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THE LINEMAN'S HANDBOOK

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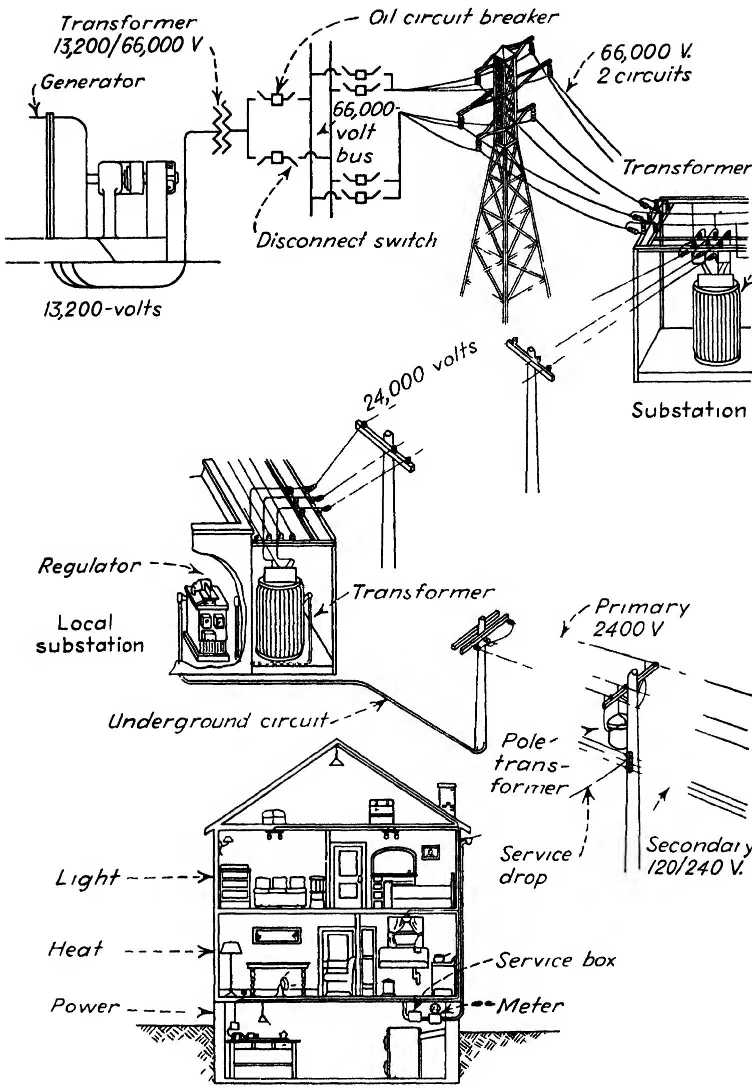

The electric system.

THE LINEMAN'S HANDBOOK

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THE LINEMAN'S HANDBOOK

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THE MAPLE PRESS COMPANY, YORK, PA.

"Hanging a Pot," one of ten original etchings of the electric utility industry by Orie Van Rye, Vice President, Worcester County Electric Company.

To all
linemen everywhere, those twentieth-century
knights of the spur
who serve for only one cause, "just service to man,"
the author respectfully dedicates this volume

THE LINEMAN*

by Chan Gardiner

They sings of the men as goes down to the sea;
Of the heroes of cannon and swords;
An' writes of the valors of dead chivalry,
An' the bravery of old knights 'n lords.

They sighs 'cause the romance of knighthood is past
'Cause there ain't no ideals any more;
They says that this world's a rollin' too fast
To develop that "esprit de corps."

But them as complains are the ones as don't know,
Who sits loose where it's warm and then kick
They ain't never seen a line saggin' with snow
An' had to get Service back—quick!

They ain't never struggled with Death at their side,
A-snappin' and hissin' and pale—
Nor clung to the towers and grimly defied
The assaults of the blizzards and gale.

They sit and are served with never a thought
Of the fellers out pluggin' like hell—
To supply at their touch the service they've bought
With a light, or the sound of a bell.

These fellers ain't togged out all shinin' in steel.
They don't ride around on no hoss—
They don't sing no songs about how they feel
In the gales when the feeders may cross.

They don't wave no banners embroidered in gold,
In Latin nobody can read;
They don't do no bragging of deeds that were bold,
Their motto is "SERVICE AND SPEED."

Their armor ain't nothin' but slickers an' boots
Their weapons are climbers and pliers,
Their battles are fought up where hi-tension shoots
An' Death lurks unseen on the wires.

They're fightin' the gales and the blizzards an' ice,
Protectin' the towers and span
With effort not measured in hours or price—
For one Cause—just Service to man!

So here's to the Lineman—the Son-of-a-Gun
That can do without sleep for a week!
That sticks to the job 'til it's every bit done
And the feeders can carry the peak.

For his is that Knighthood that's noblest by far
That highest and mightiest clan,
That's fightin' the battles of Things-as-they-are,
In the cause of the Service of man.

* *Reprinted with permission from the "Electrical Workers Journal."*

Preface

This handbook is written expressly for the apprentice, the lineman, the foreman, the supervisor, and other employees of line departments. It is primarily intended to be used as a home-study book by the apprentice lineman or the lineman to supplement his daily work experiences. Of the 38 sections in the handbook, 12 sections are devoted to a general understanding of electricity, electrical terms, and electric systems, 21 sections are devoted to actual distribution- and transmission-line construction and maintenance procedures, and 5 sections are devoted to safety.

The following eleven of the 38 sections contain material not fully treated or not included in previous editions:

Section 25: Pole Climbing—reprint of Edison Electric Institute Field Manual
Section 26: Rubber Protective Equipment—reprint of Edison Electric Institute Field Manual
Section 27: Rope, Knots, Splices, and Gear
Section 28: Tree Trimming
Section 29: Signals for Line Work
Section 30: The Prone-pressure Method of Resuscitation—reprint of Edison Electric Institute Field Manual
Section 31: Standard Technique for Executing the Back Pressure–Arm Lift Method—reprint from American Red Cross
Section 32: Pole-top Resuscitation—reprint of Edison Electric Institute Manual
Section 35: Electrical Formulas and Calculations
Section 36: Lineman's Arithmetic
Section 37: Self-testing Questions and Answers

These sections plus the expanded treatments of many topics in the other sections make this edition half again as large as the first edition.

An especial effort was made to present all discussions clearly and in simple language; in fact, a reading knowledge of the English language is all that is required to understand the book. As in former editions, a large number of illustrations showing the various steps in the construction and maintenance process are provided to assist the reader in better understanding the text; the almost 1,000 illustrations appearing in the handbook should be considered as much a part of the book as the words themselves. Illustrations bring out many details that would require many additional words to express. Nearly all the distribution-and transmission-line erection views were taken within the last year specifically for use in this edition. They therefore portray the latest practices in use today by some of the foremost electric utility companies in this country.

Methods of transmission-, distribution-, and rural-line construction have become quite standardized since the first edition of this handbook was published in 1928. The construction procedures described and illustrated are therefore in most instances representative of general practice. While each operating company has its own standards of construction which its linemen must adhere to, the procedures described explain why things are done in a given way. Such basic knowledge should be helpful to the apprentice lineman or the lineman who is interested in learning the whys and wherefores of doing things one way or another.

Safety is again emphasized throughout the book. Of course, understanding the principles involved in any operation and knowing the reasons for doing things a given way are the best aids to safety. Nevertheless, the opinion has become quite firmly established that a man is not a good lineman unless he does his work safely. It therefore behooves those engaged in line work to become familiar with the safety rules and the precautions applicable to their trade and make their observance an inseparable part of their working habits.

Emphasis is also placed on the National Electrical Safety Code. The important requirements of the code are reprinted and incorporated in the text where corresponding topics are discussed. In this way the lineman becomes acquainted with the minimum construction requirements that will ensure safety to the public and to the lineman. If more code information is desired a copy of the code known as Handbook No. 32, entitled "Safety Rules for the Installation and Maintenance of Electric Supply and Communication Lines," can be secured for a small charge from the Superintendent of Documents, Government Printing Office, Washington, D.C.

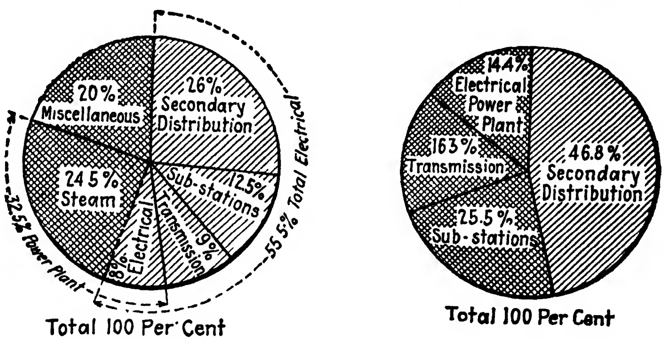
The author is well aware that one cannot become a competent lineman from a study of the pages of this book alone. However, diligent study along with daily practical experience and observation should give the apprentice lineman and the lineman an understanding of construction and maintenance procedures, and a regard for safety, that should make his progress and promotion rapid.

Edwin B. Kurtz

Contents

Introduction

The importance to the electrical industry of the lineman and his work has not always been fully appreciated in the past. The importance of the subject of line construction and maintenance, which is the work of the lineman, may be brought out by a consideration of the investment in lines and substations in an electric property. To illustrate this point see the charts here, which give, in (*a*), the division of the total investment in an average electrical property into its mechanical and electrical parts and, in (*b*), the division of the electric part only into its component parts. For example, (*a*) shows that the total investment in the average light and



(*a*) (*b*)

Charts giving distribution of investment in an average electric light and power company into its component parts as follows: (*a*) Total company investment (*b*) Electrical investment only.

power company is divided as follows: 24.5 per cent steam, which represents mechanical, 20 per cent miscellaneous, and 55.5 per cent electrical. This 55.5 per cent in turn is divided, in (*b*), into 16.3 per cent transmission lines, 22.5 per cent substations, 14.4 per cent electrical power plant, and 46.8 per cent secondary distribution system. Combining the items of transmission lines, substations, and secondary distribution systems gives a total of 85.4 per cent, which represents the portion of the electrical investment with which the linemen should be familiar. Omitting substations still leaves 62.9 per cent. In short, the lineman must know how to construct and maintain about two-thirds of the investment in the electrical part of our light and power companies.

These figures illustrate convincingly the important part linemen play in the development and operation of our electric systems. Every lineman and groundman can thus well afford to take steps to increase his knowledge of his daily work so that he will be qualified when the chance for promotion comes. Furthermore, an understanding of electrical principles and their application in electrical construction and maintenance work will do much to make the lineman's work less hazardous. These two reasons alone justify whatever time and effort is expended in studying these pages.

SECTION 1

Elementary Electrical Principles

What Is Electricity? No one knows. Ever since the day in 1753 when Benjamin Franklin drew a spark during a thunderstorm from the door key tied to his kite string, men have been seeking the answer. The most educated men have studied electricity, but to this day it cannot be said that anyone knows what electricity really is. But by

FIG. 1-1 Typical fluorescent lamp by which electricity furnishes light. (*Courtesy Westinghouse Electric Corp.*)

all this study, these wise men have learned much about it; so much that today everybody knows what electricity can do. People have learned how to use it, and they know how to handle and control it. This, after all, is all that they are interested in. It makes little difference to us whether electricity is a liquid like water or a gas like air, provided we know how it can be generated, how it can be transferred from where it is made to where we want to use it, and the nature of the devices and apparatus in which it performs the desired work.

USES OF ELECTRICITY

Electricity today is used for many different purposes. As a matter of fact, the uses to which electricity can be put are so numerous that

FIG. 1-2. Typical electric flatiron in which electricity is changed to heat (*Courtesy Westinghouse Electric Corp.*)

FIG. 1-3. Typical bread toaster, in which electricity is changed to heat. (*Courtesy Westinghouse Electric Corp.*)

one can hardly count them all. There are several general applications, however, with which everyone is familiar, and these are given in what follows.

Electricity Furnishes Light. Electricity, for example, is used to furnish light to nearly every home in our cities, to every shop and

FIG. 1-4. Typical electric range, in which electricity is changed to heat. (*Courtesy Westinghouse Electric Corp.*)

factory, and to light the busy streets of our cities. Everybody is familiar with the fluorescent lamp shown in Fig. 1-1. In an electric lamp, the electricity is changed to light.

Electricity Furnishes Heat. Electricity is used to furnish heat. The electric flatiron with which the housewife irons the clothes is a device in which electricity is changed to heat. Figure 1-2 shows such a flatiron. Figure 1-3 is the picture of a bread toaster, another device in which electricity furnishes heat. Figure 1-4 is a picture of an electric kitchen range on which complete meals can be prepared with electricity.

CLASSIFICATION OF USES OF ELECTRICITY

Used as light in	Used as heat in	Used as power in
House lamp	Range	Streetcar motor
Street light	Flatiron	Factory motor
Arc light	Ironer	Elevator
Sign light	Glow heater	Refrigerator
Floodlight	Curling iron	Washing machine
Headlight	Toaster	Vacuum cleaner
Movie projector	Waffle iron	Dishwasher
Flashlight	Water heater	Fan
etc.	etc.	etc.

Electricity Furnishes Power. The largest use to which we have been able to put electricity is to furnish power. A good illustration of a case where electricity is changed to power is the electric streetcar.

FIG. 1-5. Modern streetcar and rapid-transit car motor, with commutator covers removed, in which electrical energy is changed into mechanical power. (*Courtesy General Electric Co.*)

Everybody knows that it takes force to move a heavy streetcar on a track, and the power required for this is obtained from the electric motor. Such a motor is shown in Figs. 1-5 and 1-6. When riding on a streetcar one generally does not see this motor, but it is there. It is mounted under the floor of the car and is geared to the axle of the car.

Machine shops use electric motors to drive the lathes, millers, planers, drills, punch presses, etc. One large factory may have several hundred

FIG. 1-6 Modern heavy-duty direct-current traction motor for use on diesel-electric locomotives (*Courtesy General Electric Co.*)

FIG. 1-7 Typical electric motor of the alternating-current type. (*Courtesy General Electric Co.*)

motors installed like the one shown in Fig. 1-7. The parts of this motor are shown in Fig. 1-8.

Another field which is being electrified at present is the farm. It is now only a matter of time before many of the American farms will have all the electrical conveniences in the household and numerous small-sized motors in the barn, pump house, dairy, and shop.

To summarize, then, it is clear that electricity has many applications,

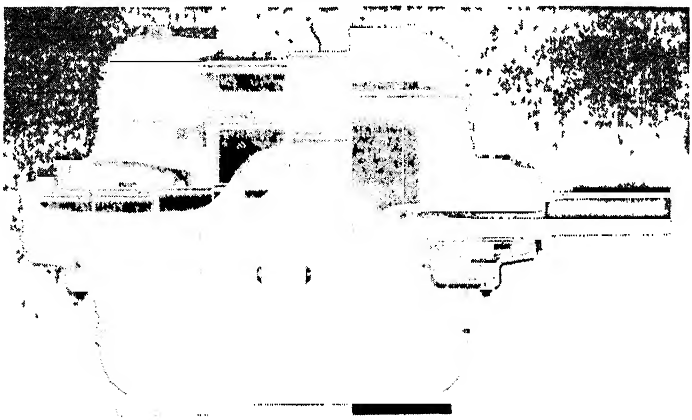


FIG. 1-8. Alternating-current motor cut away showing parts. (*Courtesy Allis-Chalmers Mfg. Co.*)

the more common of these being the furnishing of light in our homes, shops, and streets; the furnishing of heat in our homes and industries; and the furnishing of power for our homes, streetcars, factories, and farms.

ELECTRIC CIRCUIT

Compared to Water Circuit. As mentioned in the first paragraph, no one knows what electricity really is. At various times wise men believed that it was a form of matter. Some believed that it was a disturbance of the ether. Others contended that it was a kind of force. With these fancy speculations, this book, of course, has nothing to do. But the treatment of this subject can be greatly simplified if electricity is assumed to be a thin, weightless fluid. Such a fluid will then behave and act very much like water. Electricity can then be said to flow in a wire as water flows in a pipe. Everybody is more or less familiar with the flow of water in a pipe. Take a simple water circuit like the one shown in Fig. 1-9. By noting the resemblance between this pipe circuit and a typical electric circuit shown in Fig. 1-10, one can get a real understanding of the flow of electric currents.

In Fig. 1-9, water flows around the pipe circuit in the direction shown by the arrows. It is evident that this current of water flows because of a pressure which is exerted on it. This pressure is produced by the rotary pump, often called "centrifugal pump," which is driven by a belt from the steam engine. On the end of the pipe line, a water motor is connected in the line, and, therefore, all the water that flows around the circuit must pass through the motor. It is plain that in so doing it will cause the motor to revolve and, therefore, deliver power to the line shaft by means of the belt. Similarly, when an electric current flows in a wire, it flows because an electric pressure causes it to flow. Thus, the current in Fig. 1-10 is made to flow because of the electric pressure produced by the dynamo, or electric generator, which is driven by belt from a steam engine. As the electric current flows along the wire, it will be forced to flow through the electric motor. This motor will begin to revolve as the electricity begins to flow through it and thus also will deliver power to the line shaft.

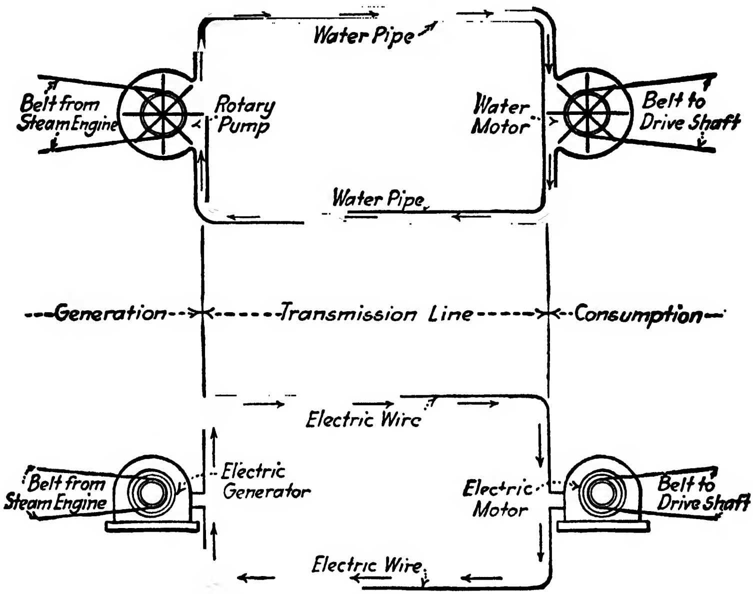


FIG. 1-9. The water system.
FIG. 1-10. The electric system.

Three Divisions of an Electric Circuit. Each of the above circuits can be seen to consist essentially of three main divisions. The section where the pressure is produced, that is, where the engine drives the generator, is called the "generator section." That part of the circuit which furnishes the path for the current from the place where it is generated to where it is consumed is the transmission section, and the section where the electricity is used or consumed is the consumption or conversion division. Conversion means "change," and it is here that electricity is changed to light, heat, or power. In an actual electric circuit like the one shown in Fig. 1-11, the three parts of the electric circuit are generating station, transmission line, and factory. The factory is the place where the power is consumed. Such an electric circuit is often called an "electric system."

The wires of the system serve to carry the electricity just as highways carry automobiles and railroad tracks carry trains. The reason one does not see the electricity moving along the wires is because it is invisible. And while the wires and transformers appear lifeless, they are very much alive and ready to do almost any work for us.

We should look upon the generation, transmission, and distribution of electrical energy as one does upon the manufacture, shipment, and delivery of goods. In comparing electricity to a manufactured product, like shoes, one should note one important difference. The manufacturer of shoes can estimate the demand for shoes and then manufacture them in advance and put them in a warehouse. Electricity, however,

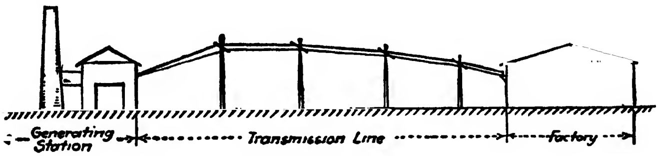


FIG. 1-11. An actual electric system.

cannot be generated in advance and stored in large quantity and delivered when needed. Electricity has to be manufactured or generated at the very instant that it is wanted. When the customer snaps his light switch or turns on the electric range, an order is flashed back through the distribution system (the retail outlet), the substation (the warehouse), the transmission line (bulk transportation), to the generator (the factory), and before the customer can remove his hand from the switch, delivery is made.

It is well to observe that the current path or the transmission line must have a return wire just as the water must have a return pipe. As is clear from Fig. 1-9, the water passes out along the pipe in one side of the circuit, through the water motor, where it does its work, and then returns to the rotary pump in the other pipe. In the same way, in Fig. 1-10, the electricity passes out along one wire to the motor, does its work, and then returns in the other wire to the generator.

ELECTRIC CURRENT

In the foregoing, it was pointed out that the flow of electricity in a wire is similar to the flow of water in a pipe. When water flows in a pipe, one speaks of a current of water or a water current. Similarly, when electricity flows in a wire, it is called an "electric current."

The Ampere. Generally we want to know how much water is flowing in the pipe, and we answer by saying "10 gal per sec." In the same way we can express how much electricity is flowing in a wire by saying "25 amp." The ampere is the unit of electric current. One can learn how much an ampere is by watching what it can do. Thus an ordinary 60-watt incandescent lamp will require about ½ amp. That means that ½ amp is flowing through it all the time that it is glowing.

A lamp as used for street lighting requires 6.6 amp, or about ten times as much current as the little house lamp. A medium-weight flatiron requires about 5 amp. A desk cooling-fan motor takes about

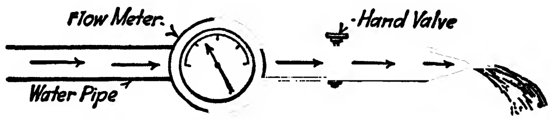


FIG. 1-12 Flowmeter in water pipe.

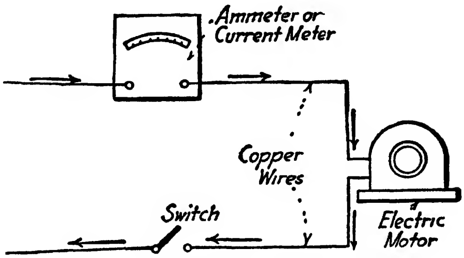
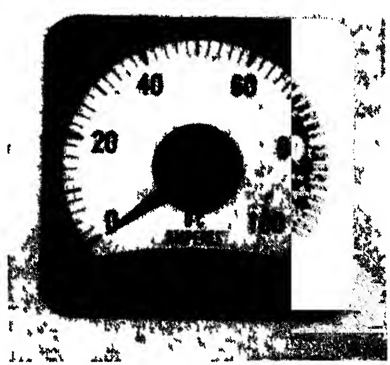


FIG 1-13 Ammeter in electric circuit

1 amp A streetcar requires about 200 amp A good-sized factory requires several thousand amperes The total flow of current from a large central generating station or generating plant may be as large as 10,000 amp These figures will give one a fairly good idea of the size of an ampere and what it will do

The Ammeter. If we wish to measure the current of water flowing through a pipe, we place a meter right in the pipe line A meter for

FIG 1-14 Typical direct-current switchboard ammeter (*Courtesy General Electric Co*)



measuring the flow of water in a pipe is called a "flow meter." When such a meter is placed in the line, water flows through it, as shown in Fig 1-12, and the meter indicates the number of gallons per second which pass through it. It is clear that the meter must be inserted in the pipe so that the water flows through it. In exactly the same way, the number of amperes of electric current flowing in a circuit can be measured by connecting a current meter or an ampere meter in the circuit, as shown in Fig. 1-13. Since such a meter is to read amperes, it is called an "ampere meter" or an "ammeter." It should be noted that the ammeter is inserted in the line in order that all the current taken by the motor may pass through the meter. Figure 1-14 shows a typical direct-current switchboard ammeter.

ELECTRIC PRESSURE

Generator Produces Electric Pressure. As stated on page 1-6, whenever a current of water is flowing in a pipe we know that a pressure is behind it which makes it flow. It may be well to note that the pump in the water circuit does not make water; it only produces a push or pressure. So also in the electric circuit, the generator does not create electricity; the generator merely produces an electrical pressure that causes electricity to flow. If there is no electrical pressure, no current will flow.

If a hand valve is put in the water circuit and the flow of water stopped, the water pressure will still be there, but there will be no flow of water through the water motor and the pipe. This everybody knows to be the case, for everybody has turned off the faucet in the kitchen sink. The water flow ceases, but the pressure is still there. So also in the electric circuit; if a switch is placed in the circuit shown in Fig. 1-13 and opened, the flow of electric current must stop because its path is now broken. The electric pressure will be there as long as the generator is being driven by the engine. Thus it is clear that there can be pressure and no current.

The Volt. In order that one may learn something about electrical pressure, one must be able to talk of its strength. This, therefore, requires a unit with which to measure it: that unit is the *volt.* We can learn how much a volt is by observing what it can do. We can note, for example, how much pressure or how many volts are required, in general, to force a current through a doorbell, an electric light, a flatiron, a washing-machine motor, a small factory motor, and a large factory motor. The most common values are as follows:

An electric doorbell requires 2 to 5 volts.
An electric light requires 115 volts.
An electric flatiron requires 115 volts.
A washing-machine motor requires 115 volts.
An electric range requires 230 volts.
An electric streetcar motor requires 600 volts.
A small factory motor requires 460 volts.
A large factory motor requires 2,300 volts.

These values simply mean that so many volts are required to push or force the working current through the devices or machines.

One can also gain an idea of the strength of electric pressure by observing how much of a shock is received when one puts his hands across the two wires of a circuit. A person in good health can just about feel 50 volts; 115 volts gives most people an unpleasant shock; more than 230 volts is dangerous; and 1,100 to 2,300 volts is likely to produce a fatal

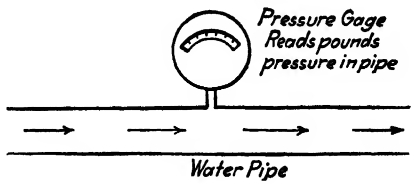


FIG. 1-15. Water-pressure gage.

shock. It is well, therefore, not to be careless with high voltages. Such voltages are always well protected, and no one except an authorized workman has any business getting near them.

The Voltmeter. If we wish to measure the pressure in a water circuit, all we do is to tap a pressure gage onto the pipe line as shown in Fig. 1-15. Everyone is familiar with such a gage. The few points to be noted are that the gage is simply tapped on the pipe line at the point at which

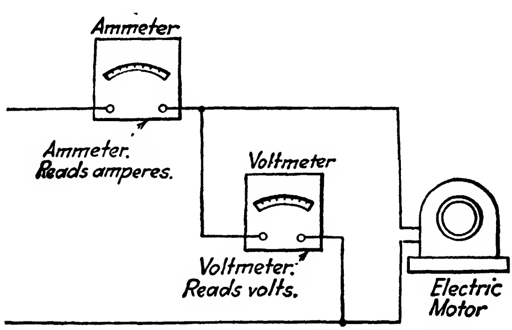


FIG. 1-16. Ammeter and voltmeter correctly connected.

the pressure is wanted, so that the pressure at that place can get up into the gage and make it indicate. It is also evident that the flow of water in the pipe is not disturbed by the insertion of the gage.

In the same manner, we can measure the electric pressure. We simply connect the two leads from a voltmeter across the line, as shown in Fig. 1-16. The current through the voltmeter will then vary directly with the voltage, and the meter can be made to read volts. It is to be noted that the current which flows to the motor does not flow through the voltmeter. This is because the voltmeter is not a part of the circuit as the ammeter is. Figure 1-16 shows the two meters, the ammeter and voltmeter, properly connected. The ammeter reads the flow of current, and the voltmeter reads the pressure which causes the current to flow. Figure 1-17 shows a typical direct-current switchboard voltmeter.

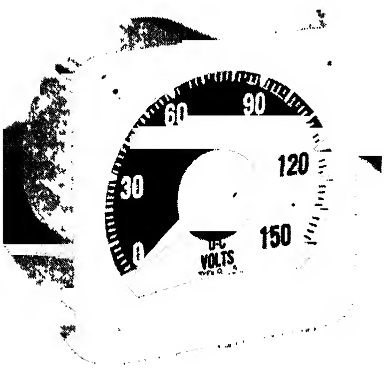


FIG. 1-17. Typical direct-current switchboard voltmeter. (*Courtesy General Electric Co.*)

ELECTRIC POWER

Water Power Depends upon Pressure and Quantity. We have likened an electric current to a current of water. When a current of water flows in a pipe in a simple circuit, as shown in Fig. 1-9, power is delivered to the water motor. We know this because the water motor revolves and can do work. The power delivered depends upon the amount of water flowing and the pressure under which it flows. This is self-evident, for more power will be developed if 50 gal of water per second flow through the water motor than if only 25 gal per sec flow through it. Furthermore, more power will be developed with 100 lb of pressure than with only 50 lb of pressure. The power delivered in the pipe line to the motor thus depends on the amount of water flowing and on the pressure.

Electric Power Depends upon Voltage and Current. In exactly the same way does the amount of power delivered by an electric circuit to an electric motor depend upon the number of amperes flowing and the number of volts of pressure. The greater the current, that is, the larger the number of amperes, the greater will be the amount of power developed by it, and the greater the pressure the more effect will the current have. The actual value of power in a direct-current circuit is equal to the product of volts times amperes, thus

$$\text{Power} = \text{volts} \times \text{amperes}$$

The Watt. The unit of power in an electric circuit is the watt. An ordinary electric lamp when connected to an electric circuit, as in Fig. 1-18, will draw about 60 watts from the circuit. An ordinary flat-iron when connected to a circuit will draw about 550 watts of power from it. A railway motor (Fig. 1-19) will draw about 120,000 watts of power. It is plain that when we come to large machines the number of watts runs up quickly. So we have chosen to call 1,000 watts a kilowatt, generally abbreviated and written kw. A kilowatt is equal to about 1⅓ hp. The above railway motor thus draws 120 kw of power, or 160 hp.

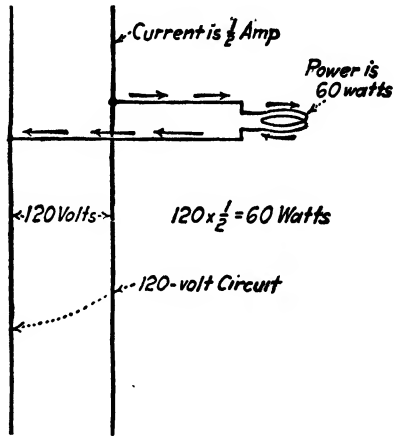


FIG. 1-18. Electric lamp taking ½ amp and 60 watts from 120-volt circuit.

The Wattmeter. To know how much power any electric device or apparatus is drawing from the line, we have to measure it. This is done by the use of a wattmeter. Such a meter registers watts or kilowatts, and by reading it one can at once tell how much any piece of apparatus is consuming. Since the amount of electrical power delivered by a circuit depends upon the amperes flowing and the volts of pressure, such a

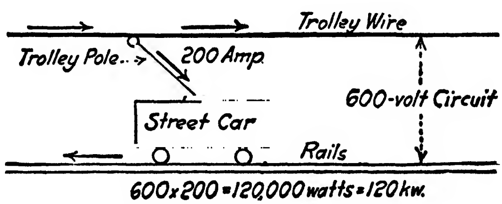


FIG. 1-19. Streetcar drawing 200 amp of current and 120 kw of power.

meter must be so connected that the entire load current flows through it and the voltage pressure is across it. The connections are as shown in Fig. 1-20. A wattmeter is, therefore, essentially a combination of two instruments, an ammeter and a voltmeter. It has an ammeter coil of low resistance, which is connected into the circuit, and a voltmeter coil of high resistance, which is connected across the circuit. A wattmeter will thus have four terminals or binding posts, two for the current-coil leads and two for the voltage-coil leads.

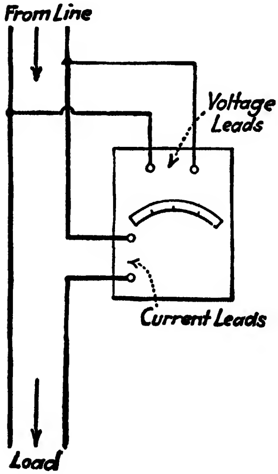


FIG. 1-20. Wattmeter correctly connected into circuit.

ELECTRIC ENERGY

Electric Energy Depends upon Power and Time. In order that electricity may do useful work, it must act for a period of time. The power expressed in watts tells how much electricity is working, and the hours express the time during which it acts. The product of these two factors gives the amount of work done. Thus,

$$\text{Power} \times \text{time} = \text{energy}$$

or

$$\text{Watts} \times \text{hours} = \text{watthours}$$

Since the unit of power, the watt, is a rather small unit, the larger unit equal to 1,000 watts is used. The unit for 1,000 is called kilo, therefore, 1,000 watts is called 1 "kilowatt." This unit is abbreviated kw. Likewise,

$$1000 \text{ watthours} = 1 \text{ kilowatthour}$$

which is abbreviated 1 kwhr. A kilowatthour can thus be thought of as

$$1{,}000 \text{ watt acting for } 1 \text{ hr} = 1 \text{ kwhr}$$

Any other combination of volts, amperes, and hours whose product is 1,000 would give 1 kwhr of energy.

The Watthour Meter. The total amount of electrical energy consumed over a period of time, such as a day or month or year, is indicated by a watthour meter. We are all familiar with the common electric house meter. This is nothing else than an integrating watthour meter which shows how much energy the lights, the flat-iron, the toaster, the washing machine, etc., consume in the course of a month. Such a meter is shown in Fig. 1-21.

Fig. 1-21 Typical single-phase alternating-current watthour meter (*Courtesy General Electric Co.*)

THE ELECTRIC PATH

Conductors. In the water circuit the pipes merely furnish the path for the flowing water. If we were to be more exact, we would say that the hole in the pipe was the path of the water, for we know it does not flow through the iron shell of the pipe. It actually passes through the opening in the pipe inside the iron shell. The hole or opening in the pipe may then be directly compared to the electric wire. The electricity, however, flows right through the hard wire. It does not need an opening. It passes right through the metal. But we find that it can travel with less difficulty through some metals than through others. It travels easily through copper; therefore we nearly always use copper wire. Copper is therefore called a good conductor. Any substance that offers little resistance to the flow of electricity is called a "good conductor." Electricity passes still more easily through silver, but silver is too expensive to be made into wires. Aluminum is now being used to some extent on long transmission lines, because of its rather good conduction and its light weight, making long spans between poles or towers possible. Iron is not a good conductor but is made use of on our streetcar lines. In a streetcar line, the current travels from the generating station along the trolley wire to the car, then down through the motor, and back to the station by way of the iron rails. The iron rails thus serve as conductors of electricity.

Insulators. In the above paragraph it was pointed out that the hole in the pipe serves as the path for the water. This does not mean to *imply that the shell of the pipe is useless and unnecessary. It is very* necessary. The shell serves to hold the water in its path. A pipe without a shell would never conduct any water. There would not be any pipe, and the water would flow everywhere. It is well to remember, then, that the shell keeps the current of water in its path.

So also in an electric circuit, there must be something to keep the current from leaving the wire. The metal of the wire is its path, but there

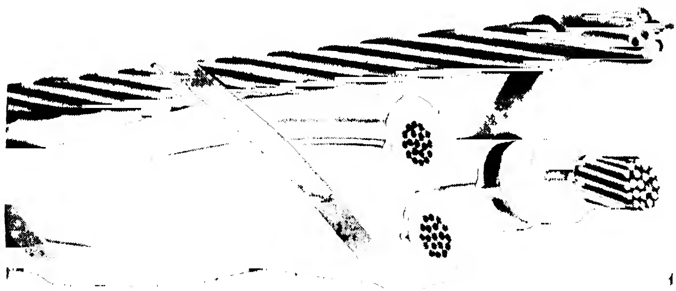


FIG. 1-22 Three-conductor self-supporting aerial cable now commonly used by electric utilities in primary and secondary power distribution. (*Courtesy The Okonite Company.*)

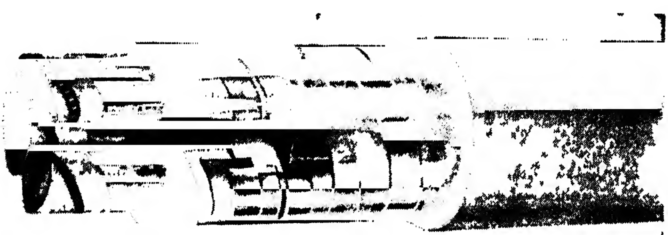


FIG 1-23 Three-conductor lead-sheathed paper-insulated power cable showing various layers of shielding and insulation. (*Courtesy The Okonite Company.*)

must be something to keep it from leaving the metal. Generally, a shell is put around the wire just as in the water pipe. This shell, however, is not iron, but is usually rubber, or silk, or cotton. The layer of rubber, silk, cotton, tape, or cambric is called "insulation," and a wire so covered is called an "insulated" wire. Figures 1-22 and 1-23 are illustrations of wires covered with different kinds of insulations. Silk and cotton are used to insulate wire when the voltage of the circuit is low. For example, cotton is used on doorbell circuits when the voltage is about 5 volts. Rubber or braid is used for house wiring where the voltage is 115 or 230 volts. Several layers of cotton and rubber have to be used on the same wire if the voltage is as high as 2,300 volts. Still higher voltages are insulated with several layers of rubber, cambric, cotton, and tape, and some even have a steel layer around the outside for protection. This is generally the case with underground cables and ocean telegraph cables where protection from animals and decay is required. Such a cable is shown in Fig. 1-24.

But even when wires are covered with cotton, rubber, or the like, it is not safe to lay them around on the ground. They are usually mounted on poles where they rest on glass or porcelain insulators, shown in Figs. 1-25 and 1-26. Glass and porcelain are good insulators of electricity.

FIG. 1-24. Three-conductor nonmetallic rubber-insulated power cable suitable for direct burial in the ground. (*Courtesy The Okonite Company.*)

FIG. 1-25. Glass-pin insulator used on low-voltage circuits to insulate the conductors from each other and from the ground. (*Courtesy Kimble Glass Co.*)

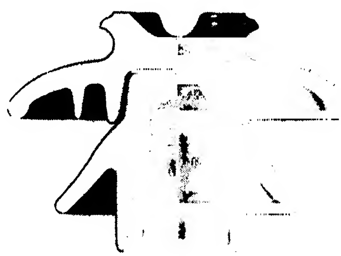


FIG. 1-26. Two-layer porcelain-pin insulator for use on medium-voltage circuits. The layers are cemented together. (*Courtesy Ohio Brass Co.*)

When wires are brought into a station, they are carefully mounted on glass or petticoat porcelain insulators (named because of their semblance to a skirt) in order that the wire may not touch anywhere, thus preventing the electricity from leaving the wire.

On high-voltage transmission lines, a number of insulators are connected in series, making a string from which the line conductor is suspended. Such a string is shown in Fig. 1-27. The greater the number of insulators in a string, the higher the voltage it can withstand.

Resistance. One can draw up an ice-cream soda faster and with less exertion through a short and large pipette than through a long and narrow pipette. Consider again the water circuit of Fig. 1-9. It is evident there that less water will flow if the pipe is long and has a small opening than if it is short and has a large opening, provided that the pressure is the same in both cases. This is quite to be expected, for in the long pipe the friction is greater because of the greater length, and if the pipe is also small in diameter the friction will be still greater because of the smaller space through which the water must be crowded. It may, therefore, be said that a long narrow pipe offers more resistance to the flow of water than a short and wide pipe.

So also in an electric conductor, the resistance a conductor offers to the flow of current will depend on its length and its thickness or diameter.

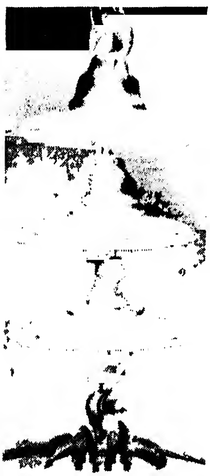


FIG. 1-27. Three-unit string of suspension insulators for use on high-voltage circuits. (*Courtesy Locke Dept., General Electric Co.*)

If the wire is very long, more friction must be overcome than if it is short; if it is also of small cross section, it will take still more effort to crowd the current through the wire.

The Ohm. The unit of resistance for wire is the *ohm*. We can picture how much an ohm is by noting how many feet of wire of a given size it takes to make an ohm of resistance. Wires used for electric purposes are supplied on the market in regular sizes of specified diameter. The No. 10 copper wire is about $\frac{1}{10}$ in. in diameter and has 1 ohm of resistance for each 1,000 ft of length. Thus 5,000 ft of this wire would have 5 ohms resistance. Another wire whose cross section is one-half as large would have a resistance of 2 ohms for every 1,000 ft of length.

Ohm's Law. From the foregoing it is clear that resistance will reduce the amount of current that will flow. The number of amperes that will flow in a circuit will, therefore, not be determined wholly by the voltage or pressure which causes the current to flow but also by the amount of friction or resistance in the wires. Thus, with a given voltage the greater the resistance of a circuit, the smaller the current will be that flows, and the smaller the resistance, the greater the current will be.

This general relation between voltage, current, and resistance is commonly called "Ohm's law." It is a law because it has been found to hold in every case It is written thus

$$\text{Current} = \frac{\text{voltage}}{\text{resistance}} \quad \text{or} \quad \text{amperes} = \frac{\text{volts}}{\text{ohms}}$$

$$\text{Resistance} = \frac{\text{voltage}}{\text{current}} \quad \text{or} \quad \text{ohms} = \frac{\text{volts}}{\text{amperes}}$$

$$\text{Voltage} = \text{current} \times \text{resistance} \quad \text{or} \quad \text{volts} = \text{amperes} \times \text{ohms}$$

The law as stated above applies only to direct-current circuits, that is, a circuit in which the current continuously flows in one direction in the wire The law is quite obvious, because it agrees with the common principle with which all are familiar, namely, that the result produced varies directly in amount with the magnitude of the effort or force and inversely with the resistance or opposition encountered

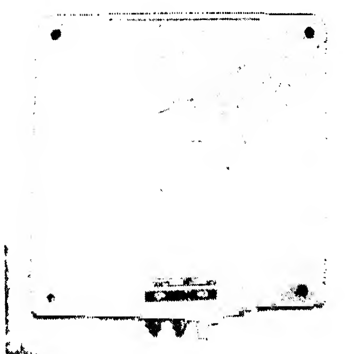


Fig. 1-28 Hand-operated field rheostat used for controlling the field current in the field circuits of motors or generators (*Courtesy General Electric Co*)

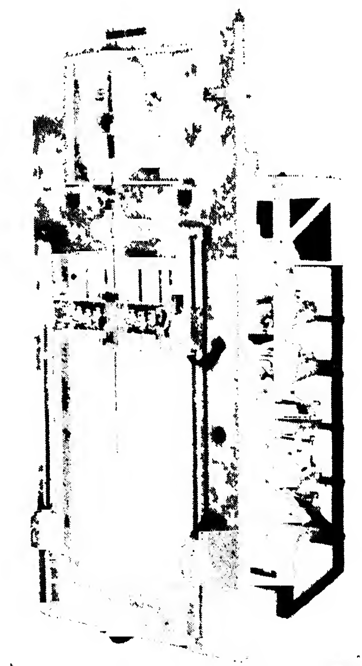


Fig. 1-29. Motor-operated field rheostat. The motor mounted at the top through the worm drive moves the contact arm up or down as desired (*Courtesy General Electric Co*)

Rheostats. Often it is necessary to reduce or increase the current in a circuit. From what was stated above this can be done if it is possible to increase or decrease the resistance in the circuit. This can be arranged for by connecting into the circuit a *resistor* which is nothing more than an object having a variable resistance, that is, one that can be changed at will. Types of such resistance boxes or resistors are shown in Figs. 1-28 and 1-29. By turning the handle of the hand-operated resistor, more or less resistance is put into the circuit and the current accordingly decreases or increases. Such resistors are commonly called "rheostats" and are used wherever it is necessary to control or regulate the current flowing in a circuit.

CURRENT DIRECTION

Hydraulic Direct Current. Up to this point in this discussion of basic principles, a water circuit has been used in which the flow of water was

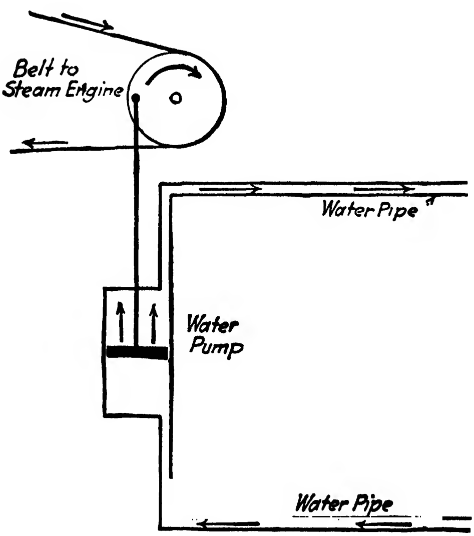


FIG. 1-30. Alternating-current water pump.

always in the same direction around the circuit; for it is evident, from Fig. 1-9, that if the engine continues to rotate in the same direction the rotary pump will rotate in the same direction, and the current of water will continue to flow in the same direction. Such a current is called a "direct current." The principal use made of direct current is for streetcars, elevators, electric furnaces, electroplating, etc.

Hydraulic Alternating Current. But if the rotary pump is replaced with a reciprocating pump, like the one shown in Fig. 1-30, the current will not flow in one direction continuously; instead the current of water will first flow in one direction, and then as the piston moves in the opposite direction, the water will also flow in the opposite direction. From Fig. 1-30, it can be seen that when the piston is moving upward the flow of water will be as shown by the arrows in the pipe circuit, and when the piston moves downward the direction of the flow of water will have to reverse. It is to be noted that in such an arrangement the engine still keeps on revolving in one direction as before. The pump, however, being of a different type, causes the current to flow in one direction for a short time and then reverses it and makes it flow in the other direction for a short time. This changing of direction continues all the time. A current that flows first in one direction in a pipe and then in the other direction is said to alternate in direction and is called an "alternating current."

Cycle. Such a water pump causes the current to change its direction two times for each stroke of the pump. When the piston moves up it has a clockwise direction around the circuit, and when the piston moves down it has a direction opposite to the hands of a clock. When the piston comes up again, it has the clockwise direction again. So the current reverses its direction two times for each complete stroke of the pump. Such a complete stroke of the pump with its two reversals of flow is called a "cycle." A cycle is, therefore, something which repeats itself.

Frequency. Frequency is the number of complete cycles made per second. If the pump made 25 complete strokes per second the pump could be said to have a frequency of 25 cycles per sec, and if it had a frequency of 60 strokes per second it could be said to have a frequency of 60 cycles per sec.

Sixty-cycle Alternating Current. It is indeed interesting to know that almost all (about 95 per cent) the electricity generated in the world is of the alternating-current type. That is to say, more than nine-tenths of all the electricity generated and consumed flows first in one direction in the wires and then in the other direction, just as the water does in Fig. 1-30, and most of this alternating current is 60-cycle alternating current. The currents in the house lamp, the toaster, the kitchen range, and the fan motor all flow for a very short time in one direction around the circuit and then quickly change and flow in the other direction. This continues all the time and at a very high rate. Indeed, these reversals generally take place at the rate of 120 per second or 7,200 per minute, making the frequency 60 per second or 3,600 per minute. This is so fast that one cannot notice any flicker in the light of the house lamp at all. Such currents are, therefore, known as "60-cycle alternating currents."

Twenty-five-cycle Alternating Current. In a few places in this country such as Keokuk, Iowa, and Niagara Falls, N.Y., the alternating current is generated as 25-cycle alternating current. Most of this current is now being changed to 60-cycle current by means of frequency changers before being delivered to the customer.

ALTERNATING-CURRENT GENERATOR

Under the discussion of electrical pressure or voltage, it was stated that a generator or dynamo produces electric pressure which causes current to flow. And now, since most of the electricity used flows in the form of alternating currents, a description of the type of generator that produces an alternating pressure will be taken up. It must be clear

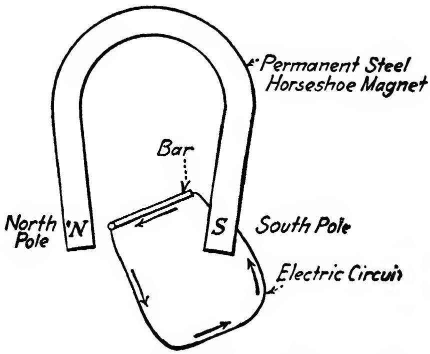


FIG. 1-31. Elements of an alternating-current generator.

that, if a current alternates, the pressure which causes it to flow must also alternate.

Elementary Type. The simplest arrangement for generating such an alternating pressure is shown in Fig. 1-31. It consists of nothing more than a steel horseshoe magnet and a bar of copper to the ends of which is attached a wire, forming the circuit shown. When this bar is moved down between the poles of the magnet so that it passes through the magnetism at the ends of the poles, an electric pressure or voltage is generated in the wire. If the bar is now raised or moved upward so that it passes through the magnetism in the other direction, a voltage will again be generated in the wire, but this time the voltage will be in the opposite direction. Hence, to obtain an alternating voltage, all that is needed is a machine in which a wire moves through magnetism first in one direction and then in the other and arrangements for connecting this moving wire to the outside circuit. Such a device is shown in Fig. 1-32 and is called an "alternating-current generator." In this elementary alternating-current generator the wire has been bent into the form of a loop or coil so that it can be rotated continuously in one direction, instead of having to move it up and down. The two sides of the coil will then alternately pass through the magnetism at the north pole and then through the magnetism at the south pole. If this loop is revolved in the direction of the arrow, the side of the loop marked *AB* will generate a voltage in a direction from *B* to *A* and the other side of the loop, marked *CD*, will generate a voltage in a direction from *D* to *C* at the instant shown. If the loop is connected to a circuit through rings

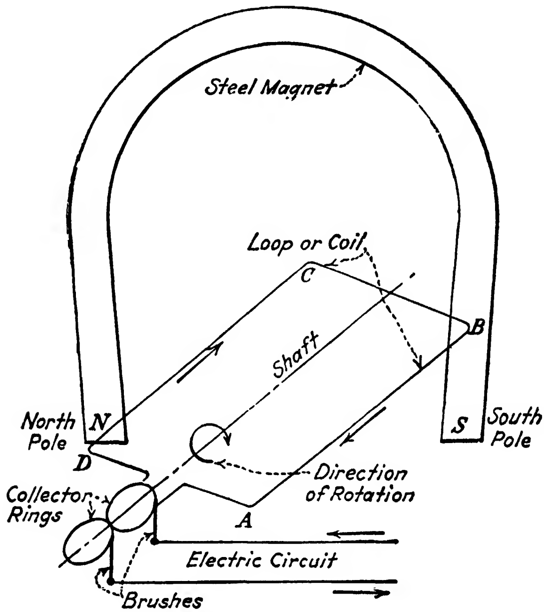


FIG. 1-32. Elementary alternating-current generator.

at the ends of the loop by means of sliding-contact brushes, a current will flow.

One-fourth of a revolution later, when the loop is in the vertical position, the sides of the loop are not passing through any magnetism, and during that instant there will be no voltage and also no current. When the loop has advanced one-half of a revolution from the first position, the wires are again passing through magnetism, causing a voltage to be generated and current to flow if the circuit is closed. This time, however, the current will flow in the opposite direction, because the wires are passing different poles. An alternating current can thus be taken from the rings. If the values of generated voltage are plotted against the corresponding positions of the coil, the curve shown in Fig. 1-33 results. This is the familiar wave of an alternating voltage. Brushes sliding on the collector rings connect the loop to the electric circuit. Such a machine is then a generator of alternating currents.

The voltage in the coil will reverse its direction twice for every revolution of the coil, just as the water changed its direction twice for every stroke of the pump. The frequency in cycles per second will then be the same as the revolutions of the coil per second. If the loop revolves 25

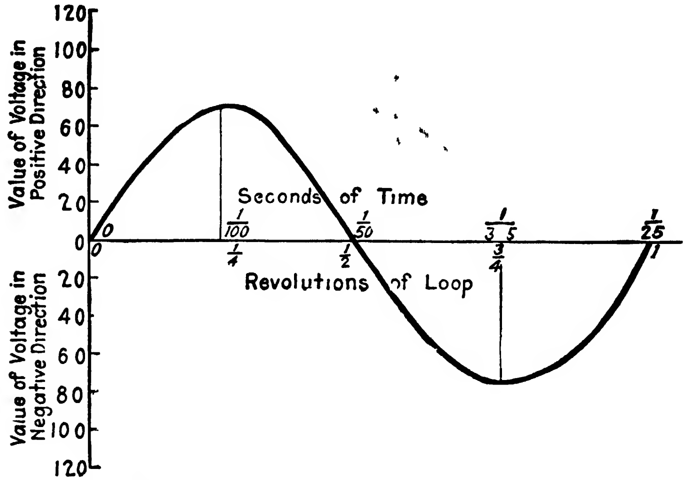


FIG. 1-33. Alternating-voltage wave This chart gives the positive and negative values of voltage for each position of the loop Zero corresponds to vertical position of loop

times per second, the frequency of the voltage will be 25 cycles per sec. The time required for each revolution and for each cycle will be $1/25$ sec.

Single-phase Generator. Such a generator as has just been described is shown in Fig. 1-34. This generator has only two slip rings which connect to a simple circuit of two wires. A generator with only two slip

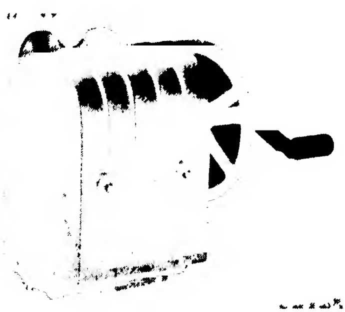


FIG 1-34. Telephone magneto alternating-current generator. (*Courtesy Kellogg Switchboard and Supply Co.*)

rings is known as a "single-phase" generator, "single phase" meaning that the circuit has only two wires.

Two-phase Generator. If another coil or loop is placed on the rotating shaft so that the wires of this loop lie halfway between those of the loop already described, and if the ends of the second loop are also brought out to another pair of slip rings, such a machine will generate two voltages, one in each loop. There would be this difference: one loop would be passing through magnetism when the other would be midway between the poles, and so the voltage in one would be a maximum while the other was zero. The voltage in one loop would therefore be ahead of the other by the time necessary for the shaft to turn through the space separating the coils, or in this case one-fourth of a revolution (see Fig. 1-35). Such a generator, generating two voltages, is called a "two-phase generator." There would be four wires leading from the machine making up the two circuits.

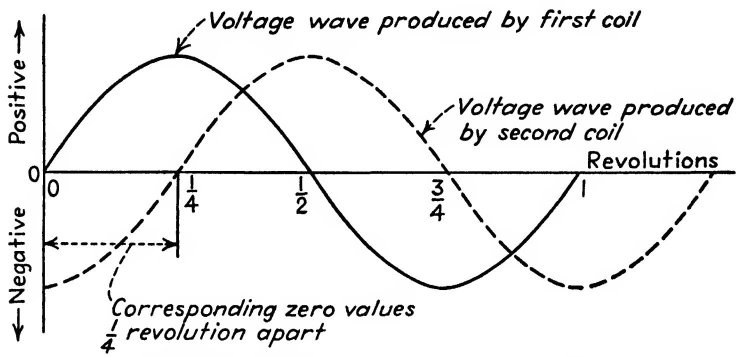


FIG. 1-35. Voltage waves of two-phase generator.

Three-phase Generator. It is not difficult to picture three coils or loops equally spaced on the shaft as were the two coils of the two-phase generator. If such a machine were built with three coils and three pairs of collector rings, one would obtain three alternating voltages in the three circuits, but each of these voltages would be a little ahead of the others (see Fig. 1-36). Such a machine would then be called a "three-phase generator of alternating currents." And if the machine were of the simple type with only two poles, the frequency of the alternations or the cycles per second would again be equal to the revolutions per second. Such a machine would have six slip rings and six wires leading from it, making up the three circuits.

It has been found, however, that the sum of the currents at any instant in three of the six wires is zero. That is to say, some of the currents are flowing away from the generator and others are flowing toward the generator at the same instant, and the net sum of the currents in three wires is zero. This fact makes it possible to do away with three of the six wires, thus making a three-phase line a line with only three wires. The generator will only have three collector rings, and only three wires are connected to the machine.

Revolving-field Alternators. In the alternators so far described, the field poles were stationary and the conductors were arranged to move past the poles. In large-sized alternators, it is better construction to have the armature conductors stationary and the poles revolve. Such

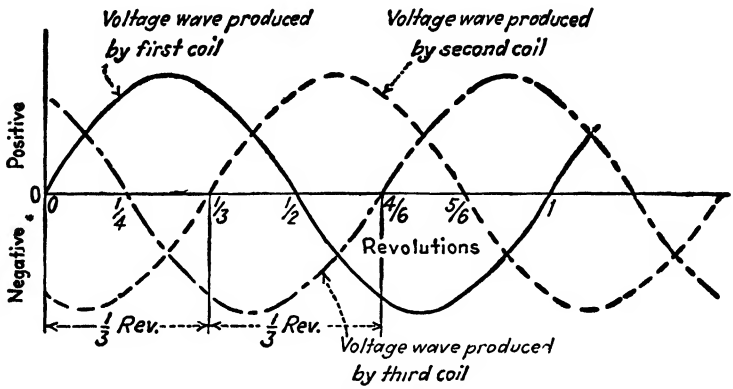


FIG 1-36 Voltage waves of three-phase generator. The corresponding zero values are one-third revolution apart

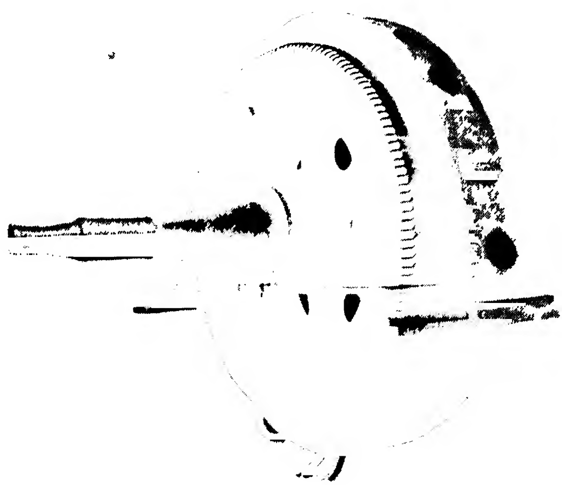


FIG. 1-37 Three-phase revolving field type alternator This machine has 32 poles and is rated 3,125 kva at 225 rpm It generates 4,150 volts, three phase, 60 cycles. It is designed to be coupled to a diesel engine. (*Courtesy General Electric Co.*)

alternators are called "revolving-field alternators" instead of revolving-armature alternators. Figures 1-37 and 1-38 illustrate this type of construction in an engine-driven machine and Fig. 1-39 in a steam turbine-driven machine. The principal advantages of the revolving-field construction are (1) the armature conductors can be more securely fastened and better insulated, and (2) the amount of material in the rotating part is considerably reduced.

Three-phase Connections. The three coils of the three-phase alternator can be connected in two ways, one to form a Y connection and the

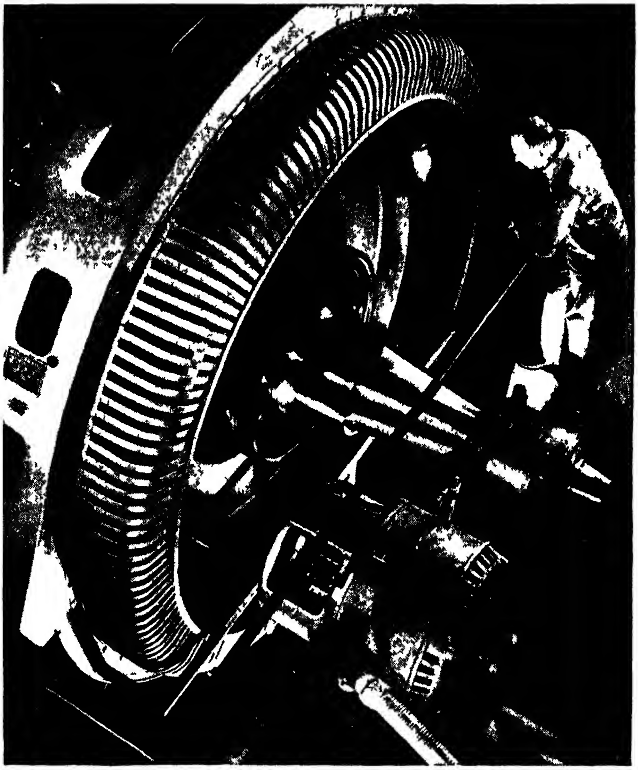


FIG. 1-38. Another view of an engine-driven revolving-field alternator running at full speed. This machine is rated 3,425 kva and is being driven by a 3,600-hp engine. The small machine in the foreground is the direct-current generator which supplies the direct current for the alternator field excitation. (*Courtesy Allis-Chalmers Mfg. Co.*)

other to form a delta (Δ) connection. In the Y connection one set of corresponding ends of each of the three coils of the alternator are connected together as shown in Fig. 1-40. The name "Y" is taken from the appearance of the connection when shown as a diagram. The three free ends of the coils connect to the three wires of the three-phase line.

In the delta connection, the three coils are connected in series as shown in Fig. 1-41. The name again is taken from the appearance of

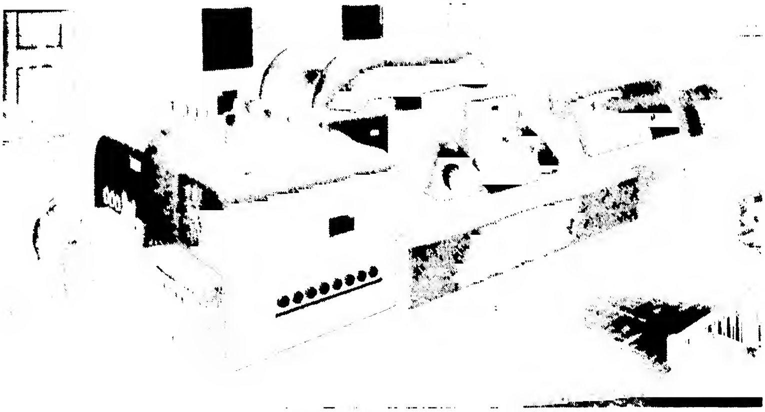


FIG 1-39 Three-phase revolving-field type alternator direct connected to a steam turbine The steam turbine is the machine on the left, consisting of both high- and low-pressure units The alternator is to the right of the turbine and the small unit at the extreme right is the direct-connected exciter The unit is rated 60,000 kw The rotor of the generator is cooled with supercharged hydrogen (*Courtesy Allis-Chalmers Mfg Co*)

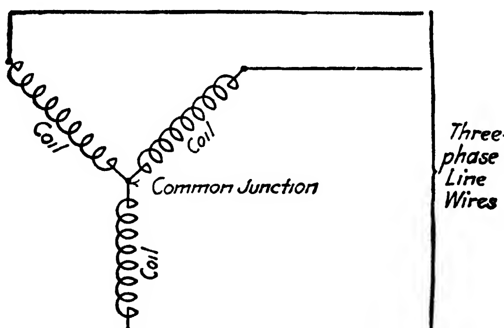


FIG. 1-40. Y connection of three-phase alternator.

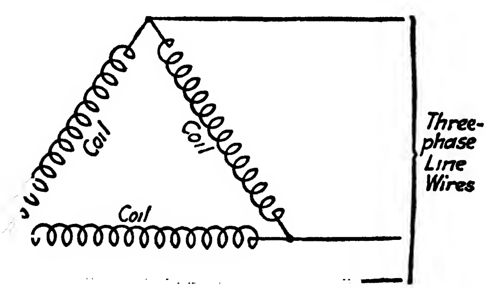


FIG 1-41. Delta connection of three-phase alternator.

the connection when shown as a diagram. The line wires are connected to the junction points or the corners of the delta.

Three-phase Transmission Lines. Since most of the electricity used in the world is of the alternating-current type, and since the most economical transmission is three phase, it would, therefore, be expected that there would be three wires on the top of long-distance transmission towers or poles. A typical three-phase transmission line is shown in

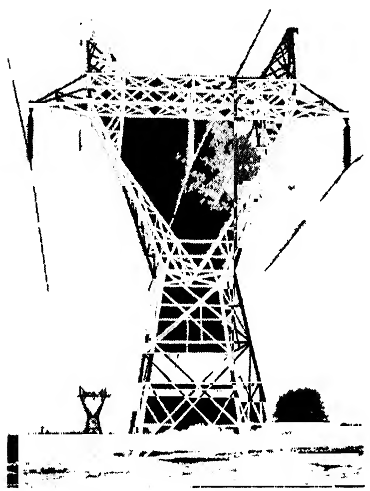


FIG. 1-42. Single-circuit 220,000-volt three-phase high-voltage transmission line. Note the long string of suspension insulators needed to insulate the conductors. Also note two ground wires at extreme top of the tower. These are used to shield the line from lightning. (*Courtesy Aluminum Company of America.*)

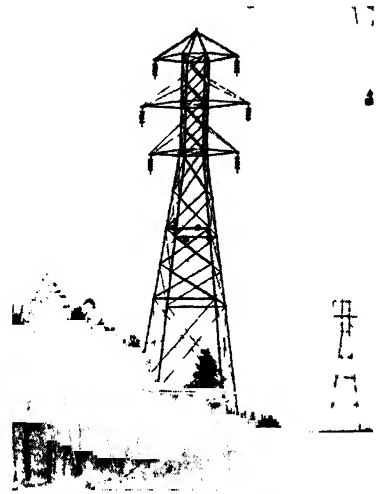


FIG. 1-43 Double-circuit high-voltage transmission line. The three conductors on each side of tower constitute a single three-phase circuit. The ground wire on the apex of the steel tower is for protection against lightning. (*Courtesy General Electric Co.*)

Fig. 1-42. In many cases, electric light and power companies want to be sure that there will be no interruption of service if any part of a transmission line breaks down; so they provide some lines with two sets of three wires each as shown in Fig. 1-43. If one line meets with an accident, the other is used. Transmission lines have occasional breakdowns due to strong windstorms which tear down the poles, sleet storms which cause heavy loads on the wires and break them, and line insulators which break and put the line out of use. Modern and well-designed transmission lines, however, seldom fail because of the elements.

Power Factor. When an alternating voltage and the current which it causes to flow rise and fall in value together and reverse in direction at the same instant, the two are said to be "in phase" and the power factor is unity. This condition is illustrated in Fig. 1-44. The same formula for power as was discussed on page **1-12**, for direct current holds for alternating current when the power factor is unity. Thus,

$$\text{Power in watts} = \text{volts} \times \text{amperes}$$

In most cases, the current and voltage waves are not in phase; that is, they do not rise and fall in value together, nor change in direction at

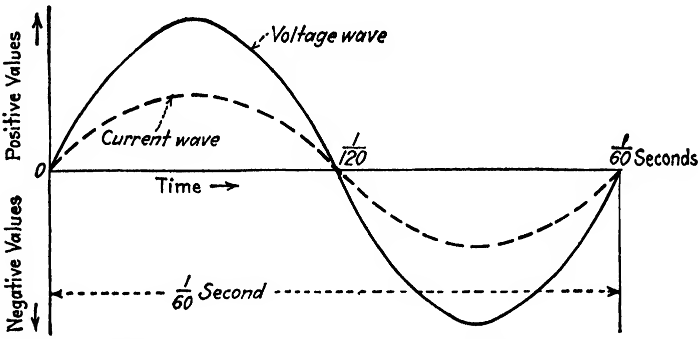


FIG. 1-44. Voltage and current waves in phase. The power factor under these conditions is unity.

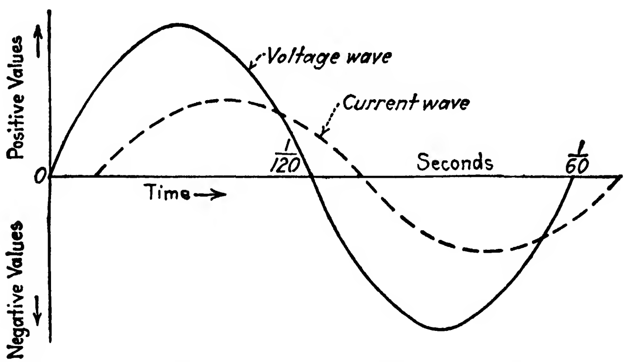


FIG. 1-45. Current wave lagging behind the voltage wave. This is the usual condition in transmission and distribution circuits.

the same instant, but instead the current usually lags behind the voltage. This condition is illustrated in Fig. 1-45 and represents the usual condition in transmission and distribution circuits. The current and voltage are now said to be "out of phase." The current drawn by idle running induction motors, transformers, or underexcited synchronous motors lags even more than the current shown in the figure.

It is only occasionally that the current leads the voltage. An unloaded transmission line or an overexcited synchronous motor or a static condenser takes leading currents from the line. In all cases when the current leads or lags the voltage, the power in the circuit is no longer equal to volts times amperes but is now

$$\text{Watts} = \text{volts} \times \text{amperes} \times \text{power factor}$$

From this the

$$\text{Power factor} = \frac{\text{watts}}{\text{volts} \times \text{amperes}}$$

and the power factor can thus be defined as the ratio of the actual power to the product of volts times amperes. The latter product is generally called "volt-amperes" or apparent power. The value of the power factor depends on the amount the current leads or lags behind its voltage. When the lead or lag is large, the power factor is small, and when the lead or lag is zero, as when the current and voltage are in phase, the power factor is unity. This is the largest value that the power factor can have. In practice the power factor is usually between 0.70 and 1.00 lagging. An average value often taken in making calculations is 0.80 lagging. Table 1-1 gives the power factors of various types of electrical equipment.

TABLE 1-1. POWER FACTORS OF ELECTRIC EQUIPMENT

Name of equipment	Power factor, per cent	Lagging or leading
Lightly loaded induction motor	20	Lagging
Loaded induction motor	80	Lagging
Incandescent lamps	100	In phase
All types of heating devices	100	In phase
Neon-lighting equipment	30–70	Lagging
Static condenser	0	Leading
Overexcited synchronous motor	Varies	Leading
Underexcited synchronous motor	Varies	Lagging

POWER-FACTOR CORRECTION

Cause of Low Power Factor. The cause of low power factor is an excessive amount of inductive effect in the electric consuming device, be it motor, transformer, lifting magnet, etc. Induction motors when lightly loaded exhibit a pronounced inductive effect. Idle transformers likewise have a strong tendency to lower the power factor.

Capacitance. Capacitance is the direct opposite of inductance, just as heat is the opposite of cold, sweet the opposite of sour, and day the opposite of night. Capacitance is the property of a condenser, and a condenser is a combination of metal plates or foil separated from each other by an insulator such as air, paper, or rubber. The capacitance, or the capacity of the condenser to hold an electric charge, is proportional to the size of the plates and increases as the distance between the plates decreases.

Method of Improving Power Factor. Since capacitance is the opposite of inductance, and since too much inductance is the cause of low power factor, the manner of raising the power factor is therefore to add capacitors to the line. Such capacitors are often mounted on poles, as

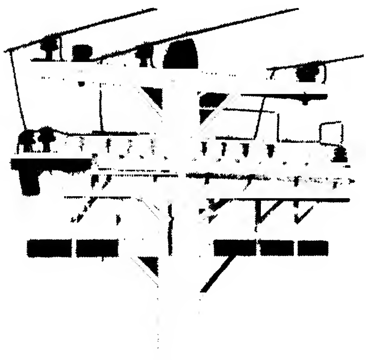


FIG. 1-46 Distribution-capacitor installation rated 180 kva, three phase, 60 cycles, 2,300 volts. The installation is composed of 12 individual capacitors, each rated 15 kva, single phase, 2,300 volts. (*Courtesy General Electric Co.*)

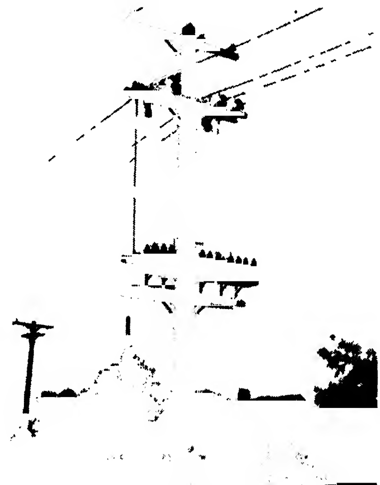


FIG. 1-47. A typical pole-mounted capacitor installation. (*Courtesy Line Material Co.*)

shown in Fig. 1-46. This illustration shows 180 kva of capacity supported on a crossarm in units of 15 kva each. Since these units are rated at 2,300 volts, they are connected directly across the line through fuses. Such capacitor installations take full-load rating at all times. They therefore operate at full capacity continuously. Figures 1-47 and 1-48 show additional views of capacitor installations.

Switched Capacitor. A switched capacitor bank is a large capacitor bank which is energized or connected to the line on a given schedule. On account of its size it is sometimes switched in a number of steps. The schedule is determined by time, circuit load, circuit voltage, or other consideration. It is therefore switched on and off to meet these requirements. The switching can be done either manually or automatically. This is in contrast with a nonswitched capacitor bank that is connected to the line at all times and is disconnected only for maintenance purposes.

Capacitor Connections. Figure 1-49 shows the detail connections for connecting a capacitor bank to a three-phase four-wire feeder. On installations greater than 180 kva, an oil switch is necessary. Each phase of the capacitor bank is fused. In general, not more than six 15-kva capacitor units should be connected to one fuse cutout. The cases of the capacitors must all be grounded. Figure 1-50 shows a typical installation of a pole-type capacitor on a 4,000-volt three-phase

FIG. 1-48. A capacitor installation on an alley H frame. (*Courtesy Iowa-Illinois Gas & Electric Co.*)

four-wire feeder. The oil fuse cutouts in the three lines and an expulsion cutout in the neutral lead are clearly visible. Figure 1-51 shows another view of a three-phase capacitor installation connected to the three-wire primary line.

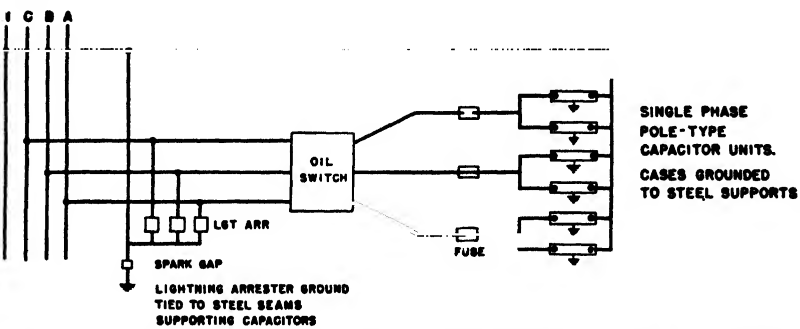


FIG. 1-49. Typical connection diagram of three-phase capacitor bank. (*Courtesy Consolidated Gas Electric Light and Power Co.*)

Caution. Capacitors and transformers are entirely different in their operation. When a transformer is disconnected from the line, it is electrically dead. Unlike the transformer and other devices, the capacitor is not "dead" immediately after it is disconnected from the line. It has the peculiar property of holding its charge because it is essentially a device for storing electrical energy. It can hold this charge for a considerable length of time. There is therefore a voltage difference across its terminals after the fuse boxes are opened.

Capacitors for use on electrical lines, however, are equipped with an internal discharge resistor, as shown in Fig. 1-52. This resistor being

FIG. 1-50. Typical installation of pole-type three-phase capacitor for power-factor improvement. Note fuse cutouts. (*Courtesy General Electric Co.*)

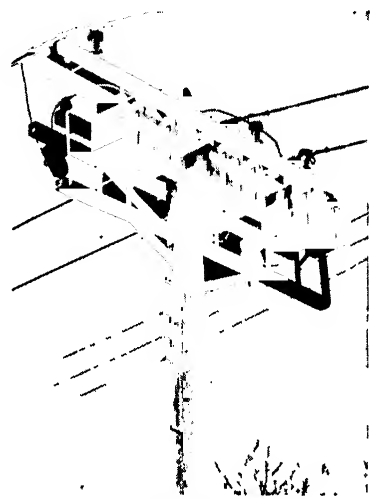


FIG. 1-51. Three-phase capacitor installation connected to a three-wire primary. Note lightning arresters and fuse cutouts. Also note secondary supported on vertical bracket. (*Courtesy Line Material Co.*)

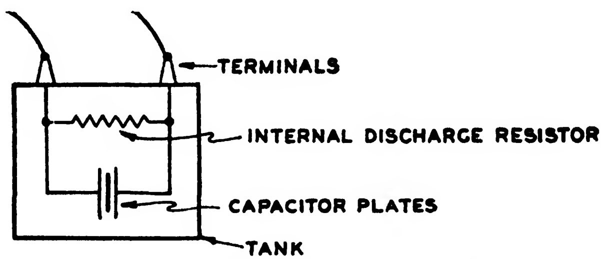


FIG. 1-52. Internal connections of a static capacitor. Note internal-discharge resistor.

connected across the capacitor terminals will gradually discharge the capacitor and so reduce the voltage across its terminals. After 5 min. the capacitor can be considered as fully discharged.

In order to be perfectly safe, however, proceed as follows: Before working on a disconnected capacitor, wait 5 min. Then short-circuit the terminals externally, and ground the terminals. Now you can proceed with the work.

DIRECT-CURRENT GENERATOR

We have carefully studied how an alternating current of water could be produced by the pump shown in Fig. 1-30. We observed that the current of water circulated around the pipe circuit first in one direction and then in the opposite direction. And we also observed that the water current reversed its direction twice for each complete stroke of the pump. All this we have carefully compared with the action of a real electric

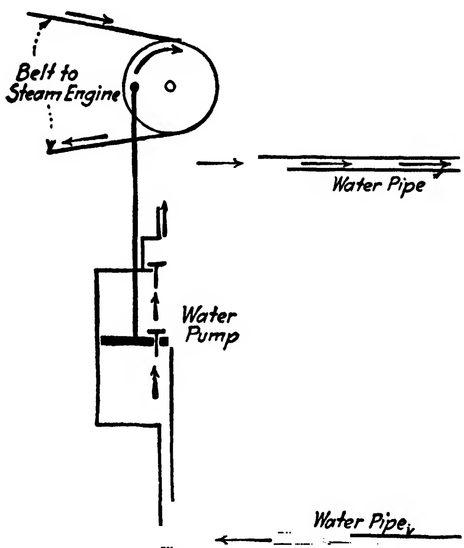


FIG. 1-53. Direct-current water pump.

generator and found that the procedures are quite alike. This much is fundamental in the generation of electricity, whether it is alternating-current or direct-current electricity. To obtain alternating current we simply fastened slip rings to the ends of the loop and connected those rings to the circuit by means of sliding brushes.

Direct-current Water Pump. To obtain a direct current of water, which is a current that flows continually in one direction, we simply have to add a set of valves to our water pump, as shown in Fig. 1-53. The water will now not be able to flow backward after it is once forced through the valve and, therefore, the direction of the water flow will always be the same. As the piston moves up, it forces the water through the top valve, and as the piston drops, the top valve closes and the lower valve rises and allows the water to fill the cylinder. When the piston moves upward again, the cylinder is full of water and more water will be forced into the circuit through the top valve as before.

Elementary Type. To obtain a direct current of electricity from the machine shown in Fig. 1-32, we simply replace the slip rings with a *commutator*. The commutator is the device which changes an alternating voltage to a direct voltage. It corresponds to the valves in the hydraulic direct-current generator. The process is called "commutation." In this simple case, the commutator consists of two bars of copper connected to the two ends of the loop or coil. These two copper bars revolve with the shaft as did the slip rings. Upon these bars rest

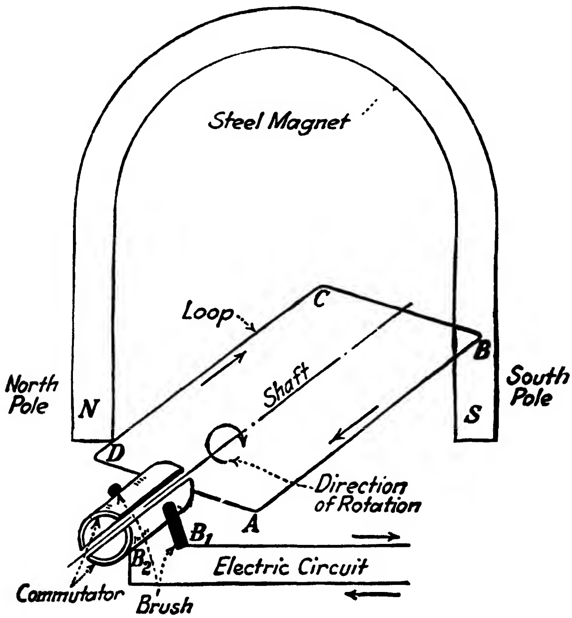


FIG. 1-54. Elementary direct-current generator.

brushes which connect the machine to the electric circuit. The general arrangement is shown in Fig. 1-54.

Commutation. From Fig. 1-54, it is clear that the commutator will first connect one side of the loop to one side of the circuit, and then as the shaft revolves it will connect the other end of the loop to the same side of the circuit. If the brushes are correctly set, this change will take place when both sides of the loop are not generating any voltage, that is, when the coil is midway between the poles. This is the point at which the current in the loop changes direction. When A side of the loop is passing the south pole, the voltage is in a given direction and feeds into brush B_1, and D side of the loop feeds into brush B_2. But when the loop has revolved to its midway position, the direction of the generated voltage in the loop is about to change, and just at this instant the ends of the loop are also changed to the opposite sides of the circuit, so that when the loop revolves still further, the voltage into the circuit will remain the same. In this way, the voltage that alternates in the loop is made to produce a pressure in the same direction in the outside circuit. Such a machine with its commutator is called a "direct-current generator."

Commercial Direct-current Generator. The principal parts of a commercial direct-current generator are shown in Fig. 1-55. These parts are the frame, the poles, the armature, the commutator, and the brushes. The purpose of the frame is to support the north and south

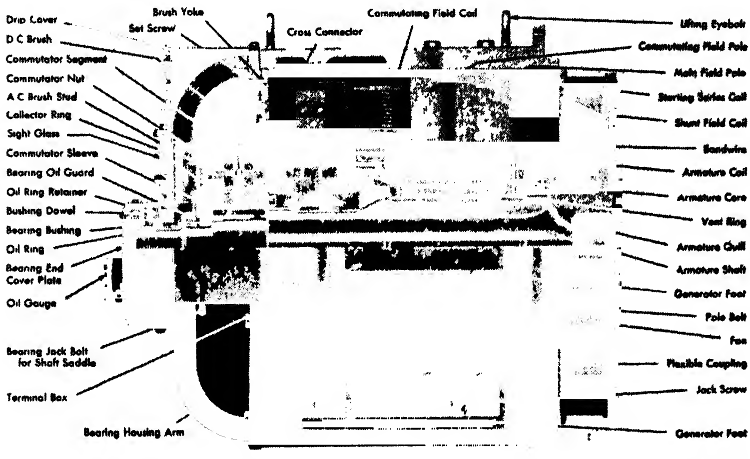


FIG. 1-55. Sectional view of a direct-current generator showing details of construction. Generator is rated 100 kw. (*Courtesy Allis-Chalmers Mfg. Co.*)

poles. The armature supports the conductors which constitute the armature winding. The commutator, which in an actual machine is made up of many copper segments, is also supported by the armature. A special brush rigging holds the brush holders and brushes. Figure 1-56 shows these parts assembled and placed in proper relation to each other.

Direct-current Circuits. Direct-current circuits, as we have seen, require only two wires, one for the outgoing current and the other for the return current. Overhead circuits carrying direct current will, therefore, consist of only two wires, except in the case of the Edison three-wire system, explained and discussed in the last part of Sec. 3. In the case of electric street railways, where the iron rail of the track serves as the return conductor, the overhead circuit consists of only one wire. This wire is called the "trolley wire." Feeders which tap onto the trolley wire are essentially part of the trolley and do not constitute a separate circuit.

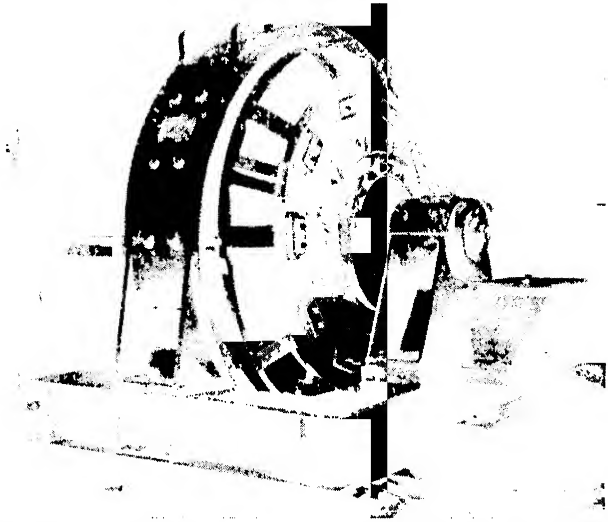


FIG. 1-56. Direct-current generator assembled. This machine is rated 250 kw, 250 volts, and runs at 225 rpm. (*Courtesy Allis-Chalmers Mfg. Co.*)

TRANSFORMERS

Uses of Transformers. The voltages necessary to obtain economical long-distance transmission are higher than can be directly generated by an alternator. Also, the voltage at which electric power is used in motors and lamps is less than that required for distribution. It is, therefore, necessary to raise the voltage at the generating station to the value required for transmission and to lower it at the point of consumption to the values required by the motors and lamps on the system. In the first case, the voltage must be *stepped up*, and in the latter it must be *stepped down*. The transformer is the apparatus used to make these changes in voltage.

The Hydraulic Transformer. To make clear how this is done, the water circuit shown in the left of Fig. 1-57 will be referred to. Since this is an alternating-current circuit the water flows to and fro or back and forth in the circuit. As it does this, it causes the piston in *B* to move up and down. But piston *B* is connected to piston *C* by a rod pivoted at *P*, so that when *B* moves up and down *C* moves down and up. The pressure in *B* is very high and the current of water is small, just like the voltage and current in a long high-voltage transmission line. In *C* it is clear that the pressure will be low and the current of water large, because the size of the piston is so much larger. Such a mechanism could thus be used to transform or step down a water circuit having a high pressure to one having a low pressure. The current on the low-pressure side would be much larger than the current on the high-pressure side.

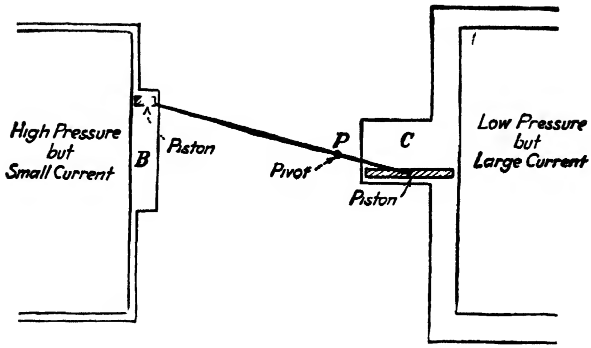


FIG 1-57 The hydraulic transformer

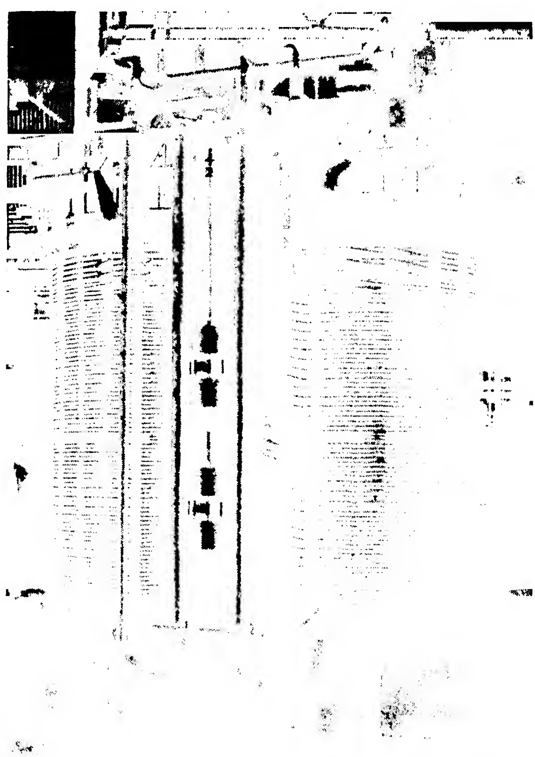


FIG 1-58 Single-phase transformer with case removed showing core and windings. High-voltage winding is rated 66,000 volts, and low-voltage winding is rated 13,200 volts Hand-operated tap changers are shown in center foreground. (*Courtesy General Electric Co.*)

It is well to note that the frequency of the current has not been changed. The only changes are the decrease in pressure and the increase in current. It should also be noted that the total power delivered has not been changed, for under the discussion of power it was pointed out that power is dependent upon the product of pressure and current. The same power can be obtained from a circuit of high pressure and small current as from a circuit that has a low pressure and a large current.

The Electric Transformer. An electric transformer operates in the same manner as the hydraulic transformer. On the high-voltage side

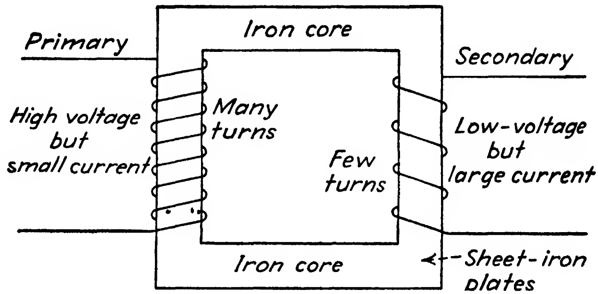


FIG. 1-59. Electric voltage transformer.

the electrical pressure is high and the current is small. On the low-voltage side the pressure is low and the current is large. One can, in general, easily tell the high-voltage from the low-voltage side of a transformer by observing the size of the insulators or bushings on the top of the transformer case. The high voltage must be better insulated than the low voltage. One generally finds, therefore, large porcelain bushings projecting from the case on the high-voltage side and smaller bushings on the low-voltage side. Figure 1–58 shows the core and windings of a single-phase transformer removed from its tank. The high- and low-voltage leads are brought out on top of the tank.

In Fig. 1-59 are shown the elementary parts of an electric voltage transformer. Sheet-iron plates are so arranged as to form a closed magnetic circuit. Upon these plates are placed two coils of insulated wire, one of which has many turns of fine wire, and the other has few turns of heavy, coarse wire. The coil with the many turns is the high-voltage coil and is called the "primary winding" in a step-down transformer. The other coil with the few turns is the low-voltage coil and is called the "secondary winding." Thus, the winding into which current is brought is the primary, and the winding from which current is taken is the secondary. The coils correspond to the two pistons in the water transformer, and the magnetic core acts as the coupler between the two pistons.

Actually, what goes on in the transformer is somewhat as follows: The voltage applied to the primary causes a current to pass through the primary coil. This current creates a magnetic flux in the core. The flux in the core cuts both the primary and the secondary coils. This cutting of the primary coil creates a countervoltage in the primary coil which very nearly equals the primary voltage applied. Thus, the current in the primary at no load is only great enough to magnetize the core at no load. The secondary coil being cut by the flux will have voltage at no load, but there is no current. Now, let us apply load on the secondary. The load current in the secondary will create a counterflux in the core which reduces the magnetic flux in the core. The reduction in magnetic flux in the core reduces the primary countervoltage. The reduction in primary countervoltage increases the difference between the applied voltage and the countervoltage. More current will therefore flow into the primary, thereby increasing the magnetic flux to its former no-load value. This again raises the secondary induced voltage to its original value. All these adjustments within the transformer take place automatically and instantaneously.

It should be noted that in a modern transformer the primary and secondary windings are not placed on separate legs, as shown in the elementary diagram of Fig. 1-59, but, instead, each winding is generally divided into two parts, and one-half of each winding is placed on each leg. This gives a more constant voltage with changes in load. Figure 1-60 shows a typical transformer from which the case has been removed. It shows clearly the magnetic core, the coils, and leads.

Transformer-core Construction. The core of a transformer can be built in various shapes. The following types are in general use:

Core Type. The core is in the shape of a rectangle. Coils are placed on two legs of the core. See Fig. 5-3.

Shell Type. The core is rectangular in shape with a central leg in addition to the core first described. Coils are placed on the central leg. See Fig. 5-4.

Cruciform Type. The cruciform core is a modification of the shell type. It is the same as though two shell-type cores were set at right angles, using a common central core for the windings.

Wound-core Type. In this type, the core is made of a ribbon of sheet steel wound in a spiral. After the core is wound and annealed, the coils are wound on the two core sides. In the smaller sizes, this type may supersede all other core types eventually. See Fig. 1-61.

Cooling. When the voltage of the primary and secondary windings are both low and the transformer is of very small size, the transformer, that is, the iron core with its two windings, is placed in a metal case merely to keep out dirt and moisture. But if the voltage exceeds 2,000 volts, the core with its two coils is placed in a tank filled with oil. The oil is a good insulator and also helps to cool the windings. It will perhaps be remembered that whenever current flows in a wire there is a friction loss in heat. An illustration of this is found in the toaster or the flatiron. The same is true in a transformer; whenever currents are flowing through the primary and secondary windings, heat is given off which must be carried away so that the transformer may not become too hot and char or burn the insulation on the wire of the coils. If it becomes too hot, the transformer will be ruined just as a person will die if he has a high temperature for a long time.

Because a transformer must not get too hot, more power can be safely drawn from it in cold weather than in hot weather. Moreover, more

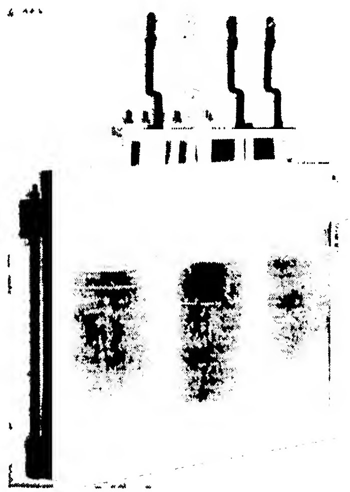


FIG. 1-60. Three-phase distribution transformer with case removed, showing core, windings, and high- and low-voltage leads. Transformer is rated 37.5 kva, 2,400/4,160Y to 240/416Y volts, 60 cycles. (*Courtesy General Electric Co.*)

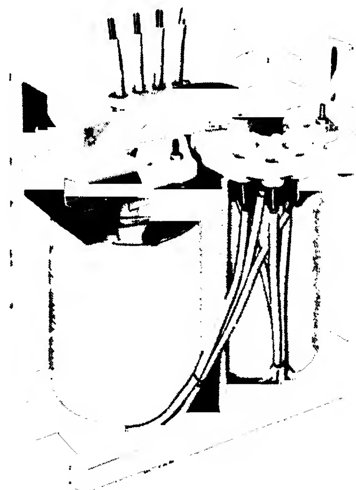


FIG. 1-61. Wound-core type of distribution transformer. (*Courtesy Line Material Co.*)

power can be taken off for short periods of time than can be taken off continuously. Any transformer too hot to touch is overheated because of an overload and should be replaced with a larger transformer before it becomes damaged.

Methods of Cooling. The oil in the tank is the principal cooling agent. It keeps the windings cool by carrying the heat from the coils to the surface of the tank. Many times the transformer case itself is built so that it has much more surface for cooling than if it were smooth. The metal sides of the tank are bent into ruffles (Fig. 1-62), or pipes are connected to the top and bottom of the tank (Fig. 1-63), so that whatever oil is in the pipes is exposed on all sides. The object in either case is to increase the surface from which the heat can radiate. This is the same principle as is used in the automobile radiator.

In very large transformers, coils of pipes through which cold water is circulated by a pump are placed in the top of the tank. The cold water in the pipes cools the oil in the tank. The water pipes are placed in the top of the tank because the hottest oil is always at the top. An illustration of this method of cooling is shown in Fig. 1-64.

FIG. 1-62. Single-phase transformer showing the tank corrugated or ruffled to increase the cooling surface. Also note oil-level gage on right. Transformer is rated 250 kva, 60 cycles, 2,400/4,160Y on high-voltage side and 240/120 volts on low-voltage side. (*Courtesy General Electric Co.*)

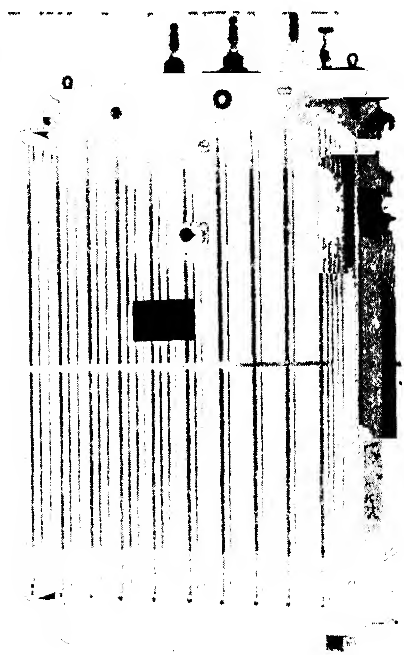


FIG. 1-63. Transformer tank, showing pipes connected to top and bottom of tank to aid in the cooling of the oil. This transformer is entirely air cooled. This three-phase oil-immersed power transformer is rated 1,000 kva, 60 cycles, 6,600Y volts on high-voltage side, and 440 volts on low-voltage side. (*Courtesy General Electric Co.*)

Transformer Temperature Limits. In general, the maximum safe temperature for such insulating materials as cotton, silk, cambric, tape, fabric, etc., is 105°C, which corresponds to 221°F. It is impossible, however, to measure the actual temperature in the transformer because the exact location of the hottest spot is not known, nor is it accessible. The temperature of the oil plus a 10 or 15° correction is usually taken as an indication of the temperature of the windings. In large power trans-

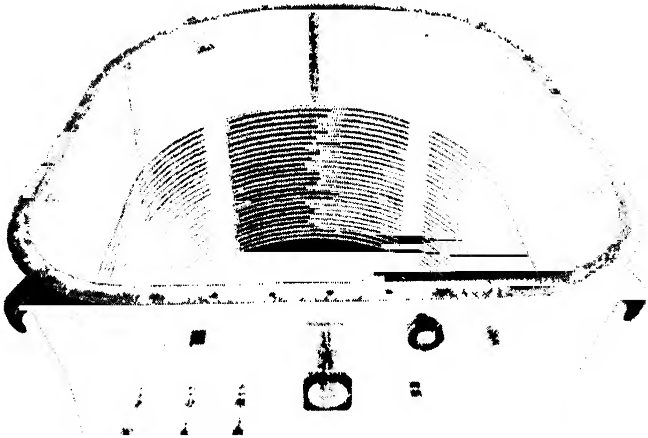


FIG 1-64 Interior view of case of water-cooled transformer showing cooling coils in which cold water is circulated The cooling coils are located in the top of the case because the hottest transformer oil is at the top This transformer is rated 23,333 kva, 60 cycles 66 420/115 000Y volts on high-voltage side and 13,200 volts on low-voltage side (*Courtesy General Electric Co.*)

FIG 1-65 Thermotel being installed on distribution transformer to indicate the largest load that the transformer has carried since the last reading It indicates the load in per cent of transformer rating (*Courtesy General Electric Co.*)

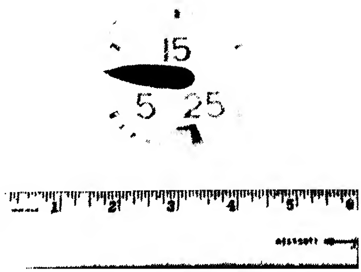


FIG 1-66 Overload indicator for use on distribution transformers The red light indicates that the transformer has been overloaded, and the dial indicates the number of times the transformer has been overloaded since the last setting The reset button returns the pointer to zero (*Courtesy Westinghouse Electric Corp.*)

formers the temperature of this oil is usually obtained by some form of thermometer, such as that shown in Fig. 1-63.

In distribution transformers devices are now being used which indicate the maximum load on the transformer in per cent of the transformer capacity. One such device, shown in Fig. 1-65, is known as the "thermotel," meaning that it tells the temperature. The rapid growth of loads on distribution systems makes it necessary, in many cases, to make a check of the loads on transformers in order to determine whether the transformer is still large enough to carry the load. Another overload indicator, illustrated in Fig. 1-66, makes use of a bimetallic thermostat embedded in the transformer winding to give an indication of the winding temperature. In addition to registering the number of times the transformer was overloaded on a dial, it also turns on a red light which is visible from the ground. A reset button makes it possible to turn the light off and return the dial to zero. Such devices as illustrated are very convenient for they record the largest load that the transformer has carried during any given period.

Three-phase Transformers. A three-phase transformer is really three single-phase transformers in one case, using a single combined core. The core has much the same shape as the shell-type single-phase transformer. However, in the three-phase, instead of having only a winding on the central leg, the two outside legs have windings also (see Fig. 1-60). Each winding acts for a separate phase, but the common core acts to supply flux for all three phases.

A three-phase transformer weighs about two-thirds as much as the same capacity in single-phase transformers. Their biggest disadvantage lies in the fact that if one phase fails the entire transformer must be taken out of service.

SECTION 2

The Electric System

General. Before beginning the study of line construction and maintenance, it is desirable first of all to have in mind the general scheme of an electric system. It is the purpose of this chapter to present a bird's-eye view of an electric system and to state briefly what each part is and what duty it performs.

An electric system comprises all the generating stations, transmission lines, substations, feeders, primary mains, distribution transformers,

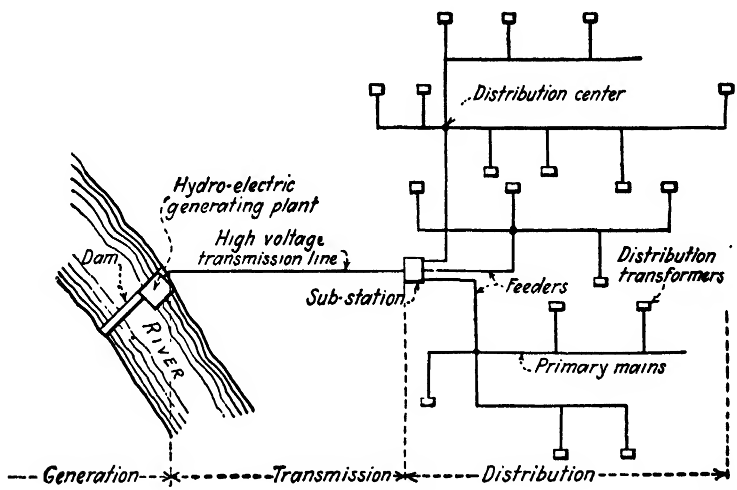


FIG. 2-1. An elementary electric system, showing one hydroelectric generating plant, one transmission line, one substation, and the feeders and mains.

secondary mains, and services which are a part of the system. Figure 2-1 shows these component parts in an elementary system and gives the relation of one to the other. The system shown contains only one generating station, one transmission line, and one substation and can thus be considered as a simple system. Of the thousands of electric systems in the United States, there are some that have as many as 10 generating stations and 80 substations. Such systems are very complex and form a most intricate network. An electric system can be large or small, therefore, as the number of connected plants and consumers is large or small. Figure 2-2 is a map of a typical electric system showing generating stations, substations, and transmission lines.

Usually a substation will be found tying the generators to the transmission lines. The substation transforms the generated voltage to the transmission voltage and protects the generating station against any trouble developing on the transmission lines. Another substation will be found tying the transmission lines to the distribution system. The

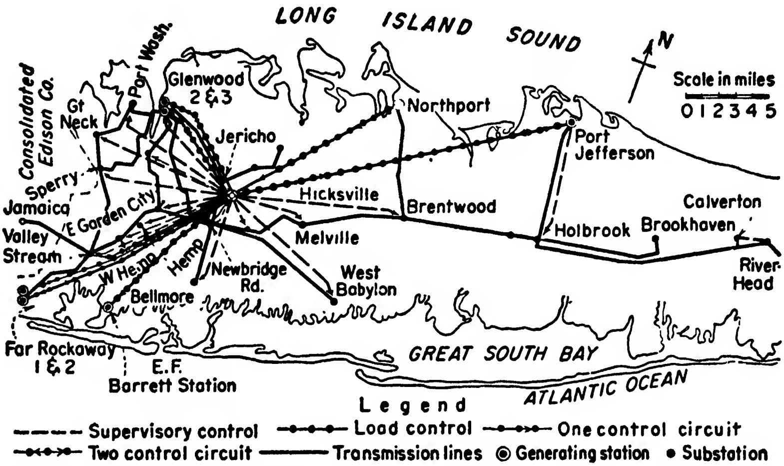


FIG. 2-2. Long Island Lighting Co. system map showing generating stations, substations, and transmission lines. (*Courtesy Long Island Lighting Co.*)

purpose of the distribution substation is to protect the substation itself and the transmission line from trouble on any distribution feeder. The substation is almost always equipped to isolate the feeder in trouble from the other feeders radiating from the substation. Where load and voltage conditions require it, the substation has the additional function of regulating the voltage on the feeders of the distribution system.

GENERATING STATIONS

Central Stations. A generating station is the plant where the energy of the coal, oil, or waterfall is changed into electrical energy.

Central generating stations have come into existence because it is inefficient for every user of power to own and operate his own power plant. It is not economical to have a prime mover located wherever a small amount of power is required. This fact has led to the development of large central power plants, often called "central stations" because of their central location among the customers or users of power.

Kinds of Stations. Generating stations may be any of the following:

1. Hydro
2. Steam:
   a. Engine
   b. Turbine
3. Internal combustion

If the generating station is a hydroelectric station, it must be located at the waterfall. This is sometimes far removed from the center of the territory to be served. Figures 2-3 and 2-4 show the exterior and interior

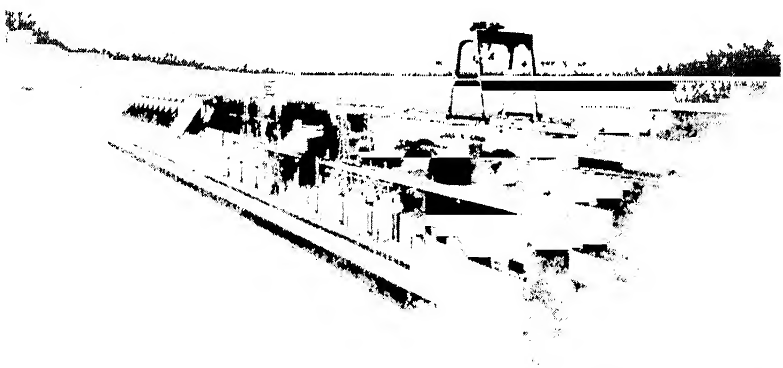


Fig. 2-3. Hydroelectric plant located on Tennessee River at Wheeler Dam. The plant contains four generating units, each rated 36,000 kva, 13,800 volts, 60 cycles, and run at 85.7 rpm. The rotor of each generator has 84 poles. (*Courtesy General Electric Co.*)

of typical hydroelectric plants. Such plants cost little to run because they do not burn fuel, but the interest and taxes per year are much higher than on steam plants, on account of the much larger investment in a dam, land flooded by backwater, etc. Water power today generates about one-fourth of the entire electrical energy generated in the United States.

If the plant is a steam plant, it may be either steam-engine or steam-turbine driven. The steam engine was used extensively in the smaller plants years ago but has practically entirely disappeared from use today. Figure 2-5 shows a typical steam-turbine installation. The turbine is used in the larger stations where large bulks of power must be produced. Single-turbine units are built to generate as much as 200,000 hp, but only a few of that size are in use today. The majority of the steam turbines are smaller units of 5,000-, 10,000-, and 50,000-hp capacity.

Many of the smaller plants today are using internal-combustion engines of the diesel type. A typical installation is shown in Fig. 2-6.

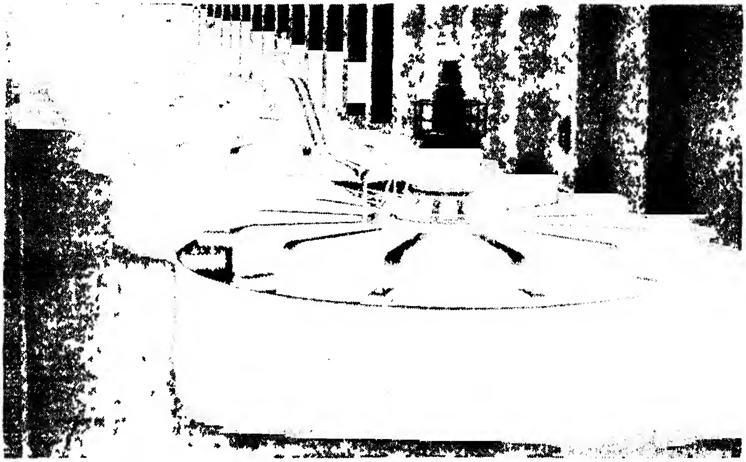


FIG. 2-4. Powerhouse of Bonneville hydroelectric plant located on Columbia River in Oregon. The plant contains 10 vertical water-wheel generating units, each rated 60,000 kva, 13,800 volts, 60 cycles, and run at 75 rpm. Each generator rotor has 96 poles (*Courtesy General Electric Co.*)

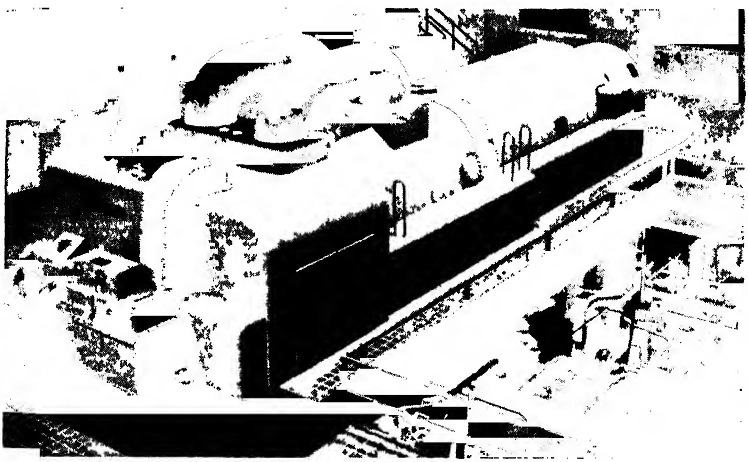


FIG 2-5. Modern steam-turbine plant showing a 44,000-kw 3,600-rpm steam-turbine generator unit The steam turbine is a combined high- and low-pressure unit. The alternator is directly coupled to the turbine shaft. The smaller unit on extreme right is a direct-current generator called an exciter because it supplies the exciting current to the alternator field. (*Courtesy Allis-Chalmers Mfg. Co.*)

Alternating-current Plants. In almost every generating plant, the generator driven by the prime mover is an alternating-current generator. About 95 per cent of all the electrical power generated is generated as alternating current. Where direct current is required, it is usually obtained by converting alternating current to direct current.

Frequencies Generated. The frequency of the alternating current generated is generally 60 cycles for all steam and gas plants. Steam turbine and gas engine plants are usually located in the center of the regions served. The power, therefore, does not have to be transmitted over long distances. To transmit alternating current at 60 cycles over short distances does not produce an excessive drop in line voltage. In the case of hydroelectric plants, which may be 100 miles or more from the load center, 60 cycles may be too high a frequency to make transmission satisfactory.

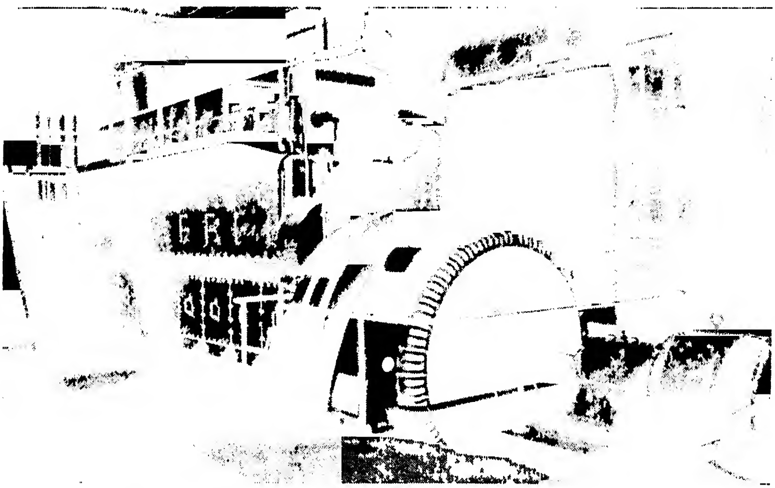


FIG 2-6 Diesel gas-engine-driven central station. Alternator is direct connected to the engine. The exciter is the small machine mounted on the floor in the foreground (*Courtesy Nordberg Mfg Co*)

Hydroelectric plants therefore sometimes generate at a lower frequency. On the Pacific coast, it is 50 cycles; and in the central and eastern parts of the United States, it is 25 cycles. Another reason why some of the hydroelectric plants, especially those in the central and eastern portions, generate at 25 cycles, is because many of them operate with a low head of water. The water-wheel speed under a low head is lower than at a high head and, therefore, would require more poles on the alternator to produce 60 cycles.

TRANSMISSION LINES

Overhead Lines. A transmission line is the set of conductors over which the electrical energy is transmitted from a generating station to a substation. A transmission line may be an overhead aerial line or an underground cable line. The distinguishing characteristics of transmission lines are that they are operated at relatively high voltages and extend over considerable distances. Figure 2-7 illustrates an overhead transmission line operating at 132,000 volts. Ten 10-in. disk insulators connected in a "string" insulate each line wire from the tower. The small wire at the apex of the tower is a so-called "static" wire or ground wire. It is directly connected to the tower and is not insulated. Its purpose is to shield the line conductors from lightning. The line consists of two three-phase circuits of three wires each and is called a "two-circuit line."

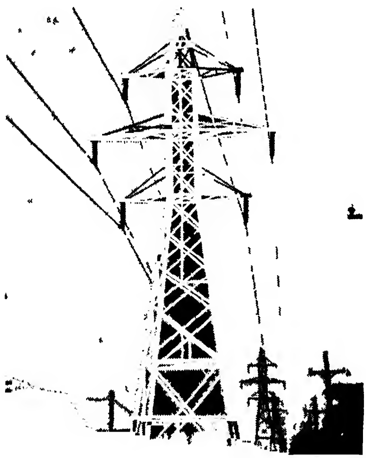


FIG. 2-7. High-voltage transmission line showing one three-phase circuit on each side of the tower and the ground wire on top center of the tower (*Courtesy Wisconsin Electric Power Co.*)

Underground Cables. In large cities it is not permissible to build high-voltage overhead lines. All high-voltage electrical circuits must, therefore, be run underground for safety. Figure 2-8 shows the underground cables leaving a large central station which carry the electrical energy to the substations that are scattered about the city. These cables are also operated at high voltages, usually 13,200, 26,400, or 33,000 volts. At the present time there is a strong desire to operate them at higher voltages, even as high as 132,000 volts. These cables are properly called "transmission cables" because they are used to transmit power to the substations from which in turn it is distributed to the customers.

Short and Long Transmission Lines. Transmission lines are sometimes classified into short and long lines. The short lines are those 5 miles long or less and usually operate at voltages from 2,400 to 13,800 volts. At this voltage the alternating-current generator is generally directly connected to the line without the use of a step-up transformer. Long transmission lines are those more than 5 miles in length and operate at voltages from 13,800 to 330,000 volts. To obtain these line voltages,

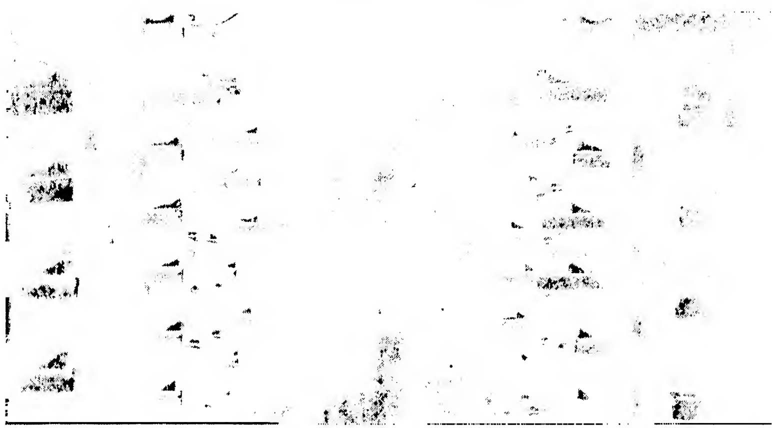


FIG. 2-8. Large numbers of high-voltage underground power cables carry electrical energy from central station to substations. View shows a manhole where the cables are spliced. The enlargements on the cables are the splices. The holes on the wall are the openings in the ducts. (*Courtesy Murray Mfg. Co.*)

the voltage generated must be raised by means of a step-up transformer before it is delivered to the line.

SUBSTATIONS

Purpose. The purpose of a substation is to change the alternating current which is delivered to it to the voltage, frequency, and kind of current required by the distribution system.

Types. There are three types of substations, namely:

1. Transformer substation:
   a. Outdoor
   b. Indoor
2. Frequency-changer substation
3. Converter substation:
   a. Rotary-converter
   b. Mercury-arc rectifier

In the transformer substation the voltage is stepped down from the value of the transmission circuit to the voltage used for distribution, commonly 2,400 volts. There is no change in frequency, and the current at the low voltage is still alternating current. A typical outdoor transformer substation is shown in Fig. 2-9 and a typical indoor station in Fig. 2-10. In the frequency-changer substation the change made is that of frequency, usually from 25 to 60 cycles, or vice versa. This change is usually also accompanied by a reduction in voltage. Figure 2-11 shows the interior of a frequency-changer substation. In the converter substation the change is in the current. The current is changed

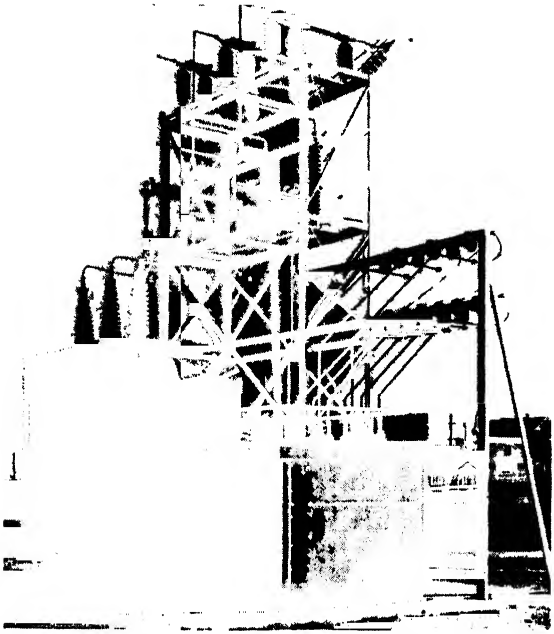


FIG. 2-9 Modern transformer substation rated 3 000 kva. View shows three-phase transformer and metal cabinets housing circuit breakers, meters, and control equipment. (*Courtesy General Electric Co.*)

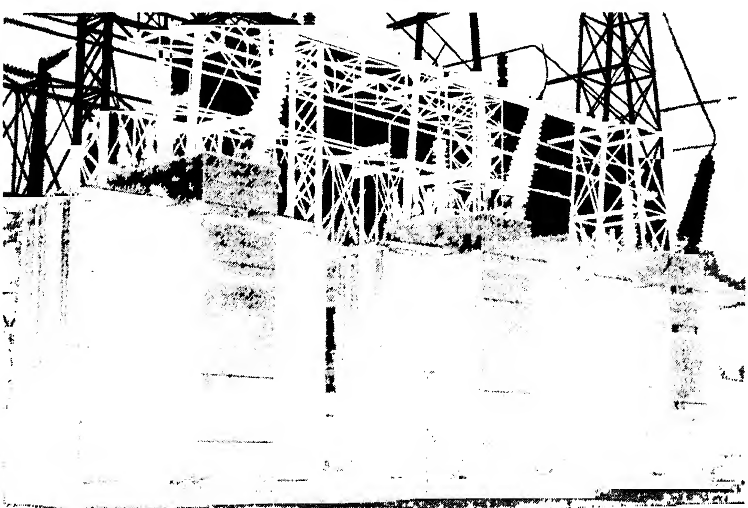


FIG. 2-10 Transformer substation showing three single-phase transformers connected into a three-phase bank. The transformers are rated 20 000/25,000/33,333 kva, depending on the cooling employed. (***Courtesy Westinghouse Electric Corp.***)

FIG. 2-11. Frequency-changer substation, showing frequency changer set with direct-connected exciter in foreground. (*Courtesy Westinghouse Electric Corp.*)

from alternating current to direct current. This can be accomplished by means of a rotary converter or a mercury-arc rectifier. This change is also accompanied by a reduction in voltage. Figure 2-12 illustrates a typical rotary substation used to change alternating current to 600 volts direct current for use by city streetcars. Figure 2-13 shows a completely automatic mercury-arc substation used for the conversion of alternating current to direct current for railway service.

DISTRIBUTION SYSTEM

Parts of Distribution System. The distribution system is the system from which electrical energy is distributed to the receiving apparatus of customers, such as lights, motors, heaters, etc.

A distribution system consists of several parts, namely,

1. Feeders
2. Distribution centers
3. Primary mains
4. Distribution transformers
5. Secondary mains
6. Services

FIG 2-12 Typical rotary-converter substation showing converter in foreground and switchboard in background (*Courtesy Westinghouse Electric Corp*)

FIG. 2-13 Mercury-arc rectifier substation used to convert alternating current to direct current for use in railway service (*Courtesy General Electric Co.*)

These parts are shown in detail in Fig. 2-14, which also shows the relation of the parts to each other. In general, all the lines in a town between the substation (or the central station, if the town is small) and the service switches of the consumers constitute the distribution system.

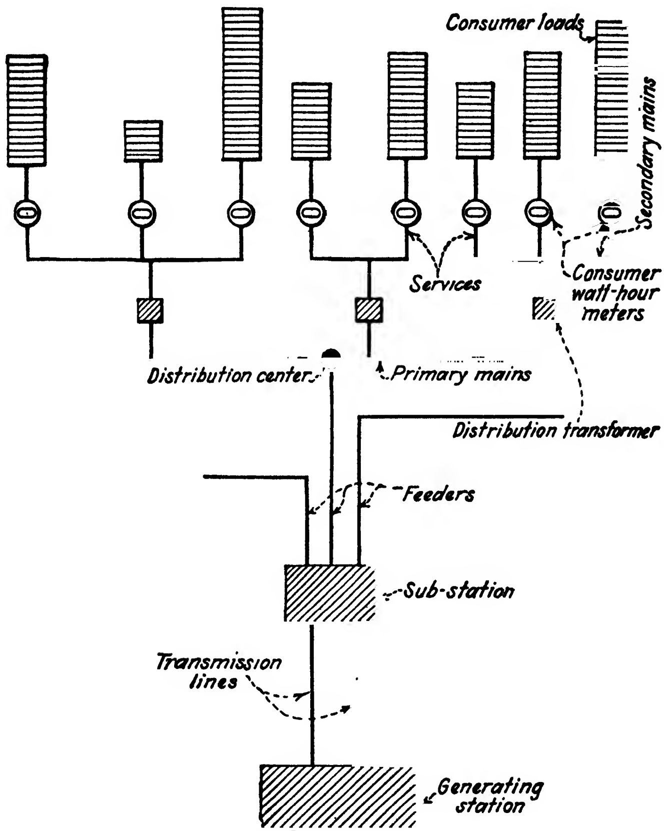


FIG. 2-14. Elements of a transmission and distribution system.

Feeders. Feeders are the conductors in a distribution system which extend from the substation (or central station, if the town is small) to the various distribution centers. No circuits or branches should be connected to feeders between these two points. Feeders may be overhead or underground. Figure 2-15 shows overhead feeders leaving a generating station. These radiate in all directions from the station.

Sometimes two feeders are used to supply the same load center, as shown in Fig. 2-16. Only one feeder is normally in use. The feed switch in feeder No. 1 is normally closed, while the feed switch in feeder No. 2 is normally open. In case of trouble on feeder No. 1, that feeder is disconnected by the circuit breaker at the substation bus, and the breaker and feed switch on feeder No. 2 are closed. In this way service to the load center may be continued without interruption.

Distribution Center. The distribution center is the location at which the feeder connects to the primary mains which it serves (see Fig. 2-17). The switches and the automatic cutouts for the control and protection of the primary mains are sometimes grouped at the distribution center. The voltage at the distribution center should be maintained practically constant from no load to full load. This is often accomplished by means

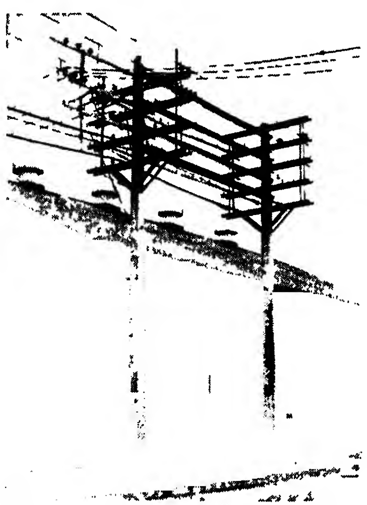


FIG 2-15. Overhead feeder lines leaving the generating station (*Courtesy Oklahoma Gas and Electric Co.*)

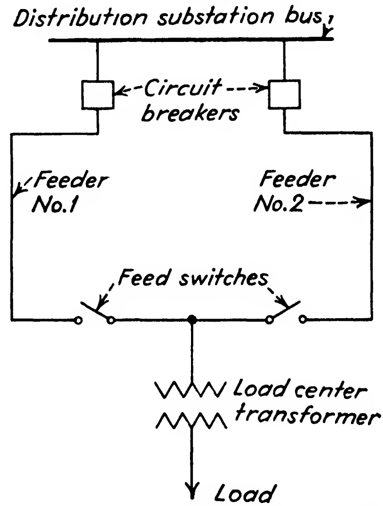


FIG. 2-16. Distribution system using two parallel feeders, one for normal use and one for emergency

of feeder-voltage regulators at the substation, described in Sec. 5. In this way the voltage at the distribution center is held constant with change in load by varying the voltage at the substation.

Primary Mains. The primary mains are the circuits which originate at the distribution center and to which are connected the primary windings of the distribution transformers. The primary mains operate at the same voltage as the feeders. Automatic cutouts, either fuses or circuit breakers, are always installed ahead of the transformers. Figure 2-18 shows the primary mains to which the transformer is tapped. The transformer cutouts, one in each line, contain the fuses which protect the transformer against overload and short circuit. The primary mains are strung on the upper crossarms and usually lie in a horizontal plane.

In business districts or heavy industrial areas, the primary mains are often connected into what is known as a primary "ring." Such a primary "ring" of primary mains is shown in Fig. 2-19. The primary main actually loops back to the same load center. A number of sectionalizing switches are inserted in the loop at the distribution transformer locations. In such a loop, power can flow around the loop in either or both directions. In case of a fault on the loop, the sectionalizing switches on both sides of the fault are opened and service is maintained on the remainder of the loop or ring.

FIG 2-17 Distribution center in an overhead distribution system. This is the point where a given feeder connects onto the several primary mains which it serves (*Courtesy Line Material Co*)

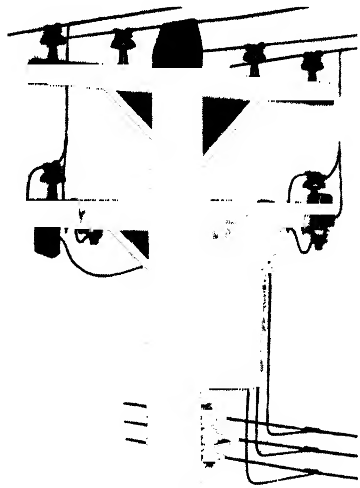


FIG 2-18 Typical distribution-transformer installation on pole. The primary mains to which the primary winding of the transformer is connected are carried on the upper crossarm. Two lightning arresters and two fuse cutouts are also mounted on the transformer crossarm The three-wire secondary is supported by means of a vertical bracket (*Courtesy General Electric Co*)

In laying out a distribution system, the territory to be served is divided into a number of districts. These districts are so chosen that the customers in each district are close to one of the distributing centers. The reason for doing this is to keep the length of mains as short as possible, thereby cutting down the voltage drop between the centers and the customers at the end of the mains. The mains are purposely made up of large wires to aid in keeping the voltage drop as low as possible.

Distribution Transformers. The function of the distribution transformer is to reduce the voltage of the primary mains, usually 2,400 volts, to the voltage required by the lighting, residence, and small-power customers, usually 120 or 240 volts. The manner in which the transformer brings about this reduction in voltage has been explained in Sec. 1 and will be further discussed in Sec. 5. The winding connected to the primary mains is known as the "primary winding," and the winding connected to the secondary mains is known as the "secondary winding." These two windings are sometimes called "high-voltage" and "low-voltage" windings. Figure 2-20 shows how the leads from the secondary windings connect onto the secondary mains. The reason the transformer is called a "distribution" transformer is because it is used in the distribution system.

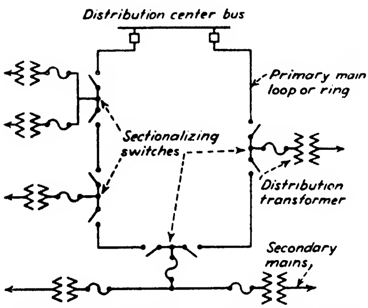


FIG. 2-19. Primary main loop or ring.

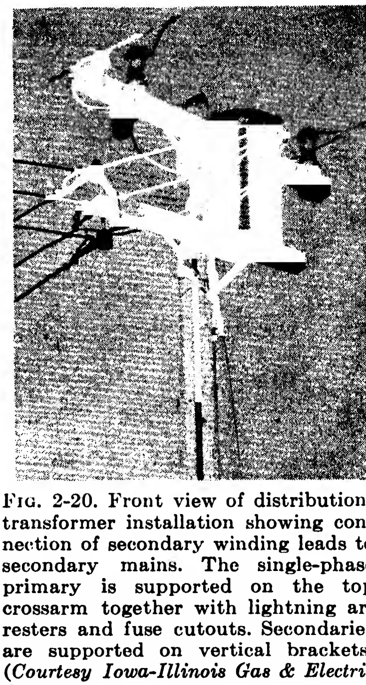


FIG. 2-20. Front view of distribution-transformer installation showing connection of secondary winding leads to secondary mains. The single-phase primary is supported on the top crossarm together with lightning arresters and fuse cutouts. Secondaries are supported on vertical brackets. (*Courtesy Iowa-Illinois Gas & Electric Co.*)

Secondary Mains. The secondary mains are the conductors which originate at the secondary winding of the distribution transformers and extend along the alleys or streets past the customers' premises. The secondary mains were also shown in Fig. 2-20. The secondary mains may be two-wire or three-wire circuits, as will be explained in the next section. These conductors are strung below the primary mains and lie either in a horizontal or a vertical plane (see Figs. 2-21 and 2-22). The secondary wires can be placed much closer together because the voltage is much lower. The common secondary voltages are 120 and 240 volts.

In extra dense business districts or industrial areas the secondaries may be interconnected to form a secondary network or grid, as shown in Fig. 2-23. This places all the secondaries in parallel and makes it

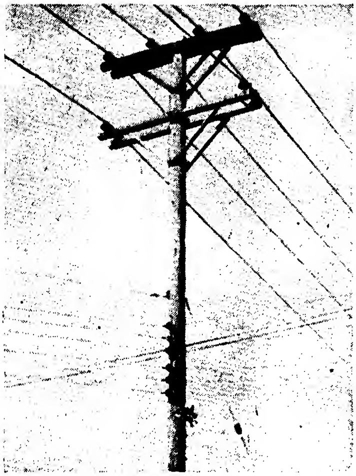


FIG. 2-21. Distribution pole showing the four-wire feeder circuit supported by top crossarm, the single-phase primary on lower crossarm, and secondaries supported on vertical brackets. (*Courtesy Line Material Co.*)

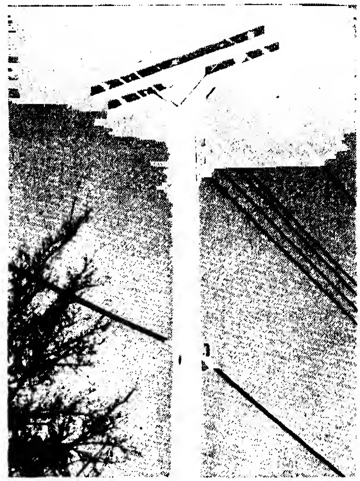


FIG. 2-22. Distribution pole showing primary mains carried on horizontal crossarm and secondary mains carried in a vertical plane on a rack below. (*Courtesy Iowa-Illinois Gas & Electric Co.*)

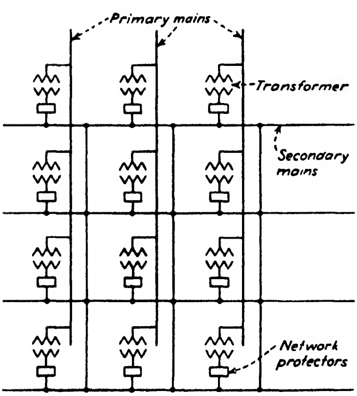


FIG. 2-23. Secondary main network.

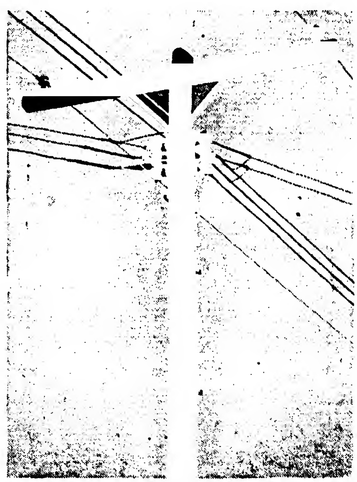


FIG. 2-24. Distribution pole showing both primary and secondary mains as well as a two-wire and a three-wire service line tapped onto the secondary mains. (*Courtesy Hubbard & Co.*)

possible for the load to be supplied from several directions and from several transformers. As a short or fault on any part of the network will short all the transformers, special network protectors must be used to protect the system.

Customers' Services. A customer's service or service connection is the set of leads which is tapped onto the secondary mains and connects onto the customer's building. These leads or wires are known as the "service drop." It is the last link of the path over which the electrical energy is brought to the consumer. Figure 2-24 shows a three-wire service tap

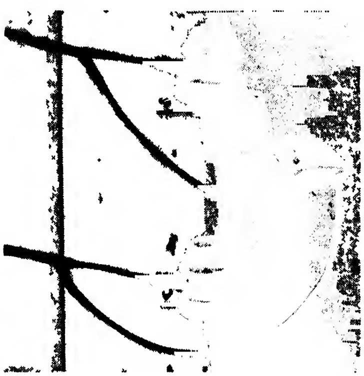


Fig. 2-25. Vertical two-wire service and service conduit. Note neat and clean manner of fastening and taping wires. (*Courtesy Hubbard & Co.*)

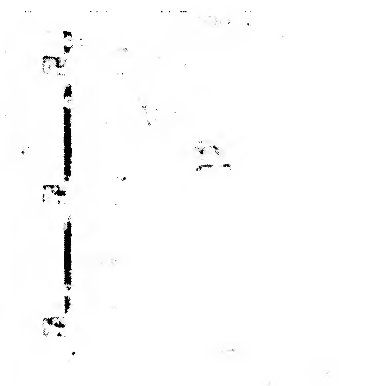


Fig. 2-26. Illustration shows use of bracket in fastening a three-wire service to the consumer's building. Cut also shows conduit through which wires enter building. (*Courtesy Hubbard & Co.*)

for a range customer and a two-wire service tap for an ordinary residence customer. Figures 2-25 and 2-26 show the manner in which a two-wire and a three-wire service are fastened to the consumer's building. They also illustrate good practice.

Summary. Figure 2-27 illustrates the various component parts and circuits heretofore described. It also shows the relation each circuit has to other circuits in the system. Beginning at the central generating station is the high-voltage transmission line which transmits the electrical energy to the transformer substation. This transmission line is usually of considerable length and may stretch over miles of country. It is always a very high-voltage overhead line. However, if the generating station is located in the city, then the lines connecting the central station with the several substations are usually medium-voltage underground cable lines. There are then usually a number of lines radiating out in every direction to the numerous substations located in various parts of the city. From each substation extend the three-phase feeders, operating at either 2,400 or 4,160 volts. At the distributing center, each feeder connects onto the various single-phase and three-phase primary mains. These mains operate at the same voltage as the feeder, except that the single-phase primary mains from a 4,160-volt four-wire three-phase feeder operate at 2,400 volts. The three-phase

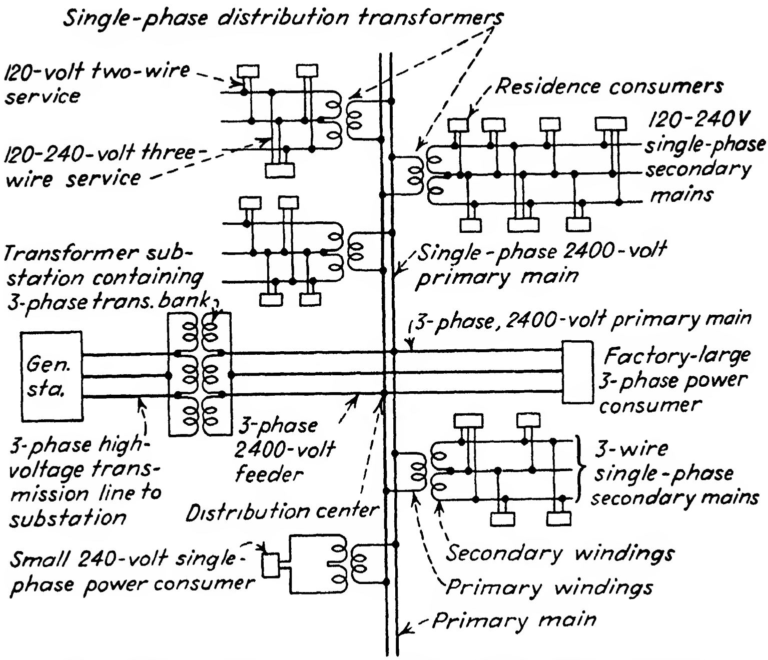


FIG. 2-27. Diagram showing various circuits and parts of an alternating-current electric system.

primary mains usually supply power direct to factories, shops, and other large users of power. The single-phase primaries have tapped onto them the primary windings of the distribution transformers. These transformers reduce the voltage from 2,400 volts to 120 or 240 volts and supply power to the two- or three-wire secondary mains. From the secondary mains the two- or three-wire services connect the numerous consumers to the system. Most of the two-wire services are 120 volts, although occasionally a two-wire service will be 240 volts. These are run to small single-phase power users.

SECTION 3

Distribution Circuits

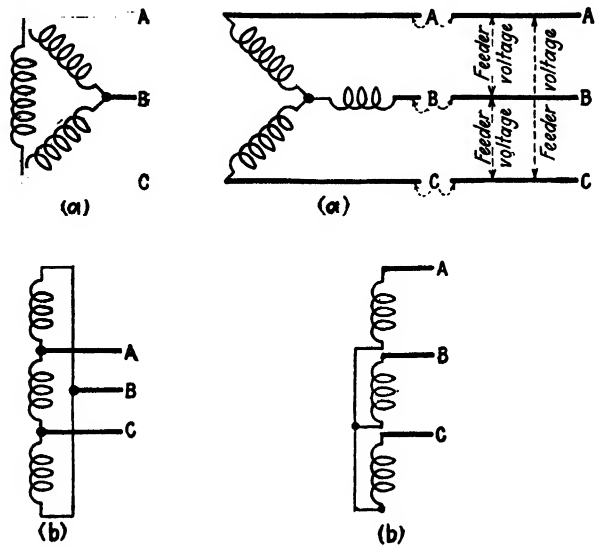
Classes. The two distinct classes of distribution circuits are alternating current and direct current. These are further subdivided as shown below. Two phase has been omitted as a means of alternating-current distribution as it is no longer in general use.

1. Alternating current
   a. Three phase
      (1) Three wire
      (2) Four wire
   b. Single phase
      (1) Two wire
      (2) Three wire
2. Direct current
   a. Two wire
   b. Three wire

Three-phase Three-wire Circuits. In alternating-current distribution systems the feeders are most commonly operated as three-phase three-wire circuits. As was pointed out under three-phase connections in Sec. 1, a three-phase circuit can be obtained from either a Y or a (Δ) delta connection of the three coils in the alternating-current generator. Similarly, in distribution systems the Y or delta connection is obtained by the proper connection of the secondary coils of the transformers in the substation. Figure 3-1 shows a three-phase three-wire distribution feeder together with the Y and the delta connections of the secondary windings of the substation stepdown transformers. The transformer secondary connections are also shown in the conventional and practical way of representation. It should be pointed out here that the Y connection is very seldom used on distribution feeders except when the feeder is operated as a four-wire feeder, as will be explained in the next paragraph. The delta connection is the standard connection for the secondaries of the transformers which supply power to feeder circuits. The voltage between any two of the three wires for both methods of connection is the same, that is, the voltages between conductors *A* and

B, *B* and *C*, and *C* and *A* are all equal. In the delta connection this voltage between line wires is the same as the transformer-coil voltage, but in the Y connection the voltage between line conductors is $\sqrt{3} \times$ the transformer-coil voltage.

As has already been pointed out the usual voltage used for feeders in distribution systems is 2,400 volts, although 4,160 volts is also in use in connection with the four-wire feeder.



(*a*) Conventional and (*b*) practical way of picturing delta connection of transformer secondaries.

(*a*) Conventional and (*b*) practical way of picturing Y connection of transformer secondaries.

Three-phase three-wire circuit.

FIG. 3-1. Three-phase three-wire distribution feeder.

Three-phase Four-wire Circuits. The three-phase four-wire feeder circuit is in general use, especially in the larger cities. This circuit can be obtained only from a Y connection of the transformer secondaries. Figure 3-2 shows this type of circuit. The fourth wire is called the "neutral" wire because it is connected to the neutral point of the Y connection.

It will be noted that the voltage between any two of the line wires is no longer equal to E, the transformer secondary-coil voltage, but instead is $\sqrt{3} \times E$. The voltage E still exists between any line wire and neutral, but the voltage between any two line wires is $\sqrt{3} \times 2{,}400 = 4{,}160$ volts. With 2,400 volts still available between any line wire and neutral, this system makes possible obtaining the same voltages as from the three-phase three-wire system.

The advantages of the four-wire feeder over the three-wire feeder are increased power-carrying capacity and better voltage regulation. Since the line voltage in the four-wire system is $\sqrt{3} = 1.73 \times$ that of the 2,400-volt three-wire system, its power-carrying capacity for the same current in the wires will also be 1.73 times as great; or what amounts to the same thing, for the same power transmitted, the current in the four-wire system will only be 58 per cent as large. Moreover, the voltage regulation is also greatly improved. Many of the large cities have changed over to this system of feeders in order to get the benefit of this

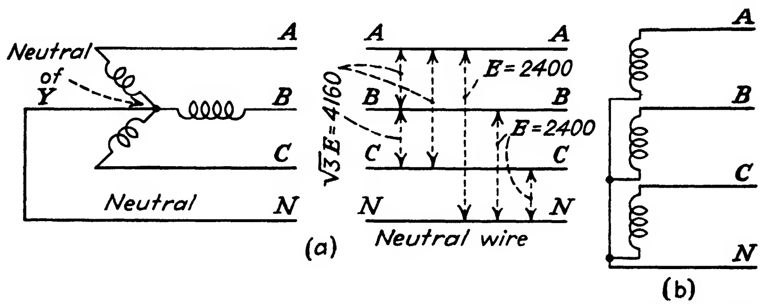


FIG. 3-2. Three-phase four-wire distribution feeder: (a) conventional and (b) practical way of picturing Y connection of transformer secondaries with neutral brought out.

increased feeder capacity. Merely stringing the fourth wire and reconnecting the transformers from delta to Y make possible an increase in load-carrying capacity of 73 per cent.

Single-phase Two-wire Circuits. A single-phase circuit is generally obtained from a three-phase circuit. It could be obtained from a single-phase alternating-current generator, but such machines are very rare today. Figures 3-3*A* and 3-3*B* illustrate how single-phase primary mains are obtained from three-phase three-wire and three-phase four-wire feeders. These single-phase primary mains are tapped to the feeder at the place called the "distribution center," as has already been mentioned. By tapping off across two line wires in the three-wire feeder, the voltage of the primary main will naturally be the same as the voltage across the line wires, normally 2,400 volts. By tapping from line wire to neutral in the four-wire feeder, the voltage of the primary main will also be 2,400 volts. This voltage is practically standard for primary mains.

An attempt is always made to keep the loads on the primary mains connected to the three phases of the three-phase line balanced so that the currents in the wires of the three-phase feeder will be the same.

Single-phase Three-wire Circuits. Secondary mains are generally single-phase three-wire circuits, although they may be only two-wire circuits. The secondary mains originate from the secondary windings of the distribution transformer. Figure 3-4 shows the single-phase two-wire primary main connecting to the primary winding of the transformer. The secondary winding of distribution transformers is nearly always made up in two coils which can be connected either in series or in parallel, as shown. They are most often connected in series. Each coil

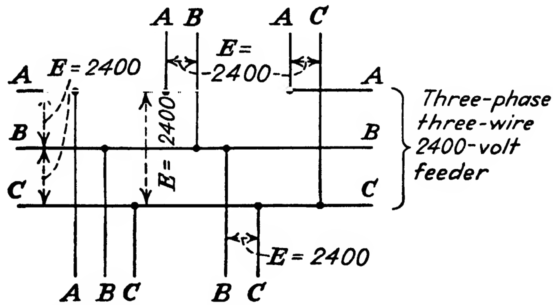


FIG. 3-3A. *ABC* is a 2,400-volt three-phase primary main, and *AB*, *BC*, and *AC* are single-phase 2,400-volt primary mains obtained by tapping the 2,400-volt three-phase three-wire feeder.

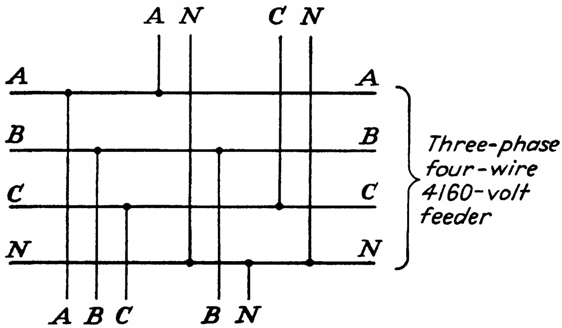


FIG. 3-3B. *ABC* is a 4,160-volt primary main obtained by tapping the three line wires, and *AN*, *BN*, and *CN* are single-phase, 2,400-volt primary mains obtained by tapping a line wire and neutral of the three-phase four-wire 4,160-volt feeder

has induced in it 120 volts, so that when they are connected in series the voltage across the outside wires is 240 volts. If the neutral wire is omitted, these outside wires form a 240-volt single-phase two-wire circuit. When the neutral wire is used, either outside wire and the neutral form a 120-volt single-phase circuit. A consumer using lamps and small household appliances would only have two service wires connecting to his premises as his load would be small and would be at 120 volts. If he should use an electric range for cooking, his service connection would consist of all three wires, because most electric ranges operate on 120 and 240 volts. Any consumer having a single-phase motor larger than ½ hp would likely operate it from the two outside wires of the secondary mains. Using higher voltage draws less current and so keeps the line loss and the voltage drop at a minimum. Any office, building or store would also take the three-wire service.

Direct-current Two- and Three-wire Circuits. A simple two-wire direct-current system is obtained directly from a direct-current generator or battery as a source. Direct current cannot be transformed by

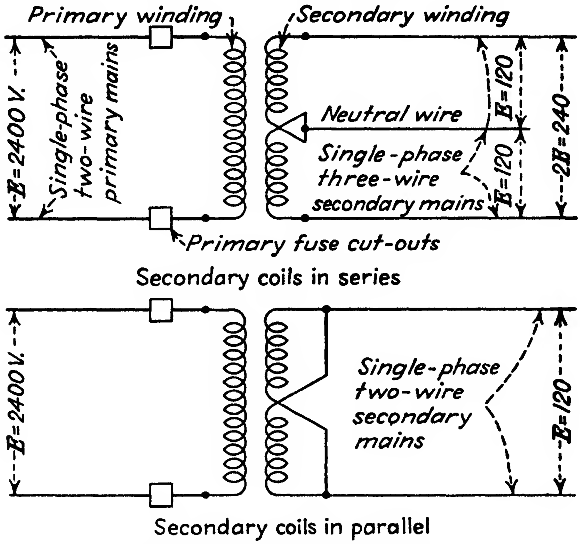


FIG. 3-4. Standard connections of common step-down distribution transformer.

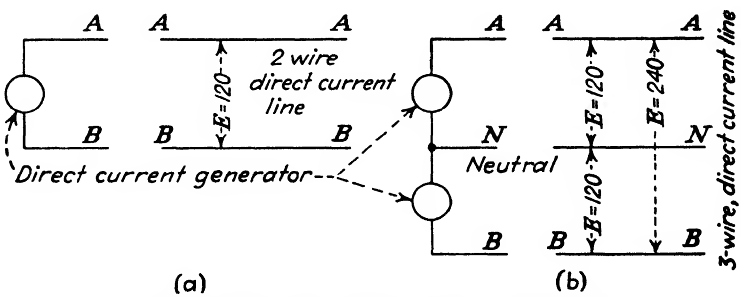


FIG. 3-5. Two- and three-wire direct-current lines.

means of a transformer as can alternating current. Figure 3-5*a* shows a simple direct-current line and *b* shows how a three-wire direct-current system may be obtained. This system is similar to the three-wire single-phase alternating-current secondary mains except that each direct-current generator takes the place of one of the transformer secondary coils. The three-wire direct-current system is generally known as the "Edison system" and is still used in the downtown areas of our large metropolitan cities.

SECTION 4

Line Materials

General. In this and the three following sections are given illustrations and brief descriptions of the different materials and equipments of which transmission lines and distribution systems are constructed. The materials and equipments discussed include line supports, crossarms, line hardware, insulators, conductors, transformers, regulators, meters, lightning arresters, disconnect switches, fuses, etc. The use of abundant illustrations should help much to acquaint the reader with these materials and to form his vocabulary in this field. Whenever possible, the merits of the types described will also be discussed.

OVERHEAD LINE SUPPORTS

Classification. Overhead line supports may be classified into two general classes, namely, poles and towers. Poles can be further classified into wooden, steel, and concrete and towers into rigid and flexible, as shown below.

LINE SUPPORTS

1. Poles:
   a. Wooden:
      (1) Cedar
      (2) Chestnut
      (3) Pine
   b. Steel:
      (1) Patented
      (2) Structural
   c. Concrete:
      (1) Solid
      (2) Hollow
2. Towers:
   a. Rigid:
      (1) Four-leg
   b. Flexible:
      (1) Two-leg

Wood Poles. Wood poles are used almost exclusively for electric distribution and also extensively for light-transmission lines and electric railways. They have come into such wide use because of their insulating qualities and low first cost.

In most cases, a single pole is used as a support, as shown in Fig. 4-1, but sometimes two poles are bolted together to form an H-frame structure, as shown in Fig. 4-2. Frame structures are used where more strength is required than can be obtained from a single pole.

FIG. 4-1. Typical construction of wooden pole, wooden crossarms, and wooden braces. (*Courtesy Locke Dept., General Electric Co.*)

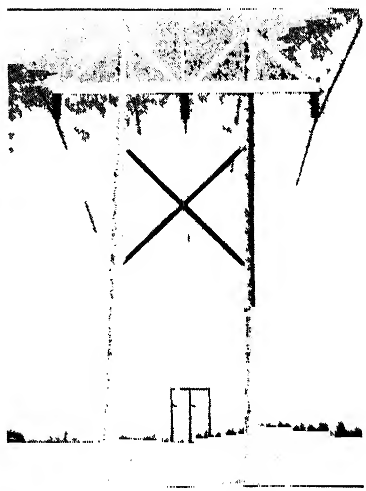


FIG 4-2 Two poles combined to make an H-frame structure. (*Courtesy Hughes Brothers.*)

Kinds of Wood Poles. The species of wood poles used in different parts of the United States is largely determined by the poles available in that locality. In the central United States, northern white cedar has been largely used because it is available in Minnesota, Wisconsin, and Michigan. This species is easily distinguished by the large butt and small top. On the Pacific coast, western red cedar is used because it grows in Washington, Oregon, and Idaho. A red cedar pole has very little taper, the butt being only a little larger than the top. In the eastern states, chestnut is generally used because it grows in the Appalachian Mountains. In the South, cypress and yellow pine are largely used. The eastern supply, however, is becoming nearly exhausted and, therefore, much northern white cedar is already being shipped East. Figure 4-3 shows the location of the various species of pole timber in the United States.

Most of the poles set today undergo preservative treatment against butt rot before being set, thereby greatly increasing the life of the pole. It is claimed that proper treatment will almost double the life of a pole.

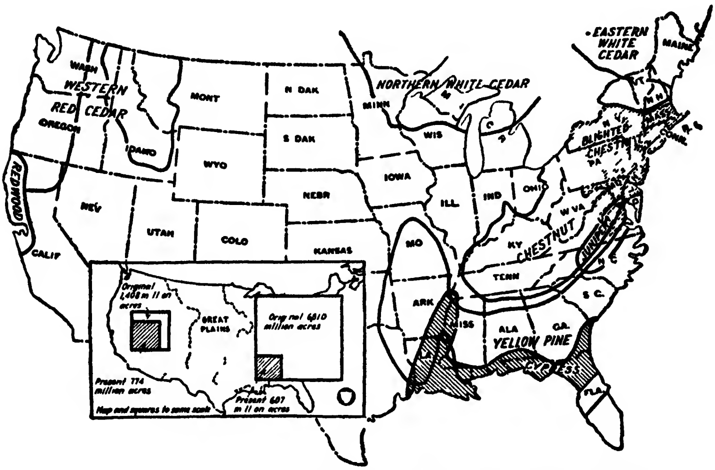


FIG 4-3 Distribution of pole timber in the United States.

Pole Classification. Wood poles are commonly classified as to length, as to top circumference, and as to circumference measured 6 ft from the butt end. The lengths vary in 5-ft steps, and the circumference at the top varies in 2-in. steps. Thus we have 25, 30, 35, 40, etc., to 55-ft lengths, and 15, 17, 19, 21, etc., to 27-in minimum top circumferences.

TABLE 4-1 LOAD RESISTANCE 2 FT FROM TOP OF CLASSIFIED POLES

Class	Load Pole Must Be Able to Withstand, Lb Force
1	4,500
2	3,700
3	3,000
4	2,400
5	1,900
6	1,500
7	1,200
8 to 10	Not specified

The circumference measured 6 ft from the butt end determines to which class numbered from one to ten a pole of a given length and top circumference belongs. The classification from 1 to 10 determines the strength to resist loads applied 2 ft from the top as given in Table 4-1. In order that poles of a given length and top circumference may withstand these forces, the circumferences measured 6 ft from the butt end must be as given in Table 4-2. This table gives these circumferences

Table 4-2. Classification of Wood Poles
(Giving required circumferences measured 6 ft from the butt and resisting moments for each class)

Pole length, ft	ASA class	Minimum circumference at top, in.	Southern yellow pine: Circum. 6 ft from butt, in.	Southern yellow pine: Resisting moment, ft-lb	Chestnut: Circum. 6 ft from butt, in.	Chestnut: Resisting moment, ft-lb	Western red cedar: Circum 6 ft from butt, in.	Western red cedar: Resisting moment, ft-lb	Northern white cedar: Circum 6 ft from butt, in.	Northern white cedar: Resisting moment, ft-lb
25	1	27	34.5	80,200	37.0	80,200	38.0	81,000	43.5	78,200
25	2	25	32.5	67,000	34.5	65,000	35.5	66,100	41.0	65,400
25	3	23	30.0	52,700	32.5	54,300	33.0	53,100	38.0	52,100
25	4	21	28.0	42,860	30.0	42,700	30.5	41,900	35.5	42,500
25	5	19	26.0	34,320	28.0	34,720	28.5	34,200	32.5	32,660
25	6	17	24.0	26,990	25.5	26,230	26.0	25,970	30.0	25,640
25	7	15	22.0	20,800	24.0	21,870	24.5	21,730	28.0	20,840
30	1	27	37.5	102,900	40.0	101,200	41.0	101,700	47.5	101,800
30	2	25	35.0	83,700	37.5	83,500	38.5	84,300	44.5	83,700
30	3	23	32.5	67,000	35.0	67,850	35.5	66,100	41.5	67,800
30	4	21	30.0	52,700	32.5	54,300	33.0	53,100	38.5	54,200
30	5	19	28.0	42,860	30.0	42,700	30.5	41,900	35.5	42,500
30	6	17	26.0	34,320	28.0	34,720	28.5	34,200	33.0	34,100
30	7	15	24.0	26,990	26.0	27,820	26.5	27,500	30.5	26,930
35	1	27	40.0	124,900	42.5	121,400	43.5	121,600	50.5	122,300
35	2	25	37.5	102,900	40.0	101,200	41.0	101,700	47.5	101,800
35	3	23	35.0	83,700	37.5	83,500	38.0	81,000	44.0	80,900
35	4	21	32.0	64,000	34.5	65,000	35.0	63,350	41.0	65,400
35	5	19	30.0	52,700	32.0	51,900	32.5	50,700	38.0	52,100
35	6	17	27.5	40,600	30.0	42,700	30.5	41,900	35.0	40,700
35	7	15	25.5	32,380	27.5	32,920	28.0	32,410	32.5	32,600
40	1	27	42.0	144,600	45.0	144,100	46.0	143,800	53.5	145,500
40	2	25	39.5	120,300	42.5	121,400	43.5	121,600	50.0	118,700
40	3	23	37.0	98,900	39.5	97,500	40.5	98,100	46.5	95,500
40	4	21	34.0	76,700	36.5	77,000	37.5	77,900	43.5	78,200
40	5	19	31.5	60,900	34.0	62,200	34.5	60,700	40.0	60,800
40	6	17	29.0	47,600	31.5	49,400	32.0	48,400	37.0	48,100
40	7	15	27.0	38,400	29.5	40,600				
45	1	27	44.0	166,300	47.5	169,600	48.5	168,500	56.0	166,800
45	2	25	41.5	139,400	44.5	139,500	45.5	139,100	52.5	137,400
45	3	23	38.5	111,400	41.5	113,000	42.5	113,400	49.0	111,600
45	4	21	36.0	91,100	38.5	90,300	39.5	91,000	45.5	89,500
45	5	19	33.0	70,200	36.0	73,800	36.5	71,800	42.0	70,300
45	6	17	30.5	55,400	33.0	56,800				
45	7	15	28.5	45,200	31.0	47,200				
50	1	27	46.0	190,000	49.5	191,900	50.5	190,200	58.5	190,100
50	2	25	43.0	155,200	46.5	159,000	47.5	158,300	55.0	158,000
50	3	23	40.0	124,900	43.5	130,200	44.5	130,100	51.5	129,500
50	4	21	37.5	102,900	40.0	101,200	41.0	101,700	47.5	101,800
50	5	19	34.5	80,200	37.5	83,500	38.0	81,000	44.0	80,900
50	6	17	32.0	64,000	34.5	65,000				
50	7	15	29.5	50,100	32.0	51,900				
55	1	27	47.5	209,100	51.5	216,000	52.5	213,600	61.0	215,600
55	2	25	44.5	172,000	48.5	180,500	49.5	179,100	57.5	180,500
55	3	23	41.5	139,400	45.0	144,100	46.0	143,800	53.5	145,500
55	4	21	39.0	155,800	42.0	117,200	42.5	113,400	49.5	115,200
55	5	19	36.0	91,100	39.0	94,900	39.5	91,000	46.0	92,400
55	6	17	33.5	73,400	36.0	73,800				

Ultimate fiber stresses

	Pounds
Northern white cedar	3,600
Western red cedar	5,600
Chestnut . . .	6,000
Southern yellow pine (creosoted)	7,400

Resisting moment $= 0.0002638fc^3$ ft-lb

where f = fiber stress in pounds per square inch and c = circumference in inches for all lengths and all top circumferences for yellow pine, chestnut, western red cedar, and northern white cedar poles. To illustrate, a class 1 pole having a length of 25 ft must have a circumference measured 6 ft from the butt of 34.5 in. if yellow pine, 37 in. if chestnut, 38 in. if red cedar, and 43.5 in. if white cedar. These circumferences provide equal strength in poles of these four kinds of wood. The exact resisting moment each pole is capable of is given in columns opposite the butt circumference. The resisting moment is the product of the force of 4,500 lb required for class 1 multiplied by the length of the lever through which this force is acting above the ground line. For the 25-ft pole, the length of this arm is 25 ft minus 2 ft (force is applied 2 ft from top of pole) minus 6 ft, because 6 ft of the pole is in the ground. This makes the length of the lever arm

$$25 - 2 - 6 = 17 \text{ ft}$$

and the resisting moment

$$4{,}500 \times 17 = 76{,}500 \text{ ft-lb}$$

In like manner other circumferences are given for the other classes and for the other pole lengths. The wood-fiber strengths on which the resisting moments of the poles are computed are given at the bottom of Table 4-2 for the different species.

The pole classification given in Table 4-2 was set up by the American Standards Association.

Size of Poles in Common Use. The length of pole used depends upon the clearances that must be maintained under the given local conditions and upon the voltages and number of crossarms that the pole must carry. In general, poles 40 to 60 ft long are used for transmission-line supports. The 30-, 35-, and 40-ft lengths are in most common use in distribution work. The 30-ft length is used in sparsely settled suburban territory, the 35-ft length in cities where one or two crossarms must be carried, and the 40-ft length for three or four crossarms. In cities where the poles are used jointly with the telephone company, the 35-ft pole is the shortest pole used.

Steel Poles. Steel poles were used to some extent years ago but have now gone out of use. The wood pole with its natural insulating property continues to be the preferred line support, except for heavy lines where the strength of the steel tower is needed.

When steel poles were used, they were of either the tubular, structural, or expanded type. The tubular pole consisted of several tubular sections of different diameter that would telescope. The structural-steel pole was built up of structural-steel shapes with the latticework riveted, bolted, or welded together. One form of the expanded type was made by cutting and expanding the web of an I beam One end was expanded farther than the other and became the base of the pole

Concrete Poles. Concrete poles were also used to a small extent in electric-power work Such poles are of greatest value where the life of wooden poles is unduly shortened by local conditions or where improved appearance is desired

Two distinct kinds of concrete poles have been made, namely, solid and hollow. The solid type is made in a trough form and is reinforced

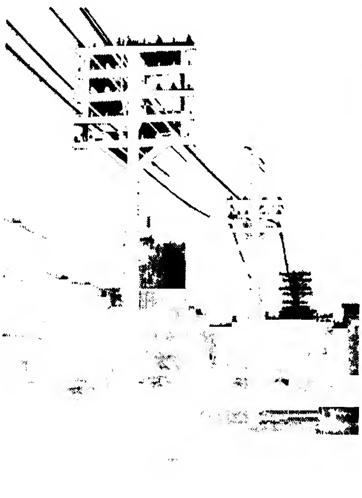


FIG 4-4 Concrete distribution pole (*Courtesy Oklahoma Gas and Electric Co*)

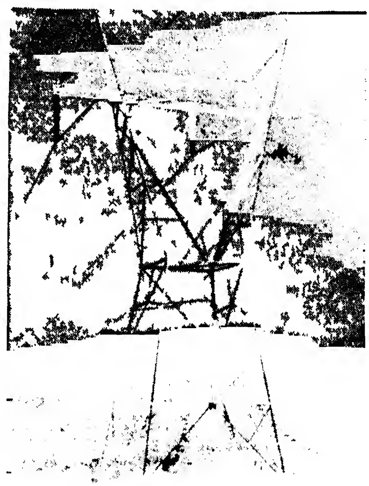


FIG 4-5 Four-legged rigid-type 230-kv transmission tower (*Courtesy Pennsylvania Water and Power Co*)

with steel rods running lengthwise Figure 4-4 shows a horizontally molded pole in service in Oklahoma The hollow-type pole is made by putting the concrete and steel reinforcing rods into a cylinder of the desired length and taper, and then the cylinder with the concrete and rods in it is revolved in a lathelike machine for a period of 10 to 15 min This operation forces the concrete to the outside, thereby forming the hollow pole. The hollow type is lighter than the solid type and, in addition, provides a means for making connections through the pole from aerial lines to underground cables or services

Steel Towers. Towers are used principally for transmission lines where the size of the line and the importance of continuity of service demand the most reliable construction obtainable The term "tower," in general, includes structures which are made of fabricated steel, have a broad base, and are 35 ft or more in height Steel structures which have a small base and are less than 35 ft high are more properly classified as steel poles.

Rigid Type and Flexible Type. Towers are either of the rigid or the flexible type. The rigid tower is firm in all directions, whereas the flexible tower is free to deflect in the direction of the line. Rigid towers, in order to be rigid, must have three or more legs, but the flexible construction consists of only two legs. Figure 4-5 illustrates the four-legged rigid-tower type. Rigid towers can resist the same strain in all directions. Flexible towers can resist strain only transversely or across the line but have very little strength in the direction of the line. They will give or deflect if there is any unbalance in conductor pull; in fact, they depend largely upon the conductors to hold them in position. For this reason they have gone out of use.

CROSSARMS

Types. Crossarms are the crosspieces on poles or the projections from towers which support the insulators and conductors of a line. There are two general types of crossarms, namely:

1. Wooden
2. Steel

The wooden crossarm (Fig. 4-6) is by far the most common and has been in use from the beginning on telephone, telegraph, and distribution

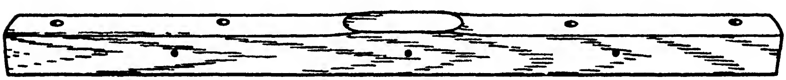


FIG. 4-6. Four-pin wooden crossarm. Note rounded top to shed rain. (*Courtesy Joslyn Mfg. and Supply Co.*)

lines. Figure 4-1, already referred to, shows typical construction of a pole and wooden crossarms. Wooden arms are made chiefly of fir and pine. The fir arm lasts better than the pine and is usually less knotty. The top of the arm is rounded slightly to permit the water to run off freely.

A special design of wooden crossarm is that shown in Fig. 4-7. This construction permits the use of suspension insulators on a three-phase line and provides approximately triangular or delta spacing of the line conductors. In addition it provides the extra insulation of the wood crossarm and therefore is suitable for intermediate transmission voltages.

For heavy trolley feeders and for steel poles, as well as for wood poles where there is exceptional stress, crossarms made of steel are used. In the simpler form, they are made up of a piece of angle iron. This is attached by means of a cast-iron collar around the pole in the case of tubular steel poles and by means of the usual through bolt and braces in the case of wood poles.

Crossarm Sizes. There are four well-recognized standard sizes of wooden crossarms, namely, 3¼ by 4¼ in., 3½ by 4½ in., 3¾ by 4¾ in., and 4 by 5 in. The first dimension given is the width, and the second is the height. The smaller sizes are standard for distribution work, and the larger sizes are quite commonly used in light transmission work.

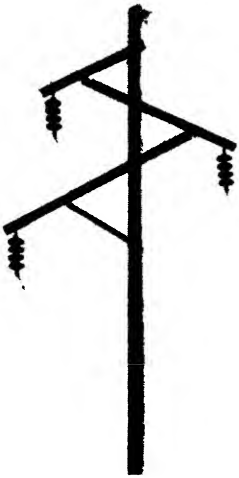


Fig. 4-7. Wood pole line using wooden crossarms arranged to provide symmetrical arrangement of the line conductors. (*Courtesy Hughes Brothers.*)

The length of the arm is fixed by the number of pinholes and the separations between them. Arms are made for two, four, six, or eight pins for distribution purposes. The two- and four-pin sizes, however, are used only in small towns or for rural service. The six-pin arm is used for general city distribution, and the eight-pin crossarm is used for heavy

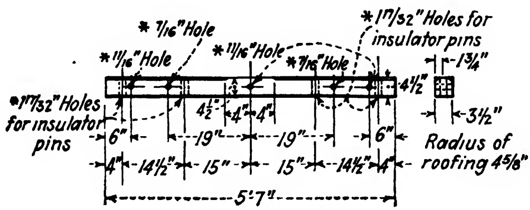


Fig. 4-8. Four-pin low-voltage crossarm.

lines. The separation between pins on distribution lines is 14½ in. and between the pins next to the pole, 30 in. The end pins are usually 4 in. from the end of the arm. Figures 4-8 and 4-9 indicate the dimensions of four- and six-pin crossarms for low-voltage construction.

Sizes Used in Practice. The sizes most commonly used for distribution work are the 3¼ by 4¼ and 3½ by 4½ in. in section. Where transformers are mounted on crossarms, a crossarm with a 4- by 5-in.

section is often used. This is also a common size for light transmission-line arms.

Side Arms. "Side arm" is the name given a crossarm when it projects entirely to one side of the pole to clear obstructions. In alleys,

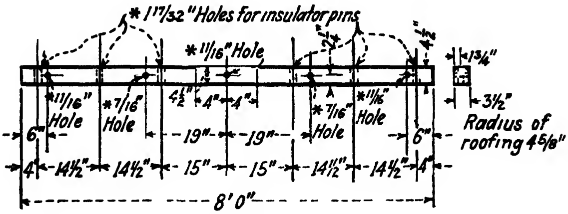


FIG. 4-9 Six-pin low-voltage crossarm.

buildings frequently make it impossible to mount crossarms symmetrically, and the arm therefore projects more on one side than on the other. Figure 4-10 shows typical side-arm or alley-arm construction. Figure 4-11 illustrates the use of side arms on a low-voltage transmission line to clear trees.

FIG. 4-10 Side- or alley-arm construction. (*Courtesy Hubbard & Co.*)

FIG. 4-11 Use of side arms on low-voltage transmission line to clear trees. Note use of wooden braces. (*Courtesy Iowa-Illinois Gas and Electric Co.*)

Double Crossarms. Double crossarms, illustrated in Fig. 4-12, are used wherever the stress on the crossarm is more than normal and where more rigid construction is necessary. Such abnormal stresses are encountered at corners, at line terminals, at angles, at curves, at crossings, etc. At these places the crossarms are used in pairs or are doubled; that is, one is placed on each side of the pole. The main purpose is to divide the stresses between two crossarms, two pins, two insulators, and two tie wires instead of having the entire pull imposed on one.

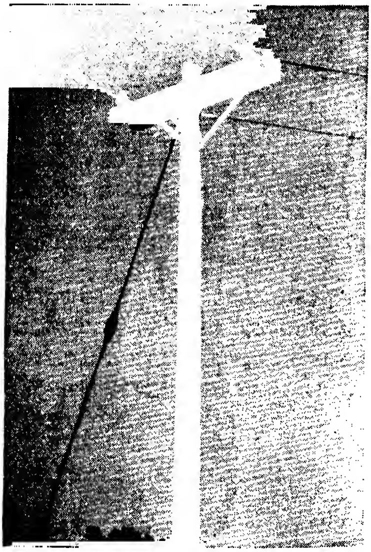


FIG. 4-12. View showing use of double crossarms on pole at turn in line. Use of two arms divides pull among two pins, two insulators, and two tie wires. (*Courtesy Iowa-Illinois Gas and Electric Co.*)

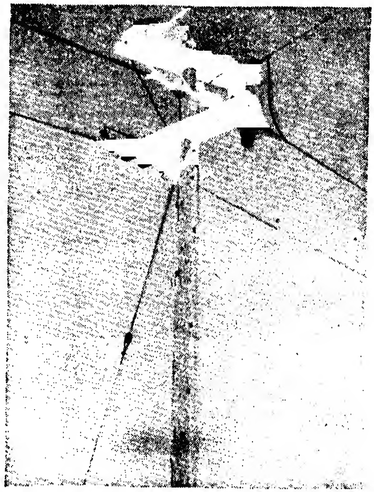


FIG. 4-13. Reverse arms used at a corner. Note the use of double arms on account of the excessive pull at the line terminal. (*Courtesy Iowa-Illinois Gas and Electric Co.*)

Buck or Reverse Arms. Buck arms are crossarms mounted at right angles to the main crossarms (see Fig. 4-13). They are used for the support of branch lines or at corners for the purpose of making a change in the direction of the line.

INSULATOR PINS

Types. The function of an insulator pin is to hold the insulator mounted on it in a vertical position.

Insulator pins are made of wood or metal. Wooden pins are usually made of locust (see Fig. 4-14). Locust is durable and retains its strength longer than other wood. Iron and steel pins are resorted to where the pins must be extra long on account of high voltage and where the tension on the conductor is large. One make is arranged to encircle the crossarm as a clamp pin, the clamp being held by bolts (see Fig. 4-15). In many cases a steel rod is used as the base in order to permit the use of a

FIG. 4-14. Standard low-voltage wood insulator pin. (*Courtesy Joslyn Mfg. and Supply Co.*)

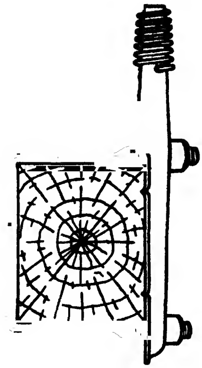


FIG. 4-15. Steel clamp pin. (*Courtesy Hubbard & Co.*)

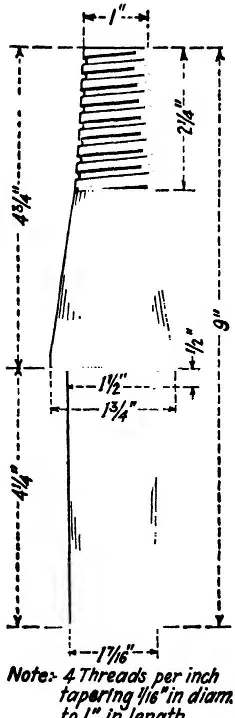


FIG. 4-16. Standard wood pin.

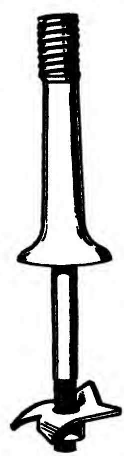


FIG. 4-17. Steel pin provided with lead threads. (*Courtesy Hubbard & Co.*)

⅝- or ¾-in. hole instead of the 1½-in. hole required by a wooden pin. This saves some of the strength of the arm.

Wood-pin Sizes. The standard wood pin for low-voltage circuits is 9 in. long. The diameter of the portion that fits into the pinhole is 1½ in. and is cylindrical in shape. Above this part is a shoulder 1¾-in. in diameter and from the shoulder the pin tapers gradually to a 1-in.

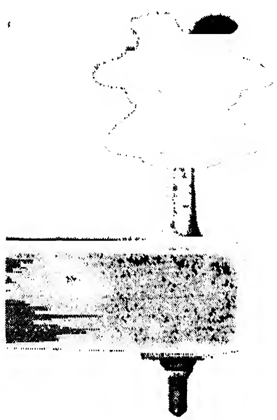


FIG. 4-18. Assembled view of wooden crossarm, steel insulator pin, and mounted porcelain-pin insulator. (*Courtesy Locke Dept., General Electric Co.*)

diameter at the point where the thread begins. The details of this pin are shown in Fig. 4-16. Over 2 in. of the top is threaded to hold the insulator.

Steel Pins. Steel pins are in general use today. An allsteel pin is shown in detail in Fig. 4-17. It has a broad base which rests squarely on the crossarm as shown in Fig. 4-18. The pin is usually provided with lead threads which prevent any localized pressure on the insulator.

POLE HARDWARE

Braces. Crossarm braces are used to give strength and rigidity to the crossarm. Metal crossarm braces are made of either flat bar or light

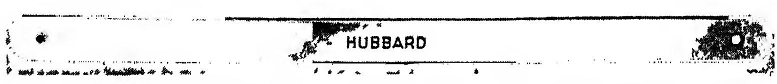


FIG. 4-19. Standard flat-strap crossarm brace. (*Courtesy Hubbard & Co.*)

angle iron. The size used varies with the size of the arm and the weight of the conductors. The usual flat-strap brace for ordinary distribution work (Fig. 4-19) is 38 in. long and ¼ by 1¼ in. One end is attached to the crossarm by means of a carriage bolt and the other to the pole by means of a lag screw. One brace extends to each side of the arm, as shown in Fig. 4-1. Angle-iron braces are made in one piece and bent

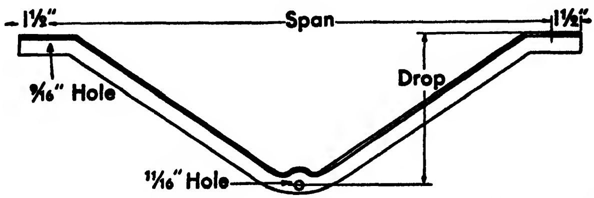


FIG. 4-20. V-shaped angle-iron crossarm brace. (*Courtesy Joslyn Mfg. and Supply Co.*)

into the shape of a V, as shown in Fig. 4-20. These braces are fitted to the bottom of the crossarm instead of the side as is the flat type.

In recent years wooden crossarm braces have come into extensive use for medium voltages. Their use increases the insulation of the line. A

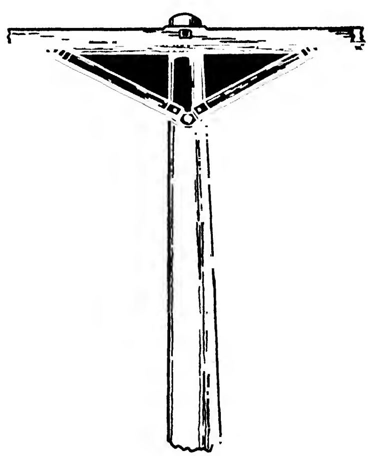


FIG. 4-21. Wooden crossarm braces used to increase insulation properties of line. (*Courtesy Joslyn Mfg. and Supply Co.*)

set of wooden braces is illustrated in Fig. 4-21, and their use is illustrated in Figs. 4-22 and 4-23.

Where crossarms extend to one side of the pole only, as is sometimes necessary in alley construction, special braces are required. The brace must be longer and more rigid. A single brace made of angle iron 1¾ by 1¾ by 3/16 in. and 5 to 7 ft long is generally used for distribution lines, and is shown in Figs. 4-24 and 4-25. The brace is provided with a step near the middle for use of the lineman.

Bolts and Lag Screws. A variety of bolts and screws are used in line construction, and only the common ones will be illustrated Figure 4-26 shows a typical crossarm through bolt used for fastening the crossarm to the pole. Its common size is 5/8 by 12 to 16 in. A bolt for attaching two crossarms, one on each side of the pole, is shown in Fig 4-27 Figure 4-28 illustrates a carriage bolt used for attaching the brace to

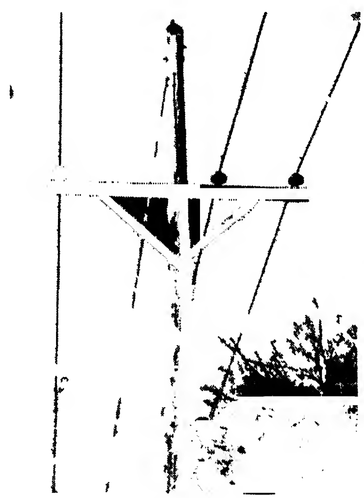


FIG 4-22 Illustrating use of wooden crossarm braces on low voltage transmission line Use of wood pole wooden crossarm and wooden braces provides considerable insulation to line in addition to that provided by the pin insulators (*Courtesy Iowa-Illinois Gas and Electric Co*)

FIG 4-23 Wooden braces used on double arms of low-voltage transmission line (*Courtesy Iowa-Illinois Gas and Electric Co*)

the crossarm The typical bolt for this purpose is 3/8 in in diameter and 4, 4½, or 5 in long Figure 4-29 shows a lag screw used to fasten the crossarm braces to the pole The recommended size is ½ by 4 in Lag screws are supposed to be screwed into place either into a small bored hole or after being started by hammering. They should be screwed into place to keep the threads from injuring the fibers of the wood

Assembly. The complete assembly of the pieces of pole hardware described above is shown in Fig 4-30. This figure also lists the standard parts and illustrates their correct use.

Pole Guys. A guy is a brace or cable fastened to the pole to strengthen the pole and keep it in position Guys are used wherever the wires tend to pull the pole out of its normal position and to sustain the line during

FIG. 4-24. Alley-arm brace. (*Courtesy Hubbard & Co*)

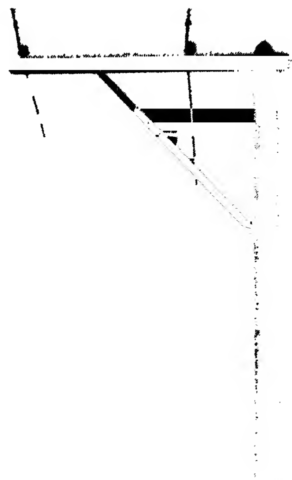


FIG 4-25 Alley-arm brace used with side arm to clear obstructions Note pole step on brace for use by lineman (*Courtesy Iowa-Illinois Gas and Electric Co*)

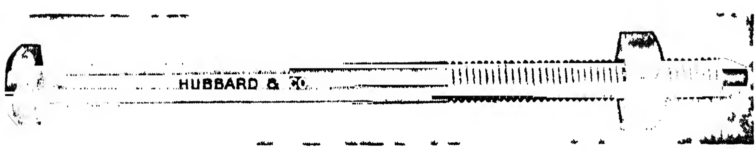


FIG 4-26 Crossarm bolt (*Courtesy Hubbard & Co*)

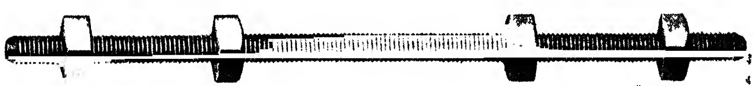


FIG 4-27 Bolt for double crossarms (*Courtesy Hubbard & Co*)

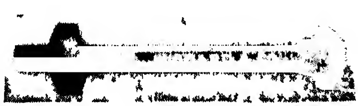


FIG 4-28 Carriage bolt for fastening brace to crossarm (*Courtesy Hubbard & Co.*)

FIG 4-29 Lag screw for fastening crossarm brace to pole. (*Courtesy Hubbard & Co*)

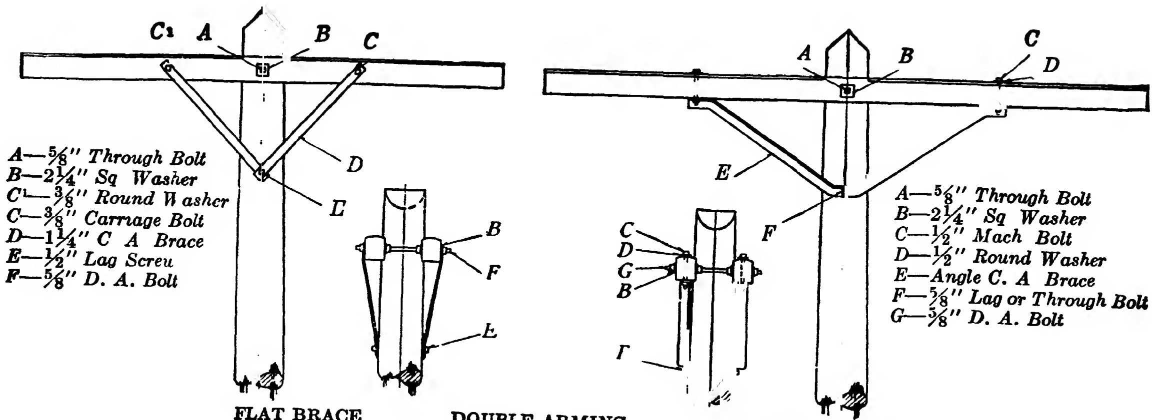


FIG 4-30 Sketches showing standard sizes and use of bolts lags and washers in single- and double-crossarm assembly. (Courtesy Hubbard & Co)

the abnormal loads caused by sleet, wind, and cold. Guys can be classified as follows:

1. Braces:
    a. Single pole
    b. Double pole
2. Wire guys:
    a. Span guy
    b. Head guy
    c. Arm guy
    d. Anchor or "down" guy:
        (1) Terminal
        (2) Corner
        (3) Line
        (4) Side
        (5) Storm
    e. Stub guy

A single-pole brace is illustrated in Fig. 4-31. It is used where wire guying is not convenient, such as along lines paralleling a highway or in marshes where anchors cannot be firmly embedded. The upper end of the brace is bolted to the pole.

A *span guy* is a wire guy running from the top of a pole to the top of the adjacent pole. This type of guy is made use of at important crossings. It is used to remove the strain from the line conductors.

A *head guy* is a wire guy running from the top of a pole to a point below the top of the next pole.

An *arm guy* is a wire guy running from one side of a crossarm to the next pole.

An *anchor* or "down" guy is a wire guy running from the top of a pole to an anchor in the ground.

Terminal guys are used at the ends of the pole lines in order to counterbalance the pull of the line conductors. Figure 4-32 illustrates a terminal guy. Corner guys, illustrated in Fig. 4-33, likewise counterbalance the pull of the line conductors.

Line guys (Fig. 4-34) are installed in straight-pole lines to reinforce the line against stresses due to broken conductors, etc.

Side guys are used to reinforce a pole line against an unbalanced side pull of the conductors (see Fig. 4-35). Such pulls are developed at curves, angles, or wherever there is a turn in the line.

A *storm guy* consists of a pair of line guys and a pair of side guys, as illustrated in Fig. 4-36. All of them are fastened to the same line support. Storm guys are placed in lines approximately every half mile to a mile to reinforce the line and to prevent the entire line from being pulled down in case the line conductors become broken at any point in the line.

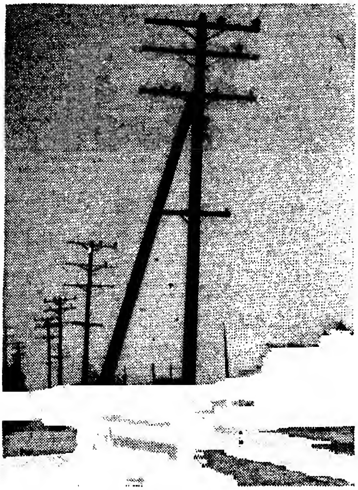


FIG. 4-31. Single-pole brace used in place of stub guy. (*Courtesy Line Material Co.*)

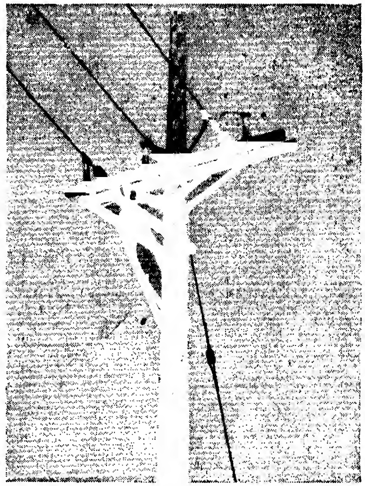


FIG. 4-32. Terminal guy at end of distribution-pole line. Guy counterbalances pull of line conductors. (*Courtesy Line Material Co.*)

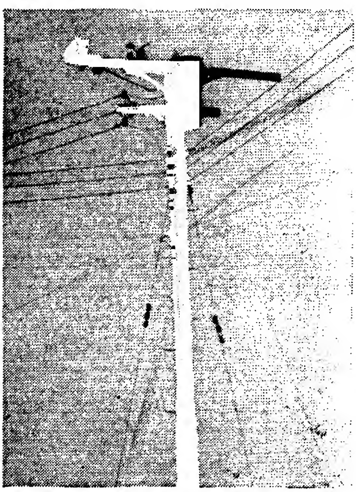


FIG. 4-33. Two corner guys opposing the pull of the line conductors in two directions. (*Courtesy Line Material Co.*)

FIG. 4-34. Side guys on wood-pole line. Note manner of attachment of guys to pole. Guy fastened to pole near crossarm has wood strain insulator in it. (*Courtesy Iowa-Illinois Gas and Electric Co.*)

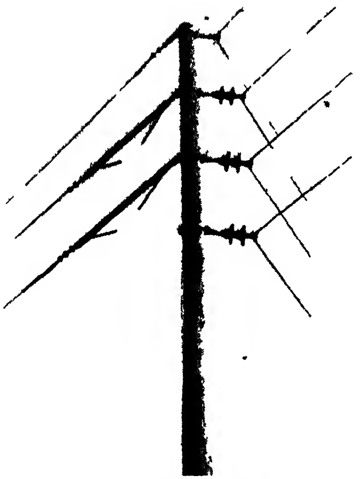


Fig 4-35 Side guys counterbalancing the side pull of the line conductors due to an angle in the line Note use of wood strain insulators in each guy (*Courtesy Iowa-Illinois Gas and Electric Co*)

Fig 4-36 Storm guys installed on an H frame Note use of two wood strain insulators in each guy (*Courtesy Hubbard & Co*)

Fig 4-37 Stub guy used to obtain clearance over a highway. Note use of double crossarms and double wood-braces on medium-voltage line. (*Courtesy Iowa-Illinois Gas and Electric Co*)

Fig 4-38 Sidewalk guy used to avoid crossing highway with guy wire (*Courtesy Line Material Co.*)

A *stub guy* (Fig. 4-37) is a means of obtaining clearance for a wire guy. When lines parallel to streets or roads must be guyed toward the direction of the street or road, a pole stub placed on the opposite side of the

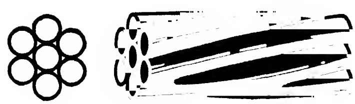


FIG. 4-39. Seven-strand steel guy cable. (*Courtesy Joslyn Mfg. and Supply Co.*)

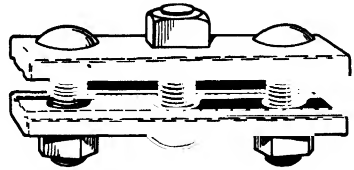


FIG. 4-40. Three-bolt guy-wire clamp. (*Courtesy Hubbard & Co.*)

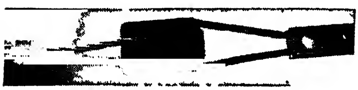
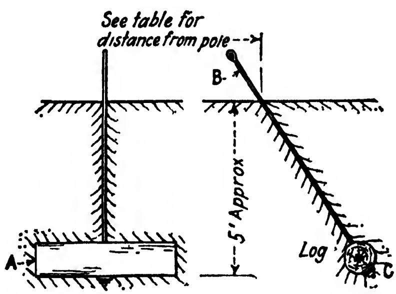


FIG. 4-41. Strain insulator inserted in guy wire. (*Courtesy Locke Dept. General Electric Co.*)

FIG. 4-42. Guy anchor rod used with log anchor. (*Courtesy Joslyn Mfg. and Supply Co.*)



Size of pole, ft	Minimum distance from pole, ft
30 and 40	15
45 and 50	20
55 and 60	25

Material		
Loc	No	Description
A	1	12" × 4' − 0" log
B	1	Anchor rod
C	1	Anchor-rod washer

FIG. 4-43. Views showing log anchor installed. Tables list materials required as well as distance from pole at which anchor should be placed for various heights of poles.

street makes it possible to obtain the necessary clearance above the street.

A *sidewalk guy*, Fig. 4-38, is a means for avoiding the necessity of crossing over the street or highway to ground the guy.

Guy Materials. A wire guy consists of the cable, cable clamps, strain insulator, and the anchor. The wire in common use is a seven-strand 5⁄16-in. galvanized steel cable (Fig. 4-39). Two full turns are usually wrapped around the pole. On soft poles where the guy wire would be apt to cut the fibers of the pole, guy plates are placed underneath the two turns. The clamp consists of two pieces of metal (Fig. 4-40) between which the guy wires are gripped as the bolts are drawn up.

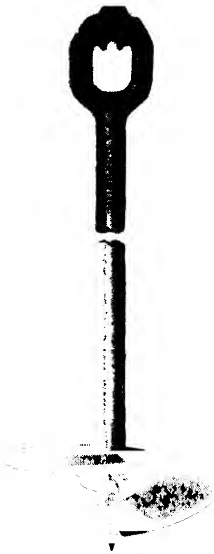


FIG. 4-44. Screw-type anchor. (*Courtesy Hubbard & Co.*)

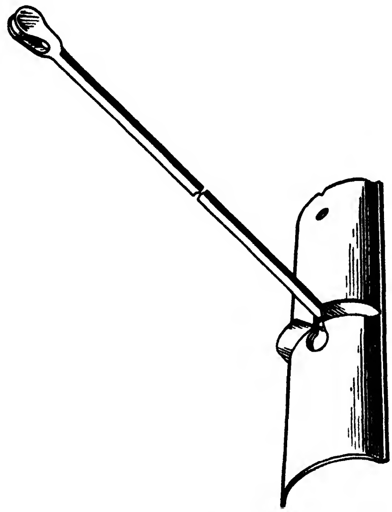


FIG. 4-45. View showing "never-creep" anchor installed. (*Courtesy A. B. Chance Co.*)

One or more strain insulators are placed in the guy (Fig. 4-41) as a means of protection to the lineman on the pole, and to any person on the ground. These are necessary because the closeness of the guy wire to primary mains or feeders is likely to permit leakage during wet weather in sufficient amount to charge the guy wire.

Anchors. Guy anchors are of many varieties. The ordinary log anchor (Figs. 4-42 and 4-43) was once in wide use, but the cost of digging it in the ground has brought several patented anchors on the market which are cheaper to install. Figure 4-44, for example, illustrates a screw-type anchor which is screwed into the ground. Figure 4-45 illustrates the so-called "never-creep" anchor which consists of two parts: a rod and a thimble eye. A hole is bored at an angle for the thimble, and the rod is pierced through the undisturbed ground to catch into the thimble. Many other designs are also on the market. All of them are easier to install than the log anchor, but where large pulls must be exerted the log anchor or "deadman," as it is often called, usually proves most satisfactory.

Pole Steps. Many poles, especially those carrying transformers, cut-outs, or a large number of circuits which require frequent attention and inspection, are often provided with pole steps to prevent damage of the wood surface from the spurs of linemen. Steps also facilitate work. The most common type of step is made of $\frac{5}{8}$-in. iron rod about 9 in. long screwed into the pole (see Fig. 4-46). A $\frac{1}{2}$-in. hole is usually bored

FIG. 4-46. Steel pole step (*Courtesy Joslyn Mfg. and Supply Co.*)

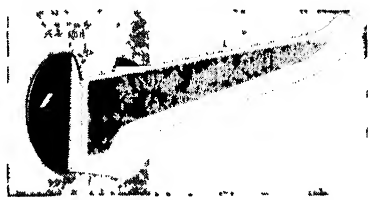


FIG. 4-47. Detachable type of pole step. (*Courtesy Line Material Co.*)

first. The end of the step is turned up to prevent the lineman's foot from slipping off. The steps are placed 18 in. apart and should not begin less than $6\frac{1}{2}$ ft from the ground.

Wooden steps made of triangular pieces of hardwood and fastened with lag screws or spikes have also been used extensively.

In the vicinity of schools and other locations where children gather, the lower steps are sometimes made removable. They can then be taken off and so prevent the children from climbing the poles and endangering their lives. The only attachments to the pole are step sockets. The steps are put into the sockets by the lineman before he climbs and removed after he comes down. Figure 4-47 illustrates steps of the detachable type.

INSULATORS

Classes. The function of an insulator is to insulate the line conductors from each other and from the pole or tower. Three classes of insulators are used on overhead lines, namely,

1. Pin
   a. Glass
   b. Porcelain
2. Suspension
   a. Cemented type
   b. Link type
3. Strain
   a. Line
   b. Guy

Pin Type. The pin insulator gets its name from the fact that it is supported on a pin. The pin holds the insulator, and the insulator has the conductor tied to it. Figure 4-48 shows a typical pin insulator in position.

Pin insulators are made of either glass or porcelain. The glass insulator is always one solid piece of glass, that is, it is a one-piece insulator,

FIG 4-48 Pin insulator mounted in position Typical low-voltage side-groove glass-pin insulator Note use of steel insulator pin (*Courtesy Kimble Glass Co*)

FIG 4-49 Porcelain-top groove pin insulators mounted in position on double crossarm Note use of steel insulator pins and crossarm spreader bolt (*Courtesy Locke Dept, General Electric Co*)

as Fig 4-48 shows The porcelain insulator (Fig 4-49) is also a one-piece insulator when used on low-voltage lines but consists of two, three, or four layers cemented together to form a rigid unit when used on high-voltage lines. It is usually one piece for voltages below 23,000 volts,

FIG 4-50 23,000-volt two-layer porcelain-pin insulator (*Courtesy Ohio Brass Co*)

two piece for voltages from 23,000 to 44,000 volts, three piece for voltages from 44,000 to 66,000 volts, and four piece for voltages from 66,000 to 88,000 volts. The use of several layers helps to spill the rain and provides a long, dry arc-over path. These layers flare out at the bottom into a bell shape. Sometimes these layers are called "petticoats" on account of their appearance, and pin insulators of this multilayer construction are sometimes called "petticoat insulators." Figure 4-50 shows a typical multilayer petticoat insulator.

Pin insulators are seldom used on transmission lines having voltages above 44,000 volts, although some 88,000-volt lines using pin insulators are in operation today.

The glass pin insulator is used on low-voltage circuits such as secondary mains and services, and the porcelain pin insulator is used on

FIG. 4-51. A string of eight suspension insulator units suspended from a wooden crossarm. Note conductor clamp at bottom of string. (*Courtesy Locke Dept., General Electric Co.*)

primary mains, feeders, and transmission lines. Where glass insulators are used on secondaries and porcelain insulators on primaries, the lineman is greatly assisted in identifying these circuits on the pole.

The smaller insulators are threaded to fit on a 1-in. pin, and the larger units are threaded to fit on a 1⅜-in. pin. When arranged to be mounted on steel pins, a thimble, threaded to fit the pin, is cemented into the porcelain.

Suspension Insulators. The suspension insulator, as its name implies, is suspended from the crossarm and has the line conductor fastened to the lower end (see Fig. 4-51). The suspension-type insulator was developed when voltages were increased above 44,000 volts. At this voltage the pin insulator becomes quite heavy, and it is difficult to obtain sufficient mechanical strength in the pin to support the insulator. The use of suspension insulators eliminates the use of the pin and makes possible obtaining any distance between the conductors and the pole or tower by merely increasing the number of insulators in the "string," as the complete unit is called.

The insulator unit consists essentially of two metal eyepieces insulated from one another with porcelain. First the porcelain is cemented into the metal cap or the top of the unit, and then the metal pin on the

FIG. 4-52. Outside view of cemented-type suspension insulator. (*Courtesy Ohio Brass Co.*)

bottom of the unit is cemented into the porcelain. A typical cemented-type suspension insulator is shown in Fig. 4-52.

The diameter of the porcelain disks varies from 6 to 10 in. or more. The 10-in. disk is perhaps the most common size.

Number of Units in String. The number of units to use in a string depends largely on the voltage of the line. Other factors, such as

TABLE 4-3. APPROXIMATE NUMBER OF DISKS REQUIRED IN SUSPENSION STRING FOR VARIOUS LINE VOLTAGES

Line voltage	Number of suspension units required in string	Line voltage	Number of suspension units required in string
13,200	2	88,000	5 or 6
22,000	2 or 3	110,000	6, 7, or 8
33,000	2 or 3	132,000	8, 9, or 10
44,000	3 or 4	154,000	9, 10, or 11
66,000	4 or 5	220,000	12 to 16

climate, type of construction, and degree of reliability required, also enter into consideration. Table 4-3 gives a general idea of the usual number of units employed for the various standard transmission voltages.

Strain Insulators. Strain insulators are used where a pull must be carried as well as insulation provided. Such places occur where a line is dead-ended at corners, at sharp curves, at extra long spans, as at river crossings or in mountainous country, etc. In such places the insulator must not only be a good insulator electrically, but must also have sufficient mechanical strength to counterbalance the forces due to the tension of the line conductors.

Strain insulators are built the same as suspension insulators except that they are made stronger mechanically. Furthermore, when a single string is not able to withstand the pull, two or more strings are arranged in multiple, as Fig. 4-53 shows.

Strain insulators are also used in guy cables, as has already been mentioned, where it is necessary to insulate the lower part of the guy cable

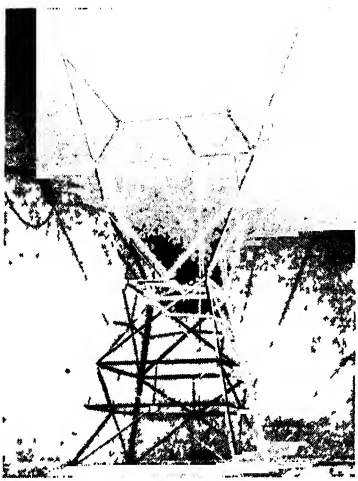


FIG. 4-53 Two strings of suspension insulators used in multiple to serve as strain insulators at 230 kv dead-end tower. (*Courtesy Locke Dept., General Electric Co.*)

from the pole for the safety of people on the ground and to insulate the upper part of the cable from the ground for the safety of linemen on the pole. As was pointed out on page 4-21 this type of strain insulator or guy insulator usually consists of a porcelain piece pierced with two holes at right angles to each other through which the two ends of the guy wires are looped (see Fig. 4-41). Since this puts the porcelain between the loops under compression, it makes for great strength.

LINE CONDUCTORS

Metals Used. Electrical conductors are the wires and cables over which electrical energy is transmitted. These conductors are made of copper, aluminum, steel or a combination of copper and steel, or aluminum and steel. They are further discussed below.

Copper. Copper is the most generally used line conductor. It conducts electric current very readily, ranking next to silver. It is very plentiful in nature, and, therefore, its cost is comparatively low. It can also be easily spliced.

Three kinds of copper wire are in use: hard-drawn copper, medium-hard-drawn copper, and annealed copper, also called "soft drawn." Copper wire is hard drawn as it comes from the drawing die. To obtain soft or annealed copper wire, the hard-drawn wire is heated to a red heat to soften it.

For transmission purposes, hard-drawn copper wire is preferable on account of its greater strength. Annealing, or softening it, reduces the tensile strength of the wire from about 55,000 to 35,000 lb per sq in. On account of this, it is not good practice to have any soldered splices when using hard-drawn wire, as the soldering anneals the wire near the joint, thereby reducing its strength. Joints in hard-drawn wire should, therefore, be made with splicing sleeves. These are described in the chapters on construction. Annealed or soft-drawn copper wire is being used in distributing lines where soldered connections are almost universally used. The tendency now is to use medium-hard copper for distribution especially for wire sizes smaller than No. 2. Soft copper wire has a yield point less than one-half that of medium-hard copper and hence stretches permanently with a correspondingly lighter loading of ice and wind.

Aluminum. Aluminum is also widely used as a transmission-line conductor, particularly on high-voltage lines. Its conductivity, however, is only about two-thirds that of copper. Compared with a copper wire

FIG. 4-54. Relative cross sections of copper, aluminum, and ACSR conductors having equal current-carrying capacities.

of the same size, aluminum wire only has 60 per cent of the conductivity, only 45 per cent of the tensile strength, and only 33 per cent of the weight. To have the same conductivity, therefore, the aluminum wire must be $100/60 = 1.66$ times as large as the copper wire in cross section. An aluminum wire of this size will have 75 per cent of the tensile strength and 55 per cent of the weight of the equivalent copper conductor. In Fig. 4-54 are shown cross sections of copper, aluminum, and aluminum-conductor steel-reinforced (ACSR) conductors which have equal conductivity or, what amounts to the same thing, equal current-carrying capacities.

The tensile strength of aluminum is only about one-half that of hard-drawn copper, namely, 27,000 lb per sq in. But since the cross section of an aluminum wire must be about twice that of copper to have the same conductivity, the actual breaking strength of the aluminum conductor is about the same as that of copper. In spite of being twice as large in section, the weight per foot is still only 55 per cent as great, as pointed out above. This fact makes aluminum conductors preferred in many cases, because the lighter weight permits longer spans and, therefore, fewer towers and insulators. This is a decided advantage in mountainous country where long spans are common. The larger size also helps to hold the corona loss down.

When an aluminum conductor is stranded, the central strand is often made of steel, which serves to reinforce the cable. Such reinforcement gives great strength for the weight of conductor. Reinforced aluminum cable is therefore especially suited to long spans where large sags are apt to occur.

Steel and Copper-clad Steel. Steel wire is used to a limited extent where very cheap construction is desired. Steel wire, because of its high tensile strength of 160,000 lb per sq in., permits of relatively long spans, therefore requires few supports. Bare steel wire, however, rusts rapidly and is therefore very short-lived. Steel is also a poor conductor compared with copper, being only about 10 to 15 per cent as good.

The shortcomings of short life and low conductivity led to the development of the copper-clad steel conductor. In this conductor a coating of copper is securely welded to the outside of the steel wire. The copper acts as a protective coating to the steel wire, thus giving the conductor the same life as if it were made of solid copper. At the same time, the layer of copper greatly increases the conductivity of the steel conductor, while the steel core gives it great strength. This combination produces a very satisfactory, yet inexpensive, line conductor. Its chief field of application is in rural districts and as branch lines supplying small towns.

The conductivity of copper-clad conductors can be raised to any desired percentage, depending on the thickness of the copper layer. The usual values of conductivity of wires as manufactured are 30 and 40 per cent.

Classes of Conductors. Conductors are classified as *solid* or *stranded.* A solid conductor, as the name implies, is a single conductor of solid

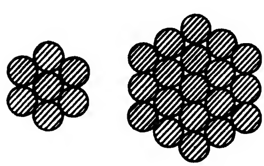


FIG. 4-55. Sketches showing arrangement of wires in 7- and 19-strand conductors. The wires are arranged in concentric layers about a central core.

circular section. A stranded conductor is composed of a group of wires made into a single conductor. A stranded conductor is used where the solid conductor is too large and not flexible enough to be handled readily.

Large solid conductors are also easily injured by bending. The size No. 0 wire is the approximate dividing line between solid and stranded conductors. The strands in the stranded conductor are usually arranged in concentric layers about a central core (Fig. 4-55). The smallest number of wires in a stranded conductor is seven. The next number of strands is 19, then 37, 61, 91, 127, etc. Figure 4-56 illustrates a typical stranded conductor. Both copper and aluminum are thus stranded.

FIG. 4-56. Typical stranded cable. (*Courtesy Western Electric Co.*)

Conductor Insulation. Conductors on overhead transmission lines are bare conductors, that is, they are not covered with any insulation. Conductors on overhead distribution circuits are usually covered with insulation. The common insulation is triple-braid weatherproof cotton. This consists of three braids or layers saturated with a black moisture-proof compound. Figure 4-57 shows a conductor and two layers of

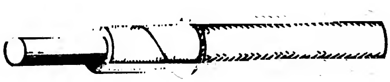


FIG. 4-57. Solid conductor insulated with two layers of braided cotton and saturated with a weatherproofing compound

braid. This insulation, of course, is not sufficient to withstand the voltage at which the line is operating, and the conductors must, therefore, also be mounted on insulators. In fact, the wires should always be treated as though they were bare. The braid insulation not only adds to the safety of work for linemen when working on live lines but also to people on the streets in case a live conductor breaks and falls to ground.

Wire Sizes. Wire sizes are ordinarily expressed by numbers. There are, however, several different numbering methods, so that in specifying a wire size by number it is also necessary to state which wire gage or numbering method is used. The most used wire gage in this country is the so-called "Brown and Sharpe" gage, also called "American Wire Gage."

Brown and Sharpe Gage. The Brown and Sharpe wire gage is shown in Fig. 4-58. This cut is full size, so that the width of the openings on the rim of the gage correspond to the diameter of the wires whose numbers stand opposite the openings. The actual size of these wire numbers is perhaps still better illustrated by Table 4-4. This table gives, for wire sizes from No. 0000 to No. 8, the diameter of the wire in inches and a full size end and side view of the wire corresponding to each number of the gage. This table should make it easy to gain an idea of the actual

TABLE 4-4. BROWN AND SHARPE WIRE SIZES (BARE CONDUCTOR)

Gage number	Diameter, in.	Full size, end view	Full size, side vie
8	0.1285		
7	0.1443		
6	0.162		
5	0.1819		
4	0.2043		
3	0.2294		
2	0.2576		
1	0.2893		
0	0.3249		
00	0.3648		
000	0.4096		
0000	0.460		

physical size of the wires commonly used in transmission and distribution work. Table 4-5 gives, in addition, the area in circular mils, the resistance in ohms per 1,000 ft, and the weight in pounds per 1,000 ft. Table 4-6 gives the same information for aluminum wire. Table 4-7 gives similar information for copper, ACSR, and copperweld conductors

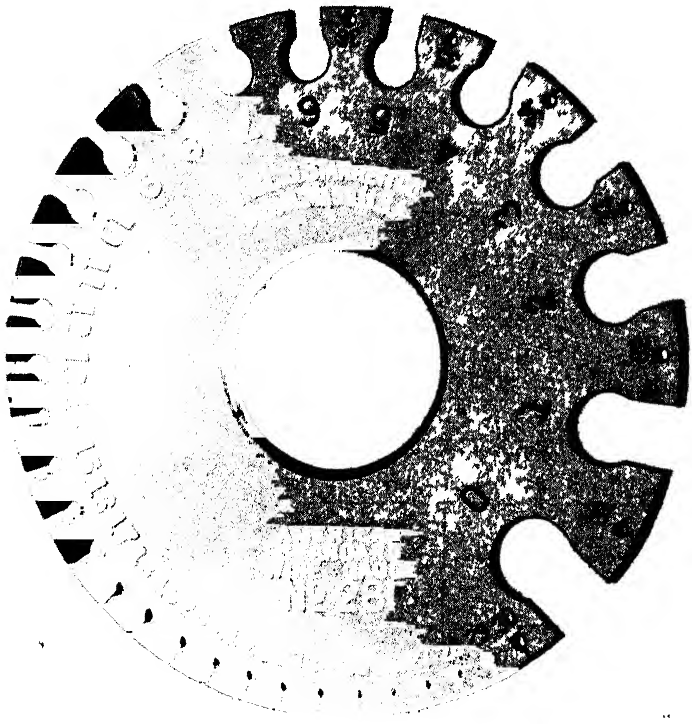


FIG 4-58 American standard wire gage Cut is full size Width of openings on rim correspond to diameters of wires whose numbers are opposite the openings (*Courtesy L S Starrett Co*)

as well as information on tensile strength and over-all dimensions for different classes of insulated coverings.

It will be noticed in Table 4-5 that with every increase of three in the gage number the cross section and weight are halved and the resistance is doubled. Also, an increase of ten in the gage number increases the resistance ten times and cuts the weight and cross section to one-tenth. Thus, for example, the No. 5 wire is three sizes smaller than the No. 2 wire. Its cross section is one-half that of the No. 2, for 33,100 is approximately one-half of 66,370; and its resistance is twice that of the No. 2, for

TABLE 4-5. COPPER WIRE (ANNEALED)

Gage number	Diameter, in.	Area, cir mils	Resistance, ohms per 1,000 ft 68°F	Weight, lb per 1,000 ft
14	0.064	4,110	2.525	12.43
13	0.072	5,180	2.003	15.68
12	0.081	6,530	1.588	19.77
11	0.091	8,230	1.260	24.92
10	0.102	10,400	0.9989	31.43
9	0.114	13,100	0.7921	39.63
8	0.1285	16,510	0.6282	49.98
7	0.1443	20,820	0.4983	63.02
6	0.162	26,250	0.3951	79.46
5	0.1819	33,100	0.3133	100.20
4	0.2043	41,700	0.2485	126.4
3	0.2294	52,640	0.1970	159.3
2	0.2576	66,370	0.1563	200.9
1	0.2893	83,690	0.1239	253.3
0	0.3249	105,500	0.09827	319.5
00	0.3648	133,100	0.07793	402.8
000	0.4096	167,800	0.06180	507.9
0000	0.460	211,600	0.04901	640.5

TABLE 4-6. ALUMINUM WIRE (HARD DRAWN)

Gage number	Diameter, in.	Area, cir mils	Resistance, ohms per 1,000 ft 68°F	Weight, lb per 1,000 ft
14	0.064	4,110	4.14	3.78
13	0.072	5,180	3.29	4.76
12	0.081	6,530	2.61	6.00
11	0.091	8,230	2.07	7.57
10	0.102	10,400	1.64	9.55
9	0.114	13,100	1.30	12.00
8	0.1285	16,510	1.03	15.2
7	0.1443	20,820	0.817	19.1
6	0.162	26,250	0.648	24.1
5	0.1819	33,100	0.514	30.4
4	0.2043	41,700	0.408	38.4
3	0.2294	52,640	0.323	48.4
2	0.2576	66,370	0.256	61.0
1	0.2893	83,690	0.203	76.9
0	0.3249	105,500	0.161	97.0
00	0.3648	133,100	0.128	122.0
000	0.4096	167.800	0.101	154.0
0000	0.460	211,600	0.0804	195.0

Table 4-7. Wire Table for Copper, ACSR, and Copperweld Conductors Giving Weight, Tensile Strength, Resistance and Dimensions

Size	Area: Cir mils	Area: Sq in	Pounds per 1 000 ft: Solid	Pounds per 1 000 ft: Stranded	Pounds per 1 000 ft: TBWP	Pounds per 1 000 ft: VCWP	Pounds per 1 000 ft: DBRC	Pounds per 1 000 ft: SBRC	Tensile strength: Annealed	Tensile strength: Hard drawn	Strands: No	Strands: Diam	Over all diameter in: Solid	Over all diameter in: Stranded	Over all diameter in: TBWP	Over all diameter in: VCWP	Over all diameter in: DBRC	Over all diameter in: SBRC	Ohms per 1 000 ft
									Copper										
	1,000 000	0 7854		3 100	3 674	3 288	3 530		29 060	45 000	61	0 1280		1 152	1 451	1 362	1 470		0 0108
	750 000	0 5890		2 320	2 822	2 498	2 673		21 790	34 310	61	0 1109		0 998	1 300	1 207	1 320		0 0144
	500 000	0 3927		1 544	1 894	1 659	1 815		14 530	21 950	19	0 1622		0 811	1 108	0 971	1 100		0 0220
	400 000	0 3142		1 235	1 553	1 337	1 473		11 620	17 560	19	0 1451		0 726	1 020	0 885	1 020		0 0275
	300 000	0 2356		926	1 174	1 021	1 139		8 718	13 510	19	0 1257		0 629	0 930	0 787	0 920		0 0367
	250 000	0 1964		772	985	853	962		7 265	11 360	19	0 1147		0 574	0 862	0 732	0 860		0 0440
4/0	211 600	0 1662	641	653	800	734	814		5 983	9 617	19	0 1055	0 460	0 528	0 660	0 685	0 780		0 0520
3/0	167 800	0 1318	508	518	653	585	663		4 745	7 556	12	0 1183	0 410	0 492	0 595	0 627	0 730		0 0656
2/0	133 100	0 1045	403	411	522	460	540		3 763	5 927	7	0 1379	0 365	0 414	0 550	0 546	0 670		0 0827
1/0	105 500	0 0829	320	326	424	370	443		2 984	4 750	7	0 1228	0 325	0 368	0 505	0 501	0 630		0 1043
2	66 370	0 0521	201	205	270	241	278		1 929	3 045	7	0 0974	0 258	0 292	0 400	0 424	0 510		0 1658
4	41 740	0 0328	126	127	164	153	190		1 213	1 970	7	0 0773	0 204	0 232	0 346	0 336	0 450		0 2584
6	26 250	0 0206	79		112	102	120	115	763	1 280			0 162		0 303	0 294	0 360	0 320	0 4108
8	16 510	0 0130	50		75	66	85	80	480	826			0 129		0 264	0 260	0 320	0 280	0 6533
10	10 380	0 0082	31		53	46	54	49	314	529			0 102		0 221	0 207	0 260	0 230	1 039
12	6 530	0 0051	20		35	32	38	35	198	337			0 081		0 200	0 186	0 240	0 210	1 652
									ACSR										
4/0		0 1939		293						8 420	6	0 1878		0 563					0 0836
2/0		0 1219		185						5 345	6	0 1490		0 447					0 1330
1/0		0 0967		146						4 280	6	0 1327		0 398					0 1676
2		0 0653		107						3 535	7	0 0974		0 325					0 2670
2		0 0608		92						2 790	6	0 1052		0 316					0 2670
4		0 0411		67						2 288	7	0 0772		0 257					0 4245
4		0 0383		58						1 830	6	0 0834		0 250					0 4245
									Type A Copperweld										
4A	41 740	0 0428		162						3 938	3			0 290					0 2610
6A	26 250	0 0269		102						2 585	3			0 230					0 4150
8A	16 510	0 0200		74						2 233	3			0 199					0 6598

TBWP = Triple braid weatherproof
VCWP = Varnished cambric weatherproof
DBRC = Double braid rubber covered
SBRC = Slow burning rubber covered

0.3133 is twice 0.1563. Furthermore, the resistance of the No. 12 is ten times that of the No. 2, for 1.588 is nearly ten times 0.1563. This general relation between gage numbers is well to remember.

The Circular Mil. The circular mil is the unit of cross-sectional area customarily used in designating the area of wires. A circular mil is the area contained in a circle having a diameter of $\frac{1}{1000}$ in. (see Fig. 4-59). A mil is a thousandth of an inch. The use of the circular mil as the unit of area came about because of the custom of using a square as the unit of area in measuring the areas of squares or rectangles. Naturally, when the areas of circles had to be measured a circle having unit diameter suggested itself as the natural unit of measurement. The circular mils of

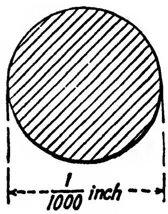


Fig. 4-59. Area of circle whose diameter is $\frac{1}{1000}$ in. is 1 cir mil.

cross section in a wire of any diameter are obtained by multiplying the diameter in thousandths of an inch by itself. Thus the number of circular mils cross section in the No. 10 wire is $102 \times 102 = 10{,}404$. The circular mils cross section of the No. 2 wire is $257.6 \times 257.6 = 66{,}370$.

Remembering the Brown and Sharpe Gage. If one can remember the relations pointed out above and the data for the No. 10 copper wire, one can build up the remainder of the table any time. The approximate data for the No. 10 copper wire are easily remembered because its resistance per 1,000 ft is 1 ohm, its diameter is $\frac{1}{10}$ in., and its circular-mil cross section is 10,000. Its weight per 1,000 ft is 31.4 lb. With these figures as a basis, one can calculate the data for the Nos. 7, 4, 1, 000, and 13, 16, 19, etc., wire numbers by using the factors 2 and $\frac{1}{2}$, remembering that for every increase in wire number of three sizes, the cross section and weight are halved and the resistance is doubled. In other words, the larger the number of the wire, the smaller the wire. To obtain the data for wires one number larger, the factors are 1.25 and 0.80, and for two numbers larger they are 1.60 and 0.625. Thus the data for the No. 11 wire are obtained by multiplying the resistance of the No. 10 wire by 1.25, that is, 1.0×1.25 equals 1.25, and dividing the cross-sectional area of 10,000 by 1.25, which equals 8,000. In the same way, the resistance of the No. 12 wire is obtained by multiplying, $1.0 \times 1.6 = 1.6$; and the cross section is obtained by dividing, $10{,}000 \div 1.6 = 6{,}250$. The data for the No. 13 wire would be obtained by using the factor 2 as explained before, and the value for the No. 14, which is one size larger than the No. 13, would be obtained by using the factor 1.25 again on the values obtained for the No. 13 wire. The results obtained in this way are, of course, approximate, but they are close enough to give one a fair idea of the wire.

Summary. The facts to be remembered regarding the Brown and Sharpe gage for copper wire are the following:

A wire which is three sizes larger than another wire has half the resistance, twice the weight, and twice the area. A wire which is ten sizes larger than another wire has one-tenth the resistance, ten times the weight, and ten times the area.

The No. 10 wire is 0.10 in. in diameter (more precisely 0.102), has an area of 10,000 cir mils (more precisely, 10,380), has a resistance of 1 ohm per 1,000 ft, at 20°C (68°F), and weighs 32 lb (more precisely, 31.4 lb) per 1,000 ft.

The weight of 1,000 ft of No. 5 wire is 100 lb.

The relative values of resistance (for decreasing sizes) and of weight and area (for increasing sizes) for consecutive sizes are 0.50, 0.63, 0.80, 1.00, 1.25, 1.60, 2.00.

The conductors of large sizes are usually specified in circular mils. For example, 500,000 cir mils, 750,000 cir mils.

To find resistance, drop one cipher from the number of mils; the result is the number of feet per ohm.

To find weight, drop four ciphers from the number of circular mils and multiply by the weight of No. 10 wire.

POTHEADS

Use. When underground transmission or distribution cables carrying voltages above 750 volts terminate at buses, or on the tops of poles, potheads are employed. Potheads prevent moisture from entering the insulation of the cable and also serve to separate the conductors sufficiently to prevent arcing between them. The most common use, perhaps, of potheads is at the junction of an underground cable with an overhead aerial line, as shown in Fig. 4-60.

Construction. A pothead consists of a pot (from which it gets its name) which slips over the lead sheath of the cable through a hole at the bottom of the pot and is flared out at the top to give the necessary separation to the conductors (see Fig. 4-61). The pot is attached to the lead sheath either by a wiped joint or by a clamping device. The pot is then completely filled with a molten insulating compound. When this insulating compound cools, it hardens, and thus makes it impossible for moisture to enter the cable. When potheads are placed outdoors, a porcelain cover is provided to prevent the accumulation of dirt on top of the compound. The cover also protects from rain and snow. In addi-

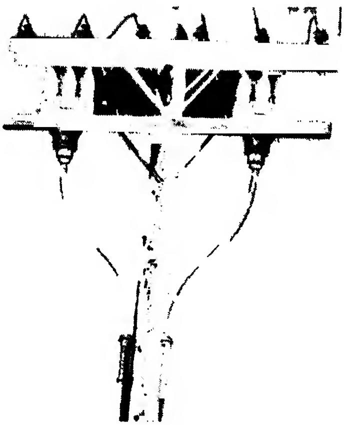


FIG 4-60 Two three-conductor potheads providing the means for connecting two underground cable lines with two overhead lines The pothead separates the conductors sufficiently to prevent arcing between them (*Courtesy G & W Electric Specialty Co*)

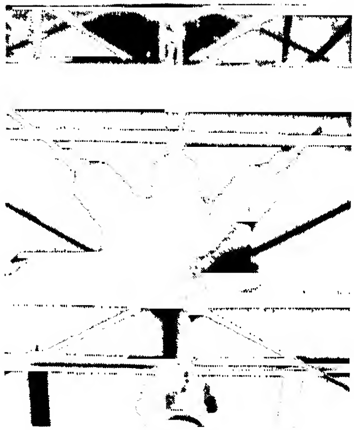


FIG 4-61 Typical three-conductor pothead. A pothead provides the means for connecting a cable to open wires (*Courtesy G & W Electric Specialty Co*)

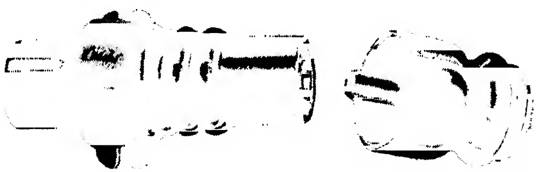


FIG 4-62 Single-conductor disconnecting-type pothead (*Courtesy G & W Electric Specialty Co*)

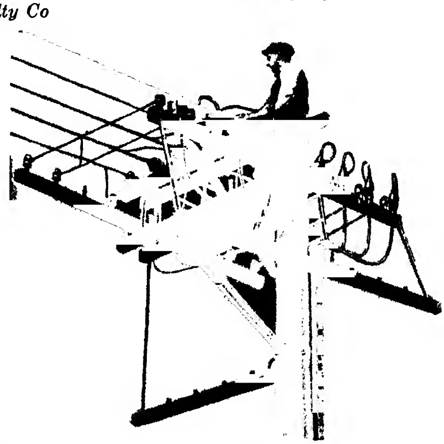


FIG 4-63 Single-conductor disconnecting-type pothead A pull upward and the line is disconnected (*Courtesy G & W Electric Specialty Co*)

tion, the cover is so shaped that it breaks up leakage paths while rain is falling.

Disconnecting-type Pothead. When cables terminate on pole tops or when it is desirable to sectionalize circuits for testing, the so-called "disconnecting" type of pothead is employed (Fig. 4-62). This pothead is arranged with an insulator-shaped cap which sits over the top of the tube and carries one member of the slip connection. The other member of the connection is fastened to the end of the cable conductor. This type of pothead is used very extensively on distribution circuits where it also serves as a disconnecting switch (see Fig. 4-63).

SECTION 5

Line Equipments

DISTRIBUTION TRANSFORMERS

Purpose. The purpose of a distribution transformer is to step down the voltage on the primary mains of a distribution system to that of the secondary mains. This in most cases is from 2,400 to 240 or 120 volts.

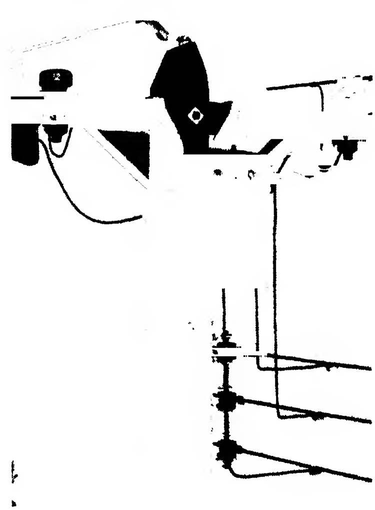


FIG. 5-1. Distribution transformer hung on crossarms of distribution pole. Installation includes lightning arresters, primary cutout fuses and ground connection. (*Courtesy General Electric Co.*)

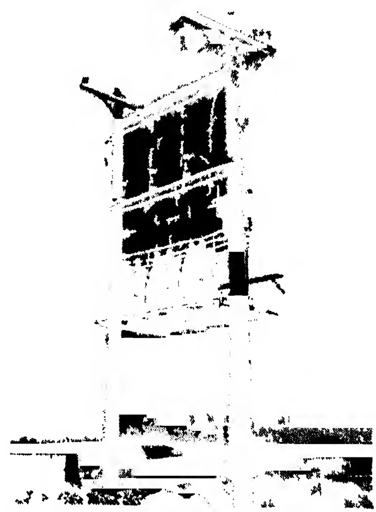


FIG. 5-2. Three single-phase transformers mounted on platform and connected into three-phase bank. Installation includes switches, fuses, and lightning arresters. (*Courtesy Victor Insulator, Inc.*)

Distribution transformers are in nearly every case located outdoors where they are hung from crossarms on poles or bolted directly to the pole, or mounted on platforms, or located in the transformer vaults of underground conduit systems. Figure 5-1 shows a typical view of a distribution transformer hung from the crossarm of one of the poles of the distribution system, and Fig. 5-2 shows a bank of three transformers mounted on a platform.

Principle of Operation. The principle of operation of voltage transformers was explained in Sec. 1 and will not be repeated here, except to state again the use of each part of the transformer. The primary winding is the winding connected to the source of power. In a distribution transformer it is the high-voltage winding. The secondary winding is the winding to which the receiving circuits are connected, which in this case are the secondary mains. The iron core is the part which links the two windings. This core has magnetism produced in it by the current

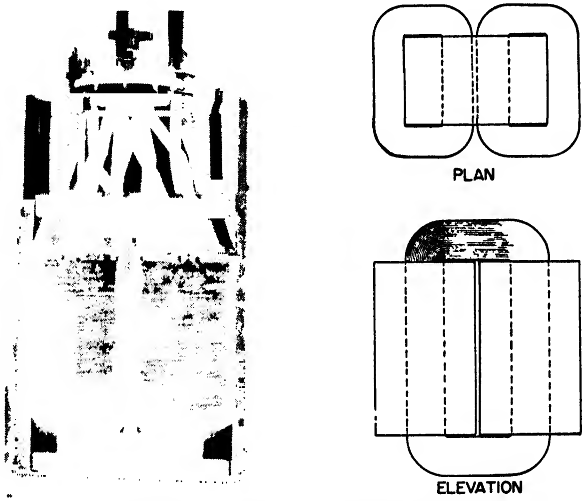


Fig. 5-3. Views illustrating core type of transformer construction. (*Courtesy Westinghouse Electric Corp.*)

in the primary winding, and because it links the secondary winding it in turn induces a voltage in the secondary winding. But owing to the smaller number of turns on the secondary winding, the voltage induced is less than the primary voltage. Distribution transformers designed to reduce the voltage from 2,400 to 240 volts have ten turns on the primary for every turn on the secondary. The secondary voltage is therefore only one-tenth of the primary voltage.

The tank contains the oil, serves to protect the coils from mechanical injury, and radiates the heat produced in the windings and core. The oil carries the heat from the coils and core to the tank sides where it radiates into the air. In the larger sizes the tank sides are corrugated or "ruffled" to provide additional radiating surface.

Standard Distribution Transformer Sizes. Distribution transformers are made in the following standard sizes: 1½, 3, 5, 7½, 10, 15, 25, 37½, 50, 75, 100, 150, and 200 kva. Transformers larger than 200 kva are classed as power transformers. A kilovolt-ampere is the same as a kilowatt when the power factor is unity. When the power factor is less than unity, the number of kilowatts is less than the number of kilovolt-amperes and is equal to the kilovolt-amperes times the per cent power factor.

Types of Transformer Construction. As no single type of construction is apt to be satisfactory over the wide range of capacity mentioned above, every manufacturer has his own type for the various ratings. Of all the forms used, two types of construction are outstanding: the core

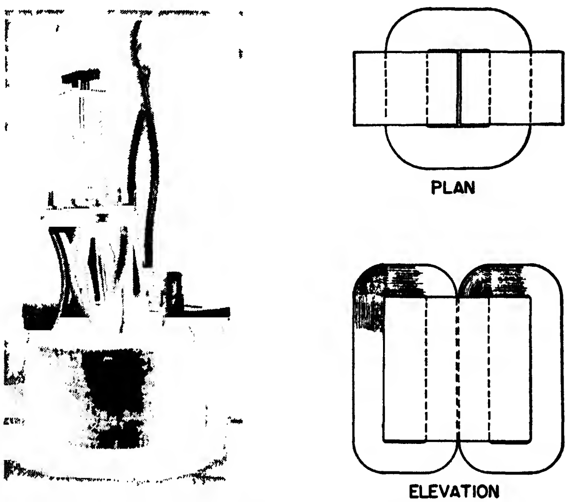


FIG 5-4. Views illustrating shell type of transformer construction. (*Courtesy Westinghouse Electric Corp.*)

and the shell type. In the core type the core is in the form of a rectangular frame with the coils placed on the two vertical sides (see Fig. 5-3). The coils are cylindrical and relatively long. They are divided, part of each primary and secondary being on each of the two vertical legs. In the shell type (Fig. 5-4), the core surrounds the coils, instead of the coils surrounding the core. The coils in the shell type are generally flat instead of cylindrical, and the primary and secondary coils are alternated.

Figure 5-5 shows a distribution transformer with the hanger irons attached; these are used for hanging the transformer on the crossarm of the pole. In Fig. 5-6 the cover is removed, showing primary leads above and secondary leads below. It will be noticed that the primary leads are better insulated than the secondary, because they operate at a higher voltage.

Transformer Connections. *Single-phase.* The usual connections of single-phase transformers met in practice are those shown in Figs. 5-7 to 5-9. In the first two cases the transformer is tapped to 2,400-volt three-phase three-wire mains, and in the last case to 4,160-volt three-phase four-wire mains. In the latter case the voltage from any line wire to the neutral wire is the line voltage divided by 1.73, which in this case

FIG. 5-5. Distribution transformer equipped with hanger iron for mounting on crossarm. The transformer brackets can also be used for direct to pole mounting by means of through bolts. Transformer is rated 5 kva, 60 cycles, 2,400 volts primary and 120/240 volts secondary. (*Courtesy General Electric Co.*)

gives 2,400 volts. The standard 2,400-volt distribution transformer can therefore be used here as well as on the 2,400-volt mains.

The secondary coils of the transformer can be connected to give either

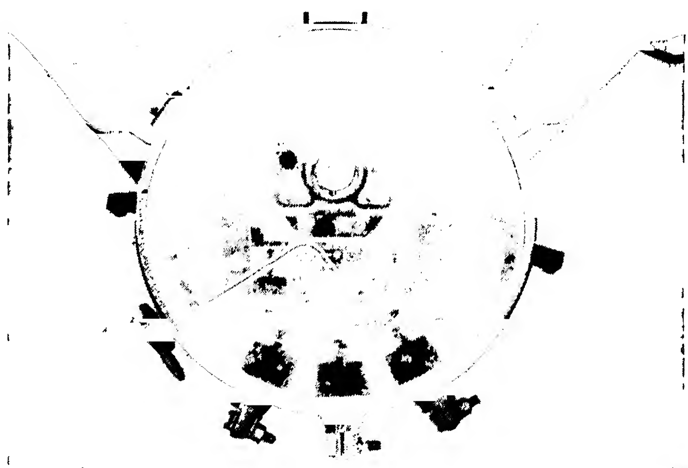


FIG. 5-6. Interior view of single-phase distribution transformer showing arrangement of equipment. The transformer is rated 10 kva, 60 cycles, 7,200 volts primary and 120/240 volts secondary. (*Courtesy General Electric Co.*)

120-volt two-wire or 240/120-volt three-wire mains. To obtain 120 volts the coils are connected in parallel as shown in Fig. 5-7, and to obtain 240 volts the coils are connected in series as shown in Figs. 5-8 and 5-9. Figure 5-10 illustrates even more clearly how the secondary coils can be connected to obtain the various secondary voltages.

Secondary connections on modern transformers are now made inside the transformer tank, as shown in Fig. 5-11.

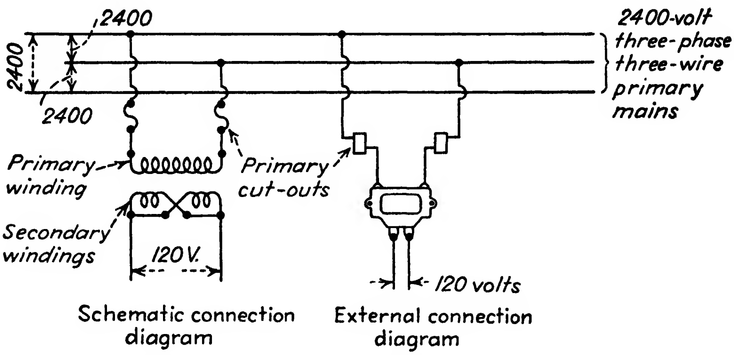


FIG. 5-7. Single-phase transformer connected to give 120-volt two-wire secondary mains. The two secondary coils are connected in parallel.

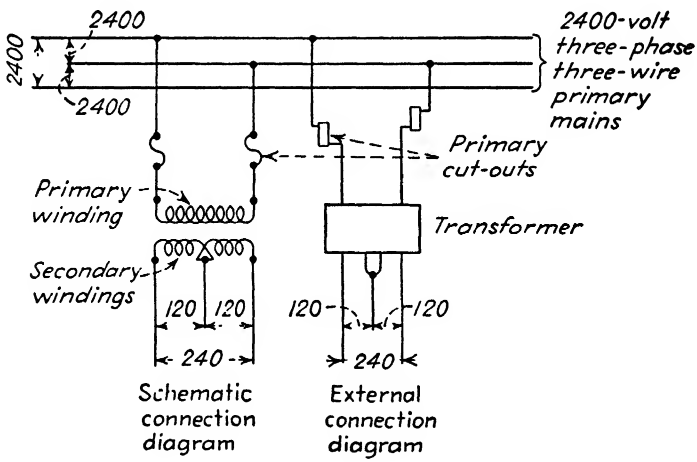


FIG. 5-8. Single-phase transformer connected to give 240/120-volt three-wire secondary mains. The two secondary coils are connected in series.

Three-phase. Standard single-phase distribution transformers are also connected into three-phase banks to deliver power to medium-sized power users. There are four possible connections, the delta-delta, Y-Y, delta-Y, and Y-delta, the first referring to the connection of the primaries and the second to the connection of the secondaries. Of the four possible connections, the two that are in most common use in distribution sys-

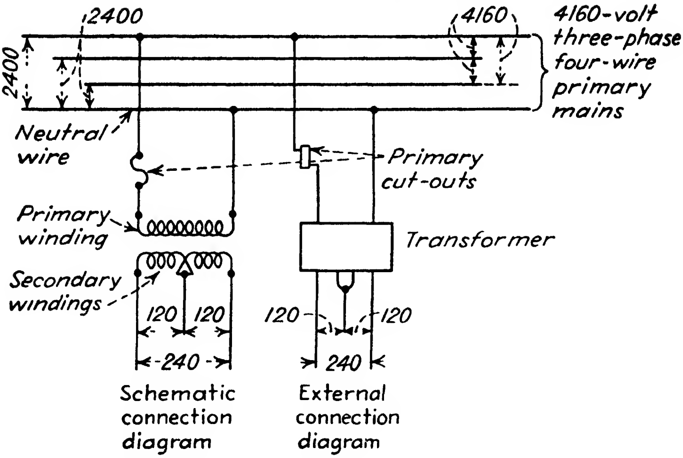


FIG. 5-9. Standard single-phase transformer connected from one line wire to neutral wire. Lead from neutral is not fused.

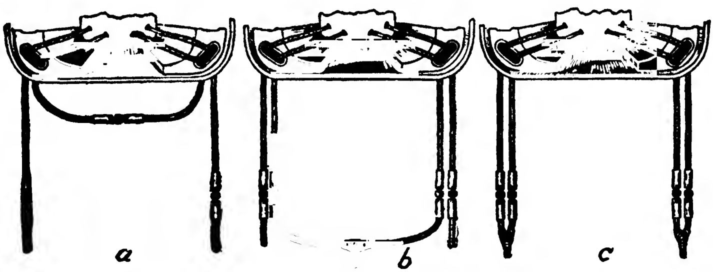


FIG. 5-10. Views illustrating the various combinations of transformer secondary-coil connections for various secondary voltages. (*a*) Connection for 240-volt, two-wire service. (*b*) Connection for 240/120-volt three-wire service. (*c*) Connection for 120-volt two-wire service.

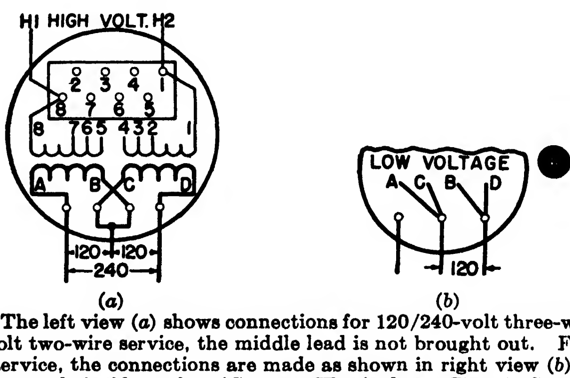


FIG. 5-11. The left view (*a*) shows connections for 120/240-volt three-wire service. For 240-volt two-wire service, the middle lead is not brought out. For 120-volt two-wire service, the connections are made as shown in right view (*b*). All connections are made inside tank. (*Courtesy Westinghouse Electric Corp.*)

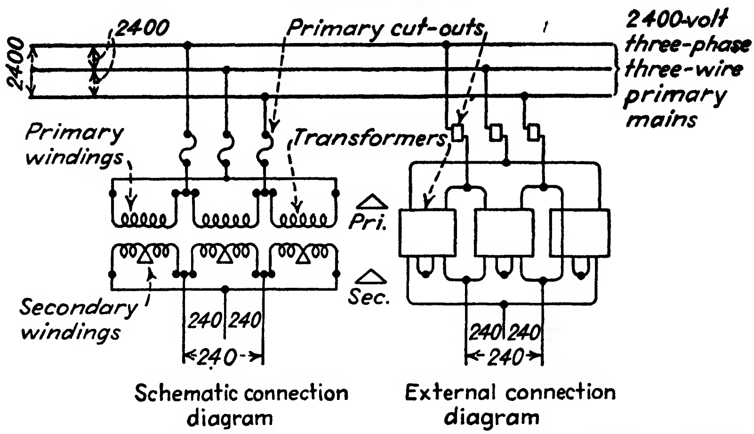


FIG. 5-12. Three single-phase transformers connected into a three-phase bank to transform power from 2,400 volts three phase to 240 volts three phase. Primaries and secondaries are connected delta.

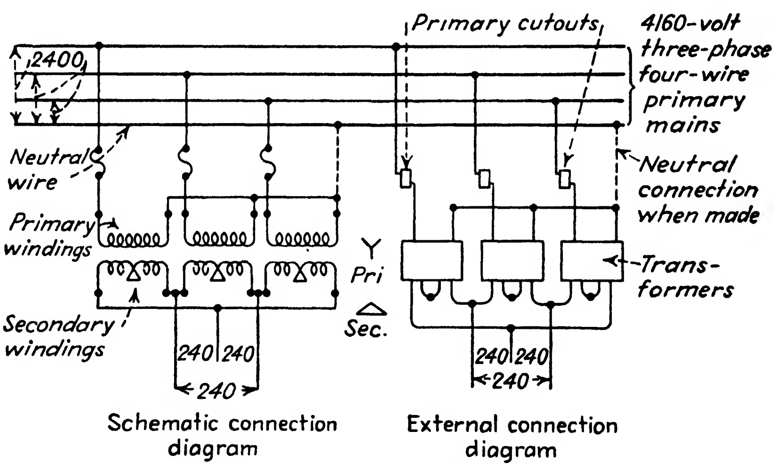


FIG. 5-13. Three standard single-phase transformers connected into bank to transform from 4,160 volts three phase to 240 volts three phase. Primary windings are connected Y, and secondary windings are connected del.a. Most companies do not connect neutral point of Y to neutral wire.

tems are the delta-delta and the Y-delta, because they permit the use of standard 2,400-volt transformers. Figure 5-12 shows the primaries connected delta onto 2,400-volt mains and the secondaries connected delta; Fig. 5-13 shows the primaries connected Y or star onto 4,160-volt mains and the secondaries connected delta. It will be recalled that a delta connection is obtained by connecting the three phases into a delta or in series and tapping off at the junctions for the lines. The Y is obtained by connecting a corresponding lead from each of the three phases together and using the remaining three free ends for the lines.

In Fig. 5-13 the neutral of the Y can be connected to the neutral wire of the line, but many companies prefer not to do this. The connection is made only when the load on the secondaries of the bank is greatly unbalanced. The reason companies do not usually make this connection is that when the neutral is connected the bank of transformers tends to balance up any other unbalanced load on the line in that vicinity. Therefore, if the neutral is to be connected, the bank must be large enough to carry its own load plus the additional load imposed by the remaining unbalanced load on the line. It is the practice of many companies, moreover, to regulate the voltage on each line separately by means of feeder regulators. If this is done, the unbalance is even greater.

Open Delta. If one of the transformers from a delta-connected bank is removed, the remaining two are said to be "open-delta connected."

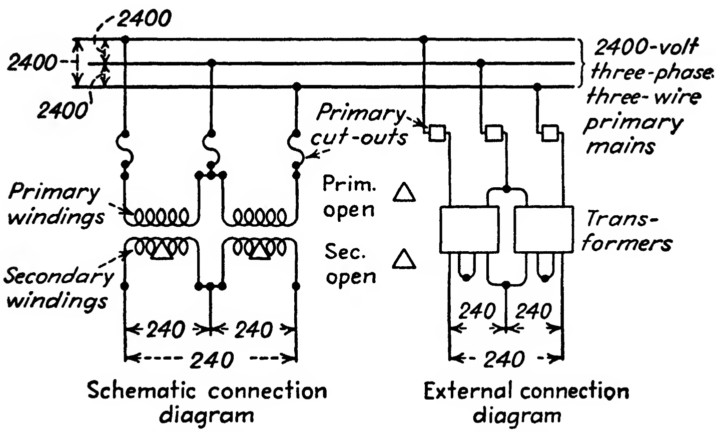


FIG. 5-14. Two single-phase transformers connected into a bank to transform power from 2,400 volts three phase to 240 volts three phase. Primaries and secondaries are connected open delta.

This can be done, and the remaining two transformers will still transform the voltages in all three phases and supply power to all three phases of the secondary mains. The connections for a 2,400-volt circuit are shown in Fig. 5-14. The capacity of the two is now, however, only 58 instead of 66⅔ per cent of what it would appear to be with only two transformers remaining. This connection is often used where an increase in load is anticipated. The third unit is added when the load grows to the point where it exceeds the capacity of the two transformers. Furthermore, if one transformer of a three-phase bank should become defective, this transformer can be removed, and the remaining two continue to render partial service.

Polarity. In connecting transformers in parallel or in a three-phase bank, it is important to know the polarity of the transformer terminals or leads. In building transformers in the factory, the ends of the windings can be so connected to the leads extending out through the case that the direction of the flow of current in the secondary terminal with respect to the corresponding primary terminal is in the same direction or in the opposite direction. When the current flows in the same direction in the two adjacent primary and secondary terminals, the polarity

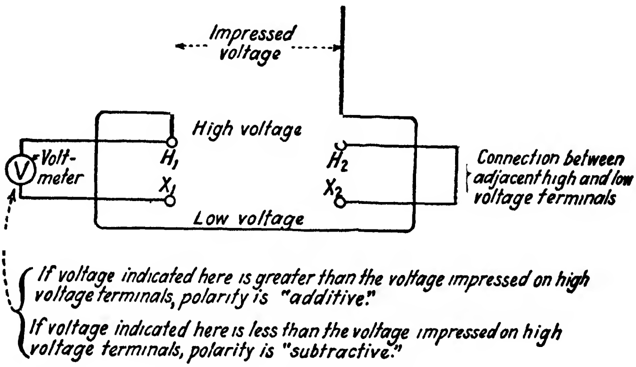


FIG. 5-15.

of the transformer is said to be "subtractive," and when the current flows in opposite directions, the polarity is said to be "additive."

Polarity may be further explained as follows: Imagine a single-phase transformer having two high-voltage and two low-voltage external terminals. Connect one high-voltage terminal to the adjacent low-voltage terminal, and apply voltage across the two high-voltage terminals. Then if the voltage across the unconnected high-voltage and low-voltage terminals is less than the voltage applied across the high-voltage terminals, the polarity is *subtractive;* while if it is greater than the voltage applied across the high-voltage terminals, the polarity is *additive* (see Fig. 5-15).

From the foregoing, it is apparent that, when the voltage indicated on the voltmeter is greater than the impressed voltage, it must be the sum of the primary and the secondary voltages, and the sense of the two windings must be in opposite directions, as in Fig. 5-16. Likewise, when the voltage read on the voltmeter is less than the impressed voltage, the voltage must be the difference, as is illustrated in Fig. 5-17. When the terminal markings are arranged in the same numerical order, H_1H_2 and X_1X_2 or H_2H_1 and X_2X_1, on each side of the transformer, the polarity of each winding is the same (subtractive). If either is in reverse order, H_2H_1 and X_1X_2 or H_1H_2 and X_2X_1, their polarities are opposite (additive).

Polarity of Distribution Transformers. Distribution transformers have for many years been made with additive polarity, while larger units have as a rule been made with subtractive polarity. The name plate of a single-phase transformer should always indicate the polarity of the transformer to which it is attached.

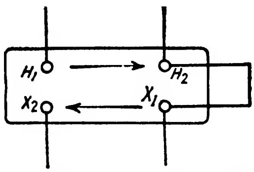


FIG. 5-16. Sketch showing polarity markings and directions of voltages when polarity is additive.

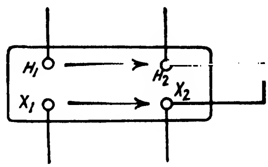


FIG. 5-17. Sketch showing polarity markings and directions of voltages when polarity is subtractive.

A joint committee of the Edison Electric Institute and the National Electrical Manufacturers Association made the following recommendations:

1. Additive polarity shall be standard for all single-phase transformers in sizes of 200 kva and below, having high-voltage ratings of 9,000 volts and below.
2. Subtractive polarity shall be standard for all single-phase transformers in sizes above 200 kva irrespective of voltage rating.
3. Subtractive polarity shall be standard for all single-phase transformers in sizes of 200 kva and below having high-voltage ratings above 9,000 volts.
4. Low-voltage terminal designations shall be in accordance with Fig. 5-18.

Use of Polarity Marking in Connecting Transformers. *Single-phase.* When connecting two or more single-phase transformers in parallel, the terminals with the same markings should connect to the same lines. This will give correct results without testing. This rule is illustrated in Fig. 5-19.

Three-phase. Figure 5-20 gives the common three-phase connections. The transformers are all of *additive* polarity. When transformers are connected in accordance with these terminal markings, the work should be correct, but it is well to make the tests outlined in Sec. 15 as a safety precaution.

Connecting Banks in Parallel. When two banks are to be connected in parallel, it is necessary to check the relative polarity of the two banks before connecting them. This may be done by connecting the second bank on the high-tension side and then connecting one of the low-tension terminals to the common bus bar; then with a voltmeter or with potential transformer and voltmeter, measure the voltage between the other two terminals and the respective buses with which they are to connect and observe the following rules:

If the polarities are alike, the voltmeter will read zero in each case.

If the polarities are reversed, the voltmeter will read double the secondary voltage. To correct the connection, reverse the connection

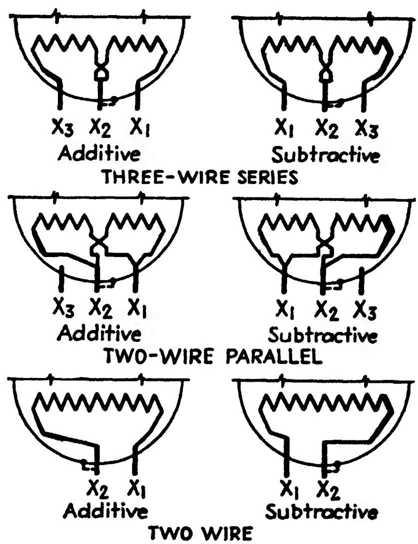


FIG. 5-18. Standard low-voltage connections for distribution transformer.

of the low-tension leads of each transformer in the second bank. In the case of three-phase transformers, it may be found most convenient to reverse the connections of the high-tension coils.

Matching Impedances. Transformers connected in parallel or in banks should as far as possible have the same per cent impedance. The per cent impedance is given on the name plate. Making the impedances the same is called "matching." Unmatched transformers in Y or delta banks cause circulating currents to flow, and unmatched transformers in parallel will not divide the load in proportion to their ratings.

Grounding of Transformer Secondaries. The term "ground" is used in electrical work to refer to the earth as the zero of potential. A ground actually consists of an artificial electrical connection to the earth, having a very low resistance to the flow of electric current. To ground a circuit or apparatus, therefore, means to connect it to the earth. For the sake of safety to life and property, all low-voltage secondary circuits must be grounded. The points to be grounded in the various kinds of secondary

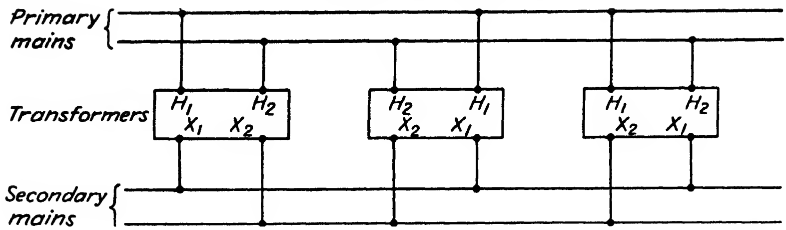


FIG. 5-19. Sketch illustrating manner of connecting single-phase transformers in parallel in accordance with polarity markings on transformer terminals.

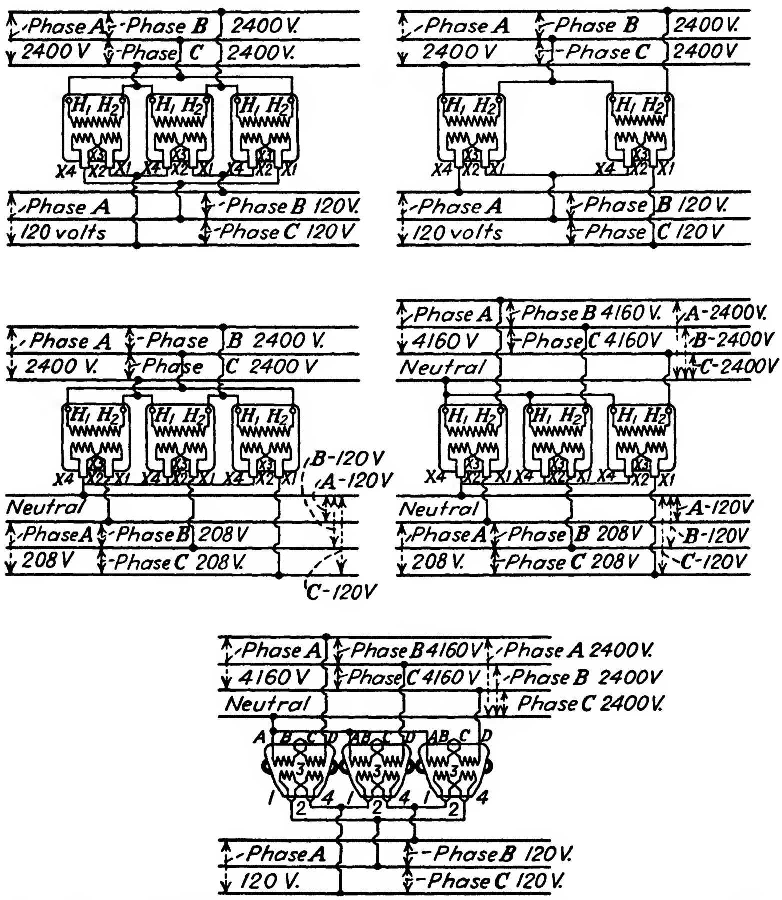


FIG. 5-20. Three-phase transformer connections showing polarity markings. All connections shown are for 2,400-volt transformer primaries, with secondaries arranged for 20 to 1 ratio. To change secondary for 240 volts or for 10 to 1 ratio, disconnect X_2 and X_3 from X_1 and X_4 and then connect X_2 and X_3 together.

mains are shown in Fig. 5-21. As will be seen from the figure, the proper place to connect the ground lead to a single-phase three-wire secondary is the neutral wire. If the secondary is a two-wire secondary, either of the two wires should be grounded. In a three-phase bank, the neutral

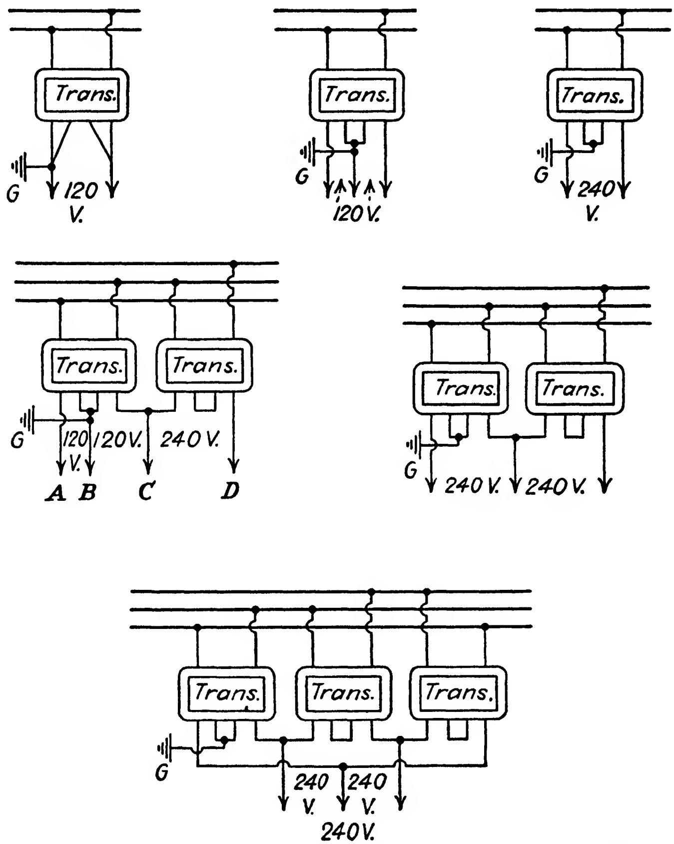


FIG. 5-21. Proper places to connect ground lead to various transformer connections.

of one of the transformers should be grounded. This holds for either delta or star connection.

The connection is made to the secondary circuit at the top of the pole, and the ground connecting wire is run down the pole to the base where it connects onto a pipe which has been driven into the ground at least 8 ft. Figure 5-22 illustrates a pipe used in making the ground connection. The pipe must be driven deep enough so that it is in moist soil all year round.

Reason for Grounding. The reason for grounding the low-voltage secondary circuit is to guard against an excessive voltage being impressed on that circuit from some external source. A conductor of the primary mains may break and fall upon the secondary conductors below it. The greatest danger, however, exists in the breaking down of the insulation in the distribution transformer, thereby bringing the secondary winding in contact with the high-voltage primary winding. If a person should

FIG 5-22 Typical pipe used for making ground connection (*Courtesy Hubbard & Co*)

then touch a bare part of the secondary circuit and should also happen to be in contact with a radiator, bathtub, gas range, or water faucet, he would be likely to receive a very severe shock Furthermore, any excessive voltage on the low-voltage fittings in lamp sockets, etc., is very apt to cause fire. If the secondary is grounded, however, a breakdown in the transformer insulation or other high-tension cross is very apt to blow the primary transformer fuses, thereby clearing the defective circuit from the source.

A secondary circuit whose voltage is greater than 250 volts is, as a rule, not grounded because it is easier to get a shock from a grounded circuit than from one ungrounded. Shocks from circuits in excess of 250 volts may prove serious.

Determining Transformer Size. The transformer capacity required to supply any given load may be estimated as follows:

Residential Loads. Residential loads may be estimated in accordance with Table 5-1, which gives the watt demand per house. As the table shows, a small house is taken as having a demand of 500 watts, a medium-sized house 1,000 watts, and a large house 1,500 watts. To determine the entire load on the transformer, add the average demand,

TABLE 5-1. WATTS DEMAND FOR RESIDENCES TO BE USED IN DETERMINING SIZE OF TRANSFORMER REQUIRED

Size of House	Watts Demand
Small	500
Average	1,000
Large	1,500

as given above, for all the residences to be served by the given transformer. The total will be the required volt-ampere rating of the transformer. Divide this by 1,000, and the result represents the transformer kilovolt-amperes capacity acquired.

Commercial Lighting. In determining the size of transformer necessary for commercial-lighting customers, such as stores of all kinds, it is first necessary to add the total connected load. This requires making a list of all lights, fans, etc., together with the wattage of each. The sum is the total connected load on the transformer. The average demand on the transformer will be 40 to 60 per cent of the connected load, depending on individual cases. This demand represents the necessary transformer capacity.

Heating and Cooking Loads. Heating and cooking loads based on ranges of 5,000-watt rating require transformer capacities as given in Table 5-2. It will be noted that the size of the transformer does not

TABLE 5-2. TRANSFORMER KILOVOLT-AMPERE CAPACITY REQUIRED FOR VARIOUS NUMBERS OF RANGES SERVED FROM THE TRANSFORMER

Number of Ranges	Minimum Size of Transformers, Kva
1	5
2 to 4	15
5 to 7	25
8 to 11	37.5

increase directly with the number of range customers. This is due to the fact that the ranges are usually not all in use at the same time. Ranges should not be connected to the secondaries more than three spans from a transformer in order to keep the voltage drop at a minimum.

Motor Loads. The transformer capacity required for motor loads is best found from the motor ratings. Add the ratings of all the motors to be supplied from one transformer or bank of transformers. Then from Table 5-3 obtain the proper percentage for the number of motors. Multiply the actual connected load by this percentage. The result is the required transformer capacity. Select the next larger standard rating.

If the transformer bank is to be open-delta connected, multiply the rating as found above by 1.35 before selecting the transformer rating required.

TABLE 5-3. PERCENTAGES BY WHICH TO MULTIPLY TOTAL CONNECTED MOTOR LOAD TO OBTAIN REQUIRED TRANSFORMER KILOVOLT-AMPERE CAPACITY
(Percentages for various numbers of motors and magnitude of connected load)

Total connected load, hp	Percentages for calculating kilovolt-ampere demand from the normal rated capacity of motors					
	1 motor	2 motors	3–5 motors	6–10 motors	11–20 motors	20 or more motors
Less than 10	83	81	75	73		
10 to 50	78	76	70	68	67	65
50 to 100	74	72	65	62	61	60
100 to 300	72	70	61	59	58	57
Over 300	70	69	58	56	55	54

Annual Load Checks. When a new subdivision in an urban area is first supplied with electric service, the smallest transformer size used by the utility is installed. This may be a 3- or a 5-kva size. This is done when the first house is connected to the secondary. If the 5-kva transformer size is used, it may remain adequate until as many as 10 houses are connected. When the load has built up to nearly full transformer rating, annual load measurements are made on the transformer to see what the actual load is. If the load has exceeded the transformer rating, a larger transformer is installed on the same secondary, or the secondary is split into sections and an additional transformer is installed on each section.

The transformer overload indicators described in Sec. 1 are also helpful in indicating when full-load rating has been reached.

Selecting Distribution Transformer Location. To determine both the size and the location of a transformer, it is best to draw a sketch of the section of line to be fed from the transformer. The sketch should show the location of each pole, the number of services to be fed from each pole, and the kilowatt demand on each service. A typical sketch is shown in Fig. 5-23. The kilowatt demand on each service is fixed by the size of the house, etc., as was explained above. The total load to be supplied by this transformer is 32 kw. Hence a 37.5-kw transformer should be installed because it is the next largest standard size.

Steps in Calculation. After a sketch is prepared, the load to be supplied from each pole is computed. This is done by adding the loads on the several services radiating from a given pole. These values of kilowatt load per pole are shown in the top row of figures in the sketch.

Now assume that the transformer is located at some central point, as at T_1. To check whether T_1 is the best location, the products of the number of spans times the loads per pole are added for both right and

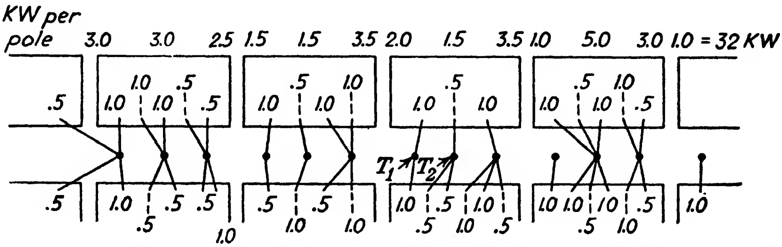


FIG. 5-23. Sketch of typical section of residential district to be served by one transformer. Sketch shows poles, services, and kilowatt demand on each service.

left sides of the pole. If these are the same, the transformer is properly located. In the example given, the kilowatt spans for the left side are 54.0 and for the right side 52.5, as shown in Table 5-4. Since the kilowatt-spans on both the right and left side are approximately equal, T_1 is the proper location for the transformer on this secondary. The

TABLE 5-4. SAMPLE CALCULATION FOR CHECKING OF PROPER LOCATION AT T_1

To Left of Pole T_1				To Right of Pole T_1			
Kw	Spans		Kw Spans	Kw	Spans		Kw Spans
3.5	× 1	=	3.5	1.5	× 1	=	1.5
1.5	× 2	=	3.0	3.5	× 2	=	7.0
1.5	× 3	=	4.5	1.0	× 3	=	3.0
2.5	× 4	=	10.0	5.0	× 4	=	20.0
3.0	× 5	=	15.0	3.0	× 5	=	15.0
3.0	× 6	=	18.0	1.0	× 6	=	6.0
			54.0				52.5

pole location giving the nearest balance in the total right and left kilowatt spans is the proper location for the transformer.

If the transformer location, however, falls on a buck arm, junction, or street-light pole, the transformer should be placed on the next pole in order to avoid congesting the pole.

It should be pointed out that the load connected to the transformer pole does not enter into the calculations for determining the transformer location. It must, however, be included in calculating the size of the transformer required.

FEEDER-VOLTAGE REGULATOR

Purpose. The function of a feeder-voltage regulator is to maintain constant voltage on an alternating-current feeder with variations in load. When the load on the feeder is large, large currents flow in the line, and a considerable drop in voltage occurs in the line, making the voltage across the primary mains at the distribution center less than normal.

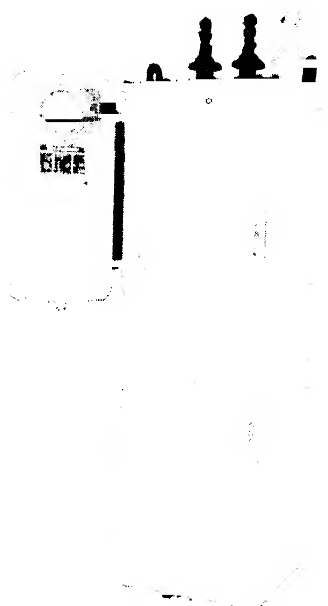


FIG. 5-24. Substation-type feeder-voltage regulator. (*Courtesy Westinghouse Electric Corp.*)

FIG. 5-25 Thirty-two step automatic feeder-voltage regulator for pole or platform mounting. The control cabinet can be removed for separate mounting at the base of the pole or on the regulator support lugs. (*Courtesy General Electric Co.*)

The feeder regulator is employed to keep the voltage at normal value at all times. A typical feeder regulator is shown in Fig. 5-24. The regulator is usually installed at the origin of the feeder, that is, in the generating station or substation. A special pole-type tap-changing regulator (Fig. 5-25) is often used on long, lightly loaded branch feeders. This regulator is mounted on poles the same as distribution transformers.

Principle of Operation. A feeder-voltage regulator is essentially a voltage transformer like those described in Sec. 1. The primary or shunt winding, which is also the high-voltage winding, is connected across the line in the same way as in an ordinary transformer (see Fig. 5-26). The secondary or series winding is the low-voltage winding and is connected in series with the line. The shunt winding is arranged so that it can be rotated on an axis. The series winding is stationary. Figure 5-27 shows the windings in their relative positions.

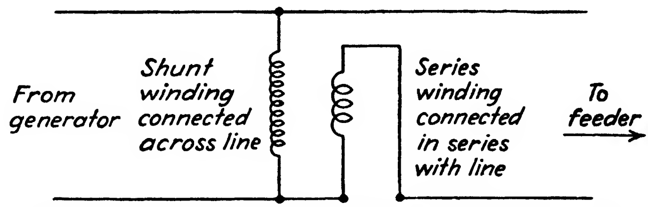


FIG. 5-26. Connections of single-phase feeder-voltage regulator.

The voltage induced in the series winding depends upon the position of the shunt winding. When the shunt winding is turned in one direction, the voltage induced in the series winding is large and is in such a direction as to add to the voltage of the line, thus raising the voltage of the feeder. When the shunt winding is turned in the opposite direction, the induced voltage in the series winding has the same value, but this time the voltage will be in such a direction as to reduce the feeder

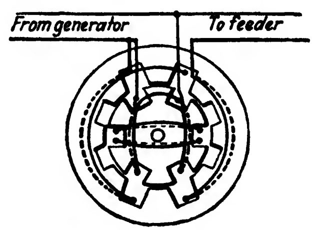


FIG. 5-27. Arrangement of shunt and series windings in a single-phase voltage regulator. (*Courtesy General Electric Co.*)

voltage. Any intermediate position of the shunt winding between these limits will increase or decrease the feeder voltage by a correspondingly smaller amount. The curve shown in Fig. 5-28 gives the values of voltage above and below 2,300 volts for different positions of the primary coil. It will be noted that the regulator can boost the feeder voltage to 2,600 volts or reduce it to 2,000 volts. This amounts to a boost and a reduction, respectively, of 300 volts. In case of a large load on the feeder, the coil will be rotated in the direction to boost the feeder voltage, thereby bringing it up to normal. In case of light load or no load, the coil will be rotated in the opposite direction. The voltage induced in the secondary will then buck the line voltage and thus keep it down to its normal value.

Method of Control. The shunt coil may be turned by hand or automatically by means of a motor. The latter method is practically the

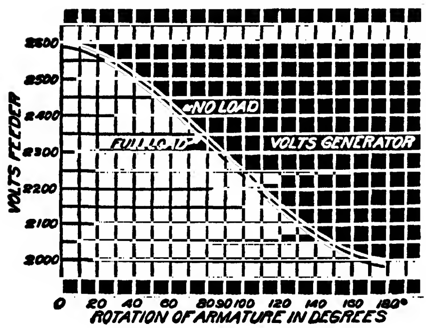


FIG. 5-28. Curves showing boosting and lowering of feeder voltage by voltage regulator. (*Courtesy General Electric Co.*)

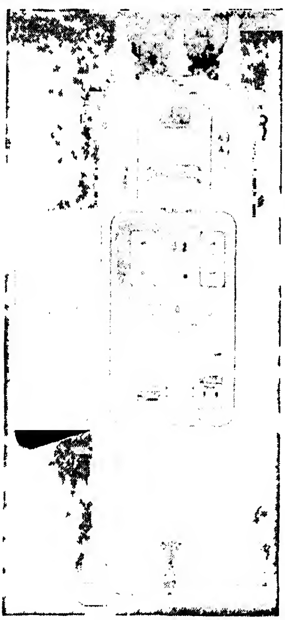


FIG. 5-29. Single-phase automatic induction-voltage regulator for indoor and outdoor service, with control cabinet door open to show accessibility of all control devices. (*Courtesy General Electric Co.*)

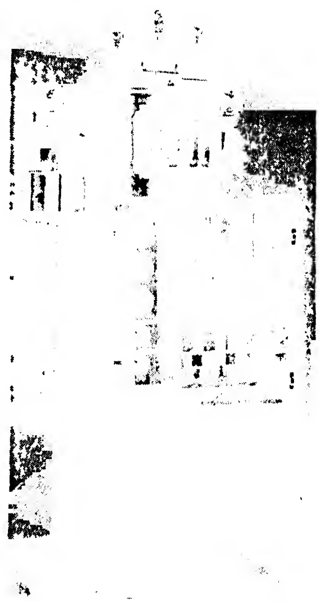


FIG. 5-30. Thirty-two-step feeder-voltage regulator designed for pole or platform mounting. Each step changes the voltage by 5/8 per cent, making the total change 20 per cent, or plus or minus 10 per cent. The regulator is essentially a transformer having the low-voltage secondary winding connected in series with the line and so arranged that the number of turns in the winding can be varied by changing the tap connection. (*Courtesy Maloney Electric Co.*)

only method used today. In the automatic control the regulator is provided with a contact-making relay, a double-pole double-throw switch, and a motor mounted on the regulator and geared to the axis of the rotating coil. This equipment is shown in Fig. 5-29.

Automatic Operation. In general, the operation is as follows: When the voltage of the feeder is normal, the plunger of the contact-making relay is in its middle position, the switch in the motor line is open, and the regulator is neither bucking nor boosting the voltage. When the voltage of the feeder drops, the relay plunger drops. This closes the switch in the motor circuit to make the motor revolve in a direction to boost the voltage. The motor revolves until the voltage is raised to the value which will lift the relay plunger to its medium position. If the voltage should rise above normal, the relay plunger would rise above its medium position, thereby closing a contact above. Closing this contact closes the motor switch in the opposite direction, thereby reversing the direction of the motor. The regulator will now buck the voltage and lower it to normal value. In every case, the shunt winding is revolved until the voltage is brought to its normal value.

Tap Changer or Step Regulator. Another type of feeder-voltage regulator is the "tap changer" or step regulator. Instead of having a movable winding as in the induction type, the voltage is changed by changing the number of turns in the secondary winding. The "tap-changing" switch is motor driven and is immersed in oil. A reversing switch provides the 10 per cent regulation on either side of the regulator neutral position. A typical tap-changing regulator is shown in Fig. 5-30.

OUTDOOR METERING EQUIPMENT

Purpose. The metering equipment that linemen should also be familiar with is that used for supplying service from transmission lines where the expense of a substation is not warranted. Feeders are often run from a transmission line at points between substations. Since the feeder voltage is then the same as the transmission-line voltage, the metering equipment used to measure the power flowing over these feeders must be designed for high voltage. Outdoor metering equipments are also frequently used in connection with outdoor substations to measure the power supplied to the various feeders.

Construction. Such metering equipments are built very compactly and for a three-phase circuit usually contain two potential transformers, two current transformers, and suitable metering devices. The metering devices may comprise a watthour meter, a demand meter, and perhaps graphic voltmeters, wattmeters, etc. The one meter always included is the watthour meter as it measures the kilowatthours of energy consumed for which the consumers on the line must pay. The potential and current transformers, commonly called "instrument transformers," are usually in a separate compartment, and the meters are in another compartment. In this way the high-voltage leads are separated from the low-voltage leads and it is not possible to come in contact with the high-voltage leads. The compartment that contains the instrument transformers is filled with oil for the higher voltages. For voltages below 15,000 volts, the outfit can be mounted on poles, the same as distribution transformers, and above that voltage it is mounted on platforms. Brief descriptions of potential and current transformers and of demand meters will now be given. Wattmeters and watthour meters were discussed in Sec. 1.

CURRENT TRANSFORMERS

Purpose. When a large alternating current is to be measured, the ammeter is not connected into the line but, instead, is connected into the circuit through a current transformer (see Fig. 5-31). Or, if a current is to be measured in a very high-voltage circuit, the ammeter is

FIG. 5-31. Typical current transformer. The heavy upper terminals are connected in series with the line, and the two small terminals under the cover connect to the ammeter. (*Courtesy Westinghouse Electric Corp.*)

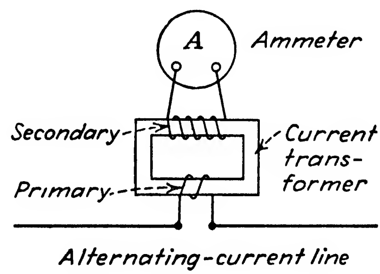


FIG 5-32 Ammeter and current transformer in alternating-current line.

again connected to the line through a current transformer. The use of a current transformer in a circuit carrying large alternating currents makes possible the use of a small ammeter, usually a 5-amp ammeter; in the case of a high-voltage circuit, the use of the current transformer insulates the ammeter from the high voltage of the line, thus making it safe to handle the ammeter.

Principle of Operation. A current transformer is similar in its operation to the voltage transformer described in Sec. 1. It, however, does not have its primary winding connected across the line but, instead, has it connected in series in one side of the line, as shown in Fig. 5-32. Standard practice today is to design all current transformers so that 5 amp will be flowing in the secondary when full-load current flows in the primary. Consequently, ammeters generally read 5 amp when full-load current is flowing in the line in which the current transformer is connected. For example, a current transformer designed for 1,000 amp in its primary would supply only 5 amp to an ammeter connected in its secondary when 1,000 amp are flowing in the primary. Such a transformer would have a ratio of 1,000 to 5, or 200 to 1.

Use with Relays. Current transformers are also used to supply current to the overload trip coils of oil switches, to the current coils of wattmeters, and to protective relays of all kinds. When they are used to supply current to the overload trip coils of oil switches, they are connected as shown in Fig. 7-11. If the current in the line exceeds normal value, more than 5 amp will flow in the secondary and, therefore, also through the trip coil. The trip coil will then pull up its plunger and trip the switch. The switch will be opened suddenly by the spring against which it was closed.

POTENTIAL TRANSFORMERS

Purpose. An instrument potential transformer is a small-capacity power transformer (see Fig. 5-33). It is used on circuits of 1,100 volts

FIG 5-33 Typical potential transformer The upper two well-insulated leads are connected to the line The lower two terminals near the bottom are connected to the voltmeter (*Courtesy Westinghouse Electric Corp.*)

and above to supply a reduced voltage to voltmeters, to the potential coil of wattmeters, and to the low-voltage releases of oil switches. If voltmeters or wattmeters were directly connected to high-voltage lines ranging from 2,400 to 330,000 volts, they would be exceedingly dangerous to read, and they would have to be well insulated. The use of potential transformers, however, makes possible the use of standard 150-volt voltmeters and 150-volt potential coils on wattmeters, and also insulates these meters from the line, thereby making them safe to handle.

Connections. The connections of the potential transformer and voltmeter on a 2,400-volt line are shown in Fig. 5-34. To arrive at the

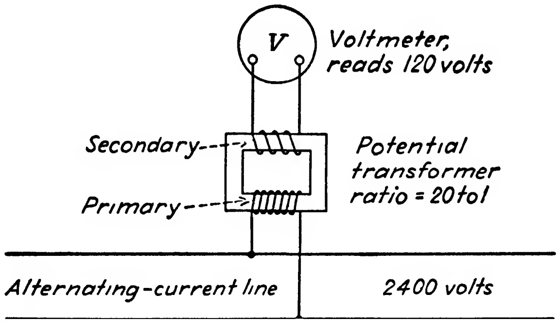


FIG. 5-34. Voltmeter and potential transformer in alternating-current line.

actual value of the line voltage, the reading of the voltmeter must be multiplied by the transformer ratio of the potential transformer. If, for example, a switchboard voltmeter reads 120, and the ratio of transformation of the potential transformer to which it is connected is 20, then the line voltage is 120 times 20, or 2,400 volts.

DEMAND METER

Purpose. The purpose of a demand meter is to record the greatest amount of power used over an interval of time of prescribed length, usu-

FIG 5-35. Combined watthour meter and demand meter. Kilowatthours are read on dial register, and kw demand is read by maximum position of pointer on circular scale. (*Courtesy General Electric Co.*)

ally 15, 30, or 60 min. Many rate schedules involve the maximum demand and, therefore, the demand must be measured.

Principle of Operation. Some meters for measuring the demand operate on the principle of a watthour meter, and others are in the form of an attachment to a watthour meter. The attachment-type watthour meter is illustrated in Fig. 5-35.

In the watthour demand meter there is a watthour meter and demand meter within one case. A pointer pusher is driven mechanically through a set of gears from the shaft of the watthour meter. At the end of each time interval, the pointer pusher is automatically returned to the zero position by a timing mechanism within the device, leaving the pointer at the maximum position which the pusher has reached during any such interval. The meter reader in addition to recording kilowatt-hours as shown by the integrating register also records the indication of the demand pointer which is in kilowatts and resets it to the zero position.

SECTION 6

Line-protective Equipment

Lightning. Everyone has seen lightning flashes (Fig. 6-1). These flashes are currents of electricity flowing from one cloud to another or from cloud to earth. They always flow by way of the path of least resistance, just as water takes the path of least resistance when it flows down the hillside. Such paths down the hillside are not generally straight but, on the contrary, are very crooked. The same is true of the

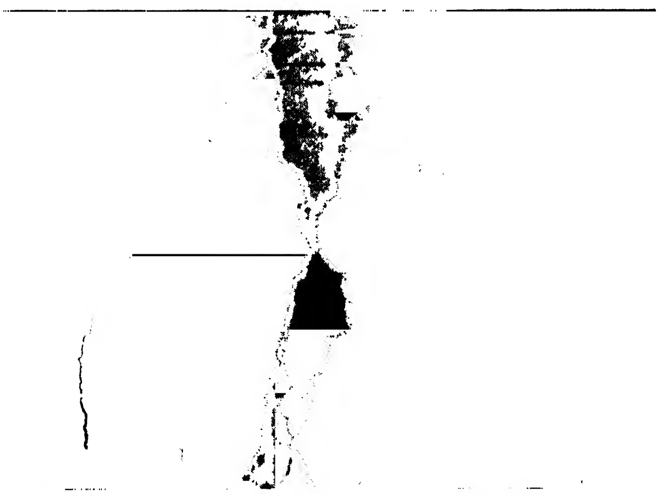


FIG. 6-1. Lightning flashes, illustrating zigzag path. Overhead distribution and transmission lines are in constant danger of being damaged by lightning. (*Courtesy General Electric Co.*)

path taken by a bolt of lightning; this fact explains the zigzag path of the flash. Trees, high buildings, towers, transmission lines, and poles are paths of less resistance than air, and therefore lightning often strikes them and flows through them to ground.

Overhead lines also have charges of electricity induced on them when charged clouds pass over them. Such charges are released when the cloud overhead is discharged as by a stroke to another cloud or to ground. When the charge is released, the voltage of the line is suddenly raised for a brief period of time. This abrupt rise of voltage is likely to be sufficient to cause insulators to flash over or to break down the insulation on the windings of transformers or other apparatus connected to the line.

Abnormal voltages on lines are also caused by the opening or closing of switches in the generating stations or substations connected to the line. These voltage surges and induced strokes are much more common than direct lightning strokes but are easier to protect against. Ground wires, lightning arresters, and protector tubes to be described below are the means used to protect electric circuits from these abnormal voltages.

GROUND WIRE

A ground wire on an overhead line is a galvanized steel or copper-clad steel cable strung along the line the same as other line conductors but is

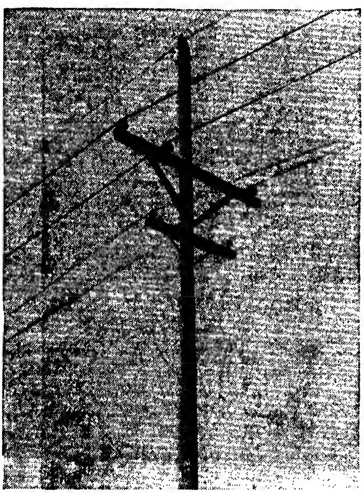


FIG. 6-2. Transmission line protected with ground wire supported on pole top. Ground wire is grounded at frequent intervals. (*Courtesy Iowa-Illinois Gas and Electric Co.*)

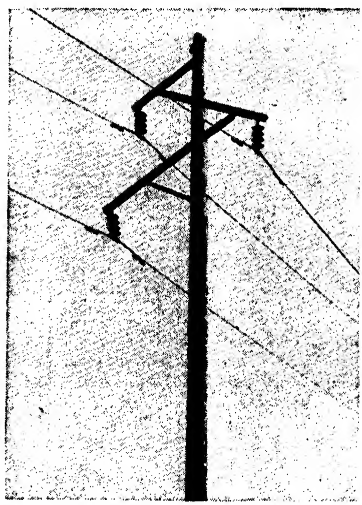


FIG. 6-3. 69,000-volt transmission line protected with overhead ground wire. Note use of Stockbridge dampers on conductors to reduce vibration. (*Courtesy Iowa-Illinois Gas and Electric Co.*)

mounted above the other conductors (see Figs. 6-2 and 6-3). The ground wire is not a part of any electrical circuit, however, but instead is connected to the earth at frequent intervals, at least every fifth pole, on pole lines. On steel tower lines it is grounded to each tower, by means of the metal clamp with which it is fastened. The ground or earth is thereby virtually brought above the transmission line and, hence, the stress on the insulators due to lightning is greatly reduced.

The chief purpose of the ground wire is to protect the insulators on the line. It is not practicable to protect insulators by means of lightning arresters, as the expense would be too great. Although the effectiveness of the ground wire is not 100 per cent, it is known to offer considerable protection. This has been verified experimentally.

LIGHTNING ARRESTERS

Purpose. Lightning arresters serve the same purpose on a line as a safety valve on a steam boiler. A safety valve on a boiler relieves a high pressure by blowing off steam until the high pressure is reduced to

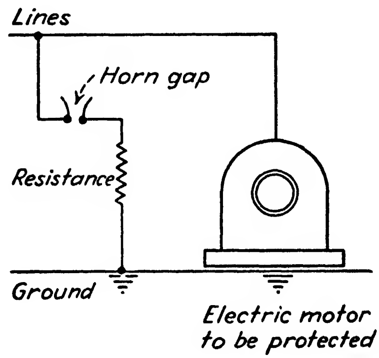


FIG. 6-4. Elementary lightning arrester consisting of horn gap and resistance.

normal. When it is down to normal, the safety valve closes again and is ready for the next abnormal condition. Such is also the operation of a lightning arrester. When a high voltage, greater than the normal line voltage, exists on the line, the arrester immediately furnishes a path to ground, and thus drains off the excess voltage. Furthermore, when the excess voltage is relieved, the action of the arrester prevents any further flow of power current. The function of a lightning arrester is, therefore, to provide a point in the circuit at which the lightning impulse may pass to earth without injury to line insulators, transformers, or other connected equipment.

Elementary Lightning Arrester. The elementary form of an arrester is a simple horn gap connected in series with a resistance, as shown in Fig. 6-4. A horn gap is the space that is formed between the two sides of a V when the lower point of the V is removed. One reason for providing the gap is to prevent current leakage when the voltage on the line is normal. If there were no lightning arrester protecting the motor shown in Fig. 6-4, the path of least resistance would likely be through the windings of the machine, to its frame, and then to ground. This, of course, would damage the machine by puncturing the insulation. If a lightning arrester in the form of a horn gap is connected from the line to the earth, however, it is likely that the lightning would find it easier to flow to ground by way of the arrester and thus leave the motor undamaged. While the high-voltage charge is being drained off, the current flow to ground is limited by the resistance in series with the horn gap

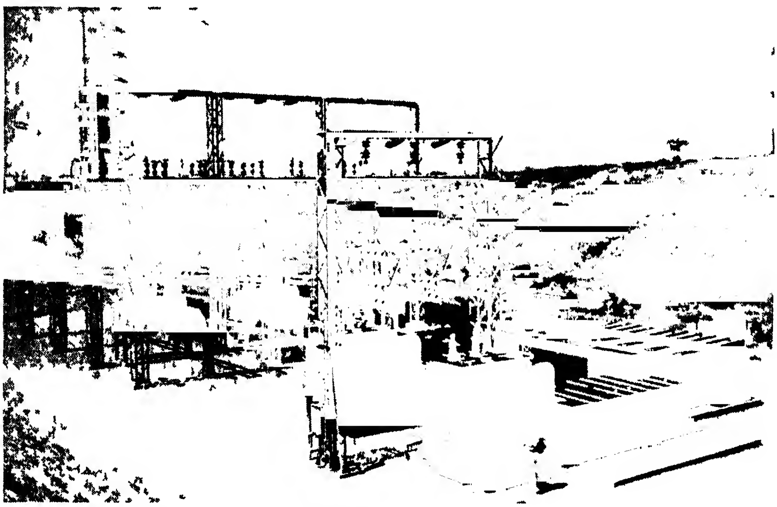


FIG 6-5. Two 7,500-kva three-phase transformers used as step-down transformer substation to reduce the transmission voltage of 67 000 volts to the distribution voltage of 4,160 volts Mounted in steel structure are high-voltage circuit breakers, disconnect switches, and lightning arresters Housed in metal cabinets are low-voltage metal-clad switchgear and metering equipments (*Courtesy General Electric Co*)

When the discharge has passed, the heat of the arc between the V gap creates an upward draft of air, which tends to carry the arc upward with it until it is stretched out to such a length that it breaks In addition the magnetic field on the inside of the V helps to force the arc upward. Thus it is clear that all this may be done without interrupting the load circuit

A lightning-arrester installation in an outdoor substation is shown in Fig. 6-5, and a close-up of thyrite lightning arresters is shown in Fig. 6-6.

Commercial types of lightning arresters are

1. Pellet
2. Autovalve
3. Thyrite
4. Granulon
5. Expulsion

FIG. 6-6. Close-up view of an installation of thyrite lightning arresters rated 46 kv. (*Courtesy General Electric Co.*)

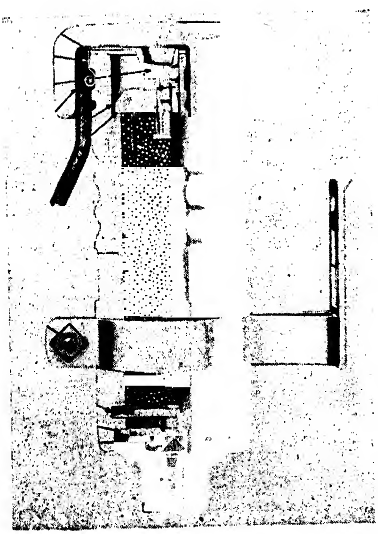


FIG. 6-7. Cross section of pellet arrester showing column of pellets in lower portion and series-gaps assembly in upper portion. Arrester is designed for pole mounting. (*Courtesy General Electric Co.*)

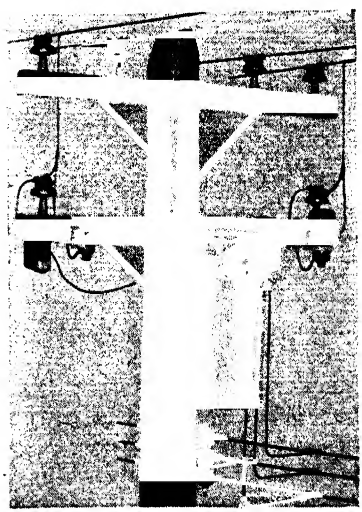


FIG. 6-8. Typical installation of pellet arrester on 2,400-volt primary circuit. View also shows low-voltage arrester connected to neutral wire. Lightning-arrester ground is directly interconnected to secondary neutral. (*Courtesy General Electric Co.*)

As all these types are used in transmission and distribution systems, they will be briefly described in the paragraphs that follow.

Pellet Arrester. *Construction.* The construction of the pellet-type arrester is illustrated in Fig. 6-7, and the manner of connecting it onto a primary circuit is shown in Fig. 6-8. The electric elements consist of a column of pellets and a series-gap assembly. The pellet column forms the valve element which prevents the flow of power-system current after the lightning surge is drained off. The series gap isolates the valve element from the line until it is sparked over by a surge.

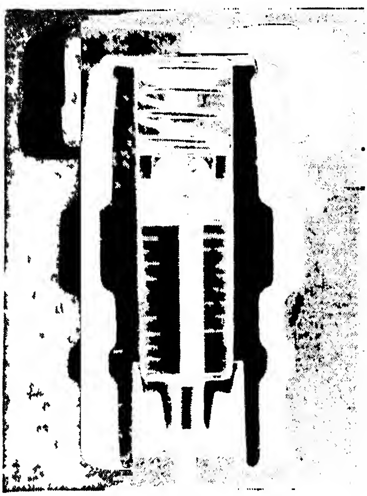


FIG 6-9 Internal view of autovalve arrester showing isolating and quenching gaps and valve elements (*Courtesy Westinghouse Electric Corp.*)

The pellets are about $\frac{3}{16}$ in. in diameter and are made of lead peroxide. They are coated with a thin coating of litharge. They are assembled in porous tube containers with metal electrodes at each end. The column of pellets is $2\frac{1}{4}$ in. in diameter, and its length is approximately 2 in. for each 1,000 volts of arrester rating.

Principle of Operation. When the lightning voltage has sparked across the series gap, the lightning discharge current flows through the column of pellets to ground. As long as the lightning current increases, the resistance of the pellet column decreases. As soon as the lightning current begins to decrease, the resistance increases. This increase in resistance continues until, at the end of the discharge, the normal system voltage is unable to maintain a current flow through the arrester, thus interrupting the flow of follow-up system current.

Autovalve Arrester. *Construction.* The autovalve arrester consists of a porous block which is the autovalve element connected in series with a spark gap. Both units are enclosed in a porcelain casing. Figure 6-9 shows the internal construction of a distribution-type autovalve

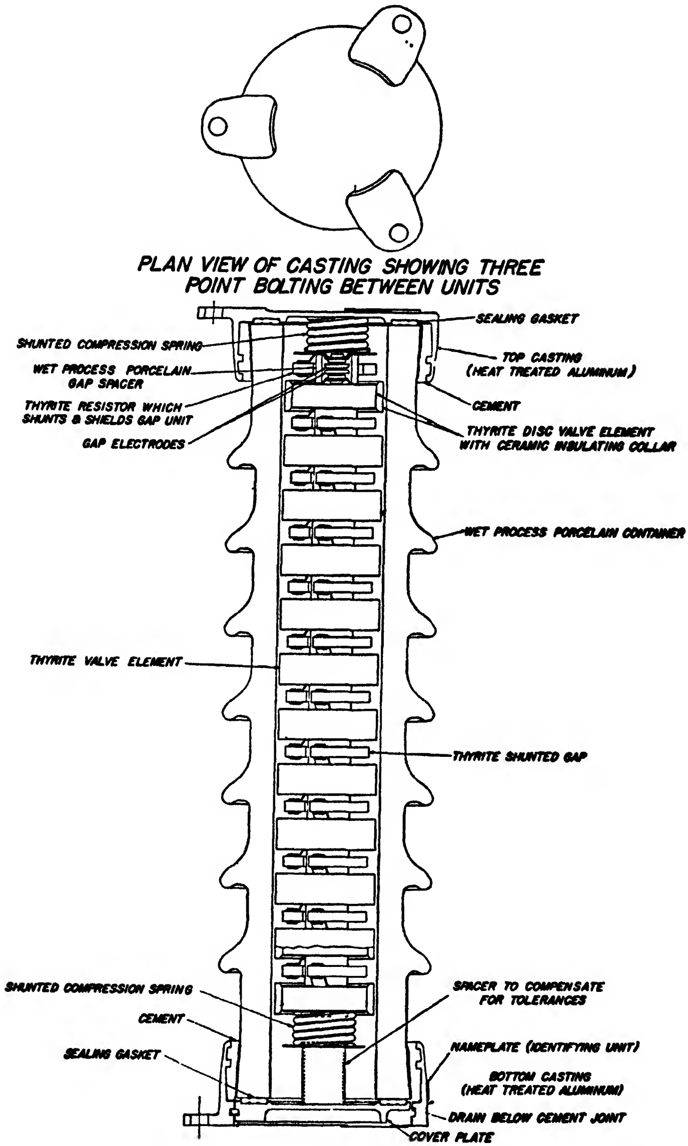


FIG. 6-10. Thyrite lightning-arrester unit with section cut away to show thyrite disks and series-gap unit. (*Courtesy General Electric Co.*)

arrester. The autovalve element is made of a mixture of ceramic material and conducting particles.

Principle of Operation. This arrester is similar to many other arresters in that the valve element has the peculiar property of conducting the lightning surge with great freedom but of offering high resistance to the passage of power current When lightning strikes the line, the high voltage causes the valve element to become readily conducting, thus quickly draining off the lightning charge When the power current

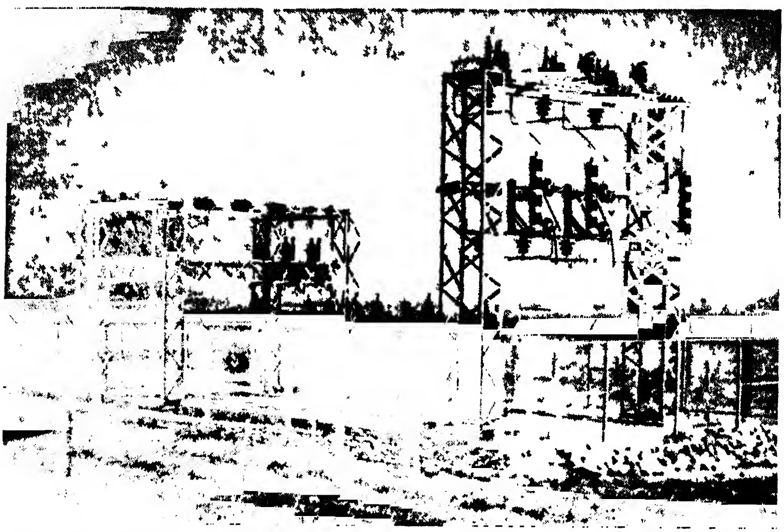


FIG 6-11 Installation of thyrite lightning arresters protecting an outdoor transformer substation. (*Courtesy General Electric Co.*)

attempts to follow to ground, the valve element cuts off the current The lightning discharge has thus been disposed of, the transformer protected, and service continued without interruption as though nothing had happened.

Thyrite Arrester. *Construction* This type of arrester consists essentially of stacked thyrite disks connected in series with a gap These two elements are enclosed in a porcelain tube covered on both ends with aluminum castings. Each unit is rated 11.5 kv. As many units as necessary to withstand the line voltage are coupled together. A cross-sectional view of a standard unit is shown in Fig. 6-10.

Principle of Operation. Thyrite is an inorganic compound of a ceramic nature which possesses the characteristic of being substantially an insulator at one voltage and becoming an excellent conductor at a higher voltage. The resistance of thyrite depends on voltage only Each time the voltage is doubled, the current which it will pass increases

12.5 times. When an excessive lightning voltage is present, the gap is sparked over, the thyrite becomes a good conductor, and the lightning is quickly drained to ground. As soon as the voltage drops to normal line value, the resistance of the thyrite increases manyfold and snuffs out the arc promptly.

An installation of thyrite arresters protecting an outdoor substation is shown in Fig. 6-11.

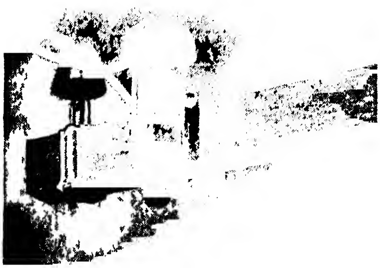


FIG. 6-12. Granulon arrester mounted on crossarm. Note pyrex housing. (*Courtesy Line Material Co.*)

FIG. 6-13. Granulon arrester showing arrester disconnected from ground by action of isolator. (*Courtesy Line Material Co.*)

Granulon Arrester. *Construction.* Like other arresters this arrester also consists fundamentally of a spark gap and a valve element connected in series between line conductor and ground. It differs from other arresters in that the elements are enclosed in pyrex glass, making the elements visible and therefore convenient to inspect. In addition, the arrester is equipped with a so-called "isolator" which disconnects the arrester from ground in case of injury to the arrester. The isolator disconnects the ground lead. Figure 6-12 shows an exterior view of the arrester in service, and Fig. 6-13 shows the arrester after the isolator has broken the ground connection.

Principle of Operation. Under normal conditions the spark gap insulates the valve element from the line conductor. Under abnormally high voltage however, such as is produced by lightning surges, the valve element becomes an almost perfect conductor. When a lightning disturbance occurs on the line, the surge sparks over the gap, permitting the discharge current to flow to ground through the valve element of the arrester. The current flows easily to ground because the valve element assumes a low resistance under high voltage. After the surge has passed to ground, the power current tends to maintain the arc across the gap and flow to ground, but under the relatively low line voltage, the valve element again assumes its former high resistance and extinguishes the arc.

The isolator acts only in case of prolonged follow current. This, of course, is an indication that the arrester has been damaged. A small amount of combustible powder is contained in the isolator. Heating due to continual flow of power current ignites the powder and blows the lower terminal off as shown in Fig. 6-13. This permits the line to remain

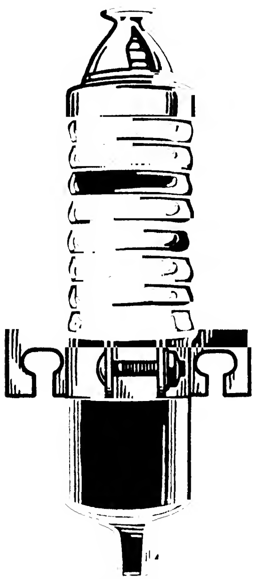


FIG. 6-14. External view of keystone expulsion-type arrester. (*Courtesy Electric Service Mfg. Co.*)

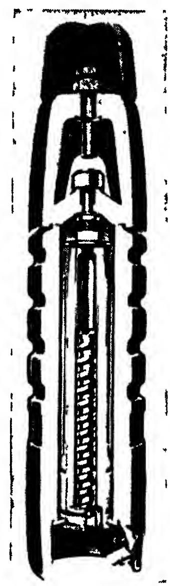


FIG. 6-15. Cutaway view of assembled expulsion arrester showing open series gap and arcing chamber. (*Courtesy Westinghouse Electric Corp.*)

in service. The patrolman seeing the hanging lead reports that the arrester has blown, and repairs are made.

Expulsion-type Arrester. *Construction.* As in other types of arresters, the expulsion-type arrester consists essentially of a spark gap connected in series with a so-called characteristic or arrester element. Both are housed in a porcelain housing as shown in Fig. 6-14. In the expulsion arrester the characteristic element consists of a hollow fiber tube which serves as the power arc quenching element (see Fig. 6-15).

Principle of Operation. The spark gap is set to spark over at a predetermined value greater than line voltage. With the spark gap so set, the circuit through the arrester is kept open under normal conditions. Under abnormal conditions, it sparks over and closes the circuit through the arrester and allows the lightning surge current to drain off to ground. When the follow-up power current flows through the arcing chamber, it produces intense heat which causes cool nonconducting gases to be given off the inner walls of the fiber tube. These gases form so rapidly that they produce an explosive blast which expels the gases through the open lower end. In so doing, the conducting gas is replaced with nonconducting gas which reduces the current flow to such a low value that it goes out at the next current zero.

PROTECTOR TUBES

Construction. Another device that is being used to protect overhead transmission lines from lightning discharges is the protector tube.

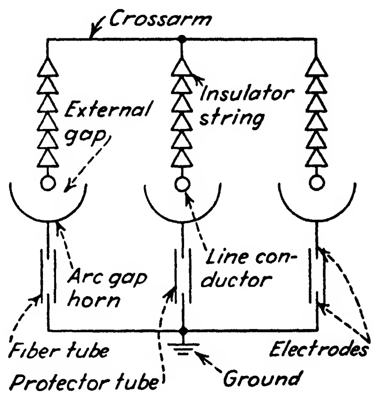


FIG. 6-16. Diagrammatic representation of protector-tube installation on a three-phase tower line.

Basically, the protector tube consists of a fiber tube with an electrode in each end. It is so designed that the impulse voltage breakdown through the tube is lower than that of the line insulation to be protected. On a transmission tower the tube is often mounted below the conductor, as shown in Fig. 6-16. The upper electrode is connected to an arc-shaped horn located the proper distance below the conductor. The arc-shaped horn maintains a constant length of external gap between the upper electrode and the line conductor even though the insulator string swings from side to side. The lower electrode is solidly grounded. An installation in which the protector tubes hang downward beside the insulator strings is shown in Fig. 6-17. In this case the tubes swing with the strings and no arc gap horns are needed.

Principle of Operation. When lightning strikes the line, the external series gap breaks down instead of flashing over the insulator string because the tube has the lower breakdown voltage. After breakdown of the gap, the power follow current volatilizes a small layer of the fiber wall and the gas given off mixes in the arc to help deionize the space between the electrodes. A pressure is built up in the tube, and the hot gases are discharged through the lower electrode which is hollow. If the

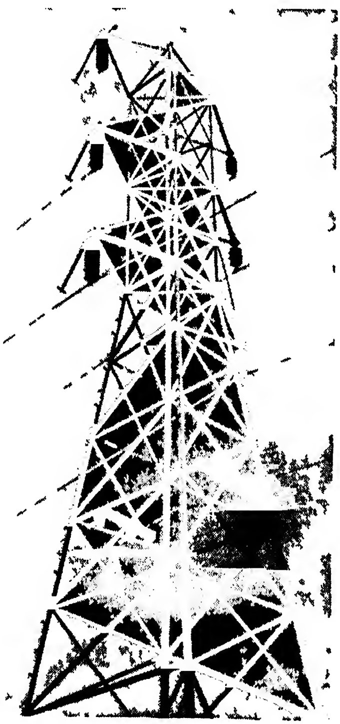


FIG 6-17 Installation of expulsion protective gaps on a 115 000-volt three-phase transmission line Tubes are mounted on one side of insulator string instead of below conductor (*Courtesy General Electric Co*)

deionizing action is sufficiently strong and if the voltage does not build up too rapidly across the tube, the arc will go out at a current zero and will not be reestablished While the tube is discharging it is a good conductor, but after the arc is extinguished it becomes a good insulator again.

SECTION 7

Line-control Equipment

Line-control equipment comprises switches, fuses, and relays. These three groups of equipment are extensively used on transmission and distribution circuits. Switches and fuses are often installed out on the lines as on poles, but relays are usually located in the stations and substations. It is therefore essential that the lineman be familiar with the first two groups of equipment mentioned, and these will be briefly treated in the following paragraphs.

SWITCHES

Switches may be divided into two general classes, namely,

1. Air-break switches
2. Oil switches:
   a. Nonautomatic
   b. Automatic

Air-break Switches. Air-break switches are ordinarily used to disconnect one dead section of line from another, such as a dead branch line from a feeder, a dead feeder from a substation, a dead substation from a line, etc. In almost every case the purpose is merely to disconnect a section which is already dead from a line or piece of apparatus for the purpose of making the disconnected line or apparatus positively *dead* electrically, thus making it safe to make repairs, tests, inspections, or changes.

Since most disconnect switches are air-break switches, they are not intended to be opened while current is flowing. If the switch should be opened while current is flowing in the line, a long arc would be drawn which might easily jump across to the other conductor or to some grounded metal and cause a short circuit. The hot arc would also melt a part of the metal, thereby damaging the switch. Only in lines carrying very small currents may disconnect switches be opened while current is flowing.

Types. Air-break switches are of many designs. Figure 7-1 shows a disconnect switch designed for use in primary mains. It is enclosed to

FIG. 7-1 7,500-volt porcelain housed primary disconnect Knife blade is hinged on special insulator so that when switch is opened the knife blade is absolutely dead Note use of special switch hook for operating the switch (*Courtesy Line Material Co*)

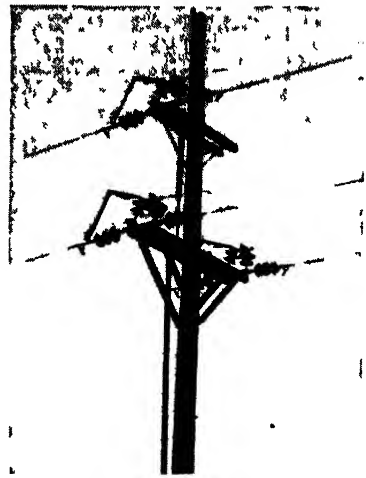


FIG 7-2 Triple-pole single-throw outdoor disconnecting switch (*Courtesy Electrical Engineers Equipment Co*)

FIG. 7-3 Single pole of high-voltage horn-gap air-break switch. Switch is in closed position. (*Courtesy Hi-Voltage Equipment Co.*)

FIG 7-4. Lineman with switch hook. (*Courtesy American Gas and Electric Service Corp.*)

protect it from the weather. Figure 7-2 shows a pole-type disconnecting switch provided with three blades, one being in each line of the three-phase circuit. This type is largely used to control outdoor substations or circuits tapped from a high-voltage transmission line. A close-up view of one pole of a high-voltage horn-gap switch is shown in Fig. 7-3.

Manner of Operating. The blade type of disconnecting switch or fuse cutout is operated by means of a switch hook such as is illustrated in

FIG. 7-5. Lineman using switch hook to open fuse cutout (*Courtesy American Gas and Electric Service Corp.*)

FIG. 7-6. Gang operated three-pole air-break switch in closed position. (*Courtesy Iowa-Illinois Gas and Electric Co.*)

Fig. 7-4. Figure 7-5 shows the lineman opening a fuse cutout by means of the switch hook.

The horn-gap type of switch is usually gang operated from the ground by means of an operating lever. Figures 7-6 and 7-7 show the switch in the closed and open position, respectively. The switch illustrated in Fig. 7-3 is operated by rotating the vertical rod in the center of the left insulator stack.

Oil Switches. *Purpose.* When a circuit carrying considerable current and operating at pressures above 600 volts must be opened while the load is on, oil switches are used. Also if it is desired to open the circuit automatically during overload or short circuit, the oil switch can be equipped with a tripping mechanism to accomplish this. Oil switches are, therefore, used where control of the circuit as well as protection from overload, short circuit, etc., is desired.

Principle of Operation. An oil switch is a high-voltage switch that is opened and closed in oil. The switch is actually immersed in an oil bath, contained in a steel tank. The reason for placing high-voltage switches in oil is that the oil may help to break the circuit when the switch is opened. With high voltages, a separation of the switch contacts does not always break the current flow, because an electric arc forms between the contacts. If the contacts are opened in oil, however, the oil will help to quench the arc. Oil is an insulator and, therefore, helps to quench the arc between the contacts. Furthermore, if an arc should form in the oil, it will evaporate part of the oil, due to its high

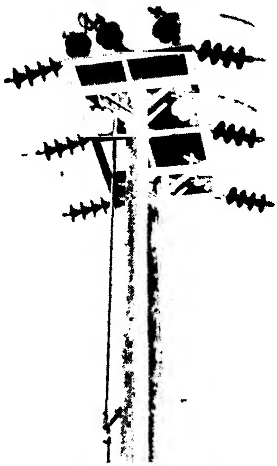


FIG 7-7. Gang-operated three-pole air-break switch in open position (*Courtesy Iowa-Illinois Gas and Electric Co.*)

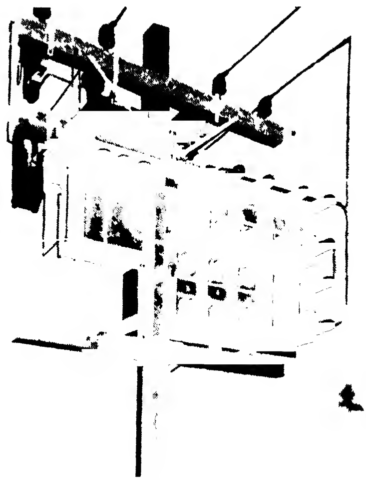


FIG 7-8. Three-phase pole-mounted oil-switch installation used to cut the capacitors shown in and out of the circuit. (*Courtesy General Electric Co.*)

temperature, and will, therefore, partially fill the tank with vaporized oil. If the tank is airtight, as it practically is in high-voltage switches, this vapor develops a pressure in the tank, which assists in quenching or breaking the arc.

Three-phase Oil Switch. The three lines of a three-phase circuit are always opened and closed by a single oil switch. If the voltage is not extremely high, the three poles of the switch are generally in the same tank, but if the voltage of the line is high, the three poles of the switch are placed in separate oil tanks. The poles are placed in separate tanks to make it impossible for an arc to form between two lines when the switch is opened or closed. An arc between lines would be a *short circuit* across the line and would probably blow up the tank.

Pole-type. A pole-type oil switch is one designed for crossarm mounting as shown in Fig. 7-8, the same as a transformer. Hangers are provided on the case for attaching to the crossarm. By mounting the

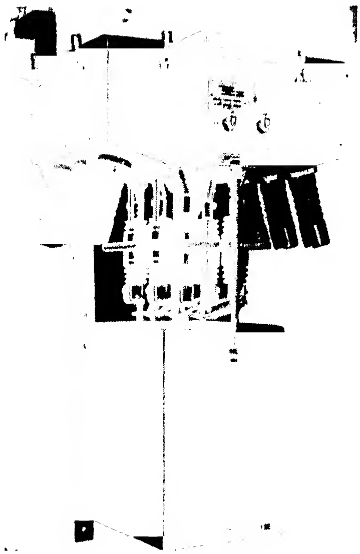


Fig 7-9 Oil tank lowered from pole-type oil switch exposing switch contacts (*Courtesy General Electric Co*)

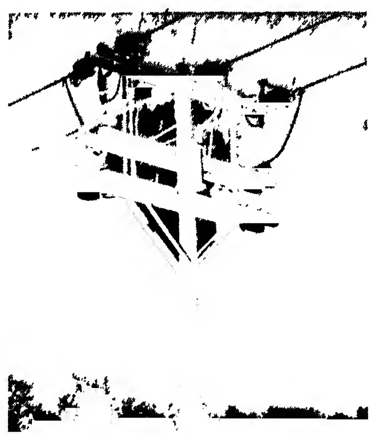
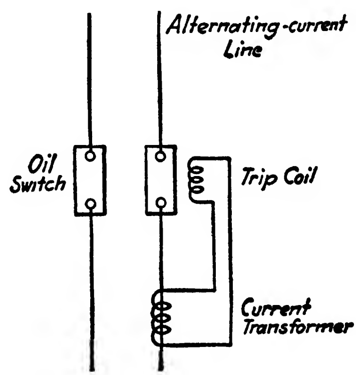


Fig 7-10 Installation of three single-pole reclosers on three-phase feeder Note also installation of three lightning arresters (*Courtesy Iowa-Illinois Gas and Electric Co.*)

switch on the pole, it is easily connected into lines so that it can be used to sectionalize feeders, cut out transformers, etc. Figure 7-9 shows a few of the construction features. Figure 7-10 shows an installation of single-pole reclosers which are essentially automatic oil switches or circuit breakers.

Fig 7-11 Current transformer used to supply current to trip coil of oil switch



Overload Trip. When an oil switch is to open the circuit automatically because of overload or short circuit, it is provided with a trip coil. This trip coil consists of a coil of wire and a movable plunger. In low-voltage circuits carrying small currents, this coil is connected in series with the line. When the current exceeds its permissible value, the coil pulls up its plunger. The plunger trips the mechanism, and a spring opens the switch suddenly.

In high-voltage circuits or in circuits carrying large currents, a current transformer is connected into the line and the secondary leads from this transformer supply the current to the trip coil of the oil switch (see Fig. 7-11). Since there is a fixed ratio between primary and secondary currents of the current transformer, the coil can be adjusted to trip at any predetermined value of current in the line.

The use of the current transformer on such circuits serves the double purpose of providing a small current for operating the tripping coil and of insulating the coil from the high voltage of the line.

FUSES

Purpose. Fuses are connected into circuits to protect the circuit and any connected apparatus against overloads or short circuits.

Principle of Operation. A fuse is an intentionally weakened spot in an electrical circuit. When the current in the circuit becomes excessive

FIG. 7-12. Plug-type fuse used principally in lighting circuits. The fuse link is visible inside. (*Courtesy General Electric Co.*)

for any reason, the fuse melts from overheating, thereby opening the circuit before the excess current can damage any part of the wiring or any connected apparatus. A fuse is generally a short piece of metal either lead or, more often, an alloy of lead and tin which will melt at low temperature. When the current through such a metal becomes excessive, the resistance offered by the metal to the flow of current develops enough heat to melt the metal.

Fuses are usually enclosed to prevent the metal from flying and doing damage or causing a fire and to aid in quenching the arc. The melting of the fuse is often accompanied by a puff of smoke of vaporized metal, which has led to the melting of the fuse being called "blowing" of the fuse.

Plug-type Fuse. The plug type is almost universally used for services in residences and for ordinary lighting branch circuits on panel boards. The fuse consists of a small cup of porcelain within which the fusible wire connects the center contact with the outer metal screw shell, as shown in

Fig. 7-12. The plug is the same size as the ordinary incandescent-lamp base.

Primary Cutout. The transformer fuse or "primary cutout," as it is often called, is a link fuse. The name "cutout" is given to it because by removing the fuse the circuit is opened the same as if a switch were opened. The fuse element consists essentially of a strip of fusible metal, usually aluminum, extended between two terminals. The cutout actually consists of two parts, the enclosing case to which the line connections are made and which is arranged for fastening to the crossarm

FIG. 7-13 Oil-fuse cutout in which fuse is immersed in oil Fuse is rated 100 amp at 2,500 volts (*Courtesy General Electric Co.*)

and the fuse holder which is made removable in order to permit the easy replacement or inspection of the fuse. A cutout in which the fuse is immersed in oil is shown in Fig. 7-13.

Proper Size of Primary Fuse. Table 7-1 gives the recommended size of primary fuse to use with different 2,400-volt single-phase transformer ratings. The table also gives the normal full-load primary-current rating of the transformer.

It is general practice not to protect distribution transformers against small overloads. To do so would cause unnecessary blowing of the fuses and frequent interruption of the service, both of which are undesirable. It is therefore customary to provide fuses which have a considerably higher current rating than the current rating of the transformer. For small-sized transformers, the fuse rating is about twice the rating of the transformer. This is clearly shown by a comparison of the normal current-rating column with the fuse-rating column in Table 7-1.

Fuses manufactured in accordance with the National Board of Fire Underwriters specifications will carry 10 per cent overload indefinitely. A fuse rated 100 amp will carry 110 amp indefinitely without blowing. This same fuse will carry 150 amp for 4 min under ordinary room temperature of 75°. Should a load of 200 amp be put on the fuse, starting cold, it will hold for ¾ min. A load of 300 amp would blow the same fuse in about 9 sec, starting cold. It will be noted that there is a time

TABLE 7-1. NORMAL FULL-LOAD PRIMARY CURRENTS AND RECOMMENDED PRIMARY-FUSE SIZES FOR 2,400-VOLT SINGLE-PHASE DISTRIBUTION TRANSFORMERS

Transformer rating, kva	Full-load primary current, amp	Recommended primary fuse size, amp
1	0.42	1
1½	0 63	2
2	0.84	2
3	1.25	3
5	2.08	5
7½	3 12	8
10	4.17	10
15	6.26	15
25	10 4	20
50	20 8	40

lag in the blowing of the fuse which depends upon the amount of the overload. Should a lineman be fusing a transformer cutout and find, upon inserting the cutout, that it blows out as soon as the contacts are

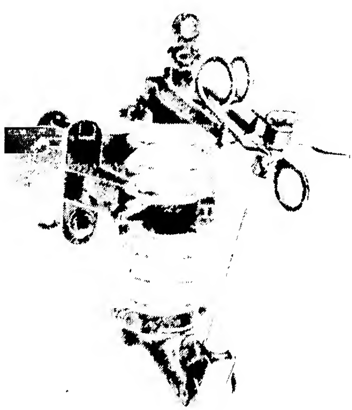


FIG 7-14 Typical automatic cutout mounted on crossarm. (*Courtesy Railway and Industrial Engineering Co.*)

made, he has a condition which is taking at least four times the capacity of the fuse or possibly a short circuit. When the fuse holds for nearly a minute and then blows, he has almost 100 per cent overload. If the fuse holds for 10 min, the overload is only 25 to 30 per cent. On a hot day, of course, the fuses will blow quicker than on a cold day.

Automatic Cutout. A cutout in the form of a disconnect switch is illustrated in Fig. 7-14. The fuse element is contained in the bakelite tube. When the fuse blows, the cutout drops out at the upper end and thus shows that it requires replacement.

The drop-out feature is produced by the use of a lever casting pivoted to the bottom of the tube. When the fuse blows, this lever, of which

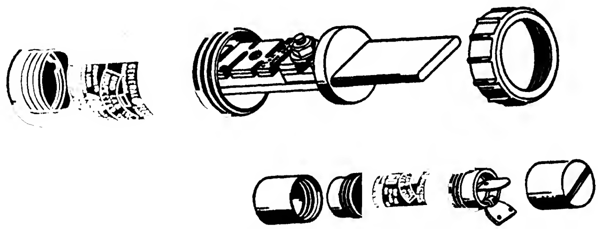


FIG. 7-15. Renewable cartridge-type fuse Only the blade shown in the inside of the tube need be replaced in case the fuse blows. (*Courtesy General Electric Co.*)

the lower contacts are a part, is forced to rotate because of spring contact pressure. This rotation shortens the distance between contacts on the tube and forces the tube to drop open.

Cartridge Fuse. The cartridge fuse is an enclosed type of fuse. The fusible element is contained within a completely enclosed insulating tube.

FIG. 7-16. High-voltage expulsion-type fuse Note fuse wire at open end of tube (*Courtesy Hi-Voltage Equipment Co.*)

This tube is called the "cartridge," because of its semblance to an ordinary shotgun cartridge. Cartridge fuses in which the element is not replaceable after the fuse has blown are called "nonrenewable" fuses. Cartridge fuses in which the fusible element may be readily renewed by the user with suitable renewal elements supplied by the manufacturer are called "renewable" fuses (Fig. 7-15). The cartridge or tube may thus be used repeatedly with new renewal elements. In this way, a considerable saving is effected, especially in the larger fuse sizes.

Expulsion Fuse. The expulsion-type fuse is essentially a link fuse contained in an explosion chamber. Figure 7-16 illustrates an expulsion fuse for use on a 7,500-volt circuit. The chamber or tube is open at one end. When the fuse blows, the metallic vapors formed create a pressure which forces them violently out at the open end. The explosive action

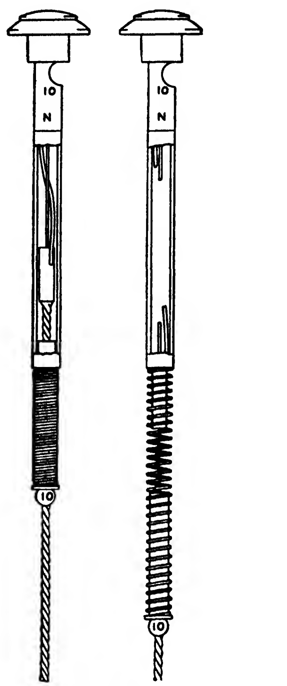


FIG. 7-17. Typical expulsion-fuse link before and after blowing. Fuses of this type are rated up to 25 amp. (*Courtesy James R. Kearney Corp.*)

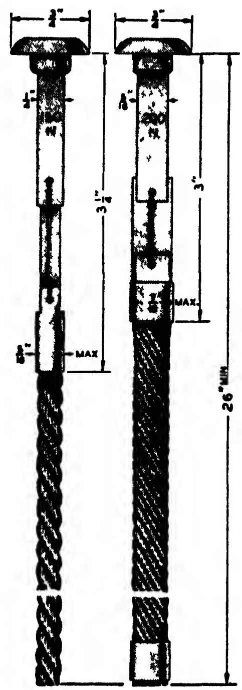


FIG. 7-18. 150- and 200-amp sizes of expulsion fuse. Note extra heavy pigtail for carrying large currents. (*Courtesy James R. Kearney Corp.*)

of the gases and the sudden expulsion through the open end extinguish the arc and open the circuit. There should always be plenty of clearance at the open end to prevent arcing to other apparatus or wires.

Expulsion-fuse Links. A typical fuse link specially designed for operation in cutouts is illustrated in Fig. 7-17. This figure shows the fuse to consist of an upper terminal button, a fusible section, and a flexible cable, or pigtail. The fuse element itself is contained in a small-bore fiber tube and is held taut by means of a compressed spring. In some other makes a tension spring is employed. The actual spring tension is carried by a very thin strain wire.

When the fuse link melts, the current is made to flow through the thin strain wire. This wire melts instantly and allows the spring to separate the fuse terminals as shown in Fig. 7-17.

In fuses of larger current ratings the fiber cylinder and the spring are omitted. The auxiliary strain wire, however, is always used. When large currents are interrupted, enough metal is vaporized and the air in

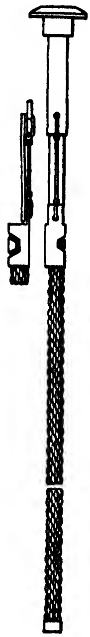


FIG 7-19 Expulsion-fuse link rated at 75 amp. Note the absence of fiber tube and spring (*Courtesy James R Kearney Corp*)

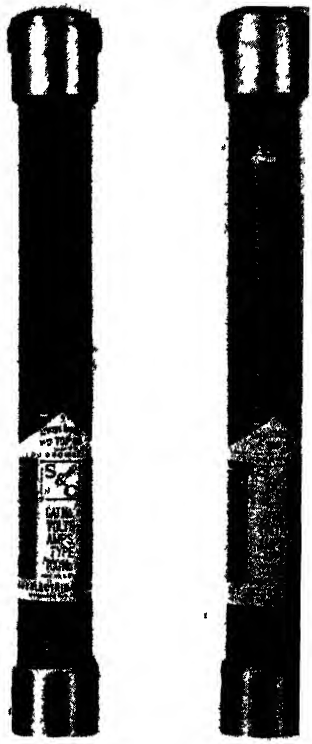


FIG 7-20 Two views of liquid fuse showing (*right*) fuse before being blown, (*left*) fuse after being blown (*Courtesy Sweitzer & Conrad, Inc.*)

the cutout is so suddenly heated that sufficient expulsive action is produced to separate the fuse terminals violently. The lower fuse terminal is usually blown out of the cutout tube. To facilitate this, the lower connection is made with a flexible pigtail (Fig. 7-18). A 75-amp fuse of this type is shown in Fig. 7-19.

Liquid Fuse. This fuse consists of a glass tube of proper length and diameter at one end of which a fusible element is mounted. The fusible element is held in tension by means of a helically coiled spring secured at the bottom end, the fusible element being attached to the upper end.

The tube is filled with an arc-quenching liquid which has a high dielectric strength. When the fusible element melts because of overload, the spring contracts very suddenly and opens a gap in the tube proportionate to the voltage rating of the fuse. As the arc is drawn down into the liquid, the liquid extinguishes or quenches it. See Fig. 7-20.

The fuse must be mounted in a vertical position and is usually held in spring clips, so that it is readily removable with the use of fuse-handling tools.

FIG. 7-21 External view of power fuse of boric acid type in position in fuse mounting. Fuse drops out when blown (*Courtesy S. and C Electric Co.*)

In case of an excessive short-circuit current, the arc produced may cause enough heat to vaporize some of the liquid within the fuse. The resulting vapor pressure might rupture the glass tube unless it is provided with a safety valve. A vent cap is provided which yields to relieve the internal pressure.

Boric Acid Fuse. The interrupting medium in this fuse is compressed boric acid. It is pressed into cylindrical blocks with a hole in the center of the block forming the bore. When an arc is drawn in the boric acid tube, the generated gas consists principally of steam formed from the water of crystallization of the boric acid. Steam is less readily ionized than organic gases and thus helps to maintain high dielectric strength around the fuse under operating conditions. There is no flame discharge when the fuse operates. (See Figs. 7-21 and 7-22.)

Because steam can be condensed, a copper-mesh condenser can be provided for indoor installations.

To replace a blown fuse, the fittings are removed from the blown fuse tube and clamped on a new fuse unit.

Boric acid fuses are made in both fixed and drop-out forms. Figure 7-23 illustrates an outdoor drop-out switch-hook-operated type.

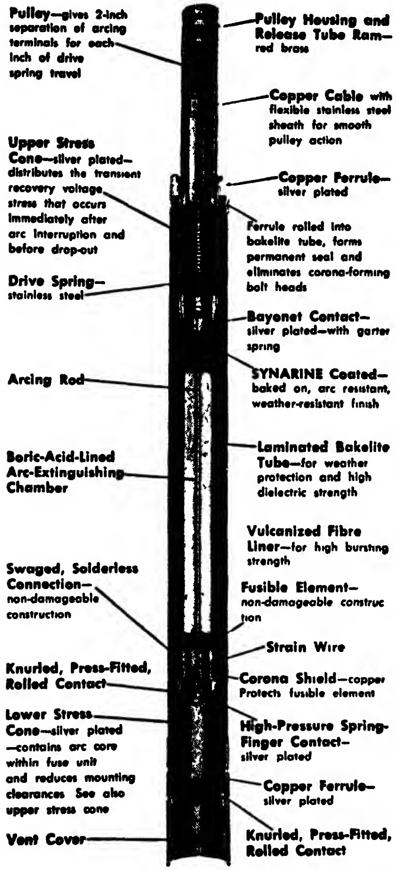


FIG. 7-22. Internal view of boric acid power fuse showing construction details. Note boric acid-lined arc-extinguishing chamber. (*Courtesy S. and C. Electric Co.*)

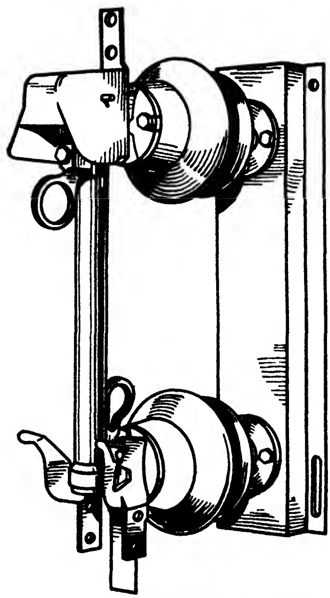


FIG. 7-23. Boric acid fuse designed to drop out when blown. Fuse is operated with customary switch hook. (*Courtesy Westinghouse Electric Corp.*)

Repeater Fuses. A repeating fuse consists of two or three fuses so mounted and arranged that when one fuse blows it drops out and the second fuse is cut in. If the fault is of a temporary nature, it will be cleared and service will be restored. If the fault is permanent, the second fuse will blow and trip out and the third fuse is cut in. This continues until all the fuses have blown or until the fault is cleared. Figures

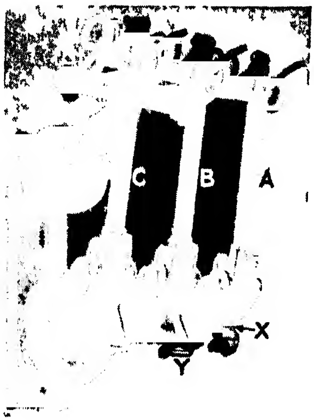


Fig 7-24 All tubes ready for operation (*Courtesy Railway and Industrial Engineering Co*)

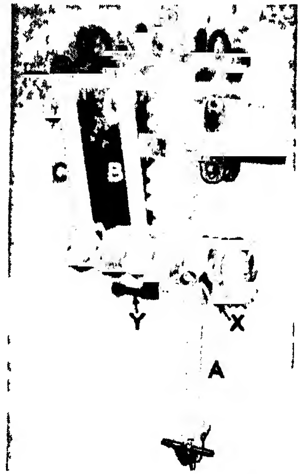


Fig 7-25 Tube *A* open, tube *B* in circuit (*Courtesy Railway and Industrial Engineering Co*)

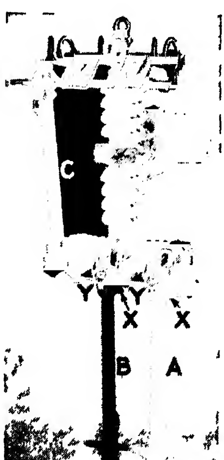


Fig 7-26 Tubes *A* and *B* open, tube *C* in circuit. (*Courtesy Railway and Industrial Engineering Co*)

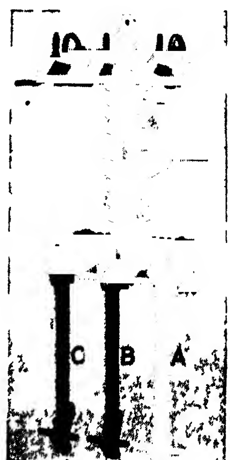


Fig 7-27 All tubes open, line disconnected (*Courtesy Railway and Industrial Engineering Co*)

7-24 to 7-27 illustrate the operation of the repeater fuse or "repeater cut-out" as it is sometimes called. Figure 7-24 shows all fuses loaded and in place. All fuse tubes are connected to the line side, but only tube *A* is connected to the load. In Fig. 7-25 a fault has occurred and opened tube *A*. In dropping open, the tube forced trip lever *X* back to the position shown and a transfer arm *Y* has placed tube *B* in the line. If the trouble has cleared, service will be restored. Tube *A* in the down position indicates to the serviceman that it has operated and the fuse element should be replaced. The tubes should be removed with a switch

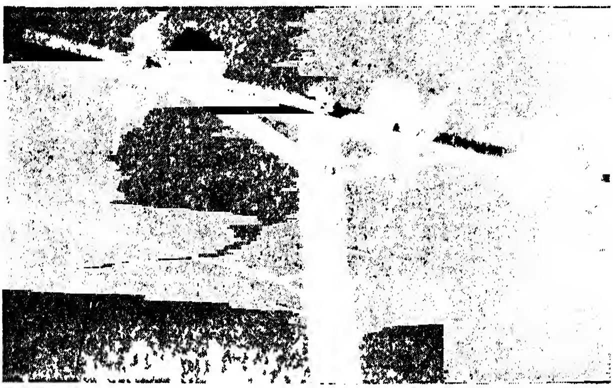


FIG 7-28. Installation of three circuit-reclosing cutouts on a three-phase feeder. Each cutout contains two fuses. Note dead-end construction, pole steps, and use of wooden crossarm braces (*Courtesy Line Material Co.*)

stick and reloaded on the ground away from all danger of contact with live circuits. After reloading, tube *A* is replaced in the mounting and closed. In closing the tube onto the line, lever *X* is automatically reset to its original position and tube *A* again carries the load. In case of a more serious fault, tubes *A* and *B* may both blow in turn, operating trip lever *X* and transfer arms *Y*, causing *C* to carry the load (Fig. 7-26). Both blown tubes would then have to be removed, reloaded on the ground, and replaced and closed. In Fig. 7-27 a permanent fault has occurred and blown and operated all the tubes. After the fault has been cleared, all tubes are reloaded on the ground and replaced in the mounting.

Another form of repeater fuse is that shown in Fig. 7-28. This fuse is known as a circuit-reclosing cutout and consists of a porcelain housing containing two fuse cartridges. When a heavy overload or short circuit occurs, the first fuse will operate and then, after a short delay, transfer the current to the second fuse. If the overload or fault is still on the circuit when the second fuse tube is connected into the circuit, the second fuse will operate in the same manner as the first and drop down into the indicating position.

SECTION 8

Fundamentals of Line Design

General. In this chapter are treated the controlling factors which govern the design of a line. The purpose of this brief treatment on line design is to give to the men who construct and maintain transmission lines and distribution systems a partial understanding of how the engineers who prepare the plans and specifications arrive at their results. In other words, the object is to give the lineman an insight into the design of the structures which he builds. It is not expected that linemen will begin to design lines, but it is hoped that they will get some satisfaction out of knowing some of the "whys" and "wherefores" regarding the lines and systems which they construct and maintain. In the following paragraphs will be discussed the selection of the number of phases, the selection of the operating voltage, the determination of the conductor size, span, pole height, etc.

NUMBER OF PHASES

Three-phase Lines. The selection of the number of phases to be used is an easy matter. Almost all lines designed today, from the smallest to the largest, are three phase. Even some new lines built into rural communities to supply electricity to farmers are being built as three-phase lines. Two-phase lines are out of date, and single-phase lines are used only in distribution systems and in some cases in connection with electrified railroads and rural electrification. Lines are very apt to be three phase, therefore, unless there is some special reason for building them otherwise.

Reasons for Three-phase. The main reasons for building lines three phase are two in number, namely:

1. A single-phase two-wire transmission line operating at a certain voltage requires a certain amount of copper in the wires to carry the load. A two-phase four-wire line would require the same total weight of copper. There would be no gain, therefore, in building the two-phase line. An equivalent three-phase three-wire line, however, will require only three-fourths as much copper. There will thus be a substantial saving in copper if a three-phase system is selected.

2. Motors operating from a three-phase line are much cheaper and more satisfactory in operation than single-phase or two-phase motors. This reason is more important than the saving in copper in the line.

SELECTION OF VOLTAGE

Historical. The voltages used on transmission lines have been steadily rising. The chart of Fig. 8-1 shows how the maximum voltage

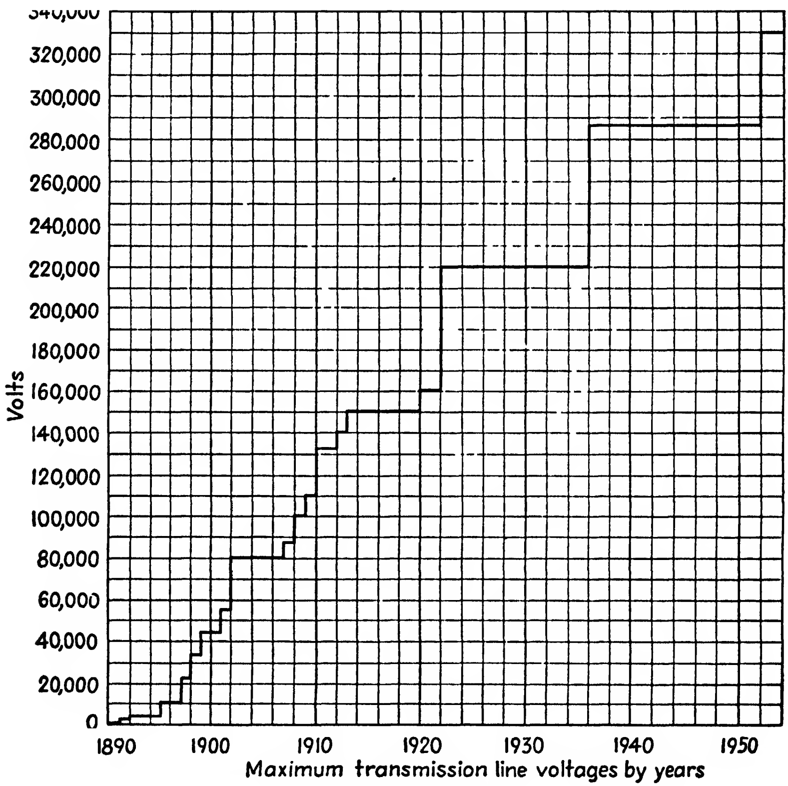


FIG. 8-1. Maximum transmission-line voltages by years.

used on transmission lines has increased during the last 65 years. In 1882, the highest voltage used was 110 volts. In 1902, it went up to 80,000 volts and remained there for 5 years. In 1913, it reached 150,000 volts and stayed there for 7 years. In 1922, it reached 220,000 volts which remained the highest voltage until 1936, when the 287,000-volt line from Hoover Dam to Los Angeles was first put into operation. In 1952 a 330,000-volt grid was put into operation in Ohio.

Figure 8-2 shows the manner in which the maximum distance of transmission has increased with the increase in voltage. It brings out very clearly that increases in voltage increase the distance over which power can be transmitted economically. This figure also gives the dates and places at which the voltages shown were first used.

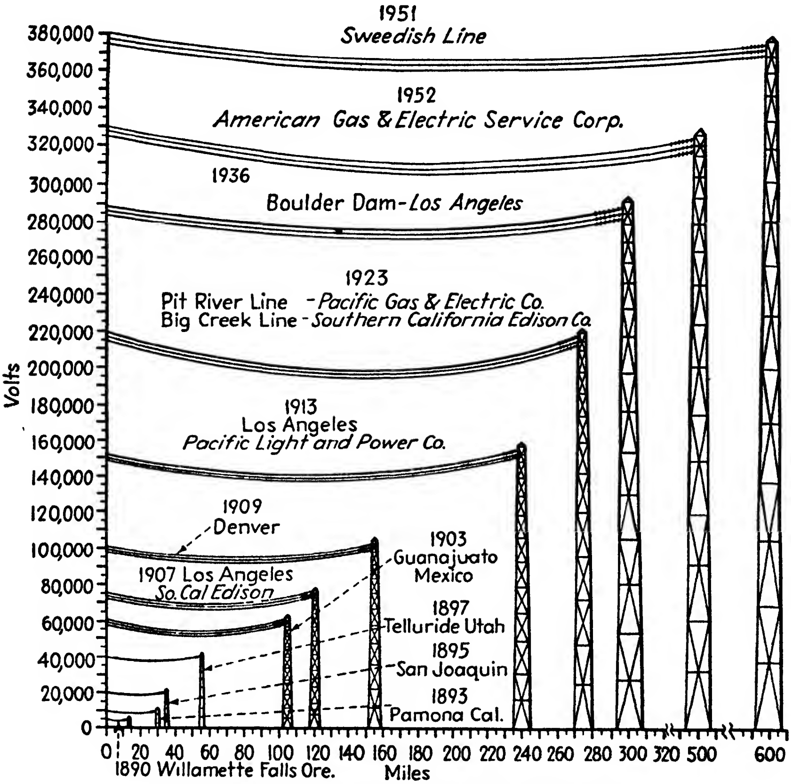


FIG. 8-2. Transmission voltages and distances.

Voltage Related to Line Length. That the voltage of a line should be related to the length of the line is expected. As a result, a rule of thumb which often comes close to giving the value of voltage to be used has come into use. This rule is to allow "1,000 volts per mile of length of line." A line 65 miles long would thus probably operate at 66,000 volts, and a 10-mile line at perhaps 13,200 volts or higher.

For long lines, 1,000 volts per mile is too low, as the chart of Fig. 8-3 shows. This chart indicates that for long lines the voltages used are more apt to be 2,000 or 3,000 volts per mile. This of course would not apply to the longest lines, for the highest voltage in use today is only 380,000 volts.

Voltage Related to Load Transmitted. That the voltage of the line should also be related to the load transmitted follows naturally. Figure 8-4 shows this to be true. Here are plotted the voltages of the 877 lines in the United States previously referred to against the megavolt-amperes the lines are carrying. A megavolt-ampere equals 1,000 kva.

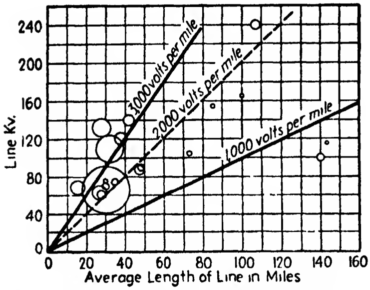


FIG. 8-3. Voltages of 877 transmission lines plotted against corresponding length in miles. (*E. B. Kurtz and J. A. Douglas, Transmission Line Analysis Indicates Ruling Tendencies, Electrical World, Sept. 26, 1931.*)

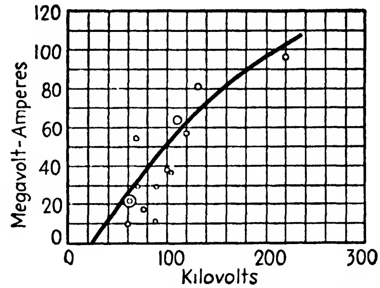


FIG. 8-4. Voltages of 877 transmission lines plotted against megavolt-amperes carried by each line. (*E. B. Kurtz and J. A. Douglas, Transmission Line Analysis Indicates Ruling Tendencies, Electrical World, Sept. 26, 1931.*)

That the voltage increases with increase of load is quite clear from the curve.

Voltage Related to Megavolt-ampere-miles. A still closer relationship exists when one relates voltage to megavolt-ampere-miles. The latter quantity represents the product of electrical load (volt-amperes) and line length (miles). This is more representative of the work done by a line than either length of line or power load alone. Figure 8-5 shows how closely the plotted points of the 877 lines lie on a smooth curve. This chart therefore shows that high voltages are used not only with long lines but also with shorter lines carrying extra large blocks of power.

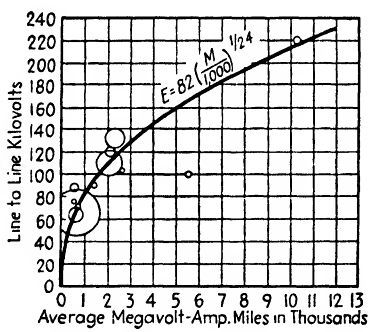


FIG. 8-5. Voltages of 877 transmission lines plotted against products of corresponding megavolt-amperes and length of line in miles of each line. (*E. B. Kurtz and J. A. Douglas, Transmission Line Analysis Indicates Ruling Tendencies, Electrical World, Sept. 26, 1931.*)

Standard Transmission Voltages. Table 8-1 gives the standard transmission voltages in use today for various lengths of line. Those marked with a star are those most frequently used. Thus, 2,200, 6,600, 13,200, 33,000, 44,000, 66,000, 110,000, 220,000, and 330,000 are the most common voltages in use today. These voltages have been standardized in order that transformers, oil switches, lightning arresters, and other substation apparatus could be standardized.

TABLE 8-1. STANDARD TRANSMISSION VOLTAGES

Length of line, miles	Standard voltages, volts
1 to 3	550 or 2,200
3 to 5	2,200* or 6,600
5 to 10	6,600* or 13,200
10 to 15	13,200* or 22,000
15 to 20	22,000 or 33,000
20 to 30	33,000* or 44,000
30 to 50	44,000* or 66,000
50 to 75	66,000* or 88,000
75 to 100	88,000 or 110,000
100 to 150	110,000* or 132,000
150 to 250	132,000 or 154,000
250 to 300	154,000 or 220,000
300 to 500	220,000 or 330,000

* These voltages are most frequently used.

The selection of the proper voltage is sometimes also governed by the voltage of existing power lines. If the lines are to be connected to other lines, as they probably will be, it is most convenient to have the lines at the same voltage. Other factors are cost of power, first cost of substation equipment, etc.

CURRENT CALCULATIONS

How to calculate the amount of current that the line conductor will have to carry will now be discussed. It will be assumed that the voltage to be used is known and that the amount of power in kilovolt-amperes (abbreviated kva) to be transmitted over the line is also known. Instead of the kilovolt-amperes, the kilowatts and power factor may be used. It will also be shown how the kilovolt-amperes and kilowatts can be obtained if the current, voltage, and power factor are known.

Single-phase. The current flowing in a single-phase two-wire circuit is given by the formula

$$\text{Current in amperes} = \frac{\text{apparent power in kilovolt-amperes} \times 1{,}000}{\text{line voltage in volts}}$$

or

$$\text{Current in amperes} = \frac{\text{power in kilowatts} \times 1{,}000}{\text{line voltage in volts} \times \text{power factor}}$$

TABLE 8-2 SINGLE-PHASE CURRENTS FOR VARIOUS LOADS AND VOLTAGES

Voltage volts	Load, kva												
	5	7 5	15	25	37 5	50	100	200	300	400	600	900	1,200
110	45 6	68 2	136 3	227	341	456	909	1,818	2,727	3 636	5,454	8,182	10,908
115	43 5	65 2	130 4	217	326	435	870	1 739	2,609	3,478	5,218	7,826	10,435
220	22 7	34 1	68 2	113 6	170 5	227 3	454	909	1,364	1 818	2,727	4,091	5,454
230	21 7	32 6	65 2	108 7	163 0	217 4	435	870	1,304	1,739	2 609	3,913	5,218
440	11 4	17 0	34 1	56 8	85 2	113 6	227	455	682	909	1,364	2,045	2,727
600	8 3	12 5	25 0	41 7	62 5	83 3	166 7	333	500	667	1,000	1,500	2,000
2,200	2 27	3 41	6 82	11 36	17 05	22 7	45 5	90 0	136 4	181 8	273	409	545
2,300	2 17	3 26	6 52	10 87	16 30	21 74	43 5	87 0	130 4	173 9	261	391	522
4,000	1 25	1 88	3 75	6 25	9 38	12 50	25 0	50 0	75 0	100 0	150 0	225 0	300 0
6,600	0 76	1 14	2 27	3 79	5 68	7 58	15 2	30 3	45 5	60 6	90 9	136 4	181 8
12,000	0 42	0 63	1 25	2 08	3 12	4 17	8 33	16 67	25 0	33 3	50 0	75 0	100 9
13,200	0 38	0 57	1 14	1 89	2 84	3 79	7 58	15 15	22 7	30 3	45 5	68 2	90 9

To illustrate the use of these formulas, take a single-phase line carrying a load of 100 kva and operating at 2,300 volts. Substituting in the first formula gives

$$\text{Current} = \frac{100 \times 1{,}000}{2{,}300} = 43.5 \text{ amp}$$

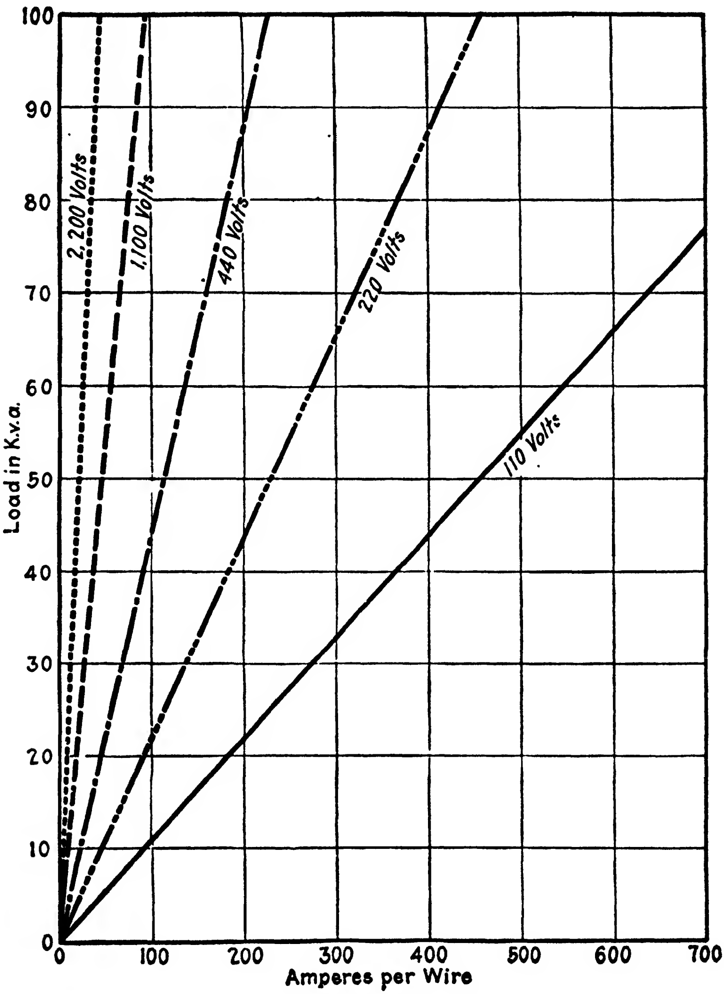


FIG. 8-6. Single-phase.

$$\text{Amperes} = \frac{\text{kva} \times 1{,}000}{\text{volts}}$$

$$\text{Kva} = \frac{\text{volts} \times \text{amperes}}{1{,}000}$$

This current just calculated is the current in each wire of the single-phase circuit. Table 8-2 gives the value of currents in single-phase circuits for the common standard voltages and values of kilovolt-ampere loads from 5 to 1,200. Figure 8-6 gives the same information except that from this chart any intermediate values can also be obtained. To find the current by use of the chart, find the value of load in kilovolt-amperes on the vertical scale, then move horizontally until the line representing the voltage is reached. From here drop to the scale on the lower edge and read the current.

Both the table and the current chart can also be used in the reverse manner to obtain the kilovolt-amperes, if the current and voltage are known. On the chart find the value of current on the scale on the lower edge, move up vertically until the line representing the circuit voltage is reached, then pass horizontally to the left and read kilovolt-amperes on the vertical scale.

If the kilowatts, power factor, and voltage are known instead of kilovolt-amperes and voltage, the second formula is used. For example, if a 2,300-volt circuit delivers 50 kw at 80 per cent power factor, the current in the line will be given by

$$\text{Current} = \frac{50 \times 1{,}000}{2{,}300 \times 0.80} = 27.2 \text{ amp}$$

If this load of 50 kw were at unity power factor, instead of 0.80, the current would be less. The kilovolt-amperes and kilowatts would be the same and the current would be 21.74 amp. This value is obtained from Table 8-2 for 50 kva and 2300 volts.

Three-phase. The corresponding formulas for currents in three-phase three-wire circuits are

$$\text{Current in amperes} = \frac{\text{kilovolt-amperes} \times 1{,}000}{1.73 \times \text{line voltage in volts}}$$

or

$$\text{Current in amperes} = \frac{\text{kilowatts} \times 1{,}000}{1.73 \times \text{line voltage} \times \text{power factor}}$$

Table 8-3 gives the values of current for the standard line voltages and for values of kilovolt-amperes ranging from 100 to 1,500. Figure 8-7 is a chart similar to Fig. 8-6 and gives the same information as Table 8-3 except that intermediate values can also be found.

To illustrate the use of the formula, table, and chart, take a three-phase line carrying 500 kva of load and operating at 13,200 volts. To find the current flowing in each line conductor, substitute in the formula; thus

$$\text{Current} = \frac{500 \times 1{,}000}{1.73 \times 13{,}200} = 21.9 \text{ amp}$$

TABLE 8-3. THREE-PHASE CURRENTS FOR VARIOUS LOADS AND VOLTAGES

Voltage, volts	Load, kva											
	100	200	300	400	500	600	700	800	900	1,000	1,200	1,500
200	262	525	787	1,050	1,312	1,575	1,838	2,100	2,362	2,624	3,150	3,940
440	131	262	394	525	656	787	919	1,050	1,181	1,312	1,575	1,970
2,200	26.2	52.5	78.7	105	131	158	184	210	236	262	315	394
2,300	25.2	50.3	75.4	100.5	116	151	176	202	227	252	302	377
4,000	14.5	28.9	43.4	57.8	72.3	86.8	100.1	116	130	145	174	217
6,600	8.75	17.5	26.2	35.0	43.7	52.5	61.2	70.0	78.7	87.5	105.0	131.5
13,200	4.37	8.75	13.1	17.5	21.9	26.2	30.6	35.0	39.4	43.7	52.4	65.7
14,000	4.13	8.26	12.4	16.6	20.7	24.8	28.9	33.1	37.2	41.3	49.6	62.0
22,000	2.62	5.25	7.87	10.5	13.1	15.7	18.4	21.0	23.6	26.2	31.5	39.
33,000	1.75	3.50	5.25	7.00	8.75	10.5	12.2	14.0	15.7	17.5	21.0	26.2
50,000	1.16	2.32	3.47	4.63	5.78	6.94	8.10	9.25	10.40	11.58	13.9	17.4
60,000	.62	1.93	2.89	3.85	4.82	5.78	6.73	7.70	8.67	9.64	11.6	14.5
66,000	.87	1.75	2.62	3.50	4.36	5.25	6.12	7.00	7.87	8.75	10.5	13.2
110,000	.52	1.05	1.57	2.10	2.62	3.15	3.67	4.20	4.72	5.25	6.30	7.88

This value could also have been obtained from Table 8-3 by looking under 500 kva and opposite 13,200 volts. Or it could also have been obtained from the chart of Fig. 8-7 by finding 500 on the vertical scale, passing horizontally until the 13,200-volt line is reached, dropping to the scale at lower edge, and reading the current.

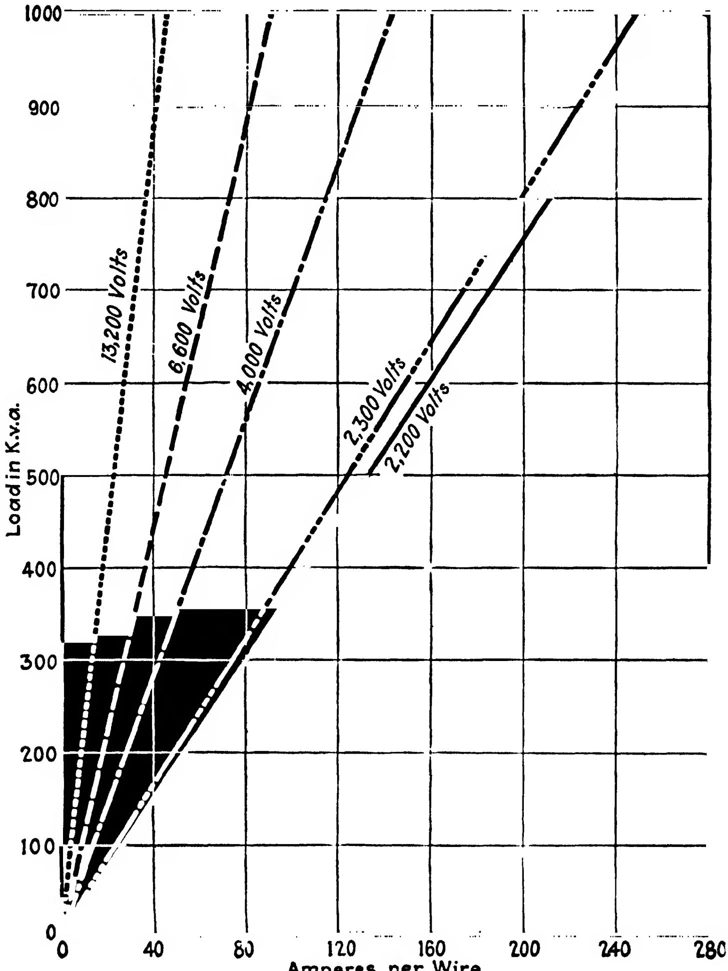


Fig. 8-7. Three-phase

$$\text{Amperes} = \frac{\text{kva} \times 1{,}000}{\sqrt{3} \times \text{volts}}$$

$$\text{Kva} = \frac{\sqrt{3} \times \text{volts} \times \text{amperes}}{1{,}000}$$

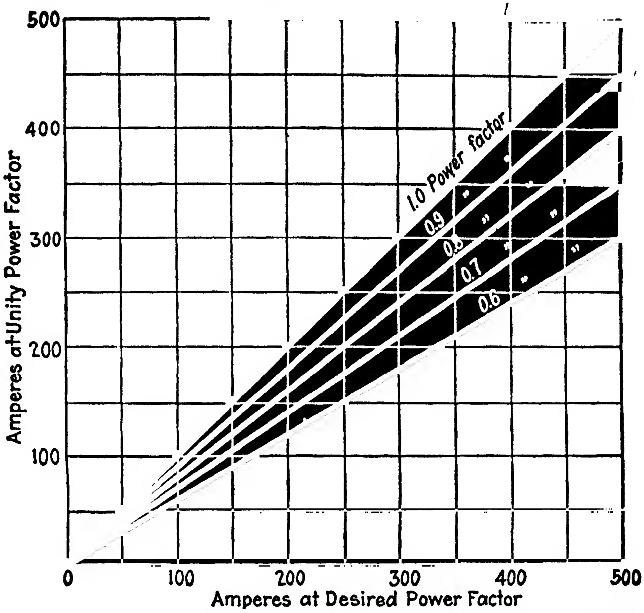


FIG. 8-8. Chart to find amperes at any desired power factor if amperes at unity power factor are known.

Amperes at Any Power Factor. If the amperes at unity power factor are known and it is desired to know what the current in amperes would be at any other power factor, the procedure is to divide the current at unity power factor by the power factor at which the current is desired; thus

$$\text{Current at any desired power factor} = \frac{\text{current at unity power factor}}{\text{desired power factor}}$$

To illustrate: If the current at unity power factor is 100 amp, the current at 0.8 power factor is

$$\text{Current at 0.8 power factor} = \frac{100}{0.80} = 125 \text{ amp}$$

The chart shown in Fig. 8-8 may also be used for this calculation. To illustrate the above case, find 100 amp on the vertical scale, pass horizontally to the desired power-factor line 0.80, drop to the lower scale, and read 125 amp.

Summary. In Table 8-4, the formulas and equations presented so far are summarized and arranged in tabular form for ready reference. It might be pointed out as a matter of interest that power factor does not have to be considered in direct-current calculations as there is no lag or

TABLE 8-4. SUMMARY OF CIRCUIT CALCULATIONS

To find	Direct current	Alternating current	
		Single-phase	Three-phase
Amperes when kilovolt-amperes and voltage are known	....	$\frac{\text{Kilovolt-amperes} \times 1{,}000}{\text{volts}}$	$\frac{\text{Kilovolt-amperes} \times 1{,}000}{1.73 \times \text{volts}}$
Kilovolt-amperes when amperes and voltage are known.	.. ..	$\frac{\text{Amperes} \times \text{volts}}{1{,}000}$	$\frac{1.73 \times \text{volts} \times \text{amperes}}{1{,}000}$
Amperes when kilowatts, volts, and power factors are known	$\frac{\text{Kilowatts} \times 1{,}000}{\text{volts}}$	$\frac{\text{Kilowatts} \times 1{,}000}{\text{volts} \times \text{power factor}}$	$\frac{\text{Kilowatts} \times 1{,}000}{1.73 \times \text{volts} \times \text{power factor}}$
Kilowatts when amperes, volts, and power factor are known	$\frac{\text{Amperes} \times \text{volts}}{1{,}000}$	$\frac{\text{Amperes} \times \text{volts} \times \text{power factor}}{1{,}000}$	$\frac{1.73 \times \text{amperes} \times \text{volts} \times \text{power factor}}{1{,}000}$

lead of current in such circuits. In alternating-current circuit calculations, the power factor is important. If its value is not known for a given circuit or line, the value 0.80 is often assumed as a basis for calculation. It will also be noted that the factor 1.73 is used in all three-phase calculations.

DETERMINING SIZE OF LINE CONDUCTOR

Factors Affecting Conductor Size. The size of a line conductor depends on a number of factors. The most important of these are the line voltage, the amount of power to be transmitted, and mechanical strength. The line voltage is a very important factor, for it will be recalled that for a given amount of power the greater the voltage, the less will the current be. That is the reason for using as high a line voltage as possible. The current in turn determines the size of the conductor.

Equally important is the magnitude of the load to be transmitted. For a given voltage, the larger the load, the larger the current. That a conductor must have sufficient mechanical strength to carry its own weight and any load due to sleet or wind is obvious if the line is to give reliable and uninterrupted service. Other factors are length of line, power factor of load, length of span, etc. These factors will be further discussed and Table 8-7 will give the proper size of conductor for various combinations of voltage, amounts of power to be transmitted, and miles length of line. The conductor size given in each case is such as will not produce more than a 10 per cent line loss or give a line regulation in excess of 10 per cent. The meaning of these terms will also be made clear.

Current-carrying Capacity. In the foregoing discussion of current calculations it was made clear how the amount of current flowing in a line could be determined if the line voltage and load to be transmitted are known. The next step is to pick the size of conductor that can carry a given current. In Table 8-5 are given the maximum current-carrying capacities of copper and aluminum wires for the wire sizes used in outdoor circuits. These values of current were obtained by experiment and are of such magnitude that the heat produced by them in the conductor will not be great enough to injure the insulation. The carrying capacities are based upon an actual temperature of the surface of the complete conductor of 150°F in still air. This is about the highest safe temperature before weatherproof insulation begins to drip. If ability to carry current were the only requirement, one could easily pick from this table the right size of conductor to be used for any given current.

While the values of current shown for the different size conductors could be carried in emergency operation, they are far too high for normal loading. Normal values would be approximately one-half of the values shown. Current-carrying capacity is not the only consideration in determining conductor size. As will be shown later, per cent line loss and voltage regulation are equally important considerations.

If no other factor would need to be considered, a good rule to follow for copper conductors is to allow 1,000 cir mils per amp. For example, a current of 300 amp would thus require a conductor having 300,000 cir mils of area.

TABLE 8-5. CURRENT-CARRYING CAPACITIES OF COPPER AND ALUMINUM CONDUCTORS WHEN USED OUTDOORS
(Values given are for bare and covered wires)

Circular mils or B. & S. gage		Outdoor conductors weatherproof insulation		Outdoor conductors bare and black	
Aluminum	Copper	Aluminum	Copper	Aluminum	Copper
1,590,000	1,000,000	2,000	1,870	1,910	1,650
1,431,000	900,000	1,920	1,820	1,780	1,580
1,272,000	800,000	1,800	1,690	1,640	1,430
1,113,000	700,000	1,570	1,575	1,510	1,280
954,000	600,000	1,540	1,515	1,290	1,100
795,000	500,000	1,342	1,210	1,110	1,010
636,000	400,000	1,132	965	930	870
477,000	300,000	867	824	765	685
336,420	No. 4/0	688	633	600	550
266,800	No. 3/0	569	530	490	460
211,950	No. 2/0	489	445	420	400
167,800	No. 1/0	430	388	364	344
133,220	No. 1	332	325	291	275
105,530	No. 2	288	275	255	252
83,640	No. 3	263	239	214	206
66,370	No. 4	220	212	200	183

Mechanical Strength. The conductor, besides requiring adequate current-carrying capacity, must be of sufficient size and strength to support itself and any additional load due to ice, sleet, and wind. The weight of the conductor for a given span can be easily computed, but the magnitude of the additional load due to sleet and wind cannot be accurately determined. For this purpose the Bureau of Standards of the United States government has divided the entire area of the United States into so-called "loading districts," as shown in Fig. 8-9. The three loading districts are known as "heavy," "medium," and "light." In the heavy loading district, the resultant loading on the conductor is that due to the weight of the conductor plus the added weight of a layer of ice ½ in. in radial thickness, combined with a transverse horizontal wind pressure of 4 lb per sq ft on the projected area of the ice-covered conductor at 0°F. In the medium loading districts the loading is that

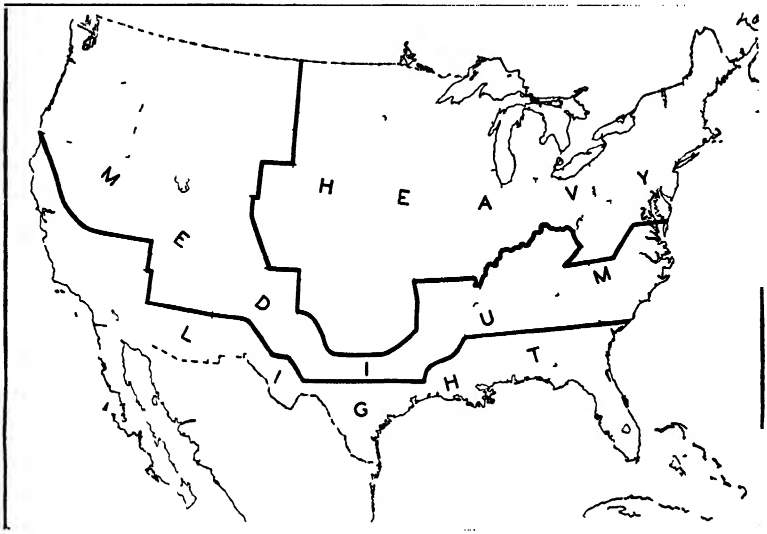


FIG 8-9 General loading map showing the territorial divisions of the United States with respect to loading on overhead wires (*Taken from National Electrical Safety Code*.)

caused by ¼ in of radial thickness of ice combined with a transverse wind pressure of 4 lb per sq ft at 15°F, and in the light loading district the loading is that produced without any ice on the conductor but with

FIG 8-10 Conductor covered with sleet and ice in New England (*Courtesy New England Power Co.*)

a wind pressure of 9 lb per sq ft at 30°F. As the map shows, the light loading district consists of the extreme South and a part of the Southwest; the medium loading district covers a band through the South and the entire West; and the heavy loading district includes the north central and northeastern states. Figure 8-10 shows a conductor covered with sleet and ice after one of the storms in New England.

The following is the statement on conductor loading as specified by the National Electrical Safety Code:

The loading on conductors shall be assumed to be the resultant loading per foot equivalent to the vertical load per foot of the conductor, ice-covered where specified, combined with the transverse loading per foot due to a transverse horizontal wind pressure upon the projected area of the conductor, ice-covered where specified, to which equivalent resultant shall be added a constant. In the table below are the values for ice, wind, temperature, and constants which shall be used to determine the conductor loading.

	Loading district		
	Heavy	Medium	Light
Radical thickness of ice, in	0.50	0.25	0
Horizontal wind pressure, lb per sq ft	4	4	9
Temperature, °F	0	+15	+30
Constant to be added to the resultant for the following types of conductors, lb per ft:			
Bare:			
Copper, steel, copper alloy, copper-covered steel, and combination thereof	0.29	0.19	0.05
Bare aluminum (with or without steel reinforcement)	0.31	0.22	0.05

In addition to the ice load, the side push due to the wind on the conductor and ice must be taken into account, as mentioned above. When the engineer has taken everything that causes tension on the conductor into account, namely, the weight of the conductor itself, the weight of the probable ice load, the transverse force due to probable high winds, and the shortening of the conductor and consequent increase of tension due to extreme cold, he multiplies the resultant pull by 2 and selects the conductor that will stand that force before breaking. This gives him a factor of safety of 2 under the worst conditions. Table 8-6 gives the ultimate and allowable strength of the common sizes of hard-drawn and annealed copper wire used in transmission and distribution lines. The allowable pull is taken as one-half of the breaking strength.

Conductor Size Related to Current and Span Length. That the size of the line wire varies with the current to be carried we have already pointed out. Likewise it has just been pointed out that the line must be mechanically strong enough to support itself and any sleet and wind load that may be imposed upon it. The longer the span or distance between

TABLE 8-6. ULTIMATE AND ALLOWABLE STRENGTHS OF HARD-DRAWN AND ANNEALED COPPER WIRE
(Allowable load is based on a factor of safety of 2)

Size of wire (B. & S. gage)	Hard-drawn copper		Annealed copper	
	Ultimate strength	Allowable load	Ultimate strength	Allowable load
0000	8,260	4,130	5,320	2,660
000	6,550	3,275	4,220	2,110
00	5,440	2,720	3,340	1,670
0	4,530	2,265	2,650	1,375
1	3,680	1,840	2,100	1,050
2	2,970	1,485	1,670	835
3	2,380	1,190	1,323	661
4	1,900	950	1,050	525
5	1,580	790	884	442
6	1,300	650	700	350
7	1,050	525	556	278
8	843	421	441	220

poles and towers, therefore, the bigger and stronger the conductor must be. Figures 8-11 and 8-12 show how closely conductor sizes are related to the product of amperes to be carried and span length. Figure 8-11 shows this relation for copper conductors and Fig. 8-12 for aluminum and ACSR conductors. The relation is linear and very distinct, meaning that the greater the product of amperes and span length, the greater the required conductor size. The product of amperes and span length is a measure of both electrical and mechanical duty that the conductor must perform.

Minimum Sizes Used. In general the smallest size of solid conductor used in overhead lines is No. 8, and the smallest size of stranded conductor is No. 0 cable. These are the minimum sizes in regions not subject to ice and sleet. In regions subject to ice and sleet, the No. 4 and No. 6 copper wire have been found to be the smallest economical copper conductors having the necessary mechanical strength.

Maximum Sizes Used. When the size of conductor to be used is larger than No. 0000 for a 60-cycle line or larger than 300,000 cir mils for a 25-cycle line, the line is generally divided into two parallel circuits. The two resulting circuits have less voltage drop than the single line, and in case one line has trouble the other line can continue to supply partial service.

Conductor Selection Tables. Tables 8-7 and 8-8 give the conductor sizes for various combinations of voltage, power, and lengths of line for

60 cycles and 0.80 power factor. In Table 8-7 the range of length of line is from 1 to 20 miles, the load from 50 to 5,000 kw, and the voltages are 2,200, 6,600 and 13,200 volts. In Table 8-8, the range of lengths of line is from 10 to 50 miles, the load from 50 to 10,000 kw, and the voltages are 22,000, 33,000, and 44,000 volts. The load, voltage, and distance of transmission are usually the known and controlling factors. With these three factors known, the conductor size can be obtained from

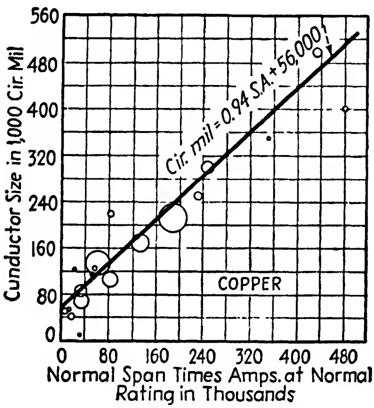


FIG. 8-11. Chart showing relation of copper-line conductor sizes in 1,000 circular mils to the product of span in feet times amperes to be carried. Plotted data represent 877 transmission lines, mentioned previously.

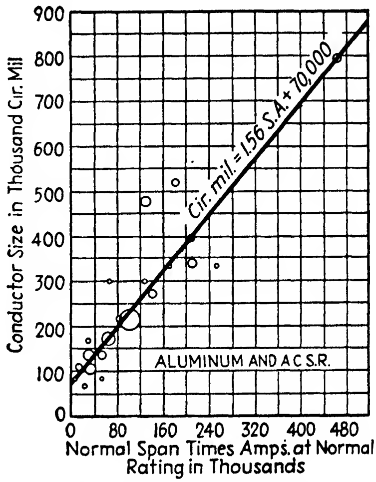


FIG. 8-12. Chart showing relation of aluminum-line conductor sizes in 1,000 circular mils to the product of span in feet times amperes to be carried. Plotted data represent 877 transmission lines, mentioned previously.

these tables. To illustrate: Let it be assumed that a transmission line is to be built between two towns 30 miles apart, that the estimated load is 1,500 kw, at a power factor of 0.80, and that this load is to be transmitted at 33,000 volts, 60 cycles. Referring to Table 8-8, under 33,000 volts is the column marked 30 miles. Following this column down to opposite the kilowatt load of 1,500 given in the first column we find the No. 4 wire size. In a similar manner the size can be obtained for other combinations of voltage, kilowatts, and miles.

Per Cent of Energy Loss. The conductor sizes given in these tables are such as will not produce a line loss greater than 10 per cent. That means that not more than 10 per cent of the power flowing over the line is wasted in the line in heating the conductors. The exact percentage of power wasted or lost in the line is given for each case opposite the letter *P*. Thus, the No. 4 wire selected above will produce a line loss of exactly 10 per cent. This is the usual limit in the design of transmission lines.

Per Cent Regulation. Furthermore, the conductor sizes given will not cause a voltage regulation to exceed 10 per cent. By "voltage regulation" is meant the change in voltage at the load end of the line when the load is removed. The per cent regulation is the percentage change figured as a part of the line voltage. Good practice is to keep this per cent voltage regulation within 10 per cent. For the case of the No. 4 conductor selected above, the percentage change in voltage is 9 per cent. That means that the voltage at the load end will not rise more than 9 per cent of 33,000, which is 2,790 volts, when the entire load of 1,500 kw is suddenly disconnected from the line.

Power-factor Adjustment. The tables referred to above are made up on the basis of an assumed power factor of 80 per cent. This is an average value of the power factor on many lines and is used for that reason. It is possible, however, to determine the conductor size for any power factor other than 0.80 by use of the adjustment factors given in Table 8-9. To illustrate the use of this table, let it be assumed that the line mentioned above is to carry a load the power factor of which will be 0.90. The area of the wire used in the foregoing illustration for the 0.80 power factor was 39,000 cir mils. By referring to the table of adjustment factors, the factor 0.79 is given for the 0.90 power factor. The area of the conductor for this new power factor is obtained by multiplying the area of the wire found for 0.80 power factor by the factor 0.79, which gives

$$0.79 \times 39{,}000 = 31{,}800 \text{ cir mils}$$

The wire size corresponding to this cross section is No. 5. This wire is smaller than the No. 4, because the current flowing at a higher power factor is less than for a lower power factor for the same kilowatt load.

SELECTION OF INSULATORS

Now that the voltage of the line and the wire size are determined, the next problem is to select the line insulators. As mentioned under insulators, in Sec. 4, on Line Materials, there are two types of insulators in general use, namely, the pin type and the suspension type.

Field of Pin Type. The pin-type insulator is used on all distribution lines and on low-voltage transmission lines. Most companies use pin-type insulators on all lines up to and including 44,000 volts. The upper limit, however, is not definite, as some companies do not use them even on 33,000-volt lines, whereas others use them on 66,000-volt lines.

Disadvantages. One objection to the use of the pin-type insulator on voltages above 44,000 volts is that the insulator is heavy, requires a long pin and an extra strong crossarm. Another objection is that if one of the petticoats of a pin insulator fails the entire insulator is useless,

Table 8-7. Size of Copper Conductor Required to Transmit Electrical Energy Various Distances at Different Voltages

(Three-phase alternating current, 80 per cent power factor, 60-cycle frequency, per cent P of energy loss to energy delivered not to exceed 10 per cent, per cent Y voltage regulation not to exceed 10 per cent, minimum size of solid conductor No. 8 wire, minimum size of stranded conductor No 0 cable)

Load		Description of tabulated information	Symbol	2,200 volts plane separation, 1 ft 2 in						6,600 volts delta separation, 1 ft 8 in			13,200 volts delta separation, 1 ft 8 in			
Kilowatts	Horsepower			1 mile	2 miles	3 miles	4 miles	5 miles	6 miles	4 miles	8 miles	12 miles	5 miles	10 miles	15 miles	20 miles
50	67	American wire gage numbers		No 8	No 7	No 6	No 4	No 3	No 2	No 8	No 8	No 8	No 8	No 8	No 8	No 8
		Area of wire required	Cir mils	16 500	19 500	29 300	39 000	48 800	58 500	16,500	16 500	16,500	16,500	16,500	16,500	16,500
		Per cent of energy loss	P	5.9	10.0	10.0	10.0	10.0	10.0	2.6	5.2	7.8	0.8	1.6	2.5	3.3
		Per cent regulation	Y	4.4	7.7	8.1	8.6	9.3	9.6	1.9	3.8	5.8	0.6	1.2	1.9	2.4
100	134	American wire gage numbers		No 7	No 4	No 2	No 1	No 00	No 000	No 8	No 8	No 6	No 8	No 8	No 8	No 8
		Area of wire required	Cir mils	19 500	39 000	58 500	78 000	114 000	161 000	16,500	17 300	25 900	16,500	16,500	16,500	16,500
		Per cent of energy loss	P	10.0	10.0	10.0	10.0	8.4	7.2	5.2	10.0	10.0	1.6	3.2	4.9	6.5
		Per cent regulation	Y	7.7	8.6	9.6	10.0	10.0	10.0	3.8	7.4	7.9	1.2	2.4	3.6	4.8
200	268	American wire gage numbers		No 4	No 1	No 000	350 000			No 8	No 5	No 3	No 8	No 8	No 8	No 7
		Area of wire required	Cir mils	39 000	78 000	161 000	320 000			17 300	34 600	51 900	16,500	16 500	16,500	21 600
		Per cent of energy loss	P	10.0	10.0	7.2	4.8			10.0	10.0	10.0	3.3	6.5	9.8	10.0
		Per cent regulation	Y	8.6	10.0	10.0	10.0			7.4	8.3	9.3	2.5	4.8	7.2	7.7
300	402	American wire gage numbers		No 2	No 000					No 6	No 3	No 2	No 8	No 8	No 6	No 5
		Area of wire required	Cir mils	58 500	161 000					25,800	51,800	77,400	16,500	16,500	24,300	32,400
		Per cent of energy loss	P	10.0	7.2					10.0	10.0	10.0	4.9	9.8	10.0	10.0
		Per cent regulation	Y	9.6	10.0					7.9	9.3	10.0	3.6	7.2	7.9	8.3
400	536	American wire gage numbers		No 1	350 000					No 5	No 1	No 00	No 8	No 7	No 5	No 4
		Area of wire required	Cir mils	78 000	320 000					34 400	68 900	117,000	16,500	21,600	32,400	43,200
		Per cent of energy loss	P	10.0	4.8					10.0	10.0	8.9	6.5	10.0	10.0	10.0
		Per cent regulation	Y	10.0	10.0					8.4	10.0	10.0	4.8	7.7	8.3	8.7
500	670	American wire gage numbers		No 00						No 4	No 0	300,000	No 8	No 6	No 4	No 3
		Area of wire required	Cir mils	115 000						43 000	86,000	280,000	16,500	27,000	40,500	54,000
		Per cent of energy loss	P	8.4						10.0	9.6	4.6	8.2	10.0	10.0	10.0
		Per cent regulation	Y	10.0						8.8	10.0	10.0	6.1	8.0	8.7	9.3

600	804	American wire gage numbers		No 000						No 3	No. 00		No 8	No 5	No 3	No. 2
		Area of wire required	Cir mils	161,000						51,600	120,000		16,500	32,400	48,600	64,800
		Per cent of energy loss	P	7 2						10 0	8 6		9 8	10 0	10 0	10 0
		Per cent regulation	Y	10 0						9 3	10 0		7 2	8 3	9 3	10 0
800	1,062	American wire gage numbers		350,000						No 2	No 0000		No. 7	No. 4	No. 2	No. 1
		Area of wire required	Cir mils	320 000						68,800	208,000		21,600	43,200	64,800	87,000
		Per cent of energy loss	P	4 8						10 0	6 6		10 0	10 0	10 0	9 9
		Per cent regulation	Y	10 0						9 8	10 0		7 7	8 7	9 9	10 0
1,000	1,340	American wire gage numbers								No. 0			No. 6	No. 3	No. 1	No. 00
		Area of wire required	Cir mils							86,000			27,000	54,000	87,000	140,000
		Per cent of energy loss	P							9 6			10 0	10 0	9 3	7 7
		Per cent regulation	Y							10 0			8 0	9 3	10 0	10 0
1,500	2,010	American wire gage numbers								No 000			No 4	No 1	No 000	400,000
		Area of wire required	Cir mils							181,000			40,500	87,000	180,000	390,000
		Per cent of energy loss	P							7 0			10 0	9 3	6 7	4 2
		Per cent regulation	Y							10 0			8 7	10 0	10 0	10 0
2,000	2,680	American wire gage numbers								350,000			No. 3	No 00	400,000	
		Area of wire required	Cir mils							360,000			54,000	140,000	290,000	
		Per cent of energy loss	P							4 7			10 0	7 7	4 2	
		Per cent regulation	Y							10 0			9 3	10 0	10 0	
2,500	3,350	American wire gage numbers											No 2	250,000		
		Area of wire required	Cir mils										67,500	230,000		
		Per cent of energy loss	P										10 0	5 9		
		Per cent regulation	Y										9 9	10 0		
3,000	4,020	American wire gage numbers											No 1	400,000		
		Area of wire required	Cir mils										87,000	390,000		
		Per cent of energy loss	P										9 3	4 2		
		Per cent regulation	Y										10 0	10 0		
3,500	4,690	American wire gage numbers											No. 0			
		Area of wire required	Cir mils										110,000			
		Per cent of energy loss	P										8 6			
		Per cent regulation	Y										10 0			
4,000	5,360	American wire gage numbers											No. 00			
		Area of wire required	Cir mils										140,000			
		Per cent of energy loss	P										7 7			
		Per cent regulation	Y										10 0			
5,000	6,703	American wire gage numbers											250,000			
		Area of wire required	Cir mils										230,000			
		Per cent of energy loss	P										5 9			
		Per cent regulation	Y										10 0			

TABLE 8-8 SIZE OF COPPER CONDUCTOR REQUIRED TO TRANSMIT
(Three-phase alternating current, 80 per cent power factor, 60-cycle per cent, per cent Y voltage regulation not to exceed 10 per cent, minimum No 0 cable)

Load		Description of tabulated information	Symbol	22 000 volts delta separation, 2 ft 6 in				
Kilowatts	Horse power			10 miles	15 miles	20 miles	25 miles	30 miles
50	67	American wire gage numbers		No 8	No 8	No 8	No 8	No 8
		Area of wire required	Cir mils	16 500	16 500	16 500	16 500	16 500
		Per cent of energy loss	P	0 6	0 9	1 2	1 5	1 8
		Per cent regulation	Y	0 4	0 7	0 9	1 1	1 3
100	134	American wire gage numbers		No 8	No 8	No 8	No 8	No 8
		Area of wire required	Cir mils	16 500	16 500	16 500	16 500	16 500
		Per cent of energy loss	P	1 2	1 8	2 4	2 9	3 5
		Per cent regulation	Y	0 9	1 3	1 8	2 2	2 7
200	268	American wire gage numbers		No 8	No 8	No 8	No 8	No 8
		Area of wire required	Cir mils	16 500	16 500	16 500	16 500	16 500
		Per cent of energy loss	P	2 3	3 5	4 7	5 9	7 1
		Per cent regulation	Y	1 8	2 6	3 5	4 4	5 3
300	402	American wire gage numbers		No 8	No 8	No 8	No 8	No 8
		Area of wire required	Cir mils	16 500	16 500	16 500	16 500	16 500
		Per cent of energy loss	P	3 5	5 3	7 1	8 8	10 0
		Per cent regulation	Y	2 7	4 0	5 3	6 6	7 8
400	536	American wire gage numbers		No 8	No 8	No 8	No 7	No 8
		Area of wire required	Cir mils	16 500	16 500	16 500	19 400	23 300
		Per cent of energy loss	P	4 7	7 1	9 4	10 0	10 0
		Per cent regulation	Y	3 5	5 3	7 1	7 9	8 2
500	670	American wire gage numbers		No 8	No 8	No 7	No 6	No 5
		Area of wire required	Cir mils	16 500	16 500	19 400	24 200	29 100
		Per cent of energy loss	P	5 9	8 8	10 0	10 0	10 0
		Per cent regulation	Y	4 4	6 6	8 0	8 2	8 5
600	804	American wire gage numbers		No 8	No 8	No 6	No 5	No 5
		Area of wire required	Cir mils	16 500	17 450	23 300	28 000	35 000
		Per cent of energy loss	P	7 1	10 0	10 0	10 0	10 0
		Per cent regulation	Y	5 3	7 8	8 2	8 4	8 6
800	1 082	American wire gage numbers		No 8	No 6	No 5	No 4	No 3
		Area of wire required	Cir mils	16 500	23 300	31 000	38 800	46 500
		Per cent of energy loss	P	9 4	10 0	10 0	10 0	10 0
		Per cent regulation	Y	7 1	8 2	8 6	8 8	9 2
1,000	1 340	American wire gage numbers		No 7	No 5	No 4	No 3	No 2
		Area of wire required	Cir mils	19 400	29 100	38 800	48 500	58 200
		Per cent of energy loss	P	10 0	10 0	10 0	10 0	10 0
		Per cent regulation	Y	8 0	8 3	8 8	9 3	9 8
1,500	2 010	American wire gage numbers		No 5	No 4	No 2	No 1	No 0
		Area of wire required	Cir mils	29 100	43 600	58 300	78 600	104 600
		Per cent of energy loss	P	10 0	10 0	10 0	9 3	8 4
		Per cent regulation	Y	8 3	9 0	9 8	10 0	10 0
2,000	2 680	American wire gage numbers		No 4	No 2	No 1	No 00	No 0000
		Area of wire required	Cir mils	38 800	58 200	86 900	127 000	186 000
		Per cent of energy loss	P	10 0	10 0	8 9	7 6	6 3
		Per cent regulation	Y	8 8	9 7	10 0	10 0	10 0
2,500	3 350	American wire gage numbers		No 3	No 1	No 00	No 0000	350 000
		Area of wire required	Cir mils	48 600	77 900	127 900	206 000	344 500
		Per cent of energy loss	P	10 0	9 4	7 6	5 9	4 2
		Per cent regulation	Y	9 2	10 0	10 0	10 0	10 0
3,000	4 020	American wire gage numbers		No 2	No 0	No 0000	350 000	
		Area of wire required	Cir mils	58 300	104 700	186 100	344 500	
		Per cent of energy loss	P	10 0	8 3	6 3	4 2	
		Per cent regulation	Y	9 8	10 0	10 0	10 0	

ELECTRICAL ENERGY VARIOUS DISTANCES AT DIFFERENT VOLTAGES
frequency, per cent P of energy loss to energy delivered not to exceed 10
size of solid conductor No. 8 wire, minimum size of stranded conductor

33,000 volts delta separation, 3 ft 0 in.						44,000 volts delta separation, 3 ft 9 in.			
15 miles	20 miles	25 miles	30 miles	40 miles	50 miles	20 miles	30 miles	40 miles	50 miles
No. 8 16,500 0 4 0.3	No. 8 16,500 0 5 0 4	No. 8 16,500 0 7 0 5	No. 8 16,500 0 8 0 6	No. 8 16,500 1 0 0 8	No 8 16,500 1 3 1 0	No. 8 16,500 0 3 0 2	No. 8 16,500 0 4 0 3	No. 8 16,500 0 6 0 5	No. 8 16,500 0 7 0 6
No. 8 16,500 0 8 0 6	No. 8 16,500 1 0 0 8	No. 8 16,500 1 3 1 0	No. 8 16,500 1 6 1 2	No. 8 16,500 2 1 1 6	No. 8 16,500 2 6 2 0	No. 8 16,500 0 6 0 5	No. 8 16,500 0 9 0 7	No. 8 16,500 1 2 0 9	No. 8 16,500 1 5 1.1
No. 8 16,500 1 6 1 2	No. 8 16,500 2 1 1 6	No. 8 16,500 2 6 2 0	No. 8 16,500 3 1 2 4	No 8 16,500 4 2 3 2	No 8 16,500 5 2 4 0	No. 8 16,500 1 2 0 9	No. 8 16,500 1 8 1 4	No. 8 16,500 2 4 1 8	No. 8 16,500 2 9 2.3
No. 8 16,500 2 4 1 8	No. 8 16,500 3 1 2 4	No. 8 16,500 3 9 3 0	No 8 16,500 4 7 3 6	No 8 16,500 6 2 4 8	No 8 16,500 7 9 6 1	No 8 16,500 1 8 1 4	No. 8 16,500 2 6 2 1	No. 8 16,500 3 5 2 8	No. 8 16,500 4 4 3 4
No 8 16,500 3 1 2 4	No. 8 16,500 4 2 3 2	No 8 16,500 5 2 4 0	No 8 16,500 6 2 4 8	No 8 16,500 8 3 6 4	No. 8 16,500 10 0 7 8	No. 8 16,500 2 4 1 8	No. 8 16,500 3 5 2 8	No. 8 16,500 4 7 3 7	No. 8 16,500 5 9 4 6
No. 8 16,500 3 9 3 0	No. 8 16,500 5 2 4 0	No. 8 16,500 6 6 5 1	No 8 16,500 7 8 6 0	No 8 17,300 10 0 7 8	No. 7 21,600 10 0 8 0	No. 8 16,500 2 9 2 3	No. 8 16,500 4 4 3 4	No. 8 16,500 5 9 4 6	No. 8 16,500 7 4 5 7
No. 8 16,500 4 7 3 6	No. 8 16,500 6 3 4 8	No. 8 16,500 7 9 6.1	No. 8 16,500 9 4 7 2	No 7 20,700 10 0 8 0	No 6 26,000 10 0 8 3	No. 8 16,500 3 5 2 8	No. 8 16,500 5 3 4 1	No. 8 16,500 7 1 5 5	No. 8 16,500 10 0 7.8
No. 8 16,500 6 3 4 8	No. 8 16,500 8 0 6 4	No. 8 17,300 10 0 7 8	No. 7 20,700 10 0 8 0	No 6 27,600 10 0 8 3	No. 5 34,500 10 0 8 7	No. 8 16,500 4 7 3 7	No. 8 16,500 7 0 5 5	No. 8 16,500 10 0 7 8	No. 7 19,400 10 0 8 0
No. 8 16,500 7 8 6 1	No. 8 17,300 10 0 7 8	No. 7 21,600 10 0 8 1	No. 6 25,900 10 0 8 4	No. 5 34,500 10 0 8 7	No. 4 43,200 10 0 9 1	No. 8 16,500 5 9 4 6	No. 8 16,500 10 0 7 8	No. 7 19,400 10 0 8 0	No. 6 24,250 10 0 8 0
No. 7 19,500 10 0 7 9	No. 6 26,000 10 0 8 3	No. 5 32,400 10 0 8 5	No. 4 39,000 10 0 9 0	No. 3 51,800 10 0 9 6	No. 2 67,300 9 6 10 0	No 8 16,500 8 8 6 9	No. 7 21,800 10 0 8 1	No 5 29,100 10 0 8.5	No. 4 36,400 10 0 8 9
No. 6 25,900 10 0 8 3	No. 5 34,600 10 0 8 7	No. 4 43,200 10 0 9 1	No. 3 51,800 10 0 9 6	No. 1 74,000 9 4 10 0	No. 0 107,000 8 1 10 0	No. 7 19,400 10 0 8 0	No. 5 29,000 10 0 8 5	No. 4 38,800 10 0 9 0	No. 3 48,500 10 0 9 6
No. 5 32,400 10 0 8 7	No. 4 43,300 10 0 9 1	No. 3 54,000 10 0 9 7	No. 2 67,300 9 6 10 0	No. 0 107,000 8 1 10 0	No. 000 166,000 6 5 10 0	No. 6 24,300 10 0 8 3	No. 4 36,200 10 0 8 9	No 3 48,500 10 0 9 6	No. 2 64,000 9 7 10 0
No 4 38,800 10 0 8.9	No. 3 52,000 10 0 9.6	No 2 67,300 9 6 10.0	No. 0 88,300 8 7 10.0	No. 000 151,500 6 9 10.0	300,000 265,000 4 9 10.0	No. 5 29,100 10 0 8.5	No. 3 43,500 10 0 9.2	No. 2 58,200 10 0 10.0	No. 1 80,600 8 6 10.0

TABLE 8-8. SIZE OF COPPER CONDUCTOR REQUIRED TO TRANSMIT (Con

Load		Description of tabulated information	Symbol	22,000 volts delta separation, 2 ft 6 in				
Kilowatts	Horsepower			10 miles	15 miles	20 miles	25 miles	30 miles
4,000	5,360	American wire gage numbers		No 1	No 0000			
		Area of wire required	Cir mils	77,600	186,100			
		Per cent of energy loss	*P*	9 4	6 3			
		Per cent regulation	*Y*	10 0	10 0			
5,000	6,703	American wire gage numbers		No 00	350,000			
		Area of wire required	Cir mils	127,000	344,500			
		Per cent of energy loss	*P*	7 6	4 2			
		Per cent regulation	*Y*	10 0	10 0			
6,000	8,043	American wire gage numbers		No 0000				
		Area of wire required	Cir mils	186,000				
		Per cent of energy loss	*P*	6 3				
		Per cent regulation	*Y*	10 0				
7 000	9,384	American wire gage numbers		300,000				
		Area of wire required	Cir mils	275,000				
		Per cent of energy loss	*P*	4 9				
		Per cent regulation	*Y*	10 0				
8 000	10,725	American wire gage numbers		400,000				
		Area of wire required	Cir mils	400,000				
		Per cent of energy loss	*P*	3 8				
		Per cent regulation	*Y*	10 0				
10,000	13,405	American wire gage numbers						
		Area of wire required	Cir mils					
		Per cent of energy loss	*P*					
		Per cent regulation	*Y*					

whereas if one insulator of a suspension string fails that unit can be replaced without loss of the remaining units.

Advantages. The main advantage of the pin-type insulator is that it is the cheaper insulator. Another advantage is that a pin insulator requires a shorter pole or tower to produce the same clearance of the conductor above the ground. The pin insulator raises the conductor above the crossarm, while the suspension insulator suspends it below the crossarm.

Pin Height. In Table 8-10 are given the average heights of the conductor above the crossarm for pin-type insulators. These figures will be used in what follows in determining the height of pole or tower.

Field of Suspension Insulator. The suspension insulator in general is used for all lines above 44,000 volts. The number of units in the string depends on the voltage of the line. The higher the voltage, the more units are placed in series in the string. The average number of units used in practice for the various line voltages are given in Table 8-11 and Fig. 8-13.

It will be noted that less than two units are never used. The reason for never using less than two units is to allow one to fail without putting the line out of service. In fact, the general practice is to put enough units in the string to permit one to fail without causing a shutdown of the line

ELECTRICAL ENERGY VARIOUS DISTANCES AT DIFFERENT VOLTAGES
tinued)

33,000 volts delta separation, 3 ft 0 in.						44,000 volts delta separation, 3 ft 9 in.			
15 miles	20 miles	25 miles	30 miles	40 miles	50 miles	20 miles	30 miles	40 miles	50 miles
No. 3 51,800 10 0 9.6	No 1 74,000 9 4 10 0	No. 0 107,000 8 1 10 0	No 000 151,500 6 9 10 0	350,000 323,000 4 3 10 0		No 4 38,800 10 0 9 0	No 2 58,000 10 0 10 0	No 0 92,300 8 4 10 0	No. 000 140,000 6 9 10 0
No 2 67,300 9 6 10 0	No 0 90,000 8 7 10 0	No 000 166,000 6 5 10 0	300,000 265,000 4 9 10 0			No 3 48,500 10 0 9 5	No. 1 83,000 8 8 10 0	No 000 140,000 6 9 10 0	250,000 242,500 5 0 10 0
No 0 88 300 8 7 10 0	No 000 151 500 6 9 10 0	300 000 265 000 4 9 10 0				No 2 58,000 10 0 10 0	No. 00 113,400 7 7 10 0	250,000 216,000 5 4 10 0	
No 00 116,700 7 8 10 0	No 0000 222,000 5 4 10 0					No 1 75,000 9 1 10 0	No 000 154,800 6 6 10 0	350,000 342,000 4 0 10 0	
No. 000 151,500 6 9 10 0	350,000 323,000 4 3 10 0					No 0 92,300 8 4 10 0	250,000 216,000 5 4 10 0		
300,000 264,000 4 9 10 0						No 000 140,000 6 9 10 0			

Length of String. The average length of string for strings three to eight units long is given in Table 8-12. It will be noted that the eight-unit string is almost 4 ft long. One objection to this type of insulator is that it requires a higher pole or tower to obtain the same clearance of conductor aboveground. The table given will be used later in determining the height of the line supports.

TABLE 8-9. POWER-FACTOR ADJUSTMENT FACTORS

Power factor	0 70	0 75	0 80	0 85	0 90	0 95	1 00
Adjustment factor	1 30	1 15	1 00	0 88	0 79	0 71	0.64

TABLE 8-10. AVERAGE HEIGHT OF CONDUCTORS ABOVE CROSSARMS FOR PIN-TYPE INSULATORS

Voltages . .	2,300	6,600	13,200	22,000	33,000	44,000	66,000	88,000
Heights, ft. . . .	0.4	0.4	0.5	0.7	0.9	1.1	1 4	1 7

TABLE 8-11. AVERAGE NUMBER OF SUSPENSION INSULATOR UNITS USED PER STRING FOR VARIOUS LINE VOLTAGES

Line Voltage	Number of Suspension Insulator Units in String
13,200	2
22,000	2 or 3
33,000	2 or 3
44,000	3 or 4
66,000	4 or 5
88,000	5 or 6
110,000	6, 7, or 8
132,000	8, 9, or 10
154,000	9, 10, or 11
220,000	12 to 16
330,000	18 to 22

TABLE 8-12. AVERAGE LENGTHS OF A STRING OF DISK-TYPE OR SUSPENSION INSULATORS

Voltage	33,000 or 44,000	44,000 or 66,000	66,000 or 88,000	88,000 or 110,000	110,000 or 132,000	132,000 or 154,000
Number of units	3	4	5	6	7	8
Length, ft	1.4	1 9	2.4	2.9	3.4	3.8

TABLE 8-13. AVERAGE CONDUCTOR SPACINGS FOR THE COMMON DISTRIBUTION AND TRANSMISSION VOLTAGES

Line Voltage	Distance between Line Conductors, In.
2,300	12 to 18
6,600	18 to 24
13,200	18 to 24
22,000	30 to 36
33,000	36 to 48
44,000	48 to 60
66,000	72
88,000	96
110,000	120
132,000	144
154,000	168
220,000	192
330,000	264

SPACING OF CONDUCTORS

Spacing. A general idea will be given here of the distance that must be provided between line conductors for various voltages. Practice differs considerably, and only approximate values can be given. The distances given in Table 8-13 and Figs. 8-14 and 8-15 represent average practice for moderate spans. The greater the span between poles or

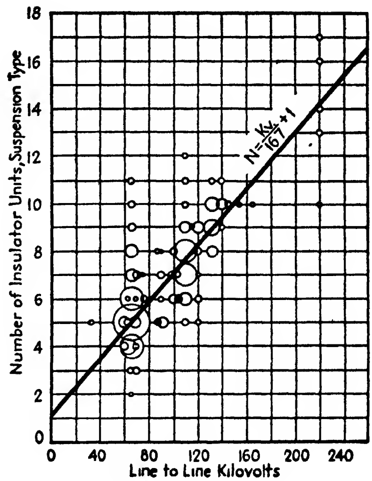


FIG. 8-13. Chart showing relation between standard line voltages and number of insulator units in suspension string. Plotted data refer to analysis of 877 transmission lines, mentioned previously.

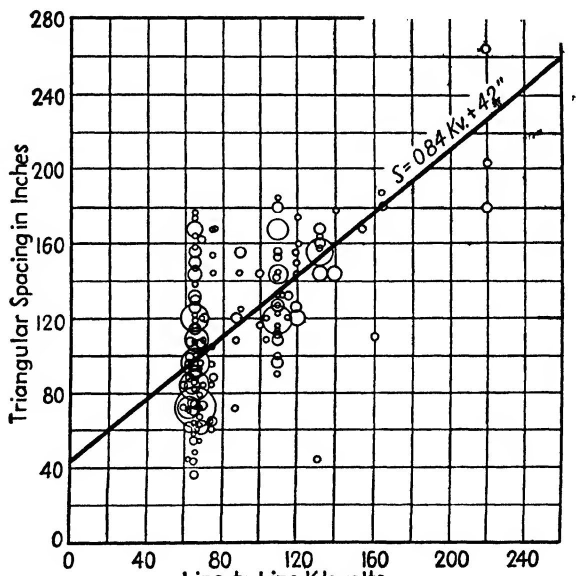


FIG. 8-14. Chart showing relation between line voltages and average triangular conductor spacing in inches. Based on analysis of 877 transmission lines, mentioned previously.

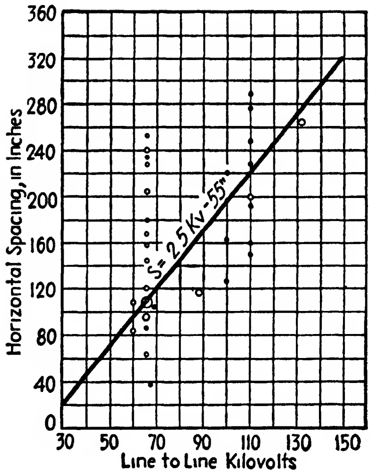


Fig. 8-15. Chart showing relation between line voltages and average horizontal spacing in inches Based on analysis of 877 transmission lines, mentioned previously

Fig. 8-16. Delta or triangular spacing of conductors of three-phase line (*Courtesy Iowa-Illinois Gas & Electric Co.*)

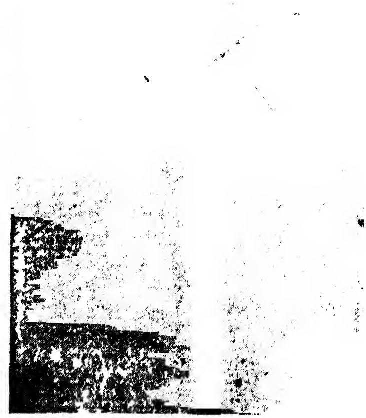


Fig. 8-17 Horizontal spacing of conductors of three-phase line (*Courtesy Iowa-Illinois Gas & Electric Co*)

towers, the greater the spacing must be, because of the greater possibility of conductors touching each other during high wind. For example, the minimum permissible spacing of a line operating at a given voltage for a 300-ft span is 4 ft; for 400-ft span, 4½ ft; for 500-ft span, 5 ft; and for 600-ft span, 6 ft.

Conductor Arrangement. Three methods of conductor arrangement are in general use. The conductors can be arranged in a triangle, commonly called "delta spacing" (see Fig. 8-16), or they can be arranged in a horizontal plane (Fig. 8-17), or in a vertical plane (Fig. 8-18). Years ago the delta arrangement was extensively used, but experience now shows that the vertical or horizontal arrangements are also satisfactory.

FIG. 8-18. Vertical spacing of conductors at a corner of a three-phase line. (*Courtesy Iowa-Illinois Gas & Electric Co.*)

When arranged in a vertical plane, there is a possibility of an unequal sleet or ice load on the three conductors, which makes an increase of conductor spacing necessary.

SPANS

General. The span is the distance between line supports, that is, the distance between poles or towers. It is evident that the longer the span, the fewer will be the number of poles or towers and the number of insulators. It is also evident that the longer the span, the larger must be the conductor in order to carry its own weight and any additional ice, sleet, or wind load. The determination of the most economical span is a complex problem and involves balancing the increased cost of the increased size of conductor and tower against the saving due to the lesser number of towers and insulators.

General Practice. The spans used in practice for pole lines range from 125 to 350 ft, and for tower lines from 450 to 800 ft. The average for pole-line spans is in the neighborhood of 250 ft and for tower lines, 600 ft. In general, steel towers are used for all transmission lines of permanent character, except where the first cost, maintenance, and life of wood poles makes the pole line the cheaper. In some sections of the country, as in the South, for example, nearly all the important lines are wood-pole lines. This is because the pines used for poles grow in that territory and the climate is such as to give a long pole life.

GROUND CLEARANCE

General. In the interests of public safety, the United States government, through its Bureau of Standards, has also recommended the minimum height at which conductors shall be strung aboveground. This height varies with the use made of the ground below. If it is a

TABLE 8-14. REQUIRED MINIMUM VERTICAL CLEARANCES OF WIRES TO GROUND OR RAILS FOR VARIOUS VOLTAGES AS GIVEN BY THE NATIONAL ELECTRICAL SAFETY CODE

(For voltages in excess of 50,000 volts, the clearances should be increased ½ in. for each 1,000 volts of excess.)

Nature of ground or rails underneath wires	Guys, messengers communication span and lightning protection wires, permanently grounded continuous-metal sheath cables of all voltages ft	Open supply-line wires arc wires and service drops, ft			Trolley contact conductors and associated span or messenger wires, ft	
		0 to 750 volts	750 to 25,000 volts	15,000 to 50,000 volts	0 to 750 volts to ground	Exceeding 750 volts to ground
Where Wires Cross Over						
Track rails of railroads handling freight cars on top of which men are permitted	27	27	28	30	22	22
Track rails of railroads not included above	18	18	20	22	18	20
Public streets alleys or roads in urban or rural districts	18	18	20	22	18	20
Driveways to residence garages	10	10	20	22	18	20
Spaces or ways accessible to pedestrians only	15	15	15	17	16	18
Where Wires Run Along						
Streets or alleys in urban districts	18	18	20	22	18	20
Roads in rural districts	14	15	18	20	18	20

railroad crossing, the wire must be strung higher than if it is an ordinary street crossing. And again, if it is a street crossing, it must be strung higher than if the line is along the road in the country. These minimum clearances are important in determining the pole or tower height necessary to produce these clearances.

Clearances. Table 8-14 gives these recommended minimum clearances for the various line voltages for railroad crossings, street crossings,

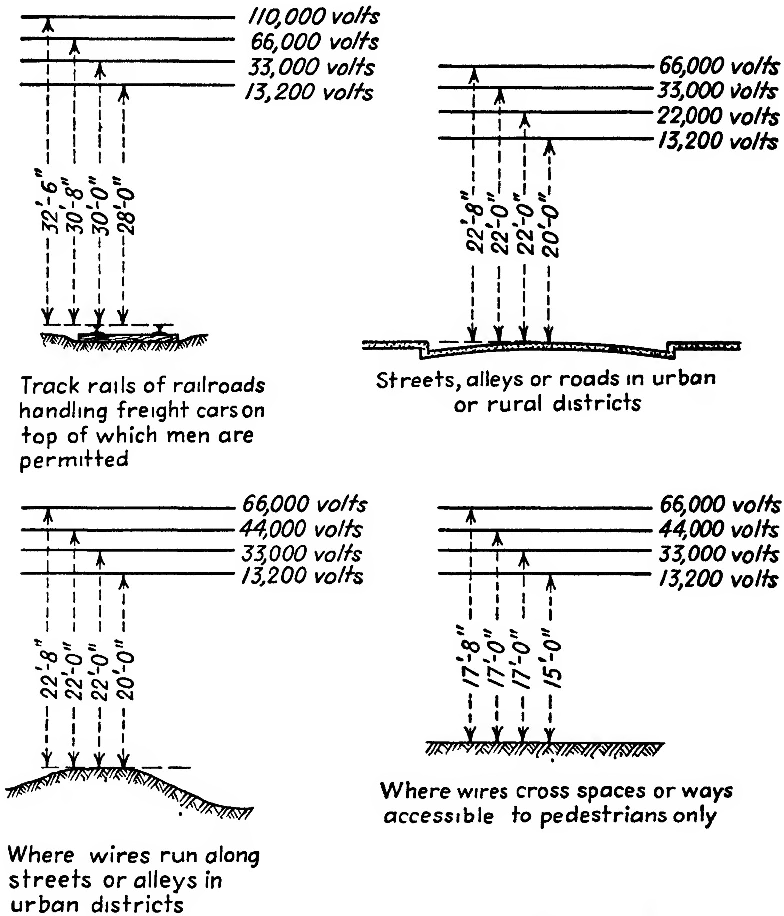


FIG. 8-19. Sketches illustrating National Electrical Safety Code recommended minimum vertical clearances of overhead-line conductor to ground or rails. Span for above clearances does not exceed 150 ft.

lines along country roads, and other places only accessible to people walking. The same information is given in Fig. 8-19. It will be noted that the clearance required above railroad crossings is greatest, then come street crossings, then lines along rural roads, and the smallest clearance is that required in places where vehicles do not travel, as on sidewalks. As shown, the range of ground clearance is from 15 to

32½ ft. For adjustment due to span length and conductor size, see NESC Rule 232B

WIRE-CROSSING CLEARANCE

General. In addition to providing a given clearance aboveground, conductors must also provide clearances in case they cross conductors of another line The line which crosses over the other line, therefore, must be carried on higher poles or towers than would be required by the ground clearance alone.

TABLE 8-15. MINIMUM RECOMMENDED CLEARANCES REQUIRED BETWEEN ANY TWO WIRES CROSSING EACH OTHER AND CARRIED ON DIFFERENT SUPPORTS

(These clearances must be increased ½ in for each 1,000 volts of excess above 50,000 volts)

Nature of wires crossed over	Communication wires including cables and messengers ft	Open supply wires 0 to 750 volts supply cables all voltages having effectively grounded continuous or messengers messengers associated with such cables ft		Open supply wires and service drops feet		Guys span wires lightning protection wires ft
		Line wires	Service drops	750 to 8 700 volts	8 700 to 50 000 volts	
Communication including cables and messengers	2	4	2	4	6	2
Supply cables all voltages having effectively grounded continuous metal sheaths or messengers messengers associated with such cables	4	2	2	2	4	2
Open supply wires						
0 to 750 volts	4	2	2	2	4	2
750 to 8 700 volts	4	2	4	2	4	4
8 700 to 50 000 volts	6	4	6	4	4	4
Trolley contact conductors	4	4	4	6	6	4
Guys, span wires lightning-protection wires, service drops 0 to 750 volts	2	2	2	4	4	2

Clearances. The minimum clearances which must be provided have also been established by the National Electrical Safety Code and are reprinted here in Table 8-15 These clearances are supposed to be sufficient to keep the wires of the different lines from coming in contact with each other during windstorms or at times of heavy conductor loading as during sleet storms. As noted in the table, the clearance between a supply line and a telephone line varies from 2 to 6 ft, depending upon the voltage, and the clearance between two supply lines also varies from 2 to 6 ft. The 4-ft clearance is perhaps the most common.

For further details and for the effect of span length and conductor size, see NESC Rule 233B.

SAG

The sag of a conductor is the dip of an aerial wire between two adjacent poles or towers (Fig. 8-20).

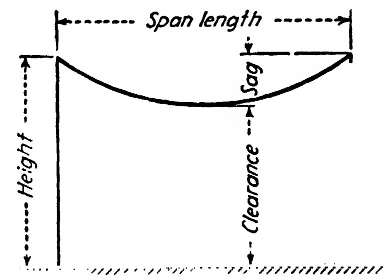


FIG. 8-20. Sketch showing meaning of span length, sag, and ground clearance.

Factors Affecting Sag. The factors affecting the sag in a conductor are the length of span, the weight of the conductor, any additional sleet or wind load on it, and the temperature. The temperature is a very important factor because, when it is hot, the conductor lengthens, and the dip is increased, and when it gets cold, the conductor shortens and tightens. If the conductor is strung too tight while the temperature is high, the conductor may break when the temperature is low. This change in length is very appreciable. For copper the shortening per mile of wire when the temperature changes from 100 to 0°F is 5.06 ft. For aluminum the shortening amounts to 6.75 ft.

Sag Tables. The changes in sag due to expansion and contraction because of changes of temperature are therefore of much importance in the construction of lines, especially the stringing of wires. In order to avoid excessive tension on conductors during cold weather, they must have the proper slack or sag. Furthermore, in order that they may not dip below the clearance required to the ground during the summertime, they must have the proper tension. Tables 8-16 and 8-17 and Figs. 8-21 and 8-22 give the normal sags and tensions for copper and aluminum conductors for various spans and temperatures at time of stringing to which the conductors should be pulled. These sags are such that no excessive strain will be put on the wire for the worst conditions of tem-

Table 8-16. Sags and Tensions for Copper Cables
(Worst condition: 0°F, ½-in. ice, 8-lb wind)

Size, B. & S. gage	Span, ft	Allowable stress,* lb	Conditions without ice or wind							
			Sag, ft				Stress, lb (total)			
			0	60	80	130	0	60	80	130
300,000	600	6,900	9.37	11.57	12.40	14.25	4,560	3,700	3,455	3,010
250,000	600	5,810	9.96	12.22	13.02	14.82	3,530	2,890	2,705	2,375
0000	600	4,850	11.32	13.58	14.31	16.02	2,637	2,205	2,090	1,867
000	600	3,870	13.20	15.37	16.18	17.21	1,795	1,547	1,480	1,337
00	600	3,100	16.03	17.95	18.55	20.05	1,179	1,049	1,016	941
0	600	2,460	19.63	21.33	21.90	23.30	764	701	685	645
0	500	2,460	12.10	14.10	14.65	15.95	837	733	708	652
1	500	1,953	15.60	17.10	17.55	18.75	527	481	463	440
2	500	1,523	20.20	21.50	21.85	22.85	325	307	301	288
3	300	1,233	7.02	8.20	8.56	9.36	266	229	219	200
4	300	972	9.48	10.29	10.56	11.34	157	143	140	130
5	300	774	12.36	13.12	13.35	13.94	95	90	88	85
6	200	614	6.00	6.64	6.84	7.34	69	62	61	56

* Allowable stress = one-half ultimate strength. Sags and tensions calculated to give allowable stress under worst conditions specified above. Coefficient of expansion = 0.0000096, modulus of elasticity = 16,000,000.

Table 8-17. Sags and Tensions for Aluminum Cables
(Worst condition: 0°F, ½-in. ice, 8-lb wind)

Size (copper equivalent)	Span, ft	Allowable,* stress, lb	Conditions without ice or wind							
			Sag, ft				Total stress, lb			
			0	60	80	130	0	60	80	130
350,000	600	6,120	8 28	11.98	13.12	15.81	2,775	1,923	1,752	1,465
300,000	600	5,250	9.63	13.28	14.35	16.86	2,053	1,495	1,383	1,183
250,000	600	4,380	11.71	14.95	16.02	18.31	1,412	1,105	1,032	903
0000	600	3,705	13.94	16.87	17.83	20.05	1,006	834	791	709
000	600	2,932	17.77	20.40	21.12	23.04	629	551	530	487
00	500	2,330	14.10	16.40	17.12	18.67	435	377	361	331
0	500	1,843	18.45	20.10	20.62	22.15	266	245	238	223
1	500	1,466	22.90	24.50	25.05	26.25	170	160	157	150
1	400	1,466	13.69	15.12	15.60	16.73	183	164	159	149
2	400	1,159	17.32	18.58	19.06	20.12	114	106	104	99
3	400	921	22.00	23.05	23.50	24.30	72	69	68	66
3	300	921	11.40	12.40	12.73	13.51	77	71	69	65
4	300	730	14.78	15.70	15.93	16.68	47	45	44	43

* Allowable stress based on 14,000 lb per sq in. Sags and tensions calculated to give allowable stress under worst conditions specified above. Coefficient of expansion = 0.0000128, modulus of elasticity = 9,000,000.

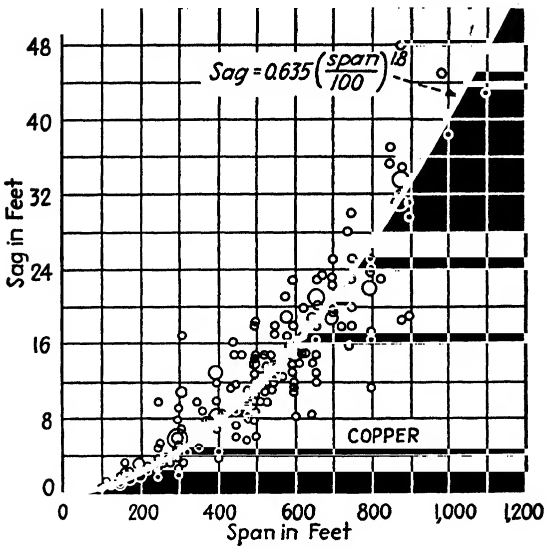


FIG. 8-21. Chart showing copper-conductor sags for various spans for 877 transmission lines, mentioned previously. The curve shows that sag is related parabolically to span length. *(Data compiled by Electrical World and analyzed by E. B. Kurtz and J. A. Douglas, Transmission Line Analysis Indicates Ruling Tendencies, Electrical World, Sept. 26, 1931.)*

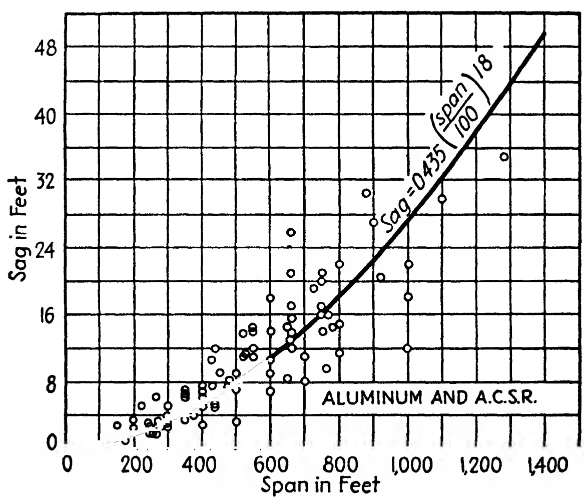


FIG. 8-22. Chart showing aluminum-conductor sags for various spans for 877 transmission lines mentioned previously. The curve shows sags to be parabolically related to span length. Comparison of this chart with Fig. 8-21 shows sags for aluminum conductors to be about two-thirds of those allowed for copper conductors.

perature, ice, and wind. The manner in which the sag is measured while stringing the wire will be discussed in the section on Pole Line Erection.

POLE OR TOWER HEIGHT

General. Another general feature of line design to be discussed is the determination of the pole or tower height. It will be assumed that

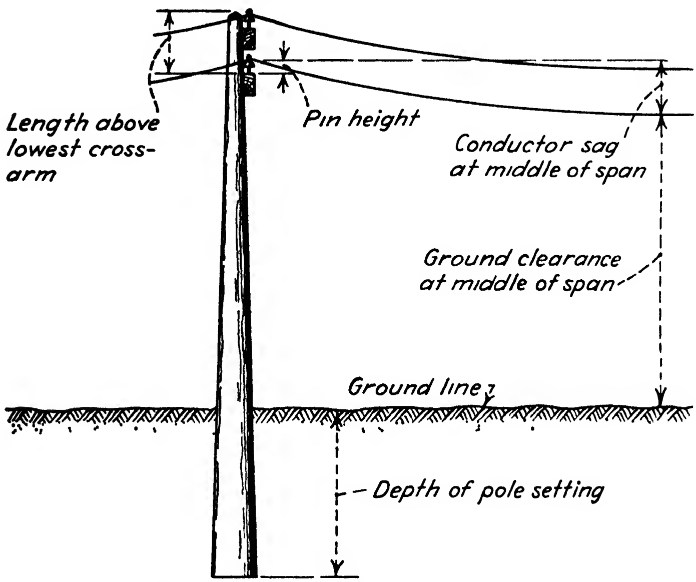


FIG. 8-23 Sketch to illustrate required pole length.

the voltage and current of the line have been determined, the conductor size has been fixed, the type of insulator has been selected, and the length of span and sag are also agreed upon. With these matters settled it now becomes a simple matter to compute the required height of the pole or tower supports. These will be treated separately below.

Pole Height. From an inspection of Fig. 8-23, it is easy to see that the length of pole required between the lowest crossarm and the ground line is equal to

$$\text{Length between lowest crossarm and ground line} = \text{ground clearance} + \text{sag} - \text{pin height}$$

The pole must be high enough to provide the clearance and the sag, but since the pin-type insulator raises the conductor, the pole height can be reduced by this amount. It will be recalled that this is an advantage of the pin-type insulator.

Below the ground line the pole must have the proper length for setting. The setting depths have been quite well standardized and are given in Table 8-18 for rock and soil. The length required above the lowest crossarm depends on the number of crossarms and can be easily determined after the number of required crossarms is known, by allowing

TABLE 8-18. RECOMMENDED POLE-SETTING DEPTHS IN SOIL AND ROCK FOR VARIOUS LENGTHS OF WOOD POLES

Length of pole, ft	Setting depth in soil, ft	Setting depth in rock, ft
20	5	3.0
25	5	3.5
30	5.5	3.5
35	6	4
40	6	4
45	6.5	4.5
50	7	4.5
55	7	5
60	7.5	5
65	8	6
70	8.0	6.0
75	8.5	6.0
80	9.0	6.5

2 ft between crossarms and 1 ft above upper crossarm. The entire pole length then becomes

$$\begin{aligned}\text{Pole length} &= \text{ground clearance} + \text{sag} - \text{pin height} \\ &\quad + \text{setting depth} + 2 \times (\text{number of crossarms} - 1) + 1\end{aligned}$$

Tower Height. The required tower height between the ground line and lowest crossarm is easily seen from Fig. 8-24 to be equal to

$$\begin{aligned}&\text{Tower height between lowest crossarm and ground line} \\ &\qquad = \text{ground clearance} + \text{sag} + \text{length of insulator string}\end{aligned}$$

The average length of suspension insulator strings of various units was given in Table 8-12. It will be noted that the suspension insulator requires a higher support than the pin-type insulator because it lowers the conductor, whereas the pin-type insulator raises it. With these general notions one can easily compute the approximate required pole or tower height.

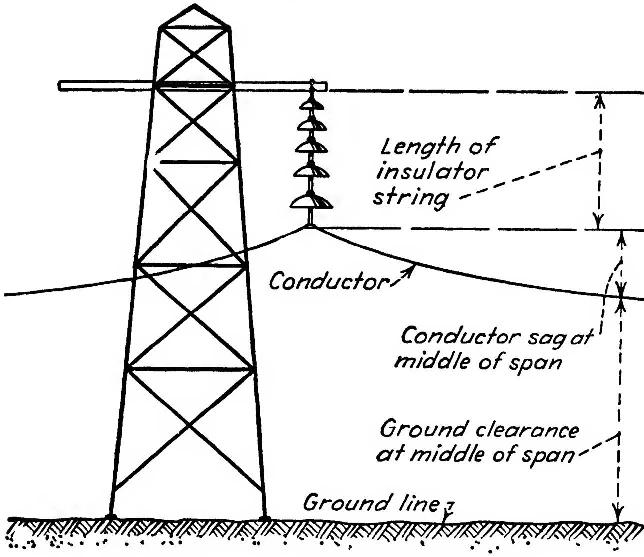


FIG. 8-24. Sketch to illustrate height of tower.

TRANSPOSITIONS

Definition. Another feature of a transmission line that the designing engineer must provide for in his layout of the line is conductor transposition. A transposition is a change in the relative positions of the conductors of a line. A typical transposition is illustrated in Fig. 8-25. It will be noted that in this transposition conductor 2 takes the place of

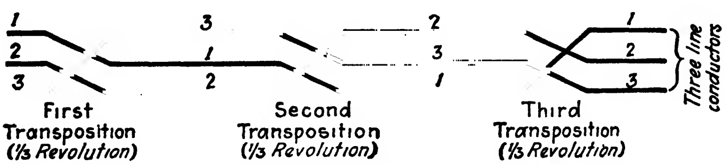


FIG. 8-25. Sketch illustrating method of transposing conductors in three-phase line. Three transpositions are required to bring conductors back to the original position.

conductor 3, 3 takes the place of 1, and 1 takes the place of 2. This is equivalent to one-third revolution of the conductors of the line. At the next transposition the conductors are shifted another one-third revolution, and at the following transposition another shift of one-third revolution is made. This brings the conductor back to its former position. The distance between transpositions is largely a matter of judgment, and varies from 10 to 40 miles.

Reasons for Transposing. Transpositions are made principally to reduce the interference which power lines produce in neighboring telephone circuits. The telephone circuits are likewise transposed (see Fig. 8-26) further to assist in the reduction of this interference. Transposition of the power lines also tends to keep the power line in balance electrically, especially if the conductors are arranged in a vertical plane.

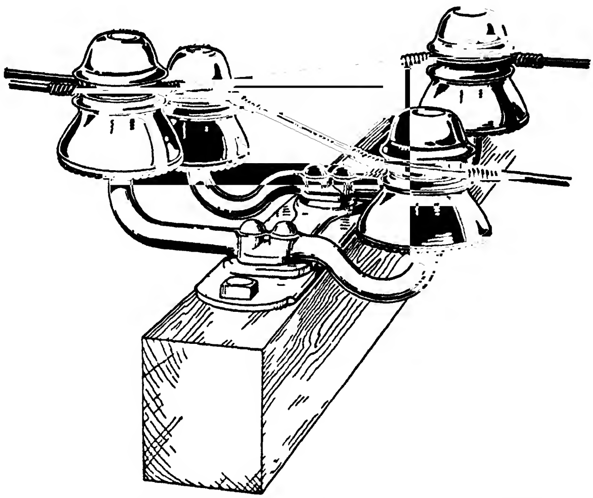


Fig 8-26 Transposition in telephone lines. The special brackets shown hold the wires apart vertically so that they will not touch each other as they are interchanged. (*Courtesy Hubbard & Co.*)

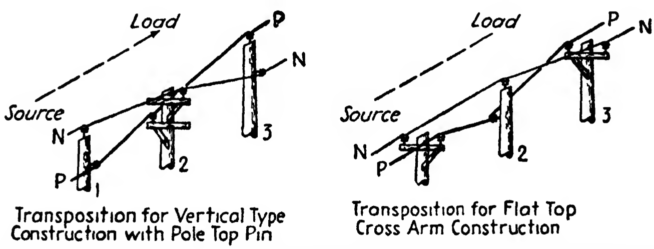


Fig. 8-27 Typical transposition methods used in vertical and flat-top single-phase construction. (*Courtesy Joslyn Mfg. and Supply Co.*)

Methods of Transposing. Transpositions are commonly made by interchanging the conductors, as already illustrated, or by dead ends and jumpers. Figure 8-27 illustrates the usual method employed in making transpositions on single-phase lines. It will be noted that with the vertical construction an intermediate pole with two crossarms is required, while with the flat-top construction an intermediate pole provided with side pin and pole-top pin is required.

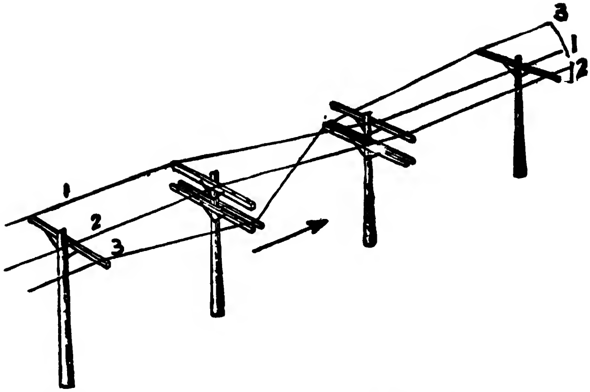


FIG. 8-28. Common method of transposing three-phase pole line in which conductors are supported on crossarms. Two of the poles must be provided with extra crossarms as shown.

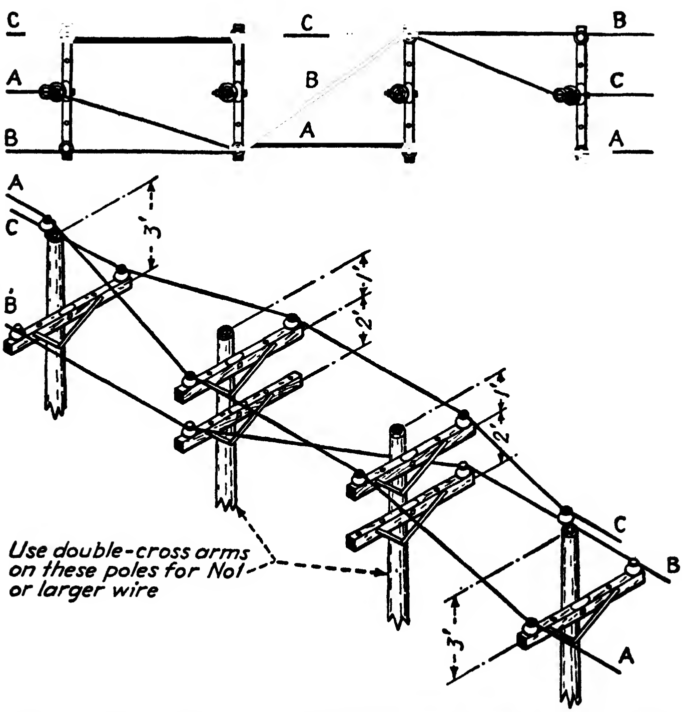


FIG. 8-29. Common method of transposing three-phase pole line in which the conductors are arranged in triangular position. Two of the poles must be provided with an extra crossarm as shown.

Figures 8-28 and 8-29 illustrate the usual manner of transposing the conductors on three-phase pole lines. Figure 8-28 illustrates the case where the conductors lie in a horizontal plane, and Fig. 8-29 illustrates the case where the conductors are arranged in a triangle, the upper one

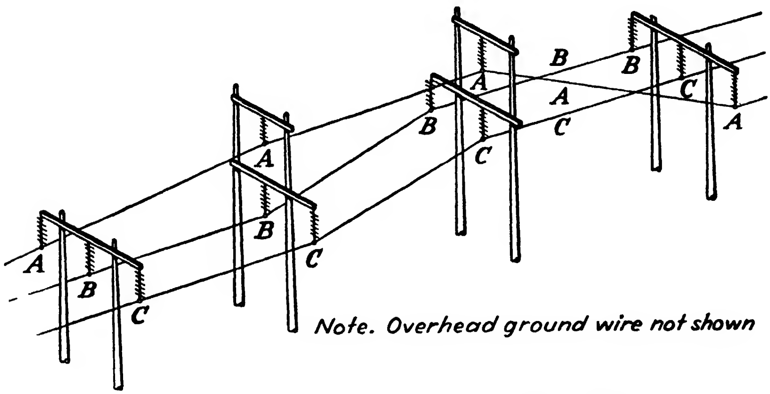


FIG 8-30 Common method of transposing three-phase H-frame pole line in which conductors are supported from suspension insulators Two special H frames provided with two crossarms each are needed to move the conductors gradually step by step into their new positions

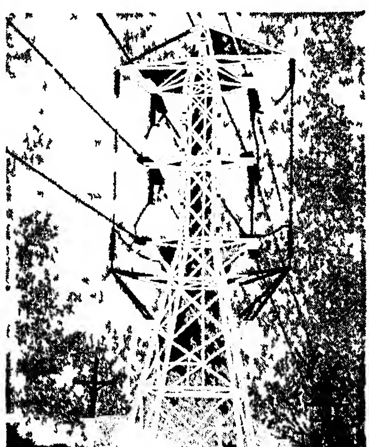


FIG 8-31 A two-circuit transposition tower on a 132 000-volt line Note that the transpositions on the two lines are opposite The left-hand line brings its top conductor down to the lowest position, the middle conductor to top position, and the lowest conductor to middle position The right-hand line brings its lowest conductor to the top position, its middle conductor to bottom position, and its top conductor to middle position Note ground wire at apex of tower (*Courtesy Wisconsin Electric Power Co*)

being supported on a pole pin. In each case resort is made to two special intermediate poles carrying two crossarms. This makes possible separating the conductors and changing their positions without having them come close to one another. In order to maintain plenty of clearance, the spans of the transposition poles or towers are usually reduced to one-half the length of the regular span. Figure 8-30 illustrates the usual method of transposing conductors on an H-frame line. Two intermediate supports are again needed, each equipped with two cross-arms. On these supports one conductor is supported on the upper arm and two on the lower arm. The dead-end jumper method is used on steel-tower transmission lines and makes use of a strain tower on which the line conductors are dead-ended. The change in relative position is accomplished by the use of short jumpers from one position to the other, as illustrated in Fig. 8-31.

DEAD-ENDING

Purpose. Dead ends are points in the line where all the strain in the line conductors is carried by the supports Dead ends are obviously

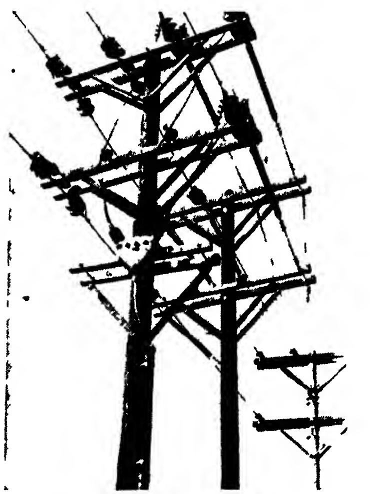


FIG. 8-32 Double-arm dead end at line terminal. (*Courtesy Iowa-Illinois Gas & Electric Co.*)

FIG 8-33 Dead-end construction at corner pole Note use of jumpers to connect conductors Also note corner down guys counterbalancing pull in both directions (*Courtesy Iowa-Illinois Gas and Electric Co*)

necessary at line terminals, for, in such cases, the line conductors do not continue into the next span and thereby counterbalance the conductor pull. Dead ends must also be provided at corners, at angles greater than 45 deg, at points where switches are inserted in the line or where the size of line conductor changes, at the ends of long spans, etc. Dead-ending makes possible withstanding unbalanced stresses by the use of special insulators and line supports.

Construction. On low-voltage pole lines a dead end usually requires double arming and guys. Where the tension in the wire exceeds the safe

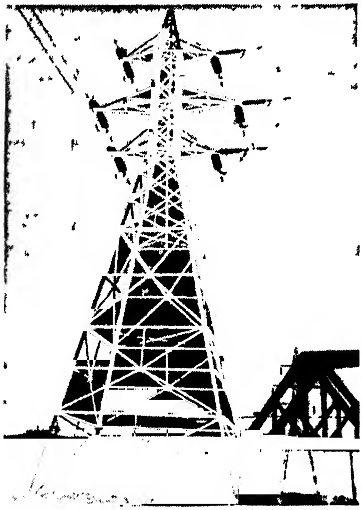


FIG. 8-34. Dead-end tower in a 132,000-volt line. This tower is a great deal larger at the base and has considerably more bracing than a straight line or tangent tower. Note the use of two insulator strings in place of one. At a dead end the insulator string must not only support the conductor but must also offset the tension in the line. Ordinarily the string hangs vertically and only supports the weight of the conductor. Each string has 12 insulator units to withstand the high voltage. The branch line turning to the right is a short span, and therefore one string is adequate. (*Courtesy Wisconsin Electric Power Co.*)

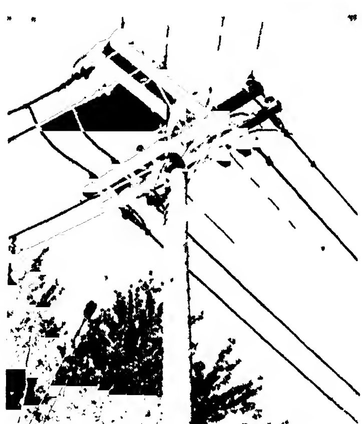


FIG. 8-35. Double-arm dead-end construction at corner pole. Note use of down guys to counterbalance pull of line conductors. (*Courtesy Iowa-Illinois Gas and Electric Co.*)

FIG 8-36. Dead end in line at sectionalizing air-break switch. Note use of strain insulators and double-arm construction. Also note operating lever of sectionalizing switch. (*Courtesy Iowa-Illinois Gas and Electric Co.*)

load of pins, strain insulators, illustrated in Fig. 8-32, should be used. A dead end on higher voltage pole construction at an angle is shown in Fig. 8-33. Here the conductors are separated in a vertical plane. Dead ends on tower construction using suspension insulators are shown in Fig. 8-34. Other examples of dead-ending of the line conductors are

FIG. 8-37. Dead-end construction at river crossing. Note use of four down guys to counterbalance pull of long span across river. (*Courtesy Iowa-Illinois Gas & Electric Co.*)

illustrated in Fig. 8-35 on a corner pole, in Fig. 8-36 on a sectionalizing pole, and in Fig. 8-37 at a river crossing.

GRADES OF CONSTRUCTION

Grades. The fourth edition of the National Electrical Safety Code specified five grades of construction for power lines, namely, A, B, C, D, and E. These grades are related to the strength of the line, that is, a grade A line is stronger than a grade B line, and a grade B line is stronger than a grade C line. The actual relative strengths of wooden poles for the three grades of construction A, B, and C are as given in Table 8-19 which is reprinted from the code.

This table shows that a grade A line must be so designed for strength that, when it is loaded with the ice, wind, etc., assumed for the district in which it is to be located, the allowable fiber stress will not exceed one-third of the ultimate fiber stress; for grade B construction, one-half of the ultimate fiber stress; and three-fourths of the ultimate fiber stress for grade C construction. To illustrate, for wooden poles having an assumed ultimate fiber stress of 6,500 lb per sq in, the table shows that the allowable fiber stress shall not exceed 2,170 lb per sq in. for grade A construction. This is exactly one-third of 6,500 for grade A construction, giving a factor of safety of 3. For grade B construction the allowable fiber stress must not exceed 3,250 lb per sq in. This is exactly one-half of 6,500, making the factor of safety 2. In grade C construction the allowable fiber stress must not exceed 4,870 lb per sq in. This is three-fourths of 6,500, making the factor of safety only 1⅓. For wooden poles, therefore, the factors of safety for grades A, B, and C, respectively, are 3, 2, and 1⅓.

In like manner the strength requirements of reinforced-concrete poles, steel towers, foundations, guys, crossarms, etc., are fixed for the various grades of construction.

TABLE 8-19. ALLOWABLE FIBER STRESSES (IN POUNDS PER SQUARE INCH) FOR WOOD POLES UNDER VERTICAL AND TRANSVERSE LOADING

Location	When installed				
	Treated poles			Untreated poles	
	For ultimate fiber stress of			For ultimate fiber stress of	
	6,500	5,000	3,600	5,000	3,600
At crossings:					
Poles in lines of one grade of construction throughout:					
Grade A	2,170	1,670	1,200	1,670	1,200
Grade B	3,250	2,500	1,800	2,500	1,800
Grade C	4,870	3,750	2,700	3,750	2,700
Poles in isolated sections of higher grade of construction in lines of a lower grade of construction					
Grade A	2,170	1,670	1,200	1,250	900
Grade B	3,250	2,500	1,800	1,670	1,200
Grade C	4,870	3,750	2,700	3,000	2,160
Elsewhere than at crossings:					
Grade A	2,600	2,000	1,440	1,670	1,200
Grade B	3,900	3,000	2,160	2,500	1,800
Grade C	6,500	5,000	3,600	3,750	2,700

Grade Changes. In the fifth edition of the code in order to obtain greater simplification grades A and E were eliminated. Grade A was actually combined with B, leaving only grade B. Grade E was likewise combined with D by changes and additions to grade D. This leaves the present grades of construction as B, C, D, and N. Grade N construction is generally defined as safe construction. In the case of poles and crossarms, for example, grade N requires the use of such initial

TABLE 8-20. GRADES OF CONSTRUCTION FOR SUPPLY CONDUCTORS ALONE, (All voltages are between wires except as indicated. Corresponding In applying the table to two-wire grounded circuits use the "to neutral"

Conductors, tracks and right of way at lower levels / Supply conductors at higher levels[a]		Constant-potential supply conductors other than direct-								
		0 to 750 volts, (0 to 750 volts to neutral)		750 to 5,000 volts. (750 to 2,900 volts to neutral)			5,000 to 8,700 volts. (2,900 to 5,000 volts to neutral)			
		Urban	Rural	Urban		Rural	Urban		Rural	
		Open or cable	Open or cable	Open	Cable	Open or cable	Open	Cable	Open	Cable
Fenced right of ways		N	N	N[b]	N	N	N[b]	N	N	N
Elsewhere than on fenced right of ways		N	N	C	N	N	C	N	N	N
Railroad tracks—main or minor		B	B	B	B	B	B	B	B	B
Street-railway tracks having no overhead contact conductor		N	N	N	N	N	N	N	N	N
Constant-potential supply conductors: 0–750 volts (0–750 volts to neutral)	Open or cable	N	N	C	N	N	C	N	N	N
750–5,000 volts (750 to 2,900 volts to neutral)	Open	C[e]	N	C	C	N	C	C	N	N
	Cable	N	N	C	N	N	C	N	N	N
5,000 to 8,700 volts (2,900 to 5,000 volts to neutral)	Open	C[e]	N	C	C	N	C	C	N	N
	Cable	N	N	C	N	N	C	N	N	N
Exceeding 8,700 volts (exceeding 5,000 volts to neutral)	Open	B[e]	C[e]	B	B	N	B	B	N	N
	Cable	C[e]	N	C	N	N	C	N	N	N
Constant-current supply conductors—open or cable		B, C or N (see Rule 242-A)								
Direct-current railway feeders—open or cable		B, C or N (see Rule 242-B)								
Trolley contact conductors—alternating or direct current		B, C or N (see Rule 242-B)								
Communication conductors, open or cable, used exclusively in the operation of supply lines		B, C or N (see Rule 242-C)								
Communication conductors—urban or rural, open or cable	Major[f]	N	N	C	C	C	B[g]	C[h]	B[g]	C[h]
	Minor[f]	N	N	C	C	C	C	C	C	C

[a] The words "open" and "cable" appearing in the headings have the following meanings as applied to supply conductors: "Cable" means the specially installed cables described in Rule 241-A, 1. "Open" means open wire and also supply cables not "specially installed."

[b] Where lines are located so that they can fall outside the fenced right of way into urban districts, the construction shall comply with the grades specified for lines not on fenced right of ways for corresponding voltages.

[c] If circumstances within a given area warrant it, supply conductors need only meet the requirements of grade C construction if the supply circuits are so constructed, operated, and maintained that such circuits will be promptly deenergized, both initially and following subsequent breaker operations, in the event of a contact with lower supply conductors or other grounded objects.

[d] Grade N construction may be used, if crossing over or conflicting with supply services only.

[e] If the wires are service drops, they may have grade N sizes and sags as set forth in tables 28 and 29 (rule 263-E).

AT CROSSINGS, AT CONFLICTS, OR ON SAME POLES WITH OTHER CONDUCTOR
voltages to grounded neutral or grounded circuits are shown in parentheses.
voltage. All references are to the National Electrical Safety Code.)

current railway feeders				Constant-current supply conductors				Direct-current railway feeders				Communication conductors used exclusively in the operation of, and run as, supply lines	
Exceeding 8,700 volts. (exceeding 5,000 volts to neutral)				0 to 7.5 amp		Exceeding 7.5 amp		0 to 750 volts		Exceeding 750 volts			
Urban		Rutal											
Open	Cable	Open	Cable	Open	Cable	Open	Cable	Open	Cable	Open	Cable	Open	Cable
N[b]	N[b]	N	N	B, C, or N (see Rule 242A)				B, C, or N (see Rule 242B)				C or N (see Rule 242C)	
B[c]	C	N	N										
B	B	B	B	B	B	B	B	B	B	B	B	B	B
N	N	N	N	N	N	N	N	N	N	N	N	N	N
B[c]	C	C[d]	N	B, C or N (see Rule 242A)				B, C, or N (see Rule 242B)				B, C, or N (see Rule 242C)	
B[c]	C	N	N										
B[c]	C	N	N										
B[c]	C	N	N										
B[c]	C	N	N										
B[c]	C	N	N										
B[c]	C	N	N										
				B, C, or N (see Rule 242A) B, C, or N (see Rules 242A and B) B, C, or N (see Rules 242A and B) B, C, or N (see Rules 242A and C)				B, C, or N (see Rules 242A and B) B, C, or N (see Rule 242B) B, C, or N (see Rule 242B) B, C, or N (see Rules 242B and C)				B, C, or N (see Rules 242A and C) B. C, or N (see Rules 242B and C) B, C, or N (see Rules 242B and C) B, C, or N (see Rule 242C)	
B[g]	C[h]	B[g]	C[h]	C[i]	C or N (see Rule 242A)	B[g, i]	C or N (see Rule 242A)	N	N	B[g]	C[h]	B, C, or N (see Rule 242C)	
C	C	C	C	C		C		N	N	C	C		

[f] Grade N construction may be used where the communication conductors consist only of not more than one insulated twisted-pair or parallel-lay conductor, or where two or more such insulated conductors are involved and these consist of service drops not grouped together in a single run.

[g] The supply conductors need only meet the requirements of grade C construction if both of the following conditions are fulfilled: (1) The supply and communication circuits are so constructed, operated, and maintained that the supply circuits will be promptly deenergized, both initially and following subsequent breaker operations, in the event of a contact with the communication plant. (2) The voltage and current impressed on the communication plant in the event of a contact with the supply conductors are not in excess of the safe operating limit of the communication protective devices.

[h] Grade C construction applies to any supply cable on jointly used poles if carried above communication attachments and supported on an effectively grounded messenger.

[i] Grade C construction may be used if the open-circuit voltage of the transformer supplying the circuit does not exceed 2,900 volts.

size as will withstand safely the loads to which they may be subjected, including linemen working on them.

Grades Related to Hazard. Different grades of construction are required to alleviate different degrees of hazard. For power lines three different degrees of hazard are recognized. The corresponding minimum construction requirements are related to these three degrees of hazard and are expressed in the three grades of construction B, C, and N. Specific strength requirements are specified for grades B and C.

While a certain danger results from the existence of overhead lines in any location, an added risk of personal injury is caused by the crossing of a supply line over a communication line, or vice versa, by crossings of one supply system over another, and by crossings of supply or communication lines over a railway. In urban districts the hazard from fallen wires is presented to many more persons than in rural districts. Superior construction should be provided where these special conditions exist to reduce the hazards as much as practicable.

One element of hazard due to the existence of an overhead line is dependent on the voltage of the line. For the purpose of discriminating with respect to this element of hazard, supply conductors have been divided into various classes according to the voltage concerned.

No requirements for provision of insulating coverings for conductors in overhead lines of any voltage have been made. While such coverings are sometimes an aid in preventing burnouts, the reduction of hazard derived from their use is problematical. Their use may even cause an added hazard for the higher voltages, because they deteriorate after being in service some years. Their use in this condition gives rise to a false feeling of security. Much more reliable and effective safeguards against the danger from fallen and crossed wires are the provision of proper wire clearances and separations and the maintenance of these clearances and separations by suitable minimum conductor sizes, sags, and strength of supports.

Required Grade of Construction. The National Electrical Safety Code also specifies the grade of construction which must be provided for supply conductors alone, or at crossings, or at conflicts, or on the same pole with other conductors. To introduce the lineman to these requirements, Table 8-20 taken from the code is given. Across the top of this table are given the various voltages of the supply conductors in question, and in the left-hand column are listed the various types of crossings, conflicts, or other conductors. At the intersection of the vertical column for a given supply line voltage with the horizontal column representing the crossing or conflict is given the required grade of construction which must be provided. For information concerning further details, the reader is referred to the code.

SECTION 9

Locating and Staking Line

LAYING OUT THE LINE

Selecting the Route. The first step to be taken prior to the design or construction of any line is to conduct a survey and make a map of the country over which the line is to pass. Figure 9-1 shows a survey party

Fig. 9-1. Survey party, consisting of a rodman and an instrumentman, surveying the route for a new transmission line. (*Courtesy American Gas and Electric Service Corp.*)

consisting of a rodman and an instrumentman surveying the route. The final location of the line is, of course, not known and, therefore, a wide strip of land must be included on the map. The main points between which the line is to be built will be known. The intervening territory should be laid out on a scale large enough to show clearly all division lines, towns, roads, streams, hills, ridges, railroads, and bridges and to permit a complete inclusion of all existing telephone, telegraph, and power lines.

With the map completed, the following principles should be used as guides in selecting the exact route:

1. *Select the Shortest Route Practicable.* The shortest line naturally is the cheapest, other things being equal. This means that the line should be a straight line between the terminals of the line, for a straight line is the shortest line between any two points.

2. *Parallel Highways as Much as Possible.* This makes the line readily accessible both for construction and for inspection and maintenance. The hauling and delivery of materials will also be greatly facilitated if this can be done.

In the case of rural lines it has become quite common to locate lines a short distance from the highway in order to miss all trees. This practice has many advantages: the trees are preserved, tree-trimming expense is eliminated, there are no outages from trees falling into the line, no long poles are required to go over trees, side arms are not required, and stub guys are not required.

3. *Follow Section Lines.* Doing this causes less damage to farmers' property and, therefore, makes it possible to purchase the right of way cheaper. Paralleling railroads is desirable for the same reason, because the farms have already been cut and, therefore, the additional damage is negligible.

4. *Route in Direction of Possible Future Loads.* If there is possibility of adding power loads, the route selected should be such as to come as near as possible to such locations, provided that the additional cost is not excessive.

5. *Avoid Crossing Hills, Ridges, Swamps, and Bottom Lands.* Hills and ridges subject the line to lightning and storms. Swamps and bottom lands subject the line to floods. Furthermore, delivery of material as well as the construction of the line becomes difficult. Extra guying and cribbing is often necessary in swamps.

6. *Avoid Paralleling Telephone Lines.* Paralleling telephone lines causes disturbances or interferences in the telephone lines by induction and therefore requires transposition of the power conductors. This adds to the cost of the line. In some cases it is advisable to move the telephone line.

Width of Right of Way. When the route of the line has been selected, permission must be obtained to run the line, or land must be purchased. This is known as the "right of way." In this connection, it should be pointed out that it is well to select several tentative routes so that in case difficulties arise in obtaining permits on any one route, or the prices demanded become inflated, another route can be chosen. Most low- or medium-voltage pole lines do not have complete right of way, that is, the owners do not possess a continuous strip of land, but only the area on which the tower or pole is located. In the case of high-voltage lines, a continuous strip of land is often acquired. Table 9-1 gives a general idea of the width of right of way necessary for different lines.

The reason for acquiring a right of way much wider than the actual space necessary is to prevent tall trees from being blown into the line and to prevent damage from forest fires. Sometimes it is possible to purchase a narrower right of way and to obtain permission to clear back the remaining distance beyond the fences.

TABLE 9-1. APPROXIMATE RANGE OF WIDTHS OF RIGHT OF WAY REQUIRED FOR VARIOUS TYPES OF LINES

Pole lines:	Feet
Single circuit	25 to 50
Double circuit	30 to 75
Two-pole lines	45 to 100
Tower lines:	Feet
Single circuit	30 to 60
Double circuit	40 to 75
Two-tower lines	45 to 100

Clearing the Right of Way. Practically all lines will traverse through some brush or timberlands. Even lines built in the Middle West, which area is generally thought of as a level prairie, may pass through forests or hilly country covered with shrubs and underbrush. Lines built in the mountainous country of the West or the hills of the East naturally pass

FIG. 9-2. Right-of-way clearing operations getting under way. Note forestry crew felling a large hickory tree with a power saw. Tree stumps are cut off close to ground line with power saw later on. (*Courtesy Wisconsin Electric Power Co.*)

through country in which the right of way must be cleared before construction can be started.

In clearing the right of way, all stumps should be cut low (see Fig. 9-2). All logs and brush should be removed for a distance of at least 25 ft under each conductor, in order that there may be ample room to assemble and erect poles or towers and later to string the line conductors.

FIG 9-3 Right-of-way clearing operations continuing Brush is burned as it accumulates. Tree trunks and large branches are cut into convenient lengths and given to adjacent property owners for removal Stump shown at left will be cut just above ground line later on (*Courtesy Wisconsin Electric Power Co*)

FIG. 9-4. A right of way for a new 132,000-volt H-frame power line properly cleared and ready for erection of H-frame structures Note the stump in the left foreground has been cut off about 3 in above the ground line The material for the H-frame structure is shown in the right background It consists of two 80-ft class 1 fully creosoted poles for the uprights, one fully creosoted 35-ft pole for a crossarm, and four crossarm braces There are also eighteen 10-in disk insulators for the three strings. (*Courtesy Wisconsin Electric Power Co*)

Any underbrush or piles of dead wood should be burned or removed, as shown in Fig. 9-3. In case they are left, they may catch fire and burn down the line or anneal the conductors and cause them to sag abnormally. Figure 9-4 illustrates a properly cleared right of way.

If it is possible, permission should also be obtained to cut the extremely tall trees immediately adjacent to the right of way. All dead limbs and branches in the adjoining strip should also be cut down as a high wind may blow them into the line.

Figure 9-5 is a plan view of a wooded section before and after clearing. The top of the figure shows an elevation of the line and bordering trees.

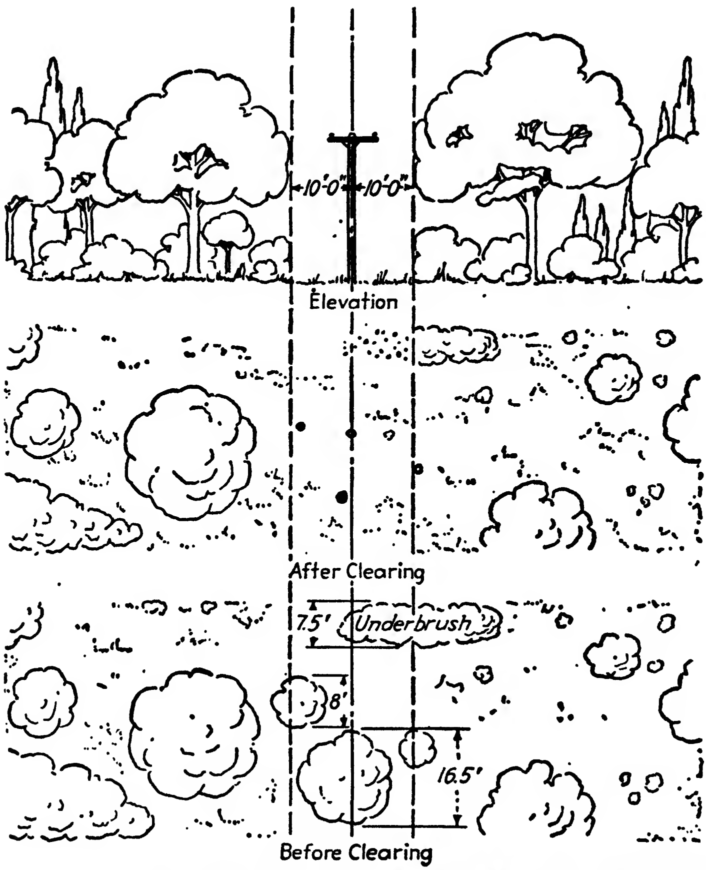


FIG. 9-5. Guide for right-of-way clearing. (*Courtesy Rural Electrification Administration.*)

The clearances indicated are the minimum requirements for a low-voltage rural line.

Chemical Brush Control. Chemicals have recently become available by means of which the growth of brush may be controlled. The chemical is sprayed onto the basal area of the shrubs or small trees from the ground line up to a height of 12 to 15 in. aboveground. The rest of the shrub need not be sprayed. However, complete encirclement of the stem or trunk with the spray solution is necessary. When applied to stumps, it prevents resprouting.

A knapsack sprayer using low pressure is desirable. Figure 9-6 shows a lineman applying the chemical to the brush. Any season of the year is satisfactory.

Locating Pole Positions on Distribution Lines. The following principles should be followed in locating pole positions in distribution systems:

On public thoroughfares poles shall be placed on the side which is most free from foreign lines and trees, care being taken in cities and towns

FIG. 9-6. Lineman applying chemical called Esteron 245 to basal areas of brush. (*Courtesy Dow Chemical Co.*)

to keep the more important streets as free as possible from primary circuits.

The same side of the road shall be used throughout the length of the line wherever this is feasible. In cities and towns, lines along alleys or streets should occupy, so far as practicable, the same side of all streets or alleys in any given town. Poles in alleys should be set as close as possible to the side lines of the alleys.

The length of spans may be increased or reduced so as to make poles come in line with property lines or fences, or to place them in positions satisfactory to adjoining property owners, wherever this is practicable. In locating poles on lot lines, either in the street or in the alley, care must be taken not to block driveways or the entrances to garages. Furthermore, care should be taken not to obstruct doorways, windows, fire escapes, gates, coal holes, and runways.

Where lines cross private property, easements shall be obtained from the property owners before any work is started.

Poles should be set on the junctions of streets and alleys to facilitate the installation of branch lines or guys.

In locating lines along a curb, the poles shall be placed so that there is a distance of 8 in. between poles and the inside edge of the curb. Poles on suburban roads where there is no curb line should be set as above specified with respect to future curb lines wherever this is practicable.

On country roads, poles should be set 18 in. outside fences, if straight; otherwise, poles should be located to give the longest straight lines between angle points, using as much of the road as possible. However, written approval of proposed locations of poles with respect to property lines and highways shall be obtained from the district highway engineer or other responsible party.

Locating Pole or Tower Positions on Transmission Lines. In locating poles or towers on transmission lines, the following general principles should be kept in mind:

1. Select high places.
2. Keep spans uniform in length.
3. Locate to give horizontal grade.

By locating the poles or towers on knolls or high places, shorter poles or towers can be used and still maintain the proper ground clearance at the middle of the span. By avoiding ravines and low places, a better footing is usually also obtained. In extremely hilly or mountainous country, towers are always located on ridges, thereby greatly increasing the span without greatly increasing the pull on the conductors. This is possible because the sag can be made very large and still maintain the required ground clearance.

In rolling country, the location should take into account the grading of the line. A well-graded line does not have any abrupt change, either up or down in the line. The conductors remain practically horizontal irrespective of the small changes in ground level. This is well illustrated in Fig. 9-7. Sometimes a change in pole position a few feet one

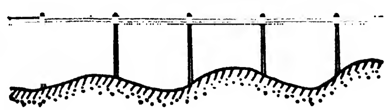


Fig. 9-7. A well-graded line. The changes in ground level do not show in the line conductors.

way or another will make it possible to use the standard pole length, whereas otherwise an odd size would be required.

In addition to the preceding general principles, the following specific rules are given in the National Electrical Safety Code:

1. Poles, towers, and their guys and braces shall not be located less than 3 ft from fire hydrants.

2. Poles, towers, and their guys and braces shall not be located less than 6 in. from curbs. This distance is to be measured from the street side of the curb.

3. Where lines cross railroad tracks, the poles or towers shall be located not less than 12 ft from the nearest track rail. At sidings a clearance of not less than 7 ft should be allowed.

Special attention should be given to the location of poles where the ground washes badly. Poles should not be placed along the edges of

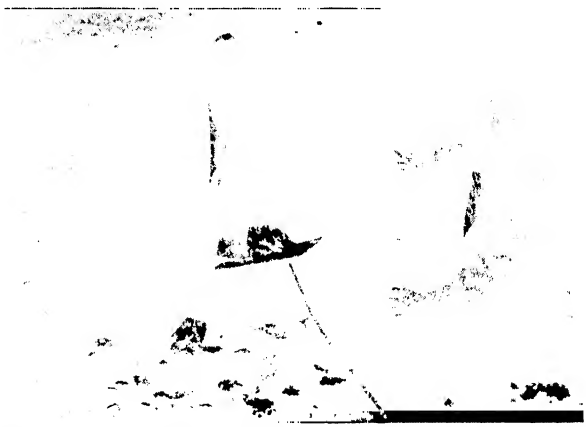


FIG. 9-8. Staking out a pole position for a new 8,320/4,800-volt primary distribution line in rural territory. (*Courtesy Wisconsin Electric Power Co.*)

cuts or embankments or along the banks of creeks or streams. When it becomes necessary to set poles on the edge of a cut, the pole should be set deep enough to protect the line in case the bank washes or crumbles away.

After the exact positions have been fixed, a stake is driven to indicate the center of the pole or tower. Figure 9-8 shows a crew driving a stake for a pole position on a new primary distribution line.

Staking Procedure on Rural Lines. The general procedure in staking out a rural line is as follows:

1. Determine all fixed pole locations and the limits that poles can be shifted. These limits are usually very narrow. These fixed locations may be established by such crossings as power and communication lines, railroads and main highways, rivers and swamps, sharp high points in the profile, fixed angles in the line, dead ends, etc.

2. Locate all tentative pole locations and the limits that these poles can be shifted. These points are usually established by transformer and service locations, rounded hilltops, minor road crossings, trees and buildings, angles, fences, taps, etc.

3. Then locate intermediate pole locations by dividing the distance between fixed locations, giving due consideration to tentative pole location limits, into such span lengths as will provide the most economical construction.

Grading the Line. The matter of locating the line supports in such a manner that the standard pole or tower height can be used has already been referred to. In many cases, it will not be possible to keep the line

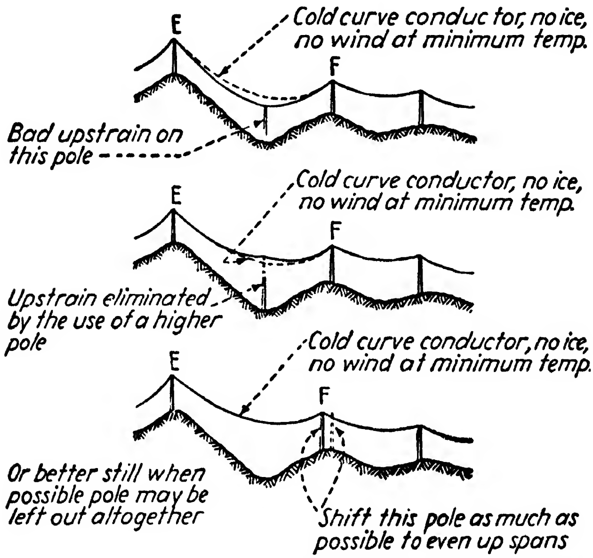


FIG. 9-9. Sketches illustrating methods of eliminating upstrain on poles or towers. (*Courtesy Copper Wire Engineering Association.*)

wires on the same level by changing the location of the support. In such cases it will be necessary to select higher or lower supports than the standard for the lines (see Fig. 9-7). The selection of the proper support height to keep the conductors from making any abrupt change, either up or down, is called "grading" the line. The permissible difference in level between adjacent supports is usually limited to 5 or 10 ft for pole lines. A difference of 5 ft is allowed on spans of 150 ft, and 10 ft on spans of 250 to 300 ft.

If it is necessary to locate a pole or tower in a low point or valley, the structure must be checked to see whether there is any upstrain or uplift, as shown in Fig. 9-9. If a reasonable increase in height of pole does not eliminate the uplift, it is necessary to dead-end and down-guy the structure.

SECTION 10

Unloading, Framing, and Hauling Poles

UNLOADING POLES

Poles are usually shipped by railroads on flat cars, as illustrated in Fig. 10-1. Great care must be exercised in unloading in order to avoid all possibility of accident.

The following procedure is widely used:

1. For absolute safety, attach cables (or ropes) to pockets *A*, throwing the cables (or ropes) over the car as per *F* of Fig. 10-1. The cables (or

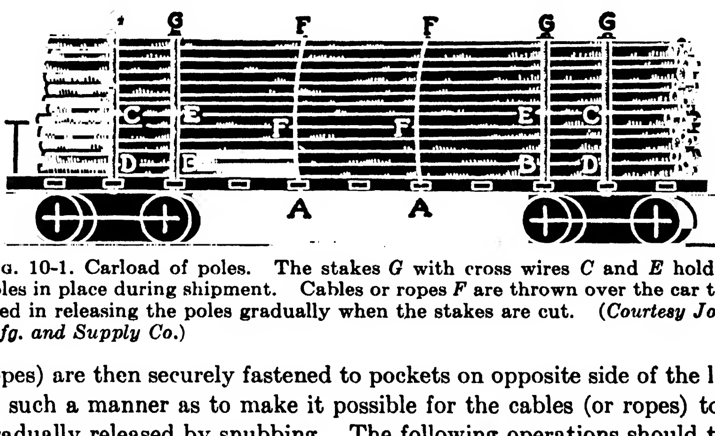


FIG. 10-1. Carload of poles. The stakes *G* with cross wires *C* and *E* hold the poles in place during shipment. Cables or ropes *F* are thrown over the car to be used in releasing the poles gradually when the stakes are cut. (*Courtesy Joslyn Mfg. and Supply Co.*)

ropes) are then securely fastened to pockets on opposite side of the load in such a manner as to make it possible for the cables (or ropes) to be gradually released by snubbing. The following operations should then be carefully performed and followed in exact order:

2. Cut the two inside stakes at *B*.
3. Cut the wires at *E*.
4. Cut the outside stakes at *D* so that they are free at the pockets but both wires *C* are still intact.
5. Cut center wires *C*, using a long-handled ax (an ordinary ax with a handle about 10 ft long), so that a man standing at the end of the car is out of danger. The stakes, having been previously cut, will swing out from the load, but the cables (or ropes) *F* will still hold the poles in position and make it impossible for the load to fall.

6. Release the snubs gradually until the poles reach the ground.

Precautions. 1. Never allow anyone on top of the load under any circumstances.

2. Never cut top wires *G*.

3. Always unload the car in the same direction that it is leaning. If yard conditions necessitate a violation of this rule, place substantial props against the load on the opposite side.

In case poles are held in position with stakes and bands, as shown in Fig. 10-2 instead of stakes and crosswires, the unloading procedure is

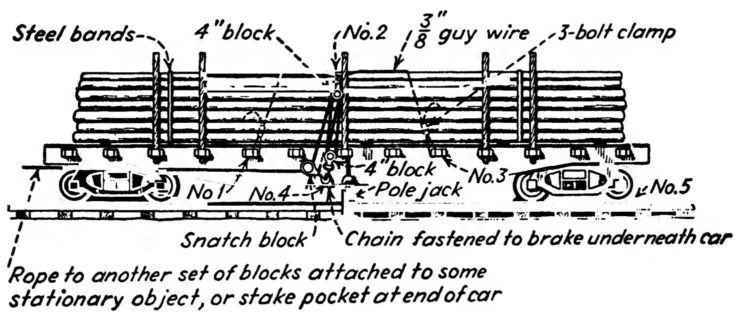


FIG. 10-2. Carload of poles. Poles are held in place with five stakes on each side and two steel bands. (*Courtesy Community Public Service Company.*)

as follows (The side of car facing you in the sketch will hereafter be referred to as *A* and the opposite side as *B*. The wheels of the car shall be chocked so it cannot move, as shown at point 5.)

1. Before any stakes or bands are removed, take some ⅜-in. (minimum) guy wire, running one end through the stake pocket twice at point 1 on side *B*, and install a three-bolt clamp as shown by the dotted line. Run guy wire over the load of poles to side *A* in bridle form, back across to stake pocket on side *B* at point 3. Then make a similar connection with a three-bolt clamp. The distance between these stake pockets will depend on the length of poles and how the stakes are spaced.

2. Fasten a chain loop to the brake underneath the car, and hook a set of 5-in. blocks (minimum) to bridle at point 2 and to chain loop at point 4 on side *A*. A snatch block shall also be installed in the chain loop at point 4. The end of the rope in blocks will run through the snatch block to another set of blocks. (For larger loads, use larger rope and blocks.) Be sure that all ropes and sheaves are thoroughly inspected before using.

3. Tighten up bridle by the use of blocks until the strain is off the stakes on side *B*. Be sure that too much strain is not placed on the blocks.

4. Take out all stakes on side *B*.

5. Use stakes or other strong material for slides from flatcar to ground on side *B* to keep the poles from rolling back underneath the car. Fasten them securely.

6. Get everyone clear of side *B* and off the car.

7. Use a pole jack on side *A* to tilt the car toward side *B* in the event side *B* (from which the poles are to be rolled) is higher than *A*; this is done so the poles will roll off better.

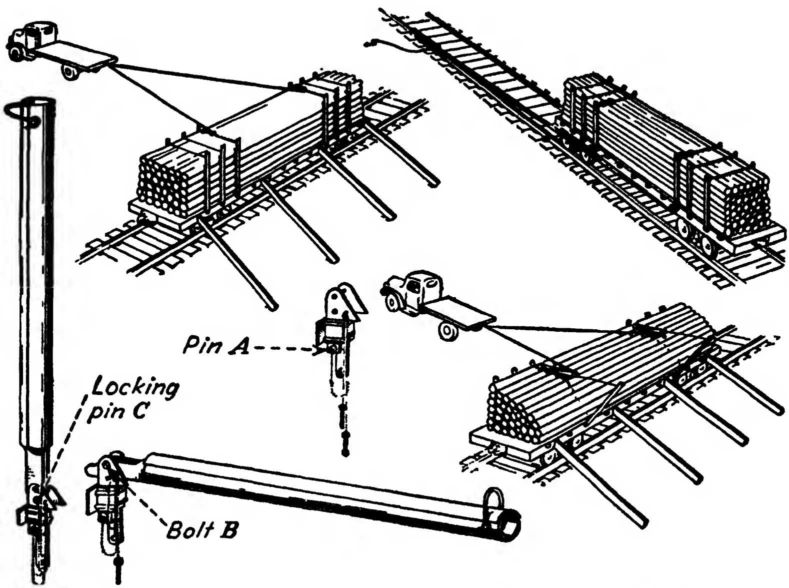


FIG. 10-3. Unloading poles with the use of special tubular stakes.

8. Take a bolt cutter and cut metal bands from side *A*. Then cut the guy wire at point 2, standing as far to the right of the blocks as possible to avoid having blocks fly back and strike you. Keep others clear too.

9. The poles remaining on the car can be rolled off by one man at each end using a bar and keeping in the clear.

Another method of unloading poles involving the use of special tubular stakes is illustrated in Fig. 10-3. The procedure to be used is as follows:

1. Set the car brakes and block the car wheels securely in both directions.

2. Install car pocket fittings (tubular stakes detached) and insert pins *A*.

3. Attach tubular stakes, and insert bolts *B*.

4. Hook in the rope blocks and chains to the clevises on the ends of tubular stakes. (Chains must be on the unloading side of the car.)

5. Pull tubular stakes to the vertical position and insert locking pins *C*.

6. Take strain on rope blocks sufficient to permit removal of wooden shipping stakes on the unloading side of the car.

7. Hook two or more skids into the car pockets (the number depends on the size and weight of the poles).

8. Remove locking pins *C* on the unloading side only.

9. Slack off the blocks so that the load comes down slowly and evenly.

10. After tubular stakes are down, see that all poles are in a safe position before unhooking the blocks.

FRAMING POLES

Trimming. Poles require several operations to be performed on them to prepare them for erection. These operations are often performed in

FIG. 10-4. Pole yard of a large electric utility company showing manner of storing poles, reels, and crossarms. Poles are piled on 12- by 12-in. creosoted timbers. Crossarms are piled neatly in background. The aluminum tag shown on butt end of some poles shows the length and the class of the pole. This tag is not removed when the pole is set. The darkened ends of the poles indicate creosote treatment to butts only. This treatment penetrates to a depth of about 1 in. The length of butt treated should be such that 1 ft of treated pole appears aboveground when the pole is set. Crane for handling poles and cable reels is shown at right. The entire pole yard should be kept free from vegetation to prevent pole rot. (*Courtesy Wisconsin Electric Power Co.*)

the pole yard (Fig. 10-4), where the poles can be readily handled with a tractor and hoist, as illustrated in Fig. 10-5. The first of these is trimming. This consists in stripping off all bark and trimming the knots off flush with the main body of the pole. This is necessary to reveal defects in the pole, prevent decay, and make the pole safer for the lineman.

Sometimes poles are shaved Excessive shaving is not to be recommended as it reduces the strength of the pole Figure 10-6 illustrates this operation The men are using drawknives to shave splinters and excessive weathering off the pole surface. In the case of a new pole,

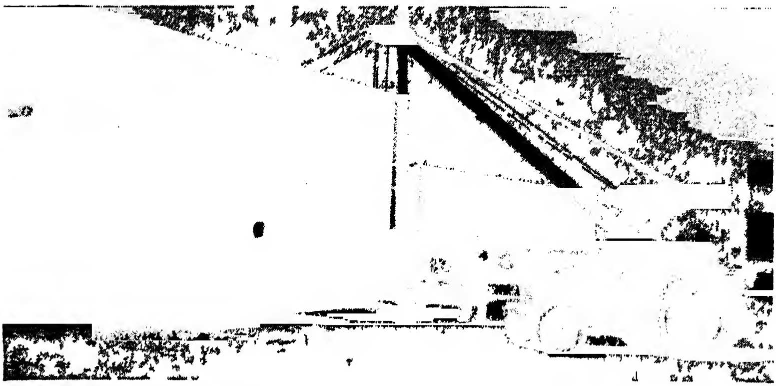


FIG 10-5 Tractor crane placing a used pole on power-saw table Usable portions of the pole are cut off with power saw to form pole stubs (*Courtesy Wisconsin Electric Power Co*)

FIG 10-6 Showing use of drawknives in shaving a pole An old pole is being shaved by pole-reclamation crew Areas on pole surface showing excessive gaffing or weathering are cleaned away (*Courtesy Wisconsin Electric Co*)

care should be taken to remove all knots and limbs smoothly so that the lineman will not be injured by any projecting pieces

Roofing. The roofing operation consists in forming a roof on the top of the pole To do this, the pole should be raised into a framing buck or allowed to rest on two supports. The pole should then be turned so that the heaviest sag or curve will be nearest the ground. This is done by having one man turn the pole at the butt end with a cant hook while another man sights along the pole and decides when the pole is in the right position. By putting the pole in this position, the direction of the roof will be up and down, and the gains will be on top. When this pole is erected in the line, the crook will be in the direction of the line. Looking along the line, the pole will appear straight. Figure 10-7 is a sketch

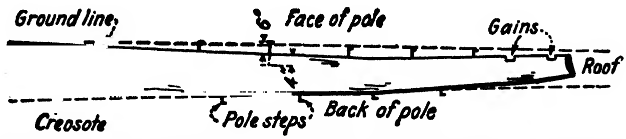


Fig. 10-7. Sketch of completely framed pole, showing relation of parts to curvature of pole.

Fig. 10-8. Pole top showing pole roof cut at 45 deg and two gains with crossarm through-bolt holes. (*Courtesy Wisconsin Electric Power Co.*)

of a pole provided with roof, gains, and pole steps and gives the correct relation of these to the crook or bend of the pole.

The roofing is performed by sawing the two sides of the pole top, as in Fig. 10-8, at an angle of 45 deg with the pole. One way of obtaining the 45-deg angle is to measure along the length of the pole a distance equal to one-half of the pole-top diameter and to saw accordingly. This roof will shed the rain and prevent any accumulation of water, thereby decreasing the possible decay.

Cutting Gains. A "gain" is the notch cut into the pole into which the crossarm is placed when mounted. Gains are cut to provide a flat surface to help maintain the arms in alignment. To cut a gain consists in first sawing along the upper and lower edges of the gain with a handsaw and then chiseling out the round portion and making a flat recess. It is good practice to hollow the gains out slightly in the center to ensure a snug fit of the crossarm, thereby preventing its rocking from side to side. There will be as many gains on a pole as the number of crossarms that the pole is to carry. In general, a pole is gained for all the crossarms whether all the crossarms are to be mounted at once or not.

The first crossarm gain is usually cut 12 in. from the top of the pole. The succeeding gains are generally spaced 24, 30, or 36 in. apart. The spacing selected depends largely on whether the pole is to carry buck arms or not. When buck arms must be provided, these are placed between the line arms at right angles. In order to permit the use of 28-in. crossarm braces the spacing between line arm and buck arm should be at least 18 in. Gains should be square with the axis of the pole and about ½ in. in depth. The height depends on the height of the

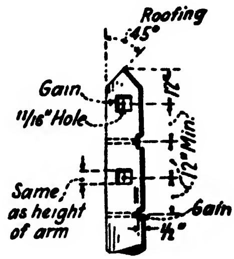


FIG. 10-9. Recommendations for the roofing and gaining of poles for low-voltage circuits.

crossarm. The crossarm should fit in snugly. Figure 10-9 gives suggested recommendations for roofing and gaining of distribution poles.

Gaining Template. In case several gains are to be cut, a gaining template is of great convenience. The use of such a template is illustrated in Fig. 10-10. In using the template the point of the roof of the template is placed over the roof of the pole and the template is shifted in position until its center line lies in line with a string stretched from the

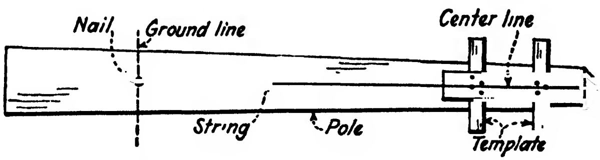


FIG. 10-10. Template for use in marking gains.

point of the roof to the center of the butt indicated by a nail at the ground line. Then the outlines of the gains are marked with a sharp tool by marking along the side pieces of the template.

Vertical Spacing of Crossarms. The vertical spacing of the crossarms, and consequently the gains, depends on the nature of the circuits and the voltages of the circuits carried by the arms. In Table 10-1 are given the minimum vertical separations specified by the National Electrical Safety Code. This table shows that adjacent crossarms carrying circuits of 8,700 volts or less should be spaced 2 ft apart. Crossarms carrying circuits operating at voltages from 8,700 to 50,000 volts are to be spaced 4 ft apart, if the circuits belong to the same utility company. If the circuits belong to different utilities, they must be spaced at least 6 ft apart.

TABLE 10-1. MINIMUM VERTICAL SEPARATION OF CROSSARMS CARRYING VARIOUS CLASSES OF CONDUCTORS AT VARIOUS VOLTAGES

(For voltages greater than 50,000 volts, the clearances given should be increased $\frac{4}{10}$ in. for each 1,000 volts of the excess)

Conductors usually at lower levels	Supply conductors; preferably at higher levels				
	0 to 750 volts and permanently grounded continuous metal-sheath cables of all voltages	750 to 8,700 volts	8,700 to 15,000 volts	15,000 to 50,000 volts: Same utility	15,000 to 50,000 volts: Different utilities
Communication conductors:					
General	4	4	6	.	6
Used in operation of supply lines	2	2	4	4	6
Supply conductors:					
0 to 750 volts	2	2	4	4	6
750 to 8,700 volts	.	2	4	4	6
8,700 to 15,000 volts:					
If worked on alive with long-handled tools, and adjacent circuits are neither killed nor covered with shields or protectors	..	.	4	4	6
If not worked on alive except when adjacent circuits (either above or below) are killed or covered by shields or protectors, or by the use of long-handled tools not requiring linemen to go between line wires	..	.	2	4	4
Exceeding 15,000 volts, but not exceeding 50,000 volts	..	..	..	4	4

Paralleling Gains. One of the difficulties encountered in cutting more than one gain on a pole is to keep the flat surfaces of the gains parallel. This can be checked by resting or hanging two squares, one in each gain (Fig. 10-11). By sighting over them it is easy to see whether the gains are properly leveled. The square can also be used to advantage in getting buck-arm gains at right angles with the line gains.

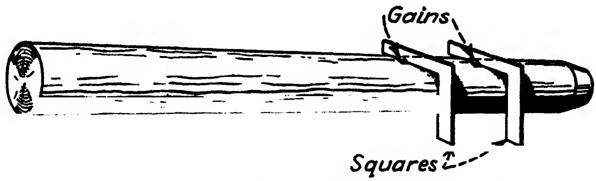


FIG. 10-11. Method of determining whether gains are cut parallel. Test is made by sighting over edges of squares. If gains are parallel, the edges of the two squares will be in line.

Boring Holes. The next operation consists in boring the holes for the crossarms. The size of the hole for the standard crossarm through bolt is $\frac{11}{16}$ in. This is for the $\frac{5}{8}$- or $\frac{10}{16}$-in. through bolt. In the pole yard this operation is generally performed with a power drill. In the field, a brace and bit would be used.

A scheme often used for locating the center of the crossarm bolt hole is to draw two diagonal pencil lines across the gain, as shown in Fig. 10-12. The intersection of these lines determines the center of the bolt

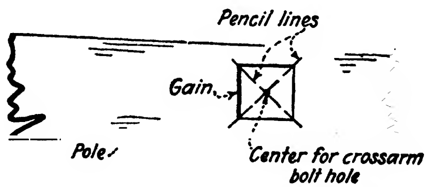


FIG. 10-12. Scheme for determining center for crossarm bolt hole. Two diagonal pencil lines are drawn as shown. The intersection of these lines is the bolt-hole center.

hole. In case the pole surface is not smooth, it is best to guess at the pole center but to measure for the vertical center.

Another scheme which takes less time is the use of a template. This consists of a short length of crossarm in which the hole has been bored. This is placed centrally over the pole in the gain, and the center is marked with a punch.

Painting. Where necessary, poles are sometimes painted. The desirability of painting is generally determined by appearance. Poles used in the streets of the larger cities are usually shaved and painted to improve appearance. Some companies make a practice of painting the roof and the gains with one or more coats of approved paint.

HAULING POLES

When poles have been properly prepared in the pole yard, they are either placed in storage or hauled to a line under construction. Loading of poles in the pole yard is generally done by the use of a tractor crane,

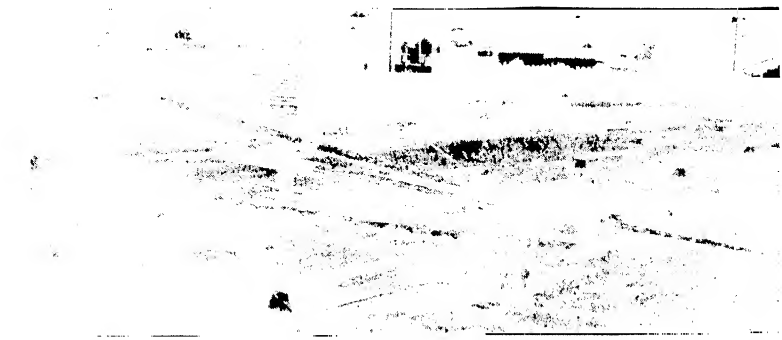


Fig. 10-13. Loading poles in pole yard onto trailer by means of tractor crane Note foreman, tractor driver, and three men steadying pole Also note attachment chained to end of pole already loaded by which trailer will be secured to truck. (*Courtesy Pacific Gas and Electric Co.*)

Fig. 10-14. Loading pole in pole yard by means of truck and crane Hoisting cable is fastened to mid-point of pole. (*Courtesy American Gas and Electric Service Corp.*)

as shown in Fig. 10-13, or by means of truck-mounted crane, as shown in Fig. 10-14. In any case a crew of several men is required. The tractor or truck driver operates the hoisting control, one or more men steady the pole, and the foreman directs the crew, as illustrated in Fig. 10-13. The

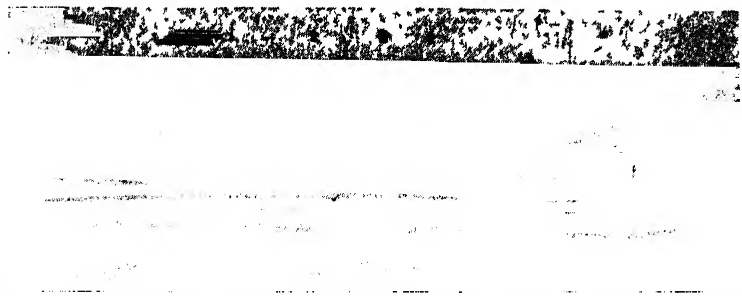


Fig. 10-15. Line-crew truck and pole trailer loaded ready to leave pole yard. Note use of warning flag on trailing end of pole. (*Courtesy Pacific Gas and Electric Co.*)

Fig. 10-16. Unloading poles from trailer in field by use of skids. (*Courtesy American Gas and Electric Service Corp.*)

Fig. 10-17. Drawing eye attached to pole.

Fig. 10-18. Drawing eye coupled to truck.

lifting cable is attached directly to the pole at its middle or to a sling which is attached to the pole at approximately the third length points. After raising the pole off the storage supports, it is transported and lifted upon the trailer (see Fig. 10-14). When the trailer is loaded and the poles are securely fastened, the poles are hauled to the desired location.

Figure 10-15 shows a crew ready to leave with the line truck and pole-carrying trailer. A red flag is fastened to the trailing pole end to warn drivers approaching from the rear. When the destination is reached, the poles are carefully unloaded by sliding or rolling them down on two skids, as shown in Fig. 10-16.

FIG. 10-19. Pulling chain fastened to trailer.

FIG. 10-20. Rear view of trailer.

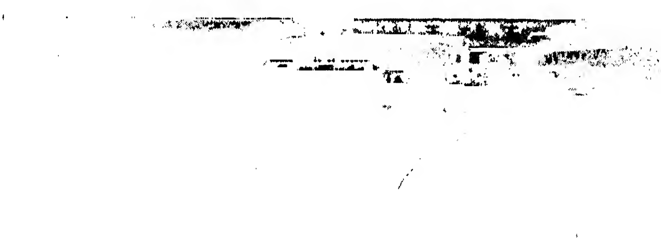


FIG. 10-21. Over-all view of trailer. (*Courtesy Pacific Gas and Electric Co.*)

Figures 10-17 to 10-21 show details of one method of attaching and pulling a pole trailer. The pole is used as a tongue for the trailer or dolly. Figure 10-17 shows how the drawing eye is clamped and chained to the pole end; Fig. 10-18 shows the manner of attaching the eye to the truck; Fig. 10-19 shows how the poles are snubbed to the trailer and how the pulling chain is fastened to the trailer; Fig. 10-20 shows the rear view of the trailer; Fig. 10-21 shows the over-all view of the pole on the trailer complete with rigging.

STEPPING POLES

Boring Holes. As pointed out in Sec. 4, such poles as require frequent climbing should be provided with pole steps to prevent damage of the wood surface from the spurs of linemen. Poles carrying transformers, cutouts, or a large number of circuits are generally provided with steps.

Poles requiring steps should have the step holes bored before being set. This is usually a simple operation if done in the pole yard where

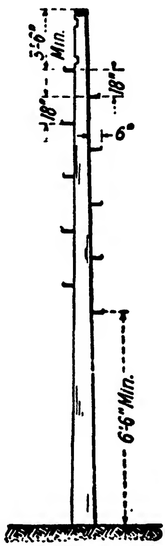


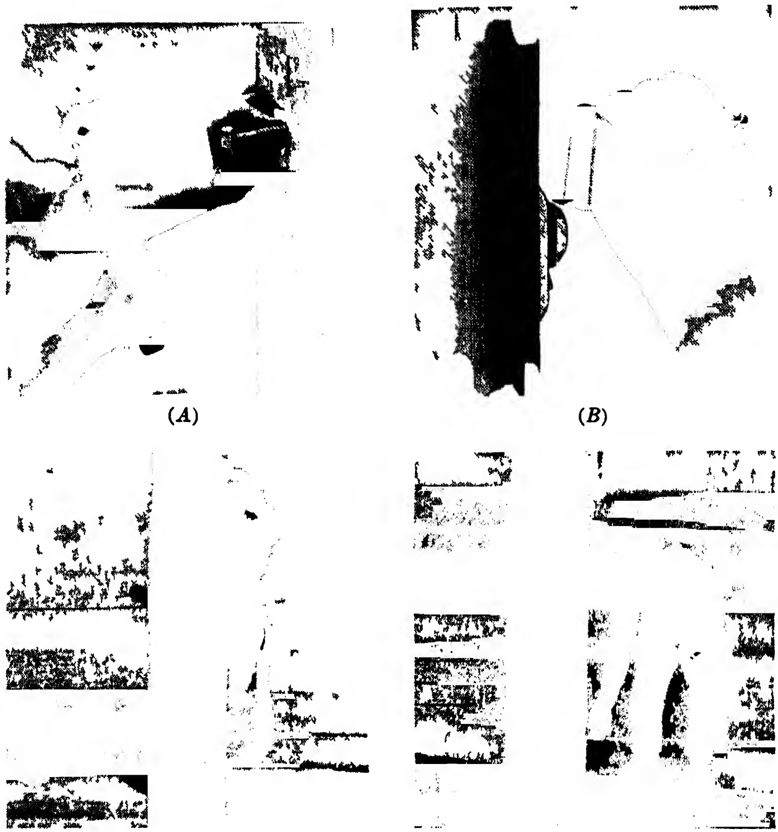
FIG. 10-22. Recommendations on location and spacing of pole steps.

power machinery is available. The hole should be ½ in. in diameter and 4 in. in depth.

Spacing. The steps should be 18 in. apart and located alternately on opposite sides of the pole. The lowest step should not be less than 6½ ft from the ground. Figure 10-22 illustrates the recommended spacing of pole steps.

Mounting. After the holes are bored, the steps are mounted in place. This may be done either before or after the pole is erected. In case it is done before the pole is erected, it is more difficult to handle the pole. This is accomplished by driving the step a slight amount and then screwing the step into the pole. The step should project about 6 in. with the foot guard pointing upward.

The mounting of one form of detachable pole step is shown in Fig. 10-23*A* and *B*. Figure 10-23*C* shows the lineman sliding the steps in



(A) (B) (C) (D)

FIG 10-23 (A) Lineman starting lag screw of detachable pole step, (B) sliding step over lag-screw head, (C) placing steps as lineman ascends pole (D) removing steps as lineman descends pole. (*Courtesy Hubbard & Co*)

place over the lag-screw heads, as he climbs the lower end of the pole, and Fig 10-23*D* shows the lineman removing the detachable steps as he descends the pole.

SECTION 11

Erecting and Setting Poles

DIGGING POLE HOLES

Diameter of Hole. The diameter of the hole is determined by the size of the pole to be set. The hole should be large enough to allow plenty of space on each side of the pole for the free use of the tamping bar. This requires at least 3 in. all around the pole. The diameter of the hole at the top should not be greater than at the bottom, but rather be larger at the bottom than at the top. A slight increase at the bottom is often necessary to allow for the shifting of the pole in lining in and to accommodate the larger diameter of the pole at the butt.

TABLE 11-1. RECOMMENDED POLE-SETTING DEPTHS IN SOIL AND ROCK FOR VARIOUS LENGTHS OF WOOD POLES

Length of pole, ft	Setting depth in soil, ft	Setting depth in rock, ft
20	5	3.0
25	5	3.5
30	5.5	3.5
35	6	4
40	6	4
45	6.5	4.5
50	7	4.5
55	7	5
60	7.5	5
65	8	6
70	8	6
75	8.5	6
80	9.0	6.5

Depth of Hole. The depth of setting is determined by the length of the pole and by the holding power of the soil or earth. The required average setting depths have been determined by experience. The recommended depths of setting in soil and rock are given in Table 11-1 and Fig. 11-1 for various pole lengths from 20 to 80 ft. It will be noted that a pole set in rock need not be set as deep as a pole set in soil. The difference for the same length of pole varies from 1½ to 2½ ft. It will also be noted that starting with a setting depth of 5 ft for a 20-ft pole the increase in depth is approximately 6 in. for each 5-ft increase in pole length.

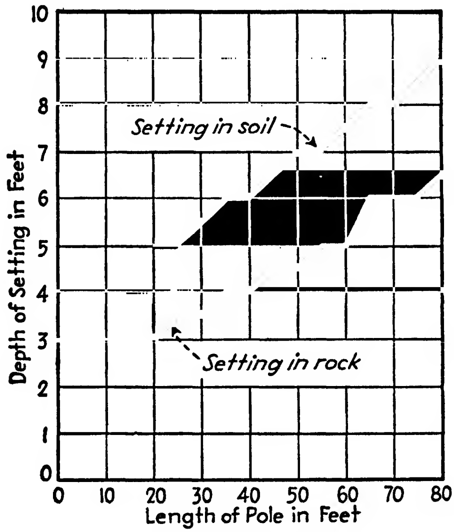


Fig. 11-1. Recommended pole-setting depths in soil and rock.

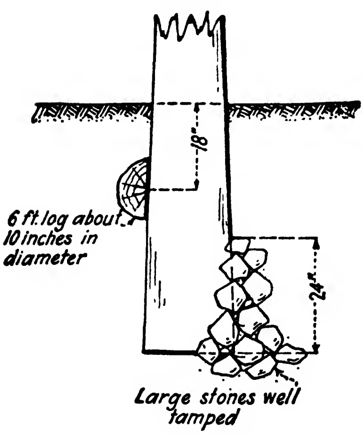


Fig. 11-2. A common and inexpensive form of crib bracing.

Poles set in sandy or swampy ground should be set considerably deeper or be supported by guys, braces, or cribbing. One form of cribbing makes use of a barrel into which the pole is set. The barrel is then filled with concrete or small stones to make the pole secure. Another simple method of crib bracing is illustrated in Fig. 11-2.

When exceptional stability is required of a pole, an artificial foundation of concrete may be placed around the base of the pole (see Fig. 11-3). This concrete filling should extend approximately 1 ft from the pole on all sides and be carried ½ ft above the ground level. The top should be beveled to shed the rain. A good mix to use is 1 to 2½ to 5, that is, 1 part cement, 2½ parts of sand, and 5 parts broken stone or gravel. Enough water should be added to make the mixture flow freely and take its place without tamping The pole must be firmly braced in position and such bracing left in position until the concrete is hard. No line work should be done on the pole within a week after the concrete is poured.

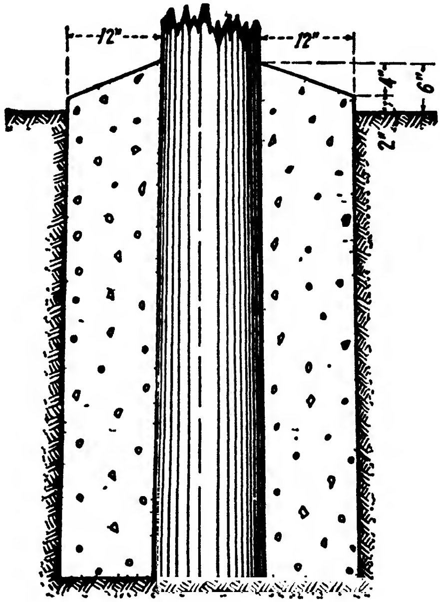


FIG 11-3 Concrete foundation for wooden pole The mixture should be made thin enough so that it will not require tamping (*Courtesy Texas Power & Light Co*)

Poles set on curves, corners, or at points of extra strain should be set at least 6 in deeper than the values given in Table 11-1. The side strain, however, should always be taken up with terminal, side, or line guys, leaving the pole to carry the vertical load only.

Digging with Shovel and Spoon. Digging holes by means of shovel and spoon is resorted to when only a few holes have to be dug or when it is impossible to use a power digger. The shovel is the straight-bladed tool built like a spade, Fig. 11-4, but the spoon has the blade at an angle, Fig. 11-5. The shovel is used to loosen the soil and the spoon to remove it from the hole. An experienced hole digger will dig the hole largely without the aid of the spoon under ordinary conditions of soil and moisture. A certain amount of practice is required to do this One must know just how to strike the soil with the shovel so that the soil will break loose from its position and yet stick to the blade of the shovel. In case the soil is very dry, the shovel can be used only to loosen the soil and the spoon must be used to lift the loose soil from the hole.

Sometimes a bar must be employed to break the earth loose, as in case of frost, rock, or hard clay. One end of the bar should be sharpened to a blunt chisel point and the other end to a round point similar to the sharpened end of a pencil. Such a digging bar is shown in Fig. 11-6.

FIG. 11-4. Straight shovel used to loosen ground in digging pole hole. (*Courtesy Leach Co.*)

FIG. 11-5. Spoon used to lift ground out of pole hole while digging. (*Courtesy Leach Co.*)

The usual procedure to be followed is to outline the hole around the stake. The diameter of this circle should be at least 6 in. greater than the diameter of the pole at the butt. For the first 2 or 3 ft of digging, it is advisable to use a short-handled shovel (Fig. 11-7), as it is more convenient to hold. The spoon will not be necessary as the earth can be lifted out with the shovel. For the remainder of the hole the long-handled shovel and spoon are used in the usual manner. Where quicksand or swamp soil is encountered and cave-ins occur, a large bottomless barrel is lowered into the hole as it is dug.

When pole holes have been dug along paved streets, near farm buildings, or on any used premises and poles are not set in at once, a red lantern should be placed near the hole. This protects the public from

FIG. 11-6. Digging bar used in hard or stony soil. (*Courtesy Leach Co.*)

FIG. 11-7. Short D-handled shovel often used in digging first few feet of pole hole. (*Courtesy Leach Co.*)

FIG. 11-8. Power pole-hole borer mounted on rear of truck and tilted forward into traveling position. Power is obtained from truck engine. (*Courtesy Highway Trailer Co.*)

accident. If the hole is to be left overnight, it should be completely covered with plank and dirt.

Digging with a Power Borer. Most pole holes are dug with a power borer at present. This greatly reduces the physical effort required and also speeds up the work. A power borer is very similar to the familiar wood brace except that it is much larger and is power driven; Fig. 11-8 shows a typical power borer mounted on the rear of a truck body. The borer can be tilted down while moving.

When a hole is to be dug, the truck is driven over the pole location and so placed that the borer is directly over the pole stake. Then the operator lowers the auger, as in Fig. 11-9, while it rotates until it has taken a full "bite." Then the auger is raised until it is above the ground and made to spin rapidly, Figs. 11-10 and 11-11, thereby throwing the dirt around and away from the hole Then the auger is lowered again, and

FIG. 11-9. Auger lowered into hole for another "bite" of ground. Note loose dirt around hole. (*Courtesy Highway Trailer Co.*)

FIG 11-10 Auger raised with full "bite" of ground. (*Courtesy Highway Trailer Co.*)

another "bite" is taken. Again the auger is raised and made to spin fast. Figure 11-12 shows a side view of a pole-hole borer discharging earth away from the hole. This is repeated until the desired depth of hole has been reached. The completed hole will have a ridge of loose dirt completely around it.

Holes of different diameter are obtained by the use of augers of different diameter. Augers having different diameters can be mounted on the digging bar. The change from one to the other can be made in a few minutes. A 9-in. size is the smallest and is generally used for the digging of guy anchor holes. The 16-, 24-, and 36-in. sizes are carried on the truck and are used for the different sizes of poles that must be set.

Sometimes the truck on which the pole-hole digger is mounted also carries a derrick as illustrated in Fig. 11-13 and Fig. 11-14. The three-legged boom is used for setting or removing poles. A steel cable from a winch in the interior of the truck passes over a pulley at the apex of th

FIG 11-11 Auger being rotated at high speed to throw dirt away from hole. (*Courtesy Highway Trailer Co*)

FIG 11-12 Side view of pole-hole borer discharging earth away from hole (*Courtesy American Gas and Electric Service Corp*)

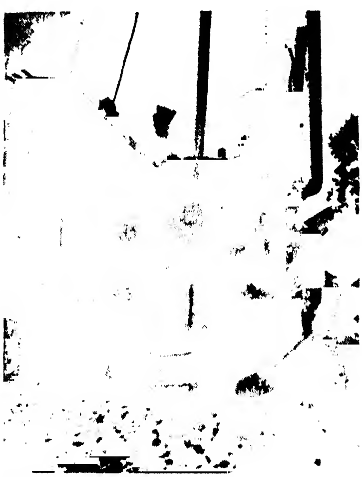


FIG 11-13 Combination derrick and pole-hole digger Operator has just brought up another "bite" of ground from the bottom of the hole The three-legged boom is used for setting and removing poles. A steel cable from a winch in the interior of the truck passes over a pulley at the apex of the derrick. The derrick is demountable and can be removed in a few minutes. (*Courtesy Wisconsin Electric Power Co.*)

FIG 11-14 Combination derrick and pole-hole digger disposing of its "bite" An assistant operator is keeping the dirt from falling back in the hole (*Courtesy Wisconsin Electric Power Co.*)

derrick. Such a combination derrick and pole-hole digger can thus be used to dig the hole and immediately afterward hoist the pole into position in the hole.

Fig. 11-15. Pike pole used in raising pole beyond the reach of the crew. Note steel spike on end of pole. (*Courtesy Leach Co.*)

ERECTING POLES

Raising Poles. *Piking Method.* The piking method is the oldest method of raising poles. It is a manual method. It gets its name from the so-called "pike pole" (Fig. 11-15) employed after the pole is lifted beyond the reach of the men raising the pole. The "piking" method is used only where one or more poles need to be set or where a truck with a derrick cannot be brought in. The use of a power boom is a faster and more economical method as only a few men are needed.

The size of the "piking" crew depends upon the length and the weight of the pole to be raised. It varies from 5 men for a 25-ft pole to 10 men for a 50-ft pole, as shown in Table 11-2. The size of the crew required is not absolutely fixed, but the numbers indicated in the table are the size of crews generally employed. As will be noted, one of the men is the jennyman, one is stationed at the butt of the pole near the hole, and the balance of the crew are called the "pikers."

The first step in the procedure of raising a pole by the piking method is to lay the butt end of the pole over the hole against a bump board or bar, as shown in Fig. 11-16. The use of the board or bar protects the walls of the hole and prevents them from being caved in by the butt of the pole as the pole is raised. In the second step, Fig. 11-17, the upper

TABLE 11-2. AVERAGE SIZE OF CREW REQUIRED TO RAISE POLES OF DIFFERENT LENGTHS

Pole length, ft	Size of crew	Number of pikers	Number of jennymen	Number of men at butt
25	5	3	1	1
30	6	4	1	1
35	7	5	1	1
40	8	6	1	1
45	10	8	1	1
50	10	8	1	1

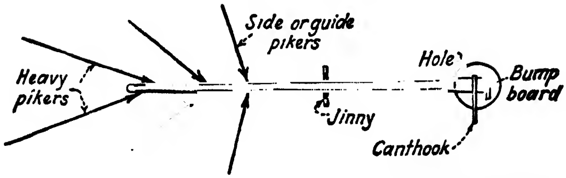


FIG. 11-16. Plan view of pole-piking method of pole raising.

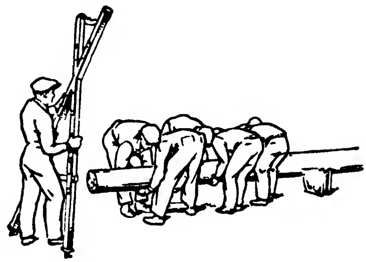


FIG. 11-17. Second step in raising a pole. Pole is being lifted from ground onto jenny.

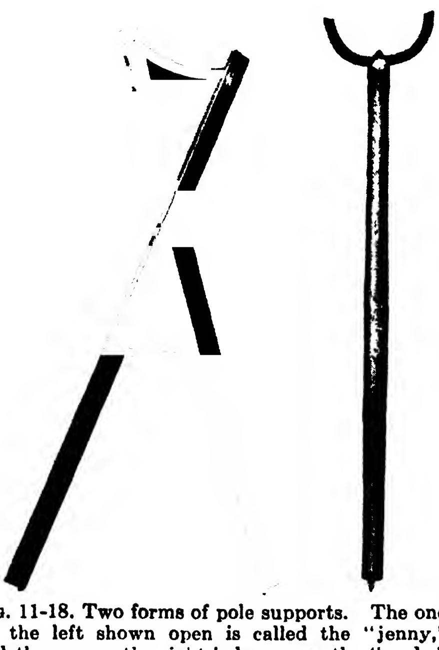


FIG. 11-18. Two forms of pole supports. The one on the left shown open is called the "jenny," and the one on the right is known as the "mule." (*Courtesy Leach Co.*)

FIG. 11-19. Cant hook used by man at butt of pole to keep pole from rolling and to turn pole if necessary (*Courtesy Leach Co.*)

end of the pole is raised and placed on the pole support. Pole supports are made in various forms, two of which are shown in Fig. 11-18. The main duty of the man at the butt is to keep the pole from rolling. This is prevented by means of a cant hook, illustrated in Fig. 11-19. In the third step, Fig. 11-20, the men stand side by side on both sides at the top end of the pole. They then push toward each other and up by use of

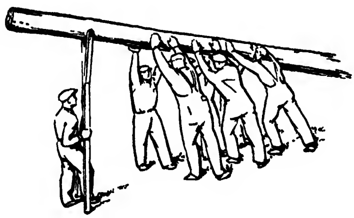


FIG. 11-20. Third step in raising a pole. Pikers have raised pole onto jenny and are now raising pole as high as they can without use of pike poles.

their arms, the jennyman catching the weight between lifts. In this manner they move along the pole until the pole is high enough to permit the use of pikes. The fourth step, Fig. 11-21, is to punch the pikes into the pole and prepare to raise the pole. As the pole is raised, the man carries the jenny forward always ready to support the pole if need be. The raising continues until "high pike" is called by one of the men.

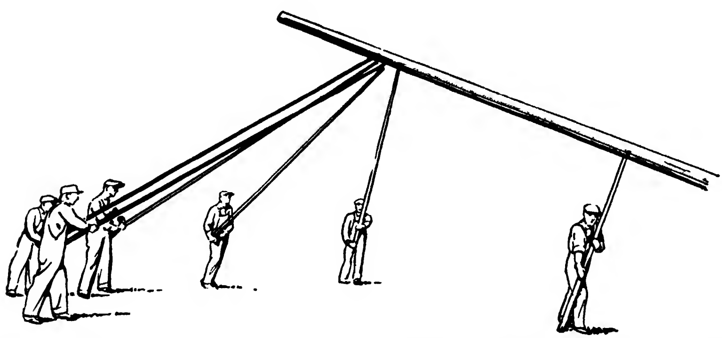


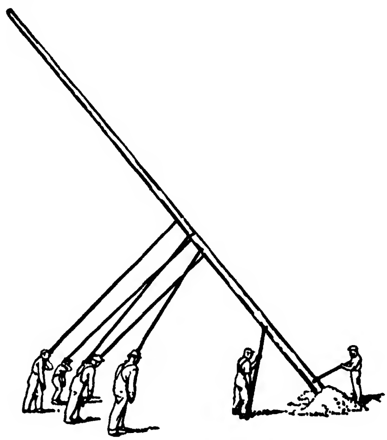
FIG. 11-21. Fourth step in raising pole. Pikers have placed pike poles against pole and are raising it into vertical position. Note how pikers are spread out.

This means that his pike is too high to be effective if raised any further. The low man brings his pike down first, because he does not have to lower his pike through the rest of the pikes, but has a clear path. The other men follow in order until all the pikes are lowered. The pole is raised in this manner until it drops into the hole. Figure 11-22 shows the pole almost raised and ready to slide into the hole. This picture shows very clearly the duty of each man in the crew. The five pikers raise the pole, the jennyman keeps the jenny always snugly under the pole, and the buttman guides the bottom of the pole and keeps the pole from rolling.

It will be noted that the pikers are not all directly underneath the pole. At least one should be well out on each side to guide the pole as well as to help lift it.

Another thing worth noting is the manner of holding the pike pole after the pole is partly raised. It is held in the palm of the hand with the other hand underneath and the arms extended downward. If the pike pole is held in this manner, the workman is in a comfortable position, and if the weight of the pole should be suddenly thrown on his pike pole, he is in a good position for grounding his pike pole or moving into

FIG. 11-22. Last step in raising a pole. All pikes have been lowered. Pole is about to slide into hole. Note jennyman and buttman with cant hook. Also note manner of pushing on pike poles.



the clear. If the pole should be a very tall pole, the pike pole can be supported on the shoulder as shown in Fig. 11-22. The pike still rests in the palm of the piker's hand. In this way the piker can exert a strong push on the pike.

If the pole to be raised is a large heavy pole, and the crew is small, it is well to "trench" the hole, that is, to cut a ditch back from the hole. The pole is then placed in this trench. This allows the pole to begin to slide into the hole earlier than if the pole lay flush on the ground. Furthermore, it allows the weight of the lower end of the pole to balance a portion of the weight of the pole above the point of the trench on which the pole is resting.

Gin-pole Method. The gin-pole method is a power method of raising poles. It should be used wherever possible, especially if the poles to be raised are over 40 ft long.

The simplest application of this method is where an old pole is replaced with a new one. A snatch block or simple pulley is tied to the top of the old pole (see Fig. 11-23). One end of the pulling rope or "bull line," as it is called, is fastened about two-thirds up on the new pole, and the other end runs to a drum or winch on a truck. In case there is not room to run the truck straight ahead, the pulling line can be run down the pole to another snatch block and then to the truck, as in Fig. 11-24. A temporary guy must then be installed to balance the side pull on the old pole. For extra-heavy poles a set of pulling blocks is used in place of the single pulley (see Fig. 11-25). These blocks reduce the pull necessary so that a heavy pole can be raised with ease. In the foregoing cases, the old pole serves as the gin pole.

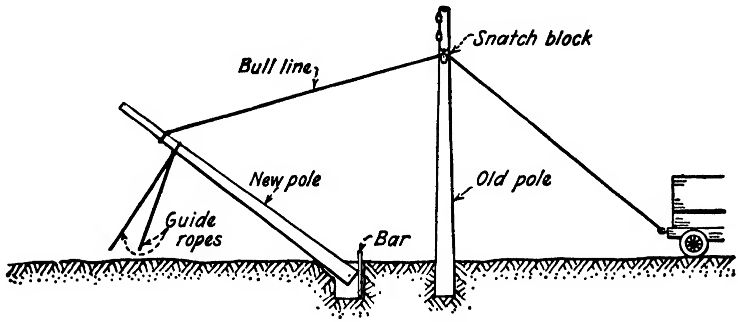


FIG. 11-23. Raising pole by use of old pole, bull line, and truck. Note also use of snatch block, bar, and guide ropes.

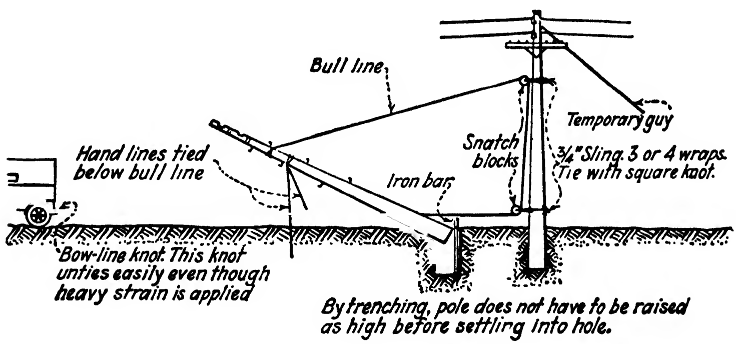


FIG. 11-24. Raising pole by use of truck and old pole when truck cannot pull straight ahead. A second snatch block and a temporary guy must be used in addition.

In using any of the power methods just described, the pole is placed in the same position as though it were to be raised by hand. The bar is placed in the far side of the hole, the butt of the pole against the bar, and the pole on the jenny. The pulling line is attached two-thirds of the way up the pole, run through the snatch blocks, and tied to the truck by means of the bowline knct. Hand lines are tied to the pole to guide it and keep it from swaying. The foreman holds the cant hooks on the butt of the pole to keep it from turning. Power is then applied, and the pole is raised until it slides into the hole.

In new construction a gin pole is part of the erecting equipment. It may be just a short pole unmounted, or it may be mounted on a gin wagon or truck. Since the gin pole need only be a little more than half as long as the pole to be raised, a small crew can raise it into position by means of pike poles. The gin pole is then guyed in all directions with rope guys. The gin pole is now as ready for use as though it were an old pole. Figure 11-26 is a diagrammatic sketch of the setup.

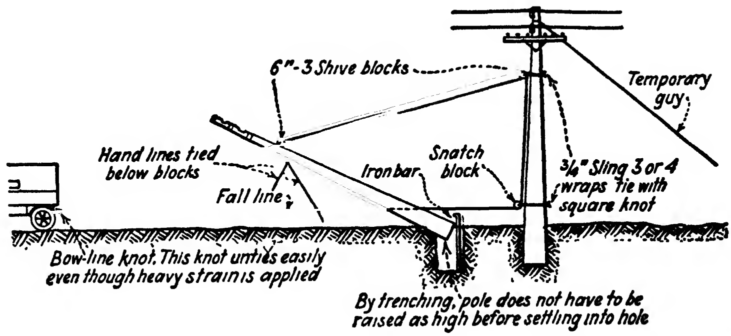


FIG. 11-25. Raising extra-heavy pole by use of truck, old pole, and pulling blocks. This method of raising poles is commonly used when replacing an old pole.

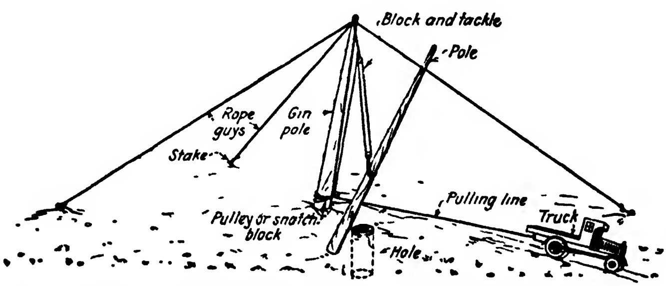


FIG. 11-26. Raising pole by gin-pole method. Function and names of equipment employed are shown.

The size of the crew required in this method of pole raising is about half that required for piking. One man is the truck driver whose duty it is to apply the engine power to the winch line as directed by the foreman. Two or more men guide and swing the pole into place in the hole.

The procedure of raising the pole is as follows: The gin pole is so located that its top is above the hole into which the pole is going to be placed. The winch line is then run out and fastened to the pole slightly above the middle of the pole. The exact position is such that the butt end overbalances the top end. Power is then applied to the winch line, and the pole is hoisted to an upright position with the butt end down. When the lower end is clear of the ground, the butt end is swung until it is over the hole, after which the pole is lowered into the hole.

FIG. 11-27. Power boom picking a 35-ft pole off the ground. Lifting cable must be attached slightly above center of gravity of the pole so that the two crewmen can balance it. Note foreman directing equipment operator sitting in the driver's seat. (*Courtesy Wisconsin Electric Power Co.*)

FIG. 11-28. Power boom carrying 35-ft pole to the hole in which it will be set. Two crewmen balance pole while foreman directs operation. (*Courtesy Wisconsin Electric Power Co.*)

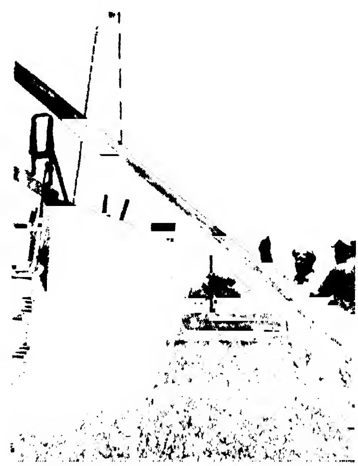


FIG. 11-29. Close-up view of pole boom, lifting cable, and crew as pole is lifted off ground. (*Courtesy American Gas and Electric Service Corp.*)

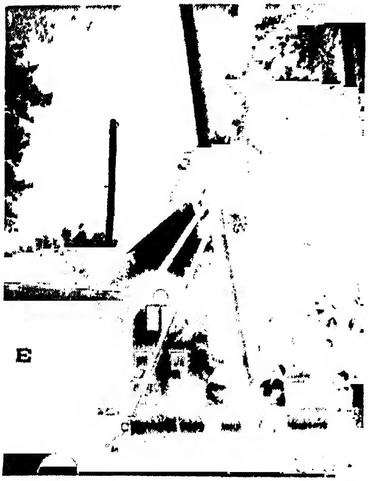


FIG 11-30 Close-up view of pole being raised with power boom One of the crew of three directs the operation as well as helps guide the butt of the pole (*Courtesy American Gas and Electric Service Corp*)

FIG 11-31 Power boom sliding 35-ft pole into its hole Two crewmen guide it while foreman directs operation (*Courtesy Wisconsin Electric Power Co*)

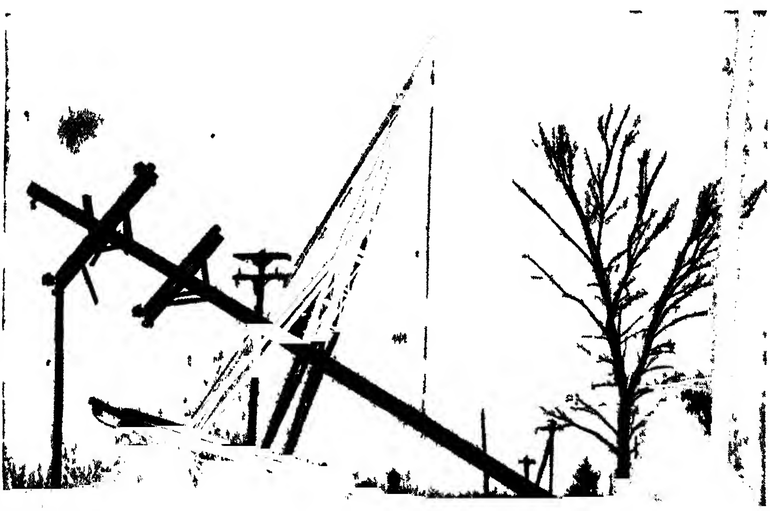


FIG. 11-32 Raising pole, complete with crossarms and hardware, by means of truck-mounted power boom. Truck is also equipped with power borer. (*Courtesy Consumers Power Co.*)

Truck Derrick Method. A method similar to the gin-pole method is that making use of a gin pole mounted on a truck, Fig. 11-27, or on a caterpillar tractor, Fig. 11-28. In either case the truck or tractor is equipped with a winch or drum that can be driven with the truck or tractor engine.

The procedure in raising the pole is the same as that using the gin pole. The hoisting cable is attached to the pole slightly above the mid-point

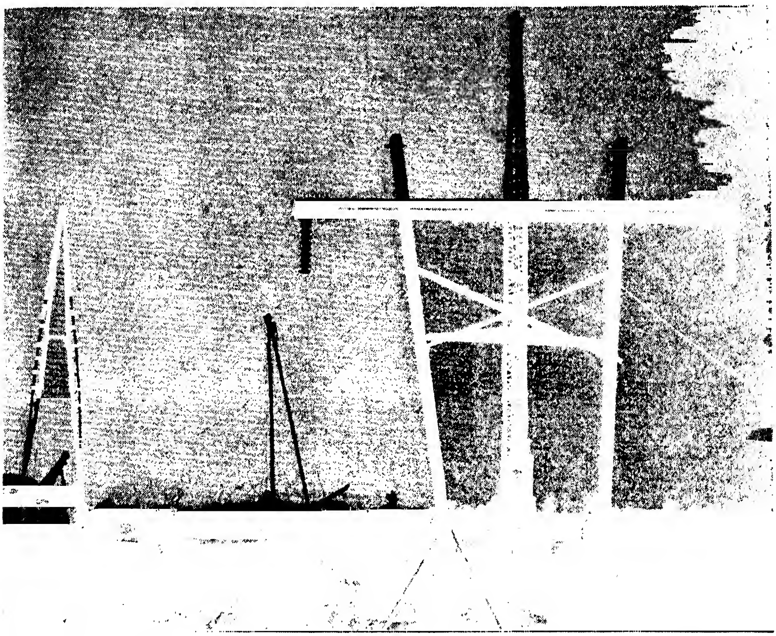


FIG. 11-33. Raising assembled H frame for 132,000-volt line with caterpillar-mounted power boom. Note use of lifting yoke to equalize lift. (*Courtesy American Gas and Electric Service Corp.*)

so that the butt end outweighs the top end. The pole is then gradually raised until it is in a near vertical position and the butt end is clear of the ground. The butt is then swung around until it is directly over the hole, after which the pole is slowly lowered into the hole.

These steps are clearly shown in Figs. 11-29 to 11-31. Figure 11-29 shows a truck equipped with power boom picking a pole off the ground; Fig. 11-30 shows the pole raised to the intermediate position while being guided by two crew men holding onto the pole butt; Fig. 11-31 shows the pole sliding into the hole.

Sometimes poles are erected with crossarms and hardware in place. Figure 11-32 shows a truck-mounted power boom erecting a pole that has two sets of double crossarms and braces in place. Figure 11-33 shows an assembled H frame being erected with a caterpillar-mounted power boom. Crossarms, braces, and insulator strings are in place. A lifting yoke to equalize the lift on the two poles is employed. Figure

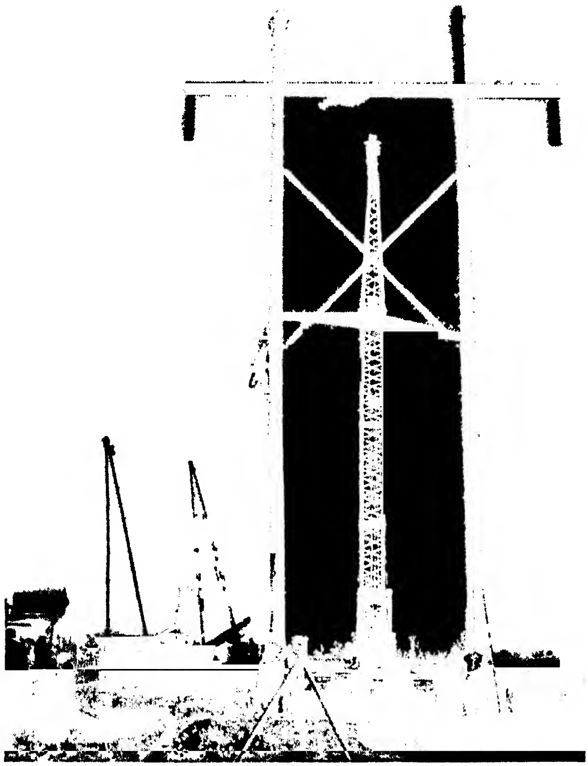


Fig. 11-34. Assembled H frame in full vertical position and poles in holes. Note use of temporary guys and pike-pole braces to obtain alignment. Lineman on pole is securing crossbraces. (*Courtesy American Gas and Electric Service Corp.*)

11-34 shows the H frame in full vertical position and the poles in place in the holes.

SETTING POLES

Facing the Poles. "Facing" the poles means turning the poles after they have been raised so that the crossarms will be on the proper side. The side of the pole on which the gains are cut is known as the *face* of the pole. Facing the pole therefore means turning the pole until the gains are on the proper side of the pole. In general, poles should be set so that the ridge of the pole roof is in line with the lead. The ridge of a junction pole should be placed in line with the main lead. The ridge of a guy stub pole should be in line with the guy.

The proper pole facings for the usual cases met in line construction are as follows:

Straight Lines. On straight lines it is customary to set adjacent poles with the gains facing in opposite directions (Fig. 11-35). This is sometimes expressed as "gain to gain" and "back to back." This provides for the maximum strength in the line.

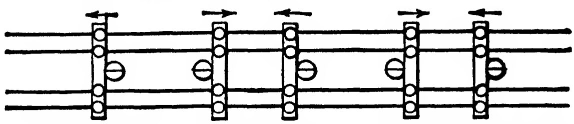


FIG. 11-35. Facing crossarms on straight lines. Every second pole has crossarm facing in the same direction.

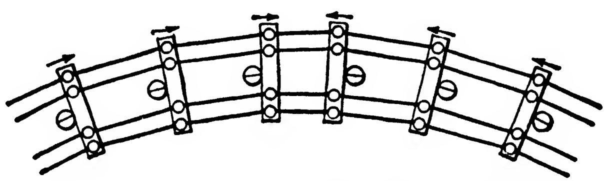


FIG. 11-36. Facing crossarms on curve. Note that the three poles on each side of the center of the curve face the curve.

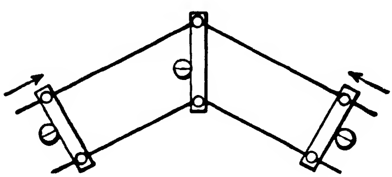


FIG. 11-37. Facing crossarms at an angle. Adjacent poles face the angle.

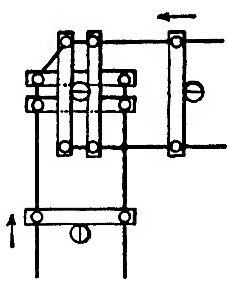


FIG. 11-38. Facing crossarms at a corner. Adjacent poles face the corner.

Curves. Crossarms on poles on each side of the center of a curve should face the center of the curve (Fig. 11-36). The pole at the center of the curve is often equipped with double arms.

Angles. Poles next to angles should face the angle, as shown in Fig. 11-37. In case of large angles the angle pole is generally double armed or dead-ended.

Corners. Poles next to corners should face the corner (Fig. 11-38). In case of city distribution, the arms on the corner pole are generally double arms as illustrated.

Steep Grade. Poles on steep grades should face up the grade as shown in Fig. 11-39.

Crossings. Poles next to crossings should face the crossings (Fig. 11-40). The poles at the intersections are generally double armed as illustrated.

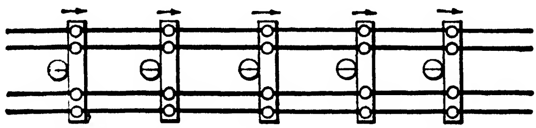


FIG. 11-39. Facing poles on steep grade. All poles face upgrade.

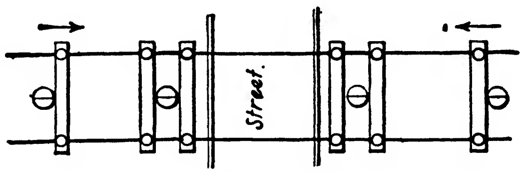


FIG. 11-40. Facing poles at a crossing. Adjacent poles face the crossing.

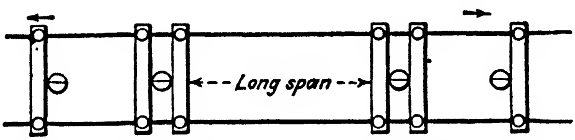


FIG. 11-41. Facing poles on long spans. Adjacent poles face away from long span.

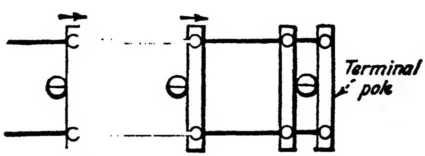


FIG. 11-42. Facing poles at terminals. Adjacent poles face terminal.

Long Spans. Poles next to poles supporting long spans should face away from the long span, thereby being in a better position to carry part of the load (Fig. 11-41). The poles on each side of a long span are generally of special construction.

Terminals. Poles immediately preceding end poles shall face toward the end of the line (Fig. 11-42). The end pole, being a terminal pole, is usually of special construction. Sometimes it is well to have the last two poles face the terminal pole.

Facing, Straightening Up, and Lining In. After the pole is raised, the facing, straightening up, and lining in are done by the setting crew. Such a crew usually consists of three, four, or five men, as shown in Figs.

11-43 and 11-44. Four men working from the four "sides" of the pole hold the pole in an upright position with pike poles resting on the ground. Two men line the pole in, one along the line and the other from the side. One or two men turn the pole with the use of cant hooks.

In order to ensure perfect alignment, the procedure shown in Fig. 11-45 may be followed: pole *c* has already been set plumb, pole *b* is being

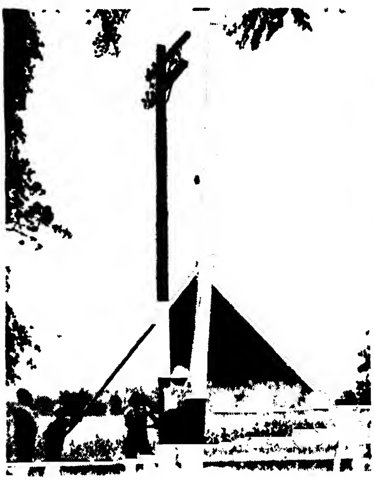


FIG. 11-43. Straightening up a pole with a five-man crew. Three men are pikers, one turns the pole with a cant hook, and the fifth sights and directs the operation. The pole must line up with other poles in the line, and its gains must line up so that the crossarms will be at right angles to the line. Note the use of the Y type of pike pole. This pike pole, with its two prongs, one on each side of Y, are less likely to fall away from pole. (*Courtesy Wisconsin Electric Power Co.*)

FIG. 11-44. Setting pole with five-man crew. Four men at pike poles resting on ground align pole as fifth man directs Note power boom used to set pole still in place on left. (*Courtesy Pacific Gas and Electric Co.*)

set plumb, and vertical rod *a* (also shown in Fig. 11-46) set on the surveyed line is being used to direct the alignment and plumbing of the pole *b* by sighting from *a* to *c*.

The first operation consists in turning the pole so that the gains face the directions outlined above. In a straight line, adjacent poles are to face in opposite directions. If the pole is being raised without the crossarms in place, a light slat can be nailed in a gain to guide the lineman in facing the pole. This is important because the crossarms should be placed at right angles to the line. The next step is to move the butt of the pole so that the pole will be in line. The pole may be shifted in the hole by prying it over with a heavy bar. An easier method is to *butt* the pole. This is done by pushing the top of the pole in the opposite direction that the butt is to be moved. By so doing the pole will pivot on the edge of the hole and force the butt over in the desired direction.

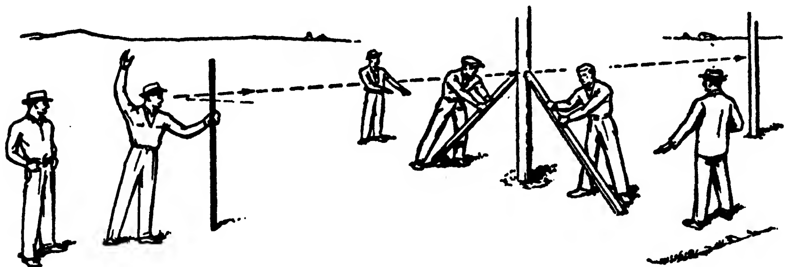


FIG. 11-45. Procedure employed in plumbing and aligning pole. (*a*) Vertical rod is being used to assist sighter at pole (*a*) plumb and align pole. (*c*) Pole has already been set and plumbed.

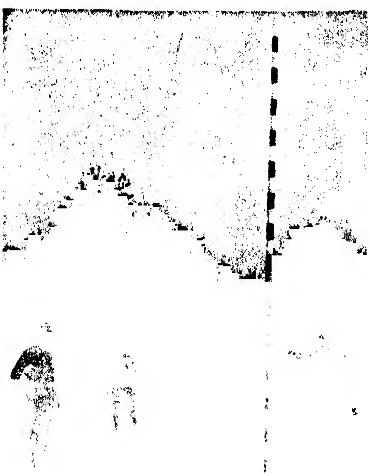


FIG. 11-46. Vertical rod used by sighter at pole *a* in Fig. 11-45 to secure alignment and plumbing of pole *b*, by sighting to pole *c*. (*Courtesy American Gas and Electric Service Corp.*)

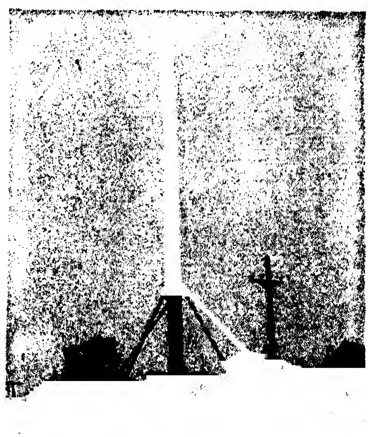


FIG. 11-47. Three-man crew aligning pole. When alignment is finished, pike poles rest on ground and hold pole in place while backfilling and tamping are done. (*Courtesy American Gas and Electric Service Corp.*)

The third step to be performed by the setting crew is straightening up the pole. This is generally done by sight by the man in the line and the man on the side (Fig. 11-47). It will be noted that one pair of men at the *pikes* take signals from the man sighting from the side, the *side liner*, and the other pair of pikers from the man sighting along the line, the *head liner*. The head liner should be about the length of one span ahead when he is lining the pole in. In the case of a straight line, he should be standing over the next hole or in line with it. The side liner should be

FIG. 11-48. Crew backfilling and tamping. Note that crew consists of one man at shovel and two tampers. Also note pike poles still in position holding pole in alignment. The dark lower portion of the pole is the creosoted butt. (*Courtesy Wisconsin Electric Power Co.*)

FIG. 11-49. Installing a creosoted block to make the pole self-sustaining. This pole happens to be at a slight angle in the line. It was set against the side of the hole on the "strain" side to give it good solid ground backing. Then No. 2 crushed stone was placed at the bottom of the hole opposite to the strain. And finally the 3 by 12 by 30-in. creosoted block was placed against the pole on the "strain" side about 6 in. below the ground. A pole set in this manner can take some side strain without being guyed. The figure shows one shoveler, two tampers, one man placing the creosoted block, and the crew foreman directing operations. Note that all men, including the foreman, wear hard plastic hats for protection against head injuries. (*Courtesy Wisconsin Electric Power Co.*)

about 30 or 40 paces out from the pole. These two men sighting direct the four men at the pike poles which way to push the upper end of the pole. Poles shall be set to stand perpendicular when the line is completed so that no pole shall be more than 2 in. out of line with the others.

In setting poles on a hillside or a sloping surface for a background to sight against, great care must be exercised, or the poles will be set leaning to one side. To avoid such difficulty the men sighting should make use of a plumb bob. A piece of lead or iron tied to the end of a thin string makes an excellent plumb bob for this purpose. Sometimes a watch suspended by its chain will serve very well unless the wind is blowing considerably.

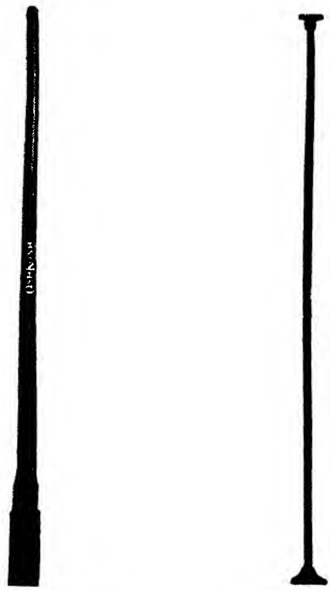


FIG. 11-50. Wood and steel tamping bars used in pole setting. (*Courtesy Leach Co.*)

When the pole is properly *lined in*, the pike poles are left in position to hold the pole in place during the backfilling and tamping operations.

Racking. Poles set at line terminals, curves, corners, and other points of abnormal stress should be given a slight rake against the direction of the pull. This should be sufficient to allow for the change in pole position caused by the continued pull of the load and the normal creepage of the anchor.

Backfilling and Tamping. After the pole is *lined in*, the hole is backfilled and tamped (Figs. 11-48 and 11-49). The size of the crew for this operation is usually four men, regardless of the size of the pole. The reason for not using more men is because four men are about all that can work around a pole. Of these four men, only one shovels the earth back into the hole while the other three tamp the earth firmly in place. Special tamping bars, as illustrated in Fig. 11-50, are used for this work.

Too much stress cannot be laid on proper tamping, as a poorly tamped hole will not hold the pole in alignment The earth should be backfilled slowly and each layer thoroughly tamped until the tamp makes a solid sound as the earth is struck So important is this step in line construction that some companies follow the rule of using "four good tampers and one lazy man at the shovel," as this combination is certain to ensure a firm setting for the pole In general, the tamping should be done so thoroughly that no dirt need be hauled away

If small stone or gravel are readily available, these should be used in backfilling as a better foundation can thus be obtained Care should be taken that plenty of earth is tamped in to fill the spaces between the stones The backfill should be piled well up around the base of the pole to allow for settling An examination should be made a month or two later and backfilling added if it has settled below the ground level.

SECTION 12

Guying Poles

Kinds of Guys. Guys fall into two classes, namely, (1) push braces and (2) wire guys. A description of these was given in Sec. 4.

As was pointed out, push braces are used today only where the anchor of a wire guy cannot be firmly embedded, as in swamps, or where the space for the wire guy is not available. Otherwise the wire guy is always used.

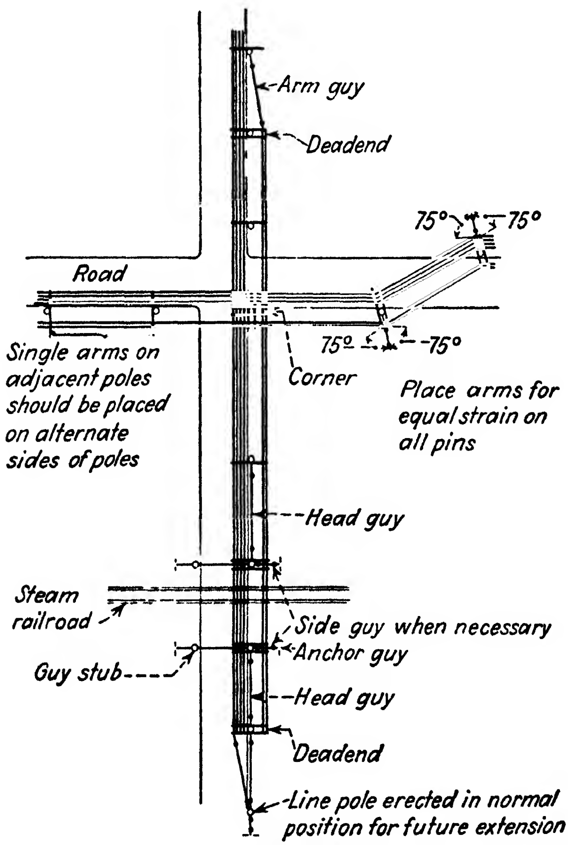


FIG. 12-1. Typical pole line showing use of arms and guys. (*Courtesy Consolidated Gas Electric Light and Power Co.*)

Where to Guy. Guys should be installed wherever the wires tend to pull a pole or crossarm out of its proper position in the line. Specific places where poles or crossarms are subjected to such side pulls are given in what follows. Figure 12-1 shows a typical pole line with numerous guy installations.

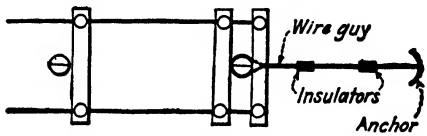


FIG. 12-2. Wire guy installed on terminal or end pole.

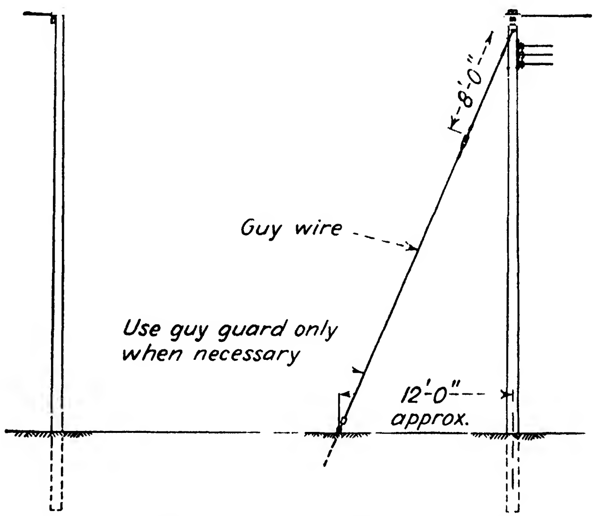


FIG. 12-3. Terminal down guy installed on a distribution line to counterbalance the pull of the dead-ended secondary mains.

Terminals. Line terminal poles should be guyed against the strain of the line conductors (Fig. 12-2). Figure 12-3 shows a terminal guy installed to balance the pull of the dead-ended secondary mains. In case of heavy line conductors, the pole next to the terminal pole is often also head guyed in the same direction. Where the guy would interfere with traffic, etc., a stub guy should be employed.

Corners. All corners should be considered as dead ends. They should, therefore, be guyed the same as terminal poles except that there will be two guys, one for the pull of the conductors in each direction (Fig. 12-4). Where the guys would interfere with traffic, etc., a stub guy should be installed.

Angles. Where the line makes an angle, a side pull is produced on the pole. Side guys should be installed to balance the side pull (Fig.

12-5). Figures 12-6 and 12-7 show side guys installed in the line as it changes from one side of the highway to the other.

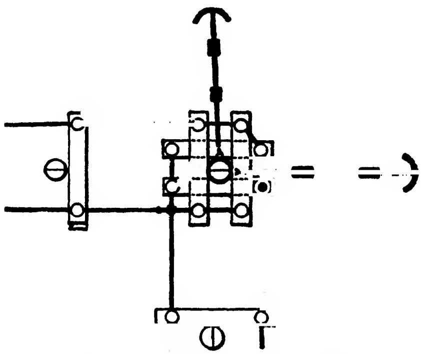


FIG. 12-4. Two guys installed on corner pole. Each guy counterbalances the pull of one set of wires.

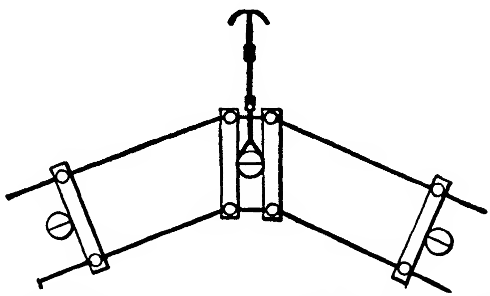
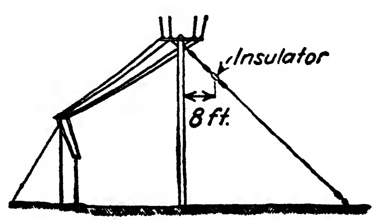


FIG. 12-5. Guy installed at angle in line. The guy opposes the side pull of the line conductors.

Branch Lines. Where a branch line takes off from the main line, an unbalanced side pull is produced. A side guy should be placed on the pole directly opposite to the pull of the branch line (Fig. 12-8).

FIG. 12-6. Down guys installed in line to balance side pulls caused by angles in the line.



Hillsides. Lines on steep hills should be provided with head or line guys, as shown in Fig. 12-9, to take the downhill strain of the line.

Crossarms. Crossarms which have more wires dead-ended on one side than on the other should be guyed on the end subjected to the greater pull to the adjacent pole (Fig. 12-10). As this strain is usually not very large, a No. 6 iron wire is commonly used for this purpose

Crossings. Electric lines crossing railroad tracks must be reinforced

FIG. 12-7 Side guys installed in line at angle to balance side pull of line conductors Note guy strain insulators, as well as dead-end insulators in line and double crossarm construction (*Courtesy Aluminum Company of America*)

by the use of double arms and head guys as shown in Fig 12-11. These guys run from the top of the pole adjacent to the track to a point about halfway down on the next pole

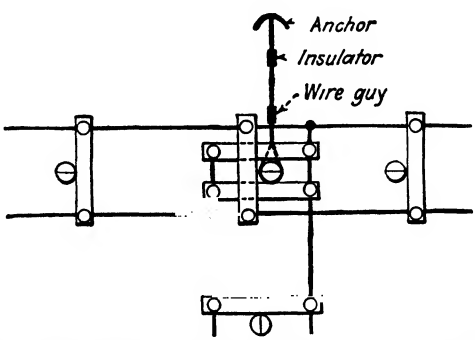


FIG 12-8 Guy installed at branch-line connection. It opposes side pull of branch line

Intervals in Line. At regular intervals of about ½ mile, storm guys are placed in a line (Fig. 12-12). As shown, a storm guy consists of four guys, two line guys and two side guys, all fastened to the same pole The line guys are usually run from the top of the pole to the bottom of the next pole. This eliminates the cost of two anchors In case of a break in the line conductors for any reason, the storm guy would prevent the pulling down of any great length of line. Such guys are called "storm guys" because they protect against failures caused by storm.

Poor Pole Foundations. In case any pole cannot be firmly set, it should be supported by guys or braces

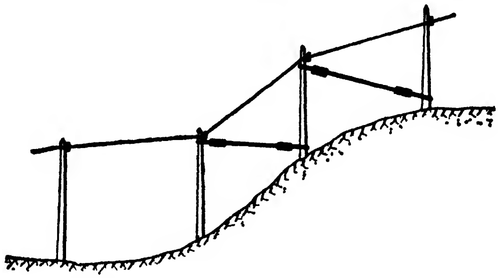


Fig 12-9 Head guys installed on steep grade.

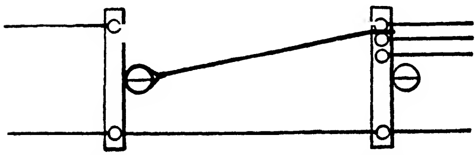


Fig 12-10 Crossarm guy Guy opposes unbalanced pull on crossarm.

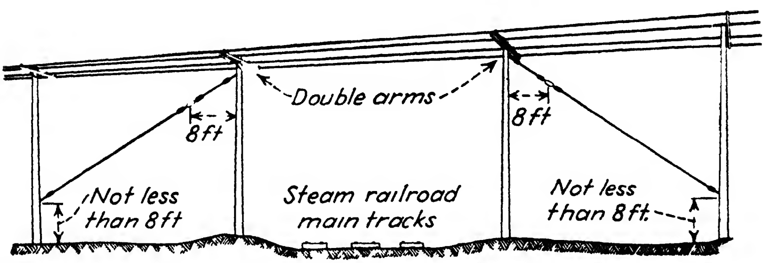


Fig 12-11. Line reinforcement by use of double crossarms and head guys of a railroad crossing.

Clearance. A stub guy is a means of obtaining clearance for a down guy. When lines parallel to streets or roads must be guyed toward the street or road, the necessary clearance can be obtained by use of a pole stub on the opposite side. This pole stub is then down guyed as shown in Fig. 12-13.

Number of Guys Required. Figure 12-14 gives the number of guy wires necessary for angle and corner poles for various sizes of a three-wire line for average conditions. From this figure one can determine at a glance the number of guys required for any combination of wire size and angle in the line. For example, the figure shows that two guys are required of $\frac{5}{16}$-in. wire to carry the pull produced by three size 0 conductors when the angle in the line is 30 deg. The chart also shows that the pole should be provided with two crossarms and strain insulators.

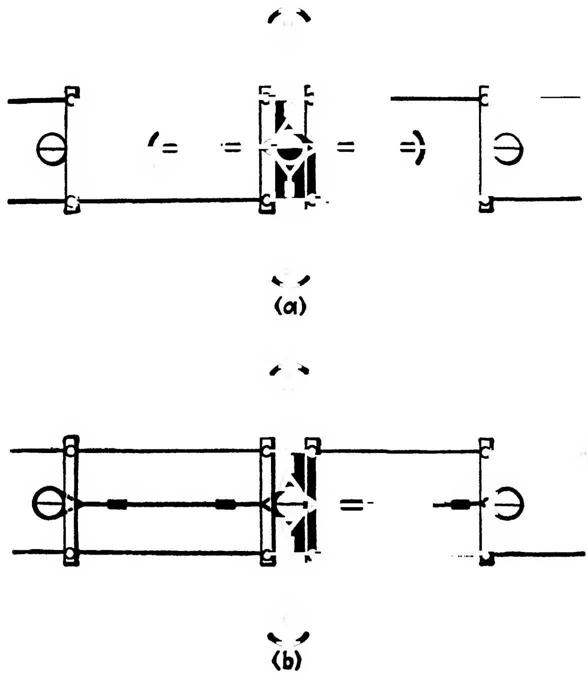


FIG. 12-12. Two methods of installing storm guys. In *a* four anchor guys are employed. In *b* two anchors and two head guys are used. Storm guys should be installed about every ½ mile in lines exposed to storms.

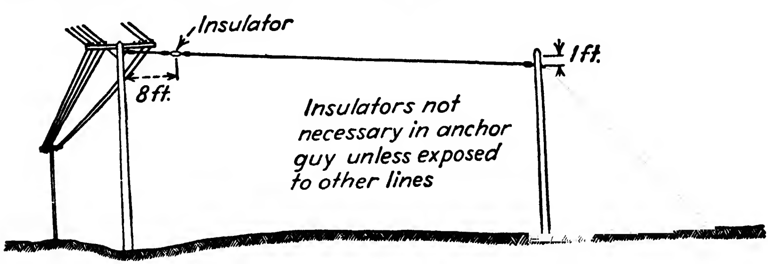
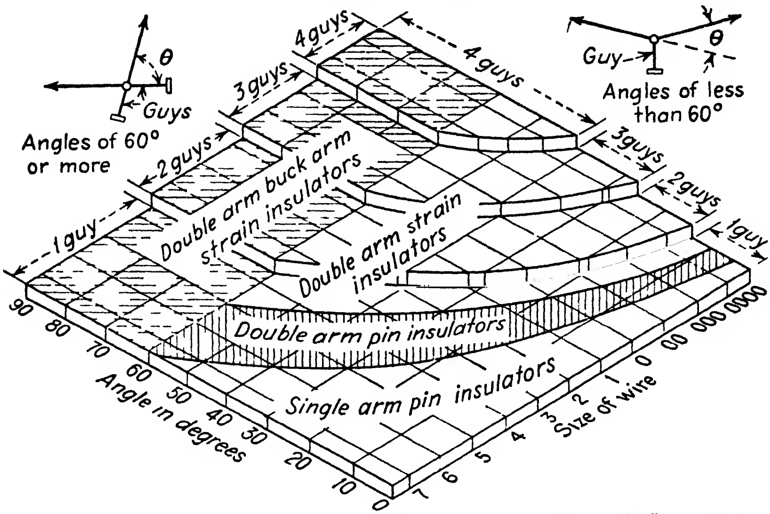


FIG. 12-13. Use of pole stub to secure clearance over highway. Pole stub is then guyed in usual manner.

When two or more guys are run to the same pole or stub, each guy should be attached entirely separate from the other.

Measuring Height and Lead on Sloping Ground. The manner of measuring the height and lead of a guy on sloping ground and of a stub pole guy is illustrated in Fig. 12-15. On sloping ground the lead is the



The number of guys as given by the chart are the number of 5/16" Siemens Martin guys, of 6000-lb. tensile strength, installed at 45° angle with the pole, necessary to balance the pull of one circuit of three wires

For buck-arm poles the chart gives the number of guys required each way

FIG. 12-14. Chart for determining number of guys and framing required on angle and corner poles. *Example* The intersection for any given size of wire and angle on the pole falls in one of four areas, indicating type of framing. It also falls in one of the four steps on the chart, indicating the number of guys required.

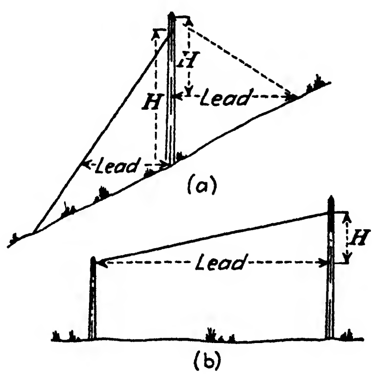


FIG. 12-15. Methods of measuring height and lead: *a*, sloping ground; *b*, stub guy.

horizontal distance from the anchor to the pole, and the height is the distance above this horizontal line, as shown in Fig. 12-15*a*. On a pole stub guy the lead also is the horizontal distance from pole stub to line pole, and the height is the vertical distance above this horizontal line; see Fig. 12-15*b*.

Strength of Guy Wire. Guy wire is used in various sizes from ¼ to ½ in. The breaking or ultimate strengths of the various types and makes are as given in Table 12-1.

If a factor of safety of 2 is used, the allowable guy tension can be one-half of the breaking strength as shown in the right-hand column.

TABLE 12-1. ULTIMATE OR BREAKING STRENGTHS OF VARIOUS SIZES OF STEEL GUY WIRES AND ALLOWABLE TENSIONS BASED ON SAFETY FACTOR OF 2

Grade	Size, in.	Breaking strength, lb	Allowable tension, lb
Common	¼	1,900	950
Siemens Martin	¼	3,150	1,575
Utilities	¼	4,500	2,250
Siemens Martin high strength	¼	4,750	2,375
Common	5/16	3,200	1,600
Siemens Martin	5/16	5,350	2,675
Specification	5/16	6,000	3,000
Utilities	5/16	6,500	3,250
Siemens Martin high strength	5/16	8,000	4,000
Common	⅜	4,250	2,125
Siemens Martin	⅜	6,950	3,475
Utilities	⅜	8,500	4,250
Siemens Martin high strength	⅜	10,800	5,400
Specification	⅜	11,500	5,740
Common	½	7,400	3,700
Siemens Martin	½	12,100	6,050
Siemens Martin high strength	½	18,800	9,400
Specification	½	25,000	12,500

Selecting Size of Guy Wire at Angles. To illustrate the procedure for determining the required size of guy wire for a side guy for various line angles proceed as follows:

1. Look up the breaking strength of the line conductor.

Examples:

Wire Size, AWG (Copper Hard Drawn)	Breaking Strength, Lb
No. 8	830
No. 6	1,280
No. 4	1,970
No. 2	3,045
No. 0	4,750
No. 00	5,927
No. 0000	9,617

A more complete table of the breaking strengths of various sizes and types of conductors is given in Sec. 4, Table 4-7.

2. Take 50 per cent, or one-half, of the breaking strength as the conductor tension under maximum loading conditions. This assumes a factor of safety of 2.

Example:

$$\begin{aligned} \text{Line tension} &= 50 \text{ per cent of breaking strength} \\ \text{For No. 2 copper} &= 50 \text{ per cent of } 3{,}045 \text{ lb} \\ &= 1{,}522 \text{ lb} \end{aligned}$$

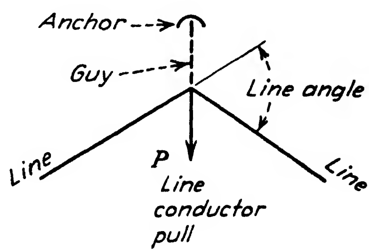


FIG. 12-16. Sketch of line making an angle. Resulting side pull shown as P. Angles of 60 to 90 deg can be considered the same as a dead end requiring two terminal guys.

3. Multiply the line tension by the constant corresponding to the angle in the line (see Fig. 12-16 for the meaning of line angle).

Line Angle, Deg	Angle Constant
10	0.174
20	0.347
30	0.517
40	0.684
50	0.845
60	1.000
70	1.15
80	1.29
90 or dead end	1.41

Example: For No. 2 copper conductor for 30-deg angle

$$1{,}522 \times 0.517 = 787 \text{ lb}$$

4. Multiply the side pull of one conductor by the number of conductors in line to get the total side pull.

Example: On the basis of three conductors, the total side pull is

$$787 \times 3 = 2{,}361 \text{ lb}$$

5. From Table 12-2 find the multiplying factor for the values of D and H to be used.

Example: On the basis of $D = H$, the multiplying factor is 1.41. Therefore, multiply the line side pull by 1.41 which gives as the tension in the guy wire

$$2{,}361 \times 1.41 = 3{,}305 \text{ lb}$$

6. From Table 12-1 based on a factor of a safety of 2, a ⅜-in. Siemens Martin cable is indicated.

TABLE 12-2. MULTIPLIERS TO USE WITH FIG. 12-17 TO DETERMINE THE TENSION IN THE GUY WIRE WHEN THE PULL OF THE LINE CONDUCTORS IS KNOWN

To find the tension in the guy wire, multiply the line conductor pull by the constant given in the table for values of *H* and *D*.

Height *H* of guy attachment on pole, ft	Distance *D* from center of pole to guy rod, ft												
	5	6	7	8	10	12	14	16	18	20	25	30	35
15	3 16	2 69	2 36	2 12	1 80	1 60	1 46	1 37	1 30	1 25	1 16	1 12	1 09
16	3 35	2 85	2 47	2 24	1 89	1 67	1 52	1 41	1 34	1 28	1 19	1 13	1 10
17	3 54	3 00	2 63	2 35	1 97	1 73	1 57	1 46	1 37	1 31	1 21	1 15	1 11
18	3 73	3 16	2 76	2 46	2 06	1 79	1 63	1 50	1 41	1 35	1 23	1 17	1 12
19	3 93	3 32	2 89	2 58	2 15	1 87	1 68	1 55	1 45	1 38	1 26	1 19	1 14
20	4 12	3 48	3 03	2 69	2 24	1 94	1 74	1 60	1 49	1 41	1 28	1 20	1 15
21	4 32	3 64	3 17	2 81	2 33	2 01	1 80	1 65	1 54	1 45	1 31	1 22	1 17
22	4 51	3 80	3 30	2 93	2 42	2 09	1 86	1 70	1 58	1 49	1 33	1 24	1 18
23	4 71	3 96	3 44	3 04	2 51	2 16	1 92	1 75	1 62	1 52	1 36	1 26	1 20
24	4 90	4 12	3 57	3 16	2 60	2 24	1 98	1 80	1 67	1 56	1 39	1 28	1 21
25	5 10	4 28	3 71	3 28	2 69	2 31	2 04	1 85	1 71	1 60	1 41	1 30	1 23
26	5 29	4 45	3 84	3 40	2 79	2 39	2 11	1 91	1 76	1 64	1 44	1 32	1 25
27	5 51	4 62	3 99	3 52	2 88	2 46	2 17	1 96	1 80	1 68	1 47	1 34	1 26
28	5 69	4 78	4 13	3 64	2 97	2 54	2 24	2 01	1 85	1 72	1 50	1 37	1 28
29	5 89	4 94	4 27	3 76	3 07	2 61	2 30	2 06	1 90	1 76	1 53	1 39	1 30
30	6 08	5 09	4 41	3 88	3 16	2 68	2 36	2 12	1 95	1 80	1 56	1 41	1 32
31	6 28	5 26	4 54	4 04	3 26	2 77	2 42	2 18	1 99	1 84	1 59	1 44	1 33
32	6 48	5 42	4 68	4 13	3 36	2 85	2 49	2 24	2 04	1 89	1 62	1 46	1 35
33	6 68	5 59	4 82	4 24	3 45	2 93	2 56	2 29	2 09	1 93	1 65	1 48	1 37
34	6 88	5 75	4 96	4 36	3 54	3 01	2 62	2 34	2 14	1 97	1 69	1 51	1 39
35	7 08	5 92	5 10	4 48	3 64	3 08	2 69	2 40	2 19	2 02	1 72	1 53	1 41

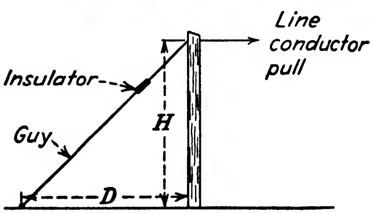


FIG 12-17 Sketch of guy installation to accompany Table 12-2 *H* is height of guy attachment to pole. *D* is distance from pole to anchor.

Selecting the Size of Guy Wire at a Dead End. The procedure for selecting the size of guy wire at a dead end is similar to that at a 90-deg angle, as the lines in both directions have to be dead-ended. The angle constant for 90 deg is 1. This simplifies the calculations as shown in the following example.

Example: Line 4 conductor copper size No. 2 dead-ended. Guy lead ratio 1 to 2.

Solution:

Breaking strength of No. 2 copper = 3,045 lb.
Maximum conductor tension ½ of 3,045 lb. = 1,522 lb.
Angle constant = 1.0. 1,522 × 1.0 = 1,522 lb.
Multiplying factor for D to H ratio of 1 to 2 = 2.24.

$$1{,}522 \times 2.24 = 3{,}409 \text{ lb}$$

For four conductors, guy tension is 3,409 × 4 = 13,636 lb.
From Table 12-1 two ½-in. Siemens Martin guys are indicated for dead-end guying in each direction.

Guy-wire Tension Tables. Values of guy-wire tension have been computed for various copper line-conductor sizes and various line angles and for three ratios of D to H. The line-conductor size varies from No. 8 to No. 0000, the line angle varies from 10 to 60 deg, and the three guy lead ratios are 1 to 1, 1 to 1½, and 1 to 2.

To use Table 12-3 select the table which has the proper ratio of D to H and then at the intersection of the vertical-line conductor column and the horizontal-angle column, read the value of guy tension. This value must then be multiplied by the number of conductors in the line.

Example: For No. 2 copper line conductor, a line angle of 30 deg, and a guy lead ratio of 1 to 1, the guy wire tension is shown to be 1,105 lb. For three conductors the total guy tension would be

$$1{,}105 \times 3 = 3{,}315 \text{ lb}$$

This value agrees with that found in previous paragraphs by actual calculation.

Determining Tension in Guy Wire. The tension in the guy wire for a given line-conductor pull depends on the distance the anchor is installed from the base of the pole. This is made clear from Fig. 12-17 and Table 12-2 where the multipliers are given for different combinations of height H of guy-wire attachment on the pole and distances D of guy from pole.

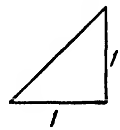
To find the tension in the guy wire, select the constant in the table corresponding to the values of H and D, and multiply the line-conductor pull by this constant. To illustrate, assume a line-conductor pull of 1,500 lb and values of H = 25 ft and D = 16 ft. The multiplier from the table is 1.85. Therefore, 1,500 × 1.85 = 2,775 lb tension in the guy.

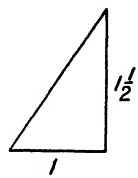
Effect of Ratio of H to D. Wherever possible the distance D should be about equal to the height H. In no case should D be less than one-third of H. Figure 12-18 and Table 12-4 illustrate how the tension in the guy wire increases as D decreases. The pull of the line conductors is assumed to be 1,000 lb. When the length of the lead on the anchor guy is equal to H, the guy tension is 1,414 lb. When D is equal to one-

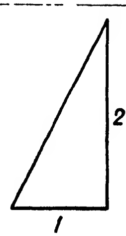
Table 12-3. Tension in Guy Wire for One Copper Line Conductor, for Various Line Angles, Conductor Sizes, and Three Values of Guy-anchor Lead

The total tension is obtained by multiplying the tension shown by the number of line conductors.

Line angle, deg	Copper conductor size						
	8	6	4	2	0	00	0000
Guy lead 1 to 1							
10	102	158	242	372	584	727	1,180
20	205	316	483	741	1,163	1,450	2,356
30	304	471	716	1,105	1,732	2,160	3,510
40	400	620	1,080	1,460	2,293	2,860	4,640
50	500	767	1,175	1,805	2,831	2,535	5,740
60 or dead end	583	908	1,390	2,140	3,350	4,180	6,890
Guy lead 1 to 1½							
10	130	200	316	477	744	928	1,505
20	262	408	616	951	1,482	1,850	3,000
30	388	600	918	1,416	2,210	2,755	4,475
40	511	800	1,190	1,875	2,920	3,650	5,920
50	638	964	1,500	2,320	3,610	4,510	7,320
60 or dead end	750	1,170	1,750	2,740	4,280	5,340	8,660
Guy lead 1 to 2							
10	161	250	383	591	922	1,150	1,866
20	325	509	768	1,180	1,836	2,300	3,720
30	480	742	1,134	1,756	2,740	3,420	5,550
40	633	990	1,475	2,325	3,620	4,530	7,340
50	792	1,209	1,860	2,870	4,480	5,600	9,070
60 or dead end	917	1,440	2,170	3,400	5,300	6,620	10,720







half of H, the guy tension is 2,236 lb. This is more than twice the pull of the line conductors. When D is one-fourth of H, the guy tension is 4,123 lb, or four times the conductor pull. However, when D is one and one-half times H, the tension is only 1,200 lb. Longer leads than H are usually required in cases where it is necessary to hold very heavy dead-end loads.

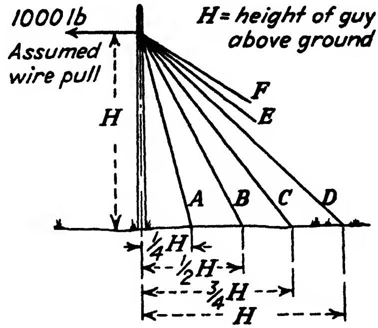


FIG. 12-18. To accompany Table 12-4. Advantage of longer leads for anchor guys in lessening the strain in the guy and compression stress in the pole. Compression stress causes bending of the pole, especially at dead ends and heavy angles and where small sizes of poles are used.

TABLE 12-4. VALUES OF GUY TENSION FOR VARIOUS RATIOS OF D TO H FOR FIG. 12-18.
Line-conductor pull is assumed to be 1,000 lb

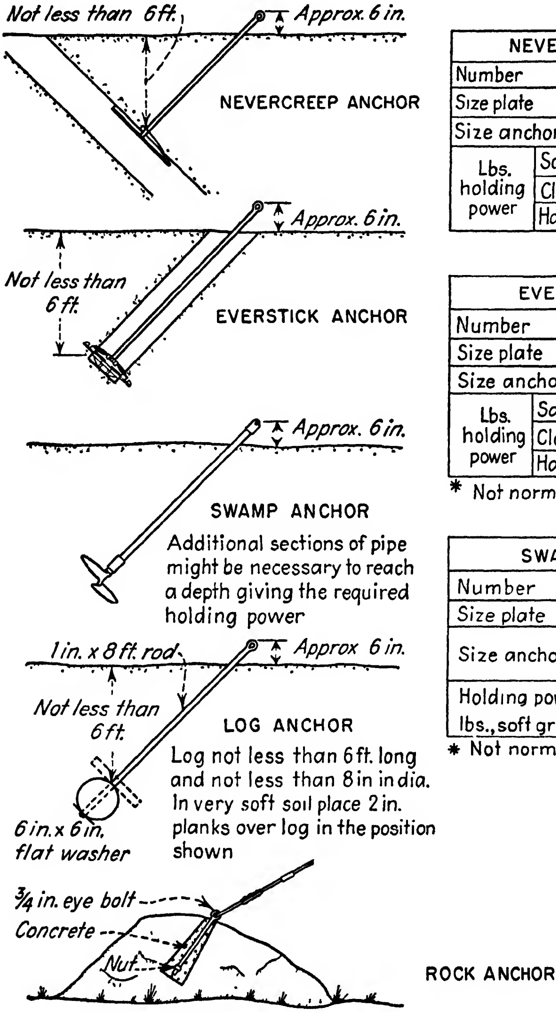
	Length of lead on anchor guy	Tension in anchor guy, lb	Compression stress in pole, lb
A	¼H	4,123	4,000
B	½H	2,236	2,000
C	¾H	1,667	1,333
D	H	1,414	1,000
E	1¼H	1,280	800
F	1½H	1,200	667

Guy Construction. The installation of a guy divides itself naturally into five steps as outlined below:

1. Digging in the anchor
2. Inserting the strain insulator in the guy wire
3. Fastening the guy wire to the pole
4. Tightening the guy wire and fastening to the anchor
5. Mounting the guy-wire guard

Digging in the Anchor. The manner of digging in the guy anchor depends on the type of anchor. See Fig. 12-19 for various types of guy anchors in general use. The screw-type anchor is screwed into the earth in the manner shown in Fig. 12-20.

The patented "never-creep" anchor is installed in the manner shown in Fig. 12-21. A more detailed view showing the lineman hanging the plate onto the anchor rod is shown in Fig. 12-22. The so called "expanding anchor" is installed by inserting the anchor into the bottom of the



NEVERCREEP ANCHORS			
Number		617	827
Size plate		6in.x17in.	8in.x27in.
Size anchor rod		⅝in.x6ft.	¾in.x7ft
Lbs. holding power	Sand	5500	16000
	Clay	11000	24000
	Hard pan	16000	32000

EVERSTICK ANCHORS			
Number		8312	10316 *
Size plate		8 in.	10 in.
Size anchor rod		¾ in x 8 ft	¾ in. x 8 ft
Lbs. holding power	Sand	12000	16000
	Clay	18000	24000
	Hard pan	24000	32000

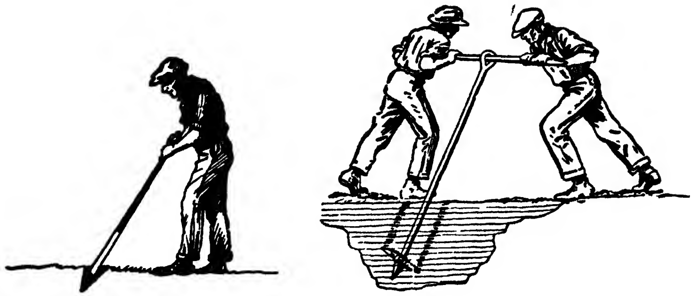
* Not normally carried in stock

SWAMP ANCHORS		
Number	7815	11315 *
Size plate	10 in.	12 in.
Size anchor rod	1½ in pipe 10 ft. long	2 in. pipe 8 ft. long
Holding power in lbs., soft ground	3000 to 6000	6000 to 10000

* Not normally carried in stock

FIG. 12-19. Various types of guy anchors in general use.

hole, Fig. 12-23, and then causing the blades to expand into the solid ground, Fig. 12-24. The "deadman," which is a log anchor, has to be dug in. First a hole is dug, and then the anchor is placed in the hole (Fig. 12-25). The hole is backfilled and thoroughly tamped. The



a *b*

FIG. 12-20. Steps in installation of screw-type anchor. (*a*) Digging small hole with bar. (*b*) Screwing in anchor. (*Courtesy Hubbard & Co.*)

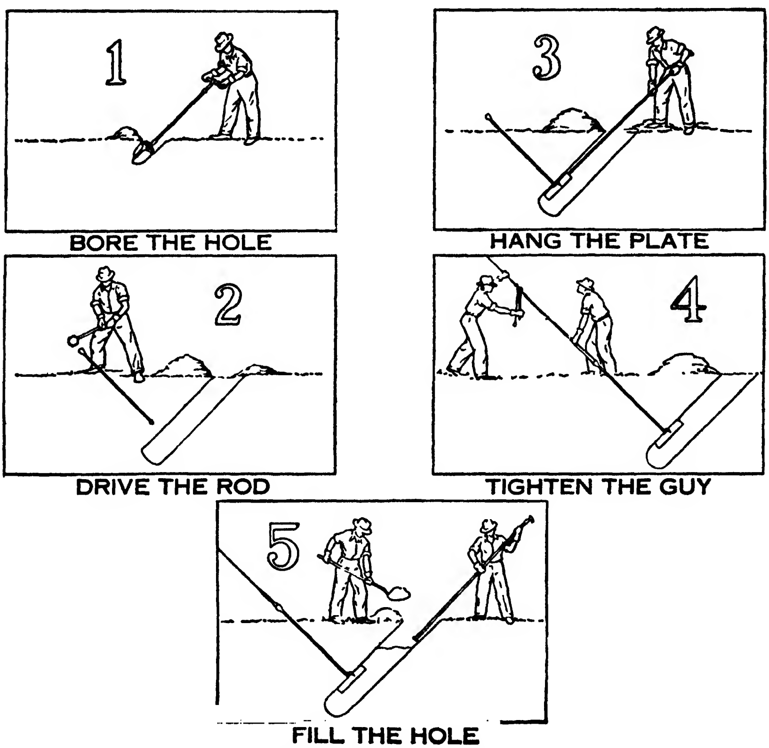


FIG. 12-21. Steps in the installation of the "never-creep" anchor. Locate the spot desired for the anchor rod and measure from that point back from the pole the length of the rod and start the hole at this point. Use an 8-in. auger, and bore the hole as nearly at right angles to the line of strain as conditions will allow. Then proceed with steps 2, 3, 4, and 5 as shown above. (*Courtesy A. B. Chance Co.*)

deadman is usually cut from a broken pole or one that is too short. It should be treated with a preserving compound so as to make its life greater than that of the pole it is holding in place.

The anchor is an important part of a line, for if the anchor fails, the guy fails, and if the guy fails, the pole fails, and if the pole fails, the corner fails, and if the corner fails, the line fails. In other words, the chain is no stronger than its weakest link, and the line is no stronger than its weakest angle or corner. The importance of proper guying has led to

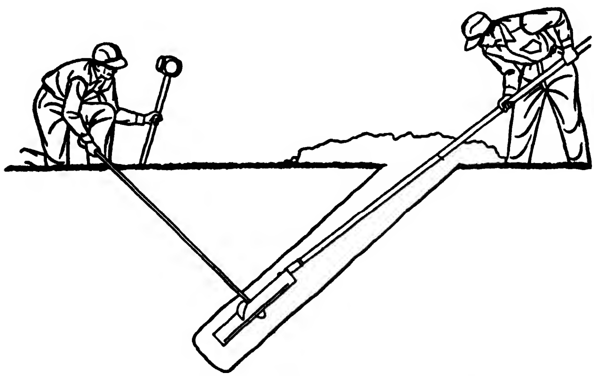


FIG. 12-22. "Never-creep" anchor plate being hung onto anchor rod. Since anchor rod is driven through undisturbed earth, this type of anchor has good holding power. (*Courtesy A. B. Chance Co.*)

the expression, "A line well guyed is half built, but a line poorly guyed is never built."

Digging the Anchor Hole with a Power Digger. Most anchor holes at present are dug with a power digger (see Fig. 12-26). Only isolated holes or holes inaccessible to a digger are dug by hand. The usual diameter of a hole is 9 in. The length of the hole should be such, as a general rule, that the anchor itself will be not less than 6 ft below the surface of the ground. Figure 12-27 illustrates the use of a power digger in digging an anchor hole in a crowded place. This digger is the same digger that is used in digging pole holes. The 9-in. auger replaces the larger size needed for pole holes.

Inserting the Strain Insulator. After the anchor has been put in place, the guy wire is cut into proper lengths, and the strain insulator is inserted. When only one insulator is used, it should be placed at about the middle of the wire. It is a simple matter to insert this insulator as standard clamps are used to hold the wire. All the clamp bolts should be tightened up securely so that the clamp will not slip.

Another method of inserting a strain insulator in a guy wire is illustrated in Fig. 12-28. This is known as the "mousing" method, which is replacing the familiar "serving" or wrapping method. In the mous-

FIG. 12-23. Lineman inserting "expanding" type anchor into anchor hole. A ram has been placed over the anchor rod to be used in expanding the anchor. Ordinarily this ram is not placed over the anchor rod until the anchor has been placed in the hole. In the collapsed position the four leaves of the anchor are drawn up. In the expanded position the leaves look somewhat like a four-leaf clover. When the top of the anchor is struck with the ram, the four leaves are caused to expand and penetrate into the hard earth at the bottom of the hole. When the anchor is closed, its diameter is 8 in. When expanded, its diameter increases to 20 in. (*Courtesy Wisconsin Electric Power Co.*)

FIG. 12-24. Lineman using ram to strike blows at anchor to cause it to expand. Four or five blows are usually required. The anchor is fully expanded when the hollow sound of the first few blows changes to a dull thud. The ram is 10 ft long, 2½ in. in diameter, has a heavy collar welded to each end, and weighs 35 lb. (*Courtesy Wisconsin Electric Power Co.*)

ing method the stub end of the guy wire does not lay parallel to the guy wire as in the "serve" method, but instead winds itself gradually around the guy wire several times. This causes more friction between guy wire and stub should it tend to slip, thus giving the joint added strength.

This insulator introduces a break in the guy wire, thus breaking the so-called "ground circuit." All guys on power lines as well as guys on telephone lines adjacent to or on the same poles as power lines should have one and preferably two strain insulators placed in them.

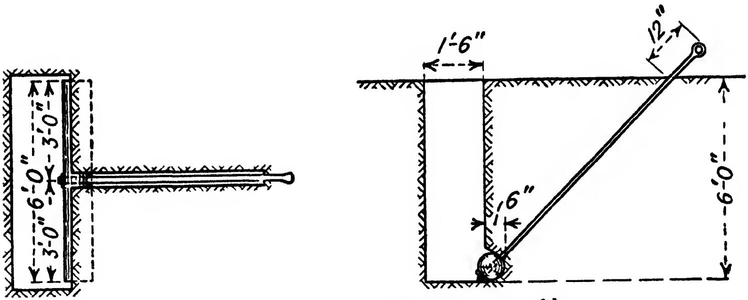


Fig 12-25 Single-rod log anchor assembly

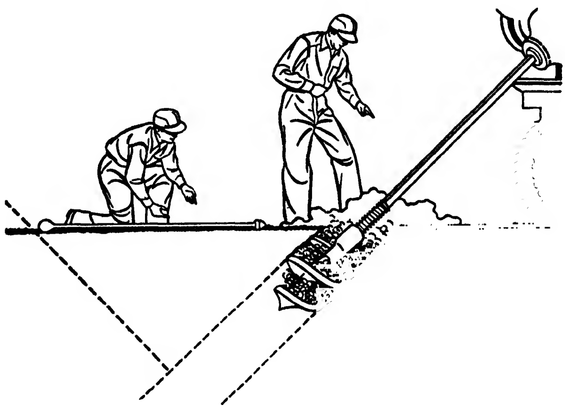


Fig 12-26 Using power borer to dig a hole for inserting the 'never-creep anchor Dashed line on left indicates position anchor rod will have when driven in place. (*Courtesy A B Chance Co*)

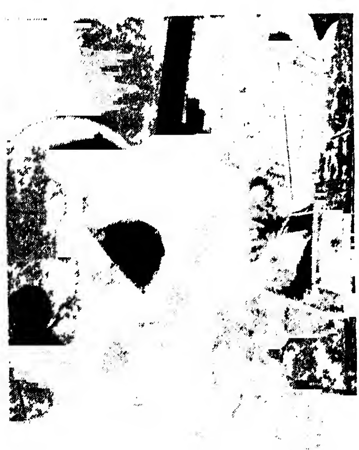


Fig 12-27 Digging a 9-in-diameter anchor hole with a power borer in a crowded place The procedure is the same as that used in digging a pole hole The hole is just 2 ft away from the building on the left and runs diagonally under a large tank (*Courtesy Wisconsin Electric Power Co.*)

FIG. 12-28. Lineman connecting a strain insulator into a guy wire at the truck. The special clamp for holding the guy wire is used. In the "mousing" method a piece of mousing wire and a mousing tool are required. The mousing wire is a 10-ft piece of No. 11 BWG galvanized wire. One end of the mousing wire, together with the guy wire, is clamped in the special truck clamp. Then the mousing tool is slipped into place over the mousing wire, and the mousing wire is wrapped tightly around the guy wire and stub. The wrapping can be to either the right or the left. In the figure the lineman is wrapping to the right. The mousing is more than half completed. (*Courtesy Wisconsin Electric Power Co.*)

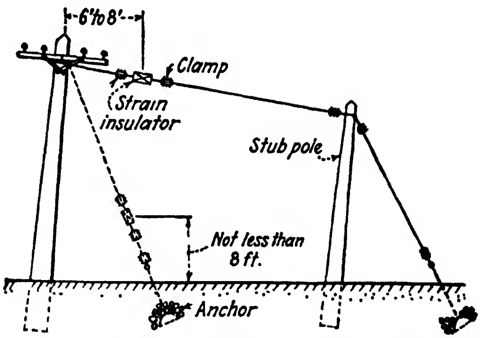


FIG. 12-29. Sketch showing simple down guy and stub guy installed on pole. Note position of strain insulator with respect to pole and ground. (*Courtesy Wisconsin Power & Light Co.*)

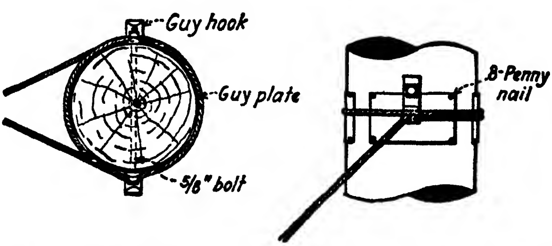


FIG. 12-30. Method of fastening guy wire to pole. Sketch shows use of guy hooks and plates.

When more than one strain insulator is placed in the guy, the upper one should be placed far enough down so as to prevent electrical contact between the line wire and the middle section of the guy. This is usually about 6 ft (see Fig. 12-29). The lower insulator likewise should be a

FIG. 12-31. Lineman fastening a pole guy with a two-bolt clamp. He is using a lag wrench for the job. Note use of through eyebolt with thimble to attach guy to pole. Also note use of block and tackle for pulling guy to proper tension. The block and tackle is sometimes preferred to the chain jack as it weighs less. (*Courtesy Wisconsin Electric Power Co.*)

FIG. 12-32. Lineman pulling up on anchor guy. Note the coffing hoist or chain jack and the two come-alongs being used. The chain jack has a 1,500 lb capacity. It replaces and is easier to use than the ordinary block and tackle. It is operated with a back-and-forth pump-handle motion of the handle. The main advantage is that it locks itself in place. It will not slack off when the hand is taken off the handle. (*Courtesy Wisconsin Electric Power Co.*)

sufficient distance above the ground to prevent a man on the ground making contact with the middle section. This distance should never be less than 8 ft.

It will be noted that the two ends of the guys, in threading through the insulator, link each other. The porcelain of the insulator is thus put under compression, making it possible to withstand a large pull. In case the porcelain should fail, the guy will still be effective because of the linking of the two ends.

Fastening the Guy Wire to the Pole. The next operation consists in fastening one end of the guy wire to the top of the pole. This consists in wrapping two turns of the wire around the pole and clamping the free end to the wire. Except where the guy wire is horizontal, two standard guy hooks (Fig. 12-30) should be placed in the side of the pole under the

FIG. 12-33 Cut-away view of "never-creep" anchor installation, showing lineman tightening up on guy wire with coffing hoist attached to guy wire with come-alongs. (*Courtesy A. B. Chance Co.*)

two turns. It is the usual practice to allow the wire to project about 1 ft beyond the clamp. This end is fastened to the main guy wire by means of eight or ten wraps of one strand of the wire.

Where the pull on the guy wire is so large that it is apt to crush the fibers of the wood, guy plates (Fig. 12-30) should also be installed beneath the two turns to protect the pole. The use of guy shims is now almost universal. With age, poles lose fiber strength and permit the guy wire to cut in badly unless the pole is protected with shims.

This method of wrapping the guy wire twice around the pole over four metal shims is giving way to the use of a through eyebolt and thimble, as shown in Fig. 12-31. Note that both the pole guy and down guy are attached to through bolts.

Guy Clearance. A pole guy wire running to a stub should provide proper clearance underneath. The minimum required clearances as given by the National Electrical Safety Code are as follows:

Guy Over	Minimum Ground Clearance, Ft
Railroads	27
Roads, streets, alleys	18
Sidewalks	15
Driveways to residence garages	10

All guy wires should also clear every wire attached to the same pole by at least 6 in. Wires not on the same pole should clear by at least 4 ft.

When a guy wire is fastened to another pole, it should be attached at least 8 ft above the ground.

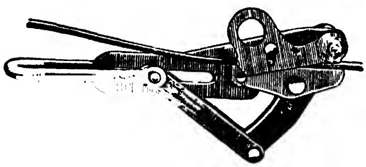


FIG. 12-34. Improved "Chicago" steel wire grip or come-along. (*Courtesy Mathias Klein & Sons.*)

Tightening the Guy Wire and Fastening to the Anchor. Guy wires should be placed on the poles and "pulled" before the line conductors are placed on the pole. If the line wires should be placed first, the poles would be pulled out of position.

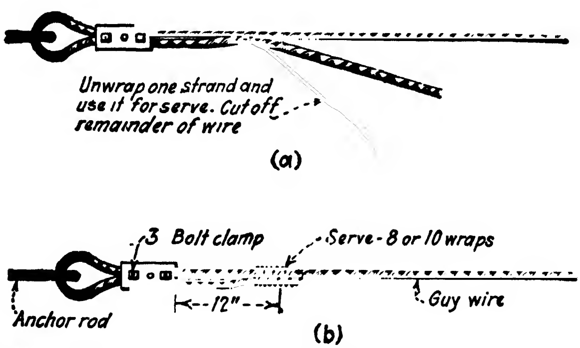


FIG. 12-35. Method of serving stranded guy wire. One strand is unwrapped as shown in *a* and then wrapped around both wires eight or ten times as shown in *b*.

A guy wire is pulled up or tightened from the ground by means of a chain jack and approved grips, as shown in Figs. 12-32 and 12-33. These grips (Fig. 12-34) are also called "come-alongs." Come-alongs or wire eccentrics will grip a straight wire at any point without slipping. The guy is drawn up until the pole is pulled over slightly toward the guy. The clamp is then attached, and the bolts are tightened securely (see Figs. 12-35 and 12-36). The free end of the guy wire is fastened to the main wire by eight or ten wraps of one of the strands, as shown in Fig.

Fig. 12-36. Lineman tightening bolts on anchor guy clamp. A two-bolt clamp is used in this instance. The lower ends of down guys are generally fastened with clamps as they are easily removed and therefore facilitate subsequent guy tightening should the guy become loose. The wrench being used is a heavy-duty ratchet called a Leach wrench. Enough end is left on the guy wire beyond the clamp for the attachment of a come-along for later retightening. (*Courtesy Wisconsin Electric Power Co.*)

Fig. 12-37. Lineman tightening a pole guy with a block and tackle. (*Courtesy Wisconsin Electric Power Co.*)

Fig. 12-38. Lineman pulling up on an overhead guy using chain jack. (*Courtesy Rural Electrification Administration.*)

12-35, or by the use of two or three Crosby clips. The clips are preferred as they are easier to remove if at a later time the guy becomes loose and has to be tightened.

In threading the guy wire through the anchor rod, a thimble should be used to protect the guy wire from a sharp bend. This is shown in Fig. 12-36.

Figure 12-37 shows the manner of pulling up on a head guy. It should be noted that the lineman on the pole does not do any direct pulling on the rope. This should always be done by a man on the ground. Figure 12-38 shows the lineman fastening the guy wire to the pole.

In Fig. 12-37 notice the method the lineman is using to pull up the block and tackle. He is pulling on the fall line to his right with his left hand and on the same rope on the other side of the sheave to his left with his right hand. His right and left hands are pulling in opposite directions; hence no extra strain is placed on his "hooks" and there is

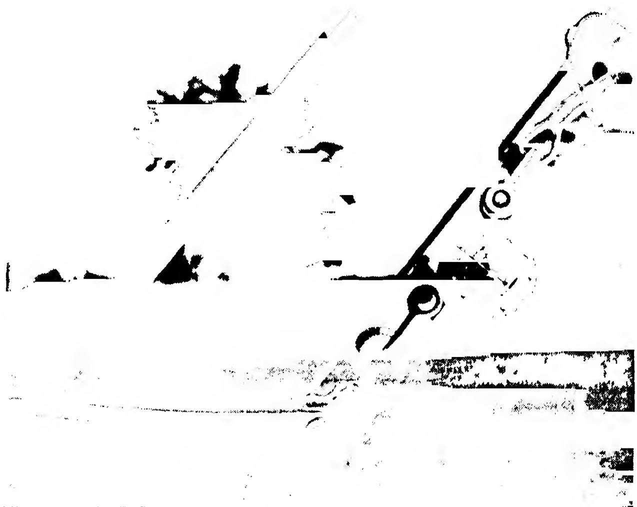


FIG. 12-39. Showing use of come-along, dynamometer, and chain jack in pulling down guy to proper tension. (*Courtesy Coffing Hoist Co.*)

less danger of breakouts. A "foul" was thrown into the set of blocks before the operation was started. This can be seen in the figure just above the lineman's left forearm. This enables the lineman to cinch the blocks to hold the strain, by pulling the fall line on the ground. When the lineman cannot by himself pull the guy wire up tight enough, the helper on the ground also pulls on the fall line. In this case the fall line is passed over the lineman's safety strap and the helper sets himself about one-half span away before he starts to pull. In this case, however, the "foul" cannot be used to cinch the strain. The helper must keep pulling on the rope until the lineman fastens the guy with a clamp.

The purpose of this pole guy is to take up the unbalanced pull on the adjacent pole by a primary line which "dead-ends" on that pole. The anchor guy shown to the left of the pole in the figure will balance the pull of the pole guy and the secondary main shown, after it has been pulled up to sag. The lineman is wearing a hard plastic hat and rubber gloves.

Figure 12-39 shows the use of a dynamometer in pulling a down guy to the proper tension.

Mounting the Guy-wire Guard. Guys should not be installed where the guys will interfere with traffic. In case this cannot be done, such

FIG. 12-40. Lineman attaching a wooden guy guard. A groove in the underside of the guard fits over the guy wire. The guy guard is laced to the guy wire by means of two turns of No. 8 soft-drawn steel wire wrapped around guy and guard. (*Courtesy Wisconsin Electric Power Co.*)

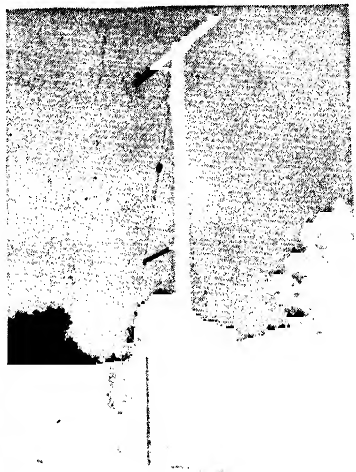


FIG. 12-41. Vertical or "sidewalk" guy completely installed with strain insulator and guy guard. This type of guy is used when the anchor must be set within 5 ft of the pole. The horizontal strut shown consists of a 2-in. galvanized-iron pipe and should have a length equal to the distance between the anchor and the pole. This type of guy is often called a sidewalk guy because the pole can be set on one side of a sidewalk and the anchor on the other. (*Courtesy Wisconsin Electric Power Co.*)

guys should be equipped with a guard. Figure 12-40 shows a lineman installing a guard. The guard should be light in color so as to be visible at night. Sometimes a wooden box placed around the wire is used for a guard. The guard should extend from a point near the ground to about 6 ft above the ground. A guard installed on a vertical guy is shown in Fig. 12-41.

SECTION 13

Mounting Crossarms, Pins, and Insulators

RAISING AND LOWERING TOOLS AND EQUIPMENT

Use of Hand Line. All materials and tools used by the lineman on the pole, other than belt tools, should be raised and lowered by hand lines or block and tackle. A hand line is a small-size rope running through a single block or pulley or simply over the crossarm. The

FIG 13-1 Groundman pulling up tools by means of hand line and tool basket In like manner pole hardware is also pulled up. Groundman should stand well to one side so that he will not be hurt if any tools or hardware should fall to ground (*Courtesy American Gas and Electric Service Corp*)

pulley should be fastened to the pole above the lineman so that the material or tools can be elevated right up to the lineman. When the hand line is not in use, the two ends of the rope should be tied together so that it cannot become unthreaded. Sometimes an endless rope is used.

The pulling up, as well as the lowering of any material or tools, should always be done by the groundman, Fig. 13-1, who is the lineman's assistant stationed on the ground. Figures 13-9 and 14-22 illustrate the use of the hand line in pulling up a crossarm and line conductor. The groundman should be well to one side so that if any material should drop it will not strike him. The lineman should never attempt to pull up any materials or tools himself, as his vision is apt to be obstructed. Furthermore, he is not in position to warn other people that materials are being raised.

In this connection it should also be mentioned that all material lowered should be lowered by means of the hand line. Never should anything be dropped or thrown down. Such practice is apt to become dangerous and a hazard to life.

Use of Block and Tackle. When heavy objects have to be raised or lowered, the block and tackle should be used. A block consists of several pulleys. It, therefore, requires a smaller force to raise the object. Figures 15-6 and 15-7 show the manner in which a block and tackle may be used in raising a transformer. The power may be applied by means of a truck or by hand. Figure 12-37 shows the use of the block and tackle in tightening up on a head guy. It should be noted that the tackle is being drawn up by someone on the ground.

The size of blocks and ropes should be chosen in accordance with the weight and size of the equipment to be raised. The blocks and rope should not only have sufficient strength to lift the objects but also should have a good margin of safety.

PLACING PINS

Spacing. The spacing of the pins is generally suited to the voltage of the circuit. In addition the spacing should provide sufficient working space for the lineman. For general distribution work the spacing is 14½ in. between centers. Wider spacings are more common on four-pin than on six-pin crossarms. The two pins next to the pole are usually spaced 30 in. apart. This should allow plenty of space for the lineman to climb through to work on the upper arms. The end pins are generally spaced 4 in. from the end of the arm.

Placing the Pins. Wooden pins are merely driven into the hole, and then a sixpenny nail is driven through the crossarm from the side to hold the pin in place. It is well not to drive the nail entirely flush with the wood. Enough of the head should project so that the lineman can catch hold of it with the pliers in case it is necessary to replace the pin. In general, all the holes are filled with pins. This serves to preserve the arm.

Metal pins which clamp the crossarm have come into extensive use. These are mounted by clamping them on the arm at the desired spacings

(Fig. 13-2). Since these pins do not require pin holes, their use avoids weakening the crossarm.

End racks or spreader brackets have also come into quite general use

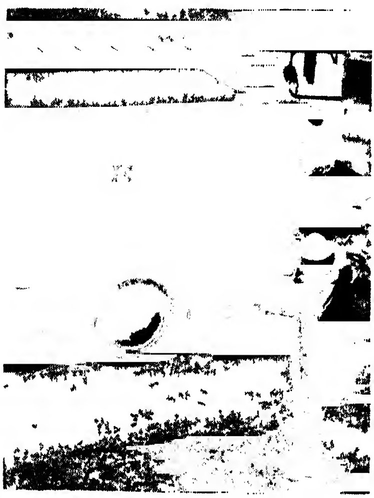


FIG 13-2 Lineman fitting up a 10-ft crossarm with four line steel clamp pins Note use of rule to get correct pin spacing Also note material and tool compartments in the side of truck (*Courtesy Wisconsin Electric Power Co*)

FIG 13-3 Lineman helper fitting up the end racks on a 6-ft secondary crossarm with spool insulators. Note that the last insulator installed is the top one, since the top of the crossarm is uppermost in the figure Thus the upper end of the bolt is the threaded end This arrangement is necessary to make it possible to replace insulators in case of breakage after the crossarm is installed. If the head of the bolt were upward, it would be impossible to get the bolt out far enough to replace the top insulator because the primary crossarm just above it obstructs it (*Courtesy Wisconsin Electric Power Co*)

for secondary crossarms. Figure 13-3 shows a lineman fitting up the end racks on a 6-ft secondary crossarm with spool insulators.

MOUNTING CROSSARMS

Kind and Number of Arms to Use. *Single Arm.* Single arms are used on straight lines where no excessive strain needs to be provided for, as in Fig. 13-4. As already mentioned, every other crossarm faces in the same direction.

Double Arms. Double arms should be used at line terminals, at corners, at angles, or at other points where there is an excessive strain (Fig. 13-5). Where lines cross telephone circuits or railroad crossings,

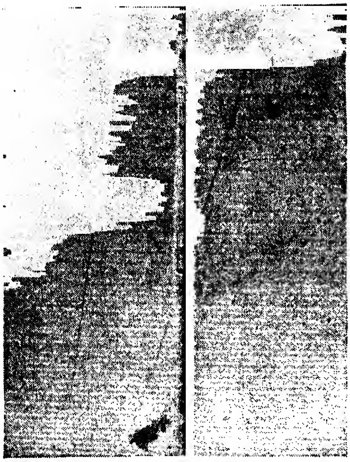


FIG. 13-4. View showing a straight run in a pole line and illustrating single-crossarm construction. Alternate arms should face in same direction. (*Courtesy Iowa-Illinois Gas and Electric Co.*)

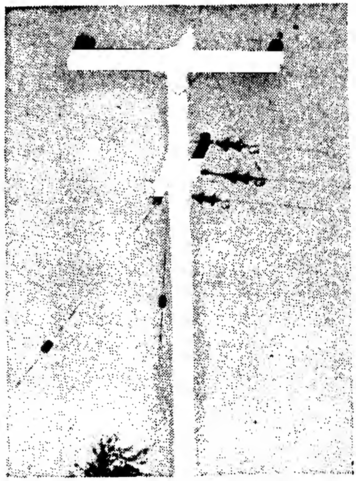


FIG. 13-5. View illustrating a three-phase buck-arm assembly. Since the line turns a corner, lines are dead-ended on double-arm construction. Pole is guyed in both directions to balance pull of dead-ended lines. Down guys make angle of about 45 deg and are equipped with strain insulators and guy guards. (*Courtesy American Gas and Electric Service Corp.*)

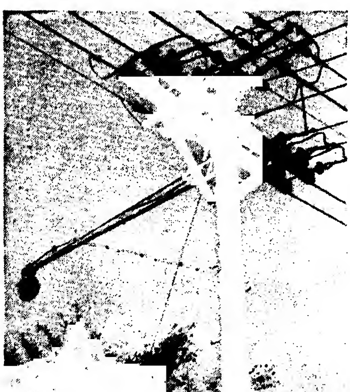


FIG. 13-6. Buck arms placed at right angles to the line arms are used in connecting a branch line to the line pole. (*Courtesy Iowa-Illinois Gas and Electric Co.*)

FIG. 13-7. Illustrating use of side arm where buildings or trees interfere. (*Courtesy Line Material Co.*)

double arms should also be used, as more than ordinary safety is required at such points. When two or more transformers are mounted on the same pole, double arms, as a rule, are used for their support.

FIG. 13-8. H-frame alley crossarm construction places poles on sides of alley and line conductors above alley. Use of H frame makes for very rigid construction capable of supporting heavy leads, capacitors, and transformer banks. (*Courtesy Iowa-Illinois Gas and Electric Co.*)

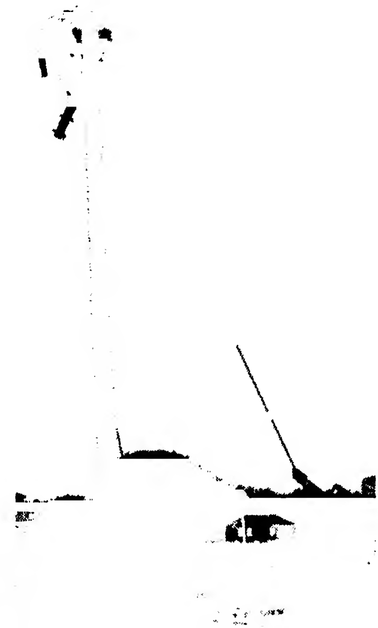


FIG. 13-9. Groundman hoisting crossarm to lineman on pole. Note that groundman stands to one side so that he is out of danger in case any materials or tools should drop. The lineman has just taken hold of the crossarm and is about to remove the handline hitch from its upper end. The groundman is holding the hand line taut to take up the weight of the crossarm. (*Courtesy Wisconsin Electric Power Co.*)

Buck or Reverse Arms. Buck arms are used at corners and at points where branch circuits are taken off at right angles to the main line (Fig. 13-6).

Side Arms. Side arms are used in alleys or other locations where it is necessary to clear buildings, etc. (Figs. 13-7 and 13-8).

Crossarm Chart. In Fig. 12-14 was given a combined guy and framing chart by means of which it is possible to determine at a glance the number of guys required for angle poles. In addition, the chart indicates where to use ordinary single-arm construction, double-arm construction, double-arm construction with strain insulators, etc. It should be remembered that the chart is intended to be used only with one three-wire circuit ranging from No. 7 to No. 0000 in wire size. To use the chart, the two things that must be known are the size of the line conductors and the angle in the line. One of these is given on one edge of the chart and the other on the other edge. The intersection of the lines for any given size of wire and angle falls in one of four areas which indicate the type of framing required. It also falls in one of four layers or

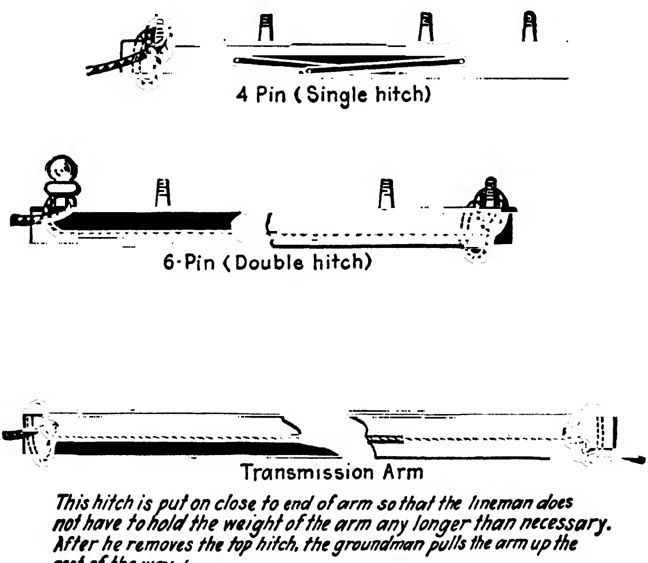


FIG. 13-10. Methods of tying hand line to crossarm for purpose of raising.

steps which indicate the number of guys required. Thus, for example, assume a circuit of three No. 2 wires on a 30-deg angle pole. The intersection of the two lines from 30 deg and No. 2 wire falls into the area indicating double arms using standard pin insulators. This intersection also falls in the first layer or step indicating that only one guy is required. If the angle should be 90 deg (a corner), the intersection would fall in the area indicating double buck arms with strain insulators, and in the second layer indicating two guys, one for each direction.

Number of Pins Required. The general practice on low-voltage lines is to use four-pin crossarms in suburban or rural districts where one single-phase or one three-phase line is all that will be required. The six-pin crossarm is standard for ordinary city distribution, except in the downtown areas where eight-pin arms are often required on account of the large number of circuits.

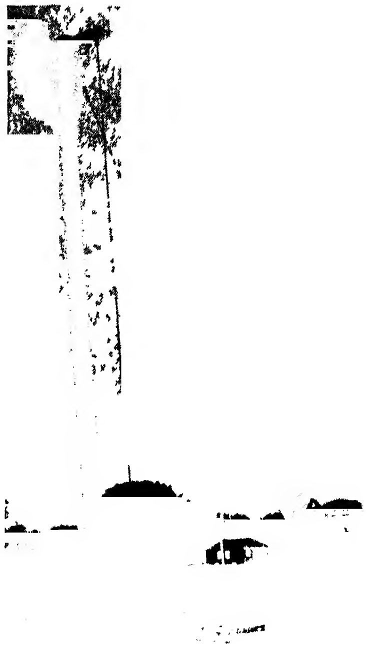


FIG. 13-11 Lineman placing the crossarm on the through bolt. Notice the "assist" given to the lineman by the helper. The hand line is still attached to the trailing end of the crossarm, and the helper is keeping it taut to take up some of the weight. The through bolt was put into the pole previously with the threaded end toward the lineman. The bolt is $\frac{5}{8}$ in. in diameter, and the hole in the pole is $\frac{11}{16}$ in. in diameter. If the bolt fits loosely, the lineman usually bends it slightly near its head end by hitting it with a hammer when it is part way in. This jams the bolt in the hole so that it will not push out when the lineman pushes the crossarm on. On secondary transmission-line construction where through-bolt strength is very important, the through bolt is installed so that the head end is toward the lineman. This places the weaker threaded end in the pole opposite the crossarm where the strain is least. *(Courtesy Wisconsin Electric Power Co.)*

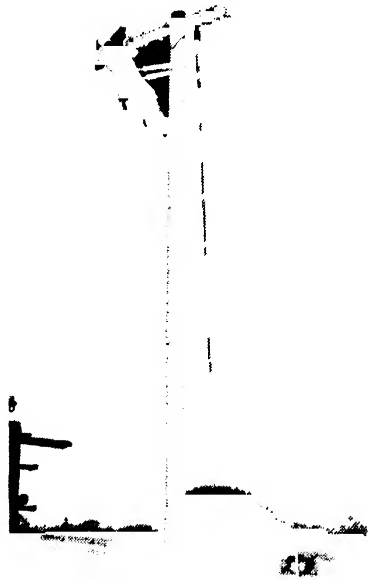


FIG. 13-12. Lineman fastening crossarm braces to the pole with a $\frac{1}{2}$- by 5-in. lag bolt. The lag bolt has a "drive" thread in that the edge of the thread toward the end of the bolt is beveled. The bolt is not driven in full length. It is left about $\frac{1}{4}$-in. off tight position. It is finally seated by three or four turns with a lag wrench.

Note the working position of the lineman. He has set himself so that he can get a good two-handed free swing at the lag. His safety strap is just long enough to place him the correct distance away. He does not have to "reach"; neither does he have to "choke up." *(Courtesy Wisconsin Electric Power Co.)*

Mounting. Crossarms may be mounted before or after the pole is erected. The practice varies. In case the crossarm is mounted after the pole is in place, the lineman climbs the pole, carrying with him his small tools (pliers, knife, and connectors), hand line, hammer, and lag wrench, and fastens the pulley of the hand line The crossarm is then

FIG. 13-13. Attaching first crossarm of a double-arm assembly. Second lineman on pole is assembling spreaders, while groundman is preparing to hoist second crossarm with hand line. *(Courtesy American Gas and Electric Service Corp.)*

FIG 13-14 Bolting the two crossarms of a double-arm assembly Lineman is driving through bolt with hammer *(Courtesy American Gas and Electric Service Corp)*

pulled up by the groundman as illustrated in Fig. 13-9. Various methods of tying the hand line to the crossarm are shown in Fig. 13-10.

The crossarm is attached to the pole (Fig. 13-11) by means of a 5/8-in. galvanized machine bolt driven from the back of the pole. A 2 1/4-in. square washer is placed under the head and the nut of the bolt, and then the bolt is drawn up.

After the through bolt is in place, the crossarm braces are attached. It is necessary first to sight the crossarm, that is, make sure it is horizontal. In case more conductors are to be carried on one side than on the other, that side can be higher, as it will settle later. The braces are usually 1 1/4 by 1/4 by 28 in. in size. Sometimes the braces are bolted to the crossarm before the arm is pulled up. The end of the brace attached to the crossarm is held in place by means of a ⅜- by 4-in. galvanized carriage bolt, and the ends at the pole are fastened by means of a ½- by 5-in. lag screw. The braces are attached on the back of the crossarm

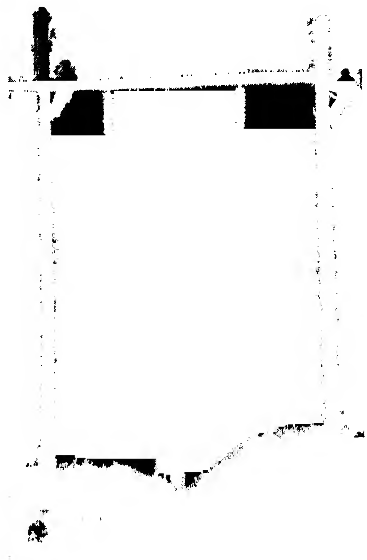


FIG. 13-15. Hoisting crossarm of an H frame. The two ends of the crossarm are hoisted simultaneously. A truck in the center background pulls on both hoisting lines at the same time. Man in foreground holds hand line in clear. Man on left directs the operation. Note sheaves at top and bottom of poles through which hoisting lines run. The string insulators are raised with crossarm. (*Courtesy Virginia Electric and Power Co.*)

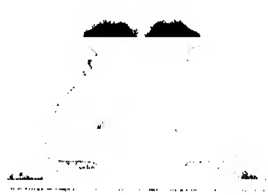


FIG. 13-16. Typical form of top-groove insulator. The conductor rests in the groove, and the tie wire is required only to keep the conductor in place. (*Courtesy Locke Dept., General Electric Co.*)

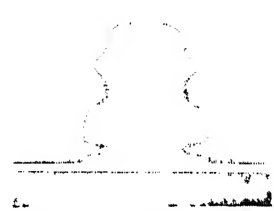


FIG. 13-17. Typical form side-groove insulator. This type of insulator is in general use with small-size line conductors. (*Courtesy Locke Dept., General Electric Co.*)

(see Fig. 13-12). When the standard 28-in. braces are used, the hole in the crossarm should be located 19 in. from the middle of the crossarm.

When double arms are placed on a pole, the arms are bolted together on each end and held a given distance apart by means of spreaders which fill in the space between the arms and make a solid structure. The second arm shall be a completely equipped arm of the same size and pin spacing as the first arm. However, no gain is cut for the second arm. Figures 13-13 and 13-14 show two steps in the installation of a double-arm assembly, and Fig. 13-15 shows the procedure employed in raising a crossarm on an H frame.

INSULATORS

Selection of Pin Insulator. Pin insulators are constructed in the top- and side-groove type (Figs. 13-16 and 13-17). Side-groove insulators are suitable for small-sized wires, and top-groove insulators are used for larger sizes of wires. Top-groove insulators are often termed "saddle-back" insulators.

Mounting the Insulators. Insulators are generally mounted in place after the crossarms are bolted to the pole. In the case of small-sized insulators, they may be placed on the pins while the crossarm is still on the ground. The larger pin insulators, however, are screwed on the pin after the crossarm is in place on the pole. This is necessary because of the weight it would give to the crossarm when equipped. Suspension or strain insulators are usually placed after the crossarm is in place for the same reason.

SECTION 14

Joining, Stringing, and Sagging Conductors

WIRING THE LINE

The wiring of the line consists of several steps, namely,

1. Reeling out the conductors
2. Splicing the conductors
3. Stringing the wire
4. Pulling up to proper tension
5. Tying in

These steps will be taken up separately in the following paragraphs.

Reeling Out the Conductors. The reeling out of the conductors may be accomplished by one of two distinct methods. In the first method, the reels on which the conductors are wound are raised from the ground so that they are free to rotate. The conductors are then pulled out, thereby rotating the reel and unwinding the conductors. This method is illustrated in Fig. 14-1. In the second method, the reels of wire are mounted on a truck or wagon so that they are free to revolve. The free ends of the conductors are fastened to a pole or tower or some other object. The truck or wagon is then slowly driven along the line, and the conductors are unwound as the reels are moved forward. Figure 14-2 illustrates this method of reeling out line conductors.

It will be noted that in the first method the conductors are pulled or dragged over the ground. This is sometimes objectionable because the wires are apt to become scratched as they are pulled over the ground, especially if the country is rough and covered with surface stone. Aluminum is more easily injured in this manner than copper.

When reels are stationary, they may be supported in various ways. Figure 14-1 shows them mounted on special trailer carriages. Another form of reel trailer is shown in Fig. 14-3. This trailer is built to carry three reels of wire. Each reel is supported on a shaft, which permits the reel to turn while wire is being strung. Each reel shaft is equipped with an external brake band which is adjusted to prevent overrunning when wire is being unreeled. This trailer could also be used to string conductors as the trailer is pulled along the right of way.

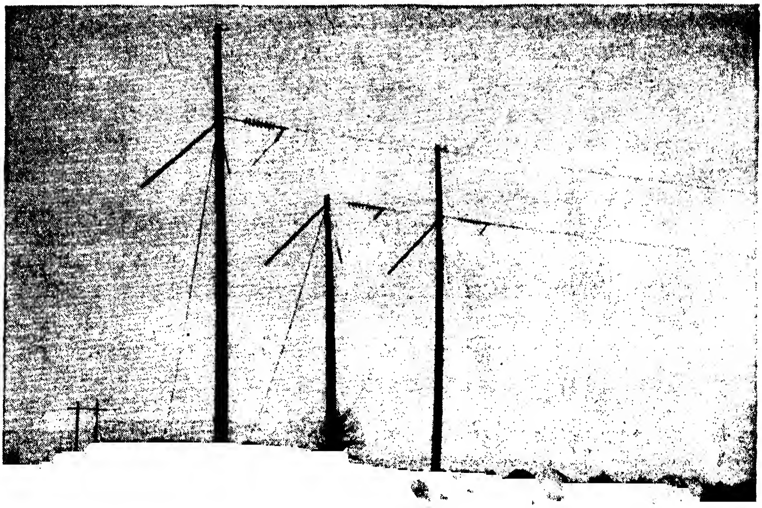


FIG. 14-1. Reeling out line conductors from stationary reels. Reels are supported on special reel carriages. Note that three reels carry conductors for three-phase 138,000-volt line and two carry the two smaller overhead ground wires. Illustration also shows the three-pole corner construction used on H-frame lines. (*Courtesy Consumers Power Co.*)

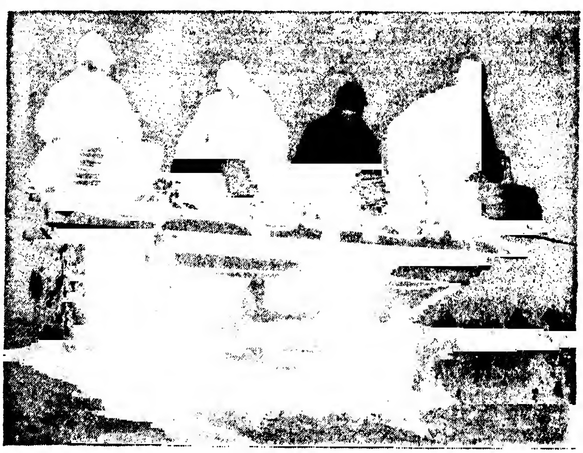


FIG. 14-2. Reeling out conductors from moving reels. The reels rotate and unwind the conductors as the truck moves forward. (*Courtesy Aluminum Company of America.*)

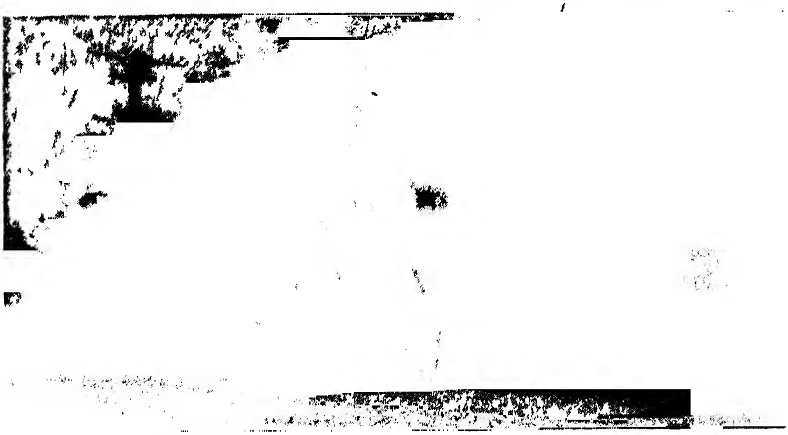


FIG 14-3. Stringing trailer in stationary position as wires are being unreeled. After the stringing trailer has been properly blocked and the reel brakes correctly set, little further attention is needed. Note brake drums on ends of reel shafts (*Courtesy Wisconsin Electric Power Co.*)

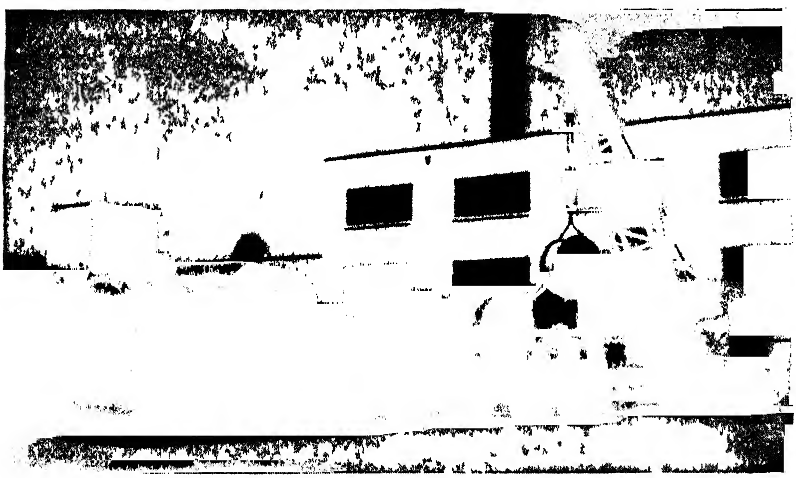


FIG 14-4 Reels of cable being loaded onto a stringing trailer. A truck-mounted crane using grappling hooks lifts the reels onto the trailer. (*Courtesy Wisconsin Electric Power Co.*)

The manner of loading the heavy cable reels onto the stringing trailer is shown in Fig. 14-4. Two grappling hooks are used to pick up a reel. The teeth of the hooks embed themselves in the wooden sides of the reel. They can be attached or removed from a reel very quickly. Figure 14-5 shows the stringing trailer fully loaded and ready to be taken to the line location.

Small reels, up to 200 lb in weight, can be set stationary or can be carried by two or more men. A reel for this purpose is illustrated in Fig. 14-6. Such reels are generally used where only a short line is built, as in extensions to distribution systems.

If the ground is rough or obstructions are present or streets must be crossed, one conductor is usually reeled out at a time, and laid up in position on the crossarm. In this way the streets can be kept clear.

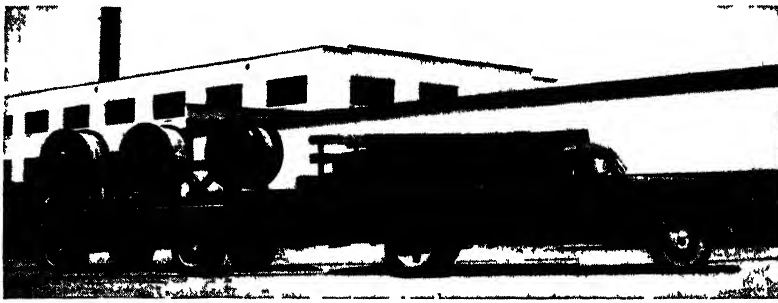


FIG 14-5. The stringing trailer fully loaded and on its way to the job Note the brake drums and adjustments on each reel. (*Courtesy Wisconsin Electric Power Co*)

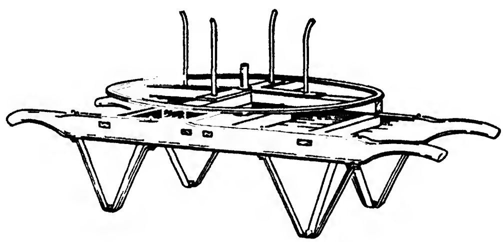


FIG. 14-6. Barrow-type paying-out reel Wire can be paid out from this reel by having reel stationary or by carrying reel forward. Note handles for carrying. (*Courtesy Leach Co.*)

When open country is being built over, however, all the conductors are reeled out at the same time.

Joining Line Conductors. Line joints are divided into three classes: (1) splices, (2) sleeve joints, and (3) compression joints. Small-sized copper wires are often spliced, but the larger sizes of hard-drawn copper wire as well as aluminum cable are usually joined by means of "splicing sleeves," or compression joints.

Making a Splice Joint. The two ends of the wires to be spliced should be scraped perfectly clean and free from insulation in case of insulated wires. The wires should be cleaned until they are bright. All rough or high spots should be removed, or a "high" joint is apt to result. After the conductors are cleaned, they should be placed together until approximately 8 to 12 in. of the ends overlap each other for the smaller sizes and 12 to 18 in. for sizes No. 4 and larger (see Fig. 14-7). Splicing clamps (Fig. 14-8), better known as "connectors," are placed on the two wires about 4 in. from the end of the wire. The connectors should grip both of the wires firmly. The wires should not be allowed to slip or turn in the connectors, or a "burned" wire will result and one of the conductors will eventually break at that point. If another connector is available, it is best to use it also by placing it about the same distance from the other end of the conductor and clamping it. The twisting should be done from both ends. This wraps each wire about the other wire. The usual number of turns to be made is four, as shown

Twist four times and solder.

Wrap with four layers of friction tape and paint with compound if covered wires are used.

Size of wire	Length of covering to be removed from each wire, in.
No. 8–No. 6	8
No. 4–No. 2	12
No. 10	18

FIG. 14-7. Standard wire splice for medium-, hard-, and soft-drawn solid copper wire.

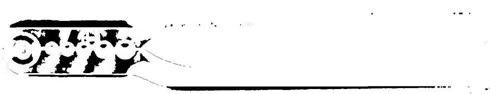


FIG. 14-8. Splicing clamp for bare wires. (*Courtesy Mathias Klein & Sons.*)

in Fig. 14-7. If more are made, the wires may *burn*. If not enough are made, the splice may give and the wires crawl apart. After the wires are given the proper number of turns, shift both connectors onto the twisted portion of the wires. This will require a shift equal to the width of the connector. Then with a pair of pliers finish the splice by serving up the ends. This is done by wrapping the loose ends of the wires about the conductors. Three or four turns are the usual number necessary (Fig. 14-7). These turns are known as "buttons." After the buttons are on, the ends should be cut close to the splice.

Splices made on soft-drawn copper conductors used in distribution systems should be well soldered. Soldering does not weaken a soft-drawn conductor. Splices made on medium-hard-drawn conductors used in transmission work should be soldered carefully because of the danger of annealing the wire. Annealing weakens hard-drawn wire to the strength of the soft-drawn wire. When the solder used is hot enough to discolor a match stick without burning, it is just right for soldering and will not burn down a medium-hard-drawn wire. When soldering a soft-drawn wire, flux is first applied; then the solder pot is held under the joint, the ladle is dipped into the solder, and the solder is poured on the joint until it is filled with solder. The solder burrs should be wiped off, and in case of insulated wires, the entire joint should be covered with friction tape to the thickness of the insulation of the line wires. Such a completed splice is known as the "Western Union" splice because it was first used by the Western Union Telegraph Company.

Making a Sleeve Joint. The best way to make a joint in medium-size line conductors is by means of the so-called "splicing sleeve." It is a special connection that ensures good electrical and mechanical joints.

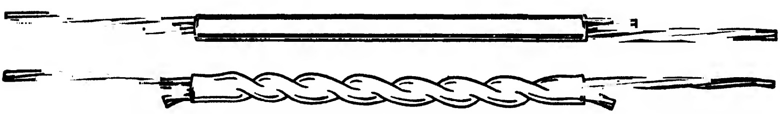


FIG. 14-9. Seamless-copper single-tube oval-type splicing sleeve. Upper view shows ends of conductors in place before twisting. Lower view shows finished splice after twisting. (*Courtesy Copper Wire Engineering Association.*)

The sleeve itself is a piece of single or double tubing (Fig. 14-9). The tubing may be either split or seamless. To make a sleeve joint, the ends of the wires should be scraped clean and bright. They are then inserted, one in each tube if double tube is used, from opposite ends so as to lie side by side. The ends of the wires should project several inches beyond the ends of the sleeve. The projecting wires are sometimes given a sharp bend to keep them from slipping out of the sleeve. The ends of the sleeve are then grasped by two sleeve clamps or twisters, illustrated in Figs. 14-10 to 14-12. The next operation consists in

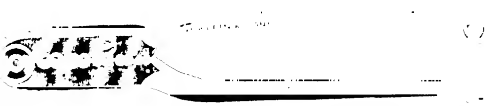


FIG. 14-10. Sleeve twister for small-size line conductors. (*Courtesy Mathias Klein & Sons.*)

giving the connectors three and one-half or four turns. The twisting should be done from both ends. Figure 14-13 shows these operations in proper order and indicates the simple manner in which this type of joint is made. In splicing stranded conductors, the clamps should be turned in the directions opposite to the twist of the strands.

Sleeves should always be made of the same kind of material as the conductor they are to be used with. If the line is a copper line, either hard or soft drawn, the sleeves should always be made of soft-drawn copper, and if the conductors are aluminum, the sleeve should be made of aluminum. In making sleeve joints in iron wires, the sleeve should be of tinned iron.

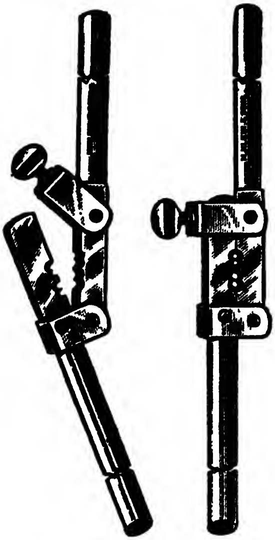


FIG. 14-11. Sleeve clamps or twisters used in making sleeve joints in large-size line conductors. (*Courtesy Mathias Klein & Sons.*)

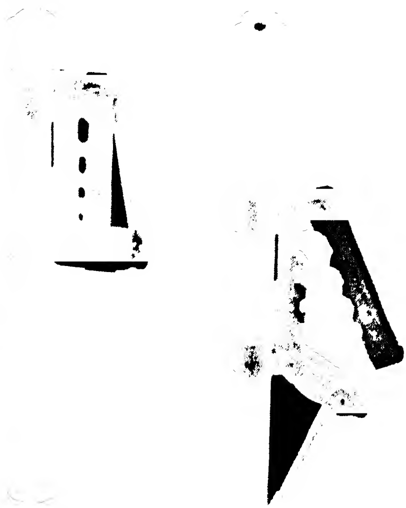
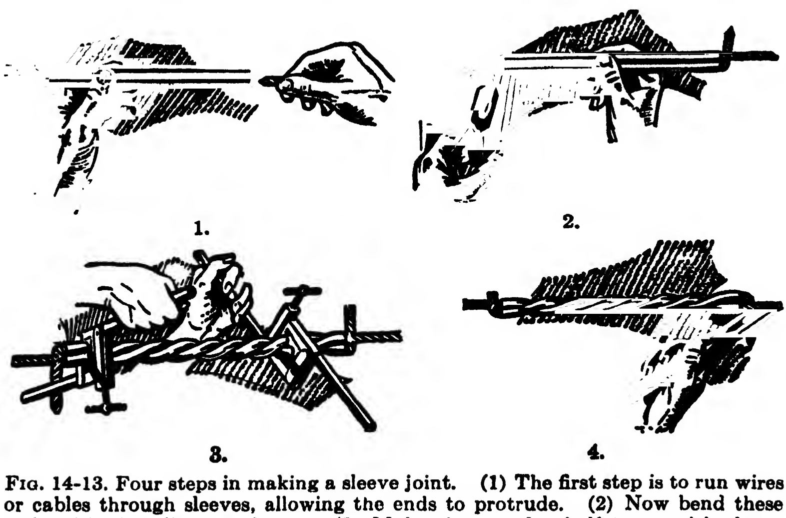


FIG. 14-12. Extra-strong sleeve twister designed to accommodate No. 3/0 solid copper, No. 2/0 stranded copper, or No. 1/0 ACSR conductors. (*Courtesy Crescent Tool Co.*)



1. 2. 3. 4.

FIG. 14-13. Four steps in making a sleeve joint. (1) The first step is to run wires or cables through sleeves, allowing the ends to protrude. (2) Now bend these ends with the pliers as shown. (3) Make three and a half turns with sleeve twisters—one on either end. Twist lightly. (4) Cut off ends, and the joint is completed. (*Courtesy National Telephone Supply Co.*)

Sleeve Joint for Aluminum Cable, Steel Reinforced. The following method of making a sleeve joint for ACSR cable is generally used for sizes 4/0 to 1/0 cable. Two sleeves are employed, and each sleeve is given four and a half complete twists distributed as shown in Fig. 14-14. This requires three different settings of the twisting wrenches as follows:

One wrench is placed at W_1 and a second wrench at W_2 on sleeve A. Looking from W_1 toward W_2, W_2 must be rotated in a counterclockwise

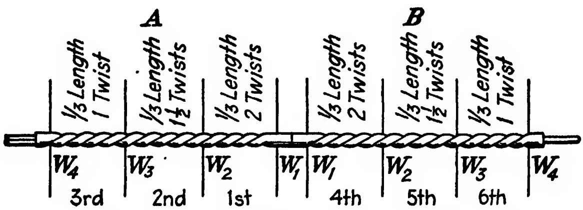


FIG. 14-14. Method of making double sleeve joint in steel-reinforced aluminum cable, sizes 4/0 to 1/0.

direction; that is, the left handle of wrench W_2 is moved from the level position downward. Give W_2 two complete turns. Remove W_2 and place at W_3, and give it one and a half turns in the same direction as at W_2. Remove W_3 and place at W_4, and give it one complete turn in the same direction as at W_2 and W_3. Repeat this procedure for sleeve B. At the ends of the joint the wrench should not be closer than ¼ in. to the end of the sleeve.

For aluminum conductor steel-reinforced cables sizes No. 1 to No. 6, each sleeve should be given four complete uniform twists as shown in

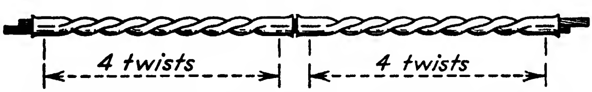
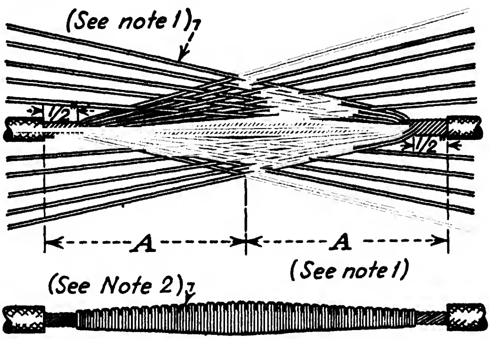


FIG. 14-15. Completed double sleeve joint for ACSR cable sizes No. 1 to No. 6. Each sleeve is given four complete uniform twists.

Fig. 14-15. This requires one setting of the twisting wrenches at the ends of each sleeve. The wrenches should not be closer than ¼ in. to the end of the sleeve.

For twisting joints consisting of a single sleeve, as used on all aluminum cables, the middle third length should be given as many complete twists as it will stand (two to three and one-half, depending upon the size of cable and length of sleeve). Then each end third length is given one complete twist.

Sunburst or Cable Joint. Very large line conductors cannot be satisfactorily joined by means of the sleeve joint described above. Since practically all line conductors of size 4/0 and larger are stranded conductors, the joint now to be described is a cable joint for use on large conductors. This joint is made by opening the ends of the cables to be joined and fitting the strands of one cable between those of the other, as shown in Fig. 14-16. This step in the process has the appearance of a sun with its rays. It is on this account that this joint is often called "sunburst." Another name often given to it is "dovetail," because the



NOTES

1. Cut strands at center of cable as per table and mesh remaining strands.
2. Serve each wire three times around cable, finish warp at upper side of splice. Provide ⅜ in. minimum distance from end of one wrap to beginning of next and solder entire splice.
3. Wrap with four layers of friction tape and paint with compound if covered wire is used.

Size of cable	No. of strands	Length of covering to be removed from each end, in.	A, in.
No. 0000	7 or 19	17	5
250,000 cir mils	7 or 19	18	5½
350,000 cir mils	19	21	6½
350,000 cir mils	37	22	7
500,000 cir mils	37	26	8

Number of strands	
In cable	To be served
7	7
19	19
37	18

Fig. 14-16. Stranded cable splice for conductors size 4/0 and larger. This joint is also called "sunburst" or "dovetail."

strands from one cable *dovetail* into the strands of the other. Then the strands are bent so that they all lie closely along the conductor. Each strand is then served six times around the conductor and the strands which lie against it, after which it is cut off close to the conductor. Figure 14-17 shows a joint completely served.

In case of copper cables the joints are generally soldered. With aluminum cables it is not practical to do this. In case the cables are covered with insulation, the joint should be taped to the same thickness as the insulation of the line wire.

Making a Compression Joint. A compression joint also makes use of a sleeve (see Fig. 14-18). Instead of twisting the sleeve, however, the sleeve is compressed with great force onto the conductor. The use of a die in compression makes the sleeve grip the conductor firmly.

The compression joint for ACSR (sizes No. 4 to 336,400 cir mils) illustrated in Fig. 14-19 consists of a steel compression joint (1) on the steel core, an aluminum compression joint (2) on the complete cable, and a pair of aluminum plugs (3) for sealing the holes in the aluminum joint through which a paste filler is injected.

FIG. 14-17. Completely served stranded aluminum cable joint. (*Courtesy Aluminum Company of America.*)

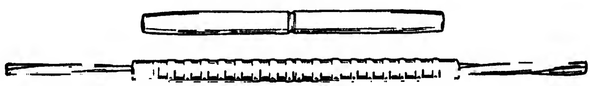


FIG. 14-18. Compression-type splicing sleeve. Upper view shows sleeve before compression, and lower view shows sleeve fully compressed. Markings on sleeve are produced by die used in compression. (*Courtesy Copperweld Steel Co.*)

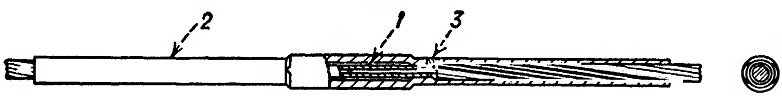


FIG. 14-19. Tubular compression joint for ACSR. (*Courtesy Aluminum Company of America.*)

Method of Applying Tubular Compression Joint. *Caution:* Before applying make sure the bores are thoroughly clean.

1 Slip the aluminum compression sleeve over one cable end, and back it out of the way along the cable.

2. Using a hack saw, cut off the aluminum strands from each cable end, exposing the steel core for a distance of a little more than half the length of the steel compression sleeve. Use care not to nick the steel core with the saw. Before cutting, serve the cable with wire just back of the cut.

3. Insert the steel core ends into the steel compression sleeve, making sure that the ends are jammed against the stop in the middle of the sleeve.

4. Compress the steel sleeve over its entire length, making the first compression at the center and working out toward the ends, allowing dies always to overlap their previous position.

5. Remove serving from the cable and measure from the center of the steel joint the distance of one-half the length of the aluminum sleeve

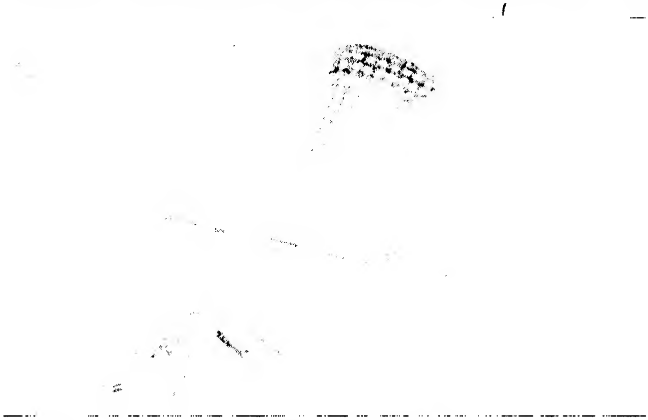


Fig. 14-20. Making a compression joint on a 336,400-cir mil aluminum cable. The compressor is operated manually by lineman in center. Note large sleeve into which conductor ends are inserted. By means of dies the press forces the sleeve to grip the conductor firmly (*Courtesy Virginia Electric and Power Co.*)

Fig. 14-21. Splicing transmission-line cables with a gasoline-driven compressor. The small gasoline engine operates an oil pump which provides the pressure for the hydraulic press. (*Courtesy Wisconsin Electric Power Co.*)

and mark the cable with tape. This will center the aluminum sleeve when slipped over the steel joint.

6*a*. Slip the aluminum sleeve up over the steel joint to the tape mark. This will center the aluminum sleeve over the steel joint.

b. Using the calking gun equipped with the tapered nozzle provided with the compressor, inject filler paste through both holes provided in the aluminum joint until the paste is visible at the ends of the aluminum joint. The preferred filler paste is composed of approximately 70 per cent zinc chromate and 30 per cent raw linseed oil by weight.

c. Insert the plugs in the filler holes and hammer them firmly in place. They will be securely locked in compressing the aluminum joint.

7. Finally, compress the aluminum sleeve. Make the first two compressions with the inner edges of the dies matching the positions stenciled on the aluminum sleeve. Make additional compressions advancing to the ends, allowing the dies always to overlap the previous position.

The operation of applying the compressor to the aluminum sleeve is shown in Fig. 14-20, where the compressor is operated manually. The person in the center is operating the pump handle of the hydraulic press. In Fig. 14-21 the power is supplied by a small gasoline engine which operates an oil pump that provides the pressure for the press.

STRINGING THE WIRE

Hoisting Up to the Crossarm. As the conductors are reeled out they are hoisted up to the crossarm. Each time a pole or tower is reached,

FIG 14-22 Hoisting up line conductor by means of hand line on rural line. (*Courtesy Reynolds Metals Co*)

the truck or tractor pulling the wires pulls a little ahead and halts, to permit each wire or cable to be hoisted up This is generally done by means of a hand line (Figs. 14-22). Hoisting to the crossarm is called "laying up."

Use of Snatch Block. In case the line uses wooden crossarms and pin insulators, the conductors are simply laid on the crossarm. But if the crossarms are steel, it is not well to rest the conductors on the crossarm, because the conductors would probably be damaged when they are drawn over the crossarms during the unreeling and tightening process.

Instead of laying them on the crossarm, they are hung in so-called "snatch blocks," shown in Fig. 14-23.

A snatch block is a single-sheave block so arranged that it opens on one side, thereby permitting the conductors to be inserted or removed

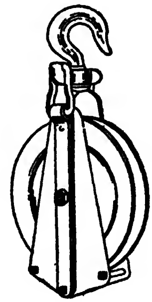


FIG. 14-23. Snatch block for cable stringing Note link by which pulley can be opened for insertion of wire. (*Courtesy Graybar Electric Co*)

without threading it through. Such a snatch block is also necessary in case the line is equipped with suspension insulators, for there would then be no good place to rest the conductors. Figure 14-24 shows the lineman placing the pulling lines in the snatch or stringing blocks over which

FIG. 14-24. Lineman placing the pulling lines in the stringing blocks over which the three line wires of a 132,000-volt line will be strung. (*Courtesy Wisconsin Electric Power Co.*)

the three line wires will be strung. Figure 14-25 shows the raising of the insulator string, snatch block, and line conductor at the same time. The snatch block really serves two purposes: (1) it is a support for the line conductor, and (2) the pulley in the block runs so easily that it aids the conductor in taking on a uniform tension throughout its length when the conductor is pulled up. The use of the snatch block also makes it

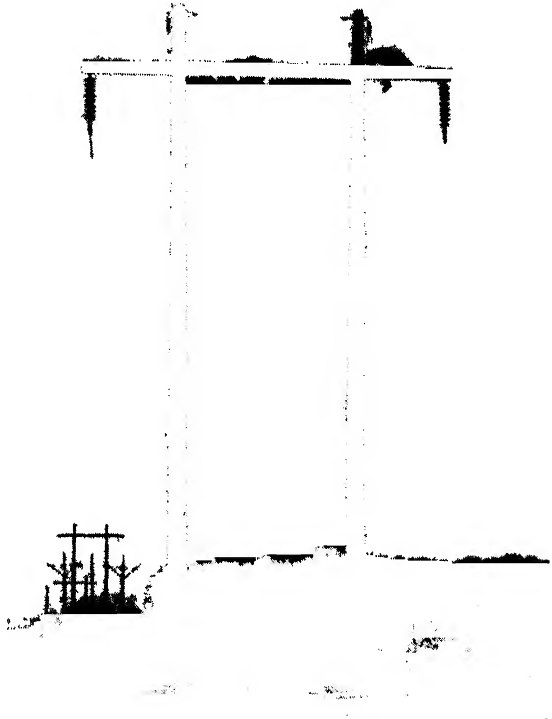


FIG 14-25. Raising insulator string, snatch block, and line conductor at the same time Line is rated 138,000-volt H-frame construction. Tractor for pulling up line conductors is shown in center background. (*Courtesy Consumers Power Co.*)

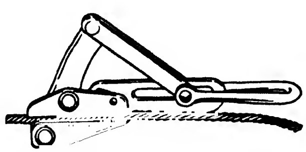


FIG. 14-26. Chicago pulling grip. All grips are so designed that the grip on the wire increases with the increase in pull. (*Courtesy Mathias Klein & Sons.*)

FIG. 14-27. Buffalo pulling grip, used in pulling up of line conductors or guy wires. (*Courtesy Western Electric Co*)

possible to hold the conductor in the most convenient position for attaching to the suspension insulator.

Pulling Up. When the conductors are hoisted in place, they are ready to be pulled up. To carry out this operation a come-along, or pulling grip, is fastened to the end of the line conductor. There are two makes of come-alongs in general use, the Chicago grip, shown in Fig.

14-26, and the Buffalo grip, shown in Fig. 14-27. Both are designed with parallel jaws that will grip the wire very firmly without injuring it. It is evident from an inspection that the greater the pull on the wire, the tighter will the grip bear on the wire. Figure 14-28 shows a Chicago grip in use. The grip is attached either to a block and tackle or to a winch line on a power truck. If man power is used, it may be necessary to *luff* on one or more sets of blocks (Fig. 14-29). To do this a second

FIG. 14-28 Chicago-type pulling grip or come-along in use, at angle pole on rural line Note manner in which wire is held by grip. Also note use of chain jack. (*Courtesy Rural Electrification Administration.*)

FIG. 14-29. Pulling up on neutral conductor in rural line with block and tackle at an angle pole (*Courtesy American Gas and Electric Service Corp.*)

set of blocks is attached to the fall line of the first set of blocks. If this is not sufficient, another set of blocks may be luffed on the fall line of the second set.

The conductors may be pulled from the top of the pole in the case of a short line extension (Fig. 14-30). The pole used to pull from must be properly guyed to withstand the strain. If there is quite a bit of pulling to be done, however, as in new construction, it is better, easier, and faster to pull from the ground (see Figs. 14-31 and 14-32). The blocks and tackle or chain jack can be handled more easily on the ground than on the pole. In case of new lines of any length the pulling up is performed with tractive power, as shown in Figs. 14-25 and 14-33. In this manner all the line conductors can be drawn up at once if desired. After the wires are pulled to the proper tension or sag, the conductors can be *snubbed* to the bottom of the pole to which the block and tackle is attached.

FIG 14-30 Lineman pulling up on line conductor at dead-end corner pole using pulling grip and chain jack Both lines on same crossarm must be pulled up together to keep pull on crossarm balanced (*Courtesy American Gas and Electric Service Corp.*)

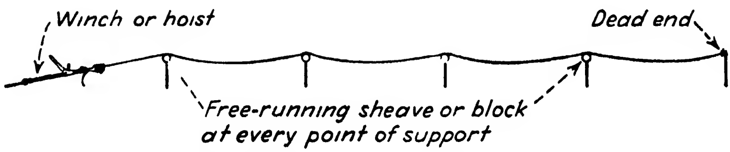


FIG 14-31 Schematic diagram of line being pulled up to proper sag Note use of free-running sheave or snatch block at every point of support

FIG 14-32 Caterpillar-tread tractor being used as motive power for pulling up a three-phase transmission line Three line wires and two ground wires are pulled up at the same time (*Courtesy Wisconsin Electric Power Co*)

FIG. 14-33 Pulling up line conductors with caterpillar tractor. Conductors have been hoisted into snatch blocks Ground wire in top sheave is being pulled up at the same time (*Courtesy American Gas and Electric Service Co*)

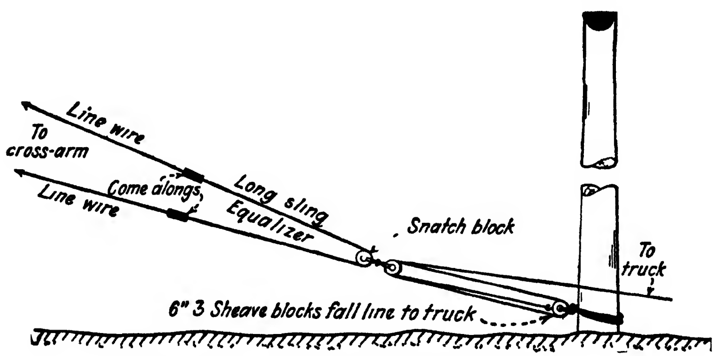


FIG 14-34 Equalizer rig for two conductors.

Care should be taken in pulling up that splices and sleeves do not catch on crossarms or in the sheaves of snatch blocks Any catch of this sort may prevent the conductor from coming up as it should

After the conductors are pulled, they should have ½ to 4 hr or more, depending upon the length of the pull, to allow them to "creep." This creep will make the tension and sag in each span uniform. Immediately after pulling, the tension is much greater near the pulling end than it is at the fixed end, and if time is not allowed for the wire to creep, the sag will not be uniform. The conductors will be too tight near the pulling end and too loose near the fixed end. If they should be tied in in this condition, it would place an unbalanced strain on the poles, crossarms, pins, insulators, tie wires, and conductors, which might lead to ultimate failure.

Use of Equalizer. When possible, an equalizer may be used in pulling up conductors in order to produce the same tension on each conductor. The simplest form of equalizer for two conductors is that shown in Fig. 14-34. It consists of a rope with a come-along on each end to grip the

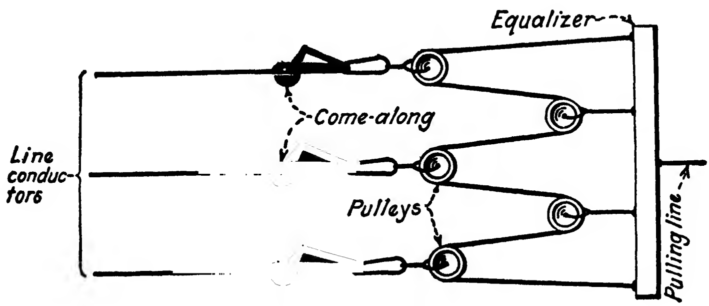


FIG. 14-35. Equalizer rig for three conductors.

two line wires. The rope runs over a snatch block to which the pulling tackle is attached. Since the rope is free to move through the snatch block, the conductors will pull up to the same tension. In using a two-wire equalizer, it is well to pull conductors on opposite sides of the pole and on corresponding pin positions at the same time; otherwise the crossarm may be turned from its normal position when the conductors are tied in.

Figure 14-35 shows an equalizer designed to pull up three conductors at a time. It is apparent that as the rig is pulled up any differences in the lengths of the line wires will be adjusted by the movement of the floating pulleys.

Sighting for Sag. In sighting for sag it is well to select a span near the middle of the length pulled up. The length of wire pulled at one time may vary from a few hundred feet to a half mile or more. In pulling a long length of wire, the conductor away from the pulling end will come up slowly because of the natural friction of the conductor sliding over the arms or through the snatch blocks. Sagging will be facilitated by soaping the conductor grooves of the supports so that the conductors will slide more freely. A span near the middle of the length pulled should therefore be selected in sighting for sag. If the section pulled up is over ½ mile in length or includes a number of curves, it is desirable to sag at more than one point.

A simple and accurate method of measuring the sag is by the use of targets placed on the poles below the crossarm, as shown in Fig. 14-36. The targets may be a light strip of wood like a lath nailed to the pole at a distance below the conductor when resting on the insulator equal to the desired sag. The lineman sights from one lath to the next. The tension on the conductor is then reduced or increased until the lowest

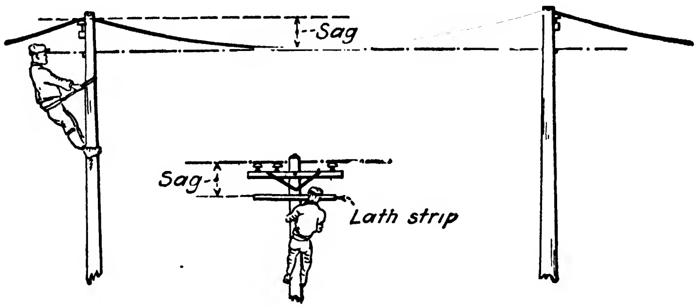


FIG. 14-36. Lineman sighting for sag by means of two lath strips nailed to poles at proper distance below the conductor when resting on the insulator. (*Courtesy Wisconsin Power & Light Co.*)

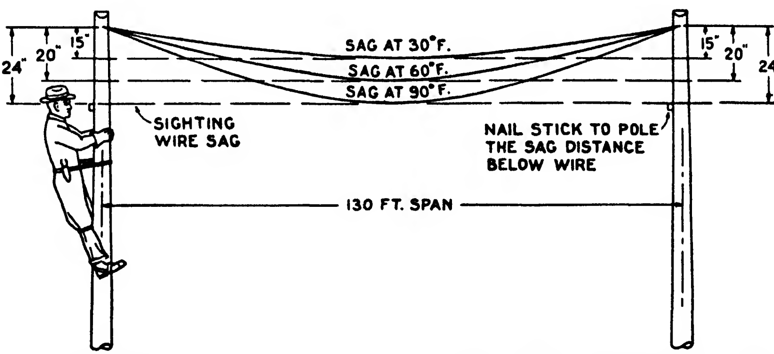


FIG. 14-37. Sketch showing how sag increases with rise in temperature. Also illustrates correct manner of sighting for sag.

part of the conductor in the span coincides with the lineman's line of sight. The desired sag is obtained from Table 14-1 for the particular span length, conductor material and size, temperature prevailing, and loading district.

It will be noted that Table 14-1 gives the sags for 30, 60, and 90°F. Careful attention must be paid to the temperature at the time of sagging in of the conductor as the sag varies considerably with temperature. This is illustrated in Fig. 14-37, where typical values of sag are shown for the three values of temperature. The reason, of course, that the sag

(*Continued on page 14-29*)

TABLE 14-1. SAGS FOR HARD- AND MEDIUM-DRAWN BARE COPPER WIRE FOR DIFFERENT SPAN LENGTHS*
(At 30, 60, and 90°F—wires without load)
(Heavy loading districts)

Size AWG No.	Grade of construction	Temperature, °F	Sags for span length, in.								
			100 ft	125 ft	150 ft	175 ft	200 ft	250 ft	300 ft	400 ft	500 ft
8	C	30	8	11	22						
		60	12	18	27						
		90	16	22	32						
6	A	30	8	11	22						
		60	12	18	27						
		90	16	22	32						
6	B	30	6	10.5	16						
		60	10	15	22						
		90	14	19.5	27						
6	C	30	6	10.5	16	28					
		60	10	15	22	33					
		90	14	19.5	27	39					
4	All	30	6	10.5	16	22	32	64	109		
		60	10	15	21	28	38	71	115		
		90	14	19.5	26.5	34	45	77	120		
2	All	30	6	10.5	13	16	18.5	35	59	129	218
		60	10	15	18	21	24	44	68	137	226
		90	14	19.5	23.5	28	31	51	75	144	234
1	All	30	6	10.5	13	16	18.5	32	51	113	195
		60	10	15	18	21	24	40	59	120	203
		90	14	19.5	23.5	28	31	47	67	130	212
0	All	40	6	10.5	13	16	18.5	31	45	100	170
		60	10	15	18	21	24	38	55	110	180
		90	14	19.5	23.5	28	31	46	63	120	190
00	All	30	6	10.5	13	16	18.5	29	42	92	157
		60	10	15	18	21	24	36	50	102	168
		90	14	19.5	23.5	28	31	44	58	111	179
0000	All	30	6	10.5	13	16	18.5	26	34	73	118
		60	10	15	18	21	24	32	42	84	132
		90	14	19.5	23.5	28	31	40	50	94	142

* Normal sags of overhead copper line conductors. The sags are given for temperatures of 30, 60, and 90°F—wires without load—for heavy, medium, and

TABLE 14-1. SAGS FOR HARD- AND MEDIUM-DRAWN BARE COPPER WIRE FOR DIFFERENT SPAN LENGTHS (*Continued*)
(Medium loading districts)

Size AWG No.	Grade of construction	Temperature, °F	Sags for span length, in. 100 ft	125 ft	150 ft	175 ft	200 ft	250 ft	300 ft	400 ft	500 ft	700 ft	1,000 ft
8	C	30	5.5	8.5	13								
		60	8	12	18								
		90	12	17	23.5								
6	All	30	5.5	8.5	13	18.5							
		60	8	12	18	24							
		90	12	17	23.5	30							
4	All	30	5.5	8.5	13	18.5	25	35	61	134			
		60	8	12	18	24	32	42	69	141			
		90	12	17	23.5	30	39	50	77	149			
2	All	30	5.5	8.5	13	16.5	20	29	41	78	139	313	
		60	8	12	18	22	26	36	50	88	150	324	
		90	12	17	23.5	28	33	44	58	100	161	334	
1	All	30	5.5	8.5	13	15.5	18.5	24.5	32	62	111	275	
		60	8	12	18	21	24	31	40	72	124	286	
		90	12	17	23.5	28	31	39	48	83	135	298	
0	All	30	5.5	8.5	13	15.5	18	23.5	29	54	95	218	
		60	8	12	18	20.5	23	29	37	64	108	239	
		90	12	17	23.5	27.5	29.5	36	44	74	120	253	
00	All	30	5.5	8.5	13	15	17	21	27	47	80	177	396
		60	8	12	18	20	22	27	33	55	92	192	415
		90	12	17	23.5	26	28	34	41	65	104	208	429
0000	All	30	5.5	8.5	13	14.5	16	19	23	41	66	140	304
		60	8	12	18	19	21	24	27	48	76	154	323
		90	12	1	23.5	25	27	30	33	57	88	171	340

light loading districts and for hard- and soft-drawn conductors. The sags for the hard-drawn copper are given for both bare and covered conductors. The sags given are intended to apply to both solid and stranded conductors.

While the sags given are those generally recommended, circumstances will sometimes call for changes. For instance, where many large conductors are carried by a pole line, greater sags than those listed for the large conductors will sometimes be advisable to reduce the loads on poles at turns and dead ends and to permit smaller longitudinal guys where such guying is required.

TABLE 14-1. SAGS FOR HARD- AND MEDIUM-DRAWN BARE COPPER WIRE FOR DIFFERENT SPAN LENGTHS (*Continued*)
(Light loading districts)

Size AWG No.	Grade of construction	Temperature, °F	Sags for span length, in. 100 ft	125 ft	150 ft	175 ft	200 ft	250 ft	300 ft	400 ft	500 ft	700 ft	1,000 ft
8	C	30	4.5	6.5	9.5	15							
		60	6	9	13	20							
		90	9	13	18	26							
6	All	30	4.5	6.5	9.5	13.5	18.5						
		60	6	9	13	18	24						
		90	9	13	18	24	30						
4	All	30	4.5	6.5	9.5	13.5	17	20	32	69	126		
		60	6	9	13	18	22	25	40	80	137		
		90	9	13	18	24	28	32	48	90	148		
2	All	30	4.5	6.5	9.5	13.5	14	16.5	24.5	50	86	193	
		60	6	9	13	18	18	20	30	59	98	208	
		90	9	13	18	24	23.5	25	37	69	110	222	
1	All	30	4.5	6.5	9.5	13.5	14	16.5	23	44	74	163	362
		60	6	9	13	18	18	20	28	52	85	178	380
		90	9	13	18	24	23.5	25	34	61	96	193	396
0	All	30	4.5	6.5	9.5	13.5	14	16.5	23	41	68	146	316
		60	6	9	13	18	18	20	27	49	79	159	335
		90	9	13	18	24	23.5	25	33	58	89	175	353
00	All	30	4.5	6.5	9.5	13.5	14	16.5	22	39	62	125	276
		60	6	9	13	18	18	20	26	46	72	140	290
		90	9	13	18	24	23.5	25	32	54	83	154	309
0000	All	30	4.5	6.5	9.5	13.5	14	16.5	20	37	57	113	225
		60	6	9	13	18	18	20	24	43	66	126	246
		90	9	13	18	24	23.5	25	29	51	76	141	264

TABLE 14-1. SAGS FOR HARD- AND MEDIUM-DRAWN COVERED COPPER WIRE FOR DIFFERENT SPAN LENGTHS (*Continued*)
(At 30, 60, and 90°F—wires without load)
(Heavy loading districts)

Size AWG No.	Grade of construction	Temperature, °F	Sags for span length, in. 100 ft	125 ft	150 ft	175 ft	200 ft	250 ft	300 ft
8	C	30	15	23	36				
		60	18	27	40				
		90	21.5	31	44				
6	A	30	15	23	36				
		60	18	27	40				
		90	21.5	31	45				
6	B	30	11	17.5	27				
		60	15	22	33				
		90	18	26	38				
6	C	30	8.5	14	22	31			
		60	12	18	27	36			
		90	15.5	22.5	32	40			
4	All	30	8.5	14	21.5	31	43		
		60	12	18	27	36	48		
		90	17	22.5	32	41	54		
2	All	30	8.5	14	21.5	23 5	30	53	89
		60	12	18	27	30	36	60	96
		90	17	22.5	32	35	42	67	103
1	All	30	8.5	13.5	21	23	27	44	72
		60	12	18	26	29	33	52	80
		90	15.5	22.5	31	34	39	59	87
0	All	30	8.5	13.5	20.5	22.5	26	42	66
		60	12	18	26	28	32	49	72
		90	15.5	22.5	31	34	38	56	82
00	All	30	8.5	13.5	20	22.5	25	38	57
		60	12	18	25	28	31	46	66
		90	16	22.5	30	34	38	53	73
0000	All	30	8.5	13.5	18.5	21	24.5	31	43
		60	12	18	24	27	30	38	50
		90	16	22.5	29	33.	36	46	59

TABLE 14-1. SAGS FOR HARD- AND MEDIUM-DRAWN COVERED COPPER WIRE FOR DIFFERENT SPAN LENGTHS (*Continued*)
(Medium loading districts)

Size AWG No.	Grade of construction	Temperature, °F	Sags for span length, in. 100 ft	125 ft	150 ft	175 ft	200 ft	250 ft	300 ft
8	C	30	11.5	18	29				
		60	15	22	33				
		90	18.5	26	37				
6	A	30	11.5	18	28				
		60	15	22	33				
		90	18.5	26	37				
6	B	30	8.5	14	22	31			
		60	12	18	27	36			
		90	15.5	22	32	41			
6	C	30	7.5	11	17.5	25			
		60	10	15	22	30			
		90	13.5	19	27	36			
4	All	30	7	11.5	17.5	24	33		
		60	10	15	22	30	39		
		90	13.5	19.5	27	36	45		
2	All	30	7	11.5	17.5	22.5	26	43	68
		60	10	15	22	27	32	50	76
		90	13.5	19.5	27	34	38	57	83
1	All	30	7	11	17	19.5	23.5	33	52
		60	10	15	22	25	29	39	60
		90	14	19.5	27	30	35	46	68
0	All	30	7	11	17.5	19.5	21.5	30	46
		60	10	15	22	24	27	36	54
		90	14	19.5	27	31	33	43	62
00	All	30	7	11	17	19	21	27	40
		60	10	15	22	24	26	33	48
		90	14	19.5	27	30	32	40	56
0000	All	30	7	11	17	18	19	23.5	33
		60	10	15	22	23	24	29	40
		90	13.5	19.5	27	29	30	35	47

TABLE 14-1. SAGS FOR HARD- AND MEDIUM-DRAWN COVERED COPPER WIRE FOR DIFFERENT SPAN LENGTHS (*Continued*)
(Light loading districts)

Size AWG No.	Grade of construction	Temperature, °F	Sags for span length, in.						
			100 ft	125 ft	150 ft	175 ft	200 ft	250 ft	300 ft
8	C	30	8.5	14	22.5	31			
		60	12	118	27	36			
		90	15.5	22.5	32	41			
6	A	30	8.5	14	22	31			
		60	12	18	27	36			
		90	15.5	22.5	32	41			
6	B	30	7	11.5	17.5	25	32		
		60	10	15	22	30	38		
		90	13	19.5	27	36	44		
6	C	30	6	9	14	19.5	26		
		60	8	12	18	24	32		
		90	11	16	22.5	29	38		
4	All	30	6.5	9	14	19	26		
		60	8	12	18	24	32		
		90	11.5	16	22	30	38		
2	All	30	6.5	9	14	17.5	21	28	45
		60	8	12	18	22	26	34	52
		90	11.5	16	22	27	32	41	60
1	All	30	5.5	9	13.5	16.5	19	26	38
		60	8	12	18	21	24	31	45
		90	11.5	16	23	26	30	38	53
0	All	30	5.5	9	14	16.5	18	24.5	34
		60	8	12	18	21	23	30	41
		90	11.5	16.5	23	27	28	36	47
00	All	30	5.5	9	13.5	16	17.5	23	31
		60	8	12	18	20	22	28	37
		90	11.5	16	23	25	28	35	45
0000	All	30	5.5	8.5	13.5	16	16.5	20.5	27
		60	8	12	18	19	21	25	32
		90	11	16	23	24.5	26	31	39

TABLE 14-1. SAGS FOR SOFT-DRAWN COVERED COPPER WIRE FOR DIFFERENT SPAN LENGTHS (*Continued*)
(At 30, 60, and 90°F—wires without load)
(Heavy loading districts)

Size AWG No.	Grade of construction	Temperature, °F	Sags for span length, in.				
			100 ft	125 ft	150 ft	175 ft	200 ft
6	C	30	18	28	44		
		60	21	32	48		
		90	24	36	51		
4	A	30	17 5	28	45		
		60	21	32	48		
		90	24	35	51		
4	B and C	30	14.5	23	36		
		60	18	27	40		
		90	21.5	31	44		
2	A	30	14.5	23	36	49	
		60	18	27	40	54	
		90	21.5	31	44	58	
2	B and C	30	11	17.5	28	40	55
		60	15	22	33	45	60
		90	18.5	26	38	50	64
1	A	30	10.5	17.5	28	40	55
		60	15	22	33	45	60
		90	18.5	26	37	50	65
1	B and C	30	8.5	13.5	21.5	31	43
		60	12	18	27	37	48
		90	15.5	22.5	32	42	53
0	All	30	8.5	13.5	20 5	29	39
		60	12	18	26	35	45
		90	15.5	22.5	31	39	51
00	All	30	8.5	13.5	20	28	36
		60	12	18	25	33	42
		90	15.5	22.5	30	38	48
0000	All	30	8.5	13.5	18.5	24.5	30
		60	12	18	24	30	36
		90	16	22.5	29	36	42

TABLE 14-1. SAGS FOR SOFT-DRAWN COVERED COPPER WIRE FOR DIFFERENT SPAN LENGTHS (*Continued*)
(Medium loading districts)

Size AWG No.	Grade of construction	Temperature, °F	Sags for span length, in.					
			100 ft	125 ft	150 ft	175 ft	200 ft	250 ft
6	C	30	14 5	22	36			
		60	18	27	40			
		90	21	31	44			
4	All	30	11	18	28	44		
		60	15	22	33	48		
		90	18.5	26	37	35		
2	All	30	8.5	13.5	22.5	31	43	
		60	12	18	27	36	48	
		90	15.5	22	32	41	53	
1	All	30	8.5	13.5	20	28	36	53
		60	12	18	25	33	42	60
		90	15.5	22.5	30	38	48	67
0	All	30	8.5	13.5	19	25	33	47
		60	12	18	24	31	39	54
		90	15.5	22.5	29	37	45	61
00	All	30	8.5	13.5	19	24.5	30	41
		60	12	18	24	30	36	48
		90	15.5	22.5	29	36	42	55
0000	All	30	8.5	13.5	18.5	24.5	30	41
		60	12	18	24	30	36	48
		90	16	22.5	29	36	42	55

TABLE 14-1. SAGS FOR SOFT-DRAWN COVERED COPPER WIRE FOR DIFFERENT SPAN LENGTHS (*Continued*)
(Light loading districts)

Size AWG No.	Grade of construction	Temperature, °F	Sags for span length, in. 100 ft	125 ft	150 ft	175 ft	280 ft	250 ft
6	A	30	14	23	36			
		60	18	27	40			
		90	21.5	31	44			
6	B and C	30	11	17.5	29			
		60	15	22	33			
		90	18.5	26	37			
4	All	30	8.5	13.5	20	26	36	
		60	12	18	25	32	42	
		90	15.5	22.5	30	37	47	
2	All	30	7	11	16	22	30	41
		60	10	15	21	27	36	48
		90	13.5	19.5	26	33	42	55
1	All	30	7	11	15	19.5	24	35
		60	10	15	20	25	30	42
		90	14	19.5	25	31	36	49
0	All	30	7	11	15.5	20	24.5	35
		60	10	15	20	25	30	42
		90	14	19.5	25	31	36	49
00	All	30	7	11	15	19.5	24	35
		60	10	15	20	25	30	42
		90	14	19.5	25	31	36	49
0000	All	30	7	10.5	15.5	19.5	24	35
		60	10	15	20	25	30	42
		90	14	19 5	25	31	36	49

is greater at the higher temperature is because of the expansion of the metal in the conductor, causing it to be elongated.

When sagging by sight, the use of sagging Ts is often preferred. A typical sagging T is shown in Fig. 14-38. The Ts are used the same as the targets except that the Ts are hung on the line conductor. They are perhaps less subject to error because they are accurately calibrated. The notches are usually spaced 2 in. apart.

The method of sighting for sag gives very satisfactory results when the sag is not less than 6 in. and when the visibility is good. If the visibility is not good, it is often helpful to provide a suitable target at the distant

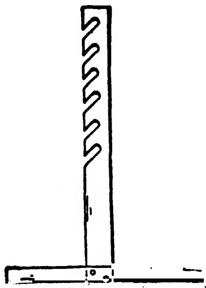


FIG. 14-38. Sagging T for use in sighting in sag.

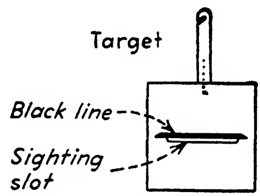


FIG. 14-39. Sighting target about 2 ft square and painted white. Black line is about 1 in. wide. Sighting slot is also about 1 in. wide.

pole for visual contrast with the conductor. This may be a piece of wood or metal approximately 2 ft square, painted white with a horizontal black line about 1 in. wide across the center. For the sighting end, a similar device may be used, having a sighting slot in place of the black line (see Fig. 14-39). The distant target and the slot are set below the support according to the desired sag, and the conductor sag is varied until the low point is in line with the two.

Sagging Line with Transit. In the case of an H-frame line, the line conductors are on one or the other sides of the poles. A lineman stationed on one pole and looking to the corresponding pole a span length away cannot include the lowest point of the conductor in his line of sight. To get around this difficulty, a transit is securely fastened to the pole at a distance equal to the desired sag below the conductor support. Then the transit is leveled. To observe the sag, the transit is sighted at the conductor at mid-span and then is swung around until in line with the pole a span length away. The sag is then observed, and the line conductor is drawn up farther if the sag is too large or relaxed if the sag is too small.

Figure 14-40 shows a three-phase 132,000-volt H-frame line preparatory to pulling up and sagging in. The three line conductors are resting

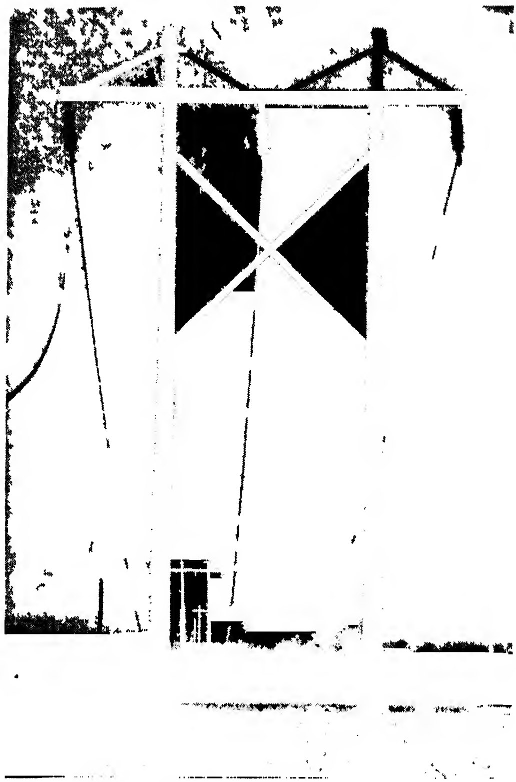


Fig 14-40 New three-phase 132 000-volt H-frame transmission line preparatory to having the line conductors pulled up and sagged in. Note conductors resting in snatch blocks (*Courtesy Consumers Power Co*)

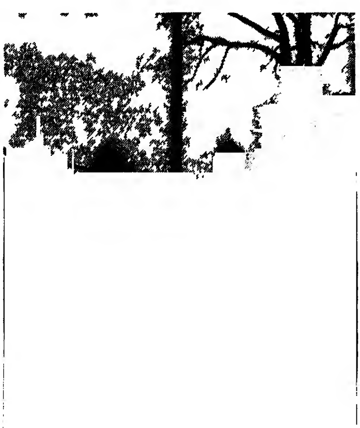


Fig 14-41 Caterpillar tractor used as motive power for sagging the line conductors on the 132 000-volt H-frame line The winch shown at rear of tractor is used for preliminary sagging and the coffing chain hoists are used for final sagging Note use of come-alongs or cable grips (*Courtesy Wisconsin Electric Power Co*)

Table 14-2. Time Sag Based on Time Required for Return of 10 Waves

Sag, in.	Time, sec	Sag, in.	Time, sec	Sag, in.	Time, sec	Sag, in.	Time, sec	Sag, in.	Time, sec
5	6.4	57	21.7	109	30.0	161	36.5	213	42.0
6	7.0	58	21.9	110	30.2	162	36.6	214	42.1
7	7.6	59	22.1	111	30.3	163	36.7	215	42.2
8	8.1	60	22.3	112	30.5	164	36.9	216	42.3
9	8.6	61	22.5	113	30.6	165	37.0	217	42.4
10	9.1	62	22.7	114	30.7	166	37.1	218	42.5
11	9.5	63	22.8	115	30.9	167	37.2	219	42.6
12	10.0	64	23.0	116	31.0	168	37.3	220	42.7
13	10.4	65	23.2	117	31.1	169	37.4	221	42.8
14	10.8	66	23.4	118	31.3	170	37.5	222	42.9
15	11.1	67	23.6	119	31.4	171	37.6	223	43.0
16	11.5	68	23.7	120	31.5	172	37.7	224	43.1
17	11.9	69	23.9	121	31.7	173	37.9	225	43.2
18	12.2	70	24.1	122	31.8	174	38.0	226	43.3
19	12.5	71	24.3	123	81.9	175	38.1	227	43.4
20	12.9	72	24.4	124	32.0	176	38.2	228	43.5
21	13.2	73	24.6	125	32.2	177	38.3	229	43.5
22	13 5	74	24.8	126	32.3	178	38.4	230	43.6
23	13.8	75	24.9	127	32.4	179	38.5	231	43.7
24	14.1	76	25.1	128	32.6	180	38.6	232	43.8
25	14.4	77	25.3	129	32.7	181	38.7	233	43.9
26	14.7	78	25.4	130	32.8	182	38.8	234	44.0
27	15 0	79	25 6	131	32.9	183	38.9	235	44.1
28	15.2	80	25 7	132	33.1	184	39.0	236	44.2
29	15.5	81	25.9	133	33.2	185	39.1	237	44.3
30	15 8	82	26 1	134	33.3	186	39.2	238	44.4
31	16 0	83	26 2	135	33.4	187	39 3	239	44.5
32	16 3	84	26 4	136	33 6	188	39.4	240	44.6
33	16 5	85	26 5	137	33.7	189	39.5	241	44.7
34	16.8	86	26 7	138	33.8	190	39.7	242	44.8
35	17 0	87	26.8	139	33.9	191	39.8	243	44.9
36	17 3	88	27.0	140	34.0	192	39.9	244	45.0
37	17 5	89	27 2	141	34.2	193	40.0	245	45.0
38	17.7	90	27 3	142	34.3	194	40.1	246	45.1
39	18.0	91	27.5	143	34.4	195	40.2	247	45.2
40	18.2	92	27.6	144	34.5	196	40.3	248	45.3
41	18.4	93	27.8	145	34.7	197	40.4	249	45.4
42	18 7	94	27.9	146	34.8	198	40.5	250	45.5
43	18 9	95	28.1	147	34.9	199	40.6	251	45.6
44	19.1	96	28.2	148	35.0	200	40.7	252	45.7
45	19.3	97	28.3	149	35.1	201	40.8	253	45.8
46	19 5	98	28 5	150	35.2	202	40.9	254	45.9
47	19.7	99	28.6	151	35.4	203	41.0	255	46.0
48	19.9	100	28 8	152	35.5	204	41.1	256	46.0
49	20.1	101	28.9	153	35.6	205	41.2	257	46.1
50	20.4	102	29.1	154	35.7	206	41.3	258	46.2
51	20.6	103	29.2	155	35.8	207	41.4	259	46.3
52	20.8	104	29.3	156	35.9	208	40.5	260	46.4
53	21.0	105	29.5	157	36 1	209	41.6	261	46.5
54	21.1	106	29.6	158	36.2	210	41.7	262	46.6
55	21.3	107	29.8	159	36.3	211	41.8	263	46.7
56	21.5	108	29 9	160	36.4	212	41.9	264	46.8

Values in this table were calculated from the formula $D = 0.12075T^2$, where D = sag in inches and T = time in seconds.

Values for the fifth return wave may be calculated from the formula $D = 0.483T^2$, or the above table may be used by dividing the time by 2.

Values for the third return wave may be calculated from the formula $D = 1.3147T^2$.

in the snatch blocks but are still resting on the ground at mid-span. Figure 14-41 shows the motive power being used for sagging the line. The winch shown is used for preliminary sagging, and the coffing chain hoists are used for final sagging. Figure 14-42 shows the lineman sighting through the transit to observe the sag at mid-span.

Sag Measurement by Timing. Accurate sagging by sighting is difficult if the spans are long or if the sags are quite small. Furthermore, if

FIG 14-42 Lineman sighting through a transit telescope at a target on the next structure while a line conductor is being drawn up during preliminary sagging operation. The thin wire hooked over the line wire near the snatch block is one lead of a portable telephone which is being used to communicate with the crew that is doing the pulling. The coil of rope on the hand line is used in the final sagging of the conductor by timing (*Courtesy Wisconsin Electric Power Co*)

the poles used in sighting are not at the same level, it is even more difficult.

In recent years a sagging method based on timing has come into general use which gives remarkably accurate results. This method is applied as follows:

Strike the conductor a blow close to one of the pole supports, and at the same time start a stop watch or note the reading of the second hand on your pocket watch. Striking the conductor causes a wave or ripple to travel along the conductor until it reaches the next pole. When it reaches the next pole, it is reflected and returns to the pole where you are stationed. Here it is also reflected, and thus starts its second round trip. This will continue until the energy of the blow has been expended. The length of time in seconds required for the wave to return to the near support corresponds to a definite sag which can be calculated or read from prepared tables or graphs. The time is independent of the span length, the size or type of the conductor, or the tension in the conductor.

Observe the travel of this wave and count the number of returns, until the wave has returned five or ten times. Upon the arrival of the fifth or tenth return wave, read the stop watch or your pocket watch and note the time elapsed in seconds. Then refer to Table 14-2 and Fig. 14-43, and read the corresponding sag opposite the time in seconds. If this is not the sag as given in Table 14-1, change the pull on the conductor, and repeat the timing operation.

This sagging method is most satisfactory if the line is not in motion. Any vibration of the line as might be caused by working on it or by a strong wind makes it difficult to determine the exact time of the return wave. The conductor should rest on the crossarm or in the snatch block to reflect the wave, although it need not be tied in.

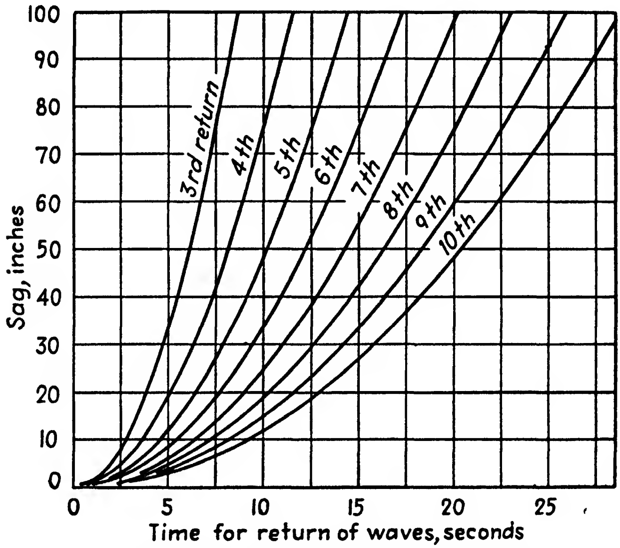


FIG. 14-43. Graphs giving relation between time in seconds and sag in inches for third to tenth return of wave. (*Courtesy Copper Wire Engineering Association.*)

The return wave may be felt by a man on the pole by placing a finger lightly on the conductor. Or readings may be made from the ground by throwing a light dry cord over the conductor about 3 ft from the support, as shown in Figs. 14-44 and 14-45. This cord may also be used to give the impulse initiating the wave. The use of the dry cord is particularly useful when the line is "hot," that is, energized.

Care must be taken not to count "one" when the impulse is given to the line, but to count "one" on the first return of the wave. In other words count, "hit," one, two, three, etc.

Use of Dynamometer. When conductors are to be strung with unusually small sags, the measuring of the sags may not be so accurate or convenient as measuring the conductor tension. This is done by means of a dynamometer which is inserted in the pulling equipment. Such a dynamometer is shown in Fig. 14-46, and the manner of using it is shown

FIG. 14-44 Sag measurement by timing The rope over the wire is used for applying an impulse to the conductor which creates a wave that travels along the wire The lineman on the ground is holding a stop watch in one hand and the rope with the other The lineman on the pole communicates directions to the pulling crew If sag is too large more pull must be applied, if sag is too small, pull must be relaxed (*Courtesy Wisconsin Electric Power Co*)

FIG 14-45 Close-up view of lineman on ground measuring the conductor sag by timing Lineman holds stop watch in one hand and rope in the other The taut rope which passes over the line conductor signals each return of the wave The time required for either 5 or 10 returns of the wave is measured with the stop watch (*Courtesy Wisconsin Electric Power Co*)

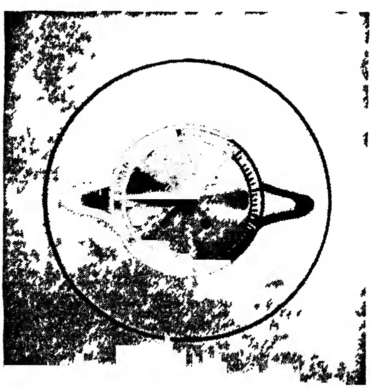


FIG 14-46 Dynamometer used in pulling up line conductors to desired tension Tension is indicated on scale on dial (*Courtesy John Chatillon & Sons*)

in Fig. 14-47. One of the pointers indicates the pull at all times, and the other will remain at the point of maximum load after the tension is released. The pull is increased until the tension shown in Table 14-3 is obtained for the desired conductor size, span length, temperature, and loading district.

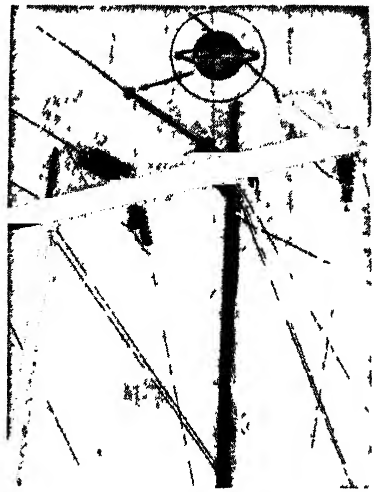


FIG. 14-47. Traction dynamometer used with block and tackle in pulling line conductor to proper tension (*Courtesy John Chatillon & Sons.*)

FIG. 14-48. Front view of shunt dynamometer attached to line conductor for measurement of tension. (*Courtesy John Chatillon & Sons.*)

Any convenient span in the section of line may be used for measuring the tension, but care should be taken that the tension is fairly uniform on all spans. After stringing, a common practice is to allow the conductor to remain untied for several hours before final measurement and tying. On a long section of line it is advisable to check the sag or tension at several spans to ensure the uniformity of the tension in the line.

The shunt dynamometer illustrated in Figs. 14-48 and 14-49 is so designed that it can be applied to the conductor without breaking in on

(*Continued on page 14-48*)

TABLE 14-3. TENSIONS IN OVERHEAD-LINE CONDUCTORS CORRESPONDING TO THE RECOMMENDED SAGS GIVEN IN TABLE 14-1
TENSIONS IN HARD- AND MEDIUM-DRAWN BARE COPPER WIRE FOR DIFFERENT SPAN LENGTHS
(Heavy loading districts)

Size AWG No.	Grade of construction	Conditions of load and temperature, °F	Tensions for span length, lb								
			100 ft	125 ft	150 ft	175 ft	200 ft	250 ft	300 ft	400 ft	500 ft
8	C	30 no load	94	92	76						
		60 no load	63	65	62						
		90 no load	47	53	54						
		0 loaded	442	503	520						
6	A	30 no load	150	145	120						
		60 no load	99	105	99						
		90 no load	74	85	86						
		0 loaded	570	630	670						
6	B	30 no load	180	180	165						
		60 no load	120	125	120						
		90 no load	84	95	100						
		0 loaded	590	650	710						
6	C	30 no load	180	180	165	125					
		60 no load	120	125	120	110					
		90 no load	84	95	100	96					
		0 loaded	590	650	710	740					

4	All	30 no load	290	280	270	260	240	185	160		
		60 no load	190	200	200	210	200	170	150		
		90 no load	135	150	160	175	170	155	145		
		0 loaded	740	840	900	960	1,000	1,000	990		
2	All	30 no load	460	450	510	590	650	540	470	380	350
		60 no load	300	310	380	440	500	430	400	350	340
		90 no load	210	240	290	340	400	370	370	340	330
		0 loaded	1,000	1,100	1,250	1,350	1,450	1,540	1,550	1,600	1,600
1	All	30 no load	580	520	650	740	820	730	670	540	490
		60 no load	380	400	470	550	630	600	580	510	470
		90 no load	270	300	370	430	500	500	520	480	450
		0 loaded	1,200	1,250	1,450	1,600	1,700	1,800	1,900	1,900	1,900
0	All	39 no load	730	720	820	930	1,050	970	950	760	710
		60 no load	480	500	600	700	800	790	790	710	670
		90 no load	340	380	460	540	630	660	690	650	630
		0 loaded	1,400	1,500	1,650	1,850	2,000	2,150	2,200	2,300	2,250
00	All	30 no load	920	910	1,050	1,150	1,300	1,300	1,300	1,050	960
		60 no load	600	630	750	880	1,000	1,050	1,100	950	910
		90 no load	430	480	580	680	790	850	930	880	850
		0 loaded	1,700	1,750	1,950	2,150	2,350	2,550	2,900	2,650	2,650
0000	All	30 no load	1,450	1,450	1,650	1,850	2,050	2,300	2,500	2,100	2,000
		60 no load	960	1,000	1,200	1,400	1,600	1,850	2,050	1,850	1,850
		90 no load	680	770	930	1,100	1,250	1,500	1,700	1,650	1,700
		0 loaded	2,500	2,500	2,800	3,100	3,350	3,750	4,100	4,000	4,150

TABLE 14-3 (*Continued*)
TENSIONS IN HARD- AND MEDIUM-DRAWN BARE COPPER WIRE FOR DIFFERENT SPAN LENGTHS
(Medium loading districts)

Size AWG No.	Grade of construction	Conditions of load and temperature, °F	Tensions for span length, lb										
			100 ft	125 ft	150 ft	175 ft	200 ft	250 ft	300 ft	400 ft	500 ft	700 ft	1,000 ft
8	C	30 no load	140	140	130								
		60 no load	94	97	94								
		90 no load	63	71	73								
		15 loaded	330	360	390								
6	All	30 no load	230	220	200	200							
		60 no load	150	155	150	150							
		90 no load	100	110	115	125							
		15 loaded	430	470	500	540							
4	All	30 no load	360	360	320	320	300	340	280	230			
		60 no load	240	250	240	240	240	280	250	220			
		90 no load	160	180	185	200	200	240	220	200			
		15 loaded	580	630	660	690	720	820	820	810			
2	All	30 no load	570	570	510	550	600	650	650	620	540	480	
		60 no load	380	390	380	420	460	520	540	550	500	460	
		90 no load	260	280	300	290	370	430	470	460	470	450	
		15 loaded	830	860	900	970	1,050	1,150	1,250	1,350	1,350	1,350	

1	All	30 no load	720	710	650	740	840	950	1,050	980	850	680	
		60 no load	480	490	470	550	630	760	850	850	770	650	
		90 no load	320	360	370	420	490	610	700	740	700	620	
		15 loaded	1,000	1,050	1,050	1,150	1,300	1,500	1,650	1,700	1,700	1,600	
0	All	30 no load	910	900	820	940	1,050	1,300	1,450	1,400	1,250	1,050	
		60 no load	600	620	600	710	830	1,050	1,200	1,200	1,100	980	
		90 no load	400	450	470	540	650	830	980	1,050	1,000	930	
		15 loaded	1,200	1,250	1,250	1,450	1,550	1,850	2,050	2,200	2,100	2,100	
00	All	30 no load	1,150	1,150	1,050	1,250	1,400	1,750	2,000	2,050	1,850	1,650	1,550
		60 no load	760	780	750	920	1,100	1,400	1,650	1,750	1,650	1,550	1,450
		90 no load	510	570	590	720	850	1,150	1,350	1,500	1,450	1,450	1,400
		15 loaded	1,450	1,500	1,500	1,750	1,950	2,350	2,650	2,850	2,850	2,850	2,850
0000	All	30 no load	1,800	1,800	1,650	2,050	2,400	3,150	3,800	3,800	3,650	3,350	3,150
		60 no load	1,200	1,250	1,200	1,550	1,800	2,500	3,200	3,200	3,150	3,050	3,000
		90 no load	810	900	940	1,200	1,400	2,000	2,600	2,700	2,750	2,750	2,850
		15 loaded	2,250	2,300	2,250	2,700	3,000	3,800	4,500	4,560	4,700	4,700	4,700

TABLE 14-3 (*Continued*)
TENSIONS IN HARD- AND MEDIUM-DRAWN BARE COPPER WIRE FOR DIFFERENT SPAN LENGTHS
(Light loading districts)

Size AWG No.	Grade of construction	Conditions of load and temperature, °F	Tensions for span length, lb										
			100 ft	125 ft	150 ft	175 ft	200 ft	250 ft	300 ft	400 ft	500 ft	700 ft	1,000 ft
8	C	30 no load	180	180	175	150							
		60 no load	125	130	130	115							
		90 no load	82	91	94	90							
		30 loaded	210	220	230	220							
6	All	30 no load	280	290	280	270	260						
		60 no load	200	210	210	200	200						
		90 no load	130	145	150	155	160						
		30 loaded	310	340	340	350	350						
4	All	30 no load	450	460	450	430	450	590	520	440	380		
		60 no load	320	330	330	320	340	470	430	380	340		
		90 no load	210	230	240	240	270	370	350	340	320		
		30 loaded	490	500	510	510	540	700	660	630	610		
2	All	30 no load	710	730	710	680	870	1,150	1,100	960	870	760	
		60 no load	510	520	520	510	670	940	900	820	770	710	
		90 no load	330	370	380	390	510	750	730	700	680	660	
		30 loaded	750	780	790	770	940	1,200	1,250	1,150	1,150	1,100	

1	All	30 no load	900	920	890	860	1,100	1.450	1,450	1,400	1,300	1,150	1,050
		60 no load	640	660	650	640	840	1,200	1,200	1,150	1,100	1,050	1,000
		90 no load	410	460	480	490	650	940	990	990	980	970	970
		30 loaded	940	970	980	940	1,200	1,500	1,550	1,550	1,550	1,500	1,460
0	All	30 no load	1,150	1,150	1,150	1,100	1,400	1,800	1,900	1,800	1,750	1,600	1,500
		60 no load	800	830	830	810	1,050	1,500	1,600	1,550	1,500	1,450	1,450
		90 no load	520	580	600	620	820	1,200	1,300	1,300	1,350	1,350	1,350
		30 loaded	1,200	1,200	1,200	1,200	1,450	1,900	2,050	2,050	2,000	2,000	2,050
0	All	30 no load	1,450	1,450	1,400	1,350	1,750	2,300	2,500	2,450	2,400	2,350	2,200
		60 no load	1,000	1,050	1,050	1,050	1,350	1,900	2,100	2,100	2,100	2,100	2,100
		90 no load	660	730	760	780	1,050	1,500	1,700	1,800	1,800	1,900	1,950
		30 loaded	1,500	1,500	1,500	1,450	1,800	2,350	2,600	2,650	2,650	2,700	2,750
0000	All	30 no load	2,200	2,350	2,250	2,150	2,750	3,650	4,300	4,200	4,200	4,150	4,250
		60 no load	1,600	1,650	1,650	1,650	2,100	3,000	3,600	3,550	3.600	3,700	3,900
		90 no load	1,050	1,150	1,200	1,250	1,650	2,400	2,950	3,000	3,150	3,350	3,650
		30 loaded	2,300	2,350	2,350	2,250	2,900	3,700	4,300	4,400	4,400	4,550	4,750

TABLE 14-3 (*Continued*)

TENSIONS IN HARD- AND MEDIUM-DRAWN COVERED COPPER WIRE FOR DIFFERENT SPAN LENGTHS

(Heavy loading districts)

Size AWG No.	Grade of construction	Conditions of load and temperature, °F	Tensions for span length, lb						
			100 ft	125 ft	150 ft	175 ft	200 ft	250 ft	300 ft
8	C	30 no load	77	77	72				
		60 no load	62	65	63				
		90 no load	54	58	59				
		0 loaded	470	520	560				
6	A	30 no load	115	115	105				
		60 no load	94	98	95				
		90 no load	81	87	87				
		0 loaded	580	640	670				
6	B	30 no load	155	155	135				
		60 no load	110	120	115				
		90 no load	94	105	105				
		0 loaded	600	680	720				
6	C	30 no load	195	190	170	165			
		60 no load	140	145	140	145			
		90 no load	108	120	120	130			
		0 loaded	640	710	760	820			
4	All	30 no load	270	280	260	240	230		
		60 no load	210	210	210	210	210		
		90 no load	155	170	175	185	185		
		0 loaded	820	900	950	1,000	1,050		
2	All	30 no load	430	440	410	500	530	460	400
		60 no load	330	340	330	400	430	410	370
		90 no load	250	270	280	340	380	370	320
		0 loaded	1,100	1,150	1,200	1,350	1,500	1,550	1,500
1	All	30 no load	560	540	510	630	710	660	590
		60 no load	400	410	410	500	570	570	540
		90 no load	310	330	350	430	490	510	490
		0 loaded	1,200	1,300	1,350	1,550	1,700	1,700	1,850
0	All	30 no load	710	690	670	820	930	910	870
		60 no load	510	530	530	660	750	780	770
		90 no load	390	430	450	550	630	680	680
		0 loaded	1,450	1,550	1,600	1,850	2,000	2,050	2,200
00	All	30 no load	890	860	840	1,000	1,200	1,200	1,200
		60 no load	630	650	680	830	970	1,000	1,050
		90 no load	480	520	570	680	810	890	910
		0 loaded	1,700	1,800	1,850	2,100	2,350	2,500	2,600
0000	All	30 no load	1,350	1,350	1,400	1,650	1,850	2,250	2,450
		60 no load	960	1,000	1,100	1,300	1,550	1,900	2,050
		90 no load	730	810	920	1,100	1,300	1,600	1,750
		0 loaded	2,450	2,500	2,650	3,000	3,300	3,850	4,200

TABLE 14-3 (*Continued*)
TENSIONS IN HARD- AND MEDIUM-DRAWN COVERED WIRE FOR DIFFERENT SPAN LENGTHS
(Medium loading districts)

Size AWG No.	Grade of construction	Conditions of load and temperature, °F	Tensions for span length, lb						
			100 ft	125 ft	150 ft	175 ft	200 ft	250 ft	300 ft
8	C	30 no load	98	98	89				
		60 no load	75	80	76				
		90 no load	61	68	69				
		15 loaded	330	400	390				
6	A	30 no load	150	150	135				
		60 no load	155	120	115				
		90 no load	93	100	105				
		15 loaded	420	460	480				
6	B	30 no load	195	190	170	170			
		60 no load	140	145	140	145			
		90 no load	110	120	120	130			
		15 loaded	450	490	520	550			
6	C	30 no load	230	230	220	210			
		60 no load	170	175	170	175			
		90 no load	125	140	140	150			
		15 loaded	480	530	560	590			
4	All	30 no load	350	340	320	290	300		
		60 no load	250	260	250	250	250		
		90 no load	180	200	210	210	220		
		15 loaded	620	680	710	750	780		
2	All	30 no load	560	540	510	530	600	560	520
		60 no load	390	410	400	440	490	490	470
		90 no load	290	320	330	360	410	430	430
		15 loaded	870	930	950	1,050	1,150	1,200	1,200
1	All	30 no load	670	670	620	750	820	900	830
		60 no load	470	490	490	580	660	760	710
		90 no load	350	390	390	480	540	640	630
		15 loaded	1,000	1,000	1,000	1,250	1,350	1,550	1,550
0	All	30 no load	870	850	790	950	1,100	1,250	1,200
		60 no load	610	630	620	710	900	1,050	1,000
		90 no load	440	490	510	610	730	880	890
		15 loaded	1,250	1,300	1,300	1,500	1,700	1,950	1,950
00	All	30 no load	1,050	1,050	990	1,200	1,450	1,750	1,650
		60 no load	750	780	770	960	1,150	1,400	1,400
		90 no load	550	610	630	780	950	1,200	1,200
		15 loaded	1,500	1,550	1,500	1,750	2,000	2,350	2,400
0000	All	30 no load	1,700	1,650	1,500	1,950	2,400	3,050	3,100
		60 no load	1,150	1,200	1,200	1,500	1,900	2,450	2,600
		90 no load	840	920	970	1,250	1,550	2,100	2,200
		15 loaded	2,200	2,250	2,150	2,600	3,150	3,750	3,950

TABLE 14-3 (*Continued*)

TENSION IN HARD- AND MEDIUM-DRAWN COVERED COPPER WIRE FOR DIFFERENT SPAN LENGTHS

(Light loading districts)

Size AWG No.	Grade of construction	Conditions of load and temperature, °F	Tensions for span length lb						
			100 ft	125 ft	150 ft	175 ft	200 ft	250 ft	300 ft
8	C	30 no load	130	125	115	115			
		60 no load	94	97	94	96			
		90 no load	73	79	79	84			
		30 loaded	220	240	260	270			
6	A	30 no load	195	190	170	170			
		60 no load	140	150	140	145			
		90 no load	110	120	120	130			
		30 loaded	310	330	340	360			
6	B	30 no load	250	230	220	210	220		
		60 no load	170	175	175	170	180		
		90 no load	130	140	140	145	155		
		30 loaded	340	360	380	400	420		
6	C	30 no load	290	290	270	270	260		
		60 no load	210	220	210	220	210		
		90 no load	155	165	170	180	180		
		30 loaded	380	410	420	440	450		
4	All	30 no load	430	430	390	390	380		
		60 no load	310	320	310	310	310		
		90 no load	220	240	230	250	250		
		30 loaded	530	560	570	600	620		
2	All	30 no load	690	680	630	690	740	870	790
		60 no load	490	510	490	540	600	720	670
		90 no load	340	380	360	430	490	600	590
		30 loaded	770	810	810	900	970	1,150	1,100
1	All	30 no load	840	840	790	890	1,000	1,150	1,100
		60 no load	600	620	600	700	790	960	950
		90 no load	410	460	470	560	640	790	810
		30 loaded	920	960	940	1,050	1,200	1,400	1,400
0	All	30 no load	1,050	1,050	990	1,100	1,350	1,550	1.600
		60 no load	760	790	750	890	1,050	1,250	1,350
		90 no load	540	590	590	700	850	1,050	1,150
		30 loaded	1,150	1,200	1,150	1,300	1,500	1,750	1,850
00	All	30 no load	1,350	1,350	1,250	1,450	1,700	2,050	2,150
		60 no load	950	990	940	1,150	1,350	1,650	1,800
		90 no load	660	730	740	900	1,100	1,350	1,550
		30 loaded	1,300	1,450	1,400	1,650	1,900	2,250	2,400
0000	All	30 no load	2,150	2,100	1,900	2,400	2,750	3,500	3,850
		60 no load	1,450	1,500	1,450	1,850	2,200	2,850	3,200
		90 no load	1,050	1,100	1,150	1,450	1,750	2,350	2,700
		30 loaded	2,150	2,200	2,050	2,500	2,900	3,700	4,050

TABLE 14-3 (*Continued*)
TENSIONS IN SOFT-DRAWN COVERED COPPER WIRE FOR DIFFERENT SPAN LENGTHS
(Heavy loading districts)

Size AWG No.	Grade of construction	Conditions of load and temperature, °F	Tensions for span length, lb				
			100 ft	125 ft	150 ft	175 ft	200 ft
6	C	30 no load	97	94	87		
		60 no load	82	85	80		
		90 no load	71	76	75		
		0 loaded	540	590	610		
4	A	30 no load	140	140	125		
		60 no load	120	120	115		
		90 no load	105	115	110		
		0 loaded	670	710	720		
4	B and C	30 no load	175	165	155		
		60 no load	140	145	140		
		90 no load	115	130	130		
		0 loaded	720	770	800		
2	A	30 no load	280	270	250	240	
		60 no load	220	230	220	225	
		90 no load	185	200	200	210	
		0 loaded	900	970	970	1,050	
2	B and C	30 no load	350	350	310	300	290
		60 no load	260	280	270	270	260
		90 no load	210	240	240	240	240
		0 loaded	980	1,050	1,100	1,100	1,150
1	A	30 no load	430	430	380	370	350
		60 no load	320	340	330	330	320
		90 no load	260	290	290	300	300
		0 loaded	1,100	1,200	1,200	1,250	1,250
1	B and C	30 no load	560	540	490	470	450
		60 no load	390	410	400	400	400
		90 no load	310	330	340	350	360
		0 loaded	1,250	1,300	1,350	1,400	1,450
0	All	30 no load	710	690	670	630	630
		60 no load	510	530	530	530	540
		90 no load	460	430	450	480	480
		0 loaded	1,450	1,550	1,600	1,600	1,700
00	All	30 no load	890	860	850	840	840
		60 no load	630	650	680	700	720
		90 no load	490	520	570	600	640
		0 loaded	1,700	1,800	1,850	1,900	2,000
0000	All	30 no load	1,350	1,350	1,400	1,450	1,550
		60 no load	960	1,000	1,100	1,200	1,300
		90 no load	730	810	900	1,000	1,100
		0 loaded	2,400	2,500	2,600	2,750	3,000

TABLE 14-3 (*Continued*)

TENSIONS IN SOFT-DRAWN COVERED COPPER WIRE FOR DIFFERENT SPAN LENGTHS

(Medium loading districts)

Size AWG No.	Grade of construction	Conditions of load and temperature, °F	Tensions for span length, lb 100 ft	125 ft	150 ft	175 ft	200 ft	250 ft
6	C	30 no load	120	120	105			
		60 no load	95	99	96			
		90 no load	80	88	88			
		15 loaded	390	420	440			
4	All	30 no load	220	220	195	170		
		60 no load	165	175	170	160		
		90 no load	135	145	150	145		
		15 loaded	530	580	590	580		
2	All	30 no load	450	450	390	390	370	
		60 no load	330	340	330	330	330	
		90 no load	250	280	280	290	300	
		15 loaded	800	850	860	900	880	
1	All	30 no load	560	540	540	530	530	560
		60 no load	400	410	430	440	450	500
		90 no load	310	330	360	380	400	450
		15 loaded	920	970	1,050	1,050	1,100	1,200
0	All	30 no load	710	690	720	730	740	810
		60 no load	510	530	560	600	620	700
		90 no load	390	430	470	510	540	630
		15 loaded	1,100	1,150	1,250	1,300	1,350	1,500
00	All	30 no load	890	860	900	950	1,000	1,150
		60 no load	630	650	700	770	840	980
		90 no load	480	520	590	650	720	860
		15 loaded	1,300	1,350	1,400	1,500	1,650	1,850
0000	All	30 no load	1,350	1,350	1,400	1,450	1,550	1,750
		60 no load	960	1,000	1,000	1,200	1,300	1,500
		90 no load	730	810	900	1,000	1,100	1,300
		15 loaded	1,900	1,900	2,000	2,100	2,150	2,450

TABLE 14-3 (*Continued*)
TENSION OF SOFT-DRAWN COVERED COPPER WIRE FOR DIFFERENT SPAN LENGTHS
(Light loading districts)

Size AWG No.	Grade of construction	Conditions of load and temperature, °F	Tensions for span length, lb					
			100 ft	125 ft	150 ft	175 ft	200 ft	250 ft
6	A	30 no load	120	115	105			
		60 no load	95	99	97			
		90 no load	80	80	89			
		30 loaded	250	260	270			
6	B and C	30 no load	150	150	135			
		60 no load	115	120	115			
		90 no load	92	105	105			
		30 loaded	280	300	300			
4	All	30 no load	290	280	280	280	280	
		60 no load	210	220	220	230	230	
		90 no load	155	175	185	210	210	
		30 loaded	430	450	470	510	520	
2	All	30 no load	560	550	540	550	520	600
		60 no load	390	410	410	440	440	510
		90 no load	290	320	340	370	700	440
		30 loaded	680	710	740	770	780	900
1	All	30 no load	690	680	700	740	790	850
		60 no load	480	490	530	580	630	710
		90 no load	350	390	430	480	730	610
		30 loaded	790	830	890	950	1,050	1,150
0	All	30 no load	860	850	890	940	990	1,100
		60 no load	600	630	690	750	810	910
		90 no load	440	490	550	610	670	780
		30 loaded	980	1,000	1,100	1,150	1,250	1,350
00	All	30 no load	1,100	1,050	1,100	1,550	1,250	1,350
		60 no load	760	780	840	920	1,000	1,100
		90 no load	550	610	680	760	940	960
		30 loaded	1,150	1,200	1,300	1,350	1,450	1,600
0000	All	30 no load	1,700	1,650	1,700	1,800	1,900	2,050
		60 no load	1,150	1,200	1,300	1,400	1,550	1,700
		90 no load	840	930	870	1,150	1,250	1,450
		30 loaded	1,750	1,800	1,900	2,000	2,150	2,350

the line to be measured for tension. It may also be left on the line while the dial shows the desired reading. The operating principle of the shunt dynamometer is based on the relation of the tension in the conductor to

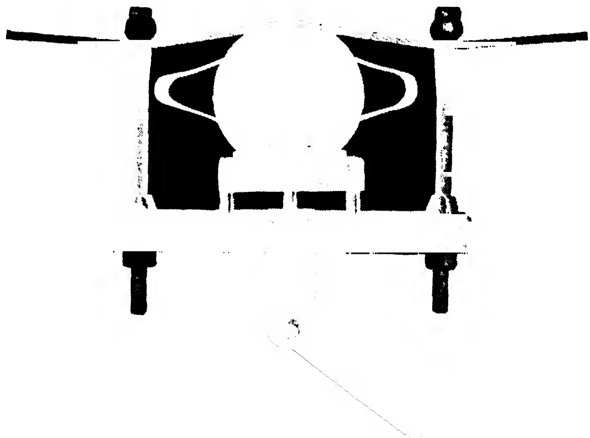


FIG. 14-49. Rear view of shunt dynamometer attached to line conductor. Tension in line conductor compresses spring. To release dynamometer, handle is turned which lowers spring away from conductor. (*Courtesy John Chatillon & Sons.*)

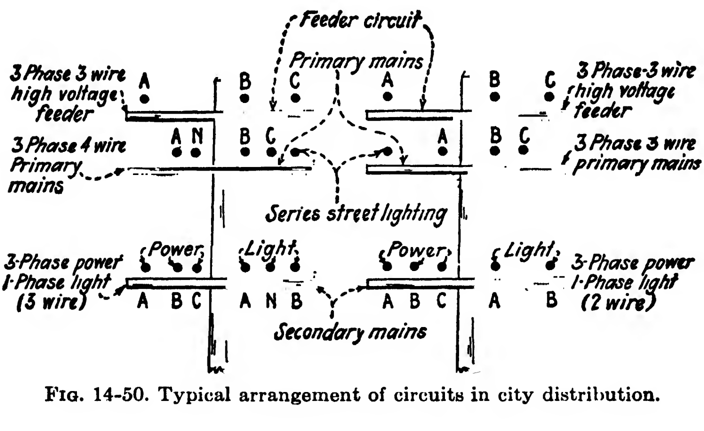


FIG. 14-50. Typical arrangement of circuits in city distribution.

the force necessary to displace it in a direction perpendicular to the axis of tension.

Routing the Conductors. In general, in city distribution, the upper crossarms should be used for the through wires or trunk lines. These are usually the feeders which are also the highest voltage circuits on the pole. The next crossarm below should carry the primary mains and any street-lighting circuits. The lowest crossarms are used for the local wires, such as light and power secondary circuits. The secondary mains are the circuits that must be tapped frequently and should, therefore, be placed low on the pole where they are most accessible (Fig. 14-50).

As far as possible, wires and circuits should be kept in the same positions on the poles in order to facilitate the tracing of circuits, and to prevent accidents due to misunderstanding as to the service the various wires on the pole supply. A rule often followed to identify the phases of a three-phase circuit is as follows: When the lineman standing under a circuit has his back to the source of power (substation or generating station) phase *A* shall be the left-hand conductor, phase *B* the middle

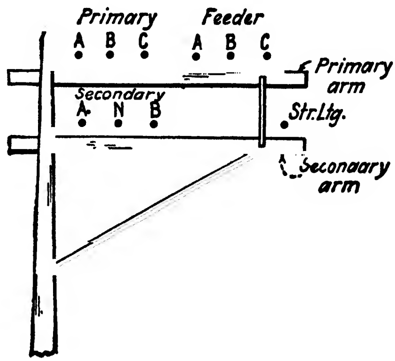


FIG. 14-51. Arrangement of circuits on alley arm.

conductor, and phase *C* the right-hand conductor. The circuit thus runs *ABC* from left to right.

Furthermore, the conductors of a given circuit should be grouped together. In case of a three-wire secondary circuit on crossarms, the neutral should be located in the middle of the other two wires. In case of a three-phase four-wire feeder, the neutral wire should be placed next to the pole. One line wire should be placed on the same side as the neutral and the other two line wires on the other side of the pole.

On alley or side arms, the high-voltage circuits should be placed on the ends of the arms and the low-voltage circuits near the pole (Fig. 14-51). In this way the danger of accidents is greatly reduced.

In heavier alley circuits, H-frame alley construction is resorted to as illustrated in Fig. 14-52. The high-voltage feeders are mounted on the top crossarm, the primary is mounted on the middle crossarm, and the low voltage secondaries are mounted vertically above the lowest crossarm. Mounting the secondaries vertically facilitates taking off the service drop connections.

Releasing Pulling Blocks. After the conductors are pulled up, a temporary dead end must be provided to hold the conductors until the next stretch of wire is pulled up and held. This temporary dead end is generally arranged for by running a head guy from the top of the last pole *a* to the butt of the next one *b*. A lineman then climbs pole *a* and hitches a come-along to the crossarm by means of a rope sling and then reaches out and slides the come-along along the wire as far as possible so that the grip will hold the wire when the pulling blocks are released. A

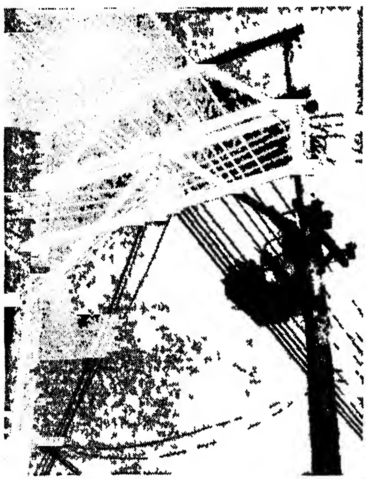


FIG 14-52 H-frame alley construction. This type of construction is very rigid and makes possible supporting heavy loads, capacitors, and transformer banks Note vertical arrangement of secondaries and services (*Courtesy Iowa-Illinois Gas and Electric Co*)

sketch showing how the setup appears when completed is shown in Fig. 14-53.

After dead-ending or snubbing is completed, the pulling blocks should be gradually released. If they should be released with a jerk, an

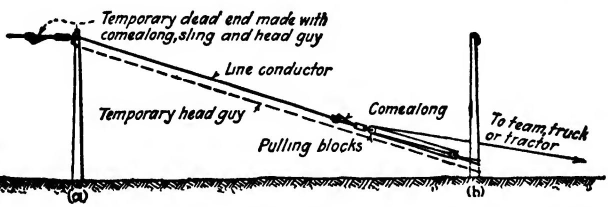


FIG. 14-53 Sketch showing manner of pulling up a line conductor and providing temporary dead end This dead end is not removed until the conductor is tied in and the next stretch is pulled up and held

abnormal stress may be placed on the conductors and their supports which might result in a failure such as the snapping of a pin, a crossarm, a guy, or even a pole in extreme cases.

TYING IN

Position of Conductor on Insulator. Conductors should occupy such a position on the insulator as will produce minimum strain on the tie wire. The function of the tie wire is only to hold the conductor in place on the insulator, leaving the insulator and pin to take the strain of the conductor.

In straight-line work the best practice is to use a top-groove or *saddle-back* insulator. These insulators all carry grooves on the side as well. When the conductor is placed in the top groove (Fig. 14-54*a*), the tie wire serves only to keep the conductor from slipping out. The groove practically relieves the tie wire of any strain and allows the entire strain

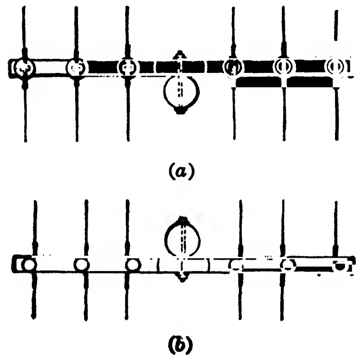


FIG. 14-54. Position of wires on insulator in straight-line work for (*a*) top-groove insulators and (*b*) side-groove insulators. Top-groove insulators are generally used with conductors size 0 and larger and side-groove insulators with size 2 and smaller.

to be placed on the insulator and pin. When side-groove insulators are used in straight-line-work, the wires should be placed as shown in Fig. 14-54*b*. The conductors on the pins nearest to the pole are placed on the side away from the pole. This is to increase the climbing space for the lineman. All other wires are placed on the pole side of the insulator. This prevents the conductors on the end pins from falling in case their tie wires break.

On corners and angles where the wires are not dead-ended, the conductors should be placed on the outside of the insulators (Fig. 14-55),

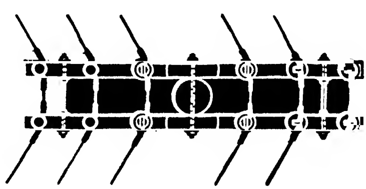


FIG. 14-55. Position of wires on both top- and side-groove insulators at angles. All conductors are placed on side of insulator so that pull is against insulator.

irrespective of the type of insulator employed. This puts the conductor pull against the insulator instead of away from the insulator.

Kinds of Insulator Ties. Conductors are fastened to insulators by the use of either (1) wire ties or (2) clamps. Wire ties are used throughout in distribution systems and almost entirely on transmission lines where the pin insulator is employed. Insulator clamps are used to a slight extent on high-voltage pin-insulator lines and entirely on suspen-

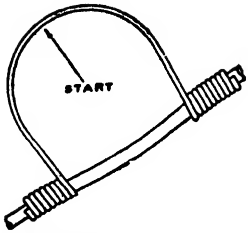


FIG. 14-56. Western Union side-groove tie.

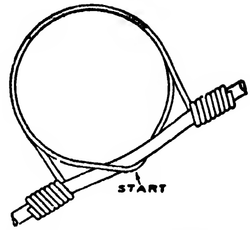


FIG. 14-57. Looped Western Union side-groove tie.

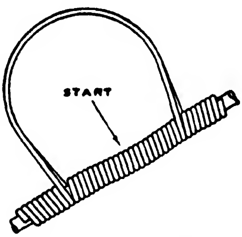


FIG. 14-58. Armored Western Union side-groove tie.

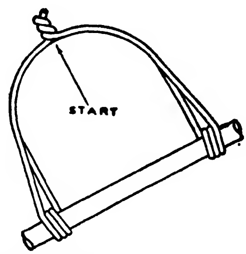


FIG. 14-59. Horseshoe side-groove tie.

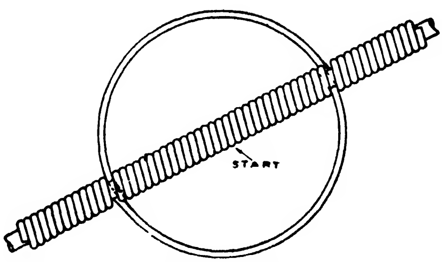


FIG. 14-60. Armored-top top-groove tie.

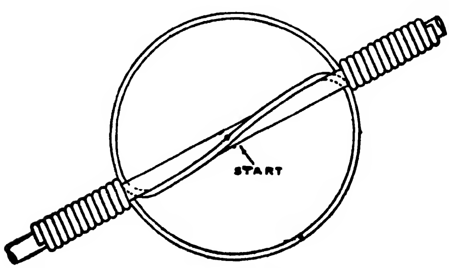


FIG. 14-61. Cross-top top-groove tie.

sion insulators. The manner of fastening conductors with clamps will be illustrated in a succeeding section.

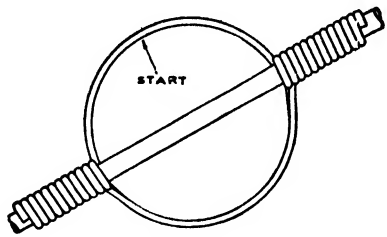


FIG. 14-62. Bridle-top top-groove tie.

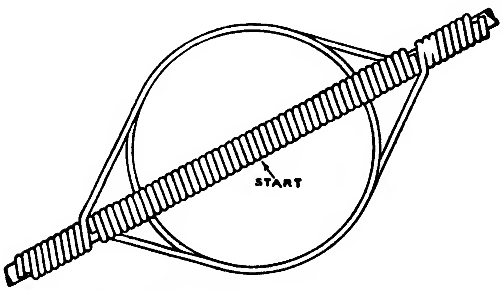


FIG. 14-63. Stirrup top-groove tie.

Wire Tires. The following wire ties have been extensively used in the past and some of them are still used on low-voltage distribution lines.

Side-groove ties:

1. Western Union
2. Looped Western Union
3. Armored Western Union
4. Horseshoe

Top-groove ties:

1. Armored top
2. Cross top
3. Bridle top
4. Stirrup, two-piece

Figures 14-56 to 14-63 illustrate the eight kinds of insulator ties listed above. Each figure shows a cut of the plan view of the tie with the insulator removed. All ties are started in the middle of the tie wire as both halves are identical.

Conductor-reinforcing Ties. Ties used for tying conductors to pin-type insulators should be relatively simple and easy to apply. They

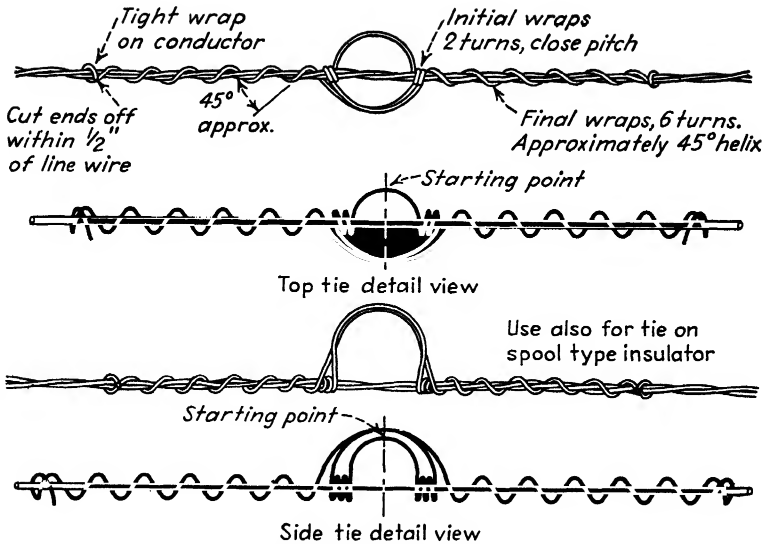


Fig. 14-64. Single-pin-type insulator tie for copper conductors. (*Courtesy Copper Wire Engineering Association.*)

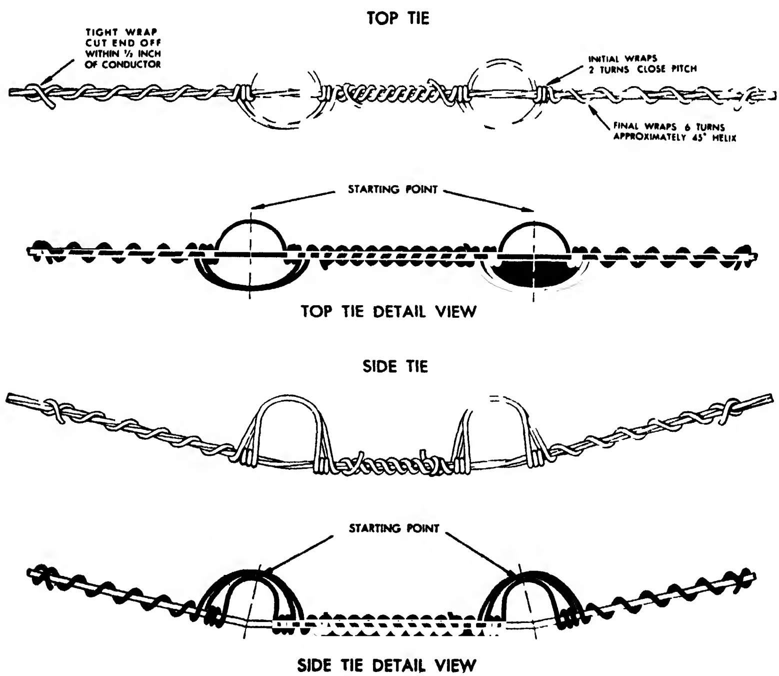


Fig. 14-65. Double-pin-type insulator tie for copper conductors. (*Courtesy Copper Wire Engineering Association.*)

should bind the line conductor securely to the insulator and, in addition, should reinforce the conductor on both sides of the insulator. Any looseness between the conductor, tie wire, and insulator will result in chafing and injury to the conductor.

The hand-wrapped ties illustrated in Figs. 14-64 to 14-67 have been widely used and when properly applied give excellent service. These

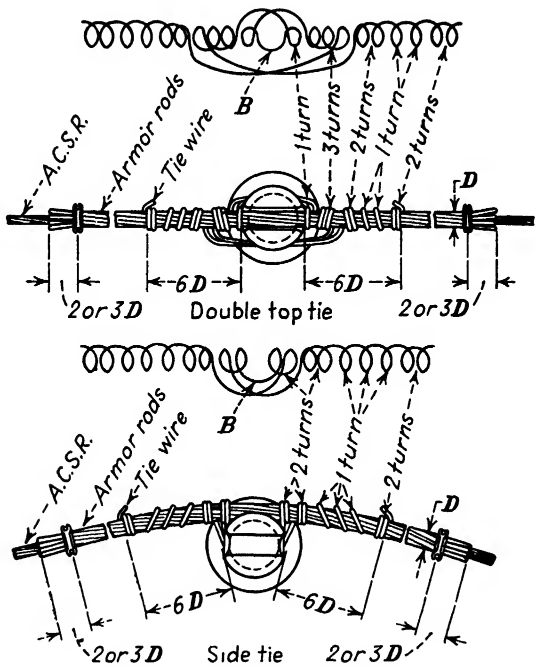


FIG. 14-66. Single-pin-type insulator tie for ACSR and aluminum cables equipped with armor rods. (*Courtesy Aluminum Company of America.*)

ties should be applied by hand without the use of pliers, and care should be taken to use the proper length and size of fully annealed tie wire specified for each conductor.

Kind of Tie Wire to Use. In general, the tie wire should be the same kind of wire as the line wire. If the line wire is a bare conductor, the tie wire should be bare also; if the line conductor is insulated, the tie wire should also be insulated. Copper tie wires should be used with copper line conductors and aluminum tie wires with aluminum line conductors. The tie wires, however, should always be made of soft-annealed wire as the hard-drawn tie wire would be too brittle and cannot be wrapped snugly. A hard tie wire might also injure the line conductor.

A tie wire should never be used the second time.

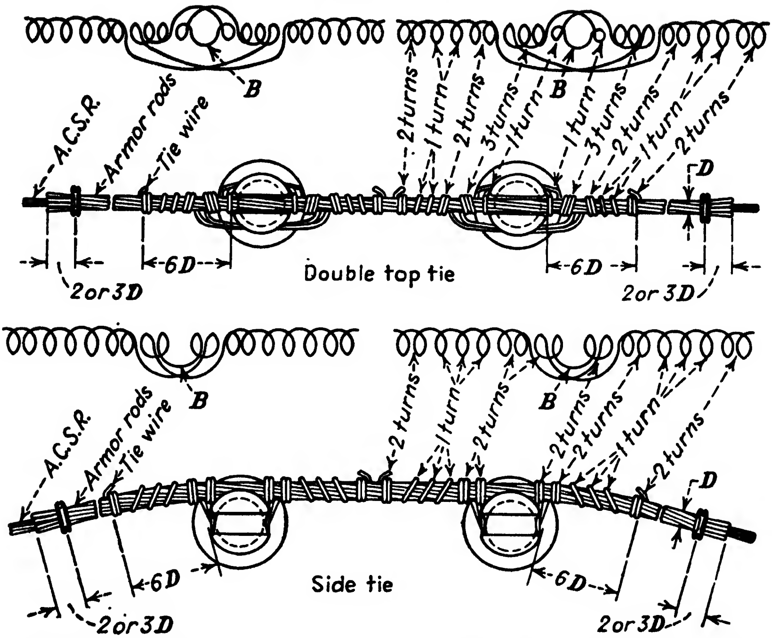


FIG. 14-67. Double-pin-type insulator tie for ACSR aluminum cables equipped with armor rods. (*Courtesy Aluminum Company of America.*)

Size of Tie Wire. Good practice is to use No. 6 tie wire for line conductors of sizes No. 4 and smaller, No. 4 tie wire for line conductors No. 1 to No. 4, and No. 2 tie wire for line conductors No. 0 and larger, as shown in Table 14-4.

TABLE 14-4. SIZE OF TIE WIRE TO USE WITH VARIOUS SIZES OF LINE CONDUCTORS

Size of Line Conductor, B. & S. Gage	Size of Tie Wire, B. & S. Gage
No. 4 and smaller	No. 6
No. 1 to No. 4	No. 4
No. 0 and larger	No. 2

Length of Wire. The length of the tie wire varies from 3 ft for a simple tie on a small insulator to 25 ft for a stirrup tie on a 50,000-volt insulator. The approximate lengths for various ranges of conductor sizes for some of the common ties are given in Table 14-5.

Rules on Good Tying Practice. 1. Use only fully annealed tie wire.

2. Use a size of tie wire which can be readily handled, yet one which will provide adequate strength.

3. Use a length of tie wire sufficient for making the complete tie, including an end allowance for gripping with the hands. The extra length should be cut from each end after the tie is completed.

TABLE 14-5. APPROXIMATE LENGTH OF TIE WIRES REQUIRED FOR DIFFERENT TYPES OF TIES

Type of Tie	Length of Tie Wire
Western Union	No. 000 bare cable, 54 in. 2,000,000-cir mil cable, 87 in.
Bridle	No. 0000 bare cable, 54 in. 2,000,000-cir mil cable, 87 in.
Horseshoe	All sizes, 39 in.
Armored Western Union	All sizes, 102 in.
Armored top	All sizes, 114 in.
Stirrup	All sizes, two pieces—each 54 in.

4. A good tie should
   a. Provide a secure binding between line wire, insulator, and tie wire.
   b. Have positive contacts between the line wire and the tie wire so as to avoid any chafing contacts.
   c. Reinforce line wire in the vicinity of insulator.

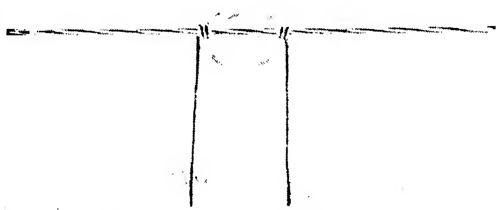
Bend tie wire around insulator *above* conductor to form a U. Both legs of the tie wire should be of equal length after binding.

Holding tie wire tightly against insulator, throw two tight close wraps around conductor on each side of the insulator—then cross legs of tie wire around insulator.

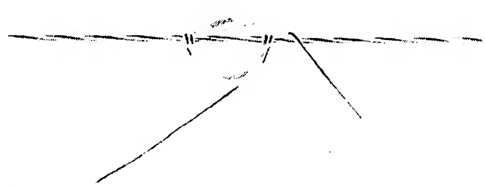
Finish like top tie with six tight 45-deg spiral wraps on each side of the insulator. Bend back ends and cut off.

FIG. 14-68. Steps in making side tie. (*Courtesy Copperweld Steel Co.*)

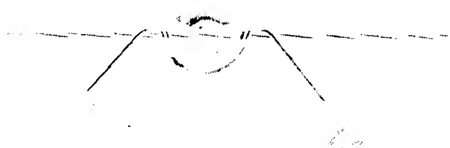
Bend annealed tie wire of proper size and length around insulator *under* the conductor, forming a U. Both legs of tie wire should be of equal length after bending.



Holding the tie wire tightly against the insulator, throw two tight close wraps around the conductor on each side of the insulator, keeping these wraps snugly against the conductor.

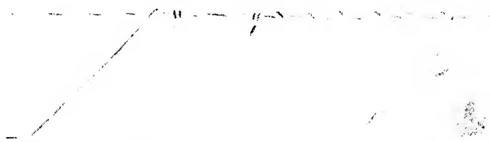


Cross the legs of the tie wire around the insulator, right to left and left to right.

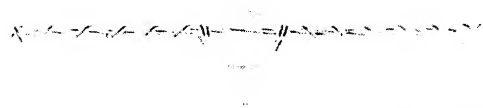


With both legs of the tie wire crossed, tightly wrap each leg spirally around the conductor at an angle of 45 deg.

FIG. 14-69. Steps in making top tie.



Complete six spiral 45-deg wraps on each side of the insulator, bending back the ends and cutting them off short.



The finished top tie—made properly and tightly—will greatly reduce any possibility of conductor chafing at the insulator.

Fig. 14-69 (*Continued*). Steps in making top tie. (*Courtesy Copperweld Steel Co.*)

5. Apply without the use of pliers.
6. Avoid nicking the line wire.
7. Do not use a tie wire which has been previously used.
8. Do not use hard-drawn wires for tying or fire-burned wire which is usually either only partially annealed or injured by overheating.

Steps in Making Ties. The simplest tie is the Western Union tie. It is universally used in distribution systems and is made as follows:

Place the middle of the tie wire on one side of the insulator and the cable on the other side, both bearing in the side groove. Each end of the tie wire is then brought around the neck of the insulator, but underneath the cable, then up and around the cable, and served closely for about seven wraps.

The looped Western Union is quite similar except that the start is made on the cable side and the two ends are wound around the insulator once before being wrapped.

Side Tie. The steps in making a typical form of transmission-line side tie are illustrated in Fig. 14-68.

Top Tie. The steps in making a typical form of transmission-line top tie are illustrated in Fig. 14-69.

CONDUCTOR VIBRATION

Causes. Any conductor supported aboveground in long spans under relatively high tension is subject to vibration. Such vibration is caused by the passage of air over the conductor at right angles to the line. As the air blows over the conductor, eddy currents are set up on the leeward side. These eddy currents oscillate, first in one direction and then in the other. When the frequency of these eddies corresponds to some natural frequency of the line conductor, a tendency to vibrate exists. Changes in velocity or direction of wind dampen the original vibration and set up

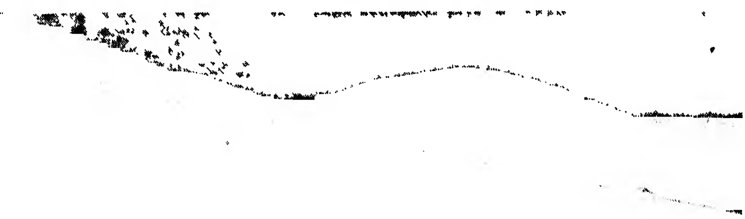


FIG. 14-70. The Stockbridge damper clamped to transmission-line conductor to reduce conductor vibration by changing natural frequency of line conductor. (*Courtesy Aluminum Company of America.*)

new ones. It is for this reason that a steady gentle breeze may set up far more destructive vibrations than high winds of unsteady force and direction.

Conductor Failure. Under certain conditions these vibrations may build up an amplitude which produces alternating stresses large enough

FIG. 14-71. ACSR line conductor cable reinforced with armor rods. These armor rods reduce vibration and protect against chafing and flashover at point of support. Increased conductor size at support provides better grip for tie wire and also reduces danger of cable slippage. (*Courtesy Aluminum Company of America.*)

to cause fatigue failure. The failure usually takes place at the point of support, very seldom at a dead end or at a joint. Failure may not be experienced over a period of years, or it may develop in a few months. When a vibration passes through a wire, the conductor tends to conform

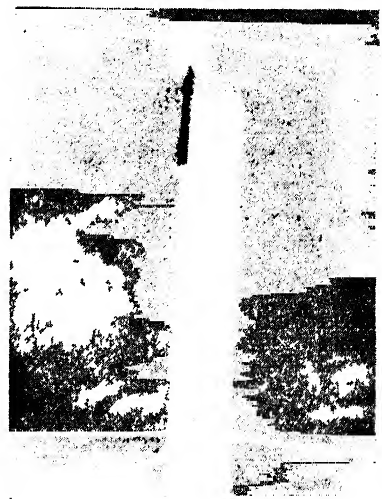


FIG. 14-72. Typical single-phase rural line illustrating the use of armor rods to minimize the effects of conductor vibration. (*Courtesy Ohio Brass Co.*)

to the wave form of the vibration. When this vibration encounters some obstacle such as a supporting clamp, it may be reflected back on itself with consequent increase in destructive stresses. More destructive still is the effect of two vibrations of similarly directed bending tendencies meeting at opposite ends of a common supporting clamp.

Remedies. Vibration fatigue of conductors may be prevented either by reinforcing the conductor at points of stress to resist the effects of repeated bending or by reducing the vibration to negligible and harmless

FIG. 14-73. Lineman applying armor rods to ACSR conductor cable. Special tools are used to twist the rods around the cable. (*Courtesy Aluminum Company of America.*)

amplitudes with damping devices. One form of damper known as the "Stockbridge" damper is illustrated in Fig. 14-70.

Another form of efficient protection is reinforcement with armor rods, as illustrated in Figs. 14-71 and 14-72. This armor consists of a spiral layer of round rods surrounding the conductor for a short distance (see Fig. 14-73). The attachment of the conductor to its support is made in the middle of this armored length (see Fig. 14-72). Since this provides a cable of much larger diameter then the conductor itself, the resistance to bending is greatly increased. This not only reduces the stress by distributing the bending but also strengthens the cable in the region of maximum bending stress.

SECTION 15

Installing Transformers and Lightning Arresters

INSTALLING TRANSFORMERS

Methods of Mounting. Small transformers are either fastened directly to the pole or hung from crossarms. Larger transformers are mounted on special racks or platforms Transformer banks composed

FIG. 15-1. Distribution transformer provided with direct-to-pole mounting brackets Transformer is rated 5 kva, 12,470/7,200 to 120/240 volts, 60 cycles (*Courtesy General Electric Co*)

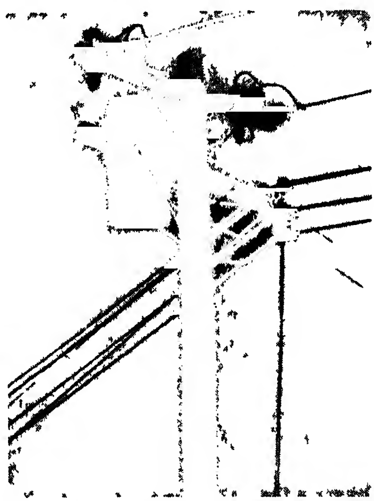


FIG 15-2. Illustration showing distribution transformer mounted on crossarm (*Courtesy Line Material Co*)

of two or three medium-sized transformers are usually also mounted on racks or platforms Figure 15-1 illustrates a distribution transformer bolted directly to the pole, Fig. 15-2 illustrates a distribution transformer mounted on a crossarm, and Fig. 15-3 illustrates a small power bank mounted on a platform. Very large transformers, however, are set directly on the ground (Fig. 15-4). A high fence must then be provided to keep persons from coming in contact with the live parts.

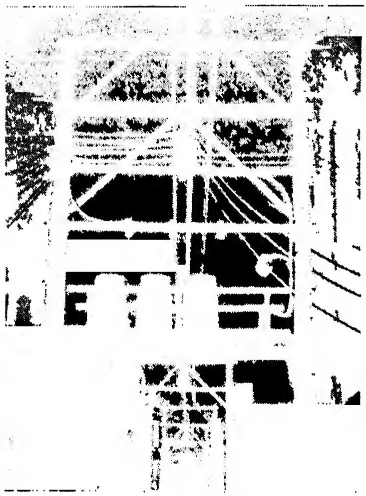


Fig 15-3 Three single-phase transformers connected into a three-phase bank and mounted on a platform supported by two poles (*Courtesy Iowa-Illinois Gas and Electric Co*)

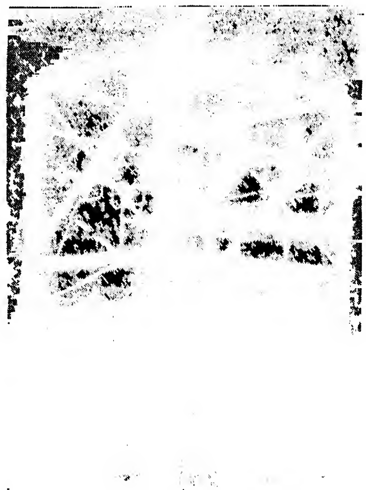


Fig 15-4 Three-phase transformer bank set on ground Note enclosing fence (*Courtesy Electrical Engineers Equipment Co*)

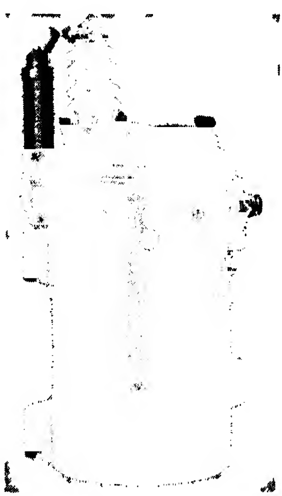


Fig 15-5 Distribution transformer supported by direct to pole mounting. Transformer is fastened to pole by bolts passing through special brackets and pole. (*Courtesy General Electric Co.*)

Fig 15-6. Raising steel I beam for an aerial platform setting Both ends of beams are lifted simultaneously by means of two hand lines, one on each pole. Note groundmen standing clear of two-pole structure (*Courtesy American Gas and Electric Service Corp*)

Small distribution transformers can be bolted directly to the pole by means of special brackets, Fig 15-5, or hung from the top crossarm when there is only one crossarm on the pole. As a rule, transformers hung on crossarms should not exceed 25 kva. If there are two or more crossarms on the pole, the transformer should be hung on the lowest arm, or even lower on separate arms It is good practice to use double crossarms with each transformer installation

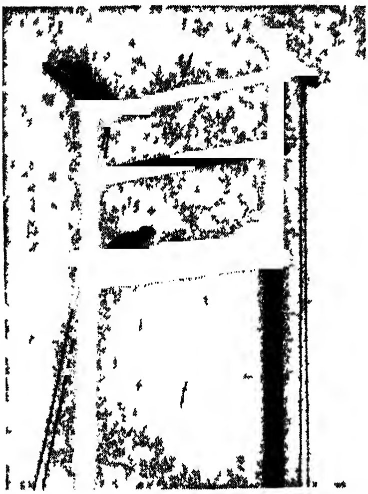


Fig 15-7 Installing planks on a two-pole aerial transformer platform (*Courtesy American Gas and Electric Service Corp*)

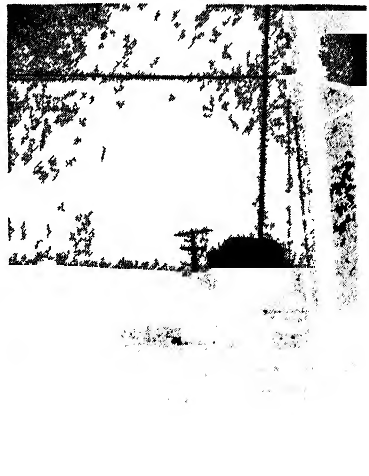


Fig 15-8 Hoisting a 15-kva single-phase distribution transformer to top of pole Note use of lifting block and guide line on transformer Also note hangers already bolted to transformer case Truck winch will provide motive power Winch is operated by truck driver sitting in driver s seat (*Courtesy Wisconsin Electric Power Co*)

Transformers should not be mounted on junction or buck-arm poles, as it makes working on such poles more hazardous for the lineman

Platforms are built of any shape or size to suit local conditions If the structure is to be permanent, the supporting members should be steel. Steel makes a good appearance and requires no maintenance (see Fig 15-6). The supporting members should be covered with flooring (see Fig. 15-7).

Hoisting the Transformers. The hoisting of the transformers is done by means of block and tackle. Figures 15-8 and 15-9 illustrate the manner of performing this operation. One set of blocks is supported by a stub extension on the top of the pole, and the other is hitched to a rope fastened to the transformer case as shown The pulling line runs through a snatch block tied to the pole near the ground. The pulling should always be done with mechanical power if possible. The line truck is generally used for this purpose. Figures 15-10 and 15-11 show a transformer being hoisted onto a platform. The platforms are always built narrow so as not to interfere with the raising or lowering. The

FIG. 15-9. Hoisting distribution transformer up pole. A 15-kva single-phase distribution transformer being hoisted to first gain. Man at truck winch controls the speed at which the transformer rises. Man on the pull-out rope is pulling the transformer away from the pole to clear the crossarm in second gain. Lineman on the pole is ready to hook the transformer hanger on hanger bolts. The pole-top extension is lashed to the pole with two lash ropes. Its lower end has a saddle which fits snugly over the secondary arm. Its purpose is to make it possible to raise the transformer higher than the top of the pole in order to hook it over the hanger bolts. Its vertical arm, with the eyebolt which holds the upper end of the block and tackle, can be moved through a small arc to center the transformer. (*Courtesy Wisconsin Electric Power Co.*)

upper support is obtained by means of a rope tied around the top of the pole supporting the platform. A rope tied to the transformer is used to guide the transformer as it is raised.

A special pole-top extension useful in hoisting transformers is illustrated in Fig. 15-12, and the manner of attaching it to the pole with chain is clearly shown.

Connections. The matter of transformer connections was treated quite fully in Sec. 5 and will not be dealt with here except to point out a few general facts.

Single Phase. When only one transformer is to be connected to a primary main, the connection is almost obvious. The two leads from the primary winding are connected to the two primary mains through a pair of cutout fuses, as shown in Fig. 15-13. The connection of the secondary coils depends upon the type of secondary service mains. If

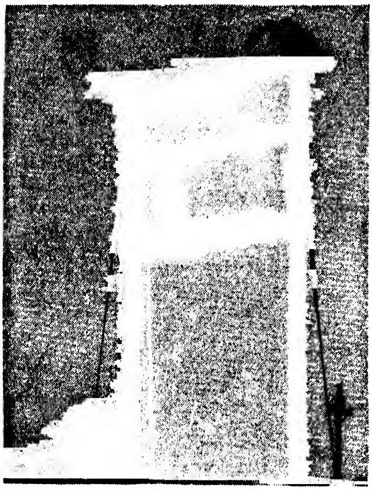


FIG. 15-10. Hoisting a 75-kva single-phase transformer onto transformer platform. Note use of hoisting block, pull-out rope, and snatch block at base of pole. (*Courtesy American Gas and Electric Service Corp.*)

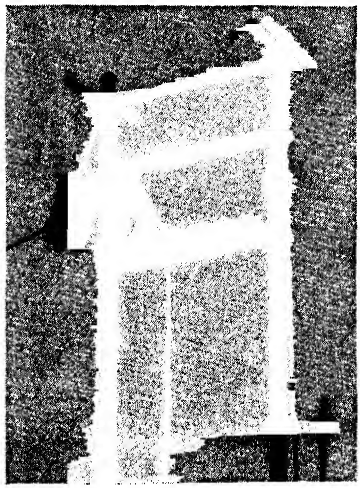


FIG. 15-11. Placing the 75-kva transformer onto the platform. Pull-out rope is taut to help transformer clear planking on platform. (*Courtesy American Gas and Electric Service Corp.*)

only 120-volt two-wire service is desired, the two secondary coils are connected in parallel, as shown in Fig. 15-13, and the two leads run to the two secondary mains. If 120/240-volt three-wire service is desired, the two secondary coils are connected in series, and then the leads from the two ends and one from the middle junction connect to the three wires of the secondary mains (Fig. 15-14). The wire leading from the junction is called the "secondary neutral wire."

The order of the above operations should be as follows:

1. Connect transformer primary leads to the primary cutouts.
2. Connect one side of each primary cutout to each line wire.
3. Connect the secondary leads to the secondary line.
4. After all necessary tests are made, insert the primary cutouts.

Three Phase. When three single-phase transformers are connected into a bank to form a three-phase bank (see Fig. 15-15), the two connections in common use are the Y-delta and the delta-delta. The former is used on 4,150-volt four-wire three-phase primary mains, and the latter on 2,400-volt three-wire three-phase mains. As pointed out in Sec. 1, a delta connection is obtained by connecting the windings of the three transformers in series forming a closed loop and tapping off at the junctions for the lines. The Y connection is obtained by connecting

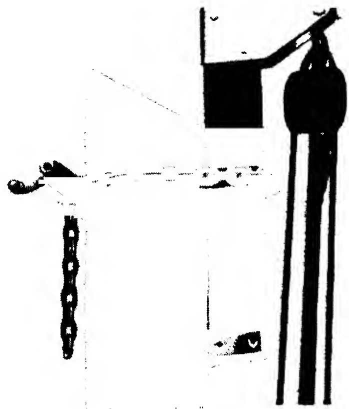


FIG. 15-12. Special pole-top extension used in hoisting distribution transformers. Note attachment provided for upper support of block and tackle. (*Courtesy James R. Kearney Corp.*)

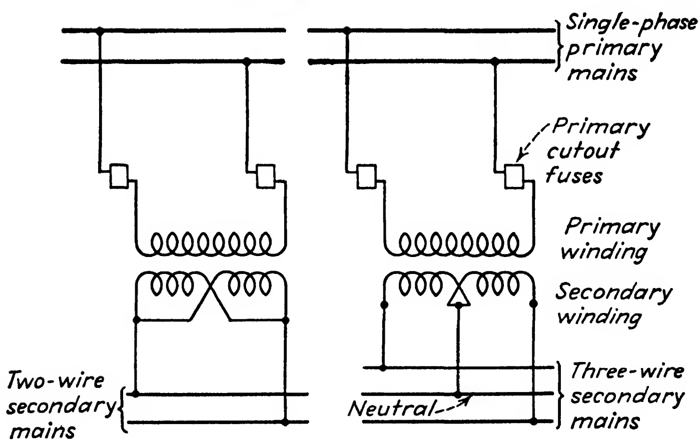


FIG. 15-13. FIG. 15-14.

FIG. 15-13. Transformer connected to two-wire secondary mains. Secondary coils are connected in parallel.
FIG. 15-14. Transformer connected to three-wire secondary mains. Secondary coils connected in series.

a corresponding lead from each of the three windings together and using the remaining three free ends for the line leads. Figures 15-16 and 15-17 show the manner of using the polarity markings on the windings to connect three single-phase transformers correctly into a Y-delta and delta-delta bank, respectively. The connections, however, should be further checked as described in the following paragraph. Figure 15-18 illustrates quite well how a transformer bank appears when the secondaries are connected delta. This figure also illustrates good practice in

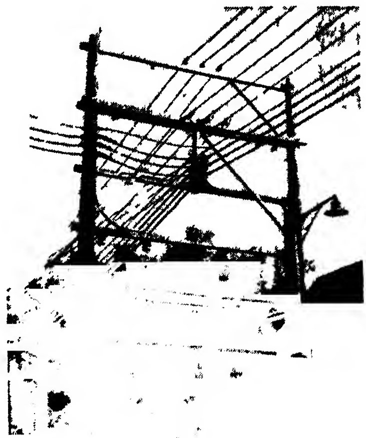


FIG. 15-15. Three-phase transformer bank having secondary windings connected in delta. Leads from secondary windings are mounted vertically in order to facilitate connecting service lines. (*Courtesy Iowa-Illinois Gas and Electric Co.*)

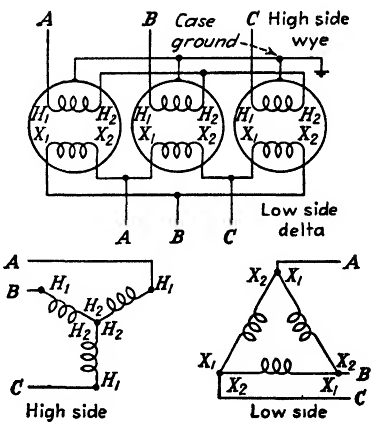


FIG. 15-16. Three single-phase transformers correctly connected to form a Y-delta three-phase transformer bank. As shown, on the Y side, the H_2 terminals are connected together to form a neutral. The H_1 terminals are connected to the supply lines A, B, and C. On the delta side, the X_1 terminal of one winding connects to the X_2 terminal of the second, the X_1 of the second to the X_2 of the third, and the X_1 of the third to the X_2 of the first. The secondary lines lead from the junctions to the load lines A, B, and C.

secondary bus mounting as well as in platform construction. Figure 15-19, similarly, illustrates a Y connection on the primary of a three-phase bank.

In connecting transformers into a three-phase bank, the primary connections should be made first, whether the primary is to be Y or delta. The primary leads may then be connected to the primary mains through the regular cutout fuses. In making the secondary connection, how-

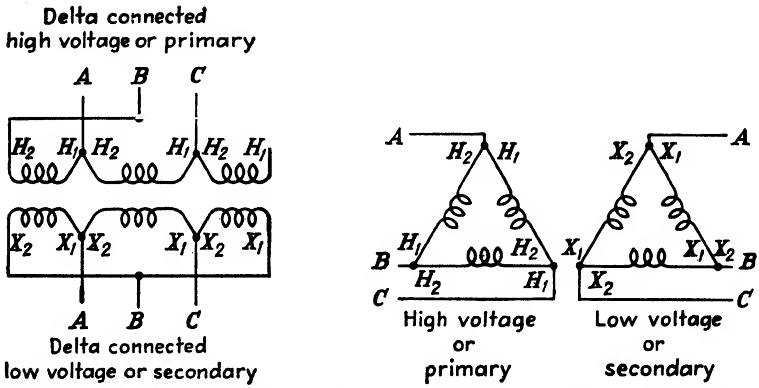


FIG. 15-17. Three single-phase transformers correctly connected to form a delta-delta three-phase transformer bank. As shown, the H_1 terminal of one primary winding is connected to H_2 of second primary, H_1 of second is connected to H_2 of third, and H_1 of third is connected to H_2 of first. Likewise, on the secondary, X_1 of first secondary winding is connected to X_2 of second, X_1 of second is connected to X_2 of third, and X_1 of third is connected to X_2 of first. This puts three windings of the primary correctly in series, and three windings of the secondary correctly in series. Primary and secondary line leads are connected to junctions between windings.

FIG. 15-18. Installing bus work on a three-phase transformer bank. The three single-phase transformers, each rated 75 kva, constitute a 225-kva three-phase bank. (*Courtesy American Gas and Electric Service Corp.*)

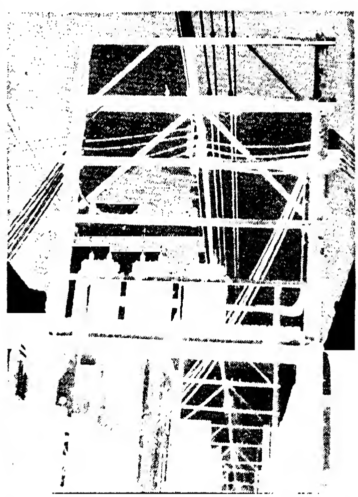


FIG. 15-19. Three-phase transformer bank having primary windings connected Y. Note three corresponding leads from transformer connected into neutral and remaining three leads connected to lines. (*Courtesy Iowa-Illinois Gas and Electric Co.*)

ever, more care must be exercised as there is a possibility of short-circuiting the bank.

Checking Secondary Delta Connection by Means of Fuse Wire. One procedure is to complete both the primary and the secondary connections before the bank is connected to the primary mains. A short length of small-sized fuse wire is inserted in the delta of the secondary, as shown in Fig. 15-20. Then the primary leads are connected to the primary

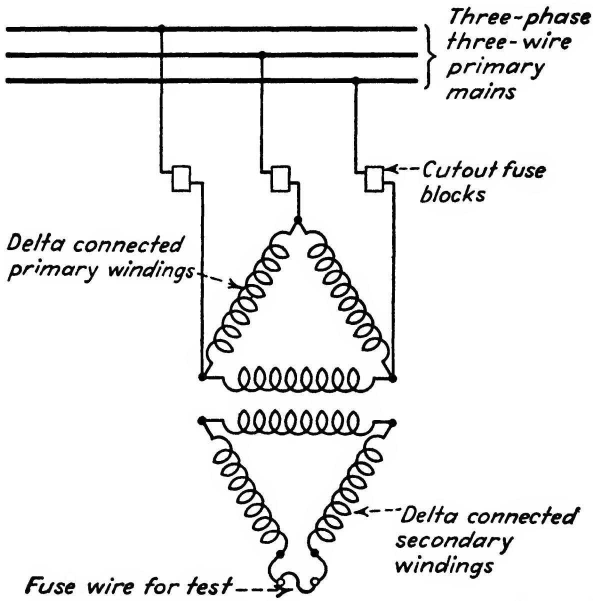


FIG. 15-20. Delta-connected transformer bank showing fuse wire inserted in secondary to test connection. If the fuse blows, one of the phases of the secondaries must be reversed.

mains by inserting the cutout fuses. If the fuse wire in the secondary does not blow when the bank is energized, the connection is OK. If the fuse blows, however, the secondary winding of one of the three transformers is reversed and the leads from it must be interchanged. Since it is not possible to tell which secondary winding must be reversed, one winding is reversed at a time and the fuse test repeated. When the fuse ceases to blow, the connection is correct.

Checking by Use of Voltmeter or Lamp. Another way of checking the secondary connection is by the use of a voltmeter or lamp. It should have a voltage rating equal to twice the secondary line voltage. The lamp or voltmeter is connected in place of the fuse wire used in the method described above (see Fig. 15-21). If the connection of the delta is correct, the lamp will not burn and the voltmeter will read zero or almost zero. But if one of the transformers is reversed, the lamp will burn brightly. If the voltmeter is used instead of the lamp, it will indicate a voltage equal to twice the voltage of one of the secondary windings. Under these conditions the delta must not be closed for a severe short circuit would result. To correct the connection, reverse the leads from one of the secondaries and repeat the test. If this does not correct

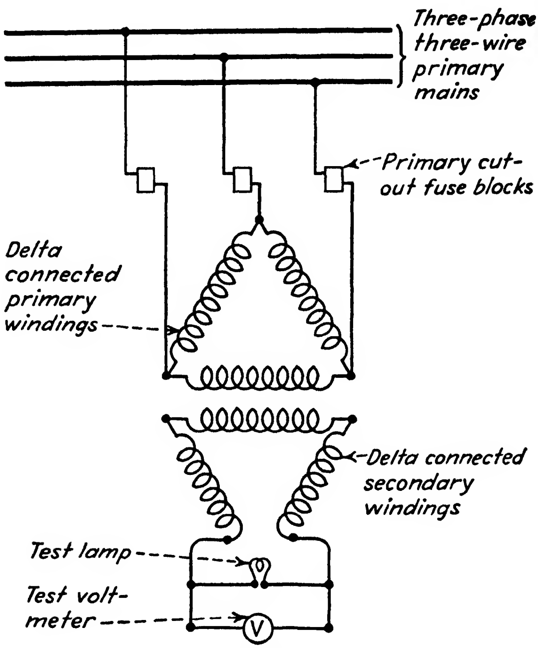


FIG. 15-21. Use of lamp or voltmeter in testing out delta connection on three-phase transformer bank. When lamp tests dark or voltmeter reads zero, the delta connection is correct.

the connection, reverse the secondary of another transformer and repeat the test. When the lamp fails to burn or the voltmeter reads zero, the delta connection is correct.

On higher voltage secondaries a small step-down potential transformer with a lamp connected to its secondary can be used in place of the lamp, voltmeter, or fuse mentioned above.

Checking Single-phase Connections. If a single-phase transformer is to be connected onto a live secondary main, care must also be taken to avoid a short circuit. The fuse wire or lamp test can also be employed here. The lamp is perhaps faster and safer. If a lamp is used, connect it across live secondary leads first to test the lamp. If the lamp burns, the lamp is in good condition. After the primary is connected, connect one lead of the secondary winding onto one of the secondary mains.

Then connect the lamp across the remaining secondary winding lead and the remaining secondary main (Fig. 15-22). If the lamp fails to burn, the connection is OK, and if it burns the two secondary leads should be interchanged.

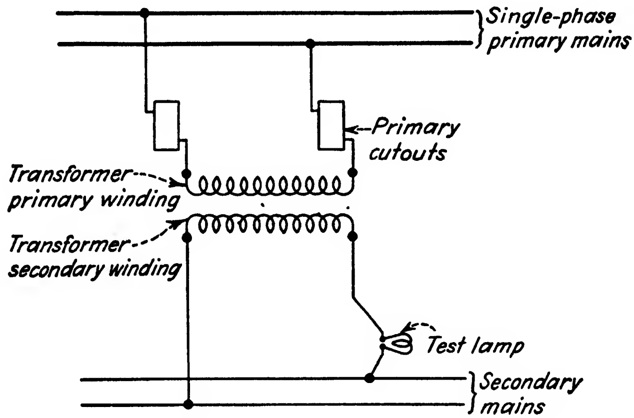


FIG. 15-22. Use of test lamp in connecting a distribution transformer to live secondary mains. When lamp tests dark, secondary leads are properly connected to secondary mains.

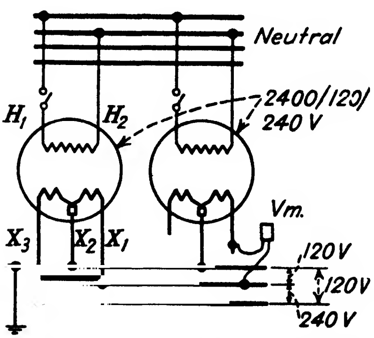


FIG. 15-23. Paralleling two single-phase transformers each for 120/240-volt three-wire service using voltmeter.

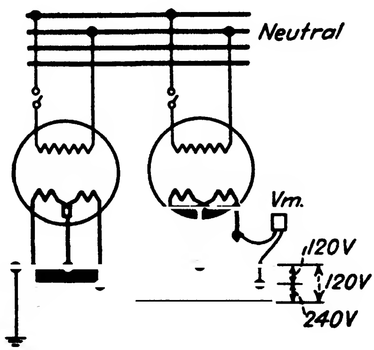


FIG. 15-24. Paralleling a single-phase transformer two wire, 120 volts with another connected three wire, 120/240 volts using voltmeter. One of two possible connections.

If the live secondary circuit is a three-wire secondary, connect the neutral lead to the grounded neutral first. Then test for voltage between one of the remaining secondary leads and one of the secondary mains as shown in Fig. 15-23. If this is the proper connection, the voltmeter will read zero or very nearly zero. To avoid confusion, it is best to connect this lead immediately to the secondary main. Now pro-

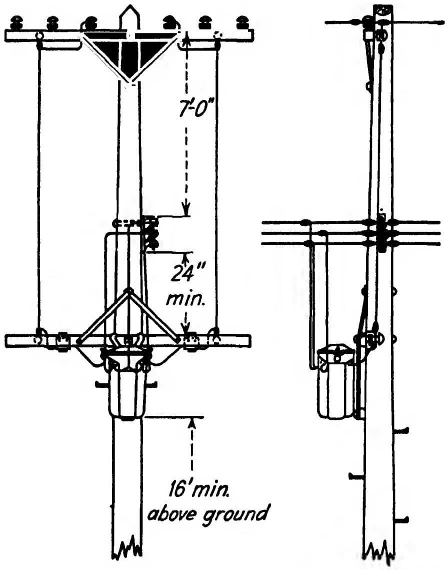


FIG. 15-25. Front and side of distribution-transformer installation. Design and dimensions given indicate good practice. Note location of primary cutout fuses.

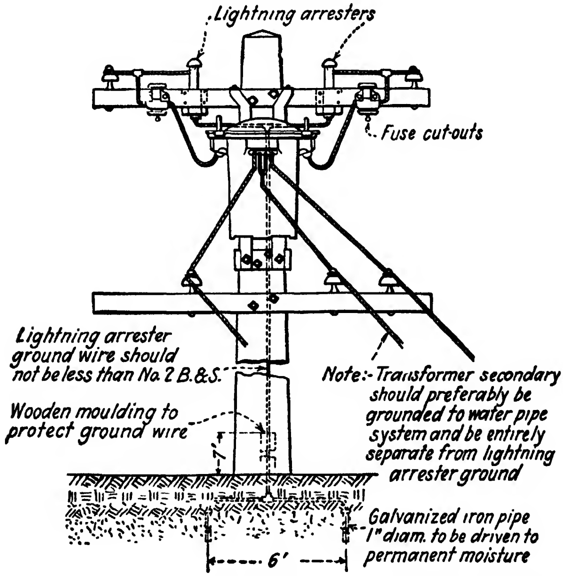


FIG. 15-26. Lightning arresters installed on transformer pole. Sketch illustrates the following features required for maximum protection: (1) arresters on same pole as transformers, (2) short direct wiring for arrester circuit, (3) reliable ground connection for arrester. (*Courtesy General Electric Co.*)

ceed to the last lead and last secondary main. This, of course, should also read zero. After completing this connection, the new transformer is in parallel with other transformers connected to the same secondary mains and will share the load connected thereto.

Figure 15-24 shows the procedure to be followed in connecting a two-wire 120-volt transformer to a three-wire 120/240-volt secondary.

Mounting Cutout Fuses. Transformers should always be protected on their primary side, so that the transformer will be disconnected from the line in case of trouble. The type of fuse used to protect distribution transformers up to 25-kva size was described in Sec. 7. It is called a "cutout" fuse because it can be removed by the lineman. Such fuses are mounted on the crossarm on which the transformer is hung in order to be readily accessible to the lineman. Figure 15-25 illustrates a complete distribution-transformer installation and shows the location of the primary fuses. The illustration also represents good practice in modern distribution construction. The fuses are fastened against the side of the crossarm by means of light bolts.

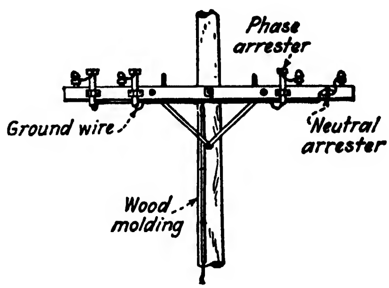


FIG. 15-27. Installation of lightning arresters on three-phase four-wire feeder with grounded neutral. One ground wire serves all four arresters.

Mounting Lightning Arresters. Lightning arresters should be placed upon the same pole with the equipment they are to protect. In case they are installed to protect a distribution transformer, they should be mounted as shown in Fig. 15-26. In this case the cutout fuses and the arresters, as well as the transformer, are mounted on the same crossarm. The leads from the line to the arrester should be as short and direct as possible as this improves the operation of the arrester. It is, therefore, best to mount them on the same arm that carries the conductors to which they are connected. Arresters installed to protect a three-phase four-wire feeder are shown in Fig. 15-27. The grounding of arresters will now be considered.

INSTALLING GROUND

What to Ground. Ground connections should be applied to the following points on distribution systems:

1. One side of each two-wire secondary
2. The neutral wire of a three-wire secondary
3. The neutral of one of the transformer secondaries of a three-phase bank
4. The ground terminal of each lightning arrester
5. The cases of transformers which are installed indoors or on ground platforms
6. One side of the secondary of each potential or current transformer

The first three items, referring to grounds on transformer secondaries, were discussed in Sec. 5, and the reasons for grounding were given.

FIG. 15-28. Lineman helper driving the ground rod for a ground connection The rod is copperweld, ⅝ in. in diameter and 8 ft long. He is using a ground-rod driver which slips over the end of the rod. The driver must be operated with short sharp strokes Care must be taken not to lift the driver above the head of the rod and have it slide off, as this might cause injury. (*Courtesy Wisconsin Electric Power Co.*)

The fact that a lightning arrester must be grounded to operate is obvious. Transformers so installed that a person may touch the transformer case while in contact with the ground are grounded for protection the same as secondary circuits or the secondaries of instrument transformers.

Types of Grounds. The principal types of grounds are as follows:

1. Water mains
2. Cable sheaths
3. Driven grounds

The first two are the best grounds obtainable, and, wherever possible, secondary grounds should be connected to them. When grounding to a water main, care should be taken to avoid cement-lined or earthenware piping, as such grounds are worthless. The best connection to a water main or cable sheath is obtained by welding or soldering the connecting wire so as to eliminate any possibility of the connection loosening or burning off. Driven grounds consist of pipes or rods driven into the ground deep enough so that they are in contact with perpetually moist soil.

It should be pointed out that grounds to gas mains are exceedingly dangerous and should be prohibited.

Installing Driven Grounds. Since the most common ground in distribution systems is the driven ground, its installation will be briefly described. A pipe or copperweld rod is driven into the ground beside the pole at a distance of about 1 ft, as shown in Fig. 15-28. The rod

FIG. 15-29. Lineman helper driving the ground rod with a sledge after he has taken it as far down as he can go with the ground-rod driver. A driving head is placed over the ground-rod end, as shown in the figure, to prevent burring or mushrooming of the ground-rod end. Before the use of the driving head, mushrooming occurred whenever the rod was driven into hard rocky ground. In very hard or rocky ground the ground rod has a tendency to vibrate excessively when struck with a sledge because of its small diameter (⅝-in.). In such a case a second man must steady the rod. This is done with a pair of long tongs or a stiff piece of wire. An ordinary piece of No. 6 W.P. copper wire is good for this purpose. One end is wrapped around the rod once or twice while the man holds the other end. The rod is never steadied by hand because of the possibility of an accident. *(Courtesy Wisconsin Electric Power Co.)*

should be driven until the top end is 4 to 6 in. below the ground level (see Fig. 15-29). If driving is difficult, a bar may be used to form the hole before the rod is driven. Another form of ground-rod driver is shown in Fig. 15-30. This driver can accommodate a rod of any length, as the driving hammer slides over the rod. If many ground rods have to be driven, a power hammer can be used, as shown in Fig. 15-31. This greatly reduces the effort required and speeds up the work.

After the rod or pipe is driven in place, connection is made with the ground wire from the pole. The actual connection to the ground rod is usually made with a heavy bronze clamp as shown in Fig. 15-32. The clamp is placed over the ground-rod end and the ground-wire end. The size of the ground wire should not be less than No. 6 B. and S. gage copper wire. Number 4 wire is generally used. When the setscrew in the clamp is tightened, the ground wire is squeezed against the ground rod. Several precautions are taken in making the actual connection to minimize the possibility of the ground wire being pulled out by frost action or packing of the ground above it. The ground wire is brought up through the clamp from the bottom. It is bent over the clamp so that it cannot pull out. The wire is trained loosely so that there is plenty of slack between the ground-wire molding and the rod.

Wooden Ground-wire Molding. The last step consists in covering the ground wire with a wooden molding. The molding protects the wire as well as the lineman. It protects the lineman by making it impossible for the lineman to ground himself by touching it while he is working on

FIG. 15-30. Another form of ground-rod driver. A heavy chuck slid over the ground-rod grips the rod. A long hollow handle is moved up and down by the operator. Each downward blow strikes the chuck housing and forces the rod farther into the earth. The chuck is automatically moved up on the rod as it is driven. Any length rod can be driven since it is fed through the hollow handle from the top. (*Courtesy James R. Kearney Corp.*)

FIG. 15-31. Lineman using power hammer to drive ground rod. Note that weight of hammer is supported by block and tackle. Also note that ground rod is driven about 2 ft from pole. This helps to keep the ground resistance as low as possible. (*Courtesy Consumers Power Co.*)

the pole. He is much more susceptible to electric shock when his body is grounded, especially when he works on the primary feeder. The ground wire is covered as completely as possible with the wood molding up near the crossarms immediately after it is installed to prevent this grounding. A short piece of molding must be cut to fit between the primary and secondary crossarms, because a short gap must be left open for the interconnection to the secondary main neutral. This gap is kept so short that the lineman cannot touch the ground wire either with his hands or his feet.

The molding should extend well down below the surface of the ground, so that in case the ground bakes out, that is, fails to make contact with moist earth, there will not be any chance of a child of animal coming in contact with the ground wire and the ground at the same time. When the installation is finally covered up, the ground wire should be completely out of sight.

Another reason for covering the ground wire is to protect persons in

FIG. 15-32. Lineman helper clamping ground wire to ground rod, which has been driven 4 in. below the surface of the ground. This connection must be made before the lightning arresters are completely connected up on the pole. If this were the last connection—the one that completes the lightning-arrester circuit to ground—the helper could get a high-voltage electric shock if one of the lightning arresters should be defective. The last connection is always made at the lightning arrester by the lineman, either to its top or its bottom terminal. Before this connection is made, the lineman makes a "flick" test to find out if either lightning arrester is defective. (*Courtesy Wisconsin Electric Power Co.*)

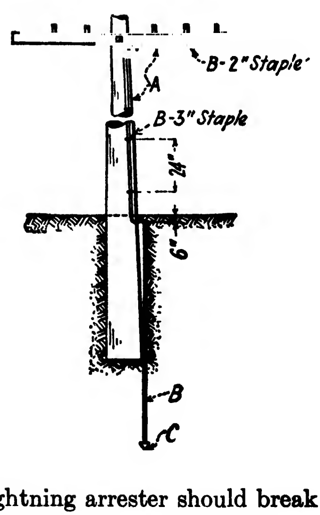


FIG. 15-33. Recommended ground-wire installation.

case of lightning-arrester trouble. If a lightning arrester should break down and allow power current to flow, the ground wire will become "hot" and remain so for an indefinite period of time if the resistance of the ground connection is high. Anyone touching the wire while it is energized could get an electric shock.

A typical complete ground-wire installation is shown in Fig. 15-33.

Ground-rod Resistance. The ground rod should be driven deep enough to be in perpetually moist earth. A depth of 8 to 10 ft is usually required to meet this requirement. Under these conditions the ground

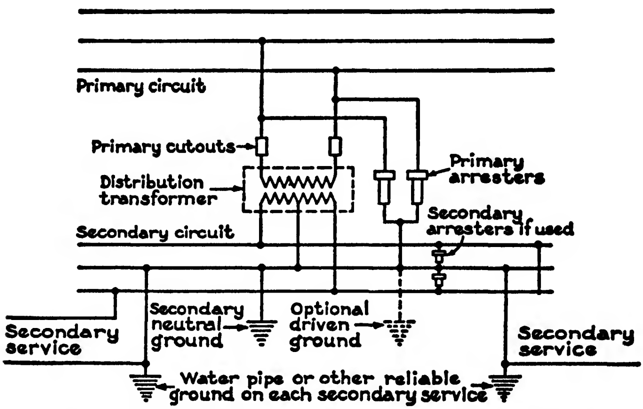


FIG. 15-34. Diagram of connections of distribution-transformer installation showing primary circuit, lightning arresters, cutouts, transformer windings, secondary circuit, and common grounds used to ground both arresters and secondary neutral at the same time. All grounds on all services and arrester installations are thus in parallel with each other. (*Courtesy General Electric Co.*)

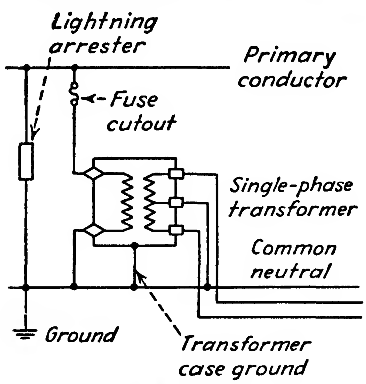


FIG. 15-35. Single-phase transformer connections on system employing common neutral. Note arrester grounded on common neutral. Also note transformer case grounded on common neutral. (*Courtesy Montana Power Co.*)

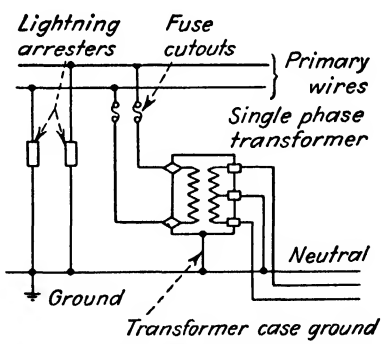


FIG. 15-36. Single-phase distribution transformer connections. Note arrester, transformer case, and secondary neutral grounded to neutral conductor which is grounded. (*Courtesy Montana Power Co.*)

resistance should not exceed 25 ohms. This resistance should be measured where water-pipe grounds are not available to the customer. This is usually done with an ohmmeter which reads directly in ohms. It is connected from a single-phase hot secondary main wire to the ground rod. The reading on the ohmmeter should be 25 ohms or less. If it is more, a second ground rod should be driven 6 ft from the first ground rod and connected with bare No. 4 copper wire buried 6 in. below the ground surface.

Common Ground for Arrester and Secondary. Modern practice favors the use of a common ground for the lightning arresters and the

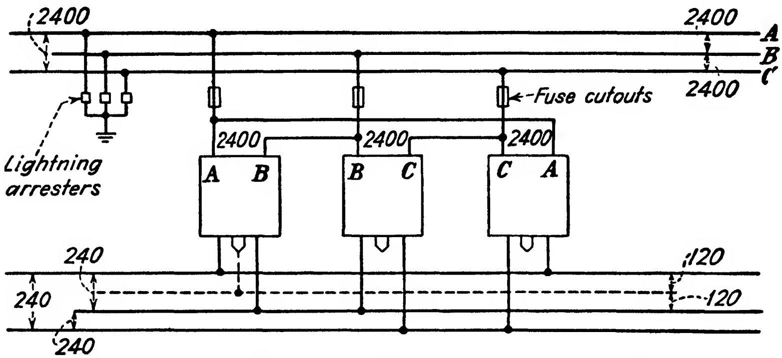


FIG. 15-37. Connection diagram for three-phase transformer installation showing fuse cutouts and lightning arresters. Transformers are connected delta-delta to 2,400-volt three-wire primary circuit. (*Courtesy Consolidated Gas Electric Light and Power Co.*)

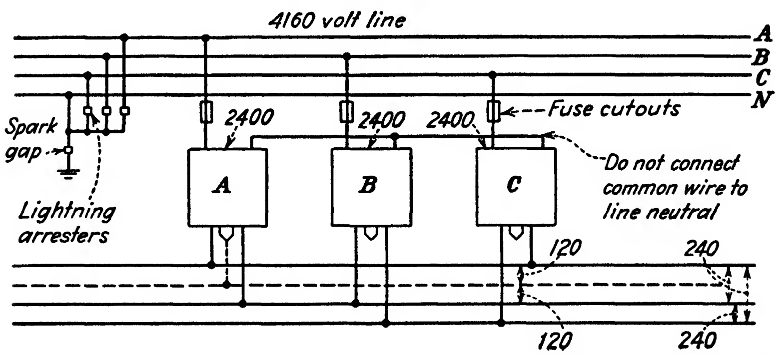


FIG. 15-38. Connection diagram for three-phase transformer installation showing fuse cutouts and lightning arresters. Transformers are connected in Y-delta to 4,160-volt four-wire primary circuit. (*Courtesy Consolidated Gas Electric Light and Power Co.*)

secondary neutral as shown in Fig. 15-34. The use of only one ground is cheaper and also reduces the amount of wire and molding running along the pole. Another advantage lies in the fact that this interconnection of the primary arrester ground to the secondary neutral (which is also grounded to water pipes on each secondary service) shunts the arrester directly across the transformer insulation from primary to secondary. This reduces the strain on the transformer insulation during a lightning discharge to the voltage drop through the arrester.

Inspection of Fig. 15-34 shows the arresters connected ahead of the primary cutouts and all grounds connected to the neutral wire. Likewise Figs. 15-35 and 15-36 show similar connections for the one-conductor and two-conductor primaries.

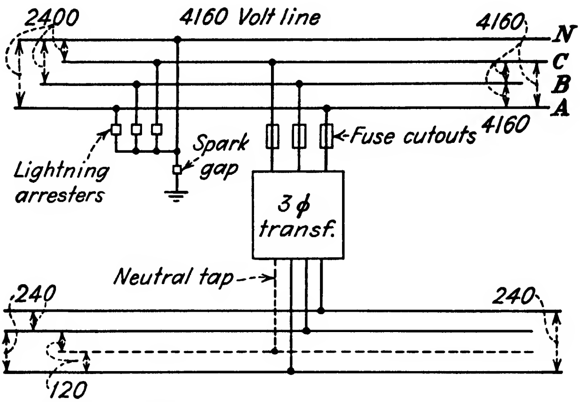


FIG. 15-39. Connection diagram of three-phase transformer installed showing fuse cutouts and lightning arresters. (*Courtesy Consolidated Gas Electric Light and Power Co.*)

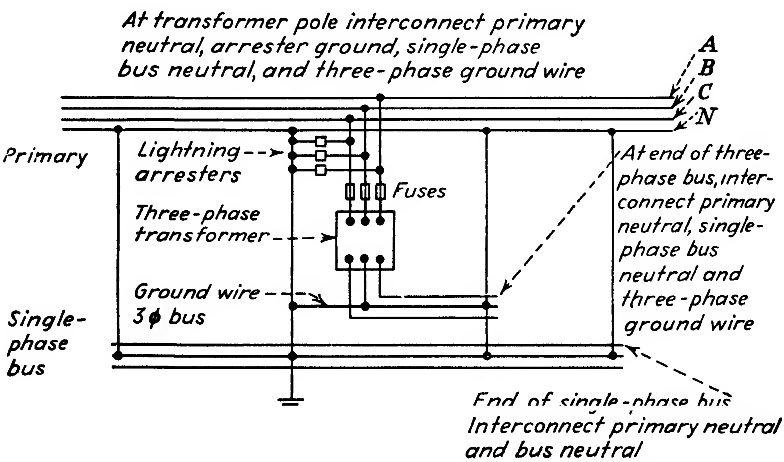
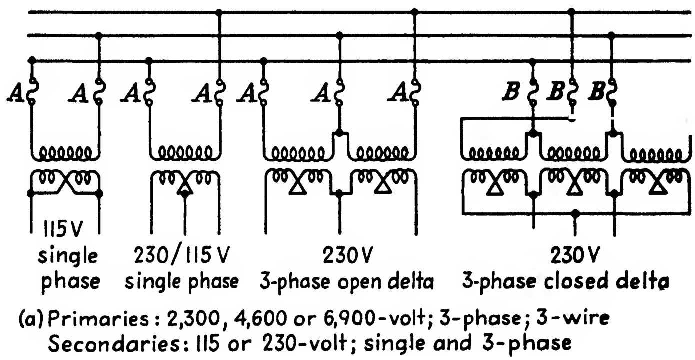


FIG. 15-40. Connection diagram of three-phase transformer installation showing fuse cutouts and lightning arresters. (*Courtesy Consolidated Gas Electric Light and Power Co.*)

Three-phase Transformer Installations. Figures 15-37 to 15-40 illustrate current practice in the connections employed in the fusing and lightning protection in three-phase transformer installations. Each supply line is separately fused with a cutout, and three lightning arresters are invariably employed. A single ground connection serves all three arresters. On the common neutral system, Fig. 15-40, the lightning arresters are connected to the common primary and secondary neutral, which in turn is grounded.

Selecting Size of Cutout Fuse. The size of fuse link for the transformer cutout depends on the kva rating of the transformer and the



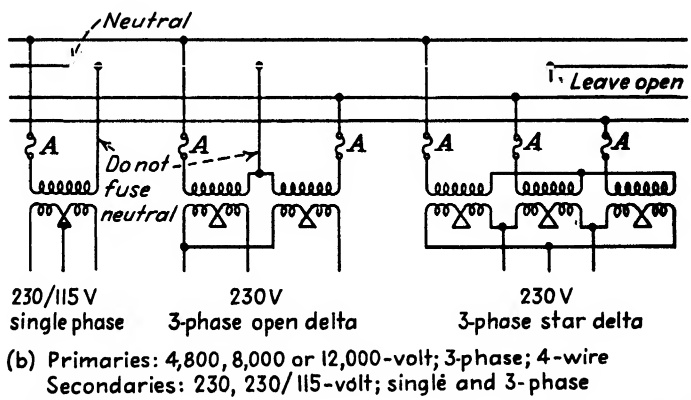


FIG. 15-41. Distribution-transformer connections, both single phase and three phase: (*a*) three wire, (*b*) four wire. *A* and *B* are references to column headings in Table 15-1. (*Courtesy West Penn Power Co.*)

transformer connection used. Figure 15-41 shows the various single- and three-phase transformer connections commonly employed on distribution systems and, Table 15-1 gives the fuse rating in amperes to be used for transformer sizes from 1½ to 200 kva for 2,300-, 4,600-, and 6,900-volt transformers. The headings at the top of table indicate the voltage and the type of connection for which the fuse size is given. Note carefully whether the fuse rating falls in the *A* or the *B* column of the table.

The CSP Distribution Transformer. The CSP distribution transformer is a completely self-protected transformer requiring no auxiliary protective equipment such as cutout fuses and lightning arresters. These are incorporated within the transformer and therefore do not have

TABLE 15-1. FUSE SIZES FOR TRANSFORMER CUTOUTS

For 4,800-volt circuits use 2,300-volt transformer column; for 8,000-volt circuits use 4,600-volt transformer column; for 12,000-volt circuits use 6,900-volt transformer column.

Transformer size, kva	2,300-volt transformers (A) Connected single phase, open delta or star	2,300-volt transformers (B) Connected closed delta	4,600-volt transformers (A) Connected single phase or open delta	4,600-volt transformers (B) Connected closed delta	6,900-volt transformers (A) Connected single phase, open delta or star	6,900-volt transformers (B) Connected closed delta
	Fuse link, amp					
1½	10	10	10	10	10	10
3	10	10	10	10	10	10
5	10	10	10	10	10	10
7½	10	20	10	10	10	10
10	20	20	10	10	10	10
15	20	30	10	20	10	10
25	30	50	20	20	10	20
37½	50	75	20	50	20	20
50	50	75	30	50	20	30
75	75	100	30	50	20	50
100	75	150	50	75	30	50
150	150	200	75	100	50	75
200	150	250	75	150	50	100

to be supplied or mounted separately. Figure 15-42 shows an exterior view of a CSP transformer, and Fig. 15-43 is a diagrammatic sketch of the transformer and its component parts. Such transformers are equipped with brackets for direct to pole mounting, but when provided with hanger irons can also be hung from crossarms as shown in Fig. 15-44*b* and *c*.

The following features are incorporated in a CSP transformer:

1. Primary-voltage lightning arresters. These are supported externally on the tank. They discharge through external discharge gaps.
2. Primary protective links in series with line leads serve to disconnect the transformer in case of internal transformer fault.

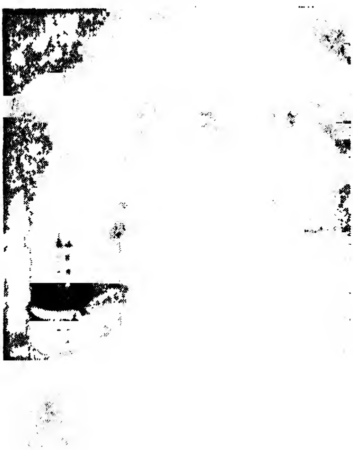


FIG. 15-42. Exterior view of a CSP distribution transformer showing sidewall primary insulator bushings, lightning arresters, secondary terminals, and secondary circuit-breaker operating lever. (*Courtesy Maloney Electric Co.*)

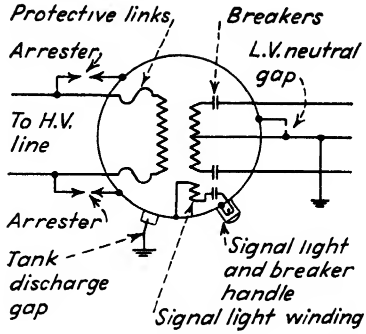


FIG. 15-43. Schematic diagram of connections of a typical CSP distribution transformer. Note primary protective links, secondary circuit breaker, lightning arresters, tank discharge gap, low-voltage neutral gap, signal lamp, signal-lamp winding, and breaker handle. (*Courtesy Maloney Electric Co.*)

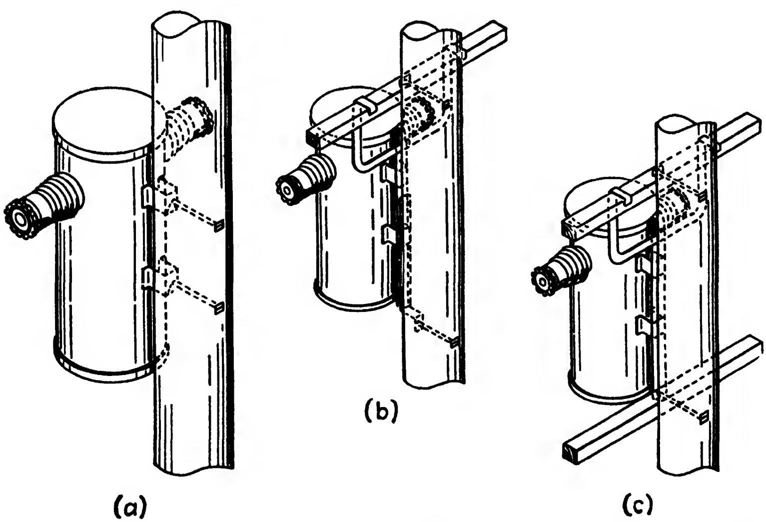


FIG. 15-44. Three mounting methods of CSP transformers. (*a*) Direct pole mounted by means of two through bolts. No crossarms required. (*b*) Crossarm mounted, using hanger irons supported by one crossarm. A special kicker bracket is used to attach lower portion of hanger iron to pole. (*c*) Crossarm mounted, using hanger irons supported by two crossarms. (*Courtesy Westinghouse Electric Corp.*)

3. *Overcurrent protection in the secondary leads provided by a low-voltage circuit breaker. This breaker is mounted above the core and coils but operates* under oil.

4. *Overload signal lamp which becomes lighted when the maximum safe operating load on the transformer is exceeded or when the secondary* breaker has tripped automatically.

5. An external operating handle for opening or closing the secondary breaker or for resetting the signal lamp and breaker tripping mechanism.

6. Secondary neutral gap to transformer tank.

7. No-load tap changer. This tap changer provides four 2½ per cent voltage taps which give a choice of four values of transformation ratio and compensate for voltage drop on long distribution lines. The operating handle is above the oil level, but the taps and contacts are under oil. The taps should be changed only when the transformer is deenergized.

To install a transformer of this type, it is only necessary to connect the high-voltage terminals to the primary line, connect the secondary terminals to the secondary mains, and to ground the neutral conductor.

SECTION 16

Stringing Secondary Mains

STRINGING THE SECONDARY MAINS

Types of Construction. Secondary mains may be supported in either a horizontal or a vertical position. When supported in a horizontal position, the usual crossarm with its braces, wood pins, and glass or

FIG. 16-1. Distribution pole showing high-voltage three-phase feeder on uppermost crossarm, single-phase primary on middle crossarm, and three-wire single-phase secondary mains on lowest crossarm. (*Courtesy Iowa-Illinois Gas & Electric Co.*)

FIG 16-2. Distribution pole showing primary mains supported on crossarm and secondary mains on vertical rack (*Courtesy Iowa-Illinois Gas & Electric Co.*)

porcelain insulators is employed. A typical view, showing a distribution pole line with a high-voltage feeder on the top crossarm, single-phase primary mains on the middle crossarm, and the secondary mains on the bottom crossarm, is shown in Fig. 16-1. When the secondary mains are supported in a vertical position, a so-called "secondary rack" is employed in place of the crossarm. This type of secondary construction is shown in Fig. 16-2. It will be noted that the conductors are spaced closely and that they must be strung on one side or the other of the pole.

Crossarm construction is generally used in light industrial or business districts, and rack construction is used in residential districts. In

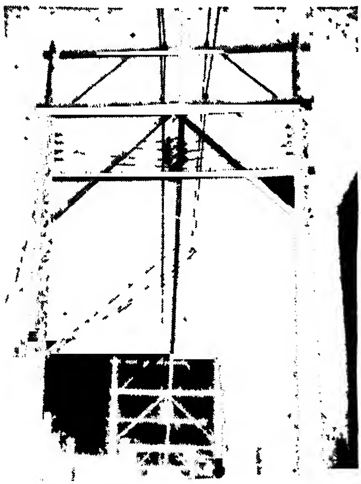


Fig. 16-3. Typical cross-alley H-frame construction used in industrial and business areas. Note transformer bank in background supported above alley. (*Courtesy Iowa-Illinois Gas and Electric Co.*)

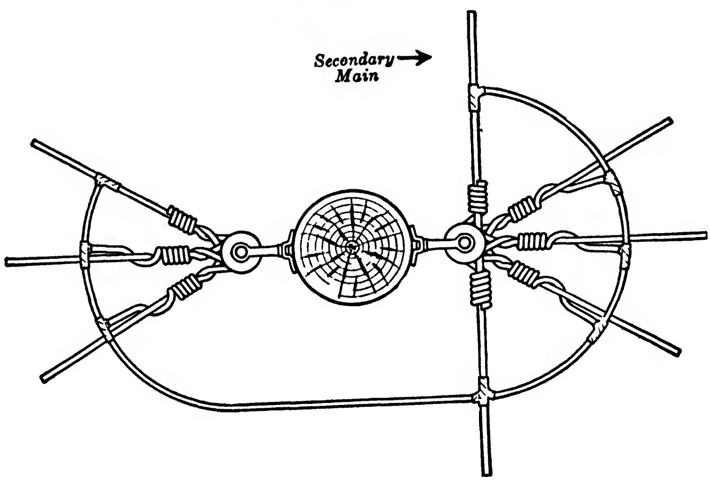
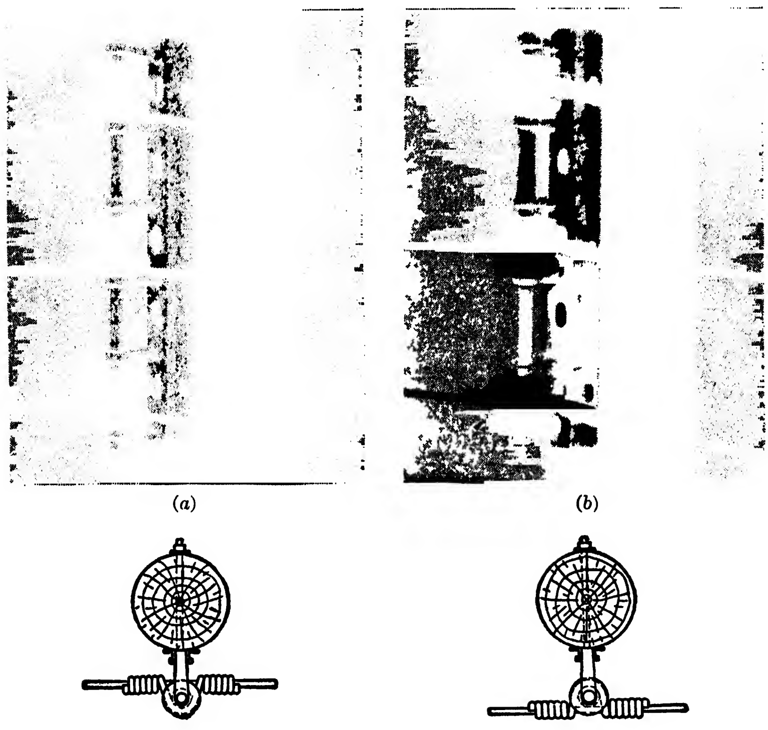


Fig. 16-4. Secondary-rack construction showing services leaving pole from both sides. This is made possible by installing a rack on each side of pole. (*Courtesy Hubbard & Co.*)

heavy business areas, it is often necessary to have separate secondaries for the power loads. And since lines in business districts are usually run in the alleys, resort is made to so-called cross-alley construction, as illustrated in Fig. 16-3. This H-frame cross-alley construction provides long crossarms on which many circuits can be supported without crowding; it also provides strong supports for capacitors, transformer banks, and metering equipment. The secondary mains are often mounted in a vertical position to make it convenient to tap service drops.

When a number of services run toward each side of the pole, Fig. 16-4, a second bracket is installed on the opposite side for support of the



(a) (b) (c) (d)

FIG 16-5 Stringing secondary mains. (a) Pulling line wires through rack. (b) Line wires tied to inside of insulator (c) Top view of line wire tied to inside of insulator. (d) Top view of line wire tied to outside of insulator. (*Courtesy Hubbard & Co.*)

services on that side. This materially reduces the climbing space for the lineman. It is for this reason that bracket construction is usually limited to residential areas where services are not so numerous and where an improvement in appearance is desired.

Position of Secondary Neutral. The position of the neutral wire in three-wire secondaries depends on the type of construction. In cross-arm construction the neutral should be placed between the two live wires. In vertical-rack construction, the neutral wire may be either the top wire or the middle wire in a three-wire secondary. Both practices are being followed. Placing the neutral wire at the top of the rack has some advantages. It will be recalled that the neutral wire of a three-wire secondary should be grounded. The neutral wire is therefore a grounded conductor. By running it on the top it will protect the secondary circuit as well as any other circuit that may break and fall across it.

FIG. 16-6. Lineman pulling up a secondary-line wire by means of block and tackle. The pole is a dead-end pole from which a service connection is to be strung Note terminal guy which takes up the pull of the secondary mains. (*Courtesy Hubbard & Co.*)

Horizontal Construction. If the secondary circuits are mounted on a crossarm, the procedure for stringing the wire and tying in is the same as already described for line conductors. The conductors are usually reeled out one at a time. A rope is thrown over the crossarm, and the end of the conductor is pulled over it. This is continued until several spans or the desired length is reeled out. The conductor to be mounted on the end pins is placed on the pole side of the insulators, and the conductor near the pole is mounted on the side of the insulator away from the pole. This is to increase the climbing and working space for the lineman. One end of the conductor is secured, and then tension is applied by means of the usual block and tackle. When the tension has been correctly adjusted, the conductor is tied to the insulators. The insulator tie in most common use for secondaries is the Western Union

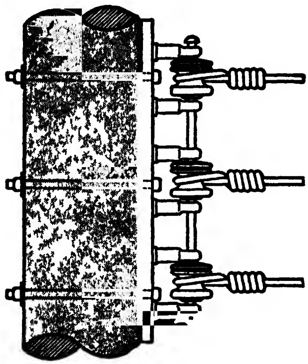


FIG. 16-7. Completed dead end on secondary-rack construction. Two or more through bolts should be used on each rack. (*Courtesy Hubbard & Co.*)

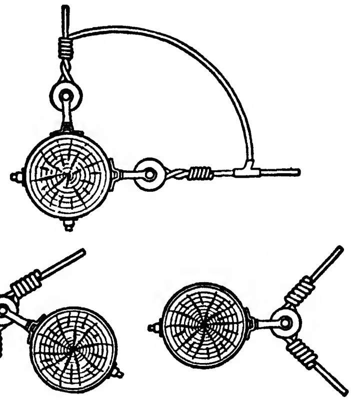


FIG. 16-8. Suggested rack construction on corners and angles. Line conductor is always placed on insulator so that the pull is against the insulator as shown. (*Courtesy Hubbard and Co.*)

(*a*) (*b*)

FIG. 16-9. (*a*) Sagger bracket in open position. (*b*) Sagger bracket in closed position. (*Courtesy Hubbard & Co.*)

tie already described. The remaining wires are pulled up likewise and tied in, care being taken that all wires have the same tension or sag.

Vertical-rack Construction. In stringing wires on bracket construction, the conductors are unreeled and passed through the rack, as shown in Fig. 16-5*a*. When the desired number of pole spans have been laid in place, the conductors are drawn up and dead-ended. As many as 10 spans can be drawn up at one time in this manner. Figure 16-6 shows a lineman pulling up a secondary main by means of block and tackle, and Fig. 16-7 shows the conductors properly dead-ended on the rack. Note the use of the terminal guy to counterbalance the pull of the line conductors.

The conductors are then lifted up to the insulator groove and tied in. The regular Western Union tie is generally used (see Fig. 16-5*b* and *c*). If the conductors are to be tied to the outside of the insulator, the Western Union tie is also used (see Fig. 16-5*d*).

In turning corners and at angles in the line, the position of the line wires on the insulators will be determined by the direction of the strain.

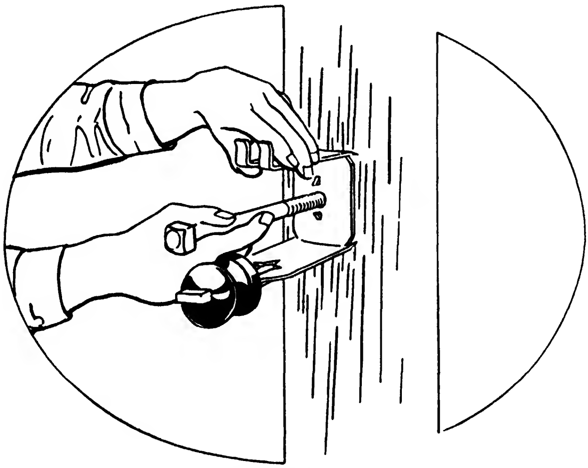


FIG. 16-10. Showing manner of inserting through bolt used to fasten Sagger bracket to pole. (*Courtesy Hubbard & Co.*)

They should always be so placed that the conductor is pulled against the insulator and not away from it. Figure 16-8 illustrates the correct positions for corner and angle construction.

Vertical-bracket Construction. Another type of vertical secondary construction makes use of the so-called patented Sagger bracket illustrated in Fig. 16-9*a* and *b*. In this type of support each conductor is supported separately by a bracket fastened to the pole with a through bolt, as shown in Fig. 16-10. The bracket is in the open position when the bolt is inserted. Bolt-head locks are provided to prevent the bolt from turning while the nut is being tightened. Since each bracket is separately supported, the bracket units may be mounted at any spacing and in whatever number that is required.

When the bracket is in the open position, the insulator spool becomes an effective wire-stringing tool. Since the insulator rotates freely on its supporting bolt, the conductor can be placed on the spool while being sagged. When the conductor is drawn up, the spool acts as a roller, thus allowing the conductor to pull up uniformly in all the spans. When the correct sag has been set, the conductor is tied in to the spool and the insulator snapped over the two keeper lugs into the vertical position. Figure 16-11*a*, *b*, and *c* shows the steps in moving the insulator from the horizontal to the vertical position and locking it in. Figure 16-12 shows a three-wire secondary tied in on three brackets.

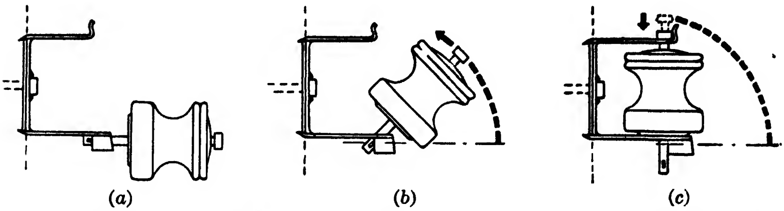


FIG. 16-11. Steps in raising insulator from horizontal to vertical position. Note keeper lugs which prevent bracket from opening. (*a*) Bracket in open position. (*b*) Bracket being closed. (*c*) Bracket in closed position, with insulator bolt head resting securely behind keeper lugs. (*Courtesy Hubbard & Co.*)

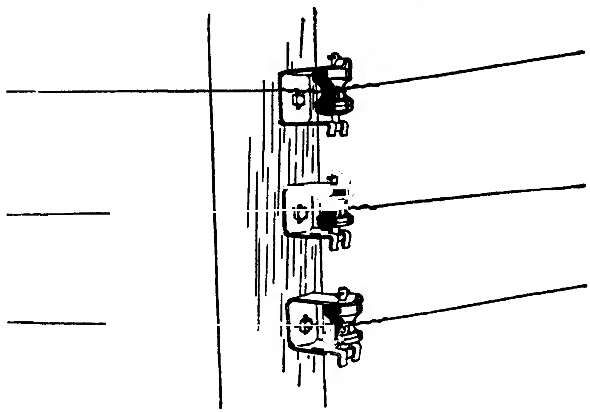


FIG. 16-12. Three-wire secondary tied in to three separately supported Sagger brackets. (*Courtesy Hubbard & Co.*)

CALCULATING SIZE OF SECONDARY MAINS

Allowable Voltage Drop. In well-designed distribution systems the voltage drop from the transformer secondary terminals to the end of the secondary in any direction should not exceed reasonable values. For secondary lighting mains, this drop is usually limited to 3 per cent and for secondary power mains to 5 per cent. These percentages apply to the voltage of the circuit. On a 120-volt two-wire circuit a 3 per cent drop would equal 3.60 volts, and on a 240-volt circuit a 3 per cent drop would equal 7.20 volts. A 5 per cent drop would be equal to 12.0 volts on a 240-volt circuit.

Estimating Table for Lighting Secondaries. The size of wire required to keep within the 3 per cent drop in ordinary lighting circuits can be roughly determined from Table 16-1. This table is based on the number of "house spans" on either side of the transformer. By *house spans* is meant the product of the number of houses served from each pole times the number of spans between the pole and the transformer. In Fig. 5-23 the number of house spans on the right of T is 74 and on the left of T is 64. If these houses are all of average size, the table shows that a three-wire secondary using No. 2 copper wire will keep the voltage drop

TABLE 16-1. APPROXIMATE NUMBER OF ALLOWABLE HOUSE SPANS ON ONE RUN OF SECONDARY MAIN FOR ANY GIVEN WIRE SIZE AND TYPE OF SECONDARY

(The demand per house is assumed at about 500 watts, and the span length is taken at 125 ft. If larger houses are to be supplied, they can be counted as two or three houses in the calculations. If longer or shorter spans are being used, the number of house spans can be changed in direct proportion. In this way the table can be used for various conditions.)

Wire size (B. & S. gage)	Maximum allowable number of house spans	
	120-volt, two-wire	120- to 240-volt, three-wire
No. 4 copper	11	44
No. 2 copper	17	70
No. 0 copper	27	113
No. 00 copper	35	139
No. 0000 copper	54	218

within 3 per cent. The services, of course, will have to be connected so as to balance the three-wire secondaries; that is, the same number of houses should be connected between each outside wire and neutral. In addition, the houses connected to both sides should be distributed along the length of the secondary, so as to make the house spans connected to each outside wire also equal if possible.

It should be noted that the houses connected to the transformer pole do not enter into the calculations.

Estimating Chart for Size of Three-wire Secondary Mains. In using the chart shown in Fig. 16-13 to find the size of secondary mains required for residential areas proceed as follows:

1. Make a secondary layout sketch similar to that shown in Fig. 16-14 and show the kilowatt demand at each pole for the residences served from that pole. A demand of 0.5 kw is assumed for each residential customer. The kilowatt demand at each pole is calculated by

multiplying the demand per customer by the number of services connected to that pole. The amount is shown on the sketch beside the pole. As an example, take the No. 5 pole. This pole serves four customers. At 0.5 kw each, the total demand at that pole is 0.5 × 4 = 2.0 kw.

2. Then the kilowatt spans are calculated for each pole by multiplying the demand at each pole by the number of pole spans between the pole

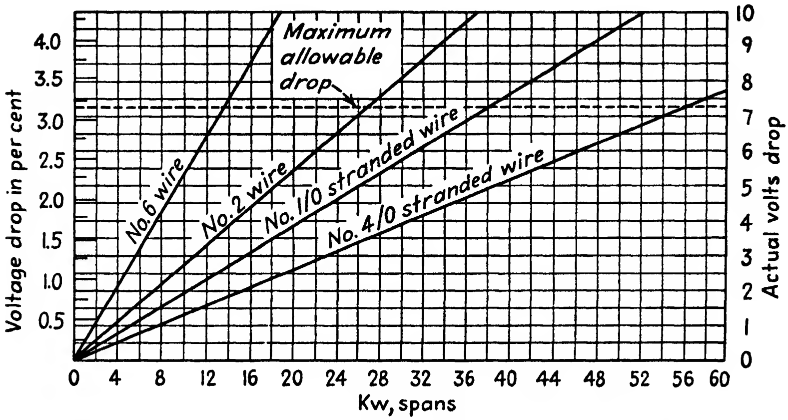


FIG. 16-13. Chart for selecting wire size for 240/120-volt single-phase 60-cycle three-wire secondary mains. Chart is based on the use of copper conductors spaced 12 in. apart. Assumed power factor is 80 per cent. Span length is 100 ft. Unbalance factor is 1.2.

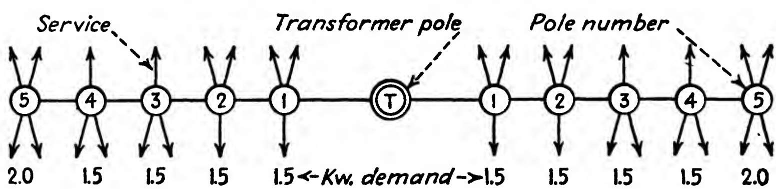


FIG. 16-14. Secondary layout sketch showing transformer pole, services at each pole, and demand at each pole. Demand per customer is assumed to be 0.5 kw, or 500 watts.

and the transformer. The No. 5 pole in the sketch, for example, has a demand of 2.0 kw and is five spans from the transformer pole. The kilowatt spans therefore are = 2.0 × 5 = 10 kw spans. These values of kilowatt spans are tabulated as shown in Table 16-2.

3. Now add the kilowatt spans served to the right and to the left of the transformer pole. The total is 25 each, for both left and right, showing that the transformer is correctly located. If these left and right values should not be approximately equal, the transformer should be moved to the next pole in the direction of the larger kilowatt span.

The kilowatt spans should be as nearly equal as possible. This is the same as saying that the transformer should be located as nearly as possible in the center of the load.

4. Now, to determine the size of wire required for the three-wire secondary mains, refer to the chart of Fig. 16-13 and find the value of kilowatt spans along the horizontal scale, which in this case is 25. Then move vertically upward on the chart until you reach the line marked "maximum allowable." The No. 2 wire is the proper size as it

TABLE 16-2. KILOWATT-SPAN CALCULATIONS FOR SECONDARY LAYOUT

The values shown in the kilowatt-spans column are the products of the kilowatt demands at each pole multiplied by the number of spans from the transformer pole. If any load is connected to the transformer pole, it does not enter the calculation for determining the wire size. However, this load must be considered when selecting the size of the transformer required. (See Fig. 16-14.)

Left Side					Right Side				
Kw		Spans		Kw spans	Kw		Spans		Kw spans
1.5	×	1	=	1.5	1.5	×	1	=	1.5
1.5	×	2	=	3.0	1.5	×	2	=	3.0
1.5	×	3	=	4.5	1.5	×	3	=	4.5
1.5	×	4	=	6.0	1.5	×	4	=	6.0
2.0	×	5	=	10.0	2.0	×	5	=	10.0
				25.0					25.0

will give a voltage drop below 3 per cent, which corresponds to 7.2 volts as shown on the right-hand scale of the chart.

The chart is based on a span length of 100 ft. If the actual average span length varies very much from this, the total kilowatt spans as calculated should be multiplied by the ratio of the actual average span to 100 ft before using the chart. Likewise, if the kilowatt demand per customer is more than 500 watts, this should also be taken into account by increasing the kilowatts per pole accordingly.

Accurate Determination of Wire Size of Lighting Secondaries. Accurate determination of the size of wire required for the secondary mains of lighting circuits can be made by use of the curves in Figs. 16-15 and 16-16. To use these curves the kilowatt demand for each house and the distance in feet between the house and the transformer must be determined. Then the demand in kilowatts and the distance in feet are multiplied to get the kilowatt distance for that house. The kilowatt distance is likewise obtained for each house and the total for all the houses on one side of the transformer. This total may be called *KD*. Next add the total kilowatt demand on the same side of the transformer and call it *K*. Now divide *KD* by *K* and get *D*, which is the

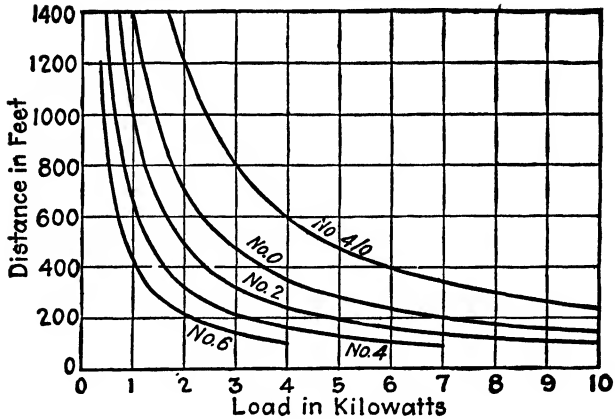


FIG. 16-15. Load curves for 115-volt single-phase lighting. Curves show distance that any load in kilowatts K can be transmitted with 3 per cent drop on lines. Voltage at load, 115 volts; spacing of wires, 8 in.; power factor of load, 95 per cent; 60-cycle current. (*Courtesy West Penn Power Co.*)

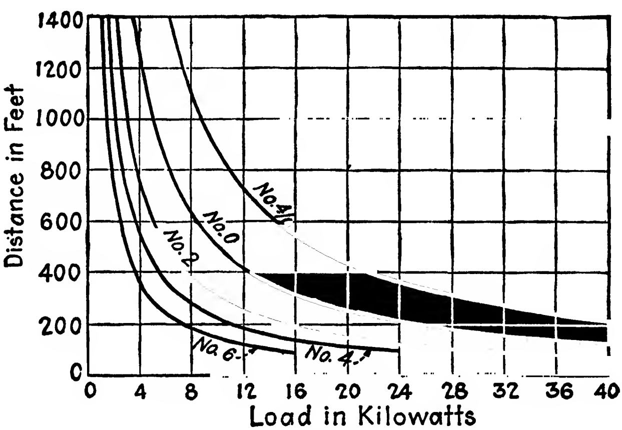


FIG. 16-16. Load curve for 230/115-volt single-phase three-wire lighting. Curve shows the distance in feet D that any load in kilowatts K can be transmitted with 3 per cent voltage drop on line, allowing for unbalance of three-wire circuit. Voltage at load, 230/115 volts; spacing of wires, 4 in.; power factor of load, 95 per cent; 60-cycle current. (*Courtesy West Penn Power Co.*)

equivalent distance in feet to which a concentrated load equal to K may be transmitted. With K and D known, refer to Fig. 16-15 for 115-volt two-wire mains or to Fig. 16-16 for 230-115-volt three-wire mains, and find the intersection of the lines from K and D. If the point of intersection does not fall directly on one of the curves, use the wire size of the curve next above the point. These curves are based on a 3 per cent voltage drop.

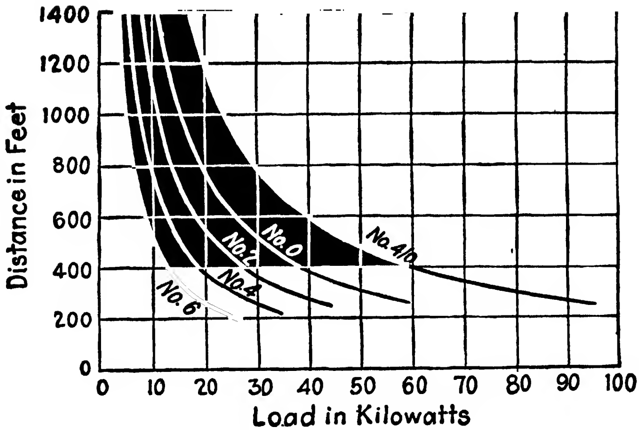


FIG. 16-17. Load curves for 230-volt three-phase power. Curves show distance in feet D that any load in kilowatts K can be transmitted with 5 per cent voltage drop on lines. Voltage at load, 230 volts; equivalent spacing, 5.05 in.; power factor of load, 80 per cent; 60-cycle current. (*Courtesy West Penn Power Co.*)

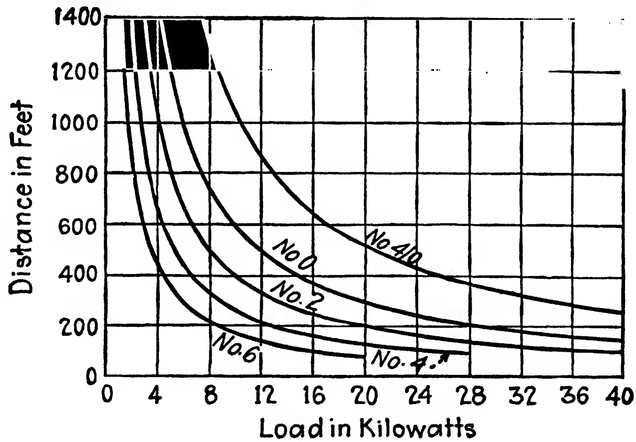


FIG. 16-18. Load curve for 230-volt single-phase power. Curves show distance in feet D that any load in kilowatts K can be transmitted with 3 per cent drop on lines. Voltage at load, 230 volts; spacing of wires, 4 in.; power factor of load, 94 per cent. (*Courtesy West Penn Power Co.*)

Three-phase Power Secondaries. In calculating the wire size for three-phase power secondaries, the procedure is the same as for lighting secondaries outlined above. In the case of power loads, however, the load can be more easily determined as the motors to be supplied and their ratings are known. The procedure consists in getting the value of each motor load K and the distance D from the transformer. Then obtain the total of the KD products, divide by K, and obtain the equivalent distance D. Now refer to Fig. 16-17 for 230-volt three-phase secondaries, and obtain the intersection of K and D. The curve on which this point of intersection falls is the proper wire size to use for a 5 per cent voltage drop.

Single-phase Power Secondaries. The procedure for single-phase power secondaries is the same as that already outlined for lighting and three-phase secondaries, except that the curves in Fig. 16-18 must be used. These curves are for 230 volts, single phase, and allow for a 3 per cent voltage drop.

SECTION 17

Installing Services

Procedure. The running of customer's services is generally performed by a two-man gang, and the various steps in the job are usually performed in the following order:

1. Installing service brackets
2. Stringing service leads, or service drops
3. Installing customer's meter
4. Testing out for polarity
5. Connecting service leads to secondary mains

Installing Service Brackets. Service brackets serve to support the service wires on the customer's building, that is, the house, store, or

FIG. 17-1. Two-wire service using two wire holders. Wire supports are arranged vertically when services are taken from vertical rack on pole. (*Courtesy Hubbard & Co.*)

FIG. 17-2. Typical three-wire residential service supported on three wire holders. (*Courtesy Iowa-Illinois Gas & Electric Co.*)

factory, as the case may be. The common bracket consists of a steel mounting on which either standard glass or porcelain insulators or special insulators better adapted for dead-ending are mounted (see Figs. 17-1 and 17-2).

The procedure for installing the service support depends largely on the material of which the building is made. If it is a frame building, such as an ordinary residence, thus not requiring heavy service wires, an individual support, one for each wire, as illustrated in Fig. 17-1 is used. This support is easily installed as the steps in Fig. 17-3 show. In case of brick or stone buildings, so-called "expansion bolts" (Fig. 17-4) are

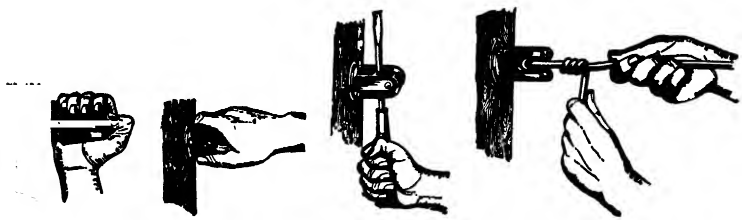


FIG. 17-3. Steps in installation of wire holder and dead-ending of service wire. (*Courtesy Hubbard & Co.*)

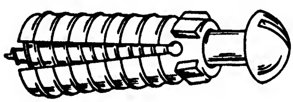


FIG. 17-4. Typical expansion bolt. As the bolt is screwed into the tapered shields, the shields are forced apart and caused to grip the sides of the hole. (*Courtesy Western Electric Co.*)

FIG. 17-5. Drilling holes in brick wall for expansion bolts to support service brackets. (*Courtesy Hubbard & Co.*)

made use of. A hole is first drilled of the required depth and diameter (see Fig. 17-5). The split nut is then inserted in the hole, and the bolt is screwed in place. The hole in the split nut is tapered. As the bolt is screwed in, the two halves of the nut are forced against the sides of the hole, causing them to grip the stone or brick. On hollow-tile walls the support may be fastened by the use of toggle bolts. A hole is drilled into the hollow tile. The toggle is then inserted. After reaching the inside of the hollow tile, the toggle spreads and bears against the back of the tile (see Fig. 17-6).

The best location for the service-wire support is either slightly above the service outlet or directly opposite. Figures 17-1 and 17-2 illustrate vertical mounting alongside the service outlet.

Service supports should be mounted about 15 ft above the ground. The practice varies slightly with different companies. Figure 17-7 shows the practice of one company which requires 12 ft for residences and 16 ft for business buildings, and Fig. 17-8 illustrates the requirement of another company which requires a minimum of 15 ft for all services.

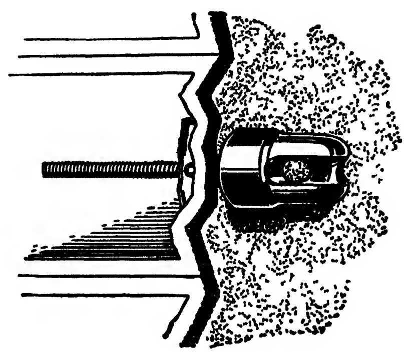


FIG. 17-6 Toggle-bolt support for service bracket on hollow-tile wall (*Courtesy Hubbard & Co.*)

Stringing the Service Drop. The service connection should be made to the nearest distribution-line pole. If this distance should exceed 125 ft, an intermediate support should be provided. This intermediate support should support the wires at least 15 ft above the ground.

After the service wires are unreeled, one of the linemen dead-ends the wires onto the service bracket (see Fig. 17-9). As soon as this is done, the other lineman climbs the service pole, pulls up the service wires, and dead-ends them on the pole (see Fig. 17-10). These wires need be pulled up by hand only, as little strain should be placed on the service supports. If the service drop wires are pulled otherwise than by hand, too great a strain will be put on the service brackets which may cause them to break or be pulled out of the building structure.

Dead-ending Conductors on Spool and Pin Insulators. The usual method of dead-ending the service wires is to take one or two turns around the spool insulator or through the hole in the service bracket and then wrap the free end of the wire around the service wire six or eight times. The wrapping should be done tightly to prevent pulling out. The insulation need not be removed except for wire sizes larger than No. 2. A length of wire, called the "tail," should be left to make the connection to the secondary main or to the meter loop at the customer's service outlet.

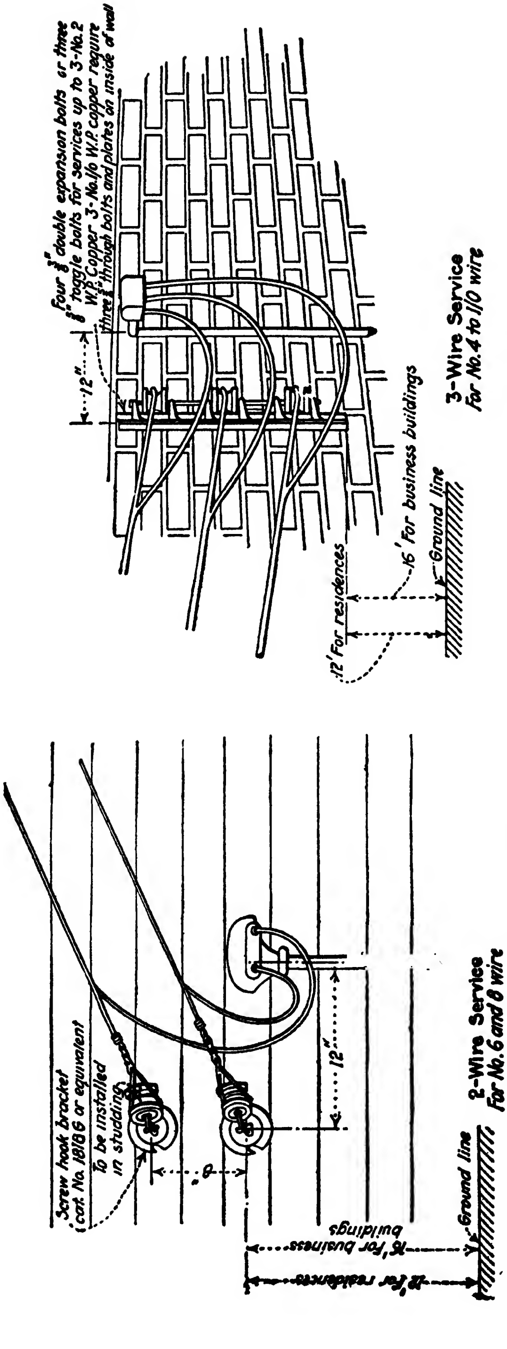


FIG. 17-7. Details of service connection for two-wire and three-wire services for residences and business buildings. (*Courtesy Kansas City Power & Light Co.*)

Figure 17-11 gives details of dead-ending (*a*) a service tap, (*b*) a secondary main using a served tap, and (*c*) a secondary main using a connector.

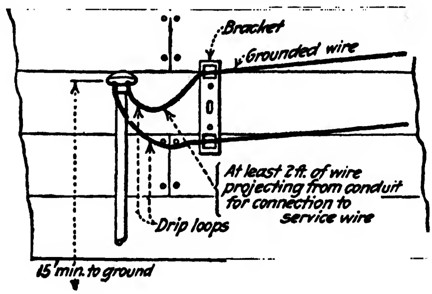


FIG. 17-8. Details of consumer's service connection. Note that the grounded wire is the top wire. (*Courtesy West Penn Power Company.*)

FIG. 17-9. Lineman preparing to insert watthour meter in newly connected customer's residence. (*Courtesy Kansas City Light and Power Company.*)

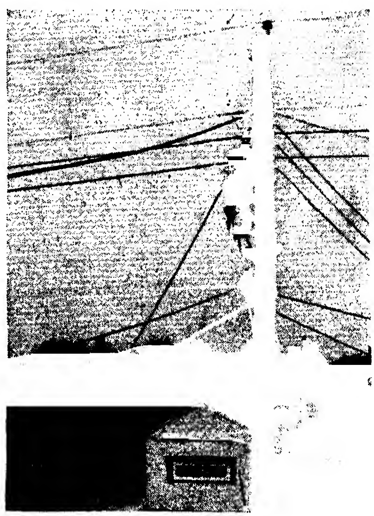
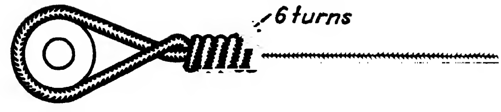
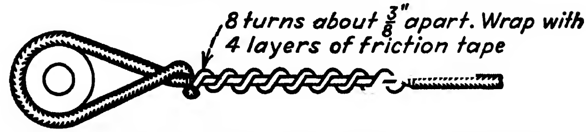


FIG. 17-10. Dead-ending service drop to new house on distribution pole. (*Courtesy American Gas and Electric (Service Corp.*)

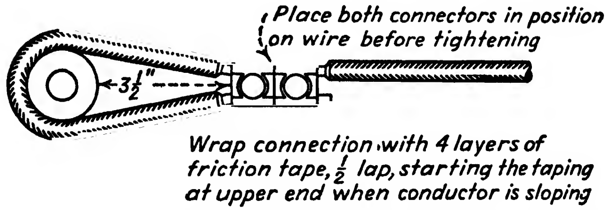
Service-pole Supports. The type of support for the service wires on the service pole depends on the type of secondary-main construction. If the secondary mains are supported by secondary racks, the same racks may also be used for the support of the service drops, as shown in Figs. 17-12 and 17-13. When the secondary mains are carried on crossarms, the use of a buck arm is a common method for supporting the services. The use of a buck arm permits taking services in all directions with equal ease. A bracket mounted or clamped on the ends of the line crossarms



(a) No.8 to No.6 service tap on spool or pin insulator



(b) Dead ending No.6 secondary line on spool insulator



(c) Dead ending No.4, 2 and 2/0 secondary wire on spool insulator

FIG. 17-11. Dead-ending conductors on spool or pin insulators. (a) Dead end of service tap. (b) Dead end of secondary main using served tap. (c) Dead end of secondary main using connector.

FIG. 17-12. Service drop wires supported on secondary-main bracket. In this instance neutral conductor of three-wire service is middle conductor. (*Courtesy Iowa-Illinois Gas & Electric Company.*)

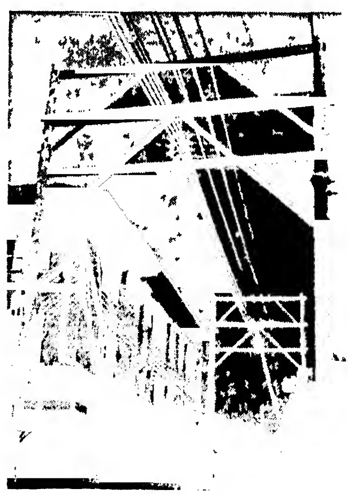


FIG. 17-13. Service drop wires supported by vertical secondary main bracket on cross-alley construction. (*Courtesy Iowa-Illinois Gas and Electric Company.*)

has also come into extended use. A typical bracket of this type is shown in Fig. 17-14. Such a bracket is called a "spreader bracket," as its principal function is to spread the wires so that they will clear each other. Spreader brackets are inexpensive, have a neat appearance, and permit of simple wiring on the pole. When services leave the service pole at such an angle that they clear the secondary mains properly, the services can be fastened directly to the secondary insulators. As mentioned above, the use of a buck-arm service bracket, or spreader bracket, makes for more rigid construction and is to be preferred.

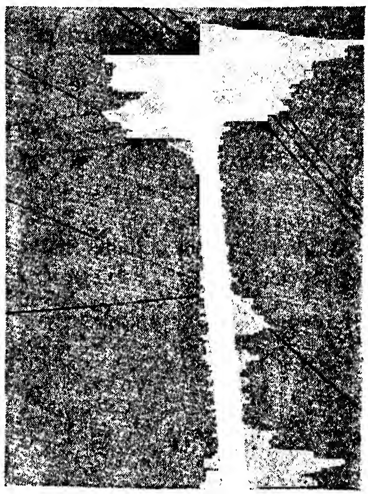


FIG. 17-14. Typical spreader brackets mounted on ends of secondary crossarm. This supports the secondary lines in a vertical position. (*Courtesy Line Material Company.*)

Size of Service Drop Wires. The wire used in overhead services is, as a rule, standard triple-braid weatherproof soft-drawn copper wire. The smallest size that should be used is No. 8 B. & S. gage. In some cases the customer's load will require that a larger wire be used. The size of service wire used for various loads is about as follows: No. 8 wire is used where the customer's connected load consists of five or less circuits rated 660 watts each. This range of load is typical of small bungalows and cottages. If the load consists of from five to nine circuits of 660 watts each, a No. 6 service wire should be used. It is sometimes advisable to supply such loads with a three-wire service, in which case the No. 8 wire would still be satisfactory. Houses larger than bungalows would represent this size load.

When ranges are to be supplied, a three-wire service using No. 4 wire is used. Services for commercial lighting and power loads are special and would have to be determined by the distribution engineer.

Table 17-1 gives the size of service wires recommended by one company.

Installing the Customer's Meter. The installation of the watthour meter is the next step in the running of the service (see Fig. 17-15). The meter is, as a rule, the property of the company and is therefore installed by the company at the time of making the service connection. The

TABLE 17-1. OVERHEAD SERVICE-WIRE SIZES FOR VARIOUS TYPES AND SIZES OF LOADS

Small residence with range or less	Three No. 8 weatherproof insulated
Large residence with range or less	Three No. 6 weatherproof insulated
Residence with range and water heater	Three No. 6 weatherproof insulated
Commerical 5 kw or less	Two or three No. 8 weatherproof insulated
Commerical 8 kw	Three No. 6 weatherproof insulated
Commercial 13 kw	Three No. 4 weatherproof insulated

Other loads: Be governed by load conditions, securing voltage drop 1 per cent for service.

details of the installation will not be discussed here as this work is generally done by a meterman and not by the lineman. In many cases, one of the men of the gang is a meterman and the other is a lineman.

While the meter is being installed, the service outlet is connected onto the service wires. The manner of making the tap or jumper connection

FIG. 17-15. Installing and testing a single-phase watthour meter by the company meterman. Outdoor meters are now generally used as they facilitate reading and testing without disturbing the customers. The socket-type meters can also be quickly replaced if necessary, with only a brief interruption of the service. (*Courtesy American Gas and Electric Service Crop.*)

will be described later when the connection of the service wires onto the secondary mains will be discussed.

Testing Service Wires for Polarity and Ground. Before the service wires can be connected onto the secondary mains, they must be tested or *lamped out* for polarity. This must be done to avoid connecting the customer ground to either of the *hot* wires of the secondaries. To do so would produce a *short circuit* on the secondary mains. The customer ground should always be connected to the neutral or grounded wire of the secondaries.

To perform the polarity, or *lamping-out*, test, an incandescent lamp is used. This should have a voltage rating equal to the voltage across the

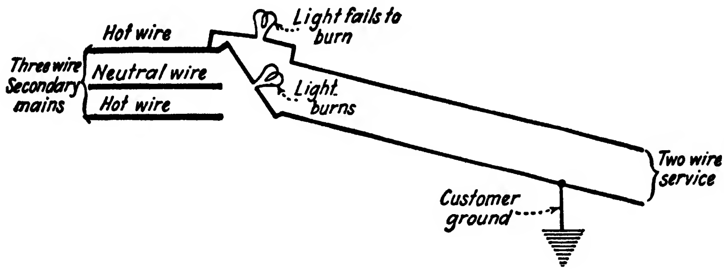


FIG. 17-16. Lamp test for polarity on two-wire service. The service wire that makes the lamp burn is the grounded wire which should be connected to the neutral or grounded wire of the secondary mains.

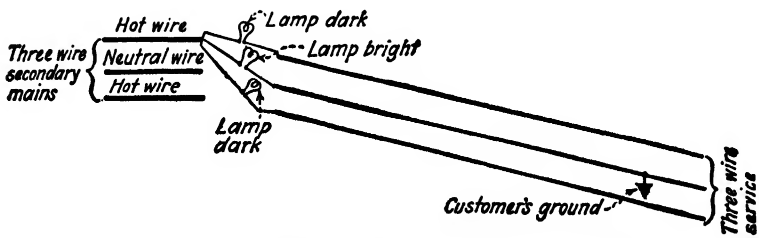


FIG. 17-17. Lamp test for polarity on three-wire service. The service wire that makes the lamp burn is the grounded wire which should be connected to the neutral or grounded wire of the secondary mains.

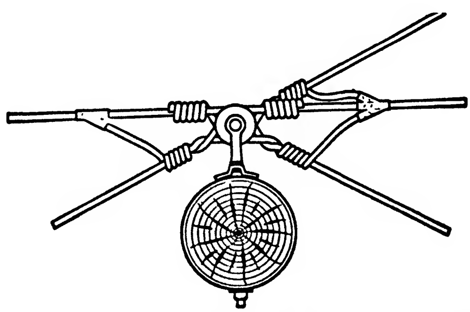


FIG. 17-18. Service connections using one rack only. (*Courtesy Hubbard & Company.*)

hot wires of the secondary. If the service is a two-wire service, the test is made as shown in Fig. 17-16. As was pointed out above, the service wire which is grounded in the customer's premises should be connected to the neutral of the secondary main. To determine which of the service wires is grounded, the lamp is connected from one of the *hot* or *live* secondary wires to one of the service wires. If the lamp burns, the service wire to which the lamp is then connected is grounded. If the lamp does not burn, that service wire is not grounded. If the service is a three-wire service, the procedure is the same except that three wires of

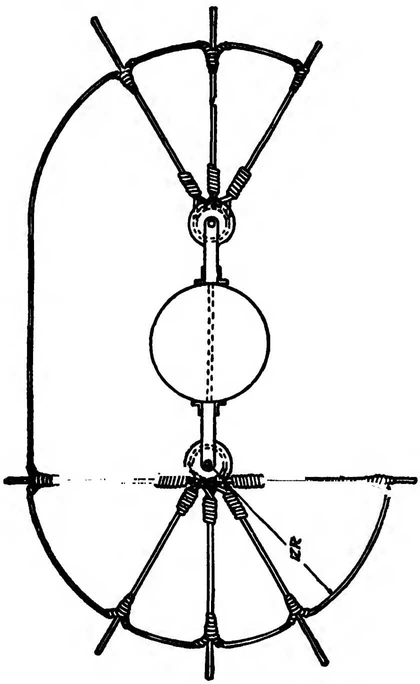


FIG. 17-19. Service connections using two racks, one on each side of pole. (*Courtesy Hubbard & Company.*)

the service must be *lamped out*. See Fig. 17-17. All one needs to remember is that the service wire that makes the lamp burn is the grounded wire and should be connected to the secondary neutral.

Flash Test for Polarity. The flash test consists in actually touching the bare ends of each of the service wires onto each wire of the secondary mains in turn. If, when touching one of the service wires onto the secondary wires, no flash takes place, the lineman takes the end of the other service wire and repeats the process. One of the two house wires will show a flash. The wire that flashes is the house ground, and the pole wire that flashes is a hot wire. The pole wire that gives the flash should then be connected to the house wire that does not flash.

The reason no serious short circuit occurs when the flash test is made is because the resistance of the ground connections is high enough to hold the current down to a low value.

Connecting to Secondary Mains. When the service leads are *lamped out,* they are ready to be connected to the secondary mains. The connection is completed by the use of a *jumper,* which is a short length of wire. The jumper must be connected to the service wire and to the secondary main.

The use of the jumper is shown in Fig. 17-18 for secondary-rack type construction. Figure 17-19 shows the same type of construction but has

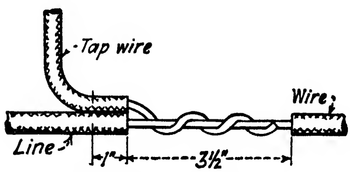


FIG. 17-20. Served tap used in connecting small tap wires to line conductors.

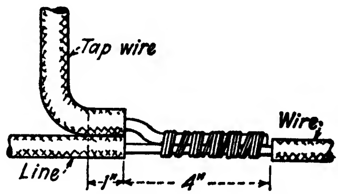


FIG. 17-21. Wrapped tap used in connecting large tap wires to line conductors.

service wires running from two sides of the service pole. In the latter illustration, one jumper is used for several service wires. As the figure shows, the jumper should not be connected closer than 12 in. from the support.

There are two general methods of connecting the ends of the jumper onto the main wires: one is by means of the soldered tap, and the other is by means of *clamp connectors.* The first method was the most common, but the latter method has several advantages and has come into quite general use.

There are two kinds of soldered taps, namely, the *served* tap and the *wrapped* tap. These are illustrated in Figs. 17-20 and 17-21, respectively. The served tap is adapted to the smaller sizes of tap wire, and the wrapped tap is best suited to the larger sizes.

The steps in making these two tap connections are as follows:

Served Tap:

1. Remove 6 in. of covering from tap wire.
2. Wrap tap wire two and a half times around line wire and solder.
3. Wrap tap with four layers of friction tape and paint with compound if covered wires are used.

Wrapped Tap:

1. Remove about 4 in. of covering from line and tap wire.
2. Tin line and tap wire.
3. Wrap with No. 12 soft copper wire and solder.
4. Wrap tap with four layers of friction tape and paint with compound if covered wires are used.

NOTE. When services are soldered to medium hard-drawn secondary wires, care should be taken not to anneal the secondaries.

Connectors. The clamp connector is easily applied. Covering is removed, and the wires are scraped clean. The two wires are then inserted in the clamp and the screws drawn up tight. Figures 17-22 and 17-23 illustrate two types of connectors.

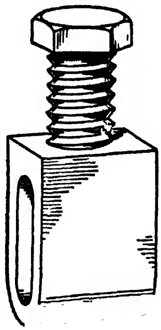


FIG. 17-22. Connector used in place of served tap for service entrance connection. (*Courtesy Joslyn Mfg. and Supply Company.*)

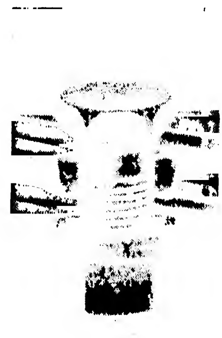


FIG. 17-23. Another type of solderless connector in common use. (*Courtesy James R. Kearney Corp.*)

A clamp connector has a number of good features. (1) No soldering is required. This speeds up the work considerably, besides doing away with the blowtorch and hot solder. (2) There is no danger of annealing the wire as no heat is applied.

SECTION 18

Tower-line Erection

General. Although the general procedure for erecting tower lines is similar to that for pole lines, the tower lines are larger and heavier and therefore present more problems. The towers require foundations, are higher and heavier, and are therefore more difficult to erect; the conductors are larger and the spans longer, making wire stringing a more difficult job; etc.

The procedure of the construction process will be given here with reference to tower lines only. Illustrations will be used extensively to show the various steps. The discussions will be limited to a description of the operations shown in the illustrations.

Order of Operations. The order of the operations in tower-line construction may be briefly outlined as follows:

1. Clearing right of way
2. Installing tower footings
3. Grounding tower base
4. Erecting towers
   a. By the "ground-assembly" method
   b. By the "piecemeal" method
   c. By the "section" method
5. Hanging insulators
6. Unreeling conductors
7. Joining conductors
8. Stringing conductors
9. Armor rodding and clipping in

These operations will be illustrated in the pages that follow, and comments will be made on the operations performed.

1. Clearing Right of Way

FIG. 18-1. A right of way properly cleared. The width of this right of way depends on whether the line is in open country or through forests. In open country a 15- to 20-ft margin should be provided on each side of the tower for single lines. In case two lines are side by side, the same distance should be provided between the towers of the two lines. If the lines pass through forests, the margin on each side of the tower should be equal to the height of the tallest trees. (*Courtesy American Gas and Electric Service Corp.*)

2. Installing Tower Footings

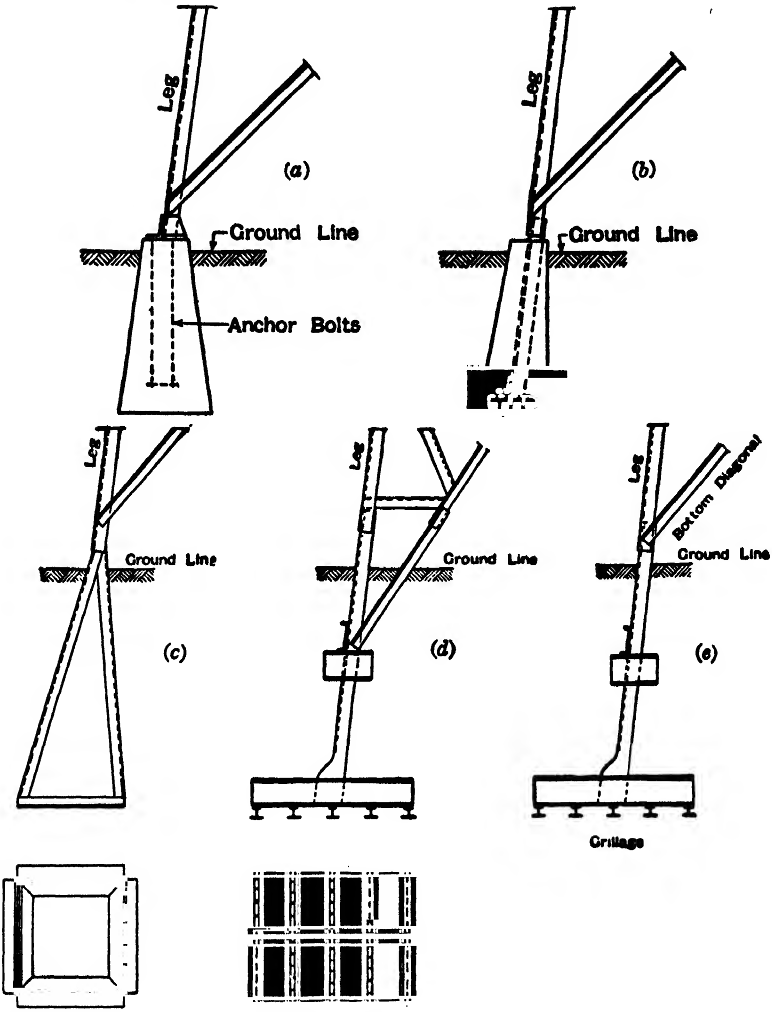


Fig. 18-2. Various types of tower footings. Since towers are not massive, footings must be provided to anchor them firmly in the ground. Footings support the tower and prevent the tower from blowing over when the lines are subjected to sleet and wind. The footings shown in *a* and *b* consist of tapering masses of concrete in which anchor bolts or stub angles are embedded. The footings shown in *c*, *d*, and *e* are merely extensions of the tower structure embedded in the earth. These extensions are enlarged so that a large bearing surface is presented. (*Courtesy American Bridge Co.*)

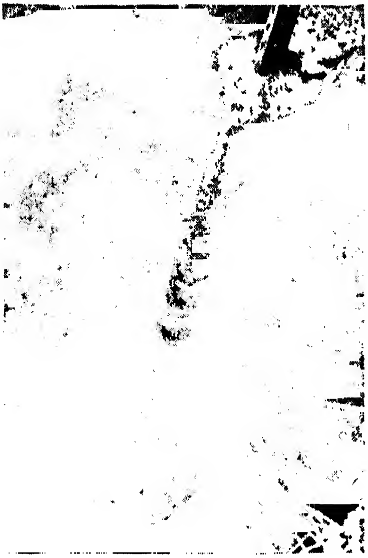


FIG. 18-3. Patented tower anchor known as "Malone" anchor. View shows ground removed to expose mass of concrete at end of tower member. (*Courtesy Blaw-Knox Co.*)

FIG. 18-4. Tower anchor consisting of a latticed steel foot. An idea of the size of this anchor can be had by comparing with the men. Linemen shown are assembling the grillage. Tower anchors are covered with concrete only at points of unusual strain such as large angles or dead ends. In open country, where the tower merely holds up the wires, ordinary earth anchors are used. These are a tripod arrangement made of heavy angle iron and provided with a "floor" of heavy channel iron. Several pieces are bolted side by side to make up the "floor." The anchors are 9 ft high. Such anchors are set in holes dug for this purpose. They are lined up with a template and then covered with earth. (*Courtesy Detroit Edison Co.*)

Fig. 18-5. Holes being dug for a 132,000-volt transmission-line tower. Note the "back-hoe" caterpillar power excavator being used. A clamshell digger could be used to equal advantage. The holes are about 15 ft square and 9 ft deep. In favorable soil such a hole can be dug in about ½-hr. This particular footing is being constructed for a 50-ft four-legged tower. (Distance from ground surface to lowest crossarm is 50 ft.) Three holes have been completed while the fourth is about half done. This tower is located at the dead end of the line adjacent to the bulk substation it will feed. The legs or anchors of this tower will be embedded in huge blocks of concrete to sustain the unbalanced pull which the line wires place on a dead-end tower. Note that one concrete form is already in place in the hole adjacent to the power digger. A second one is being assembled in the right background. These forms are bolted together. They are unbolted and removed after the concrete has hardened. (*Courtesy Wisconsin Electric Power Co.*)

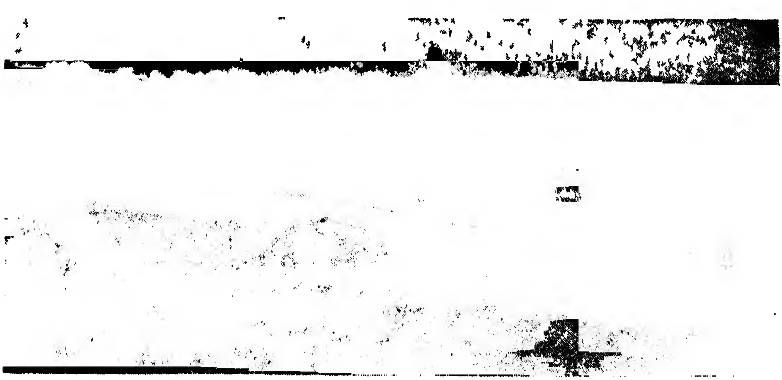


Fig 18-6. Excavating holes for steel-tower footing anchors with use of a clamshell-type digger. Line will operate at 132,000 volts. Note tower in distance partially erected. (*Courtesy American Gas and Electric Service Corp.*)

FIG 18-7 Excavating footing for steel tower anchor on 330 000-volt line by use of "back-hoe" caterpillar power excavator Towers on this line will be 148 ft high and will carry six 1 6-in diameter ACSR conductors hung from 18 suspension insulators The average span will be 1,200 ft (*Courtesy American Gas and Electric Service Corp*)

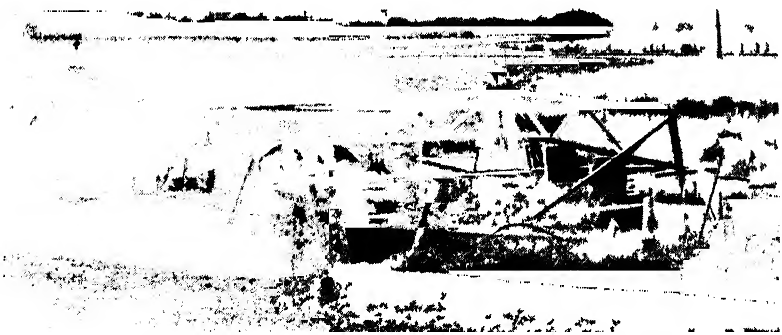


FIG 18-8 Lining up tower footings with a template Setting templates are legs of the lower part of the tower specially punched for use as a template The first two sides of the template are shown in place Two more will be installed to complete it The template which has the same dimensions as the lower end of the tower, must be used to give correct spacing and slope to the anchors which will be embedded in the concrete The anchors are bolted to this template and are held in their proper position until the concrete is poured and has hardened Note the forms for the concrete These forms are 3 ft square at the top 7 ft square at the bottom and 9 ft high One side of each form (the inner side) is vertical the other three sides are sloped For a 50-ft tower these forms are set 21 ft apart For taller towers the spacing is greater Nine cubic yards of concrete are required to fill each form or 36 cu yards for the complete tower Also note lineman sighting through transit to check the leveling of the template (*Courtesy Wisconsin Electric Power Co*)

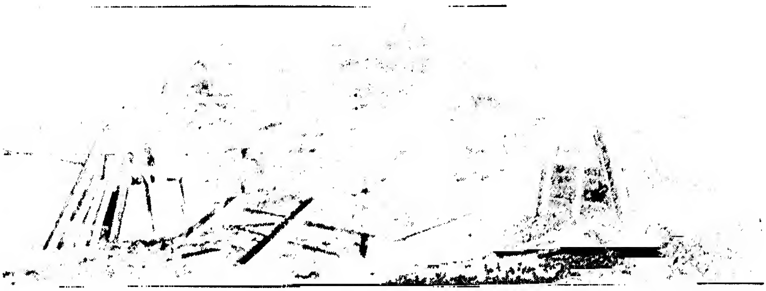


FIG. 18-9. Complete template and all four concrete forms in place all ready for the concrete. A tower anchor or stub is bolted to each corner of the template. The template is left in place until the concrete has hardened. Note the ends of the template sides extending beyond the limits of the tower footings at the corners. This extra length is used for lining up towers with a larger base than the one shown. (*Courtesy Wisconsin Electric Power Co.*)

FIG. 18-10. Backfilling tower anchor. Barrels in foreground were used to support holes in poor earth while excavating. These barrels are made in two parts so that they can be removed after the anchor is set. Pins with pulling cables are used to hold the two halves together. The barrels are ⅜ in. thick and 54 in. in diameter. (*Courtesy Detroit Edison Co.*)

3. Grounding Tower Base. All steel towers are grounded, usually by means of ground rods. Some tower bases are actually extended to buried steel footers which ground them, while others are connected to buried copper or steel wires. The usual ground rod is a ¾-in. diameter 8-ft long copperweld rod. The rods are driven into the earth at the bottom of the anchor hole, one rod near each anchor. They are so located that the concrete, if used, will cover the short end that sticks up out of the ground. Each tower leg is connected to its own ground rod.

If the tower is located near a substation, the four ground rods are often connected together with a heavy copper wire which runs around the tower in a shallow trench. The actual ground connection to the tower is made at one leg only. This connection consists of a heavy clamp bolted to the tower leg above the ground surface where it can be removed for testing purposes if need be. Often the tower ground is also connected to the substation ground by means of the same heavy copper connecting wire.

4. Erecting Towers

a. Ground-assembly Method

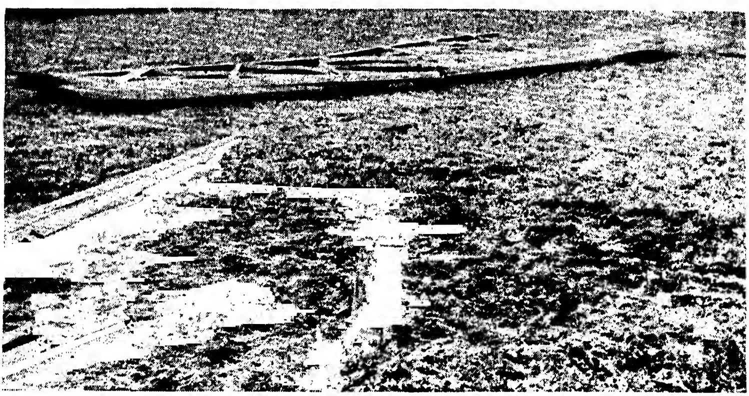


Fig. 18-11. Horizontal assembly of the base of a high-voltage transmission-line tower. The first side or panel of the tower has been assembled. Note one anchor or stub in the center foreground. With this type of assembly and modern methods of tower erection, the tower can be assembled on level land, even though it is some distance from the tower footing. Later a crane will pick up the completed tower, carry it to its location, and set it on its foundation. (*Courtesy Wisconsin Electric Power Co.*)

Fig. 18-12. A 132,000-volt transmission-line tower subassembly. This is the top of the tower, here shown, being assembled separately. It will be bolted to the bottom part of the tower after it has been assembled. Note steel in the right background being sorted and placed for the assembly of the bottom part of the tower. (*Courtesy Wisconsin Electric Power Co.*)

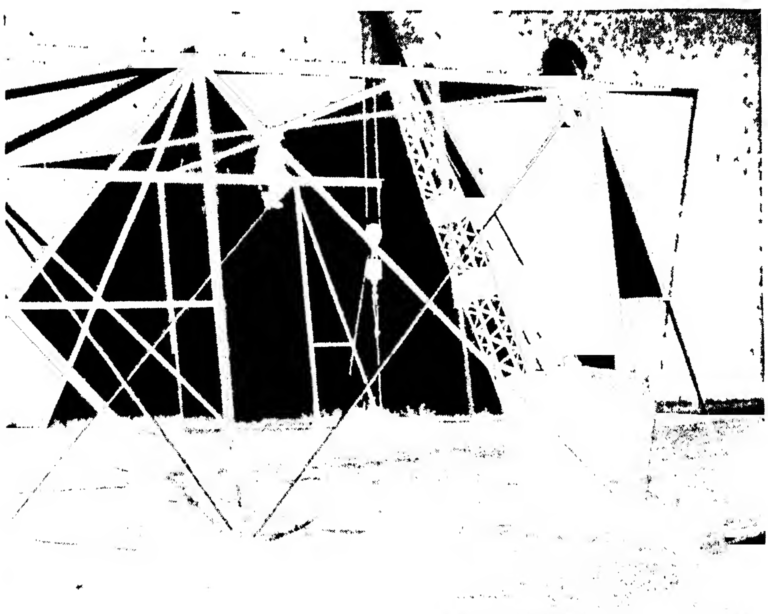


Fig. 18-13. Bottom part of a 132,000-volt transmission-line tower in process of assembly. Note the crane which is used to hoist the separate parts of the tower to workmen on the partial assembly. The workmen fit each part to its proper place and bolt it securely. (*Courtesy Wisconsin Electric Power Co.*)

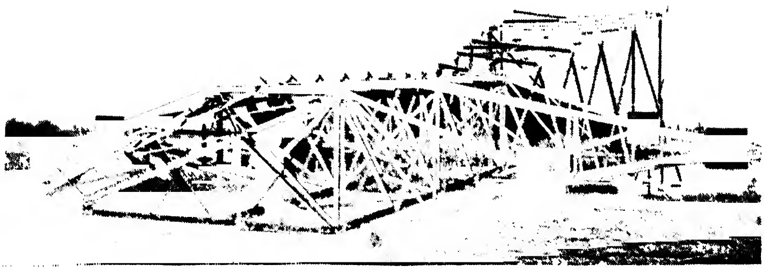


FIG. 18-14. A 132,000-volt transmission-line tower almost completely assembled. Note that the bottom part is being bolted to the subassembly of the top part This tower is almost complete and ready for erection. The dark square sections of steel shown in the top assembly are the mounts for the insulator strings which carry the line conductors. (*Courtesy Wisconsin Electric Power Co.*)

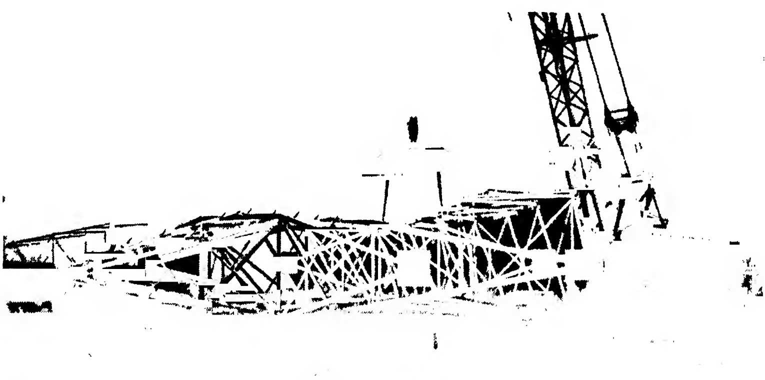


FIG. 18-15. A completely assembled 132,000-volt transmission-line tower ready for erection. The crane is about to pick the tower off the ground and carry it to its footing. This is a far cry from the old gin-pole method of erection, where the tower had to be hinged to its footings while being assembled. With this new method of erection, a level piece of ground can be picked for the tower assembly even though it is a short distance away from the tower base. (*Courtesy Wisconsin Electric Power Co.*)

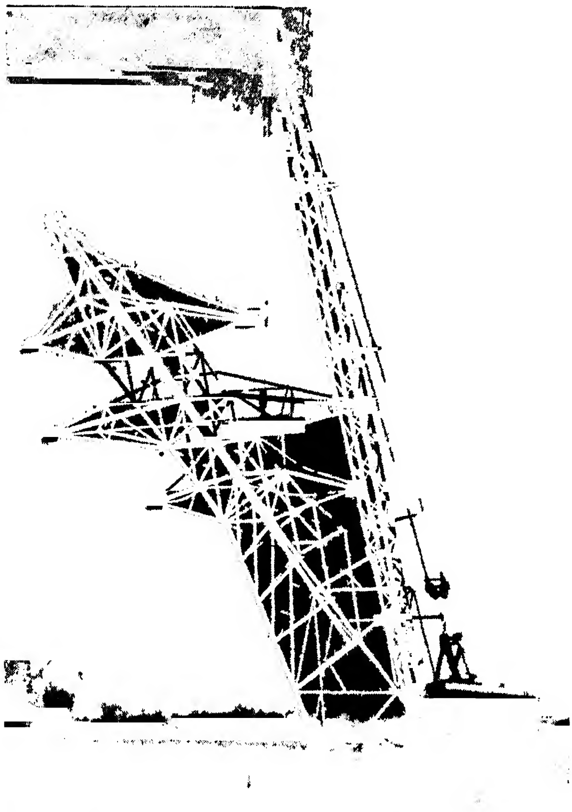


FIG 18-16 A 132,000-volt transmission-line tower being set on its footings The first leg is in its approximately correct position From this point on, the crane operator must operate his crane to get the other three legs correctly placed After that, it is just a matter of bolting the tower legs to their footings (*Courtesy Wisconsin Electric Power Co*)

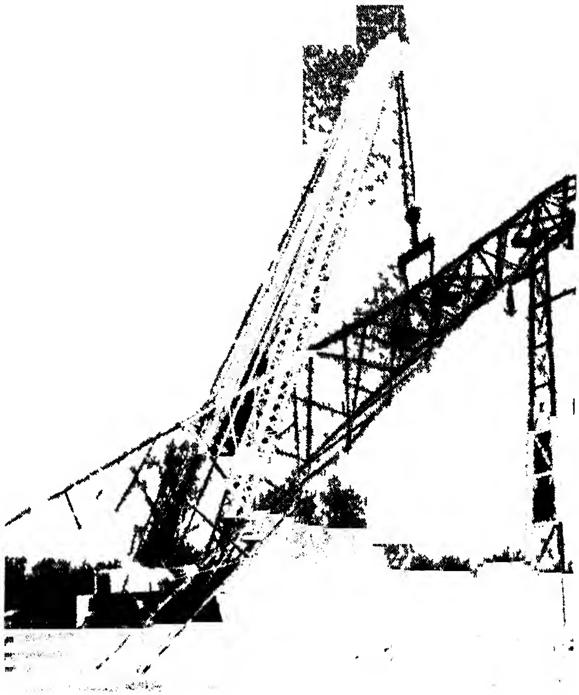


FIG 18-17 Lifting completely assembled 115 000-volt tower onto its footings by means of a mobile power crane The crane has a 60-ft boom Note footing stubs projecting out of ground directly underneath hoisting cable Also note that the tower is being erected with the insulator strings attached to crossarms They have to be securely fastened however to avoid swinging against the tower and breaking the porcelain on the insulator disks (*Courtesy Virginia Electric and Power Co*)

Fig. 18-18. A 132,000-volt transmission-line tower being bolted to its anchors or stubs after it has been placed in position The workmen are lining up bolt holes by means of drift pins so that the bolts can be inserted readily and the tower secured to its footing. (*Courtesy Wisconsin Electric Power Co.*)

b. Piecemeal Method. The following views show a number of steps in the erection of a transmission tower by the "piece-by-piece" method. This method of tower erection is similar to that used in erecting steel buildings or other permanent structures. The method is used when the towers are large and heavy and when the ground is rough.

In assembling a tower in place, light members are often simply lifted into place. Sometimes one of the corner legs is used for raising the other members. For heavier towers, a small boom is rigged on one of the tower legs for hoisting purposes. The usual procedure followed is illustrated in Figs. 18-19 to 18-31.

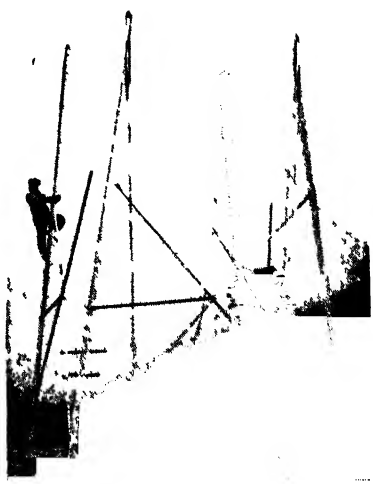


Fig. 18-19. Beginning the erection of a 45-ft corner tower by the "piecemeal" method. (*Courtesy Central Illinois Light Co.*)

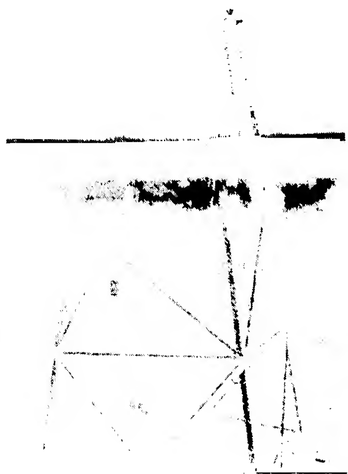


FIG 18-20 Gin pole placed on one of the corner legs for raising parts for the second section of the frame (*Courtesy Central Illinois Light Co*)

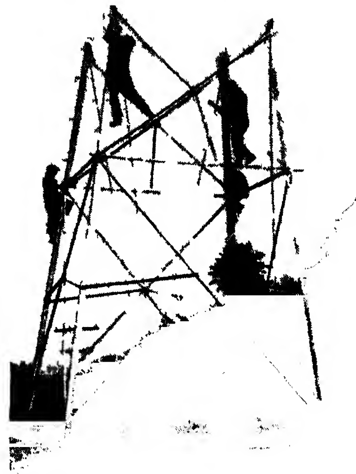


FIG 18-21 Bolting struts in position on top part of lower section (*Courtesy Central Illinois Light Co*)

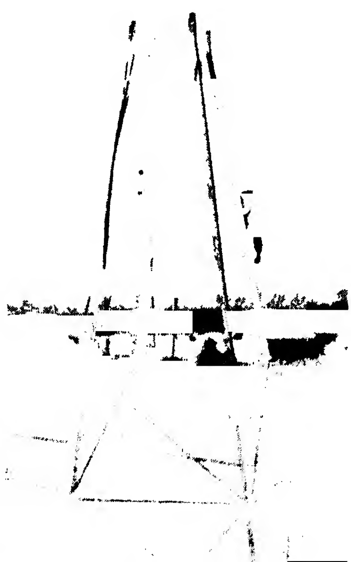


FIG 18-22 Leg members for second section in place. (*Courtesy Central Illinois Light Co.*)

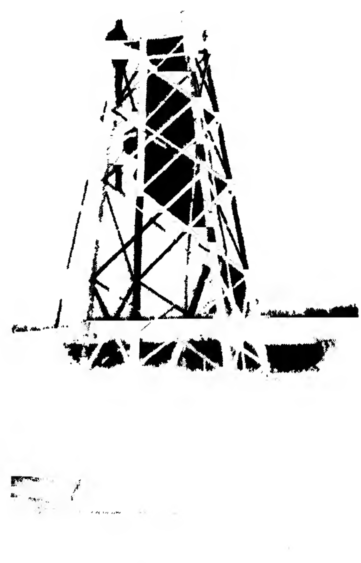


FIG 18-23 Struts on four sides of second section in place. (*Courtesy Central Illinois Light Co*)

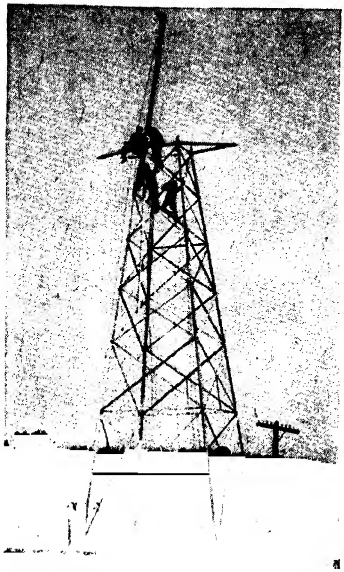


FIG. 18-24. Bottom arm of tower in place. Gin pole ready to put up first leg for third section. (*Courtesy Central Illinois Light Co.*)

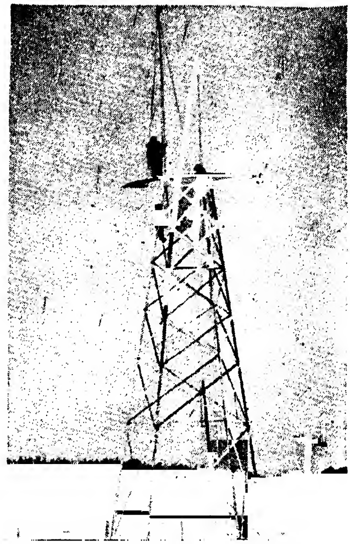


FIG. 18-25. First leg of third section in place. (*Courtesy Central Illinois Light Co.*)

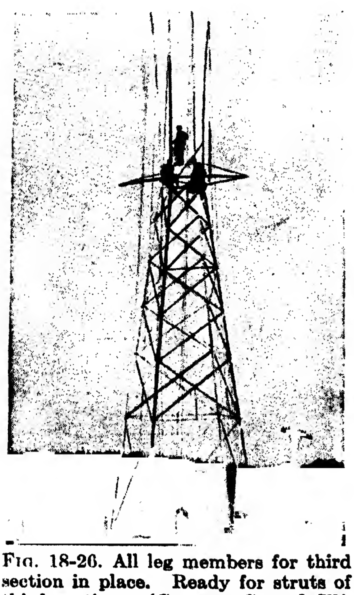


FIG. 18-26. All leg members for third section in place. Ready for struts of third section. (*Courtesy Central Illinois Light Co.*)

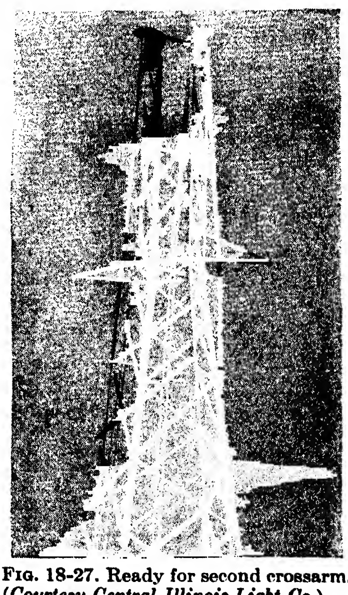


FIG. 18-27. Ready for second crossarm. (*Courtesy Central Illinois Light Co.*)

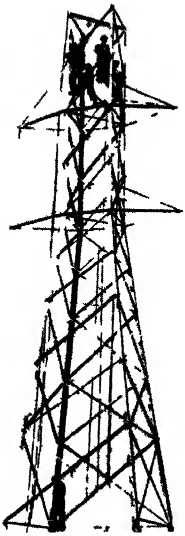


FIG 18-28 Second crossarm in position (*Courtesy Central Illinois Light Co*)

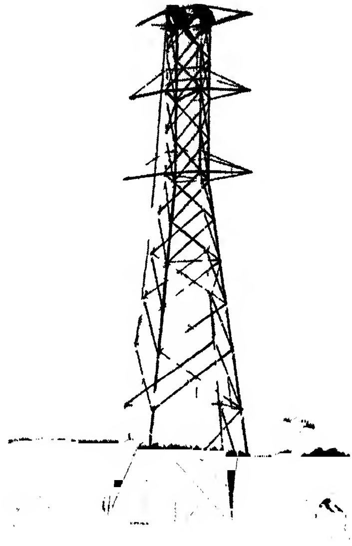


FIG 18-29 Top crossarm in place (*Courtesy Central Illinois Light Co*)

FIG 18-30 Gin pole fastened to one leg of tower Tower is being erected piece by piece and bolted into place Tower base is being completed (*Courtesy American Gas and Electric Service Corp*)

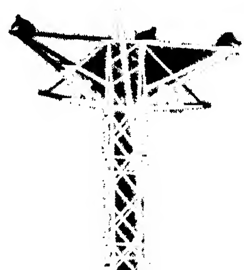


FIG 18-31 Use of gin pole in completing the erection of the top of the tower by the piecemeal method Gin pole is moved up as the tower grows Assembly of one set of crossarms is under way. (*Courtesy American Gas and Electric Service Corp*)

c. Section Method. A third method of erecting transmission towers is that of erecting by sections. In this method, flat parts or sides of sections are bolted together on the ground, then hoisted into position, and bolted in place. Figures 18-32 to 18-44 show the steps in the process. The tower erected in the photographs is 80 ft high, weighs about 8,000 lb, consists of 166 pieces, and is held together with 743 bolts. The spacing of the towers on the line is 800 ft. Each tower carries six No. 0000 copper conductors and one galvanized ground wire. The voltage of the line is 132,000 volts.

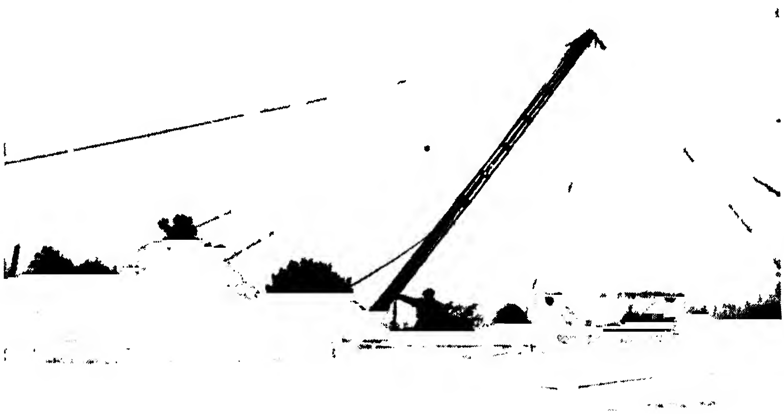


FIG. 18-32. Raising gin pole for first lift. The built-up gin pole is 30 ft long and is held in place by six guys. (*Courtesy Indiana Electric Corp.*)

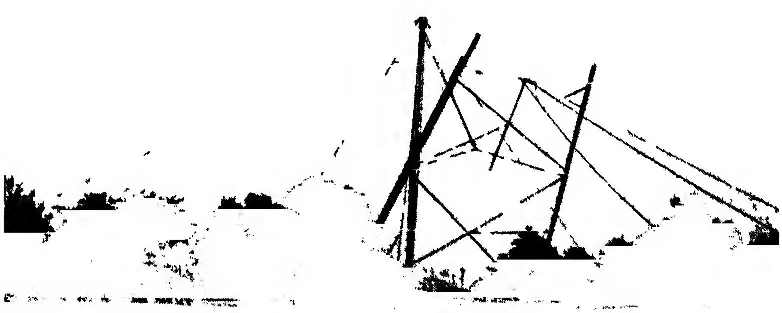


FIG. 18-33. Raising first side of first section. (*Courtesy Indiana Electric Corp.*)

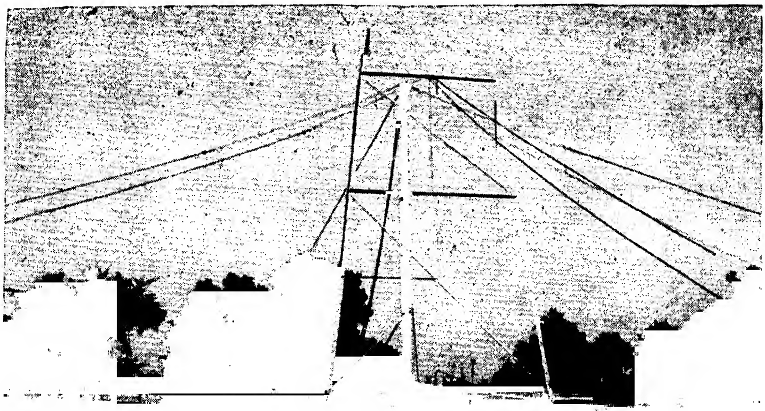


FIG. 18-34. One side of first section in place. (*Courtesy Indiana Electric Corp.*)

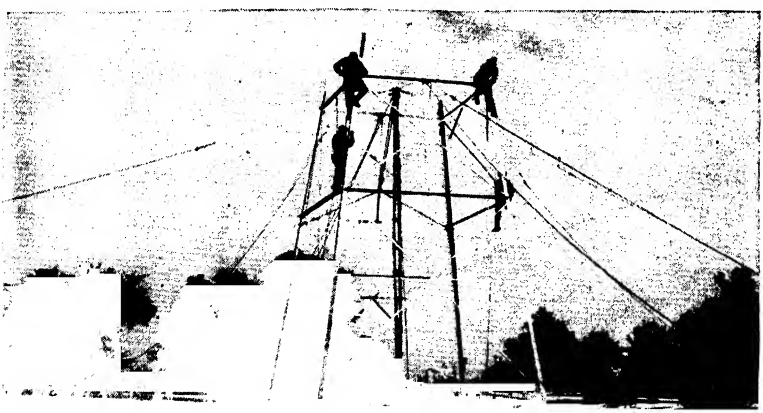


FIG. 18-35. All sides of first section in place. This required setting up only two sides (opposite sides) as the remaining two sides consist only of lacing. (*Courtesy Indiana Electric Corp.*)

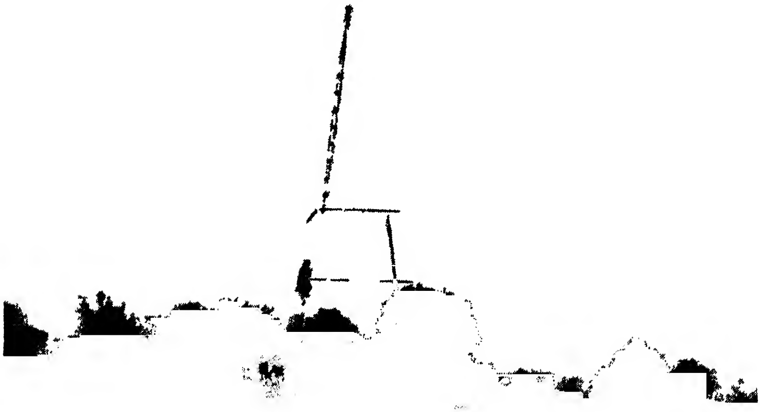


FIG 18-36 Gin pole set for second lift The foot of the gin rides on a hook over a strut on the tower immediately below the leg joint The gin then has to be properly raked and guyed into position (*Courtesy Indiana Electric Corp*)

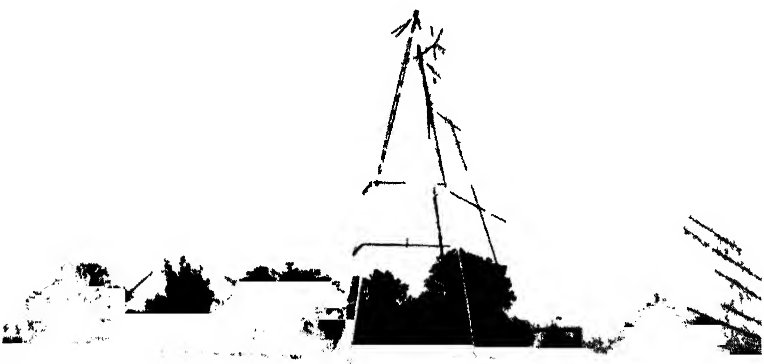


FIG 18-37. Raising first face of second section (*Courtesy Indiana Electric Corp*)

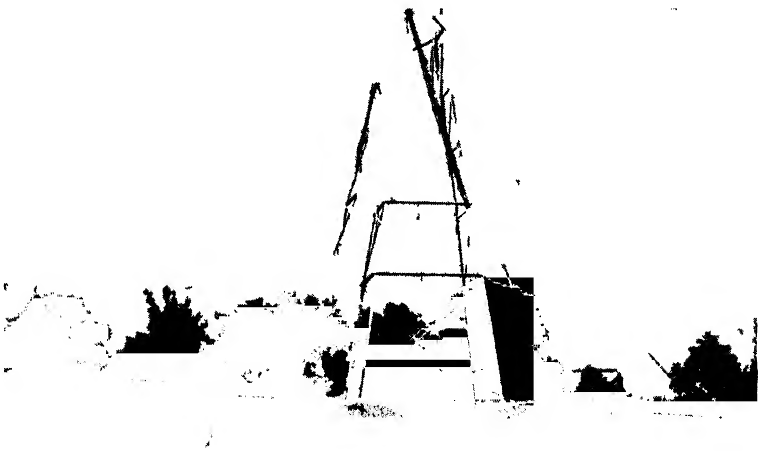


FIG. 18-38 Raising second face of second section To raise this section it is necessary to slide the foot of the gin on the strut to the opposite side of the tower After the two opposite faces are raised the lacing on the other two sides is bolted up (*Courtesy Indiana Electric Corp*)

FIG. 18-39 Gin pole raised a second time for the third lift. Again the gin is rested on a hook over a strut immediately under a leg joint. (*Courtesy Indiana Electric Corp.*)

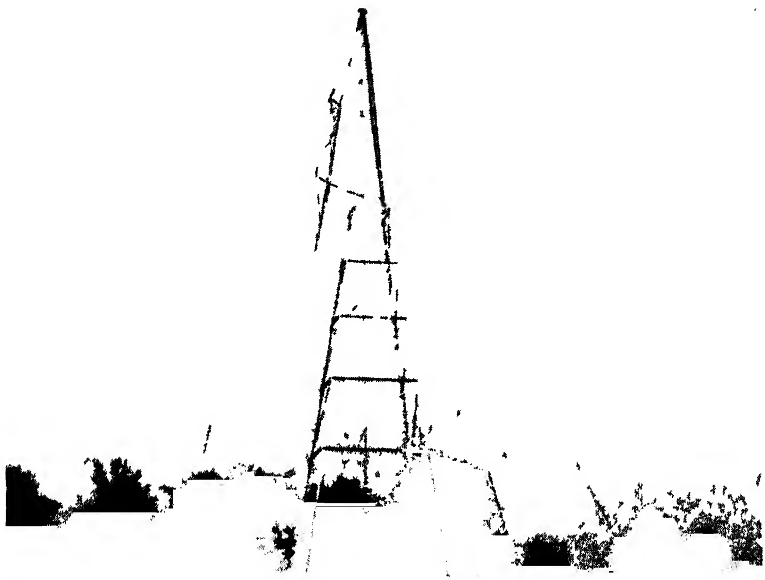


FIG. 18-40. Raising the first face of the third section. (*Courtesy Indiana Electric Corp.*)

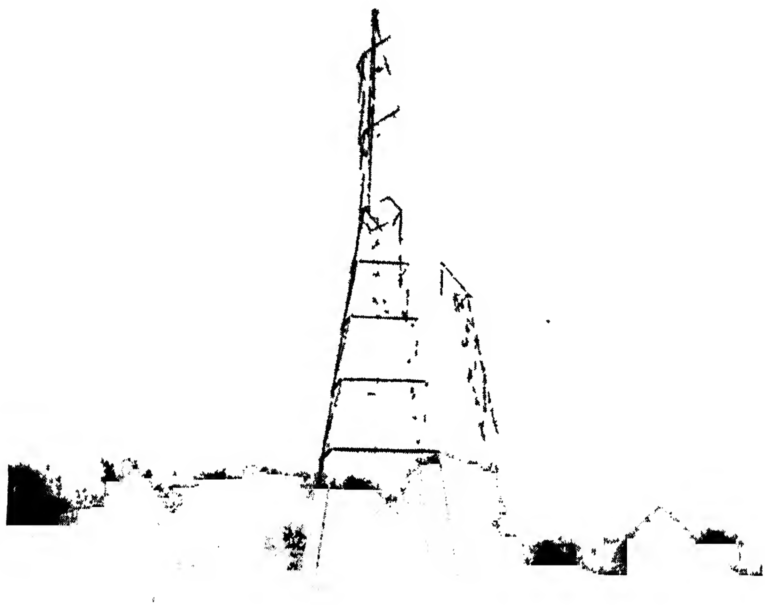


FIG. 18-41. Raising the second face of the third section. After this, the lacing on the remaining sides is bolted up.

The last lift raises the bonnet or top of the tower. After the bonnet is placed and all side lacing has been bolted up, five guys are thrown off while the sixth is used to lower the gin pole. (*Courtesy Indiana Electric Corp.*)

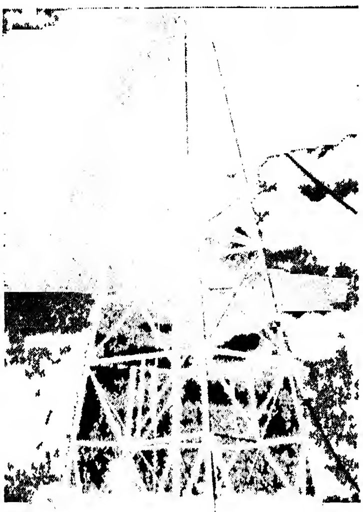


FIG 18-42 "Landing" the opposite panel in the third section The "lacing" or "spiders" on the two open sides are now being raised and attached (*Courtesy Detroit Edison Co*)

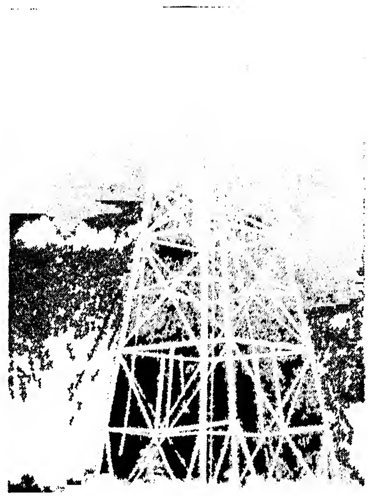


FIG 18-43 Another view of tower erection by the section method using gin pole The third section side panel is just being "landed" This panel was assembled on the ground and then raised into position with a 25-ft gin pole (*Courtesy Detroit Edison Co*)

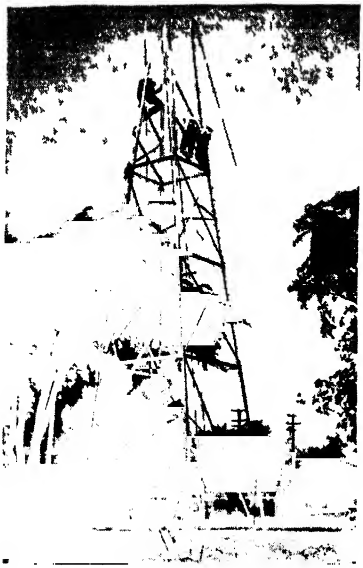


FIG 18-44 Installing "spiders" in the third section The corner legs were raised individually with a light 22-ft gin pole placed in each of the four corners in turn (*Courtesy Detroit Edison Co*)

5. Hanging Insulators

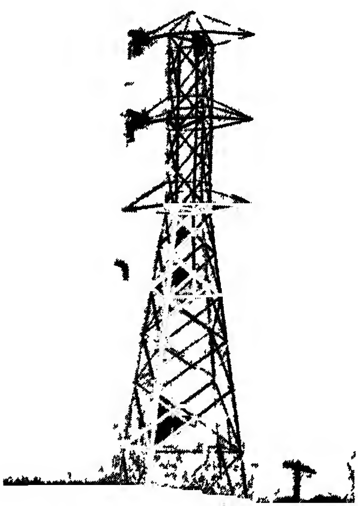


FIG 18-45 Raising suspension insulator string to crossarm This is done by the use of a hand line running over a single pulley fastened to the top crossarm (*Courtesy Central Illinois Light Co.*)

6. Unreeling Conductors

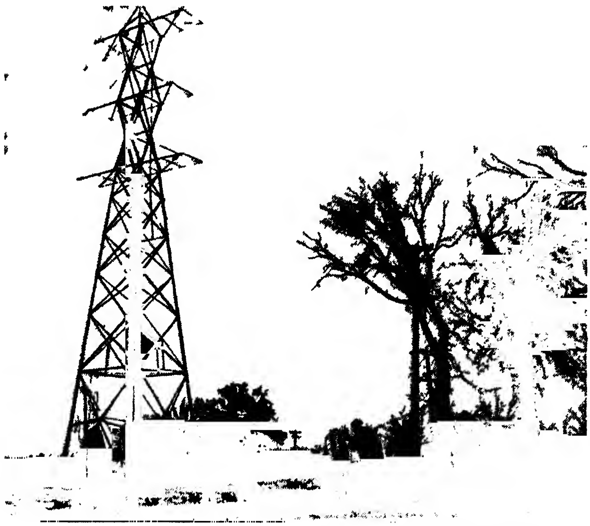


FIG 18-46 Reels set up for stringing 132,000-volt transmission-line conductors. The three line wires are on the large reels The ground wire is on the small reel The pole stubs lying on each reel act as brakes to prevent overrunning The wires pass through pulleys called snatch blocks or sheaves, which are fastened to the tower crossarms (*Courtesy Wisconsin Electric Power Co*)

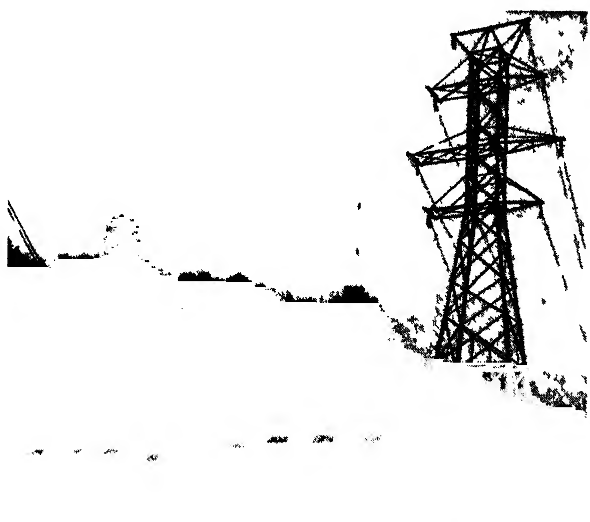


FIG 18-47 Pulling wire from reels Two circuits are being pulled at the same time Each circuit consists of the three line conductors and the ground wire. Note hand brakes on rims of reel drums Person supervising the wire stringing is in communication with driver of pulling tractor by telephone. Voltage of line is 115,000 volts. (***Courtesy Virginia Electric and Power Co.***)

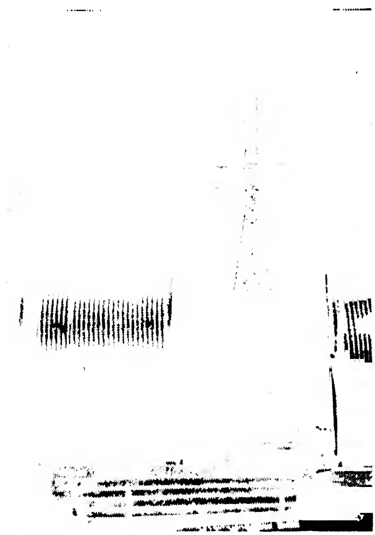


FIG. 18-48. Unreeling line-conductor cables from reels and pulling them over sagging sheaves attached to suspension insulator strings. Pulling is done by tractor at far end of line section. Conductor being unreeled is 1,275,000-cir mil ACSR expanded cable having an outside diameter of 1.6 in. Voltage of line is 330,000 volts. (*Courtesy American Gas and Electric Service Corp.*)

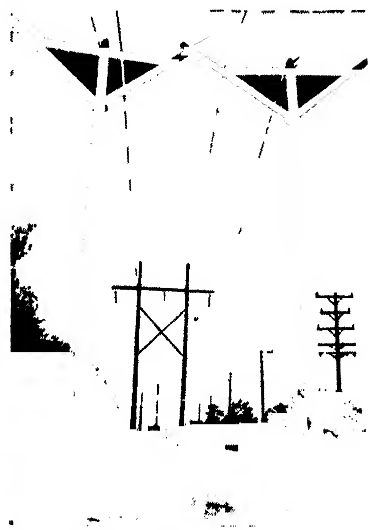


FIG. 18-49. In case conductors have to be strung over a live line, guard poles which hold the wires above the live line are used. Here shown are two guard poles carrying three line conductors and two ground wires of a 132,000-volt line over a 4,800-volt single-phase distribution feeder. (*Courtesy Wisconsin Electric Power Co.*)

7. Joining Conductors

FIG. 18-50. Joining conductor by means of a power-driven hydraulic compressor. At the instant shown, the sleeve is being compressed onto the steel core. The larger sleeve shown at right will be compressed onto the aluminum strands after the sleeve on the steel core is completed. The conductor shown is a 795,000-cir mil ACSR cable. (*Courtesy Detroit Edison Co.*)

FIG. 18-51. Compressing aluminum sleeve onto an ACSR cable by means of a power-driven hydraulic press. The cable being spliced is a 1,275,000-cir mil expanded ACSR cable having an outside diameter of 1.6 in. Note wrapping on cable to keep strands from unraveling. (*Courtesy American Gas and Electric Service Corp.*)

FIG. 18-52. Impregnating compression-sleeve cable splice with zinc chromate to prevent oxidation of joint. Note compressor has been opened to expose central portion of joint. (*Courtesy American Gas and Electric Service Corp.*)

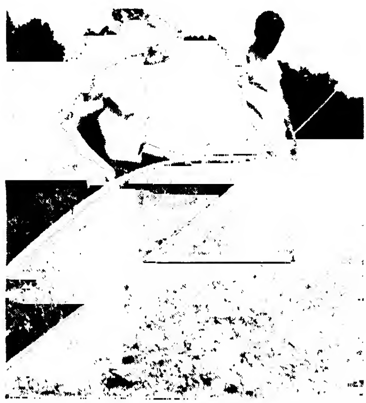


FIG. 18-53. Completed compression-sleeve joint on a 1,275,000-cir mil expanded ACSR cable having an outside diameter of 1.6 in. This cable is being installed on a 330,000-volt transmission grid. The average span over level country will be 1,200 ft, and in mountainous terrain it will be as high as 1,700 ft. The large diameter is necessitated to hold the corona loss to a reasonable value. (*Courtesy American Gas and Electric Service Corp.*)

8. Stringing Conductors

FIG 18-54 Attaching the kellum grip on a 795,000-cir mil ACSR cable. This grip is used for pulling the cable over the stringing sheaves on the towers. When the grip is in place, it is taped down to the conductor to keep it from pulling back and releasing. (*Courtesy Detroit Edison Co.*)

FIG. 18-55. Installing the pulling grip or come-along on a 1,275,000-cir mil ACSR expanded cable having an outside diameter of 1.6 in. Cable will be drawn up by the caterpillar tractor shown. Note men holding cable to keep it from kinking or becoming damaged. Voltage of line is 330,000 volts. (*Courtesy American Gas and Electric Service Corp.*)

FIG. 18-56. Cables from reels are threaded through sagging sheaves on crossarms. (*Courtesy American Gas and Electric Service Corp.*)

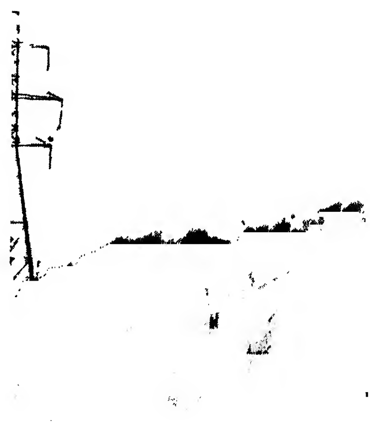


FIG. 18-57. Tractor pulling slack out of lines threaded through sagging sheaves on tower. (*Courtesy American Gas and Electric Service Corp.*)

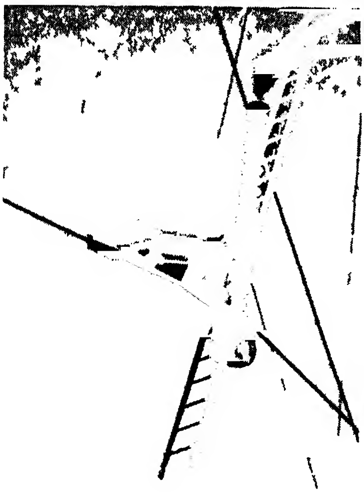


Fig 18-58 Close-up view of lineman attaching come-along to line conductor Upper conductor has come-along attached Note that cable used for sagging runs through a separate sheave Note method of supporting lineman from ladder hooked over cross-arm Also note length of suspension insulator string consisting of 18 suspension units This line is to operate at 330 000 volts (*Courtesy American Gas and Electric Service Corp*)

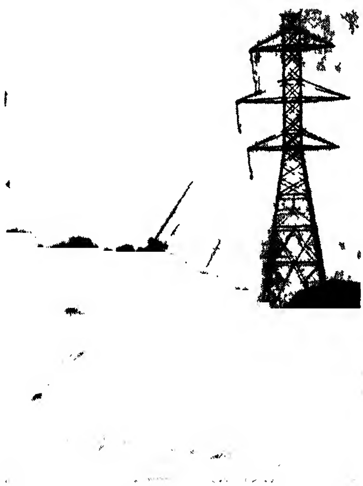


Fig 18-59 Close-up view of come-along attachment to sagging cable and tractor Supervisor of operation in lower right directs pulling up of cable by use of portable "walkie-talkie" radio (*Courtesy American Gas and Electric Service Corp*)

Fig 18-60 Foreman supervises stringing operations by portable "sound-powered" telephone connections with pulling tractor, reel, and tower men, whose positions can be alerted simultaneously (*Courtesy American Gas and Electric Service Corp*)

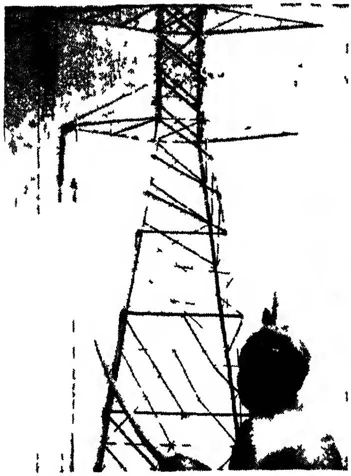


FIG. 18-61. While stringing continues, tower men keep supervisor informed of conditions at cable sheave while conductor is being pulled up (*Courtesy American Gas and Electric Service Corp.*)

FIG. 18-62. Close-up view of tower man as he observes the wire stringing and keeps supervisor informed of conditions at cable sheaves (*Courtesy American Gas and Electric Service Corp.*)

FIG. 18-63. Line conductors pulled up close to correct sag and snubbed off to earth anchors The snub must be made far enough out from the tower to keep the down pull on the crossarms to a safe value. Lineman shown is using a coffing hoist with wire grips to pull conductors up to exact sag. The conductors are 795,000-cir mil ACSR cables and have been strung over 14-in. stringing sheaves. The desired sag is equivalent to a tension of 7,000 lb. (*Courtesy Detroit Edison Co.*)

9. Armor Rodding and Clipping In

FIG. 18-64. Ascending tower on steps provided on corner leg to apply armor rods, attach corona shield, and clamp conductor to insulator string. Tower is 148 ft high. (*Courtesy American Gas and Electric Service Corp.*)

FIG. 18-65. Hoisting work platform to linemen who are to apply armor rods, attach corona shield, and clamp conductor to insulator string. (*Courtesy American Gas and Electric Service Corp.*)

FIG. 18-66. Lineman on portable work platform removing sagging sheaves, attaching corona shield, conductor clamp, armor rods, and conical vibration damper. (***Courtesy American Gas and Electric Service Corp.***)

FIG. 18-67. Close-up view of lineman on work platform removing sagging sheaves, attaching corona shield, conductor clamp, armor rods, and conical vibration dampers. (***Courtesy American Gas and Electric Service Corp.***)

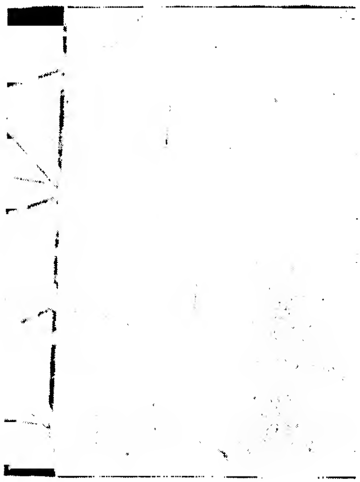


FIG. 18-68. Installing preformed armor rods on a 115,000-volt two-circuit transmission line Note special yoke used to support conductor while armor rods are being applied. (*Courtesy Virginia Electric and Power Co.*)

FIG. 18-69. Installing preformed aluminum armor rods on 795,000-cir mil ACSR conductor. The armor rods will reduce conductor damage due to vibration of conductor in wind. Men are working from a hook ladder supported from the crossarm. (*Courtesy Detroit Edison Co.*)

FIG. 18-70. Applying armor rods. Conductor has been lifted with a coffing hoist and rope sling and removed from stringing snatch block. The conductor is marked in order to center armor rods. Preformed armor rods are twisted on by hand three or four at a time. (*Courtesy Detroit Edison Co.*)

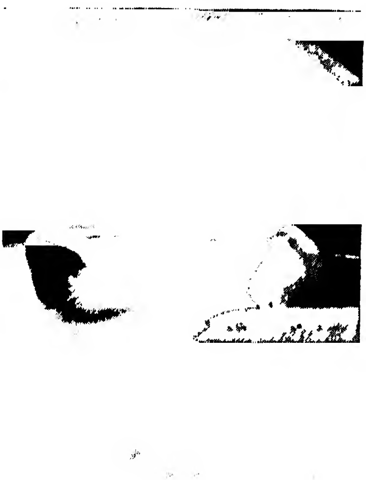


FIG 18-71 Applying armor rods When all rods are partially twisted on, the assembly is lowered into the suspension clamp and clipped in The rope and hoist are then removed The installation of the rods is then completed Oiling the rods helps installation (*Courtesy Detroit Edison Co.*)

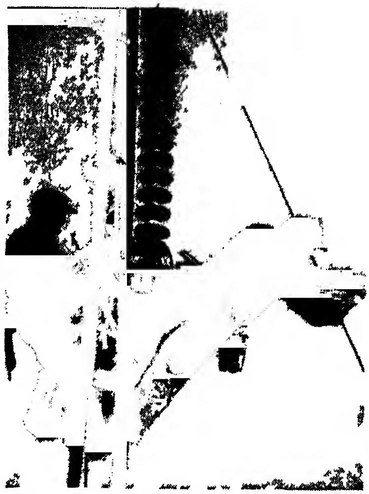


FIG 18-72 Installing armor rods on 330 000-volt line Conductor has been placed in insulator clamp Note length of 18-unit insulator string Also note chain hoist which was used in transferring conductor from the stringing sheave to the conductor clamp. Linemen are supported from ladder hooked over crossarm (*Courtesy American Gas and Electric Service Corp*)

FIG 18-73 Close-up view of linemen wrapping armor rods on cable each side of insulator clamp Note large corona shield which is also supported by the insulator clamp Voltage of line 330,000 volts (*Courtesy American Gas and Electric Service Corp*)

SECTION 19

Patrolling and Inspecting Lines

General. After electrical machinery is constructed and put into operation, it must be inspected, tested, repaired, and maintained in good operating condition. Transmission and distribution lines are working machines on which internal stresses and strains and nature's elements are constantly acting, tending either instantly or gradually to weaken one part or another of the line. Poles, towers, insulators, and conductors therefore require a certain amount of attention, from time to time, to prevent serious weaknesses developing and putting the whole system out of service. It is not always realized that every insulator on the line has the whole system in its keeping, for the failure of but one pin insulator or one insulator string will put the entire power system out of use. There is no division of responsibility among the parts. Each and every insulator, pole, tower, conductor, etc., carries the entire responsibility and therefore must do its full duty; or the whole system will fail. The necessity for periodic and frequent patrolling (see Fig. 19-1) and inspection is thus obvious if continuous service is to be rendered.

PATROLLING LINES

Requirements of a Good Patrolman. A good patrolman should concentrate on the task at hand, know just what is expected of him, and be able not only to do it but to tell others how it was done. He should be able to make complete reports indicating conditions, distinguish between hazardous and nonhazardous conditions, and furnish a list of material needed and the outages necessary to repair any trouble he reports.

Regular Patrols. A regular schedule is set up by the superintendent of lines in each division to provide for the patrolling of all important lines. All high-tension lines (25 kv and up) are patrolled regularly at intervals of 30 to 45 days, depending upon circumstances. A regular patrol might even be set up on a 2,300-volt line if the line is regarded as sufficiently important. Servicemen are not assigned to regular patrols.

Emergency Patrols. An emergency patrol is a patrol ordered over a line during an outage on the line because of the inability to keep it energized. The purpose of such a patrol is to locate as quickly as possible the trouble which prevents the line from being energized. *Servicemen, upon occasion, will be assigned to emergency patrolling* and, therefore, must be familiar with the responsibilities involved.

Assigning Patrols. An emergency patrol is organized by the superintendent of lines as quickly as possible upon request from the load dispatcher.

Night Patrols. Emergency patrols are not made after dusk or before daybreak unless service to customers is interrupted or the chief load

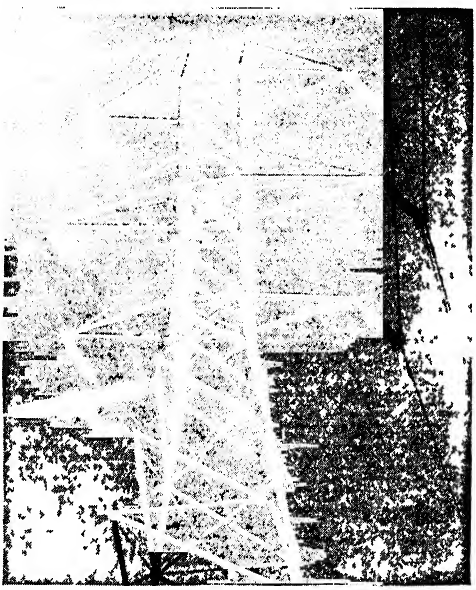


FIG 19-1 Airplane used in periodic inspection of high-voltage transmission line.

dispatcher has determined that the line in trouble is needed back in service immediately. Two men always go together on night patrols and carry suitable lights.

Extent of Patrol. Each patrolman on an emergency patrol walks from the starting point along the line in the direction specified until he finds the trouble, or meets the emergency patrolman coming from the opposite direction, or until the part of the line assigned to him has been covered.

Consider Lines Energized. When a line is being patrolled during trouble, all persons patrolling the line must consider it "hot," even though it was "dead" and grounded when they started out, unless they have obtained a "release" on the line from the load dispatcher. Should a patrolman find trouble on a line on which he holds no release, he must keep "clear" of the line until he has obtained a release on it.

Telephone Lines. If a telephone line is to be sectionalized to locate power-line trouble, the person ordered to sectionalize must first obtain a "caution order" on the power line. The telephone line may be crossed up with the power line at the location of the trouble and might be energized by tests on the power line if no release or caution has been issued.

Inspecting Outdoor Stations. Since trouble on a line may be at an outdoor substation connected to the line, all such stations passed during an emergency patrol should be inspected carefully.

Leaving the Line. Should it be necessary to leave the line before meeting the patrolman coming from the opposite direction, a note should be left with a signal attached to a conspicuous part of the pole or tower to keep the other patrolman from again covering the part already patrolled.

Reporting Trouble. When a patrolman on an emergency patrol finds trouble which may be the cause of the line outage, he should go to the nearest available telephone, report the trouble to the superintendent of lines' office, district manager, or load dispatcher, and ask for instructions about continuing the patrol, returning to headquarters, or remaining at the location of the trouble.

Reporting off Patrol. When a patrolman meets the patrolman coming from the opposite direction or reaches the end of the line without finding the trouble, he should report to the superintendent of lines' office, district manager, or load dispatcher, as soon as possible from the nearest available telephone, and ask for further instructions.

Postpone Regular Patrol. When an emergency patrol is made over a line, the superintendent of lines will move ahead the next scheduled regular patrol by approximately the scheduled time interval from the emergency patrol.

Follow-up Patrols. A follow-up patrol is a patrol ordered over a line following one or more short interruptions to the line because of the tripping of the line breakers or the blowing of fuses with power being subsequently restored to the lines. The purpose of such a patrol is to locate the cause of the interruptions and to make certain no hazards exist. The load dispatcher may approve delaying this patrol for 1 to 4 days following the trouble.

Assigning Patrols. A follow-up patrol shall be organized by the superintendent of lines upon a request from the load dispatcher.

Time Limit before Completion. A follow-up patrol ordered for any line must be completed by the evening of the fourth day after the outage requiring the patrol, unless further delay is approved by the load dispatcher.

Limit Number of Patrolmen. A follow-up patrol is organized by the superintendent of lines' office so that a minimum number of men, in addition to the regular patrolman, will be used to cover the line within the required period.

Locating Trouble. When a patrolman on the follow-up patrol finds trouble, which, upon being reported, appears to be the cause of the outage requiring the patrol, it may not be necessary to continue the patrol over more of the line. *He should notify the superintendent of lines' office, district manager, or load dispatcher from the nearest telephone and ask for instructions.*

Postpone Regular Patrol. When a follow-up patrol is made over a line and the patrol of the line is completed, the superintendent of lines will move ahead the next scheduled regular patrol by approximately the scheduled time interval from the follow-up patrol.

Patrol Reports and Records. *Report As Soon As Completed.* As soon as possible after completing a patrol of any line, the patrolman should call the superintendent of lines' office in whose division the line is located, give his name and the name of the line or sections of line he has patrolled, and make a detailed report of any trouble found.

Nonhazardous Reports. When a patrolman reports a condition which is not in need of immediate repairs, that is, where the condition is not a hazard to the line, service, or property, he should state so in his report.

Give Location. Report all trouble or dangerous conditions by naming the line and the pole number nearest to the trouble.

Keep Reporting. Report all dangerous conditions each time that the line is patrolled until the condition is corrected, unless the superintendent of lines gives special permission to cease reporting any individual trouble.

Patrolling Records. The superintendent of lines is responsible for following the patrol schedules and keeps a record of all lines patrolled in their respective divisions. The record is so set up that an immediate report can be given of the last day any line was patrolled, the type of patrol made, the person making the patrol, and the trouble card numbers covering any trouble found on the patrol. Such records are kept on file for a period specified by the manager of lines.

What to Report. The principal conditions a patrolman should report when observed along any line are as follows:

INSULATORS. Broken, cracked, badly leaning, swinging, or flashed insulators. Give the style number of the insulators when it is known, state their position on the pole, and state whether the pole is single or double arm.

POLES. Poles broken off or leaning out of line 2 ft or more at the top or requiring filling at the base. Woodpecker or ant holes that impair the strength of the pole. If a patrolman is unable to tell the extent of such holes, report the fact so that a special inspection may be arranged.

CONDUCTORS. Broken strands, blisters, burnt spots, undue or uneven sagging. Foreign objects, such as kites, kite strings or tails, pieces of wire, tree limbs, reeds, corn husks, etc., hanging on or dangerously near any conductor.

GROUND LEADS. Broken or loose from supports.

TIE WIRES. Broken off or burned.

CROSSARMS. Crossarms split, rotted, or loose; or loose, splintered, or missing braces.

Insulator Pins. Bad or broken pins, or pins partly out of crossarm.

Guy Wires. Broken or slack wires. Broken insulators.

Trees. Trees and tree limbs in such positions that they may touch, blow, break off, or fall into power or telephone wires. Any trees which would fall into the wires if they broke off at the ground line are considered dangerous and should be reported. Trees or tree limbs within 4 ft of any power wire or within 2 ft of any telephone wire should be reported. Note whether the tree is a valuable fruit or shade tree.

Supports. Any nuts off or loose from their bolts; tower members which are loose or bent out of position; the caving in of any ground dangerously close to a pole or tower.

Identifications. Pole tags, air-switch names, junction signs or station signs which are missing or mutilated beyond identification.

Right of Way. Weeds and brush in need of cutting.

Outdoor Stations

1. Transformer temperatures of 75°C or above.
2. Oil not showing in gage.
3. Oil leaks.
4. Broken, cracked, or chipped bushings and insulators.
5. Loose connections, defective wiring, leads, etc.
6. High weeds.
7. Locks not operating properly. Breaks in fence.
8. Defective arresters.
9. Signs of flashover of protective gaps on transformers and arresters.
10. Less than two complete sets of spare fuses in container.
11. Name and warning signs missing or not properly placed.

Telephone Lines and Equipment

1. Broken or cracked insulators.
2. Insulators off pins and pins pulled from poles.
3. Tree limbs within 2 ft of wire. Trees or limbs which might fall into line.
4. Wire touching pole or other structures.
5. Test all telephones and observe general conditions of booth.
6. Check for spare fuses.

Instructions for Emergency Patrolling. In case of line trouble causing outage and interruption to service, emergency patrolling may be required. The following instructions should be followed:

1. Stay away from the line. You do not have clearance on it, and it may be energized or tried out at any time.

2. Walk from your starting point in the direction specified until you find the trouble or meet the man walking toward you.

3. Report to system operator (special instructions may require report to someone else) at half-hourly intervals if you can do so without getting so far away from the line as to risk not seeing another patrolman. If you are on a cross-country line and do not pass telephones, make an effort to telephone your headquarters at least once each hour.

4. When you locate the trouble, go to the nearest telephone and report, making sure that you give exact location and as nearly as possible the extent of the damage. If you are not given specific instructions at this time, return to the breakdown and guard the public and domestic animals from accident. After you locate the trouble and report it, you can usually do a lot, even if you are alone, to speed the repairs. When you talk to the system operator, therefore, get clearance on the line, provided you are not ordered to leave the location. The system operator will ordinarily have the line opened and will be ready to issue clearance on it by the time the location of the trouble is reported to him. If you are in doubt as to what you alone can do to repair the damage while waiting for help, do not hesitate to ask for detailed instructions from headquarters.

5. If it becomes necessary for you to leave the line to telephone while patrolling, leave a note attached to a conspicuous part of the nearest pole or tower, telling where you are and what time you left the line. This will prevent any possibility of another patrolman passing during your absence. Hold-order tags are handy for this purpose, and a supply will be kept at crew headquarters for your convenience.

6. If you meet your man or reach the end of the line without finding the trouble, report to the system operator from the nearest telephone and ask for further instructions.

7. Remember that trouble apparently on a line may actually be on substations connected to the line. This is a strong possibility when unattended substations are involved. Be sure, therefore, that you inspect any substation on your section of the line, whether it be at the point from which you start patrolling, end patrolling, or along the line. Exceptions to this will be given as special instructions when necessary.

A typical patrolman's daily report form is shown in Fig. 19-2. Figure 19-3 shows another form of report filled out.

Patrolmen frequently come in contact with the public. At such times a patrolman should remember that he is the company in the eyes of persons he meets and talks to. He should be uniformly courteous and should make every effort to avoid damage to growing crops by reason of his patrolling. By closing all gates he opens and thus preventing stock from straying, he will build good will for himself and the company.

A patrolman should make the acquaintance of residents along the lines he patrols. He should tell them why patrolling is necessary and something of the importance of uninterrupted service on the lines. Many persons with this knowledge will take the trouble to report wires down or other line trouble when they see or hear of it.

PENNSYLVANIA EDISON COMPANY
PATROLMAN'S REPORT

Line From Pole No To Pole No. Date

Patrol of this Line reveals the following Conditions and Defects

Right of Way or Trees

Structures

Arms-Pins-Insulators

Conductors

Ground Wire and Grounds

Telephone Circuit and Equipment

Substations

Customer's Substations and Equipment

Special or Misc. Equipment

Line Switches

Malicious Interference

Buildings or Roads Under Construction Menacing Line

Remarks

Signed Patrolman

Dist. Foreman

FIG 19-2 A typical patrolman's daily report form (*Courtesy Pennsylvania Edison Co.*)

INSPECTING LINES

Time of Inspection. At least one general inspection should be made of the entire electric system each year. As the winter months are the hardest on the lines, the fall of the year is the best time to make the general inspection. In case two general inspections are made each year, the second inspection should be made in the spring.

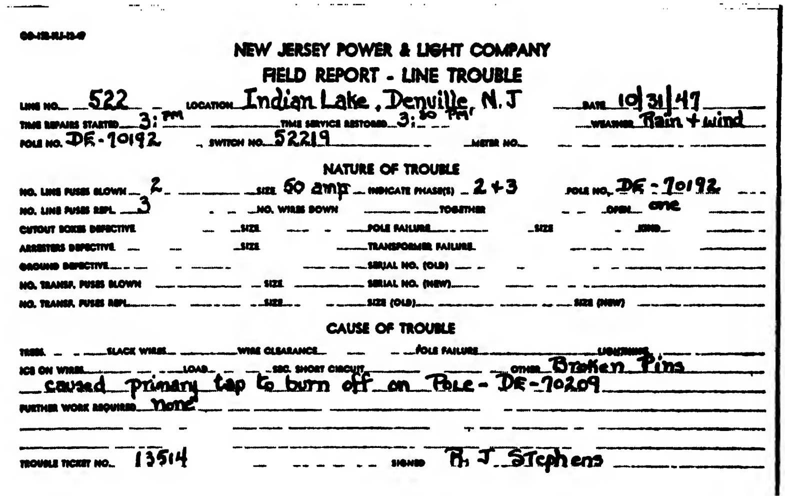


FIG. 19-3. Typical patrolman's field report filled out. (*Courtesy New Jersey Power and Light Company.*)

Inspector's Instructions. Below are given specific instructions based on operating experience to guide inspectors in looking for faults on transmission and distribution lines and transformer substations. The lines and equipment should be examined for the following defects.

Poles:

Washout at ground line.

Rotting at ground line: Scrape away the earth from around the pole at the ground line to a depth of 2 or 3 in. Use a short crowbar or hand spike to determine depth to which rot has penetrated.

Hollow rot: sound body of pole for hollow rot. For a more complete test see Fig. 19-4.

Splitting.

Effects of lightning.

Splitting or pulling of guys.

Twisting or raking.

Ground wire: See that this wire is rigidly supported and that it has not been cut or the cross section reduced to any considerable extent by linemen's spurs.

See that the connection between ground wire and ground pipe has not been weakened by corrosion or mechanical injury.

Grass around base of pole: All grass, weeds, and any inflammable material should be kept cleared away from the base of the pole for a distance of 2 ft to reduce the fire hazard.

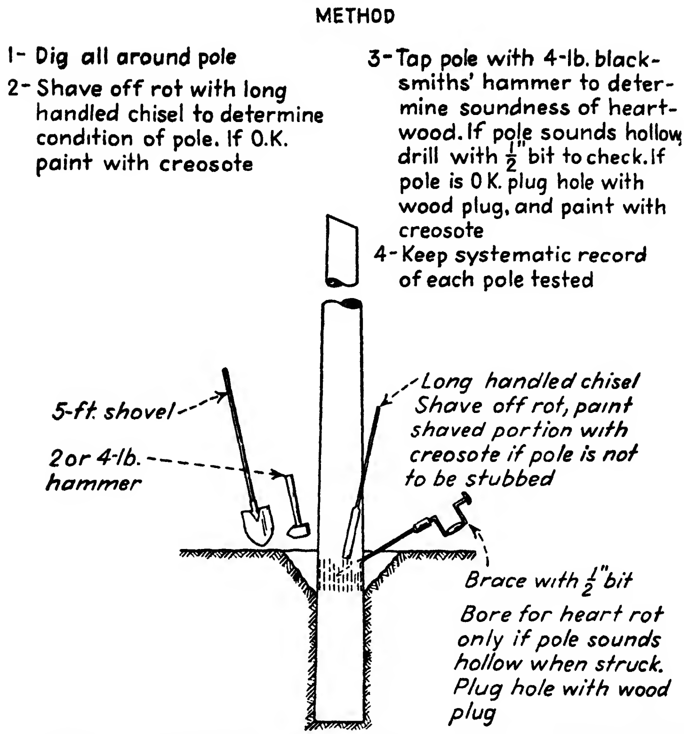


FIG. 19-4. Method of testing wooden pole for rot. (*Courtesy Montana Power Co.*)

Crossarms:

Rotting.
Splitting and twisting (especially on double arms).
Loose, broken, or missing pins.
Loose or missing braces.

Insulators:

Cracked: make close inspection for cracks.
Chipped or broken.
Unscrewed.

Wire:

Broken wires.
Short circuits.
Twisted spans.
Loose connections.

See that the wire is clear of tree twigs, limbs, kite strings, hay wire, etc.

Delay necessary brush cutting until August or September, except where there is danger of the brush fouling the lines in the interval.

Lightning Arresters (general):

Inspect pipe framework supports of arresters and paint with graphite if necessary.

Check gaps.

Check horns for loose bolts and position.

Inspect for loose ground connection.

Transformers:

Filter oil. If possible, oil should be removed from the tank; the walls of the tank and the coils should then be cleaned by flushing with oil.

Paint power transformers if necessary.

Test water-cooling coils for leaks with 75-lb air pressure.

Inspect bushings, compound and oil-filled.

Clean tanks, oil gages, thermometers, and valves.

Stop oil leaks. Do not try to stop a leak by calking, as this very often increases the leak.

Inspect bushings for leaking compound and cracks. Report leaks by joint number, cracks by disk number.

Clean bushings if transformer can be taken out of service.

Ground:

Make a mechanical inspection in the spring of all ground connections to transformer cases, transformer secondary wiring, power- and telephone-line lightning arresters.

Measure resistance of all grounds.

Oil Switches (high-tension):

Change or filter oil. Clean inside of tank and mechanism.

In internal inspection look particularly for loose bolts, loose nuts, loose and broken contacts, and dirty oil; examine conditions of alarm mechanism. Paint if necessary. Inspect and check setting of relays.

Inspect, noting particularly bearings, mechanism, bushings, oil level, and general cleanliness.

Air-break Switches (high-tension):

Inspect, adjust, tighten bolts and nuts, and see that movable parts operate freely.

Set arcing horns so that they barely touch when opened and closed.

Adjust contact to maintain full contact on all three phases without slamming the switch. Inspect stops.

Paint if necessary.

Transformer Fuse Air Switches:

Inspect for danger sign in case body can come in contact with conductors in climbing pole.

Fuses:

Inspect high-tension units for broken glass and loose connections.

High-tension Wiring:

Inspect for loose connections and crystallization due to vibration.

Structure:

Tighten all bolts.

SECTION 20

Line Testing

TESTING FOR LINE CIRCUIT FAULTS

Kinds of Circuit Faults. Overhead transmission and distribution line faults can be classified under three heads as follows:

1. Cross or short circuit
2. Open circuit
3. Ground

Any given line fault may be due to only one of the above or to a combination of any or all of them (see Fig. 20-1).

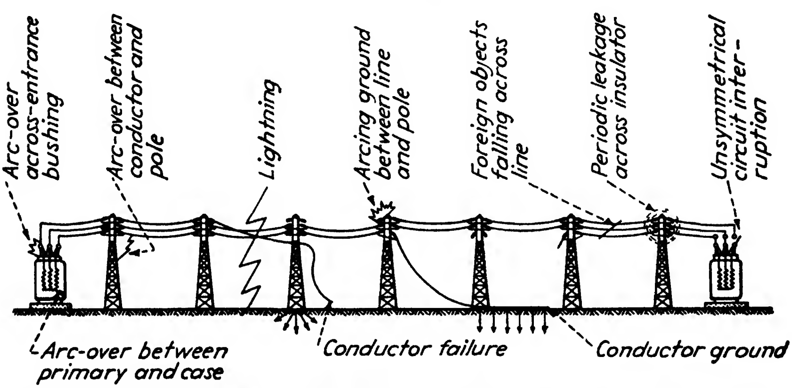


FIG. 20-1. Various types of transmission-line faults, such as insulator arc-over, short circuit, conductor failure, and conductor ground. (*Courtesy Metropolitan Device Corp.*)

Cross or Short Circuit. A line is said to have a "cross" or to be short-circuited when two or more of the conductors of the line come in contact with each other. A simple cross or short circuit is shown in Fig. 20-2. It is evident that when two or more of the line conductors become crossed the resulting short circuit will cause heavy currents to flow in the line. These currents will be so large that they will cause the overload relays on circuit breakers and oil switches to trip, thereby disconnecting the defective line. The opening of the circuit breaker or oil switch is, however, not always an indication of a short circuit as it may have opened because of an overload on the line. To determine which is the case, the operator in the station where the oil switch has opened usually closes it. If it opens again immediately, he closes it again. If it opens a third time, the operator will assume that the opening is not due to a temporary overload but is due to a line fault, whereupon the trouble department is asked to take steps to locate and remedy the fault.

Sometimes a short circuit is so severe that it burns or melts the line conductors at the point of contact. The burning may be so intense that

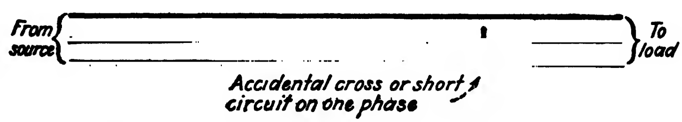


FIG. 20-2. Three-phase line showing cross or short circuit across two of the line conductors.

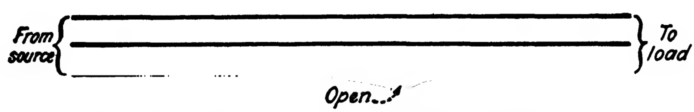


FIG. 20-3. Open in one conductor of three-phase line.

the short will be burned clear, which often results in the conductors being burned open, leaving the line *open-circuited.* This type of circuit fault is discussed below.

Open Circuit. A line is said to be "open-circuited" when one or more of the conductors of the line is broken and the broken ends are separated (Fig. 20-3). Broken conductors may be caused by heavy sleet and wind, causing an excessive weight on the conductors; or they may be burned apart in case of an accidental short circuit; etc. A broken conductor, besides causing an open circuit, often also causes a ground. The breaking of the conductor permits the ends to fall to the ground and come in contact with the earth. The cross or short circuit may, therefore, cause the other two faults at the same point in the line; and although the first fault was only a cross, the result may be a short circuit, open circuit, and ground.

Ground. A line is said to have a "ground" when one or more of the line conductors are in contact with the earth.

A line may become grounded and yet continue to operate. This is possible if the line is an ungrounded line, meaning that it does not have a permanent ground of its own. An ungrounded line with an accidental ground is shown in Fig. 20-4. This ground, of course, is not desirable, but it will not interrupt the service as it is not causing a short circuit. Figure 20-5 shows a line with a permanent ground and an accidental ground on one of the line conductors. It will be noted that this is the same as a short or cross across the two grounded conductors. A heavy current will, therefore, be caused to flow which will open the breakers and disconnect the defective line. The station operator will then proceed as described under Short Circuit.

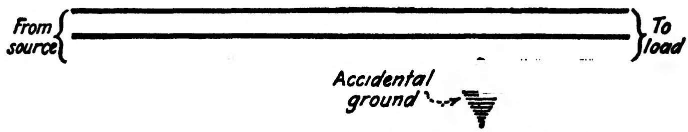


FIG. 20-4. Accidental ground on one conductor of a three-phase line.

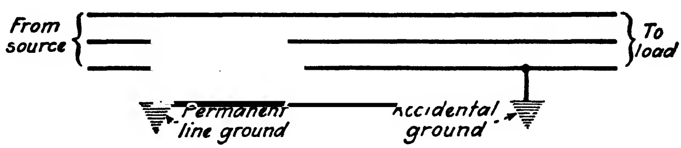


FIG. 20-5. Three-phase line with permanent ground and accidental ground causing a short circuit.

Testing Equipment. The following equipment is generally employed in making line tests:

1. Substation ground bus
2. Positive direct-current bus
3. Grounding leads with clamps
4. Cluster of lights
5. Disconnect-switch hook
6. Oil-switch locks
7. Hold-off cards

The *ground bus* is a copper bus provided in stations and substations adjacent to electrical apparatus and circuits and is permanently connected to the ground or earth. It thus provides a convenient connection to ground.

The *positive direct-current bus* is a live copper bus provided in stations and substations adjacent to electrical apparatus and circuits. It is the positive side of a circuit usually 500 to 600 volts. The other side of this circuit is permanently grounded. When the substation is close to a street-railway system, this bus is usually connected onto the trolley.

The tests hereinafter described should always be made with direct current, as alternating current may lead to wrong conclusions. When alternating current is used, the charging current may be sufficiently large to light the test lamp even when the circuit is open.

The *grounding leads* and *clamps* are copper leads of substantial size provided with clamps on the ends of a wooden stick. The stick is used

Fig 20-6 Lineman installing ground clamps prior to working on line Note cable-to-ground rod. Line conductors are thus short-circuited as well as connected to ground. (*Courtesy A B. Chance Co*)

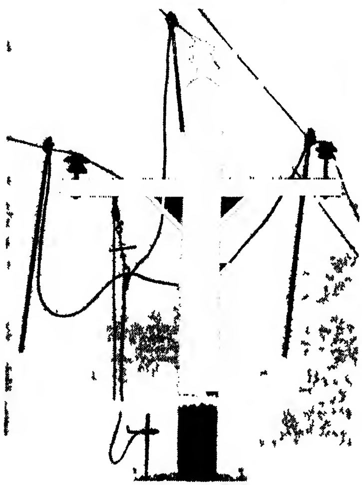


Fig 20-7 Shorting and grounding equipment properly installed on a three-phase pole line (*Courtesy Safety Live Line Tool Co*)

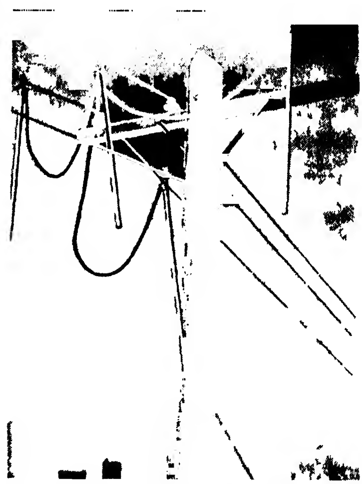


Fig 20-8 Grounding clamps installed on four-wire three-phase line Line conductor mounted on side of pole is grounded neutral (*Courtesy James R. Kearney Corp*)

to fasten the clamps to a circuit or machine (see Figs. 20-6 to 20-8). The leads are used for making a connection between the electrical apparatus or conductors and the ground bus or positive bus described above. The reason for providing the wooden stick is to prevent the operator from receiving a shock in case the circuit or machine to which the leads are being connected should still be at a high voltage.

The *cluster of incandescent lights* usually consists of five or six 110-volt incandescent light bulbs connected in series and provided with terminals so that they can be conveniently connected from the 600-volt positive bus to the ground bus or to a conductor or machine. Before using this cluster for testing, it should be connected from the positive bus to the ground bus to make sure that the lamps are all in good condition.

Disconnect-switch hook is the hook used for opening and closing disconnecting switches.

HOLD OFF

Line No.
Apparatus...
For..
....Department
Instructed to open hook switches?..............................
Instructed to put on ground wires?..............................
Time wanted..........M date..........191 Date of order..........
Operator receiving order...
Opened and grounded by...........Time......M date........191
O. K'ed by.................... Time......M date........191
To..................................Operator
Ordered closed by..
Closed by............................Operator
Time closed.........M date..............191
Remarks...
....
....
One hold off card is to be made out for each crew, working on feeder or apparatus. All cards are to be made out in ink.

FIG. 20-9. Hold-off card. (*Courtesy Wisconsin Electric Power Co.*)

Oil-switch locks are devices used to lock out oil switches to prevent making live any machine or line which is being held out of service for some purpose.

Hold-off cards are red cards fastened to oil switches when it is desired to keep the switch open. Figure 20-9 illustrates a typical form of these cards. Space is provided on each card for designating the line to be kept dead, the reason for holding out, the nature of the work in progress, the person requesting the holding out, the name of the chief operator authorizing it, the day and time at which ordered out, and the signature of the operator placing the card. Space is also provided for indicating the day and hour of removal, the name of the chief operator authorizing the removal, the name of the person requesting the removal, and the name of the operator removing same.

Testing Precautions. Before any testing is done on a line, the line must be made dead; otherwise it is not safe to work on. The following are the usual steps for making a line dead.

1. The chief operator will order the operators on each end of the line to open the oil switches on their respective ends of the line.

2. He will also order that the disconnects on both ends of the line be opened.

3. He will then order that a hold-off card be displayed at the control of the open oil switches.

4. He will then order that the oil switches be locked *open* by means of the lock provided for this purpose. This makes it impossible for anyone to close the oil switch carelessly, in spite of the hold-off card.

5. The operator will then test the line side of the disconnects with the switch hook for static spark, to make sure that the line is dead before proceeding with the test. If no discharge occurs, the line may be considered dead. It is advisable, however, to perform the next step.

6. Connect the ground leads to the station ground bus first, and then connect the free ends to the line to be tested. Making this connection not only grounds each wire of the line but also shorts the three wires of the line or cable (if three-phase) and so gives positive assurance that the line is safe to touch or handle. If the line had been alive, a violent short would have resulted when the grounding leads were attached. The grounding leads, however, are fastened to the ends of the wooden sticks, and thus the operator receives no shock, even if the line is alive when the grounding cable is connected.

Testing a Line or Feeder for Ground. *Procedure.* 1. Kill the line as outlined above under Testing Precautions.

2. Remove the ground clamps.
3. Connect one terminal of the light cluster to the positive bus.
4. Connect the other terminal of the cluster to each conductor of the

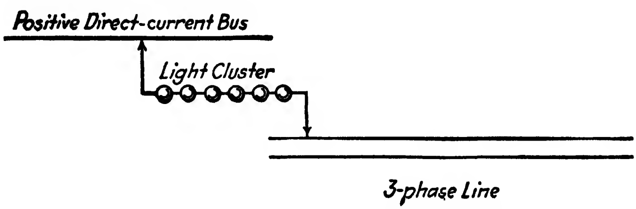


FIG. 20-10. Connections for ground test.

line to be tested in turn (see Fig. 20-10). Each conductor should be tested separately. If the lights do not burn when the connection is made, the line is not grounded. If the lights burn when connected to one of the conductors of the line, that conductor is grounded. If the line is *dead grounded*, the lamps will burn brightly; but if the line is only partially grounded, the lamps will burn dimly.

NOTE. The ground test on a direct-current feeder is performed in a similar manner.

Testing the Circuit for Cross or Short Circuit. *Procedure.* 1. Kill the line as outlined above under Testing Precautions.

2. The operators on both ends of the line will then remove the ground clamps.

3. The operator performing the test will then ground one conductor only of the line.

4. The same operator will then test each of the other two conductors (if three-phase) for ground, as described above under Testing for Ground (see Fig. 20-11). If a ground is indicated on one or both of the

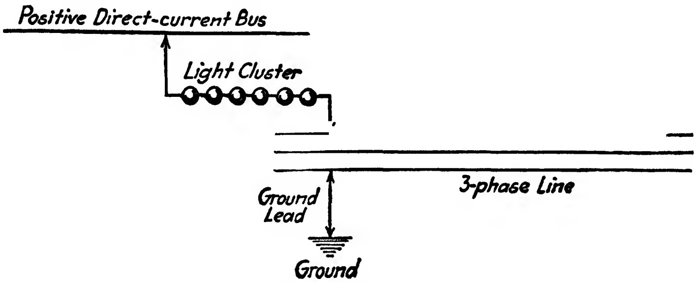


FIG. 20-11. Connections for cross test.

conductors, these conductors are crossed with the grounded conductor.

5. Repeat the test with one of the other conductors grounded, in order to cover the various possible conditions.

6. Report the results to the chief operator.

Testing a Line for Open Circuit. *Procedure.* 1. Kill the line as outlined above under Testing Precautions.

2. Remove the ground clamps on your end of the line if you are performing the test. The operator on the other end will not remove the ground clamps.

3. Connect one terminal of the light cluster to the positive bus.

4. Connect the other terminal of the cluster to each conductor of the line in turn (see Fig. 20-12). If a test shows that each conductor is

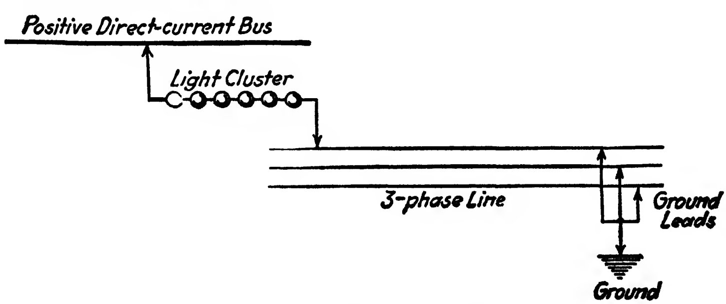


FIG. 20-12. Connections for open test.

grounded, the line is OK. If any conductor does not show that it is grounded, that conductor is open, that is, it is not continuous but has a break in it.

5. Report the results to the chief operator.

NOTE. The test for open circuit should always be made after both the ground test and short-circuit test show that neither of these faults exists. If a cross should exist when the *open* test is made, the conductor might test OK and still be open.

Locating the Fault. After the nature of the fault has been determined by test, it remains to locate it so that repairs can be made. The two most common methods employed on overhead circuits are

1. Patrolling
2. Sectionalizing

The first method is the most common and the most direct. A man sent out to inspect the line can usually locate the trouble, for a wire lying on the ground or two line wires in contact are easily noticed. In many cases the trouble may even be promptly reported by some person outside the company who has noticed the failure.

In dense distribution systems the location of the trouble may, however, not always be evident from an inspection. In such cases the sectionalizing scheme is employed. This consists in disconnecting one feeder of the system at a time and noting whether the fault is cleared. The feeder that removes the fault when the feeder is disconnected is the faulty one. A thorough inspection of this feeder is then made and the fault located.

TESTING GROUND RESISTANCE

Maximum Allowable Value. Artificial grounds must be tested periodically to determine whether the ground connection is still satisfactory. It is obvious that the grounding of equipment and lines for protection of persons must be thoroughly reliable. The maximum resistance that grounds are usually permitted to have before being improved or replaced is 25 ohms. When this value is exceeded, a new ground is generally installed.

Simple Test. The simplest ground-resistance test consists in connecting a wire from one of the ungrounded secondary mains to a good ground such as a fire hydrant, water tap, etc., through a fuse (see Fig. 20-13). A 5-amp fuse should be used with secondary circuits which have 120 volts to ground, and a 10-amp fuse should be used with circuits which have 240 volts to ground. If the ground is satisfactory, the fuse will blow. The blowing of the fuse is proof that the resistance is low enough to permit sufficient current to pass to blow the fuse. In the case

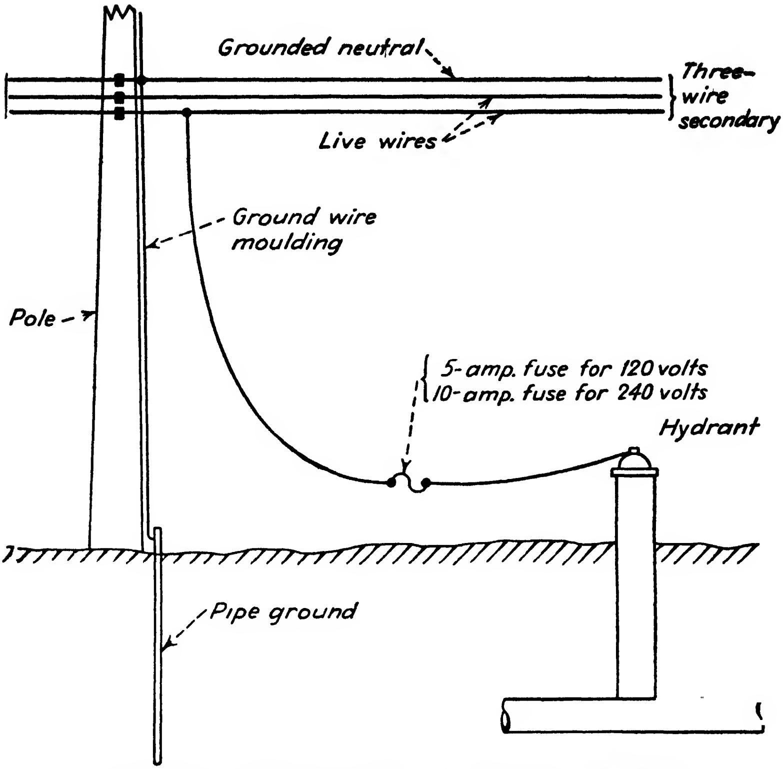


FIG. 20-13. Connections for making test of ground resistance.

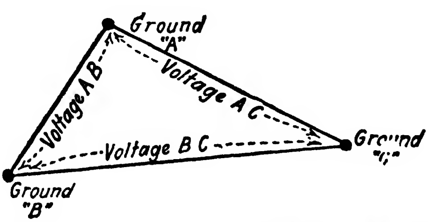


FIG. 20-14. Plan view of grounds and voltages between grounds in making ground-resistance measurements.

of the 5-amp fuse it shows that the resistance is less than $R = {}^{120}/_{5}$, or 24 ohms; in the case of the 10-amp fuse it shows that the resistance is less than $R = {}^{240}/_{10}$, or 24 ohms.

Measurement of Resistance. A convenient method of measuring the resistance of ground connections is shown in Fig. 20-14. In this method three ground connections are necessary. Therefore, in testing the ground on a transformer, in which case there are usually two grounds, one for the lines and one for the arrester, a third ground will have to be provided temporarily. In case there is only one ground to be tested, two temporary grounds will have to be driven. For the temporary ground a piece of No. 0000 solid copper wire 3 or 4 ft long is recommended.

In the test, the voltage drop between each pair of grounds must be measured, in other words the voltage drop from A to C, A to B, and B to C (Fig. 20-14). It is best to take a reverse reading in each case, to eliminate errors which might be caused by a difference of potential which often exists between grounds. In making the calculations, the average of the positive and reverse reading should be taken as shown in the sample problem. The accuracy of the tests depends on the accuracy of the voltmeter reading, and therefore it is important to give the voltmeter time to settle.

Ground-resistance Measurement Equipment. The equipment shown in Fig. 20-15 consists of a 6-volt storage battery and a 15-5-1.5-volt range voltmeter, together with a single-pole double-throw switch and connections.

Procedure in Obtaining Readings. Connect terminal 1 on the switch to one ground to be tested and terminal 3 on the switch to another ground to be tested. Then connect the test clip to terminal 1 and obtain battery potential by closing the switch blade to terminal 1. Next, throw the switch blade over to terminal 3 to obtain the positive reading. Then to obtain a reverse reading, move the test clip to terminal 3 and throw the switch blade over to terminal 1.

SAMPLE DATA AND CALCULATION

Positive reading $A + C$	6 15 volts
Reverse reading $A + C$	6 25 volts
Average reading $A + C$	6 2 volts
Battery voltage	6 35 volts
Positive reading $A + B$	5 7 volts
Reverse reading $A + B$	5 15 volts
Average reading $A + B$	5 42 volts
Battery voltage	6 35 volts
Positive reading $B + C$	5 65 volts
Reverse reading $B + C$	5 2 volts
Average reading $B + C$	5 42 volts
Battery voltage	6 35 volts

After obtaining the average voltage drop from A to C, B to C, and A to B, the resistance of each pair of grounds in series may be found from the following formula:

$$R = r\left(\frac{d}{dl} - 1\right)$$

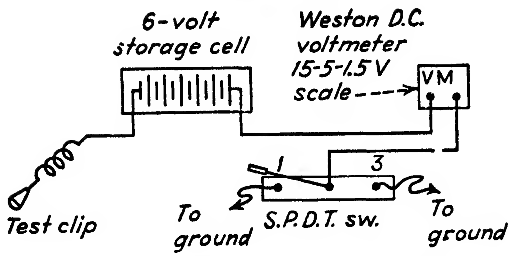


FIG. 20-15. Connections of equipment used in measuring ground resistance. (*Courtesy Oklahoma Gas and Electric Co.*)

where R = resistance of two grounds in series
r = resistance of voltmeter (770 ohms)
d = open-circuit voltage of battery
dl = deflection of voltmeter with grounds connected in the circuits

The following is the method of determining the resistance of each ground after readings have been taken, as shown above:

$$\text{Resistance of } A + C = 770\left(\frac{6.35}{6.20} - 1\right) = 18 \text{ ohms}$$

Solving in a similar manner:

$$A + B = 131 \text{ ohms}$$
$$B + C = 125 \text{ ohms}$$

Solving for values of A, B, and C:

$$A + C = 18 \qquad (1)$$
$$B + C = 125 \qquad (2)$$
$$A + B = 131 \qquad (3)$$

Subtracting Eq. (1) from Eq. (3):

$$\begin{aligned} A + B &= 131 \\ \underline{A + C} &= \underline{\ \ 18} \\ B - C &= 113 \end{aligned} \qquad (4)$$

Adding Eqs. (2) and (4):

$$\begin{aligned} B + C &= 125 \\ \underline{B - C} &= \underline{113} \\ 2B &= 238 \\ B &= 119 \text{ ohms} \end{aligned}$$

Substituting value of B in Eq. (2):

$$119 + C = 125$$
$$C = 125 - 119 = 6 \text{ ohms}$$

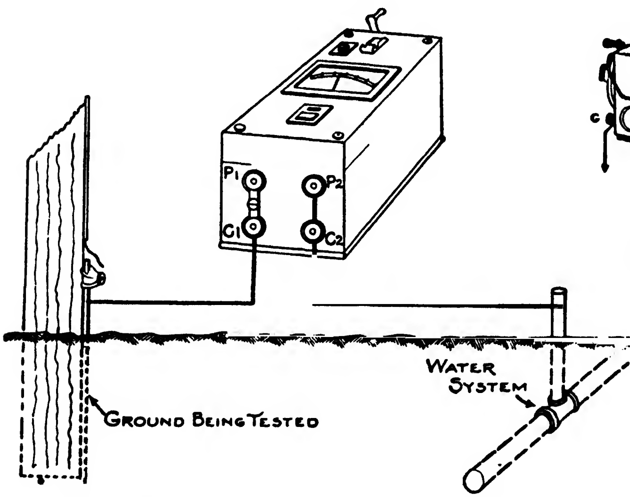
Substituting value of C in Eq. (1):

$$A + 6 = 18$$
$$A = 18 - 6 = 12 \text{ ohms}$$

In any case, the resistance of a ground for electrical equipment should not exceed 25 ohms. Where the ground resistance is found to exceed 25 ohms, one or more additional grounds should be driven several feet away and connected in multiple with the ground which does not come up to standard, and the test should then be repeated to make sure that the combined resistance is less than 25 ohms.

MEASURING GROUND RESISTANCE WITH MEGGER

The easiest way to measure the ground resistance is with a low-range Megger. The procedure to be followed is fully discussed in Sec. 21.



Showing how to connect the "Meg" Ground Tester for the Direct Reference method.

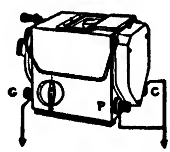


FIG. 20-16. Direct-reference Megger method for measuring ground resistance of ground rod. The instrument reads the resistance to earth of the ground under test plus that of the water system. (*Courtesy J. G. Biddle Co.*)

Direct-reference Method. By connecting the Megger ground tester to the ground being measured and a well-grounded water system or grounded neutral system, as shown in Fig. 20-16, a direct reading in ohms can be made. The resistance indicated is, however, the combined resistance of the two grounds in series. If the water system or grounded neutral is known to have a very low ground resistance, the resistance read on the Megger is largely that of the ground to be measured.

Auxiliary Ground Method. This method requires the driving of two auxiliary ground rods, as shown in Fig. 20-17. If the Megger ground tester is used, the *G* terminal is connected to the ground under test, the

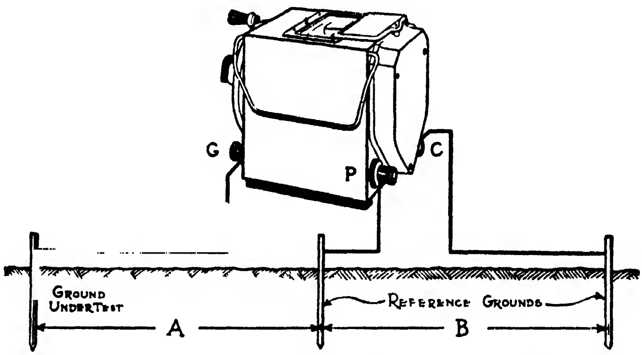


FIG 20-17. Auxiliary ground method of measuring ground resistance of ground rod. Auxiliary ground rods should be 50 and 100 ft or more, respectively, from the ground to be measured. The Megger will read resistance to earth of the ground under test. (*Courtesy J. G. Biddle Co.*)

P terminal to the middle (auxiliary) ground, and the *C* terminal to the remote (auxiliary) ground. The crank of the Megger is then turned at the proper speed, and the pointer on the scale will indicate the resistance to earth of the ground under test. For accurate results under ordinary conditions with ground rods 8 ft down in the earth, the distance *A* and *B* should each be 50 ft or more. The auxiliary ground rods need be driven only 3 to 5 ft into the earth.

SECTION 21

Field Testing of Line Insulators

Methods Employed. Several methods of testing line insulators in place on the line have been evolved. One method requires that the line be *dead,* while the others are used while the line is *live.* The various methods can be classified as follows:

- I. Line dead
  - 1. Megger method
- II. Line live
  - 1. Short-circuit method
    - *a.* Metallic
    - *b.* Spark gap
  - 2. Telephonic method
    - *a.* Noninsulated
    - *b.* Insulated
  - 3. Voltage-distribution method

THE MEGGER METHOD

This method requires the shutting down of the line during the test. This is a disadvantage as it is often inconvenient and always expensive to shut down the line. There is an advantage, however, in that it is safer to do the testing if the line is dead.

A Megger testing set consists of a hand-driven direct-current generator and a direct-reading ohmmeter mounted in a box. Figure 21-1 illustrates a typical Megger. It is used to measure high resistances. The scale of the ohmmeter reads directly in "megohms." One megohm is equal to one million ohms.

The Megger test consists in measuring the insulation resistance of each individual insulator on the line. A good insulator has a high resistance, but a faulty or defective insulator has a low resistance, compared with the good insulator. Defective insulators are usually caused by cracks in the porcelain.

To apply the test, the two leads from the Megger are connected to the two sides of the insulator. In the case of a cemented-type suspension insulator, one lead is connected to the cap and the other to the pin. A Megger fork is often used to facilitate making these connections from the pole or tower. This fork has two metal tines which are rigidly supported and insulated from each other. The tines are 10 to 20 in. long

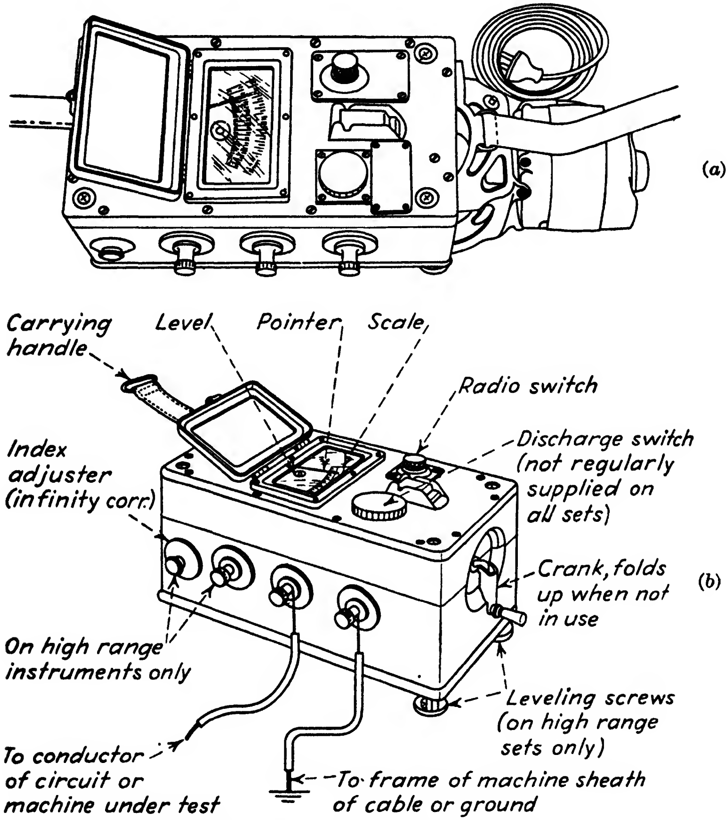


Fig. 21-1. (*a*) A typical high-range motor-driven Megger testing set ready for use. (*b*) Sketch giving names of parts and connections to circuit under test. (*Courtesy James G. Biddle.*)

and spaced about 5 to 6 in. apart. Insulated leads should be attached to the tines, and these should be sufficiently long to reach from the top of the highest tower to the Megger on the ground. The handle on the fork should be long enough for a man working on the tower to reach any insulator.

After the temporary connections are made, the crank of the Megger is turned at the proper speed and the resistance of the insulator is read on the scale. If the reading is high, usually infinity or equal to that of a good insulator, the insulator is OK. If the resistance is less than that of a good insulator, usually less than 500 megohms, or even zero, the insulator is defective and should be replaced.

Steps in Megger Testing. The operations in Meggering line insulators should be made in the following order:

1. Have line made dead at source.
2. Ground the line in as many places as possible before beginning work. This is accomplished by connecting the ground line to the steel tower or ground before attaching it to the line and then attaching the other end of the ground line to the line conductor by means of a hook or clamp on end of a dry wooden stick.
3. Place one tine of the megger fork on the fittings on each side of the insulator unit. Twist to ensure a good contact between the fork tines and the fittings.
4. With the fork leads connected to the earth and the line terminals of the Megger testing set, obtain a reading of the insulation resistance of the insulator. If the reading is infinity, the insulator is OK.
5. Test the whole string of insulators in a similar manner.
6. Remove the Megger fork.
7. Remove the ground connection from the line (first) and then from the tower.

Warning. In order to avoid the danger of a shock, it is necessary to proceed strictly as above. Do not Megger an insulator unless the ground circuit is connected. This connection removes any static charge that may be left on the line conductor.

NOTE. During humid weather, Megger tests should be made late in the day or during falling temperature to obtain best results. This avoids surface leakage as the dew point is reached.

Pilot Insulator. One of the other present-day uses of the Megger in connection with line-insulator testing is that involving the use of the pilot insulator. This insulator is not in active use but is merely located outdoors where it is subjected to the same climatic changes as the insulators in the line. The resistance of this insulator is measured periodically to determine the need for hot-line insulator washing in regions where salt or other deposits form on the insulator.

SHORT-CIRCUIT METHOD

Metallic Short-circuit Method Applied to Suspension Insulators. This method of testing insulators is often called "buzzing the insulators," and the tool used to make the test is known as the "buzz stick." The line on which the insulators are to be tested must be live.

The tool used is a treated stick 8 to 12 ft long. On one end of the stick an adjustable wire fork is fitted. One prong of the fork has a metal ball on its end (see Figs. 21-2 and 21-3). Both prongs of the fork are electrically connected.

Steps. There are two steps to buzzing a string of insulators. The first step is called "feeling out"; the second step is called "shorting

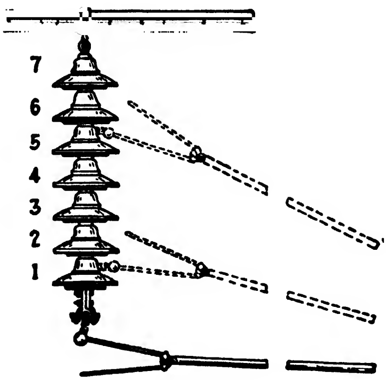


FIG. 21-2. Buzz stick and manner of using in feeling out suspension insulator units. The line is live when this operation is performed. (*Courtesy Johnson Mfg. Co.*)

out." The feeling-out operation always precedes the shorting-out operation and determines the general condition of the string. While it does not definitely determine the exact condition of the string, it gives a fair indication and shows whether or not the shorting-out operation can be applied without the danger of flashing over or puncturing the string of

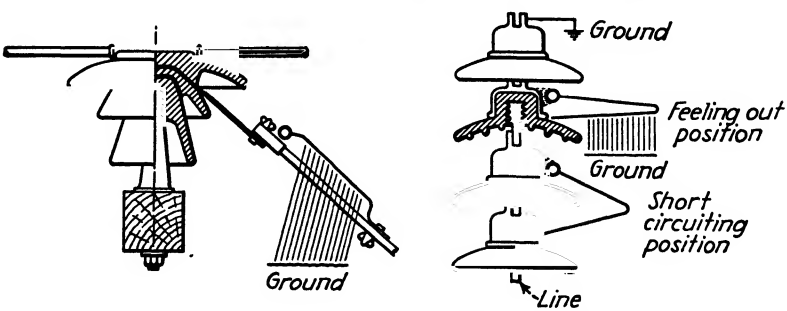


FIG. 21-3. Electrical circuits for Johnson buzz sticks. Left view shows pin-type insulator stick; right view shows suspension-type insulator stick. (*Courtesy Oregon State Engineering Experiment Station, Reprint Series No. 1.*)

insulators. The shorting-out operation always follows the feeling-out operation, except in those cases where the feeling out of the string has indicated that it would be dangerous to apply it. The shorting-out operation locates the defective insulator unit.

To Feel Out a String of Insulators. Touch the ball of the buzz stick to the line conductor and draw it away slowly (Fig. 21-2). This produces a distinct buzzing sound which continues to be audible. In the case of 110,000 volts this sound continues until the ball is 2½ or 3 in. away. The intensity of the spark, however, should be judged by the sound and not by its length. Repeat this operation on insulator cap 1. The sound should be less and follow the ball a shorter distance. The same operation is repeated with insulator caps 2, 3, 4, 5, 6, and 7. It will be found that the sound is less for each cap as the distance from the line increases, until on cap 5 or 6 there is very little or no sound and the sound from cap 7 is louder than that from 5 or 6. These results indicate

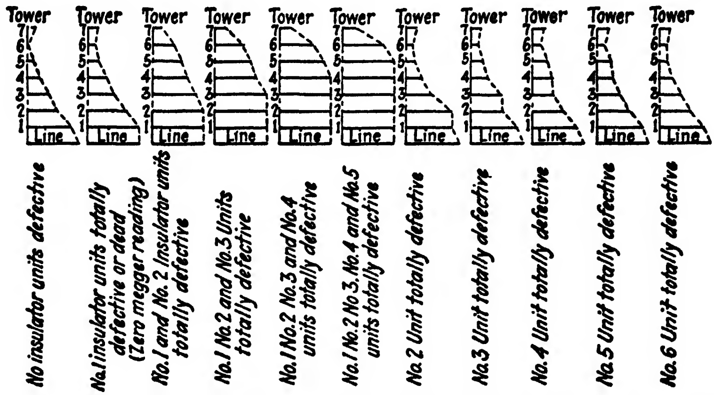


FIG. 21-4. Sound diagrams in first step or feeling process in testing suspension insulators with the buzz-stick method. (*Courtesy Johnson Mfg. Co.*)

a perfectly good string. Figure 21-4 gives the sound diagrams for a good string and for various combinations of defective units.

Assume that insulator 2 is totally bad, in other words dead (Megger reading zero). In this case the sounds from caps 1 and 2 will be equal. Assume that insulator 5 is bad; then caps 4 and 5 will produce equal sounds, and the sound from cap 6 will be very much increased. Assume that insulators 2, 3, and 4 are dead; then the sounds from caps 1, 2, 3, and 4 will all be equal, and the sounds from caps 5, 6, and 7 will be very much increased. In other words, the sound from the cap of a dead insulator is the same as the sound from the cap of the next insulator to it, nearest the line.

The feeling-out operation is for the purpose of determining, without the possibility of flashing or puncturing the string, if there is a sufficient number of good insulator units left in the string to stand the line potential when one of the good insulator units is shorted out during the shorting-out process. Roughly, on 110,000-volt lines there must be at least three good units to stand the shorting-out process; on lower voltages there must be at least two good units, except on voltages such as

11,000 and 13,000 where there are only two insulator units per string; then only one unit need be good.

Shorting Out a String of Insulators. Touch the horn of the buzz stick on which there is no ball to the line conductor. Hold this horn in contact with the line and make and break contact with the buzz ball on the other horn with cap 1 (Fig. 21-5). There will be produced a snappy spark on making and breaking contact with cap 1. The intensity of the spark is judged by its sound and not by its length. Then hold the horn on which there is no ball in contact with cap 1, and make and break contact with the ball with cap 2. A snappy spark will be produced on making and breaking contact with cap 2, but the intensity of

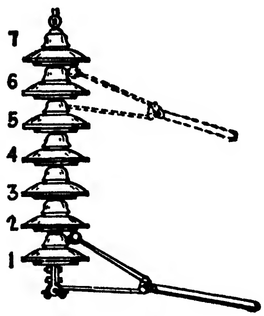


FIG. 21-5. Second step or shorting process in testing suspension insulators by means of buzz stick. (*Courtesy Johnson Mfg. Co.*)

the spark will be less than when the horn was held in contact with the line conductor and the ball touched to cap 1. Repeat this operation across each insulator unit in the string. It will be found that the intensity of the spark will diminish as the distance from the line increases until insulator 7 is shorted out. The spark across this unit will be found to be more than across unit 6. The above condition indicates a perfectly good string. Figure 21-6 gives the sound diagram for a good string and for various combinations of defective insulators.

Assume that unit 2 is dead (Megger reading zero). When this unit is shorted out as described above, there will be absolutely no spark. Assume that unit 6 is dead; then no spark will be produced across it when it is shorted out.

With dead insulators in any number and any combination, the results will be the same, that is, absolutely no spark across the dead unit. This, however, is the case only when the units are absolutely dead.

When the lines are maintained while under operation, the tester precedes the maintenance crew and locates and marks with paint, by means of a brush on the end of a stick, the most defective insulators. The maintenance crew follows the tester, replacing the marked insulators while the line is alive. After this is done the line is buzzed again, and at this time the less defective insulators are located and replaced. A line which is maintained dead will require, as a general rule, more frequent testing than when maintained while at operating voltage.

The Silent Insulator in a String. In every string of insulators, regardless of the make, the number of insulators in the string, or the voltage on the line, there is one insulator in the string the cap of which will give the minimum spark both in the feeling-out process and the shorting-out process. This insulator is generally the second one from the crossarm. After a tester has tested a sufficient number of strings on a given line, he can easily locate this silent cap, for he will recognize the character of the

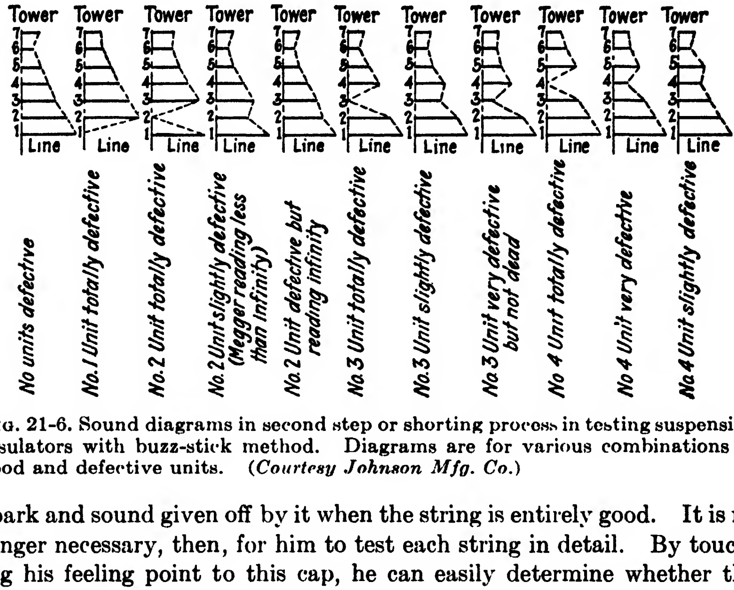


FIG. 21-6. Sound diagrams in second step or shorting process in testing suspension insulators with buzz-stick method. Diagrams are for various combinations of good and defective units. (*Courtesy Johnson Mfg. Co.*)

spark and sound given off by it when the string is entirely good. It is no longer necessary, then, for him to test each string in detail. By touching his feeling point to this cap, he can easily determine whether the string is entirely good or not. If the spark from the cap is normal, he can pass on; if it is abnormal, he should buzz the entire string out definitely to locate and mark the defective insulators. A tester soon becomes expert and will be able, by touching the cap of the silent insulator, to tell the number of defective units in the string, although it is always necessary to buzz the entire string out definitely to locate these units. Too many insulators per string will cause several silent insulators; too few insulators will result in there being no truly silent insulator.

Metallic Short-circuit Method Applied to Multiple-part Pin-type Insulators. The tools used in applying this method to pin-type insulators are of two types. One is called a "feeling stick." It consists of a stick about 1¼ in. in diameter and about 8 ft long, composed of suitable insulating material, at one end of which is fixed a sharp metal point of suitable shape, the shape depending on the type of the insulators to be tested. This metal point is known as the "feeling point." The other is called a "shorting stick" (buzz stick). It also is a stick about 1¼ in. in diameter and about 8 ft long, of suitable insulation material, with a continuous metal fork attached to one end, the shape and dimensions of the fork depending on the shape and dimensions of the insulators to be tested.

Procedure. In this method there are also two distinct steps, one known as the "feeling process," and the other as the "shorting process." In testing an insulator, both the feeling process and the shorting process must be used. The feeling operation or process always precedes the shorting operation or process and determines and indicates the general

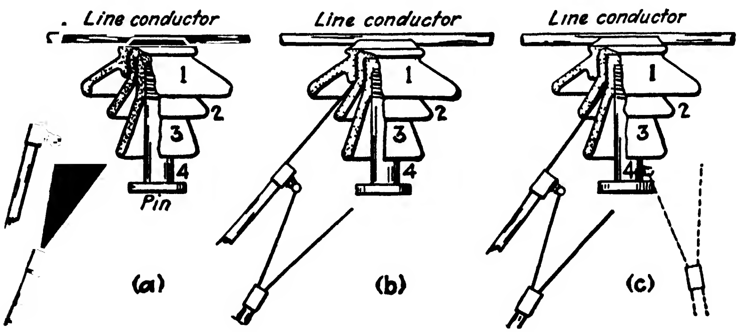


FIG. 21-7. First step or feeling process in testing a multiple-layer pin insulator. (*Courtesy Johnson Mfg. Co.*)

condition of the insulator. From these indications it is easy to judge whether or not the shorting operation can be applied without danger to the line or to the men making the test. Sometimes the feeling operation indicates that the shorting operation cannot be applied at all, as is always the case with very defective insulators. The feeling operation is very inaccurate, but its results will show if the application of the shorting operation would be dangerous. The shorting operation is prohibitively dangerous unless preceded by the feeling operation. Its application must therefore be governed according to the indications of the feeling operation.

To Feel Out an Insulator. Touch the feeling point of the feeling stick to the line conductor (Fig. 21-7). While maintaining this contact, touch the ball of the buzz stick to the metal cuff on the end of the feeling stick and draw it slowly away from the cuff. A distinct buzzing sound will be produced, which in the case of a 66,000-volt line will be audible until the ball is 1 in. or more away. Repeat the operation with the point of the feeling stick resting firmly on the cement between porcelain parts 1 and 2 (Fig. 21-7). The sound will not follow the ball so far as when the feeling stick was in contact with the line conductor, if porcelain part 1 is perfect. When porcelain part 1 has become defective, the sound drawn from the cuff on the end of the feeling stick when the point of the feeling stick is resting on the cement between porcelain parts 1 and 2 will increase, approaching nearer and nearer the sound produced when the feeling point was in contact with the line conductor.

From the above, it is natural to conclude that when part 1 is totally defective the sound from the line and the sound from the cement between parts 1 and 2 will become equal. This natural conclusion is only seldom verified by what actually happens on the line. The sounds approach near enough to equality, under almost any conditions, to excite suspicion about part 1, but it is the very exceptional case when they become equal.

Repeat the operation by touching the feeling point to the cement between parts 2 and 3 (Fig. 21-7). If part 2 is perfect, the sound given off will be less than the sound given off between parts 1 and 2. The nearer to equality the sounds approach, the more defective part 2 is. When part 2 is totally defective, the sounds from the cement on each side of the part will in all cases be equal. This operation is repeated for each unit part of the insulator, and the difference (the greater the difference, the nearer perfect the porcelain part) in the sounds given off by the cement on each side of any part indicates the degree of defectiveness of the part between the cement sections.

When the last part is reached, which, in the case of the insulator shown in Fig. 21-7, is part 3, the feeling operation is made on the cement on one side and the pin on the other side.

When the feeling process gives indications which would tend to show that an insulator is very defective, there is no need to use the shorting process. When the feeling process indicates that the insulator is entirely good, however, the shorting process should be used. This process locates parts which are only slightly defective and also parts which are totally defective.

To Short Out an Insulator. The shorting process should be applied to an insulator only after the feeling process has been first used and has clearly indicated that it would be entirely safe to apply it. Those parts of the insulator under test which seem to show indications of being defective during the feeling process should be shorted first. This is desirable, because if one of the good parts were shorted first the insulator might flash; whereas, by shorting the defective parts first, the number of good parts remaining is definitely established, as is also the degree of defectiveness of each defective part.

To short an insulator of more than two parts, two feeling sticks are required. Place the feeling point of a feeling stick firmly against the cement between parts 1 and 2. Place one horn of the fork of the shorting stick against the line conductor and hold it there. Then make and break contact with the cuff on the feeling stick with the ball on the other fork of the shorting stick (Fig. 21-8*a* or 21-8*b*). A snappy-sounding spark will be produced. If the top skirt or part is perfect, the sound of the spark will be that of the normal good top skirt. If the top skirt is defective, the sound of the spark will be less than the normal spark of the perfect top skirt. As the top skirt becomes more and more defective, the spark obtained will decrease in intensity but will seldom or never reach zero.

Place another feeling point on the cement between parts 2 and 3 and short with the shorting stick between this feeling point and the feeling point on the cement between parts 1 and 2, as described above for part 1 (Fig. 21-8*c*). A snappy spark will be produced, the sound of which, when part 2 is good, will be less than the spark produced across part 1

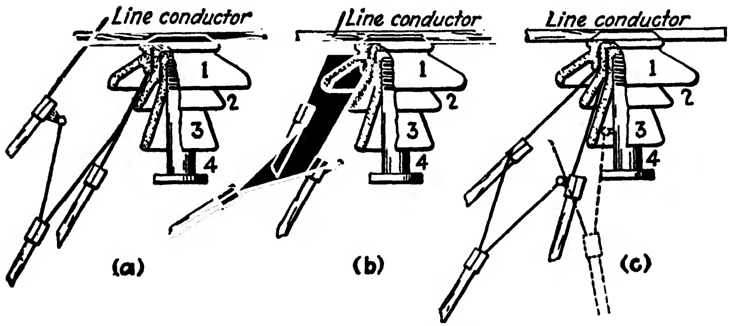


FIG. 21-8. Second step or shorting process in testing multiple-layer pin insulator. (*Courtesy Johnson Mfg. Co.*)

when part 1 is good. The sound of this spark will decrease as part 2 becomes more and more defective and will be zero when part 2 is totally defective or dead.

The same conditions hold good for all the remaining insulator parts. When the last part, 3, is reached, the shorting is done between a feeling point on the cement parts between 2 and 3 and the pin supporting the insulator, if the pin is metal. If the pin is wood, a feeling point is forced as far as possible up inside the insulator next to the wood pin and the shorting is done between this feeling point and the feeling point on the cement between parts 2 and 3.

In the case of wood pins the bottom skirt acts very much like the top skirt.

The ball on the shorting stick or buzz stick should always be used away from the line conductor during the shorting-out process.

Spark-gap Method. Because of the inconvenience of handling two or more sticks in testing pin insulators as required in the method discussed above, a method has been evolved making use of a buzz stick with a spark gap.

Buzz Stick. The instrument consists of an insulating stick 1¼ in. in diameter and 8 ft or more long (Figs. 21-9 and 21-10), at one end of which is a steel feeling point A fastened to a steel cuff B; a brass ball C is secured to the end of a spring wire D, which spring wire is secured at the end H to the insulating stick. From the spring wire D, an insulating string E runs through stick I and down to friction sheave G. By turning friction sheave G and winding up cord E, the brass ball C is pulled toward B against the action of spring wire D. It is evident that by turning friction sheave G in one direction or the other the distance from the brass ball C to steel cuff B can be varied at will. The friction on sheave G is sufficient so that sheave G will not creep under the pull of spring wire D. Therefore, brass ball C can be set definitely and permanently in any position with reference to steel cuff B. Also, the operator, by using finger loop F, can vary the distance between B and C rapidly between the maximum opening governed by the setting of G and the position in which C actually touches B.

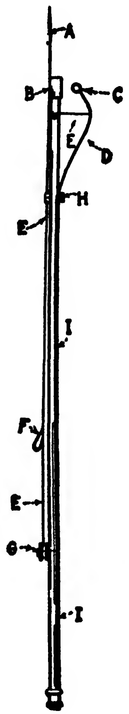


FIG. 21-9. Combination stick for the feeling and shorting of multiple-part pin insulators. A, steel feeling point. B, steel cuff. C, brass ball. D, spring wire. H, spring-wire anchor. E, insulating string. F, finger loop. G, friction sheave. I, insulating stick. Diameter of stick $1\frac{1}{4}$ in., length 6, 8, 10, 12 ft; weight, 3 to 5 lb. (*Courtesy Johnson Mfg. Co.*)

Steps: 1. The steep point A of the buzz stick is placed against the line conductor (Fig. 21-10*a*). Then sheave G is turned so as to decrease the distance from B to C until a continuous spark jumps between B and C. This setting should be the greatest distance at which a continuous spark can be obtained between B and C. It will be found that the spark can be judged by sound more conveniently than by sight.

2. Place feeling point A against the cement between parts 1 and 2. Place finger in the finger loop and pull gradually until a continuous spark is reestablished between B and C.

3. Place feeling point A against the cement between parts 2 and 3, and by means of the finger loop F decrease the distance between B and C until a continuous spark occurs between B and C.

4. Allow feeling point A to remain on the cement between parts 2 and 3. Pull the ball hard against the steel cuff B and draw a spark from the steel pin carrying the insulator.

If, in following the above steps, the distance between B and C

decreases in the right proportion for each successive step, the indications would be that of a good insulator. Should a continuous spark occur, however, with the same setting on the cement on each side of any one insulator part, the indications would be that of a totally defective part. If, in step 4, no spark is drawn between the head of the buzz stick and the pin, part 3 would be totally defective. It is perfectly apparent that part 3 should never be shorted out until the other insulator parts have

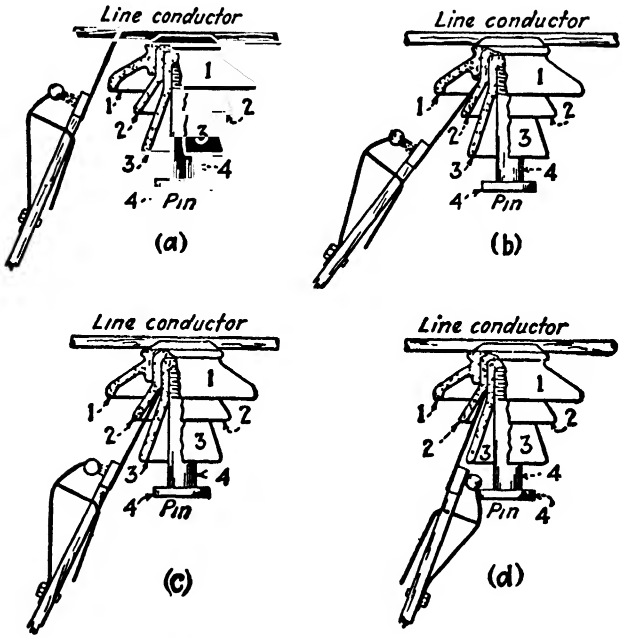


FIG. 21-10. Steps in testing of pin insulator with special pin-insulator buzz stick (*Courtesy Johnson Mfg. Co*)

been tested and shown to be in perfect condition. If parts 1 and 2 are not OK when part 3 is shorted out, a flashover is likely to occur which will put the line out of service.

The tester very quickly learns the proper settings of the gap for any given type of insulator. If at any time he discovers that it is not necessary to diminish gap *B* to *C* as much as his experience indicates, it would indicate a slightly defective insulator part. In other words, the difference in the setting of gap *B* to *C* on the two sides of any insulator part is a measure of the condition of the insulator part. Maximum setting for a particular part indicates a perfect part. A totally defective part has the same gap setting on both sides. A slightly defective part has a gap setting on each side which becomes nearer and nearer equal as the part becomes more and more defective.

TELEPHONIC METHOD

Principle of Operation. Testing by this method also consists in measuring the voltage across each shell of a pin insulator or across the individual units of a suspension string. The electrical circuit for this purpose is made up of an air gap connected in series with a resonated circuit. Figure 21-11 shows the circuit for both the pin-type insulator

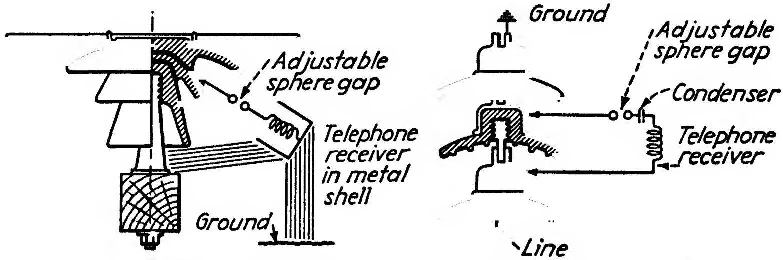


FIG. 21-11. Electrical circuit for Doble type A and type B testing instruments. (*Courtesy Oregon State Engineering Experiment Station, Reprint Series No.* 1.)

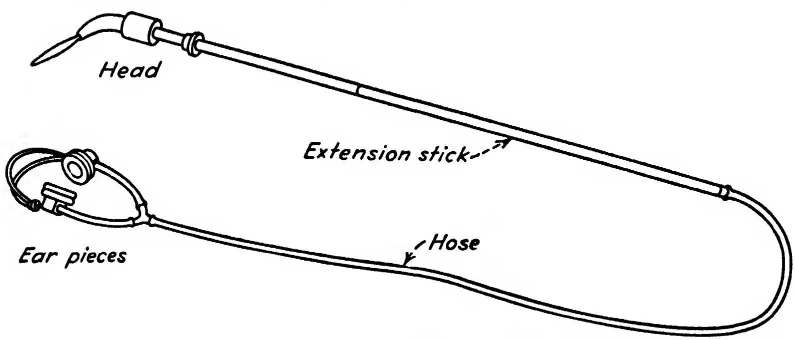


FIG. 21-12. Telephonic-type live pin-type insulator tester showing head, extension stick, hose, and earpieces. (*Courtesy Doble Engineering Co.*)

tester and the suspension-type insulator tester. In the suspension insulator tester one terminal of this circuit is connected to the cap and the other to the pin. In the pin-type insulator tester one terminal is touched against the cement layer between the insulator shells while the other terminal is merely a capacity to ground. If the voltage across these terminals is sufficiently large, a spark will jump across the gap and a sound will be heard in the telephone headset. The air gap is adjustable and indicates the magnitude of the voltage.

Pin-type Tester. The pin-type tester is illustrated in Fig. 21-12 and is seen to consist of a head, extension stick, hose, and earphones. It will be noted that one end appears like a bill. This is so formed as to be easily placed against the cement layer between the shells. The stick is a hollow tube of impregnated wood, making it a good insulator. The flexible hose connects the lower end of the hollow tube to the earpieces. The electrical circuit mentioned before is located in the head with the spark gap so arranged that it can be adjusted by turning the bill.

Suspension-type Tester. The suspension-type tester is illustrated in Fig. 21-13 and is seen also to consist of a head, stick, hose, and earpieces. Only the head is different from the pin-type tester.

The head contains the electrical circuit shown in Fig. 21-11. The spark gap is adjustable as in the pin-type tester. The sound produced

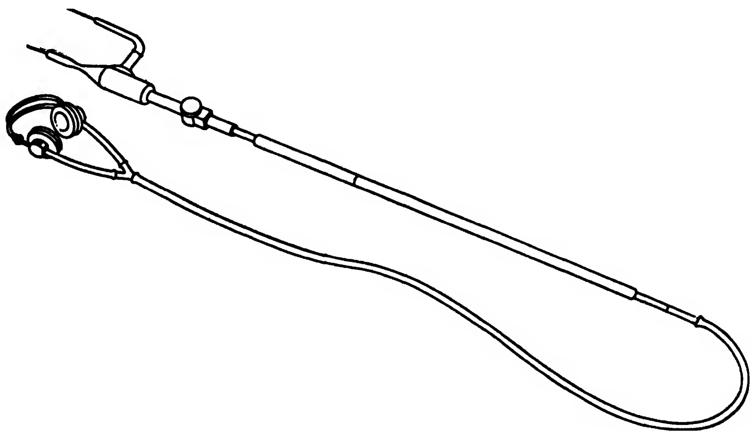


FIG. 21-13. Telephonic-type live suspension-type insulator tester, showing head, stick, hose, and earpiece. (*Courtesy Doble Engineering Co.*)

by a spark discharge across the gap is transmitted down through the hollow tube through the rubber hose to the earpieces.

Operating the Pin-type Tester. In using this tester the operator climbs the pole or tower and there with the earphones on his head brings the upper end of the tester or bill in contact with the insulator. In the case of the pin insulator, contact is made with the cement layer between the shells of a multipart pin insulator, as shown in Fig. 21-14.

If with the correct gap setting a certain easily recognized sound is heard in the earpieces, an abnormal voltage is present, indicating that the insulator is defective. It is not necessary to note the volume of this sound, as any sound indicates a bad insulator while silence indicates a good insulator.

Operating the Suspension-type Tester. To operate this tester the lineman climbs the pole or tower, fastens his safety belt, and then with earpieces in place places the two points in the head across the insulator so that they contact the insulator hardware. Figure 21-15 shows a lineman on a pole listening for insulator defects with this type of tester.

With the correct gap setting for a good disk, the sound of the discharge across the gap should be heard. If this sound is not heard in the earpieces, the insulator disk is not carrying the proper potential and is

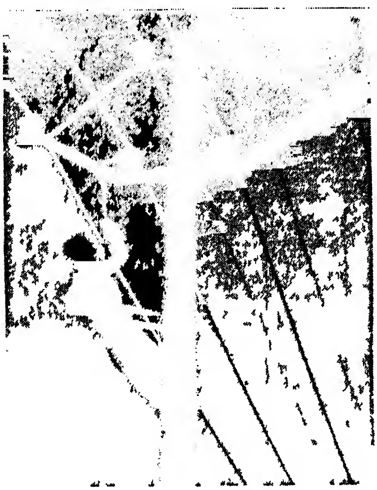


FIG 21-14 Lineman testing pin insulator by use of insulated-type telephonic tester (*Courtesy Doble Engineering Co*)

FIG 21-15 Lineman using telephonic-type suspension insulator tester on live line (*Courtesy Doble Engineering Co*)

defective. With this tester a sound indicates a good insulator while silence indicates a bad insulator

VOLTAGE-DISTRIBUTION METHOD

Principle of Operation. All live-line insulator testing requires a knowledge of the voltage distribution over the units of a suspension string or across the shells of a multipart pin insulator. Unfortunately this distribution is not uniform, which would make the voltage across all units the same. Instead the distribution is quite uneven, that is, the voltage across the unit nearest the line conductor is several times as great as the voltage across the unit nearest the crossarm or support. A typical distribution curve for a 64,000-volt line is shown in Fig. 21-16. The solid-line curve is the curve for a perfect insulator string. This shows almost five times as much voltage across the unit nearest the conductor as across the unit next to the support.

Now, if for any reason one or more units become defective, the distribution curve becomes distorted. This is illustrated in Fig. 21-16 by the dashed-line curve which is the curve when unit No. 7 is defective.

Therefore, if the voltage across each unit of a string can be conveniently measured, defective units can be easily located. Any unit whose voltage reading is lower than the reading for a like unit on a string in good condition would show that the former unit is not withstanding its share of the voltage and is therefore defective. Actually, if a unit is very defective, the voltage drop across it will approach zero, as the broken-down insulation tends to act as a conductor. Ordinarily, if a reading is less than 60 per cent of the average reading, the unit is probably defective. Similar distribution curves for a good and a defective pin insulator are shown in Fig. 21-17.

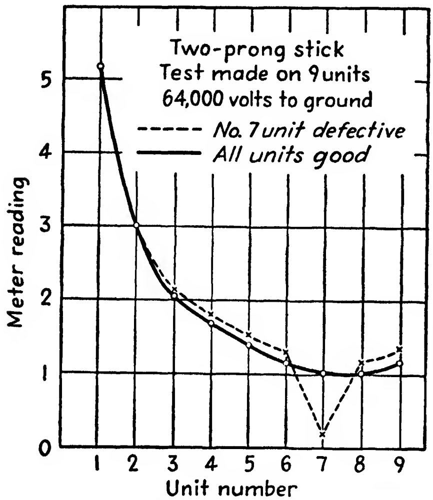


FIG. 21-16. Voltage-distribution curves for a nine-unit suspension string. The solid line is for a string in good condition; the dashed line is for a string with No. 7 unit defective.

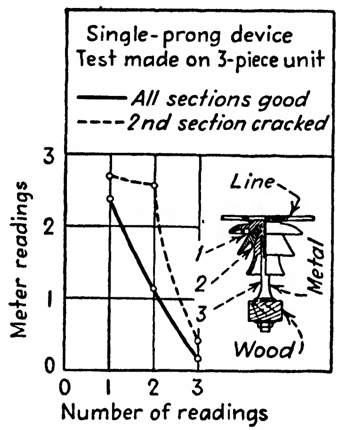


FIG. 21-17. Voltage-distribution curves for a good and a defective three-part pin insulator.

Description of Tester. One make of tester employing a meter for reading the voltage distribution is illustrated in Figs. 21-18 and 21-19. The first is for pin insulators and is referred to as the "single-prong" instrument, and the latter is for suspension or strain insulators and is referred to as the "double-prong" instrument. The meter on which the voltage is read is mounted on the end of the insulated stick. Although this meter actually is an ammeter, being actuated by a condenser current, its readings are proportional to the voltage; therefore it may be looked upon as a voltmeter.

Procedure. The procedure to be followed is obvious from the description of the tester and the illustrations shown. In the case of disk-type insulators in a string or insulators in a stack, the two prongs are touched to the metal portions on both sides of the insulator and readings are taken on the meter. Since the two prongs actually are the

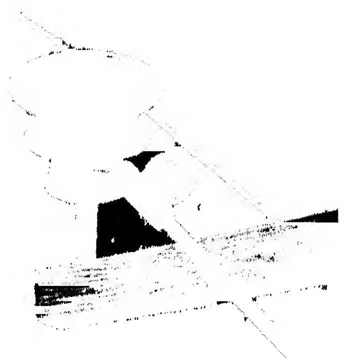


FIG. 21-18. Testing pin insulator with single-prong meter-type tester. (*Courtesy Railway and Industrial Engineering Co.*)

FIG. 21-19. Testing suspension insulator with double-prong meter-type tester. (*Courtesy Railway and Industrial Engineering Co.*)

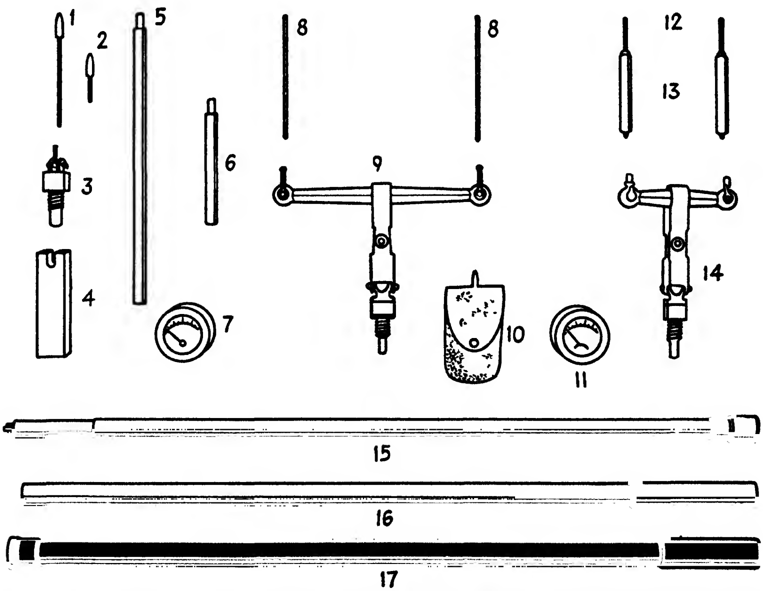


FIG. 21-20. Parts of meter-type live-line insulator tester. (*Courtesy Railway and Industrial Engineering Co.*)

leads from the voltmeter, the readings give the voltage drop across the insulator. These readings are then compared with those for the corresponding units on a perfect insulator string. If any of the readings are much lower, the units are defective.

In the case of multilayer pin-type insulators, the prong is inserted between the porcelain layers until it makes contact with the cement. This prong is one lead from the voltmeter. The other lead from the meter connects to a condenser made of several metal tubes located in the hollow of the stick. The metal tube is one plate of the condenser, and the earth is the other plate. The condenser is made variable by providing two metal tubes of different length. The longer one is used at all times unless the reading goes off the scale. Then the shorter one is used. On the other hand, if the reading is too small and needs to be increased, both tubes may be joined and used.

On a two-piece insulator a reading of the upper part will give the condition without testing the bottom part. If the upper part should be bad, the meter reading will drop. If the lower part is bad, the meter reading on the upper part will be above normal.

This type of insulator tester is made with different type heads and a variety of contact tips to fit the many types of insulators in use (see Fig. 21-20). The holding stick is furnished in three sections for convenience in reaching the insulator.

SECTION 22

Live-line Maintenance

Nature of Work. The trend in electric-system management today is to do more and more of the testing, repair, and maintenance work while the lines are live. The reason for this is to reduce the number of times the service is interrupted, or the number of "outages" as the interruptions in service are called. Live-line maintenance has been made possible by the development of special tools and procedures for such work.

Under live-line maintenance a great variety of work is included. The most common of these live-line operations are as follows:

1. Replacing insulators
   a. Pin
   b. Suspension
   c. Strain
2. Replacing crossarms
3. Replacing poles
4. Tapping a hot line
5. Cutting slack in or out
6. Splicing conductors
7. Installing vibration dampers
8. Installing armor rods
9. Phasing conductors

The most important single item is the replacement of insulators. Transmission systems require the constant replacement of insulators. Live-line work, therefore, resolves itself chiefly into the detection of the defective insulators and the replacement of these insulators while the system is live. The testing of insulators on live lines was treated in the previous section.

It will not be the object here to give detailed instructions covering the procedure of every live-line maintenance job. This would be impossible because of the great variety of jobs and types of line construction and special conditions. This section is, therefore, intended to give the reader only a general conception of the methods and procedures employed in the most fundamental operations of live-line maintenance work.

The maintenance of high-voltage lines while energized, or "hot," may appear on first thought to be hazardous, especially when compared with working on dead lines or on low-voltage lines with rubber gloves and blankets. Actually, however, the work is just as safe because the lineman is continually conscious of the fact that the lines are "hot" and of the need to be careful. Furthermore, there is no possibility of the line being "hot" when it was thought to be dead as when working on dead lines. Also there is no possibility of confusion with live duplicate circuits. For in live-line or "hot-stick" work every conductor is "hot" and every operation is planned and performed accordingly.

Tools. "Hot-line" tools are of great variety, but the more generally used can be classified as follows:

1. Wire tongs
2. Saddles or wire-tong supports
3. Auxiliary arm
4. Tie sticks
5. Insulated links
6. Strain carrier
7. Platform
8. Wooden hoods
9. Insulated tools

Most of the actual live-line work is performed by means of slender wooden poles or sticks provided with special metal fittings or tools on the ends. The wooden sticks serve as an insulator. In order that the wood may always be a good insulator, it must be kept as dry and as clean as possible. Scratches, scars, or other abrasions on the sticks will damage the wood surface and permit moisture and dirt to enter the fibers of the wood. Moisture and dirt will form conducting paths along the hot stick which will render it hazardous for use.

A typical set of utility live-line maintenance tools is shown in Fig. 22-1, and a special hot-line tool trailer is shown in Fig. 22-2. Some of the more commonly used tools will be briefly described in the following paragraphs.

Detecting Moisture. The presence of moisture is recognized by the formation of a slight brush discharge from the tool handle. This discharge makes itself known by a fuzzy feeling when the stick is handled with the bare hands. If it is very fuzzy, it is not safe. A stick with a light fuzz is safe, although one with no fuzz is the safest. An absolutely dry tool makes no sound when the wood composing it is touched directly to a high-voltage conductor. Very few tools, however, will be found in this condition unless the weather is very dry or the tool has just come out of the drying house.

Live-line tools should always be handled with bare hands or with workmen's gloves so that fuzz or leakage can be readily felt. The tool can be held at any point along its length at which there is no fuzz. The detection of a fuzzy feeling warns the lineman that he is getting too close to the line. This broad warning can be distinctly felt with the

FIG. 22-1. Typical utility live-line tool set, designed for use on rural lines having voltages up to 13,200 volts. (*Courtesy James R. Kearney Corp.*)

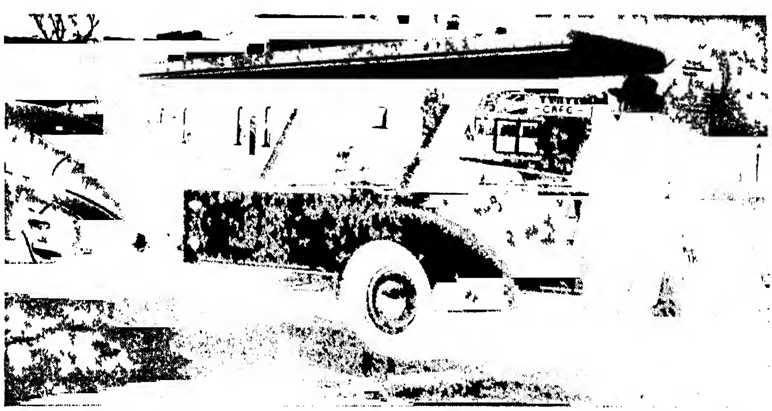


FIG 22-2 Special hot-line tool trailer. Note elevated cover. (*Courtesy A. B. Chance Co*)

bare hand by sliding it gently along a stick in contact with a live line. Tools showing leakage should be tested and dried if necessary.

Wire Tongs. Wire tongs are used primarily in handling live conductors. They are sometimes referred to as lifting sticks or holding sticks. A tong consists of a long wooden pole with a hook clamp on one end and a swivel on the other (see Fig. 22-3). The hook clamp is opened or closed by turning the wooden pole. A live conductor is clamped by placing the hook over it and turning the pole until the jaws of the hook are completely closed. The swivel clevis on the other end is for the application of lifting tackle.

The wire tong is used to hold the conductor away from the point where work is to be done, as when replacing an insulator or a crossarm.

FIG 22-3 Wire-tong mode of wooden pole, conductor clamp, and swivel (*Courtesy A. B. Chance Co.*)

The simplest case is illustrated in Fig. 22-4 where the wire tongs are used to hold the live-line conductor on a rural line to one side while a transformer is being installed. A more complicated operation is illustrated in Fig. 22-5 where a number of wire tongs are used to hold the three conductors of a three-phase line away from the pole while the pin insulators are replaced.

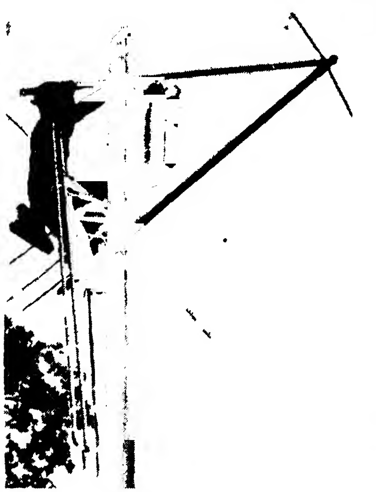


FIG. 22-4. Lineman using two wire tongs to hold live conductor on rural line to one side so as to clear working space needed in installing transformer (*Courtesy A. B. Chance Co.*)

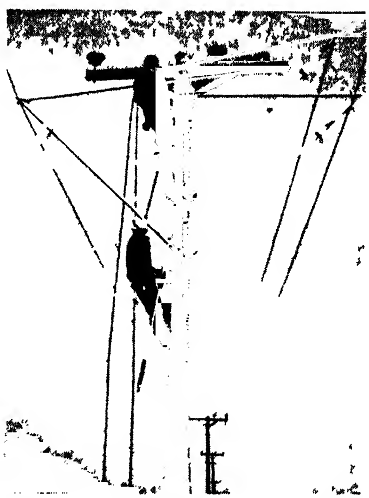


FIG. 22-5. Lineman moving third-line conductor into the clear, preparatory to changing pin insulators One pair of wire tongs is used to hold each line conductor away from the pole. (*Courtesy A B Chance Co.*)

Wire-tong Supports. A wire-tong support serves the special purpose of guiding and holding a wire tong in a fixed position after the conductor has been moved. A typical tong support is shown in Fig. 22-6. The support consists essentially of a base or saddle fastened by a chain to the pole or tower. A swivel clamp is mounted on the saddle. The wire tong slides between the jaws of this clamp, while the swivel action

FIG. 22-6. Typical wire-tong base for anchoring tong to pole. (*Courtesy James R. Kearney Corp*)

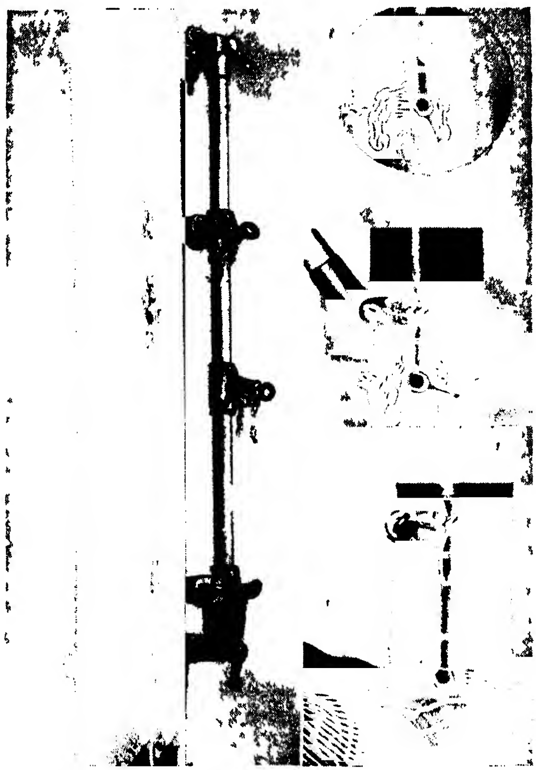


FIG. 22-7. Multiple wire-tong support. Each support can be clamped in any position along the rod. (*Courtesy A. B. Chance Co.*)

permits movement of the tong in all directions. Wing nuts are used to tighten the jaw of the clamp onto the tong.

A multiple form of tong support is illustrated in Fig. 22-7. When a number of saddles are needed on the same side of a pole or tower, a slide type of wire-tong support may be used. This support consists of a round rod secured to the pole at each end by means of a chain. On the rod are placed the tong holders. These holders slide up and down the rod freely but can be clamped in any position. One to six tongs can be supported from one fastening, as shown in Fig. 22-5. The rod is available in lengths up to 6 ft.

Insulated Tension Link. An insulated tension link is a wood strain insulator with a conductor clamp on one end and a swivel on the other,

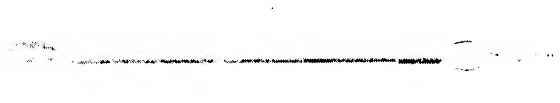


FIG. 22-8. Insulated tension link used to spread line conductors for pole installations and removals, when pulling conductors in the clear of structures for maintenance work, and when handling extremely heavy conductors on H frame and tower lines. (*Courtesy James R. Kearney Corp.*)

as shown in Fig. 22-8. It is commonly used between the line conductor and the rope tackle when pulling conductors in the clear of structures, when changing insulators, crossarms, or poles. Figure 22-9 shows two tension links in use when changing pin insulators. The wire tongs hold the conductor at the desired distance, and the links keep the tongs from swaying toward the pole. Figure 22-10 shows the use of six tension members to hold the six line conductors clear of the pole while changing

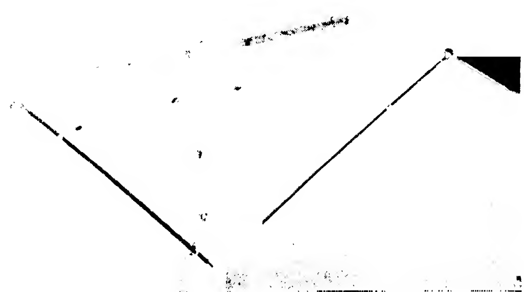


FIG. 22-9. Two tension links holding line conductors at proper distance from pole. (*Courtesy James R. Kearney Corp.*)

crossarms. Figures 22-11 and 22-12 show the use of two hot sticks in tension to support the line conductor on a high-voltage transmission line while another hot stick is used to keep the conductor from swaying.

Auxiliary Arm. An auxiliary arm is an arm that is used to support the line conductors temporarily while the insulators or crossarms are being replaced. It may be used to raise and support the conductors vertically, or it may be used to support one or more conductors to one side horizontally. Figure 22-13 shows an auxiliary arm used as a lifting crossarm, and Fig. 22-14 shows it used as a side arm. Figure 22-15 shows a lineman transferring a second line conductor from the main crossarm to the auxiliary arm by means of wire tongs. An auxiliary arm is especially useful where it is desired to install a pole of greater

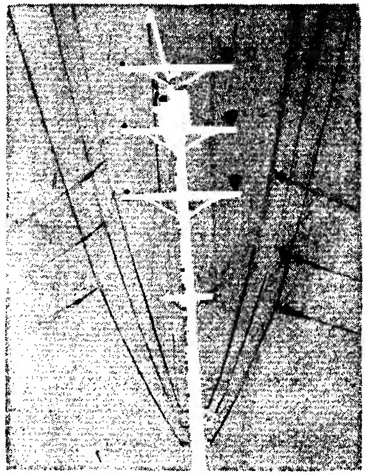


Fig. 22-10. Six tension links holding line conductors clear of pole while changing crossarms. (*Courtesy Safety Live Line Tool Co.*)

Fig. 22-11. Using hot sticks to change insulators on a live 132,000-volt line. The conductor is supported by two hot sticks and prevented from swaying by one horizontal stick. Insulator string is still in vertical position. (*Courtesy American Gas and Electric Service Corp.*)

height or where low-voltage lines must be cleared preparatory to working on higher voltage lines above them. Clamps are provided on the top of the arm to hold the conductors securely.

Strain Carrier. The strain carrier is used to take the load off strain or suspension insulators while the insulators are changed. Two types of

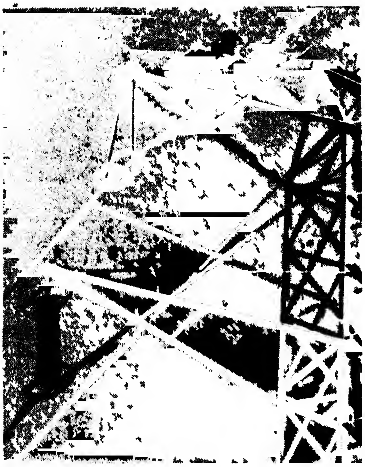


Fig 22-12 Using hot sticks to change defective insulators on a live 132,000-volt line Note two tension hot sticks used to support the line conductor, and one hot stick to keep the line conductor from swaying A fourth hot stick is being used to pull the insulator string away from the line so that the defective insulator units may be replaced Note use of insulator shields on ends of insulator strings and use of Stockbridge dampers on line conductors (*Courtesy American Gas and Electric Service Corp*)

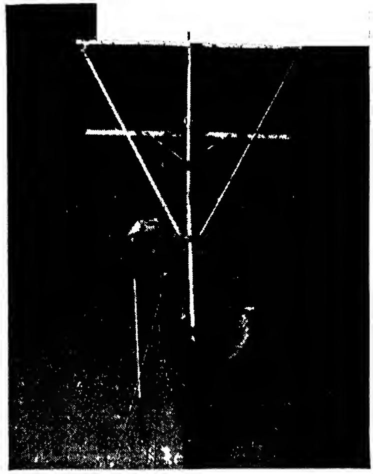


Fig 22-13 Auxiliary arm used as lifting crossarm to hold line conductors well above normal position to clear working space while a new crossarm is being installed (*Courtesy A B Chance Co*)

Fig. 22-14 Auxiliary arm used as side arm to hold two line conductors to one side. The third conductor is held in the clear on the opposite side wire tongs. (*Courtesy A. B. Chance Co.*)

Fig. 22-15 Lineman transferring second line conductor from main crossarm to the auxiliary crossarm by the use of wire tongs The third line conductor will be held off on the opposite side of the pole with the wire tongs (*Courtesy American Gas and Electric Service Corp.*)

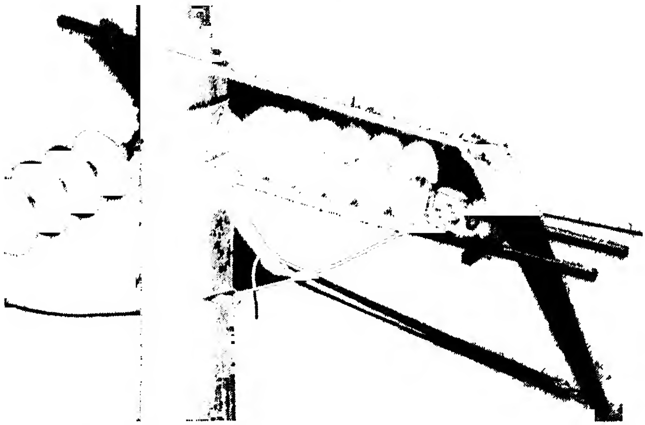


Fig. 22-16. Light-duty strain carrier of the rocker-arm type. Illustration shows strain carrier mounted on corner pole and used to relieve the insulator string of conductor pull. (*Courtesy James R. Kearney Co.*)

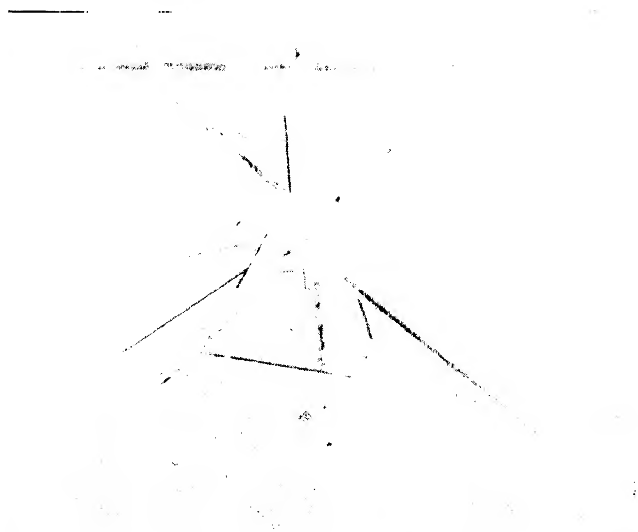


Fig. 22-17. Insulator string supported by cradle while being lowered into vertical position. Note two wooden tension rods supporting conductor. (*Courtesy A. B. Chance Co.*)

strain carriers are in use, one for light loads up to about 2,000 lb and one for heavy loads up to about 10,000 lb.

The light-duty strain carrier consists of two rocker arms hinged on a bar, Fig. 22-16. By bringing together the two rocker arms, the insulator string is compressed, and the insulator units may be removed and replaced.

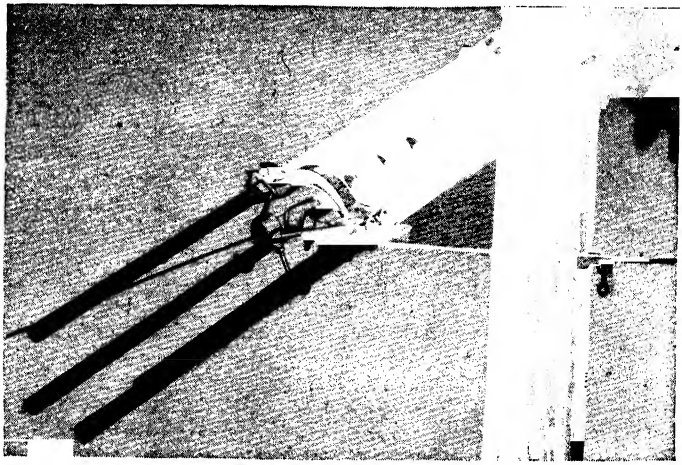


FIG. 22-18. Heavy-duty strain carrier mounted on dead-end pole. Note two-pole cradle provided to support insulator string after being uncoupled from line-conductor clamp. (*Courtesy James R. Kearney Co.*)

FIG. 22-19. Heavy-duty strain carrier in use on tower line. Illustration shows suspension string moved from vertical to horizontal position away from live conductor for replacement of defective insulators. Illustration also shows use of special platform. (*Courtesy A. B. Chance Co.*)

The heavy-duty strain carrier consists of two parallel wooden rods which are set astride the insulators. The strain is relieved by taking up screws on the ends of the wooden rods, thereby compressing the insulator string. The insulator string is supported in a cradle consisting of two wooden rods below the insulator string shown in Fig. 22-17.

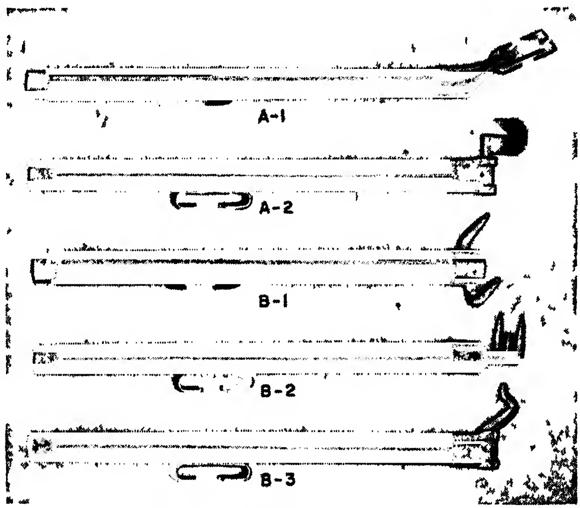


FIG. 22-20. Tie sticks for use on live lines (*a*) Blade type: (1) fixed, (2) rotary (*b*) Prong type (1) two prong, (2) three prong, (3) rotary prong.

The strain carrier may be used on either pole or tower construction, as shown in Figs. 22-18 and 22-19

Tie Sticks. Tie sticks are used to fasten or unfasten the tie wire which holds the conductor to the pin-type insulator (see Fig. 22-20). Tie sticks are usually also equipped with a small double hook called the

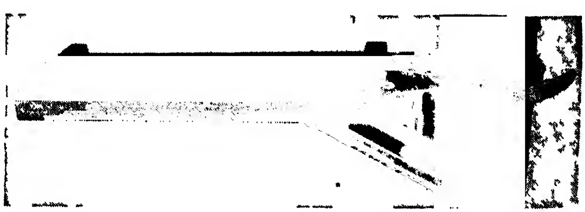


FIG. 22-21. Small utility platform. (*Courtesy A. B. Chance Co.*)

tie-wire assistant. It is fastened to the tie stick a short distance from the end. It has several uses, such as prying loose the ends of old tie wires that may be wrapped close to the conductor, holding the conductor down in the insulator groove while being tied in, or as a means of hanging the tie stick on the conductor when not in use.

Platform. The platform is small and collapsible and may be secured to the pole or tower. Figure 22-21 shows a small utility platform, and Fig. 22-22 shows a more elaborate type designed for hot-line work. This platform is equipped with a hand railing. Its use enables the lineman to

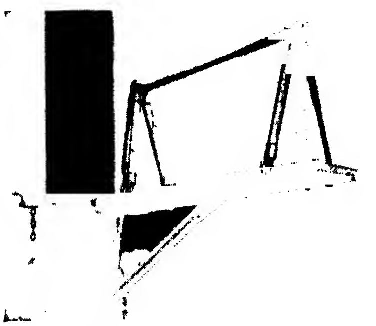


FIG. 22-22. Insulated platform designed for live-line maintenance work. (*Courtesy James R. Kearney Co.*)

FIG. 22-23. Insulated insulator cover. (*Courtesy James R. Kearney Co.*)

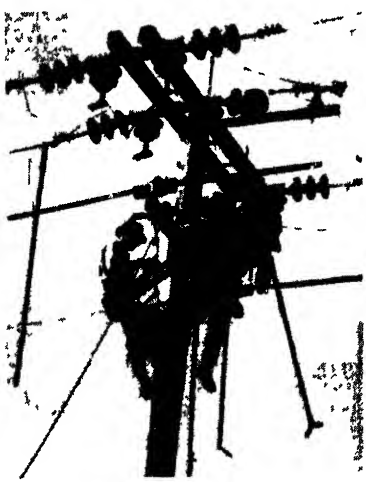


FIG 22-24. Insulator hood and line guards in use in live-line maintenance work. (*Courtesy A. B. Chance Co.*)

reach farther out from a pole or tower and thus perform the work with greater ease.

Insulated Hoods. Insulated hoods are available to place over conductors and insulators to add to the safety of linemen doing hot-stick work (see Figs. 22-23 and 22-24).

Insulated Tools. Many other tools can be adapted to hot-line work by mounting them on the ends of insulated poles. Among these are pliers, wire cutters, tree trimmers, cotter-key pullers, screwdrivers, fuse pullers, saws, wrenches, brushes, and clamps. Some of these are illustrated in Fig 22-25.

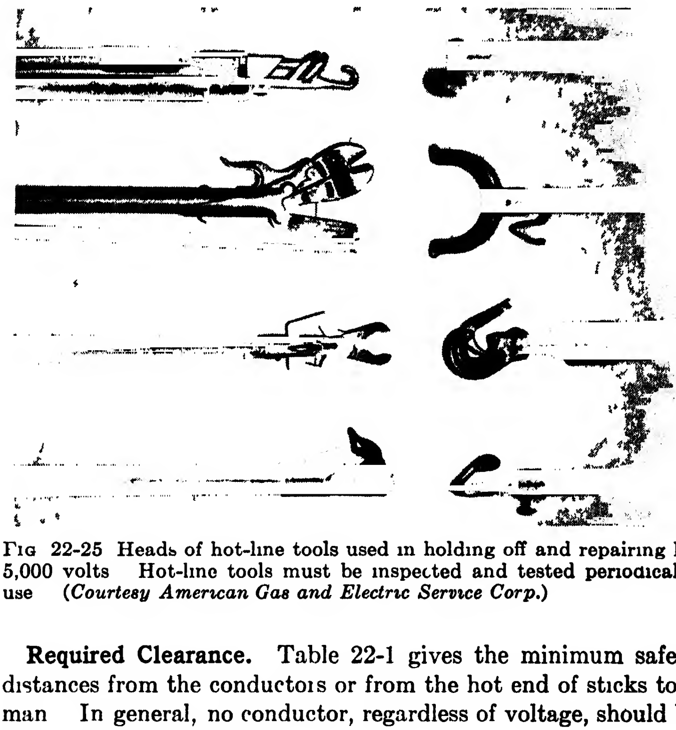


Fig 22-25 Heads of hot-line tools used in holding off and repairing lines above 5,000 volts Hot-line tools must be inspected and tested periodically for safe use (*Courtesy American Gas and Electric Service Corp.*)

Required Clearance. Table 22-1 gives the minimum safe working distances from the conductors or from the hot end of sticks to the lineman In general, no conductor, regardless of voltage, should be within the reach of any lineman.

Table 22-1

Line Voltage, Volts	Minimum Clearance, Ft
2,200 to 6,600	1
13,200 to 33,000	2
44,000 to 66,000	3
110,000 to 132,000	5

CHANGING PIN INSULATORS

Order of Steps. The principal parts of a pole line are the conductor, insulator, crossarm, and pole. Since the conductor hardly ever fails, live-line maintenance resolves itself into replacing insulators, crossarms, and poles. To replace one of these requires that the conductors must be untied from the insulators, removed, and held in the clear. When so held the insulators or crossarms, or both, can be removed and replaced. If the pole is to be replaced also, the best practice is to set the new pole first and then to mount all wire tongs and saddles and other tools on the new pole. In this way the old pole, which usually is weak, will not have to be specially guyed for this operation.

The steps in the process are performed in the following order.

1. Fasten wire tongs to conductor.
2. Untie conductor from insulator.
3. Move conductor into clear.
4. Remove old insulator, or crossarm, or both.
5. Mount new insulator, or crossarm, or both.
6. Return conductor to insulator.
7. Tie in conductor.
8. Remove wire tongs or auxiliary arm.

Moving Line Conductor. Three methods for moving line conductors into the clear are available:

1. Wire-tong method
2. Auxiliary-arm method
3. Combination of wire-tong and auxiliary-arm method

Wire-tong Method. In the wire-tong method the conductor is moved and supported by the use of two wire tongs, one being used for lifting,

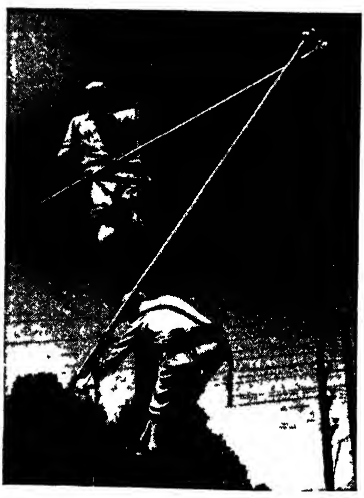


FIG 22-26. Two wire tongs being used to hold live conductor on a rural line in the clear while lineman is preparing to replace the pole-top pin. The lower longer tong is the lifting tong and supports the conductor, the shorter upper tong is the holding tong and is used to hold the conductor firmly, at the proper distance from the pole. (*Courtesy American Gas and Electric Service Corp.*)

called the lifting tong or stick, and the other for holding, called the holding tong or stick (see Fig. 22-26). The lifting stick is clamped onto the conductor to be moved, and its saddle is fastened to the pole in such a position that several feet of the swivel end of the lifting stick extend through the saddle. The saddle clamp is then tightened onto the stick by turning the wing nut. Next a set of blocks is attached between the saddle and the swivel on the end of the lifting stick. This block and tackle will later be used to lift and move the conductor out of reach.

Another saddle for the holding stick is fastened to the pole just below the crossarm braces. The holding stick is now clamped onto the conductor and placed in the top saddle.

The conductor may now be untied from the insulator by means of the insulated tie sticks. After the conductor is untied, it is ready to be pushed out of reach. To move the conductor, pull up on the set of blocks, thereby raising the conductor off the insulator. If the outer

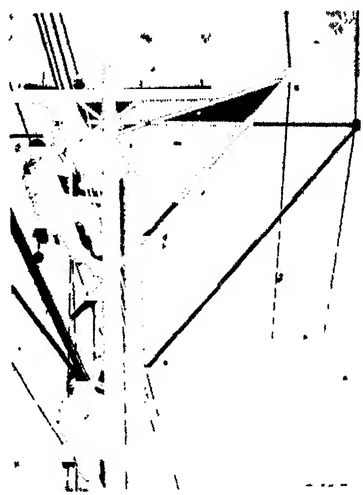


FIG. 22-27. Three sets of wire tongs holding three live conductors firmly in the clear while a new pole and crossarm are being installed. The tongs are all supported on the old pole (*Courtesy American Gas and Electric Service Corp.*)

conductor is being moved, the distance raised should be about 10 in. If the center conductor is moved, it should be raised enough to clear the end of the crossarm. When the conductor has been moved outward to a safe working distance, the saddle clamps on both sticks are tightened firmly. The blocks are then removed.

The same procedure is repeated for the other two conductors. The other outside conductor is moved next, and the inside or center conductor is moved last, as it must be moved above one of the outer conductors. The saddles for the sticks supporting the outer conductors may be placed on opposite sides of the poles, while a saddle extension may be used for the saddles supporting the middle conductor. Figure 22-27 shows three live conductors of a three-phase four-wire circuit moved in the clear by means of wire tongs preparatory to changing the pole and crossarm.

After the insulators, or crossarms, or both have been replaced, the above procedure is reversed and the conductors are brought back in. As the conductors are returned, they are tied in, using the special tie sticks.

For heavier construction such as wishbone, H frame, or at angles in the line, the same procedure may be followed except that an insulated link stick with blocks may be used to help move the conductor away from the insulator. The top holding stick should still be used because it helps to stabilize the conductor on the link stick.

Auxiliary-crossarm Method. Where construction permits, the work of moving conductors may be simplified by the use of the auxiliary crossarm. The auxiliary crossarm may be used to lift all conductors from a

FIG 22-28 First step in transferring outermost conductor to auxiliary arm consists in attaching lifting and holding tongs to conductor. Lineman is shown tightening saddle clamp on lifting tongs. (*Courtesy A. B. Chance Co.*)

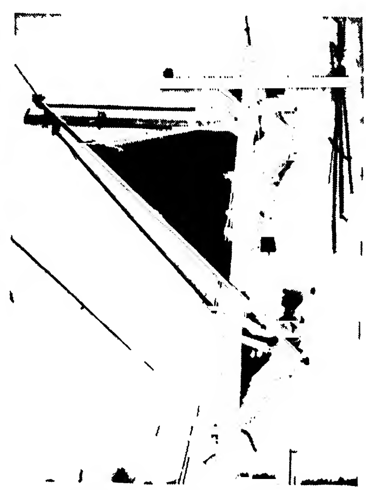


FIG 22-29 Moving first conductor out onto auxiliary arm by means of wire tongs. Note use of block and tackle on lifting tongs to assist in supporting weight of conductor. (*Courtesy A. B. Chance Co*)

crossarm vertically at one time, or it may be used to hold two or more conductors out on one side of the pole.

Mast Arm. When the auxiliary arm is used as a mast arm, that is, in lifting the conductors up from a crossarm, two saddles are mounted on the pole. The first saddle is mounted just beneath the crossarm braces. The assembled mast arm is then placed in position in this saddle and pushed up against the conductors and clamped into position. The lower saddle is then mounted on the pole below the point where the bracing is fastened to the mast arm, and the main lifting pole is clamped in position. Saddle extensions should be used if necessary.

The conductors are then untied from the insulators with the tie sticks and placed in the holders on the mast arm provided for that purpose. When all the conductors have been transferred, the whole mast crossarm assembly is lifted up until the conductors are in the clear.

If the line makes an angle greater than 5 deg, it is advisable to "side guy" the mast arm, using an insulated link stick and a rope.

Side Arm. When the auxiliary arm is used as a side arm, it should be placed on the two-conductor side of the pole. One end of the side arm is mounted on a saddle at a point just below the crossarm braces. The conductors are then transferred to the holders on the side arm provided for that purpose with the use of lifting and holding tongs. The outside conductor is moved first, as shown in Fig. 22-28. The two tongs have just been attached to the live conductor. In Fig. 22-29 the conductor is

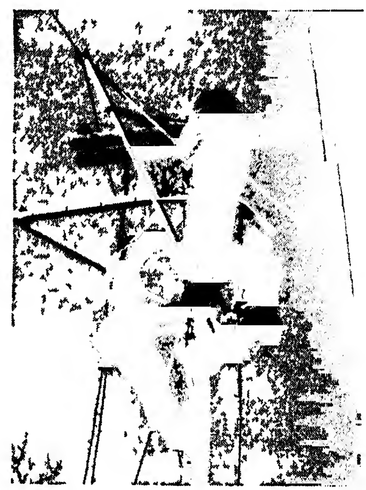


FIG. 22-30. Beginning the transfer of the second conductor to the holder on the auxiliary arm. Note use of block and tackle fastened to upper end of lifting tongs. This provides steadier control of conductor movement, both outward and return. (*Courtesy A. B. Chance Co.*)

being placed in the outermost holder on the auxiliary arm. A block and tackle fastened to the upper end of the lifting tongs is also used to assist in moving the conductor. In Fig. 22-30 the tongs are shown fastened to the second conductor preparatory to transferring it to the auxiliary arm.

The third conductor on the opposite side of the pole is moved and supported with wire tongs.

Removing the Tie Wire. The tie wire is untied by starting to unwind the end of the tie wire with the tie-wire blade on the tie stick, as shown in Fig. 22-31. If the tie wire has no end which can be easily reached with the blade of the tie-wire stick, an end is made by cutting the tie wire at some convenient point with a hack saw. The tie wire is then unwound by pulling the end of the tie wire, if it points away from the pole. If the end of the tie wire points toward the pole, it is started by pushing up with the blade of the tie-wire stick. After this has been done, the old tie wire is easily unwrapped with the head of the tie stick. If it has a long wrapping, it should be cut with the hack saw as soon as the untied portion becomes difficult to handle. If it gets too long, there also is danger of it touching the other conductor and shorting the line.

During the process of removing old tie wires and tying in, the lineman should not be allowed to sit on the crossarm or put his legs or arms through the braces, but should be made to stand with his full weight in the climbing hooks, his feet as close together as possible, and should be instructed to lean back in his safety belt and keep his hands off the pole, crossarms, and crossarm braces. If he will do this, he will benefit from the insulation properties of the pole and crossarm.

Tying in Conductor. Particular mention should be made of the procedure employed in tying the conductor onto the new insulator. Special provision is made for this by providing the new insulator with special tie

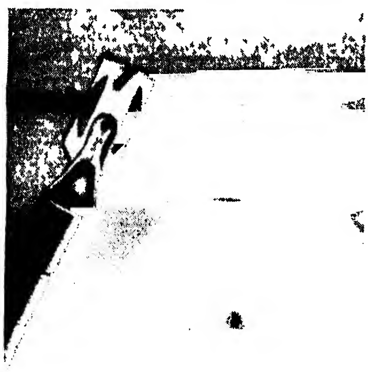


FIG 22-31. Removing tie wire with blade-type tie stick. (*Courtesy A B Chance Co.*)

wires before the insulator is screwed in place. Figure 22-32*d* shows the insulator in place with the tie wires fastened to the insulator. Figs. 22-32 *a*, *b*, and *c* show the details of the tie wires and the method of fastening them to the insulator. Each piece of the tie wire is placed in the neck of the insulator and bent until the ends meet (both ends being the same length). They are then given a couple of twists close to the neck of the the insulator and allowed to extend horizontally in the same direction as the top groove of the insulator, one pair of tie-wire ends extending out in opposite direction from the other side of the insulator, as shown in Fig. 22-32*c*. These ends are now bent over the top of the insulator, as shown in Fig. 22-32*d*, so that in screwing the insulator on the pin the tie-wire ends will not come in contact with any part of the live line. The insulator is then sent up on the pole and screwed onto the pin until it is tight and with the top groove of the insulator parallel to the line conductor. The line conductor is then placed in the top groove of the insulator, care being taken that both ends of the tie wire in the same pair of ends come on the same side of the line conductor and that the two pairs of tie-wire ends come on opposite sides of the line conductor. When in this position the insulator is ready to be tied in. The tie stick is used for this purpose. The man making the tie should be well below the crossarm. The tie stick is passed up on the far side of the line conductor from the pair of tie-wire ends on that side of the insulator. One horn of the tie stick is put through the loop in the end of the tie wire nearest the insulator. This end is then pulled downward. The same is then done with the other end of the tie wire. When both ends are then pointing downward, the end of the tie wire which was first pulled

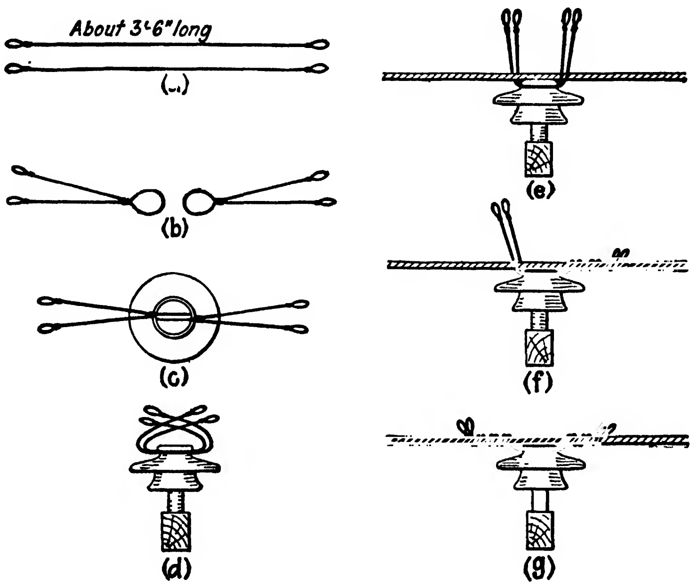


FIG. 22-32. Steps in tying in conductor by use of live-line maintenance tools. Tie wires are attached to insulator before insulator is screwed in place on pin. (*Courtesy Johnson Mfg. Co.*)

down is pushed upward with a stiff punch on the other side of the line conductor; the other tie wire is likewise pushed up. By repeating this operation, both ends of the tie wire are thus served up to the loops in their ends. These loops can then be removed if desired, although there is no reason for removing them, by cutting them with a hack saw and breaking them off or by twisting them with a tie stick until they break off close to the line conductor. Obviously, the same method can be used in tying the line conductor in the neck of the insulator as will be necessary on angles. In the case of double arms half of the above tie is made on one insulator and half on the other insulator.

This is by no means the only tie which can be applied; any desired form of tie can be made. This particular tie is chosen here only because it lends itself to a clear and accurate description and is perhaps the easiest tie to learn.

The sketches in Fig. 22-33 illustrate the most common types of hot-line ties in use. Note that both wires on one side of an insulator are turned in the same direction and that both wires on the other side of the insulator are turned in the opposite direction. They are started from

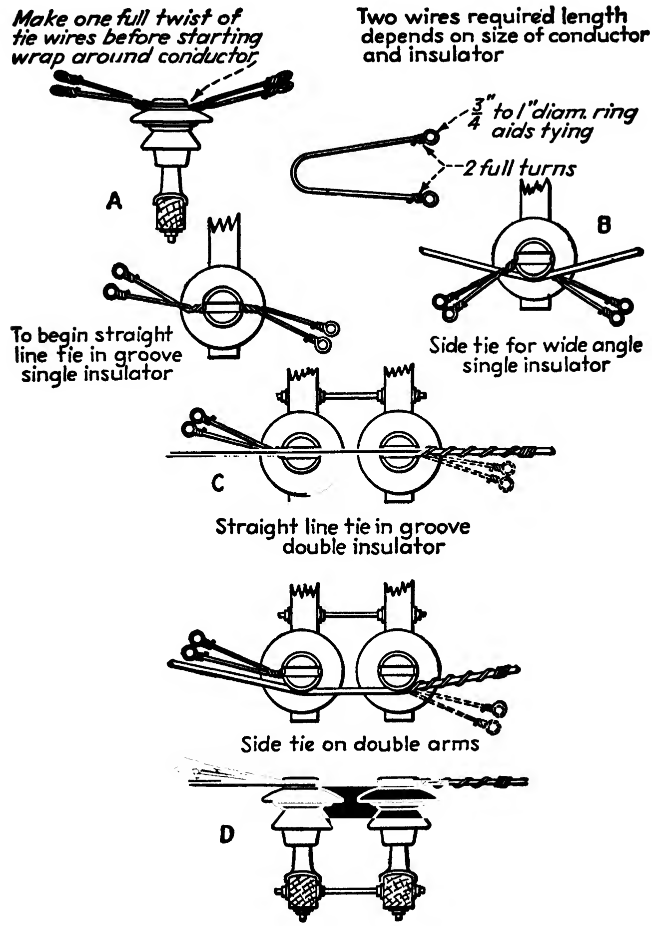


FIG. 22-33. Most common types of hot-line ties. (*Courtesy A. B. Chance Co.*)

the top and bottom of the conductor as in *B* and *D*, Fig. 22-33, or from opposite sides of the conductor as in *A* and *C*. This provides a self-snubbing action which prevents the conductor from rolling and assists in holding the conductor tightly against the cap of the insulator.

Note that eyes are shown on all ties. A lightweight stick with the prong-type head and this type of tie (Fig. 22-34) make a very satisfactory working combination. Some linemen prefer having the tie with-

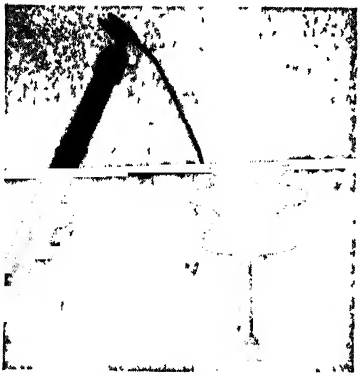


FIG. 22-34. Tying in a conductor using tie wires, provided with eyelets, and prong type of tie stick. (*Courtesy James R. Kearney Corp.*)

FIG. 22-35. Tying in line conductor with blade type of tie stick. (*Courtesy James R. Kearney Corp.*)

FIG. 22-36. Two linemen completing the insulator tie on the live middle conductor by the use of insulated tie sticks. (*Courtesy American Gas and Electric Service Corp.*)

FIG. 22-37. Lineman tying in conductor on rural line with tie stick. Conductor is held down in insulator groove by means of wire tongs. Note saddle which supports upper end of tongs. Also note that line conductor is provided with armor rods. (*Courtesy American Gas and Electric Service Corp.*)

out eyes. In this case the blade-type head is more convenient (Fig. 22-35). The use of eyes is especially helpful in untying as it makes it unnecessary to pry up the ends of the tie wire.

A handy tie stick is one with the blade-type head on one end and the prong-type head on the other.

Figure 22-36 shows two linemen, each provided with a stick, tying in the middle line conductor. Both outside line conductors are already

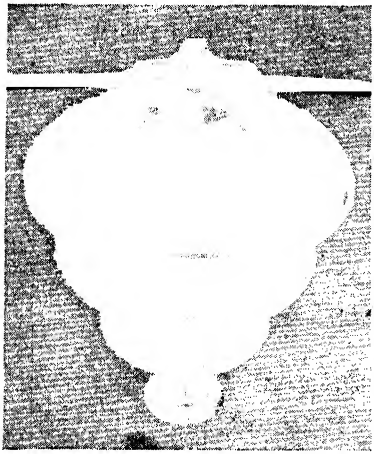


FIG. 22-38. Clamp-top type of pin insulator using a clamp instead of the usual tie wires to hold the conductor in position. (*Courtesy Ohio Brass Co.*)

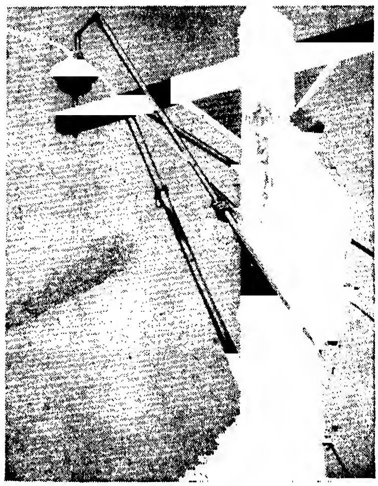


FIG. 22-39. Lineman unscrewing the two nuts that hold the keeper piece over the conductor. Note that the lifting and holding tools are already attached to the conductor and secured to the pole. (*Courtesy James R. Kearney Corp.*)

tied in. By working on opposite sides of the pole, all work is accessible to one or the other lineman. Figure 22-37 shows a lineman tying in the live conductor on a rural line.

Removing Conductor from Clamp-top Insulators. In case the pin insulator is of the clamp-top type, the removal of the conductor from the insulator is greatly simplified. Likewise, the fastening of the conductor is also made easy.

The clamp-top insulator, illustrated in Fig. 22-38, is similar to other pin insulators except that it has a bolted clamp cemented to the top. Two carriage bolts hold the keeper piece over the conductor.

To remove the conductor, therefore, it is only necessary to unscrew the two nuts. This is done by means of a special ratchet wrench and socket secured to the end of an insulated handle. Figure 22-39 shows the lineman performing this operation, and Fig. 22-40 is a close-up view

FIG. 22-40. Ratchet wrench and socket for loosening the nuts on clamp top bolts. (*Courtesy James R. Kearney Corp.*)

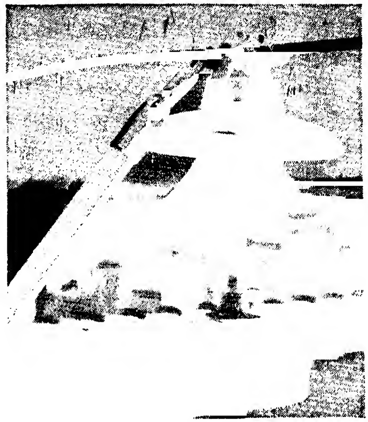


FIG. 22-41. Cradle for lifting the clamp, a suitably formed wire inserted in a standard hot-stick socket. (*Courtesy James R. Kearney Corp.*)

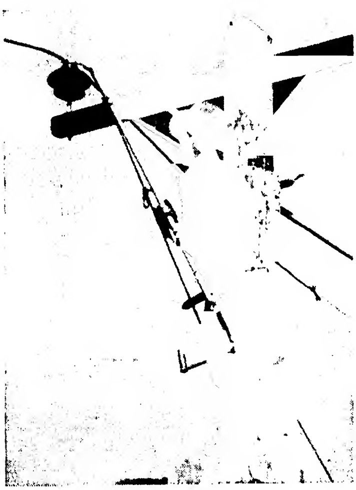


FIG. 22-42. Lifting the clamp from the supporting pintles with the wire cradle. (*Courtesy James R. Kearney Corp.*)

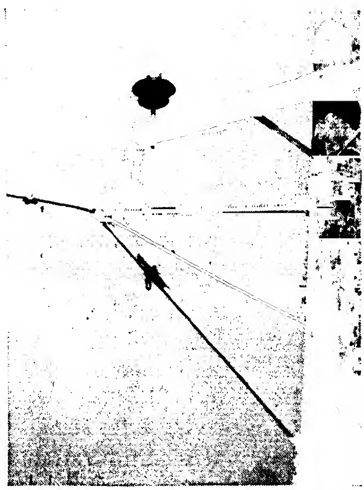


FIG. 22-43. With the clamp slid away from the clamp-top seat, the hot conductor can be moved away from the insulator as shown. (*Courtesy James R. Kearney Corp.*)

of the ratchet wrench and socket for loosening the nuts on the clamp-top bolts. Before this is done, the lifting and holding tools are attached to the conductor and secured to the pole.

After the nuts are loosened and backed off about 5/8 in., the conductor is raised slightly, about 1/2 in., to take its weight off the clamp seat. The clamp is then lifted from the supporting pintles with a special wire cradle mounted on the opposite end of the lineman's insulated handle and slid along the conductor away from the insulator. A close-up view of this process is shown in Fig. 22-41, and a view of the lineman performing this operation is shown in Fig. 22-42. With the clamp slid away from the clamp-top seat, the hot conductor is free and can be moved to any desired position to clear the insulator. The completed untying is shown in Fig. 22-43.

For attaching the conductor to the insulator the reverse procedure is followed.

CHANGING STRING INSULATORS

The majority of string insulators are used on steel-tower lines. The principal parts of a steel-tower line are the steel tower, steel crossarm, suspension insulator string, and conductor. At crossings, angles, and dead ends, strain insulators take the place of the suspension string. It is thus obvious that the only live-line maintenance work possible on tower lines will be the replacement of suspension or strain insulators. The steel towers, steel crossarms, and conductors seldom fail.

Order of Steps. In order to replace any defective units in the insulator string, the weight of the conductor must be taken off the string. This is accomplished by the use of the strain carrier. By drawing up on the strain carrier, the insulator string is relieved of the conductor load and can then be disconnected from the conductor clamp. The lineman is then free to remove and replace one or more of the insulator disks. When this is accomplished, the conductor load is transferred back to the insulator string and the strain carrier is removed. These steps can be listed as follows:

1. Attach strain carrier.
2. Draw up on strain carrier.
3. Disconnect insulator string.
4. Replace defective insulator units.
5. Reconnect insulator string.
6. Release tension from strain carrier.
7. Remove strain carrier.

Clearing Working Space. Before proceeding with the work the lineman should make sure that sufficient working space is available and that the required clearance from live conductors can be maintained. If protective gaps are in the way, they should be pushed out of the way or removed temporarily. Jumpers around dead-end strings should also be pushed out of the way and held away by use of a holding stick in the regular manner.

Use of Strain Carrier. The strain carrier is then placed in position. As the suspension string hangs vertically, the strain carrier also hangs vertically. No cradle for supporting the insulator string will be needed. The fixed end of the carrier is hooked onto the conductor on opposite sides of the clamp. The adjustable or take-up end is fastened to the crossarm, allowing enough slack in the tightening arrangement for taking the strain off the insulator string.

After the strain is taken off the insulator string, the insulators hang limply and may be disconnected from the strain clamp. This requires pulling out a cotter key or pin. This is performed with a cotter-key puller, which consists of a special cotter-key pulling hook fastened to the end of another hot stick. If the cotter key is hard to pull out, the conductor load on the string should be further reduced by additional tightening of the strain carrier.

With the insulator string now free from the clamp, the string can be removed and the defective insulator units replaced. It has been found preferable in most cases to remove the entire string of insulators rather than to replace the insulator disks singly. This is especially so when the insulator string is short, consisting of only two or three disks. The insulator string may be removed by using a shepherd hook, fork stick, lifting yoke, sling, or other suitable device.

After the insulators are replaced, the string is reconnected to the clamp. The cotter pin is installed by the use of a special cotter-key replacer. The cotter key is spread by means of a screwdriver fastened to the other end of the cotter-key replacer hot stick. The strain is now transferred to the insulator string by letting off on the strain carrier. The carrier and other tools should then be removed in the reverse order of their installation.

Wire-tong Method. In many cases, especially on light pole lines, the suspension insulators may be replaced with the use of wire tongs or hot sticks instead of the strain carrier.

The procedure is similar to that used with pin-type insulators. The conductor and clamp are secured with a lifting tong. The assembly is then pushed away from the pole or tower a distance of about 6 in. The lifting tong is then secured in its saddle clamp. The holding tong is now fastened to the conductor, and the conductor is then pulled back to the pole or tower. This will cause the conductor to be raised slightly and thus transfer the conductor load onto the lifting tong. The insulator string will now hang limply. The insulator string may now be disconnected from its clamp and the line conductor moved farther out of the way (see Fig. 22-44). A link stick may be used in pulling the conductor away or in pulling it back, but the holding tong should always be used as it will help to stabilize the conductor in its position away from the pole or tower. After the defective insulator units are replaced, the

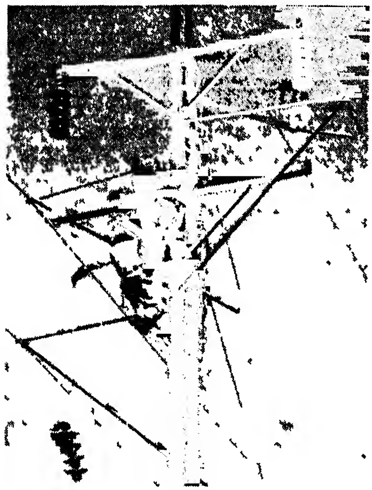


FIG 22-44. Wire tongs used in replacing defective suspension insulators on a 66,000-volt line Note use of link stick and rope blocks on line conductor on right side of pole. (*Courtesy A. B. Chance Co.*)

conductor is pulled back in and the string is reconnected to the conductor clamp. All tongs and other tools are then removed in reverse order of their installation.

REPLACING STRAIN INSULATORS

Procedure. The strain carrier is first placed in position as with suspension insulators. Since the strain-insulator strings are somewhat horizontal, the carrier can be slid over the insulators out to the line conductor. The fixed end of the carrier is attached behind the strain clamp on the span side of the clamp. The adjustable or take-up end of the carrier is fastened to the pole, crossarm, or tower, allowing enough slack in the tightening arrangement for taking the strain off the insulator string. The cradle for supporting the slack string of insulators is then placed in position by hanging the adjustable hook over the conductor and fastening the other end to the crossarm. When the insulator string is short, that is, consists of only two or three disks, the supporting cradle need not be used, as the insulators can then be handled by means of a yoke arrangement on the end of a hot stick.

The next step is to take the conductor load off the insulators. This is accomplished by drawing up on the strain carrier. In the "buck-saw" type of strain carrier, this is done by pulling together the ends of the two hinged members, using a set of blocks. In the "cradle" type of strain carrier the conductor load is transferred to the carrier by taking up on the jackscrew at the rear of the two tension members.

After the strain is taken off the strain insulator string, the string may be disconnected from the clamp (see Fig. 22-45). The defective insulator disks may now be replaced and the complete string reconnected to

FIG. 22-45. Disconnecting strain insulator string from conductor clamp. Note use of insulated utility platform. Also note cradle support for insulator string. (*Courtesy Victor Insulator Co.*)

the clamp. The conductor load is then returned to the strain-insulator string by letting off on the strain carrier. All hot-line tools should now be removed in reverse order of their placement.

PULLING SLACK

String Insulator. The same general procedure is followed when pulling or removing slack from a conductor when the line is energized as is used when the line is deenergized. When the lines are energized, properly insulated tools and insulated links must of course be used. The order of work is as follows: The pulling grip or come-along is attached to the conductor with a tie stick, holding stick, or other hot stick. An insulated link stick is next attached to the pulling eye of the come-along. A set of blocks is now placed between the end of the link stick and the pole, crossarm, or tower. The conductor is then secured by taking up on the set of blocks. After the conductor is thus secured, the clamp holding the conductor to the insulator string is loosened by unscrewing the nuts on the holding bolts by means of a socket wrench fastened on the end of a hot stick. The slack is then taken up by pulling further on the blocks. All pulling on the blocks should be done from the ground, if possible. When sufficient slack has been removed, the conductor clamp is tightened by use of the insulated socket wrench. If all the unwanted slack cannot be pulled in one operation, the foregoing procedure is repeated until the desired conductor sag is obtained. When sufficient slack has been pulled, the blocks, insulated stick, and pulling grip are removed. The pulling grip is loosened by tripping the releasing lock with a tie stick or other hot stick.

Pin Insulator. The same procedure is followed when pulling slack in a line supported on pin insulators. Instead of unscrewing the nuts on the conductor clamp, the tie wires holding the conductor to the insulator are loosened but not removed. Then the slack is pulled up and held while the insulator ties are remade.

CUTTING OUT CONDUCTOR

If a short length of conductor needs to be cut out of the line, the slack can be pulled in both directions from the same pole or tower. The extra conductor may then be cut out, the conductor spliced and then refastened to the insulators.

In order not to interrupt the flow of current in the line when the conductor is cut, a jumper is placed around the section where the conductor is to be cut out. However, before the ends of the jumper are tapped onto the conductor, the jumper must be firmly held away from the lineman by means of a holding tong or stick securely fastened to the pole or tower. An insulated link stick with rope may also be used for this purpose. The ends of the jumper are then clamped onto the live conductor. The desired length of conductor is cut out of the line, and the ends are spliced. After the splicing is completed, the jumper is removed.

If the line conductor is a stranded cable, extreme care must be taken to prevent the cable from unraveling and allowing the wires to get out of control.

SPLICING LIVE CONDUCTORS

The procedure for splicing a hot conductor with live-line tools is as follows: The conductors to be spliced are pulled tight with blocks, using link sticks on the come-alongs for insulation (see Fig. 22-46). The ends of the conductors are held in position with holding sticks. The splicing connector is next fastened to the end of one conductor. Then the end of the other conductor is brought over and placed in the connector. The connector is now firmly fastened, completing the splice. Insulated tools, of course, are used for all the operations.

TAPPING LIVE LINE

Taps are easily made to live conductors by the use of appropriate equipment. The conductor to be tapped to the live line is first fastened

FIG. 22-46. Removing come-alongs after completing a splice on a hot line. Note use of insulated link stick on come-alongs. (*Courtesy A. B. Chance Co.*)

to the body of a special tapping clamp and is then held with a hot stick and hooked over the live-line conductor. The clamp is then tightened by turning the screw head of the clamp, using the hot stick for this purpose.

APPLYING VIBRATION DAMPERS

Vibration dampers of different types may be applied to lines while energized, using live-line tools for their installation.

A special tool simplifies the installation of the Stockbridge type of damper on live conductors, Fig. 22-47. The damper is placed in the head of the tool, as shown in Fig. 22-48. A spring holds the damper clamp in place whether it is open or closed. With the damper clamp in the open position, the damper is placed on the live conductor. The locking nut on the bottom of the clamp, which has previously been placed in a socket, is tightened by turning the hot stick. The tool is removed by pulling down on the hot stick, compressing the spring, and turning the stick a quarter turn to engage the socket in a locked position on a projecting lug on the head of the tool. The tool may then be easily lifted away. A ring is provided on the side of this tool for attaching the link stick and hand line or blocks for aid in handling heavy dampers of this type.

APPLYING ARMOR RODS

In order to install armor rods, it is first necessary to remove the conductor from the insulator in the usual manner and move it with wire

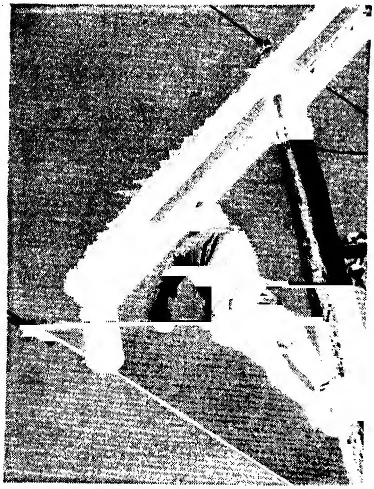


FIG. 22-47. Applying Stockbridge vibration damper to live line with special tool. (*Courtesy A. B. Chance Co.*)

FIG. 22-48. Vibration damper placed in special tool preparatory to fastening to live-line conductor. (*Courtesy A. B. Chance Co.*)

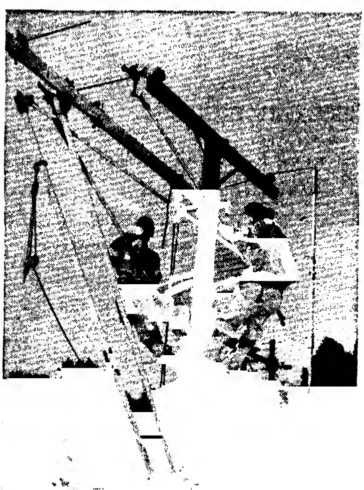


FIG. 22-49. Line conductors supported by an auxiliary side arm while armor rods are applied with special "hot" tools. (*Courtesy American Gas and Electric Service Corp.*)

tongs to a suitable working position, as shown in Fig. 22-49. In this case the conductors are supported on an auxiliary side arm. The armor rods are then applied with a special tool, Fig. 22-50. The tool consists essentially of two split wheels into which different size dies are set. The armor rods are placed into these dies, and the assembly is placed around the conductor by means of holding or clamping sticks. The wheels or holders are rotated in the proper direction, depending on the lay of the wire, one holder moving clockwise and the other counterclockwise. The rotation of the holders is accomplished by means of hooks fitted onto hot sticks engaging lugs on the holders. At the same time the holders are rotated, they are moved apart, starting near the center of the armor rods and moving toward the ends. The rotary movement of the holders is continued until the armor rods are completely and tightly twisted into place. The holders are then pushed off the rods and removed by means of clamp sticks or other hot sticks.

Armor clips are then inserted on each end of the armor rods and clamped into place by tightening the bolt nuts. Special spring sockets

FIG. 22-50. Special tools used to apply armor rods while line is live. (*Courtesy A. B. Chance Co.*)

mounted on the ends of hot sticks are used to tighten the nuts, the spring being used to thrust the saddle into place as soon as the two halves of the clip are in alignment.

PHASE SEQUENCE

Phase sequence is the sequence or order in which the three voltages of a three-phase system appear. The phase sequence of a three-phase system is often desired in order to

1. Determine the direction of rotation of polyphase motors
2. Determine the proper connections for paralleling three-phase transformer banks, generators, and power buses
3. Determine the proper connections for watthour meters, instruments, and relays

Phase-sequence Indicator. One type of phase-sequence indicator, like that illustrated in Fig. 22-51, makes use of a small capacitor connected in Y with two small neon lamps. When used, the terminals of the Y are connected to the conductors of the three-phase circuit of which the phase sequence is to be determined A schematic diagram of the connections is shown in Fig 22-52

Operation. When the phase-sequence indicator is connected across a three-phase line as shown in Fig 22-52, an unequal distribution of voltage occurs in the three arms of the Y network This makes the voltage

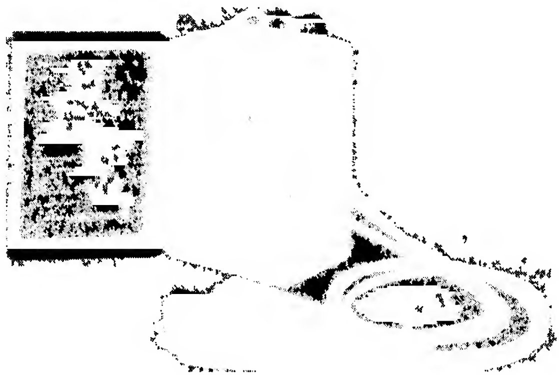


FIG 22-51 Phase-sequence indicator showing two neon lamps and three connecting leads This particular model can be used on 120- 240-, and 480-volt circuits (*Courtesy General Electric Co*)

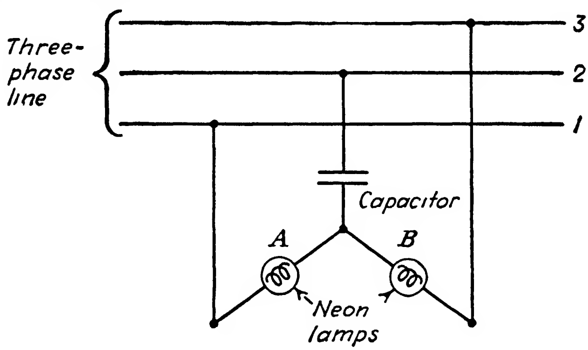


FIG 22-52 Phase-sequence indicator connected to three-phase line Indicator consists of a capacitor and two neon lamps *A* and *B* connected in Y

across one of the neon lamps considerably greater than across the other for a given phase rotation In fact, if the voltage across the darker lamp falls below the minimum breakdown or ignition value, the lamp will cease to glow completely. Consequently, only one of the neon lamps glows brightly at a time The one that glows brightest indicates the phase rotation of the line voltages.

Determining Phase Sequence. Phase sequence or rotation is designated as 1-2-3 or 3-2-1. The first order is engraved on the case under the left-hand (*A*) lamp, and the second order is engraved under the right-hand (*B*) lamp. The leads which are used to measure the phase sequence of the three-phase line are identified with engraved markings of 1, 2, and 3.

To use the phase-sequence indicator, the voltage-selector switch is first set to the desired voltage. The three leads of the instrument are then connected to the lines to be measured. One lamp should then glow much more brightly than the other. If the left-hand (*A*) lamp glows

FIG. 22-53 Lineman making final check of phase sequence with phase-sequence indicator before putting load on line. (*Courtesy General Electric Co.*)

brightest, the phase sequence is 1-2-3, and if the right-hand (*B*) lamp glows brightest, the phase sequence is 3-2-1. Figure 22-53 shows a lineman making a final check of phase sequence with a phase-sequence indicator before putting a load on the line.

In order to check the sequence indicated, interchange any two of the leads. This changes the order, and therefore the first lamp should become dark and the second lamp should become bright. This also serves as a check on the condition of the lamps. If one of the lamps should fail to glow during this test procedure, it should be replaced with a new neon lamp and the checking procedure repeated.

PHASING OUT

Phasing out is absolutely necessary when a new line is to be paralleled with another line, new or old, and after repairs or changes have been made on either of two lines which have previously operated in parallel. It is necessary in the latter case because of the possibility of interchanging conductors when making repairs or changes.

The process of "phasing out" consists of determining whether the phases of a given line or apparatus correspond with the phases of another line with which it is to operate in parallel. This problem arises most frequently at sectionalizing switches. The voltage across corresponding lines or phases should be zero. Therefore to determine if

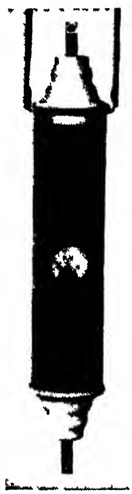


FIG. 22-54 Phasing-out voltmeter rated 5 kv. Illustration shows transparent plastic tube, two lead terminals, voltmeter, and carrying strap. (*Courtesy General Electric Co.*)

FIG. 22-55. High-voltage detector rated 7,500 volts Illustration shows two resistors, lamp housing, insulated leads, and leather carrying strap (*Courtesy S and C Electric Co*)

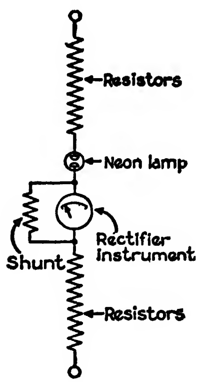


FIG. 22-56 Phasing-out voltmeter, with two series resistors, neon lamp, and voltmeter. A third resistor is shunted around the rectifier-type voltmeter to permit the lamp to glow in case of an open circuit in the rectifier instrument. (*Courtesy General Electric Co.*)

zero voltage exists across corresponding lines it is necessary to read the voltage. This is done with a "phasing-out" voltmeter.

Phasing-out Voltmeter. Two makes of "phasing-out" voltmeters are illustrated in Figs. 22-54 and 22-55. In each case the instrument consists of a high resistance connected in series with a voltage-indicating device. The one shown in Fig. 22-55 uses an indicating lamp to show the presence of voltage, and the one shown in Fig. 22-54 uses an indicating lamp and a miniature voltmeter to show the presence of voltage. Using both a lamp and a voltmeter serves as a check upon each other. The indicating lamps used are the glow-lamp type which can withstand considerable overvoltage. Schematic diagrams of the circuits and components used in these two makes of voltage detectors are shown in Figs. 22-56 and 22-57.

Phasing-out Procedure. Since the operation of high-voltage paralleling is usually done through an oil circuit breaker, the usual procedure in

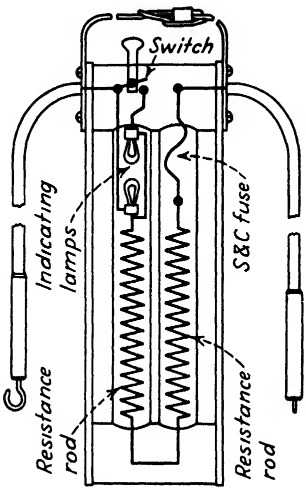


FIG. 22-57. Voltage detector, with two resistance rods, two indicating lamps, fuse, switch, and leads. (*Courtesy S. and C. Electric Co.*)

FIG. 22-58. Lineman using phasing-out voltmeter to take high-voltage readings on electric distribution lines of the Cleveland Illuminating Co. (*Courtesy General Electric Co.*)

"phasing out" is to open the disconnects on one side of the oil circuit breaker and then close the oil circuit breaker so that the corresponding blades and contact jaws of the open disconnects are alive from the two sources that are to be paralleled. The phasing-out voltmeter or voltage detector is then used to detect the presence of any difference of potential between a blade and the corresponding contact jaw of each disconnect. If the lamp or voltmeter gives no indication as the two leads are successively applied to each pair of the three disconnect terminals, then no potential exists between each jaw and blade. This then shows that the correct phases are connected to each of the two parts of the respective disconnects. If the lamp should glow when the leads are applied to two of the three phases, then these two phases are interchanged; if the lamps glow on all three phases, then all three phases are interchanged.

Figure 22-58 shows two linemen using a phasing-out voltmeter to check distribution circuits.

SECTION 23

Rural Lines

Rural Electrification. The bringing of electricity to the farm is called "rural electrification." This is accomplished by one of the following methods:

Method A. By extension of the lines of distribution systems from the cities and towns located within the farming territory to be electrified

Method B. By the use of a separate system of lines originating from a centrally located substation supplied by a high-voltage transmission line or from a centrally located power plant

If method A is used, lines would probably not extend out more than a limited distance from the cities where they originate and would likely operate at the same voltages as those used in the city distribution systems.

If method B is used, the lines would generally consist of several multiphase lines radiating in various directions from the substation. These multiphase feeders would extend through the heart of the load-center area. From each of these feeders, single-phase branches would extend laterally, that is, to both sides into the farming territory.

The branch lines would extend down each highway on which farms are located. Opposite each farmstead a step-down transformer would be connected which would reduce the line voltage to 120/240-volt three-wire service for use in the home and barns.

The two-wire single-phase branch line extending down the country road supplies a multitude of services:

It brings *light* to the farm in the form of the incandescent or fluorescent lamp.

It brings *power* to the farm in the form of the electric motor.

It brings *running water* to the farm home and barn in the form of the automatic water pump.

It brings modern *appliances* to the farm in the form of the electric range and dishwasher.

It brings *ice* to the farm in the form of the electric refrigerator.

It brings *entertainment*, *news*, and *market*, *crop*, and *weather service* in the form of the alternating-current-operated radio and television receiving set.

A typical electrified farmstead is shown in Fig. 23-1.

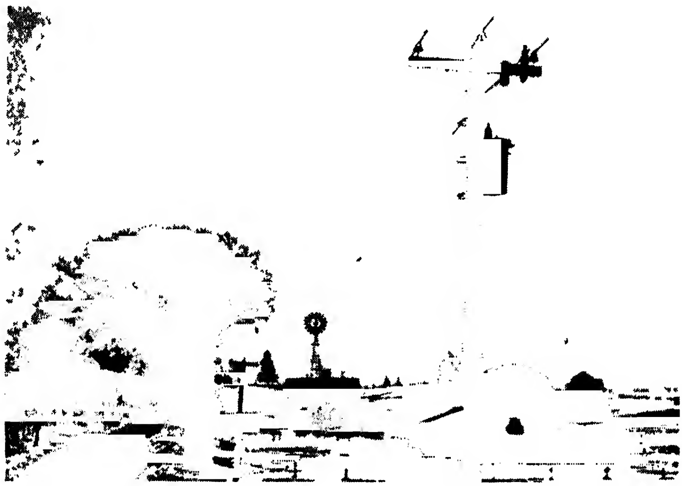


FIG. 23-1. A typical electrified farmstead, showing primary line, step-down transformer, arrester, fuse cutout, and three wire secondary mains. (*Courtesy Aluminum Company of America.*)

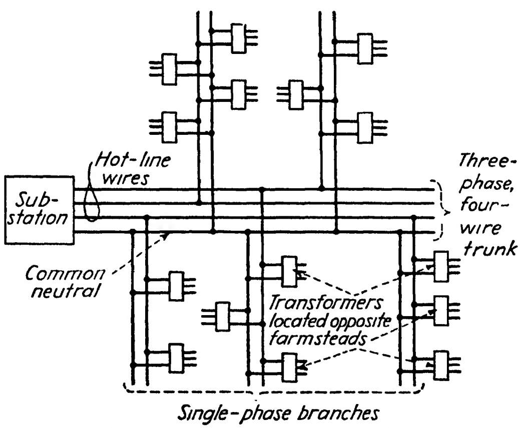


FIG. 23-2. Typical rural electrical system, showing substation, three-phase trunk, single-phase laterals, and step-down transformers.

Typical Rural System. A typical rural electric system would thus consist of one or more load-center areas with a substation for each load center. Three or four main multiphase feeder lines would radiate from each substation, and a large number of single-phase branch lines would extend in both directions from the multiphase trunks. Step-down transformers located near the farms step the voltage of these single-phase lines down to 120 and 240 volts for farm use. These component parts of the system can be represented as shown in Fig. 23-2. A more complete schematic diagram showing generating station, transmission line with

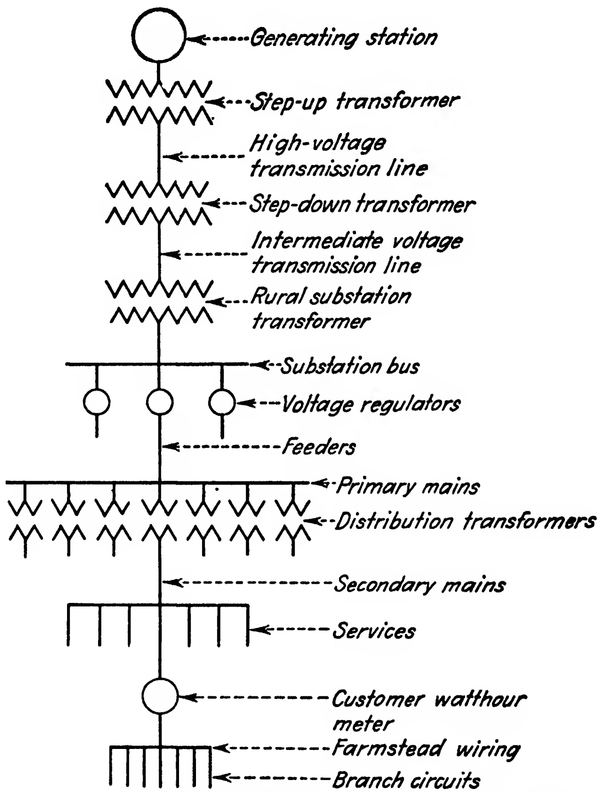


FIG. 23-3. Complete rural electrification, generation, transmission, and distribution system.

step-up and step-down transformers, substation, voltage regulators, primary multiphase mains, single-phase mains, distribution transformers, secondary mains, customers' service lines, watthour meters, and farm wiring is shown in Fig. 23-3. A typical load-center area showing feeders and branches is shown in Fig. 23-4. This load-center area covers approximately 300 sq miles (17 miles square), contains over 500 miles of line, and serves upward of 1,500 customers. The source of power shown here is a high-voltage transmission line. In case no transmission line is available, an electric generating plant would replace the substation.

Size of System. The area covered by a system would ordinarily include several townships, but could be large enough to embrace one or more counties.

A system embracing several load-center areas could cover less than

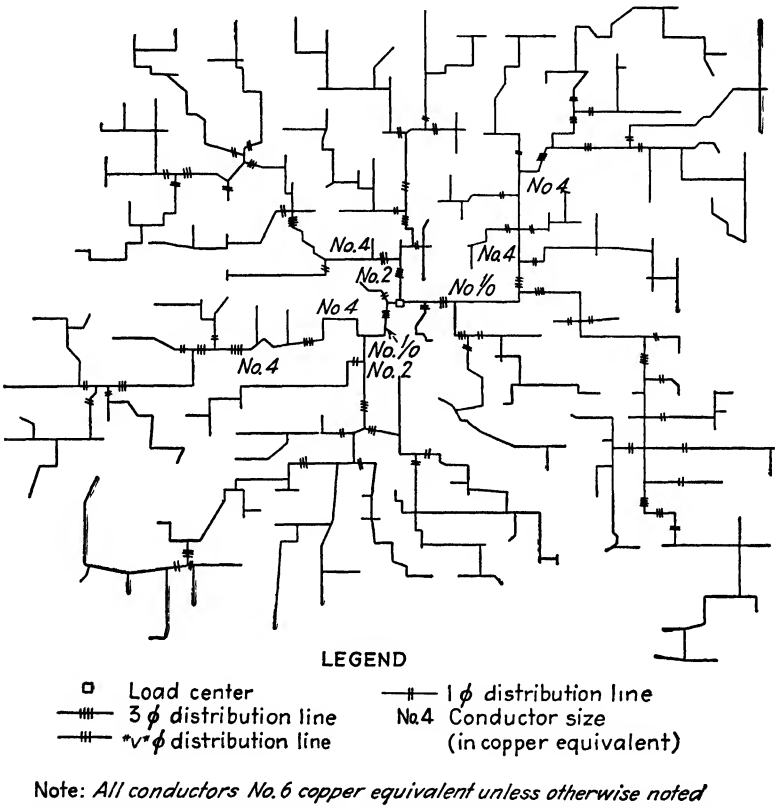


FIG. 23-4. Typical load-center area. Scale 1 in. = 4 miles. (*Courtesy of Electrical World, Dec.* 17, 1951.)

100 sq miles (10 miles square) or could cover as many as 2,500 sq miles (50 miles square).

The total number of farms served could number in the hundreds or thousands. Since there are about three farms per mile of line on an average, a system of 900 customers would consist of about 300 miles of line. A system having 6,000 customers would consist of about 2,000 miles of line. Few systems have less than 1,000 miles of line or less than 2,500 customers.

An average rural system would have one-eighth to one-sixth of its mileage in multiphase lines, and about five-sixths to seven-eighths of its mileage in single-phase lines.

Some of the multiphase feeders are often not complete three-phase four-wire feeders, but instead are V-phase feeders. V-phase feeders consist of two of the three-phase conductors and neutral. The third line conductor can be added as the load grows and additional line capacity is needed.

Size of Substation. The kva rating of the substation is determined by the number of connected farms and by the kw demand made by each

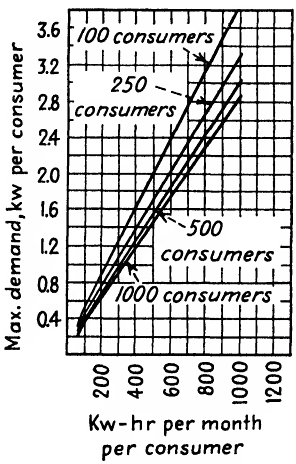


FIG. 23-5. Relation between monthly kwhr consumption per customer and kw demand per customer made on the substation at time of peak load. (*Courtesy of Electrical World, Dec.* 17, 1951.)

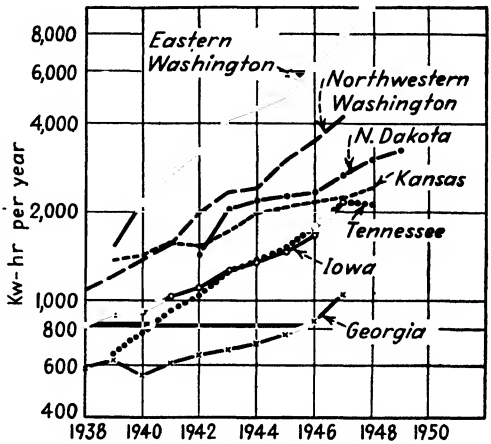


FIG. 23-6. Consumption of electricity per farm per year from 1938 to 1950 in various regions in the United States. (*Courtesy U.S. Department of Agriculture.*)

farm. The load demand made by each farm is taken as somewhere between 500 to 1,000 watts, or 0.5 to 1.0 kw. This allowance is the average amount of demand that each customer makes at the time the total load or demand on the system is greatest, that is, at the system peak.

This average demand made by each consumer as measured at the substation varies with the monthly kwhr consumption per consumer and with the number of consumers served by the substation. The graphs in Fig. 23-5 show this variation in demand with monthly consumption for 100, 250, 500, and 1,000 customers per load-center area.

An inspection of this chart shows monthly consumptions as high as 1,000 kwhr per month per customer. The average consumption at the present time is about 250 kwhr per month. This naturally varies with the type of farming, electric rate charged, age of system, etc. On a newly energized system, the consumption may average only 100 kwhr per month, whereas on an established system it may run as high as 300 kwhr. Figure 23-6 shows how the consumption of electricity per farm per year has increased over the years from 1938 to 1950 for certain typical farming areas in the United States.

The yearly figures based on the monthly consumption is easily calculated as follows:

50 kwhr per month corresponds to 600 kwhr per year
100 kwhr per month corresponds to 1,200 kwhr per year
250 kwhr per month corresponds to 3,000 kwhr per year
500 kwhr per month corresponds to 6,000 kwhr per year

To determine the total demand on the substation multiply the number of consumers within a load-center area by the individual demand in kilowatts. To illustrate, assume a load-center area having 1,000 customers and an individual demand of 0.8 kw per customer. This corresponds to an average monthly consumption per customer of about 250 kwhr. The total load on the substation would be $1,000 \times 0.8 = 800$ kw. To the total energy requirements of the customers connected to one substation, an additional 15 to 20 per cent must be added to cover transmission and distribution losses.

Rural substations usually range from 500 to 2,000 kva in size. The most common sizes are 1,000 and 1,500 kva.

Single-phase transformers are universally used as they can be connected into three-phase banks to form either the open-delta or the closed-delta connection. The cost of a spare also is less when single-phase transformers are employed.

Load Factor. The system load factor (which is the ratio of the average load to the maximum load) averages about 35 to 40 per cent for systems with several hundred customers or more.

Applying this load factor to the total load given above would make the average load equal to 35 per cent of 800, or 280 kw.

A load factor of 35 per cent shows that the load is not very constant. A farm load is high during mealtime or chore time when the electric range is on or when chores are being done, such as milking cows or pumping water, etc. In between times it may run low. For comparison, a large electric system supplying a city and associated industry may have a load factor as high as 55 per cent.

Selection of Type of Three-phase Feeder. Two distinct types of three-phase feeders are available for rural service, namely,

1. Three-wire delta-connected at substation.
2. Four-wire star-connected at substation. The fourth conductor in this system is known as a "common neutral" and originates at the neutral point of the star or Y connection of the transformer bank.

Each of these systems has advantages and disadvantages, but the star four-wire system appears to be distinctly superior for rural electric service and is therefore generally used.

Advantages of the Delta-connected System. 1. Only three wires are required in the three-phase trunk feeder.

2. The substation may be operated with only two single-phase transformers until the load has grown to a point requiring the third transformer. The transformer connection employing only two transformers is known as the "open-delta" connection and is described in Sec. 5. This same connection can be employed in case one single-phase transformer of the three-phase bank becomes defective. This, however, reduces the load which can be carried to 58 per cent of the full bank.

3. The voltage from any wire to ground is approximately zero; hence the line is not nearly so sensitive to ground faults such as trees swinging against the conductors, broken insulators, etc.

4. When feeder-voltage regulators are required, only two units are needed. Likewise only two potential and current transformers are needed for metering at the substation.

5. Because the voltage from any conductor to ground is normally zero, there is less hazard to linemen working on the line while it is hot.

Advantages of the Star-connected System (Four-wire). 1. If the same substation transformers are used as in the delta system, they would have their secondaries connected from line to neutral, thereby giving a line voltage which is $\sqrt{3}$ times as large as in the delta system. A higher line voltage is thus obtained with no increase in cost of the transformers.

2. Since this system employs a neutral which is multigrounded, the cost of the farm transformer is less because only one transformer bushing is required on each transformer. In the delta system, both high-voltage terminals must be insulated. For the same reason, only one line insulator, one lightning arrester, and one cutout are required. Such a transformer installation with only one high-voltage bushing, one arrester, and one cutout is shown in Fig. 23-7. These savings more than offset the cost of the fourth wire in the three-phase portion of the system.

3. Fewer leads and connections are required on the pole when only one arrester, one cutout, and one bushing per transformer are required.

4. The system is safer generally, since there is a definite phase voltage between each line and ground (see Fig. 23-8). When a line conductor falls to ground, a short circuit results which will cause the fuse or circuit breaker to open and disconnect the defective conductor from the supply source. In the delta system the fallen line conductor would remain live and a hazard until removed from the ground.

5. Since the star-connected feeder operates at $\sqrt{3}$ times the voltage of the delta-connected feeder, its voltage regulation will be only one-

third as great, which naturally results in more satisfactory service. This is further explained below.

6. When the neutral conductor on the single-phase primary and the neutral on the secondary are connected together, the large number of grounds brings the resistance of the neutral wire entering the customer's

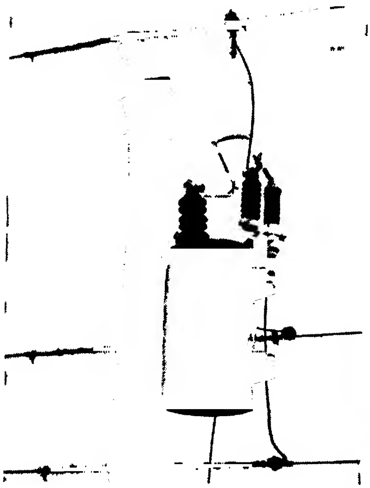


FIG 23-7 Rural-line 7,200-volt single-phase transformer showing high-voltage bushing, lightning arrester, and flip-open fuse cutout. Note brackets for mounting transformer directly on pole. (*Courtesy General Electric Co*)

FIG 23-8 Corner pole view of single-phase primary line showing live phase wire supported by means of strain insulator string and grounded neutral supported by metal clamp. (*Courtesy Ohio Brass Co*)

premises to such a low value (below 3 ohms and sometimes less than 1 ohm) that the voltage from the neutral to ground is held to a nominal value.

7. By using the same neutral on both primary and secondary circuits, no additional neutral is required when a secondary circuit is constructed under the primary line. Figure 23-9 shows by diagrammatic sketch a primary line made up of a phase wire and neutral and a secondary line built under the primary. Note that the grounded neutral conductor is common to both circuits. This results in a saving in cost of one conductor, pole height, etc.

Table 23-1 gives a summary comparing some of the facts pertaining to the merits of the delta system and of the Y system employing the common neutral. A line-to-neutral voltage of 7,200 volts is assumed.

Voltage Selection. The selection of voltage for a rural electric system depends (1) upon the size of the area to be served and (2) upon the load to be delivered. The greater both of these factors are, the higher the voltage required to give satisfactory service.

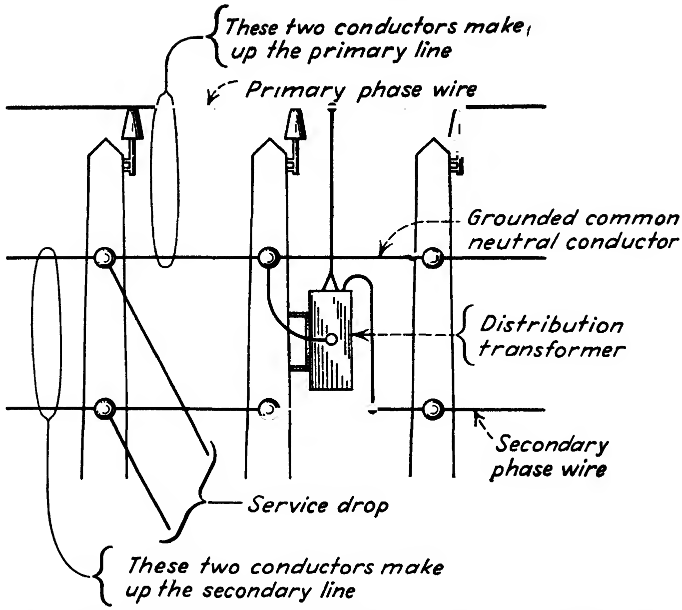


FIG. 23-9. Use of common grounded-neutral conductor for both primary and secondary circuits.

The four voltages in most common use for rural electric service are as follows:

4,150 volts from line to line, with 2,400 volts from line to neutral
8,300 volts from line to line, with 4,800 volts from line to neutral
12,450 volts from line to line, with 7,200 volts from line to neutral
24,900 volts from line to line, with 14,400 volts from line to neutral

The line-to-line voltages given above are the voltages used on the multiphase trunk feeders, while the line-to-neutral voltages are the voltages used on the single-phase lines.

As will be noted, the line-to-neutral voltages of 2,400, 4,800, 7,200, and 14,400 volts are standard voltages and are the voltages at which the transformers, arresters, and insulators have to operate. Equipment for these voltages is carried in stock by manufacturers and is therefore readily available.

The above voltages are in the order of one, two, three, and six. It will be shown in Table 23-2 that doubling the voltage increases the power delivery capacity four times and trebling the voltage increases it nine times. Or stated in another way, the 4,800-volt line will carry the same power four times as far as the 2,400-volt line, and the 7,200-volt line will carry the same power nine times as far as the 2,400-volt line.

TABLE 23-1. FEATURES OF DELTA-CONNECTED SYSTEM AND OF Y-CONNECTED SYSTEM EMPLOYING A COMMON NEUTRAL

Feature	Delta-connected system	Y-connected system employing common neutral
Line voltage (line to line)	7,200 volts	12,450 volts
Phase voltage (line to neutral)	None	7,200 volts
Single-phase distribution transformer connection	Line to line	Line to neutral
Single-phase branch-line connection	Line to line	Line to neutral
Transformer protection consists of	Two lightning arresters, one in each line, connected to transformer tank and ground; two fuses, one in each line; secondary windings are isolated from primaries and have separate grounds	One lightning arrester in line wire; arrester connected to transformer tank, secondary neutral point, and ground; secondary neutral interconnected to primary ground

TABLE 23-2. RELATIVE CAPACITY OF THE FOUR COMMONLY USED RURAL LINE VOLTAGES

Based on the use of No. 4 copper conductors spaced 3 ft apart with 4 per cent voltage regulation, 90 per cent power factor, and a transmission distance of 10 miles.

Type of line	Power delivered, kw	Relative power carrying capacity, per cent
Three phase:		
4,150 volts, Y connected, 4 wire......	39.9	100
8,300 volts, Y connected, 4 wire......	160.0	400
12,450 volts, Y connected, 4 wire......	360.0	900
24,900 volts, Y connected, 4 wire......	1,440.0	3,600

Effect of Voltage on Per Cent Voltage Regulation. The per cent voltage regulation of the above four voltages for a given power transmitted will be in the order of one, one-fourth, one-ninth, and one thirty-sixth. This can be easily shown as follows: When the voltage is doubled and the power remains the same, the current is halved. Half the current flowing through the same line will cause half the former line drop. The per cent line drop now becomes the ratio of half the drop to twice the voltage. That ratio therefore will be only one-fourth as large. Likewise, trebling the voltage cuts the current to one-third and the line drop to one-third. But since we must now take the ratio of one-third the drop to three times the voltage, we find the per cent voltage drop only one-ninth as great. These conclusions can be summarized by saying that for the same power transmitted the voltage regulation varies inversely as the square of the voltage.

The above reasons are summarized in Table 23-2 where the amounts of power that can be transmitted at these voltages over a 10-mile line are compared. It will be noted that the 8,300-volt line can deliver four times as much power as the 4,150-volt line, and the 12,450-volt line can deliver nine times as much power as the 4,150-volt line. Four is the square of two, and nine is the square of three.

Since good voltage regulation is always desired, the higher voltage will be preferred. Transformer, insulator, arrester, and pole costs, however, also increase with voltage. A compromise is therefore usually made by selecting an intermediate voltage.

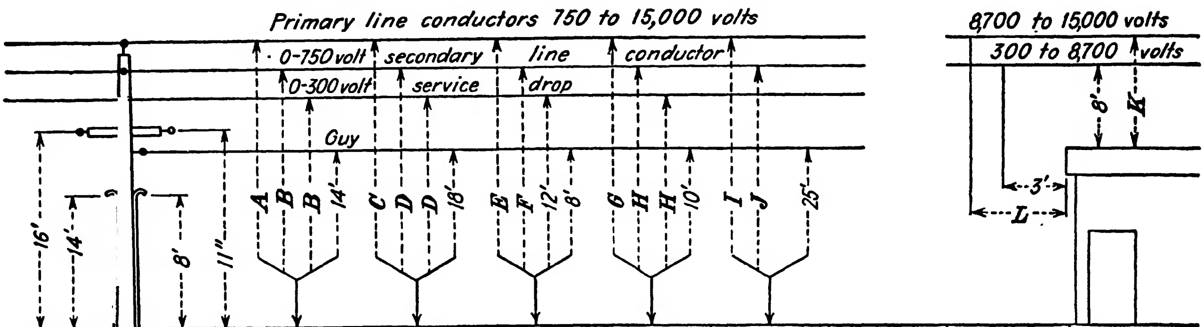
Line Supports. Wood poles are in common use on rural lines. In general, 30- and 35-ft poles are the minimum sizes used, with higher poles being installed where greater clearances must be maintained as over roads, railroad crossings, etc. In most cases the poles are treated in order to increase their life.

Conductors. The four types of conductors in use on rural lines are

1. Copper
2. Aluminum cable steel reinforced (ACSR)
3. Copperweld or copperweld copper
4. Steel

The type of conductor to be employed is largely determined by the load density, that is, the number of customers per mile. If the number of farms per mile is high, say six to ten, then a better grade of line can be justified. The spans can be shorter, and the conductor should be of low resistance. In this case spans of about 250 ft with copper as the conductor might be employed. If the density were three or four per mile, the spans would run between 300 and 500 ft and copperweld copper or ACSR conductors would likely be employed. These two conductors are stronger mechanically and can support themselves better in the longer spans. If the farm density should be much less than three farms per mile, spans of 500 to 700 ft might be employed and the copperweld or steel conductor used to provide the required mechanical strength for the long spans.

Conductor Sizes. *Three-phase Trunks.* Conductors radiating from the substation vary in size from No. 4 to No. 0 copper equivalent, the No. 4 and No. 2 being the most common.



Open wire on pole adjacent to vehicular traffic / Open wire on pole not adjacent to vehicular traffic	Along roads in rural districts		Across roads in rural districts, streets, alleys		Spaces or ways accessible to pedestrians only		Across driveways to resident garages		Across railroads handling boxcars			Buildings	
Basic span length	A	B	C	D	E	F	G	H	I	J		K	L
150												8'-0"	8'-0"
175	18'-0	15'-0"	20'-0"	18'-0"	15'-0"	15'-0"	20'-0"	10'-0"	28'-0"	27'-0"			

For heavy loading district except for 3-strand conductors each wire of which is 0.09 inches or less in diameter

Clearances in table are increased for spans above the basic span length

FIG. 23.10. Minimum basic clearances as recommended in the NESC Rule 232A.

Single-phase Branches. Single-phase branch lines are usually size No. 6 copper equivalent.

Clearances over Ground and Rails. The clearances of the conductors to ground, along roads, across roads, over ways accessible to pedestrians only, across driveways, across railroads, and along and over buildings are summarized in Fig. 23-10. The clearances shown are the minimum recommended by the National Electrical Safety Code in Rule 232A.

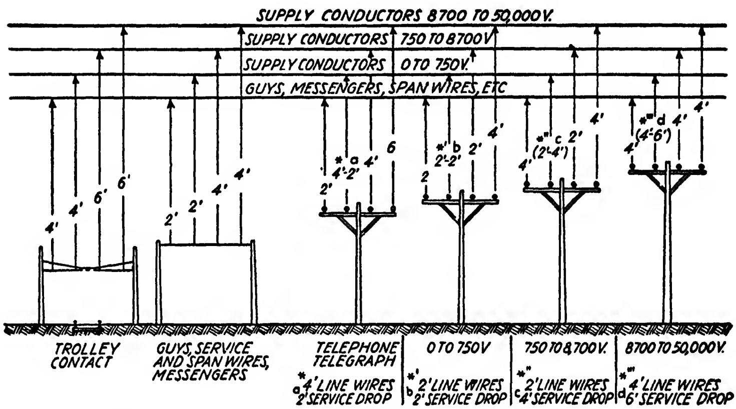


FIG. 23-11. Minimum wire crossing clearances as recommended in the NESC Rule 233A.

The figure shows clearances for the primary line conductors with voltages from 750 to 15,000 volts, the secondary line conductors with voltages from 0 to 750 volts, and the service drops with voltages ranging from 0 to 300 volts.

The clearances are those which should obtain at 60°F, with no wind.

Wire-crossing Clearances. Figure 23-11 shows the recommended minimum clearances between rural lines and other lines such as trolley contact, guys, service and span wires, telephone and telegraph, and electric power lines having voltages from 0 to 750, 750 to 8,700, and 8,700 to 50,000 volts. These clearances are to exist at 60°F and no wind. For further details see NESC Rule 233A.

Line Protection. The two main causes of service interruption on rural lines are (1) short circuits and (2) flashover.

Short circuits may result from line conductors swaying together during high wind, branches falling into the line causing conductors to come in contact or to break and fall to the ground. Trees coming in contact with the live phase wires may cause a ground and thus short the line. Line conductors swaying together can be kept at a minimum by designing the line with adequate separation between line conductors and with the proper sag. Maintaining liberal clearances to trees to prevent grounding the line conductor is also a good safeguard.

Flashovers are caused by electrical storms. Since a rural electric system covers a large area, it is exposed to much lightning which causes voltage surges. These surges may cause insulator flashover with a resultant excessive flow of power current which must be interrupted by the action of some circuit-opening device.

FIG. 23-12 Enclosed type of fuse cutout connected in transformer primary line being opened by lineman with hot-line tool. (*Courtesy James R. Kearney Corp.*)

FIG. 23-13 Open type of link cutout fuse mounted on special support on rural transformer. Illustration also shows close-up view of high-voltage terminal bushing and lightning arrester. (*Courtesy General Electric Co.*)

The two classes of equipment used to protect lines against these two forms of line disturbances are circuit-opening devices and lightning arresters. These are discussed below.

Circuit-opening Devices. The four types of circuit-opening devices used on rural lines are

1. Fuse cutouts
   a. Single
   b. Repeater
2. Oil circuit recloser
3. Sectionalizer
4. Circuit breaker

Fuse Cutouts, Single Fuse. Fuse cutouts may be either the enclosed type, illustrated in Fig. 23-12, or the open type, illustrated in Fig. 23-13.

In both types the fuse proper is enclosed in a tube which controls the fuse blowing. Both the closed and open types of cutouts may be either indicating or nonindicating. In the indicating type of enclosed cutout, the door falls open when the fuse is blown. In the indicating open type, the fuse tube is moved out of the circuit when the fuse melts. The indicating types are preferred for rural lines because the maintenance man can locate blown fuses or system trouble more readily.

FIG. 23-14. Installation of several repeater fuses on a rural line. (*Courtesy James R. Kearney Corp.*)

Repeater Fuse. The repeater fuse (see Sec. 7) is a set of two or three fuses so arranged mechanically that when one fuse blows the second fuse is automatically connected into the circuit. If the fault (short circuit or overload) is still on the line, the second fuse blows, and the third fuse is cut into the line in the same manner. In the majority of cases the second fuse will hold, thereby avoiding a power interruption. Furthermore, it becomes unnecessary for a maintenance man to make a trip into the country immediately to locate and replace a fuse in order to restore service. Of course, in case the fault remains on the line for all three fuse operations, immediate manual attention will be required. A good many faults, however, are temporary or burn themselves clear, thus clearing the line.

Since rural-line fuses are slow-burning, they are quite suitable for the protection of the main three-phase feeder (see Fig. 23-14). On rural lines approximately 90 per cent of the faults are transitory, that is, of very short duration. Therefore the fault often clears before the fuse in the main feeder has time to burn or blow. Hence the power supply is not interrupted. Fuses are therefore often installed on the main feeder and are so graded that the lowest ratings are near the end of the feeder and the highest ratings near the substation. Thus, a typical feeder might employ four sets of repeater fuses, rated 15, 25, 35, and 50 amp, located progressively toward the substation.

It is essential that all repeater-fuse installations be inspected after each severe storm in order that any blown fuses may be replaced. In

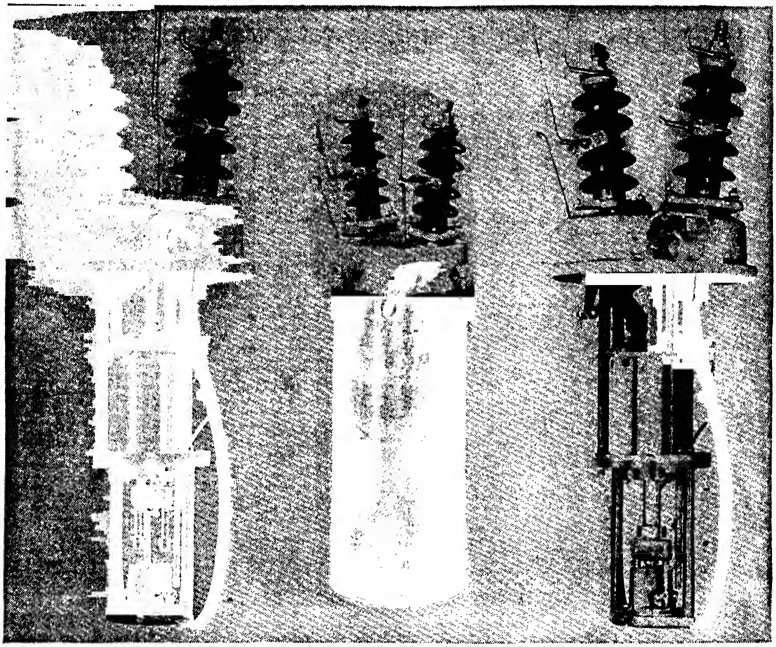


FIG. 23-15. External and internal views of a typical oil-circuit recloser. The left figure shows the breaker open; the right figure shows it closed. (*Courtesy Line Material Co.*)

this respect, the repeater fuse is at a disadvantage over the recloser, described below, as it is capable of resetting itself.

Oil Circuit Recloser. The oil circuit recloser is essentially an oil circuit breaker (see Figs. 23-15 and 23-16). It opens the circuit when an overload or short circuit comes onto the line. This is accomplished by the use of a series-solenoid tripping coil. The recloser, however, does not remain open but closes within a second or two. If the fault is still on the line, it will reopen. After another second, it recloses again. If the fault remains on the line after three or four operations, the recloser locks out until it is manually reclosed. The reclosers are usually equipped with counters to indicate the number of operations.

Since the tripping of the recloser depends on magnetic action, it can act instantly. This is in contrast with a fuse, in which the action is thermal and where some time must elapse to melt the metal. By the use of a special timing control, the instantaneous action can be changed to delayed action. In fact a typical recloser can be arranged so that it will open instantly the first and second time and slowly the third and

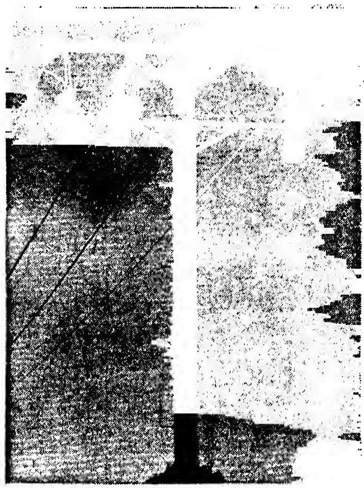


FIG. 23-16. Three oil circuit reclosers installed in a four-wire three-phase feeder. Note fourth or neutral wire is not dead-ended. Also note lightning-arrester installation and pole steps. (*Courtesy Line Material Co.*)

fourth time. This enables the recloser to clear temporary faults without allowing other slower acting protective devices in the same line, such as fuses, to blow; at the same time a permanent fault will not

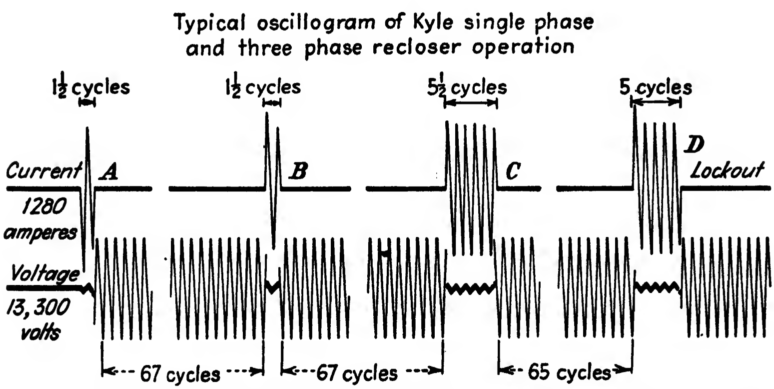


FIG. 23-17. Oscillogram showing four operations of a typical recloser. After fourth operation, recloser locks open. (*Courtesy Line Material Co.*)

become cleared during the first and second operation, but will remain on the line to blow the fuse during the slower third or fourth openings.

An oscillogram showing the four opening and closing cycles of a typical recloser is shown in Fig. 23-17. In the first two actions, *A* and

B, the short-circuit current is cleared in 1½ cycles, but in actions *C* and *D* the short circuit remains on the line for 5½ cycles. It is during these latter longer periods that other protective devices, such as fuses, in the same circuit would blow. Such procedure would thus restrict the permanent fault to the district beyond the fuse and maintain service on the remainder of the system. But if the fault is not cleared in this manner, the recloser would open the fourth time and lock itself out. It

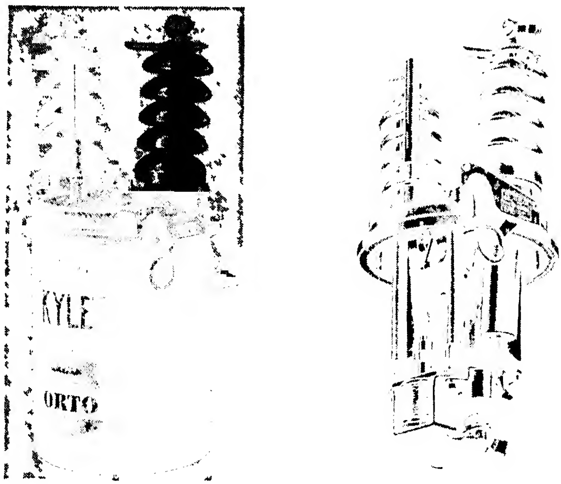


FIG. 23-18. Single-phase sectionalizer, rated 14.4 kv, designed for rural electric service; external and internal views. (*Courtesy Line Material Co.*)

would then have to be reset manually by operating the switch on the side of the case after the faulty condition is removed.

Reclosers are usually used on the single-phase branch lines or laterals. If trouble develops on the branch line, it will be disconnected before the fuses in the feeder have time to act. This makes possible removing the faulty line without interrupting the main three-phase supply. This satisfies the requirement that the circuit-opening device farthest from the substation should operate first for any faulty condition beyond it.

In some instances, fuses are used on short branches from the single-phase lines which will coordinate with the oil circuit recloser located at the point of tap on the three-phase line. In case the fault occurs on the small branch, the oil circuit recloser will operate once or twice on a high-speed cycle, in an attempt to clear the fault. If the fault still persists, it will operate on a slow-speed cycle during the third and fourth operation, forcing the fuse to blow, yet resetting itself and restoring the service on the remainder of the single-phase line.

Sectionalizer. A sectionalizer is a protective device used to sectionalize a branch line at the time of fault if the branch line is protected with a recloser. The sectionalizer is not a current-interrupting device, and therefore the sectionalizer must operate during the periods that the back-up recloser has left the line open as it goes through its cycle of operation. A typical sectionalizer is shown in Fig. 23-18. The sectionalizer is preset to lock out after the first, second, or third operation of the recloser.

In Fig. 23-19, *A* is a recloser protecting the branch line in which *B* and *C* are sectionalizers. A fault occurring beyond *C* should be isolated by sectionalizer *C*, and a fault between *B* and *C* should be isolated by action

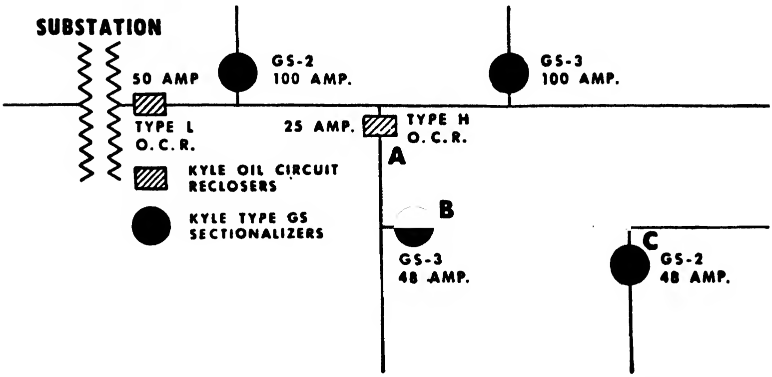


FIG. 23-19. Simple rural electric system showing a branch line protected by recloser *A* and sectionalizers *B* and *C*. *C* is set to open on the second operation of *A*, and *B* is set to open on the third operation of *A*. (*Courtesy Line Material Co.*)

of sectionalizer *B*. This is accomplished by setting *C* to open during the second operation of the recloser and setting *B* to open during the third operation of the recloser. Following the opening of the sectionalizer contacts, the recloser reenergizes the line and restores service to the remainder of the branch line.

Circuit Breaker. Circuit breakers are often used at substations to switch the transformers in or out of the circuits and are also often used to sectionalize lines. Sometimes they are used at junction points of important lines.

A circuit breaker acts like a fuse, that is, whenever the current exceeds certain predetermined values, either because of a fault on the lines or because of overload conditions, it automatically opens the circuit. After tripping open it may have to be closed manually, or it may be arranged to reclose automatically after a short delay. It may repeat this cycle a definite number of times, if the fault or overload is not cleared. After the specified number of cycles, the breaker locks itself in the open position, that is, with the circuit open. Circuit-breaker contacts may operate in oil or in air. If they open in oil they are called oil circuit breakers and if in air they are called air circuit breakers.

A typical pole-top oil circuit breaker was shown in Fig. 7-8.

Lightning Arresters. Lightning arresters serve to protect the transformer with which they are associated as well as the insulators on the line. The various types are described in Sec. 6. One item of note which has already been mentioned is that only one arrester is required on the single-phase lines of a solidly grounded neutral system. This reduces considerably the amount of protective equipment required on a

FIG. 23-20. Link type of fuse cutout used on a rural line. (*Courtesy James R. Kearney Corp.*)

FIG 23-21. Lineman attaching hot-line clamp to live primary conductor with hot-line tool. Note fuse cutout is in open position Also note direct pole mounting of transformer with through bolts. (*Courtesy James R Kearney Corp*)

pole top and makes available more climbing space for the lineman. A typical installation was shown in Fig. 23-7.

In some cases the arrester consists of a double spark gap connected between the top of the primary bushing and the transformer case. This still further lessens the cost but has the disadvantage that the follow-up power current is not broken by the arrester itself. A line fuse, recloser, or circuit breaker must therefore act to break this current. Unless this portion of the system is protected by an oil circuit recloser, and not by a fuse which must be replaced, a regular lightning arrester should be used.

Transformer Protection. The step-down transformers are generally protected by some type of fuse arranged so that it can also be used as a disconnect switch or "cutout." The cutout is lifted out in case the fuse needs to be replaced or in case it is necessary to disconnect the transformer from the hot line. Two types of cutout-fuse installations are shown in Figs. 23-20 and 23-21.

The CSP Rural Transformer. The CSP rural distribution transformer is a "completely self-protected" transformer requiring no auxiliary protective equipment, such as cutouts and lightning arresters. Instead these are incorporated and included with the transformer itself and, therefore, do not have to be mounted separately see Fig. 23-22.

FIG 23-22 CSP rural transformer mounted direct to pole Illustration also shows primary lead, three-wire secondary connections, and ground lead. (*Courtesy General Electric Co*)

FIG 23-23. CSP rural transformer equipped with special hanger iron for crossarm mounting. (*Courtesy General Electric Co*)

Such transformers are provided with brackets for direct to pole mounting, but when equipped with hanger irons they can also be hung from crossarms (Fig. 23-23).

A CSP rural transformer designed for operation on a four-wire three-phase solidly grounded neutral system has the following features incorporated within itself (see Fig. 23-24):

1. A primary voltage lightning arrester supported externally on the tank and grounded to the tank.
2. High-voltage primary fuse located internally in series with the high-voltage line lead. This serves to disconnect the transformer in case of internal fault in the transformer itself.
3. Overcurrent protection in the secondary leads provided by a low-voltage circuit breaker mounted above the transformer core and coils but below the oil level. This breaker protects the transformer against overload and short circuits.
4. Overload signal lamp which becomes lighted when maximum safe operating load on the transformer is exceeded.
5. An external operating handle for opening or closing the secondary breaker or to reset the signal lamp and breaker-tripping mechanism.

6. Provision for tap changing, either by changing the connection to studs or by means of a tap-changing switch.
7. Permanent connection of secondary neutral lead to internal tank wall.
8. External tank grounding stud.

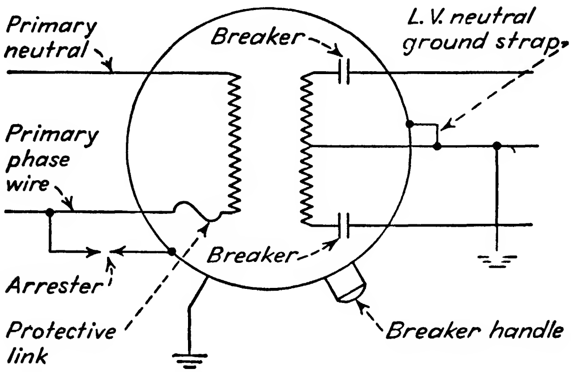


FIG. 23-24. Connections of a typical CSP distribution transformer designed for operation on a grounded-neutral rural line. Note single protective link, single high-voltage lightning arrester, secondary circuit breaker, secondary neutral ground to tank, and tank ground. (*Courtesy Maloney Electric Co.*)

To install a transformer of this type it is only necessary to bolt it to the pole, connect the high-voltage terminal to the primary phase wire, connect the low-voltage terminals to the secondary mains, and connect the tank grounding stud to the ground rod.

Voltage Regulators. As mentioned before, one of the important problems in the operation of a rural electric system is that of maintaining a relatively flat line-voltage curve. The problem is made difficult because of the great length of lines in miles operating at relatively low voltage.

Voltage regulators installed at the substation can be expected to hold the 12,450-volt bus at constant voltage. All the voltage drop therefore will be in the main feeder line, the single-phase branch line, the distribution transformer, and the secondary mains and service. By proper adjustment of the taps on the distribution transformers along the line, all customers can be assured of nearly normal rated voltage. In general, the variation in voltage at the customer's meter should not vary more than 10 per cent, that is, a variation of 5 per cent above and 5 per cent below the nominal system voltage. The total of 10 per cent may be due to 5 per cent voltage drop in the primary line, a 3 per cent voltage drop in the step-down transformer, and a 2 per cent voltage drop in the secondary lines and services running from the transformer to the customer's meter.

When the regulation exceeds the percentage values given above, use is made of one of the following types of regulators:

1. Induction type, described in Sec. 5.

2. Step type. These are made with two to four steps and are less costly than an induction regulator both in first cost and maintenance. The capacity or kva rating of a regulator as a rule need be only 5 to 10

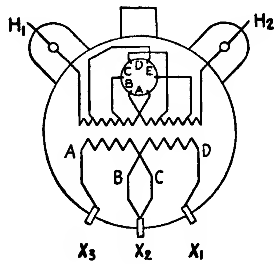


FIG. 23-25. Tap-changing equipment on rural line transformer. The wiring diagram shows the manner of changing number of turns in primary coil. (*Courtesy Line Material Co.*)

per cent of the load carried by the line. Step regulators are generally designed to provide a 10 per cent buck or boost and thereby provide the desired voltage on the substation bus.

3. Tap changers on transformers. These are built as an integral part of the step-down transformer and usually provide for four 2½ per cent

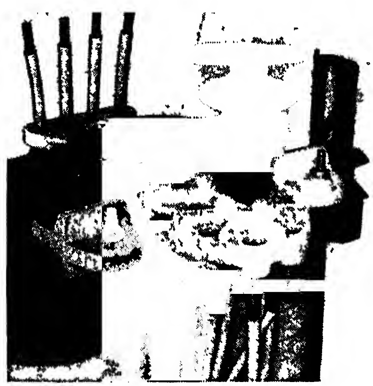


FIG. 23-26. Ratio adjuster on a rural transformer. (*Courtesy Line Material Co.*)

taps below normal in the high-voltage winding. Views of a typical transformer equipped with tap changer are shown in Figs. 23-25 and 23-26. The desired tap is selected by turning the operating knob.

The tap leads may be carried to a so-called "ratio adjuster," which has a handle extending through the top of the tank. When this is done, the taps can be changed while the transformer is in service. If a ratio adjuster is not provided, the tap leads are taken to a connection block inside the tank. In this case the connection can be changed only when the transformer is taken out of service and deenergized.

SECTION 24

REA Manual of Operation and Maintenance Practices of Rural Lines*

Duties of Manager. Upon completion of construction of a rural electric cooperative line, the project passes into the third and final stage; that is, it becomes an operating entity. The operation of the property will be handled by a manager, and his duties consist primarily of seeing that the project is operated safely and economically and that continuous service is provided on the lines.

He shall immediately make himself thoroughly familiar with the line and the location of all sectionalizing devices.

He shall give prompt and immediate attention to the restoration of service in case of interruptions. This means that he should be available 24 hr in the day.

He is responsible for the addition of new customers to the existing lines and for increasing the load on the system.

He shall continually watch and inspect his property in order to correct any faults that may develop, before they cause interruptions to service.

He is responsible for all work done on the lines, for tools and their condition, and shall regularly inspect all tools used, to be certain that they are in proper condition.

He shall give instruction in first aid and shall see that each employee receives and practices the Schaefer prone-pressure method of resuscitation.

He shall, further, assure himself that each employee has read and understands the cooperative safety rules.

He shall work under the direction of the board of directors, shall not make any obligation for the expenditure of funds without proper authority from the board, and shall see that all Federal, state, county and municipal regulations are observed.

He shall assure himself that each of his employees is fit and competent to do the work required of him.

Operation and Maintenance Practices. Operating and maintenance methods will probably vary in different localities, but there are many general practices which it would be advisable for the cooperative to

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follow until more definite information has been received relative to the needs of the project. Such suggestions as are made here should be amended to conform with the demands of a particular system.

Meter Reading. It should be the duty of the manager or his assistant to read and record each individual meter on the system once each month. A standard form should be used to record the readings to aid the clerk in billing.

Inspections and Operations. When the project is first in operation, the manager should immediately set up a schedule of inspection that is to be followed. As time goes on, the manager will be in a position through experience to make any necessary amendments to this schedule.

These inspections should cover patrolling of the lines for visible defects such as defective poles, broken insulators, excessive wire sag, or any other conditions that may cause future failure. Detailed inspections should also be made at regular intervals as to the operating efficiency of switches and circuit breakers, transformers, etc.

Replacements and Repairs. Replacements and repairs should be made when necessary in accordance with construction standards and safe practices. Methods of replacing poles, insulators, conductors, transformers, and other operating equipment should, of course, be determined after an analysis has been made of the danger involved, labor available, and work necessary to do the job.

Voltage and Overload Study. Frequent tests will need to be made when the project is first energized to ascertain if proper voltage is being received by the customers. This voltage should be within a range of 5 per cent above or below 120 volts delivered at the customer's meter. It may be necessary, as a result of this study, to make tap changes on the supply transformers or install regulators and buck or boost transformers. It will probably also be necessary, after the project develops, to make load tests on supply transformers and distribution transformers which appear to be overloaded.

Restoration of Service. Prompt restoration of interrupted service is obviously one of the most important functions of the manager. Service should be restored in the quickest and most economical way possible, consistent with safety.

The cooperative employees should be available at all times, and arrangements should be made to obtain assistance for emergencies or storm trouble.

The cooperative should establish telephone headquarters, make arrangements to have calls received at all times, and notify the consumers of such arrangements. Frequent calls at regular intervals should be made to his headquarters by the manager when out on a complaint call.

A list of customers requiring special service in the interest of community health and safety, such as hospitals, water and fire companies, telephone companies, radio stations, doctors, etc., should be maintained by the manager. These customers should receive first consideration when an extensive wholesale outage occurs.

The cooperative should be equipped with a service truck, usually a one-half ton pick-up, outfitted with proper and sufficient tools and material to locate and repair minor trouble both on the line and on the consumer's premises. Such trucks cannot be paid for from construction funds. Before purchasing any truck, the matter should be taken up with REA, since suggestions can often be made that will be beneficial in the purchase.

In order to eliminate as many unnecessary calls as possible, the consumers should be given some instruction in replacing fuses on the consumer's side of the meter.

Much time can be saved if the manager ascertains by telephone the extent of outage before proceeding to a particular location. Permanent repairs should be made, where possible, when the trouble is located, or temporary service should be arranged to accommodate the customer until permanent repairs can be made. Any repairs on consumer's appliances or equipment that can be made quickly, provided the manager is not pressed for time, should be completed by him.

Safety rules and practices should be observed by the manager at all times in locating and repairing trouble.

Tree Trimming. Trees that are permitted to grow up into overhead lines cause many outages to the system. It is necessary, therefore, to maintain a constant vigil to prevent this and adhere to a definite program of inspection and tree trimming.

The trees not only cause grounds on the system in their contacts with conductors but also cause wires to burn down, and broken limbs or trees may cause one or several poles to break during a storm.

After an inspection of the system is made, the trees selected should be trimmed, either by the manager or his assistants, or a contractor, in accordance with methods generally accepted and approved by tree surgeons as having the least damaging effect on the life of the trees. Existing laws or ordinances should, of course, be complied with in these operations.

All branches should be cut off flush at the junction with another limb, and dead wood which would strike live conductors, if broken off, should be removed. All cuts of one inch or more in diameter should be treated with an approved tree paint.

When the necessary trimming to obtain wire clearance spoils the shape of the tree, additional trimming should be done to give the tree a satisfactory shape and appearance. The property owner's permission should be obtained for all tree trimming.

Safety Practices and Methods. It is important that the manager and his assistants observe those recognized safety practices and methods in the construction, operation, and maintenance of the system as will give the utmost protection to persons and property.

The manager and all others working on the line should obtain, read, and apply the safety rules published by the Bureau of Standards of the Department of Commerce and their handbooks.

"Manual of First Aid Instructions" prepared by the Bureau of Mines

No. 6, "Safety Rules for the Installation and Maintenance of Electrical Supply Stations"

No. 7, "Safety Rules for the Installation and Maintenance of Electric Utilization Equipment"

No. 8, "Safety Rules for the Operation of Electrical Equipment and Lines"

No. 9, "Safety Rules for Radio Installations"

No. 10, "Safety Rules for the Installation and Maintenance of Electrical Supply and Communication Lines"

These handbooks may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D.C.

Consumers should be advised of the proper method in handling electrical apparatus located on the consumer's premises and the desirability of calling on the cooperative when they are in doubt as to the proper procedure.

Work on Consumer's Premises. The work done by the cooperative on the consumer's premises may be divided into three classes:

1. Restoring service
2. Service for which there is a charge
3. Gratuitous service

On most electrical distribution systems, approximately 90 per cent of the outages occur on the consumer's side of the meter, usually caused by faulty wiring appliances or equipment. On a rural distribution system, it would appear practical to advise the consumers on the proper method of replacing fuses as this will eliminate many service calls.

It also may be advisable for the cooperative employees, when restoring service on a consumer's premises, to make such minor repairs as will put appliances or equipment back into immediate service.

If repairs necessitate labor involving half an hour or more, an established charge should be quoted and the consumer given the privilege of ordering the work done by the cooperative or some outside firm.

Right of Ways and Permits. Right of ways, easements, and permits which may be necessary for the construction, operation, and maintenance of the line should be obtained by the cooperative with the assistance of the attorney.

All laws, ordinances, and requirements of the state and local governing bodies, utilities, and railroad companies should be complied with in obtaining these documents. When obtained, these documents should be filed in a permanent file.

New Business. The manager is responsible for increasing the energy sales of the system and, therefore, should solicit new business by signing up customers located adjacent to existing lines and groups of customers where line extensions may be necessary. This work, of course, should be done in accordance with rules and regulations approved by the board of directors.

Accidents and Claims. The manager should make a complete report of all accidents and claims on standard forms and forward a copy to the attorney. The attorney should be held responsible for the proper disposition of all claims for and against the cooperative. The manager at the direction of the attorney may be able to settle many of the minor cases.

Maps and Records. Proper maps and records should be made, maintained, and kept by the cooperative.

Such records include complete detailed maps of the system, meter records, transformer records, pole cards, tool and equipment records, cost records, budgets, accident and claim reports, right of ways, easements and permits, meter readings, trouble reports, and all other data which may be necessary for the proper operation of the lines.

Energizing Lines. *Responsibilities.* The project superintendent should be the first person consulted regarding the energizing of any part of a line. He will have checked the number of customers to be certain that at least two customers per mile are connected and ready to be served. He will have arranged for an operator or crew to assume responsibility for the operation of the energized lines.

The construction contractor should advise the project engineer that the lines are ready for final inspection. This notice should be in writing. He should also advise that the lines are clear and ready for energizing.

The project engineer should satisfy himself that all lines have been constructed in accordance with the plans and specifications. He will advise REA that the lines are ready for final inspection. He will receive permission from REA before any lines are energized.

The project attorney should be consulted to be certain that all insurance requirements as outlined by REA are in order.

Setting of Meters. All meters should be set by men employed and paid by the borrower under the supervision of the project superintendent. Meter sockets purchased by the borrower should be installed by the house-wiring contractor at locations designated by the project superintendent.

Operating Organization. The operating organization selected by the borrower should be responsible for the complete operation and maintenance of the lines, including the restoration of service, installation and reading of meters, collections, new construction, solicitation of new business, including house wiring and plumbing, preparation of budget, maintenance of operating records, preparation of operating reports, purchases of supplies and materials, maintenance of proper customer relations, and administration of the policies formulated by the board.

All arrangements for operation of the lines should be made before any part of the line is energized.

At the beginning of operations the personnel should be a minimum. The amount of equipment should also be a minimum. On small projects the possibility of part-time personnel or arrangements with an outside maintenance concern should be considered.

No operator should be considered unless he is a first-class lineman experienced with similar voltages on electrical distribution systems. He should have had experience on trouble work and be able to read blueprints and make out individual reports. He should be familiar with the purchasing and storing of materials. He should be able to instruct and manage part-time employees for emergency work.

Energizing Procedure. Only those sections of a line which can be definitely and completely isolated from all other sections upon which the contractor's crews are working should be energized.

The project engineer should advise the contractor in writing that specific lines will be energized at a given time.

The project superintendent should check to be certain that all men are in the clear before any line is energized.

The project engineer should be present.

The procedure as outlined below should then be followed by the operating men:

Test the substation (no load).

Test the main feeder (no load) with all laterals disconnected.

Connect transformers of individual customers to be served from the main feeder.

Test the service and check the meter for each customer.

Connect each lateral to the main feeder separately.

Connect each transformer on each lateral separately.

Test the service and check the meter for each customer.

Repeat for each lateral.

Should defects be noted which the contractor must correct, the line will be deenergized and, if possible, the switch locked open. If not possible to lock open, wooden stop blocks should be used to prevent inadvertent closing. If the line is deenergized by means of a fused disconnect switch, the door, if possible, should be removed. The phase wires should also be grounded before work of any kind is done. This ground must be removed before leaving the location.

SAFE PRACTICES FOR ELECTRIC TRANSMISSION AND DISTRIBUTION

General. Employees should acquire the habit of being cautious, heeding warning signs and signals, and warning others whom they see in hazardous situations.

Employees whose knowledge does not warrant them to approach or handle live electrical equipment and lines should keep away from them.

No employee should do work on or about live equipment or lines for which he is not properly qualified, except under the direct supervision of an experienced and properly qualified person.

Employees whose duties require them to work on live electrical equipment or lines should use every possible safeguard to prevent injury to themselves or others.

Employees should avoid startling anyone who is working in a hazardous position.

Workmen should not proceed with work beyond the limit of their manager's orders, except in an emergency, and only then if they are entirely familiar with the work.

First Aid. The borrower should provide first-aid kits for use in giving first-aid treatment only. All injuries should receive subsequent competent medical attention.

If an injury requires a second treatment, this second treatment is not first aid and the injury should be retreated and re-dressed by an authorized doctor.

It should be the duty of employees to acquaint themselves with the rules of first aid and resuscitation within a week after employment.

Every employee should be taught the prone-pressure method of resuscitation, regardless of the nature of his duties, and should be required to practice this method at stated intervals. The booklet on the prone-pressure method of resuscitation should be given to each employee.

Reporting Defects and Dangerous Conditions. It should be the duty of every member to report any dangerous or defective condition of poles, wires, or any piece of apparatus which comes to his attention.

When a condition hazardous to the safety of the public is found, such as crossed or fallen wires, broken poles, and so forth, adequate means should be adopted to prevent accidents. The proper person should be notified of the trouble, and he should warn unauthorized persons to keep away from energized equipment or lines.

Accidents of all kinds involving cooperative property, or public property, in which the cooperative may become involved, should be reported immediately.

Fire Fighting. It is the duty of all employees to report to the manager any evidence of fire hazards and, where possible, to familiarize themselves with the location of sand pails, fire extinguishers, and hose.

Before using fire-fighting apparatus around electrical equipment, the following precautions should be observed. The extinguishing liquid must be of an insulating character if used on live electrical equipment; otherwise the electrical equipment must be deenergized. The employee using the fire-fighting apparatus must fully understand its use. Soda acid extinguishers should never be used on electrical fires.

Fire extinguishers should be furnished by the cooperative for use on all project automobiles, trucks, and similar equipment.

Combustible materials such as boxes, cartons, rags, waste, oil-soaked or paint-covered cloths, shavings, wastepaper, and other inflammable materials create serious fire hazards and should not be allowed to accumulate on or about cooperative property or equipment.

Supervision. It is the duty of every superintendent or manager to enforce the regulations herein provided. They are instructed to take immediate corrective action on any evidence of violation of these safe practices.

Frequent inspections of safety equipment and tools should be made. The use of defective tools should be prohibited and all tools and equipment should be in good condition before being put into use.

Climbing. After arriving at the job and prior to starting work, each lineman should inspect his body belt, safety belt, climbers, and other tools.

Before a lineman attempts to climb a pole he should determine by inspection and/or test that the pole is safe to climb. If there is any doubt about the condition of the pole before or while climbing, it must be pike poled on four sides so that it is safe to work on.

Before going up a pole, the lineman should fix in his mind the conditions on the pole and their relation to the job which he is about to do. He should determine in his own mind how best to protect himself in his working position.

In choosing the climbing side, every effort should be made to avoid weather checks, knobs, knot holes, rotten spots, and places which have been cut badly by the gaffs of linemen's climbers, nails, metal signs, and so forth, in order that the climber shall not cut out. When poles are stepped, make use of such steps in climbing. The climber should not use the side of the pole where the ground wire is attached. Linemen should avoid standing on mail boxes, telephone boxes, fences, crossarm braces, secondary racks, conductors, insulator pins, and so forth, as hand holds. When poles are coated with ice, special care should be used in climbing.

When a pole is raked or leaning, the climber should use the upper side whenever possible. The practice of sliding or coasting down a pole should be prohibited.

When two or more linemen are ascending a pole, the second man should not start climbing until the first man is in a safe position or, when descending, until the first man is on the ground.

Ordinarily, no lineman should work directly under another lineman on the same pole, except in emergencies. When this condition is necessary, extreme care should be taken to prevent tools or other objects being dropped upon the man below.

On arriving at his working position, the lineman should put his safety belt around the pole or some other suitable support and make sure that the snap is properly caught in the D ring before trusting his weight to the belt.

Safety belts should not be placed around the pole above the top crossarm when the latter is within 12 in. of the top of the pole.

Safety belts should not be attached to insulator pins, crossarm braces, span wires, guy wires, or around crossarms beyond the outside pin. Neither end of the belt should be allowed to hang loose either in ascending or descending a pole or structure. Both ends of the safety belt should be fastened to the D ring.

Linemen should not attach metal hooks or other metal devices to body belts. Metal chains and keepers should not be used. Use leather straps or rawhide thongs with hard wood or fiber keepers.

Care should be taken to prevent the snaps on safety belts coming in contact with anything that may open the snap and thus release the safety belt. The tongue of the snap on the safety belt should face away from the body.

Linemen's belt tools should be so secured that they will not fall out of the tool belt. A lineman should carry a minimum number of tools in his belt. All other tools should be kept on the ground until they are required and then raised by means of a material bag attached to a hand line, unless the tool is too large to be safely raised in this manner, in which case it should be raised by means of a hand line.

When transferring wires and equipment from an old pole to a new pole, the old pole should either be lashed to the new pole, or guyed, or both, as the conditions may require.

Before a lineman cuts an overhead conductor, he should make sure that it will fall clear. Where there is possibility of the falling line coming in contact with another wire, or doing other damage, it should be lowered with a hand line.

Steel guy wire is springy. Care should be taken that the ends when cut do not whip and cause injury. This applies both to installing and removing guy wires and refastening wires on reels.

Hand lines should be carried up a pole uncoiled, the end attached to the rear of the lineman's body belt. When a lineman is climbing with a hand line, he should take care to prevent the line from fouling on any pole attachments.

Climber gaffs should be at least 1¼ in. long, inner surface, and kept sharp. The climbers should fit properly, and the straps should be in good condition. Climbers should not be worn on work for which they are not required, nor while men are traveling to and from work.

A separate compartment should be provided for the storage of rubber gloves or other rubber goods, and not used for other purpose.

Clothing. Employees should wear suitable clothing when working on or about live equipment and lines or moving machinery. In particular, they must keep their sleeves rolled down and buttoned at the wrist. They should avoid wearing unnecessary metal or inflammable articles.

Disconnect Switches and Fuses. Disconnect switches on high-tension and primary lines should not be opened or closed by any other means than switch sticks or operating gear provided for this purpose. The man using the switch stick should assure himself of a secure footing and proper clearance from other equipment and should wear rubber gloves.

When a lineman is about to pull a fuse, a disconnect, a primary cutout or do anything which he suspects might cause a flash, he should protect his eyes by wearing goggles or turning his head and protecting his eyes and face with his arm. He should wear rubber gloves, use a "hot stick," and secure himself to the pole with his safety belt.

Grounding. Approved copper grounding cables and clamps, or approved grounding chains, should be used to ground high-voltage lines, which have been deenergized, before work of any kind is done on these circuits.

The normally live parts which are to be grounded should next be tested for any indication of voltage, the employee carefully keeping all portions of his body at the distance required from such parts when alive, by the use of suitable insulating rods or handles of proper length or other suitable devices.

The grounding device should first be connected to a low-resistance ground before it is brought into contact with the deenergized line to be grounded. When a grounding chain is used, it should be so constructed that it is unnecessary to touch the chain either in installing it on or removing it from the line. In removing a grounding device the connection between the device and the line should be broken before the connection is broken between the device and the earth. Rubber gloves should always be used while the grounding device is in contact with the line.

Handling Live Equipment. Before starting work on electrical equipment or lines, tests should be made to determine if they are dead or alive. They should always be considered alive unless they are positively known to be dead and adequately grounded.

When lines are worked dead, short-circuiting devices and, where possible, grounds must be applied between the job and each possible source of electrical energy. Lines which are killed should be blocked and tagged.

Workmen whose employment incidentally brings them within proximity of electrical equipment or lines, the danger of which is not familiar to them, shall proceed with their work only when properly instructed and protected.

No employee shall go or take any conducting object within the distances named below from any exposed live part at or above the voltage specified, except as permitted by this rule.

Operating Voltage	Distance, Ft
7,500	1
15,000	2
50,000	3
70,000	5

Distances for intermediate voltages are to be determined by interpolation.

No person should work alone in testing or experimental work on or about parts on which the voltage can exceed 750 volts, except in routine testing when the live parts are properly guarded.

Employees should not use metal tapes or tape lines having metal strands woven into them, metal bound rules, metal scales or gages, wire-bound rules, wire-bound hose or rope with wire core when working on or near energized equipment or lines.

Extreme care should be used in avoiding contact with secondary wires which are carried on racks on the rear of houses. Many metal roofs are grounded.

In wet weather or at night at least two employees should be provided where work is done on live lines, the voltage of which is in excess of 750 volts, except in trouble or emergency work.

All ungrounded metal parts of devices on switchboards should be handled as if operating at the highest voltage to which any portion of the equipment is subject, unless these parts are known by test to be deenergized.

Bare fingers or hands should not be used to determine whether a circuit is alive. Never remove or replace fuses in live circuits above 750 volts unless rubber gloves are worn and a "hot stick" is used.

In handling portable motors or lamps, first make sure that the external metal frame is not alive by leakage from live parts within. Have such portable devices inspected at least once daily during the period of their use.

Inspection of Tools and Equipment. Linemen's belts, safety belts, climbers, and other equipment, including any tools owned by the employees and used on cooperative work, should be inspected at least each 30 days. The use of defective tools and equipment should be prohibited.

Ladders. Ladders set up in walkways or roadways should be adequately protected against traffic.

All straight ladders and extension ladders should be equipped with approved antislip devices or otherwise safely secured. Ladders should be all wood.

Employees should inspect each ladder before using it. A routine inspection should be made of all ladders at least once every 6 months, and ladders in daily use should be checked as used and inspected every 30 days. A record of such inspection should be kept on file.

The horizontal distance from the wall to the foot of the ladder should not be more than one-quarter the length of the ladder.

Lifting. In order to avoid the possibility of body sprains and strains, the following safe practices for lifting should be observed:

1. Avoid lifting from insecure positions or in such a way that the back is twisted.
2. Spread your feet apart in order that you may have a solid foundation.
3. When lifting, keep the back as near upright as possible.
4. Use the arm and leg muscles for lifting.
5. If there is a feeling of strain, stop lifting until you get help.

Meters and Current Transformers. Special care should be exercised in opening circuits at meter connections until the circuits have first been properly opened or shunted.

Before working on an instrument or other device in a current transformer secondary circuit always bridge the device with jumpers, so that the circuit cannot be opened at the device. A circuit should never be opened at meter connections until it has been bridged elsewhere.

Joints or loose ends of wires should never be left unprotected.

Protective Devices. Linemen should carry their rubber gloves in canvas glove bags attached to their belts, except when the gloves are being worn, or in regular storage compartments on trucks.

All work on pole lines including the application and removal of rubber protective equipment should be done from below, if practicable.

If it is necessary to work from above, all conductors within reach shall be covered with rubber protective devices.

Rubber gloves should be worn when grounding chains and other grounding devices connected to hand line are being applied to and removed from lines.

Rubber coats, hats, and boots should not be considered as protection against energized equipment. Their only purpose is for protection against inclement weather.

Particular care should be used during hot, humid weather and during wet weather, when conditions are ideal for electric shock.

While climbing a pole or while changing from one working position to another on a pole, the lineman should look carefully around him to see that he has proper clearance from conductors and that they are properly covered.

Leather protectors should be used over rubber gloves, and they must be used only for the protection of the gloves.

A lineman should test his rubber gloves by means of the electric test at least once every 2 weeks.

While wearing rubber gloves and protectors, linemen should take care to keep their hands away from points where arcs may be established, in order to prevent danger of burns through the gloves.

Protection of the Public. When stringing wires, linemen should not allow them to sag so as to endanger pedestrians or vehicles. Traffic must be diverted by a watchman, or otherwise protected.

During construction work every precaution must be taken to protect the public and their property. In case of any obstruction in the street or walkway, they should be protected by barricades, using also red flags or danger signs by day and red lights by night.

Pedestrians and vehicles should be kept away from locations where poles, wires, or other equipment are being worked upon or are in a weakened or dangerous condition.

In all cases where trenches or holes are left open in traveled highways or walkways, they should be properly barricaded, or covered, if possible, and at night must also be provided with a sufficient number of red lights.

Hand lines, materials, tools, and so forth, must not be scattered around streets, sidewalks, highways, and so forth, but should be kept in a neat, orderly manner, where they will not be liable to cause accidents.

Good blocking is essential when setting up reels, skids, and other equipment, and the rights of pedestrian and vehicular traffic should be kept in mind. Reel lags and boards with nails protruding should not be left lying around.

Raising and Lowering Materials—Pulling Wires and Cables. Tools and materials should not be thrown up to workmen on elevated structures or poles and should not be thrown to the ground by the workmen. They should be raised or lowered by means of hand lines or in material bags. Tools or materials should not be laid on crossarms, but should be kept in the material bags, tied to a hand line or in the lineman's belt.

Large tools and materials which cannot be easily stored in a material bag should be lowered to the ground when not actually being used on the pole.

When tools or materials are being raised or lowered, workmen should stand clear at all times, and they should avoid coming directly under any load until it is properly placed and secured. Avoid sudden jerks on the lifting cables. When tools and materials are being raised or lowered, care should be taken to prevent contact with any lines or equipment, both for the purpose of avoiding the dropping of such objects and for the purpose of avoiding interference with operation and maintenance of service to customers.

Workers should not place their hands on chains, ropes, or cables at places near where they pass through blocks, pulleys, or guides. They should not stand unnecessarily near chains, ropes, or cables under tension which might cause them to break and whip.

Telephone Lines. When working in proximity to telephone wires or cables, they should always be treated as if energized and subject to the same precautions as electric light and power lines.

Tree Trimming. When trimming trees, employees should avoid tree limbs which are unsound or of insufficient strength to sustain their weight. Climbers must not be worn when climbing trees. Rubber gloves should be used when trimming branches that do or may contact energized wires or equipment.

Trucks. When hauling material that projects behind the body of the vehicle, the extreme end shall carry a red flag during the day and a red light at night, and when turning corners extreme care should be exercised so that the projecting portion of the load will not come in contact with persons or property. If necessary, an assistant should stand guard until the corner has been turned.

Materials and tools shall be securely stowed on the trucks so that no one will be subjected to the hazard of falling or shifting objects. Pike poles should be carried on the truck with the points forward. Sections of rubber hose or other suitable protection should be placed over the points when the pikes are not in use.

SECTION 25

*Pole Climbing**

Climbing equipment is used many times a day during the construction, operation, and maintenance of pole lines for the electric light and power industry. It is the purpose of this section to furnish instruction in its use and care so that it may be handled in a safe and proper manner.

The hazards of climbing can be reduced by ordinary precautions. Pole attachments must be avoided so you will not strike them and be thrown off balance. Attention to the pole surface will keep you from placing a gaff in unsound wood, in a defect, or against a metallic object. Attentive and skilled use of the equipment will help to avoid such accidents and the resultant injuries.

The belt and safety strap, properly used, provide for security and full use of the hands when in working position. Look to see that a safety snap is on the D rings; use the safety strap even when the working position seems otherwise secure; make certain that a safety strap cannot slip over the top of a pole. Make these practices a habit. You will be repaid when a minor incident does not result in a serious accident.

The rescue hitch, described on page 25-22, has been used many times in practice from all possible pole positions. It requires only equipment usually available and is secure without risk of further injury to the man.

Pole-climbing equipment consists of a leather or fabric body belt and safety strap and a pair of climbers. Figure 25-1 shows a lineman wearing equipment in the approved manner.

The equipment allows a person to climb, stand, or change position on a pole when no other suitable means of support is available. It also allows the free use of both hands while in any position on the pole.

The body belt consists of a waist strap and a pad (see Fig. 25-2). The *waist strap* is usually provided with a holster for pliers and with loops and snaps to hold other tools. The belt is usually made in even-numbered sizes varying by 2 in. in length, measured between the center lines of the buckle roller and the middle punched hole. The proper length to order is the distance in inches around the body where the belt will be worn, as shown in Figs. 25-3 and 25-4. The *pad* has a D ring

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Fig. 25-1. Ready to climb.

Fig. 25-2. Body belt with holster and loops.

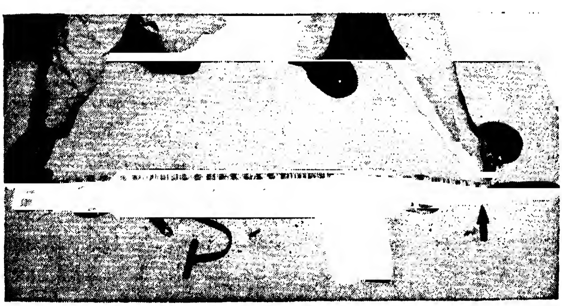


Fig. 25-3. Measuring waist strap.

FIG. 25-4. Measuring individual for waist strap

FIG 25-5 Pad and D rings

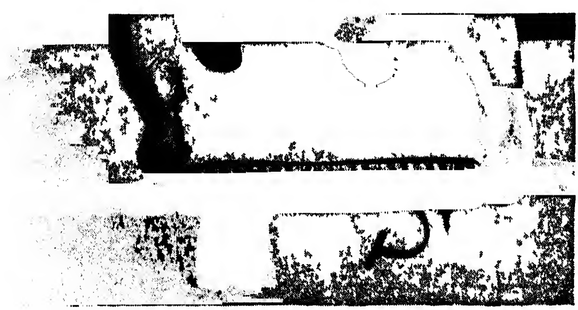


FIG. 25-6. Measuring pad.

attached at each end to hook in the snap hooks of the safety strap (Fig. 25-5). It is made in sizes varying 1 in. in length, measured between the center lines of the heels of the D rings (Fig. 25-6). The length to order is found by measuring the distance around the back of a person from the prominent part of one hip bone to the prominent part of the other, at the points where the belt is to be worn, plus 1 in., as shown in Fig. 25-7. It is more comfortable and less tiring to wear the belt resting on the hips, as in Fig. 25-8. The waist strap should be snug without being tight. Pass the end of the waist strap through the keeper and draw down snug in order to hold the tongue of the buckle properly in the hole of the belt.

The safety strap gives security and support to the body when working on a pole. Snap hooks, shown in Fig. 25-9, are attached to the ends of

FIG. 25-7. Measuring individual for pad.

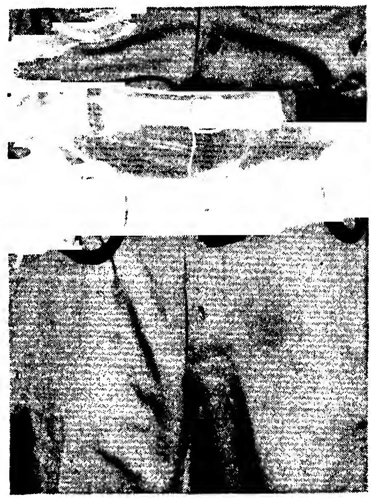


FIG. 25-8. Belt correctly fitted.

FIG. 25-9. Leather safety strap.

this strap to hook into the D rings on the body belt. By adjusting the buckle, the safety strap can be made longer or shorter so that the body may be maintained at a proper distance from the pole (see Fig. 25-10). Lengthen the strap when working on a pole of large diameter, and shorten it when working on a pole of small diameter.

When the safety strap is not being used, wear or carry it with both snap hooks fastened to the D ring on the left side of the body belt if right-handed and on the right side of the belt if left-handed. The snap

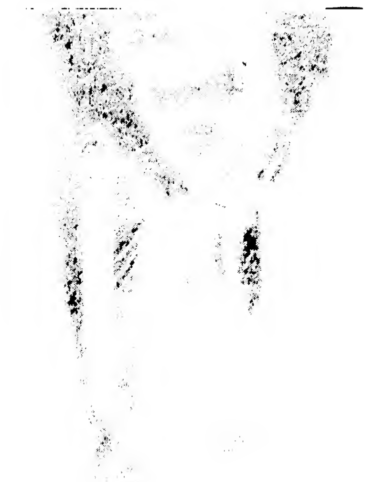


Fig 25-10. Adjusting length of safety strap

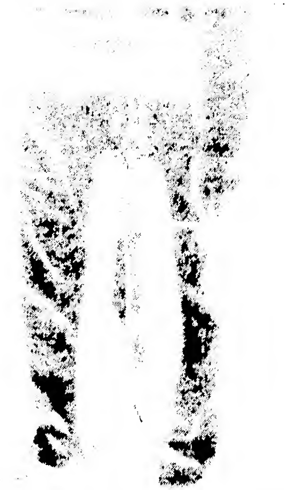


Fig. 25-11. Position of idle strap.

Fig 25-12 Climber irons

Fig 25-13. Measuring climber length

hook on the double end should hang with the keeper facing outside. The other snap hook should have the keeper facing inside (see Fig. 25-11).

Lineman's climbers (Fig. 25-12) are used for climbing, standing, and changing position when working on poles and to support a person on a pole when no other suitable means of support is available. The heat-treated steel points or gaffs are firmly attached to the leg irons. The condition of the gaffs on climbers is of great importance because gaffs which are loose, dull, short, or improperly sharpened are a hazard to use.

Climbers are made in adjustable or fixed lengths from 15 to 19 in. by ½-in. steps. It is important that climbers of proper length be selected so that they fit comfortably. The top of the iron should normally extend to about one-half inch below the inside low point of the knee joint (see Fig. 25-13). They are fastened to the legs by means of both foot and leg straps (see Fig. 25-14). Tighten them so that both the foot

FIG 25-14. Pads and leg strap for climbers.

FIG 25-15 Placing foot strap through metal loop.

and leg straps fit snugly, but not so tight as to make them uncomfortable when climbing. Wear shoes with tops extending above the ankles for climbing, as they support the ankle and prevent the foot straps from chafing.

Foot straps (Fig. 25-15), after having been passed through the metal loop on the outside of the climber, should be folded so that the buckle will rest over the top of the foot. The location of this buckle can be used for identifying the right and left climbers, as shown in Fig. 25-16

The end of the foot strap should extend toward the outside and to the rear of the foot, as in Fig. 25-17. It should always be passed through the strap keeper to prevent being caught on the gaffs or caught in any manner that might open the buckle or create a tripping hazard.

A climber pad is provided to prevent the leg iron from chafing the leg. It is equipped with loops, and the leg strap is passed through these and the metal loop at the top of the climber (see Figs. 25-18 and 25-19).

Before the leg straps are fastened, pull the trouser legs up as shown in

FIG. 25-16. Location of buckle on right foot.

FIG. 25-17. Foot strap properly buckled.

FIG. 25-18. Climber pad.

FIG. 25-19. Threading strap through pad and metal loop.

Fig. 25-20 so that they are loose and baggy at the knees and fold in the pant leg snugly against the calf.

The leg strap is passed around the leg so that the strap end will extend to the rear on the outside of the leg. In this position, shown in Fig. 25-21, the strap cannot interfere with leg motion. When the climbers are properly adjusted, the wearer will feel comfortable and his trouser legs will not catch on the gaffs. The proper adjustment is shown in Fig. 25-22.

CLIMBING

Protect the hands and arms by wearing gloves and keeping the shirt sleeves down and buttoned when climbing or descending poles.

Ascend a pole by climbing without haste and with confidence in the climbing equipment.

1. Before climbing, *inspect* a pole for unsafe conditions such as cracks, nails, tacks, attachments, rot, and loose pole steps (Fig. 25-23). Any

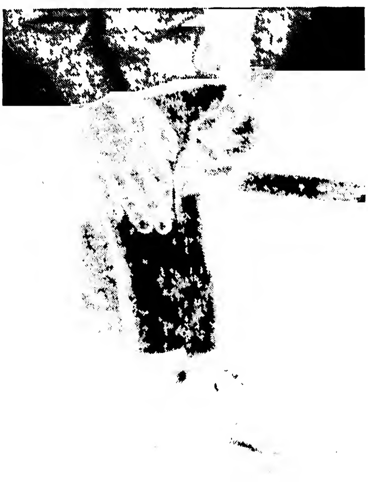


FIG. 25-20. Adjusting trouser leg.

FIG. 25-21. Leg strap properly buckled.

hazards should be corrected or reported. Remove rocks, planks, or other objects which would be likely to cause injury at the foot of poles. Metal or wood signs other than municipal attachments, radio aerials, clothes lines, and the like should be either removed on sight or reported, in accordance with company policy on such matters. Inspect the pole visually while ascending or descending to avoid placing the gaffs in hazardous spots.

2. The correct position of the feet is shown in Fig. 25-24. The length of each step should be approximately 8 in. The angle between the climbing iron and the pole should be approximately 30 deg.

3. Keep the hips, shoulders, and knees a comfortable distance away from the pole. Watch the gaffs to see that they are being placed in sound wood (Fig. 25-25).

Fig 25-22 Ready for climbing

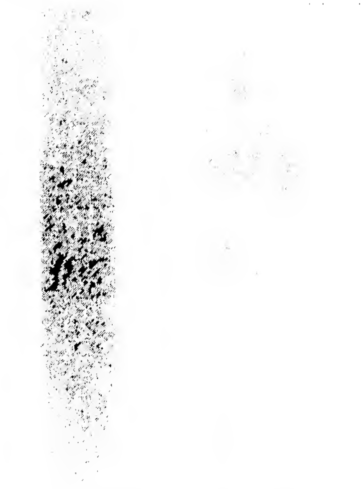


Fig 25-23 Visual inspection

Fig 25-24 Position of climber taking first step.

Fig 25-25 Watching gaffs while climbing.

4 The weight of one's body may ordinarily be sufficient to force the gaffs into the pole However, on hard-wood poles it may be necessary to use additional force by jabbing the gaff sharply into the wood of the pole Then proceed to raise the body into position for the second step The hand on the side of the body on which the leg is up is raised with or slightly before the foot

5 Shift the weight gradually from one leg to the other leg before

removing a gaff from its position in the pole. Then lift the first gaff out of the pole. The freed gaff is then raised *upward and out* to its new position, see Fig. 25-26, then *downward and in* to its new hold in the pole. The horizontal distance between gaff positions across the pole should be approximately 4 to 6 in., depending on the pole size.

In descending a pole these same fundamentals apply. Take short steps, keep the hips, shoulders, and knees away from the pole. Keep a 30-deg angle between the shank of the climber and the pole, and keep the

FIG. 25-26 Placing the gaff.

climber gaffs and the hands in the correct positions. The weight of the body may ordinarily be sufficient to set the climber gaffs when descending except on hard-wood poles as described above.

To disengage a gaff embedded too deeply, press the sole of the shoe against the pole. This action provides sufficient leverage to raise the gaff from the pole. It is poor practice to break the gaff from the pole by allowing the knee to fall away from the pole as this method usually splinters and unnecessarily damages the pole.

Look at the gaffs as they are placed in the pole and not at the ground while descending. *Observe* the pole so as to avoid placing the gaffs in hazardous spots. Never slide down any portion of the pole.

NOTE: Use portable pole steps when the lower portion of the pole has been bored for them. This will avoid gaff marks, which might otherwise cause personal injury or tear clothing.

On partially stepped poles use climbers only on the unstepped portion of the pole, except to secure a correct working position in the stepped portion. Wear climbers only when the job calls for climbing regularly and for working on poles. *Always remove climbers when working on the ground for an extended period of time.*

It is hazardous to stand at the foot of a pole while a lineman is working above, ascending or descending. Warn all persons, especially children, to keep away for the following reasons:

1. He may drop tools.
2. He may dislodge splinters and chips.
3. A lineman's gaff may cut out.

A second lineman, preparing to ascend, should always wait until the first man has reached the working position and placed his safety strap.

Fig. 25-27. Climb the "high side."

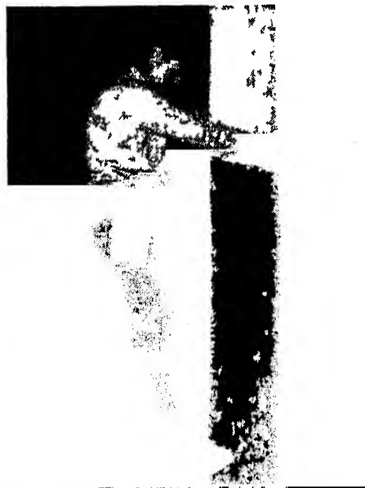


Fig. 25-28. Position while placing gaff

In descending, one lineman should remain in his work area until the other has reached the ground. If possible on poles which are wet or on which there is snow or ice, climb with the gaffs engaging the slippery side of the pole in order that the hands may engage the drier side and reduce the hazard of slipping.

Pins, crossarm braces, insulators, and hardware other than pole steps do not furnish a safe support as they may pull loose or break. The gloved hands may be cut on such devices that may be rough or broken. Do not use this equipment for support by the hands or for attachment of the safety strap.

In climbing *leaning or crooked poles*, keep on top of or above the lean or bend, as shown in Fig. 25-27.

In summarizing, remember to take short steps approximately 8 in. up, keep the leg rigid at a 30-deg angle with the pole after it bears the full body weight, and hold hips, shoulders, and knees away from the pole.

Always take very short steps when beginning to climb. The distance between steps lengthens naturally with practice (see Fig. 25-28).

Belting Off. The proper method to follow in making a safety strap ready to use is simple and should be made a habit. The following practices are recommended:

1. Place both feet at the same level and with both gaffs properly set, hold on to the pole with the right hand, and reach for the safety strap with the left hand (Fig. 25-29).

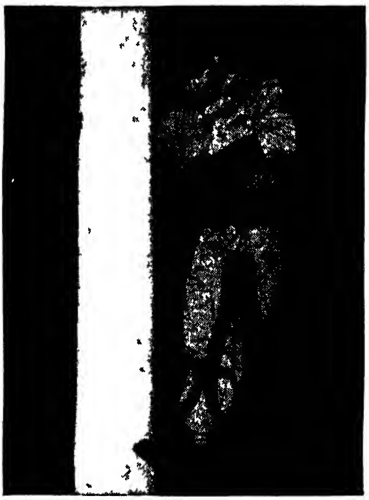


FIG 25-29. Reaching for strap.

FIG. 25-30. Pressing keeper on snap.

2. With the left hand unfasten the snap hook on the single end of the safety strap from the D ring. Check to *see* that the other snap hook of the safety strap is engaged in the D ring (Fig. 25-30).
3. Pass the safety strap around the pole with the left hand until the safety strap can be grasped by the right hand (Fig. 25-31).
4. Hold on to the pole with the left hand and after determining that the safety strap is flat against the pole, not twisted, and not resting on a sharp object, such as a nail, metal sign, or the like, carry the strap to the right D ring (Fig. 25-32).
5. Fasten the snap hook of the safety strap to the right D ring with the keeper facing out (Fig. 25-33).
6. *Watch* the D ring when fastening the snap hook of the safety strap and make sure that the fastening is properly made. *A click heard when fastening the snap hook to the D ring does not mean that the connection is securely made* (Fig. 25-34).
7. The body may now be moved back, supported by the safety strap. Hold the right side of the safety strap with the right hand when leaning

FIG. 25-31. Passing strap to right hand.

FIG. 25-32. Holding strap in right hand.

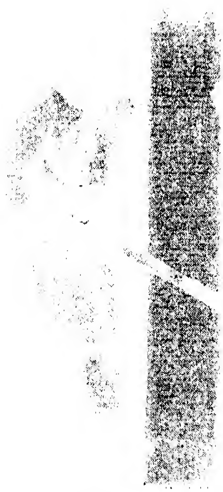


FIG. 25-33. Snapping strap on D ring.

FIG. 25-34. Checking snap hook.

back as an additional precaution, before removing the left-hand hold from the pole (Fig. 25-35).

The Safety Strap in Use. When the safety strap is in use, the double end of the strap should be attached to the left D ring and the single end of the strap to the right D ring as shown in Fig. 25-36. The snap hooks should be attached to the D rings with the keepers turned *outward* from the belt, never otherwise. In this position the snap hooks are less likely to become disengaged. *This practice is extremely important and should always be followed.* It is also most convenient for engaging or disengaging the snap hook.

Fig. 25-35. Checking strap.

Fig. 25-36. Position of strap in use.

To remove the safety strap proceed as follows:

1. Hold on to the pole with the left hand.

2. Release the tension on the safety strap by moving the body *slightly* toward the pole.

3. Unfasten the snap hook from the right D ring with the right hand.

4. Pass the end of the safety strap around the pole with the right hand until the strap can be grasped by the left hand.

5. Hold on to the pole with the right hand, and fasten the snap hook of the loose end of the safety strap to the left D ring with the keeper facing in, and above the snap hook already engaged.

NOTE: If a person is left-handed the operations and functions performed by the hands described above will be reversed.

Always wear the body belt and safety strap when working aloft. This allows the use of both hands for doing work while on the pole, by giving support to the body without use of the hands (Fig. 25-37). Even if the working position calls for standing or kneeling on a crossarm, the safety strap should be placed around another crossarm or the pole for support, as in Fig. 25-38. Never place the safety strap around the top of a pole *above* the level of a top crossarm position for support.

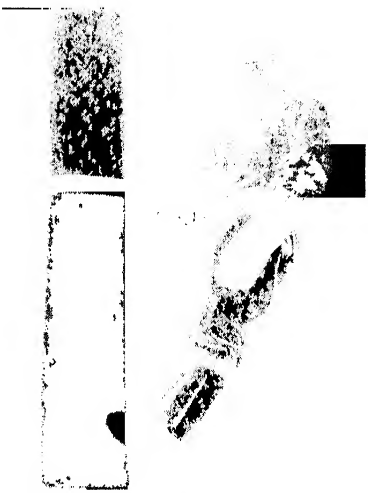


FIG. 25-37. Free use for hands.

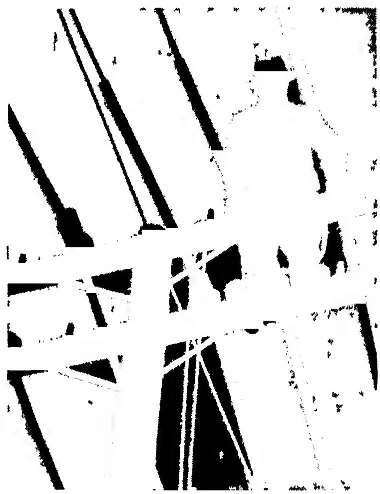


FIG. 25-38. Safety strap always in use.

The safety strap should always have both ends fastened to one D ring while climbing or descending a pole. If the strap is allowed to hang with one end loose, it becomes a hazard, particularly to fellow workmen. The correct position is shown in Fig. 25-39.

In the event that work is performed near the top of a pole with no top crossarm installed, place a long machine bolt through the top gain hole temporarily to prevent the safety strap from sliding up and off the pole as in Fig. 25-40.

Moving up or down on pole use one hand around the pole for support and release the tension from the safety strap by moving the body slightly toward the pole. The safety strap may then be shifted higher or lower with the free hand, as illustrated in Fig. 25-41. Always wear the body belt on the outside of coats and other outer garments so that the D rings will be in clear view (Fig. 25-42).

The Beginner. Practice at the base of a pole until the proper climbing position for the feet, arms, and body is acquired. Place the feet on the

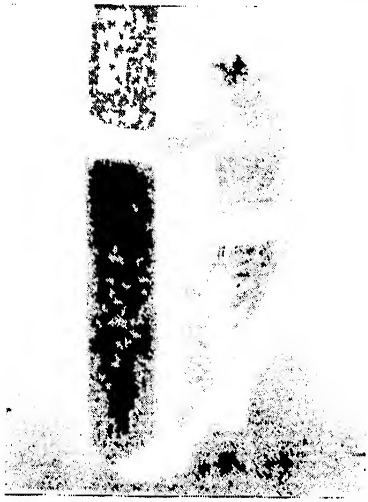


Fig 25-39. Strap position while climbing

Fig 25-40 Keeping safety strap on pole

Fig 25-41. Moving safety-strap position

Fig. 25-42 Belt worn outside coat

ground at about a 90-deg angle with each other and with the side of the arch of each foot against the sides of the pole Extend both arms out forward in a horizontal plane from the shoulders and hold on to the back of the pole with the hands Thrust the hips well back from the pole with the legs and arms straight until the body is in a position as shown in Fig 25-43

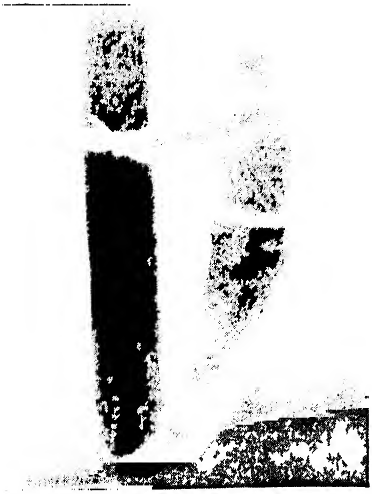


FIG 25-43. The apprentice in practice position.

FIG. 25-44. The apprentice—practice climbing.

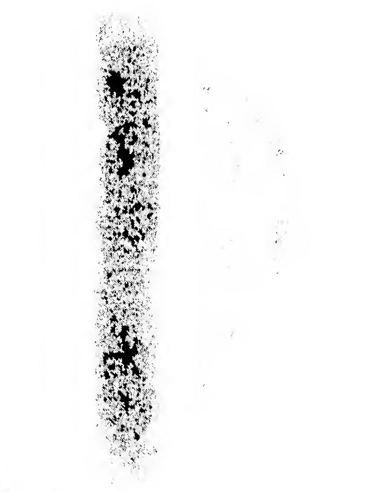


FIG 25-45 Ready to place strap

Before a person is permitted to climb he should be taught the proper method of handling a safety strap This can be accomplished by standing on the ground at the base of a pole without wearing climbers and going through the operations described on pages 25-12 and 25-13.

Practice climbing on a medium-size smooth practice pole which has not been badly cut by previous climbing. Start using climbers by first confining climbing to a section between the ground and 3 ft above the ground. This permits one to learn to climb without fear of falling. Before starting to climb, inspect the pole from the ground for cracks, knots, holes, tacks, and nails, as the presence of any of these may deflect a gaff and obtain an insecure foothold. (See Fig. 25-44.)

Practice placing the safety strap around the pole and fastening it to the D ring while on the pole. Stand on the pole with both legs straight and both gaffs in the pole at a point approximately 2 ft above the ground level for the first trials, shown in Fig. 25-45. This is the position for placing the strap when in the working position at any location on the pole. Then proceed to place it around the pole as described on pages 25-12 and 25-13.

CARE OF LEATHER

An inspection is recommended before starting work each day by the foreman and the lineman using the climbing equipment. They should examine the

Leather or fabric for cuts, cracks, tears, enlarged eye holes in straps or wear that might affect its strength, and for hard and dry leather.

Stitches for breaks, ragged strands, and loose or rotted threads.

Hardware for breaks, cracks, fractures, loose anchorage, or wear that might affect the strength of the equipment, for improper action of keeper on snap hook, and for length, width, thickness, and sharpness of gaffs.

Repair or replace the defective part as soon as it is possible to do so. The equipment will serve its purpose longer and more faithfully as a result.

Clean and dress the leather used for climbing every third month to keep it soft and pliable. Do this more often if equipment is subjected to paint stains or excessive moisture from wet weather or perspiration.

To clean leather: 1. Wipe off surface dirt with a sponge dampened with water only.

2. With a clean moist sponge and a neutral soap, work up a thick creamy lather to remove embedded dirt and perspiration.

3. Wipe off with a cloth.

4. Work up a lather again with saddle soap, and rub it well into all parts of the belt or strap.

5. Wipe off with a cloth.

To dress leather: 1. While the leather is still damp, apply a leather dressing, working it lightly into the leather with the hands. *Always clean any leather before dressing it.*

2. Let the belt or strap dry in a shady place for about 24 hr.

3. Rub vigorously with a soft cloth to remove any excess oil.

Use only a limited amount of leather dressing prepared from an animal or vegetable source. Never use any type of mineral oil or grease.

Never store or dry wet leather near sources of heat such as an open fire, stoves, hot steam pipes, or radiators. Artificial heat will cook or burn leather, making it hard, brittle, and weak.

Store body belts and safety straps in compartments away from sharp-edged tools.

GAFFS

Gaffs on climbers should be inspected and checked frequently for length, width, and thickness with a "gaff gage," as demonstrated in Figs. 25-46 to 25-50.

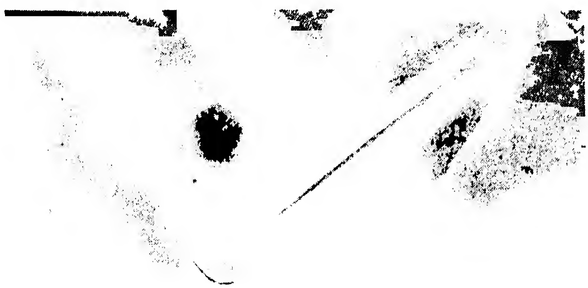


FIG. 25-46. Checking for minimum length.

FIG. 25-47. Proper width ½ in. from point.

To sharpen a gaff proceed as follows:

1. Use a clean, sharp 10-in. mill file.
2. Set the climber against a small block of wood in a vise, if one is available, with the underside of the gaff uppermost. File from the heel to the point, holding the file flat on the surface, raising the file on the back stroke (Fig. 25-51). Keep the file clean to avoid scoring the gaff steel.
3. Remove only sufficient material to obtain a good point.
4. Do not make a needle point. Round over slightly to the point by tipping the file slightly over at that portion, as in Fig. 25-52.

Fig 25-48 Proper width 1 in from point

Fig 25-49 Proper thickness ½ in from point

Fig 25-50 Proper thickness 1 in from point

Fig 25-51 Filing underside of gaff

FIG. 25-52. Rounding the point slightly.

FIG. 25-53. Filing for proper width.

FIG. 25-54. Checking for minimum length.

5. The outside of the gaff should not be materially changed. If it is necessary to remove any metal to obtain the proper width, be careful not to round off toward the point or a tendency to "cut out" will result. (See Fig. 25-53.)

6. The length of the gaff for climbing wood poles should not be less than 1⅛ in. measured on the underside from the heel of the gaff to the point (see Fig. 25–54). When climber gaffs wear to 1⅛ in. long, they should be regaffed or a new pair of climbers obtained.

RESCUE HITCH

A rescue hitch for lowering a lineman from a pole top to the ground can be provided easily and quickly with a body belt and safety strap if

Fig. 25-55 Placing rope over crossarm.

Fig. 25-56. Measuring out 5 ft of rope.

required on occasion. By making use of the equipment available on the spot, a saddle can be rigged that will support a person without injury to his body and be strong enough to carry the weight of any person involved.

1. Place the lowering rope in a free running position over a support on the pole, such as a crossarm, suitable to carry the required weight, as in Fig. 25-55.

FIG 25-57 Tying rope to D rings

FIG. 25-58 Tying bowline

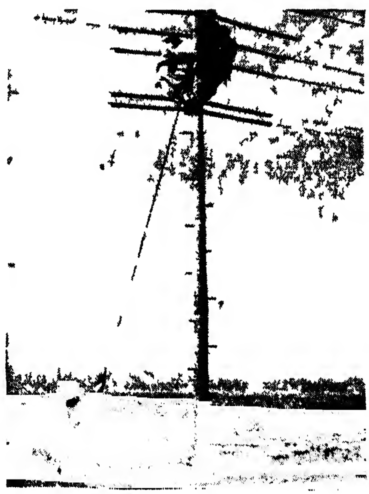


FIG 25-59 Groundman holding rope.

2 At a point about 5 ft from the fall end of the rope (see Fig. 25-56), tie two half hitches around one D ring of the body belt

3. Then tie two half hitches around the second D ring, leaving about 12 in. of slack rope between D rings (see Fig 25-57)

4. Figure 25-58 shows the correct method of tying a bowline knot with the remaining end to the fall rope leading to the D rings

5. The man on the ground should take a firm grip on the standing end of the rope (Fig. 25-59) but should not pull it tight

6 Unsnap the single-strap end of the safety strap from the body belt and pass it from the front to the back between the legs of the person to be lowered Pass the safety strap around the outside of the leg on the

FIG. 25-60. Placing strap around leg.

FIG. 25-61. Attaching snap hook to right D ring.

FIG. 25-62. Sliding belt up to position.

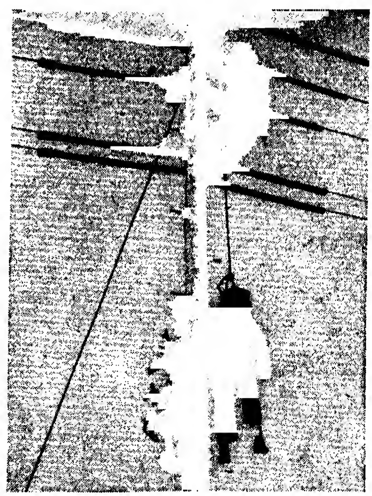


FIG. 25-63. Lineman being lowered.

side on which the loop end of the safety strap is worn, as shown in Fig. 25-60.

7. Then pass the single-strap end through the loop of the safety strap in front and engage its snap hook with the same D ring from which it was removed (Fig. 25-61).

8. Unbuckle the waist strap of the body belt and work the belt up to a chest position and the safety strap into the crotch position. This is

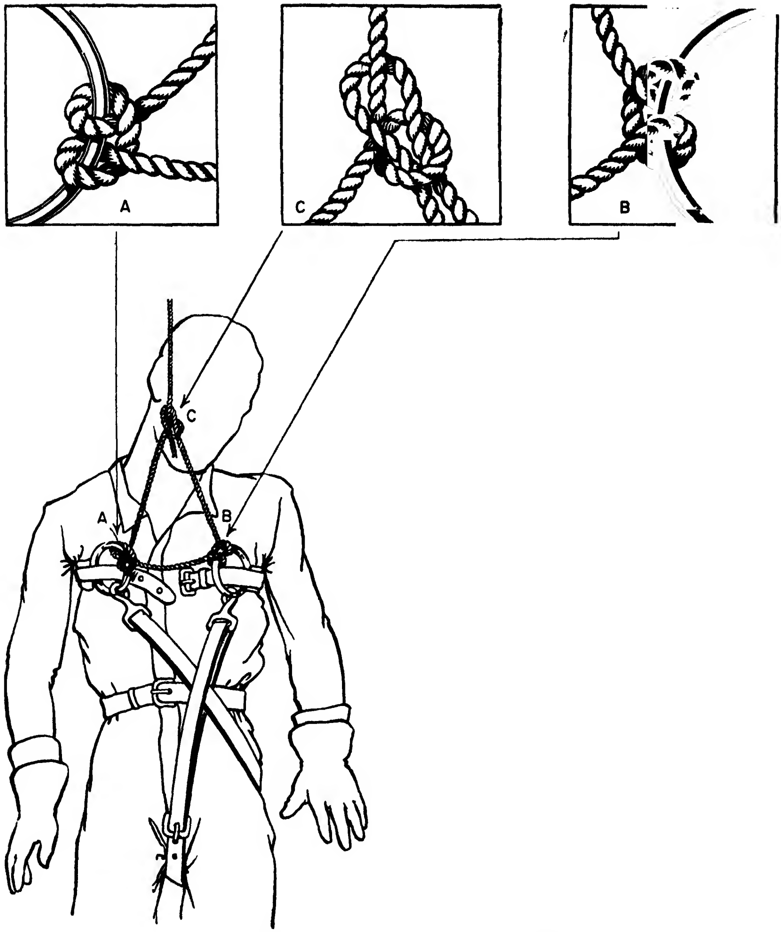


Fig. 25-64. Knot details of rescue hitch.

shown in Fig. 25-62. The saddle is now ready for the man on the ground to take a strain and proceed with the lowering operation (Fig 25-63).

The placement and tying of knots in the rescue hitch are shown in detail in Fig. 25-64, *A*, *B*, and *C*.

SECTION 26

*Rubber Protective Equipment**

Rubber protective equipment for the use of linemen working on overhead lines is designed for handling energized conductors safely and for safeguarding work areas to prevent electric shock or flash. It is the purpose of this section to direct attention to the application and care of such devices.

Accidental contacts with conductors on poles can be prevented by reasonable precautions. If wires are first identified and possible points of contact spotted, the work can be laid out with the protection as a part of the job. The proper number and type of protective devices can then be selected with which to eliminate these contacts.

A variety of rubber protective devices, suitable for the work and structures encountered, should be carried on every line truck. Protection against electric shock or flash is then a matter of applying the devices properly before and during the progress of the work and removing them in correct sequence.

The voltage limitations and the physical nature of rubber protective equipment must be thoroughly understood to ensure adequate protection. Whether used alone or supplemented by other insulating material, the equipment must not be relied upon to provide protection with voltage stresses through the walls of the devices in excess of their rated voltages.

Careful and thorough visual inspection of rubber protective equipment, made regularly, will give valuable information regarding its condition. As rubber ages, it becomes hard or brittle and loses its qualities of toughness and elasticity. Such rubber may pass a voltage test in the laboratory and yet fail mechanically during use or inspection.

To be effective, rubber protective equipment must be given proper care. Storage in special compartments, containers, or racks will ensure its good condition.

A number of good practices are described on the following pages. By applying the principles upon which they are based, line work may be made safe regardless of field conditions.

* Reprinted with permission of the Edison Electric Institute.

The reward for these efforts will be twofold. The chance of a shock or a flash will be very greatly reduced, and the linemen will realize a sense of security and protection that cannot be obtained in any other way.

THE EQUIPMENT

Rubber protective equipment used on overhead electric lines includes gloves, sleeves, line hose, hoods, blankets, and shields. The application of some of these devices is shown below.

This equipment allows linemen to work on and around wires on a pole with protection against electric shock or flash. By its full use in the work area, a change of position can be made as the work progresses, with a minimum degree of hazard. (See Fig. 26-1.)

FIG. 26-1. Make this your pattern of protection.

Rubber gloves are probably the most important of all the protective devices in this series. They are made in lengths varying from 14 to 19 in., measured from the tip of the second finger to the edge of the cuff. They are available in sizes and half sizes from 9 to 12 in., measured in inches around the palm at the base of the knuckles. Two classes of gloves are available. Class A with a maximum rubber wall thickness of 0.065 in. is intended for use without protector gloves by persons who wear rubber gloves only occasionally on light work or when severe moisture conditions prevail. Class B with a maximum rubber wall thickness of 0.050 in. is intended for use with protector gloves on work requiring regular wear such as on electric lines.* Rubber gloves are made in curved-finger and straight-finger styles. The curved-finger glove tends to reduce the amount of rubber flexing into the palm when handling tools and the hand may not tire as readily. The selection between straight- and curved-finger gloves is a matter of choice.

* American Standards Association Standard C59.12-1942 and American Society for Testing Materials Standard No. D120-40.

Leather protectors for class B rubber gloves are made to protect the rubber against injury and wear.* However, the cuffs on leather protectors purposely do not extend to the full length of the rubber glove, thus providing a gap for protection from current leakage. They should be used only over rubber gloves for work on electric lines and equipment. They should *not* be used alone as work gloves for general handling of materials and other matter. They are known by the same size number as the rubber gloves they are made to cover, but in practice the next

FIG. 26-2. Protection for the hands

size larger is sometimes preferred. Figure 26-2 shows a lineman adjusting leather protectors over his gloves.

Liners of cotton or other fabric are made to wear under rubber gloves to absorb perspiration. Care should be taken to prevent perspiration running down over the outer surface of the rubber glove, which might greatly increase current leakage over the wet surface. Liners also keep the hands from direct contact with cold rubber during winter temperatures.

Rubber sleeves worn with rubber gloves give protection to the full length of the arms and the shoulders against contacts with energized parts or conductors.† Sleeves are especially important to wear when making taps and wrap splices or when handling the untied end of an energized wire. Buttons or interconnecting straps across the shoulders hold full-length sleeves in position, as shown in Fig. 26-3.

Elbow-length sleeves (Fig. 26-4) are made for use where additional protection of the forearm only is necessary.† They are shaped to fit the arm and give more protection than the longest rubber gloves.

Line hose (Fig. 26-5) are long split-tube rubber insulating devices for covering line wires, leads to apparatus, jumpers, taps, and grounded

* American Standards Association War Standard J6.3-1945 for Specification Details.

† American Standards Association War Standard J6.5-1945.

wires.* A self-locking lip prevents the hose from becoming detached or exposing the conductors on short bends. Line hose are made in 3-, 4½-, and 6-ft lengths with inside diameter ranging from ¼ to 1½ in. The most common diameter for electric line work is 1 in.

FIG. 26-3. Rubber sleeves

FIG. 26-4 Elbow-length sleeves

Connector-end line hose (Fig. 26-6) have a built-on feature that permits sections to be interlocked or coupled together

Line-hose connectors (Fig. 26-7) are rubber devices which overlap and couple together the butted ends of two line hose on the same conductor They also serve to couple the ends of line hose which are separated by a bulky tap joint. Friction tape may be used to hold ends of line hose together if connectors are not available.

FIG 26-5 Rubber line hose

Short lengths of line hose for leads and taps may be made by cutting line hose into 8-, 12-, and 16-in. lengths or as desired. Sound portions of damaged lengths of long hose may be used for making these short pieces. These are illustrated in Fig. 26-8.

* American Standards Association War Standard J6.1-1945.

Insulator hoods or **pin saddles** (Fig. 26-9) are used in conjunction with line hose to cover tie wires and conductors at insulators.* Hoods are made with one of the extending arms larger than the other. This permits the large arm to overlap the small arm of an adjoining hood

Fig 26-6 Connector-end line hose

Fig 26-7 Line-hose connectors

Fig 26-8 Line hose for leads and taps

Fig 26-9 Insulator hoods

when two hoods are required to cover a pair of insulators on double crossarms

Linemen's shields or pigs fit over one or two insulators on single or double crossarms and insulate the conductor and tie wires Some pigs are equipped with two straps and nonmetallic fastenings to hold them in place.

Dead-end and utility covers, as shown in Fig 26-10, are designed to cover dead-end insulators and live parts of similar bulk completely and

* American Standards Association War Standard J6 2-1945

quickly. They are equipped with straps and slot fasteners for attachment. A hand hold is provided on each side for ease in handling.

Wood or fiber shields are sometimes used to cover conductors, insulators, and other parts or apparatus. They are of special design and are usually applied by means of sticks of insulating material such as are used for hot-line tools.

Rubber blankets (Fig. 26-11) are adaptable to a great variety of conditions.* They are used folded, wrapped, or suspended in any

FIG. 26-10. Dead-end and utility covers.

FIG. 26-11. Rubber blankets.

position to provide an insulating barrier. They are used to cover secondary racks, cutout boxes, arresters, guy wires, transformers, potheads, and other live or grounded parts that are within the area of physical reach.

PLANNING

Before leaving for a job, determine if the work planned will require additional items of rubber protective equipment to supplement those carried on the truck. Truck stock should be increased at the stockroom to meet the requirements of the work that is scheduled for the day.

On arrival at the job, a tailboard briefing before the work starts will give the crew an opportunity to learn what is to be done, to have unusual hazards pointed out, and for each man to be instructed in his assignments.

Preventing accidents is a matter of concern to each member of the crew. A four-step method is suggested which is simple to use, easy to remember, and unlimited in its application. Knowing what he is expected to accomplish, each man can apply the four-step method for preventing accidents to every job he does. These are the steps:

* American Standards Association War Standard J6.4-1945.

1. Size up the job.
2. Plan to control the hazards.
3. Work the plan.
4. Follow through.

Size up the job to spot the hazards on the pole. Be sure you have all the information you need to understand and plan the job. Locate and identify the conductors, apparatus, and grounds *before* climbing, as demonstrated by the linemen in Fig. 25-12.

Plan to control the hazards by protecting against them or by removing them (see Fig. 25-13). Plan to protect the hands with gloves. Plan to

FIG. 26-12. Sizing up the job

FIG. 26-13. Planning hazard control

protect the arms with sleeves if conditions require them. Plan to cover completely all energized parts that will be within reach of any part of the body. Plan also to cover all grounds which will be within reach of any part of the body when energized parts are also within reach.

Plan to wear rubber gloves while climbing or working on installations or structures in the vicinity of live distribution circuits or wires that may become alive by remote or accidental means. A lineman wearing gloves is seen in Fig. 26-14. Some companies insist on a policy of wearing rubber gloves from the time the lineman leaves the ground. Experience has indicated the soundness of this policy.

Ground work may involve the possibility of live contacts on the ground through the material being handled while pulling in wire over structures, tending reels, handling wet ropes or while setting wet or treated poles near primaries, as shown in Fig. 26-15. For these jobs wear rubber gloves and protectors and keep all other parts of the body clear of the wires or parts being handled.

Pull rubber gloves on the hands with care so that the pulling fingers will not injure the cuffs (see Fig. 26-16). Use the thumb and the side of the forefinger to pull the gloves on lightly at several points around the cuff, particularly in cold weather when the gauntlet fits snugly over clothing.

Work the Plan. Raise rubber protective equipment to the working position by means of bags, as shown in Fig. 26-17. Special canvas bags

FIG. 26-14. Wear rubber gloves.

FIG 26-15 Ground work

FIG. 26-16. Donning rubber gloves.

FIG. 26-17. Raising rubber protective equipment.

for line hose, tools, and equipment not only allow raising and lowering to be done safely, but make a receptacle for holding rubber goods during changes in the pattern of protection.

Completely cover up the nearest wires and parts first (see Fig. 26-18). Cover up the distant and far-reaching ones last so that it will not be necessary to reach over or between unprotected wires or parts. Always protect in this sequence, reaching up before climbing through to cover conductors and parts before the arms, head, and body can ever make contact with them.

Put on the type of protective device that is needed from the first point of possible contact, working upward and out from the pole, as demonstrated by the lineman in Fig. 26-19. Safe movement will then be provided through conductors and apparatus. Work areas will then be safeguarded before they are entered.

FIG 26-18. Cover wires completely.

FIG. 26-19. Put on proper protective device

FIG 26-20 Avoid glove damage.

FIG 26-21 Eliminate exposure.

Follow Through. Avoid damage to rubber gloves and rubber protective equipment when working on the pole. Tools, sharp ends of tie wires, wood splinters, and pole-line hardware cause cuts and snags. When untying line wires, use a pair of pliers for the entire operation to avoid snags to rubber gloves and leather protectors (see Fig. 26-20).

As work progresses and it becomes necessary to change the working position, move or add rubber protective equipment to afford continuous protection at all times. By doing this, exposure will be eliminated or localized at the point where the actual work is being performed (see Fig. 26-21).

Experience has shown that to provide complete protection from contacts with primary wires the *second point of contact* such as grounded guys, apparatus, and secondary wires must be covered with protective equipment (Fig. 26-22).

METHODS

Install line hose by pressing one end on the wire to engage the lock. Then slip the hose onto the wire for the remainder of its length. Starting at the nearest point the hose will slide along the wire, making it unnecessary to reach far out. The hose may then be slid back until the near end is over the tie wire and against the insulator.

FIG. 26-22. Cover second point of contact.

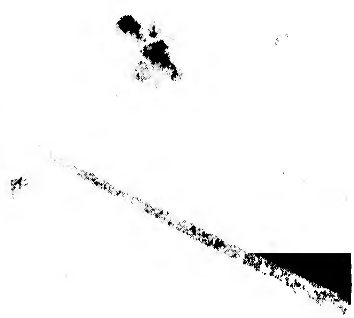


FIG. 26-23. Installing hoods.

Install hoods (Fig. 26-23) by placing them squarely over the insulator and pressing downward. The side walls will spread, and the flanges of the hood will slide over and grip the underside of the insulator. When applying hoods to side tie insulators keep that part of the hood marked *line side* toward the side of the insulator on which the wire passes.

On double crossarms, place the first hood by the method already described with the small end of the hood toward the uncovered insulator. Apply the second hood with the large arm in position to overlap the small arm of the first hood (see Fig. 26-24).

When using *pigs* (Fig. 26-25) apply them by pressing each *pig* down over the insulators until the conductor is covered. The straps, if any, are then fastened. Examine the underside to be sure that it is closed.

Rubber blankets are wrapped around or over apparatus. They are fastened in position with marlin, friction tape, or wooden clamp pins. Some blankets are made with a series of molded holes along the sides to permit the blanket to be fastened with nonmetallic buttons.

Clamp pins make the use of rubber blankets more convenient and secure by clamping the edges together or by clamping the blanket to apparatus. The wood clamps are sent up the pole with the blankets in a canvas bag ready for use, as shown in Fig. 26-26.

FIG 26-24 Installing hoods on double crossarms

FIG 26-25. Applying pigs

FIG 26-26. Clamping pins

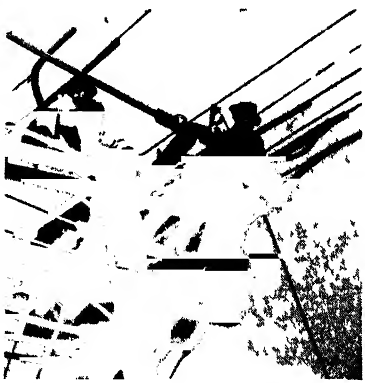


FIG. 26-27 Remove top device first.

Ozone from strong sunlight or high-voltage corona causes rubber to develop small cracks or become porous. To reduce such damage, rubber equipment should not be left in the sunlight or near live conductors for any unnecessary length of time. Corona cutting takes place more rapidly when rubber is deformed or under tension in the vicinity of high voltages. Because of the facts mentioned above, rubber gloves should not be worn inside out because the rubber is under tension when reversed from its original vulcanized form.

When all work is completed and the protective devices are to be removed, start by removing the topmost and most distant ones first

(Fig. 26-27). As each piece is removed, place it in a bag for lowering. Remove line hose by spreading the lock from the wire, detaching the nearest end, and drawing the hose toward you.

Remove a hood by a sharp tug to roll it sideways over the insulator, as shown in Fig. 26-28. The side walls will spread, releasing the lock from

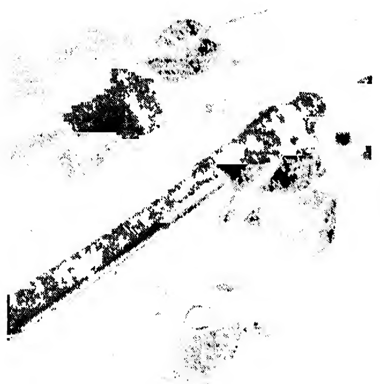


FIG 26-28. Removing a hood.

FIG. 26-29. Removing pigs.

FIG. 26-30. Removing blankets

FIG. 26-31. Lowering protective devices.

under the insulator. The ribs on the sides of the hood serve as finger grips for ease in handling.

Remove *pigs* by releasing the straps, if provided, and lifting straight up (see Fig. 26-29). Remove all rubber devices in an order which permits descending in a completely protected zone.

Blankets are removed by releasing the rope ties, clamp pins, or buttons, as shown in Fig. 26-30.

Figure 26-31 shows a lineman lowering protective devices in a suitable bag. All rubber devices should be lowered in bags or containers by a hand line.

On reaching the ground and if the lineman has no further need for rubber gloves, he is responsible for drying them out and storing them in his rubber-glove bag or suitable compartment, as shown in Fig. 26-32.

Fig. 26-32 Drying and storing gloves

Fig. 26-33 Separating wet equipment.

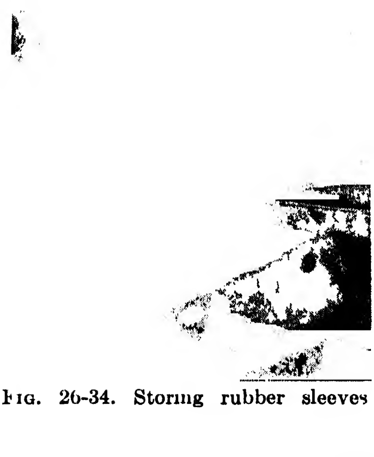


Fig. 26-34. Storing rubber sleeves

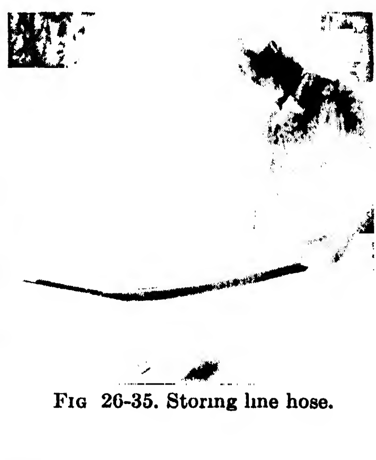


Fig. 26-35. Storing line hose.

HANDLING

Separate wet rubber gloves, leather protectors, and liners for drying. Flush rubber gloves regularly with clear water. Wash them periodically with water and a mild soap and rinse thoroughly. Dry a rubber glove inside and out by *wiping*. Rubber gloves should not be stored inside out. Keep rubber gloves free from dirt or oil and store them in a glove compartment or bag. Dry out leather protectors at normal room temperatures *away from* a source of artificial heat. Wash liners regularly with water and a mild soap, rinse thoroughly, and dry (see Fig. 26-33).

Store rubber sleeves flat or in a roll, never folded, as in Fig. 26-34. Keep all rubber protective devices clean and free from oil, in their proper compartments away from tools or equipment that might damage them.

FIG. 26-36 Storing hoods

FIG. 26-37 Storing pigs

FIG. 26-38. Storing rubber blankets.

FIG. 26-39 Air testing rubber gloves.

Store line hose in long compartments or trays in their natural shape to prevent their becoming deformed. Keep rubber protective devices in dark cool compartments and preferably away from the truck roof. See Fig. 26-35.

To conserve space and help the hoods retain their shape, two hoods may be stored together by inserting the *line side* of each hood within the other, as pictured in Fig. 26-36.

Store pigs in compartments that provide ample space to prevent their being deformed, as demonstrated by the lineman in Fig. 26-37.

Store rubber blankets flat or in a roll and never folded. Keep them in a designated compartment or round metal cannister. The correct method is shown in Fig. 26-38.

FIG. 26-40. Compressing air in glove.

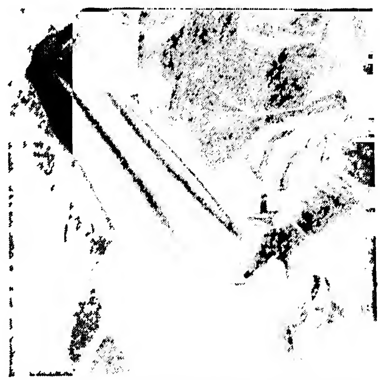


FIG. 26-41. Inspecting rubber sleeves.

FIG. 26-42. Inspecting leather protectors

FIG. 26-43. Making laboratory inspections.

MAINTENANCE

Rubber protective equipment must be regularly inspected to be sure that it is fit for use. Frequent inspection in the field and periodic tests at the laboratory prevent the use of defective equipment. Look for embedded foreign material, cuts, punctures, deep scratches, and bruises.

Each lineman should test his rubber gloves regularly by the *air test* (see Fig. 26-39). Test them at least each morning and afternoon before starting work and more often if there is any possibility of punctures. Inspect the entire glove surface visually, including the gauntlet portion, for embedded foreign material, cuts, deep scratches, and punctures.

Compress air inside the glove by starting at the gauntlet end and rolling the cuff tightly up to the bottom of the palm, as shown in Fig. 26-40.

Hold the roll securely in one hand to prevent the escape of air, and with the other hand go over the surface of the palm, fingers, and thumbs

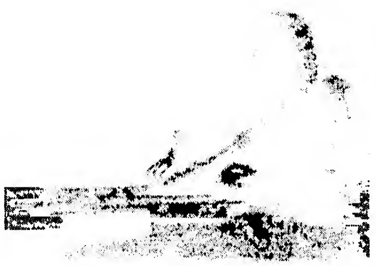


FIG 26-44 Monthly field inspection

FIG 26-45 Examining line hose

FIG 26-46 Spreading the hose

FIG. 26-47 Holding the hose.

searching for defects and embedded foreign material and listening for air leaks. Release the air and examine the gauntlet for cuts and tears. Identify defective gloves to prevent reuse, and replace them promptly.

Inspect rubber sleeves, examining both the inside and outside for cuts, deep scratches, bruises, punctures, and embedded foreign material. Rolling or stretching the rubber will aid in revealing defects (see Fig. 26-41). Replace defective equipment immediately.

Inspect leather protectors (Fig 26-42) for broken stitches, tears, cuts, or holes which allow mechanical injury to rubber gloves. Replace them immediately when found defective.

Laboratory inspections and tests, visual and electrical, are periodically made by practically every company to check the condition of rubber protective equipment. An inspection of this type is illustrated in Fig. 26-43. Rubber gloves and sleeves, being more subject to wear and tear, are usually tested more frequently than line hose, hoods, or blankets.

FIG. 26-48. Grasping new short section.

FIG. 26-49. Inspecting insulator hoods and pigs.

FIG. 26-50. Tagging defective equipment.

Make a monthly field inspection of all rubber protective equipment on the truck, as shown in Fig. 26-44. Each man should be instructed to make careful and thorough inspections of all items. Remove all rubber goods from the truck to a clean dry surface and wipe off any oil or dirt.

Examine line hose thoroughly inside and out. To examine the inside, hold the hose in the left hand with the slit of the hose at the top and the lock at the far side as demonstrated in Fig. 26-45. Spread the hose open with pressure from the right thumb and bend both ends down (see Fig. 26-46). This will expose the inside of the hose in that particular portion between the hands. Holding the hose firmly with both hands, move the left hand up and the right hand down to pass a short section over the crown of the bend for inspection. Then slide the right hand up the hose toward the left hand (see Fig. 26-47). Holding the hose with the right hand, as pictured in Fig. 26-48, drop the left hand to grasp a new short section, repeating the operation. Pass the hose through the hands from one end to the other.

Inspect insulator hoods and pigs thoroughly on the outside. Examine the inside by spreading the side walls to discover possible defects, as are the linemen in Fig. 26-49.

Examine rubber blankets by rolling them two ways at right angles to each other for each surface. By watching the top of the roll, any cuts or punctures can be detected.

Tag or mark for replacement all rubber protective devices found to have deep cuts or cracks, tears, or punctures, as shown in Fig. 26-50. Store all others in their proper compartments or containers for safe storage.

SECTION 27

Rope, Knots, Splices, and Gear

ROPE

Manila Rope. Manila rope is made from manila fiber which is spun into a yarn with a twist from left to right. A number of yarns are drawn through a tube to form a single strand. During this drawing, the twist is from right to left. Three of these strands are "laid" to form a rope with the twist from left to right. Because the successive twists in the yarn, strand, and rope are in opposite directions, one twist offsets the

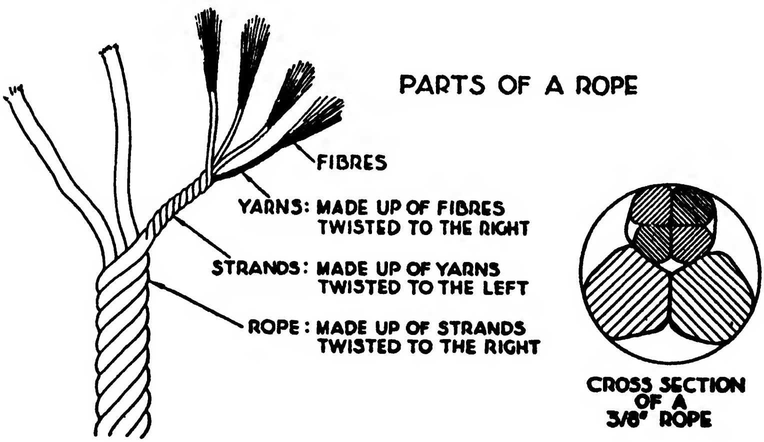


FIG. 27-1. Parts of a manila rope.

other and the rope holds together. Figure 27-1 shows the parts of the rope and a cross section of the rope. The finished rope is light yellow in color. It is hard, but pliant, and has a smooth waxy surface.

Rope sizes and lengths commonly used in linework are as given in Table 27-1. The last column lists the manner in which the rope ends are made up. The meaning of eye splice, back lash, or whipped end is illustrated in Fig. 27-2.

Various Uses of Rope. *Bull Rope.* Bull ropes are used for raising or lowering heavy pieces of equipment, for temporary guys, for setting poles, for holding out heavy transformers, and for lowering large limbs and trunks of trees.

Hand Lines. Hand lines are used for raising and lowering light material and tools or for holding small transformers away from a pole while

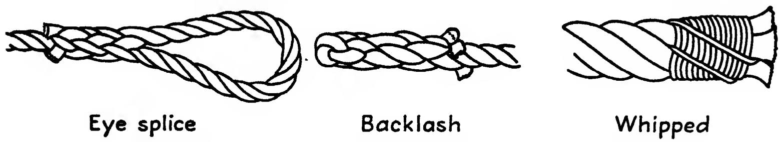


FIG. 27-2. Three ways of finishing the ends of a rope.

the latter is being raised. In addition, the 3/8-in. hand line is used as a throw line.

Running Line. The running line is used for pulling in several span lengths of wire at one time.

Safety Line. The safety line is used only for lowering a man to the ground.

TABLE 27-1. SIZES OF MANILA ROPE USED FOR VARIOUS PURPOSES

Name	Size, in.	Length, ft	How ends are made up
Bull rope.......	3/4	100	Both ends whipped
	1	200	One end whipped, eye splice in other end
Hand line......	3/8	75	Eye splice in both ends
	1/2	75	Eye splice in both ends
	1/2	150	Eye splice in both ends
Running line....	1/2	600	Eye splice in both ends
Safety line......	1/2	100	One end backlashed, and painted red, eye splice in other end
Sling...........	1/2	20	Both ends whipped
	3/4	20	Both ends whipped
	1	20	Both ends whipped
	1	30	Both ends whipped
	1 1/8	20	Both ends whipped

Slings. Slings are used for lashing tools or material in place, for attaching blocks and snatch blocks to a pole, for lashing an old pole to a new pole temporarily, and for tying line wires up temporarily.

Care of Rope. The life of rope depends upon the care and handling of it. Care begins from the time a new coil of rope is unwrapped and prepared for using.

To avoid kinks in uncoiling new rope, the coil should be layed flat on the floor with the inside end down. Pull the inside end up through the center of the coil and unwind counterclockwise. A new coil usually has a tag on the end giving directions on removing rope from it. To remove the wrong end or pull it through the coil in the wrong direction results in placing many kinks in the rope and consequent excess strain on the fibers. The kinks will remain in the line after many days of use.

Rope should never be dragged over the ground or over sharp objects. Dragging rope over another rope also will result in damage to both.

When tying rope to an object that has sharp corners, the rope should be padded to prevent cutting the fibers.

Rope that has become wet should not be permitted to freeze. If a rope has become full of mud or sand, it should be flushed with a hose and permitted to dry.

Never hang up rope where it will be exposed to heat, as high temperatures will harm the rope.

Learn how to do up hand lines and blocks and hang them up in the truck in their proper places.

When storing large rope, it is best to place it on wood gratings above the floor where it is well ventilated.

All rope used in line work should be kept dry. Dry rope is a fairly good insulator and is frequently thrown over energized conductors. A wet rope is not a good insulator and would certainly be dangerous both to personnel and equipment, if so used. Rope should never be used on conductors over 5,000 volts even when dry.

Safe Loadings. The safe working loads for various sizes of manila rope are given in Table 27-2. These loads are based on a factor of safety of 5 for new rope. Rope in service for more than 6 months should have the safe working loads reduced to one-half of the values shown.

TABLE 27-2. SAFE WORK LOADS FOR VARIOUS SIZES OF MANILA ROPE

Rope size, diam, in.	Safe work load, lb		Length per lb	Full coil (approx)	
	New	6 months service		Length, ft	Weight lb
3/8	270	135	29 ft	1,450	50
1/2	530	265	13 ft 6 in.	1,200	90
5/8	880	440	8 ft 7 in.	1,200	141
3/4	1,080	540	6 ft 1 in.	1,200	200
7/8	1,540	770	4 ft 5 in.	1,200	270
1	1,800	900	3 ft 8 in.	1,200	324
1 1/4	2,700	1,350	2 ft 4 in.	1,200	502
1 1/2	3,700	1,850	1 ft 7 in.	1,200	720

Column 2 is for new rope, and column 3 is for rope that has been in use for 6 months or more. It should also be remembered that a knot has 50 per cent of the strength of the rope and a splice has 80 per cent of the strength of the rope.

KNOTS AND KNOT TYING

Knots are used for fastening a rope to an object or for joining two ends of a rope. The knot or hitch used must hold the strain to be applied without damaging the rope or the load. The knot used must also be one that can be tied or loosened easily and quickly.

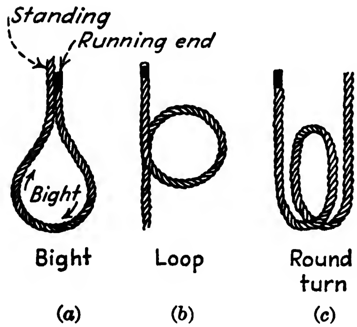


FIG. 27-3. Terms used in knot tying.

Terms Used in Knot Tying. All knots and hitches are a combination of the three different kinds of bends: the bight, the loop, and the round turn (see Fig. 27-3).

For convenience in describing the method of making various knots, the following terms will be used: "standing part," "bight," and "running end" (see Fig. 27-3*a*). The standing part is the principal portion, or longest part of the rope; the bight is a loop formed with the rope so that the two parts lie alongside each other; and the running end of a rope is the free end that is used in forming the knot.

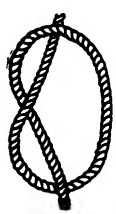


FIG. 27-4. Overhand knot. The overhand knot is the simplest knot made and forms a part of many other knots. This knot is often tied in the end of a rope to prevent the strands from unraveling or as a stop knot to prevent rope from slipping through a block.

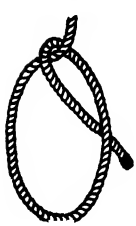


FIG. 27-5. Half hitch. A half hitch is used to throw around the end of an object to guide it or keep it erect while hoisting. A half hitch is ordinarily used with another knot or hitch. A half hitch or two thrown around the standing part of a line after tying a clove hitch makes a very secure knot.

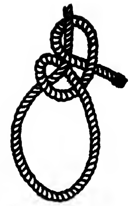


FIG. 27-6. Two half hitches. This knot is used in attaching a rope for anchoring or snubbing. It is easily and quickly made and easily untied.

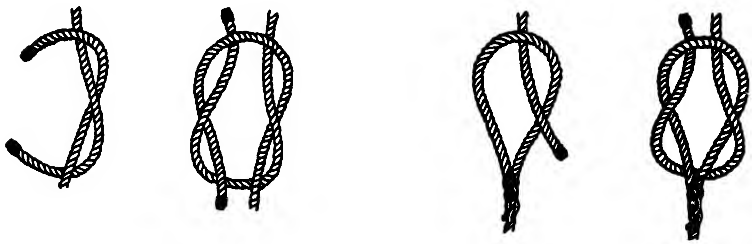


FIG. 27-7. Square knot. The square knot is used to tie two ropes together of approximately the same size. It will not slip and can usually be untied even after a heavy strain has been put on it. Linemen use the square knot to bind light leads, lash poles together on changeovers, on slings to raise transformers, and for attaching blocks to poles and crossarms.

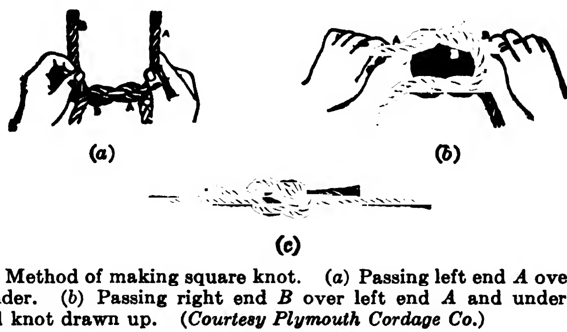


FIG. 27-8. Method of making square knot. (*a*) Passing left end *A* over right end *B* and under. (*b*) Passing right end *B* over left end *A* and under. (*c*) The completed knot drawn up. (*Courtesy Plymouth Cordage Co.*)

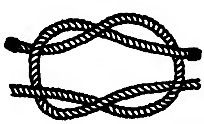


FIG. 27-9. Granny knot. Care must be taken that the standing and running parts of each rope pass through the loop of the other in the *same* direction, i.e., from above downward, or vice versa; otherwise a granny knot is made, which will not hold.

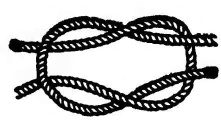


FIG. 27-10. Thief knot. In tying the square knot the standing part of both ropes must cross, as otherwise a useless knot known as the thief knot is formed.

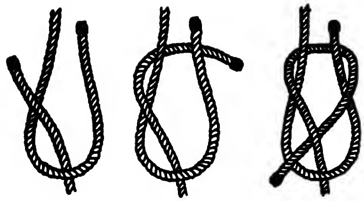


FIG. 27-11. Single sheet bend. The single sheet bend is used in joining ropes, especially those of unequal size. It is more secure than the square knot but is more difficult to untie. It is made by forming a loop in one end of a rope; the end of the other rope is passed up through the loop and underneath the end and standing part, then down through the loop thus formed.

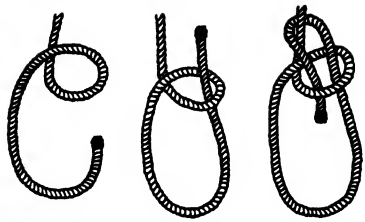


FIG. 27-12. The bowline. The bowline is used to place a loop in the end of a line. It will not slip or pull tight. Linemen use the bowline to attach come-alongs (wire grips) to rope, to attach tail lines to hook ladders, and as a loose knot to throw on conductors to hold them in the clear while working on poles.

(*a*) (*b*) (*c*)

FIG. 27-13. Method of making bowline knot. (*a*) Threading the bight from below. (*b*) Leading around standing part and back through bight C. (*c*) The completed bowline. (*Courtesy Plymouth Cordage Co.*)

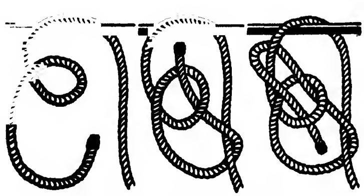


FIG. 27-14. Running bowline. This knot is used when a hand line or bull rope is to be tied around an object at a point that cannot be safely reached, such as the end of a limb.

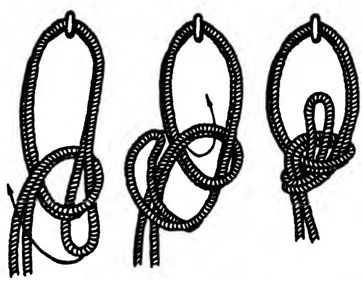


FIG. 27-15. Double bowline. This knot is used to form a loop in the middle of a rope that will not slip when a strain is put upon it.

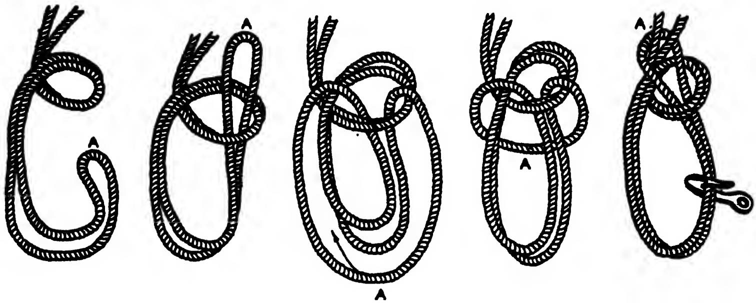


FIG. 27-16. Bowline on a bight. The bowline on a bight is used to place a loop in a line somewhere away from the end of the rope. It can be used to gain mechanical advantage in a rope guy by doubling back through the bowline on a bight much as a set of blocks. The bowline on a bight also makes a good seat for a man when he is suspended on a rope.

To tie this bowline, take the bight of the rope and proceed as with the simple bowline; only instead of tucking the end down through the bight of the knot, carry the bight over the whole and draw up, thus leaving it double in the knot and double in the standing part. The loop under the standing part is single.

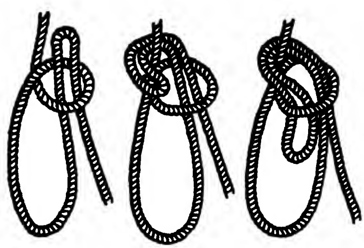


FIG. 27-17. Single intermediate bowline. This knot is used in attaching rope to the hook of a block where the end of the rope is not readily available.

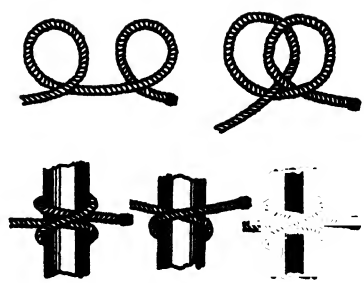


FIG. 27-18. Clove hitch. The clove hitch is used to attach a rope to an object such as a crossarm or pole where a knot that will not slip along the object is desired. Linemen use the clove hitch for side lines, temporary guys, and hoisting steel.

To make this hitch, pass the end of the rope around the spar or timber, then over itself, over and around the spar, and pass the end under itself and between the rope and spar as shown.

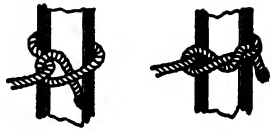


FIG 27-20 Timber hitch The timber hitch is used to attach a rope to a pole when the pole is to be towed by hand along the ground in places where it would be impossible to use a truck or its winch line to spot it The timber hitch is sometimes used to send crossarms aloft This hitch forms a secure temporary fastening which may be easily undone It is similar to the half hitch but is more secure Instead of the end being passed under the standing part of the rope once, it is wound around the standing part three or four times, as shown in the figure

FIG 27-19 Clove hitch used for lifting (*Courtesy General Electric Co*)

FIG 27-21 Rope timber hitch and half hitch The timber hitch will not slip under a steady pull but may slip when slack To make the timber hitch more secure a single half hitch may be taken a little farther along on the spar. (*Courtesy General Electric Co.*)

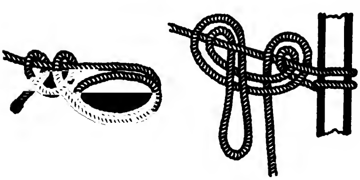


FIG 27-22 Snubbing hitches Knots used for attaching a rope for anchoring or snubbing purposes.

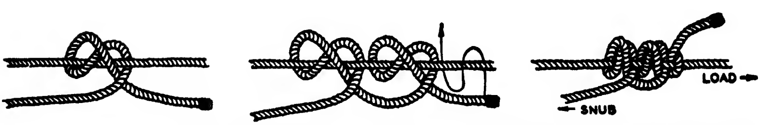


FIG 27-23 Taut rope hitch. This knot is used in attaching one rope to another for snubbing a load.

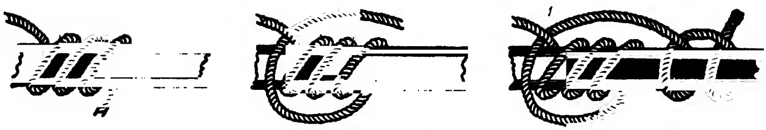


FIG. 27-24. Rolling bend. The rolling bend is often used for attaching the rope to wires that are too large for the wire-pulling grips. It is also used for skidding poles or timber.

FIG. 27-25. Blackwall hitch. This hitch consists of a loop with the end of the rope passed under the standing part and across the hook. Under load the hauling part jams the end against the hook. This hitch should be used only where the strain is steady and there is no hazard if the hitch slips. It is exceedingly useful when the hitch has to be made quickly or where the hitch must be changed frequently. (*Courtesy General Electric Co.*)

SPLICES

Eye Splice. When it is desirable to have a permanent eye at the end of a rope, such as a hand line, it can be formed by splicing the end of the rope into its side, thereby making an eye or side splice.

The steps in making the eye splice are illustrated and described in Fig. 27-26.

Short Splice. The short splice is sometimes called a butt splice because the line is unlayed and the ends are butted together. This splice can be used where it is desirable to splice together two ropes which are not required to pass over a pulley. This splice can be made quickly and is nearly as strong as the rope. As the diameter of the rope is nearly doubled, this type of splice is too bulky to pass through a sheave block.

The steps in making the short splice are illustrated and described in Fig. 27-27.

Long Splice. The long splice is sometimes known as a running splice. It is used to splice rope where it is undesirable to increase the diameter of the rope. A good long splice is hard to detect without close examina-

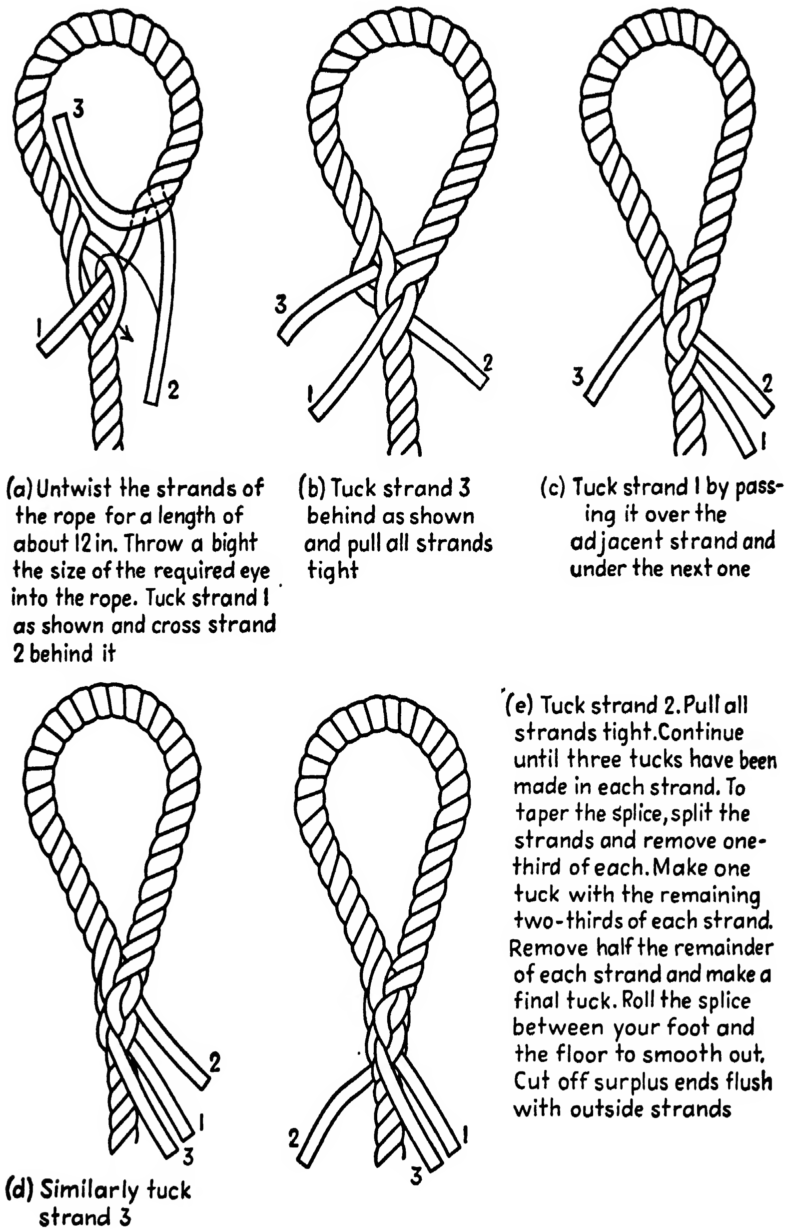
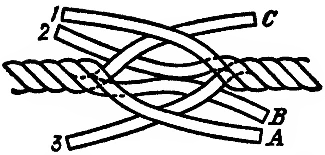
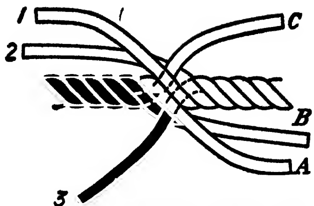


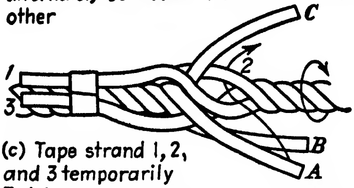
FIG. 27-26. Eye splice, fiber rope.



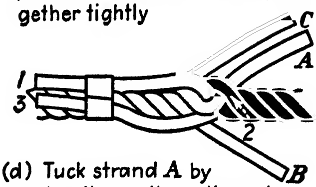
(a) Untwist strands of each rope for a length of about 12 in. Marry the two ropes by laying the strands of one rope alternately between the strands of the other



(b) Butt the ends of the rope together tightly

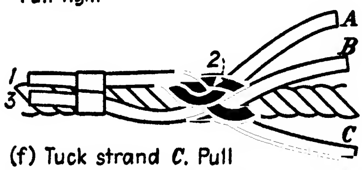


(c) Tape strand 1, 2, and 3 temporarily
Twist the rope as shown to provide an opening to tuck strand *A*

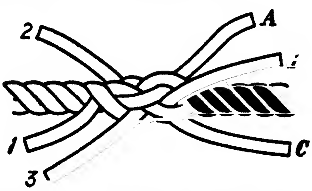


(d) Tuck strand *A* by passing it over the adjacent strand and under the next one
Pull tight

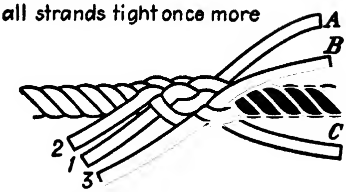
(e) Similarly tuck strand *B*



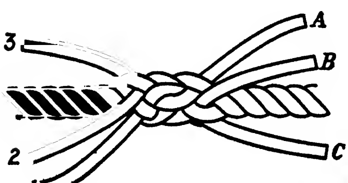
(f) Tuck strand *C*. Pull all strands tight once more



(g) Remove tape and tuck strand 1

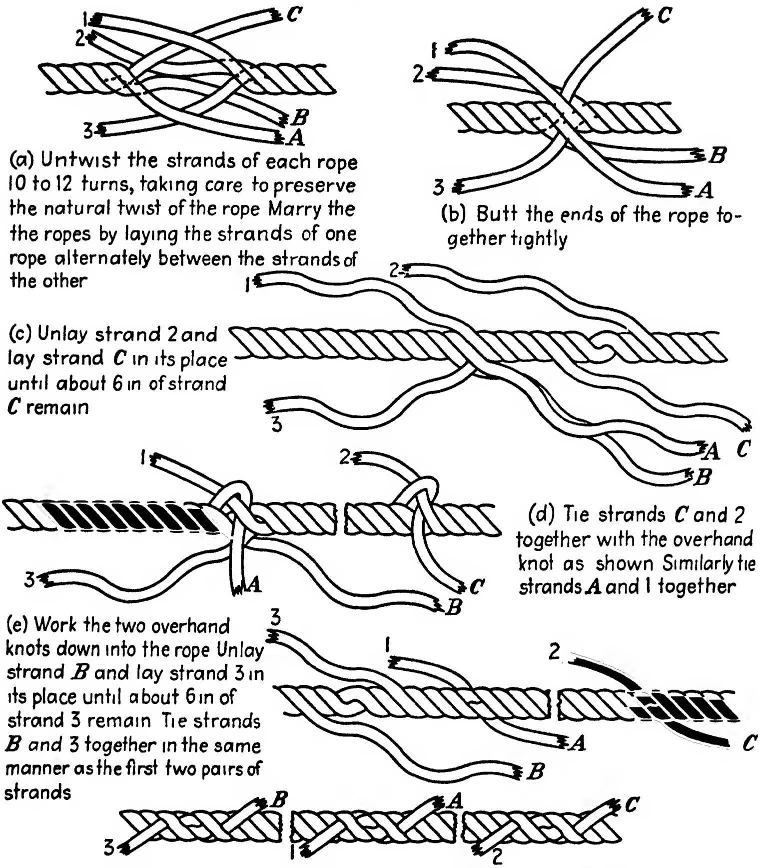


(h) Tuck strand 2



(i) Tuck strand 3. Pull all strands tight. Continue until three tucks have been made in each strand. To taper the splice, split the strands and remove one-third of each. Make one tuck with the remaining two-thirds of each strand. Remove half of the remainder of each strand and make a final tuck. Roll the splice between your foot and the floor to smooth out. Cut off surplus ends flush with outside strands

FIG. 27-27. Short splice, fiber rope.



(a) Untwist the strands of each rope 10 to 12 turns, taking care to preserve the natural twist of the rope Marry the the ropes by laying the strands of one rope alternately between the strands of the other

(b) Butt the ends of the rope together tightly

(c) Unlay strand 2 and lay strand *C* in its place until about 6 in of strand *C* remain

(d) Tie strands *C* and 2 together with the overhand knot as shown Similarly tie strands *A* and 1 together

(e) Work the two overhand knots down into the rope Unlay strand *B* and lay strand 3 in its place until about 6 in of strand 3 remain Tie strands *B* and 3 together in the same manner as the first two pairs of strands

(f) Untwist each strand a little to make it lay flat and tuck it by passing it over the other strand of the knot and under the adjacent strand To taper the splice, split the strands and remove one-third of each Make one tuck with the remaining two thirds of each strand Remove half the remainder of each strand and make a final tuck Roll the splice between your foot and the floor to smooth out Cut off surplus ends flush with outside strands

Fig 27-28 Long splice fiber rope The long splice is used for permanently joining two ropes which must pass through a close fitting pulley tion and will run freely through a sheave or blocks. Using a running splice, a damaged part of a long line can be removed from the line without detracting from its usefulness. The strength will be reduced, however.

The steps in making the long splice are illustrated and described in Fig. 27-28.

Reduction in Strength Due to Knots and Splices. Table 27-3 shows the extent to which the strength of manila rope is reduced when used in connection with some of the common knots and splices

TABLE 27-3. PERCENTAGE STRENGTH OF SPLICED OR KNOTTED ROPE

Type of Splice or Knot	Percentage Strength
Straight rope	100
Eye splice	90
Short splice	80
Timber hitch or half hitch	65
Bowline or clove hitch	60
Square knot or sheet bend	50
Overhand knot (half or square knot)	45

ROPE GEAR

Slings. The simplest sling consists of a short piece of rope whose ends are spliced together to form an endless piece of rope. Slings are used for lashing tools or material in place, for attaching blocks or snatch blocks to a pole, for lashing an old pole to a new pole temporarily, and for tying line wires up temporarily. Slings should be 6 to 10 ft long,

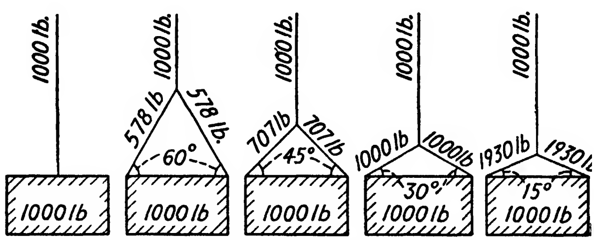


FIG 27-29 Sample loading of parts of lifting slings For loads other than 1,000 lb, use direct ratios. Sling angles less than 30 deg from horizontal are not recommended

depending, of course, on their planned use. Slings can also be made with an eye on one end and a dog knot on the other end.

Slings are also made of three-strand manila rope, spliced for a hook at one end and a hook or ring at the other.

Safe Loads. Before attempting to lift a load with a manila-rope sling, the weight of the load should be carefully estimated and a sling of the proper size selected. The greatest load can be lifted when all legs of the sling are in a vertical position and the least when the legs are nearly horizontal. Table 27-4 shows the safe loads that can be lifted with slings of different diameter rope when the legs are vertical and when they make angles of 60, 45, and 30 deg with the horizontal. When a rope sling has been in service for 6 months or more, even though it

TABLE 27-4. SAFE LOAD FOR SLINGS WHEN ROPE IS NEW

Approximate diameter of rope, in.	Safe load for single-leg vertical sling, lb	Safe load for double (two-leg) sling, lb, degree of angle with horizontal		
		60 deg	45 deg	30 deg
½	475	820	670	475
¾	970	1,675	1,375	970
1	1,620	2,800	2,290	1,620

shows no signs of wear or damage, the loads placed on it should be limited to one-half of those shown.

Figure 27-29 illustrates the manner in which the strain on the rope sling is increased when the angle with the horizontal decreases. Thus

FIG. 27-30. A typical three-part block and tackle. (*Courtesy A B. Chance Co.*)

at 60 deg the strain in the legs of the sling is only 578 lb for a 1,000-lb weight, whereas it is 1,930 lb for a 1,000-lb load when the angle is reduced to 15 deg. This is almost twice as great as the weight of the load lifted. At 30 deg the strain is 1,000 lb, which is the same as the weight of the load. Sling angles smaller than 30 deg are therefore not recommended.

If the sling is attached around a sharp corner, it should be carefully padded to prevent cutting.

Block and Tackle. Block and tackle are used for applying tension to line conductors when sagging in, for applying tension to guy wires, when

LOAD LIFTED	DIAGRAM OF RIGGING
2 times safe load on rope (approx.)**	Single block 2 parts Single block
3 times safe load on rope (approx.)**	Double block 3 parts Single block
4 times safe load on rope (approx.)**	Double block 4 parts Double block
5 times safe load on rope (approx.)**	Triple block 5 parts Double block
6 times safe load on rope (approx.)**	Triple block 6 parts Triple block
7 times safe load on rope (approx.)**	Quadruple block 7 parts Triple block

FIG. 27-31. Lifting capacity of block and tackle. **Less 20 per cent approximately for friction.

hoisting transformers, and for other general-purpose hoisting (see Fig. 27-30).

The use of block and tackle has two advantages: (1) the user can stand on the ground and pull downward while hoisting or lifting a load; (2) the manual force applied need only be a fractional part of the load lifted.

Mechanical Advantage. To find the pull required to lift a given weight, divide the weight by the number of ropes running from the movable block. The lead line or fall line is not to be counted. However, there is always some friction loss around the sheaves. This can be estimated at 20 per cent and added to the load to be lifted. The sketches in Fig. 27-31 show the various combinations of block and tackle employed to give mechanical advantages from 2 to 7. As mentioned above, the ratio of load to pull on the fall line is given by the number of ropes running from the movable block. The load that may be lifted is therefore the mechanical advantage times the safe load on the rope. For block and tackle using ½- and ¾-in. rope the safe loads are as given in Table 27-5. Normal uses for 4-in. blocks are sagging No. 4 and No. 6

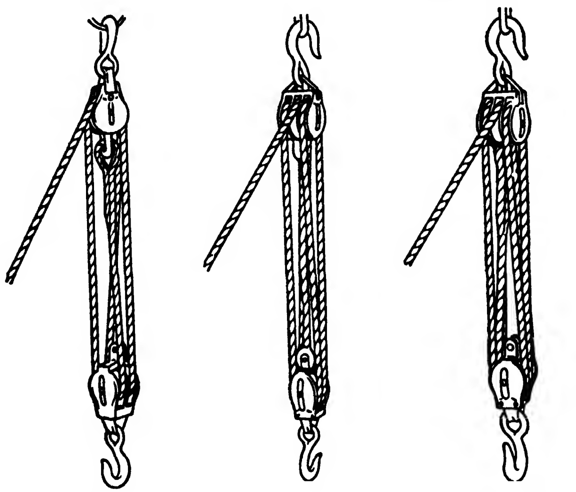


FIG. 27-32. Four-, five-, and six-part blocks and tackle

conductors and raising distribution transformers rated up to 37½ kva single phase. The 6-in. blocks are used for heavier work up to the limit of the tackle. Blocks having mechanical advantages of 4, 5, and 6 are illustrated in Fig. 27-32.

TABLE 27-5. SAFE LOADS ON BLOCK AND TACKLE USING ½- AND ¾-IN. MANILA ROPE

Tackle	Safe load, lb	
	4-in. block (½-in. rope)	6-in. block (¾-in. rope)
4 part (2 + 2).......	800	1,650
5 part (2 + 3).......	1,000	2,100
6 part (3 + 3).......	1,250	2,350

Mechanical advantages are 4, 5, and 6.

SECTION 28

Tree Trimming

Time for Pruning. Heavy pruning should properly be done in early spring or late fall. Electric companies have, as a rule, more time for this work during late fall, winter, and early spring; as a result, that is the time when heavy trimming is generally done. Furthermore, at that time of the year the leaves are off and it is easier to determine which branches should be taken off.

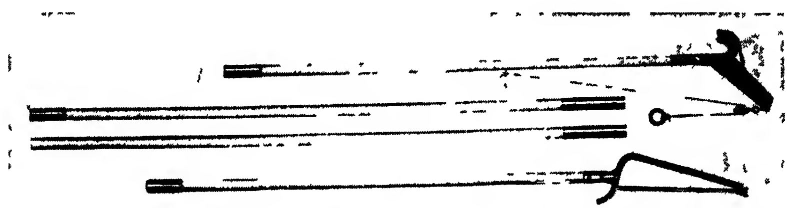


FIG. 28-1 Typical tree-trimming tools. View shows saw, hook with knife spring, and extension handles. (*Courtesy Leach Co.*)

Maples and birches, however, should never be cut between Dec. 1 and the time the leaves are out in spring, as the exposed wood filled with sweet sap is then subject to decay. Furthermore, wounds made at this time will often bleed badly, and the company may be called upon to pay for ruined clothes; during freezing weather icicles may form and drop on the first warm day.

Pruning Tools. The following tools are needed in tree trimming:

One 3-ft one-man saw for large limbs.

One small saw, 20 to 22 in. long, with coarse teeth so set as to make a wide cut.

One sharp drawshave or chisel.

One pole pruner with 12- to 14-ft handle (Fig. 28-1 and Fig. 28-2) and several hand lines, bull rope, and tackle.

One extension ladder 28 to 30 ft long.

Tree-pruner Equipment. For safety and proficiency, tree pruners should always work in ropes while in trees. These usually consist of a safety line with body sling, either as one unit or two separate parts in combination. Figure 28-3 illustrates the correct position of the body sling. A body sling is made up of a combination of rope and leather supports. It consists of a single loop around the waist with separate big loops all crossed in front at the center of the body. The safety line

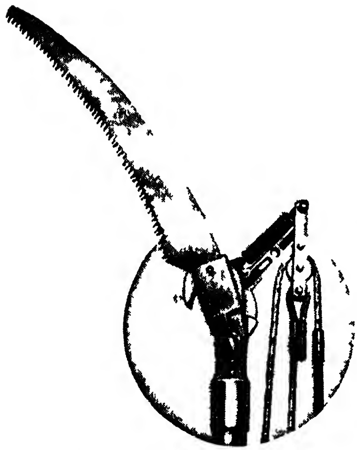


Fig 28-2 Close-up of tree-trimming head showing saw and hook with knife spring. (*Courtesy A. B. Chance Co.*)

Fig 28-3 Manner of fastening body sling and safety line The safety line is attached to the body sling with a clove hitch and secured by a taut line hitch (*Courtesy Edison Electric Institute*)

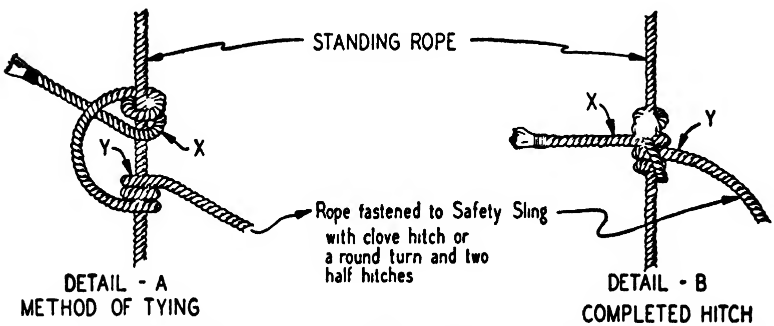


Fig 28-4. Tying a taut line hitch to a standing rope (*Courtesy Edison Electric Institute.*)

is a ½-in. rope 100 ft long attached to the body sling in front at the center of the body by means of a clove hitch and secured with a taut line hitch. The manner of tying a taut line hitch is illustrated in Fig. 28-4. The taut line hitch is used to regulate safely and easily the working position and is a device of major importance to all tree workers.

Permission. Permission for trimming must always be obtained first, either from the owner of the tree or from the city tree warden or forester, as the case may be. After the trimming rights are obtained, the trimming should be done by skilled men under the supervision of the person who obtained the trimming rights.

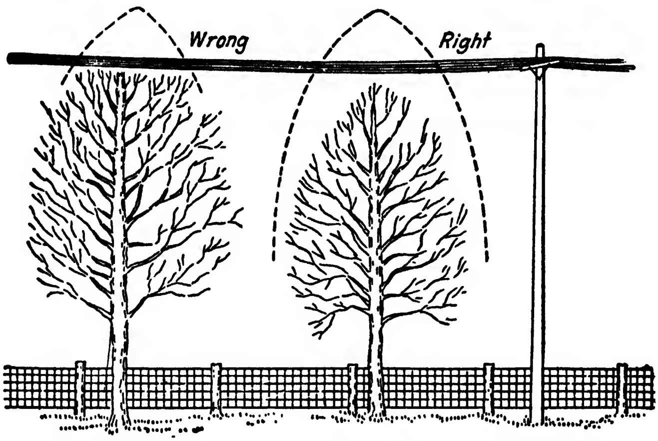


FIG. 28-5. Wrong and right method of trimming a tree that is growing into the line conductors. (*Courtesy Wisconsin Power & Light Co.*)

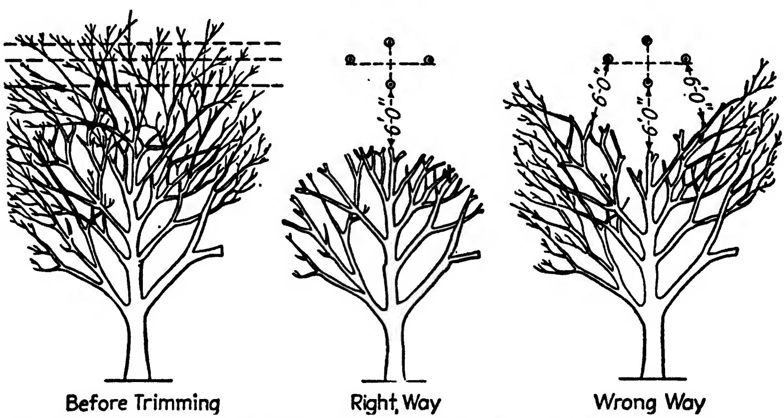


FIG. 28-6. Right and wrong ways of trimming a tree that has grown into the overhead line wires. (*Courtesy REA.*)

Right and Wrong Methods. Before giving in detail the various steps in pruning, a few illustrations will first be shown of the right and wrong methods of trimming. Figure 28-5 shows the right and the wrong method of trimming a tree that is growing up into the line conductors. Such a tree must be trimmed to remove the possibility of grounding the line conductors. Furthermore, broken limbs or trees falling onto the line wires may cause one or more poles to break during a storm. Where considerable trimming has to be done as in this case, the tree should be trimmed up so that it will be symmetrical as before and not flat topped. This is further illustrated in Fig. 28-6. While the trimmed tree on the

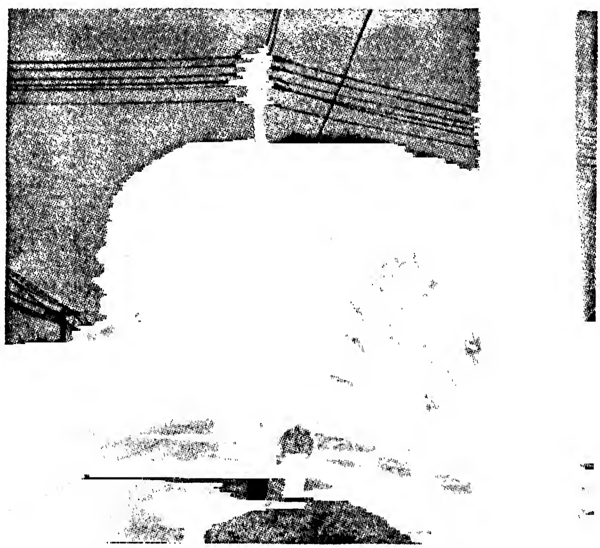


FIG. 28-7. A nicely shaped tree with ample clearance below line wires, one year after trimming. (*Courtesy Asplundh Tree Expert Co.*)

right will not interfere with the conductors, its appearance is very unsightly. In this case additional trimming should be done to restore the shape of the tree. The final appearance should be as shown in the middle view of Fig. 28-6. In general, no parts of the tree should be closer than 6 ft from open wiring. A well-trimmed tree is shown in Fig. 28-7.

TREE-TRIMMING PROCEDURE

Removing Large Branches. The procedure in the removal of a large side limb is shown in Fig. 28-8. The first cut is an undercut 10 to 12 in. out from the place where the final cut is to be made. This cut should be as deep as convenient. The sawing is usually continued until the weight of the limb binds the saw. The second cut is made about 6 in. farther out on the upper side of the branch. The reason for shifting out a few inches is to prevent the bark from being stripped back beyond the point of the final cut when the limb falls. The third cut is made from below close to the crotch or trunk of the tree. The fourth is from above, also close to the trunk. After the final cut has been made with the saw, a drawshave, chisel, or sharp knife should be used to smooth up the wound so that water will not collect and cause decay.

Lowering Large Limbs. Large branches that might cause damage to the line conductors or other property in falling should be carefully lowered with tackle. Figure 28-9 illustrates the manner of lowering a large limb which would otherwise fall directly into the line conductors. Before sawing the branch off, the branch is supported with two ropes, one at the butt and the other well out toward the end. The ropes are run through crotches in the branches above and secured to the trunk of

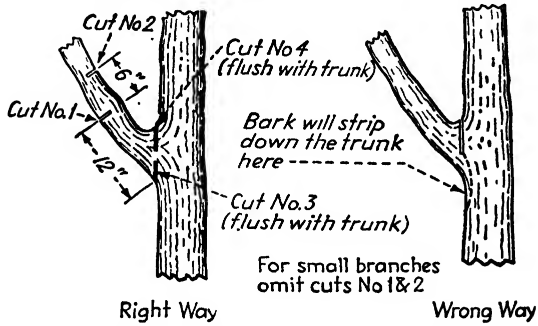


FIG. 28-8. Steps in right and wrong removal of a large side limb. (*Courtesy REA.*)

the tree. A third rope known as the guide rope is fastened to the branch at such a point that it can be used to swing the branch out from over the line conductors. After the sawing is completed, the branch is swung out to clear the line and then gradually lowered by means of the two supporting ropes.

Removing Vertical Branch. If the limb to be removed is a vertical limb, only two cuts are necessary, as shown in Fig. 28-10. If an attempt is made to remove the limb with one cut from above as shown in the right-hand view of Fig. 28-10, the bark will strip down on the trunk below the limb. Both cuts should be made approximately at an angle so that the stub will not collect water and start rotting. The first cut is upward and should continue about halfway through the limb. The second cut is downward as shown in the figure. This cut is continued until it meets the first cut. When the cut is completed, the stub should present a smooth surface.

Removing Small Branches. In the case of small branches it is not necessary to make three separate cuts. One cut with the saw close up against the limb, as shown in Fig. 28-11, is all that is necessary. Small twigs can be cut off with long-handled pruning shears. If small twigs are cut off on one side of a tree, it is well to trim the tree all round so as to keep the tree symmetrical. When trimming trees, all dead branches should be cut off as well as the ends of long scraggly limbs which have grown unsightly.

Treating the Wounds. After the wound is smoothed, it should be dressed with a heavy application of antiseptic. Common lead paint (white lead and oil—no turpentine) made the color of the bark is often

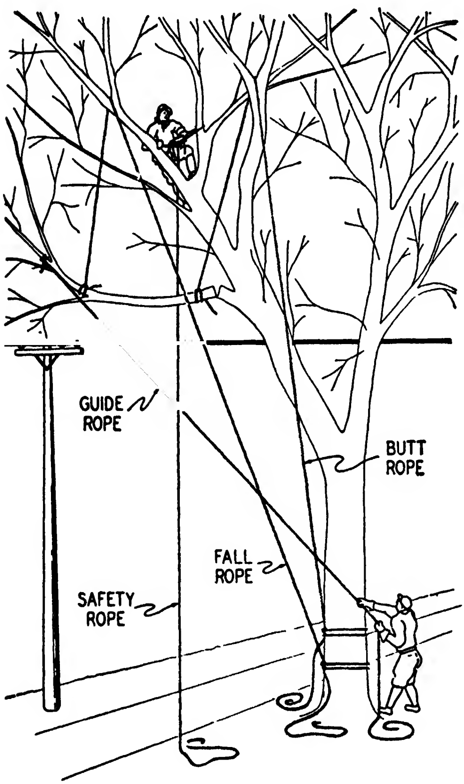


FIG. 28-9. Lowering large or hazardous limb with rope tackle. The two supporting ropes are called butt and fall rope; the third rope is the guide rope. (*Courtesy Edison Electric Institute.*)

used. Carbolineum or coal tar may also be used. Two or three coats should be applied if necessary.

Removing Brush. All brush and rubbish must be hauled away at once and not left overnight.

Poisonous Plants. When trimming trees and removing brush, there is always the possibility that a lineman may encounter plants which may cause skin poisoning. These include the following:

Poison Ivy. A plant that sometimes climbs trees and poles. It is also a crawling plant. Poison ivy has broad and glossy leaves always in clusters of three leaflets, two branching from the stem 1 in. or less below the center one.

Poison Oak. A low-growing erect plant, never climbing. The leaves are broad but not always glossy. Leaves in clusters of three. The dark green leaves are permanently and very heavily hairy on the undersurface.

Poison Sumac. A shrub or small tree which may grow to a height of

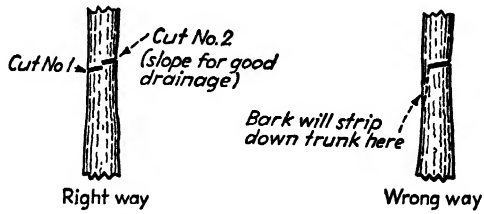


FIG. 28-10. The right and wrong steps in the removal of a large vertical limb. (*Courtesy REA.*)

20 ft. Smooth, glossy leaves are in the form of 7 to 13 oblong leaflets (always an odd number). Grows in swamps and low areas.

The poisoning from these plants is caused by an oily substance which gets on a person's skin. The poison can be conveyed by smoke, insects, clothing, and direct contact. The poisoning is more likely when the

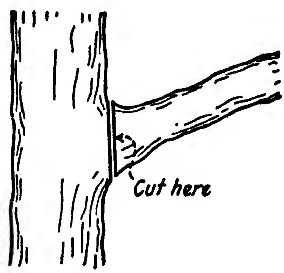


FIG. 28-11. How a small branch can be removed with a single cut.

skin is covered with perspiration. No one should consider himself immune to these poisons at all times nor after having had an attack.

If a worker suspects that he has been exposed to these plants or their oil, he should wash exposed areas of skin with warm water and ordinary brown laundry soap. Another way to prevent poisoning is to wash the exposed skin in rubbing alcohol and then rinse in clear water and dry the skin. No brush should be used, because it would irritate the skin.

SECTION 29

Signals for Line Work

In line construction many operations are performed with the use of power machines, such as hoists, cranes, winches, tractors, and trucks. The operators of these machines are given directions by the person directing the job. As the directions must often be given from a distance, hand and arm signals are employed.

The signals shown in the following illustrations have become quite standardized and are those generally used. Persons directing operations must be clearly visible at all times. Stopping the motion of any

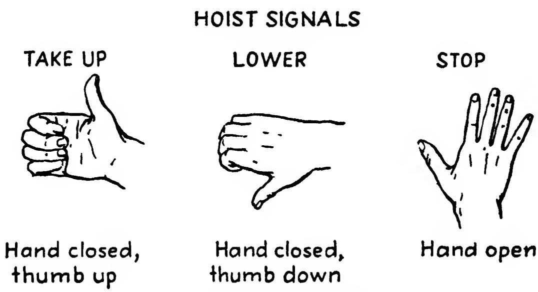


FIG. 29-1. Hoist signals.

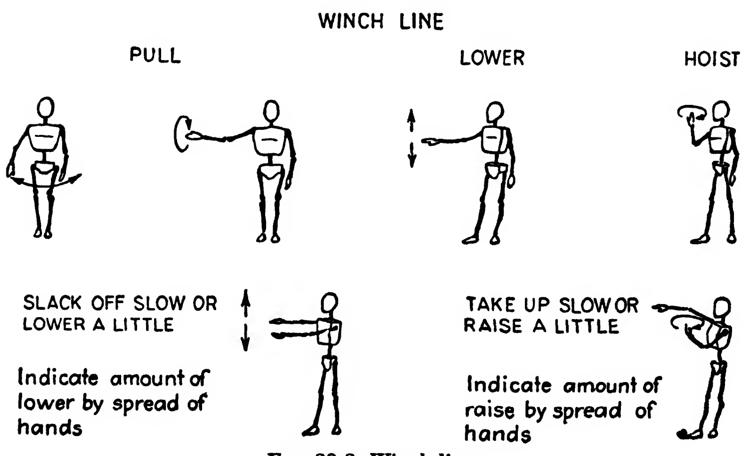


FIG. 29-2. Winch line.

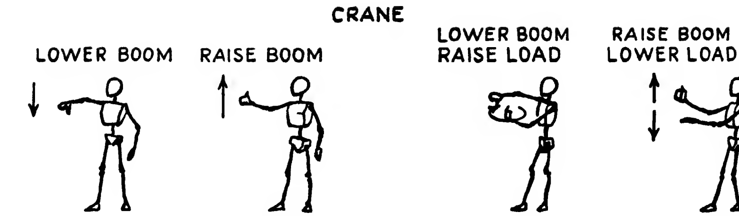


Fig 29-3 Crane

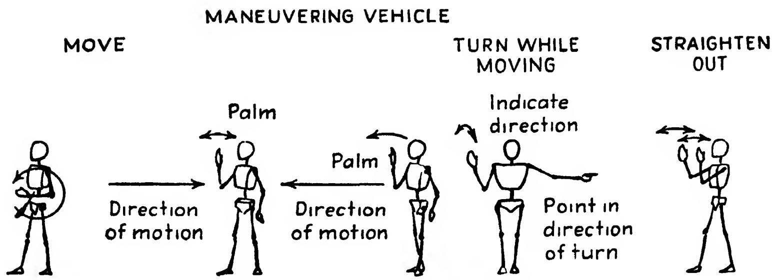


Fig 29-4 Maneuvering vehicle

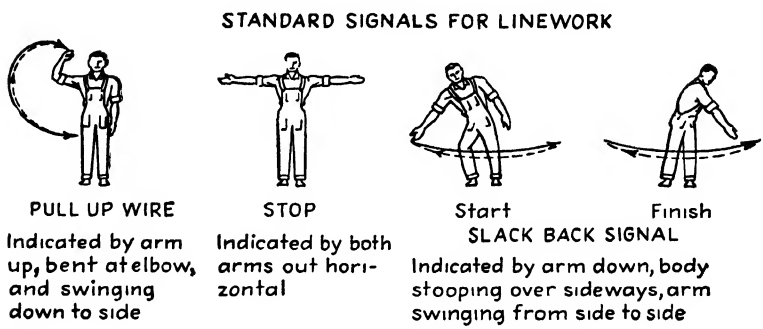


Fig 29-5 Standard signals for line work

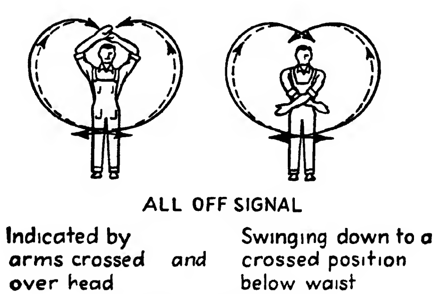


Fig 29-6 All-off signal.

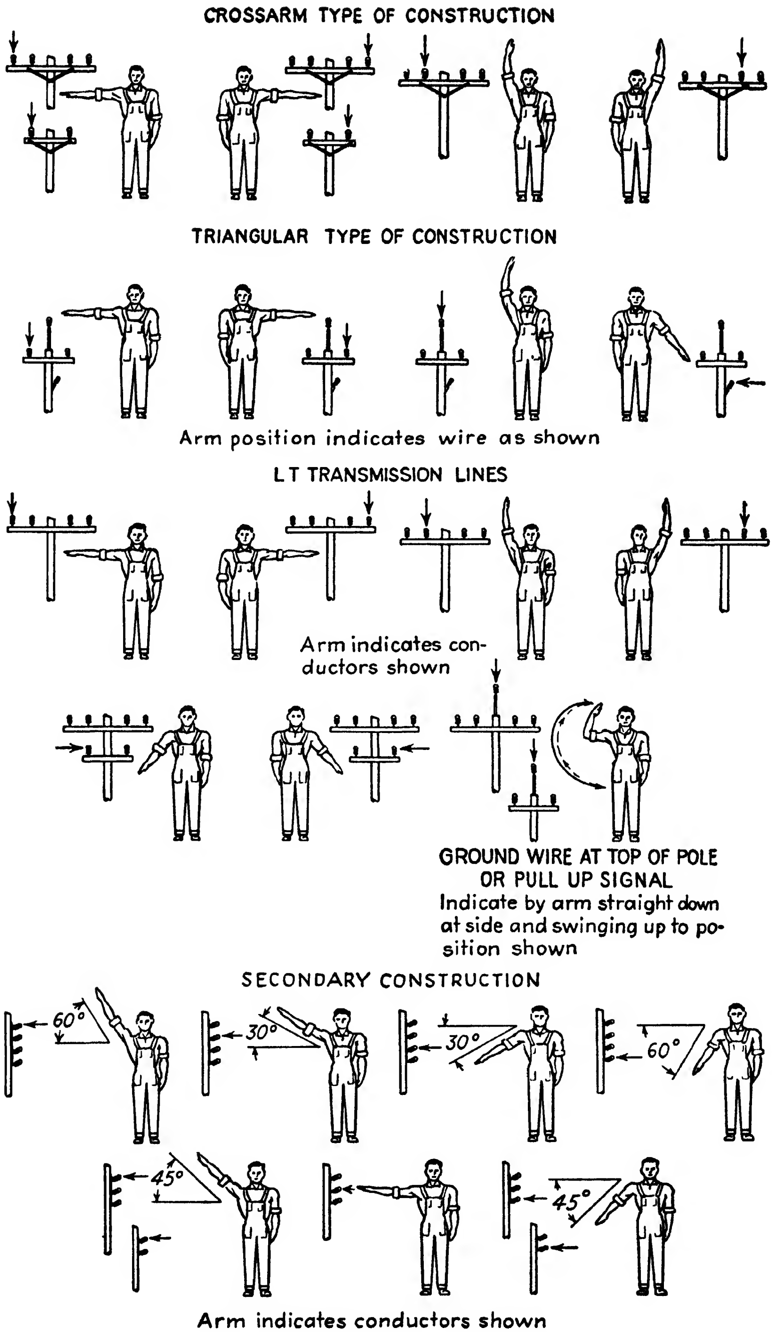
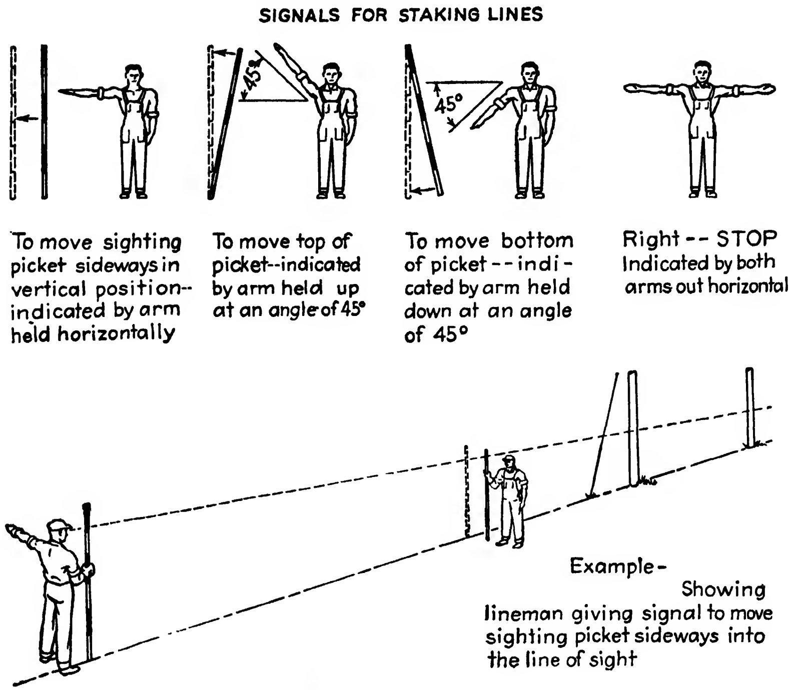


FIG 29-7. Line conductor signals.

Fig. 29-8. Signals for staking lines.



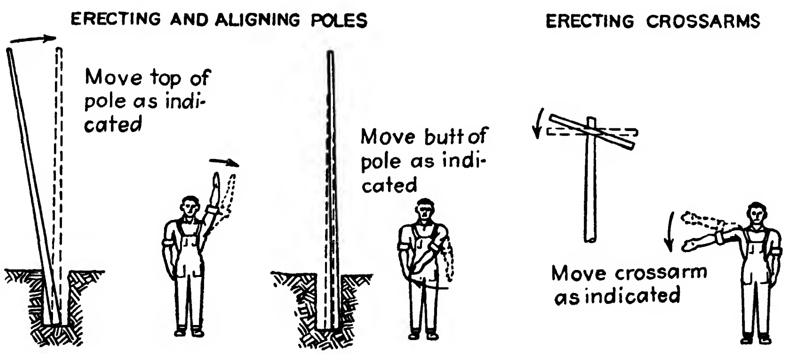


Fig. 29-9. Erection signals.

signal indicates to stop and hold. A sharp cry from anyone also means stop and hold. This, however, is the only signal that is accepted from anyone other than the person directing the work.

Figures 29-2 to 29-4 are reproduced through the courtesty of the Public Service Electric and Gas Company. Figures 29-1 and 29-5 to 29-9 are reproduced through the courtesy of the Ontario Hydro-Electric Power Commission.

SECTION 30

The Prone-pressure Method of Resuscitation

Follow These Instructions Even If the Patient Appears Dead. As soon as possible feel with your fingers in the patient's mouth and throat and remove any foreign body (tobacco, false teeth, etc.). If the mouth is tight shut, pay no more attention to it until later. Do not stop to loosen the patient's clothing, but immediately begin actual resuscitation. Every moment of delay is serious. Proceed as follows:

STANDARD TECHNIQUE

1. Lay the patient on his belly, one arm extended directly overhead, the other arm bent at elbow and with the face turned outward and resting on hand or forearm, so that the nose and mouth are free for breathing (see Fig. 30-1).

2. Kneel, straddling the patient's thighs, with your knees placed at such a distance from the hipbones as will allow you to assume the position shown in Fig. 30-1.

FIG. 30-1. Position in which patient should always be placed and kept until conscious; also first position of operator starting artificial respiration.

Place the palms of the hands on the small of the back with fingers resting on the ribs, the little finger just touching the lowest rib, with the thumb and fingers in a natural position and the tips of the fingers just out of sight (see Fig. 30-1).

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3. With arms held straight, swing forward slowly so that the weight of your body is gradually brought to bear upon the patient. The shoulder should be directly over the heel of the hand at the end of the forward swing (see Fig. 30-2). Do not bend your elbows. This operation should take about 2 sec.

4. Now immediately swing backward so as completely to remove the pressure (see Fig. 30-3).

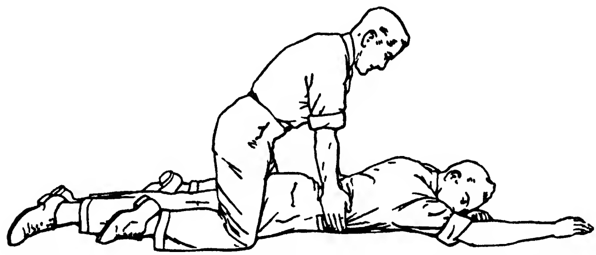

FIG. 30-2. Second position of operator giving artificial respiration.

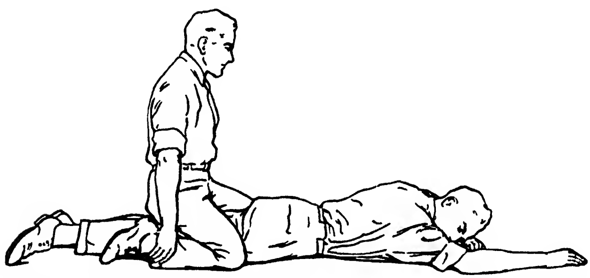

FIG. 30-3. Third position of operator giving artificial respiration.

5. After 2 sec, swing forward again. Thus repeat deliberately twelve to fifteen times a minute the double movement of compression and release, a complete respiration in 4 or 5 sec.

6. Continue artificial respiration without interruption until natural breathing is restored, if necessary, 4 hr or longer, or until a physician declares the patient is dead.

7. As soon as this artificial respiration has been started and while it is being continued, an assistant should loosen any tight clothing about the patient's neck, chest, or waist. *Keep the patient warm.* Do not give any liquids whatever by mouth until the patient is fully conscious.

8. To avoid strain on the heart when the patient revives, he should be kept lying down and not allowed to stand or sit up. If the doctor has not arrived by the time the patient has revived, he should be given some stimulant, such as one teaspoonful of aromatic spirits of ammonia

in a small glass of water, or a hot drink of coffee or tea, etc. The patient should be kept warm.

9. Resuscitation should be carried on at the nearest possible point to where the patient received his injuries. He should not be moved from this point until he is breathing normally of his own volition and then moved only in a lying position. Should it be necessary, because of extreme weather conditions, etc., to move the patient before he is breathing normally, resuscitation should be carried on during the time that he is being moved.

10. A brief return of natural respiration is not a certain indication for stopping the resuscitation. Not infrequently the patient, after a temporary recovery of respiration, stops breathing again. The patient must be watched, and if natural breathing stops, artificial respiration should be resumed at once.

11. In carrying out resuscitation it may be necessary to change the operator. This change must be made without losing the rhythm of respiration. By this procedure no confusion results at the time of change of operator and a regular rhythm is kept up.

GENERAL POINTS TO BE OBSERVED IN ALL CASES REQUIRING RESUSCITATION

Take Care of the Patient. An unconscious person becomes cold very rapidly, and chilling means a further strain on a vitality already weakened. Experience has shown that the cold to which the victims of gassing, electric shock, or drowning are often carelessly exposed is probably the most important cause of pneumonia, and this disease is the most dangerous aftereffect of all these accidents. As far as possible keep the patient covered and warm both during and after resuscitation. Use hot pads, hot water bottles, hot bricks, radiant heaters, or other similar means, but remember that an unconscious man has no way of telling you when he is being burned.

Do not permit the patient to exert himself. If it should be necessary to move him, keep him lying down.

Medicines and Medical Help. Never give an unconscious man anything to drink. It may choke him. Medical science knows no drug which of itself will start the breathing in a patient whose breathing has ceased.

There is great danger of prematurely ceasing resuscitation. Breathing has been reestablished after 8 hr of resuscitation in cases of electric shock and of gas asphyxiation. Therefore, the ordinary and general tests for death should not be accepted, and any doctor should make several very careful examinations and be sure specific evidence, such as the onset of rigor mortis, is present before the patient is pronounced dead and resuscitation is stopped.

GAS POISONING AND THE INHALATION TREATMENT

What Carbon Monoxide Does. The reason that automobile exhaust gas, the gases from coal heating furnaces, the smoke from fires, producer gas, coke-oven gas, blast-furnace gas, carbureted water gas, coal gas, and other manufactured gases are poisonous if actually breathed is that they all contain carbon monoxide.

When carbon monoxide is breathed, it combines with the blood. The more carbon monoxide there is in the blood, the less oxygen the blood will hold.

The gas victim becomes asphyxiated just as if he were being gradually choked to death. As low as one-tenth of 1 per cent of carbon monoxide, or even less, in the air will kill a man in time; 1 per cent will kill in a few minutes.

If the patient does not die in the gas but is removed to fresh air, the carbon monoxide leaves the blood in a few hours. The quicker it is breathed out of the blood, the better are the chances of recovery. If the asphyxiation has not been too long or severe, and the first-aid treatment has been prompt and correct, the patient will recover completely.

Protect Yourself. Do not breathe gas yourself even for a short time. If it does not overcome you, it will cut down your strength. If you have to go into gas to get a man out, remember that nobody is immune. Protect yourself.

A handkerchief tied about the nose and mouth is not a gas mask; many have died in the belief that it is. It does not stop carbon monoxide; it simply filters off the irritating fumes in smoke, but carbon monoxide itself does not irritate the throat and has no smell. It gives no warning. It often paralyzes the legs first, and so suddenly that the man even though conscious may fall down and cannot walk or crawl.

If you must go into gas or smoke, wear a mask equipped with an air hose or an oxygen-breathing apparatus.

Get the Man Out of Gas. When a man is overcome by gas, the first thing to do is to get him into fresh air quickly. Fresh air does not mean out of doors in cold weather. Many men have walked from a warm room containing gas to collapse into the cold outside air. Take the patient to a room free from gas and comfortably warm. Be quick, but do not be unnecessarily rough. Remember you are dealing with a human being.

If the patient is not breathing or is breathing weakly, start artificial respiration at once and have someone else telephone the utility company for an inhalator to be used in conjunction with artificial respiration.

The Use of Inhalation to Drive Carbon Monoxide Out of the Blood. In gas poisoning, oxygen used properly helps to drive the carbon monoxide from the blood. Sometimes the patients do not breathe well after they are brought out of the gas. In fact, some stop breathing entirely.

Even those who breathe normally often cannot get the gas out of their blood fast enough to prevent their being very sick or even dying afterward. Pure oxygen does not stimulate the breathing. For this reason it is recommended that a mixture of about 5 per cent of carbon dioxide and 95 per cent oxygen be used. The carbon dioxide causes the patient to breathe much more deeply and thus allows the oxygen to drive the carbon monoxide out of the blood very rapidly. The carbon dioxide also keeps the breathing from stopping. It starts breathing more quickly in those on whom it may be necessary to do artificial respiration. It is useless to try to give an inhalation with a tank and funnel or any such makeshift. An approved inhalator with its oxygen–carbon dioxide tank and close-fitting mask must be used.

It should be distinctly understood that the inhalator is an aid to resuscitation and does not take the place of the prone-pressure method. The two may be used simultaneously until the patient breathes without assistance, after which the inhalation may be continued if necessary.

General Directions for Giving the Inhalation Treatment. Without interrupting the rhythm of respiration, an assistant should put the mask over the patient's nose and mouth. The lower part should go well down on the chin. Press down firmly over the nose. Try to prevent leaks.

As soon as the mask is properly applied, adjust the apparatus to give the patient an ample supply of the oxygen–carbon dioxide mixture. In any case continue the inhalation for at least 20 min. In severe cases the inhalation should be prolonged. In using the inhalation treatment, the patient should be kept in the prone position, and when treatment is prolonged a better chance for recovery is given if the head is 6 or 8 in. lower than the feet. This position promotes the flow of blood to the heart.

ELECTRIC SHOCK

Breaking the Contact. The victim must be freed from contact with the line conductor as promptly as possible. Use a dry stick, dry rope, dry coat, or other nonconductor. Use of your own hands without protection is dangerous and may add another victim to the accident.

The Action of the Electric Current. In electric shock the current may pass through the breathing center at the base of the brain and cause this center to stop sending out the nervous impulses which act upon the muscles responsible for breathing. As a consequence, breathing stops abruptly. If the shock has not been severe, after a time the breathing center recovers and resumes the vitally necessary duty of sending impulses to the muscles of breathing. In such cases the immediate use of the prone-pressure method substitutes this artificial breathing for the natural respiration of the patient. As has been pointed out, the current may so paralyze the breathing center as to require 8 hr for recovery, and the prone method must be used unceasingly through this entire time.

Victims of electric shock of this sort are unconscious, but in them the heart and blood circulation continue. Their treatment demands artificial respiration with the greatest possible promptness. The method for giving this and the general points for the care of such patients have been given.

In some cases the electric current affects the heart. Under these circumstances the heart suddenly ceases to pump blood. Many cases of electric shock escape this heart effect, and even an experienced examiner requires time to assure himself it has occurred. Consequently, it is the duty of those first reaching the shocked person to give artificial respiration by the prone method at once and to continue until natural breathing is restored or until the onset of rigor mortis.

DROWNING

In a case of drowning favorable for resuscitation, breathing has ceased, but the heart beat and the circulation of the blood continue.

Start artificial respiration at once. The pressure you must exert is the best means of forcing water out of the lungs and breathing passages. If, during artificial respiration, the body can be placed on a door or other flat surface, so that the head and chest are 6 to 8 in. lower than the feet, drainage of water from the air passages will be assisted and the circulation of the body improved.

Pay particular attention to maintaining warmth. The wet body chills rapidly.

SECTION 31

*Standard Technique for Executing the Back Pressure–Arm Lift Method**

Position of the Subject (Fig. 31-1). Place the subject in the face-down prone position. Bend his elbows and place the hands one upon the other. Turn his face to one side, placing the cheek upon his hands.

Position of the Operator (Fig. 31–2). Kneel on either the right or left knee at the head of the subject, facing him. Place the knee at the

Fig. 31-1. Position of the subject.

Fig. 31-2. Position of the operator.

side of the subject's head close to the forearm. Place the opposite foot near the elbow. If it is more comfortable, kneel on both knees, one on either side of the subject's head. Place your hands upon the flat of the subject's back in such a way that the heels lie just below a line running between the armpits. With the tips of the thumbs just touching, spread the fingers downward and outward.

Compression Phase (Fig. 31-3). Rock forward until the arms are approximately vertical, and allow the weight of the upper part of your body to exert slow, steady, even pressure downward upon the hands. This forces air out of the lungs. Your elbows should be kept straight and the pressure exerted almost directly downward on the back.

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Position for Expansion Phase (Fig. 31-4). Release the pressure, avoiding a final thrust, and commence to rock slowly backward. Place your hands upon the subject's arms just above his elbows.

FIG. 31-3. Compression.

FIG. 31-4. Position for expansion phase.

Expansion Phase (Fig. 31-5). Draw his arms upward and toward you. Apply just enough lift to feel resistance and tension at the subject's shoulders. Do not bend your elbows, and as you rock backward the subject's arms will be drawn toward you. Then drop the arms to the ground. This completes the full cycle. The arm lift expands the chest by pulling on the chest muscles, arching the back, and relieving the weight on the chest.

FIG. 31-5. Expansion.

The cycle should be repeated twelve times per minute at a steady, uniform rate. The compression and expansion phases should occupy about equal time, the release periods being of minimum duration.

Additional Related Directions. It is all important that artificial respiration, when needed, be started quickly. There should be a slight inclination of the body in such a way that fluid drains better from the respiratory passage. The head of the subject should be extended, not flexed forward, and the chin should not sag lest obstruction of the respiratory passages occur. A check should be made to ascertain that the tongue or foreign objects are not obstructing the passages. These aspects can be cared for when placing the subject into position or shortly thereafter, between cycles. A smooth rhythm in performing artificial respiration is desirable, but split-second timing is not essential. Shock should receive adequate attention, and the subject should remain recumbent after resuscitation until seen by a physician or until recovery seems assured.

SECTION 32

*Pole-top Resuscitation**

Definition. Pole-top resuscitation is a technique by means of which artificial respiration may be given to a lineman who, while working on a pole, receives an electric shock which suspends normal respiration. Aid can thus be given immediately without the delay incident to lowering the victim from the pole in order that he may be laid in the prone position.

Pole-top resuscitation is intended to supplement the prone-pressure method and is for use as an emergency measure under those conditions where it is impossible to quickly place the shock victim in the prone position.

GENERAL INSTRUCTIONS

Signal. Any member of a line crew who observes that a man on a pole has received an electric shock shall clearly and distinctly call out. This is to be followed by an immediate indication of where the victim is and the calling out of his name.

Precautions. Those who go to the aid of an electric-shock victim on a pole shall take all precautions for their safety. Rescuers who are on poles shall descend carefully. Whereas it is important that the victim be reached and artificial respiration started as quickly as possible, undue haste, with the accompanying exhaustion of rescuer or operator, may lessen his ability to do what is required when he reaches the victim.

Protection. The rescuer shall wear rubber gloves and rubber sleeves (if required) and, as he climbs and approaches the victim, he shall observe pole conditions and in the safest way to himself proceed to free the victim from contact, if this is necessary. He must do this in a safe manner that does not expose any unprotected portion of his body to contact with the victim's body or any nearby uncovered elements of the electrical system (Fig. 32-1).

Procedure. The rescuer shall examine surrounding conditions and, if satisfied that artificial respiration can be safely administered, proceed to do this with the least delay after freeing the victim from contact, if this is necessary.

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He will not take time to place rubber protective equipment in proper position or restore any that has become dislodged unless this is essential to the safe administering of resuscitation.

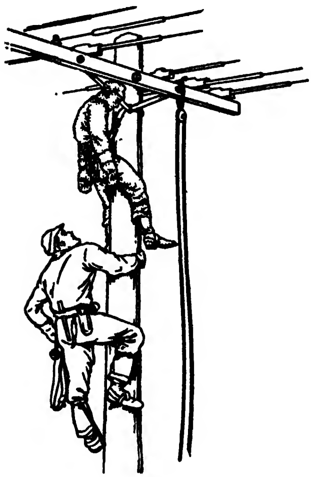

FIG. 32-1. Rescuer observes pole conditions and plans his action. He will remove any tools from victim's belt that may injure victim or himself.

If he should decide that it is not safe to attempt resuscitation, he shall proceed with arrangements for lowering the victim as quickly as can be safely done.

POLE-TOP TECHNIQUE

Clearing the Victim. The first person to reach the victim clears him from electrical contact, letting him hang alongside the pole from the safety strap.

Administering Artificial Respiration. The operator (one who will administer artificial respiration) takes a position on the pole below the victim, and after placing his safety strap around the pole (at a point above victim's spurs) proceeds to work his way upward with one leg of the victim on either side of his safety strap and with the victim's body between himself and the pole (see Alternate Approaches on page 32-5). Tools which may interfere with resuscitation or injure the rescuer should be removed from the victim's belt. When the safety strap is as high as possible between the legs of the victim, the victim is held in a straddle position on the operator's safety strap. The operator takes a step up and places the victim in position for resuscitation. The victim's safety strap should remain around the pole and can be effectively used by the operator as an aid in keeping the victim in the desired position. It should not be unsnapped or cut until the victim is to be lowered or is effectively supported by a hand line.

If the victim's mouth can be quickly examined, it should be cleared of foreign substances and the tongue pulled forward to clear the air passage. No time should be wasted on these details. The head should then be pushed slightly forward.

The operator encircles with his arms the waist of the victim (underarm), placing both hands on the abdomen, thumbs below the lower ribs and fingers touching (Fig. 32-2).

With his arms and hands, the operator compresses the victim's abdomen in an upward motion. At the finish of the stroke, the hands

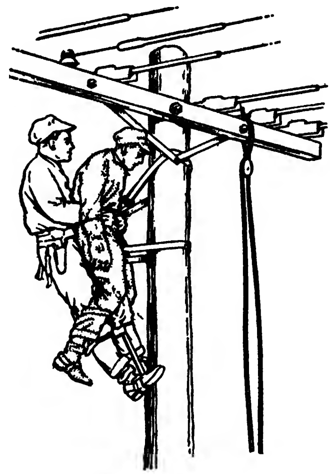

FIG. 32-2. Victim in position on operator's belt for artificial respiration by the pole-top method. Note that operator's hands are below victim's belt.

are cupped with the fingers depressing the abdomen under the breastbone. The pressure is then quickly released and reapplied at a frequency of twelve to fifteen per minute, until the victim regains consciousness or is to be lowered to the ground.

If the victim recovers sufficiently to breathe naturally, the operator should retain him in position and under control until the violence sometimes associated with recovery has passed and the victim has become rational. The operator must be prepared to restrain the victim's arms in any case of violence whether during or after resuscitation and thus prevent any second contact where conditions make this possible. Artificial respiration is to be immediately resumed if the victim again ceases to breathe.

Additional workmen, as assembled, will obtain and arrange rope rigging on the structure, securing the victim to the lowering line without interfering with the operator's motion (Figs. 32-3 and 32-4).

Lower to the Ground. As soon as the tackle has been adjusted, the victim is lowered to the ground (see When to Lower Victim on page 32-6). A fiber hand line of strength equivalent to at least a ½-in. diameter manila rope should be used. Lines of ⅝ or ¾ in. are considered preferable. This line should first be passed over a crossarm and not over crossarm braces, sharp-edged surfaces, or through a pulley. The line should be passed under the arms and secured, preferably in front, by at least three half hitches (see Alternate Hitches on page 32-8).

Lay on the Ground. Whether or not the victim has fully recovered and is breathing when he reaches the ground, he should be laid prone at once and in proper position for the immediate administering of artificial

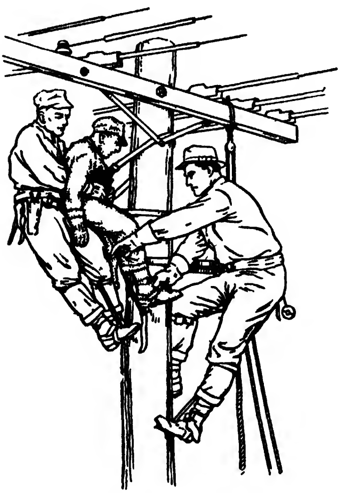

FIG. 32-3. Assistant rescuer removes climbers and all remaining tools from victim's belt. Attached to his belt is the rope which will be used to lower the victim.

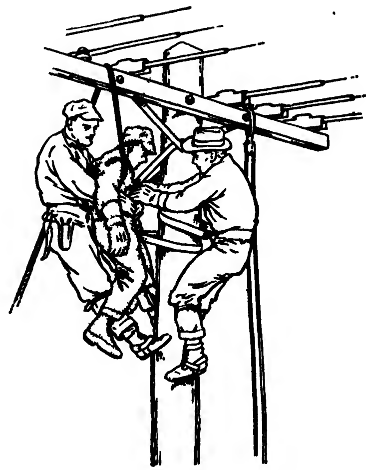

FIG. 32-4. Assistant rescuer has put line hose in position to cover exposed wire and placed adequate line about victim's body. Strain is taken by assistants on ground, and victim's belt is removed.

respiration by the prone-pressure method if this should become necessary. At this time the victim must receive proper treatment for shock and especially be kept warm. When it is apparent that artificial respiration is no longer necessary, care of the victim should be continued in accordance with regular first-aid procedure until medical help is obtained.

PROCEDURE OF ASSISTANT RESCUERS

Assistant rescuers should wear rubber gloves. Rubber sleeves should also be worn by any assistant who, in his movements, may expose his arms to contact with wires that are alive or may become alive. Assistants should be very deliberate, taking care not to interfere in any way with the operator.

Assistants should make certain that neither the victim nor the operator is exposed to live conductors and should cover all possible sources of contact, making certain that line hose, blankets, etc., have not shifted. They should remove the victim's climbers and also any remaining tools from his belt to prevent possible injuries.

They should stand by to assist in lowering the victim to the ground when the operator gives the word (see last paragraph under When to Lower Victim on page 32-8).

Medical aid should be summoned as soon as possible.

TRAINING OF CREWS ESSENTIAL

In order that this method may be administered in the most efficient manner, all line crews who are to use it should be trained and drilled in this technique until it has been thoroughly mastered. Such training will eliminate loss of time, increase efficiency of the resuscitation process, put rescuers at ease, and avoid needless haste, thus guarding against accidents.

It is recommended that crews that have been trained practice the pole-top method and the prone-pressure method on regular schedule of not less than once in every 3-month period.

Training procedure must ensure the safety of both rescuers and practice victims. Of special importance is care in the placing of safety belts, fastening snaps in D rings, and the correct position of operator's spurs in pole.

AFTER-SHOCK PRECAUTIONS

A victim of electric shock should not be allowed, after resuscitation, to climb down the pole or other structure unassisted. He should be supported by a hand line and lowered thereby.

Attention is called to the importance of immediate rest for any victim of serious electric shock, especially if there has been unconsciousness. He should be under constant observation and should not be allowed to sit up or walk until placed in the care of a doctor.

GENERAL COMMENTS

Other Applications. Pole-top resuscitation may also be applied in situations where artificial respiration is required but where the victim cannot be placed quickly in the conventional prone position, such as when in a boiler between tubes.

Alternate Approaches. Experience has shown that other methods of placing the victim in position are practicable and even preferred under some conditions. The more common variations from the method described are as follows:

One Leg over Head. Rescuer puts his safety strap about pole a little below the line of the victim's body belt. Rescuer then grasps one of victim's legs, lifting it well above rescuer's head. Rescuer then swings victim's body so that he passes his head under and between victim's legs. The victim should now be astride rescuer's safety. Rescuer takes two short steps upward and proceeds with resuscitation (Fig. 32-5).

Side Saddle. Rescuer places safety strap around pole on a line with the victim's hips. Rescuer then reaches down and takes hold of

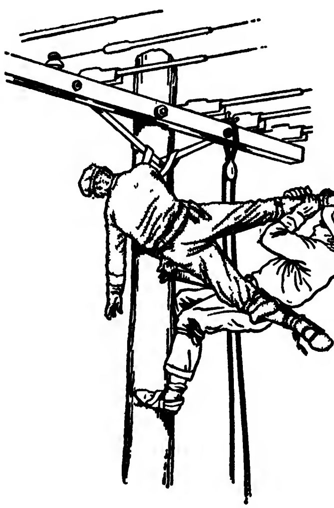

FIG. 32-5. "One-leg-over-head" method of placing victim in position on rescuer's belt. Technique employed guards against injury to rescuer's person or gloves from victim's spurs.

victim's legs slightly below the knees and elevates them, making the victim's body pivot in his own safety belt. He then takes two short steps upward, pulls victim back against his chest, and proceeds with resuscitation. (This procedure is found to be desirable when pole conditions make impossible or difficult the approaches suggested under Lower to the Ground or in preceding paragraph. It can be used either right or left as pole conditions make desirable.) (Figs. 32-6 and 32-7.)

Both Legs over Head. Rescuer places safety strap around pole on a line with victim's hips. Rescuer then reaches downward and grasps both legs of victim slightly below the knees and swings both legs over his head. This places the victim on rescuer's safety strap in side-saddle position with legs over one side. Rescuer then proceeds with resuscitation. (This is an alternate to the "side saddle" for conditions where it is best to swing the victim's legs over to the other side of the operator.) (Figs. 32-8 and 32-9.)

When to Lower Victim. The length of time that resuscitation should be continued on the pole will depend upon circumstances. Everything

FIG. 32-6. "Side saddle"—first position—with right hand under victim's knees and left hand on shoulder, rescuer pivots victim in his belt.

FIG. 32-7. "Side saddle"—final position—with victim's body balanced in his belt, rescuer has moved up and pulled victim onto his belt.

FIG. 32-8. "Two legs over head"—first position—rescuer places right hand on victim's right leg iron as shown and with left hand keeps victim's legs together.

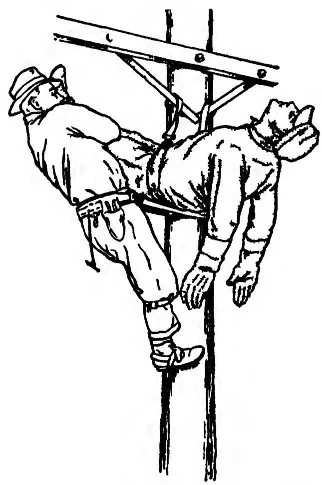

FIG. 32-9. "Two legs over head"—second position—rescuer has swung victim's legs to other side of pole. As victim's body pivots in belt, rescuer proceeds to complete side-saddle position as before but reversed. See Fig. 32-7.

considered, it is deemed desirable to get the victim down from the pole as soon as this is advisable; but the operator applying artificial respiration renders the more valuable service by continuing uninterruptedly with resuscitation.

Present good practice suggests the following:

In the interest of promoting careful, unhurried action, a minimum of 50 respirations is suggested before lowering. This accomplishes two desirable things:

It relieves all workers of anxiety—affording a period of approximately four minutes for preparations to lower.

It provides for the giving of artificial respiration for a sufficiently long time to effect resuscitation in many cases and establishes a good beginning for those who will need to be worked on longer.

Pole conditions and also the condition of the victim will determine how much longer resuscitation should be continued on the pole. If conditions are not too favorable, victim should be lowered when all is ready. If victim is showing signs of recovery and pole conditions are not unfavorable, resuscitation should be continued somewhat longer. If it is desired to continue with pole-top resuscitation for longer periods, possibly involving changes in operators, and even to giving resuscitation while lowering, the details can be worked in to the company procedure and the linemen trained accordingly.

When the victim is revived on the pole and pole conditions are favorable, it is suggested that the victim be kept on the pole in relaxed position under the control of the operator for a few minutes. This will lessen the likelihood of a relapse into unconsciousness which sometimes occurs when shock victims attempt any physical exertion too soon.

Experience has suggested the following technique when a still unconscious victim is to be lowered from a position such as is shown in Fig. 32-4. The assistants on the ground take the weight of the victim on the hand line, and at a moment agreed upon by the operator and the assistant rescuer the operator drops down below the victim. The assistant rescuer swings over and with hands on back and abdomen of victim maintains the cadence and gives resuscitation until the first rescuer has moved down and out of the way. If there are wires of any description below which the victim will have to clear as he is lowered, the first rescuer will take a proper position to guide the victim past or through these wires. At a signal from the second rescuer to the assistants on the ground, he moves out of the way and the victim is promptly lowered and placed in position for the immediate resumption of artificial respiration by the prone-pressure method with a minimum of delay.

Alternate Hitches. The only standardization that is essential in the manner in which the victim is secured to the hand line concerns the requirement that the method be positive and safe in all respects.

An alternate method to that given under Lower to the Ground that has been found practicable, particularly when it is desired to continue resuscitation while the victim is being lowered, is one in which the line is fastened to the two D rings of the victim's belt. Such support, however, is close to the center of gravity of the victim and is, therefore, not suited to free lowering of the victim unless the victim's safety belt is first placed under the armpits and properly secured to maintain him in upright position while being lowered.

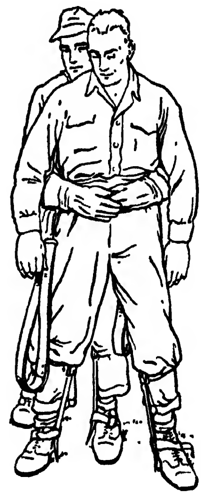

FIG. 32-10. First position of hands, relaxed, before inward, upward motion to raise abdominal organs.

Effectiveness of the Method. Tests and experiments conducted in 1939 by Drs. W. B. Kouwenhoven, D. R. Hooker, and O. R. Langworthy, of Johns Hopkins University, reported in "A Comparison of the Relative Efficiency of the Schafer and Pole-top Methods of Artificial Respiration" (A.I.E.E. Technical Paper 40–150, *Electrical Engineering*, February, 1941; *Transactions*, Vol. 60) show that ventilation of the lungs obtained by the pole-top method is adequate and that the subject receives sufficient oxygen to satisfy his needs.

The object of the pole-top technique is to raise the abdominal organs against the diaphragm in a manner such that pressure will be exerted on the diaphragm uniformly across the body. Extreme pressure must be avoided, and localized pressure in the center is undesirable and will lessen the effectiveness of the resuscitative effort. The cupping of the hands is to prevent the hands sliding apart and off the victim and is not for the purpose of giving localized center pressure. The arms should gently but firmly restrain the outward movement of the abdomen at the sides (Fig. 32-10).

SECTION 33

*Accident-prevention Course for Linemen**

ACCIDENT PREVENTION

Purpose. The majority of the accidents which occur at present are preventable. The purpose of the Accident-prevention Course for Linemen is to prevent accidents, to prevent partial disability and loss of time, and to prevent loss of life.

Causes of Accidents. Roughly, causes of accidents may be put into three classes: first, accidents resulting from lack of supervision or lack of knowledge; second, accidents resulting from personal carelessness; third, accidents resulting from the contributory negligence of others.

Accidents which may be charged to "supervision or lack of knowledge" are included in the following tabulation:

1. Class of work beyond mental or physical ability of employee
2. Lack of proper instruction
3. Improper tools or devices
4. Method pursued not suitable for work
5. Protective devices not used
6. Protective devices not provided
7. Rules or instructions not observed
8. Lack of proper inspection and maintenance (defective tools, materials, and devices)

Accidents which may be charged to "personal carelessness" are grouped as follows:

1. Mental condition of employee
2. Failure to think
3. Mechanical manner of doing work (lack of concentration)
4. Haste
5. Poor judgment
6. Willfulness
7. Physical condition of employee
8. Intemperance

* Reprinted through the courtesy of the Accident Prevention Committee of the National Electric Light Association.

9. Conditions beyond control:
   a. Elements
   b. Nonindustrial
10. Contributory negligence of others

Scope of Lessons. In compiling the following lessons, every effort has been made to make them flexible enough to be readily altered in individual cases to meet local requirements. Differences in the installation of equipment, in methods of operation, inspection, and maintenance would make impossible the publication of one set of lessons which would be applicable to all properties or units of all properties. It will, therefore, be necessary to rearrange, to eliminate, and to supplement the lessons so that they will be suited to local needs.

In any one system or organization it would be very desirable to have not more than one set of lessons for the same class of work.

Practicing Safety. That the lessons may have the best results, it is essential that safety be considered and practiced in all departments at all times; the real benefits to be gotten from lessons of this character will be realized only when they come to be considered as routine work and not as involving extra and laborious operations.

The benefits which can be derived from safe practices cannot be expected immediately to follow the introduction of these methods. Time is required, partly on account of the fact that a lineman is called on to handle a great many jobs, each under a different condition (different poles, wire arrangement, installation of equipment and fixtures, etc.). The justification for the use of safe practices is found in those organizations where they have been in use for several years; there, great benefits to linemen have been realized.

Responsibility for Accidents. To secure the best results in any undertaking, organization responsibility is required; and this responsibility should, in every case, be properly placed.

To secure best cooperation on the part of linemen in the application of lessons, proper executive indulgence must be had. The chief responsibility for the proper application of lessons rests with the designated company official. When this official has expressed himself positively in the matter of accident prevention, it will be found that the subordinates will immediately cooperate.

Arrangement of Lessons. The following instructions have been grouped as far as possible under the name of the equipment to which they refer.

Questions

1. Mention five accidents which have recently occurred to men working near you or to yourself.

2. Classify each of these according either to lack of supervision or lack of knowledge or to personal carelessness (see Causes of Accidents).

3. How could each of these accidents have been prevented?

GENERAL

Qualification of Linemen. When a second-grade lineman attempts to do the work usually done by a first-class lineman, or when a third-class lineman attempts to do the work usually done by a second-class lineman, he must appreciate the higher grade of work expected and the additional precaution required in the advanced grade, and, unless he feels competent both to perform the work satisfactorily and exercise the proper caution, he should not attempt to do the higher grade work until he has received special instructions in the grade of work required.

Repeating Messages. To avoid misunderstandings and to prevent accidents, each person *receiving* an unwritten message covering the handling of lines and equipment shall immediately repeat the message to the sender; each person *sending or transmitting* an unwritten message shall immediately require that the message be repeated to him. Each party to the conversation must satisfy himself as to the other's identity. This should be done before any work on the lines and equipment involved is undertaken.

Inspection. Before climbing any pole, a lineman should satisfy himself as to the following: type and position of circuits on the pole, with their direction of feeds; what work he is about to do on the pole, and just how he expects to do it; that he has a sufficient amount of each kind of insulating equipment on hand thoroughly to protect his working position from all live wires which may cause electric shock. He should consider the ground and traffic conditions and should arrange to protect and guard these against all hazards.

All dangerous conditions noticed along the line by an employee should be reported to his superior as soon as practicable.

Use Caution. Make it a habit to be cautious. Be on the lookout for warning signs and signals.

Warn others when they seem to be in danger near live equipment or lines.

When a lineman works near live equipment or lines, each move and each operation should be planned. Care should be used in moving from place to place. A lineman should avoid slipping, stumbling, or backing into wires or equipment which may be alive.

Keep Mind on Work. A lineman should keep his mind on his work at all times. He should think of what he is doing continuously, not allowing anything else to cause him to worry.

Protection. Lines and equipment near the working position may be alive. A lineman should *personally* protect himself from all of these lines and all of this equipment. A lineman should not depend on other linemen to protect him. Where the protection has been supplied by other linemen, it should, wherever possible, be checked by the lineman who will work near this protection.

Live Parts. Each electric-line wire should always be considered as being alive (unless positively known to be dead and grounded) and worked on as a live wire as soon as the wire has been put over the first crossarm, or as soon as it has been connected to any equipment which might make it alive. Electric equipment should be considered alive and worked on as such as soon as this equipment has been connected to a live-line wire, or a wire considered alive.

Avoid Live Equipment. All unprotected lines and equipment should be looked after with due caution.

Talking. While linemen are working on or near lines or equipment, there should be no more talking than is absolutely necessary for the proper handling of the work.

Horseplay. Each lineman, each groundman, and each other employee assigned to line work must remember that while on duty he is engaged in work which is perfectly safe while all precautions are taken, but which becomes dangerous through carelessness, chance taking, and "horseplay." "Horseplay" should not be allowed while linemen are going to or from work or while engaged in line work.

Taking Chances. A lineman should take no chances. He should guard against every possible accident. By taking proper precautions, he will be able to do better work and he will help every other employee to do better work. A lineman who uses safe practices continuously and who receives proper recognition from his superiors will soon interest other employees who might be inclined to be careless or to take chances. A lineman should *always be careful.* The most efficient man is always careful.

Preliminary Qualification. Each lineman should qualify himself in the resuscitation drill (Schaefer prone-pressure method) and see that the man working with him is familiar with this method of resuscitation.

Questions

1. If you had received telephone instructions to do a job at another point of the system, and while you were on the way to the new job you realized that the instructions were not clear or not complete, what would you do before beginning work on the new job?
2. In undertaking a new job, what inspections would you make first?
3. Where you are one of two linemen assigned to a high-voltage job, is it important that your mate know how to resuscitate?

POLES

Carting. Where poles are carted so that one end of the pole projects beyond the rig, an indicator should be placed at the rear end of the pole to warn traffic and pedestrians of the projection. In the daytime this indicator should be a red flag or sign. At night a red lantern should be used as the indicator.

Temporary Storage. Where poles are stored temporarily in roadways before erection or removal, they should be placed as close as possible to the curb or edge of the roadway. They should not be stored at points in the road where there are sharp turns. Each pole should be placed so that its top faces the direction of traffic. Poles stored on highways should not have crossarms or steps attached.

Poles temporarily stored in roadways should be protected from traffic at night by means of red lamps or other means at the disposal of the company to avoid possible accidents.

Pole Setting. Where it is necessary to blast in excavating for a pole location, every precaution must be taken in the handling of dynamite and in protecting the surface against flying pieces of rock and dirt. All men in the gang must be kept clear of the blast and all traffic must be guarded.

When it is necessary to keep pole holes open over night in a district where pedestrians pass, each hole should be properly barricaded with at least one red light displayed so as to sufficiently warn passers-by, care being taken that the barricading itself does not have projecting nails or any other feature present which might injure pedestrians coming in contact with it.

When the erection of a pole requires that it be laid across a highway so as to endanger traffic in both directions, two men should be assigned to guarding and warning traffic on the highway while this danger exists; each man to guard one direction of traffic, and to be stationed at least 100 ft away from the pole being erected, in order that the traffic can be sufficiently warned.

Where poles are raised by means of derricks and gin poles, linemen and ground hands should avoid standing close to the derrick, gin, or the pole being raised, whenever the work in hand does not require that they remain in this position, so as to avoid possible injury in case the pole should fall.

Piking. When poles are piked, the men should handle the pikes firmly so that they will not cut out and fall on other workmen. All work in the operation of piking poles should be done under the direction of and following the signals from the man in charge.

Backfilling. When pikes are used to hold a pole while the backfilling is being tamped, they should be firmly grounded in all directions when necessary to prevent the pole from falling. Pikes should not be removed until the backfilling is sufficient to hold.

After a pole has been set, all obstructions to traffic must be removed before the gang handling the pole setting moves away.

Inspection. Before a lineman attempts to climb a pole, he should make sure that it is strong enough to carry him safely. Poles which are decayed or badly raked must be securely guyed or braced before a lineman attempts to climb. Where pole butts cannot be inspected for decay, as in the case of poles set in concrete pavements, poles should be securely guyed or braced before the lineman ascends.

Bracing. On pole-replacement or pole-removal work, no pole shall be climbed for the purpose of clearing it of all wires and cables until it has been first guyed or braced securely to offset any change in strain which may be caused by the removal of these wires and cables.

In connection with the removal of poles, guys shall not be removed until all temporary supports have been securely located. Temporary supports are taken to mean pikes, digging bars, rope, block and tackle, rope guy lines, etc.

Removal. All members of the crew who are not actually engaged in the removal of poles should stand clear so as to avoid possible injury in case of the pole falling. All pedestrian traffic and all highway traffic, where necessary, should be stopped in both directions while a pole is being removed.

Climbing. Before a lineman climbs he must first find out the position of all high-voltage wires and the direction of feeds. He must determine the best climbing space, especially at junction poles. In choosing a climbing space, it is desirable, if possible, to climb on the sidewalk side up to a point just below the lowest gain.

In choosing climbing space, every effort must be made to avoid ground wires, where they are located on the poles being climbed. Wherever possible, it is desirable to have ground wires on the opposite side from that part of the pole chosen for climbing.

Weather checks, knots, shakes, rots, and hard places should be avoided to prevent the cutting out of the spurs. For the same reason tin signs, nails, and tacks should be avoided while climbing. All unauthorized tags, signs, and advertising display cards on poles should be removed.

In climbing, a lineman should avoid standing on mail boxes, fire-alarm boxes, pole-telephone boxes, and similar foreign equipment which may be attached to the pole or located near it.

Where steps are provided, they should be used in every case. As a lineman climbs up a pole having steps, he should try each step before trusting his weight upon it. Steps which are bent should be avoided even though they appear secure.

The hook on all pole steps should be maintained pointing up.

Where a coating of ice covers the pole, the pole steps or any part or all of them, special care must be taken in climbing up and down the pole. Where climbers are used, care must be taken to prevent spurs from cutting out. Where steps are used, care must be taken to avoid slipping.

When more than one man is climbing up or down a pole at the same time, the second lineman, going up or down the pole, should allow the first man sufficient time to avoid spurring or other conflicts with the first lineman.

Where a pole is leaning or raked, a lineman should use the upper side wherever possible, so that in case the pole should fall the lineman will have a better chance to jump and there will not be as much chance of the pole falling on him.

Where steps are not provided, climbers should be used by lineman in coming down a wood pole. Except in unusual emergencies, a lineman should not jump from a pole, slide down a pole, or attempt to "coast" from the working position to near the ground level before using his spurs.

Support. The safety belt should never be put around that part of a pole above the top crossarm when the latter is located close to the top of the pole.

Questions

1. How should long poles be carted?
2. What precautions would you take in storing poles temporarily in roadways and highways?
3. What precautions would you take: (*a*) Where it is necessary to blast a pole hole? (*b*) Where it is necessary to leave a pole hole unfilled overnight?
4. In the erection of poles, what precautions does your company take to prevent accidents: (*a*) To employees? (*b*) To street and highway traffic?
5. (*a*) Why should a lineman always inspect the butt of a pole before he begins to climb? (*b*) What other inspections should be made by a lineman before he begins to climb?
6. Should pole steps be used when they are provided? Where they are not provided, what precautions should be taken to prevent climbers cutting out?
7. What should be done by a lineman to avoid spurring another lineman?
8. What precautions should be taken in connection with the removal of wires and poles?

LOCAL CONDITIONS

Roadway

Clearances. Wires should be strung and maintained so as to clear the roadway by an amount not less than that specified by the rules governing these conditions.

Wires and guys which are being strung should be kept clear of the roadway. Where it is necessary temporarily to block the roadway while wires and guys are being installed, one or more members of the gang should be assigned to guard traffic in one or both directions, as may be necessary.

Guarding. In congested districts ground hands should be assigned to the street and highway at pole locations where work is being carried on. It should be the duty of these ground hands to warn street and highway traffic of the danger. In addition, danger signs may be used near the bases of all the poles in question and the ground space may be roped off (Figs. 33-1 and 33-2).

Raising and Lowering Material and Tools. Tools and material should not be thrown from the ground to a lineman working aloft on a pole Large tools should not be stored by linemen on crossarms Linemen should never throw tools or material from aloft to the ground Insulated tool bags should be used for raising tools aloft, for storing small

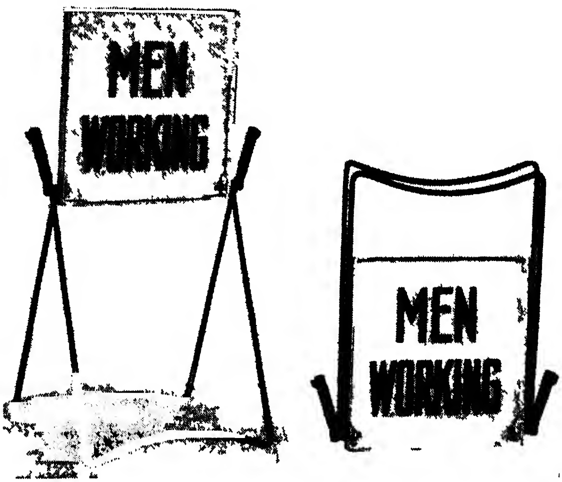

FIG 33-1 Traffic danger sign

tools at the working position, and for lowering tools to the ground Small-sized material should also be raised and lowered in insulated tool bags Tools which are not in use should be stored in the trucks Where tool bags are not practical, *dry* hand lines may be used

Inspection. All dangerous conditions noticed by linemen, ground hands, and other employees should be reported as soon as possible

Railroad or Railway

Clearances. A lineman working on railroad or railway right of way should always keep lines, messengers, guys, hand lines, material, and tools clear of the track, unless he has instructions to the contrary from his foreman

All material should be so stored and all men should so place themselves at all times that they will not be drawn toward the train or car by suction

Train Schedules. The foreman of a gang working on a railroad or railway right of way should keep himself informed at all times of the approach of all trains. He should keep all his men advised so that they cannot possibly be caught off guard. It is usually possible to secure this information from train dispatchers or from station agents.

General. All employees assigned to work on railroad and railway right of way should take special precautions in walking along the tracks and in crossing the tracks, particularly in the case of trunk lines where trains are apt to approach from both directions at the same time.

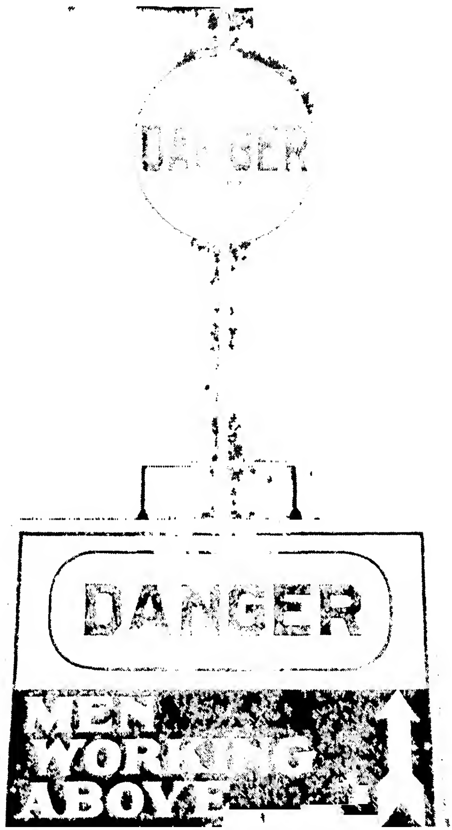

FIG. 33-2. Traffic danger sign and flag.

Other Lines

Clearances. Where linemen are working on jointly occupied poles, or where linemen are working on a line which crosses the line of another company, the linemen should take every proper precaution to prevent material and equipment from coming into contact with the second line while this material or equipment is being raised or lowered. They should also prevent wires, guys, messengers, or cables which they are pulling up or cutting from coming into contact with parts of the second line

Every reasonable and proper effort must be made not to interfere with the operation and maintenance of the second line.

Questions

1. Why is it necessary to keep all line wires, tools, and equipment clear of the roadway, street, and highway?
2. What would you do if you saw a bad line condition while you were on or off duty?
3. What special precautions would you take when you are working on or close to a railroad or railway right of way?
4. What precautions would you take where the lines you are working on are carried: (*a*) Across other lines? (*b*) On poles which carry other lines?

CROSSARMS, PINS, INSULATORS, ETC.

Crossarms

Installation. The dimensions of all drilled holes should be checked for diameter of drill and spacing of holes in the case of metal arms, before these arms are raised aloft.

Where metal arms are to be raised through high-tension wires, protectors or similar portable insulation should be securely wrapped about all parts of the crossarm so as to prevent the crossarm coming into contact with live high-tension wires. Where it is impossible to provide satisfactory portable insulation, the high-tension wires should be "killed" while metal arms are being raised aloft.

Where hand lines are used to raise crossarms, the former should be lashed well to the latter and tested thoroughly by hand before the arms are raised from the ground.

Where braces are attached to the crossarm before the arm is raised, the free ends of the braces should be tied in well to the crossarm to prevent them from falling out of position and coming into contact with live wires while the arm is being raised.

All men not engaged in actually raising crossarms should stand clear. Linemen and ground hands on the ground who are engaged in raising a crossarm should keep their eyes on the crossarm from the time that it leaves the ground until it is received aloft.

While crossarms are being raised amid traffic, ground hands should be stationed as guards to warn street and highway traffic. Where street danger signs are available, they should be used. In congested districts the pole should be roped off.

Only one crossarm should be raised at a time.

Support. A lineman should not put his safety belt around a crossarm for support unless he is positive that the crossarm will support him. Where it is necessary to use this means of support, double arms should be used in preference to single arms wherever available.

The safety belt should never be put around the end of the crossarm—it might slip off.

Trimming. Where it is necessary to use longer through bolts than are required for a job and the free end of the through bolt projects more than 2¼ in. beyond the holding nut, this projection may cause injury to a climbing lineman and should, therefore, be cut off within ½ in. of the nut. The sharp edges of the end of bolt cut off, in this case, should be rounded to prevent the chances of injury to a workman.

Insulator Pins

Installation. Wooden insulator pins should always be installed so that the grain of the wood is in the same direction as the line, to secure greater strength.

Wooden insulator pins should be inspected for cracks, checks, knots, worm holes, bark, shakes, and rot before they are installed. Where wooden pins are attached to the crossarms at the storeroom, they should again be inspected on the job for cracks before the crossarms are raised aloft. Defective pins should be replaced immediately.

Where insulator pins are attached to crossarms before the crossarms are raised, care should be taken in raising the crossarms that the pins do not foul any wires. Wherever necesssary, a guide line should be attached to the crossarm before it leaves the ground to avoid fouling.

Support. Insulator pins should never be used as supports for lineman's safety belts.

Insulators

Transportation. In carrying insulators to the job, they should be packed carefully in a separate box. No other line material or tools should be packed in this box.

Inspection. Before insulators are raised aloft, they should be inspected. Only sound insulators should be installed.

Installation. Where insulators are passed through live lines, they should be raised to the working position carefully in an insulated canvas tool bag or other insulated container. Tools or other equipment which might crack, chip, or break them should not be raised in the same container or bag with the insulators. Insulators shall be placed upon the crossarm pins only when the wire is to be immediately attached. The insulators shall always be screwed up tightly on the pins.

Guy-strain insulators should be installed wherever necessary. Guy wires to wood poles should be equipped with strain insulators to insulate the working positions on the pole from ground potential. Line and side guys whose upper part is liable to be made alive by contact with falling high-tension wires should be equipped with guy strain insulators so that street and highway traffic coming in contact with the lower part of the guy will be fully protected. Head guys should be equipped with strain insulators so that high-tension wires falling on one part of the guy will not make the other end (attached to a working position on another pole) alive. Wherever guy strain insulators are installed, the splicing should be done so that the guy is not weakened by the addition of the strain insulator. Guy strain insulators should clear the ground by at least 8 ft.

Guy strain insulators should be installed only in those cases where they will be effective in giving full protection. A guy strain insulator which will safely withstand only 5,000 volts should not be installed on a 15,000-volt line, for instance. It would not give the required protection, and its installation might result seriously.

Testing. Only qualified linemen should be assigned to testing insulators where this involves the climbing of poles, towers, or structures.

When a man is testing insulators, he should assume a position such that he will not be liable to become blind temporarily from an arc. He should take all the precautions which would ordinarily be taken by a lineman or substation operator in the usual performance of their respective duties, when approaching high-tension lines or equipment.

Replacement. In the replacement of defective pin-type or suspension-type insulators on a circuit the operating voltage of which is too high to be handled practically with rubber gloves, special precaution must be taken. When this work is done while the line is alive, care must be exercised to see that as safe a distance as is practicable is maintained between the lineman and all live parts of the line. When this work is done while the line is "dead," the line should be "shorted" and, when practicable, be discharged to ground, all the while the line is handled as a dead line.

(NOTE: Guy strain insulators are sometimes termed "breaker insulators" or "breakers.")

Braces

Installation. The same care should be taken in inspecting, raising, locating, and lowering all types of metal braces as should be taken in the case of metal crossarms referred to in a previous paragraph of this section.

Questions

1. How would you guard metal crossarms while they are being raised through high-voltage wires?

2. (*a*) When braces are attached to crossarms before they are raised on a pole, what precautions should be taken to prevent the braces from falling out of position and coming into contact with live wires? (*b*) What would you do to prevent a crossarm from slipping out of the hand-line lashing while it is being raised?

3. What precautions should be taken while crossarms are being raised?

4. Why should pins be inspected for soundness before they are installed and before insulators are attached?

5. What precautions should be taken in raising crossarms through live lines, when pins are attached beforehand?

6. How should insulators be handled: (*a*) On the truck? (*b*) While being raised?

7. Why should insulators be carefully inspected before they are installed?

8. Consider several points in the lines of your company where there are bends, turns, grades, lateral feeds, and line equipment requiring guys. Why are guy strain insulators used at each point where they are installed?

9. Explain the steps you would take to protect yourself while testing insulators supporting live lines.

10. (*a*) What precautions would you take in replacing insulators on dead lines when there are live lines nearby? (*b*) What precautions would you take in replacing insulators on live lines?

WIRES

Line Wires

Inspection. Before a lineman undertakes any work on a pole, tower, or structure, he should first make a complete inspection from the ground of the position of all high-voltage wires and find out the direction of feed in each case. He should determine the best and safest climbing space, especially in the case of wood junction poles.

He should determine the necessary amount and kind of portable protective insulation which is required and should take this material from the truck and inspect it carefully before he attempts to climb into the high-voltage wires.

A lineman should test his rubber gloves, using the "air" test, on each new job. The rubber gloves should not be worn, however, while a lineman is climbing the lower part of a pole, tower, or structure, as they might be injured or punctured by wood splinters, nails, etc.

Each time a safety belt is used, a lineman should test it by applying his weight against the safety so as to make sure that the safety belt is in good condition and that the snaps are securely fastened to the D rings and that there is no chance that the snaps will cut out while the safety belt is being used. While a lineman is making this test he should be ready to support himself with both hands in case the safety should fail.

Climbing Space. Climbing space should not be used for temporary or permanent wires, fixtures, or attachments. It should be kept clear at all times.

Protection. Waterproof covering on line wires should not be depended on for protection. Weather conditions may spoil this covering. Often, weatherproof covering will appear to be in good condition when it is actually in very poor condition.

All high-tension wires near the working position should be protected with portable protective insulation, where the voltage of these wires will permit of using this portable insulation safely. Nearby wires should be taken to include all adjacent line wires, laterals, taps, and risers.

In those cases where the voltage is so high that portable protective insulation cannot be safely applied, the lines, taps, laterals, and risers located near the working position and carrying this high voltage should be killed, discharged to ground, and grounded on all sides of the working position before any work is undertaken.

Except in those cases where full protection can otherwise be provided, only one lineman should be allowed to climb a pole before the portable protective insulation is installed.

Portable protective insulation should be installed one piece at a time, so that the lineman applying this insulation will at all times be protected. This will usually necessitate applying insulation to the nearby points first and to the distant points last. While a lineman is applying portable protective insulation, he should wear his rubber gloves.

Where it is necessary to do two or more jobs in one working position, only one job should be uncovered at a time. For instance, suppose that it is necessary to cut two taps into a 2,300-volt line to supply 2,300-volt single-phase energy to another point in the system. In that case, the first tap should be made with all other adjacent wires fully protected with portable protective insulation. When the first tap has been tied in and insulated, it should be covered at all points with portable protective insulation before the point on the second wire where the second tap will be made is uncovered.

Where dead wires are located near the working position, they should be considered as being alive at full voltage unless they are effectively grounded at a point near the working position.

Where it is necessary to stand on transformer cases, pole-type voltage regulators, pole-type constant-current (series street lighting) transformers, and similar line equipment mounted on wood poles, the covers of this type of equipment should first be covered with rubber mats. Where this type of equipment is mounted on grounded steel poles, the tops of the cases should not be insulated with rubber mats. Where rubber mats are installed, a lineman standing on them should take care that his spurs do not touch the mat. A lineman should always use his safety when he is standing on a case of this kind.

On wood poles, all wires at ground voltage in the working space should be covered with protective insulation whenever any other conductors in the working space are also covered with portable protective insulation. On grounded steel towers, it is not necessary to provide protective insulation for wires at ground voltage in the working space.

Working Position. A lineman should wear his rubber gloves at all times while working on high-tension wires of voltages for which the gloves will give full protection. In wet weather, a lineman should wear his rubber gloves while he is working on secondary circuits whenever he is so instructed by his foreman.

A lineman should never lean over or crowd through unprotected wires. He should place himself so that he will not be liable to fall on high-voltage wires should an accident occur. Such an accident might be liable to occur from cutting out of one snap of his safety or from his spurs cutting out.

Whenever possible, a lineman should work on wires from below.

A lineman should not move backward against wires or equipment that may be alive.

A lineman should do one thing at a time and should keep his eyes on his work at all times. Care should be taken to avoid slipping and stumbling.

When a lineman is working on live lines or equipment, he should never allow any part of his body to come close to any live or grounded parts other than that being worked on.

When a lineman is close to high-tension lines or equipment, he should avoid touching ground wires, guy wires, span wires, metal pipes, metal conduits, metal poles, metal sheaths, signal wires, signal equipment, transformer cases, transformer hangers, street-lighting fixtures, and other metal parts.

When a lineman is in contact with signal lines or signal equipment, metal sheaths, metal pipes, metal conduits, ground wires, or metal fixtures on poles, he should avoid coming close to high-tension lines or equipment, guys, or span wires.

Where it is necessary for a lineman to walk out on crossarms, the wires of which are covered with blankets, line protectors, or other type of portable insulation, he should take particular care that his spurs do not touch the insulation.

Where linemen are working at two or more levels on a pole or tower, the linemen working at the lower level should be prepared at all times to step aside when they are working in the climbing space, so as to permit the men working at the upper level free use of the climbing space. Men working in the climbing space on the lower level should always stand clear while material and tools are being raised to and lowered from the upper level. The ground hand assigned to the raising and lowering of material should not begin to raise or lower until all linemen on the lower working level are clear of the climbing space.

Tools and small material required at the working space should be stored in an insulated tool bag when not being used. Large tools and material which cannot be easily stored in tool bag should be kept in the truck when not actually being used aloft.

Stringing Wires. In stringing wires, care must be taken not to put kinks into any part. Kinks reduce the strength of the wire and may result in fallen wires later.

In the handling and stringing of weatherproof covered wires, care must be taken not to injure the weatherproof covering.

A lineman should not change the strains on a pole by adding wires until he is satisfied that the pole will safely stand the altered strains.

Wires which are being strung should not be allowed to sag so as to come close to the sidewalk, street, or highway. Where these wires may interfere with sidewalk and highway traffic, at least one watchman should be assigned to guard the street and highway in one or both directions, as may be necessary.

While a lineman is stringing wire on a wood pole, he should avoid coming in contact with all ground wires, messengers, sheaths of cable, metal pipes, metal conduits, guys, lighting fixtures, span wires, signal lines, signal equipment, and other attachments which may be at or near ground voltage.

In stringing wire, a lineman should avoid bringing it into contact with live lines. Where it is necessary to string wires near live lines, *dry* hand lines or other suitable means should be provided and used. Rubber gloves should always be worn.

Where there is a possibility that the wire being strung may come into contact with live wires, the lineman should assume that the wires being strung are at the same voltage as the wires of the live line, and he should protect the wires being strung in the same way that he protects the live wires.

Splicing. Where rubber gloves are worn in making a splice in wires, they should always be worn when insulation is being put over the splice.

While a splice is being soldered, solder catchers should be used to prevent molten solder from falling and striking other employees below or on the ground, as well as persons on the street or highway below. A splice should be dry before solder is applied.

In making a splice, care should be taken to make it as strong as the line wire which is spliced to prevent later breaks and fallen wires.

Tying-in Wires. Wires should be tied in at all insulators securely so as to prevent the possibility of wires becoming loose at points of support and possibly falling to the ground. Where double arms are provided, line wires should be tied in well to insulators on each arm. This applies to pin-type insulator work.

Tying In. Where it is necessary to tie in two parallel circuits which are connected at one or more points on the line, the several phase wires should be tested with a potential transformer or other means so as to make sure that the phase wires of one circuit are being connected to the corresponding phase wires of the other circuit.

Where it is necessary to tie in two lines connected with different sources of energy, as for instance tying in line connected with station A and line connected with station B, at least one line should be made dead while the splice is being made unless means are available at the splicing point to synchronize one line against the other before they are connected.

Grounding. No high-tension lines should be approached and no grounding attempted by linemen until satisfactory arrangements have been made so that the lines at the point in question may be grounded. All possible points of misunderstanding should first be cleared before work of this character is undertaken.

Where a line or part of a line has been *killed* and grounded, a lineman should make sure before he touches any of the wires that the grounds have been located between all sources of power and the point at which the work is being done.

Where there are other lines on the same or on nearby poles in the same general direction, there is always a possibility that the section of line about to be worked on may not be at ground voltage. Special care should be taken in those cases to place local grounds on each side of the section being worked on to secure positive protection against accidental shock.

All circuits connected to the grounded wires to be worked on should be checked for apparatus which is apt to operate after service has been disconnected. These circuits should also be grounded to avoid a possible feedback.

Placing Grounds. The grounding device should first be attached to a good ground connection supplied for the purpose, and the other end of the grounding device should then be attached securely to the wires or equipment to be grounded.

Where grounding chains are used, they should be first inspected for condition. Chain which will not permit of a low-resistance connection should not be used. In applying grounding chains, they should be tightened well when they are being installed. *Dry* hand lines should always be used in installing ground chains. Where there is more than one circuit on a pole, it may be impossible to safely apply ground chains, and in those cases ground clamps or other grounding equipment should be used.

Where it is necessary to ground lines having a weatherproof covering, special provision should be made for this work.

Removing Grounds. The removal of grounds should be handled in the reverse order to that used in placing the grounds in position—that is, that end of the ground wire attached to the line wire or equipment should be removed *first* and then the other end, connected to the ground, should be removed.

A lineman should never change the strains on a pole by removing wires until he is sure that the pole will safely stand the altered strain. Where a pole will be weakened by the removal of the wires, it should be guyed as may be necessary before these wires are removed.

Before a lineman cuts a wire aloft, he should make sure how it will fall. Where a wire may touch live lines, suitable *dry* hand lines or other means should be used in lowering it.

Lines which are being cut or rearranged should not be allowed to sag so that they will fall directly on or be blown against (1) other lines, (2) signal lines, (3) signal equipment, (4) metal sheaths of cables, (5) metal pipes, (6) ground wires, (7) metal fixtures on poles, (8) guy wires, (9) span wires.

Wires which have been cut or which are being rearranged should not be allowed to fall near or on roadway where there is danger to traffic. Where it is impossible to keep these wires clear of the roadway by at least 10 ft or more, depending upon the voltage of the adjacent lines, all street and highway traffic should be guarded in one or both directions, as may be necessary. All employees working on lower levels of poles where the cutting is taking place and all employees on the ground should be notified well in advance of the cutting so that they may stand clear.

Fallen Wires. It shall be the duty of all employees to watch for fallen wires. When an employee finds a fallen wire carrying a high voltage in a more or less congested district, he shall stand by it so as to protect all street and highway traffic from it. He shall, as soon as possible, instruct someone else from those available in the neighborhood to telephone to headquarters either to have the wire *killed* or to have it raised from the ground. This employee shall not leave the fallen wire until he has been so instructed by the official in direct charge of the fallen wire.

Fire. All lines close to a fire should, where necessary, be cut dead immediately to protect the firemen fighting the fire. They should not be made alive again until all danger has been removed. Where lines are located close to a fire, the lines should be inspected carefully, the insulators should be inspected for cracks, and the crossarms and poles should be inspected for charring, before the lines are restored to service.

Street-lighting Wires

The foregoing paragraphs (under Line Wires) refer to street-lighting lines where they apply.

Alive. Street-lighting wires, unless grounded, should be considered alive at all times. The voltage of street-lighting circuits should be considered as being that of the highest voltage wires occupying one or more poles on which the street-lighting circuit is run, in those cases where this voltage is in excess of the street-lighting voltage. This is necessary in view of the fact that sometimes street-lighting wires become crossed with high-tension wires during the day time.

Secondary Circuits. Where street-lighting circuits are equipped with series lighting transformers, the secondary side of this transformer circuit should be effectively grounded on one side.

Foreign-wire Attachments

General. All foreign-wire attachments, such as signal lines, signal equipment, and so forth, should be considered alive and should be avoided at all times, unless otherwise protected. While a lineman is working on high-tension lines he should be careful not to disturb foreign lines and equipment which may be attached to the same pole.

Ground Wires

Installation. Ground wires should be installed clear of all line equipment which would ordinarily be considered as insulated from ground, such as crossarm braces, through bolts, pole steps, transformer cases, street-lighting fixtures, etc.

Ground wires on wood poles should be protected, when necessary, by a suitable guy plate to prevent the guy wire from cutting into weatherproof covering on the ground wire and to prevent the pole end of the guy wire from becoming grounded.

Ground wires should be protected with molding of approved type throughout the entire effective working length of the pole and also for a distance above the ground as may be required by the regulation to cover.

Guys

Make-up. Insulators should be connected into the guy-wire line before the guy wire is set in place. Rubber gloves should not be worn while the insulated guy line is being made up.

Installation. In new work, guys should generally be installed before line wires are strung. In reconstruction work, guys should be installed before any changes are made in the line wires.

In installing guys, care must be taken not to place excessive pulls on the pole and wires already in position.

Guys should be so installed as not to interfere any more than necessary with the climbing space and should clear all high-tension wires as far as practicable.

Guy-strain insulators should be provided wherever necessary to secure the required amount of insulation.

Guys should be carefully installed on poles to prevent them from becoming loose. Where necessary, a lag screw, a through bolt, or hook may be used to prevent the guy from slipping down the pole. These screws and bolts should not interfere with climbing and should be so placed that they will not be used as steps. Where guys are liable to cut into the surface of a pole, the pole should be protected at the point where the guy is attached by a guy plate. The plate must be well secured to the pole to prevent the possibility of injury to a lineman climbing up or down the pole.

All guys which are anchored should be installed so that the guy does not interfere with street or highway traffic. Where these guys are located near street or highway, they should be equipped with traffic guards conspicuously painted or marked so that they can be the more readily seen at night. (Traffic guards are sometimes called "anchor shields.")

In installing a guy wire, the guy must not be allowed to come into contact with or close to live wires on the pole. Where such a condition may arise, a *dry* hand line should be used.

Guy wire should be so installed that it will not rub against any messenger or signal cable carried under supply lines.

Guy wire containing snarls or kinks should not be used for line work.

Guy wires should not contain any more splices than absolutely necessary. Standard guy clamps or other positive clamping devices should be used in making all stiff-steel guy-wire splices.

Guys should not generally be attached to trees, but when this is most practicable the condition of the tree should be examined carefully before guys are attached. Guys should be attached to only sound and stiff trees or limbs of trees. Wherever necessary, guys should be held from trees by means of tree blocks. Where guys are anchored to trees, provision must be made for tree growth.

Removal of Guys. Before wires and guys are removed, the condition of the pole at the ground line must be determined. If the butt of the pole is found to be weak, it should be securely braced before any changes in pole strain are made.

Where the removal of wires from a pole will so change the strain as to present a dangerous condition, the pole should be braced temporarily to make such changed conditions safe.

Where it is not possible to install side guys, buckstayed guys may be necessary. Buckstayed guyed poles are sometimes called "self-supporting" poles. The buckstay should be so installed that it will not interfere with climbing and that it will not interfere with street or highway traffic. Buckstayed guys should not be used in connection with climbing.

Questions

1. What inspections should a lineman always make each time before he climbs a pole?

2. How would a safety belt be tested each time before it is used, to make sure that the D ring is properly seated under the snap keeper?

3. Why is it necessary to keep the climbing space clear at all times?

4. Why is it impossible to depend on weatherproof covering as insulation?

5. (*a*) On what class of high-voltage wires may portable protective insulation be used? (*b*) What class of high-voltage wires should be "killed" when they are close to the working position or when they are to be worked on?

6. Explain how you would use portable protective insulation when it is necessary to handle two jobs on adjoining or nearby high-voltage wires.

7. Why is it necessary to consider dead wires in the working position as being alive?
8. When it is necessary to stand on transformer cases, how should the covers be protected when these transformers are mounted on wood poles?
9. Why is it necessary to cover wires, at or near ground voltage, with portable protective insulation when it is necessary to work on nearby high-voltage lines?
10. What precautions should a lineman take in selecting his working position?
11. While a lineman is working on high-tension lines and equipment, what types of line fixtures, attachments, and equipment should be avoided?
12. What precautions should be taken while linemen are working on two or more levels?
13. What should be done with small tools when they are not being used aloft?
14. What provisions should be made for possible rescue after electric shock: (*a*) In dry weather? (*b*) In wet weather?
15. What precautions should be taken in stringing wire?
16. Why is it necessary to have a splice dry before solder is applied?
17. What precautions should be taken in tying-in wires on insulators?
18. Before two live circuits are connected permanently, why is it necessary to phase out these circuits?
19. Why is it necessary to synchronize one line against the second line before the two lines, connected to different stations, are tied in permanently?
20. What preliminary arrangements should always be made before a high-voltage line is grounded at one or more points on the job?
21. When should grounds be applied, and how should they be attached?
22. What precautions are necessary in applying ground chains?
23. How should grounds be removed?
24. What precautions should be taken when it is necessary to cut live wires?
25. What should a lineman do when he finds a fallen wire?
26. What protection should be given to firemen working close to high-voltage wires?
27. What precautions should be taken in working on or near street-lighting wires?
28. What precautions should be taken in attaching ground wires to wood poles?
29. What precautions should be taken in stringing guy wires?
30. When should traffic guards be installed?
31. What precautions are necessary where guys are attached to trees?
32. What precautions are necessary in the removal of guys?

TRANSFORMERS

Autotransformers, Pole-type Voltage Regulators, Etc.

Installation. All frames and tackle used in the erection of pole-type transformers should be carefully inspected each time before they are used. Defects should be repaired satisfactorily before the frames and tackle are used.

Wherever possible, junction poles, subsidiary poles, and street-lighting poles should not be used as transformer poles. Where conditions are such that it is necessary to install transformers on junction poles, subsidiary poles, and street-lighting poles, special care must be taken to maintain proper climbing space and to avoid crowding of wires and equipment.

Transformers should be installed only on poles strong enough to carry their weight. Transformer poles should be straight and, where necessary, guyed to prevent leaning or raking of the pole after the transformer is hung.

When transformers are raised or lowered, all men of the gang should stand clear and traffic should be guarded. In congested traffic, the pole space should be roped off.

Double crossarms should be provided for each transformer installation.

Where transformers are installed, the climbing space should be carefully maintained so that it will not be necessary for a lineman in climbing up or down a pole to come close to the transformer case.

Connection. Pole-type transformers should not be connected in circuit unless they are supplied with a sufficient amount of good-quality oil.

Where pole-type transformers are replaced, the new transformers should be checked for phase rotation carefully before service is restored, so that the new service conditions will be the same as before the change. This is particularly important where the service load consists of elevators and some types of power machinery where a change in motor rotation might cause a serious accident.

In the installation of a distribution-type transformer on the line, first the primary leads should be connected to the primary cutouts; second, one side of each primary cutout should be connected to each line wire; third, the secondary leads should be connected to the secondary line; fourth, when all necessary tests have been made, the primary plugs should be installed in the cutouts.

Before transformers are connected permanently to the line, polarity tests should be made so as to make sure that the transformers are connected properly.

Inspection and Maintenance. Only qualified linemen and trouble men should be allowed to climb poles to inspect and test pole-type transformers.

The transformer windings should be completely disconnected from line on both sides, that is, primary and secondary, before the oil is changed. Where it is impracticable to disconnect the low-voltage secondary which is not then alive, the secondary side may be effectively grounded in preference to disconnecting. Transformer oil should not be allowed to come into contact with rubber gloves and rubber goods.

Fusing. The placing or replacing of fuses on the high-tension side of pole-type transformers should be done only by qualified linemen and trouble men. In phasing out a transformer or in testing it for polarity, small-size fuses should preferably be used.

In replacing fuses, a lineman should be careful to avoid contact with live lines, grounded lines, the casing of transformers, street-lighting fixtures, signal lines, signal equipment, the metal sheathing of cable, metal conduits, metal pipes, span wires, trolley feeders and similar lines, fixtures, and equipment.

In replacing fuses and in installing fuses in new cutouts, a lineman should shield his eyes as far as possible with one arm against possible flashes of the fuse. In this type of work he should take a firm stand on the pole and have his safety belt well secured so that he will not be liable to slip and fall if a flash occurs.

Testing. Only authorized persons should be allowed to make tests on transformers, autotransformers, and similar equipment. Where it is necessary to take a sample of oil, the drain plug used in drawing this sample should be securely tightened after the sample has been withdrawn, so as to prevent leaks.

All temporary leads used in testing, such as secondary leads of potential transformers, thermometer leads, and recording-voltmeter leads, should be securely supported on the pole and should clear all traffic. The position of these leads should not interfere with the climbing space or with maintenance work which may be required while the testing is in progress.

Substations. Where it is necessary for linemen to work on substation transformers, each lineman should fully acquaint himself with all the operating rules applying at that substation before he undertakes any work. He should ask for the equipment he wishes to work on. He should follow out all instructions of the substation operator, and he should report to the substation operator when he has finished his work.

Protection. All linemen working on or near transformers or parts of transformer circuits, such as fuses, high-tension taps, etc., should wear rubber gloves and safety belts. Where it is necessary for a lineman to stand on a pole-type transformer or similar equipment, he should place a rubber mat on the cover to insulate himself from possible grounds or crosses in the windings. In standing on pole-type transformers, a lineman should take care that his spurs do not puncture the rubber mat he uses to insulate the transformer cover.

It is very often customary to install lightning arresters and lightning-arrester ground wires on transformer poles. While a lineman is working on poles which are furnished with lightning arresters and lightning-arrester ground wires, he should be careful to avoid touching the lightning-arrester equipment and he should avoid coming into contact with the ground wire.

Questions

1. Describe the method used by your company in installing transformers; mention the safety precautions which are taken in raising transformers.
2. What precautions should be taken in connecting transformers to live lines?
3. What steps should be taken by a lineman before he begins work on transformers located in substations?
4. What protection should be provided where it is necessary to work near live transformers?
5. Consider an important, heavily loaded pole on your system: (*a*) What precautions would be necessary in installing a transformer on this pole? (*b*) How would you protect yourself in connecting the transformer to the line?
6. Why is it necessary to avoid contact with all wires, cables, fixtures, and equipment near transformers which are being worked on?

STREET LIGHTING

Installation. Lighting fixtures should be hung clear of the climbing space and clear of foreign interests. All bolts, lag screws, and other hardware used in securing the fixtures to poles should be carefully trimmed to prevent accidents to linemen climbing up and down the poles.

The leads connecting the series street-lighting circuit to the street-lighting unit should be held securely away from the pole and away from the climbing space. The slack in the leads should be so arranged that they will not be blown into other supply lines or into signal lines and signal equipment.

Where the street-lighting units are connected to the secondary side of a series street-lighting transformer, this low-tension circuit should be effectively grounded on one side.

Each street-lighting unit should be provided with a suitable cutout or absolute cutout to permit of the removal of the lighting unit without opening the series street-lighting circuit.

Street-lighting units, globes, and reflectors should be securely installed so that there will be no danger of their falling into the roadway.

Clearance. Lighting fixtures should be hung clear of the roadway so as not to interfere with traffic.

Inspection, Maintenance, and Cleaning. Street-lighting line wires and street-lighting fixture wires should always be considered alive unless they are held off effectively from all sources of energy and unless all are effectively grounded.

Where ladders are used to clean street lamps, they should be securely fastened to the pole before they are put in use. Ladders should be so located that they will not interfere with traffic.

Where trucks with elevated or elevating platforms are used to maintain street-lighting units, these platforms should be provided with insulated floors so that linemen, trouble men, and cleaners will not be liable to shock while they are maintaining the units.

Testing. The regular testing of street-lighting circuits for open circuits, short circuits, and grounds should be undertaken at a regular hour each day when linemen will be clear of these circuits.

Protection. All linemen and trouble men engaged in street-lighting work of any description should always wear rubber gloves. Where it is necessary to climb poles, the working position on the pole should be protected as outlined under Wires and Transformers.

Questions

1. What precautions are necessary in putting up and connecting lighting fixtures?
2. In working near wires of street-lighting circuits, why is it necessary to protect them from possible contact?
3. What precautions are necessary in cleaning and replacing street-lighting units?

HARDWARE

Storage. No hardware should be stored in the compartments which are used for the storage of rubber gloves or other rubber goods and for the storage of linemen's belts and linemen's climbers.

Where linemen travel to and from the job in the same truck which is used to carry hardware, the hardware should be secured well in the truck so that there will be no chance of its being thrown on linemen.

In the handling of galvanized hardware, care should be taken not to cut or in other ways remove the galvanized surface.

Installing. A lineman should not carry pieces of line hardware in his coat pockets or in his belt while he is climbing up or down a pole.

All small or moderate-sized pieces of hardware should be raised and lowered from a pole by means of an insulated canvas bag or other insulated container and *dry* hand line. All large pieces of hardware should be raised by means of a *dry* hand line to which the material is securely tied. Wherever necessary, a guide line should be attached to large pieces of hardware so that the hardware may be prevented from coming into contact with live wires while it is being pulled up to the working position. Only *dry* hand lines and *dry* guide lines should be used. Where the raising of large, heavy pieces of hardware is necessary, guards should be stationed at the foot of the pole to protect street and highway traffic in one or both directions, as may be necessary. All employees on the ground should stand clear of hardware which is being raised aloft.

No hardware should be stored upon the crossarms on poles. All hardware should be kept in the truck until it is required aloft. No hardware should be stored on the street or highway.

Maintenance. Where the removal of hardware would weaken any part of the members of a pole structure, temporary supports shall be put in place before the hardware is removed or replaced.

Questions

1. What precautions should be taken in the storage of line hardware on a line-department truck?
2. How and when should hardware be raised to and lowered from the working position on a pole?
3. Where the raising or lowering of hardware would be dangerous to street or highway traffic, what precaution would you take to protect this traffic?

TOOLS, ETC.

General. All tools must be maintained in first-class condition. Defective tools should be properly marked and returned to the toolroom for repairs or scrapping. Broken handles should be replaced. Loose heads should either be repaired or replaced. Tools with mushroomed heads should be dressed wherever possible. In those cases where it is not possible to dress mushroomed heads properly, the tools should be scrapped and replaced. All defective tools which cannot be repaired must be scrapped and replaced with tools in satisfactory condition.

The cutting edges of all tools should be maintained in good condition.

Tools shall not be thrown from the ground to the working position or from the working position to the ground. Canvas tool bags or other insulated containers should always be used, attached to *dry* hand lines, in raising tools from the ground to the working position, and in lowering tools from the working position to the ground. Large tools should not be stored at the working position.

Pike Poles. The gaff of pike poles should be maintained sharp and secured well to the pole. Handles of pike poles should be maintained sound and free from splinters.

"Deadmen." The yoke of deadmen should be maintained free from cracks and should be secured firmly to the top of the pole. Poles should be maintained sound and free from splinters. The bottom of the pole should be fitted with a spike. The spike should be secured well and maintained sharp. Where the condition of any part of a deadman is such that it cannot be maintained properly, new parts should be secured or the whole deadman should be scrapped and replaced.

Measuring Rules. Metal rules, metal measuring tapes, cloth rules or cloth measuring tapes with metal strands, or wood rules with metal trimmings should not be used on standing poles. Overhead measurements should be made by *dry* hand lines or *dry* wood molding. The actual length found by "laying off" the line or molding may be measured on a tape or rule placed on the ground.

Ladders. Wherever practicable, ladder shoes should be used to prevent the possibility of ladders slipping.

Ladders should be so placed that the horizontal distance from the point of support to the foot of the ladder shall not be less than one-fourth of the length of the ladder and not more than one-half of the length of the ladder.

In using a ladder, a lineman, trouble man, or groundman should not attempt to reach sideways so far as to throw his weight off the ladder.

Ladders must not be set up in rigs or trucks which may be started while a man is working from them.

Ladders must not be set up in a walkway or roadway exposed to traffic unless there is a guard stationed at the foot of the ladder to guard traffic.

Ladders must not be placed on a roof unless there is a piece of board under the feet of the ladder to protect the roof.

Ladders must never be placed on slanting, oily, slippery, or icy footings unless they are securely fastened and protected to prevent slipping or twisting.

Ladders must always be placed securely in position before they are put into use. Where it is necessary to shift the position of a ladder, the man on this ladder should remain on the ground while the shifting is being done.

Platforms. Linemen should not stay on the platform of a tower wagon which is moving in traffic, as, for instance, between jobs.

Tools and equipment should not be stored on the platforms of tower wagons. These should always be stored in the bottom of the wagon.

Where the platforms of tower wagons are apt to come into contact with trolley wires, trolley span wires, highway or railway bridges, they should be provided with means for lowering, and in these cases a tower wagon should always travel from job to job with the platform lowered.

Canvas Tool Bag. A canvas bag, pail, or other insulated container should be used for the raising and lowering of all tools to and from the working position on the pole and for the storage of small tools at the working position. No metal should be used in making the bag (Fig. 33-3).

The bag should be kept free from broken glass, broken pieces of porcelain, nails, and other material which might puncture rubber gloves and portable protective insulation.

Axes. The use of hand axes should be avoided in line work. In those cases where axes cannot be eliminated, they should be carried up and down the pole in tool bags. Linemen should never carry axes up and down poles in their tool belts.

Saws. Full-length saws should not be used among wires when there is possibility that line wires, taps, or services may be short-circuited or grounded by them.

FIG. 33-3. Insulated canvas tool bag.

Soldering Equipment. Soldering tools should be kept on the ground except when actually in use on the pole.

Solder pots which will not drip or throw solder to the ground should be used.

Where solder is being used aloft, a solder catcher should be placed immediately under the point where the solder is being poured, so as to prevent drippings from falling to the street. In congested districts, a guard should be stationed on the ground to direct traffic. If necessary, the pole in question should be roped off.

In working with solder a lineman must be careful that the solder does not injure his rubber gloves.

Hand lines, canvas tool bags, and all other line equipment should be kept free from splashes of solder.

Furnaces, Etc. Gasoline and kerosene should be stored in cans of approved safety type, and these cans must be clearly marked. Furnaces must not be lighted while they are in an enclosure, such as a manhole, vault, truck, etc.

Furnaces should be lighted where there is plenty of air. Where they are burned on the street, care must be taken not to interfere with street or highway traffic.

A furnace windshield must always be used and must be placed on the side of the furnace from which the wind is blowing—that is, the windward side. On the opposite, or leeward side, the shield should be opened a little to prevent overheating of the furnace.

A defective furnace should be exchanged immediately for one in good operating condition.

Portable Lamps. The cords of portable lamps should be maintained in first-class condition. Frayed or broken cords should be respliced and reinsulated wherever possible. Where this is impossible, the cords should be replaced and the old cords tagged and returned to the storeroom for scrapping.

Test lamps should be provided with nonmetallic guards (Fig. 33-4).

Fig. 33-4. Nonmetallic portable light guard.

Flash Lamps. Flash lamps must be used in all cases where light is required: in basements, vaults, manholes, battery rooms, garages, or other locations where the possibility of explosion from the use of open flames exists or may exist.

Flash lamps should not be used on poles among high-tension wires unless the metal parts are fully insulated. Where flash lamps are used for pole work, they should be provided with suitable insulated handles which will permit of their being attached to *dry* hand lines for raising and lowering.

Belt Tools. Belt tools should be so secured that they will not be apt to fall from the tool belt.

A lineman should carry only pliers, screwdrivers, and connectors in his tool belt. All other tools should be kept in the truck until they are required and then raised by means of an insulated canvas tool bag and *dry* hand line.

Screwdrivers. Screwdrivers having a metal shank extending through the handle should not be used for electrical work.

Insulation. The handles of pliers, screwdrivers, and similar tools may be covered with insulation, such as rubber tape with friction tape outer covering, varnished cambric, or high-grade molded rubber for improvement of grip, but this should not be depended upon as insulation.

The use of covering on tools shall not, however, permit of work being done without the use of rubber gloves where these rubber gloves are required.

Questions

1. (*a*) Why is it dangerous to use tools having loose or mushroomed heads? (*b*) What steps should be taken to have these repaired?
2. Why should all tool handles be maintained free from splinters?
3. (*a*) What precautions should be taken in making measurements near or among high-voltage lines, or wires, cables, fixtures, or attachments which may be crossed with high-voltage wires? (*b*) How should the measurement be laid off on a rule or tape?
4. What precautions would you take in handling ladders: (*a*) To prevent them from slipping? (*b*) To prevent them from falling? (*c*) To protect street and highway traffic?
5. What safe practices are necessary in the use and operation of tower wagons?
6. (*a*) What is the object of an insulated canvas tool bag? (*b*) How should it be maintained?
7. Mention the care you would take in the use of solder.
8. How should furnaces be used and maintained?
9. (*a*) What tools should be carried in the body belt? (*b*) Why is the use of screwdrivers with metal shanks through the handles dangerous? (*c*) How should insulated screwdrivers and pliers be maintained?

RUBBER GOODS

In this accident-prevention course, rubber goods are taken to include portable protective insulation, rubber coats, and rubber boots, where they are used for protection. Portable protective insulation does not include rubber coats, rubber boots, or rubber gloves (Fig. 33-5).

Care. Rubber goods should not be put away wet. If it is necessary to put away wet rubber goods at night, they should be dried thoroughly the following day.

Oil should not be allowed to come into contact with rubber goods. Where oil falls on rubber surfaces, it should be removed immediately.

Rubber goods should not be stored in hot places.

On trucks, rubber goods should not be carried in compartments with tools or other equipment.

Rubber goods should not be carried in linemen's pockets with tools or other equipment.

Rubber goods should not be left on the ground. While they are not in actual use on the pole, they should be stored in the proper compartment in the truck.

Rubber blankets should be rolled and not folded. When they are being rolled, their surfaces should be brushed clean to prevent dirt from being embedded in the surface of the rubber.

FIG. 33-5. Line hose in position over conductor.

Where rubber blankets, line protectors, and similar insulation are installed aloft, linemen walking across the crossarms should be careful not to spur these protectors and blankets with their climbers.

Rubber hose should be dried before it is stored. It should be laid in a flat position; no part of the hose should be strained.

Rubber coats should preferably be hung on hangers when they are being stored. At other times they should be rolled up, but not folded.

All portable protective insulation should be inspected frequently and regularly for defects. They should also be subjected to electrical breakdown tests periodically. Where defects are found, the piece should be marked with a rejection tag and sent to the storeroom for replacement. New pieces should be electrically tested for breakdown before they are assigned to the line force.

Use. Portable protective insulation should always be installed before work on live parts of or in excess of 300 volts to ground is undertaken. Wires and equipment which are liable to be at ground voltage should also be protected with portable protective insulation. In wet weather lower-voltage lines and equipment should be protected, as may be necessary (Figs. 33-6 and 33-7).

In locating portable protective insulation at the working position the lineman should first apply this insulation to all nearby points, and he should then continue to apply the insulation progressively in all directions until the most distant point requiring insulation has been protected

—that is to say, a lineman should always be protected while he is applying portable protective insulation. Rubber gloves should always be worn while portable protective insulation is being installed.

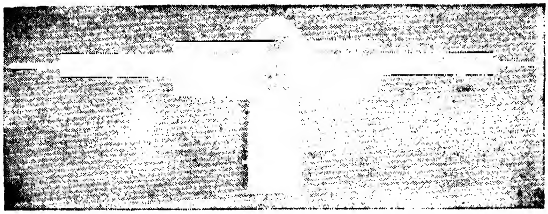

FIG. 33-6. Line hose and insulator hood in position on crossarm.

FIG. 33-7. Line protectors or "pigs."

In the removal of portable protective insulation from wires and equipment, the reverse order should be maintained. A lineman should remove the most distant piece of insulation first and remove the nearest piece of insulation last, in such a way that he will be at all times protected. Rubber gloves shall be worn at all times while portable protective insulation is being removed.

Questions

1. How should wet rubber goods be handled?
2. How should rubber coats be stored? (*a*) On the truck? (*b*) In the storage room?
3. How should rubber mats be stored in the truck?
4. How should other types of portable protective insulation be stored in the truck?
5. How would you inspect portable protective insulation?
6. In what ways can you best assist caring for rubber goods properly?

7. (*a*) How would you install portable protective insulation? (*b*) How would you remove it?

8. Consider a heavy pole on your system; suppose that you had to work on one of the high-voltage wires; explain fully how you would protect yourself, what kind of portable protective insulation would you use, and how would you apply it? (A complete diagram or photograph of the pole should be used.)

RUBBER GLOVES

Storage. Where rubber gloves are used with leather outer gloves or cotton under gloves, they must not be put away until they have been separated from the leather outer gloves and the cotton under gloves.

A lineman should not put his rubber gloves into his coat or trousers pockets where there may be tools and line material. Gloves carried in this way are liable to injury.

While the gloves are not being used on the job, they should be stored in a separate compartment on the truck. No tools or line material should be stored in this compartment. Rubber gloves should be available at all times when the lineman needs them on the job.

Manual Tests. At each job before a lineman puts on his rubber gloves he should test each glove mechanically for cuts and weak spots by rolling it up tightly beginning at the gauntlet end; he should notice if any air escapes through the palm, the thumb, or the fingers of each glove. This is usually called the "air" test. Gloves which show weak spots or air leakage in this test should not be used for voltage protection.

Electrical Tests. Rubber gloves should be subjected to an electrical breakdown test periodically. Tests should be conducted in accordance with the National Electric Light Association specifications. Gloves which show defects in this test or which do not fully comply with the specifications should be replaced with good gloves.

Discarding. When rubber gloves become defective while they are in service, they should be exchanged for good gloves.

Inner Gloves. Cotton gloves may be worn under the rubber gloves; their use may be found to make the rubber gloves more comfortable.

Protecting Gloves. To protect rubber gloves from injury, leather gloves may be worn over the rubber gloves. Protective leather gloves may be worn over the rubber gloves when wires are being spliced, when solder is being handled, when it is necessary to move about in the working position, when line wires are being tied in on insulators, and when any other work is being done where the rubber gloves would be liable to injury.

When Not to Be Used. Rubber gloves must not be worn while linemen are going to and from work in a rig, truck, or other conveyance.

Rubber gloves should not be worn for those ground jobs where the possibility of accidental contact with live wires and equipment does not exist.

Rubber gloves should not be worn while a lineman is climbing up or down the lower part of a pole below the lowest crossarm carrying supply lines, supply equipment, signal lines, or signal equipment.

When Used. Rubber gloves must be worn by a lineman while he is putting portable protective insulation on line conductors and pole equipment.

A lineman must wear his rubber gloves while he is removing portable protective insulation from line conductors and pole equipment.

Rubber gloves must be worn by a lineman when he is making tests on the high-tension and low-tension sides of transformers when they are being connected in circuit for the first time, when they are being tested, and when they are being inspected for burnouts.

All linemen and trouble men should wear rubber gloves while they are removing and replacing fuses and cutouts on primary distribution circuits.

Linemen should wear their rubber gloves while they are stringing wire near to live lines and live equipment exceeding 300 volts to ground.

In using rubber gloves, care must be taken to keep hands away from contact points where an arc may form. A burn through a rubber glove may be serious.

Rubber gloves should not be interchanged. Each lineman who requires rubber gloves should be provided with them before he is allowed to climb, and he should use only these gloves and no one else's in his work. When his gloves become defective, he should turn them in for another pair.

Rubber gloves must be worn by linemen on all work where the voltage of the part being handled is near, or more than, 300 volts to ground or where, in the case of low-tension lines and equipment, they may become crossed with high-voltage lines. In working on lines and equipment of 300 volts and under in wet weather, a lineman should wear his rubber gloves whenever, in the opinion of his foreman, it is necessary to use them.

Questions

1. How should rubber gloves be stored?
2. How and when should rubber gloves be tested on the job?
3. What procedure is necessary to prevent the use of defective gloves?
4. (*a*) Why may leather outer gloves be necessary? (*b*) When may they be worn over rubber gloves?
5. When should rubber gloves *not be* worn?
6. When should rubber gloves *be* worn?
7. Why are rubber gloves necessary?

LINEMEN'S BELTS

General

Specifications. The National Electric Light Association specifications are recommended for linemen's belts. It is suggested that all new belts be purchased in accordance with these specifications and that old belts be repaired to conform with them.

Personal Use. Each employee authorized to climb should be equipped with a complete belt (body and safety belt), and he should use no other.

Use. Linemen's belts and safety belts shall be used for no other purpose than that for which they are intended. They should not be used as slings for hoisting materials. In emergencies, as in cases of electric shock, *dry* hand lines may be attached to a lineman's belt and the belt used in connection with lowering him.

Storage. In going to jobs, linemen's belts should be stored in a satisfactory way in proper compartments on the truck or rig to protect them and to prevent them from being cut by tools, rubbed by files, and from being caught under heavy line material. At night, body and safety belts should be stored carefully in compartments assigned for their storage on trucks and rigs or in other suitable places where no other equipment will be stored.

Inspection. Body and safety belts should be inspected carefully periodically for condition of

1. Leather
2. Leather near the holes
3. Rivets
4. Stitches
5. Buckles
6. D rings
7. Snaps

Belts which are weak or defective in any respect should not be used.

Repairs. Where repairs are necessary, they should be made immediately. Belts which have been repaired must be reinspected after the repairs have been completed. In case the repairs have not been made in a satisfactory manner, the belt should be withheld from use until the necessary repairs have been made properly or until a new belt has been provided. Only first-class material should be used in making repairs to linemen's belts.

Maintenance. The leather of a lineman's belt should be treated occasionally with neat's-foot oil to keep it soft and pliable.

Body Belts

Maintenance. No more holes than are absolutely necessary should be cut or punched into a body belt. Holes weaken the leather.

The attachment of metal parts to body belts should be avoided wherever possible. Metal chains and keepers (dogs) should not be used. In their place there should be used leather or rawhide strings with hard wood or fiber keepers.

D Rings. D rings should be placed so that they will be supported from the inside of the body belt. A lineman will then be less liable to fall in case the D rings pull out.

Safety Belts

Use. Care must be taken by linemen in the attachment of snaps to D rings. Care must be taken that the D ring is within the hook and that the keeper of the snap is closed fully before any weight is applied to the safety belt.

After a safety belt is snapped in place, a lineman should test it by carefully throwing the weight of his body against the safety to make sure that it is properly fastened before he undertakes any work. While this test is being made, the lineman should have his hands close to the pole or other support so that he may readily grasp the support in case the safety should pull out. This test should be made each time the safety belt is used in a new position.

Safety belts should be so secured that there will be no possibility that they will cut out by being accidentally pressed against line equipment.

Safety belts should not be supported from insulator pins, insulators, line wires, or crossarms which may be weak or rotted. They should not be attached to a pole above the top crossarm. They should not be attached to vertical braces, crossarm, or transformer braces. They should not be attached to a pole close to a guy where the guy is furnished with pole plates or guy hooks. Safety belts should not be attached to pole steps or trimmers hooks. The safety belts should not be attached so that they may slip off.

The safety belt must not be secured to crossarms and similar equipment which are being removed.

When the safety belt is being put in place, care must be taken that it is not twisted and that it does not foul material which will give way when strain is applied.

Inspection. Snaps on safety belts should be closely inspected for defective and tight jaws and for weak or defective keeper springs. Snaps should also be inspected for cracks in the metal.

Questions

1. How should linemen's belts be stored?
2. What parts of a body belt should be examined in an inspection?
3. What parts of a safety belt should be examined in an inspection?
4. How should the leather be kept soft and pliable?
5. (*a*) What should be done in the matter of repairs? (*b*) What steps should be taken to make sure that repairs have been made properly?
6. (*a*) Why should the use of metal parts on body belt be avoided? (*b*) How can this be done?
7. How should D rings be secured to a body belt?
8. Show how snaps should be fastened to D rings.

9. What points of the snap should be inspected carefully to prevent them from cutting out?

10. (*a*) How should the safety belt be tested? (*b*) How often should this be done?

11. Where, at the working position, should the safety belt be secured?

12. In what ways can your body and safety belts be improved so as to make them safer?

CLIMBERS

Straps. The leather straps should be treated occasionally with neat's-foot oil to keep the leather pliable and soft. Straps should be inspected frequently and should be maintained in good condition at all times. Straps which cannot be properly repaired should be replaced immediately.

Pads. The use of pads is recommended. They should be maintained in satisfactory condition and when they become worn should be replaced.

Gaffs. The gaffs or spurs should be maintained sharp. Where gaffs are worn so that they cannot be made to grip wood easily, they should be replaced with new ones. (In some cases manufacturers are able to replace gaffs in a satisfactory manner. Linemen should never attempt to make these repairs themselves.)

Personal Use. Each lineman should be equipped with a pair of satisfactory climbers, and he should use no others. Climbers should not be loaned or borrowed.

Storage. When climbers are not in use, they should be stored in a separate compartment in the rig or truck. They should never be placed in the rubber-glove or rubber-goods compartments. They should be wiped clean and dry before they are stored.

When climbers are being stored, they should be wrapped in pairs and fastened with their straps.

Use. Climbers should *not be* worn (1) when linemen are traveling to and from a job; (2) when linemen are piking poles; (3) when linemen are on the ground for a great length of time.

While linemen are standing on rubber mats covering transformers and while they are standing or walking about on crossarms on which there are rubber mats, rubber protectors, and similar portable protective insulation, they should use care that the gaffs of the climbers do not puncture the surface of the portable protective insulation.

In climbing poles, linemen should be careful to put the spurs in only sound wood and to avoid all knots, loose wood, checks, cracks, decayed spots, nails, ground wires, and similar attachments. A lineman should so use his spurs as to prevent the possibility of their cutting out.

When it is necessary to climb ice- or sleet-covered poles, special care must be taken to seat the gaffs in the wood of the pole securely so as to avoid cutting out.

Where steps are provided, they should always be used.

In coming down a pole, a lineman should always use his climbers. He should not jump or "coast."

In working on a pole, a lineman should be careful in using his climbers so as not to injure any other linemen working nearby.

Questions

1. How should straps be maintained?
2. Why is it necessary to use long gaffs, and why should they be maintained sharp?
3. When should climbers *not be* worn?
4. When should climbers *be* used?
5. What precautions should be taken in moving about crossarms on which there is portable protective insulation?
6. How should climbers be used in climbing up and down poles?

HAND LINES

Specifications. Hand lines should be at least twice as long as the height of the highest crossarm on the system.

Hand lines with metal strands or cores should not be used.

New hand lines should be examined closely for metal strands or cores before they are used.

No metal wire and no metal hooks should be used in the making up of new hand lines.

Where it is necessary to connect two hand lines permanently, a splice should be made. No metal wire or clamps should be used in making the splice. The strength of the splice should not be less than the strength of any part of the line. Knots, friction tape, cord, or marlin should not be used in joining the two parts of the line. Splices should not be bulky.

Each end of the line should be tied well to prevent unraveling of the strands.

A hand line should be strong enough safely to lower a man from a pole.

Hand lines with worn or frayed parts should be scrapped immediately and replaced with hand lines which are in good condition.

Use. Hand lines should be carried up a pole uncoiled and attached to the back of the body belt. When a lineman is climbing with a hand line, he should take care to prevent the hand line catching on pole attachments.

Dry hand lines should always be used in connection with stringing wires where these wires may come into contact with high-voltage lines or with lines which may themselves be crossed with high-voltage lines.

Hand lines should not be pulled over sharp bends, sharp edges, live wires, or surfaces with splinters.

Hand lines should be kept free from solder, oil, and grease.

Hand lines should be kept free from snarls and knots.

When hand lines are not in use, they should be rolled up and stored in the truck. (This applies except when hand lines are being dried out.) Hand lines should never be allowed to lie on the street or highway.

Where hand lines are served out on poles, at least one ground hand should be stationed at the foot of the pole to take care of the loading and unloading of the hand line and to see that the ends of the hand lines are kept free of all street and highway traffic.

Care. Hand lines should not be stored while they are wet.

Hand lines should be kept *dry*. In wet weather they should be kept under cover when not actually in use; and when they become wet, in use, should be laid aside to dry and replaced with *dry* lines.

Rescue. One hand line should be kept in reserve and maintained *dry* at all times for use in case of possible rescue of a lineman from a pole. In dry weather this line should be strung over the top crossarm on the pole. In wet weather, the hand line should be kept in a protected part of the truck where it will not be liable to become wet. Where a line gang is working on several poles, more than one hand line may be provided for use in connection with rescue after electric shock.

Questions

1. Why should no metal parts be used in the construction of hand lines?
2. Why are bulky splices in hand lines undesirable?
3. Why is it necessary to use only *dry* hand lines?
4. Why should hand lines be kept free from solder, oil, and grease?
5. Why is it necessary to keep hand lines off the street and highway?
6. What other precautions are necessary in the use of hand lines?
7. How should a reserve hand line be held in readiness for use in case of rescue?

GOGGLES

Type. If for any reason goggles are used, a type of goggle with a minimum amount of exposed metal or exposed celluloid is recommended. Goggles should conform to the recommendations of the Accident Prevention Committee of the National Electric Light Association as published in the *Proceedings* of the thirty-ninth convention (1916) of that association.

Question

1. What type of goggle should be used for line work?

JEWELRY, CLOTHING, ETC.

Clothing. Linemen should avoid the use of overalls, dungarees, jumpers, and coats having metal buttons, metal straps, and similar metal fittings. Bone buttons should be used in every case. Buttons should be sewed in place with thread. Loose clothing should not be worn.

Linemen should not wear shoes with nailed soles. Shoes should have sewed soles.

Linemen should not wear caps with covered metal buttons or with wire reinforcing in the visors. Derby hats with wire in the brim should not be used by linemen.

In the wintertime, linemen should not wear ear caps with metal ear frames and having metal connecting strips between each ear piece. Woolen caps which will fit well over the ears should be worn in these cases.

Linemen should not wear suspenders and armbands with metal buckles and other metal parts. They might come close to live parts and cause serious, if not fatal, injury.

Jewelry. Linemen should be instructed not to wear rings of any kind on their fingers while they are working on a pole near lines or equipment which are or may be alive.

Metal key chains or metal keepers for key rings should not be worn on the outside of clothing. There is always a possibility that they may come into contact with live lines or live equipment.

Metal watch chains should not be worn by linemen. There is always a possibility that watch chains may come into contact with live lines or live equipment while a lineman is climbing through narrow spaces or while he is reaching to outboard positions on the crossarms.

A lineman should not wear any pins or metal buttons (such as club or association pins and buttons). These pins and buttons oftentimes have sharp edges which may result in cuts. They may also be the cause of electric shock and burns from electrical contact.

Questions

1. Why should a lineman avoid the use of metal buttons, wire, or metal in his clothing?
2. Why is it dangerous for a lineman to wear rings while he is working on live equipment or live lines?
3. Why should a lineman avoid wearing jewelry while he is working on high-voltage lines?

INSPECTION

Ground Work. Inspectors assigned to the inspection of poles should be provided with the same equipment and tools as are furnished to linemen for similar work on this equipment.

Work Aloft. Where inspection involves the climbing of poles and going among high-tension wires, only qualified linemen should be assigned as inspectors.

Inspectors' tools, belt, climbers, and rubber gloves should be subject to the same care and supervision as is given to linemen's equipment.

Inspectors assigned to the inspection of fixtures, cutouts, connections, and all lines and equipment located on a pole, tower, or structure, should be given full protection; at hazardous locations lines should be removed from service and grounded, if necessary, in order that a thorough inspection may be safely made.

Where inspectors are required to climb poles, towers, or structures, ground hands and other assistants should be provided as may be necessary.

Poles, towers, structures, guy lines, and line fixtures and equipment should be given thorough periodic inspection.

Question

1. What precautions should be taken by line inspectors?

MISCELLANEOUS LINE EQUIPMENT

Air-break Switches. The handles of air-break switch levers should be effectively connected with ground by means of a ground wire so as to fully protect the lineman or other authorized person operating the switch.

The hinges of air-break switches should be sufficiently stiff (and maintained so at all times) so that when the blades have been turned into the open position there will not be any tendency for them to fall back on live clips. The switch should be inspected from the ground, platform, or other safe place, after it has been opened, to see that all blades have opened a proper distance.

Where single-throw air-break switches are opened, they should be opened to the maximum amount.

Double-throw air-break switches should be opened so that the blades clear both sides of the switch by an equal amount.

Provision should be made in every case for the locking of air-break switches whenever it may be necessary. Space should be allowed for the attachment of several locks at one time.

Horn-gap Switches. After lightning arresters have been charged, the horn-gap switches forming part of the lightning-arrester circuit should be opened to normal running position immediately. Where horn-gap switches are allowed to remain closed, in the charging position, serious injury may result.

Horn-gap switches should be fully opened and completely separated from all live lines and equipment whenever it is necessary to work near the lightning arrester.

Lightning-arrester Equipment. Where rubber gloves will not give sufficient protection, pole-type lightning arresters should never be touched or approached unless they are completely disconnected from all live lines and live equipment and are effectively connected to ground at the line side of the arrester.

Larger types of lightning arresters (such as aluminum-cell and oxide-film types) should never be touched or approached unless they are completely disconnected from all lines and live equipment and unless all parts have been discharged to ground and effectively grounded.

Larger types of lightning arresters (such as aluminum cell and oxide film) should always be provided with screens or fences which will prevent possible contact while parts of these arresters may be alive. The screen or fence should be provided with a gate large enough to permit of the removal of individual units. The gate should be provided with a lock, the key of which should be kept by an authorized person.

Choke Coils. Choke coils should never be approached or touched unless they are disconnected from all live lines and equipment, and unless they have been discharged to ground and grounded.

Disconnect Switches. Disconnect switches may be used with care to open a live line, but not under load.

Disconnect switches should be carefully used to open sections of dead lines where these lines parallel other high-tension lines.

Disconnect switches may be carefully used to open a tie line or to break two parallel high-tension lines.

Two or more high-tension lines connected separately with two or more generating systems should not be connected by disconnect switches on the line unless means are provided for synchronizing these several lines.

Fuses. Where fuses are taken out of circuit, they should be removed entirely from the fuse boxes.

A lineman should always shield his eyes when he is installing or removing fuses.

Oil Switches. Where an oil-switch case is not permanently and effectively grounded, it should be considered alive until the oil switch is disconnected from the circuit and all parts are grounded.

Oil-switch cases should not be removed from the oil-switch mounting unless the whole switch has been removed from service and is thoroughly and effectively grounded.

Where an oil switch is removed from service and grounded, the grounds should be so placed that they will not be disturbed or removed during the time that the oil switch is disconnected from service.

Oil switches used for line work should be so provided that it may be possible to lock the handles in the open position whenever necessary. Space should be allowed for the attachment of several locks at one time.

Current Transformers. The secondary circuits of current transformers must be connected to ground at all times while the transformers are in service.

The secondary circuits of current transformers should never be opened. Where it is necessary to remove any parts of the secondary circuits, these parts should be provided with jumpers before the circuit is disturbed, to avoid the opening of circuits.

No parts of current transformers should be approached or touched unless these transformers are completely disconnected from circuit and effectively grounded.

Potential Transformers. A dead lamp connected on the low-voltage side of a potential transformer should not be considered as a positive indication of the condition of the high-voltage side. Voltmeters, in addition to lamps, should also be connected to the low-voltage side. Lamps should first be connected in circuit and the voltmeters used as an extra check.

The low-voltage side of potential transformers should always be permanently and effectively connected with ground.

Where the type of design and method of installation require, insulated tongs should always be used in connection with the removal and installing of potential transformer fuses. Where the high-tension voltage is such that rubber gloves would offer protection, they should always be worn while fuses are being changed.

Time Clocks. Where time clocks are mounted on poles and other structures, they shall be attended only by qualified linemen.

Where time clocks are provided with high-voltage connections, a lineman should always wear his rubber gloves in winding, resetting, and otherwise maintaining the clock.

Questions

1. What precautions should be taken in the operation of air-break switches?
2. What precautions should be taken in charging lightning arresters of the aluminum-cell type?
3. Why is it necessary for linemen to avoid coming close to lightning arresters while they are connected in service?
4. What precautions are necessary in the operation of disconnect switches?
5. Explain the steps you would take before beginning work on oil switches.
6. What precautions should be taken in the maintenance of current transformers and the secondary circuits of current transformers?
7. (*a*) Explain how you would use a potential transformer for checking high voltages. (*b*) Why is a "black" lamp not a positive indicator?
8. Explain how you would remove the fuses from potential transformers used by your company.

OPERATIONS

Removal of Lines and Equipment. Where the voltage of the lines or equipment is such that it would be unsafe to work on them alive, where the lines and equipment to be worked on are installed in a congested condition, or where the lines or equipment are located so close to high-tension lines as to make work on the former unsafe, the high-tension lines in question should be removed from circuit and effectively grounded during the whole of the time when men are working on, or adjacent to, these lines.

Before high-tension lines and equipment are disconnected from service to permit the making of repairs, replacements, and additions, the necessary arrangements should be made as far in advance as possible for the removal of these lines and equipment. The request for the disconnection of these lines and equipment should be supplemented with a full description of the work to be done and the manner in which it is proposed to do this work. Where the work is involved or complicated, the description should be supplemented with one or more drawings if necessary.

Where two or more gangs, crews, or departments intend to work on the same line or line equipment at the same time, separate requests should be made out by each of these.

These requests should be made to the load dispatcher, operator, or other official of the company responsible for this department of the company.

No work shall be attempted until the full approval has been received from the load dispatcher, operator, or company official responsible.

Before work on the line is undertaken the person responsible for this work should make sure that all substation and generating station equipment which must be removed from circuit has been disconnected, and where station or substation grounds are necessary, that these have been applied.

Where station or substation equipment is removed from service, all switches disconnected should be tagged. These tags should show the work being done, for whom the circuit was removed, and should contain such other information as may be necessary. One tag should be issued for each gang, crew, or department for whom each piece of station or substation apparatus has been disconnected. Switches in stations and substations should be blocked or otherwise protected against accidental reclosing while men are working on outside circuits and equipment served by these station or substation switches.

Where it is necessary to make preliminary arrangements for the removal of lines and equipment, the person in charge of this work or his designated representative should make all the arrangements. The load dispatcher should not act on word from any other member of the crew, gang, or department. Each person receiving a telephone message should repeat it to the sender for the purpose of checking. The sender should note the receiver's name, and the receiver should obtain sender's name. In telephone conversations, all circuits should be referred to by number, location, position, or other means which may be available. Exact locations and positions should always be given.

When the high-tension equipment has been disconnected from the generating station or substation sources of supply, the lines or equipment near the working position should be protected by grounding on all sides of the working position, so that linemen will be safeguarded against electric shock at all times. In connection with grounding the line, a workman should never place himself in a position where he will be liable to electric shock. The line should be discharged to ground before it is grounded.

In the temporary disconnection of high-tension lines, care must be taken not to interrupt service to fire pumps or manufacturing operations where continuous service is required.

Restoring of Lines and Equipment to Service. When all linemen are clear of the high-tension lines and equipment which have been removed from service, advice to that effect should be telephoned or conveyed in another way to the load dispatcher, operator, or other company official responsible by the person in charge of the gang, crew, or department handling the work. This person must necessarily be the one who arranged for the temporary removal of service from this high-tension line or equipment. This advice should not be given, however, until all linemen are clear, all work restored to normal condition, and all danger to street or highway traffic removed.

Where it is necessary to leave a job before it is completed, as, for instance, where it is necessary to restore temporary service to a line or a piece of equipment during the evening and work will be continued on the following day, all temporary work should be so secured as to permit of continuous service and as to prevent the possibility of wires or equipment falling to the ground and resulting in accident to street and highway traffic below.

Where conditions are such that work of an emergency character is necessary, all repairs should be made in such a way as to eliminate accidents. Complete repairs should be undertaken at the earliest possible date following.

As each job is reported completed to the load dispatcher, operator, or other company official handling the work, the corresponding tags should be removed from each piece of station and substation equipment which had previously been *held off* and tagged for that job. Where the same equipment is *held off* and tagged for two or more men or gangs, care must be taken by the person reporting the completion of his part of the work not to call for the removal of tags covering the work of those men or gangs who are still working on the line equipment involved. After the tags have been removed, they should be filled out so as to show when they were removed and by whose authorization.

Each step in the removal of station and substation equipment and the reconnection of station and substation equipment, as well as each conversation held in connection with the removal and connection of this equipment, should be carefully noted by the load dispatcher, operator, or the company official handling this work. In the event that the lives of linemen are endangered, the load dispatcher, operator, or the company

FIG. 33-8. Rubber glove ready for test and inspection.

official handling this work should act immediately in safeguarding the men working on the lines.

Questions

1. What preliminary arrangements should be made before high-voltage lines are disconnected and grounded?
2. Why is it necessary for each line crew or gang to make its own request for a high-voltage circuit and to provide its own protection?
3. Why is it necessary that only one representative of the gang or crew make all arrangements with the load dispatcher or his representative for the disconnection and later connection of all high-voltage lines and equipment?
4. Why is it necessary to repeat each telephone conversation?
5. What precautions should be taken where it is necessary to restore a line to service temporarily before it is possible to complete the work permanently?

METHOD OF TESTING RUBBER GLOVES BY COMPRESSION (AIR)

The following test should be made on rubber gloves at each job before they are put on for the first time; in connection with this test, each glove should be carefully inspected for possible defects in the palms, fingers, and thumbs. Where weak or punctured parts are indicated by this test, the gloves should be immediately replaced with a pair in good condition before a lineman approaches high-voltage lines, high-voltage equipment, or lines which may be alive through contact with high-voltage lines.

Gloves should first be inspected for general condition, softness, and size. The surface of rubber gloves should then be brushed with the hand before they are rolled up to prevent the possibility of material adhering to the surface puncturing the rubber when the lower part of the glove is wrapped up tightly. Each glove should be tested separately.

The gauntlet end should then be turned back a very short distance and rolled up tightly.

When the glove has been rolled up to the bottom of the palm, it should be held securely with one hand so as to prevent the escape of the air inside the glove. The other hand may be used in going over the surface of palm, fingers, and thumb in looking for punctures and weak spots. A glove, completely rolled up and ready for test and inspection, is shown in Fig. 33-8.

Gloves which pass this test satisfactorily may be worn. Leather protective gloves may also be worn over the rubber gloves, as outlined in the text, to protect the rubber gloves from injury.

SECTION 34

First Aid

1. GENERAL*

First aid tells what to do until the doctor comes. It may mean the difference between life and death, between rapid recovery and long hospitalization, between temporary disability and permanent injury. In every case, proper first aid reduces suffering and makes the physician's job easier when he assumes the care of the patient. The responsibilities of the first aider stop when the physician's begin.

The following general directions of first aid will enable you to approach your problem more intelligently.

1. *Keep the injured person lying down in a comfortable position, his head level with his body, until you know whether the injury is serious.*

This is a prevention against fainting and helps prevent the condition called "shock" which is discussed later. An untrained person usually wants the patient to sit up, or tries to help him stand up. You may raise the patient's head if his face is flushed. If he vomits you may turn his head to one side to prevent choking. Otherwise, the rule is to keep him lying down with his head level.

2. *Look for hemorrhage, stoppage of breathing, poisoning, wounds, burns, fractures, and dislocations. Be sure you find all his injuries.*

Pain is an important indication of any injury. When examining an injured person, let him guide you to possible severe injuries. When you examine an injured person, remove enough clothing to determine the extent of his injury. Rip the seams if you can. Taking off the clothes in the usual manner may cause unnecessary suffering and may aggravate the injury. If you see blood soaking through the clothing or running out of a coat sleeve, remove enough clothing to provide a clear view of the wound.

You can determine whether the patient is breathing, in most cases, by inspecting his chest closely for a few seconds. If asphyxiation has caused stoppage of breathing, as in drowning, gas poisoning, or electric shock, artificial respiration is the immediate requirement. Artificial

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respiration is also applied for head injury, if the patient stops breathing and turns blue.

In case several persons are injured in one accident, it is most important that the first aider quickly survey the entire situation and determine which victims have injuries that require immediate attention.

Find out whether the patient is conscious by talking to him. If he is, he can usually tell you where he has been hurt. Remember that, if a patient is unconscious or semiconscious after an accident, the cause is usually a head injury. Bleeding from one or both ears or from the nose, if there is no direct injury to these parts, usually indicates a fractured skull.

Examine the lips and mouth for burns or discolorations. These are the signs of poisoning. Bloody froth on the lips may indicate epilepsy. Smell the patient's breath for evidence of poison, particularly when there does not appear to be any actual physical injury.

Feel the patient's pulse. But remember that failure to find a pulse is not an indication of death. Note the color of the face. A flushed or normal color means a strong pulse and good circulation. A pale face means a weak pulse and poor circulation. Do not give stimulants in cases of severe bleeding, suspected internal bleeding, or head injury.

3. *Keep the injured person warm.*

Avoid overzealous application of external heat, but maintain normal body temperature. This is essential to prevent serious shock. If the weather is cool, it is important to wrap the patient underneath as well as cover him.

4. *Send someone to call a physician or an ambulance.*

Your messenger must provide this information: the location of the injured person; the nature, cause, and probable extent of injury and the supplies available; what first aid is being given. Obviously all this information is essential, so that the physician will know exactly where to come, what equipment he will need, and what measures to suggest should be taken before his arrival.

5. *Keep calm and do not be hurried into moving the injured person unless it is absolutely necessary.*

You should not move the patient until you have a clear idea of the nature and extent of his injuries and have given first aid.

6. *Never give water or other liquid to an unconscious person.*

Water may enter the windpipe and strangle the unconscious person. But if the injured person is conscious and if there is no evidence of severe abdominal injury, give him all the water he wants, slowly and in sips. Whiskey and brandy are not proper first-aid stimulants. They may do considerable harm. Hot tea and hot coffee are satisfactory, particularly if the patient is cold.

7. *Keep onlookers away from the injured.*

They frequently interfere with the treatment.

8. *Make the patient comfortable and keep him cheerful, if possible.*

Quiet his fears and keep him hopeful. It is important for him to have a good mental attitude in order to promote cooperation and aid recovery.

9. *Don't let the patient see his own injury.*

In severe cases, don't let him know that he is badly hurt. Be sure that nothing is done to cause him further injury. You can avoid distress and confusion by notifying the patient's family properly. Tell them where the patient is, and whether he is being taken to a hospital, and give them any other helpful information of this nature. But it is not your job to describe the patient's injuries or to give the family any medical details.

Checking What You Know

1. Is it proper to allow a patient to sit up before determining the nature of his injury? Why?
2. What information should be passed on to a doctor in summoning him to an accident case?
3. Why it is not well to allow the patient to see his own injury?
4. What indications are there of good blood circulation?
5. What does bleeding from the ears or nose often indicate?
6. What easy way is there of determining whether or not a patient is breathing?
7. Why should water or other liquid never be given to an unconscious person?

2. BLEEDING AND ITS CONTROL

It was general practice some years ago, before setting a chestnut pole, to shave the pole with a drawknife and smooth the knots with a double-bit ax.

A line crew working in a certain town in western Pennsylvania was replacing some condemned poles. A goundman was removing the protruding knots with an ax. During this operation the ax slipped out of his hand and traveled about 10 ft, striking another groundman on the right cheek, resulting in a 5-in. incision, severing the artery.

A groundman working nearby immediately put pressure on the carotid artery (in neck) and called for help. A compress bandage was applied with knot tied firmly on the wound, thus exerting enough pressure to stop bleeding. The injured employee was then moved to a physician's office for professional care. The fact that his fellow workmen were trained in first aid saved this employee from great loss of blood, which would have endangered his life.

Loss of blood sufficient to result in death can result from a hundred-and-one everyday accidents of a less spectacular nature.

Circulation

To understand bleeding and its control you must know something about the mechanics of blood circulation.

The circulation of the blood is carried on by the heart, the pump which forces the blood by its beat into the arteries, capillaries, and veins which form a closed system that brings the blood back eventually into the heart through the veins. The purpose of circulation is to carry oxygen and food in the blood to all parts of the body and to bring back the waste products and carbon dioxide for elimination, thus sustaining life. To maintain a normal circulation, the blood must flow with a certain force provided by the heart, and by the elasticity of the walls of the blood vessels, and by the presence of enough blood to fill the system. This force is called the blood pressure. Blood pressure may fall whenever any element of the circulation is at fault. This discussion deals with hemorrhage, or as commonly called, severe bleeding.

Bleeding

Bleeding is stopped usually by the formation of a clot at the cut edge of injured blood vessels. The blood is always a liquid when it circulates in blood vessels, but when the vessels are broken or cut, the blood flowing from the wound tends to coagulate, or clot. Three to six minutes is the normal time required to form a clot. The blood of some people lacks the ability to form a clot, or else takes a long time to do so. Such persons are known as "bleeders," and sometimes they bleed to death from a small injury.

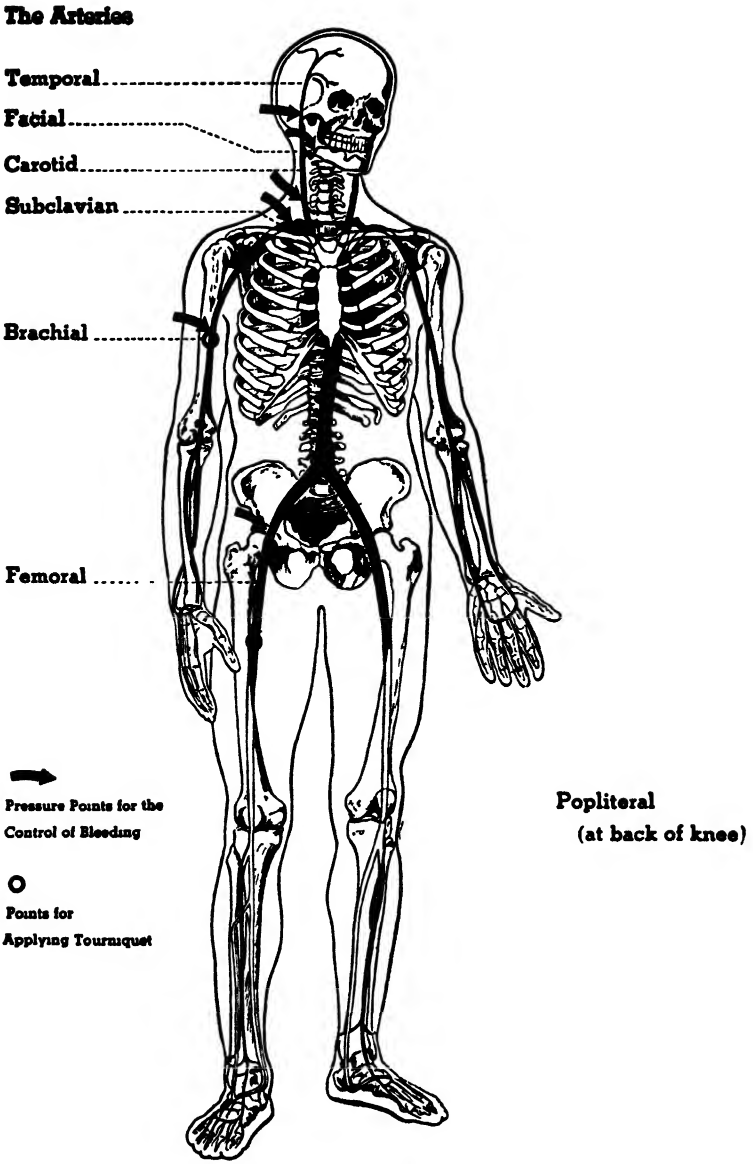
Arteries

Arteries are blood vessels which carry the blood away from the heart. For first-aid purposes, we need to consider only those from which serious bleeding is likely to occur. Many arteries not mentioned here are buried deep in the body, and if these protected arteries are injured, first aid can do little to control their bleeding. To control bleeding from a cut *artery*, pressure is necessary. The *pressure is applied between the cut and the heart*, at some point where the main artery to the injured part lies close to the bone, because it is necessary to have a firm object against which pressure may be applied, hence the name "pressure point."

There are *six principal points where hand or finger pressure against a bone may stop bleeding from a cut artery.* (See Fig. 34-1.)

For the arteries to the head and neck:

1. In the neck at the side of the windpipe against the backbone
2. Just in front of the ear, against the skull



PRESSURE POINTS
TO CONTROL ARTERIAL BLEEDING

FIG 34-1.

3. About an inch forward from the angle of the jaw, where a large branch crosses the jawbone

4. Behind the inner end of the collarbone, down against the first rib

Digital Pressure (Applied with Finger or Thumb) is Much Easier Controlled and More Adaptable to Pressure Points Than Any Other Type

There are six important pressure points on each side of the body:

1. **The temporal artery, with the pressure point immediately in front of the middle portion of the ear, which should take care of bleeding on the scalp and upper portion of the head.**
2. **The carotid artery, with the pressure point located deep down, about an inch to the outer side of the Adam's apple, taking care of bleeding in the neck or the head.**
3. **The subclavian artery, with the pressure point deep down behind the center of the collar bone, against the first rib, taking care of bleeding around the shoulder or in the arm.**
4. **The brachial artery, which is pressed against the bone of the upper arm, about its middle, by pulling the biceps or larger muscle of the upper arm to the outer side, taking care of all bleeding below that point.**
5. **The femoral artery, the pressure point of which is against the bone of the thigh, high up on the inner side about 3 inches below the inner margin of the hip bone, taking care of all bleeding in the thigh or leg.**
6. **The popliteal artery, the pressure point of which is easily found in the hollow of the knee, taking care of all bleeding on the back surface of the leg.**

Some authorities add the facial artery as shown in the diagram, on the chin.

You should feel the arterial pulse in every case, otherwise you are not pressing the artery. Pressure should be sufficient to stop this pulsation.

FIG. 34-2.

5. On the body side of the upper arm, halfway between the shoulder and elbow

For the arteries to the lower limbs:

6. In the mid-groin, as it passes over the pelvic bone

Capillaries

Capillaries are those extremely small vessels at the ends of the arteries. They form a complete network over all the parts of the body. If you stick a point of a fine needle anywhere in the body, blood will come. It oozes from the capillaries, and *this kind of bleeding offers no serious problem of control.* The blood will ordinarily clot of its own accord, but a slight pressure directly over the wound will hasten clotting.

Veins

The capillaries join together to form larger vessels called "veins," which carry blood back to the heart. These veins constantly join others and become larger. The number of veins carrying blood back to the heart is much greater than the number of arteries carrying it away from the heart. Large veins are not as well protected as the arteries and are much more frequently cut. Many veins are visible on the surface of the body. One or two large veins lie beside almost every large artery.

There is only one practical way to tell whether bleeding comes from an artery or a vein. *Blood from an artery usually comes in spurts.* From a vein it comes in a steady flow.

Bleeding from veins can usually be controlled by direct pressure. First, however, you must cover the wound with a compress (or clean handkerchief), if at all possible. Elevating the bleeding part is helpful. You may *also exert pressure on the sides of the wound,* particularly the side *away from the heart.*

Application of Tourniquet

A tourniquet should be a flat band at least 2 in. wide. It should never be a rope, wire, or sashcord. A triangular bandage folded to form a narrow cravat is excellent, but a belt, stocking, handkerchief, or something similar will do. Wrap the material twice around the limb, if possible, and tie a half knot. Place a short stick or similar article on the half knot, and tie a square knot over it. Twist the stick rapidly to tighten the tourniquet, thus pressing on the artery and stopping the flow of blood. Hold the stick in position by the ends of the bandage already applied or by another cravat looped around the end of the stick and tied around the limb.

Be careful not to get the tourniquet too tight; there is danger of permanently damaging the arteries. REMEMBER: *A tourniquet is always a dangerous instrument and should not be used if the bleeding can be checked readily otherwise.* Don't cover a tourniquet with a bandage or splint. It may be forgotten and not loosened when it is necessary.

Never leave a tourniquet tightened for more than 15 minutes at a time. Loosen it and check to see if bleeding has stopped, if not, tighten for another 15 minutes.

Shock is present in all cases of serious bleeding. It should always get prompt attention as soon as bleeding is controlled.

Checking What You Know

1. How would you treat a wound with severe bleeding? What would you think of first?
2. Describe the use of tourniquets in controlling arterial bleeding.
3. Why it is necessary to loosen a tourniquet at intervals?

4. How would you control bleeding from a vein?
5. Where are the six principal arterial pressure points?
6. How can you tell whether bleeding comes from an artery or a vein?

3. SYMPTOMS AND TREATMENT OF SHOCK

A Case Where Prompt Prevention Treatment Paid

A crew with its foreman left the garage first thing in the morning for a routine job. This job involved climbing a 40-ft chestnut pole. This pole, a corner one, was old and had been climbed a lot. There was a cardboard sign tacked to it, and there was plenty of evidence that many other signs had been there because of the many tack heads showing. One of the linemen started up this pole and climbed about nine feet when he cut out. His other hook caught about three or four feet down and held momentarily. At this point the man's head and shoulders were on the left side of the pole and both his feet were on the right side. He was grasping the pole, but the right glove was on the cardboard sign. His other hook let go, his hand slipped off the sign, and he fell to the ground, a distance of about six feet measured from his hooks. He received a fractured vertebra and bruises to the left side and arm.

The weather was cold, 8° above zero. The man did not lose consciousness. He was suffering from pain in his left hip and did not notice pain in the back immediately. The crew started first aid at once. All indications pointed to a seriously injured hip. The man was covered right away, both on top and bottom. When he was being inclined so that the bottom blanket could be put underneath, the patient discovered that his back hurt far worse than his hip. He was able to move his legs, thus indicating that there was nothing broken around the hip and that if his back was broken the spinal cord was not injured yet.

The patient was carried on his back in the blanket to a nearby garage. The ambulance was summoned. Hot-water bottles and glass jars filled with hot water were procured and placed along his legs and body and also between his legs. He was thus kept warm. During all this time it is noted that the patient was not moved unnecessarily. He was moved to the garage to keep him warmer. He was not rolled onto a blanket because of a suspected back fracture. The method of moving him ensured against injury to the spinal cord, resulting in paralysis. In addition to this he was relieved of more pain.

Although there was no definite evidence of shock in this case, nevertheless it was present but not nearly to the extent that would have materialized had precautionary measures not been taken. The first-aid treatment was preventive in nature. The treatment was done so well and so quickly that the patient's good condition was commented on by the doctor at the hospital.

The fact that the patient was in competent hands as soon as he was injured contributed in no small way to his quick recovery.

Types of Injuries Where Shock Is a Serious Factor

Any person severely injured in any one of these ways

Severe hemorrhage
Burns
Crushing injuries
Fractures of bones
Shell, bomb, and bullet wounds
Injuries to the chest and head

will develop shock and treatment must be started immediately without waiting for symptoms of shock to develop. Shock is easier to prevent than cure.

Definition of Shock

Shock is a depressed state of all body functions due to failure of the blood circulatory system.

How It Works

As a result of this circulatory weakness, not enough oxygen and food substances are carried to the body cells, nor do the lungs and kidneys eliminate waste products efficiently. The mounting waste in the body and in the blood stream depresses the already impaired vital centers in the brain.

Breathing becomes rapid and shallow owing to the injury or because of the irregular or insufficient supply of oxygen to the nerve center which governs breathing.

The surface temperature of the body falls because the lack of sufficient oxygen lowers all cell activity. Sweating is usual.

The recuperative processes of the body are lowered. In time, this contributes to the bad effects of the original state of shock, causing it to become more severe. The vicious circle, once it is established, produces rapidly deepening shock until it reaches a point at which the damage done to the circulation and the nerve centers governing them cannot be repaired. After that point, treatment will not be successful.

Factors That Contribute to Shock

Age. A strong healthy adult can stand injuries that would cause shock in the young, the old, or the feeble.

Loss of Blood. Loss of blood may be the beginning of shock, and the continuation of hemorrhage will deepen it.

Pain. Pain caused by the original injury, if it is allowed to continue, will intensify the shock state or may produce it.

Exposure. Exposure to cold, either air or water, or to excessive heat will increase the chance of shock.

Rough Handling. The person in shock is made worse by any rough or unwise transportation, examination, or handling. The common practice of jackknifing a seriously injured person into the back seat of an automobile with no regard for his injuries and then driving at top speed to the hospital cannot be condemned too strongly.

Symptoms of Shock

For the first aider, it is much more important to know that shock always occurs with *burns* of any extent, *wounds that bleed, broken bones,* and *injuries of any magnitude* affecting any part of the body than it is to learn the effects produced by shock after it reaches a point where recovery may be impossible.

Early Symptoms

1. Patient complains of a feeling of great weakness, faintness, and sometimes of dizziness and nausea.
2. Skin on face and extremities becomes cold and moist with perspiration.
3. Face becomes pale.
4. Eyes appear vacant. Pupils become wide and dilated.

Late Symptoms

1. Whereas at first the patient responded to questions, he now has great difficulty in arousing himself. Unconsciousness is the next step.
2. Pulse becomes more rapid, weaker, and more difficult to feel. It finally becomes imperceptible.
3. Nausea and vomiting often occur.
4. Breathing is shallow and rapid, later becoming sighing respirations alternating with shallow breaths.

These signs and symptoms are those of a late stage of shock. By the time they appear, the vicious circle of disastrous changes in the body has started and the patient's life is in danger.

Every injured person is potentially a patient in shock and should be regarded and treated as such whether symptoms of shock are present or not.

Prevention of Shock

Control Bleeding. The loss of any blood is a direct injury to the circulatory system. Therefore, the first treatment of shock is to control the bleeding as outlined previously.

Artificial Respiration. The fact that a person is not breathing, because of drowning or contact with electricity, is a direct injury to the circulatory system. After bleeding has been controlled, respiration should be given artificially.

Position. Keep the body horizontal or tilt the body by raising the feet slightly. In any case keep the head low. Do not place a pillow under it. The exceptions to this rule are:

1. In case of a bad head injury and a fractured skull is suspected, keep the head level and do not elevate the feet.

2. In case the patient has an obvious chest injury and has difficulty in breathing, he should be kept horizontal with the head raised slightly so that breathing is easier.

Heat. The patient should be kept comfortable but not hot. He should be covered enough to conserve body heat, the amount of covering depending on the temperature of the surrounding air. Cover placed on top of him will not protect him underneath if he is lying on the cold ground. If the patient complains of the cold or if it is wintertime, it will be necessary to use hot-water bottles, glass jars filled with warm water, etc. Too much heat is dangerous because it causes sweating and body fluid is then lost.

Transportation. There is usually no great hurry to move the patient if first aid has been given. It is best to wait for the ambulance and to move the patient only on instructions from the doctor.

Stimulants. The use of stimulants in first-aid treatment of shock is without value, and neither time nor energy should be lost in administering any drug or chemical, because there is no evidence that any of them has the slightest favorable influence.

Fluids. Do not pour fluid of any sort down the throat of an unconscious person. He may inhale it and drown, or it may irritate the lungs and cause pneumonia.

Warm fluids such as tea, coffee, milk, or water may be given if the patient is conscious except:

1. When he has an abdominal injury
2. If there is nausea or vomiting
3. If he is to reach the hospital soon where an operation is necessary

Massage or Rubbing the Arms and Legs. This is of doubtful value. It is better to keep the patient quiet.

Study Questions

If you can answer these questions you will have **a fair idea of shock and** how to treat it.

1. What is shock?
2. What are the factors contributing to shock?
3. What are the four kinds of injuries in which shock is always present?
4. What are the symptoms of shock?
5. Who may develop shock and when must treatment be started?
6. In what position should a person in shock be placed? If he has severe head injury?

7. What is important to remember about the use of heat in shock treatment?

8. Should fluids be given a person in shock? If the person is unconscious? If the person has an abdominal injury?

4. TREATMENT OF OTHER INJURIES

Chemical Burns

Burns caused by acid or alkali should be washed immediately with large quantities of water, until the chemical is thoroughly washed away. If a chemical gets into the eyes, they must be held open to make certain that all the chemical is washed out. Creosote may be removed from the skin with alcohol or soap and water; however, alcohol should not be used near the eyes.

After the chemical has been neutralized or washed off, the burned surface should be completely covered with a sterile dressing, as quickly as possible, and bandaged in place. Do not bandage until the chemical has been completely removed as the confined chemical will cause a more severe burn. No ointments or antiseptics should be used. If the burn is quite serious, a nearby doctor may be called to relieve the pain before the injured is transported to the hospital. Treat for shock until the doctor arrives.

Other Burns

Burns caused by hot liquids, hot objects, flames, electric flashes, and overexposure to the sun's rays should be completely covered with a sterile dressing, as quickly as possible, and bandaged in place. No ointments or antiseptics should be used. If the burn is quite serious, a nearby doctor may be called to relieve the pain before the injured is transported to the hospital. Treat for shock until the doctor arrives.

Dislocations

When a bone is out of place at a joint, it is called a dislocation. The pain is often intense; there is deformity of the joint, and swelling occurs rapidly.

No one except a doctor should attempt to reduce (put back in place) a dislocation, because of the danger of further injury to the blood vessels, nerves, tendons, and muscles around the joint.

In the case of dislocated finger or jaw, the injured should be sent to the doctor's office, but in all other cases of dislocation, the injured person should be made as comfortable as possible without moving the injured joint until the doctor has arrived or given instructions over the phone as to the procedure to be followed.

Head Injuries

A person who has received a serious blow on the head or has been rendered unconscious for even a short period should be kept warm and quiet and not be moved, except under the instructions of a doctor.

Fractures

A fracture is a broken bone. Pain and tenderness are present at the point of the break. The broken part may be deformed, and the end of the broken bone may protrude through the skin.

In case the end of the broken bone protrudes from the skin, a sterile dressing should be applied. If necessary, pressure may be applied between the wound and the heart to stop bleeding.

Keep the injured person warm and comfortable. Do not attempt to straighten a fractured limb.

Fractures are to be splinted before moving the injured person. If a fracture of the wrist or forearm is suspected, the men on the job may improvise a splint or use the wire splint provided in some kits. Employees with severe injuries or suspected fractures of foot or ankle are not to be allowed to walk. Transportation must be arranged. If the fracture is of a thigh or hip, the nearest doctor must be summoned to apply a traction splint before moving the patient to the hospital.

Sprains

Sprains are injuries to joints. They may be described as temporary dislocations. The bone is thrown out of place just as in a true dislocation, but immediately snaps back into place. The wrists and ankles are most frequently sprained. The pain is often intense, and swelling over the joint takes place rapidly.

The injured is sent to the doctor's office and should be given assistance as needed, so that it will not be necessary to use the injured member.

Foreign Bodies in Eyes

Foreign particles blown into the eyes usually lodge on the inner surface of the eyelid and cause a flow of tears. Never rub the eye, as this may cause the particle to become embedded in the eyelid or eyeball.

A particle on the pupil of the eye is not always painful and is not easily located by an inexperienced person. If it is suspected that there is anything on the pupil of the eye, the injured should be sent to the doctor.

Bowing the head and slowly moving the eyelids will usually cause tears to dislodge and wash a foreign body out of the eye. If this fails, grasp the lashes of one lid and draw it out and over the other lid. This may detach the foreign body.

If a foreign body is not removed by the method described above, someone skilled in first aid may roll the eyelid back and attempt to remove the object by lightly brushing it with a corner of a sterile compress. If this method fails, the injured should be sent to a doctor.

Heat Exhaustion

Heat exhaustion is just what the name implies: exhaustion or collapse due to severe heat.

When a person is working in high temperatures, the chief means of keeping the body temperature normal is by sweating. Sweating removes salt from the body, and this loss of salt is the chief cause of heat exhaustion. To prevent heat exhaustion, use more salt on the food eaten or use salt tablets provided on the job. As many as five tablets a day may be required to replace the salt lost by excessive sweating.

Heat exhaustion usually begins with dizziness, nausea, and an uncertain, staggering gait. There may be vomiting and pains in the stomach and limbs. The face is pale, and perspiration, particularly of the forehead and face, is profuse. The entire body may be clammy.

The patient may become faint and unconscious unless he lies down. The pulse is weak, the breathing is shallow, and the patient may become cold, even though he is in a warm place. Remove the patient to circulating air and treat for shock. Have the patient lie down, keep him warm, and administer stimulants, such as hot tea or coffee. Give several salt tablets with several swallows of water.

Send for a doctor at once.

Sunstroke and Heatstroke

These conditions have the same symptoms, although the causes may be slightly different. If due to direct exposure to the sun's rays, it is called "sunstroke." If due to excessive indoor heat, it is called "heatstroke." Exposing the head to the sun without protection of a hat or cap and the wearing of too heavy clothing are contributory causes of sunstroke or heatstroke.

The symptoms are pains in the head, dizziness, hot dry skin with face flushed, and rapid and full pulse. If the case is at all severe, the patient is usually unconscious. The body is usually relaxed, but convulsions may occur.

The first-aid treatment consists of reducing the patient's temperature. Remove at once to a cold place. Loosen and remove as much clothing as possible. Lay on the back with the head and shoulders somewhat elevated. Apply cold to the head and body. To do this, cold wet cloths or ice wrapped in cloths should be put on the face, neck, chest, and in the armpits.

Give no stimulants. Give cool drinks after consciousness returns.

Send for a doctor at once.

Wounds

Scratches, Abrasions (Not Bleeding Freely and Treated on the Job). These minor injuries which do not require a doctor's attention must be washed with white soap and running water, using as a washcloth the small 3-by 3-inch sterile gauze pads provided in the first-aid kits. This washing should continue for five minutes, to make certain that as many germs as possible are washed out of the wound. No antiseptics should be used. After the wound is dried with another sterile gauze pad, it must be covered with a sterile dressing to prevent germs from getting into it. On the day after the injury, the man in charge shall inspect the wound, to make certain that it is healing satisfactorily and that infection is not setting in. The usual signs of infection are pain, swelling, redness, heat, pus, red streaks, swollen glands, and tenderness. If any of these signs of infection are present, the injured person must be sent to the doctor.

Cuts or Lacerations (Sent to the Doctor). These wounds should not be washed with soap and water, because they are to be treated by a doctor. As soon as possible, a sterile dressing to cover the injury completely should be applied and bandaged in place, and the injured should be sent to the doctor. If the laceration is quite serious, a nearby doctor should be called to relieve the pain before the injured is transported to the doctor's office or to the hospital.

Puncture Wounds

Puncture wounds caused by pointed objects, such as nails, slivers, and ends of wires, should be covered with a sterile dressing, and the injured should be sent to the doctor.

Do not attempt to remove embedded slivers or clean out puncture wounds. This should be left for the doctor to do.

Frostbite

Frostbite is an injury resulting from freezing a part of the body. The nose, cheeks, ears, toes, and fingers are the points most frequently frostbitten.

Frostbite is more likely to occur when a high wind is blowing. This removes heat from the body very rapidly. There is usually considerable pain if the hands or feet are frosted, but often frosted ears, cheeks, and nose are not painful and the victim is not aware of his condition until told by someone else. The frosted area becomes a peculiar grayish-white because of ice actually frozen in the tissues. These injuries should be bandaged and the injured sent to the doctor.

Rubbing the frosted surface does more harm than good by bruising, tearing, or breaking off the frozen body tissue. Contrary to a rather common belief, rubbing with snow is especially bad.

SECTION 35

Electrical Formulas and Calculations

General. In this section the most common electrical formulas are given and their use is illustrated with a problem. In each case the formula is first stated using the customary symbols, the same expression is then stated in words, then a problem is given, and finally the substitutions are made for the symbols in the formula from which the answer is calculated. Only those formulas which the lineman is apt to have use for are given. The formulas are divided into three groups, direct-current circuits, alternating-current circuits, and electrical apparatus.

DIRECT-CURRENT CIRCUITS

Ohm's Law. The formula for Ohm's law is the most fundamental of all electrical formulas. It expresses the relationship that exists in an electrical circuit containing resistance only between the current flowing in the resistance, the voltage impressed on the resistance, and the resistance of the circuit, thus

$$I = \frac{E}{R}$$

where I = current, amp
E = voltage, volts
R = resistance, ohms

Expressed in words, the formula states that current equals voltage divided by resistance, or

$$\text{Amperes} = \frac{\text{volts}}{\text{ohms}}$$

Example: How much direct current will flow through a resistance of 10 ohms if the pressure applied is 120 volts direct current?

Solution: $$I = \frac{E}{R} = \frac{120}{10} = 12 \text{ amp}$$

Ohm's law involves three quantities, namely, current, voltage, and resistance. Therefore, when any two are known, the third one can be found. The procedure for solving for current has already been illustrated. To find the voltage required to circulate a given amount of current through a known resistance, Ohm's law is written as follows:

$$E = IR$$

In words the formula says that the voltage is equal to the current multiplied by the resistance, thus

$$\text{Volts} = \text{amperes} \times \text{ohms}$$

Example: How much direct-current voltage is required to circulate 5 amp direct current through a resistance of 15 ohms?

Solution: $$E = IR = 5 \times 15 = 75 \text{ volts}$$

In like manner if the voltage and current are known and the value of resistance is to be found, the formula is stated as follows:

$$R = \frac{E}{I}$$

Expressed in words the formula says that the resistance is equal to the voltage divided by the current, thus

$$\text{Ohms} = \frac{\text{volts}}{\text{amperes}}$$

Example: What is the resistance of an electrical circuit if 120 volts direct current causes a current of 5 amp to flow through it?

Solution: $$R = \frac{E}{I} = \frac{120}{5} = 24 \text{ ohms}$$

Power Formula. The expression for the power drawn by a direct-current circuit is

$$P = EI$$

where E and I are the symbols for volts and amperes and P is the symbol for power in watts.

Expressed in words the formula says that the power in watts drawn by a direct-current circuit is equal to the product of volts and amperes, thus

$$\text{Power} = \text{volts} \times \text{amperes}$$

Problem: How much power is taken by a 120-volt direct-current circuit when the current flowing is 8 amp direct current?

Solution: $$P = EI = 120 \times 8 = 960 \text{ watts}$$

The power formula given above also contains three quantities or terms, namely, watts, volts, and amperes. Therefore, when any two of the three are known, the third one can be found. The procedure for finding the power when the voltage and current are given has already been illustrated. When the power and voltage are given and the current is to be found, the formula is written thus:

$$I = \frac{P}{E}$$

In words the formula states that the current equals the power divided by the voltage, thus

$$\text{Amperes} = \frac{\text{watts}}{\text{volts}}$$

Example: How much direct current would a 1,000-watt load draw when connected to a 120 volt direct-current circuit?

Solution: $$I = \frac{P}{E} = \frac{1{,}000}{120} = 8.33 \text{ amp}$$

In like manner, when the power and current are known, the voltage can be found by writing the formula thus:

$$E = \frac{P}{I}$$

Expressed in words the formula says that the voltage is equal to the power divided by the current, thus

$$\text{Volts} = \frac{\text{watts}}{\text{amperes}}$$

Example: What direct-current voltage would be required to deliver 660 watts with 6 amp direct current flowing in the circuit?

Solution: $$E = \frac{P}{I} = \frac{660}{6} = 110 \text{ volts}$$

Line Loss or Resistance Loss. The formula for computing the power lost in a resistance when current flows through it is

$$P = I^2R$$

where the symbols have the same meaning as in the foregoing formulas.

Expressed in words the formula says that the power in watts lost in a resistance is equal to the square* of the current in amperes multiplied

* Squared means to multiply by itself.

by the resistance in ohms, thus

$$\text{Watts} = \text{amperes squared} \times \text{ohms}$$

Example: Compute the watts lost in a line having a resistance of 4 ohms when 8 amps direct current is flowing in the line.

Solution: $P = I^2R = 8 \times 8 \times 4 = 256$ watts

ALTERNATING-CURRENT CIRCUITS

Ohm's Law. Ohm's law is the same for resistance circuits when alternating voltage is applied as when direct voltage is applied, namely,

$$I = \frac{E}{R}$$

and

$$E = RI$$

and

$$R = \frac{E}{I}$$

In the above, E is the "effective" value of the alternating voltage and I the "effective" value of the alternating current. (See Direct-current Circuits for examples.)

Ohm's Law for Other Than Resistance Circuits. When alternating currents flow in circuits, these circuits may exhibit additional characteristics besides resistance. They may exhibit inductive reactance or capacitive reactance or both. The total obstruction offered to the flow of current is then called "impedance" and is represented by the symbol Z. Ohm's law then becomes

$$I = \frac{E}{Z}$$

and

$$E = IZ$$

and

$$Z = \frac{E}{I}$$

where I = current, amp
E = voltage, volts
Z = impedance, ohms

Example: Find the impedance of an alternating-current circuit if 120 volts alternating current causes a current of 30 amp alternating current to flow.

Solution: $Z = \frac{E}{I} = \frac{120}{30} = 4$ ohms impedance

Impedance. The impedance of a series circuit is given by the expression

$$Z = \sqrt{R^2 + (X_L - X_c)^2}$$

where Z = impedance, ohms
R = resistance, ohms
X_L = inductive reactance, ohms
X_c = capacitive reactance, ohms

Example: If an alternating-current series circuit contains a resistance of 5 ohms, an inductive reactance of 10 ohms, a capacitive reactance of 6 ohms, what is its impedance in ohms?

$$\begin{aligned} Z &= \sqrt{R^2 + (X_L - X_c)^2} \\ &= \sqrt{5 \times 5 + (10 - 6)^2} \\ &= \sqrt{25 + (4 \times 4)} \\ &= \sqrt{41} = 6.4 \text{ ohms} \end{aligned}$$

Note. The values of inductive and capacitive reactance of a circuit depend upon the frequency of the current, the size, spacing, and length of the conductors making up the circuit, etc. For distribution circuits and transmission lines, values may be found in appropriate tables.

It will be observed in the expression for Z that, when neither inductive reactance nor capacitive reactance is present, Z reduces to the value R, thus:

$$Z = \sqrt{R^2 + (0 - 0)^2} = \sqrt{R^2} = R$$

Likewise when only resistance and inductive reactance are present in the circuit, the expression for Z becomes

$$Z = \sqrt{R^2 + (X_L - 0)^2} = \sqrt{R^2 + X_L{}^2}$$

Example: Compute the impedance of an alternating-current circuit containing 3 ohms of resistance and 4 ohms of inductive reactance connected in series.

Solution:

$$\begin{aligned} Z &= \sqrt{R^2 + X^2} = \sqrt{3^2 + 4^2} \\ &= \sqrt{3 \times 3 + 4 \times 4} = \sqrt{9 + 16} \\ &= \sqrt{25} = 5 \text{ ohms impedance} \end{aligned}$$

Line Loss or Resistance Loss. The formula for computing the power lost in a resistance or line is

$$P = I^2R$$

where the symbols have the same meaning as above. Expressed in words the formula says that the power in watts lost in a resistance is equal to the current in amperes squared multiplied by the resistance in ohms, thus

$$\text{Watts} = \text{amperes squared} \times \text{ohms}$$

Example: Compute the power lost in a line having a resistance of 3 ohms, if 20 amp are flowing in it.

Solution: $$P = I^2R = 20 \times 20 \times 3 = 1{,}200 \text{ watts}$$

Power Formula. The power formula for single-phase alternating-current circuits is

$$P = E \times I \times \text{pf}$$

where P = power, watts
E = voltage, volts
I = current, amp
pf = power factor of circuit

Expressed in words the formula says that the power in watts drawn by a single-phase alternating-current circuit is equal to the product of volts, amperes, and power factor. If the power factor is unity or one, the product is simply that of volts and amperes.

Example: How much power is delivered to a single-phase alternating-current circuit operating at 120 volts if the circuit draws 10 amp at 80 per cent power factor?

Solution:
$$\begin{aligned} P &= E \times I \times \text{pf} \\ &= 120 \times 10 \times 0.80 \\ &= 960 \text{ watts} \end{aligned}$$

The power formula given above contains four quantities, namely, P, E, I, and pf. Therefore, when any three are known, the fourth one can be determined. The case where the voltage, current, and power factor are known has already been illustrated. When the voltage, power, and power factor are known, the current can be computed from the expression

$$I = \frac{P}{E \times \text{pf}}$$

Example: How much current is drawn by a 10-kw load from a 220-volt alternating-current circuit if the power factor is 0.80?

Solution:
$$\begin{aligned} I &= \frac{P}{E \times \text{pf}} \\ &= \frac{10{,}000}{220 \times 0.80} = 5.7 \text{ amp} \end{aligned}$$

In like manner if the power, voltage, and current are known, the power factor can be computed from the following formula:

$$\text{pf} = \frac{P}{E \times I}$$

Example: What is the power factor of a 4-kw load operating at 230 volts if the current drawn is 20 amp?

Solution:

$$\text{pf} = \frac{P}{E \times I} = \frac{4{,}000}{230 \times 20}$$
$$= 87 \text{ per cent power factor}$$

Three Phase. The power formula for a three-phase alternating-current circuit is

$$P = \sqrt{3} \times E \times I \times \text{pf}$$

where the symbols have the same meaning as for single phase. The additional quantity in the three-phase formula is the factor $\sqrt{3}$, expressed "square root of three," the value of which is

$$\sqrt{3} = 1.73$$

Example: How much power in watts is drawn by a three-phase load at 230 volts if the current is 10 amp and the power factor is 0.80 per cent?

Solution:

$$P = \sqrt{3} \times E \times I \times \text{pf}$$
$$= \sqrt{3} \times 230 \times 10 \times 0.80$$
$$= 3{,}183 \text{ watts}$$

The three-phase power formula also contains four quantities as in the single-phase formula. Therefore, if any three are known, the fourth one can be determined. The case where the voltage, current, and power factor are known was illustrated above. When the power, voltage, and power factor are known, the current in the three-phase line can be computed from the formula

$$I = \frac{P}{\sqrt{3}E \times \text{pf}}$$

Example: If a 15-kw three-phase load operates at 2,300 volts and has a power factor of 1, how much current flows in each line of the three-phase circuit?

Solution:

$$I = \frac{P}{\sqrt{3}E \times \text{pf}}$$
$$= \frac{15{,}000}{\sqrt{3} \times 2{,}300 \times 1.0} = 3.75 \text{ amp}$$

If the only quantity not known is the power factor, this can be found by using the following formula:

$$\text{pf} = \frac{P}{\sqrt{3} \times E \times I}$$

Example: Find the power factor of a 100-kw three-phase load operating at 2,300 volts if the line current is 40 amp.

Solution:

$$\begin{aligned} \text{pf} &= \frac{P}{\sqrt{3} \times E \times I} \\ &= \frac{100{,}000}{\sqrt{3} \times 2{,}300 \times 40} \\ &= 62.5 \text{ per cent power factor} \end{aligned}$$

Volt-Amperes. Often loads are given in volt-amperes instead of watts or in kva instead of kw. The relationships then become

$$\text{va} = E \times I \qquad \text{for single phase}$$

and

$$\text{va} = \sqrt{3}E \times I \qquad \text{for three phase}$$

In using these quantities it is not necessary to know the power factor of the load.

Line Loss or Resistance Loss (Three Phase). The power lost in a three-phase line is given by the expression

$$P = 3 \times I^2R$$

where I = current in each line wire
R = resistance of each line wire

The factor 3 is present so that the loss in a line wire will be taken three times to account for the loss in all three wires.

Example: If a three-phase line carries a current of 12 amps and each line wire has a resistance of 3 ohms, how much power is lost in the resistance of the line?

Solution: $P = 3 \times I^2R = 3 \times 12 \times 12 \times 3 = 1{,}296$ watts

ELECTRICAL APPARATUS

Motors

Motor Direct Current. The two quantities that are usually desired in an electric motor are its output in horsepower, hp, and its input current rating at full load. The following expression for current is used when the motor is a direct-current motor:

$$I = \frac{\text{hp} \times 746}{E \times \text{eff}}$$

The formula says that the full load current is obtained by multiplying the horsepower by 746 and dividing the result by the product of voltage and per cent efficiency. (746 is the number of watts in 1 hp.)

Example: How much current will a 5-hp 230-volt direct-current motor draw at full load if its efficiency at full load is 90 per cent?

Solution:
$$I = \frac{\text{hp} \times 746}{E \times \text{eff}} = \frac{5 \times 746}{230 \times 0.90} = 18.8 \text{ amp}$$

Motor Alternating Current, Single Phase. If the motor is a single-phase alternating-current motor the expression for current is almost the same, except that it must allow for power factor. The formula for full load current is

$$I = \frac{\text{hp} \times 746}{E \times \text{eff} \times \text{pf}}$$

Example: How many amperes will a ¼-hp motor take at full load if the motor is rated 110 volts and has a full load efficiency of 85 per cent and a full load power factor of 80 per cent?

Solution:
$$I = \frac{\text{hp} \times 746}{E \times \text{eff} \times \text{pf}} = \frac{0.25 \times 746}{110 \times 0.85 \times 0.80} = 2.5 \text{ amp}$$

Motor Alternating Current, Three Phase. The formula for full load current of a three-phase motor is the same as for a single-phase motor except that it has the factor $\sqrt{3}$ in it, thus:

$$I = \frac{\text{hp} \times 746}{\sqrt{3} \times E \times \text{eff} \times \text{pf}}$$

Example: Calculate the full load current rating of a 5-hp three-phase motor operating at 220 volts and having an efficiency of 80 per cent and a power factor of 85 per cent.

Solution:
$$I = \frac{\text{hp} \times 746}{\sqrt{3} \times E \times \text{eff} \times \text{pf}} = \frac{5 \times 746}{\sqrt{3} \times 220 \times 0.80 \times 0.85}$$
$$= 14.4 \text{ amp}$$

Motor Direct Current. To find the horsepower rating of a direct-current motor if its voltage and current rating are known, the same formula is used as for current except the quantities are rearranged, thus:

$$\text{hp} = \frac{E \times I \times \text{eff}}{746}$$

Example: How many horsepower can a 220-volt direct-current motor deliver if it draws 15 amp and has an efficiency of 90 per cent?

Solution:
$$\text{hp} = \frac{E \times I \times \text{eff}}{746} = \frac{220 \times 15 \times 0.90}{746} = 4.0 \text{ hp}$$

Motor Alternating Current, Single Phase. The horsepower formula for a single-phase alternating-current motor is

$$\text{hp} = \frac{E \times I \times \text{pf} \times \text{eff}}{746}$$

Example: What is the horsepower rating of a single-phase motor operating at 440 volts and drawing 25 amp at a power factor of 88 per cent if it has a full load efficiency of 90 per cent?

Solution:
$$\begin{aligned}\text{hp} &= \frac{E \times I \times \text{pf} \times \text{eff}}{746} \\ &= \frac{440 \times 25 \times 0.88 \times 0.90}{746} \\ &= 4.65 \text{ hp}\end{aligned}$$

Motor Alternating Current, Three Phase. The horsepower formula for a three-phase alternating-current motor is

$$\text{hp} = \frac{\sqrt{3} \times E \times I \times \text{pf} \times \text{eff}}{746}$$

Example: What horsepower does a three-phase 220-volt motor deliver if it draws 10 amp, has a power factor of 80 per cent, and has an efficiency of 85 per cent?

Solution:
$$\begin{aligned}\text{hp} &= \frac{\sqrt{3} \times E \times I \times \text{pf} \times \text{eff}}{746} \\ &= \frac{\sqrt{3} \times 220 \times 10 \times 0.80 \times 85}{746} = 3.6 \text{ hp}\end{aligned}$$

ALTERNATING-CURRENT GENERATOR

Frequency. The frequency of the voltage generated by an alternating-current generator depends on the number of poles in its field and the speed at which it rotates, thus:

$$f = \frac{p \times \text{rpm}}{120}$$

where f = frequency, cps
p = number of poles in field
rpm = number of revolutions the field rotates per minute

Example: Compute the frequency of the voltage generated by an alternator having two poles and rotating at 3,600 rpm.

Solution:
$$f = \frac{p \times \text{rpm}}{120} = \frac{2 \times 3{,}600}{120} = 60 \text{ cps}$$

Speed. To determine the speed at which an alternator should be driven to generate a given frequency, the following expression is used:

$$\text{rpm} = \frac{f \times 120}{p}$$

Example: At what speed must a four-pole alternator be driven to generate 60 cycles?

Solution: $$\text{rpm} = \frac{f \times 120}{p} = \frac{60 \times 120}{4} = 1{,}800 \text{ rpm}$$

Number of Poles. If the frequency and speed of an alternator are known, the number of poles in its field can be calculated by use of the following formula:

$$p = \frac{f \times 120}{\text{rpm}}$$

Example: How many poles does an alternator have if it generates 60 cycles at 1,200 rpm?

Solution: $$p = \frac{f \times 120}{\text{rpm}} = \frac{60 \times 120}{1{,}200} = 6 \text{ poles}$$

TRANSFORMER

(Single Phase)

Primary Current. The full load primary current can be readily calculated if the kva rating of the transformer and the primary voltage are known, thus:

$$I_p = \frac{\text{kva} \times 1{,}000}{E_p}$$

where E_p = rated primary voltage
I_p = rated primary current

Example: Find the rated full load primary current of a 10-kva 2,300-volt distribution transformer.

Solution: $$I_p = \frac{\text{kva} \times 1{,}000}{E_p} = \frac{10 \times 1{,}000}{2{,}300} = 4.3 \text{ amp}$$

Secondary Current. The expression for secondary current is similar to that for primary current, thus:

$$I_s = \frac{\text{kva} \times 1{,}000}{E_s}$$

where I_s = rated secondary current
E_s = rated secondary voltage

Example: A 3-kva distribution transformer is rated 2,300 volts primary and 110 volts secondary. What is its full load secondary current?

Solution:
$$I_s = \frac{\text{kva} \times 1{,}000}{E_s}$$
$$= \frac{3 \times 1{,}000}{110} = 27 \text{ amp secondary}$$

SUMMARY OF ELECTRICAL FORMULAS

Current

1. *Direct Current.* To find the current when the voltage and resistance are given:

$$I = \frac{E}{R}$$

2. *Alternating Current.* To find the current when the voltage and resistance are given:

$$I = \frac{E}{R}$$

3. *Alternating Current.* To find the current when the voltage and impedance are given:

$$I = \frac{E}{Z}$$

4. *Direct Current.* To find the current when the voltage and the power are given:

$$I = \frac{P}{E}$$

5. *Alternating Current, Single Phase.* To find the current when the voltage, the power, and the power factor are given:

$$I = \frac{P}{E \times \text{pf}}$$

6. *Alternating Current, Three Phase.* To find the current when the voltage, the power, and the power factor are given:

$$I = \frac{P}{\sqrt{3}E \times \text{pf}}$$

7. *Alternating Current, Single Phase.* To find the current when the volt-amperes and the volts are given:

$$I = \frac{\text{va}}{E}$$

and

$$I = \frac{\text{kva} \times 1{,}000}{E}$$

8. *Alternating Current, Three Phase.* To find the current when the volt-amperes and the volts are given:

$$I = \frac{\text{va}}{\sqrt{3}E}$$

and

$$I = \frac{\text{kva} \times 1{,}000}{\sqrt{3}E}$$

Voltage

9. *Direct Current.* To find the voltage when the current and resistance are given:

$$E = IR$$

10. *Alternating Current.* To find the voltage when the current and resistance are given:

$$E = IR$$

11. *Alternating Current.* To find the voltage when the current and impedance are given:

$$E = IZ$$

Resistance

12. *Direct Current.* To find the resistance when the voltage and the current are given:

$$R = \frac{E}{I}$$

13. *Alternating Current.* To find the resistance when the voltage and the current are given:

$$R = \frac{E}{I}$$

Power Loss

14. *Direct Current.* To find the power loss when the current and resistance are given:

$$P = I^2R$$

15. *Alternating Current, Single Phase.* To find the power loss when the current and the resistance are given:

$$P = I^2R$$

16. *Alternating Current, Three Phase.* To find the power loss when the current and the resistance are given:

$$P = 3 \times I^2R$$

Impedance

17. *Alternating Current.* To find the impedance when the current and the voltage are given:

$$Z = \frac{E}{I}$$

18. *Alternating Current.* To find the impedance when the resistance and the inductive reactance are given:

$$Z = \sqrt{R^2 + X_L^2}$$

19. *Alternating Current.* To find the impedance when the resistance, inductive reactance, and capacitive reactance are given:

$$Z = \sqrt{R^2 + (X_L - X_c)^2}$$

Power

20. *Direct Current.* To find the power when the voltage and the current are given:

$$P = EI$$

21. *Alternating Current, Single Phase.* To find the power when the voltage, the current, and the power factor are given:

$$P = E \times I \times \text{pf}$$

22. *Alternating Current, Three Phase.* To find the power when the voltage, the current, and the power factor are given:

$$P = \sqrt{3}E \times I \times \text{pf}$$

Volt-Amperes

23. *Alternating Current, Single Phase.* To find the volt-amperes when the voltage and the current are given:

$$\text{va} = E \times I$$

and

$$\text{kva} = \frac{E \times I}{1{,}000}$$

24. *Alternating Current, Three Phase.* To find the volt-amperes when the voltage and the current are given:

$$\text{va} = \sqrt{3}E \times I$$

and

$$\text{kva} = \frac{\sqrt{3}E \times I}{1{,}000}$$

Power Factor

25. *Alternating Current, Single Phase.* To find the power factor when the power, the volts, and the amperes are given:

$$\text{pf} = \frac{P}{E \times I}$$

26. *Alternating Current, Three Phase.* To find the power factor when the power, the volts, and the amperes are given:

$$\text{pf} = \frac{P}{\sqrt{3} \times E \times I}$$

Motor

27. *Direct-current Motor.* To find the current when the horsepower of the motor, the voltage, and the efficiency are given:

$$I = \frac{\text{hp} \times 746}{E \times \text{eff}}$$

28. *Alternating-current Motor, Single Phase.* To find the current when the horsepower of the motor, the voltage, the efficiency, and the power factor are given:

$$I = \frac{\text{hp} \times 746}{E \times \text{pf} \times \text{eff}}$$

29. *Alternating-current Motor, Three Phase.* To find the current when the horsepower of the motor, the voltage, the power factor, and the efficiency are given:

$$I = \frac{\text{hp} \times 746}{\sqrt{3}E \times \text{pf} \times \text{eff}}$$

30. *Direct-current Motor.* To find the horsepower of the motor when the voltage, the current, and the efficiency are given:

$$\text{hp} = \frac{E \times I \times \text{eff}}{746}$$

31. *Alternating-current Motor, Single Phase.* To find the horsepower of the motor when the voltage, the current, the power factor, and the efficiency are given:

$$\text{hp} = \frac{E \times I \times \text{pf} \times \text{eff}}{746}$$

32. *Alternating-current Motor, Three Phase.* To find the horsepower of the motor, when the voltage, the current, the power factor, and the

efficiency are given:

$$\text{hp} = \frac{\sqrt{3}E \times I \times \text{pf} \times \text{eff}}{746}$$

Generator

33. *Alternating-current Generator.* To find the frequency of the generator when the number of poles and the rpm are given:

$$f = \frac{p \times \text{rpm}}{120}$$

34. *Alternating-current Generator.* To find the rpm of the generator when the number of poles and the frequency are given:

$$\text{rpm} = \frac{f \times 120}{p}$$

35. *Alternating-current Generator.* To find the number of poles of the generator when the frequency and the rpm are given:

$$p = \frac{f \times 120}{\text{rpm}}$$

Transformer

36. *Alternating-current Transformer, Single Phase.* To find the primary current when the kva and the primary voltage are given:

$$I_p = \frac{\text{kva} \times 1{,}000}{E_p}$$

37. *Alternating-current Transformer, Single Phase.* To find the secondary current when the kva and the secondary voltage are given:

$$I_s = \frac{\text{kva} \times 1{,}000}{E_s}$$

SECTION 36

Lineman's Arithmetic

The purpose of this section is to bring together tables of weights and measures and other common relationships used by linemen in solving typical lineman problems. Sample lineman problems with their solutions are also given to ensure a correct understanding of the tables.

ADDITION AND SUBTRACTION

TABLE 36-1. ADDITION TABLE

Horizontal Column

Vertical Column											
1	2	3	4	5	6	7	8	9	10	11	12
2	4	5	6	7	8	9	10	11	12	13	14
3	5	6	7	8	9	10	11	12	13	14	15
4	6	7	8	9	10	11	12	13	14	15	16
5	7	8	9	10	11	12	13	14	15	16	17
6	8	9	10	11	12	13	14	15	16	17	18
7	9	10	11	12	13	14	15	16	17	18	19
8	10	11	12	13	14	15	16	17	18	19	20
9	11	12	13	14	15	16	17	18	19	20	21
10	12	13	14	15	16	17	18	19	20	21	22
11	13	14	15	16	17	18	19	20	21	22	23
12	14	15	16	17	18	19	20	21	22	23	24

To add a number in the vertical column to any number in the horizontal column, move horizontally to the right from number in the vertical column until underneath the number in the horizontal column. The sum of the two numbers will be given in the square.

MULTIPLICATION AND DIVISION

TABLE 36-2. MULTIPLICATION TABLE

Horizontal Column

Vertical Column

1	2	3	4	5	6	7	8	9	10	11	12
2	4	6	8	10	12	14	16	18	20	22	24
3	6	9	12	15	18	21	24	27	30	33	36
4	8	12	16	20	24	28	32	36	40	44	48
5	10	15	20	25	30	35	40	45	50	55	60
6	12	18	24	30	36	42	48	54	60	66	72
7	14	21	28	35	42	49	56	63	70	77	84
8	16	24	32	40	48	56	64	72	80	88	96
9	18	27	36	45	54	63	72	81	90	99	108
10	20	30	40	50	60	70	80	90	100	110	120
11	22	33	44	55	66	77	88	99	110	121	132
12	24	36	48	60	72	84	96	108	120	132	144

To multiply a number in the vertical column by a number in the horizontal column, move to the right from the number in the vertical column until directly underneath the number in the horizontal column. The product of the two numbers is given in the square.

LENGTH OR LINEAR MEASURE

TABLE 36-3. LINEAR MEASURE

12	inches (in. or ″)	= 1 foot (ft or ′)
3	feet	= 1 yard (yd)
5½	yards or 16½ ft	= 1 rod (rd)
5,280	feet	= 1 mile (mi)
1,760	yards	= 1 mile (mi)
320	rods	= 1 mile (mi)

Lengths are measured in inches, feet, yards, rods, and miles.

MEASUREMENT OF TIME

TABLE 36-4. TIME MEASURE

60 seconds (sec)	=	1 minute (min)
60 minutes	=	1 hour (hr)
24 hours	=	1 day (d)
7 days	=	1 week (wk)
52 weeks 12 calendar months 365 days	=	1 year (yr)

Time is measured in seconds, minutes, hours, days, weeks, months, and years.

MEASUREMENT OF WEIGHT

TABLE 36-5. WEIGHT MEASURE

16 ounces (oz)	=	1 pound (lb)
100 pounds	=	1 hundredweight (cwt)
2,000 pounds	=	1 ton (T)

Weights are measured in ounces, pounds, hundredweights, and tons.

DRY MEASURE

TABLE 36-6. DRY MEASURE

2 pints (pt)	=	1 quart (qt)
8 quarts	=	1 peck (pk)
4 pecks	=	1 bushel (bu)

Dry measure is expressed in pints, quarts, pecks, and bushels.

LIQUID MEASURE

TABLE 36-7. LIQUID MEASURE

2	pints	=	1 quart (qt)
4	quarts	=	1 gallon (gal)
$31\frac{1}{2}$	gallons	=	1 barrel (bbl)

Liquids are measured in pints, quarts, gallons, and barrels.

SQUARE MEASURE

TABLE 36-8. SQUARE MEASURE

144	square inches (sq in.)	=	1 square foot (sq ft)
9	square feet	=	1 square yard (sq yd)
$30\frac{1}{4}$	square yards	=	1 square rod (sq rd)
640	acres	=	1 square mile

Areas are measured in square inches, square feet, square yards, square rods, acres, and square miles.

CUBIC MEASURE

TABLE 36-9. CUBIC MEASURE

1,728 cubic inches (cu in.)	=	1 cubic foot (cu ft)
27 cubic feet	=	1 cubic yard (cu yd)
1 cubic foot	=	7.28 gallons
1 gallon	=	231 cubic inches

Volumes are expressed in cubic inches, cubic feet, and cubic yards.

ELECTRIC POWER AND ENERGY

TABLE 36-10. ELECTRICAL UNITS OF POWER AND ENERGY

1,000 watts (w)	=	1 kilowatt (kw)
746 watts	=	1 horsepower (hp)
1 kilowatt	=	$1\frac{1}{3}$ horsepower
1,000 watthours	=	1 kilowatthour (kwhr)

Electrical power is measured in watts, kilowatts, or horsepower. Electrical energy is measured in watthours or kilowatthours.

WEIGHTS OF COMMON MATERIALS

TABLE 36-11. WEIGHTS OF COMMON SUBSTANCES PER CUBIC FOOT

Water	62.4 lb per cu ft
Ice	56.9 lb per cu ft
Gasoline	46.8 lb per cu ft
Iron, cast	450.0 lb per cu ft
Steel	490.0 lb per cu ft
Brass	506.0 lb per cu ft
Copper	556.2 lb per cu ft
Aluminum	165.6 lb per cu ft
Brick	125.0 lb per cu ft
Sand	115.0 lb per cu ft
Wood: oak	47.0 lb per cu ft
Yellow pine	38.0 lb per cu ft
White pine	38.0 lb per cu ft
Douglas fir	34.0 lb per cu ft

CIRCLES

1. The diameter of a circle equals twice its radius. $D = 2R$ (Fig. 36-1).

2. The circumference of a circle equals 3.1416 times its diameter (3.1416 equals approximately $3\frac{1}{7}$) (Fig. 36-2).

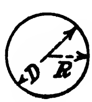


FIG. 36-1

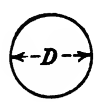


FIG. 36-2

3. The diameter of a circle equals 0.3181 times its circumference.

AREAS

1. The area of a square or rectangle equals the length times the width (Fig. 36-3).

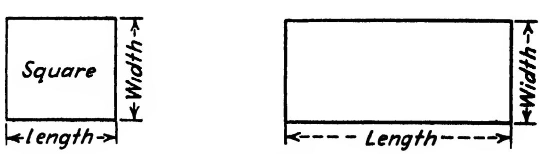


FIG. 36-3

2. The area of a circle equals the radius squared times 3.1416 (Fig. 36-4).

3. The area of a triangle equals the length of the base times ½ the height (Fig. 36-5).

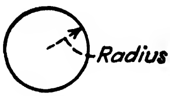


FIG. 36-4.

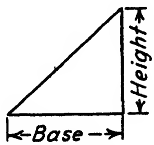


FIG. 36-5.

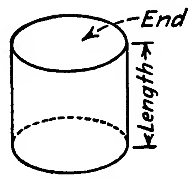


FIG. 36-6.

4. The outside area of a cylinder equals its length times its circumference plus the areas of the two ends (Fig. 36-6).

VOLUMES

1. The volume of a box is equal to its length times its width times its height (Fig. 36-7).

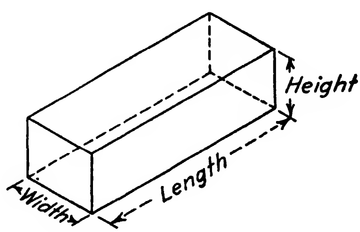
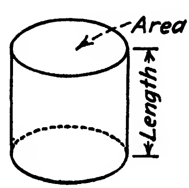


FIG. 36-7.

2. The volume of a cylinder is equal to the area of one end times its length, or the radius squared times 3.1416 times its length (Fig. 36-8).

FIG. 36-8.



SAMPLE PROBLEMS AND SOLUTIONS

1. A truck's governor is set at 45 mph. How far can it travel in 8 hr? *Answer:* The total mileage traveled in 8 hr will be eight times the number of miles per hour, or $8 \times 45 = 360$ miles.

2. If a power line is to be constructed with 12 towers per mile, how many towers will be required for 11 miles of line? *Answer:* If each mile of line requires 12 towers, 11 miles of line will require $12 \times 11 = 132$ towers.

3. What power will be required to supply 250 lamps if each lamp is rated 60 watts? *Answer:* The total wattage represented by the 250 lamps is $250 \times 60 = 15{,}000$ watts, or $15{,}000/1{,}000 = 15$ kw.

4. The net weight of a shipment of 125 copper splicing sleeves is 150 lb. If each sleeve weighs 1.2 lb, is the shipment count correct? *Answer:* If each sleeve weighs 1.2 lb and there are 125 sleeves, the total weight should be $125 \times 1.2 = 150$ lb. The count is therefore correct.

5. A lineman uses a block and tackle that gives him an advantage of 3 to 1. How many pounds of force must he apply to lift a transformer that weighs 180 lb? *Answer:* Since the block and tackle gives the lineman an advantage of 3 to 1, he will only have to apply a force equal to one-third the weight of the transformer to be lifted or $\frac{1}{3}$ of $180 = 180/3 = 60$ lb.

6. An electric heater is rated 750 watts. How many kwhr will it use in 4 hr? What will be the cost of operation at $1\frac{1}{2}$ cents per kwhr? *Answer:* In 4 hr the heater will consume $4 \times 750 = 3{,}000$ watthours $= 3$ kwhr. At $1\frac{1}{2}$ cents per kwhr, this will cost $1\frac{1}{2} \times 3 = 4\frac{1}{2}$ cents.

7. Five groundmen can do a piece of work in 4 hr. How long will it take one groundman to do the job? *Answer:* If five groundmen can do a piece of work in 4 hr, the job takes $5 \times 4 = 20$ man-hours total. Therefore one groundman can do the job in 20 hr.

8. How much rope would you get to make a set of blocks that would extend 18 ft, using a three-sheave pulley at the top and a two-sheave pulley at the bottom? *Answer:* Six lengths of rope of 18 ft each will be required. The total length required will therefore be $6 \times 18 = 108$ ft.

9. If there are 250 washers of a certain size in a pint, how many would a bushel hold? *Answer:* A bushel would hold

$$4 \times 8 \times 2 \times 250 = 16{,}000 \text{ washers}$$

10. What is the horsepower rating of a 1,000-kw generator? *Answer:* Since 1 kw equals $1\frac{1}{3}$ hp, 1,000 kw equals $1{,}000 \times 1\frac{1}{3} = 1{,}333$ hp.

11. If transformer oil weighs 8.125 lb per gal, how much weight is added to a transformer if it is filled with 30 gal of oil? *Answer:* Total weight added equals $8.125 \times 30 = 243.75$ lb.

12. A gallon of gasoline weighs approximately $8\frac{1}{3}$ lb. What weight will be added to a line truck if it requires 20 gal of gasoline to fill the tank? *Answer:* The weight added by 20 gal of gasoline equals

$$20 \times 8\tfrac{1}{3} = 166\tfrac{2}{3} \text{ lb}$$

13. If it takes three men 8 hr to dig 12 pole holes, how long would it take one man to dig the holes? How long would it take six men? *Answer:* If three men require 8 hr to dig 12 pole holes, a total of $3 \times 8 = 24$ man-hours is required. Therefore one man could dig the 12 holes in 24 hr. Six men could do the work in one-sixth of the time, or $\frac{1}{6}$ of $24 = 4$ hr.

14. A kilowatt is 1,000 watts. What is the kilowatt consumption of the following group of lights?

6 lamps rated 200 watts	9 lamps rated 60 watts
4 lamps rated 100 watts	3 lamps rated 40 watts

Answer:

No. of Lamps	Rating in Watts	Total Watts
6	200	1,200
4	100	400
9	60	540
3	40	120
		2,260

Total wattage is, therefore, 2,260 watts or $2{,}260/1{,}000 = 2.26$ kw

15. How many acres in a right of way 2 rods wide and 10 miles long? *Answer:* A mile is 320 rods long. Therefore the number of square rods in a strip of land 2 rods wide and 3,200 rods long is $2 \times 3{,}200 = 6{,}400$ sq rods. Since there are 160 sq rods in an acre, the right of way contains $6{,}400/160 = 40$ acres.

16. A lineman works 40 hr a week at $1 an hour and 8 hr of overtime at $1\frac{1}{2}$ times the regular rate. What will be the amount of his pay check? *Answer:* For the 40 hr he will earn $40 \times \$1 = \$40$. For the 8 hr overtime he will earn $8 \times \$1.50 = \$12.00$.

Total amount of earnings is $40.00 for regular time
12.00 for overtime
$52.00 total for week

17. The following short pieces of wire are required for a job: $6\frac{1}{2}$, $10\frac{1}{4}$, $5\frac{3}{8}$, and $7\frac{11}{16}$ in. How many feet of wire are required? *Answer:* As this is a problem in addition, the numbers to be added should be arranged in a vertical column, thus:

$$\begin{array}{rl} 6\frac{1}{2} \text{ same as } & 6\frac{8}{16} \\ 10\frac{1}{4} \text{ same as } & 10\frac{4}{16} \\ 5\frac{3}{8} \text{ same as } & 5\frac{6}{16} \\ 7\frac{11}{16} \text{ same as } & \underline{7\frac{11}{16}} \\ \text{Total } & 28\frac{29}{16} \text{ in.} \end{array}$$

But since the fractions are not expressed in the same denominator, the denominators must be changed as shown above. The numerators of the fractions can now be added, giving $\frac{29}{16}$. This of course is equal to $1\frac{13}{16}$. Adding this to 28 gives a total of $29\frac{13}{16}$ in. Since there are 12 in. in each foot, the total length of wire is 2 ft $5\frac{13}{16}$ in.

18. A 25-ft pole is set in the ground 5 ft. What fractional part of the pole is aboveground? *Answer:* If 5 ft is in the ground $25 - 5 = 20$ ft are aboveground. This is $\frac{20}{25}$ part, or four-fifths, of the total pole length, or 0.80 of the total pole length.

19. A block-and-tackle set is made up of one two-sheave pulley, one one-sheave pulley, and 100 ft of $\frac{5}{8}$-in. rope. If the double pulley weighs $3\frac{1}{2}$ lb, the single pulley $2\frac{3}{4}$ lb, and the rope 8 ft per lb, how much will the block and tackle weigh? *Answer:*

$$\begin{aligned} \text{Weight of two-sheave pulley} &= 3\tfrac{1}{2} \text{ lb} \\ \text{Weight of one-sheave pulley} &= 2\tfrac{3}{4} \text{ lb} \\ \text{Weight of 100 ft of rope at 8 ft per lb} &= \underline{12\tfrac{1}{2}} \text{ lb} \\ \text{Total weight} &= 18\tfrac{3}{4} \text{ lb} \end{aligned}$$

20. The total length of a reel of cable is 300 ft. If 1 ft of this cable weighs $1\frac{3}{4}$ lb, what is the weight of the reel? *Answer:* The total weight of the reel of cable will be the product of the number of feet times the weight per foot: $300 \times 1\frac{3}{4} = 300 \times \frac{7}{4} = 525$ lb.

21. A line truck makes a round trip to a point 35 miles from the warehouse in 3 hr and 30 min driving time. What is the miles per hour average for the truck? *Answer:* The total distance traveled is $2 \times 35 = 70$ miles. Since the time required is $3\frac{1}{2}$ hr, the average speed is the ratio of the distance divided by the time, or $70/3\frac{1}{2}$, or $70/\frac{7}{2}$, or $\frac{70}{7} \times 2 = 20$ mph.

22. If 1 hp is the equivalent of 0.746 kw, what is the total kilowatt load of two 10-hp motors? *Answer:* The two motors total 20 hp. Since each horsepower represents 0.746 kw, the two motors total $20 \times 0.756 = 14.920$ kw.

23. The distance around a circle is 3.1416 times the distance across at the center. A coil of wire has 15 turns and is approximately 21 in. across. About how many feet in the coil? *Answer:* Each turn of wire will be $21 \times 3\frac{1}{7} = 66$ in. long. The 15 turns will be $15 \times 66 = 990$ in. in length, or 82.5 ft in length.

24. If there are 7.21 gal in 1 cu ft, what is the gallon capacity of a tank containing 12 cu ft? *Answer:* The capacity of the tank is

$$7.21 \times 12 = 86.52 \text{ gal}$$

25. A standard barrel contains 31.5 gal. How many barrels are there in a tank that holds 5,000 gal? *Answer:* The number of barrels in the tank equals 5,000/31.5 = 158.73 barrels.

26. A truck carries six coils of rope measuring $30\frac{1}{2}$ ft, $45\frac{3}{4}$ ft, 88 ft 4 in., 12 ft 6 in., and 36 ft 3 in., respectively. What is the total yardage of rope carried? *Answer:* This is another problem in addition; therefore arrange the numbers in a vertical column, thus:

$30\frac{1}{2}$ ft	same as	$30\frac{6}{12}$
$45\frac{3}{4}$ ft	same as	$45\frac{9}{12}$
88 ft 4 in.	same as $88\frac{1}{3}$ or	$88\frac{4}{12}$
12 ft 6 in.	same as $12\frac{1}{2}$ or	$12\frac{6}{12}$
36 ft 3 in.	same as $36\frac{1}{4}$ or	$36\frac{3}{12}$
		$211\frac{28}{12}$ ft

First the inches have to be changed to fractions of a foot, that is, 4 in. is $\frac{1}{3}$ ft, 6 in. is $\frac{1}{2}$ ft, and 3 in. equals $\frac{1}{4}$ ft. Then the whole numbers and the numerators of the fractions are added, giving $211\frac{28}{12}$. $\frac{28}{12}$ of course is equal to $2\frac{4}{12}$, giving a total of $213\frac{4}{12}$ ft, or 213 ft 4 in. Since there are 3 ft in a yard, the total yardage of rope carried is $\frac{213}{3} = 71$ yd 4 in.

27. A 30-gal drum of oil was sent out to refill four transformers. If the transformers required the following amounts, how much oil was returned to the warehouse?

Transformer 1 required	3 gal 2 qt
Transformer 2 required	6 gal 3 qt
Transformer 3 required	9 gal 1 qt
Transformer 4 required	7 qt

Answer: This is a problem in addition; therefore arrange in vertical column as follows:

Transformers	Gallons Used		
1	$3\frac{1}{2}$	same as	$3\frac{2}{4}$
2	$6\frac{3}{4}$	same as	$6\frac{3}{4}$
3	$9\frac{1}{4}$	same as	$9\frac{1}{4}$
4	$1\frac{3}{4}$	same as	$1\frac{3}{4}$
			$19\frac{9}{4}$

The $\frac{9}{4}$ is equal to $2\frac{1}{4}$ gal. Therefore the total oil used is $21\frac{1}{4}$ gal, leaving $30 - 21\frac{1}{4} = 8\frac{3}{4}$ gal in the drum.

28. Find the total amount due on the following bill of materials:

80 wireholders at	33 cents
65 house racks at	86 cents
100 pole-top pins at	46 cents
42 thimbleye bolts at	18 cents

A discount of 10 per cent ($\frac{1}{10}$) is allowed for cash. What will be the amount of the bill if paid in cash? *Answer:* Arrange cost of materials as follows:

Name of Article	No. of Articles	Cost per Article	Total
Wireholders	80	0.33	$ 26.40
House racks	65	0.86	55.90
Pins	100	0.46	46.00
Bolts	42	0.18	7.56
Total			$135.86
Less 10% or $\frac{1}{10}$th			13.58
			$122 28

The net cost of goods if paid in cash is therefore $122.28.

29. A spacer bolt is required for a crossarm installation as follows: Thickness of pole $6\frac{3}{16}$ in., thickness of crossarm 4.5 in., washer $\frac{1}{8}$ in., $\frac{5}{16}$-in. nuts, and allowing 0.75 in. for the eye nut. What length bolt is required? How much too long is an 18-in. bolt? *Answer:* As this is a problem in addition arrange numbers in a vertical column:

Pole	$6\frac{3}{16}$	same as	$6\frac{3}{16}$
Crossarm	4.5	same as	$4\frac{8}{16}$
Washer	$\frac{1}{8}$	same as	$\frac{2}{16}$
Nut	$\frac{5}{16}$	same as	$\frac{5}{16}$
Eye nut	0.75	same as	$\frac{12}{16}$
Total			$10\frac{30}{16}$

First change the fractions to a common denominator. Then add the whole numbers and the numerators of the fractions, giving $10\frac{30}{16}$. $\frac{30}{16}$ of course is equal to $1\frac{14}{16}$. Adding this to 10 gives $11\frac{14}{16}$ or $11\frac{7}{8}$ in. An 18-in. bolt would be about 6 in. too long.

30. How many crossarms that measure $3\frac{3}{4}$ in. $\times$ $4\frac{3}{4}$ in. $\times$ 10 ft can be hauled on a $2\frac{1}{2}$-ton truck if they weigh 48.5 lb per cu ft? *Answer:* Each crossarm weighs $\frac{48.5 \times 3\frac{3}{4} \times 4\frac{3}{4} \times 120}{1,728} = 60.14$ lb. A $2\frac{1}{2}$-ton truck will carry $2,000 \times 2\frac{1}{2} = 5,000$ lb. Therefore it can carry $5,000/60.14 = 83$ crossarms.

31. A cubic foot of iron weighs 450 lb. What is the weight of 100 crossarm braces that measure $1\frac{1}{4} \times \frac{1}{4} \times 28$ in.? *Answer:* The cubic foot in one crossarm brace equals $\frac{1\frac{1}{4} \times \frac{1}{4} \times 28}{1,728} = 0.0051$ cu ft. The cubic foot in 100 braces equals $100 \times 0.0051 = 0.51$ cu ft. The weight of 100 braces, therefore, equals $450 \times 0.51 = 229.5$ lb.

32. The average circumference of a class 6, 40-ft pole is 29 in. If such a pole weighs 45.75 lb per cu ft, what should be the weight of one pole? *Answer:* The volume or number of cubic feet in the 40-ft pole is equal to its length multiplied by the area of the base, or

$$40 \times \pi \frac{(29/12 \times \pi)^2}{4} = 18.4 \text{ cu ft}$$

If each cubic foot weighs 45.75 lb, the pole will weigh

$$45.75 \times 18.4 = 843 \text{ lb}$$

33. A groundman digs the following pole holes: eight holes each 24 in. by 6 ft, four holes each 18 in. by 5 ft. How many cubic yards of dirt did he handle? *Answer:* A post hole is cylindrical in shape; therefore its volume equals the depth of the hole times the area of the hole.

$$\begin{aligned}
\text{Area of 24-in. hole} &= \frac{\pi 2^2}{4} = \pi \text{ sq ft} \\
\text{Area of 18-in. hole} &= \frac{\pi\left(1\frac{1}{2}\right)^2}{4} = 1.75 \text{ sq ft} \\
\text{Volume of 24-in. hole} &= \pi \times 6 = 18.84 \text{ cu ft} \\
\text{Volume of 18-in. hole} &= 1.75 \times 5 = 8.75 \text{ cu ft}
\end{aligned}$$

Total volume of dirt moved equals

$$\begin{aligned}
8 \times 18.8 &= 150.40 \\
4 \times 8.75 &= \underline{\ \ 35.00} \\
&\ 185.40 \text{ cu ft}
\end{aligned}$$

Since there are 27 cu ft in a cubic yard, the number of cubic yards moved equals $\frac{185.40}{27} = 6.9$ cu yd.

SECTION 37

*Self-testing Questions and Answers**

The following examination questions may be used by the reader to determine his progress in lineman training. The questions are given in five groups. The first set should be used to determine whether the reader is qualified for promotion from groundman to an apprentice or second-class lineman. The last set should be used to determine whether the reader is ready to be promoted from second-class lineman to first-class lineman. The second and third sets are used to measure the progress of the apprentice lineman's skill and knowledge. In general it can be said that, if the reader answers three-quarters of the questions correctly, he can consider himself as having passed. Usually it is good practice for an employee to serve as groundman for 1 year. The time given to apprenticeship may vary from 1 to 2 years. It is desirable that this apprenticeship include 6 months with a construction crew.

SET I—FOR PROMOTION FROM GROUNDMAN TO APPRENTICE LINEMAN

1. *a.* What is the Schaefer method of artificial respiration? *Answer:* Prone pressure.

b. When is this method used? *Answer:* Electric shock, drowning, carbon monoxide poisoning, injuries, etc.

c. What are the most vital things to be checked while applying this respiration? *Answer:* Foreign substances in mouth, such as false teeth, tobacco, chewing gum; loosen tight clothing; keep patient warm.

d. How long should this respiration be applied? *Answer:* Until natural breathing is restored or rigor mortis has set in.

* These questions are reprinted with permission from *Electrical World*, Aug. 18, 1945; Sept. 1, 1945; Sept. 18, 1945; and Oct. 2, 1945. They were prepared by C. T. Malloy, General Superintendent of Transmission, Distribution, and Communication of the Southern California Edison Co. of Los Angeles, Calif., and are used by that company as the basis for oral examinations to determine if the apprentice lineman is making satisfactory progress and furthermore to determine if the field foreman is teaching the apprentice enough to prepare him for advancement.

e. What should be done when the patient comes to? *Answer:* Keep patient quiet and treat for shock.

f. What procedure should be followed in case a man has a severe cut on one hand? *Answer:* Elevate hand if not fractured; control bleeding at pressure point in arm.

2. *a.* How should belts and hooks be stored in a truck? *Answer:* Body belts stored separately from climbers.

b. What size and type of rope should be used in a hand line for general line work? *Answer:* ½-in. manila or sisal material.

c. What very important features should be checked when selecting a pulling grip for use? *Answer:* Size and type.

d. When should a safety belt be replaced? *Answer:* After 25 per cent depreciation.

e. Describe several conditions that would render climbers unsafe for use. *Answer:* Improper size, gaffs less than 1¼ in., straps in poor condition.

f. When is it necessary to use a safety belt? *Answer:* On poles, towers, platforms, or other elevated structures.

3. *a.* Why is a bowline knot used? *Answer:* Will not slip, easily untied.

b. If you were dragging a pole behind a tractor with a 1-in. rope: How would you fasten the rope (1) at the tractor, (2) at the pole? *Answer:* (1) Bowline knot, (2) pole tongs and bowline knot.

c. Why is a square knot used instead of a granny knot? *Answer:* Square knot will not untie under stress.

d. Where would you use a clove hitch? *Answer:* To tie other long tools or sticks to hand line.

e. For what is a grapevine hitch used? *Answer:* To attach rope to wire for snubbing purposes.

f. Are two half hitches the same as a clove hitch? *Answer:* Yes.

4. *a.* Does height bother you? *Answer:* No.

b. What three things must be checked before climbing a pole? *Answer:* Condition of pole, location of working position, climbing space.

5. *a.* How deep should a gain be cut into a pole? *Answer:* Not less than ⅝ in. or more than ⅞ in. deep.

b. What side of a pole is gained for a line arm? *Answer:* Concave side.

c. Is it permissible to install a buck arm on a pole in other than at right angles to the line arm? *Answer:* No.

d. What is the standard separation of line arms on 66-kv lines? *Answer:* 5 ft 6 in.

e. What is the minimum separation of bond wires and incidental hardware on crossarms? *Answer:* 1½ in.

f. When installing a double arm, is the arm separation at the space bolts supposed to be the same as at the pole? *Answer:* ¼ in. less.

6. *a.* Is it permissible for one lineman to work directly under another at a lower working level on the pole? *Answer:* Yes, but not advisable.

b. Should two men climb a pole at the same time? *Answer:* No.

c. How close to each other should three bolt clamps be installed on a guy wire, when more than one clamp is being used? *Answer:* 2 in.

d. Where should the groundman be while you are working on the pole? *Answer:* At least 15 ft from pole.

e. Where should tools and small material be stored at working level? *Answer:* In canvas bag or bucket.

f. What must be done before you change the strain on any pole? *Answer:* Test pole for soundness.

7. *a.* How do you give the signals for: *a* "Take it up easy"? *Answer:* Refer to standard signals for line work.

b. "Slack off"? *Answer:* Same as for *a.*

c. "All off"? *Answer:* Same as for *a.*

d. "Take it up"? *Answer:* Same as for *a.*

e. "Cut it loose"? *Answer:* Same as for *a.*

8. *a.* On examination, how do you determine if a circuit is a primary or secondary circuit? *Answer:* Check for "high-voltage" signs or proper colored paint on voltages above 750 volts.

b. Are any markings used to distinguish high-voltage circuits from secondary or grounded circuits? What? *Answer:* Yes. Same as *a.*

c. Can you distinguish a communication circuit from a secondary circuit? How? *Answer:* Yes. Usually by pin spacing and size of conductor.

d. On a pole that has communication, secondary, primary, and transmission circuits, what is the normal position of each circuit on the pole? *Answer:* Transmission at upper level, primary at next level, then secondary and communication at lower level.

9. *a.* When is it permissible to drop material or tools from a pole without using the hand line? *Answer:* Never.

b. Why do our safety rules require the use of rubber gloves when working on energized lines? *Answer:* To protect workmen from energized conductors and equipment.

c. Safety belts for general use must be equipped with what kind of snaps? *Answer:* Drop forged.

d. Is it permissible for a man to work on a job without a shirt? *Answer:* No.

10. *a.* Who is responsible for the breaking of any law with a truck? *Answer:* Truck driver.

b. What precautions must be taken when a truck is parked beside a highway or street and the crew is working nearby? *Answer:* "Men at work" signs properly stationed.

c. Is it necessary for a lineman to have a chauffeur's license to drive a truck? *Answer:* No.

d. What procedure must be followed when towing long poles in metropolitan areas? *Answer:* Display proper rear signals and secure assistance of traffic officer.

11. *a.* What is the usual thing you look for in trying to locate a flashover? *Answer:* Pits and burns on insulators, conductors, tie wires, and hardware.

b. Why are manila rope lines used for raising poles when it is necessary to rig the tackle above the primary position? *Answer:* Wire rope and cable not permitted above level of primary voltage because they are not insulators.

c. When a snatch block is attached at the base of a pole, should the hook of the block be installed up or down? *Answer:* Preferably down.

12. *a.* Why is "good housekeeping" essential on the job? *Answer:* For safety.

b. Who is responsible for "good housekeeping" besides the foreman? *Answer:* Every member of the crew.

13. *a.* What is meant by being "safety minded"? *Answer:* Thinking of the safety factor of every job.

b. How is safety best promoted on the job? *Answer:* Through the influence of the foreman.

c. Can you suggest any improvements that will increase safety? *Answer:* Channels are always open for safety suggestions.

14. *a.* Is "taking a chance" ever justified? *Answer:* No.

b. Why are old poles always inspected very carefully before the strain is changed on the pole? *Answer:* To determine if they will stand the change in stress.

SET II—FOR CHECKING PROGRESS OF APPRENTICE LINEMAN

1. *a.* What advantage does the pole-top method of artificial respiration have over the Schaefer method? *Answer:* The time factor in applying artificial respiration.

b. How long since you have practiced each method? *Answer:* Give time. (Should be practiced at regular intervals.)

c. Do you feel confident of your ability to apply artificial respiration properly? *Answer:* Yes.

2. *a.* Have you had experience enough so that you feel you are adept in climbing poles and towers? *Answer:* Yes.

b. Should the climbers be used where the pole is stepped? *Answer:* Not in portion of pole where steps are installed.

3. *a*. Describe the standard side and top ties used on insulators on communication circuits. *Answer:* Refer to text.

b. What is the proper method of making a splice in a communication wire? *Answer:* Compression splice.

c. What is the proper working position (in relation to the wires being worked on) for working on communication conductors? *Answer:* Work from below wherever possible.

4. *a*. How often are you required to practice artificial respiration? *Answer:* State.

b. How often are transmission circuits patrolled? *Answer:* State.

c. What is to be checked when patrolling lines? *Answer:* Conductors, insulators, poles, towers, and right of way.

5. *a*. How many tucks of each strand are necessary to furnish the strength of the rope in a splice? *Answer:* Three tucks.

b. Are there any advantages to be gained in "feathering" the strands as they are being spliced? *Answer:* Usually none.

c. Why is a long splice used instead of a short splice? *Answer:* More strength and does not increase size of rope.

d. Demonstrate your ability to splice. *Answer:* Demonstrate.

6. *a*. What hours are you "on call" on workdays? *Answer:* State.

b. Who must be notified when there is a serious accident? *Answer:* Dispatcher.

c. How can arrangements be made for calling if you are to be away from home during "on-call" hours? *Answer:* By contacting dispatcher.

7. *a*. What are the most important factors to be considered in splicing conductors? *Answer:* Size and type of splicing material, clean conductors, proper installation.

b. Why is Vaseline or Calol grease used in making splices in transmission conductors? *Answers:* To eliminate possibility of corrosion.

c. Describe the procedure to be followed in making a conductor splice with a splicit. *Answer:* Describe.

8. *a*. Why do standard construction methods provide for greater clearances and strength requirements than is required by railroad commission orders? *Answer:* Greater protection for workmen and company property.

9. *a*. Have you had any difficulty in adapting yourself to this type of work and particularly with the other men? *Answer:* No.

10. *a.* How should rubber protective equipment be stored on the truck? *Answer:* In bags or canisters in boxes on the truck reserved for this equipment.

b. When should rubber protective equipment be used? *Answer:* When possible to make contact with any voltage from 250 to 7,500 volts.

c. What wires should be protected by rubber? *Answer:* One each side of workmen, also at feet and one on each side of one being worked on.

11. *a.* When is it necessary to use a safety belt? *Answer:* Whenever working in an elevated position, such as poles, ladders, platforms, etc.

b. Is it safe to attach a safety belt above the top arm on a pole? *Answer:* No.

c. How often should a safety belt be inspected? *Answer:* Every time it is used.

d. Name several conditions that are common to a safety belt when it is unsafe for further use. *Answer:* Snaps, cuts, cracks, or common wear which will lessen the strength of the strap 25 per cent.

12. *a.* Why are trees trimmed to keep the wires clear? *Answer:* To eliminate line outages and damage to conductors and trees.

b. What procedure is necessary before trees are trimmed? *Answer:* Secure consent of all parties concerned.

c. Is there any reason to shape a tree in addition to just cutting the limbs that may contact the wires? If so, why? *Answer:* Yes. Public relations.

d. Describe the precautions that must be followed to trim a tree safely. *Answer:* Use of safety belt and lines; limbs must not be permitted to contact energized conductors.

13. *a.* What does "getting in series with a circuit" mean? *Answer:* Making contact between the ends of same conductor.

b. What does "accidentally grounding a circuit" mean? *Answer:* Making contact to ground of one or more phases.

c. What does it mean to "short" a circuit? *Answer:* Connecting one phase to one or more phases of same circuit.

d. What does an "open circuit" mean? *Answer:* Opening in one or more phases of same circuit.

14. *a.* How is a "clearance" to work on a circuit secured? *Answer:* Check switching and dispatching procedure.

b. What precautionary steps are taken to prove a circuit "dead" after a "clearance" is had on that circuit? *Answer:* Install shorts and grounds.

c. Why are shorts and grounds installed on a deenergized circuit before working on the line? *Answer:* To prove the line dead.

d. State the correct procedure for installing and removing a short and ground from a "dead" circuit. *Answer:* To install, attach grounding device to ground first and stand clear. To remove, remove device from conductors before detaching from ground.

SET III—FOR CHECKING PROGRESS OF APPRENTICE LINEMAN

1. *a.* What would you check before climbing a pole with several circuits, and tell what might influence your judgment in deciding which side of the pole to climb. *Answer:* Condition of pole, decay, plumb, climbing space, position of circuits, arms, etc.

2. *a.* Are there advantages in maintaining a standard method of construction? *Answer:* Yes.

b. What is the standard number of the crossarm used for 66-kv construction? *Answer:* See construction standards.

c. After completing work on a pole, what do you inspect to assure yourself that nothing has been overlooked and that the job is safe? *Answer:* Recheck of all work.

d. What is the proper depth for setting a 60-ft pole in firm soil? *Answer:* 8 ft.

e. How do you measure the depth of a pole hole on a hillside? *Answer:* From the lower side of the hole.

3. *a.* What is the normal tension of No. 4/0 copper conductors on a 66-kv wood pole line? *Answer:* Approximately 1,400 lb.

b. At what percentage of the rated breaking strength is hemp rope considered safe for working loads? *Answer:* 20 per cent.

c. If it is necessary to apply a strain on a tower at other than the cross arm, how is this position determined to prevent damage to the tower? *Answer:* Where cross members intersect and attach to tower legs.

d. How would you rig a line to prevent undue stress on the end of a tower crossarm when raising a heavy load? *Answer:* One sheave at the end of the arm and one at the tower proper.

4. *a.* Is it necessary to oil the wire rope used in line work when it is in use regularly? *Answer:* Yes.

b. Why is it necessary to maintain the wire rope on a drum tightly and closely wound? *Answer:* To prevent kinks, bruises, and slippage.

c. What extra precautions must always be taken by the truck driver when it is necessary for a man to work on a wire that is supported by a winch line? *Answer:* Must remain at controls and keep winch locked.

5. *a.* Why are rope lines used in working through and above primary circuits? *Answer:* Rope is not a conductor.

b. Why must a pressure-treated pole be set with extra care when being raised through energized lines? *Answer:* May conduct as much as 90 per cent to ground.

c. When do you consider it necessary to take a circuit out of service when raising poles? *Answer:* When impossible to set with proper clearances.

d. Is it permissible to use regular rope in positions where it may contact lines of 66 kv or over? *Answer:* No.

6. *a.* If you find an emergency condition that requires the line be taken out of service for repairs, whom do you call to make arrangements? *Answer:* Dispatcher.

b. How do you double check to be sure you are asking for the proper line out of service? *Answer:* Check with dispatcher.

c. How do you test the line to be sure it is "dead"? *Answer:* By shorting and grounding device.

d. The pole to be grounded has a telephone line, secondary, and a primary circuit below the line to be grounded. Describe how you would apply the ground. *Answer:* By securing ground to pole through loops at each conductor level.

7. *a.* Is it permissible to have any intoxicants with your lunch? *Answer:* No.

b. Are men permitted to change their days off to attend personal business? *Answer:* State regulation.

c. Are you required to perform routine work in the rain? *Answer:* No.

d. Who is responsible for your work and advancement? *Answer:* Foreman.

8. *a.* What would you do with a man who had fainted? *Answer:* Lay patient down with head low, feet elevated; keep patient warm.

b. What would you do in case a man were bitten by a rattlesnake? *Answer:* Apply tourniquet, open wound, call doctor, keep patient calm.

c. How would you take care of a sprained ankle? *Answer:* Ankle bandage, immobilize.

d. Name the major pressure points to stop bleeding. *Answer:* Temple, neck, under collarbone, upper arm, upper thigh, and knee.

9. *a.* What is the standard arm spacing for 66 kv on wood poles? *Answer:* 5 ft 6 in.

b. When installing three-bolt clamps and more than one is used at the same location, should the clamps be separated? *Answer:* Yes.

c. Why are double arms installed with the ends pulled closer together than at the poles? *Answer:* To take care of shrinkage at the pole.

10. *a.* What must be inspected at each tower or pole when making a patrol? *Answer:* Conductors, insulators, structure, and hazards to public property.

b. What is the purpose of making periodic patrols of a line? *Answer:* Ensure continuity of service, protect public.

c. What conditions, other than line conditions, must be reported when patrolling a line? *Answer:* Pertinent to public and private property.

SET IV—FOR PROMOTION FROM APPRENTICE LINEMAN TO FIRST-CLASS LINEMAN

1. *a.* Why are transmission and communication circuits transposed? *Answer:* Neutralize induction on circuits.

b. How do you install a "physical" transposition in a communication circuit? *Answer:* Describe.

c. How do you install a No. 2 phantom transposition in a communication circuit? *Answer*: Describe.

2. *a.* In using live-line tools, what must be guarded against? *Answer:* Maintain specified distance from conductors as per voltage classifications.

b. Name the routine procedure for care of live-line tools. *Answer:* Keep dry, clean, and in good condition.

c. Is wire covering ever relied upon for safety? *Answer:* No.

3. *a.* What are the more important features of the job that must be explained to a groundman to enable him to grasp the work in hand? *Answer:* Existing hazards, precautions, best way to apply.

4. *a.* Describe the procedure to be followed in making a 220-kv conductor splice. *Answer:* Describe.

5. *a.* When does a guy wire need an insulator breaker in it? *Answer:* When in proximity to voltages less than 35,000 volts.

b. What is the minimum height of a telephone line across the railroad track? *Answer:* 27 ft.

c. Who is responsible that installations are in accord with commission safety orders? *Answer:* Foreman.

6. *a.* How is time worked accounted for? *Answer:* By clerk through work-order accounts.

b. Why are material maps made? *Answer:* For permanent records of company property.

c. How is material accounted for? *Answer:* By clerk through work-order accounts.

7. *a.* Where would you check first for trouble on a communication circuit where it is known that lightning storm was in progress when the trouble occurred? *Answer:* At lightning arresters on communication circuit.

b. What are the most common causes of transmission-line trouble? *Answer:* Flashovers on insulators.

8. *a.* Name several locations on your patrol that have conditions that may be a source of trouble. *Answer:* Name.

SECTION 38

Definition of Electrical Terms

Lineman's Lingo.* Linemen have developed quite a vocabulary of their own pertaining to their work, which is expressive and sometimes picturesque. The following list of words is typical of some that are in general use. The accepted meaning is given with each word.

baloney—Cable.
baloney bender—A wireman who works with heavy cable.
bible—The electric code.
bicycle—A chain drill for boring holes.
boomer—A lineman who works on the installation of new transmission lines.
bottles—Glass insulators.
bull pen—Where the construction crew collects before and after work.
bunching the job—Quitting the job.
clum some—A greenhorn lineman.
drifter—A lineman who wants to see the world.
equalizer—A pair of connectors when used in a fight.
floater—A lineman who would quit in the middle of the job.
gopher—A "go for this and go for that" helper.
goulash—Insulating compound.
grunt or ground hog—A lineman's helper.
half-power—A lineman who could not follow the lead of the rawhide leader; sometimes a lineman working off a jag.
hooks—Early form of climbers which go down outside the legs, called "Westerns" because they were standard with the Western Union.
jew conductor—A ground return.
lady slippers—Name applied to new climbers by old-timers.
limberneck—Green lineman.
narrow-back—An inside wireman.
persuader—A hammer.
rabbit scrap copper—Collected and traded for tobacco and liquor.
roughneck—A trouble chaser.
skinner—Man who drives the wagon.
slave market—The office of an employment agency.
wire twister—Indoor electrician.

* Abstracted from an article by Arthur Huntington, "The Lineman and His Lingo," *The Edison Electric Institute Bulletin*, October, 1939.

Electrical Terms:

ampere—The unit of current flow of electricity. It means the same with reference to electricity as does the number of gallons per minute when referring to the flow of water through a pipe. A 60-watt 110-volt tungsten lamp takes 0.545 amp to make it give the proper light.

apparent load—Current in amperes times emf in volts gives apparent load in volt-amperes. Used for alternating-current circuits because the current flow is not always in phase with the emf; hence, amperes times volts does not give the real energy load.

capacitor—An electrical device for storing a charge of electricity and returning it to the line. It is used to balance the inductance of a circuit, since its action is opposite in phase to that of inductive apparatus, *i.e.*, it throws the current ahead of the emf in phase. It is made of alternate plates of tinfoil and insulating material, the size of plates and thickness of insulation determining the capacity for holding electric charge. Capacity is measured, practically, in microfarads, or millionths of a farad.

circular mil—The area of a circle 0.001 in diameter. The circular-mils area of a wire varies as the square of the diameter: For No. 36 B. & S. wire, the diameter is 0.0005 in. and the area 25 cir mils. For No. 14 wire, the diameter is 0.06408 in. or 64.08 mils and the area is $\overline{64.08^2}$ or 4,107 cir mils.

dielectric—A nonconducting or insulating material. The dielectric value of a material is measured by comparing it with that of a like thickness of air taken as unity: glass, 3 to 8; porcelain, 4.4; treated paper, 2 to 4; paraffin and various forms of rubber, 2.2 to 2.5; mica, 6; water, 80.

exciting current—Current used for energizing the field coils of a motor or generator to create magnetic flux in the pole pieces. It also refers to the no-load current drawn by a transformer.

horsepower—A unit of power equal to 746 watts.

inductance—The coefficient of self-induction of a circuit. The effect is to cause current to lag behind emf in phase. It depends on the size and shape of the circuit, cross section and shape of conductor, magnetic properties of the conductor and the surrounding medium, and on the frequency of the current reversal and resistance of the conductor. It is, therefore, difficult to compute except for simple wire circuits suspended in air. The unit for measurement is the henry, or the millihenry ($\frac{1}{1000}$ henry).

induction motor—One in which rotor current is set up by transformer action from alternating currents supplied to the stator windings. The rotor currents are induced by those in the stator, hence the name, "induction motor."

kilowatt—1,000 watts.

kilowatthour, kwhr—Equal to 1,000 watthours.

line loss—Power used up in overcoming the resistance of the transmission line to flow of electric current. It varies with the resistance of the line and as the square of the current flowing. Also known as I^2R loss.

mil—$\frac{1}{1000}$ inch.

ohm—The unit of electrical resistance about equivalent to the resistance of 1,000 ft of No. 10 copper wire.

phase—The relative time of change in values of current or emf. Values which change exactly together are in phase. Difference in phase is expressed in degrees, a complete cycle or double reversal being taken as 360 deg. A 180 deg phase difference is complete opposition in phase.

potential—Voltage or difference in electric pressure between two parts of a circuit or between a circuit and an outside point.

power factor—The relation of real to apparent power in an alternating-current circuit. It depends on the difference in phase between current and emf and is equal to the cosine of the angle of phase lag or lead of the current.

regulation—Steadiness of maintaining the value of emf or current. Controlled by generator or transformer action or by a special regulator. Good regulation should hold voltage variation within 3 per cent of normal.

repulsion motor—An alternating-current motor which operates by repulsion of armature conductors by the stator field.

resistivity—The specific resistance of a substance; the resistance in ohms of a centimeter cube of the material to flow of current between opposite faces.

rheostat—A resistance introduced in a circuit to cause drop from voltage applied to the point where current is used. It may be metal or liquid and is utilized chiefly for regulating the emf on field coils and motor armatures.

rotor—The rotating part of an alternating-current motor. Usually the secondary of an induction motor, but may be applied to the revolving field of a synchronous motor.

sag—In transmission lines, the distance that the lowest point of a span is below the straight line between supports.

series wound—Applies to generators or motors having the armature and field windings connected in series.

shunt wound—Applies to generators or motors having the field winding in shunt across the armature.

slip ring—A solid ring with brush bearing on it for conveying alternating current to or from the armature or rotor of an alternating-current machine. Also used for feeding current to the revolving field of a synchronous motor or generator.

span—The distance between adjacent supports on a line.

squirrel cage—Winding for a rotor of an induction motor made of solid bars joined to connecting rings at each end.

synchronous condenser—A synchronous motor with overexcited field, throwing the current ahead of the emf in phase, thus giving a condenser effect. Used for raising the power factor of an inductive circuit.

synchronous motor—An alternating-current motor having the field excited by direct current. It runs at a constant speed determined by the number of poles and frequency of the current supply.

three phase—A term applied to circuits or machines carrying three voltages 120 deg apart in phase.

two phase—A term applied to circuits or machines carrying two voltages 90 deg apart in phase.

volt—The unit of electrical pressure similar to the pounds pressure on a steam gage.

watt—The unit of electric power; to find the watts consumed in a given electrical circuit, such as a lamp, multiply the volts by the amperes, by the power factor.

watthour—Unit of electrical energy being equal to the work done by 1 watt during 1 hr.

wattless component—That part of the current in an alternating-current circuit assumed to be 90 deg out of phase with the emf, hence resulting in no useful work.

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