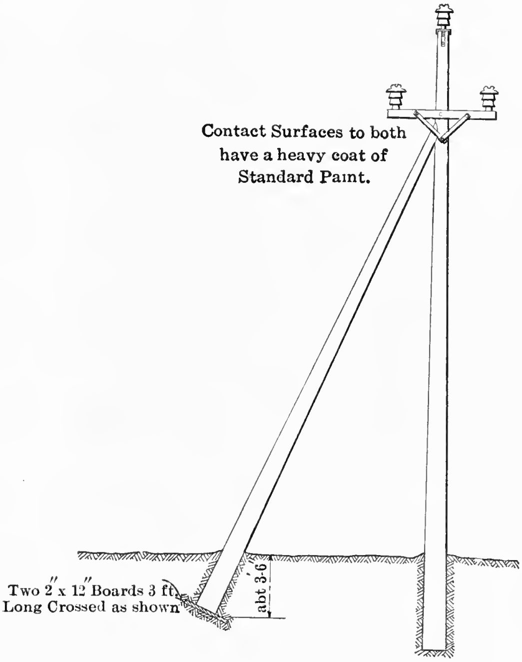


Fig. 145.—Push brace.

Standard methods of wire guying are shown in Figs. 148 and 149; these are the arrangements ordinarily followed in transmission line work for light and heavy angles respectively; a push brace should preferably be used where the line is built on or closely adjacent to a highway, etc., where the "corner" is such that a wire guy would strike in the road and it would be necessary to carry the guy across the road to a guy stub. Where a corner is heavy enough to require the guying shown in Fig. 149, the poles on either side of the corner should be double-armed and head guyed as shown. Special head guying will also be required where severe vertical angles are encountered, such as will be met with in hilly country, and also where, on account of the contour of the country, the crossing of rivers or swamps, etc., unbalanced spans may be called for, necessitating side guying also if the spans be long. At railroad crossings the two poles on each side of the crossing span are usually required to be strongly guyed.

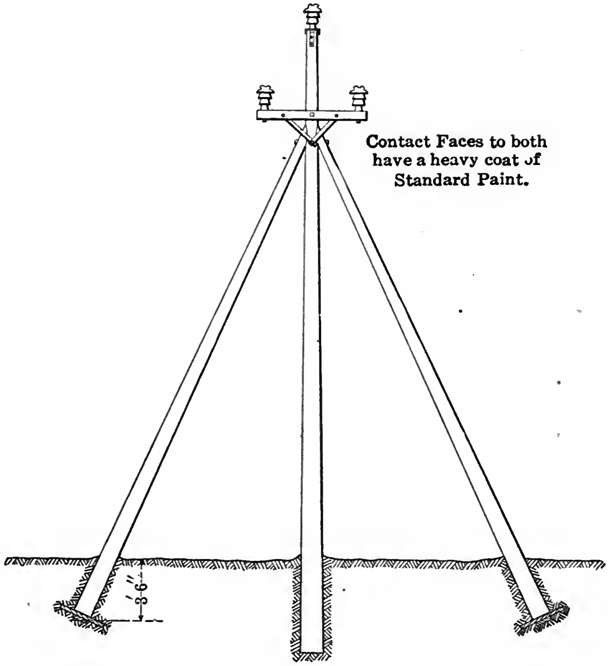


Fig. 146.—Double push brace.

Where conditions are such that it is impossible to secure right-of-way for a guy, such as may occur where a high-tension line is built along a public highway or in cases where easement for the erection of a line is secured only on one side of a line fence and it is impossible to arrange for guying privileges on the other side, a truss arrangement as shown in Fig. 150, known as a "buck-stayed" or self-supporting pole must sometimes be used. The employment of this means of avoiding the placing of the regular guys is expensive and less satisfactory than a straight guy, and should not be used where any other solutions of the problem are possible.

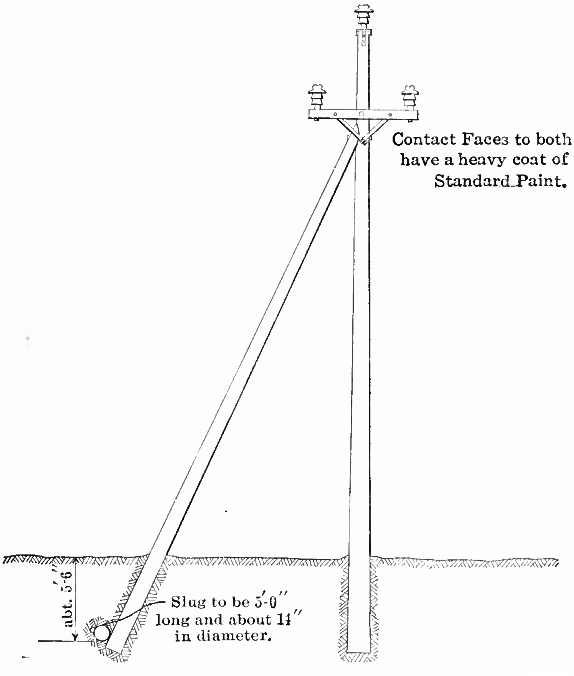


FIG. 147.—Push and pull brace.

Storm guying consists in reinforcing poles at certain intervals along the straight stretches of the line, to resist strains in all four directions so as to localize structural line failures and prevent them from becoming cumulative on long tangents. Fig. 151 shows the customary installation of storm guys, which, however, have not been much used in transmission line work, though there are many cases where they should really be employed.

For push braces, the size pole required depends upon the length of the line pole and the load it carries, but in no case should a brace be used having a top diameter of less than 6 in.; the brace should, under ordinary circumstances, be set with its butt about 3 ft. in the ground and at a distance away from the line of about one-third the height of the pole, measured along the surface of the ground; braces should be similar to the line pole and if preservative treatment be given the line poles, the brace pole should also be treated. At the point of contact of the brace with the pole, the end of the brace should be scarfed to fit but the pole itself should not be gained in any way.

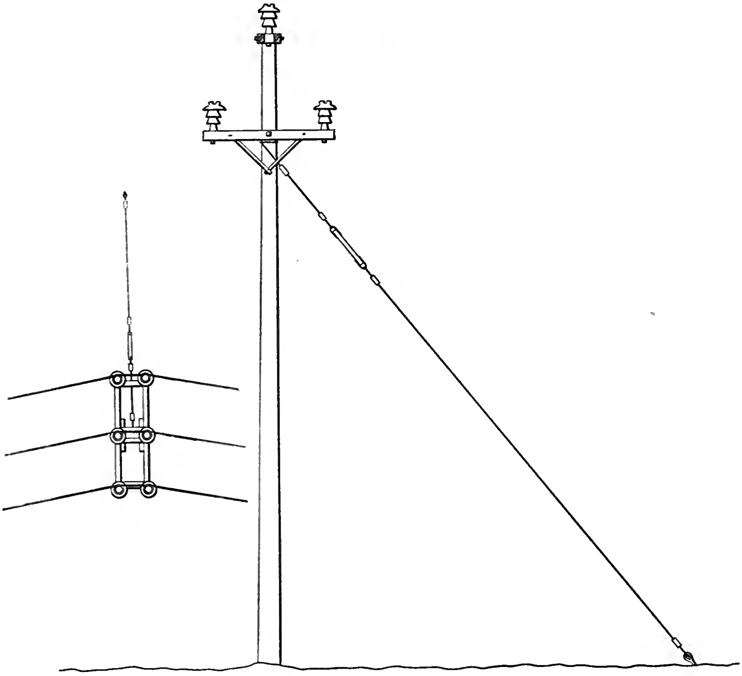


Fig. 148.—Standard wire guy.

A good, even bearing of the brace upon the pole should be secured, the ordinary method of laying out a brace and of determining the correct bevel of the brace top being to measure the distance from the brace through bolt to the ground and at right angles thereto, the distance from the pole to the brace hole, then starting from the ground line of the brace pole as it lies

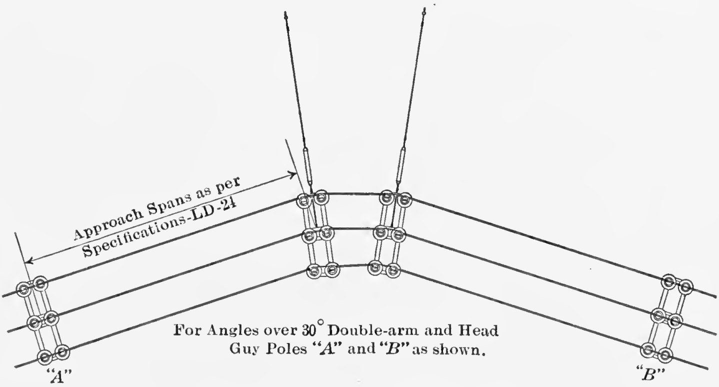


FIG. 149.—Heavy comb guying.

FIG. 150.—"Buck-stayed" or self-supporting pole.

on the ground, measure out these distances with a right angle between them and the bevel of the brace end will be indicated by the line of the tape and this will be naturally the point at which the pole is to be sawed off, the taper of the line pole being allowed for. While this is the method of laying out used by old-time line foremen generally, a far simpler method is to measure directly from the point on the pole where the center of the brace will strike, to the center of the brace hole and take the bevel with a bevel-square, from the line of the tape.

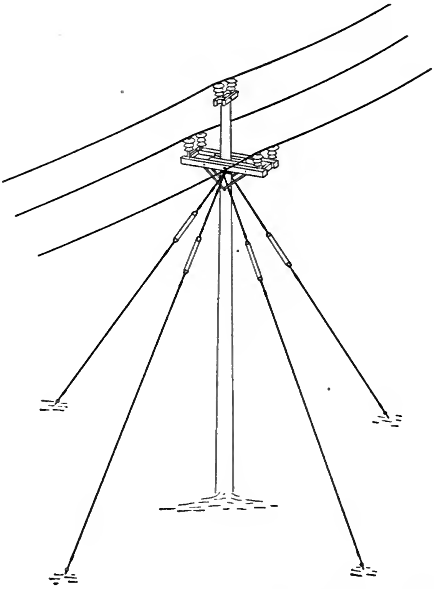


FIG. 151.—Storm guying.

The top of the brace pole should be carried up as far on the pole as clearances to the conductors will allow, with due consideration of the strain and the cost of brace-pole timber of the various lengths.

The erection of brace poles in the lighter sizes may be accomplished by piking, but as the guying crews should preferably be made up of as few men as possible, they are in most cases pulled up with a pair of blocks. If the timber be untreated, a liberal coat of tar, paint, or some good preservative, should be applied to both surfaces at the point of contact; the through bolt should be galvanized, be not less than 3/4 in. in diameter, and should be provided with heavy washers on each side.

In the installation of wire guys the location of the point of attachment of the guy to the pole in high-tension work is determined by the electrical clearance required, though for pin-type insulators, as a rule, the guy can be brought up immediately under the bottom cross-arm; where suspension insulators are employed, the guy under ordinary arrangements, will have to be placed lower down and greater clearances allowed. Clever angle construction where long-span (300 ft.) wooden pole work with suspension insulators is employed, is shown in Fig. 152; this type of corner construction has been used by the Madison

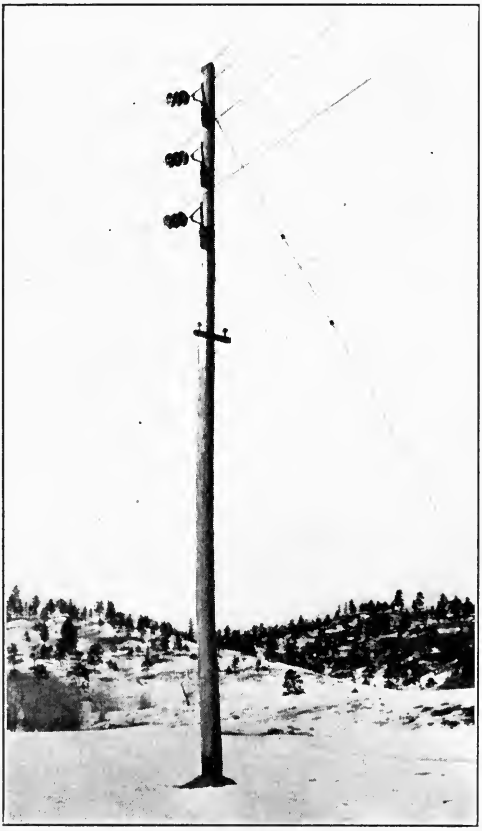


Fig. 152.

River Power Company and works out very satisfactorily. The condition to be sought for in any of this work is to bring the guy or brace as near as possible to the point of the resultant of the strains set up by the deflection of the wires.

The guy is attached to the pole by taking two complete turns around it and fastening with one three-bolt clamp for general conditions and two where unusually heavy strains are encountered; the ends of the guys should extend 8 in. or 10 in. beyond the end of the clamp and should be lightly made up to the guy proper by serving with a few turns of one of the strands of the cable. A strain insulator should be made up into the guy, about 6 ft. or 8 ft. out from the pole; here, instead of using clamps, many companies make up the cable on either side, the work being done as much as possible by the men when weather conditions prevent work outside; where the connections are made up two or three turns should be made with the full cable before unstranding and serving; galvanized guy thimbles should be used at all points where a metal to metal turn through eyes, etc., is made with the guy strand.

With the guy made up on the pole, the other end of it is passed through the eye of the anchor rod, the slack pulled out, and a pair of 4-in. or 6-in. double blocks with a come-a-long, preferably of the eccentric type, at each end, is hooked on to the guy proper and to the end; the guy is then pulled up to the required tautness, usually enough to rake the pole back a little so that it will be nearly straight when the strain is placed upon it, and is fastened with a three-bolt clamp in a manner similar to that of the other end.

For wire guys, only stranded cable, preferably seven-strand, should be used, and it should be of first-class material and galvanized. For transmission line work of any importance whatever, 3/8-in. strand should be the smallest size allowed on the job regardless of the strain; a schedule should be worked out for the direction of the foreman which will give in tabular form the size and grade of strand to be used for various ranges of line angles and distances of anchor from butt of pole, thus standardizing the construction and ensuring uniformity in the work; two or three different strands will cover all ordinary conditions. In the case of a line that has been staked out with an instrument, the guy anchor locations may also have been made and, from the data as to the horizontal deflections in the line and the vertical angles of the guys, the strain and the size of strand required can be determined in the office for each and every case and an exact definite schedule given to the foreman.

There are four regular grades of stranded guy or messenger cable, the standard, the Siemens-Martin, the high strength and the extra high strength; the first two are the grades used for general guying purposes, the latter two being employed very little in transmission work except as ground wire or as conductors for long-span river crossings, etc., where their great tensile strength makes them valuable; the standard is the cheapest and the most easily handled, and is less susceptible to injury from kinking or nicking, etc., than the Siemens-Martin or the other higher-strength strands and is, therefore, the most used for guy work. Where heavy strains are encountered and where first-class construction all the way through is demanded, Siemens-Martin may be used; this grade shows a greater uniformity in strength and toughness than the standard and is, therefore, often specified where the strains could be as well handled with the standard. On the other hand, it appears that the galvanizing on the steel higher-strength strand does not afford the effective life that it does on standard.

In Table IX is given data on the Siemens-Martin grades of strand, with approximate prices prevailing in 1911 for purchases in mile quantities.

TABLE IX

		Standard strand, galvanized		Siemens-Martin strand, extra galvanized	
Diam., in.	Approx. wt. in lb. per 1000 ft.	Approx. strength, lb.	Price per 1000 ft.	Approx. strength, lb.	Price per 1000 ft.
1/4	125	2,300	$6.20	3,060	$8.00
5/16	210	3,800	7.90	4,860	10.80
3/8	295	5,000	9.70	6,800	14.40
7/16	415	6,500	13.20	9,000	18.40
1/2	510	8,500	15.75	11,000	22.40
5/8	....	....	....	19,000	34.80

The figures on prices will give a comparison of the relative costs of the two grades; it will be noted that the standard, as given, is with single galvanizing and the Siemens-Martin with double dip. The cost of the standard for extra galvanizing is about 10 per cent. more than the tabulated figures.

The galvanizing of guy strand in particular of all line material, should be first class and should be in accordance with the recognized standards for that work, and should, preferably, be double dip. A set of general specifications for galvanizing giving methods for the conduct of tests, is given in the Appendix.

For the fastening of guy strand, three-bolt galvanized clamps should always be used, rather than two-bolt; clamps of the Crosby type are not suitable for permanent installation; for ordinary work, the standard rolled steel or malleable-iron clamps are satisfactory, but where, for special work, the high-strength strands may be required, clamps with curving grooves such as that illustrated in Fig. 153 are preferable; all clamps should be galvanized to correspond with that of the strand used and should have grooves rounded off a little at the ends to prevent any possibility of cutting. In addition to the regular flat type of clamp, there are several patented types that are very good.

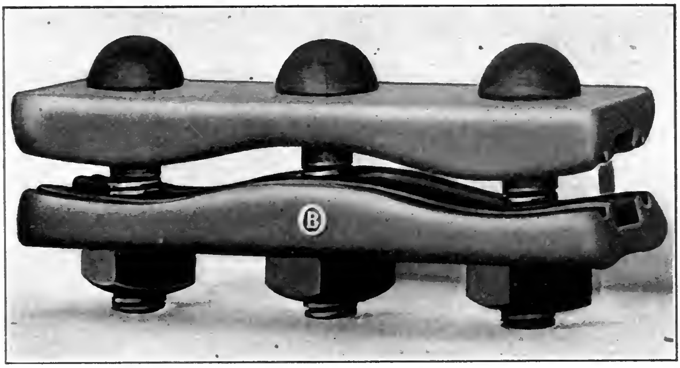


Fig. 153.—Guy clamp.

Anchors for guys are numerous; everyone with a genius for mechanical contrivances appears to have brought out a patent anchor. Among them are the screw type, the scoop or flat expanding plate designs that are buried with the use of an earth auger, the straight malleable-iron plate deadman, and various kinds of harpoon-like designs.

Fig. 154.—8-in. anchor.

The first of these is nothing more than an earth screw, see Fig. 154, which in the smaller sizes is set in the ground by means of a special wrench, which is really a long-shank socket wrench with adjustable handles, that upon the unscrewing of the threaded eye at the end of the anchor rod, is slipped over the rod and down to engage a square shoulder on the anchor proper; in the larger sizes, such as shown in cut, the rod is made heavy enough so that the anchor can be installed by inserting a digging bar through the eye and using it as a lever in turning the anchor into place. The advantage of the screw type of anchor, of course, is the fact that it does away with digging, and the installation cost is consequently low. For light strains in average soil, it works out quite well, though it is liable to creep under a good steady strain and is difficult to set in stony or coarse gravelly soil.

The scoop and the expanding types of anchors require the digging of holes of small diameter with an earth auger, and then for a certain type the enlargement of the bottom of the hole by means of a special tool, as shown

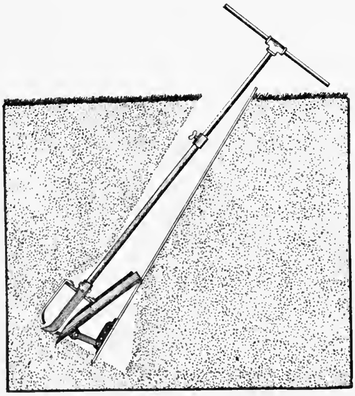


Fig. 155.

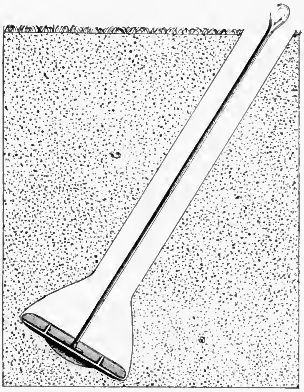


Fig. 156.

in Fig. 155; the blade of this latter type of anchor, shown in Fig. 156, is about twice as long as it is wide and is suspended from the rod so that it can be swung on its short axis to allow its introduction in the hole, which is bored slightly larger in diameter than the width of the blade; upon reaching the enlarged bottom of the hole it is pushed into its natural position at right angles to the axis of the rod, by means of a digging or a tamping bar.

The expanding types are placed in straight auger holes in the same manner as the foregoing and then by hammering a shoulder or lug with a tamping bar, multiple disks or arms are projected into the walls of the holes, the special claims of the manufacturers of this type of anchor being that the bearing is on undisturbed earth.

For light lines and for telephone work, several different types of anchors have been developed which present only a nominal resistance to being driven into the ground with a maul and which, upon a reversal of strain or upon giving the rod a turn, project blades or wings into the earth, acting like a barbed arrow.

While any of the patent anchors, such as described above and others, have their own sphere of usefulness, the criterion of their value in any particular soil, is the effective bearing area that they possess. Consequently they have not been given much serious consideration in heavy transmission work, though it may be truly said that very little intelligent effort is usually made to seek the most economical and satisfactory appliances in the guying of most high-tension lines. Therefore, the "safe and sane" theory has been applied to anchorages for guys, and the deadman type is often used throughout, where at points of lighter strain, the use of some other type would be as satisfactory and of lower cost.

The deadman, slug, or sleeper anchor consists usually of a piece of sound pole, 10 in. to 16 in. in diameter and from 5 ft. to 8 ft. long, buried 6 ft. or 7 ft. in the ground; where it is impossible to go as deep as this economically, the length and diameter of the deadman is increased or the bearing area extended by placing timbers over the log at right angles to it. To the deadman is attached a galvanized anchor rod, usually 3/4 in. or 1 in. in diameter and 7 ft. to 8 ft. long, provided with a 4-in. × 4-in. × 1/4-in. galvanized washer; Fig. 157 shows a typical deadman anchor. Wherever the soil will stand it, the hole for the deadman should be dug along the lines shown dotted in Fig. 157, the object being to disturb the earth in direct bearing as little as possible so that there will be no possibility of anchor creepage. Where treated poles are used, the deadman should, of course, be subjected to the same process. In place of wooden deadmen, stones and malleable or cast-iron plates are used somewhat where their area is sufficient to handle the strain, and experiments have been made with concrete, tamped into the hole after the insertion of rod and reinforcing steel.

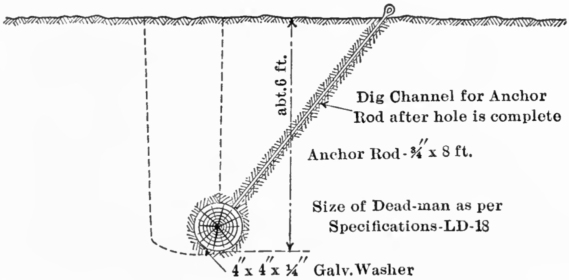


Fig. 157.—Dead-man or long anchor.

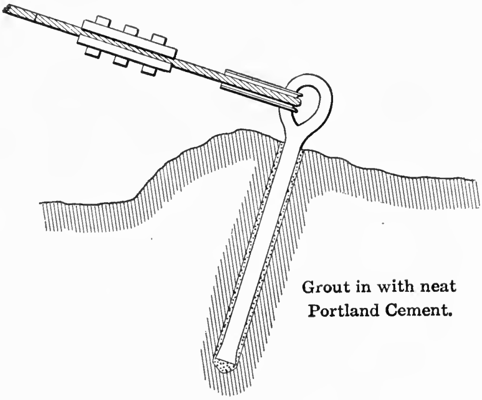


Fig. 158.—Rock anchor.

It often happens that anchors must be set in rock, and Figs. 158 and 159 show methods of doing this. The setting shown in Fig. 158 is for places where hard homogeneous ledge rock is encountered, and eye-bolts 1 in. or so in diameter and 12 in. to 16 in. long should be used; the eye-bolt should be nicked or scarred along its shank or upset slightly at its lower end and should be grouted in with neat portland cement, care being exercised to see that the hole is drilled only a little larger than the bolt. Where the rock is softer or stratified, an ordinary guy rod, split and fox-wedged into a hole 2 ft. or 3 ft. deep and set in neat portland cement as shown in Fig. 159, is very satisfactory.

The cost of the different patent anchors varies with the locality and the quantities purchased, but in amounts of fifty or so, the plain screw-type will cost in the 8-in. size about $4.50 each, the 10-in., $6.50 and the 12-in., about $9.10 each, laid down throughout the Middle West; the scoop type, such as the Miller, with an 8-in.×20-in. plate and 3/4-in.×8-ft. galvanized rod will cost laid down in the Middle West about $2.50 each and with a 9-in.× 25-in. plate and a 1-in.×9-ft. galvanized rod about $4 each; the plain malleable-iron plate type of anchor will cost about $1.60 each for average strains encountered with 30-ft. to 40-ft. poles, and $2.75 each for 45-ft. to 60-ft. poles.

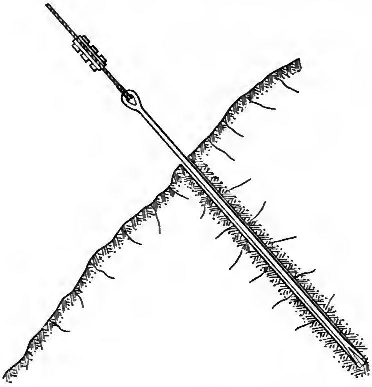


FIG. 159.—Rock anchor.

The old reliable, the deadman or log anchor, is the cheapest of all as far as cost of material is concerned, a 6-ft. slug costing not more than 40 cents or 50 cents, with a 3/4-in.×8-ft. galvanized rod at about 60 cents and about 5 cents for fitting, giving a total cost of the anchor ready to distribute at $1.05 to $1.15 each.

The strain that the different types of anchors will hold in various kinds of soil is largely a matter of conjecture, as no series of comparative tests have ever been made to the knowledge of the writer. The usual assumption made in the calculation of the strains that an anchor will stand, is that the ultimate load is the weight of the volume of earth included by lines drawn from the edge of the exposed surface of the earth at an angle of about 30 degrees from the vertical, plus the weight of the anchor. This assumption holds fairly well with tests made by D. R. Scholes of the Aermotor Company, noted by him in the 1907 *Transactions of the American Institute of Electrical Engineers* and with experiments carried out by Mr. Fraser of the Southern Power Company also reported in the 1907 *Transactions*, but it is questionable how it applies to strains at varying angles from the vertical and for surfaces other than flat, such as that presented by a log; and it is natural that the general assumption will not hold for wet soils.

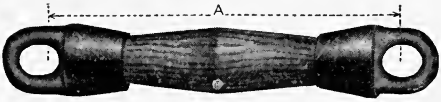


Fig. 160.—Guy insulator.

In the wire guying of wooden poles, it is now the general practice to insert some kind of a strain insulator in the guys about 6 ft. or 8 ft. out from the pole, the insulator being of wood, porcelain or composition; the function of this insulator is to prevent injury or damage resulting from contact of persons or animals with a guy which may be charged from leaky insulations, etc., and also to prevent burning of the pole at the point of attachment of a guy due to similar conditions.

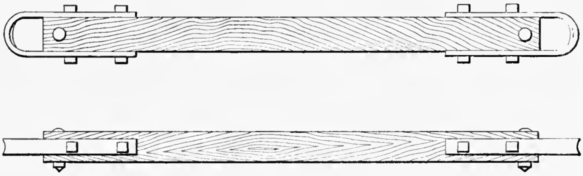


Fig. 161.—Wood guy insulator.

Wooden insulators, either the type shown in Fig. 160 or a design like Fig. 161, the latter usually "home-made," have been used to a great extent in transmission line work, the former as a rule in lighter and lower-voltage work and the latter in lengths as great as 6 ft. or 8 ft. in the heavier construction and higher voltages. The wood strains shown in Fig. 160 are made in sizes from 6 in. to 48 in. and longer, for ultimate breaking strains up to 20,000 lb. or more; the wood generally used is hickory and is given a preservative and insulating treatment. On a typical high-tension line in the Middle West the guy strain insulators were of 2 1/2-in.×2 1/2-in.×30-in. oak, boiled in linseed oil, the design being similar to that shown in Fig. 161; where larger strain insulators have been employed, such as 4-in.×4-in.×6-ft. oak used in some Western lines, they have often been used untreated. Where wooden insulators are used, however, they should always be given some treatment and as a general thing hard maple, oak or hickory should be used.

The objection to the use of wood is that it is susceptible to destruction by burning in case of heavy leakage; for this reason insulators of porcelain, interlinked or cemented, or some of the compositions, have been installed in the latter lines to a great extent.

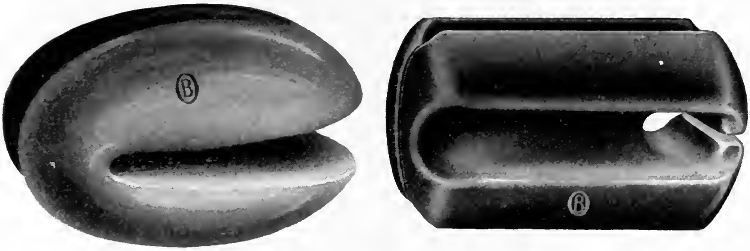


FIG. 162.—Porcelain circuit breaks.

Porcelain is the most favored for high-class line construction, though its cost is appreciably higher than that of wooden insulators for the average sizes that have been used in transmission work. There are two general types of porcelain circuit breakers that have been used for guy work, the first, a straight ball or "goose egg" as shown in Fig. 162, and the other, designs of the same type used for suspension insulator work, such as are illustrated in Figs. 163 and 164.

The first-mentioned, the ball type, is used mostly on lower-voltage lines, while the latter kinds are beginning to be used where heavy wood strains have been used heretofore.

The use of composition strain insulators is confined mostly to distribution and street railway work, though at times employed on lines which carry the lower voltages.

In cost the wood strains for the average of sizes will run about the cheapest, though some of the porcelain designs will compete very closely for certain conditions; a 14-in. design will cost about 28 cents each laid down in quantities of 100 in the Middle West, and the 48-in. about 75 cents.; these figures are for manufactured insulators and those of the design shown in Fig. 161, made up locally will cost, for a 2 1/2-in.×2 1/2-in.×48-in. oak insulator boiled in linseed oil or paraffine, from 50 cents to 60 cents each in like quantities.

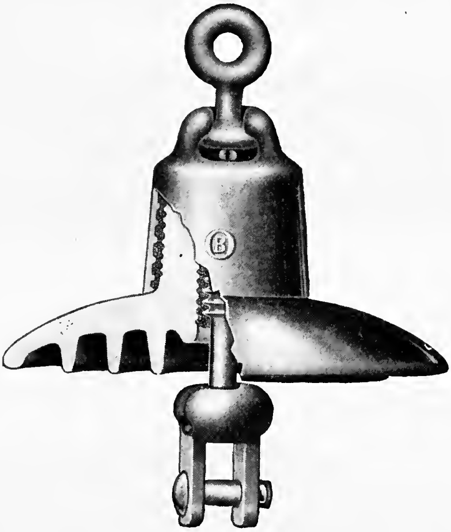


Fig. 163.

The ball type of porcelain strain insulators in the sizes used in the lighter construction will cost from 20 cents to 30 cents laid down almost anywhere in the East or Middle West; the cemented type of strain insulator, similar to the kind shown in Fig. 163, will cost for the 10-in. size, about 90 cents to $1 f.o.b. factory with the required fittings, and various manufacturers list their insulators of this diameter and general design to stand from 9000 lb. to 18,000 lb. Smaller sizes of this design of insulator are being brought out especially for guying work.

The interlinking types, such as illustrated in Fig. 164, have an advantage over the design just discussed, in that they provide a mechanical connection between the two parts of the guy in the event of the failure of the insulator. This type in the 6 1/2-in. size will cost about 75 cents each at the factory and will stand an ultimate load of about 7500 lb., while the 10-in. size will cost about twice as much. This type of insulator is, in fact, practically a ball type of insulator with the grooves enclosed and a flange added to increase the leakage surface.

The composition insulator is so rarely used in transmission line work that data on the various sizes are unnecessary; as a rule, the costs are above those of any of the others.

Fig. 164.

Cost data on the guying of transmission lines are difficult to secure and the unit figures obtained are extremely variable, owing to the great differences in conditions; one line may require guys at average distances apart of a quarter of a mile and another at intervals of a mile; in one case the soil may be a sandy loam and in another it may be tough hard clay; the work may be carried on in the summer time here and in the midst of winter there. All of these factors must be taken into consideration in making comparisons of costs; furthermore, even under practically similar conditions as to type of construction, soil, climate, weather, etc., the engineer for one line may have different ideas as to what depth of set and size of anchors will be required for a certain strain and this again makes for variations in costs.

For transmission line work a crew of four men and a team, made up of a lineman sub-foreman, one lineman, a groundman, and a team and teamster, make a good size gang for average work; the crew should, under general conditions, be kept as small as possible as in transmission work the guys are usually not at very close intervals and if a large gang is used the percentage of dead time, that is, time required in moving from one job to another, will be excessive.

The cost of setting push braces for a line of 9-in. top, 40-ft. poles with a crew of the foregoing size, with the foreman at $3, lineman at $2.75, groundman at $2 and team and man at $4 a day was about $2.65 each, not including general supervision or the hauling of the pole, the latter averaging about 45 cents. These poles were culls from the line poles and were very heavy; they were set 3 1/2 ft. in the ground and were about 32 ft. long; the soil was a sandy loam, the work was done in the late fall and winter and the braces averaged about 1 1/2 miles apart, guys being generally used. Push braces for a line of 7-in. top, 35-ft. northern cedars, using brace poles, 28 ft. to 29 ft. long with 6-in. tops, cost for erection labor, exclusive of hauling and general supervision, about $1.60 each with a wage scale about the same as for the preceding case; the soil was a medium clay and the braces were about 1 mile apart.

The cost of placing guys complete for a line of 40-ft. poles, using deadmen 6 ft. long and from 12 in. to 16 in. in diameter buried 6 ft. deep in sandy loam, including the placing of the guy, with a wood strain cut in, and the hauling, but not including general supervision, was about $2.75 each; 3/8-in. standard and Siemens-Martin strand were used. The crew consisted of a foreman at $3, one lineman at $2.75, two groundmen at $2, and a team and man at $4 a day; the work was carried on in the late fall.

For a line of 7-in. top, 35-ft. cedars, log anchors 5 ft. to 6 ft. long and about 12 in. in diameter, buried about 6 ft. in medium clay soil, with a 3/8-in. standard strand guy placed, including a porcelain strain insulator in same, cost about $3.90 each, not including general superintendence; the wage scale was about the same as for the previous case.

In *Engineering-Contracting* for May 27, 1908, the labor cost of installing deadmen anchors with guys complete, is given as $2.03; this was for a telephone job in a small town and the standard pole height was 30 ft.; no data is given as to wage scale, size of anchor, kind of soil, etc.

In the same journal for Feb. 5, 1908, the total labor cost for installing guys with ground stubs is given as $3.25 each; the line poles here were 30 ft. to 33 ft. chestnut, the soil was a red sandy clay and the wage scale for a ten-hour day was, foreman $3, lineman $2.50, groundman $1.50, and team and man $4.50.

CHAPTER XI

STRINGING WIRE

For the commercial transmission of electrical energy, we have available copper, aluminum, bi-metallic, and iron or steel wire.

Copper has been the most used in all kinds of construction, possessing as it does the highest conductivity, a strength and hardness greater than that of any other metal with the exception of steel and iron, great resistance to corrosion from oxidation, and qualities of ductility and malleability that make it easily worked; it has a fairly low temperature coefficient and not being subject to rapid oxidation, as is aluminum, can be easily soldered.

Copper wire is usually classed in two grades,- annealed and hard drawn, which differ both in their mechanical and their electrical properties; varying with the size of the conductor, annealed solid copper wire will have a tensile strength of from 30,000 lb. to 42,000 lb. and annealed stranded wire of from 29,000 lb. to 37,000 lb. per square inch; hard drawn will run from 45,000 lb. to 68,000 lb. per square inch for the solid wire and from 43,000 lb. to 65,000 lb. for the stranded. The elastic limit for solid annealed copper wire is 6000 lb. to 16,000 lb. per square inch and for annealed strand from 5800 lb. to 14,800 lb.; for hard-drawn solid wire it runs from 25,000 lb. to 45,000 lb. and for hard-drawn strand from 23,000 lb. to 42,000 lb. per square inch, as given in the American Steel & Wire Company's hand-book.

There are intermediate grades of hardness and strength, such as medium hard drawn, which are sometimes called for on account of a desire to avoid the greater liability to injury through nicking or kinking in stringing, to which the hard drawn is susceptible; hard-drawn wire is also more liable to break in time at its supports where it is tightly clamped, as on a pin-type insulator. The conductivity of annealed copper wire referred to Matthiessen's standard is from 99 per cent. to 102 per cent., and that of hard-drawn wire from 96 per cent. to 99 per cent., as ordinarily given by wire manufacturers; the temperature coefficient of linear expansion for copper wire, per degree Fahrenheit, is 0.0000096.

In specification for transmission copper it is usual to call for a conductivity of not less than 98 per cent. for annealed or soft-drawn wire and not less than 97 per cent. for hard-drawn, based upon Matthiessen's standard.

Annealed wire is practically never used nowadays in transmission work, and for conductors larger than No. 4 B. & S. it is customary to employ a stranded wire on account of the greater ease and safety in handling, and greater strength than that of a solid wire of corresponding section; on account of the greater increment in the base price of seven-strand over that of three-strand cable, the latter is sometimes used for medium-size conductors, due consideration being also given the fact that the individual strands become quite small in some of the lighter seven-strand conductors; in most cases, however, depending upon the circular mills, either seven-strand or nineteen-strand cables are used for the conductor sizes required in transmission work.

The standard method of making up strand is to use a core wire of the same size and kind as the other strands, but in many cases a hemp-center cable has been used and in some instances a steel-core wire; the object of the hemp center is to place all strands under equal strain, primarily, though the reduction of skin effect is also a slight factor, while the use of a steel core is prompted by a desire for a greater total breaking strength.

Aluminum possesses a valuable characteristic for line purposes in that its weight for the same conductivity is only about one-half that of copper; on the other hand, its diameter is about 1.37 and its area about 1.64 times that of copper of equal conductivity.

The main features that have deterred engineers from using aluminum to a great extent in the United States, however, have been partly its low tensile strength and high coefficient of expansion, which required careful attention to the stringing of a line to avoid overstraining at maximum load conditions, and partly the close relationship existing between the aluminum and the copper markets. In other words, there has never been enough economy shown over copper to warrant, in the United States, the general use of aluminum with its requirements of greater care and more exacting allowances of sag. The fact also that some trouble was experienced in the earlier days of electrical transmission from crystallization of aluminum conductors, together with the impossibility of making splices or connections of good conductivity in the manner followed in copper work, has likewise had its bearing on the question; with the introduction of stranded conductors altogether and the use of sleeve splices, these troubles have been practically eliminated, but the prejudice has not altogether been removed.

The conductivity of aluminum will run about 60 per cent. to 63 per cent., based upon Matthiessen's standard, being given as 62 per cent. in the table of properties issued by the manufacturers. Its tensile strength in stranded conductors is about 24,000 lb. to 27,000 lb. per square inch, with an elastic limit of about 14,000 lb. Comparing hard-drawn copper and aluminum conductors of the same conductivity, and basing the comparison upon aluminum having about 60 per cent. the conductivity of the hard-drawn copper, the tensile strength of the aluminum conductor is only about 65 per cent. of that of the copper line wire that would be required for the same service.

The temperature coefficient of linear expansion of aluminum per degree Fahrenheit is 0.0000130, as against copper at 0.0000096.

Bi-metallic wire, describing copper-clad as the one commercially available, consists of a steel core with an intimate covering of copper, the purpose being to combine the strength of steel with the conductivity and non-corrosive qualities of copper; its greatest field has been in telegraph and telephone construction, but it is also being advocated for transmission line work, not only for ground-wire purposes, but for conductors also. Very likely it will work out well for conductor purposes in the construction of light lines, where with the use of long spans, it is desirable and necessary to employ conductors of greater strength than would be required from electrical considerations alone.

Attempts were made over forty years ago to effect a practicable combination of copper and steel to form a conductor of greater conductivity than steel and of lesser depreciation, but the wire as then manufactured did not hold up in commercial use, being subject to rapid corrosion through electrolytic action; with the method devised by Monot of effecting a weld between the steel and the copper, it is claimed, and the claim is justified by its performance in practical work, that copper-clad wire now is a commercial success, as far as freedom from electrolytic action is concerned.

As given by Roebling, bi-metallic wire has a tensile strength about 25 per cent. greater than that of hard-drawn copper, and a conductivity about 65 per cent. of that of pure copper, no data being given as to the relative proportion of the two metals; in the *Electrical World* beginning Dec. 22, 1910, F. F. Fowle presents a series of articles bearing upon the subject of compound wires, giving the results of tests and investigations, as to electrical properties mainly; in his articles the aluminum-coated wire has also been taken up though this is not as yet a commercial proposition. Mr. Fowle gives for No. 6 B. & S., with a core diameter of 0.13 in. and a shell thickness of 0.016 in. a conductance ratio to hard-drawn copper of 0.4408, noting that the rated ratio for this wire is 40 per cent.

Copper-clad wire has been employed with very satisfactory results for ground-wire purposes in place of steel, as under the high frequencies to which it is subjected in lightning protection it presents a much lower impedance, and at the same time it possesses the mechanical qualities desirable.

From an economical standpoint, for general use as a line conductor material it does not present as great advantages as might be expected, the price of No. 2 B. & S. copper-clad wire on a certain job being 13.5 cents per pound while No. 0 copper with hemp center costs 17.7 cents per pound, the prices being f.o.b. the job in each case; comparing properties and cost of this wire with those of the other materials and taking into consideration the scrap value, which ought also to have a bearing upon the matter, it would appear that the use of copper-clad for conductor purposes will be limited, in the case of average transmission lines, to that portion of the work where extra long spans may be required, though for light lines that are to be carried in comparatively long spans throughout it will work out economically; it will also of course have a place in telephone work, where the telephone line is carried on the same structures as the high-tension wires.

Steel is limited in use for energy transmission almost entirely to special long-span work, such as is encountered in river crossings, etc., though there are a few instances where it has been used under other circumstances in important work on account of its strength, as for instance the 2-mile terminal line through the city of Syracuse, N. Y., where for a 60,000-volt single circuit construction, 7/16-in. galvanized plough-steel strand was used for conductors. It has also been employed for some construction work where the prime requisite was cheapness.

For general line purposes, outside of guying, the Siemens-Martin grade of steel strand has been mostly employed; the conductivity of steel strand runs from 8 per cent. to 11 per cent. of that of copper and its coefficient of linear expansion per degree Fahrenheit is 0.0000064.

Wire for transmission line work is usually shipped on wooden reels, but in the smaller sizes, No. 10 to No. 6, such as may be required for the telephone line, it may come in burlapped coils. The length of wire per reel is usually specified by the purchaser, not limited by manufacturing conditions, and depends upon the size of the conductor, the topography of the line, the method of stringing and the size and weight of the reels loaded; in medium sized copper strand, lengths of from 1 mile to 2 miles per reel are common, and in the larger sizes from 3000 ft. to 4000 ft. per reel is often specified.

The overall diameter of reels will ordinarily run from 50 in. to 70 in. with an outside width of 27 in. to 33 in., giving a barrel diameter of from 24 in.; to 30 in. ordinarily and an inside width of 22 in. to 28 in. Reels are wound so as to leave, when fully loaded, about 3 in. or so of clearance between the cable and the rim of the reel, to allow of their being rolled in handling, without danger of injuring the wire; ordinarily the cable is protected by a layer of tough paper and a covering of burlap, but where hard-drawn copper is to be handled through rough rocky country, it is often well to specify that the reels be lagged.

In preparing shipping direction for wire, especially copper, not only should convenient locations with reference to the line be selected, but attention should be given to ensuring proper storage facilities upon arrival; copper in particular is a commodity that is more or less easily convertible into cash, and it is just as well to use a little discretion and avoid tempting fate by providing for storage space in a warehouse where the wire can be kept under lock and key.

In unloading reels from the cars they should be weighed and the weights checked against those billed, noting any discrepancies or any indications that reels have been disturbed; if it is not possible to check the weights, each reel should at least be given a careful inspection.

When the crews are ready to begin stringing wire the reels should be hauled out and left at farm-houses as close as possible to the points where the material will be needed; the reels, set on edge and solidly blocked in the box, can be hauled out in ordinary farm-wagons; the cost of distribution is such a variable quantity, owing to the fact that it is usually not hauled directly to the place where it is to be used, that it is impossible to do more than to approximate it, but on a weight basis it ought not to exceed from $1.75 to $2.25 per ton delivered, including loading at the storehouse and unloading at destination, with figures based upon an average haul of 5 miles on fair country roads with teams at $4 per ten-hour day; in mountainous or rough country, the figures will be much higher.

FIG. 165.—Loading reel wagon.

Running-out, stringing, pulling-up, and tying-in wire is usually carried on by one gang, completing the erection of the wire as it goes, though in some cases the wire has been run out and carried up on the arms by one gang while another crew followed, pulling-up and tying-in.

Running out of the wire may be done by mounting the reel on the axle of a two-wheeled reel cart and uncoiling the wire on the ground as the team draws it along, Figs. 165 and 166 showing a typical cart of this kind; or the reel may be jacked up on portable frames and held immovable, and the wire run out by hooking a team on the end of the cable, the wire being carried up on the arms as each structure is reached and either pulled through over them, in the case of wooden arms, or passed through snatch-blocks. With pin-type insulators, the wire can be pulled through alright in short lengths by laying it in the wire groove of the insulator or in the case of wooden construction, on the cross-arm, but this method requires care and is not as satisfactory as the use of snatch-blocks. The use of reel wagons is best adapted to the stringing of medium size conductors with lengths of 1 1/2 miles to 2 miles of wire on a reel, where the line supports are close together, and where pin-type insulators are used; where suspension-type insulators are employed and where large conductors with short lengths of cable per reel are to be strung with supports far apart, the unreeling and stringing from fixed reels will usually work out best.

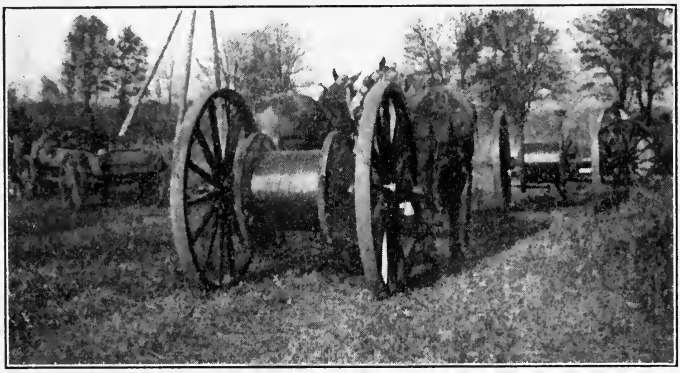


Fig. 166.—Reel wagon.

Where reel wagons are used to run out the wire for, say a single-circuit line with a ground wire, either two or four wagons will be used simultaneously; where the job is of any size the use of four wagons, either with a team for each cart or with two teams taking alternately two reels a mile at a time, is advisable; the teams are generally placed in charge of a handyman or a lineman who will help out the teamsters as needed, clear obstructions from the path of the teams, open fences for them, etc.

Following the teams will come, in the case where two teams are used alternately with two sets of reel wagons and the "going" is fair, a crew of about four linemen and four groundmen in charge of the crew foreman; this crew will carry the wires up on the cross-arms, the teams being far enough ahead so that all the wires on the structure will have been run out and can be pulled up at one climbing; the usual method of pulling a wire up on the arm in short-span work is for the linemen on the poles attended each by a groundman, to pull it up hand over hand with a hand line, all working together; in long-span construction the hand line is reeved through a single-sheave block or, in the case of a heavy conductor, a pair of light blocks are used, and the groundmen hoist the wire to the men on the structure. When the wire is raised up on to the structure it is usually laid in the wire groove of the insulator in the case of the pin type, or is placed in snatch-blocks or cable rollers in the case of the suspension type.

Where the reels are set on stands and held fixed while the ends of the wires are drawn out by a team usually all the wires on one side of a structure are run out at the same time, and with some little trouble wires for both sides of the supports can be drawn out simultaneously with one team by unhooking the set for one side at each support and passing it around the structure, using a sort of running board; this is liable to bring injury to the wire, delays the team, requires extra men, and even in the case where the total number of wires on the structures is only four, it is doubtful if it will prove as economical as having two teams and pulling out the conductors for each side separately, or using one team and working one side at a time, though the latter will require the climbing of each tower twice.

As the team passes each tower and proceeds far enough beyond to give a little slack, the wires are pulled up and dropped into snatch-blocks; these snatch-blocks, in the case of suspension insulators, are supported so that when the wire is in them it will be approximately at the level of the cable clamps on the insulator; as noted previously, sometimes in wooden pole work rollers are not used, the wires being pulled along over the arms, a method that should not be used for stretches of any length.

When about a mile stretch of line, or a reel's length if less than that, is run out and hung, the crew will prepare to pull up; this is done either by the same men who have been hanging the wire up or by another section of the crew, depending upon the rate of speed with which it is desired to carry on the work.

In the past it was the practice to pull one conductor at a time, but now in practically all work it is customary to pull all three of the wires of a circuit at the same time, the same tension in each being insured by the employment of an equalizer. This equalizer consists of an arrangement of single-sheave blocks reeved as shown in Fig. 167, and connected to an equalizer bar of oak, 4 in. × 6 in. in section or of any other size that may be required; to the hook of each of the three "floating" single-sheave blocks is attached a wire grip, and with these each clamped to its wire, it is obvious that as tension is applied to the

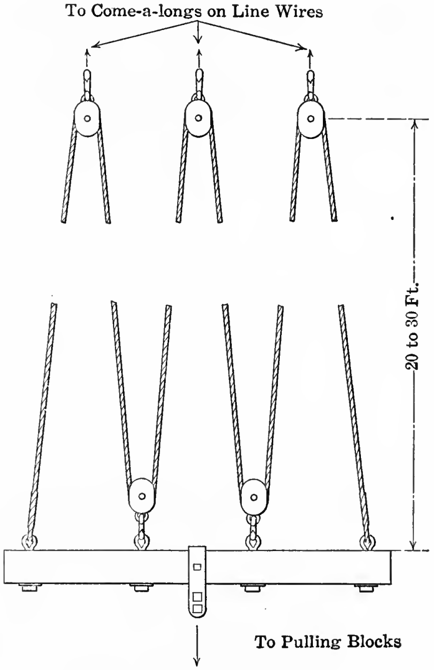


Fig. 167.—Equalizer rig.

system by means of the main pulling blocks, any inequalities in the lengths of these three wires will be adjusted by the movement of the floating single-sheave blocks, so that all wires will be pulled up under the same tension. An arrangement similar to the above, using three single-sheave blocks with a three-sheave block in place of the bar, is also used, but is hard to rig and hard to keep from fouling, the arrangement described being preferable; it is evident that by the use of additional blocks, these schemes can be adapted to the simultaneous pulling up of any reasonable number of wires.

With the line wires spliced at the far end, the general routine of pulling up is as described in the following, the work being outlined for a wooden pole line in particular though necessarily the same applied to any kind of construction.

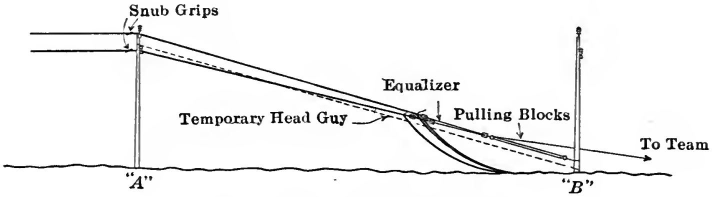


FIG. 168.—Pulling up wire.

Referring to Fig. 168, *A* is the last pole upon which the wires have been carried; the pulling blocks are first hooked into a sling about the butt of *B*, the next pole ahead and extended about 50 ft. or 60 ft., these blocks being 8-in. three sheave and reeved with 7/8-in or 1-in. line for average work; next the pulling grips fastened on the floating equalizer blocks are slipped on to their individual wires, the equalizer bar carried back and the pulling blocks hooked into the clevis of the bar; then a team is hooked on to the fall line of the blocks and the wires are drawn to the proper tension, or a pair of luff-blocks may be used in place of the team; when the wires have been pulled to the required tension or sag, the determination of which is discussed later in the chapter, the fall line is snubbed and a head guy, either of rope or a piece of guy strand is run from the top of pole *A* to the butt of *B*; with this head guy in place, a lineman climbs pole *A* with a wire clamp or grip for each wire. He first fastens each grip to the cross-arm by means of a rope sling, and then reaches out and slides the grip out in place on the wire so that upon slightly slacking off the pulling blocks these snub-grips or holding-come-a-longs take the strain, making a dead-end pole temporarily out of pole *A;* the men now go back and tie in the stretch pulled up and then go ahead again hanging up the wire and preparing the next mile stretch for pulling, the holding grips and head guy being of course left on *A* until the next pull is made and held. In tower work the method is the same, except that there are no handy snubbing poles and stakes must generally be driven for the pulling blocks; under the weather conditions usually prevailing when wire is strung, in most cases towers will not require head-guying to hold the temporary dead-end, though where tower anchors have been newly set, it is often better to be on the safe side.

The grips or wire clamps used should preferably be of the parallel-jaw type, similar to the Buffalo grip, for general work.

The splicing of line conductors of any of the materials is preferably done with sleeving, though in the case of copper very satisfactory results can be obtained from the use of the "sunburst" or cable splice for strand, and a modified Western Union for solid wire; the danger of injury in making up these splices where hard-drawn wire is used, together with the longer time required for the making of a joint and the fact that as good an electrical connection is not secured, usually makes the use of sleeve splices an economical consideration.

In making up sleeve splices, from three and one-half to four complete turns should be taken and the twisting should be done from both ends, care being taken not to split the sleeve or nick the conductor; where sleeves are made with a joint, care should be taken to see that they do not open up at this point. The twisting should be done with special tools and the connectors or splicing clamps for this purpose should be made heavy enough to stand the work without springing, should fit snugly to the sleeve end, and should be made with a long enough leverage so that the maximum size of sleeve for which they are intended, can be made up with ease. There are several types of clamps supplied by sleeve manufacturers, some of them made for use on three or four sizes of sleeve by means of a rotating jaw on one side, which have to the writer's knowledge been so inadequate that the splicers preferred to use two monkey wrenches set up tight, in place of them.

In the making of the "Sunburst" or cable splice, the length of the completed joint should be from thirty to forty times the diameter of the conductor; the strands at the neck or the point of interlacing, should be laid as straight and as smoothly as possible avoiding all kinks, and the serving should be done without nicking the strands or the conductor. In the making up of Western Union joints not much of an attempt has evidently been made to secure the best possible results from that type of connection, and we find joints that are both mechanically and electrically weak; rough comparative tests made by the writer in corroboration of the tests on iron wire joints published in the *Electrical World* for Nov. 17, 1910, make it clear that a very good mechanical splice of the Western Union type can be made in copper by giving from five to six complete turns in the "neck" of the joint with about three short close turns at each end; in the tests of iron wire in the smaller sizes cited above, it was found that five turns in the neck of the joint would give it a breaking strength equal or better than that of the wire.

In general, there is usually no trouble in making up test specimens of splices that will develop the full strength of the cable, but the matter of insuring the same standard in the field will require skilled splicers and close inspection; in this regard the sleeve joint lends itself to a greater uniformity.

The writer once had occasion to make a few tests of the ordinary joints, sleeve, "Sunburst," and Western Union, as made up by average linemen in the field; the tests were made in a standard testing machine and are interesting. The first joint was a 7-in. sleeve splice in No. 5 hard-drawn copper with about three and one-half turns; this stood the pull without any apparent slipping until 650-lb. load was applied, whereupon the wire pulled through a little, the failure taking place at about 800 lb. outside the sleeve where the wire slipped through the sleeve had straightened out; a Western Union joint in No. 5 hard-drawn wire failed at 610 lb. slipping considerably before breaking; this joint was made up with about two and one-half to three turns in the "neck" and three to four end turns, being about 7 in. overall.

In a comparison of the strengths of sleeve and "Sunburst" splices in No. 2 copper strand, the former broke at 2760 lb., failing at a point just outside of the end of the sleeve, and the latter at the middle of the joint where the interlacing takes place, at 3000 lb., the strand itself, No. 2 nominal, made up of seven strands of No. 10 B. & S., broke at 3310 lb.

It will be noted that these tests are not necessarily representative of splices in general, being merely made for information in a certain case; it may be also noted that the sleeves used were of the seam type and that they split easily so that the linemen rather undertwisted them in most cases.

The labor cost of making splices will vary from a few cents up to $1.50 or more, depending upon the size of the conductors and the kind of splice; sleeves themselves will run 10 cents to $1 for the sizes called for in average line work. Copper sleeves are used for copper and for steel wires, being made of greater thickness and tinned, where used for steel; Aluminum conductors require a sleeve of that material.

In heavy construction work where the larger sizes of conductors in short lengths are used, a lineman with a helper will be steadily employed at splicing and if the conductors be unusually large he may require two men; where the conductor is medium size and comes in long lengths with few field cuts required, two of the men in the stringing gang can be used for the making up of joints, working with the main gang otherwise.

The deflection or sag allowed for similar lines under identical weather conditions varies in about the same way as the assumptions as to the extreme load for which towers should be designed. It is not within the scope of this work to consider the various methods of calculation, but in passing the writer may note that for one particular job, where a seven-strand cable a little larger than No. 2 B. & S. was to be strung in 500-ft. spans, recommendations from three engineers as to the sag to be given at a certain temperature were respectively, 11 ft., 20 ft., and 27 ft.

The standard maximum loading for the calculation of deflection as now recommended by the leading engineering societies is a 1/2-in. coating of sleet all around the conductor, with a wind pressure of 8 lb. actual per square foot of the projected area of the sleet-covered conductor, the sag to be such that with this load the tension in the cable will be less than its elastic limit if the temperature drops to zero degrees Fahrenheit, or as it is sometimes specified, the wire is to have a factor of safety of two at this load and temperature. This standard assumption of maximum loading should, of course, be used with discretion as there are some localities where it may be exceeded, and a great many where it will never occur; a study of Weather Bureau records will enable the engineer to determine his particular conditions and govern his assumptions accordingly; it is certain that a large percentage of the transmission lines in the Middle West have not been strung in accordance with a loading as heavy as the one quoted, and it takes lots of mental suasion and a few cuss words to make some of the old-time line foremen understand the necessity of giving even the deflections that have been allowed.

For methods of computing sag, the reader is referred to the article by Mr. Blackwell in the 1904 *Transactions* of the International Electrical Congress and to those by Mr. Robertson, Mr. Thomas, and Messrs. Pender and Thompson in the 1911 *Transactions* of the American Institute of Electrical Congress.

For the guidance of the construction foreman, a curve or a table giving the sag or tensions at various temperatures for the standard length of span, should be made up.

In pulling up wire, most companies now use a dynamometer, a heavy spring scale, to measure the tension exerted, but the general method followed in the past has been to sight for the deflection; where this method is used a man is stationed up on a pole or tower, at about the middle of the section being pulled, with his eye at a distance below the conductor support equal to the desired deflection, and as the wire is drawn up he lines in the low point of the sag with a mark at the same point on the next structure; while the general custom is to take these reference points on part of the structures themselves, the better way is to make up two rods marked off in feet and tenths and provided with some sort of a movable target or indicator similar to a level rod; these rods can be arranged to hang from the conductor support or some other desirable place, and by means of the targets closer results can be obtained than are possible where points on the structures themselves are assumed.

For accurate results, however, in modern long-span work especially, a dynamometer should be employed and the wires drawn up to the actual tension required for the particular span at the existing temperature; where all three wires of a circuit are pulled at the same time with an equalizer as described earlier in the chapter, it is sufficient to use a dynamometer in one leg only, as the tensions will adjust themselves equally.

The sags in all the spans will also adjust themselves ordinarily and take the same relative deflections as the span sighted, or in the case of wires pulled to a certain tension will take practically uniform sags corresponding to the tension; where long lengths of line are pulled and no rollers or blocks are used, it is well to leave the strain on for fifteen or twenty minutes before beginning to tie in.

Tying in or fastening wires to their insulators is accomplished either by the use of tie wires or some form of clamp arrangement; in most cases with pin-type insulators wire ties have been used, but for the suspension type, clamps are invariably employed for transmission work.

In Fig. 169 is shown a method of wire tying that has been used very extensively and has always been satisfactory; in tying by this method, standing facing in a direction at right-angles to the line, the tie wire is bent into the shape of a long narrow "U" and pulled in from the back of the insulator so that the bottom of the "U" rests in the tie-wire groove and the sides, coming below the conductor, extend toward the man tying; then the ends or sides of the "U" are brought up and over the conductor so as to take one turn around it on each side of the head of the insulator, which brings the ends back in order to point at the workman as before; then the tie ends are each brought around the front of the head to the opposite side of the insulator, in the tie groove, under the conductor in each case and then around and served out as shown in the illustration.

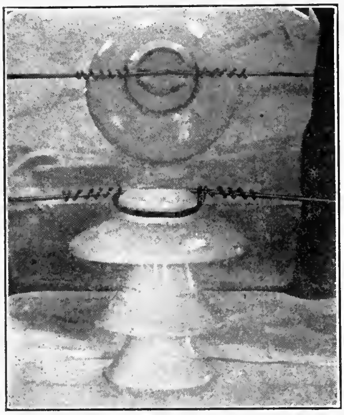


FIG. 169.—Common high tension tie.

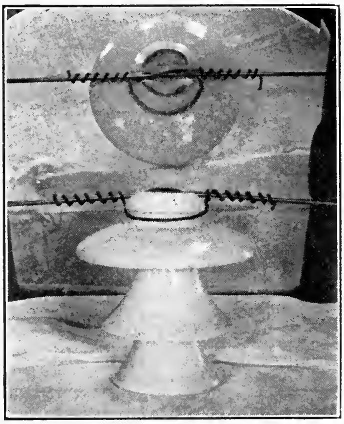


FIG. 170.—Figure 8 tie.

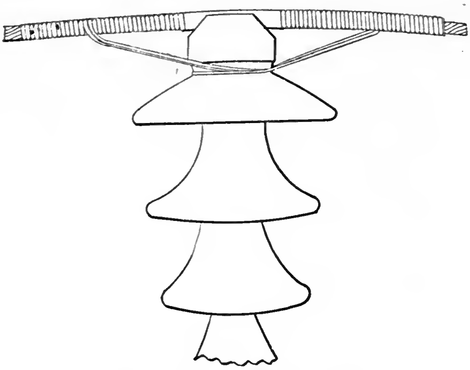


FIG. 171.—Mershon tie.

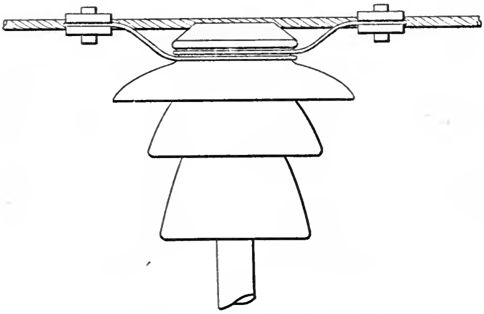


FIG. 172.—Kern River tie.

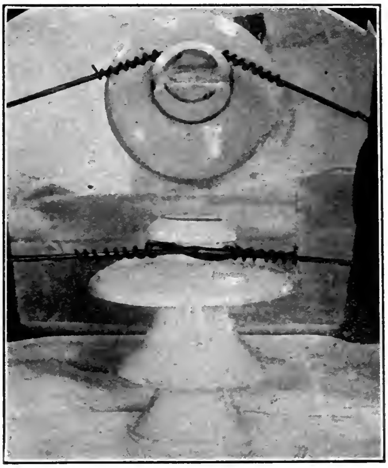


FIG. 173.—Angle tie.

In Fig. 170 is shown another tie, known as the "figure-8," where the tie is begun by having the middle of the tie wire at the center of the insulator head and then bringing the ends down into the tie-wire groove on opposite sides of the conductor, coming back under the conductor on each side, and around the head to the opposite side, where it is served out as shown; the claim for this tie is that the cross-over at the top helps to bind the conductor and prevents slipping. The writer's personal experience with this kind of a tie has not been very satisfactory, as with standard insulators it has been found to work loose; where the insulator has a deep tie-wire groove and is well recessed at the ends of the conductor groove, with careful attention to the bringing of the tie from the top cross-over of the head into the side groove, this tie will work out well, and it has been found satisfactory in several installations. With the tie just described, a shorter length of tie wire is necessary than in the case of the one first noted.

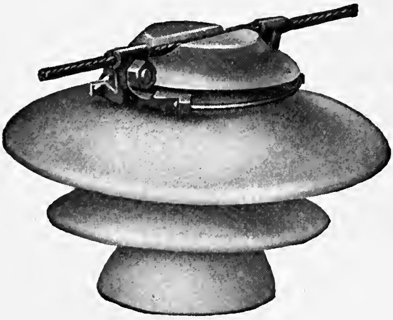


Fig. 174.—Clark line clamp.

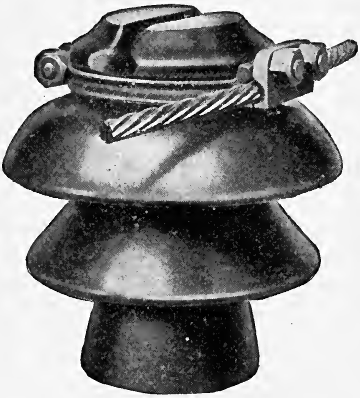


Fig. 175.—Clark angle clamp.

In the Niagara, Lockport & Ontario transmission work, a double-loop tie, as shown in Fig. 171, was employed, a tie wire being looped around the head of the insulator in each direction and the double ends served out together; the advantages of this tie as noted by Mr. Mershon in the 1907 *Transactions* of the American Institute of Electrical Engineers on page 1297, are that the full strength of the tie wire is developed and that it does not injure the soft aluminum cable as other types of ties would.

A tie such as shown in Fig. 172, used in the Kern River transmission work and also on the lines in connection with the Roosevelt Dam Reclamation project, is very similar to the tie just described except that the ends of the loop are secured by special clamps instead of being served out on the conductor.

For angle or corner work, the conductor is tied in on the outside of the insulator with what is known to telephone men as a "copper" or "long-distance" tie; this tie is shown in Fig. 173, and the writer's experience with it both on hard drawn and soft wire has been very satisfactory.

Wire ties for copper conductors should be of annealed copper and for aluminum, should be a soft wire of that metal; the size of the tie wire will depend upon the gage of the line wires and the type of tie used, but as a general thing from No. 8 to No. 4 ties will be used in average work.

FIG. 176.—Suspension insulator clamp.

Mechanical clamps in the place of wire ties, have been used extensively, such as those manufactured by the Clark Electrical & Manufacturing Company shown in Figs. 174 and 175; the employment of mechanical clamps is often specified by railroads for high-tension crossings; as will be noted they are made for both straight line and angle work. On some work a type of mechanical clamp has been used consisting of a cast-iron cap cemented over the head of the insulator, to which is bolted a cover plate, the cap and plate being provided with a groove in which the conductor is clamped.

For fastening conductors to pin-type insulators on strain towers, with two or more insulators in series, either a loop and clamp arrangement similar to the tie shown in Fig. 172, only heavier, or a yoke connecting the head of the insulators together so as to divide the strain equally between them, is used, the conductors being clamped to this yoke; an arrangement of this kind is illustrated in Fig. 138.

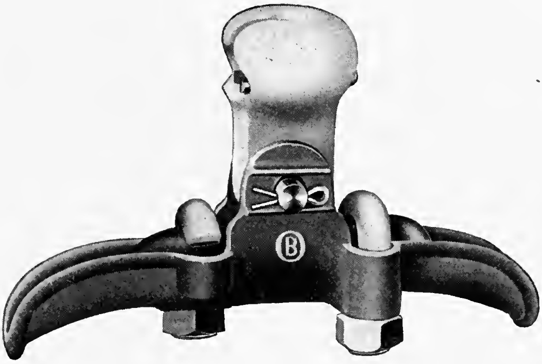


Fig. 177.—Suspension insulator clamp.

A conductor is usually dead-ended on pin-type insulators by making a "figure 8"; this consists, in the case of a two-pin dead-end, in taking a turn around the head of the first insulator, then going back to the next one and taking a turn around that in the reverse direction, bringing the end back to the front insulator on the opposite side from which it left; the end is then either served up or fastened with a clamp in the same manner as a guy.

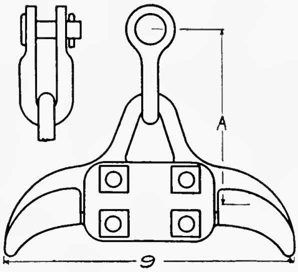


Fig. 178.—Suspension insulator clamp.

For the attachment of line conductors to suspension-type insulators various designs of clamps have been developed;

typical kinds furnished by representative insulator manufacturing companies for straight line and for strain service, are shown in Figs. 176, 177, 178, 179, and 180.

The features that a clamp for this purpose should have, are those of a broad enough bearing area so as not to injure the conductor, a curved wire groove, flared slightly at the ends, and a short, freely moving connection to the insulator to avoid kinking when insulators are deflected on account of unequal temperature changes in adjacent spans; a clamp should also be designed with as few parts as possible, and be so arranged as to permit the conductor to be supported by it before the clamping is applied.

Fig. 179.—Strain insulator clamp.

In all cases where aluminum wire is used, a protecting sleeve of the same metal, about 1/16 in. in thickness, is slipped over the conductor at the point of clamping, and in several cases the same protection has been used on copper lines.

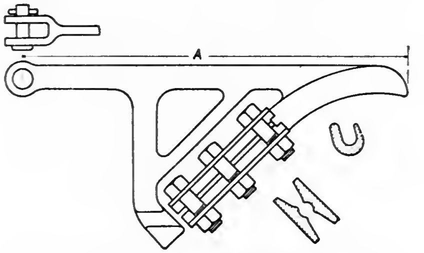


Fig. 180.—Strain insulator clamp.

For the attachment of ground wires to a structure, either a flat clamp or a U-bolt arrangement is generally used, though in wooden pole construction a pin support provided with a pony insulator has been employed in some cases; the flat-plate clamp is preferable to a U-bolt, as the latter is more liable to cut the ground wire in time; in tower work a plate clamp is generally supplied, though in some instance in lieu of the same, the top casting of the tower was provided with a head and groove to which the ground wire was tied in with a regular insulator tie.

Where, in the case of wooden pole construction, it is necessary to run a tap to ground from the top of the pole, a No. 6 or No. 4 copper wire should ordinarily be used, though heavy galvanized iron wire has been employed in some instances; this is either bolted in under the ground wire clamp or served out on the wire itself where a pin and insulator support is used for the ground wire, and then brought down the pole, stapled every 2 ft. or 3 ft.; in driving the staples, care should be taken not to kink or cut the wire. In the case of steel structures set in concrete, a copper wire is usually clamped to one or two of the corner posts inside the footing, and brought out to the ground.

The grounding is accomplished by driving a 3/4-in. or 1-in. galvanized pipe into the ground, by burying a copper or a galvanized iron plate, by the use of some one of the patent grounds, or by making a coil of a few turns of the ground tap and dropping it into the bottom of the hole as the pole is set; of these the first two mentioned are the ones that are best adapted to transmission linework; the use of a small coil of wire does not give much contact area and is of questionable value for this particular purpose also, inasmuch as the impedance offered to a high frequency current must be greater than that of the other types.

The pipe ground is the most economical to install and allows inspection the most readily; as ordinarily used it consists of a length of pipe from 7 ft. to 15 ft. long driven into the ground as closely into the butt of the pole as possible, the shorter length of pipe being employed where the top of the pipe is driven flush with the ground and the longer where it is desirable to bring the connection of the ground tap to the pipe at a point where it cannot be injured, as might occur, and does, where the pipe is driven flush with the ground in tilled land. The connection of the tap to the pipe may be made by soldering it down the side of the pipe for a few inches or to a cap screwed on top, or by stuffing a piece of waste down into the pipe so as to bring the top of it about 3 in. or 4 in. down, placing the wire inside, with its end doubled back several times, and filling with solder.

Considering the work of stringing wire as a whole, the size of the crew that will be required will depend upon the number of wires, their size, the length of span, the type of insulator and the voltage, the character of the country, the total amount of work, and the design and arrangement of the supports; for average work the wire gang will run from ten to twenty-five men with from one to five teams. The proportion of linemen to groundmen depends upon the character of the construction, but as a general thing about half the men are linemen, though some tower work has been done complete without the use of anything but ordinary unskilled labor. The cost per mile of wire for stringing complete will run from $6 to $30 for sizes from No. 10 B. & S. to 250,000 circ. mil copper; where single-circuit line is strung the cost is higher per mile of wire than where the construction is double circuit.

On an 11,000-volt, single-circuit, steel pole job in Colorado, where the supports averaged 35 ft. in overall length, the contract price for stringing No. 3 B. & S. copper was $50 per mile of line or $16.67 per mile of wire.

On another job, a double-circuit steel tower line in Utah, carrying two ground wires, six No. 0 B. & S. hard-drawn copper strand, and two telephone wires, the cost of stringing per mile of line was $43 for the ground wires, $94 for the conductors, and $27.50 for the telephone circuit, or per mile of wire, respectively $21.50, $15.66 and $13.75; this is a 45,000-volt line carried on 45-ft. towers in 500-ft. spans, two unit suspension-type insulators being used. The wage scale averaged about 30 per cent. to 40 per cent. higher than that in the East or the Middle West.

The erection of No. 2 stranded copper on a single-circuit and ground, 40-ft. wooden pole line in the Middle West using 60,000-volt pin-type insulators, was about $12 per mile of wire, with linemen at $2.75, groundmen at $2 and teams at $4 a day.

In the Sanitary District work, the cost of stringing wire on the 60-ft. overall steel poles is given at $26 per mile of conductor; 270,000 circ. mil aluminum wire was used and the work was done by contract.

The *Electrical World* for Sept. 9, 1911, gives the cost of wire stringing on the Amherst Power Company job, as $145 per mile of line; this is a single circuit line of No. 2 copper, with a ground wire of 7/16-in. steel and two telephone wires of 1/4-in. steel, a total of six wires; averaging the six wires as being the same, the cost per mile of wire will be $24.16, or we may say about $25 per mile for the conductors; this line is only 8.5 miles long, one power wire was threaded through the structure, and the work was done by contract; the towers are 45-ft. standard with 60,000-volt, pin-type insulators.

In the line construction of the Ontario Hydro-Electric Power Commission's 110,000-volt system, the cost of stringing ground wires and conductors on the double-circuit construction is given in the *Electrical World* for Jan. 13, 1912., as $130 per mile average; the conductors are No, 000 and No. 0000 aluminum and the ground wires, of which three were strung on the double-circuit towers, are 5/16-in. steel strand, and the average cost per mile of wire strung, figuring the power and the ground cables roughly on the same basis, is $14.44. In the single-circuit work where three No. 000 aluminum cables and two ground wires were strung, the average cost per mile of line is given as $80 or averaging on the same basis as before, is $16 per mile of wire.

CHAPTER XII

Cost Data for Typical Transmission Lines

Much difficulty is encountered in securing accurate cost figures of transmission line construction, with information as to conditions obtaining during the course of the work, the wage scale, etc., and often what little is given out may be hedged in with conditions so as to make it valueless. The costs given herein are *bona fide* figures which are noted without any attempt to make undue comparisons or criticisms, the desire being merely to include and call attention to all features making for an unusually high or an extra low cost figure.

We may begin with a light 13,200-volt line, interesting to many because many lines of this moderately low-voltage construction are being built, following the general tendency to connect the smaller villages with the large towns.

This line is built in Iowa with 6-in. top, 30-ft. northern cedars as standard, set with a standard spacing of 135 ft.; a few poles are of greater length, some up to 50 ft., and some of the poles are 7-in. top; the butts of the poles were treated; the digging was fair as the soil was average loam. The pole top has one wire at the top mounted on a malleable iron, pole-top pin, with the other two wires carried on a two-pin 36-in. standard arm below, to give a triangular conductor spacing; the cross-arm pins are of wood, 11 in. × 1 1/2 in., and the insulators are Locke No. 2643. The three line wires are No. 6 B. & S. bare copper; the total length of line is 7 1/2 miles.

The total cost complete is given as $625.82 per mile, and this figure includes $20 per mile for tree trimming; it may also be noted that this line was originally built single-phase and the third wire run in afterward, which would naturally bring the mile cost a little higher than if all the work as it stands had been done at once.

In heavier wooden pole construction, a typical example is a 50,000-volt to 60,000-volt line of 7-in. top, 35-ft. cedars built in the eastern part of the Middle West; this line is built with a standard pole spacing of 125 ft. and poles are arranged with two arms, a 5-in. × 7-in. × 5-ft. arm at the top with a 5-in. × 7-in. × 8-ft. arm 5 ft. below; the 5-ft. arm carries a 1/4-in. B. W. G. solid galvanized ground wire and one of the No. 2 copper strand conductors; the lower arm carries the other two phase wires; the ground wire is carried on a pony insulator at the end of a tall wooden pin and the line insulators are standard three-part 11 in. supported on treated wooden pins. This line was built prior to the drop in the price of copper in 1907 and the mile cost complete, with a total length of line of about 40 miles, is given as about $2169.

A 60,000-volt line using the same cross-arm arrangement as in the case just described, on 9-in. top, 40-ft. cypress poles, was built in the north central part of the Middle West in 1908-09; these poles were set in 125-ft. spans and carried a single circuit of copper strand made up of seven No. 10 B. & S., a No. 5 hard-drawn copper ground wire and a No. 10 B. & S. copper telephone circuit. The cross-arms were long-leaf yellow pine of the dimensions given in the preceding description, and were through-bolted with 3/4-in. plain bolts, and braced with 2-in. × 5/16-in. galvanized braces. The line pins were of the separable type with the thimble cemented in the insulator at the factory; the ground pins were a standard wood-based steel bolt pin with extra shank and carried a porcelain pony insulator to which the ground wire was tied in; ground taps were made at every fifth pole with No. 8 B. & S. soft-drawn copper soldered to a 7-ft. length of 3/4-in. galvanized pipe which was driven full length into the ground at the butt of the pole; galvanized malleable iron brackets lagged to the pole, carried the 3-in. telephone insulators. This line was built through a well-settled country with a sandy loam soil, was about 25 miles long, and used the public highways for about one-third of its length; the cost per mile complete, not including general expense or general supervision, averaged $2041.

In the *Electrical World* for Jan. 13., 1912, the cost of the Calgary, Can. 55,000-volt line is given as about $2000 per mile. This line is about 50 miles long and is built with 40-ft. cedars spaced thirty-five to the mile, or about 150 ft. apart; at the top of the pole is carried a 1/4-in. seven-strand galvanized steel ground wire, with a single pin bracket-arm extending out from the pole about 3 1/2 ft. down from the top supporting one of the phase wires, and a regular two-pin cross-arm below this at the ends of which are the other two phase wires; 7 ft. below the main conductors is a two-pin telephone arm, carrying the private telephone line. The line conductors are No. 0 aluminum carried on standard porcelain insulators; the overhead ground wire has taps to ground at every third pole; every tenth pole is double-armed and double-pinned, and is provided with head and side guys.

In steel tower construction a typical single-circuit line with ground wire was that built in the north central part of the Middle West in 1908; this line was constructed with 50-ft., 2300-lb. galvanized towers set eleven to the mile or with 480-ft. spans, through a sparsely settled country for more than a third of the distance and was not very accessible, requiring long hauls in distributing the material, and necessitating the establishment of camps to accommodate the construction crew for most of the work. The total length of line was about 46 miles and included a river crossing on special structures, where the working conditions were very unfavorable, and about 5 miles of extremely bad bottom ground; in general the digging was fair as the soil was a sandy loam.

The towers were of standard four-post design bolted to anchor stubs, set in the ground without any concrete; the insulators were a standard four-part 66,000-volt design, supported on separable type pins with galvanized fittings; the conductors were of seven-strand copper, made up of No. 10 B. & S. wire, giving a section between No. 1 and No. 2 B. & S., and the ground wire was the same as the line conductors; this latter was tied in on the top casting in the same way as the line wires to the insulators; at transpositions, railroad crossings, etc., and at certain intervals along the line, Clark clamps were used in place of the regular wire tie. A telephone line of No. 5 hard-drawn copper was carried on the towers about 7 ft. below the lowest high-tension conductor, being supported on a 3-in. porcelain insulator cemented to malleable-iron galvanized pins.

The right-of-way for this line was secured under easement, and the construction work was carried on from late summer to the end of that year; the cost of the work complete, but not including general expense, general supervision, or interest during construction, averaged $2928 per mile.

Another steel tower line of about the same voltage, length and capacity was built in the northeastern part of the Middle

West at a cost of $2008 per mile average, no information being given as to whether right-of-way and engineering were included; it is stated however that no linemen whatever were used in the work.

In this work the standard towers were a three-post design, 40 ft. high set ten to the mile or with a span length of 528 ft.; these towers carry three No. 2 copper strand conductors, and a telephone circuit, but no ground wire and are designed for a total tower load of 4000 lb. They weigh only 1600 lb., being much lighter than would be used in the East for that size of conductors and span, judging from description of line work in that section of the country as given in the technical journals. The insulators were a standard four-part, 14-in., 60,000-volt design; the conductors are arranged in an equilateral triangle with 6-ft. spacing.

This line was built by the same company at about the same time and under about the same conditions as the wooden pole line previously described and noted as costing $2169 per mile, so that for the same voltage and line conductors, and, as it happens, based upon equal lengths of line, the steel tower construction was erected at a first cost actually lower than that of the wooden pole work. As previously noted no linemen were employed in the steel tower construction, even the stringing of the wire being carried on with common labor, and this feature is cited as having made possible the low cost of the work. As noted in Chapter VI, the possibility of using unskilled labor for most portions of steel tower construction should really make for a general lower cost than now obtains.

Another tower line, that of the Amherst Power Company built in 1910, is described in the *Electrical World* for Sept. 9, 1911, and cost data for various parts of the work and the total, are given. This line is constructed with 45-ft. four-post towers as standard with a regular span length of 500 ft.; the structures are of the double "A" or the so-called Rockingham type with 3-in. × 3-in. × 3/16-in. corner posts, 2-in. × 2-in. × 1/8-in. girts and diagonal members of 1 1/2-in. × 1 1/2-in. × 1/8-in. in the bottom panels, with 1/2-in. round rods the rest of the way. The insulators are a standard four-part, 66,000-volt design 14 7/8 in. in height and are supported on extra heavy 2-in. pipe pins; the line wire is seven-strand No 2 copper, tied in with a double loop tie of No 4 B. & S. wire served out around the conductor on each side of the head; a 7/16-in. galvanized steel ground cable is carried at the top of the tower and a telephone circuit of 1/4-in. steel wire is supported 10 ft. below the line conductors. Towers were set in earth or concrete according to the nature of the soil encountered.

A 1200-ft. river span is carried on two special structures giving the conductors a clearance to ground of 60 ft.; the line conductors here are a 1/2-in. Siemens-Martin cable dead-ended to four-standard insulators at each tower arranged in series and provided with cast-iron caps to which is bolted a 4-in. × 1/2-in. steel flat.

The total length of this line is only 8.5 miles, so that the cost of the river span and some concrete protection given the towers near the river, affect the average mile cost more than they would in the case of a longer line. The cost per mile for labor on this line is given at $772, not including contractor's profit, and the material cost is given at $2140, or a total of $2912 for labor and material.

These figures are merely for labor and material as noted and do not include engineering, right-of-way and contractor's profit, which the figures previously given have, or the equivalents.

The cost figures for labor alone on a double-circuit line built in the West will be interesting; the standard tower for this line weighed about 4400 lb. and was a standard four-post design, arranged to carry two ground wires, two three-phase 45,000-volt circuits of No. 00 copper on suspension insulators, and a telephone circuit; one ground wire and three conductors were arranged vertically on each side of the tower head, with a standard height to ground of 45 ft. All of these towers were set in concrete and the soil was stony for about half the distance and sandy the rest of the way; the work was done by contract and the total length of line was only 4.2 miles, with a span length of 528 ft., so that the total number of towers was forty-two.

The total labor cost per mile, not including any engineering work, was $1009; the men were quartered in a camp which was practically self-supporting, and the contractor was paid the following scale of wages for the labor he furnished:

Common labor and groundmen	28	cents per hour.
Linemen	45	cents per hour.
Foreman	50	cents per hour.
Teamsters with team and wagon	56¼	cents per hour.

A 66,000-volt double-circuit tower line recently built in the northern part of the Middle West, with a length of 20 miles to 25 miles, is a good example of suspension insulator construction. The towers are standard four-post galvanized angle structures 40 ft. in height and weigh about 2650 lb.; they are designed to carry one No. 2 B. & S. copper-clad ground wire, two three-phase circuits of No. 0 hard-drawn copper with hemp center, and a telephone circuit of No. 12 copper-clad wire in 528-ft. spans; the insulators are a standard design of the suspension type, and three units are used on straight line work. The towers are set in concrete throughout.

An expensive river crossing, requiring two 180-ft. towers, was necessary in this work; these two towers alone in place cost about $10,000, the foundation cost being about $1,500; naturally with the total length of line only 20 miles to 25 miles, the high cost of this river crossing brings the average mile cost up appreciably; the right-of-way for this line cost $26.50 per tower and the copper was bought on a 16-cent base.

The cost of the construction complete, not including the special work at the river crossing, averaged $4340 per mile, and $4807 per mile, including everything.

Total figures on the cost per mile of the 40,000-volt combination tower and steel-pole line of the United States Reclamation Service in Arizona will be interesting; this is the original double-circuit line about 65 miles long, built from the Roosevelt Dam into Phoenix, Arizona, with a total of 610 towers and 276 tripartite steel poles. The towers are four-post, angle-iron braced, galvanized-steel structures 30-ft. in height, of quite light design, single-braced in the regular type, with angle and special towers double-braced. The structures are arranged without a ground wire and carry four conductors in a horizontal plane at the top of the tower on a channel-iron arm, and the other two below on a shorter arm, the conductors being arranged in inverted deltas with 4-ft. spacing; the tower spacing varies from 360 ft. to 400 ft. The steel poles are those described in Chapter V, varying in overall length from 40 ft. to 50 ft. with three weights of poles in each length; they are set in concrete for one-tenth of their length and the conductors are arranged as on the towers excepting that the short arm is at the top in this case; the spans in the pole work vary from 300 ft. to 400 ft.

Outside of the supports, the details of the construction are the same for both the tower and the pole work; the insulators are a standard three-part design, shipped knocked down and assembled in the field; the line conductors are six-strand copper with hemp center, equivalent to No. 1 B. & S. and are tied in with a double loop and clamp tie.

This line passes through some very rough country and the labor was Indian, to a great extent; the cost per mile complete averaged $4400.

In flexible tower line construction, the writer has been unable to secure any total-cost-per-mile figures but through the courtesy of the Archbold-Brady Company., obtained data as to the cost of structures of this type erected complete, as noted below.

The first case is a line in New York State with the double-circuit tower shown in Fig. 34, *b*; this tower is 36 ft. in height from the ground to the lowest conductor (ultimate), and is designed to carry one 3/8-in. ground wire, two three-phase 33,000-volt circuits of No. 00 copper strand, and two 1/4-in. steel telephone wires in 400-ft. spans; at the present time only four of the six line wires have been strung. The cross-arms are malleable iron. This line was constructed through a rather rough country with a fair number of angles and quite a bit of rock work, with several swampy stretches; the stubs for the A-frames and the anchor towers were set in earth, while heavy corner, and dead-end towers were set in concrete. The cost of this line, exclusive of right-of-way, pins, insulators and wire, but including the labor of stringing wire, is given as about $1600 per mile.

A 60,000-volt line in New Hampshire, 20 miles long, employed the structure shown in Fig. 34, *c*; this tower is also 36 ft. in height from the ground to the lowest conductor, with a 6-ft. vertical spacing between conductors, and is designed to carry a 3/8-in. steel ground wire and two three-phase circuits of No. 00 copper, with only one circuit installed at the present time. About one-third the length of this line was through extremely rough country and required a large number of anchor and angle towers; the remainder of the construction was through average country with quite long tangents; four railroad crossings were made which added considerably to the cost of the work; the anchor towers are spaced approximately 1 mile apart and occasionally in between, the A-frames were head-guyed. The cost of this work, not including right-of-way, pins, insulators, and wire, averaged about $1800 per mile.

In single-circuit construction, with this class of structure and suspension-type insulators, several 60,000-volt lines have been recently built; the tower used was 32 ft. in height from the ground to the lowest conductor, with a width at the ground of 6 ft.; the main members were a 9.75 lb. 7-in. channel, braced with 2 1/2-in.×2 1/2-in.×1/4-in. girts and 5/8-in. rod diagonals, and the structure was designed to carry a ground wire and a three-phase circuit of No. 1 or No. 2 copper in 400-ft. to 440-ft. spans, the insulators being swung, from angle-iron bracket-arms. With the smaller wire the structures may be guyed and anchor towers used only at the ends of the line, but with four-post structures at heavy angles. Lines recently constructed as described have shown an approximate cost of from $850 to $900 per mile, the figures including the structures set, but not right-of-way, insulators, wire, or in this case, the stringing of the wire.

Cost data on steel pole construction are not abundant, what little are available being confined to work where a patented pole has been used.

The first case is a light 13,200-volt line built in Iowa in 1911; this line is about 15 miles long, follows the public highways, and consists of 36-ft. steel poles set in concrete with an average setting of eighteen to the mile; the poles carry a three-phase circuit of No. 6 B. & S. hard-drawn copper, with no ground wire; the conductors are arranged in the form of an equilateral triangle with a spacing of 5 ft.; the pins are of steel with lead tops, the ridge pin being screwed into the top casting of the pole and the other two carried on a 64-in. angle-iron cross-arm, with a light angle-iron brace; six 60-ft. and four 50-ft. poles were used at points along the line. The insulators used on the steel poles were a standard 23,000-volt type.

The company which constructed and is operating this line, gives the average cost per mile as $610.56; the wooden pole line of which the above line is a continuation, and which has been described at the beginning of this chapter cost $625.82. The manager of the company states that they secured exceptional prices on all their material for the steel line and really believes that under similar conditions, the first cost of the steel line might be a little higher than that of the wooden pole construction for 13,200 volts.

Another line built in Colorado with this same patented pole, used a 35-ft. length as standard, with other sizes, as necessary, from 25 ft. to 45 ft. long; these poles were arranged with a 5-ft. conductor spacing in the same manner as the design for the line just described, and the poles were spaced from sixteen to eighteen to the mile, set in concrete; the line voltage is 11,000 volts and the conductors are No. 3 B. & S. copper.

The cost of this line complete is given as a little over $1000 per mile, with a total length of line of about 15 miles. It may be noted that one-fifth of the distance was solid rock setting and the rest of the way the soil was a coarse gravel; the work was done by contract.

The cost of concrete pole lines is somewhat problematical for work carried on under the average conditions that will obtain in transmission line construction, in that most of the work done up to the present time has been carried on under conditions especially favoring the handling and erection of that kind of poles.

In and around Oklahoma City, Oklahoma, the cost is given by J. M. Brown, superintendent of lines for the Oklahoma Gas & Electric Company, as about 50 per cent. greater than that of wood of corresponding length and size; it may be noted that the above company has about 40 miles of this type of construction in service, but that their experience is confined mostly to city distribution work. Other sources of information give as an estimate that concrete pole lines will cost about 25 per cent. less than that of steel pole construction of equivalent safe strength.

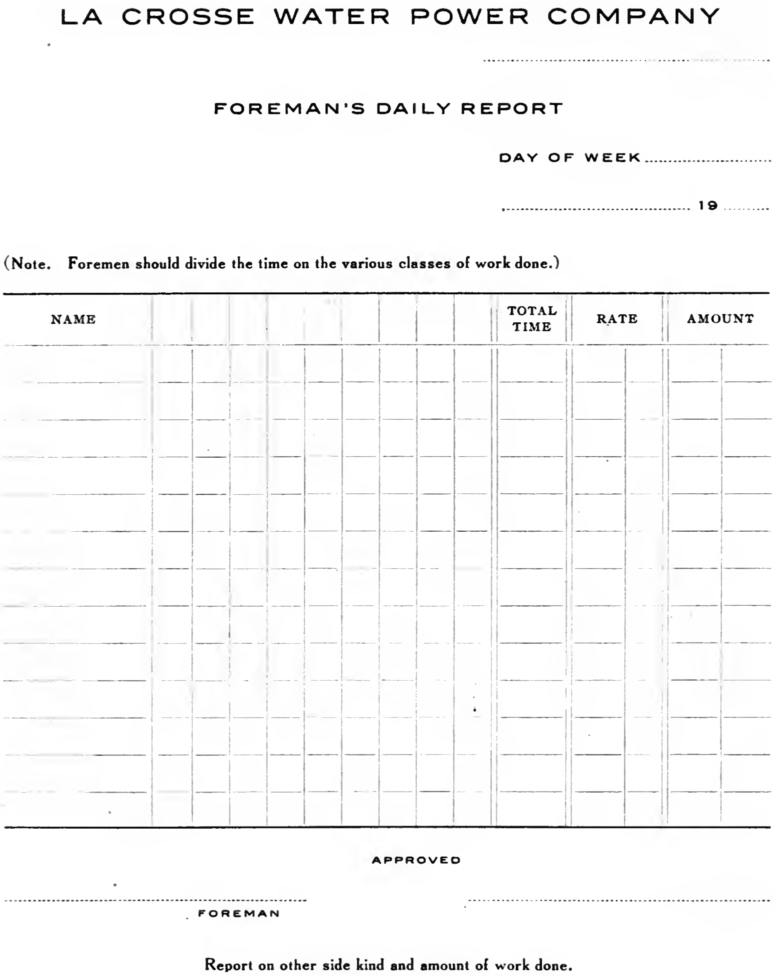
CHAPTER XIII

ORGANIZATION AND TOOLS

The actual planning and systematic preparation for the carrying out of a transmission line project deserves more attention than has usually been accorded it in the past. When a hydro-electric development is to be put under way, the various steps and operations, with the most economical methods of carrying them on, are carefully studied and decided upon, and estimates are made of the time required in the form of a prospective log of the work, the details of the work and progress on the coffer-dams, excavation, dam, core-walls, power-house, etc., etc., being carefully worked out, but the transmission line is usually lumped off, to be gone into more thoroughly when the work is to be started.

The reason for leaving the construction of the line to the last is apparent where the work of development is to extend over a term of two or three years, as it would be poor business policy to pay interest on dormant investment, but on the other hand, the practice that often obtains of neglecting the line until it is too late to carry on the work in an economical manner, cannot be too strongly condemned. With initial line work often amounting to from 15 per cent. to 25 per cent. of the total cost of the development, it should merit as close attention as other features of the work.

In opening up a job, the keystone of the organization is of course the general foreman; he should be a man of not only constructive ability but executive as well, and remembering the sad fact that very many high-class line foremen are addicted to the use of alcoholic stimulants to excess, it is well to add that he should be of temperate habits; a "booze-fighting" foreman usually means a "booze-fighting" crew and a break in the work just as often as pay day comes around. A man who can use his head and cope with unforeseen difficulties and who can get an efficient day's work out of his crew, is a valuable man in any kind of construction work and especially so in line work; the measure of a foreman's efficiency is not necessarily determined either, by his ability to drive his men; a crew that is worked along smoothly and easily will usually show a better day's progress than one that is being constantly pushed; also



LA CROSSE WATER POWER COMPANY

....

FOREMAN'S DAILY REPORT

DAY OF WEEK ....

.... 19 ....

(Note. Foremen should divide the time on the various classes of work done.)

NAME										TOTAL TIME	RATE		AMOUNT	

APPROVED

....

FOREMAN

Report on other side kind and amount of work done.

Fig. 181.—Form for reporting on line work.

if the foreman be gentlemanly, diplomatic, and a good "mixer," he can do the company service of inestimable value in establishing a good will and friendly feeling toward it among the people residing in the territory traversed. To the general foreman, within limits, should be left the selection of the crew foremen.

With the general foreman, the engineer can make plans for the handling of the work, the methods to be employed for the digging, raising, setting, etc., the assembling of the crews, the intervals between the beginning of the various steps, the probable time required for the different operations, etc., all of which should be definitely decided upon to bring the work to completion within a certain specified time.

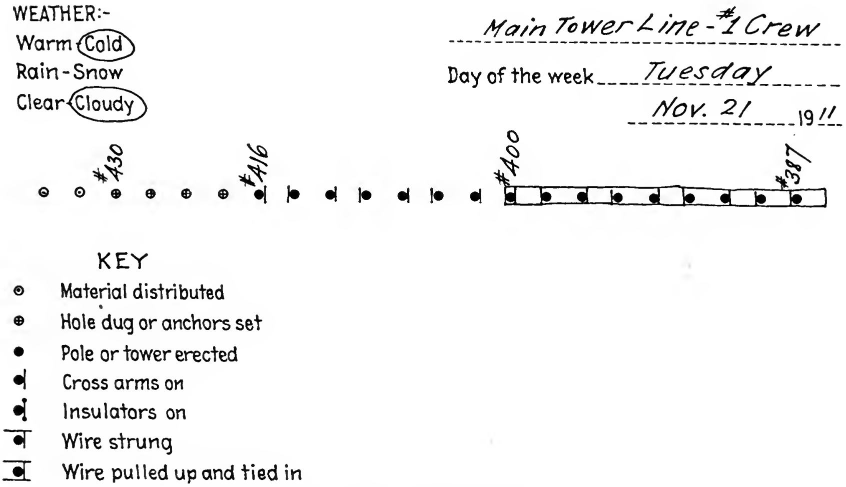
The matter of reporting the time of the men should also be given study; the system that is much used is to have the foreman of each gang keep the time of his men in a standard time book, and then in addition to that, make out for each day a report on a form such as shown in Fig. 181, the report to be approved by the general foreman and mailed to the office. A better plan is to have one timekeeper or more as may be required, to take care of this work rather than to leave it to the foremen, though the latter will, of course, make out the daily reports.

As will be noted, this report is a distribution and progress report, that is, the time of the men is distributed in the vertical columns so as to be charged to the various operations in which they may have been engaged during that working day; letters, or numbers, are usually employed to designate the different operations, as, for instance, "A" may be "clearing right-of-way," "B," "distributing poles," etc., so that the labor cost of the various parts of the work can be segregated easily and without involving the foremen in too much "red tape."

On the reverse side of the sheet is a log of the day's progress of the crew from which the general foreman and the engineer can determine the headway made in the work, and keep track of the relative efficiencies of the different crews.

Often graphical progress charts are used in addition to the daily reports made on the reverse side of the distribution sheet described or sometimes are incorporated with it, the latter being preferable; these usually take the form shown in Fig. 182, below.

This report made out daily by the crew foreman and mailed in with the time reports, allows a total chart to be plotted in the office so that the engineer is not only well in touch with the daily progress of the different crews, but knows the actual condition of the work at the end of each day, for the complete job. The weather report noted on the progress chart gives the conditions under which the day's work has been prosecuted and helps in determining the causes for a variation from the rate at which any crew has been generally working.



WEATHER:-
Warm [✓ Cold]
Rain-Snow
Clear [✓ Cloudy]

Main Tower Line -#1 Crew
Day of the week Tuesday
Nov. 21 1911

FIG. 182.—Progress chart.

A close check on the handling of all material is necessary, and it is a good policy, where the magnitude of the work warrants it, to employ a material man to take charge of all incoming shipments, checking them over and reporting shortages, breakages, etc., to the general foreman to whom he should be directly responsible, and also to issue to the various crew foremen, material as needed, for which receipts should be taken; where the work is carried on at several diverse points simultaneously, he will of course have such assistants as may be required. At each place where a material man is stationed he should keep a stock book, preferably loose leaf, with the sheets arranged as shown in Fig. 183, a new book being made up for each month and the sheets for the previous period filed away. This method of keeping

MATERIAL RECORD

COMMODITY.. FOR MONTH OF..........................19......

INCOMING MATERIAL

DATE	FROM WHOM RECEIVED	QUANTITY	REMARKS
	Brought Fwd. from last month		
	Total		

OUTGOING MATERIAL

DATE	DESTINATION	QUANTITY	SIGNED FOR BY
	Total		
Balance on hand at end of month			

Fig. 183.

track of the material gives a good record of incoming and outgoing material and at the same time shows clearly what is at hand at any time, being in fact a perpetual inventory.

The problem of keeping tab on company tools is a bothersome one; linemen proper, furnish their "hooks," belt and safety, pliers and connectors as a rule, but groundmen do not carry any tools at all; so, in steel tower work especially, the company must furnish practically everything in the way of tools on the job. Wrenches, hammers, etc., are highly prized as "souvenirs" by the average construction man and few jobs are completed without having a considerable number of tools charged up as "lost," regardless of all efforts to the contrary.

The system that for ordinary line work, where each crew has a team and teamster, has worked out very well for the writer, is to charge each foreman with a tool box equipped with all the necessary hand tools, and with a complement of shovels, spoons, pikes, blocks and tackle, etc., etc., depending upon the work being done, and hold him personally responsible for the same; the teamster, however, acts as the actual toolkeeper and issues to the men the tools they may require upon arriving at the job, checking them in and locking the chest at the close of the day's work; the foreman will, of course, hold him responsible for tools that are issued and not turned in. With all tools thus checked in each evening, the loss of tools can be reduced to a minimum.

A tool chest properly fitted with trays and with the place for each tool outlined or silhoutted, will very materially aid the toolkeeper in keeping tab on his outfit of hand tools; in connection with the foregoing it may be well to note that a saw-filing outfit and a small portable grindstone are a very profitable part of the tool equipment, not only ensuring suitable facilities for the maintenance of the edged tools, etc., but providing a means of employment for the straight-time men on rainy days.

The problem of housing and feeding a crew in the field is one that is omnipresent, and resorting to camps by no means absolves one from the trials and tribulations incident to other means of providing sustenance. Where there are a number of small villages located near the line, the crew can be quartered in the local hotels—the "s" is usually missing—where the commercial traveler pays tribute at the rate of $2 a day, the town folks at about $4 per week, and the company whatever the "traffic will bear," usually about $1 a day in the Middle West. When the crew is staying at a hotel at some little distance from the line, the noon meal is either packed up in the morning and carried along, or a hot lunch is sent out to the boys at noontime; the latter method is a much better policy as a man can do far better work on a warm meal than he can on a cold lunch, and the additional expense of providing for the warm meal is amply compensated for on the progress chart.

Again quite frequently it is possible to send one of the men out in the morning and arrange for dinner for the crew at some farm-house close by, where the "haus-frau" is not averse to adding to her pin-money in this way.

Where it is not feasible to undertake the extra distance to a village, where the country is fairly well settled it is often possible to quarter the men among the nearby farmers entirely, though as a rule the accommodations at a farm-house are quite limited and the crew will have to be divided up among a half-dozen different places; with the men scattered in this way it is harder for the foreman to keep track of things that are going on and to maintain discipline. This method of providing for a crew, however, works out very well where the crew is not so large, and the class of farm-houses is such, that they can all be taken care of at two or three places.

Where the crew is too large to be quartered on farms and where there are no villages close in to the line, as well as in the case of a line passing through unsettled country, a camp must be established for the accommodation of the men. There are two ways of handling the camp question, either the company itself can operate it, or the privilege can be turned over to some "boarding boss," who contracts to furnish meals and sleeping quarters for a certain minimum number of men at so much a day or week, the same being charged against each man on the pay-roll and deducted from his check; this guarantees the "boarding boss" against loss and at the same time provides the company with a means of insuring reasonably good service to its employees.

Where the company itself attempts to operate the camp, it usually finds the proposition to be an expensive experience, due to the fact that the foreman of the crew, who will be in charge of the whole as a rule, has generally no knowledge of the economical carrying on of this part of the work, and furthermore has no time to devote to it during the day, with the result that he has to depend upon the camp cook for the handling of the details, with neither knowledge nor opportunity for proper checking. Also in the matter of purchasing and getting in supplies, the company is handicapped by the fact that it always costs a corporation more for supplies and service than it does a private individual in a case like this, for the reason that the foreman has no time, and the cook usually no inclination, to investigate weights, qualities and prices; on the other hand the "boarding boss" is usually a local man who in small camps personally attends to most of the cooking, does all his own purchasing, has his own "tote-wagon," and who has no other duties to attend to save those of keeping up the tent homes of the crew and providing their meals on schedule time, so that he is in a position to observe all the economies possible to the average housewife. Where a camp contract can be made with a reliable and capable man, the same should certainly be done, as the company will be spared a great expense and annoyance.

For a camp equipment to take care of about thirty or so men, two 14-ft.×20-ft. wall tents pitched end to end will make a good bunk tent, and a similarly arranged pair of the same size will be sufficient for a cook and mess tent; the bunks in the sleeping tent are usually straw-filled ticks laid on the ground with a tarpaulin or a loose board floor underneath, and provided with plenty of blankets if the work be carried on in cold weather; when required, two sheet-metal stoves will provide all the heat necessary to keep the tent comfortable. For the mess tent the table will usually consist of a top of light inch-boards cleated together and supported on light horses, while the seats will be long wooden benches; for the cook tent the necessary complement of pots, dishes, and pans, with a sheet-metal camp cook stove, will have to be provided.

Where the conditions are such as to require a camp, it is the general rule for a commissary to operate in connection with it, where the men can procure overalls, socks, handkerchiefs, tobacco, etc.

Where the work is carried on in the winter time and teams must be quartered in camp, some sort of a barn tent will also have to be provided.

The manner in which the services of teams will be secured will vary with the character of the country passed through and the season of the year during which the work is prosecuted.

In a well-settled farming community it will be almost impossible to hire teams for hauling material during the summer months and also at times in the spring and fall, but during the winter period any number will be available and generally at from $3.25 to $3.75 a day in the Middle West, so that under such conditions it is most economical to arrange matters so that the heavy material will be hauled out in the winter time; where sleighing can be figured on the advantages of hauling out poles and towers on sleds with the greater loading possible, should also be taken advantage of.

In the small villages along the line, however, it is usually possible to secure such teams as will be needed, and in carrying on work in the summer months these will have to be depended upon; in isolated regions and in non-agricultural districts it often happens that it is necessary to contract for the hauling with a teaming contractor from some nearby town, either on a tonnage or a per diem basis.

Where teams are required steadily to attend the crews in the course of the construction, they may be placed on a day basis and the teamsters provide their own maintenance and that of their team, or they may be hired at so much a month with all expenses paid; where the teams are from the locality in which the work is going on, the writer has found it to be more satisfactory and more economical to secure them on the former basis, as the stablemen and farmers along the line usually have one scale of prices for local people and another for transients, with often an extra tax on corporations.

In the prosecution of any work remote from quick medical attendance, a contingency that should be provided for is that of accident. The foreman of each crew should be furnished with an emergency chest, equipped with bandages, absorbent cotton, antiseptics, etc. In the case of an accident, the foreman should be instructed to summon competent medical attendance at once if at all warranted and if the case be serious, he should wire the general foreman or the main office; in the event of any accident, however slight, incurred in the course of the work, the foreman should be required to make out a complete report of the same on blanks provided for that purpose; a form much used for that purpose is given below:

This form is adapted to general construction and properly filled out will give a complete record of the happening.

Prompt and considerate attention to personal injury cases should be the policy always; and it has been the experience of most large companies that a fair and square deal accorded to injured employees will in most cases do away with damage suits.

REPORT OF ACCIDENT TO AN EMPLOYEE

Of ....

Of (Give full address).................*Street; City*.................*State*.................

In case of fatal accident or serious injury, telephone or telegraph at once —giving date of inquest if any.

INJURED PERSON'S NAME? ....About how old?..............
Wages?........................ Nationality?...
Address in full?..Married or Single?..............
Occupation?...How long employed?..............
In whose employ at time of accident?...
Had he done similar work prior to this employment?..............................

DATE OF ACCIDENT?..............191.... Hour.......M. Was light good?.......
PLACE WHERE ACCIDENT OCCURRED? ....

Describe the place, machinery, tools, staging, etc., connected with the accident. } ....
....
Was it sound and in good working order?..............Who can prove this?..........

Nature and extent of **INJURY?** ....
Taken home or to hospital?.........Attending doctor's name and address?.........
(If hospital, which one.)
Period of disablement?....................Has injured resumed work?..............

Names and addresses of witnesses? ....
....
Give statement made by injured person as to cause of accident, and names and addresses of those who heard it. } ....
....
....
Name and address of foreman in charge of work?..................................
Where was he at time, and what was he doing? ....
Was accident due to want of ordinary care on part of injured person? ....

Narrate below how the accident happened, its causes, etc., illustrating if possible, by a rough sketch.

....
....
....
....
....

Notes made out by.........................*whose position in our employ is*...................
Date of Notice..191....

APPENDIX A

Standard Specifications for White Cedar Telegraph, Telephone and Electric Poles

Sizes, 5-in., 25-ft. and upward. Above poles must be cut from live growing timber, peeled and reasonably well proportioned for their length. Tops must be reasonably sound, and when seasoned must measure as follows: 5-in. poles, 15 in. circumference at top end; 6-in. poles, 18 1/2 in. in circumference at top end; 7-in. poles, 22 in. circumference at top end. If poles are green, fresh cut or water soaked, then 5-in. poles must be 5 in. plump in diameter at top end, 6-in. poles must be 19 1/2 in. in circumference, and 7-in. poles 22 3/4 in. in circumference at top end. One way sweep allowable not exceeding 1 in. for every 5 ft.; for example, in a 25-ft. pole, sweep not to exceed 5 in.; and in a 40-ft. pole, 8 in.; in longer lengths 1 in. additional sweep permissible for each additional 5 ft. in length. Measurement for sweep shall be taken as follows: That part of the pole when in the ground (6 ft.) not being taken into account in arriving at sweep, tightly stretch a tape line on the side of the pole where the sweep is greatest, from a point 6 ft. from butt to the upper surface at top, and, having so done, measure widest point from tape to surface of pole and if, for illustration, upon a 25-ft. pole said widest point does not exceed 5 in. said pole comes within the meaning of these specifications. Butt rot in the center including small ring rot outside of the center; total rot must not exceed 10 per cent. of the area of the butt. Butt rot of a character which plainly seriously impairs the strength of the pole above ground is a defect. Wind twist is not a defect unless very unsightly and exaggerated. Rough large knots if sound and trimmed smooth are not a defect.

APPENDIX B

SPECIFICATIONS FOR STEEL TOWERS FOR TRANSMISSION LINE

General.—Whenever the word "purchaser" is used herein it is understood to refer to the purchaser's engineer or the authorized assistant of said engineer.

Whenever the word "contractor" is used herein it is understood to refer to the party or parties to whom the contract for the work, or any part or parts of the work, may be awarded, or the authorized agent of such party or parties.

Whenever the word "work" is used herein, it shall, except where by the context another meaning is clearly intended, mean the whole of the materials and labor and other things required to be done, furnished and performed by the contractor under these specifications.

The towers covered by these specifications are to be used to support the insulators, conductors, and ground wire for an electric-power transmission line.

The towers shall be designed to support

6 line conductors,
1 3/8-in. seven-strand steel ground wire,
2 telephone wires.

The arrangement of the conductors, ground wire and telephone line supports and pins shall be in accordance with drawing 2134-S, hereto attached and a part of these specifications.

Strength of Towers.—The assembled tower shall be required to stand the following mechanical load tests without distorting appreciably or causing any member to exceed its elastic limit.

1. At conductor pin tops:
   1500 lb. in any direction perpendicular to the axis of the pin.
2. Ground wire support at clamp:
   1500 lb. applied in any direction perpendicular to the axis.
3. Tower structure:
   6000 lb. applied at the middle cross-arm in any direction perpendicular to the axis of the tower.

The base of each tower shall be 14 ft. square and the legs provided with detachable ground stubs 6 ft. long supplied with suitable footing plates not less than 2 ft. 6 in. in length.

The standard height of the towers shall be 36 ft. measured from the ground stub joint to the lowest conductor.

Metal steps shall be provided to within 8 ft. of the ground so as to allow of safe access to either circuit while the other is alive.

Insulator pins for the line conductors shall be of the separable type in general accordance with the dimensions given on drawing 2134-S, and shall be easily detachable from the cross-arm; they shall also be designed to permit their installation on the cross-arm without the insulator thimble. The insulator thimble shall be arranged with suitable grooves for cement and shall be delivered to the insulator factory for installation in the insulators as directed, at the expense of the contractor.

Telephone-line pins shall be of steel with a threaded lead top similar to the standard telephone pin and shall be bolted to the telephone cross-arm.

The members of the tower structure shall be made to bolt together throughout and every part shall be arranged for ready assembly in the field with wrenches.

The quality of the steel used in the construction of the towers shall be in strict accordance with the latest specifications for structural plate and rivet steel as adopted by the Association of American Steel Manufacturers.

The towers are to be furnished complete with the necessary footings, cross-arms, insulator-pins, ground-wire clamp, steps, bolts, nuts and washers and all parts of the structures shall be thoroughly galvanized by the hot process or the sherardizing process after all punching, cutting and other machine work is completed. The galvanizing shall be in accordance with the specifications for galvanizing attached hereto.

Drawings.—The contractor shall submit with his proposal duplicate drawings showing the tower and the details thereof.

Inspection.—Purchaser shall be permitted to place an inspector in the factory of the contractor, who shall be given free access and shall be granted authority to reject any or all such towers or parts thereof which do not come up to the strict requirements of these specifications.

Shipment.—Towers are to be shipped "knocked down" with similar members tied securely in bundles of approximately 100 lb. each; the members shall be systematically numbered or lettered so as to allow of their being easily assembled. All parts that cannot be bundled, such as pins, bolts, washers, etc., shall be shipped in boxes or kegs, in unit packages for each individual tower, and same shall be marked with the tower height for which they are intended.

Quantity.—The number of towers to be furnished under these specifications is 380; it is agreed, however, that twenty additional towers may be ordered at the same price, but the delivery of these extra towers, as well as the special towers hereafter mentioned, must be specified at the time the contract is signed.

Special Towers.—In addition to the above, the contractor is asked to submit proposals for twelve 45-ft., four 50-ft. and four 60-ft. towers to meet with these same specifications, and also for five transposition towers, arranged as per drawing 2135-S.

Price.—Proposals shall state the price per tower in accordance with the specifications, f.o.b. ...., together with the time required to complete the contract.

APPENDIX C

SPECIFICATIONS FOR PIN TYPE INSULATORS—LINE VOLTAGE 66,000 VOLTS

The *insulator manufacturer* shall be required to furnish all facilities and equipment for making the tests and inspections as specified here below and shall allow at all times free access to such facilities and equipment to the inspector or authorized representative of the purchaser until the entire order is accepted by same.

The *insulator company* agrees to deliver to the inspector finished ware at the rate of 2000 pieces a day continuously for every week day after arrival of said inspector at the insulator factory in response to a written notification from the *insulator company* that the order is ready for inspection and test.

GENERAL SPECIFICATIONS

The insulator shall be made of first class evenly fired porcelain ware; each part, and the insulator assembled as a whole, shall be symmetrical and not appreciably warped.

Glaze.—The surface of the ware shall be uniformly covered with a medium thickness of smooth brown or slate colored glaze free from grit, same to be hard and firm and to not become dull, scale off, nor show any signs of checking severely when allowed to stand exposed to the elements for a period of three months or subjected to a series of six sudden temperature variations of 15° F.

This glaze shall cover all portions but top surface of head and inside of head, and surface on intermediates where exposed to cement.

MECHANICAL INSPECTION

A mechanical inspection shall be made of all insulators and those shall be rejected which contain open holes or cracks within

4 in. of the head, inside or outside, in the case of the top shell or 4 in. from the tops in the case of intermediates. Beyond this range all closed cracks 1/2 in. in length or over, if of a weakening character rendering the shell edges easily broken by a blow, shall not be accepted.

Air Cells.—Occasional samples of the ware shall be broken to see that they do not contain air cells or foreign matter.

Fragility.—The insulator shall withstand, under the below conditions,

eight charges of No. 6 shot, and
four charges of No. 4 shot without breaking.

The assembled insulator shall be rigidly mounted upon its pin 40 ft. above ground and the man doing the testing shall stand fifteen paces from the base of the pole.

The testing shall be done with a No. 12 gage choke-bore shot gun.

The charge shall consist of 3 1/4 drams of smokeless powder and 1 1/8 oz. of shot, Winchester Leader shell being preferred.

Strain Test.—The insulator shall not exceed 16 in. in height over all and when mounted upon its pin shall be capable of withstanding without injury to or a loosening of any of the parts, a stress of 2000 lbs. applied at the tie groove from any direction in a plane at right angles to the axis of the insulator.

The Cement used in assembling shall be of the best quality of portland, neatly run in and thin enough to fill every irregularity, then allowed to firmly set, at least forty-eight hours, before being disturbed.

ELECTRICAL TESTS

One insulator of each particular design shall be subjected to the following tests with insulator assembled on its metal pin. (By spark gap, American Institute of Electrical Engineers' curve.)

A piece of the line conductor 4 ft. in length shall be tied or fastened to the insulator as upon the line and used for one terminal.

Dry Test.—Fifteen minutes continuous, 180,000 volts.

Wet Test.—Fifteen minutes, 125,000 volts continuous. Spray nozzle, 5 ft. distant; 1/4-in. precipitation per minute at 45° angle from insulator axis.

Puncture Test.—Each part of the sample shall be soaked for forty-eight hours continuously in water, then inverted in 1/4 in. of water which shall form one electrode and the part shall act as a receptacle for 1/4 in. of water which shall be the second electrode, and a voltage shall be applied continuously for fifteen minutes between these electrodes, the voltage to be held just below arc-over point.

The entire order of insulators shall be subjected to the following inspection and test:

I.—A general mechanical inspection of all the parts in view of locating and rejecting those having objectionable fissures, distortions, etc.

The inspector should use a light-weight mallet to rap each part and note the "ring" which will assist in showing up those that are defective.

II.—Electrical tests upon the entire lot of insulators shall be as follows:

(a) Puncture test—as specified above for sample, omitting the forty-eight hour absorption test.

(b) Dry test—complete insulators, assembled, are to be mounted upon metal pins and tested between the tie-grooves and pins with 180,000 volts alternating current continuously for ten minutes minimum and two minutes after the last breakdown, that is, if a group of the insulators are being tested simultaneously and after nine minutes one insulator fails, the test must be continued two minutes longer upon the entire group.

BOXING

The purchaser will advise the *insulator company* previous to placing the contract whether the insulators shall be shipped set "knocked down" in barrels or boxes, or shipped set up in crates and will also supply specific shipping instructions or means of disposal of the ware within three days after the inspection begins.

APPENDIX D

Specification for Galvanizing for Iron or Steel

These specifications give in detail the test to be applied to galvanized material. All specimens shall be capable of withstanding these tests.

A. *Coating.*—The galvanizing shall consist of a continuous coating of pure zinc of uniform thickness, and so applied that it adheres firmly to the surface of the iron or steel. The finished product shall be smooth.

B. *Cleaning.*—The samples shall be cleaned before testing, first with benzine or turpentine, and cotton waste (not with a brush), and then thoroughly rinsed in clean water and wiped dry with clean cotton waste.

The sample shall be clean and dry before each immersion in the solution.

C. *Solution.*—The standard solution of copper sulphate shall consist of commercial copper sulphate crystals dissolved in cold water, about in the proportion of thirty-six parts, by weight, of crystals to 100 parts, by weight, of water. The solution shall be neutralized by the addition of an excess of chemically pure cupric oxide (Cu.O). The presence of an excess of cupric oxide will be shown by the sediment of this reagent at the bottom of the containing vessel.

The neutralized solution shall be filtered before using by passing through filter paper. The filtered solution shall have a specific gravity of 1.186 at 65° F. (reading the scale at the level of the solution) at the beginning of each test. In case the filtered solution is high in specific gravity, clean water shall be added to reduce the specific gravity to 1.186 at 65° F. In case the filtered solution is low in specific gravity, filtered solution of a higher specific gravity shall be added to make the specific gravity 1.186 at 65° F.

As soon as the stronger solution is taken from the vessel containing the unfiltered neutralized stock solution, additional crystals and water must be added to the stock solution. An excess of cupric oxide shall always be kept in the unfiltered stock solution.

D. *Quantity of Solution.*—Wire samples shall be tested in a glass jar of at least two (2) in. inside diameter. The jar without the wire samples shall be filled with standard solution to a depth of at least four (4) in. Hardware samples shall be tested in a glass or earthenware jar containing at least one-half (1/2) pint of standard solution for each hardware sample.

Solution shall not be used for more than one series of four immersions.

E. *Samples.*—Not more than seven wires shall be simultaneously immersed, and not more than one sample of galvanized material other than wire shall be immersed in the specified quantity of solution.

The samples shall not be grouped or twisted together, but shall be well separated so as to permit the action of the solution to be uniform upon all immersed portions of the samples.

F. *Test.*—Clean and dry samples shall be immersed in the required quantity of standard solution in accordance with the following cycle of immersions.

The temperature of the solution shall be maintained between 62° F. and 68° F. at all times during the following test:

First: Immerse for one minute, wash and wipe dry.
Second: Immerse for one minute, wash and wipe dry.
Third: Immerse for one minute, wash and wipe dry.
Fourth: Immerse for one minute, wash and wipe dry.

After each immersion the samples shall be immediately washed in clean water having a temperature between 62° F. and 68° F., and wiped dry with cotton waste.

In the case of No. 14 galvanized iron or steel wire, the time of the fourth immersion shall be reduced to one-half minute.

G. *Rejection.*—If after the test described in Section "F" there should be a bright metallic copper deposit upon the samples, the lot represented by the sample shall be rejected.

Copper deposits on zinc or within one inch of the cut end shall not be considered causes for rejection.

In the case of a failure of only one wire in a group of seven wires immersed together, or if there is a reasonable doubt as to the copper deposit, two check tests shall be made on these seven wires and the lot reported in accordance with the majority of the sets of tests.

GENERAL SPECIFICATIONS FOR HIGH-TENSION LINK TYPE INSULATORS

1. *General.*—The intentions of these specifications is to provide for all labor, tools and material required to furnish and deliver, f.o.b. . . . . . , in complete and satisfactory condition, as provided for in these specifications, approximately five-hundred (500) complete high-tension link type suspension insulators, and approximately two-hundred (200) complete high-tension link type strain insulators, as outlined below.

2. *Drawings.*—With his proposal, the bidder shall submit drawings showing the general type and dimensions of the insulator parts and of the assembled insulators he proposes to furnish.

After the contract has been awarded, the contractor shall send the company four signed blue prints of drawings showing the general design and the details of insulator and accessories. One print will be checked and returned to the contractor with approval or criticism noted, and three prints will be retained by the company for its files.

The contractor shall notify the company promptly of any changes which may be necessary in any drawing, print of which has been submitted to the company for approval, and on which action is pending. After a drawing has been approved by the company, the contractor shall make no changes until he has received the written consent of the company.

The contractor shall be responsible for the correctness of all drawings even though they may have been approved by the company.

Besides the drawings mentioned above, the contractor shall furnish such additional drawings and information regarding the general design, construction, connections, number and size of parts as may be required by the Engineer.

Any materials ordered, or work commenced before the approval of the drawings, shall be at the contractor's risk.

3. *General Requirements.*—The insulators will be used for a sixty-six thousand (66,000) volt, delta connected three-phase, 60 cycle transmission line carried on steel towers. The line will be located in a country subject to severe lightning and wind storms and will be operated in connection with a transmission system comprising about 120 miles of line.

The insulators are to be furnished complete with all links, clamps, bolts, and other parts necessary to make them complete and ready to bolt to the cross-arm and to receive the line wire.

The connecting links and insulator hardware shall be such design as will allow of the ready replacement of any unit in the string or permit of the addition of one or more units to the string without requiring any change whatsoever or any variation from the standard type of unit.

The operating voltage shall be approximately twenty-five thousand (25,000) volts per porcelain unit.

4. *Workmanship and Materials.*—All workmanship and materials shall be first-class and the best of their respective kinds, and must be in full accord with the best modern engineering practice. Only the very best grade of electrical porcelain clay shall be used. The fracture of the porcelain ware must not show blow-holes, cracks, checks, or other flaws, and must not show a glossy surface as same will be taken to indicate overfiring.

The entire surface of the ware excepting such areas as are necessary for supporting the ware in the kilns, must be uniformly coated with a dark brown glaze. The glaze must be hard, smooth, even, and continuous without crazing or other flaws.

The connecting links and all hardware shall be thoroughly galvanized, either by the hot process or the sherardizing method, after all punching, cutting and machining has been done. Bolts and nuts shall be electro-galvanized or sherardized after threading. All galvanizing shall be first class and in accordance with the standard specifications appended hereto.

5. *General Design.*—The insulators shall consist of porcelain disks or units strung in series with connecting links of approved design.

The disks or units shall consist of one piece of porcelain and shall not be less than ten (10) inches in diameter and shall be assembled on approximately six (6) inch centers.

The weights of the assembled insulators shall be approximately:

Suspension type . . . . . units . . lbs. net
Strain . . . . units . . lbs. net

6. *Mechanical Tests.*—The insulators, completely assembled with standard fittings and arrangement, shall withstand a mechanical test equivalent to a pull between conductor clamps and

cross-arm fastening of six-thousand (6000) pounds. At least three insulators from each shipment shall be subjected to this test.

7. *Electrical Test.*—Tests shall in all cases be conducted upon the standard assembled insulators, arranged as for service. The standard strings shall be placed under a mechanical load of 1500 lb. applied to them in their normal operating position, and while under this strain they shall be subjected to the following wet and dry tests:

Dry Test.—The assembled insulator shall withstand the continuous application for ten (10) minutes of a 60-cycle voltage of three (3) times the rated line voltage, or 198,000 volts, with one terminal connected to the suspension eye and the other to the conductor clamp.

Wet Test.—The assembled insulator shall withstand the continuous application for fifteen (15) minutes of a 60-cycle voltage of two (2) times the rated line voltage, or 132,000 volts, applied to the suspension eye as one terminal and the conductor clamps as the other, while the insulator is subjected to a spray of clear water giving a precipitation of one-fifth of an inch per minute, with the spray striking the insulator at an angle of 45 degrees from the vertical.

For this test the testing transformer shall be of reasonable capacity for that class of work, the wave form of the voltage shall be approximately a sine curve, and the voltage measurement shall be made with a spark gap using No. 3 sharp needles, using the standard spark gap curve of the American Institute of Electrical Engineers.

At least three insulators from each shipment shall be subjected to these tests.

8. *Inspection.*—The company shall have the right to have an inspector at the place of manufacture, who will have the authority to reject any or all such insulators or parts which do not conform to the strictest interpretations of these specifications.

If from any one firing, two (2) per cent. of the porcelain parts show indications of being overfired, all parts or units from that firing shall be rejected.

The contractor shall allow the company's inspector free access to his factory during the process of manufacture and testing. All testing shall be done by and at the expense of the contractor.

9. *Packing.*—The contractor will state the standard number of

parts per barrel, crate or box, and the method of packing. All such containers shall be plainly and correctly marked with the number and kind of parts therein.

10. *Final.*—It is the intention of these specifications to include all labor, materials, special tools and parts, properly to construct, test and deliver the apparatus as herein described, excepting only such labor and materials as are specially mentioned as being furnished by another contractor, and any labor, materials, fittings or apparatus required to properly complete the work hereinbefore described in the spirit of these specifications, but not especially mentioned, shall be furnished by the contractor without extra charge.

It is intended also that these specifications shall be sufficiently broad to allow all manufacturers of first-class insulators, to submit under them, and any bidder who finds anything in them prohibitive to the free exercise of his best skill and design in the making of insulators to fulfill the requirements, may submit propositions pointing out wherein he cannot conform to the specifications, and will also submit complete detailed specifications of the insulators and accessories which he proposes to furnish in place of those specified herein.

APPENDIX F

Specifications For Creosote Oil

The oil used shall be the best obtainable grade of coal-tar creosote, that is, it must be a pure product of coal-tar distillation and must be free from admixture of oils, other tars, or substances foreign to pure coal-tar. It must be completely liquid at 38° C. and must be free from suspended matter; the specific gravity of the oil at 38° C. must be at least 1.03.

When distilled according to the common method, that is, using an 8-ounce retort, asbestos covered, with a standard thermometer bulb one-half (1/2) inch above the surface of the oil, the oil should show no distillation below 210° C., not more than 25 per cent. below 235° C. and the residue above 335° C., if it exceeds 5 per cent. in quantity must be soft. The oil shall not contain more than 3 per cent. water.

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