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Fundamentals of HV Electrical Power Distribution

PDH Credits:

15 PDH

Course No.:

EPD101

Publication Source:

Original Courseware

Based in part on materials from the US Navy (NAVEDTRA)

"Fundamentals of HV Electrical Power Distribution"

Release Date:
2018

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Fundamentals of HV Electrical Power Distribution

Introduction

Overview

Power Distribution System - includes all parts of an electrical system between the power source and the customer's service entrance.

It includes overhead and underground transmission methods and the equipment required for the control and protection of the system and personnel.

Power Source

The power source may be a local generating plant. Or it may be a high-voltage transmission line feeding a substation that reduces high voltage to a level suitable for local distribution. Often, the source of power will be generators connected directly to a load.

Overhead Distribution Systems

This course will be mainly concerned with the overhead distribution system. Generally speaking, an overhead distribution system can be installed and maintained more efficiently than an underground system.

Also, for equivalent conductor size, an overhead system has higher current capacity and offers greater flexibility for future system modifications.

In this course, you will learn the basics in constructing and maintaining a power distribution system as well as the component parts of the system.

Safety Concerns in Power Distribution

Safety is the most important topic covered in this course. The potential for an accident is present during all construction and maintenance operations but is much greater for crew members working on power distribution systems.

High voltage conditions require heightened awareness of the potential for serious injury or death caused by carelessness and of the necessity of taking precautions to ensure the safety of all personnel.

Safety with Equipment

Cranes, earth augers, bucket trucks, and line trucks with booms capable of contacting high voltage lines because of their height must be operated with caution.

Maintain a minimum separation of 10 feet between the equipment and the energized power circuits at all times.

The equipment must be maintained in first-class mechanical condition., with “SAFETY FIRST” as the primary goal.

Personnel Safety

It is the line crew's responsibility to ensure the SAFETY of all personnel working on power distribution lines, and observe the following safety precautions:

- Ensure that all hot-line equipment is routinely tested according to the manufacturer's specifications before use.
- Ensure that all hot-line equipment, including rubber gloves, is stored in appropriate containers to provide the required physical protection.
- Perform air leak tests on rubber gloves before each use.
- Never use rubber gloves without the leather outer protectors.
- Ensure that the hard hats of crew members are rated to withstand 20,000 Vac and that no metal devices are or have been attached to them.
- Ensure all members of the line crew are trained in first-aid techniques for treating victims of electrical shock.
- Ensure that no individual is ever allowed to work alone near circuits or devices conducting electrical energy over 30V AC.
- Tag and lock out all circuits that are de-energized to perform work.
- Install ground sets between the electrical source and your work on all de-energized circuits when the disconnecting means is not in sight or when the potential for contact between the de-energized circuit and an energized circuit is present.

Minimum Clearances

Maintain a minimum of 3-foot clearance between personnel and any live power circuit or device conducting between 600 and 20,000 Vac. Higher voltages require an increased separation of personnel and energized circuits.

The Lineman's and Cableman's Handbook, the Safety of Electrical Transmission and Distribution Systems, MIL-HDBK-1025/10, and Occupational Safety and Health Administration (OSHA) instructions are a few of the references you need to learn more about job safety.

Distribution Systems

Components of a Power Distribution System

A power distribution system includes all elements of an electrical system between the power source and the customer's service entrance.

The power source may be either a local generating plant or a high-voltage transmission line feeding a substation that reduces the high voltage to a voltage suitable for local distribution.

Depending on the type of system, the distribution system will consist of some combination of the following components, substations, distribution transformers, distribution lines, secondary circuits, secondary service drops, and safety and switching equipment.

The distribution system may be underground, overhead, or a combination of the two.

Distribution Substations

Distribution substations change the transmission or generator voltage to a lower level, providing voltage sources for the distribution circuits supplying power to the customers.

Substations may be attended by operators or designed for automatic or remote control of the switching and voltage regulating equipment. Most large new substations are either automatic or remotely controlled.

Distribution Transformers

A distribution transformer is an electrical transformer used to carry electrical energy from a primary distribution circuit to a secondary distribution circuit.

Distribution transformers are installed in the vicinity of each customer to reduce the voltage of the distribution circuit to a usable voltage, usually 120/240 volts.

The image above shows an example of a bank of 3 conventional type step-down distribution transformers.

Step-up Transformers

Long-distance transmission of electricity requires a voltage higher than normally generated. A step-up transformer is used to produce the high voltage (example above).

Step-down Transformers

As most common electrical equipment will use 120/208 volts, a distribution transformer (step-down) is required to reduce the high-primary voltage to the utilization voltage of 120/208 volts. The various types of transformer installations are discussed later in this course.

Transformer Protection

Regardless of the type of installation or arrangement, transformers must be protected by fused cutouts or circuit breakers, and lightning arresters should be installed between the high-voltage line and the fused cutouts.

Types of Single-Phase Distribution Transformers

Three general types of single-phase distribution transformers are in use today:

- **Conventional type** - requires a lightning arrester and fuse cutout on the primary-phase conductor feeding the transformer.
- **Self-protected (SP) type** - has a built-in lightning protector.
- **Completely self-protected (CSP) type** - has the lightning arrester and current overload devices connected to the transformer and requires no separate protective devices.

Primary Distribution Circuits

Distribution circuits (primary main circuits) originate from the distribution substation.

Primary mains carry over 600 volts, but generally they operate between 2.4kv and 34.5kv (kilovolts).

Primaries can be found in single-phase or three-phase configurations and generally operate as three-phase, three-wire or three-phase, four-wire circuits.

Secondary Circuits

Secondary circuits (secondary mains) originate from the secondary windings of a distribution transformer and are 600 VAC or less.

The secondary circuits are also configured either delta or wye and are also used for the same type of loading as the primary circuits.

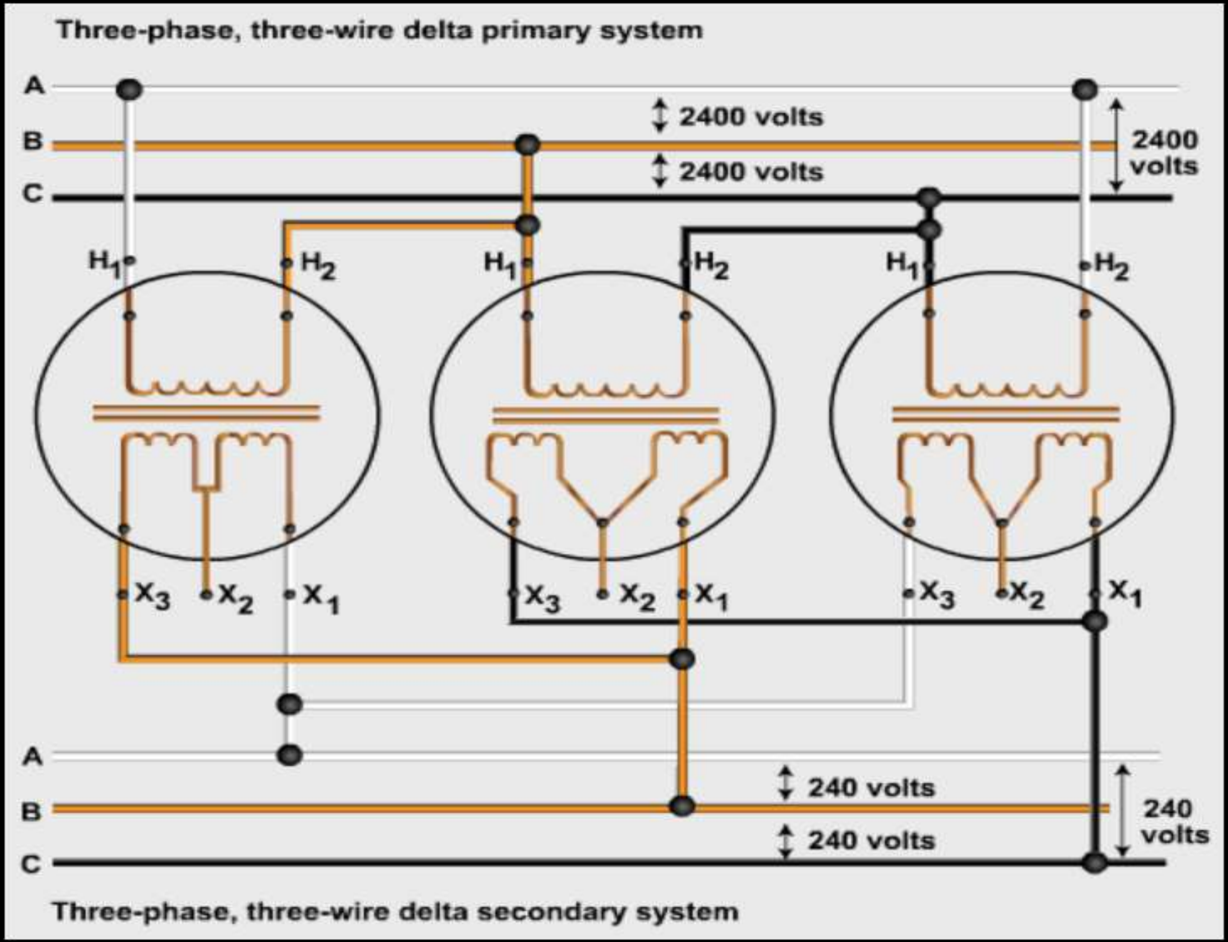
Secondary circuits are either:
Three phase - meaning they have three live conductors
Single phase - which can be one or two live conductors and a neutral

Delta Configuration

The delta system is a three-phase, three-wire system configuration. The symbol for the delta configuration is "Δ". Only one voltage exists in a delta system. This voltage is obtained between any two of the three phase conductors in the system.

This is a phase to-phase connection and is therefore a LINE voltage.

Since there is no neutral in a delta system, there is no potential from any energized phase to neutral or ground as long as the delta system remains pure (no grounds).



Delta Type System

The delta type (Δ) system, shown above, is used when most of the load in an area is commercial, consisting of motors and other three-phase equipment.

Wye Configuration

This system configuration is a three-phase, four-wire system and is the preferred system used by our military services. The symbol for the wye configuration is “Y ". The wye system has two voltage potentials: LINE and PHASE.

Phase-to-phase (LINE) voltage is obtained between any two of the three energized phases. Phase-to-neutral (PHASE) voltage is obtained from any one of the three energized phases and the neutral conductor.

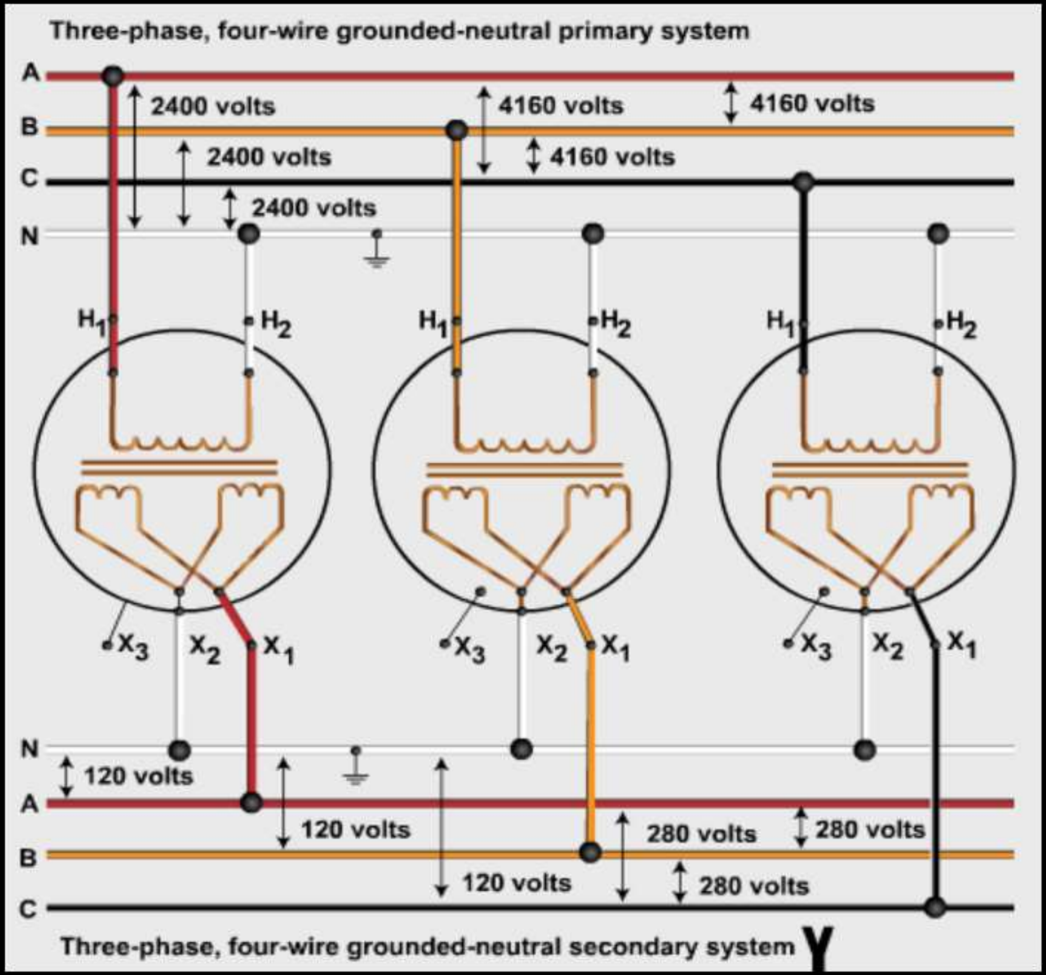
The energized phases are designated with the first three letters of the alphabet: A, B and C (This phase designation applies to all systems). The neutral conductor is the fourth wire of this system and is designated with the letter N.

Neutral Conductor (in Wye System)

The neutral conductor is connected to the ground at predetermined locations to ensure that it remains a de-energized conductor.

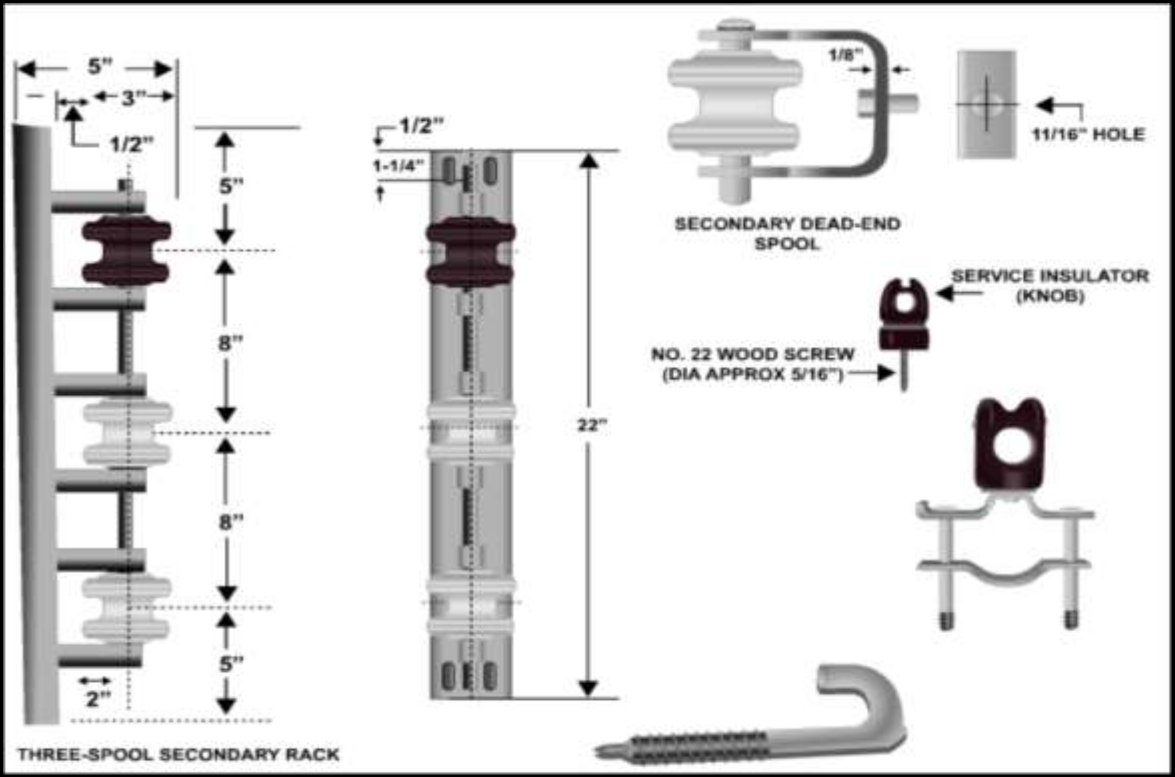
The earth also serves as an alternate path back to the voltage source if the neutral conductor should break its path.

The neutral is not an energized conductor, but should be treated as such since accidental opening of the conductor causes current to flow.



Wye Type System

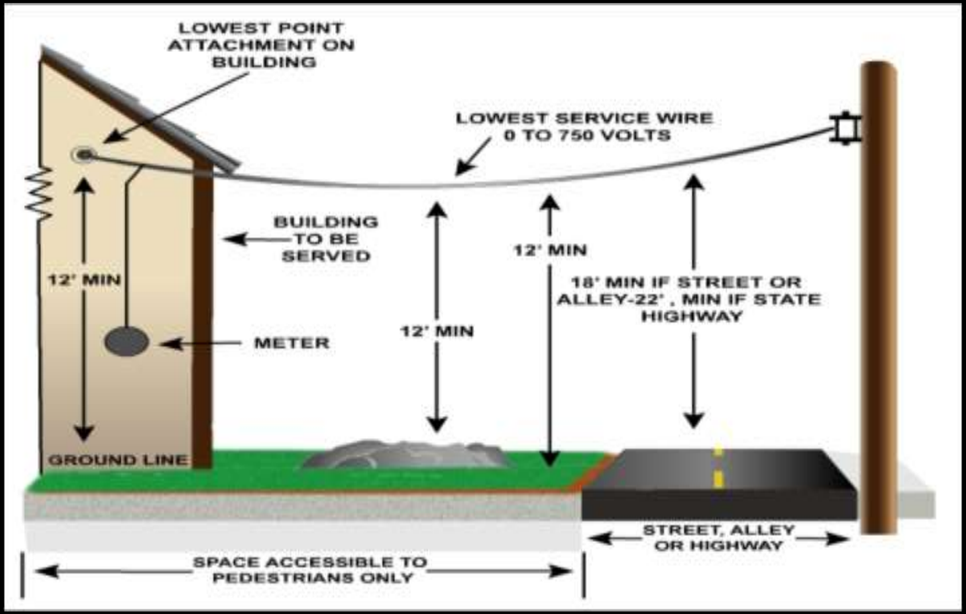
The wye (Y) system, shown above, is used primarily for residential use and where lighting makes up a substantial portion of the load.



Service Drops

A service drop is the combined conductors used to provide an electrical connection between a secondary distribution circuit and a user's facility (residential, commercial, industrial, etc.).

There are different ways of installing the service drop. Some typical secondary racks used to install service drops are shown above.



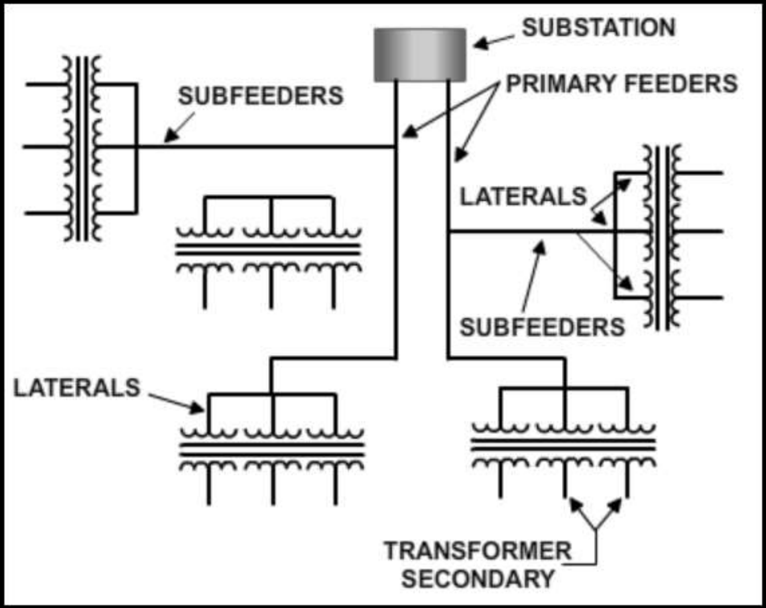
Service Rack

Whether a rack has individual conductors or self-supporting service cable, known as triplex or quadraplex, to provide a service drop, you must maintain the minimum aboveground distance recommended by the NEC©.

In the example above, this distance is 12 feet over lawns, driveways, or walkways accessible to pedestrians and 18 feet over roads or alleyways subject to truck traffic. When the nearest distribution pole is over 125 feet from the facility to be connected, you must provide an intermediate support pole*.

** (Local code requirements should be consulted as well as the most recent edition of the NEC or National Electrical Code)*

Circuit Designs



Radial Distribution Circuit

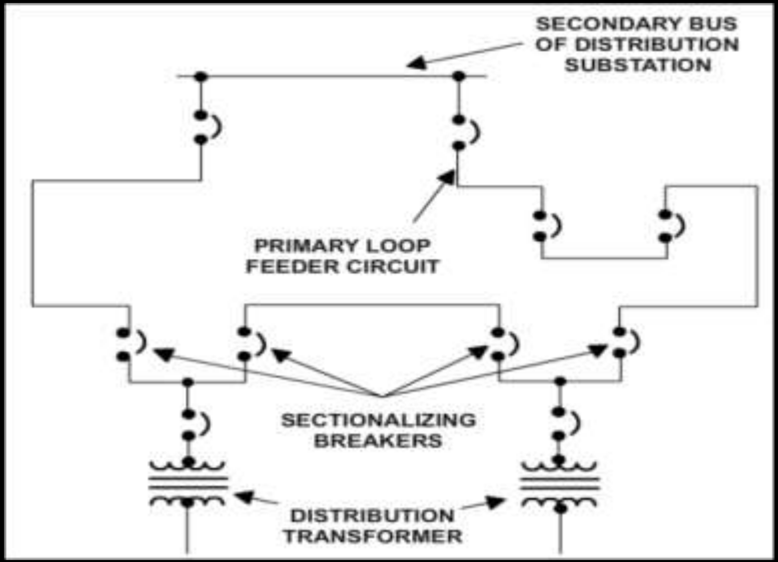
The image above shows a representative schematic of a radial distribution system. Note that the independent feeders branch out to several distribution centers without intermediate connections between feeders.

The radial distribution system is the most frequently used system because it is the simplest and least expensive to build. Although operation and expansion are simple, it is not as reliable as most systems unless it uses quality components.

Effect of a Fault in a Radial Circuit

A fault or loss of a cable, primary supply, or transformer will result in an outage on all loads the feeder serves. Furthermore, electrical service is interrupted when any piece of service equipment must be de-energized to perform routine maintenance and service.

You can improve service from this type of feeder by installing automatic circuit breakers that reclose the service at predetermined intervals. If the fault continues after a predetermined number of closures, the breaker will lock out until you clear the fault and restore service by hand reset.



Loop/Ring Circuit

The loop, or ring, system of distribution starts at the substation and is connected to or encircles an area serving one or more distribution transformers or load centers. The conductor of the system returns to the same substation.

The loop system, shown above, is more expensive to build than the radial type but is more reliable. It may be justified in an area where continuity of service is of considerable importance, for example, a medical center.

Sectionalizing the Circuit

In the loop system, circuit breakers sectionalize the loop on both sides of each distribution transformer connected to the loop.

Pilot wire relaying or directional overcurrent relays ordinarily control the two primary feeder breakers and the sectionalizing breakers associated with the loop feeder.

Use pilot wire relaying when there are too many secondary substations to obtain selective timing with directional overcurrent relays.

Faults in the Primary Loop

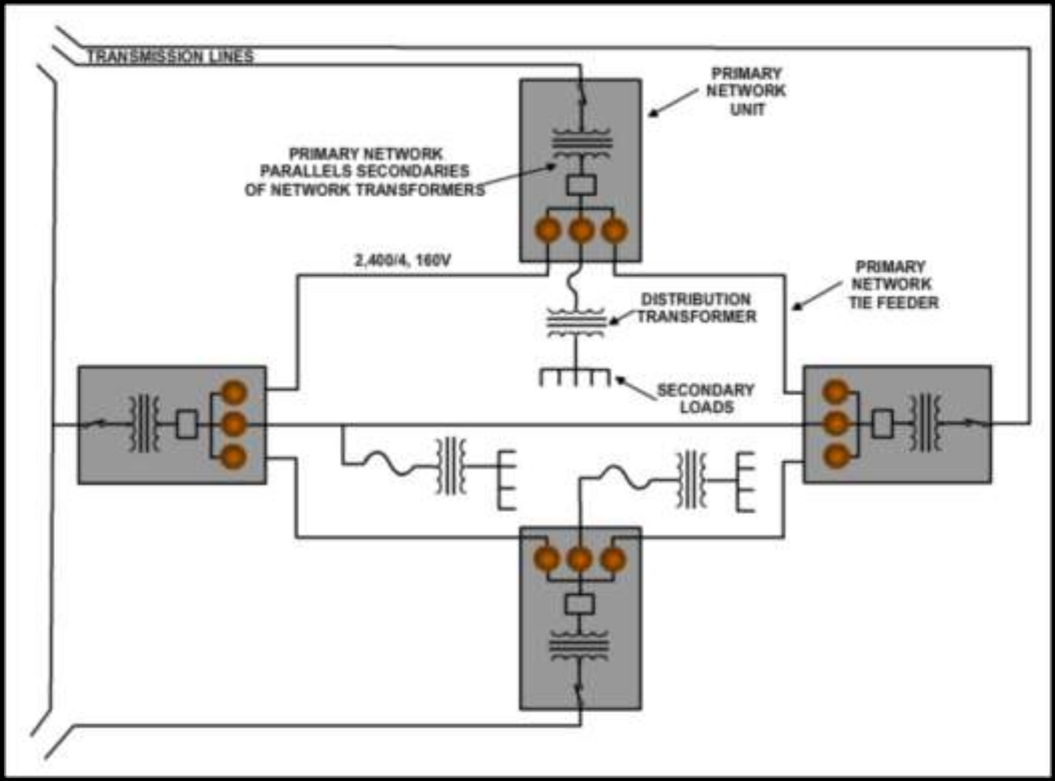
When there is a fault in the primary loop, the breakers in the loop nearest the fault clear it, and the system breakers supply power the other way around the loop without interruption to most of the connected loads.

Because the load points can be supplied from two or more directions, it is possible to remove any section of the loop from service for maintenance without causing an outage at other load points.

Faults Adjacent to Substation

If a fault occurs in a section adjacent to the distribution substation, the entire load may have to be fed from one side of the loop until repairs provide sufficient conductor capacity in the loop to permit operation without excessive voltage drop or overheating of the feeder when either side of the loop is out of service.

If a fault occurs in the distribution transformer, the breaker in the primary leads clears it, and the loop remains intact.



Network Distribution Circuit

The network and radial systems differ with respect to the transformer secondary. In a network system, above, the transformer secondarys are paralleled; in a radial system, they are not.

Most Flexible - The network is the most flexible type of primary system; it provides the best service reliability to the distribution transformers or load center, particularly when the system is supplied from two or more distribution substations.

Flexibility vs. Economics

Power can flow from any substation to any distribution transformer or load center in the network system.

The network system is more flexible with regard to load growth than the radial or loop system and is adaptable to any rate of load growth can extend service readily to additional points of usage with relatively small amounts of new construction.

The network system, however, requires large quantities of equipment and extensive relaying; therefore, it is more expensive than the radial system.

From the standpoint of economy, the network system is suitable only in heavy-load-density areas where the load center units range from 1,000 to 4,000 kVA.

Transformers in a Secondary Network System

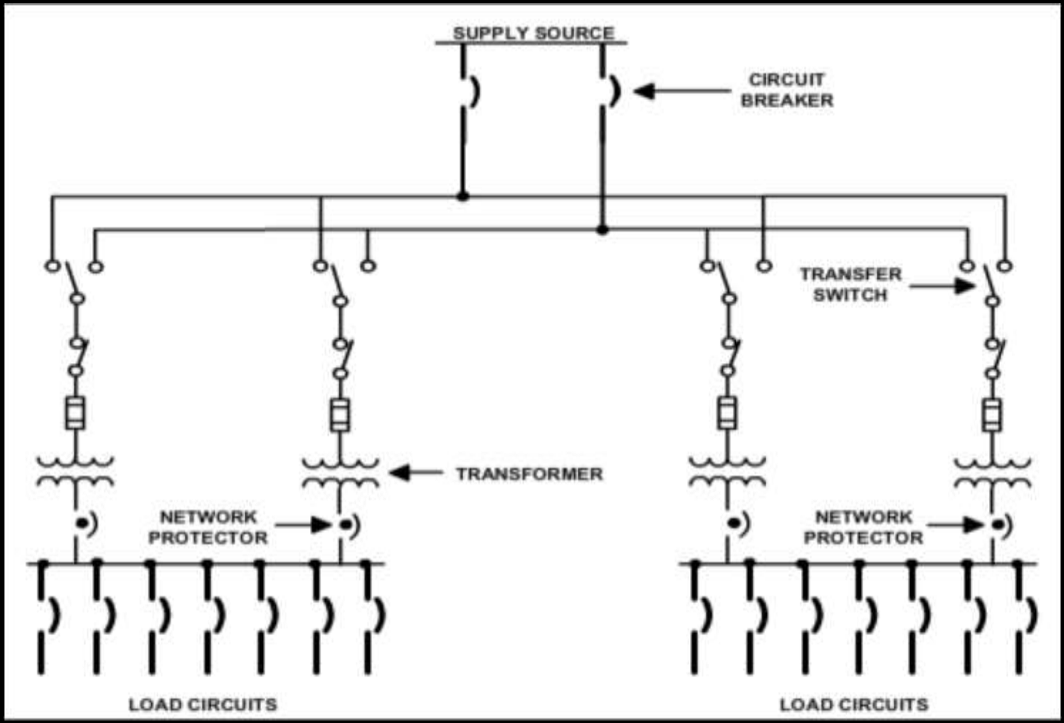
The transformers of a secondary network distribution system are connected in parallel through a special type of circuit breaker, called a network protector, to a secondary bus.

Radial secondary feeders are tapped from the secondary bus to supply loads. A more complex network is a system in which the low voltage circuits are interconnected in the form of a grid or mesh.

Transformers in a Primary Feeder

If a primary feeder fails or a fault occurs on a primary feeder or distribution transformer, the other transformers start to feed back through the network protector on the faulted circuit.

This reverse power causes the network protector to open and disconnect the faulty supply circuit from the secondary bus. The network protector operates so fast that there is minimal exposure of secondary equipment to the associated voltage drop.



Primary Selective System

In some instances, a primary selective system can provide a higher degree of reliability. A primary selective system can also provide protection against loss of a primary supply, (image above).

Each unit substation is connected to two separate primary feeders through switching equipment to provide a normal and an alternate source.

When the normal source feeder is out of service for maintenance or a fault, an electrician switches the distribution transformer, either manually or automatically, to the alternate source.

An interruption will occur until the load is transferred to the alternate source.

More Expensive - The cost of a primary selective system is somewhat higher than that of a radial system because it duplicates primary cable and switchgear.

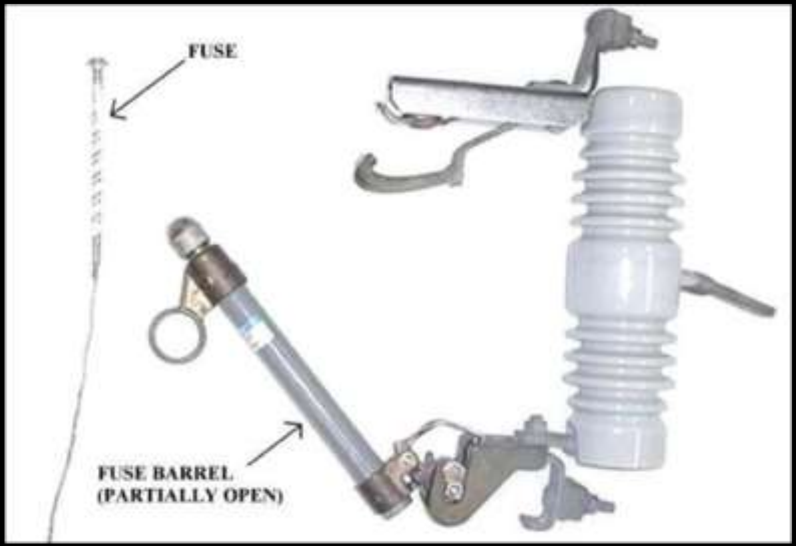
Initial Layout of a Distribution System

]In laying out a distribution system for a region, divide the region into a number of sections.

Choose the sections so that the load in each section is close to one of the distribution centers. Take this action to keep the length of the mains as short as possible and to keep the voltage drop low between the distribution and the loads.

The distribution or load centers should be located as near the electrical load center as possible.

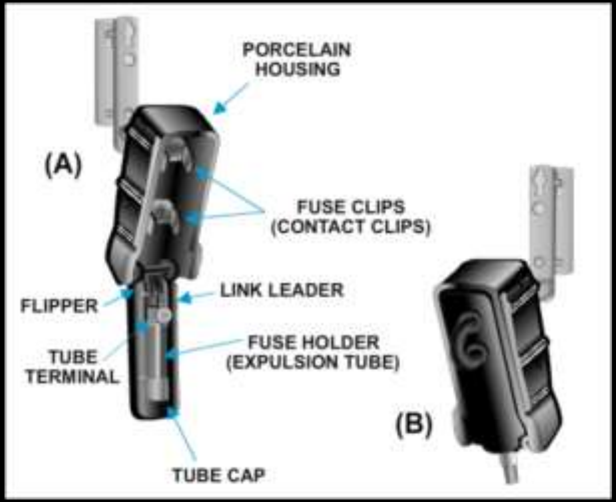
Control and Protective Devices



Distribution Cutouts

A distribution cutout provides a high-voltage mounting for the fuse element that protects the distribution system or the equipment connected to it.

The image above shows an open type of distribution cutout. Installations of transformers, capacitors, cable circuits, and sectionalizing points on overhead circuits use distribution cutouts.



Enclosed Distribution Cutout

In an enclosed distribution cutout (see image above), the fuse clips and fuse holder are mounted completely within an enclosure.

A typical enclosed cutout has porcelain housing and a hinged door supporting the fuse holder. The fuse holder is a hollow vulcanized-fiber expulsion tube.

With an enclosed distribution cutout , the fuse link is placed inside the tube and connects with the upper and lower line terminals when the door is closed.

When the fuse blows or melts because of excessive current passing through it, the resultant arc attacks the walls of the fiber tube, producing a gas that blows out the arc.

The melting of the fusible element of some cutouts causes the door to drop open, signaling to the lineman that the fuse has blown. A fuse link cannot distinguish between a temporary or permanent fault.

Open-link Distribution Cutout

This type of cutout differs from the open cutout in that it does not use the fiber expulsion tube. Spring terminal contacts support the fuse link. An arc-confining tube surrounds the fusible element of the link.

During fault clearing, the spring contacts provide link separation and arc stretching. The arc-confining tube is incorporated as part of the fuse link.

Open Distribution Cutout

Open cutouts are similar to the enclosed types, except that they do not use a housing. The open type is made for 100- or 200-amp operation.

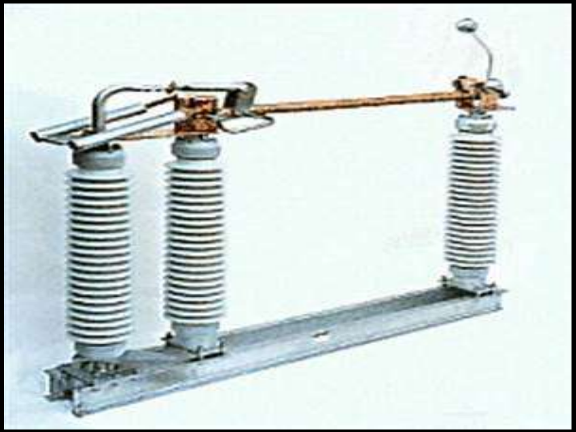
Some cutouts can be up rated from 100 to 200 amps by using a fuse tube rated for 200-amp operation.

Switches

A switch is used to disconnect or close circuits that may be energized. High-voltage switches can be tripped remotely using a variety of mechanisms or tripped manually.

Depending on their purpose in the system and their physical makeup, switches are divided into three general classes: air, oil, and vacuum switches.

These three classes can be further subdivided (depending on their function) into disconnects, circuit breakers, or reclosers.



Air Switches

As their name implies, air switches are switches whose contacts are opened and use air to insulate their contacts when current flow is interrupted.

An air-circuit breaker switch can have both blade and stationary contacts equipped with arcing horns. These horns are pieces of metal between which the arc forms when a circuit-carrying current is opened.

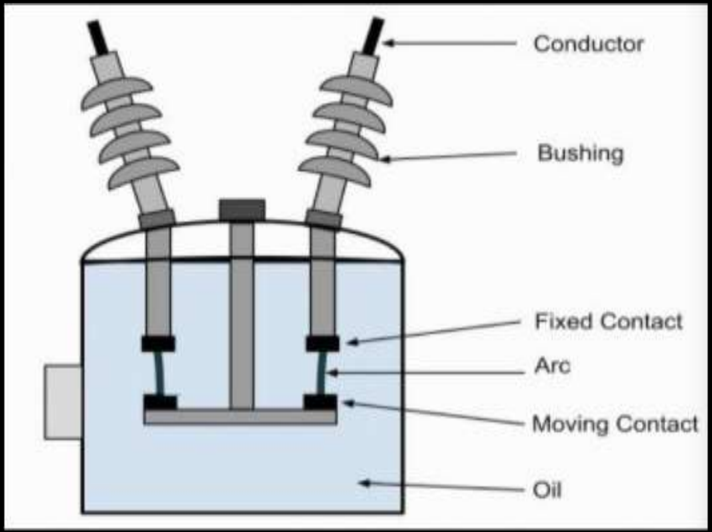
These arc horns are drawn further and further apart until the arc finally breaks. Air-break switches are usually mounted on substation structures or on poles and are operated manually from the ground or automatically.

In a three-phase circuit all three switches, one for each phase are opened and closed together. The switch shown above, is for a single phase.

An air-disconnect switch is not equipped with arcing horns or other load-break devices.

It therefore cannot be opened while current is flowing. If the disconnect switch should be opened while current is flowing in the line, an arc would likely be drawn between the blade and its stationary contacts. The hot arc would melt part of the metal, thereby damaging the switch.

The purpose of a disconnect switch is to isolate a line or a piece of equipment for the purpose of making the disconnected line or equipment dead electrically, thus making it safe for repairs, tests, or inspections.



Oil Switches

An oil switch is a high-voltage switch whose contacts open and close in oil. Oil switches may be used as disconnect, circuit breakers, or reclosers.

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.

The image above shows an OCB, or oil circuit breaker, usually found in high voltage electrical substation applications.

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 helps to quench the arc. Oil is an insulator, therefore, helps to quench the arc between the contacts.

The three lines of a three-phase circuit can be 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 in separate containers.

Circuit Reclosers

The circuit reclosers most commonly used in power distribution is electronic reclosers, oil reclosers, or vacuum reclosers. These reclosers all operate in essentially the same manner.

Reclosers come in single or three-phase models and can either be pole-mounted (shown above) or installed in a substation.

These reclosers provide overload protection and are designed to open a circuit in an overload condition and then automatically reclose the circuit.

Clearing Faults/Singleshot Mode for Reclosers

If the fault on the system has cleared, the recloser remains closed. If the fault has not cleared, the recloser trips again, and after a short interval, recloses the system for the second time. If the fault has not cleared on the third time, the system will open and stay open.

The recloser also has a manual lever or electronic control to set the recloser on what is commonly referred to as "singleshot" action.

When linemen are working in the general area of a circuit, they place the recloser in the singleshot mode. Then should a mistake occur, causing the circuit to trip, it will not reset itself automatically

Underground Considerations

Components in Underground Electric Distribution Systems

Underground electric distribution circuits have been installed underground for many years.

Conventional underground systems employ some, if not all, of the following: conduits encased in concrete, manholes, ducts and trenches, direct burial cable and risers or potheads, underground power cables, and underground communication cables.

After it has been determined that the load density is high enough to justify the expenses associated with an underground system, the system must be designed; and then construction may begin.

Manholes in a Power Distribution System

Manholes, handholes, and vaults are designed to sustain all expected loads that may be imposed on the structure.

The horizontal or vertical design loads consist of dead load, live load, equipment load, impact, load due to water table or frost, and any other load expected to be imposed on or occur adjacent to the structure.

The structure should sustain the combination of vertical and lateral loading that produces the maximum shear and bending moments in the structure.

Manholes are necessary in a power distribution system to permit the installation, removal, splicing, and rearrangement of the cables.

A manhole is merely a subterranean vault or masonry chamber of sufficient size to permit proper manipulation of the cables.

Arranged on the sides of the vault are devices that support the cables. The layout of the region to be supplied with power, largely determines the location of manholes.

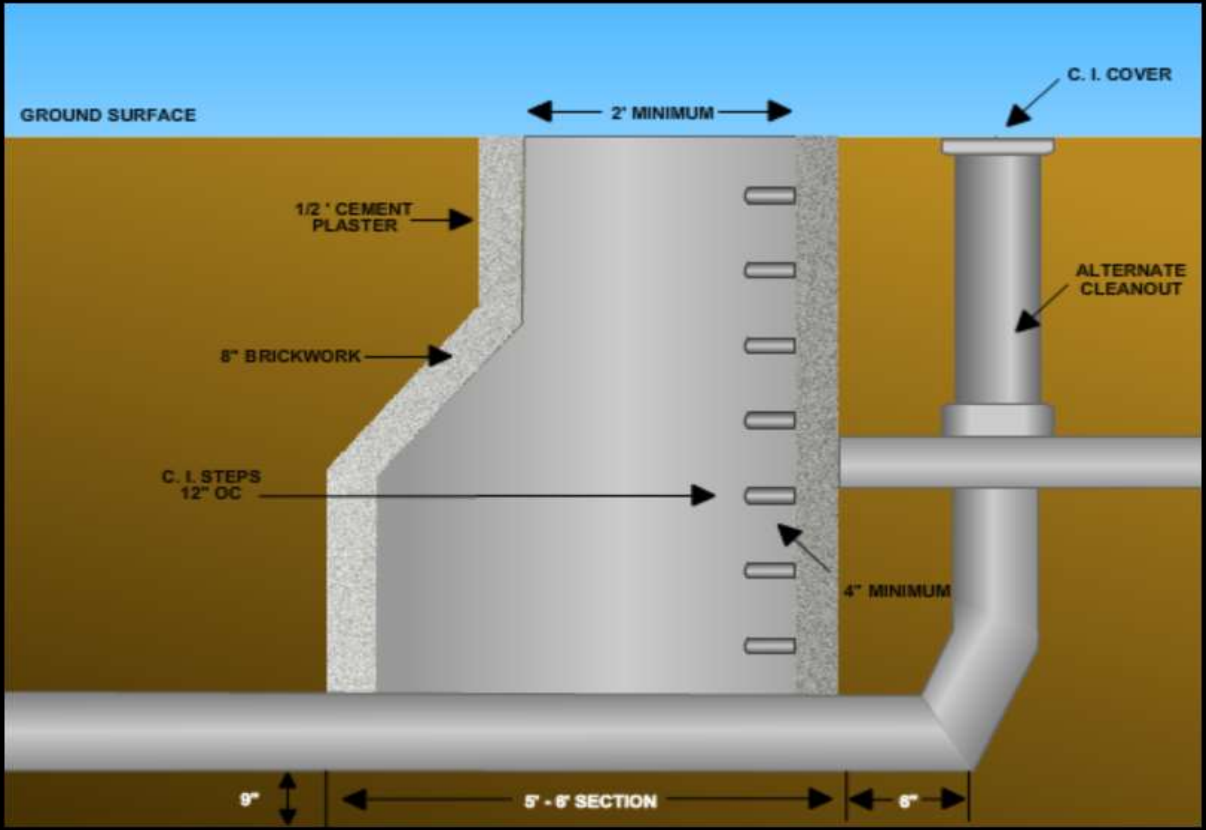
Manhole Spacing

Whenever a branch or lateral extends from the main subway, there must be a manhole, and there must be manholes at intersections of subways.

In general, cables are not made in lengths exceeding 400 to 600 feet; and as it is necessary to locate splices in manholes, the distance between manholes cannot exceed these values.

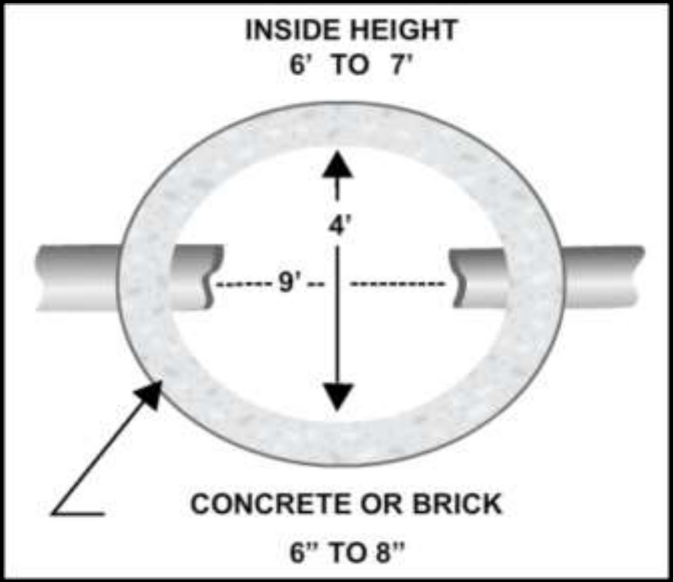
Furthermore, it is not advisable to pull in long lengths of cable because the mechanical strain on the conductors and sheath may become too great during the pulling-in process. Manholes should be located no more than 500 feet apart.

The lines should preferably be run straight between manholes. Manholes come in many shapes and sizes to meet the ideas of the designer and to satisfy local conditions.



Manholes

The image shows an example of a typical manhole. If there are obstacles at the point where a manhole is to be located, you must modify the form of the manhole to avoid them.



Elliptical Manholes

The form approximating an ellipse, shown above, is used so that the cables will not be abruptly bent in turning them around in the manhole.

Rectangular Manholes

When using the rectangular type of manhole shown to the right, care should be taken to not allow the cables to bend too sharply.

Manhole Sizing

The size of a manhole will vary with the number of cables it can accommodate; but, in any case, there must be sufficient room to work in the manhole. A 5- by 7-foot manhole is probably the largest required in isolated plant work, while a 3- by 4-foot manhole is about the smallest.

When a manhole contains transformers, the manhole is larger to allow for working space around the transformer and for ventilation. Allow about 2 or 3 feet of volume per kva of transformer rating.

Manhole Construction

Manholes are built of brick, concrete, or both. When many manholes of the same size are required and there are no subterranean obstructions, concrete are usually the cheapest and the best material.

But when only a few are to be constructed or when there are many obstructions, a manhole with a concrete bottom, brick sides and a concrete top is probably the best.

You can construct such a manhole without having to wait for concrete to set before you can remove the forms. There is a growing use of precast concrete manholes shipped directly to the project site.

Manual Construction of a Brick Manhole

Build a manhole with brick walls by first pouring the concrete floor and then building up the brick walls thereon. If the manhole is large, the roof can be either of steel-reinforced concrete or of brick set between rails.

Probably for installations in which only a few manholes are to be built, the brick-between-rails method is the best. For a small manhole, no masonry roof is necessary, as the cast-steel manhole cover forms the roof.

Make cement mortar for building brick manholes or for conduit construction by mixing together 1 part cement, 3 parts sand, and about 1/3 part water, all by volume.

Manual Construction of Concrete Manhole

Build a concrete manhole by first pouring the concrete floor and then erecting the form for the sides. In a self-supporting soil, the sides of the hole constitute the form for the outside of the manhole.

If the soil is not self-supporting, there must be an outer form of rough planks (plywood), which is usually left in the ground.

Place steel reinforcing, such as old rails, in the concrete top of a large manhole. All reinforcing steel should be completely encased in concrete to prevent corrosion.

Manhole covers should always be made of cast steel and covers should be round so that they cannot drop into the hole accidentally.

Ventilation Requirements

So-called watertight covers are seldom used now, as it is not feasible to make a satisfactory watertight cover at reasonable expense.

In a watertight enclosure, the cover should not be fastened down as accumulated gas in a manhole may explode, shattering the vault and cover. Use a ventilated cover to allow gas to escape.

The newer types of cover have ventilating slots over approximately 50 percent of their area.

Dirt and water will get into the hole, but the dirt can be cleaned out and the water will drain out and no harm will result; however, if there is no ventilation, an explosion of gas may occur and do great damage.

Ventilation using Forced Air

Before entering a manhole, the vault must be ventilated to remove all toxic or explosive gases and ensure adequate oxygen for survival.

Forced air ventilation, respiratory protection, an observer on the surface, and a safety harness and line may be required for safe entry. Consult a supervisor before entering any manhole.

Proper Drainage for Manholes

When feasible, a sewer connection should lead from the bottom of every manhole. A strainer made of noncorrosive wire should protect the mouth of the trap.

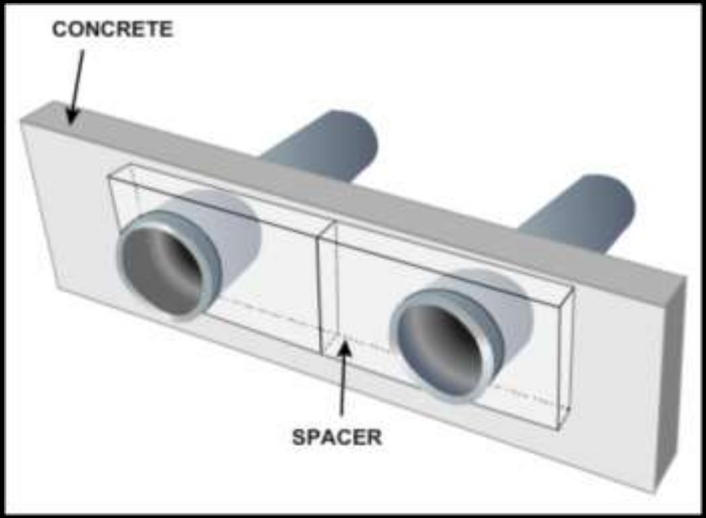
If you cannot make a sewer connection, there should be a hole in the manhole floor so that water can drain out. A pocket under the manhole filled with broken rock will promote effective drainage.

Ducts and Trenches

Duct line and manhole systems provide the best available underground system. Such a system allows for growth and permits cost-effective replacement of existing cables or cable terminations damaged by faults or made obsolete by aging.

Concrete encasement provides the cables with minimum susceptibility to damage and optimum safety to personnel. Several types of underground ducts are in general use, such as fiber, wood, vitrified tile, iron pipe, asbestos composition polyvinyl chloride (PVC), and concrete.

The most common type typically used is PVC.

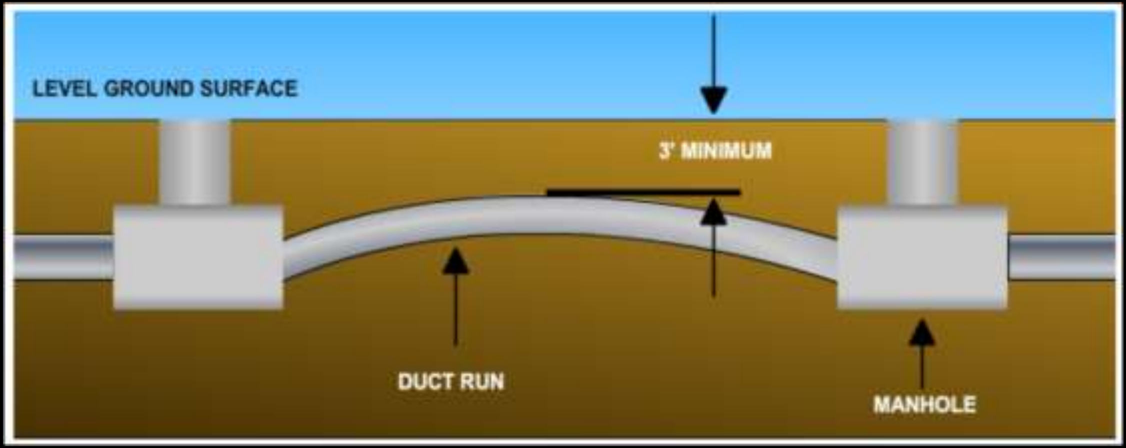


Spacing in Ducts

An underground installation usually consists of several duct lines. Stagger joints between sections so the joints in several lines do not all occur at the same place. To ensure staggering, use starting sections of different lengths at the starting manhole.

For duct set in concrete, there must be at least 3 inches of concrete around each line of duct. Where concrete encasement is specified, concrete should have strength of not less than 2,500 pounds per square inch when cured for 28 days.

Use spacers like the one shown in the image above to accomplish the 3-inch spacing. The upper lines of the duct must be a minimum of 3 feet below the ground surface.



Locating The Trench

The location of the trench varies according to ground condition. The trench should run as straight as possible from one manhole to the next. To ensure drainage, slope the line downward about 1 foot but never less than 3 inches every 100 horizontal feet.

When one manhole cannot be located at a lower level than the other, the tine must slope downward from about the midpoint both ways toward the manhole, as shown in the above image.

Dig the trench to the desired depth and tamp the bottom hard to ensure a solid bed for the 3-inch bottom layer of concrete. Embed spacers in the bottom layer of concrete for a depth of about 1 inch before the concrete sets to ensure a solid base.

Direct-burying Cable

Burying cable directly in the ground is a widely used method for installations of single circuits for which the cost of duct construction would be prohibitive.

Some of the more common applications of direct burial cable are as follows:

- Street-lighting circuits, especially where outlying sections are without ducts
- Connecting residences to mains
- Railroad yards, railway-signal circuits and airport lighting
- Lighting and power circuits for amusement parks, sports fields, and industrial plants
- Crossing under small lakes and streams

Armored Cable Types

Both nonmetallic-armored cable and metallic-armored cable (parkway cable) are used for direct burial in the earth.

The nonmetallic-armored types are lighter in weight, more flexible, and easier to splice and are not subject to rust, crystallization, induced sheath power loss, or trouble from stray currents.

On the other hand, they do not give good protection against mechanical injury.

Trenching of Direct-bury Cable

Direct burial of power cable is normally accomplished with a backhoe digging a trench large enough to permit bed preparation; whereas, communications cable is laid in a small trench created by a chain type of mechanical trencher.

Install cables at a minimum depth of 30 inches for power cables of 600 VAC or over and 18 inches for communications cables. Installing cables at 30 inches or greater will protect them against extreme mechanical hazard, such as at street intersections or under roadways.

Place the power cables in a 3-inch thick bed of sand. When backfilling a direct burial cable, place plastic streamers in the trench 12 to 18 inches above the cable. These streamers will alert future personnel conducting digging operations to the presence of the buried cable.

Using Markers for Direct-Bury Applications

At intervals of 200 feet and at turns in the buried cable, you should also place small Concrete markers along the entire length.

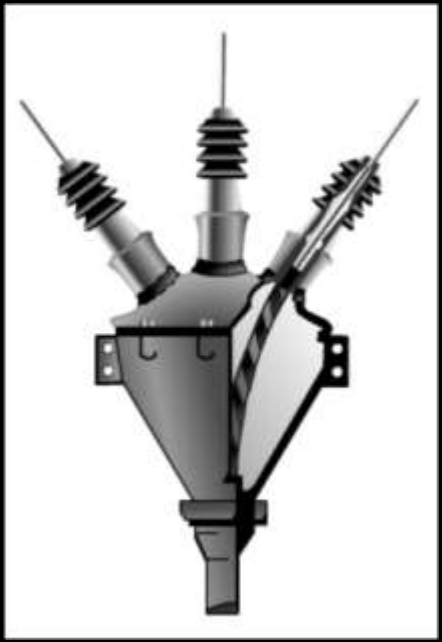
These precautionary signs help prevent some future human-related damages to the buried distribution systems. The marker should state the type of cable that is buried, such as power or communications, and the voltage or number of pairs.

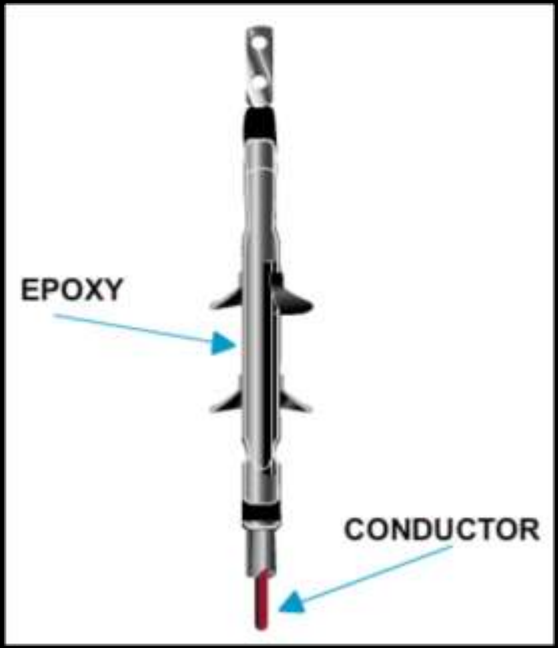
Recommended Cable Types for Direct-Burial

Types UF and USE cables are code-designated single-conductor or multi-conductor cables suitable for direct burial in the earth.

The NEC® includes rules for the protection of underground conductors when the supply voltage exceeds 600 volts.

These rules were introduced to minimize the hazards of “dig-ins.” Section 300.50 of the NEC® covers such rules.





Risers and Potheads

For connection of underground distribution circuits at any location, you must prepare the end for termination.

In earlier times electricians accomplished this preparation with a pothead, as shown in the left image above, but they now do it with special kits which provide plastic molds to be placed over individually prepared phases. The molds are poured full of epoxy. The new way is much more efficient and clean. The image on the right shows the new style.

Inspecting Risers

Inspect the riser pole for underground distribution circuits when you inspect or maintain overhead lines, shown above.

The inspection should include the disconnect switches or fused cutouts, the lightning arresters, the operation of the arrester ground leads isolation devices, the riser cables and potheads or termination, support of the cables, conduit or U-guard, and identification of the circuit and pole conditions.

Underground Power Cables

Underground cables have various types of insulation and sheaths. Because higher voltages generate more heat, the amount of voltage carried determines the composition of the insulation.

Rated 15KV and Below - Cables rated at 15 kilovolts and below usually have rubber or varnished cambric insulation and a PVC or rubber sheath.

Rated 600V to 425KV - Those rated at 600 volts to 425 kilovolts have oil-impregnated paper insulation and a PVC sheath.

Rated 5KV and Above - Cables rated at 5 kilovolts and above have metallic tape shields between the insulation and sheath for mechanical protection.

Exceptions to this requirement are for single conductor(1/0) cable with a PVC sheath and three-conductor (3/0) belted type of cable.

New Cabling Types - Much of the new cable being installed is crosslinked-polyethylene (XLP) or ethylene propylene rubber (EPR).

These are called solid type of insulations. The size and number of conductors in the cable depend on the job requirements.

Underground Communications Cables

The most common types of underground communications cables in use today are steel armored with plastic insulation, plastic insulated with aluminum armor, and the new shielded fiber-optic cables.

Pulling-in Cable

When installing a new run of duct, a “pulling wire,” is used. This is usually a low gauge iron wire.

With this wire, you pull in a wire rope to which is attached the cable for pulling in.

Sometimes, when the duct has been in the ground a long time, the original iron pulling wire may be rusted so that it is not strong enough to pull the wire rope through.

Using Pneumatics to run Cable

For a 400- to 500-foot run, it would be difficult to push a fish tape through the duct. The job can be simplified by using an air compressor to blow a chalk line cord through the duct.

To do this, take a small cloth and tie the chalk line end to the four comers, so the cloth functions like a small parachute.

With the air hose in the end of the duct and the cord free to run out, you will be able to blow the cloth through to the next opening, even on a long run of duct.

Cleaning Ducts

Quick-coupling duct rods (about 1 foot long and 1 inch in diameter) are connected together with a wire brush or other duct rod leader at the head to facilitate cleaning of cable ducts. Push the rods through manually or by means of power equipment.

Leave a 12-gauge galvanized steel wire attached to the leader in the duct for the cable pulling crew.

Moisture inside a cable causes deterioration of the insulation; therefore take precautionary measures to avoid accumulation of moisture inside the cables. Before pulling a cable, ensure that the cable ends are sealed against moisture invasion.

Rigging Manholes for Cable Pulling

There are a number of ways to rig manholes for cable pulling. The most common method is using the winch on the truck and a pulling frame; see image above.

Other methods include using a cable pulley attached to a timber block which, in turn, is supported by a wedge or by attaching the cable pulley to the manhole wall by means of an embedded eye.

When using this method, make sure that the lower sheave is in line and level with the duct in which you will pull the cable. To prevent injury to the cable by sharp edges, line the duct mouth with a shield.

Using a Feeding Tube for Cable Pulling

When pulling cables into a long duct, use a feeding tube or bell for applying a lubricant at the duct mouth. Make sure you use the lubricant specified by the manufacturer of the cable.

The image above shows a cable reel in proper position over the manhole so that the bend in the cable is not reversed as the cable is unreeled. All cable reels are marked with an arrow indicating the direction in which they must be rolled.

Comply with this arrow when placing the reel at a manhole so that it turns in the proper direction as cable is pulled from the reel. Place the reel as near as practical to the manhole and raise it on reel jacks just enough to clear the ground.

Installing the Cable Run

Assume that the winch line has been drawn into the duct, as the test line was pulled out. Now attach a basket grip to the end of the underground cable on the reel. Secure the end of the basket to the cable with a tight wrap of tape or wire.

A swivel connection is necessary between the basket and the pulling cable to relieve twisting of the rope.

If the cable reel is within sight of the winch, it will take four people, in addition to the winch operator, to do the job safely.

Pulling the Cable

One person attends the reel to see that the cable rolls off the reel properly. Another in the manhole guides the cable into the duct.

Both inspect the cable as it unreels and immediately signals "stop pulling" when a defect appears in order to make a closer inspection for possible damage to the sheath.

A third stationed in the other manhole at the pulling end signals "stop pulling" when the cable appears. The fourth crew member, above ground at the pulling-end manhole, relays signals to the winch operator.

This procedure enables the winch operator to concentrate on his job of seeing that the winch line is wound onto the reel properly.

Finishing the Cable Pull

The speed for pulling cable into a duct varies with the length of the duct and cable sizes. You can successfully pull in a single cable at 75 feet per minute (fpm) in a clear straight duct.

When you are handling more than one cable, reduce the speed to about 20 to 25 fpm, to prevent the conductors from crossing as they enter the duct.

When the “stop pulling” signal is given, make sure there is sufficient slack in both manholes for splicing or terminating the cable. Adjust the slack with the cable basket grip. Exercise care to prevent injury to the cable insulation.

Remove the binding tape and the basket grip from the cable. Then cut the cable to the desired length and seal the cutoff end in the manhole unless splicing is done immediately.

You must also seal the end of the cable remaining on the reel. In addition, check the seal on the end of the cable that has traveled through the duct, and reseal it if it has been broken from the strain.

Dangerous Gases

Gases may be dangerous for several reasons. The gas concentration may be explosive if it is made up of methane, sewer gas, natural gas, concentrations of spilled gasoline, or other liquid fuel vapors. As a general rule, these gases are heavier than air and will concentrate in low areas, such as manholes and ducts.

They will remain there until they are dispersed. These gases are toxic as well as explosive. Other toxic gases are chlorine, ammonia, and a variety of the sulfide combinations. Still other gases deplete the oxygen in the manholes and duct systems.

Lack of oxygen can be as deadly as explosive or toxic gases. For these reasons, underground structures must be tested before workers enter them.

Test Sets

The images above show two common types of test sets used for identifying carbon monoxide and combustible gases; a carbon monoxide tester (left) and an explosimeter (right).

Only personnel who are specifically trained and certified may conduct tests of these types for safe entry.

(PPE) Personal Protective Equipment

Working on Energized Lines

It is not always possible or practical to de-energize lines, so you need to have a way to safely handle energized conductors and equipment. Use of hot-line tools and personal protective equipment in these circumstances is required. Knowing proper operation and maintenance of these tools and equipment are vital to job completion on energized lines.

It is mandatory that the shop supervisor inspect all the shop's protective equipment every six months. Supervisors maintain records showing the inspection date, dates of moisture and electrical tests, and the date the next 6 month inspection is due.

The purpose of this inspection is to ensure that the users of the rubber protective equipment are performing their inspections, but you must not depend upon the supervisor's inspection to keep you safe. Always inspect each item of protective equipment before you use it.

Rubber Protective Equipment

Types - Electricians use two kinds of protective equipment when working with energized lines:

- personal rubber protective equipment that the electrician wears
- Protective equipment installed on lines and equipment to protect personnel from accidental contact

Color Code	Class	Proof Test Voltage		Max. use Voltage - AC	
		AC	DC	Ph to Ph	Ph to Grd
Red	0	5,000	20,000	1,000	600
White	1	10,0000	40,000	7,500	4,4000
Yellow	2	20,0000	50,000	17,0000	10,0000
Green	3	30,0000	60,000	26,5000	15,0000
Orange	4	40,0000	70,000	36,0000	20,0000

Color Coding Standard

The American National Standards Institute/American Society of Testing and Materials (ANSI/ASTM) categorize rubber protective equipment into five classes by setting the maximum working voltage and di-electric test voltage for each.

The classes are identified by color, and rubber protective equipment will have a colored label stating the type, size and class of the equipment. The colored label identifies the class rating of the rubber protective equipment at a glance.

See Table above for the ANSI/ASTM color codes.

Personal Rubber Protective Equipment

Rubber goods can be manufactured from natural rubber, which is called Type I, or from synthetic rubber, called Type II. Type II rubber goods are more prevalent because they are less susceptible to deterioration from corona, ozone, aging and weathering. Both types of rubber are susceptible to chemical deterioration from heat, sun, and especially petroleum products.

Signs of chemical deterioration are: checking, swelling, softening, hardening or becoming sticky. At the first sign of chemical deterioration, the equipment should be removed from service.

Rubber Gloves

The most important article of protection for linemen or cablemen is a good pair of rubber gloves with the proper dielectric strength for the voltage of the circuit they will work on.

Rubber gloves are used for intentional contact with energized lines while performing tasks, and must be rated at or above the voltage of the system on which they are being used. Leather gauntlets are worn over the gloves at all times to protect them from damage.

These gauntlets must be 2 inches to 5 inches shorter than rubber glove length, depending upon system voltage. While using rubber gloves, use glove dust (100% talc powder) or cotton glove inserts to avoid skin irritation and prevent the rubber from sticking to your skin.

Carefully Inspecting Safety Gloves

Inspect rubber gloves inside and out before each use. You must also give them a field air test before each use. Accomplish this by pinching the open end closed and rolling it toward the fingers. This will trap air inside the glove.

Roll the end until the fingers and palm expand, then hold the glove close to your face. Look, listen and feel for air leaking, indicating damage (fine tear, pin hole). Electrically test rubber gloves upon receipt and every 3 months thereafter if in use.

If the gloves are stored on a shelf, test them every 12 months. If you find any defects during any inspection or test retire the gloves from service by cutting off one of the fingers.

Properly Storing Safety Gloves

Store rubber gloves in a canvas glove bag (seen above) 2 inches longer than the rubber glove length. Never store gloves folded or inside out.

Gloves must be clean and dry when stored; if they make contact with any chemicals, especially petroleum based chemicals such as hydraulic fluid, grease or oil, wipe down the gloves as soon as possible after the contact.

The ANSI standard ANSI/ASTM D120, Standard Specification for Rubber Insulating Gloves, covers lineman's rubber glove specifications.

Rubber Sleeves

Linemen working on high-voltage distribution circuits must wear rubber sleeves (image above), in conjunction with rubber gloves to provide protection for arms and shoulders against incidental contact with energized surfaces.

Inspect sleeves inside and out before each use. Stretching and rolling the sleeves on a flat surface will assist in finding defects.

Electrically test sleeves every 12 months. If you find defects during any inspection or test, remove the sleeves from service. Store sleeves clean and dry in a canvas bag or rolled up (not folded) to protect against mechanical and chemical damage.

Rubber Insulating Line Hose

Linemen can cover primary distribution conductors with rubber insulating line hose to protect themselves from an accidental electrical contact; see image above.

The line hoses are manufactured in various lengths with inside-diameter measurements of 1 to 1 l/2 inches. They are split lengthwise to facilitate installation, and designed to be fitted together end-to-end.

Maintaining Line Hoses

Inspect hoses inside and out before each use. Any cuts or abrasions deeper than one-quarter of the thickness of the rubber are unacceptable. Electrically test hoses upon receiving them from the manufacturer and retest them every 12 months.

The lineman should be sure that the voltage rating of the line hose provides an ample safety factor for the voltage applied to the conductors to be covered.

All line hoses should be cleaned and inspected regularly. A hand crank wringer can be used to spread the line hose to clean and inspect it for cuts or corona damage.

In-service care of insulating line hose and covers is specified in ANSI/ASTM D1050, Specification for Rubber Insulating Line Hoses.

Rubber Insulating Insulator Hoods

Pin type or post type of distribution primary insulators can be covered by hoods. The insulator hood properly installed will overlap the line hose, providing the lineman with complete shielding from the energized conductors.

Insulator hoods (image above; on left), like all other rubber insulating protective equipment, must be treated with care, kept clean, and inspected at regular intervals.

Use canvas bags of the proper size attached to a handline to raise and lower the protective equipment when installing or removing it.

Conductor Covers

A conductor cover, fabricated from high dielectric polyethylene, clips on and covers conductors up to 2 inches in diameter. A positive air gap is maintained by a swinging latch that can be loosened only by a one quarter turn with a clamp stick.

Insulator Covers

Insulator covers are fabricated from high dielectric polyethylene and designed to be used in conjunction with two conductor covers.

The insulator cover fits over the insulator and locks with a conductor cover on each end. A polypropylene rope swings under the crossarm and hooks with a clamp stick, thus preventing the insulator cover from being moved upward by bumping or wind gusts.

Crossarm Covers

High dielectric strength polyethylene crossarm covers are used to prevent tie wires from contacting the crossarm when the electrician ties or unties conductors adjacent to insulators.

It is designed for single- or double-arm construction with slots provided for the double-arm bolts.

Flanges above the slots shield the ends of the double-arm bolts. See example above.

Pole Covers

Polyethylene constructed pole covers are designed to insulate the pole in the area adjacent to high-voltage conductors. Pole covers are available in various lengths. Positive-hold polypropylene rope handles are knotted through holes in the overlap area of the cover.

The image on the left is a pole cover, which is used along the pole's length. The image on the right is a pole top cover.

Rubber Insulating Blankets

Rubber blankets (above) cover odd-shaped objects (neutral clevis, transformer bushings, etc.). The blankets are secured with large “clothespins,” and available with or without a slot.

Maintaining Safety Blankets

Inspect blankets before each use by laying them flat and rolling them to stretch and expose any cuts or holes. Roll the blanket twice on each side, with the second roll 90 degrees from the first.

As with rubber gloves, any cuts or abrasions deeper than one-quarter of the thickness of the rubber are unacceptable.

Test blankets upon receipt and every 12 months thereafter. Store blankets clean and dry flat on a shelf, hung from storage hooks, or rolled in a protective canister.

If blankets are rolled for storage, do not tape them. Tape adhesive will chemically deteriorate the rubber.

Do not store rolled blankets in a metal canister. Rust from a metal canister will degrade the blanket's ability to protect.

Safety Hat

Linemen, cablemen, and groundmen wear hard hats, or safety hats, to protect them against an impact from falling or moving objects and against accidental electrical contact of the head with energized equipment.

In addition, hard hats protect the worker from sunrays, cold, rain, sleet, and snow. The first combined impact-resisting and electrical insulating hat was introduced in 1952.

The hat was designed “to roll with the punch” by distributing the force of a blow over the entire head. This feature is accomplished by a suspension band which holds the hat about an inch away from the head and lets the hat work as a shock absorber.

Safety Hat (continued)

The hard hat is made of fiberglass, or plastic material, and has an insulating value of approximately 20KV. New helmets are manufactured to withstand a test of 30KV without failure.

The actual voltage that the hat will sustain while being worn depends upon the cleanliness of the hat, weather conditions, the type of electrode contacted, and other variables. The wearing of safety hats by linemen and cablemen has greatly reduced electrical contacts.

Physical injuries to the head have been practically eliminated as a result of workers on the ground wearing protective helmets. Between OSHA and most companies' safety rules require linemen, cablemen, and groundmen to wear safety hats while performing physical work.

Hot-Line Tools

Hot Line Tools

De-energizing lines is not always possible or practical, so you need to have a way to safely handle energized conductors and equipment. Hot-line tools are used in these circumstances. Hot line tools allow workers to perform work on energized lines and system components without the fear of electrocution.

There are many types of hot line tools, also called “hot-sticks.” They are constructed of fiberglass with aluminum “heads” in different configurations.

Inspect and Maintain Hot Line Tools

Knowing proper operation and maintenance of these tools and equipment are vital to job completion on energized lines.

In this section, you will learn the types of hot line tools and their purposes, inspections and tests performed on them, and how to maintain these items.

Switch Stick

This hot line tool is used to safely open and close disconnect switches and fuse cutouts. Switch sticks are available in lengths from 2 to 20 feet. See above.

Grip All (Shotgun)

The grip all stick, as seen above, is commonly referred to as a “shotgun”. It’s primarily use is to install and remove ground sets and hot line clamps, although its design and versatility enables its use in a variety of other applications.

Grip-alls are available from 4 to 12 feet in length.

Universal Stick

The universal stick has a head designed to mount a wide variety of tools or equipment items adapted for use with this stick. Items ranging from screwdrivers to socket wrenches to voltmeters can be attached to it.

The image shows a universal stick with a switch stick attachment.

Others (Tie Sticks & Wire Cutters)

As stated, there are many different kinds of hot sticks; a few more are worth mentioning:

Tie sticks (shown above) are used to tie and untie conductor ties on energized lines. The heads of the sticks can be fixed or rotating blades or prongs. In the image above, the top stick has a rotary blade, while the bottom stick has a rotary prong.

Wire cutters

Wire cutters (above) are used to cut energized conductors, jumper wire, or tie wire. This tool operates in a similar manner to a standard set of bolt cutters.

Extendo (Telescoping) Sticks

There are also telescoping sticks called “extendo” sticks. These range in size from six feet long when fully extended to 35 feet long. Most extendo sticks are equipped with universal heads.

Maintenance of Hot-line tools

Since these sticks are used on energized high voltage lines, maintaining them is critical to personnel safety, requiring an inspection of hot stick tools prior to each use.

Look for:

- damaged or broken parts
- cracked or broken insulation
- all moving parts operate freely
- general appearance of tools

Hot Stick Tester

Inspecting hot line tools is a good way to identify problems you can see. To identify problems you cannot see, you must rely on dielectric testing. Like inspections, perform testing of hot-line tools every six months.

The purpose of the hot stick tester is to determine the dielectric strength of hot sticks. It operates on the same principles as the High Potential DC test set, only in a much more user friendly way.

The hot stick tester (as seen in the image) is a portable way to test the dielectric strength of hot sticks.

Using a Hot Stick Testing Device

By simply placing the tester onto a stick, you bring two leads into contact with the fiberglass surface. One lead applies 1800 volts, and the other lead measures the amount of current that leaks between the leads.

This leakage current appears on a meter mounted to the tester. The meter face is divided into two halves; one half marked “passes test” and the other half marked “dry out & retest.”

Zeroing the Meter – Hot Stick Tester

By simply plugging the meter into an outlet and placing it on the stick, you will get an instant reading of good or bad. Like any meter that tests resistance, the hot stick tester has to be calibrated or “zeroed” before use.

Do this by turning the ZERO knob counterclockwise, then plug in the tester and switch it on. Turn the ZERO knob until the meter needle aligns with the ZERO line on the meter face. (See image above)

Testing the Tester for Proper Operation

Once the meter is zeroed, you can test it for proper operation. Do this by using the "check stick" that comes with the meter. The check stick is a piece of hot stick that is intentionally faulted. Placing the meter on the check stick should cause the meter needle to fully deflect to the "dry out & retest" section.

If the meter properly reads the check stick as bad, it is functioning properly and you are ready to test your sticks. To begin testing, place the tester on one end of the hot stick. Take overlapping readings from one end to the other, testing the entire stick.

Never slide the tester along the hot stick, always lift it clear before repositioning to avoid scratching the finish on the stick. Rotate the stick 90 degrees and test again. Repeat the process to test all four quadrants of the stick.

The total number of test segments performed on each stick will vary; just be sure to test each stick for its entire length in overlapping sections on all four quadrants. When complete testing on all four quadrants, repeat the entire procedure with the stick wet.

Wet Testing of the Tester

For the wet test, position the stick horizontally and spray it with distilled water. Use only distilled water, as it has no impurities and will leave no conductive residue on the stick. Tap water and bottled water have minerals that will leave residue when they evaporate.

The objective is for the water to bead up on the glossy surface. Avoid over wetting, as this makes the beads of water form a continuous, conductive line. When the stick is properly wetted, use the same procedures as for the dry test. All readings should be in the green "passes test" range.

Prior to testing ensure the stick is clean, waxed, and inspected for nicks or abrasions. Sticks with operating rods (such as shotguns and wire cutters) must be disassembled and the components tested separately.

If the stick fails any test, clean, wax, and test it again. If it fails a second time it probably has internal damage and must be returned to the manufacturer for reconditioning.

Care and Maintenance of Hot Line Tools

Keep hot sticks kept clean and waxed, with a glassy appearance. When using hot sticks, never allow them to come into contact with the ground.

When on the jobsite,
keep hot sticks in the hot line trailer, on a portable rack, or on a clean tarp spread for the purpose. Always use the right stick for the job, and never use a damaged stick.

Store sticks in a dry location designed specifically for the purpose. Hot line trailers are ideal places to store hot line tools; they are equipped with rubber coated hooks and tie downs to support and secure the sticks.

Never store a stick dirty or wet. Wipe down each stick before storing.

Installation of Overhead Distribution Equipment

Introduction

In the construction and maintenance of power distributions systems, you should be aware of the overhead distribution pole locations and the types of overhead distribution equipment used.

An excellent source of information on distribution systems is The Lineman's and Cableman's Handbook.

Many different types and makes of overhead distribution equipment are in use today.

This section will cover some of the standard equipment you will install and maintain, such as poles, transformers, capacitors, and interrupting and protective devices.

Establishing a Route for the Power lines

When doing so, you need to consider the following recommended actions:

- Install utility poles in the same location, especially on upgrade projects.
- Install power distribution systems underground whenever possible.
- Conduct a survey using a map to chart the territory where the distribution lines are to be routed (for large areas, aerial photography is faster and more accurate).
- Ensure that the survey map is large enough to clearly show all buildings, roads, streams, hills, ridges, railroads, bridges, and any existing power and communications lines.
- Select the straightest and shortest route whenever possible.
- Route the new distribution system near or in the general direction of future load demands.

(continued)

- Make the distribution system readily accessible for construction, inspection, and maintenance by paralleling them to existing streets and highways.
- Avoid crossing hills, ridges, and swamp areas whenever possible to reduce the possibility of lightning and wind damage. These areas also increase costs because they require additional materials and make maintenance more difficult.
- Coordinate with communication companies to prevent the induction of interference with their existing lines.
- Select a route that is away from residential areas and does not damage the environment.
- Keep major traffic routes free from primary circuits, especially in nonindustrial areas
- Keep distribution lines on the same side of the road whenever possible.
- Avoid blocking drives, entrances, exits, or fire escapes when installing branch lines or guys.
- Locate poles 2 feet from the curb, and plan for future street-lighting circuits.

Poles

Utility poles that support electrical lines must be designed to support the conductors, insulators, and shield conductors in a manner that provides adequate electrical clearances. You must maintain a safe clearance when the conductor temperature is elevated as a result of a large amount of current flowing in a circuit and also when the conductors are ice coated or strong winds are blowing.

The three most common types of poles you will be working with are wood, reinforced concrete, and steel. Other less common types of poles in use are aluminum, fiber glass, and polysil.

Use of Wooden Poles

Power lines supported by wood-pole structures are generally the most economical. In the United States, the southern yellow pine, western red cedar, and Douglas fir are the most commonly used species of tree for pole wood.

All wooden poles are given a preservative treatment (normally pressure treated) to resist damage from insects and rotting. The service life of the utility pole can be doubled by preservative treatment.

Hazards Associated with Creosote Poles

Many of the older poles now in use were treated with creosote. Creosote is a toxic compound that irritates the skin and sometimes causes blistering.

It is also carcinogenic and is being phased out because of groundwater contamination problems. Do not burn used creosote contaminated poles. They must be disposed of in EPA approved landfills.

Use extra care when working around poles treated with creosote. Avoid prolonged skin contact and wash thoroughly after handling. Launder clothing contaminated with creosote separately from family clothing.

Wood Treatments for Utility Poles

Creosote oil, pentachlorophenol, and chromated copper arsenates have been used for preservation treatment of wood poles.

Newer poles are treated with less toxic chemicals and, therefore, are safer to work with and also easier to climb (because the treatment softens the wood).

They are environmentally acceptable because they do not contain materials that are toxic to mammals.

Pole Classifications

Wooden utility poles are classified by the length, circumference at the top of the pole, and the circumference measured 6 feet from the bottom of the pole.

Pole sizes begin at 20 feet and are increased in 5-foot increments up to 100 feet in length. The pole top circumference increases 2 inches for every class of pole.

There are 10 classes of wooden poles numbered from 1 to 10. Class 1 is the smallest, class 10 the biggest. The ANSI's publication Specifications and Dimensions for Wood Poles (ANSI 05.1) provides technical data for wood utility poles.

Anchors

The anchor is the foundation of the pole line, and its purpose is to take the strain of all the weight of the equipment installed on a pole line.

For example, on a straight pole line the strain of equipment, hardware and conductor support devices is distributed evenly along all the poles through the conductors.

At the end of a pole line, or wherever the pole line changes direction, the strain is borne by only one pole. If left unsupported, this one pole will slowly be pulled toward the rest of the pole line until it collapses.

To prevent this, a guy wire and anchor are installed. The guy wire transfers the strain from the pole to an anchor that is firmly imbedded in the earth.

Anchor Selection Criteria

Anchors are designed to meet specific soil conditions. The type of soil must be known before selecting a certain type of anchor.

Anchors come in many forms and have different methods of installation.

You must consider three things when deciding what type of anchor to use:

- the type of soil in which the anchor will be installed
- the holding capacity requirements
- the type of installation equipment available

Subsurface Soil Conditions

In relation to the holding power of anchors, most soils can be divided into three general types:

- **Hard soils** - include everything from solid bedrock to compact clay gravel mixtures.
- **Ordinary soils** - include gravels, medium firm clay, loose sand/gravel mixtures and
- compact coarse sand.
- **Soft soils** - include soft clay, compact fine sand, fill, and marshy soils.

The holding power of an anchor depends on the soil, so the anchor must be designed to hold well in the soil into which it is installed.

Care should be taken, when determining soil type, because an anchor that holds very well in ordinary soil will not hold at all in soft soil, and a soft soil anchor cannot be installed in hard soil without damaging the anchor.

Note, that if the soil does not hold the anchor, the anchor will not support the pole line.

Holding Requirements

Holding capacity is the amount of pull, in pounds, the anchor must withstand. Since strain is transferred from pole to pole through the conductors, at a minimum, an anchor must be able to withstand tension equal to the combined breaking strength of the conductors.

As an example, suppose you need to install an anchor for a pole that terminates four 1/0 Aluminum Conductor Steel Reinforced (ACSR) conductors (conductors will be discussed in greater detail later in this block).

According to wire specification charts, each conductor of this type and size has a breaking strength of 4,280 pounds.

Since there are four of them the total breaking strength is 17,120 pounds. Your anchor installation must be able to withstand a minimum of 17,120 pounds of tension.

Installation Equipment

When selecting an anchor, always take into consideration the type of equipment available to you. It would be foolish to install an anchor by hand if a line truck could do it in less time with considerably less effort. Conversely, there may be times when the line truck cannot get to where the anchor will be installed.

The type of equipment required will be determined by both the installation location and the type of anchor to be installed.

Hand tools such as shovels, digging spoons and digging bars could be required.

Types of Anchors

The term anchor is used as a collective term, but the anchor actually consists of the anchor rod and the anchor assembly. This section addresses three varieties of anchors.

These three types of anchors are manufactured and are commonly used because of their ease of installation.

Another type of anchor, called a deadman, is not manufactured. This anchor is made of a 6 to 8 foot long piece of treated power pole and an anchor rod.

It is installed 6 feet deep in loose or sandy type of soil, with an angle of pull for the guy wire and rod assembly equal to 45 degrees.

The deadman anchor is not widely used today because of the time and effort required to place it.

Rock Anchor

The rock anchor is installed in the hardest soil of all: solid rock. It is designed to fit into a hole drilled into the rock (called a pilot hole), then opened by turning the anchor rod.

As you can see from the image to the right, when the anchor is opened it will expand against the sides of hole. This wedging action holds the anchor in place.

Expansion Anchors

The expansion anchor is the most popular type and is designed to be placed in the ground and then expanded with the aid of the tamping bar.

Once expanded, the anchor is secure and strong enough to secure the guy. Expansion anchors are commonly used in ordinary soils.

Like a rock anchor, the expansion anchor requires a pilot hole. Unlike the rock anchor, an expansion anchor does not hold by wedging itself against the sides of the hole; instead, the anchor is expanded into the undisturbed soil surrounding the pilot hole.

Screw Anchor

Screw anchors (as seen in image to the right) are commonly installed in soft soils. Unlike the rock and expansion anchors, the screw anchor does not require a pilot hole.

The anchor is simply screwed into the ground, where it holds itself in place.

If the soil is soft enough, two people can do this by sliding a digging bar through the eye of the anchor rod and walking in a circle to screw the anchor in.

If a line truck is available to aid in the installation, the screw anchor can also be used in ordinary soil with excellent results.

Equipment and Tool Requirements

For a Rock Anchor - Since rock anchors need a pilot hole, you will need tools, such as a jackhammer, a hammer, or a chisel and hammer, to make a hole in solid rock. You will also need a digging bar to turn the anchor rod to open the anchor.

For an Expansion Anchor - Since the expansion anchor requires a pilot hole in the soil, you will need digging tools or the auger from the line truck. Once the anchor is in place, expand it with a special tool called an anchor buster. This is like a large slide hammer, which is fitted around the anchor rod and then used to pound on the top of the expansion anchor, flattening and expanding it. You will also need shovels and tampers to backfill and tamp the pilot hole.

For a Screw Anchor - The screw anchor does not need a pilot hole, so you do not need digging tools. If you are installing the screw anchor manually, use a digging bar to thread through the eye of the anchor rod for turning it. If you are using the line truck, fit an adapter to the Kelly bar of the line truck and use the auger motor to screw the anchor into the ground.

Anchor Installation Procedures

To install an anchor, you need to know two things: how far from the pole the to place the anchor, and at what angle to install the anchor. You can find both these items of information on the staking sheet or the specification sheet for the individual pole.

The distance from the pole to the anchor is called the "lead", and should be listed in feet. The angle will be listed in degrees, and will most likely be 45°. This is the preferred angle for most guy wires, and you always install the anchor at the same angle as the guy.

Whether digging a pilot hole or simply screwing the anchor into the ground, bear in mind that when you apply tension to the anchor, the eye of the anchor rod should be 6 inches above grade.

Rock Anchor Installation

To install a rock anchor, first make a pilot hole. The easiest method is to have the equipment shop jackhammer the hole for you, but you can do it yourself with a hammer drill or a hammer and chisel, if necessary. Once the pilot hole is made, slide the closed anchor into the hole, and then open the anchor by turning the anchor rod.

The easiest way to do this is by sliding a digging bar through the eye of the anchor rod and walking in a circle. When you are finished, fill in the pilot hole with a bag of ready mix concrete to keep it from filling with water and debris.

Expansion Anchor Installation

Like a rock anchor, the expansion anchor also requires a pilot hole. Dig the hole deep enough so the anchor rod eye will be 6 inches above grade when tension has been applied. Remember to dig the hole at the same angle as the guy wire.

Then insert the expansion anchor and anchor rod into the hole, fit an anchor buster to the anchor rod (if an anchor buster is unavailable, a ten-foot piece of heavy 2 inch conduit or pipe will work), and work the anchor buster up and down to expand the anchor. As the anchor buster pounds on the top of the anchor, the anchor flattens out and penetrates the undisturbed soil around the pilot hole.

This undisturbed soil holds the expansion anchor in place. When the anchor is completely flattened and expanded, backfill and tamps the pilot hole all the way to the top.

Screw Anchor Installation

Screw anchor installation is very simple. To install a screw anchor manually, you must install it in soft soil. Simply slide a digging bar through the eye of the anchor rod and have two people walk in a circle, being careful to maintain the required angle.
In ordinary soil, manual installation is difficult or impossible, so you must use the line truck.

Begin by removing the auger from the Kelly bar, then attaching the adapter to the end of the Kelly bar. Attach the adapter to the screw anchor, and simply use the auger motor to screw the anchor into the ground. Remember to keep the proper angle, and turn the anchor in until the eye of the anchor rod is six inches above grade.

Anchor Rods

The anchor rod serves as the connecting link between the anchor and the guy cable.

The rod must have an ultimate strength equal to, or greater than, that required by the down guy assembly.

Anchor rods vary in diameter from 1/2 to 1 1/4 inches and in length from 3 1/2 to 12 feet.

Guy Wiring for Overhead Poles

Pole Guys

When constructing power lines, you will need a means of strengthening poles and keeping them in position.

To accomplish this, you can use guys, anchors, and braces.
Anchors are buried in the ground, and guy wires are connected to the anchors and attached to the pole, or you can use a push brace.

The guys and braces counter the horizontal strain on the pole caused by conductors, pole-line components, and abnormal loads, such as snow, sleet, or wind. The image above shows an example of where a guy wire was needed.

Purpose of Guying Poles

A guy is a brace or cable fastened to the pole to strengthen it and keep it in position.

Use guys whenever the wires tend to pull the pole out of its normal position and to sustain the line during the abnormal loads caused by sleet, wind, and cold.

Guys counteract the unbalanced force that dead-ending conductors impose on the poles; by changing conductor size, types, and tensions; by changes in angles in the transmission or distribution line, and by changes in pole line elevation.

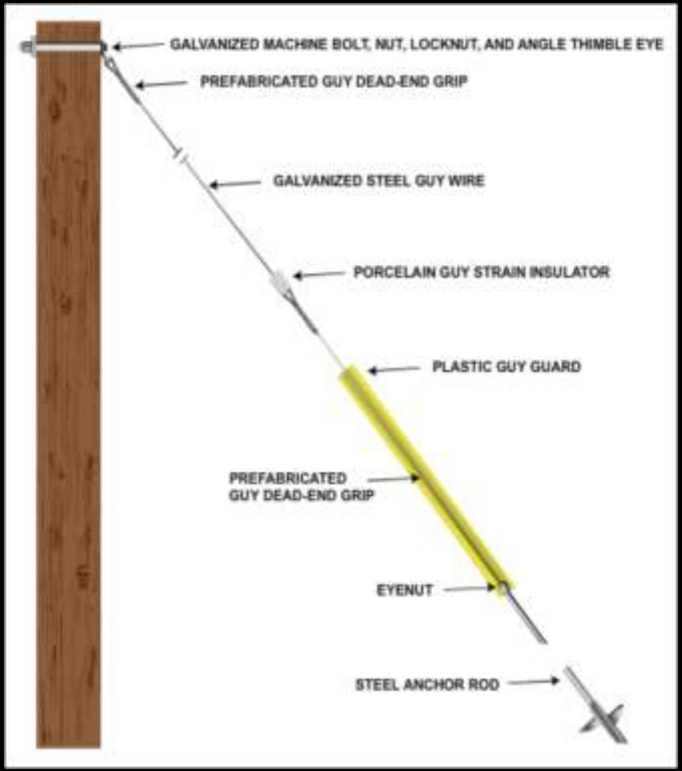
The guy counteracts the horizontal component of the force while the pole or supporting structure acts as a strut resisting the vertical component of the forces.

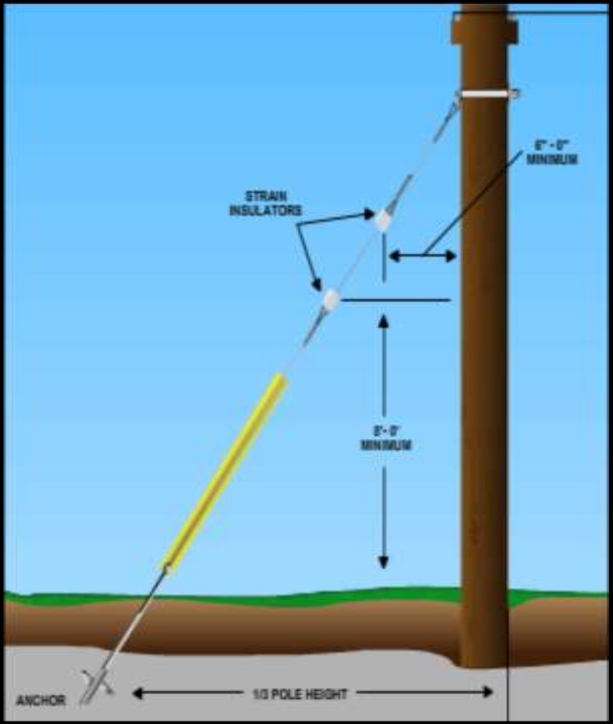
Types of Guys

Down Guy

A "down guy" consists of a wire running from an attachment near the top of the pole to a rod and anchor installed in the ground (image to the right).

This type of guy is preferable if field conditions permit its installation since it transfers the unbalanced force on a pole or structure to the earth without intermediate supports.





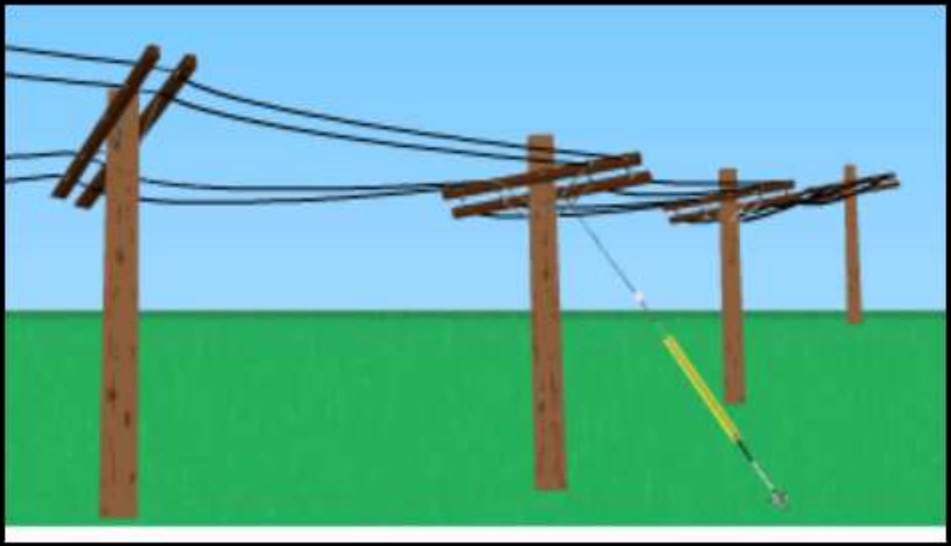
Dead End Guy

A down guy used at the ends of pole lines to counterbalance the pull of the line conductors is called a "terminal guy" or a "dead end guy" (image above).

All corners in the line are considered dead ends.

Corner Guy

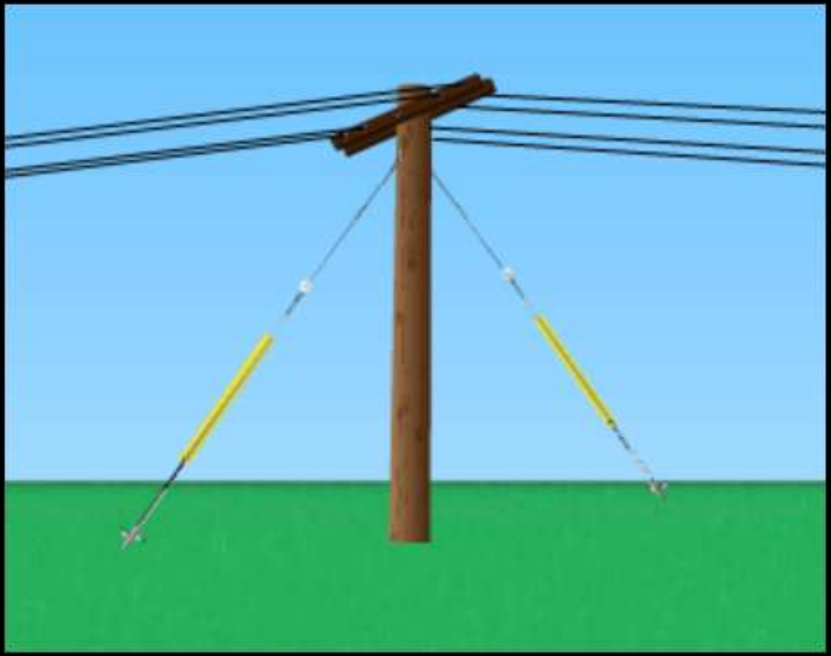
Corner poles should be guyed the same as terminal poles, except that there will be two guys, one for the pull of the conductor in each direction (image above).



Side Guy

When the line makes an angle, it produces a side pull on the pole. Install side guys to balance the side pull (image).

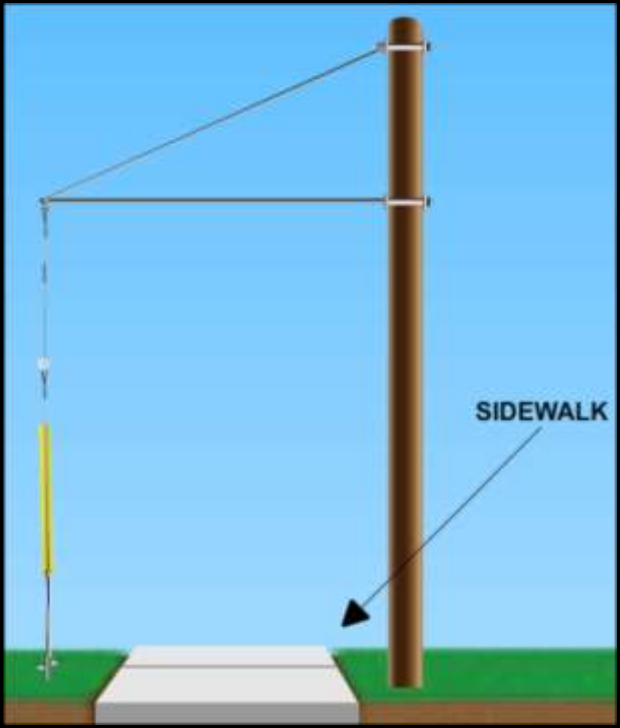
When a branch line takes off from the main line, it produces an unbalanced side pull. Place a side guy on the pole directly opposite to the pull of the branch line.



Storm Guy

Guys are installed at regular intervals in transmission lines that extend long distances in one direction to protect the lines from excessive damage from broken conductors.

Guys installed to protect the facilities and limit the damage if a conductor breaks are called "line guys" or "storm guys" (image).



Sidewalk Guy

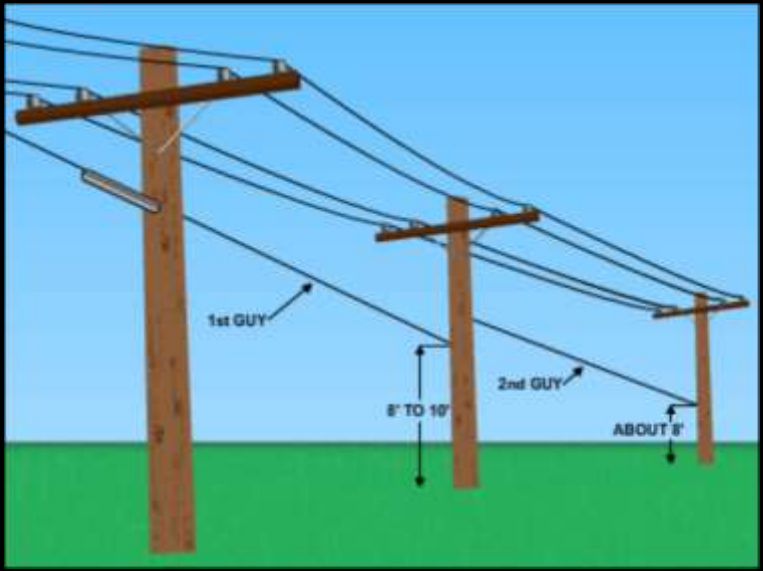
A “sidewalk guy” is an anchor guy with a horizontal strut at a height above a sidewalk sufficient to clear pedestrians (image).

Span Guy

A span, or overhead guy consists of a guy wire installed from the top of a pole to the top of an adjacent pole to remove the strain from the line conductors. The guy transfers the strain on a pole to another structure.

This may be to another line pole or to a stub pole on which there is no energizer equipment.

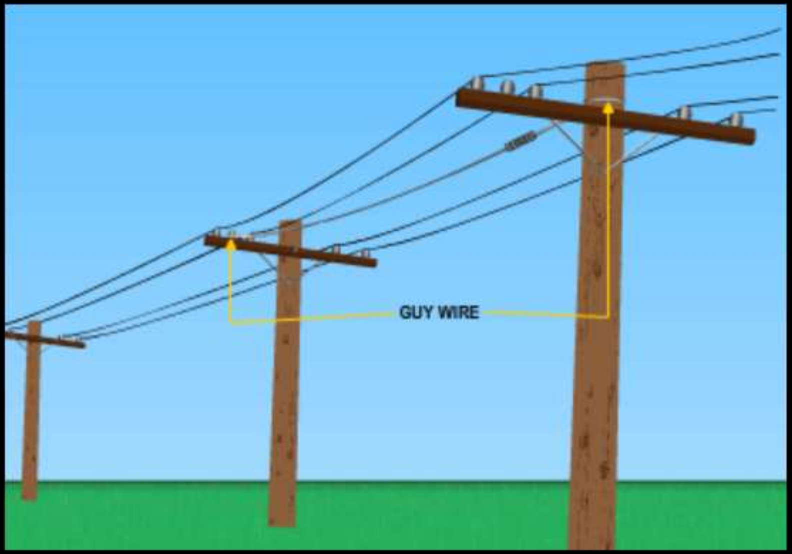
A span guy is always installed to extend from the strain pole to the same or lower level on the next line pole.



Head Guy

A guy wire running from the top of a pole to a point below the top of the adjacent pole is called a "head guy" (image).

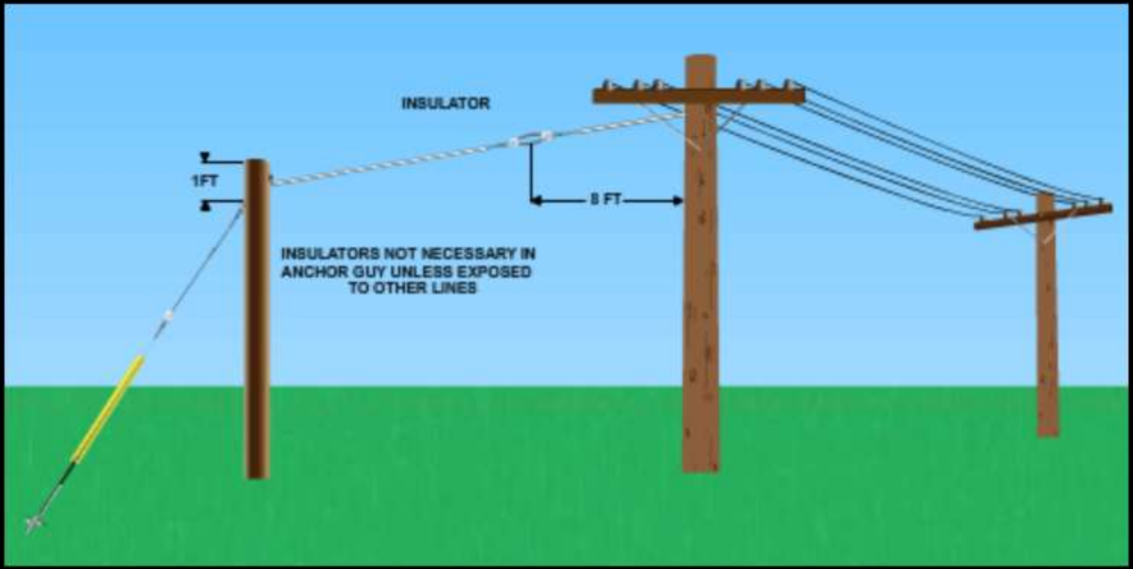
Lines on steep hills are normally constructed with head guys to counteract the downhill strain of the line.



Arm Guy

A guy wire running from one side of a crossarm to the next pole is called an "arm guy."

Arm guys counteract the forces on crossarms that have more wires dead-ended on one side than on the other (image).



Stub Guy

A guy wire installed between a line pole and a stub pole on which there is no energized equipment is called a "stub guy" (image).

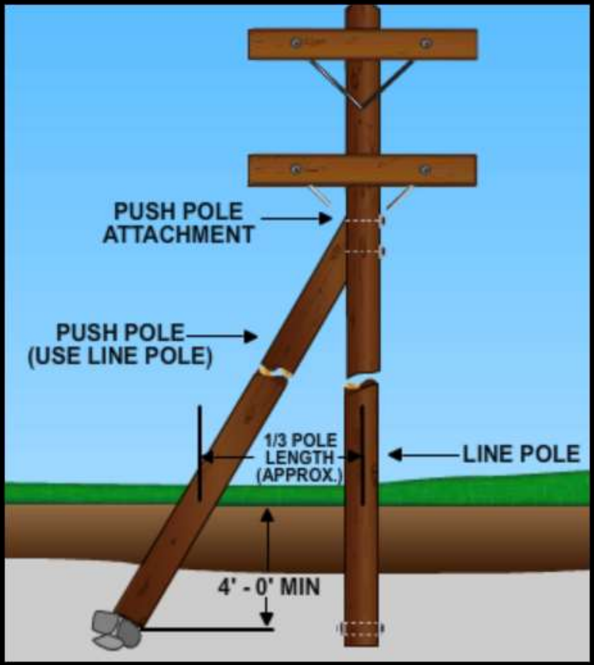
A down guy is used to secure the stub pole. This type of guy is often installed to obtain adequate clearance for guy wires extending across streets or highways.

Push Guy

A push guy, or a push brace, is used when it is impossible to use down guys (image).

When it is impossible to obtain sufficient right-of-way for a pole guy, the push brace can usually be installed.

The push guy is constructed from an old power pole and a special bracket called a push brace attachment.



Attachment Devices for Guy Wires

Guy Wire Attachment

The guy wire must be attached both to the utility pole and to the anchor rod. There are three methods of attachment.

Three-bolt Clamp

A three-bolt clamp (image) is so named because it has three bolts designed to clamp two grooved pieces of steel together on a guy wire.

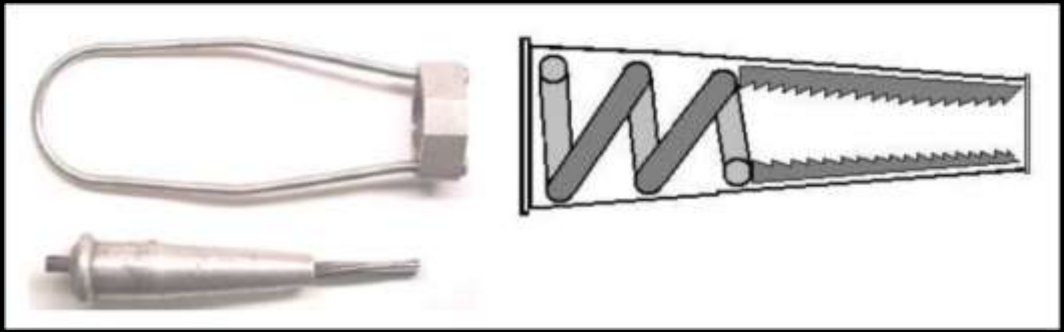
It has two outer bolts facing one way and a center bolt facing the other way.

When tightening, evenly torque the three bolts to grip the wire uniformly. These clamps are easy to remove and re-apply.

Preform Guy Wire Grip

A preform guy wire grip (aka preform wrap) is a quick method of attachment that requires no tools to apply or remove. You simply wrap the preformed wrap onto the wire, and when you apply tension, the wrap holds the wire much like the toy finger handcuffs you played with as a child.

The more tension applied to the wrap, the tighter the wrap holds the wire. Once tension has been applied to a preform wrap, it can still be removed, but it cannot be reused. The image above shows a preform wrap before installation and a preform wrap being applied to a guy wire.



Automatic Locking Clevis

Automatic locking clevis (aka automatics) guy wire attachments are devices with spring-loaded jaws inside the body of the device. The guy wire can be inserted into the jaws, but cannot be removed unless the spring pressure is released with a screwdriver.

Automatics install very quickly; however, they cannot be reused once tension has been applied. The image above shows an automatic guy attachment.

The cartridge at the bottom of the left image is shown in a cutaway view in the right image.

Associated Anchoring and Pole Hardware

Anchor Rods

The guy wire is attached to the "eye" of the anchor rod. Rods are available with an oval eye or a thimble eye, each of which allows only one guy wire to be attached to the anchor rod. Twin eyes allow two guy wires to be attached to one anchor rod, while a triple eye will hold three guy wires.

Triple eyed anchor rods are normally the best choice for most installations as they allow for future growth on the pole.

The image shows an oval eye, a twin eye and a triple eye, from top to bottom. You can purchase anchor rods in various lengths and diameters, according to need.

Pole Hardware

Guy wires are attached to the utility pole with a thimble eyebolt, a thimble eye nut or a thimble eye washer.

Thimble eyebolts - are standard 5/8 inch bolts forged with a thimble as the head of the bolt. Thimble eyebolts come straight or with the thimble bent at a 45 degree angle.

Use the straight variety for span guys and head guys; use the bent thimble eyebolts for down guys and sidewalk guys.

Thimble eye nuts - are used just like standard nuts, except each one comes with a straight thimble eye forged onto it. Because the thimble is straight, thimble eye nuts are used for span guys and head guys; if you need a bent thimble, you must use a thimble eye washer.

Thimble eye washers - are stout washers forged with a thimble eye at a 45 degree angle for use with down guys and sidewalk guys. Install the thimble eye washer under a nut, making sure you tighten the nut down snugly.

When using a thimble eye nut, spin the nut on the bolt until at least two full threads of the bolt are visible. Never use a bent thimble for a span guy or a head guy, and never use a straight thimble with a down guy or sidewalk guy.

Eyebolts and eye nuts can be purchased with oval eyes suitable for mounting insulators and other line hardware, but never use an oval eye to attach a guy wire. The sharp bend around the oval places undue stress on the wire. Always use a thimble eye for attaching guy wire.

The image above shows the different thimble eyebolts.

Equipment and Tool Requirements

Guy Wire Grip

To properly tension a guy wire, some equipment is required.

A guy wire grip (image) is a tool used to hold the guy wire as tension is applied.

It is designed so that when clipped onto the guy wire, applying tension causes the jaws to close tighter.

The jaws are equipped with small teeth to bite into and hold the steel guy wire.

Dynamometer

A dynamometer (image) is a device that measures tension in foot pounds. When using a dynamometer, you will also need a reference chart that gives you the proper amount of tension to apply.

Anchor Grip

If you need a way to attach to the anchor rod, use an anchor grip (image shows an anchor grip on a thimble eye rod).

The anchor grip is a two-piece steel tool that bolts onto an exposed anchor rod, providing an eye for attaching a chain hoist.

Chain Hoist

A chain hoist (sometimes called a “come-along”) is used to apply tension to the guy wire (image). Chain hoists are available with different capacities; be sure to use one strong enough to apply the required tension to your guy wire.

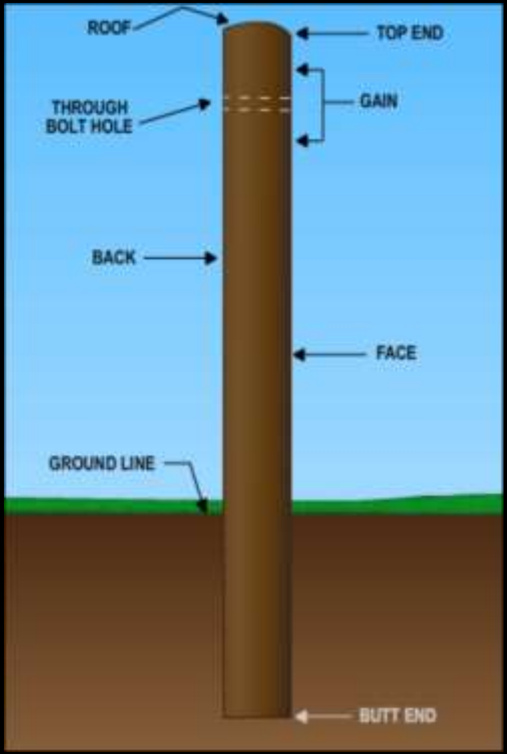
Framing Poles

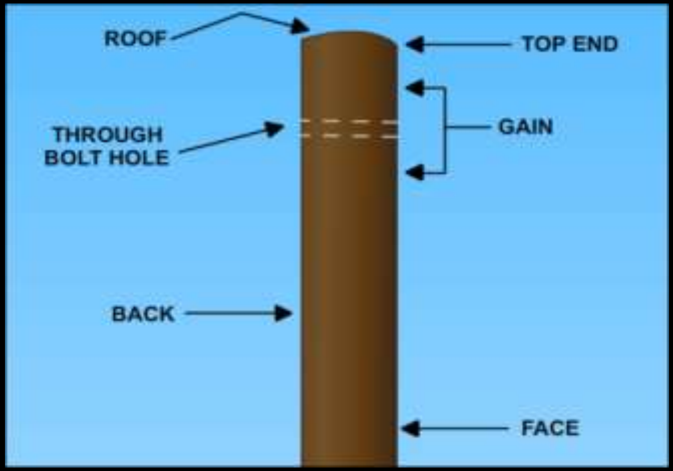
Framing a pole consists of the following actions: determining the face and back of the pole, cutting the roof and gain, and drilling holes for mounting hardware.

The image to the right shows that the face of any pole is on the inside of any curve the pole may have. This allows the wire strain on the crossarm to be against the curve of the pole.

This also dictates positioning of the gain on the face of the pole, except for gains on comer poles, when lower crossarms are mounted at a 90 degree angle to the main distribution line.

The roof or top of the pole is cut sloping at a 15 degree angle from the face to the back of the pole; however, the new pressure-treated poles do not require roofs.





Pole Gain

A gain should be 1/2 inch deep in the center, slightly concave, and located 12 inches from the top of the pole.

The width of the gain should be the height of the crossarm to be used. Spacing of succeeding gains depends on the voltage of the lines to be placed on that level. This information is contained in the project specifications and drawings for any new work for which you are tasked.

To drill holes for mounting crossarms, use a template that can mark the center, or draw two diagonal pencil lines across the gain.

The intersection of these two lines determines the center of the gain and the place to drill the hole. The nominal size hole is 1 1/16 inch for a 5/8 inch through bolt.

Length of Pole (ft)	Setting Depth (ft)	
	In Soil	In Rock
20	5.0	3.0
25	5.5	3.5
30	5.5	4.0
35	6.0	4.0
40	6.0	4.0
45	6.5	4.5
50	7.0	4.5
55	7.5	5.0
60	8.0	5.0

Installing Poles

The depth for a pole hole depends on the length of the pole and the composition of the soil. A hole in firm, rocky terrain does not need to be as deep as a hole in soft soil.

The table above gives recommended depths for poles from 20 to 60 feet long in firm soil and in rock.

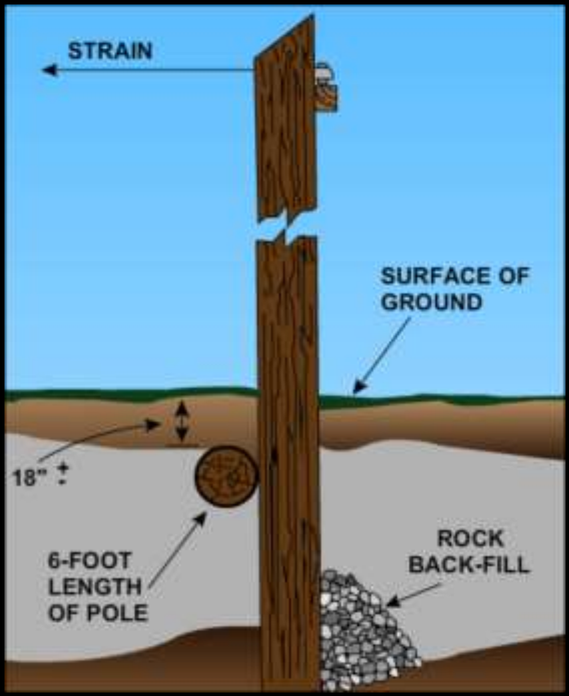
Cribbing around Poles

A pole set in sandy or swampy soil must be supported by guys, braces, or cribbing.

Cribbing means placing some firm material around the part of the pole below the ground.

One method of cribbing is to sink an open-bottom barrel in the hole, set up the pole in the barrel, and then fill the space around the base of the pole with concrete or small stones after the pole has been plumbed (brought to the vertical).

Another method of cribbing is shown in the image to the right.

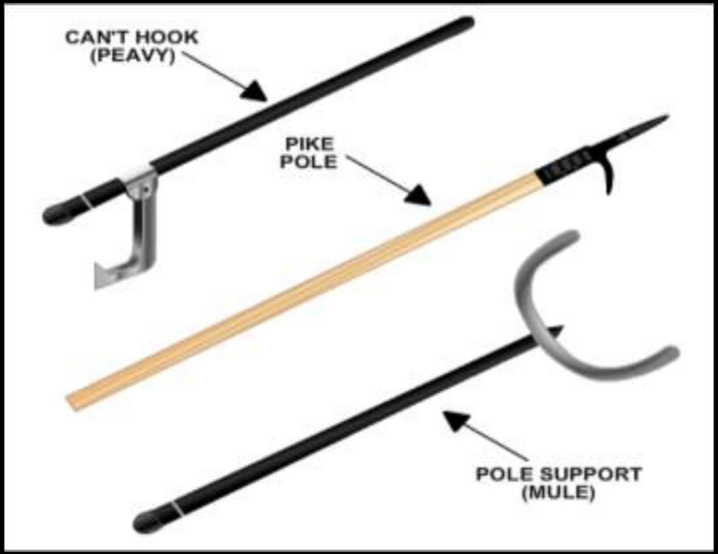


Erecting Poles

When an earth auger is available, the job of erecting poles is relatively simple. Place a sling around the approximate midpoint of the pole and heave it up with a winch. Then a pole claw holds it in place.

The truck then proceeds to the hole or is pre-positioned at the hole site, and the base of the pole is guided in as the winch lowers away (image).

Since the butt, or base, is heavier than the top end, raise the pole to an almost vertical position.



Tools used for Piking up a Pole

In the absence of this equipment, the pole must be "piked up" meaning that the pole is placed with the base adjacent to the hole and the upper end supported on either a "mule" or a "jenny."

A jenny is a wooden support made in the form of an X, and a mule is a wooden support made in the form of a Y. The upper end is then "piked" into the air by crew members using pike poles.

A cant hook (peavy), pike pole, and pole support (mule) are shown in the left image, while the right image shows the tool used to position a pole manually for erection.

Manually Digging the Hole

There may be a power-driven hole digger available, but in the absence of one of these, you must dig the holes with hand tools. Use a "digging bar" to loosen the soil.

You can remove about the first 2 feet of depth with a short-handled shovel. Below that, loosen the earth with an earth auger or long-handled shovel, and haul it up with a long-handled device called a spoon. Hole depths vary from 3 to 8 feet depending if digging in soil or rock.

A hole should have a diameter about 6 inches larger than that of the base of the pole to allow room for tamping backfill. It should be a little larger at the bottom to allow for plumbing the pole.

Piking up a Pole

The procedure for piking up a pole:

The "butt man" holds and guides the butt of the pole with a cant hook (or peavy). This is a handle with a hook designed to grasp the pole when pressure is applied to the handle.

As the upper end of the pole is raised, a crew member keeps the jenny or mule in approximate contact by moving it toward the butt. The "butt board" is a length of plank set in the hole and long enough to protrude above the surface.

It prevents the butt of the pole from sliding past the hole and also prevents the butt from caving in the side of the hole. After the pole has reached an upright position, it is "faced", meaning it is rotated with the cant hook to bring the crossarm gain to proper position.

Properly Aligning or "Facing" Poles

On a straight line crew members set adjacent poles with crossarms facing in opposite directions, as shown above. This procedure, called facing "gain to gain" or "back to back," provides for maximum strength in the line. Poles are always faced in the direction of hills, curves, and dead ends to allow the most strain to be placed on the face and against the curve of the poles.

After the pole has been faced, it must be plumbed vertical. To do this, four pikers on four sides of the pole act on signals given by one crew member who sights along the line and another who sights from one side. In some cases, a small amount of rake or lean (approximately 12 inches) is left to allow for a wire strain or the normal give of a guy.

Safely Piking Poles

Do not use the pike-pole method of setting poles unless there are enough crew members to do the work safely. In using pikes the crew must stand far enough apart so that they will not interfere with each other.

Never brace a pike pole on your stomach. If the pole shifts your way, you will not be able to get clear. Never rely on unmanned pikes alone to support a pole, while a crew member is on it. Keep pike-pole tops covered at all times except when actually in use.

Backfilling and Tamping in a Pole

After the plumbing the pole, backfill the hole and the tamp the backfill down firmly. Backfill gradually, in shallow layers, and tamp down each layer thoroughly. Usually two or three crew members tamp, and one shovels.

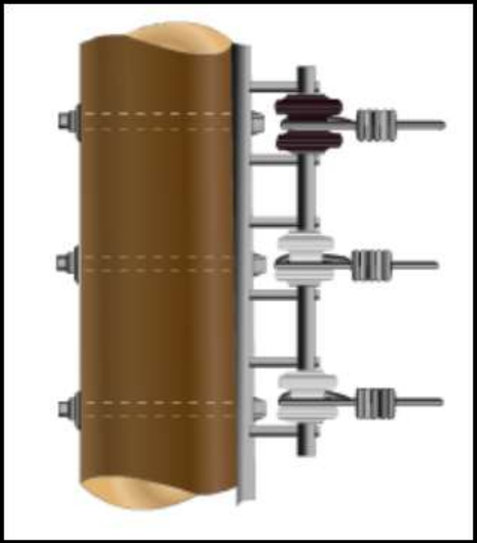
When the hole has been filled to the ground line with tamped backfill, bank the remaining excavated soil is banked in a mound around the base of the pole to allow for subsequent settling (image).

As a pole is being raised, it is safest to assume that at any moment something may slip or break Stand as far away from the pole as possible if you are not in the raising crew.

Installing Guys

Guys are assembled using seven-strand galvanized steel guy wire, a strain insulator (of a different design from and not to be confused with the strain insulator used for dead ending a conductor), and three bolt clamps or preformed guy grips.

The dimensioning of the guy is determined by the height of the pole, by the amount of strain it must counteract, and by the climate when the guy is installed.



Secondary Racks

Secondary conductors may be strung on crossarms but are usually put on secondary "racks." These racks are made in sizes to accommodate two, three, or four conductors.

A secondary rack is mounted on the side of a pole (for a straight run) or on the inside of a pole (for a dead end).

A rack is fastened to the pole with lag bolts on a straight line with a through bolt at the top and a lag screw at the bottom, or with through bolts with nuts for a dead end or when a branch line takes off from the main line.

The image above shows a dead end secondary rack.

Dead-end secondary rack

On a straight line without excessive strains, crossarms are singly-mounted face to face or back to back. At line terminals, corners, angles, or other points of excessive strain, crossarms are doubled. When a power line crosses a railroad or a telephone line, crossarms is also doubled.

A rod passing through the insulators and brackets on a rack holds the insulators to the rack, as shown on the previous page. On a straight line or inside angle, the conductor is run on the inside of the insulator. On an outside angle, it is run on the outside. Always place the conductor here with strain against the insulator.

The image above shows rack arrangements at comers and angles.

Types of Crossarms

Crossarms

A crossarm is a specially treated wooden member secured to a pole and used to mount various types of circuit protection devices and support distribution conductors.

Standard cross-section dimensions for wood crossarms (width by height) are:

- 3 1/4 inches by 4 1/4 inches
- 3 1/2 inches by 4 1/2 inches
- 3 3/4 inches by 4 3/4 inches
- 4 inches by 5 inches

The length of the crossarm depends on the number of conductors it must support and the spacing between them. Typically, 4 and 6 conductor crossarms are 8 feet in length. In your naval service you may come across larger wooden crossarms or crossarms made of steel. These crossarms are designed to support increased strain or to use with transmission lines carrying higher voltages.

Crossarm Lengths

The length of the crossarm depends on the number of conductors it must support and the spacing between them.

Typically, 4 and 6 conductor crossarms are 8 feet in length, however, there are occasionally larger wooden or steel crossarms.

These crossarms are designed to support increased strain or to use with transmission lines carrying higher voltages.

Single Crossarms

Single arms are used on straight lines when no excessive strain needs to be provided (image). When you install crossarms, face every other crossarm in the same direction. Use single crossarms when the pole line is straight or line angle change is less than 10 degrees.

On a straight line without excessive strains, use crossarms singly-mounted face to face or back to back.

Double Arms

Use a double arm at line terminals, corners, angles, or other points when there is an excessive strain (image). At line terminals, corners, angles, or other points of excessive strain, double crossarms. When a power line crosses a railroad or a telephone line, you also need to double crossarms. Use two crossarms at points where the line angle change is from 11 to 30 degrees.

Double arms provide support when two or more transformers are mounted on the same pole. As a rule, use double arms whenever lines cross points that require more than ordinary safety.

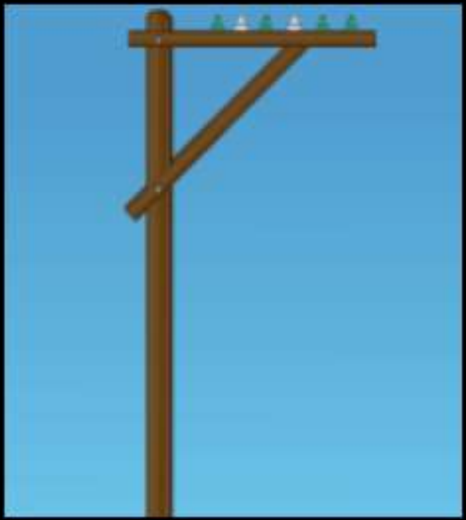
Double crossarms utilize one through bolt and two double arming bolts. Double arming bolts, also called DA bolts, and are long bolts without heads that extend through both crossarms at the extreme ends of the arms.

Buck Arms

Buck arms are used at points where the line makes a change of between 31 to 90 degrees, or where the conductors deadend. Buck arms look like the double crossarm, except they use four double arming bolts in construction compared to just two on the double crossarm.

These provide additional strength to the arm and an attachment point for the suspension insulators used with a buck arm configuration. You add a second set of buck arms in order to make a line angle change.

When installing the second set of arms, install them 2 to 4 feet below the first set of arms, 3 feet being the most common spacing. Again, the exact spacing will depend on system voltage. (See image)



Side Arms

Side arms are used in alleys or other locations when it is necessary to clear buildings. (See image).

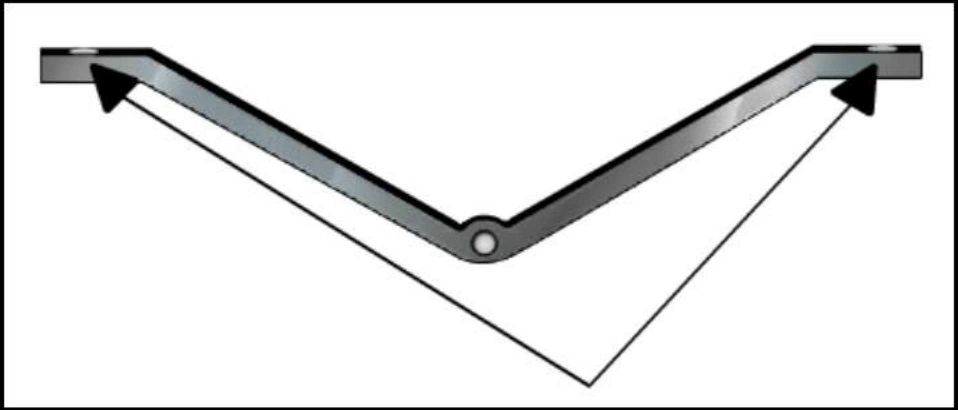
Crossarm Hardware

Line hardware consists of the miscellaneous bolts, nuts, braces, and clamps used to fasten crossarms, guys, and other equipment to the pole.

Crossarm Braces

Braces give strength and rigidity to the crossarm. Metal crossarm braces are made of either flat bar or light angle iron. The size of a brace varies with the size of the arm and the weight of the conductors. The usual flat-strap brace for ordinary distribution work (image) is 38 inches long and 1/4 by 1 1/4 inches.

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.



Standard flat-strap crossarm brace

Angle iron braces are made in one piece and bent into the shape of a V, as shown in the image above. These braces are fitted to the bottom of the crossarm instead of the side, as is the flat type.

Crossarm Installation

On most pole-line construction, hardware and crossarms are installed on the ground before setting the pole.

This is the easiest and most efficient method; however, sometimes it is necessary to upgrade or build on to an existing system, and then the arm must be installed on a pole that is already standing.

Mounting Crossarm to Pole

When you mount the crossarm on the pole before the pole is set, tighten the through bolt, but leave the crossarm braces hanging loose. Once the pole is set, level the crossarm and secure the braces to the pole.

Finally, draw the through bolt completely tight. Do not raise the arm with the insulators installed; send them up last and spin them on after securing the arm. Remember that the grooves of pin insulators must line up with the conductors.

Mounting and Aligning Insulators on Crossarm

To properly align a pin insulator, adjust the pin, not the insulator. Spin the insulator onto the pin until snug, but do not exert excessive force as the porcelain or plastic will break.

When the insulator is snug, loosen the nut on the insulator pin (bottom of the crossarm) and turn the entire pin/insulator assembly to align the groove.

Retighten the nut on the insulator pin when you are satisfied with the alignment.
To mount the crossarm after the pole is set, a worker on the ground pulls it up to a lineman in a working position.

Bracing

Braces are usually fastened to a crossarm with 3/8-inch by 4-inch carriage bolts. Each brace comes down diagonally and is attached to the pole at the lower end with a 1/2 inch lag screw.

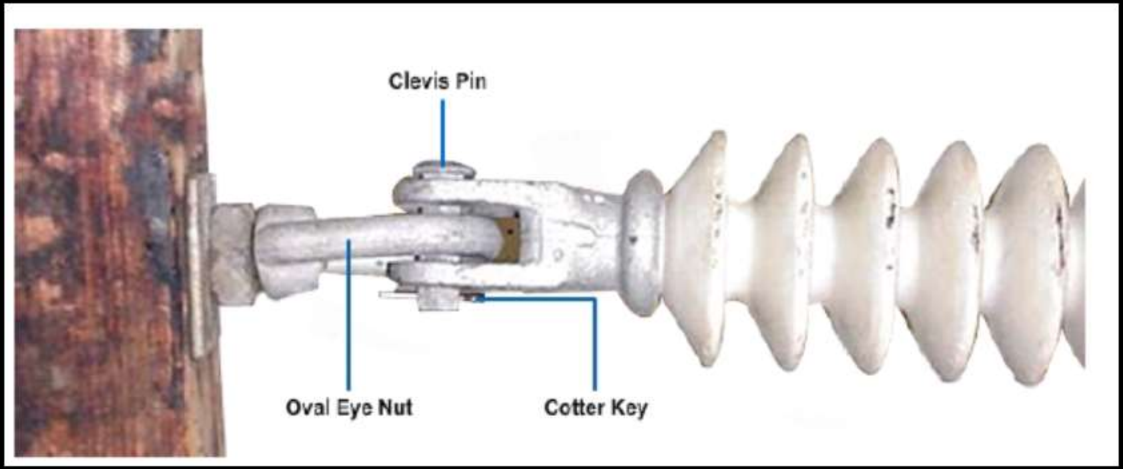
Double and Buck Crossarm Installation

When installing double crossarms and buck arms, mount all the hardware on one crossarm and install it first; the number of DA bolts depends on whether it is a double arm or a buckarm.

See image above. One of the DA bolts is threaded all the way and has two square washers and two nuts on each bolt between the arms.

The bolts should be set up loosely in order to allow free movement, making alignment of the second arm easy. When installing each crossarm, follow the same procedures as for the single arm.

Types of Insulators

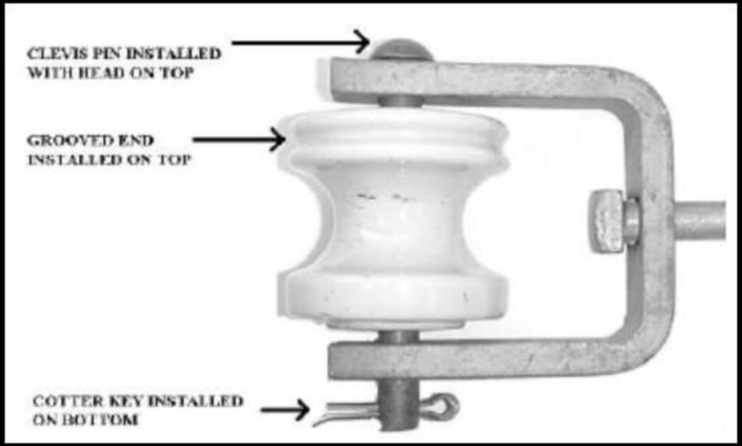


Mounting Insulators to Crossarms

If you use pin insulators, follow the procedures described for the single crossarm. If you use suspension insulators, you will need to install an oval eye nut or an oval eyebolt on which to hang the insulator.

Mount suspension insulators to the oval eye with a short clevis pin and cotter key. Be sure to install the cotter key(s) on the side of the insulator closest to the pole.

This is much more convenient for a climber than having to fumble for a small cotter key on the opposite side of the insulator from the pole. (See image)



Clevis Assembly

Installing a clevis and spool insulator is relatively simple. Mount the through bolt/clevis assembly to the pole, and then secure the spool insulator in the clevis with a clevis pin and cotter key.

Ensure the spool insulator is correctly oriented with the grooved end on top, and drop the clevis pin through the clevis/spool from above with the cotter key inserted on the bottom side. (image)

Insulators

An insulator is a material that prevents the flow of an electric current and can be used to support electrical conductors.

The function of an insulator is to separate the line conductors from the pole. Insulators are fabricated from porcelain, glass, and fiberglass, treated with epoxy resins and rubberlike compounds.

In determining the size and type you need, you should consider the designed voltage of the circuit, conductor size, length of the pole-line spans, and cost of the various insulators.

The most common types of insulators found are:

- Pin
- Post
- Suspension
- Strain

Pin Insulators

The pin insulator is the most commonly used insulator on overhead distribution systems today. It is screwed on a steel or lead insulator pin (thus the name) mounted to a crossarm or on some variation of armless hardware.

Pin insulators have a groove across their tops, designed to hold the conductor. This groove must be positioned in-line with the conductor it is supporting. Pin insulators are used when the right-of-way is narrow.

Pin insulators are made of either glass or porcelain. The glass insulator is always one solid piece. The porcelain insulator is also a one-piece insulator when used with low voltage lines but will consist of two, three, or four layers cemented together to form a rigid unit when used on higher voltages (image).

Pin insulator Hardware

An insulator pin holds the insulator mounted on it in a vertical position. Insulator pins are made of wood or metal. Wooden pins are usually made of locust, a durable wood that retains its strength longer than other woods. Iron and steel pins are used whenever the pins must be extra long because of high voltage and whenever the tension on the conductor is great.

One make is arranged to encircle the crossarm as a clamp pin, the clamp being held by bolts. In many cases, a steel rod is used as the base to permit the drilling of a 5/8 or a 3/4 inch hole in the crossarm.

Steel pins are in general use. Steel pins have a broad base which rests squarely on the crossarm, as shown above. The spacing of the pins is generally suited to the voltage of the circuit. The spacing should provide sufficient working space for the lineman. For general distribution work, the spacing is 14 ½ inches between centers.

Post Insulator

A post insulator is similar to a pin insulator but is used for longer, heavier spans. The post insulator is seen mostly on sub-transmission and transmission lines. It is not mounted on a pin; its base is bolted onto the crossarm.

Suspension Insulators

As their name implies, suspension insulators (as seen above) are suspended from a crossarm, pole or armless hardware in either a horizontal or vertical position.

The suspension insulator can be installed in series with other suspension insulators to accommodate higher line voltages.

Older suspension insulators were made of porcelain but the insulators we use now are made of polymer or epoxy material (plastic).

Strain Insulator

The strain insulator looks exactly like the suspension insulator but is designed to hold much heavier physical loads. Strain insulators are used to carry a pull as well as provide insulation. Such places occur whenever a line is dead-ended, at comers, at sharp curves, at extra long spans, at river crossings, or in mountainous country.

In such places the insulator must not only be a good insulator electrically but it also must have sufficient mechanical strength to counterbalance the forces due to tension of the line conductors. (See image above).

Spool Insulators

The spool insulator (shown in image) is used to support the system neutral or secondary wires.

Spool insulators never support high voltage wires. You will most often see spool insulators mounted directly to the pole with a clevis supporting distribution system neutrals.

Electrical Conductors

Conductors

The wires and cables which transmit electrical energy are made of copper, aluminum, steel, or a combination of copper and steel or aluminum and steel.

A conductor is a material that readily permits the flow of an electric current.

Materials that conduct electricity, other than those mentioned, are not generally used to make wires and cables for economic or physical reasons.

Copper Conductors

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

Three kinds of copper wire are in use: hard-drawn copper, medium-hard- drawn copper, and annealed copper, also called "soft drawn."

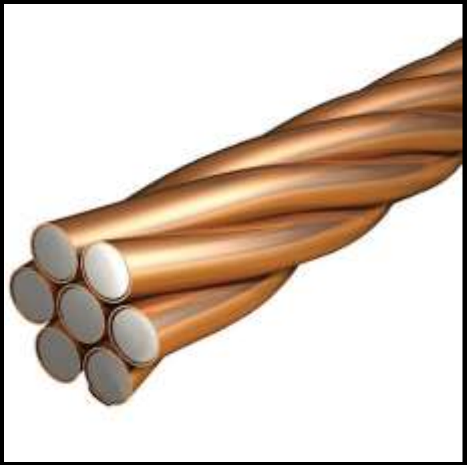
For overhead line purposes, hard-drawn copper wire is preferable on account of its greater strength. Medium-hard-drawn copper can be used for distribution lines usually for wire sizes smaller than No. 2.

Aluminum Conductors

Aluminum is widely used for distribution and transmission line conductors. Its conductivity, however, is only about two thirds that of copper.

Compared with a copper wire of the same physical size, aluminum wire has 60 percent of the conductivity, 45 percent of the tensile strength, and 33 percent of the weight. The aluminum wire must be 100/60 = 1.66 times as large as the copper wire in cross section to have the same conductivity.

When an aluminum conductor is stranded, the central strand is often made of steel that serves to reinforce the cable. Such reinforcement gives added strength for the weight of conductor. Reinforced aluminum cable called ACSR (aluminum-conductor steel-reinforced) is especially suited for long spans.



Copperweld Steel Conductors

In this type of conductor, a protective copper coating 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 gives it greater strength. This combination produces a satisfactory yet inexpensive line conductor. Its chief field of application is for rural lines, guy wires, and overhead ground wires.

The conductivity of copper-weld 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 percent.

Classes of Conductors

Conductors come in two classes, solid and stranded. A solid conductor is a single conductor of solid circular section. A stranded conductor is composed of a group of small conductors in common contact.

A stranded conductor is used when the solid conductor is too large and not flexible enough to be handled readily. Large solid conductors are also easily damaged by bending.

The need for mechanical flexibility usually determines whether to use a solid or a stranded conductor, and the degree of flexibility is a function of the total number of strands. The strands in the stranded conductor are usually arranged in concentric layers about a central core.

The smallest number of wires in a stranded conductor is three. The next number of strands is 7, 19, 37, 61, 91, 127, and so forth. Both copper and aluminum conductors may be stranded.

Conductor Sizes

Conductor sizes are ordinarily expressed by two different numbering methods: the American Wire Gauge (AWG) and the circular mil.

The AWG conductor sizes are numbered from 30 to 1, and then continue with 0, 00, 000, and 0000 (or 1/0, 2/0, 3/0, and 4/0, respectively). Number 30 is the smallest size and 4/0 the largest in this system.

As an example of the actual physical size of the conductors commonly used in transmission and distribution work, refer to the chart to the right. Refer to Chapter 9 of the NEC for complete table listings.

Gage Number	Diameter, In.	Full Size, Side View	Full Size, End View
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		

Circular Mil

The circular mil is the unit customarily used in designating the cross-sectional area of wires. A "circular mil" is defined as the area of a circle having a diameter of 1/1000 of an inch.

The circular mils of cross section in a wire are obtained by squaring the diameter expressed as thousandths of an inch. For example, a wire with a diameter of 0.102 inches (102 thousandths of an inch) has a circular mils cross section of 102 x 102 = 10,404.

Conductors larger than 4/0 AWG are designated in circular mils. These range from 250,000 to 2,000,000 circular mils (250 MCM or 2,000 MCM).

Installing Conductors

Installing Conductors

There are several acceptable methods for stringing out and raising conductors. The method you use depends upon where the new pole line is located and what kind of equipment is available to you.

You may place the wire reels on a truck or wire trailer and drive along the right of way unreeling the wire, or you may use a running block (image) or over the crossarm methods.

Mounting the Reels

No matter how you string the wire, you will have to mount the reels on some support that allows them to revolve freely. Usually you do this by raising a reel on reel jacks, as shown above.

Put a metal rod strong enough to support the reel through the hole in the center, and jack up the rod and reel on each side. You may have to fasten down the bases of the jacks to keep the strain from upsetting the reel. When you are jacking up, it is necessary only to raise the reel just clear of the deck.

Stringing Wire

When stringing wire in rough terrain, the best method is to anchor a reel to the ground at the end of the line by means of guys run to driven stakes.

Then run a rope line over the crossarms or through running blocks mounted on the crossarms for a distance of 1,000 to 1,500 feet. A lineman accomplishes this by climbing each pole and placing the rope in place.

After stringing the rope over the crossarms, secure one end to the wires to be pulled, and take a couple of turns with the other end around the winch drum on the line truck.

Then rotate the drum to haul in the rope and the wires with it. As each wire passes a crossarm, a lineman must climb the pole to set the wire in proper position and guard against twisting.

Properly Feeding the Wire

To keep a paying-out reel from revolving too fast, set a brake or drag against the reel. This can be simply a board, held against the outer edge of the reel by a helper.

As a wire or wires are being pulled, enough crew members must be stationed along the way to establish a chain of signal communication from the head of the line back to the line truck.

Pull several feet past the last dead-end pole to ensure there is enough conductor for sagging and cut the conductor at the reel.

Placing the Neutral Conductor

Always place a neutral conductor on a center crossarm insulator or on a pole-top insulator. Butting the neutral on a center pole insulator gives the lineman a clear space around the pole to climb through; that is, it ensures that the hot wires are a considerable distance apart.

Pulling In Conductors

When the conductors have been hoisted in place on the crossarms and dead-ended on one end, you are ready to start "pulling in"; that is, heaving on the conductors until each has been raised to proper sag. You can do this with a tackle equipped with conductor grips or individually, using a conductor grip and a come-along.

A conductor grip is a clamp device that grips the wire tightly when a strain is applied to the grip. When you are pulling two or more wires at once, it is best to use the equalizer. This device distributes the strain equally on all the wires.

Measuring the Sag

When wires have been pulled to approximately the desired sag, a lineman goes to the center span to measure the sag. Measurement at the center of each span ensures uniformity.

Three common ways of measuring sag are by dynamometer, by timing vibration, and by the use of targets.

Dynamometer

A dynamometer is an instrument that is installed in the pulling line and that measures the strain of the pull. Use it in conjunction with a chart that gives the desired pull tension for a given conductor size, span length, and temperature.

A traction dynamometer, also installed in the pulling line, provides direct readings on the face of the dial.

Timing Vibration

The timing-vibration process is done by striking the wire sharply near one of the pole supports and timing with a stopwatch the interval that elapses as the impulse from the blow ravels to the next pole and returns.

This system is not accurate when wind is swinging the line or when someone is working on the line in an adjacent span.

Targets

The target-sighting method is a simple and accurate means for measuring sag.

Target measure sag by nailing slat targets, such as a couple of pieces of wood lath, at the point on each pole below the conductor insulator.

A lineman then sights from one slat to the other.

Sagging Procedures

Once the conductor is positioned, you must sag and secure it. Properly sagging the conductor allows for expansion and contraction during temperature changes.

It also minimizes strain on the pole and related hardware and aids in maintaining conductor spacing in high winds.

Sagging Chart

To determine the proper sag for your conductors, consult a sagging chart (right).

The chart will reference the conductor type, ruling span length (both found on the staking sheet) and the outside temperature to determine how much your conductors should sag in the middle of the span.

Table 7-3 – Sagging chart.

No. (AWG)	Temperature (Degrees F)	Sag in inches for span lengths of					
		100 ft	125 ft	150 ft	175 ft	200 ft	250 ft
6	30	5.5	8.5	13. 5	18.50		
	60	8.0	12.0	18.0	24.0		
	90	12.00	17.00	23.5.	30.00		
4	30	5.5	8.5	13. 5	18.50	25.00	25. 0
	60	8.0	12.0	18.0	24.0	32.00	42.0
	90	12.00	17.00	23.5	30.00	39.00	50.00
2	30	5.5	8.5	13. 5	16.50	20.00	29. 5
	60	8.0	12.0	18.0	22.0	26.00	36.0
	90	12.00	17.00	23.5	28.00	33.00	44.00
1	30	5.5	8.5	13. 5	15.50	28.50	24.50
	60	8.0	12.0	18.0	2.0	24.0	31.0
	90	12.00	17.00	23.5	28.00	31.00	39.00
0	30	5.5	8.5	13. 5	15.50	18.50	23.50
	60	8.0	12.0	18.0	20.5	23.5	29.0
	90	12.00	17.00	23.5	27.50	29.50	36.00
00	30	5.5	8.5	13. 5	15.50	17.50	21. 0
	60	8.0	12.0	18.0	20.0	22.0	27.0
	90	12.00	17.00	23.5	26.00	28.00	34.00
0000	30	5.5	8.5	13. 5	14.50	16.50	19.50
	60	8.0	12.0	18.0	19.0	21.0	24.0
	90	12.00	17.00	23.5	25.00	27.00	30.00

Sagging the Conductors

Once you have determined the amount of sag by consulting a sagging chart, you are ready to sag the conductors. Begin by securing all the conductors to one end of the pole line.

Do this by clamping the conductors into a dead end "shoe" (see image), then affixing the shoe to the suspension insulator on the dead end pole.

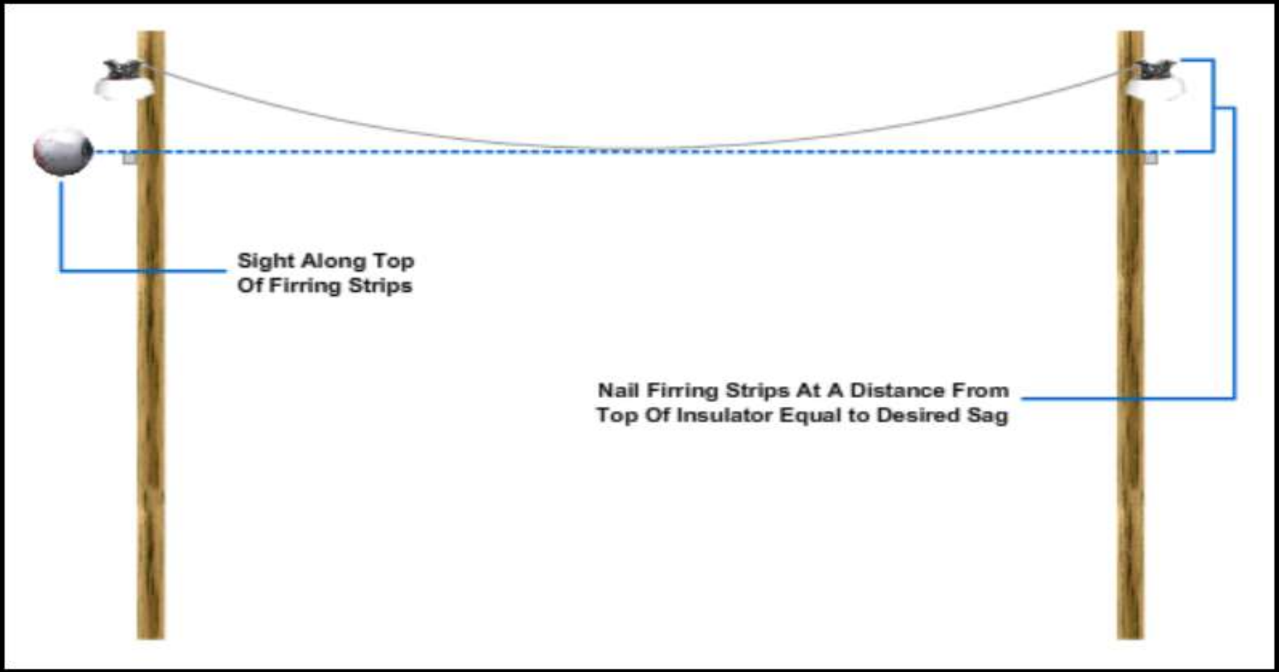
Once you have secured the conductors at one end of the pole line, proceed to the dead end pole at the other end of the pole line. Hang a dead end shoe from the suspension insulator you will sag first.

This will be the top conductor if you are using armless construction or one of the outside conductors if you are using crossarm construction. Hang a small block and tackle from the ring on the dead end shoe.

Using Conductor Grips

The ground support person will then attach a conductor grip to the conductor and raise it on the handline. A conductor grip works like a guy wire grip, except conductor grips do not have teeth in the jaws. Teeth would damage the conductor, so the jaws are smooth. Never use a guy wire grip on a conductor.

Attach the other end of the small block and tackle to the conductor grip, (see image) and remove the handline. The conductor is now suspended from the suspension insulator by the small block and tackle, which the climber can adjust in and out to get the proper amount of sag.



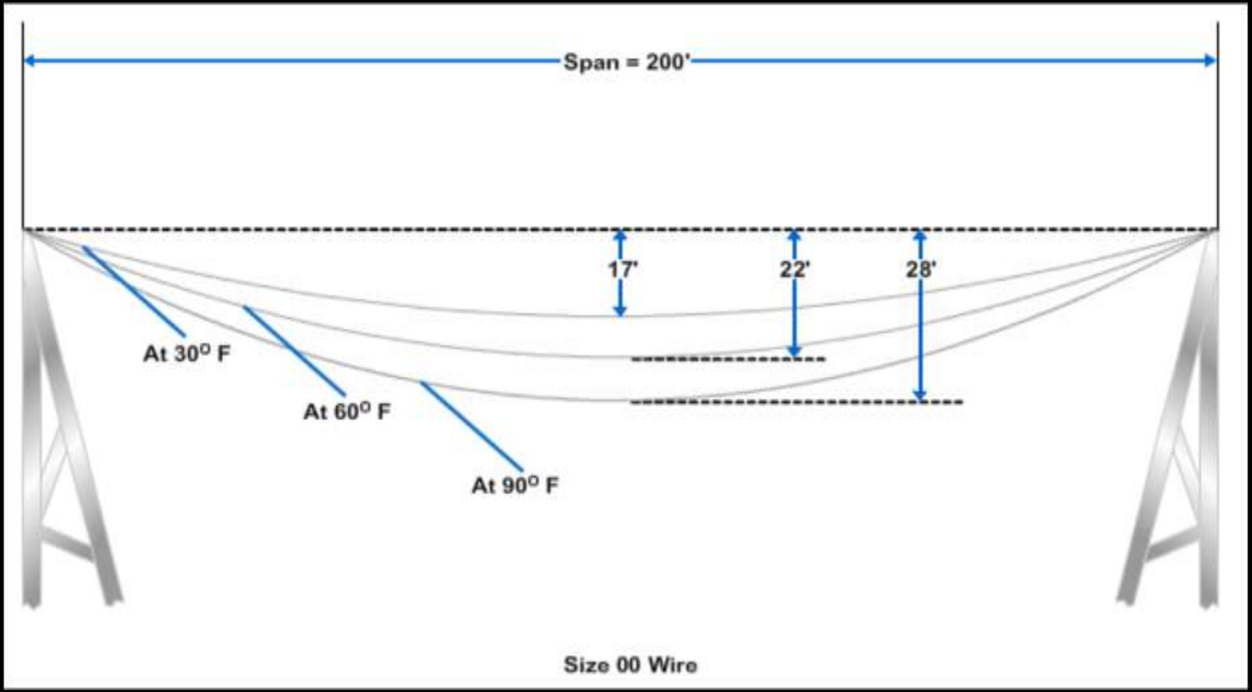
Achieving the Correct Amount of Sag

There are several methods to achieve the correct amount of sag; the sighting method (see image) will be presented here. This entails mounting dowels or similar thin strips of wood (called furring strips) to two utility poles, below the tops of the insulators at a distance equal to the desired amount of sag.

When the two furring strips are in place, an electrician can sight along the top of the strips and adjust the conductor until it intersects with their line of sight. Thus, if the furring strips are mounted 12 inches below the tops of the insulators, when the conductor intersects the line of sight, it will be sagging 12 inches in the middle of the span.

Adjusting the Conductor

Adjust the conductor with the small block and tackle until it reaches the proper sag. Then secure the conductor in the dead end shoe, and remove the small block and tackle along with the conductor grip. Then repeat the process for the remaining conductors.



Equalizing the Line Tension

After the wires are "sagged in," allow a rest period of from 1/2 hour to 4 hours (varying according to the length of the pull) to let the wires adjust themselves to the tension in the pull.

They will gradually "creep" until tension in all the spans is equalized. After they have crept to the final position, you are ready to "tie in." The image above shows the effect of temperature on the sag in a 200-foot span of 00 wire.

Tying in Conductors

Once the conductors are properly sagged, you must secure them on the insulators using conductor ties. Conductor ties keep the conductors on the insulators, and maintain proper sag.

Types of Conductor Ties, and Tying Procedures

When installing conductor ties, you have the choice of using a preformed tie wire or fabricating the ties by hand. Always use new, fully annealed wire for ties. Hard drawn wire is brittle and cannot be pulled up against the conductor and insulator.

When using an aluminum conductor, you are required to cover it with armor rod at each insulator to provide physical protection against rubbing or pitting caused by the elements.

These armor rods are wrapped on the conductor by hand and require no special tools. Another important requirement is the use of ACSR-rated deadend shoes, splice connectors, and all other devices that come in direct contact with an aluminum conductor. This is to prevent electrolysis from the physical contact of dissimilar metals..

Preformed Conductor Tie

Preformed tie wires (shown above) work on the same principle as preformed guy wire wraps. They are installed on the insulator and then wrapped around the conductor, holding it tight.

Preforms are a very quick and easy way to secure conductors to insulators, but they are not "one size fits all." Preforms must be ordered for specific size/type insulators and specific size/type conductor.

Hand Fabricated Tie

To fabricate a conductor tie by hand, use a piece of soft-drawn tie wire as shown above. Use aluminum tie wire for aluminum conductors (including ACSR), and copper tie wire for copper conductors. You will use #2, #4 or #6 AWG tie wire, depending on the size of the conductor. The two basic types of ties are the top tie and the side tie, and the conductor's position on the insulator will determine the type of tie made.

Cut a six- foot piece of soft-drawn tie wire and wrap it around a 2 inch pipe, a soda can, or your hand to form a coil of wire. Separate the coil in the center to create what you see in the above image. This shape makes it easier to handle while on the pole. When forming your tie on the insulator, keep in mind that the key to a good tie is to wrap it as tightly as you can.

Top Ties

Use top ties (left image) to secure the conductor when it is in the top groove of the insulator. You use top ties on poles where there is no angle change.

Side Ties

Use the side tie (right image) when the conductor pulls against the side of the insulator. This occurs on pin insulators when there are line angle changes. You will also use the side tie on spool insulators. Use the following steps to fabricate a side tie.

Protective Devices

Protection from Overcurrent and Overvoltage

Transformers and other equipment on pole lines are very expensive to purchase and very time-consuming to install. To keep them in good working order, you must protect them from overcurrent and overvoltage conditions. You do this by installing protective devices.

You must protect transformers from overvoltage and overcurrent conditions that can cause damage. The two devices that provide this protection are lightning arresters (image above) and fuse cutouts.

Lightning Arresters

The purpose of lightning arrestors is to protect against overvoltage. They provide a low impedance path to ground for lightning and transient over voltages, such as those arising from operating high voltage switches, without injury to line insulators, transformers, or other connected equipment.

When there is an overvoltage condition, the lightning arrestor provides a path to ground to drain off the excess voltage. Once the overvoltage condition has dissipated, the arrestor restores the circuit to a normal condition and prevents the further flow of current to ground.

Overvoltage protection is only one function of protective devices; you must also protect against overcurrent conditions.

Types/Specifications for Arresters

Lightning arresters are designed to permit normal circuit operations at designed voltages. Lightning arresters are essential in all areas of power line construction. These include distribution, secondary, intermediate, and station distribution.

The four different specifications of arresters, (next page) have different spark over voltages, current discharge capabilities, and maximum surge discharge capabilities.

Secondary arresters -used on service and other low-voltage alternating-current circuits.

Distribution arresters - used on primary distribution systems to protect insulators, distribution transformers, and other equipment.

Intermediate type of lightning arrester - is often used on substation exit cables and other locations on the distribution system needing a high level of lightning and surge protection.

Substation types of arresters - are used in substations and generating stations to provide a high level of surge protection for the major pieces of equipment. Surge voltages can be generated by operating switches in the electric transmission system as well as by lightning. Various types of lightning arresters are in use today. The valve, pellet, and air gap are the most common and likely-to-be-seen types in the field.

Valve Type Arrestor

Lightning arrestors have evolved over the years. The valve type arrestor, is the most common type in use today, and consists of a porcelain or polymer (plastic) housing filled with silicon carbide or metal oxide valve blocks.

These valve blocks act as non linear resistors, which keep normal line voltage from passing through the arrestor but conduct surge voltages to ground.

The valve-type arrestors using metal oxide valve blocks are the most modern, and provide more precise control of the voltage level at which the arrestor begins conducting surge voltages to ground.

Isolation Devices on Arrestors

Valve type arrestors are normally equipped with an isolation device, the function of which is to separate the ground lead from the arrestor if the arrestor should fail, the black portion on the bottom of the arrestor is the isolation device.

If the arrestor fails to limit normal line voltage from flowing to ground through the arrestor, the isolation device will heat up due to current flow, and an explosive rivet will blow the ground lead clear of the arrestor. This is the only visual indication an electrician has of a problem with the arrestor.

Classes of Valve Type Arrestors

The valve type arrestor comes in four classes: secondary, distribution, intermediate, and station. Secondary arrestors are used on low voltage circuits ranging from 175 to 650 volts.

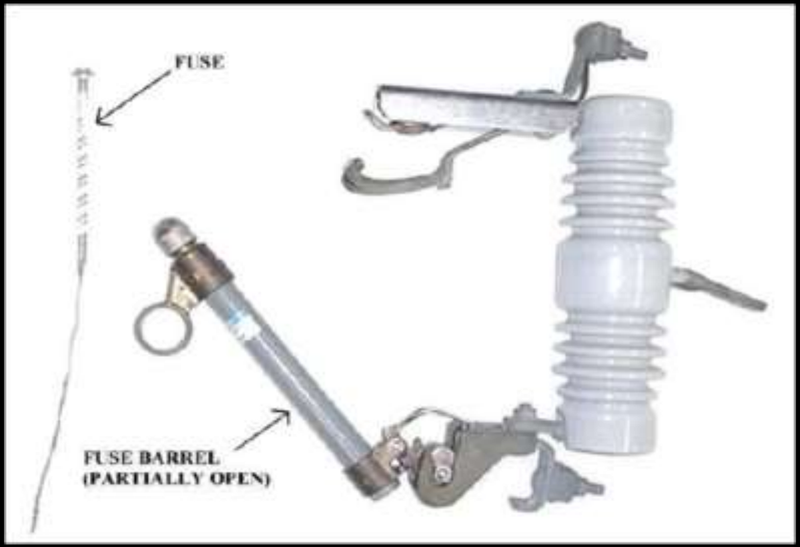
The distribution arrestors are the most common and range from 3 to 30 KV. These are used to protect transformers and other equipment. Intermediate arrestors are used on substation exit cables and where high levels of surge protection are needed.

They range in size from 3 to 120 KV. Station type arrestors are used in substations and generating stations for protection of major equipment and range are 3KV and higher.

Fuse Cutout

The purpose of fuse cutouts (image above) is to protect against overcurrent. Fuse cutouts are inexpensive protective devices put in the circuit to open the circuit when an overcurrent condition occurs.

The fuses are made from a short piece of wire, which is a weak link intentionally placed in the circuit. When this wire heats up due to overcurrent, it melts. This is commonly referred to as “blowing the fuse.” This creates an open, which de-energizes the connected equipment to prevent or limit damage from current overloads and short circuits.



Open Type Fuse Cutout

Like lightning arrestors, fuse cutouts have evolved over the years. There is more than one variety in use, but the one we are going to discuss is the “open type” which is the type most commonly used on overhead distribution lines today.

The open type distribution cutout houses the actual fuse link in a barrel, as shown above. When the fuse link blows, the barrel swings down, creating an easily visible indicator.

The fuse links come in two different types: “K” (kwick) and T (tardy). The K type fuse provides a means of protection against instantaneous fault currents. The T type fuse will withstand the rated current for a set period of time before it will blow.

Sizing of Protective Devices

Before installing a protective device in your distribution system, you must know what voltage and/or current ratings are required of the distribution system. A lightning arrestor is sized according to the voltage of the wire it is protecting.

Wye System - On a wye system you multiply the phase voltage by 1.25. For example: on a wye system of 7200/12470 VAC the phase voltage is 7200 VAC. Multiply this by 1.25 (7200 X 1.25) to give you 9000. Use a 9kV lightning arrestor.

Delta System - On a delta system the arrester must be equal to or greater than the line voltage. If you have a delta circuit of 13,800 VAC, your lightning arrestor has to be equal to or greater than13,800 VAC. If an arrestor is not available in the exact voltage you need (like 13,800), go with the next-largest size.

Sizing of Fuse Cutouts

Fuse cutouts are sized according to voltage and amperage. The cutout should be sized according to the voltage of the system in which it is installed, while the fuse it holds should be sized according to the Full Load Current of the equipment it is protecting.

To determine the proper size fuse, consult a fusing chart in one of the standard electrical references, such as The Lineman's and Cableman's Handbook.

A good practice is to print up a chart of proper fuse sizes (see table to the right) and keep it handy.

FUSE SIZES

KVA	12,470Y / 7200	12,470	12,470
	Wye primary	Delta primary	Delta primary
	1- and 3-phase	single phase	three-phase
3	1	1	1
5	1	1	1
1	2	1	1
15	3	1	3
25	5	3	5
37.5	6	5	6
50	8	6	10
75	12	8	12
100	15	10	15
167	30	15	30
250	40	25	50
333	50	30	65
500	80	50	80

Mounting Protective Devices

Lightning arrestors and fuse cutouts are mounted together, either on a crossarm or armless hardware.

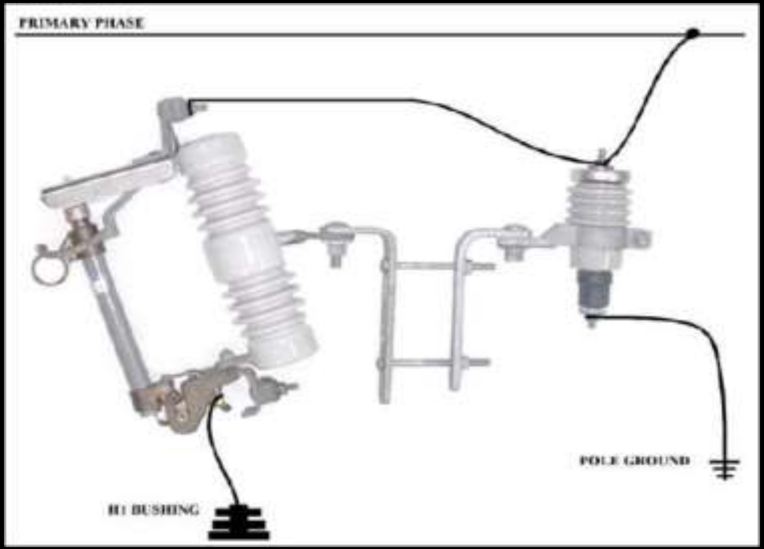
Mount the devices as close as possible to the phase to which they will be connected and to the equipment they are protecting. This keeps the jumper wires short. Ensure that when you mount the fuse cutout, it has sufficient room to allow the fuse barrel to swing freely.

If mounting to a crossarm, use L brackets (shown above) and carriage bolts. If mounting to armless hardware, simply bolt to the standoff arm.

Connecting a Lightning Arrestor

When making connections on protective equipment, use soft- or medium drawn wire. Either copper or aluminum is acceptable. Make the wires as short as possible.

Connections on a lightning arrestor are simple. Connect the top of the arrestor to the primary phase with a hotline clamp. Connect the bottom of the lightning arrestor to the pole ground with a compression fitting or a split-bolt connector.



Connecting a Fuse Cutout

To connect a fuse cutout, install a jumper wire from the top of the fuse cutout to the top of the lightning arrestor.

One piece of wire is often used to connect both the fuse cutout and the lightning arrestor to the primary phase.

Connect the bottom of the fuse cutout to the H1 bushing on the transformer.

Grounding

Grounding in the power distribution system is important. The grounding system protects you and the distribution system when faults occur and aids in the suppression of noise.

Grounds are required every quarter mile on a power distribution line and at every pole when equipment, such as transformers, regulators, capacitors, switches, circuit breakers, and lightning arresters, is installed. The maximum resistance of any distribution ground is 25 ohms, but a lower resistance is desired.

Installing Grounds

The electrical configuration of the primary distribution system, (Wye or Delta), will determine how to install the grounding system. Wye connected electrical distribution systems should be provided with a grounded neutral connection.

The neutral wire is physically connected to earth with a wire that runs down the pole and either attaches to a ground rod or is wrapped around the butt of the pole. Such intentional grounding minimizes the magnitude and duration of over voltages, thereby reducing the probability of insulation failure and equipment damage.

Where systems are delta-connected, no ground will be provided. Neutrals for each voltage level should be grounded independently at each electric power source, at transformer secondaries and at generators.

Connecting to the Neutral

The two common ways to connect a grounding conductor to the system neutral in a Wye connected electrical distribution systems is by way of a split bolt connector or a compression (sometimes called a “crimp”) connection.

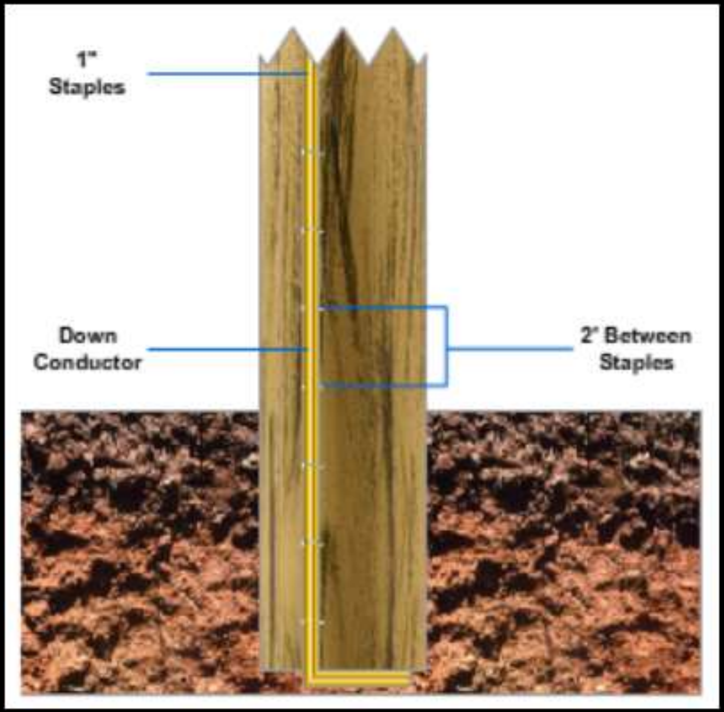
The preferred method is to use a compression connection, as it provides a tighter connection and requires no maintenance. Split-bolt connectors have to be periodically re-tightened. The ground conductor shall have an ampacity of not less than 1/5 that of the conductor (neutral) to which it is attached.

A common size ground conductor used for the system ground is No. 6 AWG soft-drawn copper. This is the same size conductor often used for lightning arresters, pole grounds, and transformer (case) equipment grounds.

Connecting to the Equipment Ground

If system and equipment grounds are on the same pole, they are bonded together and will usually share the same down conductor.

All equipment mounted on poles are required to be grounded and will have some type of connection terminal built in for this purpose. Connections are made with the down conductor using these terminals.



Connecting to the Pole

The down conductor is secured to the pole using in one inch staples. The staples are hammered in place at 2 foot intervals along the length of the pole. (See image)

Locate the grounding conductor on the same side of the pole as the neutral and in a quadrant opposite the climbing space (face) of the pole.

Connecting to the Grounding Electrode

In general, use a minimum 5/8 inch diameter, 8 foot long copper-clad ground rod as the ground electrode. Install the rod 1 to 2 feet away from the pole, and drive the rod until its top is 2 feet below the surface.

Attach the down conductor to the ground rod using an exothermic weld, a compression connector, or a ground rod clamp. The exothermic weld is the preferred method of connection since it is a maintenance free connection. (See image)

Since the resistance of the earth varies, depending upon the soil's composition, moisture content, and temperature a singular ground rod may not enable you to obtain the required ground resistance of 25 ohms or less.

When there is insufficient ground resistance

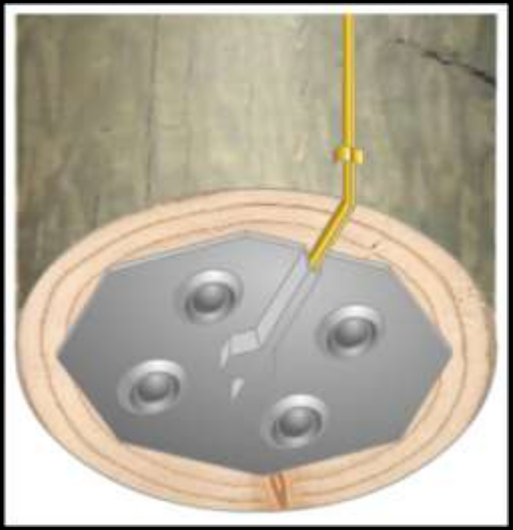
When one ground rod does not provide the required ground resistance, you will have to install additional ground rods or use longer rods as necessary. The space between additional ground rods should never be less than six feet.

Since the ground's resistance usually decreases with depth (because of increased moisture), the use of longer ground rods is normally the first approach you will want to take to obtain a suitable resistance reading. The reason is purely a matter of economics.

Grounding to Metallic Water Pipes

Another option available in obtaining a suitable ground is to make a connection of the down conductor to metallic-water pipes. While connections to a metallic-pipe water system usually provides a very low ground resistance, there is the possibility that water pipe maintenance or other work might result in accidental disconnection of grounds and create a hazardous condition.

Such connections should only be provided as a secondary backup to driven ground rods.



Low Soil Resistivity

In areas of very low soil resistivity, you may use butt wraps (see image) and butt plates; however, only use these types of grounding electrodes as system grounds (a ground rod must be installed for all equipment grounds). A butt wrap is a spiral of wire placed on the bottom of the pole.

It starts at the outside circumference of the butt and circles inward making seven turns. The coil is “shorted out” to itself to prevent it from acting as an inductor which would try to limit current flow.

Shorten it by stapling the ground wire to each coil as it crosses on its way back out to the edge of the pole. The process of installing a butt ground on a pole is obviously something that needs to be done prior to setting the pole in the ground.

Transformers

Transformers are an essential part of any overhead distribution system. Without transformers, you could not provide useable power to the customer. (See image)

Check for Proper Voltage Ratings

Before installing a transformer into a distribution system, you need to conduct a few checks.

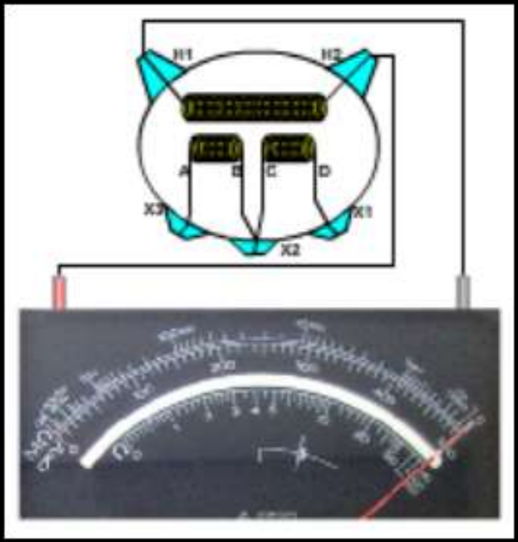
Check the data plate on the transformer (the data plate is a steel tag the manufacturer attaches to the transformer that lists all the important information about the transformer) to ensure the high voltage rating matches your system voltage and the low voltage rating matches the customer's needs.

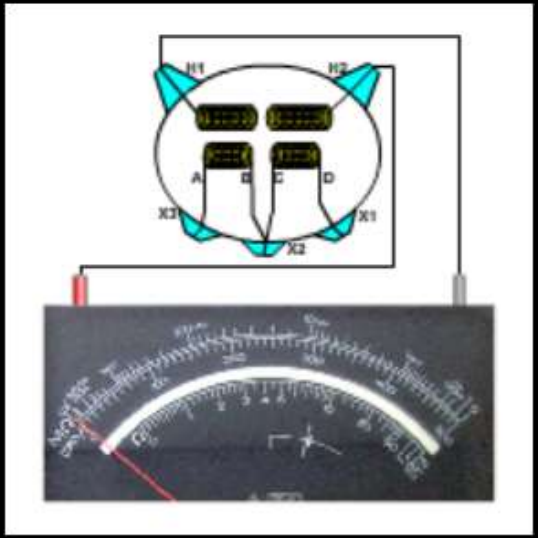
Also, ensure the KVA of the transformer is sufficient to supply the load.

Check the Condition of the Unit

Regardless of whether the transformer is new, rebuilt or used, always check the condition of the unit before installing it.

Use a megohmeter (also called a megger) to test the windings of the transformer for faults. A megger is just a high powered ohmmeter, used to measure very high resistance. In this application, you will be using it as a continuity tester to determine if any of the windings in the transformer are open, shorted, or grounded.

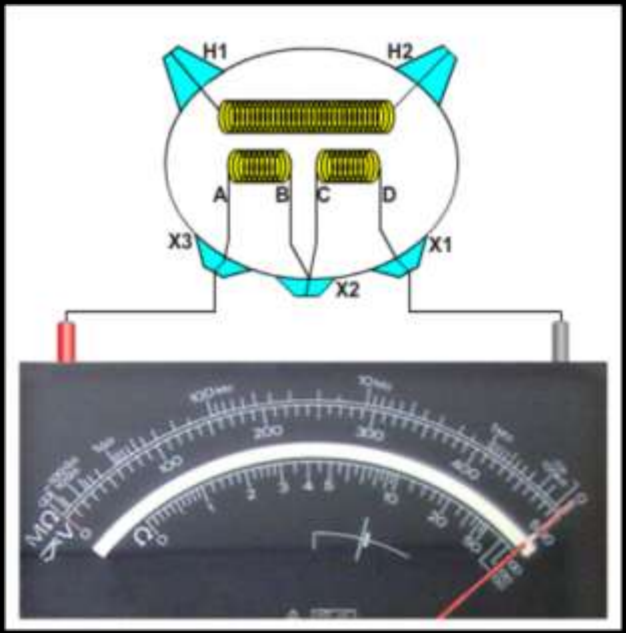


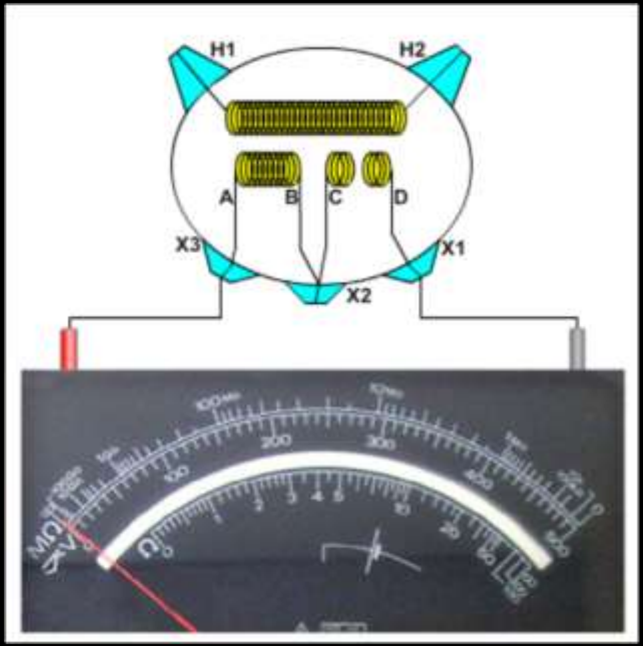


Testing the Primary Windings

To test the primary winding for opens, connect the megger to the primary bushings. If the megger measures zero resistance (meaning there is a continuous piece of wire from one bushing to the other, with no resistance to the flow of electricity), then there is no open.

(See left image) If the megger reads infinity (the megger reads an infinite amount of resistance because there is no path for electricity to flow) that means there is an open in the winding. (See right image)

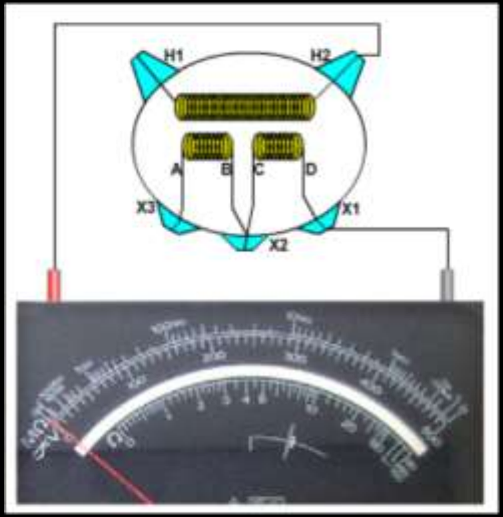


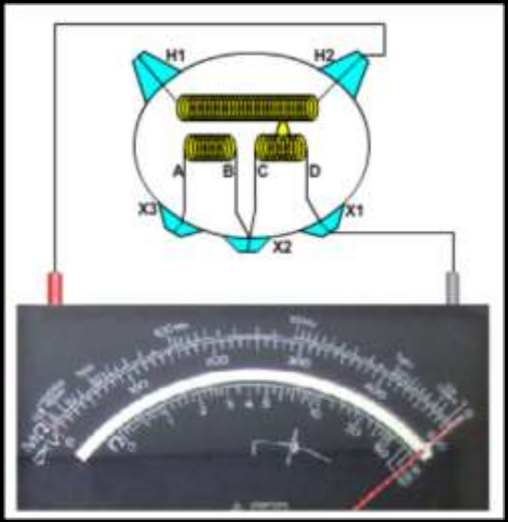


Testing the Secondary Windings

Test the secondary windings for opens in the same way you checked the primary winding. If the secondary windings are connected in series, you can test both at the same time.

Again, a megger reading of zero indicates that there is no opens in the winding. (See left image) A megger reading of infinity means there is an open, and the transformer is unusable. (See right image)



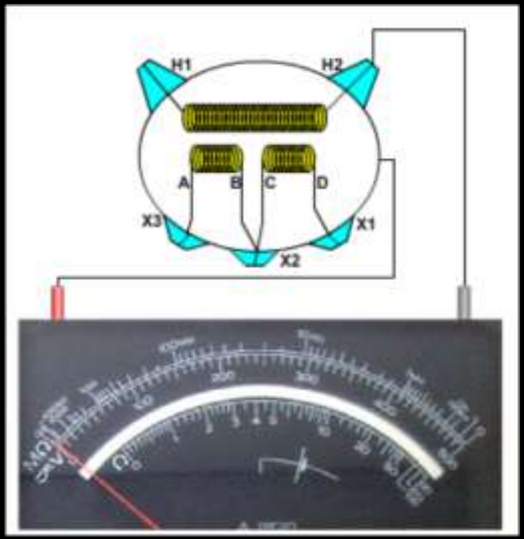


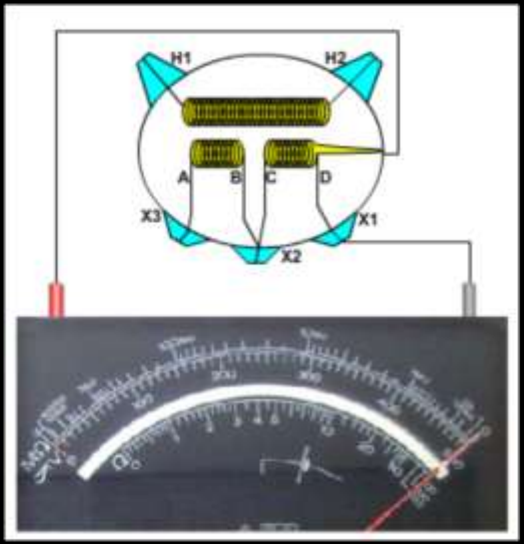
Testing for Shorts

When testing for a short, you are checking to see if the primary winding and the secondary winding are touching. The windings are wound together in layers on the core of the transformer, insulated from each other by a thin coating of varnish and oil impregnated paper.

If the insulation fails, the transformer will not work properly, and could even explode if the short is bad enough. To test for a short, connect one lead of the megger to the primary winding and connect the other lead to the secondary winding.

A reading of infinity means there is no short, meaning the windings are not touching and there is no path for electricity to flow. (See left image) A reading of zero means the windings are shorted (see right image) together and the transformer is unusable.





Testing for a Ground

Checking for a ground means you are testing to see if one of the windings is touching the case of the transformer, which will be connected to ground when it is installed.

You test for a grounded winding by connecting one lead of the megger to the transformer case and connecting the other lead to each of the windings. A reading of infinity means there is no ground (left image); a reading of zero means the winding you are connected to is grounded (right image) to the case, and the transformer is unusable.

Testing Dielectric Strength of Oil

Before installing and applying power to any equipment that is filled with oil, test the oil in an oil tester to make sure it retains the proper di-electric strength.

If the oil is contaminated, it will not insulate properly and the equipment will be damaged or destroyed if voltage is applied to it.

The oil is tested between two circular electrodes set in a test cup. Space the electrodes one-tenth of an inch apart, and apply and increase voltage until an arc jumps across the electrodes. The voltage level at which this happens is an indication of how much dielectric strength the oil has.

Procedures for Dielectric Strength Test

When dielectrically testing an oil:

1. Take sample from the bottom of the oil tank. This will be the most contaminated oil, and you want to check the worst of the oil (if the worst of the oil passes, you know the remaining oil will also pass).
2. Allow the sample to sit for at least 8 hours to allow air bubbles to dissipate.
3. Before filling test cup, gently swirl sample jar to distribute impurities (do not shake – this will introduce air bubbles).
4. Slowly fill test cup to a level not less than 2 centimeters above the electrodes.
5. Place cup in tester and allow to stand not less than two minutes or more than three minutes.
6. Apply voltage and increase (no faster than 3000 volts/second) until an arc jumps across the electrodes, and note the reading on the voltmeter.
7. Empty test cup into second sample jar for return to transformer.
8. Repeat steps 4-7 for a total of five tests.

Check for consistency in readings. If readings are consistent, average the five readings and compare the result to a chart such as the one shown in table 7-5. This chart was developed by the ASTM.

DIELECTRIC BREAKDOWN VOLTAGE	
NEW OIL AS REC'D	28KV MIN/36KV AVG
NEW OIL PROCESSED	30KV MIN/36KV AVG
NEW OIL TAKEN FROM NEW EQUIPMENT	30KV MIN/36KV AVG
OIL FROM EQUIPMENT IN SERVICE	
69KV AND BELOW	25KV MIN
69KV TO 288KV	29KV MIN

Verify Oil Purity

Check for consistency in readings. If readings are consistent, average the five readings and compare the result to a chart such as the one shown in the chart above, which was developed by the ASTM.

If the oil does not meet the minimum requirements, it must be replaced or filtered to remove impurities. Ensure the oil is at the proper level before putting the transformer into service.

Check the Mechanical Condition

Once you complete the electrical tests and verify the condition of the oil is, check the mechanical condition of the unit. Check for cracked or leaking bushings, cracked welds and rust. Ensure the mounting brackets are not bent, and the lift points are in good condition.

Installation Locations

When conducting overhead line construction, transformers are usually installed on the utility poles, but occasionally they may be mounted on concrete pads. When more than one transformer is mounted to a pole, the weight must be distributed equally on both sides of the pole.

Where to Place the Transformers

When conducting overhead line construction, transformers are usually installed on the utility poles, but occasionally they may be mounted on concrete pads.

When more than one transformer is mounted to a pole, the weight must be distributed equally on both sides of the pole.

Pole-Mounted Transformers

Transformers can be mounted directly to the pole. This type of installation is the cheapest way to install a transformer because it requires very little hardware. The size and weight restrictions depend largely on the class of the pole.

Three phase transformer banks (consisting of three single phase transformers wired together) can be installed on a pole by using a cluster bracket. Cluster brackets come in two types: through-bolt and radial (sometimes called wrap around). The through-bolt bracket mounts on two through bolts installed in the pole.

The radial bracket requires no holes to be drilled; it is clamped around the pole and tightened, squeezing the pole. Up to three 100 kVA transformers can be installed using a cluster bracket; see image.

On Pads

Even in an overhead distribution system, transformers are sometimes placed on concrete pads. This requires a riser pole to transition the overhead primary phases to underground cable, which is then run to the pad.

The main benefit of mounting on a pad is that any size transformer can be placed on a pad. An added benefit is that a pad mount transformer being fed from underground makes for a more attractive installation.

Installing Transformers on a Pole

Transformers can be installed directly to poles using either the manual method or the truck method. The equipment available to you, as well as the location of the work, will determine what method you use.

To install a transformer manually, you will need a transformer gin (as shown in the image), a large block and tackle, a transformer sling, and a tagline. If you use a truck to install a transformer, you will need a transformer sling and a tagline.

Manual Installation of Transformers

To install a transformer to a pole manually, gather the equipment listed above, along with hand tools, a handline, and mounting hardware (two through-bolts, two flat washers, two nuts).

The climber ascends the pole to the appropriate working height and belts in. He/she will then install the handline above the work area in order to raise and lower equipment and tools.

Consult the specification sheet, and drill the holes for the two through-bolts in the proper location. Use a brace and bit to drill the holes from the side of the pole where you will install the transformer. When you have drilled both holes, raise the transformer gin and install it directly over the through-bolt holes as high as possible.

Maneuvering the Transformer into Place

Raise the block and tackle next and hang it in the ring of the transformer gin. Install the through bolts so the bolt heads extend 2 inches. on the transformer side of the pole. No washers are required under the bolt heads.

Ensure the through bolts are the proper length; no more than 2 inches. of a through-bolt should extend from the pole after tightening. While the through bolts are being installed, the ground support person can prep the transformer to be raised.

Move the transformer to the base of the pole directly below where you are going to install it. When you move a transformer, NEVER lift it by the bushings.

In order to raise the transformer, you must hook a transformer sling over the lifting points and then attach it to the block and tackle. You must also attach the tagline using a timber hitch.

Mounting the Transformer

The ground support person raises the transformer with the block and tackle, while guiding it away from obstructions on the pole by using the tagline. When it is within reach, the electrician on the pole will help guide the transformer until the mounting brackets are slightly above the through bolts.

The climber directs the ground support person to raise or lower the transformer while he/she guides the mounting brackets to capture the heads of the through bolts.

With the through bolt heads captured in the mounting brackets and the weight of the transformer on the through bolts, the climber tightens the top bolt and then the bottom bolt. When the transformer is secure, the lifting equipment can be removed.

Truck Installing a transformer using a truck differs from a manual installation only in the method of raising the transformer.

All procedures are the same, except the ground support person raises the transformer with the winch line of the truck instead of a block and tackle.

Service Drops

Service drops are a critical part of delivering electricity to our customers. The service drop conductors take power from the transformer and distribute it to the various loads.

The purpose of a service drop is to distribute the low voltage (secondary) from the transformer to the customer(s).

Single-Phase Service Drops

Single phase service drops are used mostly for residential housing and streetlights. The term “single phase” refers to the fact that the service drop is distributing power from a single phase transformer.

Since single phase distribution transformers can provide one or two voltages, single phase service drops can be one phase and a neutral or two phases and a neutral.

Three-Phase Service Drops

Three phase service drops are used mostly for industrial and commercial areas. The term “three phase” refers to the fact that the service drop is distributing power from a three phase transformer or from three transformers connected together to give three phase power.

Facilities with large lighting loads or large motor loads require three phase power. A three phase service drop will have three conductors and may also have a neutral.

Types of Conductors

Before installing a service drop, consider the type of conductor best suited to your needs. A service drop is merely a bundle of conductors. You can hang these conductors as several single conductors or use “plex” conductors.

If the secondary will use very large conductors (due to a large amount of current), you will want to use a single conductor installation. If the load is not very large, plex conductors are the wise choice.

Single Conductors

Single conductors are used for large secondary loads. The large load requires large conductors and this makes a plex conductor arrangement too awkward to handle.

Plex Conductors

Plex conductors consist of a piece of ACSR with one, two, or three insulated aluminum conductors twisted around it. The ACSR holds the weight of the entire assembly and acts as the neutral, while the insulated conductors carry the low voltage to the customer.

If there is one insulated conductor and one bare piece of ACSR, it is called duplex. Triplex is two insulated conductors wrapped around one bare ACSR conductor. Quadraplex is three insulated conductors wrapped around one bare ACSR conductor.

Size of Load

The size of the load determines the size of the conductor you will install. The conductor must be large enough to safely carry the amount of current the customer needs.

Span Length

Another consideration is span length. Span length is the distance a conductor runs between two supports.

The maximum span length for a service drop is 125 feet. If the span is longer, it requires an intermediate support pole.

Clearances

Base the clearance height for conductors on both the voltage they carry and where they are located.

Service drops not subject to vehicular traffic require a minimum clearance of 12 feet, while service drops that span an alley or a street require a minimum clearance of 16 feet.

The clearance is measured at the lowest point of the sag.

Attachment Devices

The last pre installation consideration is how to secure the service drop. You can use a number of different attachment devices to secure service drops.

Spool Racks

Spool racks are rows of spool insulators placed on a steel support that separate the spools and provide an attachment point to poles or other supports. (See image)

Spool racks are used for single conductor installations.

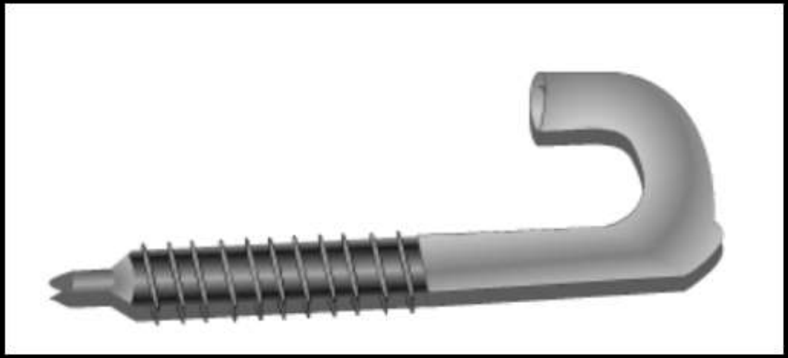
Attach the conductor to the spool by passing the conductor around the insulator and wrapping it back onto itself.

Clevis

A clevis and spool insulator, above, is commonly used to support plex conductors. You will most often see spool insulators mounted directly to the pole with a clevis supporting distribution system neutrals.

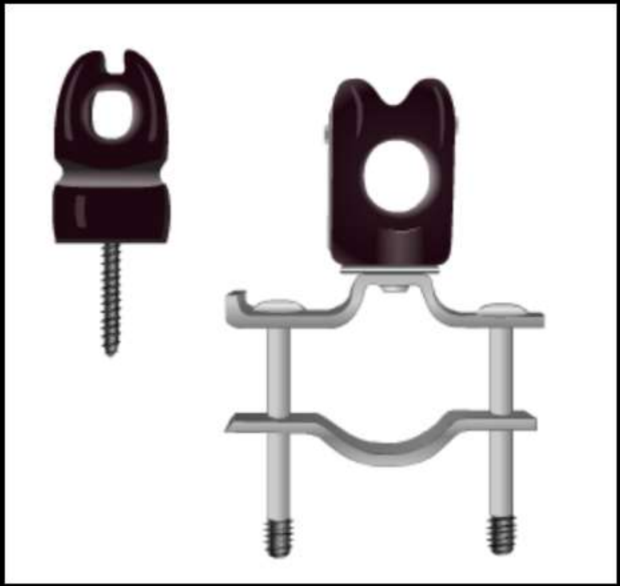
Installing a clevis and spool insulator is relatively simple. you can see that a through bolt is fitted through the clevis. Mount the through bolt/clevis assembly to the pole, and then secure the spool insulator in the clevis with a clevis pin and cotter key.

Be sure to correctly orient the spool insulator with the grooved end on top and drop the clevis pin through the clevis/spool from above with the cotter key inserted on the bottom side.



J-Hook

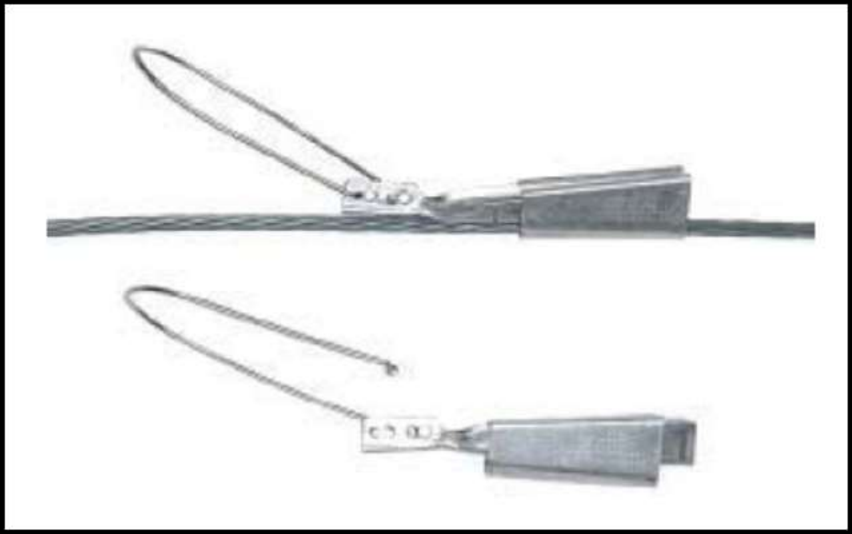
A J hook is a lag screw with a curved head so that it resembles a "J". (See image) You drive it into the pole like a lag screw and use it in conjunction with a wedge clamp.



House Knob

House knobs, as seen in the image above, are small insulators either screwed in like a lag screw or clamped around a pipe.

They are designed for smaller sized conductors because they cannot withstand the strain of large conductors.



Wedge Clamp

A wedge clamp (see image) is a wedge-shaped piece of steel with a wedge shaped sliding sleeve that is placed on the ACSR conductor in a plex arrangement. The clamp tightens as strain is placed on it.

It has a wire that fastens and unfastens to allow attachment to a spool insulator, J hook or other device. The wedge clamp is sized according to the size of the conductor, and is the quick, easy way to attach plex conductors.

Installing a Secondary Service

The first step in installing a secondary service is to roll out the conductors. The secondary conductor comes on a wooden reel or coiled up. Place the conductor at the service pole (the load side), and roll it out to the utility pole (line side).

Stretch the conductor across the ground from the service pole to approximately 5 feet. beyond the utility pole and then cut. It is important to have conductors of adequate length because splices are undesirable.

After cutting the conductors, attach the service drop to the support device at the service pole. Leave enough extra wire to make your connections.

When the connection is secure, climb the utility pole and raise the service drop conductors on a handline.

Sag secondary conductors by hand to achieve the proper clearance, and attach them to the attachment device. Again, leave enough conductor to make connections, and then cut off any excess wire.

Make the Load Side Connection

Once you have properly sagged and secured the conductor at both ends, make the electrical connections. Before making any connections, ensure the customer's service equipment is de-energized, and if possible also de-energize the transformer. This ensures that voltage is not provided to the customer until you have checked it. Make the load-side connections first, then the line-side connections.

To make the load-side connections, you must splice the service drop conductors to the customer's service entrance cable. Use either compression connections or mechanical connections, and when the connection is complete, tape over the exposed connection and any exposed conductor. Tape the connections thoroughly to prevent shorts and grounds. It is not necessary to tape the neutral connection.

Make the Line Side Connection

To make line side connections to the transformer, simply strip the insulation from the conductors and clamp them in the appropriate secondary bushings.

Once you complete the line side connections, energize the transformer. Before you turn on the customer's service equipment, take voltage readings to make sure the output is the correct voltage and within allowable tolerances for the customer. Once you determine that the correct voltage is coming from the transformer, you can energize the customer's service equipment.

Transformer Connections

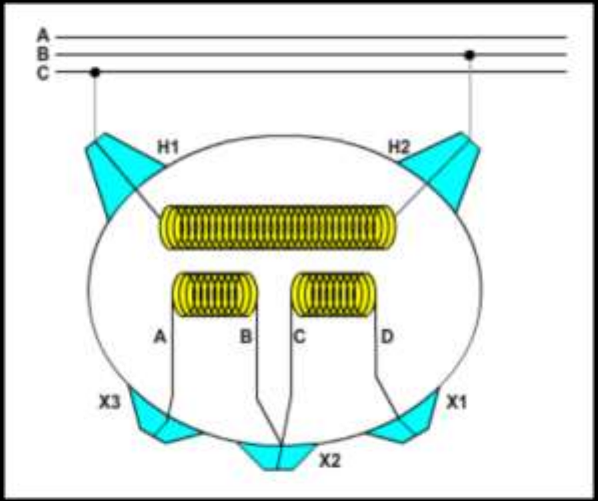
We use transformers every day and don't even realize the important role they play in our lives. In this section you will learn how to connect a single-phase transformer, including the factors to consider when making the primary and secondary connections.

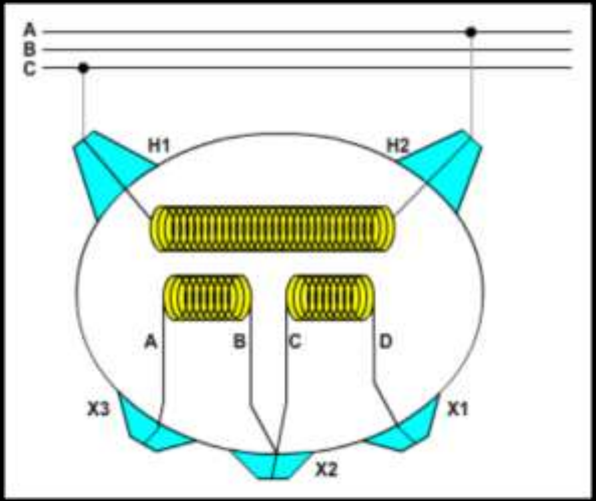
Transformers step up or step down voltage to a usable level for the customer. As an example, the voltage coming into an installation is 69,000 volts, which is stepped down to 7200/12470 volts before being distributed throughout the base. Another transformer steps down the 7200/12470 voltage to 480/277 volts. This voltage is used for power and lights.

Ground Connection

The first connection made to all transformers once they are in position is the equipment ground (sometimes called the case ground).

(See image) Make this connection by installing a ground lug, then installing a piece of wire from the ground lug to the pole ground. You must attach the pole ground to a ground rod; a butt wrap cannot be used for an equipment ground.





Primary Connection

After safely grounding the case, connect the primary. You will connect the primary in one of two ways, depending upon the distribution system voltage and how the high voltage rating of the transformer matches up.

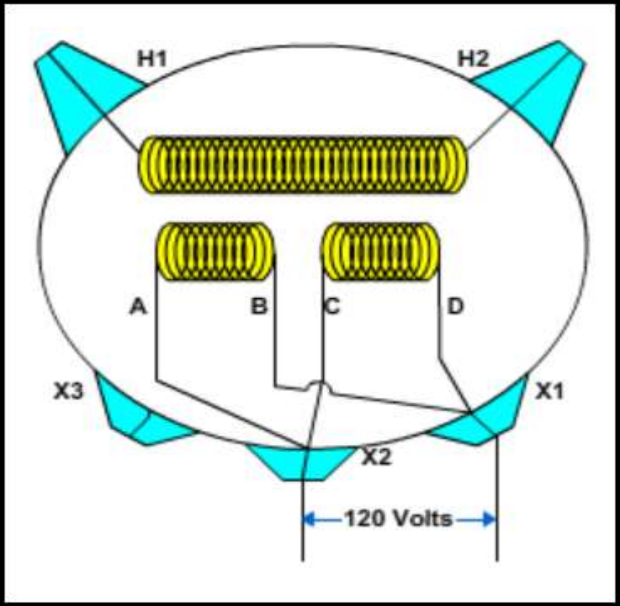
You will use either a line voltage connection (image on the left) or a phase voltage connection (image on the right).

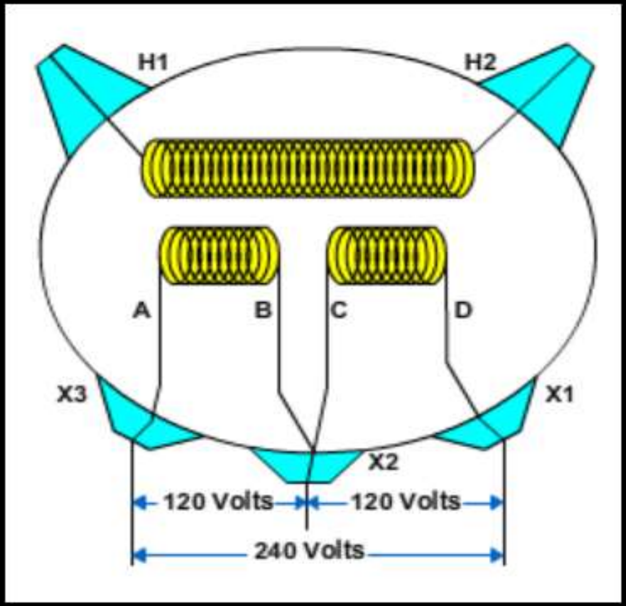
Line Voltage Connection

Make the line voltage connection by connecting the H1 bushing to a phase and the H2 bushing to a different phase. This connection utilizes the system line voltage to power the primary winding of the transformer.

Phase Voltage Connection

Make the phase voltage connection by connecting the H1 bushing to a phase and the H2 bushing to the system neutral. This connection utilizes the system phase voltage to power the primary winding of the transformer.





Secondary Connections

Single phase pole mount distribution transformers have two identical secondary windings which can be connected in one of two ways. If the low voltage rating of the transformer is 120/240 volts, then each winding provides 120 volts.

If you connect the windings in parallel, the transformer will provide only 120 volts (see image-left).

If you connect the windings in series, you can still get 120 volts from one winding, but you can also get 240 volts by measuring across both windings (see image-right).

Three-Phase Connections

Industrial, commercial and institutional facilities use threephase power. One way to provide this power is with a three phase transformer. Another way to provide three phase power is to "bank" three single phase transformers together.

See image above. Banking transformers involves hanging three transformers on a pole and making internal, primary and secondary connections to provide three-phase power to the customer.

Just like the primary distribution system, three-phase secondaries can be either wye or delta. The needs of the customer will determine what kind of secondary they need.

Delta secondaries are used for heavy power loads (like factories), while wye secondaries are used when the load is evenly split between power and lights (like the schoolhouse). You can provide either a delta or a wye secondary, depending on how you make the internal and secondary connections on the transformer bank.

Underground Distribution Systems

Confined Space

Confined Space is addressed in an Occupational Safety and Health Agency (OSHA) program that pertains to private industry and agencies throughout government. S

ince
this program is very extensive, you should only be concerned with knowing the sections that directly affect you as an apprentice electrician and that the program's standards require mandatory compliance.

In particular you need to know that the most common confined spaces to which you will likely be exposed are manholes, trenches, crawl spaces, underground vaults, and hardened missile and communication silo complexes.

Manholes are a key subsystem of any Underground distribution system. Manholes, by definition, are holes in the ground that allow entrance to utilities such as electrical, water, and sewer.

Features of a Confined Space

A confined space is an area that has the following three features:

- Is large enough to enter and perform work
- Has limited or restricted means of entry or exit (something you can not easily get into or out of). For example: tanks, silos, trenches, manholes and crawl spaces
- Is not designed for continuous employee occupancy (like an office or lab area).

Since manholes have these features, you are required by federal standards to follow certain procedures for safe entry.

Permit Required

Confined spaces are classified as permit required or non-permit required.

A "permit required" confined space has one or more of the following characteristics:

- Contains or has a potential to contain a hazardous atmosphere.
- Contains a material that has the potential of engulfing the entrant.
- Has internal configuration such could trap or asphyxiate an entrant with inwardly converging walls or a floor that slopes downward and tapers to a smaller cross-section.
- Contains any other recognized serious safety or health hazard.

Permit required spaces

Permit required spaces are those that have need of the following: entry supervisor, attendant, and entrant.

All entry personnel must be trained in confined space entry, rescue procedures, and safe work practices. Workers must posses an entry permit that outlines the conditions of the space upon and during entry into the confined space.

The entry supervisor, normally the crew leader at the job site, has overall responsibility on the site. This supervisor ensure that personnel on the site are trained, that all safety equipment is available ready for use, and permit conditions are met.

Attending the Manhole

The attendant must maintain communication with the entrants at all times. They are to remain outside the space and not attempt any rescue that involves entry until the rescue team has arrived. They are to make rescue attempts only by means of a lifeline prior to the rescue team's arrival.

If the attendant must leave for any reason, they are to order the entrants to exit the confined space. They also prevent unauthorized persons from entering the permit-required space.

The entrant must follow all safe work practices required by supervisory personnel. The entrant will wear a harness and be connected to the rescue equipment at all times. He or she must also notify the entry supervisor when hazards exist that have not been corrected and if they are taking any medication.

Non Permit Required Spaces

A non permit required confined space is a space that does not contain or, with respect to atmospheric hazards, have the potential to contain any hazards capable of causing death or serious physical harm. Most manholes fall into this category.

A non permit required confined space will be evaluated at least annually to ensure conditions have not changed to make it a permit-required space.

A non permit environment does not require permit, attendant, or site supervisor. The only requirement is to test the atmosphere prior to entry to verify that the work environment is a safe.

It is an industry standard to have a minimum of two workers at the job site of a non permit confined space.

Physical Hazards

Even if a confined space is classified as a non permit required space, the space may still contain other physical hazards, such as rodents, poisonous snakes, insects, slippery surfaces and deteriorated ladders.

Introducing Hazardous items onto Confined Spaces

Workers often intentionally or unintentionally introduce hazards into the confined space area. For example, some cleaners and heat sources used during the cable splicing process may create a hazardous condition within the confined space.

Using a cigarette lighter as a light source or failing to redirect the exhaust fumes of work vehicles or gasoline powered manhole pumps or blowers can inadvertently introduce hazardous conditions.

You must be constantly aware of the equipment and chemicals in your work area to avoid creating a hazardous confined space.

Prepare Manhole Area

Knowing the procedures to test and prepare a manhole can help minimize the hazards associated with confined spaces.

Because manholes are generally located in populated areas that are subject to pedestrian and vehicular traffic, you as well as the general public are subject to the hazards created by open manholes and the unavoidable presence of motor vehicles.

These factors will obligate you to provide safe guards and perform preliminary actions prior to the work actually being performed.

Examples of safe guards and preliminary actions are: set up traffic control equipment, remove manhole cover, and pump out water as required.

Setup Traffic Control Equipment

Several devices provide protection for personnel working in and around a manhole. Some of these are manhole guards, barricades, cones, and signs (see image)

If a manhole is in a vehicle traffic area, use cones to redirect the flow of traffic around the manhole and signs to control the flow of traffic.

If the manhole is on a sidewalk, place barricades around the manhole to prevent people from falling into the open hole. These traffic-warning devices are of little value unless properly displayed.

Remove Manhole Cover

Manhole covers vary in weight depending on the type of manhole and its location. It is not uncommon for a manhole cover to weigh 200 to 350 pounds. Because of this, two people are required for safe removal and reinstallation. They lift the cover using manhole hooks and the leg muscles. They must never lift with their backs.

If snow, ice, or other conditions cause insecure footing around the manhole cover, clear the working area with a shovel or broom.

Other options are to spread ashes, sand, or other suitable material around the cover to ensure firm footing. Your feet must be placed so they will be clear of the cover as it is removed. Since two people will be involved in the removal, good communications and coordinated action will be essential to the task at hand.

Frozen Manholes

If the manhole cover is encased in ice do not strike it with a steel or iron tool. The striking of steel or iron against a steel cover may cause an explosion if the manhole contains a combustible gas.

Use a hardened bronze cold chisel to remove the ice. The bronze cold chisel will not cause sparks when it strikes the manhole cover.

Do not use an open flame or salt to thaw ice around or over the cover. An open flame may also cause an explosion if a combustible gas is present in the manhole. A salt solution seeping into the manhole may contribute to cable and equipment corrosion.

Avoid.....

As a last note, never strike the center of a manhole cover to break it loose of ice; this may cause it to crack, especially in extremely cold climates. You must wear personal protective equipment when working in a manhole.

This equipment will include safety toed boots, gloves, and a hard hat. Use gloves to protect your hands as you grip the manhole cover hook and maneuver the cover out of the way. Safety toed boots protect your feet, and a hard hat protects your head while you are in the general work area and down inside the manhole.

Pump out Water as Required

In order to perform preliminary atmospheric detection testing or work in a manhole, you must first remove any water that may be present. Use powered water pump equipment to remove the water in a timely manner. There are two categories of water pumps, permanent and portable. Each will pump water out of a manhole, and each has its own particular area of use.

An example of a permanently installed water pump is the automatic sump pump. As the water level rises, a float closes a switch activating the pump. These pumps are not used in many manholes mainly for two reasons, cost and power supply. Installing pumps in every manhole would be very expensive, and most manholes are not equipped with available power.

Auto/Portable Sump Pumps for Manholes

Manholes with an automatic sump pump generally contain critical components or equipment (i.e., transformers or load break elbows) supporting the underground distribution system and are entered often in support of maintenance on that equipment.

An example of a portable pump is the submersible pump, seen in the above image. This type of pump is brought to the job site by the worker. Some models require a 120 volt AC power source, while others run from a vehicle battery or hydraulic system.

This type of pump can extract any amount of water that may be found within a manhole, however, if time is a factor it is not the pump of choice Since it can only pump a relatively small volume of water per minute. (All pumps are rated by gallons per minute).

Large Capacity Pumping

In cases where time is a factor a gasoline powered pump, as seen above, is best suited. This pump can remove large quantities of water in a short period of time.

These pumps come in several different styles depending on the manufacturer. When you operate the pump, ensure the unit is located downwind from the manhole. This will prevent exhaust fumes from entering the manhole.

The discharge line on all three types of pumps should be placed approximately 10 feet downhill from the manhole opening to prevent the water from running back into the hole.

Harmful Gases and Gas Detection

Description of Gas Detector

Before entering a manhole, always check the atmospheric conditions with a gas detector. The gas detector is a rechargeable, battery-powered instrument that uses three independent sensing elements operating simultaneously.

Gas detectors are designed to detect combustible gases, toxic gases, and oxygen deficiency conditions. Most detectors have both audible and visual alarms. If the detector senses an unfavorable condition, a light will illuminate and a buzzer will sound.

Combustible Gases

Combustible or explosive gases are usually natural gas or hydrocarbon fuels. Two examples of hydrocarbon fuels common to military installations are gasoline and jet fuel.

These fuels are highly explosive; therefore, be careful when you encounter them in a manhole.

Do not smoke or bring open flames near a manhole. Use only approved lighting and heating equipment in a manhole since the making or breaking of an electrical circuit may cause an arc.

Toxic Gases

There are several toxic (poisonous) gases you may come in contact with while working in and around manholes. Some of the more common gases are carbon monoxide, hydrogen sulfide, and mangrove gas (swamp gas).

These gases are very dangerous and in the case of hydrogen sulfide, respiratory paralysis may result within a matter of seconds.

Oxygen Deficiency or Excess

The normal amount of oxygen in the air is 20.8%. When the amount of oxygen is reduced to 12% or less, blood starvation begins and will cause death within one to three minutes. Sometimes, difficulty in breathing or a ringing sensation in the ears can be a sign of oxygen deficiency, but this does not always happen.

For this reason, air in manholes containing less than 19.5% oxygen is considered dangerous and no one will enter the manhole until corrective action has been taken to correct the deficiency.

Too much oxygen is also dangerous. The gas detector will detect that occurrence as well. A reading of more than 23.5% oxygen is considered a dangerous condition.

Inspect Gas Detector

It is very important you inspect the gas detector prior to each use. Make sure that you follow the inspection procedures outlined in the operation manual; your life may depend on it.

During the inspection procedures, you are required to purge the detector prior to each use. This cleans off all contaminants from the sensors, ensuring that no faulty readings occur during calibration. Do this in a fresh air environment to prevent any contaminants from entering the meter during calibration.

Lower Meter and/or Hose

Since some gases are heavier than air; they still can be present at the top of the manhole while other types may be towards the bottom. For this reason you must take air sample readings at several levels by slowly lowering the meter or the meter's hose towards the bottom of the manhole.

Do not allow the meter or meter's sample tube to contact the floor of the manhole as the gas detector could draw in dirt or water, obstructing the airflow to the meter. If the test indicates it is safe to enter, you may climb into the manhole and check the corners and duct openings as well. If the non-permit confined space is determined safe, then you can remove the detector and put it away.

Permit-required Spaces must be Continuously Monitored

However, it is highly recommended to leave the detector in the space during the entire time the space is occupied. In a permit-required space, the meter must remain in the space and continuously monitor the environment.

As stated previously, most detectors will have both audible and visual alarms. If one or both of them are activated during the initial test, you must ventilate the manhole to correct the deficient condition prior to entering.

Retest as Necessary

If the initial test proves the atmosphere is safe, you may enter the manhole and begin working.

Situations which would require a Retest

- When the manhole is covered with a tent or tarpaulin, it is recommended that it be tested in intervals not to exceed 2 hours.
- While working in a manhole being ventilated with a power blower because of previous detection, test the atmosphere every hour.
- Retest after the removal of any previously secured duct plug or plugs.

Each installation will have its own local policy on how often you should retest the atmosphere. Know what the local policy is and retest the atmosphere accordingly.

Safety

It is important to always keep safety in mind while working in and around manholes. Manhole work can be fatal if you do not take the proper procedures. Always prepare the work area by setting up and using traffic control equipment. This will draw attention to the work site and prevent people from getting too close.

Never, under any circumstances, enter a manhole without testing for both explosive and toxic gases and oxygen deficiency. Remember, testing manholes is done to ensure a safe environment.

Do not forget prior to each use to test the gas detector to ensure it is functioning properly. Once you enter the manhole, it is recommended that you leave the detector on. Do not take hazardous materials into the manhole; this may create an unsafe work environment.

Remember, a manhole can be deadly if you do not follow proper procedures and remain alert to the signs and symptoms that may be indicators of a serious atmospheric problem.

Manhole Ventilation

Purpose of Ventilation

If the manhole atmosphere proves to be unsafe, you must ventilate the manhole. Ventilating procedures prevent or correct hazardous atmospheres in manholes by supplying fresh air.

There are three methods of ventilation: forced air, natural, and sail.

Forced Air

This is the best method of ventilating a manhole. The forced air method uses a gasoline powered power blower (see image) to force fresh air into a manhole. Like the portable pumps that you learned about in an earlier lesson, power blowers are brought to the job site by the worker.

A blower hose and/or manhole saddle are attached to the power blower and routed into the manhole, forcing in fresh air.

Natural

The natural method is simply taking the manhole cover off of the manhole being worked and letting the air naturally circulate.

This method of venting a manhole is the least effective. One reason this method is so ineffective is that a gas heavier than air could lie in the bottom of the manhole and not be forced to rise out.

Sail

The sail method uses the wind to ventilate a manhole. Use a piece of plywood or some other material for this method. Lift up the edge of the plywood facing the wind until the plywood forms about a 45 degree angle with the manhole opening. The wind is thus trapped and forced into the manhole, removing the bad air.

You can enhance the effectiveness of both the natural and sail methods by opening several adjacent manholes along the route of the manhole to be worked.

This process works on the same principle as opening a window on one side of your house and then opening an outside door, creating a draft between the two points.

Procedures to Ventilate - Forced Air

Just like every other piece of equipment, you must first inspect the power blower and its accessories prior to use. If it is gas powered, check the oil and gas levels to ensure they are adequate. Place the power blower downwind from the manhole.

This will prevent the exhaust fumes from entering the space being ventilated. Connect the hose to the blower and to the saddle. Lower the saddle into the manhole and secure it with the manhole cover.

Turn Unit On

Once the pre operation check and initial set up of the unit and accessories have been completed the blower can be started. Move the choke lever all the way over to the "on" position.

Pull the pull rope to start the engine. Once the engine starts, slowly move the choke lever towards the "off "position while keeping the engine running. Allow the engine to warm up prior to applying any load.

Retest Requirements

Local installation policies and procedures will govern additional testing of non permit confined spaces. In addition to that guidance you must comply with the following requirements:

- If the initial atmospheric test proves unsatisfactory, ventilate the manhole for a minimum of ten minutes and retest. If the retest proves satisfactory, you may enter the manhole or vault, though you must maintain continuous ventilation the entire time you occupy the space.

- If the retest proves to be unsatisfactory, ventilate for a longer period of time and/or notify your supervisor so they can contact experts, such the base Fire Department. Local procedures will dictate your actions.

Safety

It is very important that you keep safety in mind at all times when working in and around manholes.

The process of ventilating a manhole or other confined space is not hazardous in itself; however, failure to comply with required safe practices and retesting requirements could lead to catastrophic results.

Wear ear protection if the situation warrants it. Open only as many manholes as you can provide adequate protection for. Remember, you are responsible for protecting not only yourself and fellow team members, but also the general public.

When off loading portable power equipment at the job site, ensure you have help. This equipment can be heavy and is often awkwardly designed.

It is your responsibility to ensure that these precautions are being met. The life you save may be your own!

Manhole Rescue

It is very important that you keep safety in mind at all times when working in and around manholes. The process of ventilating a manhole or other confined space is not hazardous in itself, however, failure to comply with required safe practices and retesting requirements could lead to catastrophic results.

The wear of ear protection should be considered if the situation warrants it. Only open as many manholes as you can provide adequate protection for. Remember, you are responsible for not only protecting yourself and fellow team members, but also the general public.

Avoid Injuries

When off loading portable power equipment at the job site, ensure you have help. This equipment can be heavy and is often awkwardly designed. Use proper lifting procedures where required. Also, be aware of hot exhaust ports and never refuel gasoline powered equipment until it is allowed to cool.

Remember do not permit anyone to introduce an open flame into or the local proximity of a manhole and ensure that any gas operated vehicle or equipment's exhaust is kept downwind of the opening. It is your responsibility to ensure that these precautions are being met. The life you save may be your own!

Tripod

The tripod provides a firm anchoring point for the rescue winch (see image on next page) It is made mostly of lightweight aluminum and is easy to set up and transport. At the top of the tripod, on the underside, are two rings.

These rings enable two rescue winches to be attached (if two people are working in the manhole) or a rescue winch and a pulley with rope to lower material into the manhole. The legs are extendable and should be fully extended prior to use.

Winch

The winch assembly has a retractable lanyard and is designed to act as a fall restraint (see image). The retractable lanyard gives individuals attached to it the ability to move around without having cable slack around their feet. As they climb down the ladder, the cable will pay out. As they climb up, the cable will retract.

If a person were to fall climbing into the manhole, the fall restraint would activate, stopping the individual. A person using one of these devices must be wearing a full body harness. The rescue line is connected to the "D" ring of the harness.

On the side of the unit is a handle to crank the individual up if a rescue is deemed necessary. Inspect the tripod and winch prior to set up at the job site. Inspect the tripod for cracks in the legs and make sure the nuts and bolts are tightened. Pull the cable out of the rescue winch and ensure it is good repair.

Rescue Rope

A manhole rescue requires two rescue ropes. Both should be at least 1/2 inch in diameter and as long as the depth of the manhole plus 15 feet.

Rescue Procedures

The Confined Space program provides specific guidance as to the who, what, where and when of manhole rescues based on the category of the confined space. While it will be important for you to be intimately familiar with the guidance once you are assigned to an operational unit, for now all that is important is that you know that you cannot attempt a rescue that involves entering a permit required confined space until a rescue team arrives.

The only rescue you are permitted to attempt is one that uses rescue equipment to which the victim is already connected by way of a lanyard and harness. There are many ways (dependent on available equipment) to perform a confined space rescue.

Evaluate Situation

Before ever attempting a rescue, you must first determine if a rescue is even warranted.

Take note of the worker's position and call to him or her to see if you get a response. Call out a second time if you do not get a response from the first inquiry. The worker may be preoccupied with work or cannot hear you due to a high noise level from outside. If you get no response then consider a rescue.

Check to see what position the victim's body is in with respect to any hardware or equipment that may hinder the rescue. Try to detect what might have caused the victim to lose consciousness. Do this by using your sense of sight, smell and taste. Is there evidence of fire, smoke or an acrid taste to the air?

Anyone of these conditions are good indicators that the victim may have been electrocuted. Keep your surroundings in mind and know what you're going to do prior to committing yourself. In a non-permit required confined space rescue be prepared to get in and out with the victim as soon as possible.

Provide for Personal Protection

This “step” should be happening throughout the entire process. A rescuer’s personal safety is of primary importance. If the rescuer is injured, nobody will be saved. The first thing you do is wrap a rescue rope twice around your chest and secure it with 3 half hitches. This is your rescue you if you should be overcome by whatever affected your victim.

Use caution when entering the manhole. Make sure you remain conscious of your surroundings. Don't get caught up in the rescue rope. To ensure you do not become electrocuted, attempt to turn off suspected energized circuits or physically isolate the circuit either by moving it or moving the victim from it prior to attempting the rescue. Don personal protective rubber equipment. If the victim appears to have been overcome by dangerous gases, and you have help, turn on a power blower to ventilate the space during your rescue attempt.

Call for Help

If the victim did not respond to you and you feel a rescue is necessary, call for help prior to entering the confined space. You are not an expert in rescue or medical care, even if you have received some training in these areas.

It is always better to call the experts to the job site. In today's military most electrical work centers have radios installed in their trucks and/or have hand held radios for you to use at the job site.

These radios give you ready access to contact emergency personnel if the need ever arises. If no radio is available, send a runner to the nearest phone or do whatever is necessary to get help.

Raise Victim out of Manhole

Using pre attached rescue equipment (i.e., Tripod/Winch assembly, Windlass crank), or rescue ropes, raise the victim out of the manhole using the applicable procedures:

- Rescue lanyard and harness equipment already attached to victim. (Tripod/Winch)
- Raise the victim until his or her buttocks clear the manhole rim.
- Position the victim’s back toward the direction you want to lay him or her.
- Grab one leg of the tripod and tip it over to allow the victim to lie on his or her back.
- Provide first aid as necessary.

Rescue rope to be tied onto victim

Rescuer ties a rescue rope around his or her chest with three half-hitches. (This allows someone to rescue you if you should be overcome by the same thing that affected your victim.)

The rescuer carries the free end of the rope into the confined space (and ties it around the victim. (The rescue rope should be wrapped twice around the body and under the arms of the victim. Tie the rope with a bowline at the back of the body.)

If there is help available, the helper(s) should brace themselves and at the call of the rescuer, pull the victim from the manhole. As the helper(s) pull the rope, the rescuer should assist by lifting the victim as much as possible.

(If no help is available, then position the victim directly below the confined space entrance, climb out, (make sure you do not get tangled in the rescue rope) and pull the victim clear of the confined space.

As soon as the victim is clear of the confined space, allow the victim to lie on his or her back and give any first aid that is necessary.

Safety

In addition to hazardous gases and oxygen levels, there are certain other hazards that you need to be aware of so that you can exercise proper ground safety practices in order to avoid accidents.

Entering or leaving confined spaces - Enter and leave manholes or vaults only by means of a ladder. Do not step on cables or cable hangers.

Handling tools and materials - Do not throw tools or materials into or out of manholes or vaults. Use buckets or hand lines for lowering and removing tools and equipment.

Low Voltage energized equipment - Low voltage (less than 600 volts) equipment is especially hazardous in or around confined spaces. Contact between faulty equipment and grounded surfaces or the damp, well-grounded floors and a wall often results in electrocution.

Recommendations are to use only approved tools or pneumatic tools and low voltage (24 volt) lighting systems in manhole and vault facilities. Sealed, spark proofed flash lights are suitable sources of lighting.

Underground Duct Systems

Underground distribution systems provide the highest degree of reliability, protection, and ease of maintenance of any type of system construction. These advantages are derived through the use of duct systems and manholes.

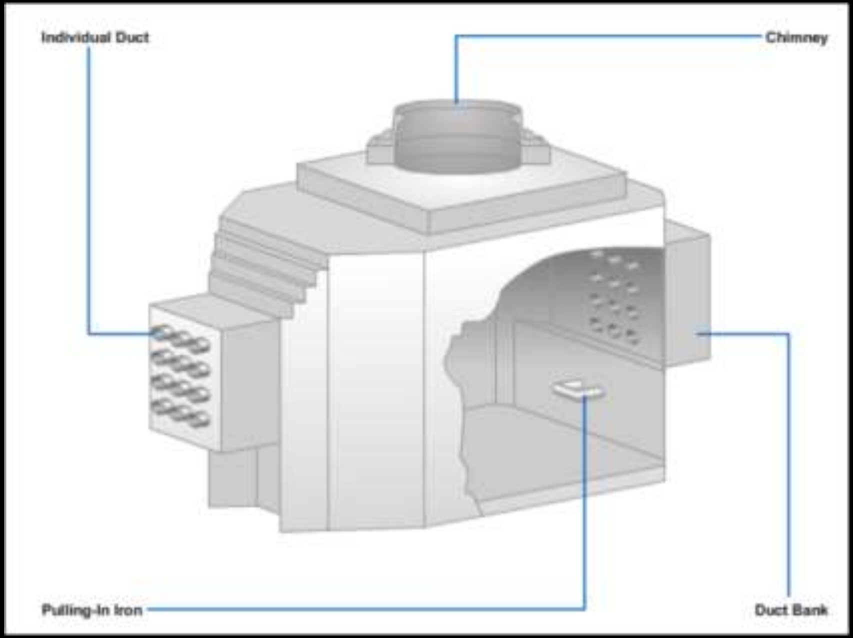
An added benefit of underground duct systems is that the general public sees it as a way of improving the appearance of their surroundings. Because of this, most newly constructed power distribution systems supporting population centers are now installed underground.

As an electrician who will be pulling stand-by duty, you will want to ensure that your efforts toward the installation of a duct system are of the highest standards. If you do otherwise, you may find yourself being called out to make repairs during the worst of times.

Install Duct System

Duct systems provide a means to distribute power to the customer while enabling you to install, access and repair the power cables with relative ease.

This type of system provides better protection of power cables than Overhead or Direct burial systems. It is much more expensive to install; however, the benefits far outweigh the cost.



Manholes

A manhole is a chamber in the underground duct system, large enough for personnel to enter, to and from which cable is pulled. (image) The manhole's main purpose is to allow access for splicing and testing of underground cables.

Manufacturers generally construct pre-cast manholes of concrete at the factory and truck them to the site where they will be installed in the ground.

Manhole Specifications

These manholes must provide the same inside dimensions, strength, and sealed joints as the monolithic (made of one piece) cast-in-place manholes constructed of reinforced concrete or brick. No matter what type of construction method is used manhole sizes will not be less than 4 feet wide, 6 feet long, and 6 feet deep.

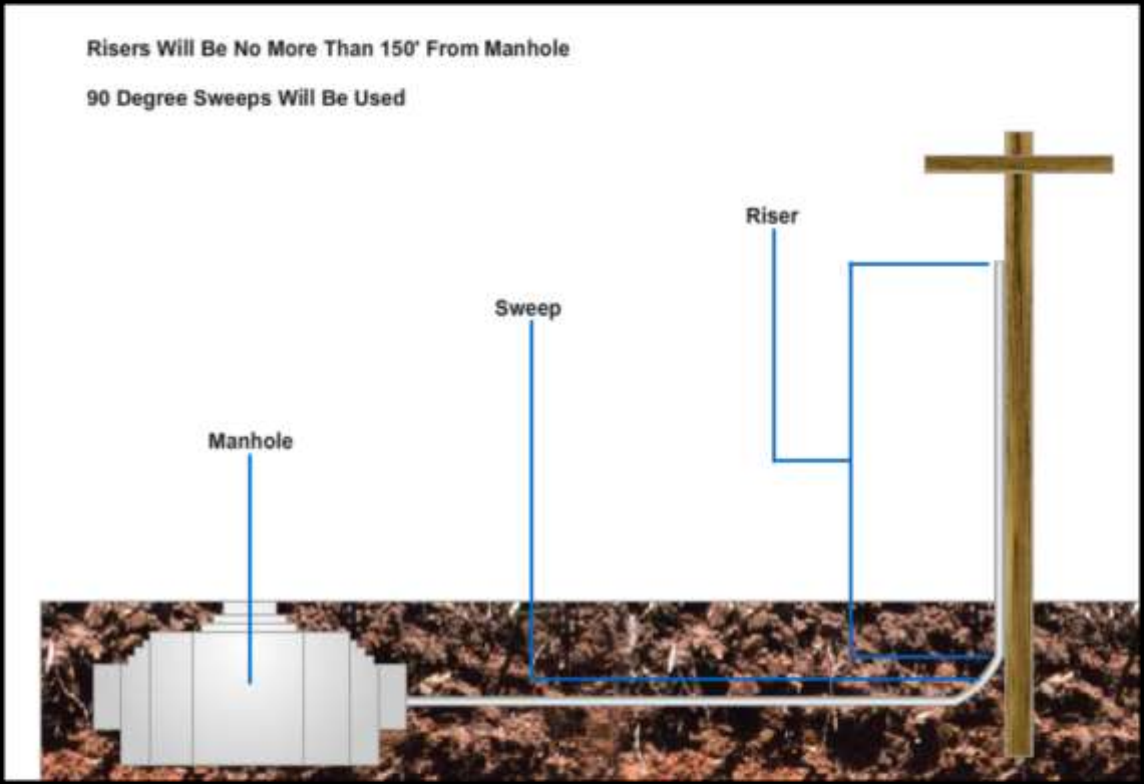
The access opening to the surface must be at least 32 inches in diameter. The shape and size of the manhole depends on the number and size of ducts and the directions in which they leave the manhole.

Spacing

To limit the stresses placed on power cable being pulled through the ductwork of a manhole, engineers have determined that the following maximum distances must be observed.

These maximum distances limit the pulling tensions to acceptable values for installation of common types and sizes of cable:

- Maximum distance between two manholes is 600 feet.
- Maximum distance between manholes on curved sections is 300 feet.
- Maximum distance between a manhole and a riser is 150 feet.



Risers

A riser (see image above) is used on utility poles to transition the cable from the ductwork to a surface device (transformer, capacitor bank or switch) installed on the pole.

The cable will be run from the manhole to the riser where a 90 degree sweep is used to make the one and only authorized change of cable direction permitted when transitioning an underground cable to an overhead connection.

Manhole Installation

The area used for manhole installation must be clear of gas lines, water mains, and other utilities. Use a backhoe to dig the opening for the manhole. The bottom of the hole should be level compacted soil without any large rocks or obstructions that could prevent the manhole from settling properly.

A crane is often used to lift the manhole from the trailer and place it in the hole. Ducts are installed prior to backfilling around the manhole. The area around the manhole must be backfilled and compacted with sand or excavated material that is fine and dry. A manhole neck is used to extend the manhole opening to the finished grade.

Cabling Ducts

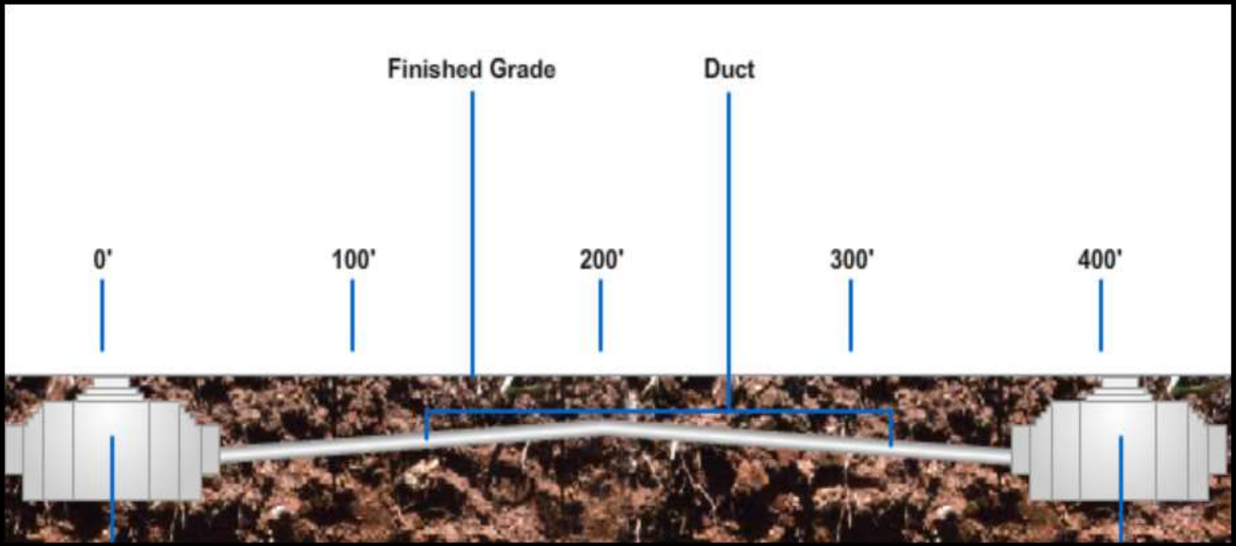
In the simplest of terms ducts are hollow tubes commonly called conduit. A section of conduit is placed together with other conduits to form an underground duct system.

The underground cables are pulled into the ducts between manholes. The duct system provides maximum protection for the cable and allows easy maintenance of the system.

Duct Construction

Ducts can be made out of fiber, plastic (PVC-polyvinyl chloride), metal, concrete, tile, or composite materials; however, you will most commonly will work with PVC (polyvinyl chloride) or metal. The size of the duct depends on the size of cable(s) being installed.

The duct diameter should be at least 1/2 inch to 3/4 inch larger than the cables installed. Four inch ducts are normally used in Underground distribution systems.



Duct Runs

Duct runs should be as short and straight as possible. Bends should be laid out on the greatest possible radius to avoid sharp curves.

The run should also be slightly sloped toward one or both manholes to allow water drainage from the ducts and into the manholes. The slope should be 4 inches for every 100 feet of duct length (image).

Duct Configuration

Ducts, as shown above, are arranged in the manhole in various ways. The number of ducts in a run depends on the ducts required and the number of spare ducts needed for future growth. This number may vary from two to the recommended maximum of nine ducts in the run. (Note: Experience has proven that installing just the exact number of ducts needed has not been favorable in the long run.

In order to accommodate future load growth, the established practice is to install at least 25% more duct work than what has been planned for use at the time of initial installation. For example, if the plan calls for four ducts to be used, you would install at least one extra duct run for future growth.)

Duct Spacing

The distance between ducts should be at least 2 inches. The cables installed in these ducts will generate a small amount of heat that will ultimately affect the current carrying capability of those cables.

The space between the ducts will help dissipate the heat. If the ducts are to be encased in concrete, at least 3 inches of concrete should be placed around the outside as well.

Where to install Cabling Ducts

As a general rule, install ducts where they will cause the least amount of disturbance. Do not run a duct system through the middle of a parking lot when you can go around it. This is to avoid subjecting the duct system to the weight of vehicles as well as having to dig up pavement during the installation and possibly when repairs are required.

Avoid crossing over or under other utilities i.e., water, sewer, and communications, as much as possible. If you have to cross them, you must follow strict separation standards.

Avoid placing duct runs through muddy, shifting, or corrosive soils when possible. If there is no option, construct the duct runs in such a manner as to minimize movement and direct exposure to corrosion. This will usually entail encasing the duct work in concrete.

Cabling Ducts near Roadways

Ducts which run near roadways should be installed parallel to the road and under the shoulder to limit the possibility of damage by traffic. If they are run parallel under the road, ducts should travel under only one lane of traffic.

Specific Procedures when Installing Ducts

Specific procedures to install duct are as follows: Begin by laying the duct midway between two manholes and work toward the manholes. Install the ducts in spacers (image) placed at no more than 5 foot intervals along the run.

These spacers will provide the minimum 2 inches between ducts and 3 inches between the duct and the bottom of trench required to dissipate the heat from cables placed in the duct work.

If the duct work is to be encased in concrete, the concrete should extend 3 inches on top, bottom and to the sides of the ducts supported by the spacers.

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Plastic Ducts

Plastic (PVC) ducts are joined together with a driven sleeve (coupling). Usually the driven sleeve is manufactured onto one end, which is commonly referred to as the bell-end. PVC conduit can be cut to the required lengths using any coarse-toothed saw.

The PVC is then cleaned of all dirt or other contaminates prior to joining. Once assured that the PVC is clean the pieces are joined together using PVC cement to ensure a watertight seal.

Metal Ducts

Metal ducts are joined with a screw-on coupling. Pipe wrenches are used to tighten the ducts to the coupling to give it mechanical stability. No sealant is required.

Cable Racks

Cable racks are attached to the walls of a manhole and are made of galvanized metal with insulating porcelain saddles.

Cable racks are used to support high voltage cable within a manhole. They enable the cable to be secured off of the floor and out of the way of personnel entering and exiting the manhole.

Besides protecting the cable and its splices from accidental damaged by inadvertent contact, cable racks also provide for placement of the cables within the manhole in a neat and organized fashion, enhancing the ability to perform maintenance and troubleshooting actions.

Rack Spacing

Cable racks should be positioned so that every splice rests between two racks. There must be at least six inches of cable between the edge of the splice and the porcelain saddle on which the cable rests.

Rack spacing will normally be about 3 to 4.5 feet apart for electric power cables. Actual spacing depends on the size of the cable and its maximum bend radius. At least two racks should be located on each wall except where that would interfere with duct entrances.

Advantages of Duct Systems

Advantages - Underground duct systems provide increased electrical service reliability, and greater physical protection compared to Overhead and Direct burial cable systems.

In addition, they allow for ready access by electricians for testing, repair, and replacement of cables, system equipment, and components.

Disadvantages of Duct Systems

The disadvantages of underground duct systems are few.

The biggest drawback is that the initial cost of installing one is significantly higher than the other two types of construction.

Of lesser concern is that manholes are restrictive in terms of work area and may contain dangerous gases, insects, reptiles, and water.

Safety Issues with Duct Systems

Installation of an underground duct system will pose a whole new array of safety related hazards not previously discussed. Where there are excavations, as is the case when installing manholes and digging lengthy trenches, there will usually be heavy construction equipment. This equipment is dangerous not only to operate, but also to work around.

The large areas of ground that will be opened up will require barricading to make unauthorized people are made aware of the hazardous construction area and keep them out.

Holes and trenches dug deeper than they are wide and capable of engulfing the personnel working in them will be classified as confined spaces and require compliance with a host of new safety related standards, such as shoring up the sides of the trench and holes.

Proper Lifting Procedures

The use of proper lifting procedures when moving ducts and having enough workers on site will be especially important to any safe installation project. Projects are usually accomplished in phases and build off of existing systems, so it is important that no one let their guard down and become complacent.

Check the manholes, even if they are newly installed, for dangerous gases before entering. Wear personal safety equipment and goggles while drilling holes in concrete to mount cable racks and while operating other powered equipment.

Buried Cable

New cable technology and improved methods of installation are responsible for the growing trend toward direct burial cable systems. Direct burial means the cable is buried directly in the ground and covered with earth.

This type of installation gives satisfactory service where only a relatively few buildings or load centers are involved and a suitable cable route is available.

Trenches

A trench is a long narrow cut in the ground with steep sides. The trench is the key feature that characterizes the direct burial system. Because of this the trench warrants further discussion.

A trench can be a permit required confined space if it meets established criteria under OSHA's Confined Space program. You do not need to know the specific criteria, but what is important for you to know is that trenches cannot be taken for granted.

Permit-Required Confined Space - Trenches

A key characteristic that classifies trenches as a permit required confined space is that they contain a material, dirt that has the potential of engulfing the entrant. Because a trench can easily cave-in causing the "entrant" to become engulfed, you must always maintain an awareness of your as well as your co-workers' position when working Direct burial installation projects.

Trenches are dug using construction equipment or by hand. The method of excavation will depend on a number of factors such as the availability of equipment, length of run, and proposed route of the trench.

Depth of Trench

A trench's depth is also based on a number of factors; however, all will meet the minimum depths listed below. These depths are based on the amount of voltage the cable will be carrying.

- Bury cable to a minimum depth of 36 inches for primary voltages of 22KV to 40KV.
- Bury cable to a minimum depth of 30 inches for primary voltages of 600V to 22KV.
- For voltages of 600V and below, the depth is determined by NEC® requirements.

Extra Depth due to Permafrost Conditions

Other factors that may require you to bury cables deeper are extremes in temperature or wet areas. In extremely frigid locations such as the Arctic and Antarctic, a condition known as permafrost exists.

Permafrost is a permanently frozen layer of ground that is comparable in hardness to concrete. Under these conditions, cables will need to be buried more deeply than previously mentioned.

In extremely cold areas the earth is subject to freezing, and it will be important to bury the cable below the frost line to avoid damage by the expansion and contraction of the earth during freezing and thawing.

The frost line is the depth in the soil where the earth is not subject to freezing. In areas that are extremely wet, cables may need to be buried more deeply then previously mentioned to keep them from “floating” to the surface.

Ground-level Equipment

Laying cable in a trench is just part of the installation of a Direct burial system. The ultimate reason for installing cables is to supply power to a piece of equipment that will supply power to the customer. At the end of Direct burial trenches, there will need to be a transformer, switch, or some other piece of equipment to serve the end purpose.

Pad-mounted Transformers

Pad mounted transformers, as shown above, are used to change the primary voltage to a secondary voltage. In a Direct burial system, these transformers are generally placed on pads, hence the name pad mounted transformer. These pads are normally made of concrete, but are sometimes constructed using other types of material such as plastic.

Enclosures

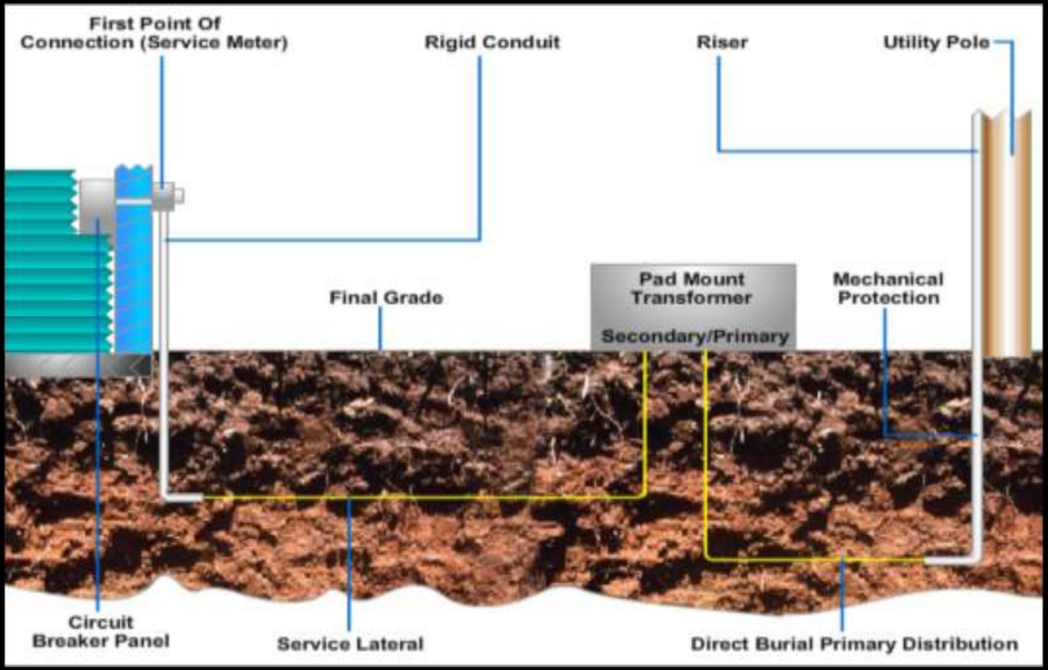
An enclosure is another type of pad-mounted equipment (image). It can house a wide variety of electrical components, such as switches, cable terminations, and even pole type transformers.

Power Cables

The cables you are burying to distribute electricity around the base fall into two categories, depending on the voltage they carry.

Feeder

The high voltage cable run from the substation to the transformer is known as the feeder. It will supply power to the general areas requiring it. The transformer and secondary circuits will further distribute the power to the customer.



Service Laterals

Service laterals are the buried service conductors from a transformer to the first point of connection on a building. The service lateral is similar to the service drop you learned in the Overhead block of instruction. The only real difference is that the conductors are installed directly in the ground rather than being supported in the air.

A service lateral can come from a pad mount transformer, an enclosure, or down a riser from a pole-mount transformer. Service laterals can be installed in a duct or directly buried. The procedures for the installation of service laterals are the same as for Direct burial cable. Above is an example of what a service lateral coming from a pad mount transformer looks like.

Advantages of Direct Burial Systems

There are a few advantages to a direct burial system. It is cheaper to install than an underground duct system, yet affords a good amount of protection from storm damage.

It also has lower maintenance cost than an overhead system. Like the underground duct system, it is also aesthetically appealing. Since the cables are thermally insulated by the earth, their year-round temperature only varies by a few degrees, which extends the useful life of the cable.

Disadvantages of Direct Burial Systems

The disadvantages of a Direct burial system are that the cables, no matter how well designed, are susceptible to damage from all conditions that may exist in the soil such as corrosion, water leakage, and shifting of the ground.

These cables are also easily damaged when subjected to compressive forces and digging operations. In addition to the physical susceptibilities, direct burial systems are difficult to troubleshoot and maintain (no access to cable except for termination points) and replacing a damaged cable is nearly impossible.

Installing Direct Burial System

Installing a Direct burial system is a fairly simple process and requires less effort and expense than the underground duct system.

The steps are: dig the trench, install the bedding material, cable, and cable marker tape, then back fill and, finally, install cable route markers.

Excavate Trench

As stated earlier, trenches can be dug either by hand or using heavy equipment. Two of the most common types of excavating equipment are trenchers and backhoes.

Backhoe

The backhoe, as seen in above image, is used for wide trenches or when no other equipment is available.

Buckets of different widths can be used depending on the desired width of the trench.

Trencher

The trencher is the preferred equipment with which to install a Direct burial system (see image). They are available in a variety of sizes and models and are specifically designed with the task of excavation in mind.

Trenchers used to support military requirements are capable of digging trenches of various widths, usually ranging from 8 inches to 24 inches and depths of as much as 84 inches depending upon the type of trencher used.

Trenchers can also be equipped with a hydraulically controlled dozer blade for back filling operations.

Cable Plow

The cable plow, shown above, is a type of trencher ideally suited for wide open unobstructed trenching operations. Most cable plows open the trench, lay the cables, and cover the cables all in one operation.

Cable plows will offer the distinct advantage of saving time and money and minimizing the disturbance to an area.

Install Bedding Material

The trench must be free of rocks or sharp objects that might damage the cable. If the ground is rocky or you suspect that the ground could damage the cable, use a cushion of sand. The most common practice is to trench 3 inches deeper than the required cable depth and place 3 inches of sand in the bottom of the trench before installing the cables.

In areas where vehicular traffic is likely (roads, driveways, etc.), the cable must be protected, at a minimum, with rigid conduit. Conduit protects the cable from the compression forces of the vehicles and makes replacement easier.

An additional benefit of placing the cable in conduit is that there will be no need to replace pavement that would otherwise have been removed had re-trenching been required.

Installing Cable into the Trench

The cable is placed in the trench as soon as possible either during (as in the case of a cable plow) or immediately after the trenching operation. All cable placement will be done under constant supervision to be certain that no damage to the cable occurs during the laying operation. Clear all tools and equipment not needed for this process from the trench area.

Whenever possible, pay out the cable from a reel mounted on a moving vehicle or trailer. Support the cable reel so that it can be turned easily without placing undue strain on the cable.

Place the cable carefully in the trench by hand. Lay the cable in the trench with some slack in it, since a tightly stretched cable is likely to be damaged as back fill material is added, and the slack will allow the cable to expand and contract during extreme temperature changes. Do not drag the cable should over sharp edges of the pay-off equipment, parking lots, roadways, or anything else that may damage it.

Install Marking Tape

Cable marking tape serves as a warning that there are energized high voltage cables buried below. It is generally a roll of brightly-colored plastic tape about two inches wide, usually marked with the words "CAUTION – ELECTRIC CABLE BELOW" or some similar statement.

This cable marking tape will let future excavators know there is an electrical line below. It must be placed at least 12 inches above the cable it protects for the entire length of the cable run and is unrolled into the trench midway through the back filling process.

Back Fill using Suitable Material

If sand is protecting the cable, add an additional 6 inches of it on top of the cables after they are installed to further protect them from the back fill material.

When you back fill the trench, it should be as free of rocks as possible so as not to cut or damage the cable during tamping operations and as the ground settles.

Tamp the back fill material well to keep the trench from settling when it rains. Remember to install the cable marking tape at the appropriate time during the back filling process.

Install Cable Route Markers

The primary purpose of cable route markers is to identify the location of buried cable and any splices that have been made in it. Markers are available in different styles and made of different materials. Most of them provide the capability to stamp ID info such as the circuit/splice ID number, size and type of cable etc. You will use these markers to locate circuits requiring repair or maintenance on associated system components.

Cable markers must be placed every 200 feet or anywhere a cable changes direction. They are also required at every splice in the direct burial system. The markers are to be installed 2 feet from the right side of the trench being marked as you look toward the circuit's supply point (line side).

When cables are used in lighting circuits and if the lighting poles show the direction and change in the system, cable markers are not required.

Protection Options Above Finished Grade

Direct buried cables emerging from the ground shall be protected by an enclosure or rigid conduit extending at least 8 feet above the finished grade (see image). This is required to protect them from physical damage caused by lawn mowers or vehicular traffic and to prevent personnel from coming in direct contact with the cables.

Protection Options Below Finished Grade

Protection shall extend below grade a minimum of 18 inches. Generally, the cable is run through a riser to protect it as it enters and exits the ground.

Safety

Keep these safety items in mind as you install direct buried cables:

- Be alert for moving vehicles.
- Use the proper hand signals when directing vehicles and equipment.
- Know where you are in reference to the trench so you do not fall into it.
- Coordinate with other shops to ensure you have clear path for your trench.

Determine whether the trench is considered a confined space or not. If you have any doubts, ask your supervisor about it. If it is, you will need to process a confined space permit and shore the trench walls prior to entry.

Underground Cable

Today, more and more distribution systems are being built underground to leave the area looking as natural and undisturbed as possible. These systems perform in different environments and the materials from which they are constructed must be adapted.

Unlike overhead construction, underground distribution systems use cable to distribute power from the substation to the customer, and more than one cable can be installed at the same time.

This economy of effort will serve you well should you ever have to repair cable or cables within an underground duct system.

Rigging Set Up to Install Cable in a Duct

Rigging set up refers to the actions required to pre position equipment used to physically pull cable through the ducts into the manholes.

Pulley Diameter

During the cable pulling process, you will be running the cables over several pulleys. If the diameter of the pulley is too small, the cable will bend too sharply, resulting in damage to the internal layers of the cable. Depending on manufacturer specifications and the reference you use, the minimum bending radius may vary.

As a general rule, the minimum bending radius of primary cable is 12 times the overall diameter of the cable. This means if your cable has a diameter of 1inch, the minimum size pulley you could use while pulling cable would have a diameter of 24 inches, with a radius of 12 inches. As a rule, the minimum bending radius for secondary cable is 6 times the diameter of the cable.

Pulley Position during Rigging

Pulley position is the most important part of rigging. Proper placement will prevent damage to the cable while it is being pulled into the duct. If you are pulling cable into a manhole, adjust the pulleys to keep the cable from scraping against the top or bottom of the duct opening. Also, place them to prevent the cable from coming in contact with the manhole opening.

If you are pulling cable into or out of an enclosure, position the pulleys to keep the cable from rubbing on the duct openings as well as the enclosure.

When it comes to pulley positioning, keep in mind that you want to prevent the cable from rubbing on anything so neither the cable nor the equipment is damaged. There are several different types of pulleys available, each having its' own purpose.

Anchoring the Pulley with Pulling Eye

Anchoring the pulley is important as well. You must use chain or rope capable of handling the tension of the pulling operation. Manholes will have a “pulling-in iron” (also referred to as a pulling eye) constructed into the wall of the manhole (see image). Its sole purpose is to provide an anchoring point to attach pulleys.

If you are pulling into an enclosure, you may use the boom of the line truck as one of your anchoring points. Positioning the boom over the duct opening and hanging a pulley from the winch line may be all you need to prevent the cable from rubbing on the duct opening and/or enclosure.

There is more than one way to position and anchor pulleys when pulling cable. The manhole or enclosure’s configuration and size may be different every time. Check out your surroundings and find the best scenario to position and anchor your pulleys.

Select the Duct

Before pulling cable, you must determine which duct or ducts are going to be used. For the most part this information will be provided to you on prepared blueprints or drawings.

If no blueprints or drawings are available, then you will be required to make a decision based on established practices used in the career field.

Blueprints/drawings

During the planning phase, an electrical engineer will assign the ducts to use. The electrical engineer will make this clear using blueprints or drawings that will be included in the work order package. Your responsibility is simply to install the cable or cables through the ducts and manholes he or she has designated.

Experience has shown that because of the long periods of time that elapse between envisioned projects and their actual installation, changes to the initial planned drawings are sometimes required. If this situation arises, you will have the responsibility of proposing recommended changes to the engineer based on established practices.

Location of Cables

Select the duct to be occupied throughout the entire length of the proposed run while maintaining the same relative position in the duct bank throughout all manholes where possible.

When selecting the duct for any particular cable, do not assign a duct whose occupancy of cables may block other vacant ducts or block a racking position. Try to select a duct that will allow the heat that is generated to dissipate.

Typically, the outer ducts in the duct configuration are the coolest and are generally reserved for high voltage cables while the inner center ducts are filled with low voltage and control cables.

Try to place longer cable runs in the bottom ducts and shorter cable runs in the upper ducts. This is possible if you are running several cable runs during the same job. If not, use the lower ducts first and then work upwards so you use the upper ducts last. This prevents you from having to install cables under an existing run at a later date.

Prepare Cable and Duct for Installation

Once you have selected the duct into which you will be pulling cable, you are ready to prepare the duct and cable for installation.

Test Cable

It is always best to test a cable prior to its installation, since installing a faulty cable is obviously a waste of valuable time. All cable should receive an initial acceptance test, using a DC high potential test set when it first arrives from the manufacturer.

Since cable may be sitting around in a storage yard or warehouse for years before it is needed, you will conduct a second test for cable faults, using a megohmmeter, prior to transporting the cable reel from the storage area.

Rodding the Duct

Before you can install cables, you need to check the duct system for structural integrity and then clean it as necessary. This is done through a process called rodding.

Rodding is accomplished by inserting a number of short, jointed wooden rods or a flexible fiberglass or steel rod into the duct starting at one manhole and going to the next. Two types of wooden duct rods that you may encounter are the screw and quick-coupling.

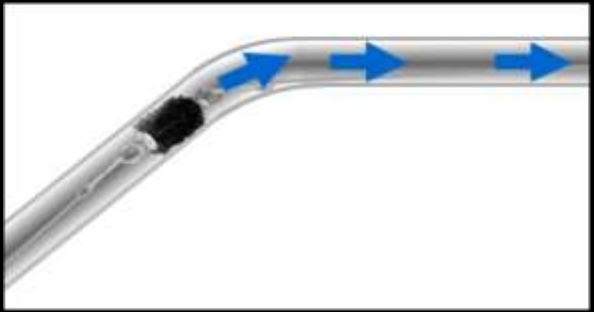
Both types generally come in 3 or 4 foot long sections and are approximately 1 inch in diameter. They fasten together, as their names imply; screw type rods are connected by screwing one section into the next, while quick-coupling rods use an interlocking joint to join one rod to the next.

The actual process of rodding is accomplished by linking one rod to the next, inserting them into the duct, assembling more rods, pushing the joined rods farther into the duct until the first rod appears at the distant manhole.

Types of Duct Rods

While you may encounter wooden duct rods, the most common duct rod used today is a continuous piece made of fiberglass or steel as shown in the image. It is inserted into the duct and pushed the entire length of the run.

Rodding is done from one end of the conduit run to the other and not from both ends to the middle. If the conduit run is on a slope, rodding operations should proceed from the top toward the bottom of the slope (let gravity help you). If you encounter an obstruction, you can use various leaders to try to dislodge it.



Cleaning Mandrels

Once you have pushed the rod through the entire length of the run, attach the "cleaning" rope and pull it back through the duct. This rope will then pull in a heavier pull rope. Cleaning mandrels can be attached between these ropes, cleaning the duct as you pull in the pull rope.

Cleaning mandrels are used to clear obstructions from the duct that may damage the cable during the pulling process. They come in different types depending on the application (large objects, small pieces of concrete, dirt).

The image to the left, shows two different types of cleaning mandrels. The image on the right shows one way a mandrel is connected for use. In some cases, the pull rope will be pulled in using the duct rod and not the "cleaning" rope. If you use this method, attach one side of the mandrel to the pull rope and the other end to the cable to be installed. In either situation, the duct requires cleaning prior to cable installation.

Process for Duct Cleaning

The duct cleaning process includes following steps:

1. Use the duct rod to pull in the pull rope.
2. Attach a cleaning mandrel between the pull rope and the cable to be installed.
3. Pull the cable into the duct.
4. As the cable is being pulled in, the duct is being cleaned at the same time.

Prepare Manholes

After you have tested the cable, cleaned the duct, and installed a pull in rope through the duct, you are ready to rig the pulling-in manhole with pulling apparatus.

There are
two methods in which you can install cable and each method is dependent on the type of pulling apparatus to be used.

One method uses a pulling frame and the other a pulling-in sheave and manhole sheave.

NOTE If a manhole contains pulling in irons, either type of equipment may be used. However, if no pulling in irons are present, only the pulling frame can be used.

Cable Pulling Frame

The pulling frame consists of a pulley near the top and one near the bottom to guide the cable. Set up of this equipment entails adjusting the height of the two pulleys to prevent the cable from rubbing on the duct and/or manhole openings as it is being pulled in.

Adjustments are required at each and every manhole in which the pulling frame will be installed, since the depths and the height of ducts are subject to change depending on the type and size of the manholes.

Cable Pulling Sheave

The other method of cable installation requires the use of a pulling sheave and a manhole sheave. In order to rig a manhole using this method, attach the pulling sheave to a pulling-in iron in the manhole and install the manhole sheave over the manhole collar. The pulling sheave (image on the right) is anchored by a chain or heavy-duty rope to the pulling-in iron embedded into the wall of the manhole.

You will need to make adjustments to the length of the chain or rope in order to position the bottom of the pulling sheave so that it is in line with the duct into which the cable will be pulled.

The manhole sheave (image on the left) consists of one or more pulleys and just fits over the manhole collar. Its purpose is to prevent the cable from rubbing on the manhole collar as it is being pulled out of the manhole towards the line truck. There is no adjustment for the manhole sheave.

Check for Proper Alignment

No matter what method of installation used, be sure to check all equipment for proper alignment and operation before actually beginning the cable pull.

Failure to do so will more likely than not result in damage to the equipment or cable and possibly injury to you or your co-workers.

Proper Setup of a Cable Reel

The cable reel may be set on a trailer or on cable jacks as shown in the above image. Regardless of the method used, the reel has to be set up at the feeding manhole on the same side of the manhole as the duct run in which the cable will be installed. The cable will be payed out carefully from the top of the reel.

If you are using cable reel jacks, inspect them prior to use to ensure they operate correctly and are clean, lubricated as required, and capable of supporting the required cable reel. The stand will support a lot of weight, so it is important that they work properly during the pulling process.

Proper feeding from a Cable Reel

Never pay out the cable from the bottom of the reel since this will put a reverse bend on the cable, causing interior damage to the cable components. This affects the way that the layers seat, causing air pockets that could lead to cable failure.

If the duct run contains a curve, set up the cable reel at the manhole nearest the curve.

Pulling through the curve first will make for an easier pull. If you use cable reel jacks, ensure they are set on a firm, level surface to prevent them from sinking into the soil or falling over.

Rigging the Feeding Manhole

The first thing you do when rigging the feeding manhole is to set up the cable guide and the cable lubricator if one is used. The cable guide is a flexible metal tube that protects the cable as it is pulled into the duct (see image).

Cable guides come in different sizes depending on the size if the duct. The nozzle (the end that will be placed inside the manhole) slips into the duct opening. The cable enters the cable guide through the funnel at the top.

Cable Lubricators

Cable lubricators are sometime used in cable pulling operations. Their use depends on a number of factors such as the size of the cable to be pulled, number of cables already in the duct being pulled into, the length of the duct run, and the number of bends or angle of bends expected to be encountered.

If you use a cable lubricator, the cable will feed through it and the cable guide before entering the duct.

The lubricator is used to coat the cable sheath with a lubricant that helps the cable slide through the duct.

Special cable lubricant is put into the lubricator. As the cable is pulled, it will draw some of the lubricant into the duct with it.

The lubricant should be applied very liberally. The average amount of lubrication is 6 to 8 pounds per 100 feet of one 3 inch diameter cable or three 1inch diameter cables.

Prior to Pulling in the Cable

Once you have installed the pulling-in apparatus and positioned the cable reel, the cable is ready for installation. Prior to actually pulling in the cable three final actions are required.

They are sealing of the end of the cable that is being pulled, attaching the pull rope or winch line, and setting up the line truck.

Clean and Seal Cable Ends

You must seal the cable ends to prevent moisture and dirt from entering the cable while you pull it through the duct.

If moisture or dirt is allowed to enter the cable during the pulling process, cable failure may occur and cause you to repeat the entire cable-pulling process.

Attention to small details such as this can prevent unnecessary damage to cable and save you a lot of time in re-accomplishing the job.

Attach Pulling Rope/Winch Line to Cable

After sealing the cable end, attach the pull rope or winch line to the end of the cable using a basket grip (see image). Slide the basket grip is slid over the cable end to use as the attachment point for the rope or winch line.

If the basket grip does not have a swivel manufactured into it, placer one between the grip and the pull rope or winch line. This swivel will prevent the cable, pull rope or winch line from twisting as you pull in the cable. When installing or removing basket grips, be alert for broken strands as they become worn with use.

After attaching the pull rope, place a marker on it approximately 20 feet ahead of the cable to alert personnel at the pulling end that the cable is nearing the manhole entrance. This marker could be something as simple as electrical tape wrapped around the pulling rope or winch line.

Use Line Truck to Pull Cable

The capstan on the line truck is normally used when pulling cable into a duct using a pull rope; otherwise the bed winch is used.

The speed at which the cable is drawn into the duct will vary and be dependent on such factors as the number and the size of the cables, the length of the pull, and curves in the duct.

It is always a good practice to begin the pull slowly and adjust the speed from there.

Proper Cable Pulling Speed

The average cable pulling speed is 40 feet of cable per minute for a single cable and 20 feet of cable per minute for two or more cables. Pulling speeds below 20 feet per minute are considered to be low, while speeds above 60 feet of cable per minute are considered to be high speeds.

Avoid pulling at high speeds as much as possible due to the difficulty in properly lubricating and inspecting the cable as it comes off of the reel.

Once the 20 foot advance marker appears in the pulling manhole, reduce the pulling speed significantly. You will need to pay close attention at this point in the pull to ensure that the cable continues to roll unobstructed over the pulleys.

For safety purposes, no one should be inside the pulling manhole during any part of the pulling-in operation and everyone needs to stay clear of the pulling rope or winch line while it is under tension.

Cable Slack

Once the cable comes out of the duct opening, it will follow the contour of the manhole wall and be placed on the cable racks. Additional cable must be pulled to allow for splicing, testing, removal of damaged ends, and proper racking.

The length of cable required in each manhole depends on the size of the manhole and whether the cable will be spliced or not.

As a general rule, the length of excess cable required for splicing and testing usually amounts to 1 1/2 feet per cable or 3 feet per section. Specific lengths should be recorded on the blueprint or drawing of the cable being installed.

Remove Damaged Ends

During the pulling process, the cable ends are sometimes damaged. If this occurs, remove the ends prior to racking and splicing. Remove the basket grip and cut the damaged cable ends off with cable cutters.

Once you have cut the cable ends you must seal them to prevent moisture and dirt from entering the cable while it is waiting to be spliced or terminated.

You should perform an insulation resistance and continuity test on the cable immediately after installing it.

These tests will enable you to determine if the cable has sustained any damage during the pulling in operation and enable you to replace it, if it is defective, prior to repositioning your rigging apparatus, cable reels, barricades, manhole guards etc.

Cleanup Job Site

Once the cable has been pulled in, been confirmed as being good, and sealed, clean and properly store tools and equipment. Although not a popular task, these actions are important to the job.

By taking care of your tools and equipment you can be assured that they will continue to provide safe dependable service and be where you will expect to find them when the next job comes along.

Cable in Duct Upgrades

Under ordinary circumstances, underground cable is removed only when repair in the field has become impracticable or the load requirement has been upgraded. In these situations you may be able to install replacement cable, while cutting out the steps of rodding the duct, installing a pulling in wire, and installing a pulling in rope or winch line.

If the pull is expected to be relatively easy you may be able to use the existing cable as the "pull rope". Attach the new replacement cable to the existing cable using basket grips and a swivel between them. Perform all other procedures as required.

Have Properly Trained Personnel

There are some safety factors to consider when installing cable in an underground duct system.

Of primary importance is that all work crew members assigned to the installation be intimately aware of their position responsibility and be thoroughly acquainted with all applicable sound and hand signals.

The crews should have a full compliment of trained personnel to perform the position duties required at each manhole.

Cable Feeding Crew Members

As a minimum, the cable feeding manhole must have a crew consisting of a crew supervisor, cable reel tender, and cable feeder/lubricator.

The crew supervisor is responsible for monitoring the overall job, interpreting signals, relaying communications, and acting as the worksite safety monitor.

The cable reel tender is required to inspect the cable for damage as it is being fed into the manhole and to ensure that the cable comes off of the reel in a controlled manner.

The cable feeder/lubricator is needed to ensure that the cable feeds properly into the cable guide and monitors the lubricant level.

Pulling Crew Members

The crew assigned to the pulling manhole should consist of a manhole supervisor, a rigging equipment tender, and truck operator.

The manhole supervisor interprets signals, relays communications, and acts as the manhole safety monitor.

The rigging equipment tender monitors the pull rope or winch line as it feeds through the rigging equipment and watches for the advanced cable marker. The truck operator controls the pull rope or winch line take-up speed.

Safety in Cable Installation and Removal

Other safety factors to consider when undertaking cable installation or removal operations are:

1. Before entering a manhole or excavation, test for dangerous gases or oxygen deficiency using correct testing procedures.
2. Protect all open manholes, trenches, or other excavations with guards, barricades, covers, flags, or other suitable warning devices.
3. Do not bring flames closer than 10 feet to a manhole.
4. Use only standard, approved lighting apparatus in manholes.
5. Stay clear of the pulling equipment when placing cable in and removing it from the manhole.
6. Before the initial pull is made on the cable, personnel should leave the manhole. Also, at any other time when the pulling line is tensioned to an unusually high degree, no one should be inside the manhole area.
7. Exercise caution when entering and leaving manholes located on traveled thoroughfares.
8. Always use a ladder to enter or leave manholes and have hands free of materials or tools when ascending or descending the ladder.
9. A co-worker should always be stationed by the manhole entrance to provide help and perform the duties of a safety person. That co-worker should initiate conversation with the worker at 10 minute intervals ensure everything is all right.

Underground Transformers

Transformers used in support of underground distribution systems will serve the same purpose as pole mounted transformers used in an overhead system. However, the procedures to install them are very different.

Underground transformers are either installed on pads (pad mounted) or in vaults. The term "Vault" identifies an enclosure above or below ground which is used for the purpose of installing, operating or maintaining electrical distribution equipment or cables. See image.

How a transformer is installed will depend largely upon where it will be located in the system and what it is being connected to. Besides providing power to the customer, transformers must be installed properly to ensure that they are kept at a safe distance from other equipment and people.

Pre Installation Requirements - Transformer Size

Prior to the actual installation, your first order of business is to determine the size or KVA rating of the transformer to be installed.

The electrical engineer or shop supervisor will normally select the size of the transformer; however, if that does not occur, you will be able to make the determination based on the customer's proposed load requirement.

If the transformer being installed is replacing a faulty one, the same size is normally installed.

The KVA rating, voltage levels, and all necessary information about the transformer can be found on the data plate usually located inside the transformer cabinet on the secondary side.

Other Factors when Selecting a Transformer

Other factors that affect the selection process are the physical size and weight limitations posed by the customer's facility.

You will need to determine if there is enough room in the vault or outside pad area large enough to accommodate the size of a particular replacement transformer.

Determine if the doorway is large enough to accept the transformer, and if the floor or support pad are sufficient to support the weight.

The physical size and weight will also help you decide what type of vehicle is required to transport the transformer to the job site.

Transformer Weight

You must know the weight of the transformer to determine the kind of vehicle and rigging equipment you will need to transport and install the transformer. The weight of most transformers can be found on the data plate.

With this information, you can select installation equipment and a sling capable of lifting and moving the transformer. If either of these items is underrated they may fail, causing the transformer to crash to the ground during the installation process.

This could obviously cause external and internal damage to the transformer. If you cannot determine the weight, notify the shop supervisor for assistance.

Installation of Transformers

The methods used to install transformers in underground distribution systems will be based on the type of equipment used to perform the task and the actual location of the installation.

Because of size and weight considerations, installation of most transformers will require the use of heavy equipment of some sort and experienced licensed operators.

Delivery of the Transformer

Most transformers you will install on outside pads can normally be transported and placed in position using a line maintenance truck.

However, some of the power transformers (see image) might exceed the lifting capacity of the line truck. In this case, you may require a crane or heavy capacity forklift to assist you in positioning larger transformers.

Rolling Transformer on Metal Conduit

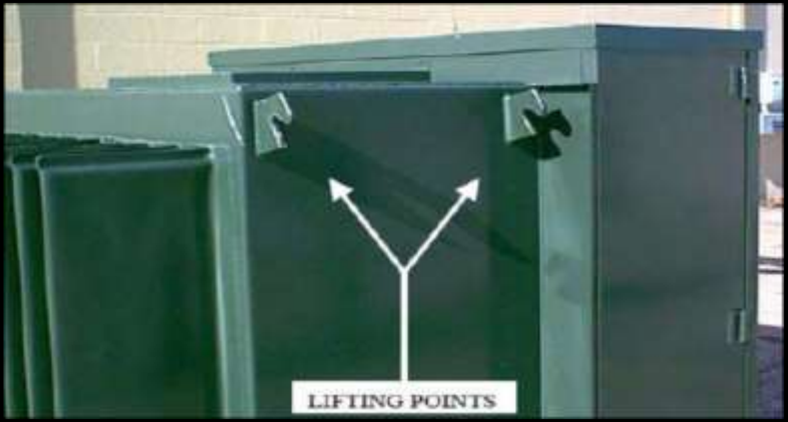
Some transformer installations will be performed inside a vault. Since the final positioning of a transformer inside an enclosed room would be difficult using a large support vehicle, you will need an alternate means of moving and positioning the transformer.

Rigid metal conduit (RMC) can be used to roll transformers to their final position inside a vault. A line truck or crane can be used to position the transformer near the doorway and on top of the conduit that has been placed on the ground.

Forklift

You can use a forklift if the vault has a door large enough and a ceiling high enough to allow it to enter.

No matter what piece of equipment you use to position the transformer, the equipment and the attachment slings must be of sufficient size to handle the weight of the transformer.



On Pad

To install a transformer on a pad, attach the sling(s) to the “manufactured” lifting points already on the transformer (see image).

These lifting points are positioned over the tank containing the oil and transformer windings since this is where the majority of the weight is located. Do not attach slings to any point other then those designed by the manufacturer.

Attach the other end of the sling(s) to the piece of equipment being used to lift the transformer. Position taglines near the bottom of the transformer prior to lifting.

These taglines will enable you to maneuver the transformer as needed and keep you a safe distance away from it and any crush points should it fall or swing out of control.

To Install a Transformer in a Vault

The procedures to install a transformer in a vault are basically the same as those for installing a transformer on a pad. The only exceptions are the use of taglines and support vehicles.

Because of the space limitations of vaults, the support vehicle will only be used to transport the transformer to a close proximity of the vault's entrance.

From there, unless the support vehicle is a forklift capable of driving through a door, the transformer is laid on top of rollers (Rigid conduit) and pushed to the desired location.

As the transformer is pushed, it will roll over top of the conduit. As it rolls over and past each stick of conduit, that piece of conduit is taken from the back and placed in front of the transformer to continue the moving process until the transformer reaches its final position.

Anchor

Whether the transformer is installed on a pad outside or within a vault it will need to be anchored down.

Anchoring ensures the transformer does not move and cause damage to the conduits and/or the cables being connected to it. Bolting it down to the floor or concrete pad generally does this.

Restricted Access

The last step in the installation process is to either install or verify the installation of a secure fence and posted warning signs for transformers installed outside. (Note: An enclosed fence is not required for enclosed pad-mount transformers)

All transformers must have warning signs identifying the equipment as being a “High Voltage” danger. These warning signs can be posted either directly on or around the transformer’s immediate area.

Isolate, Troubleshoot and Trace Underground Cable

When a system's circuit or equipment does go down, you will be required to find the problem (troubleshoot) and make the necessary repairs. Obviously you will want to perform these tasks with the system power turned off.

When you take the necessary actions to de-energize the circuit or equipment, it can be said that you have "isolated" them from the energized distribution system.

You will need to locate underground cable, identify what type of faults the cable may have, and create a safe work environment to perform troubleshooting and make repairs as necessary.

Reasons for Isolating and Grounding of Circuits

There are many reasons you may need to isolate and ground a portion of your distribution system.

It may be required to perform maintenance or repairs to the system or to prepare to install larger transformers for a system upgrade.

Whatever the reason, you must perform isolation and grounding procedures whenever you open or close a switch or device that is out of sight of the work area and whenever the power will be turned off to a section of a circuit or piece of equipment.

The procedures have been developed to protect life and property. They must be used to clear cable circuits and equipment for the safe accomplishment of work in a DEENERGIZED condition.

These actions will enable you to perform work on electrical circuits and equipment in a safe, systematically controlled manner.

Electrical Switchgear

The main piece of equipment used to isolate a circuit is some type of switchgear.

Switchgear provides a means to stop the flow of electricity to the entire distribution system or just a portion of it.

Switchgear can be found in the substation, at the junction of feeders, in between two circuits, or anywhere the engineer decided it was necessary to provide a means to isolate the circuit.

The main purpose of switchgear is to isolate the circuit.

Out-of-Service Protection

Before performing any repair on a piece of electrical equipment, be absolutely certain the source of electricity is open and tagged or locked out of service.

Whenever you leave your job for any reason or whenever the job cannot be completed the same day, be sure the source of electricity is still open or disconnected when you return to continue the work.

Electricians have died because they did not follow proper tag and lockout procedures. These procedures are a must. It takes time to do it, but it is worth the time to save a life.

OSHA Safety Color Codes

OSHA has established specific colors to designate certain cautions and dangers. The list below shows the accepted usage:

Red - Fire protection equipment and apparatus; portable containers of flammable liquids; emergency stop buttons; switches

Yellow - Caution and for marking physical hazards, waste containers for explosive or combustible materials; caution against starting, using, or moving equipment under repair; identification of the starting point or power source of machinery

Orange - Dangerous parts of machines; safety start buttons; the exposed parts (edges) of pulleys, gears, rollers, cutting devices, and power jaws

Purple - Radiation hazards

Green - Safety; location of first aid equipment (other than fire fighting equipment)

Lockout/Tagout Procedures

Utilization of proper Lockout/Tagout procedures is required as described in 29 CFR 1910.147.

This standard covers the servicing and maintenance of machines and equipment in which the unexpected energization or start up of the machines or equipment or release of stored energy could cause injury.

Lockout Device

A Lockout Device is a positive means to hold an energy-isolating device in a SAFE position in order to prevent the energizing of a machine or equipment. A single padlock may be used for single, individual lockout procedures. See image.

Examples are:

- Padlock (key or combination)
- Chain and padlock
- Adapter pins
- Self locking fasteners

Tagout Device

A tagout device is a prominent warning device which can be securely fastened to an energy isolating device. It will indicate that the energy isolating device and equipment being controlled WILL NOT BE OPERATED until it's removal.

The tagout device is constructed and printed so that exposure to weather conditions will not cause it to deteriorate. It shall be substantial enough to prevent inadvertent or accidental removal with the use of excessive force or unusual techniques.

Tag attachment means, shall be of a non-reusable type, hand self-locking non-releasable with strength of no less than 50 pounds.

Tag Labeling

The tag shall warn against hazardous conditions if the machine or equipment is energized.

The tag shall include a legend such as:

- DO NOT START
- DO NOT OPEN
- DO NOT CLOSE
- DO NOT ENERGIZE OR OPERATE

It shall have the name of the person installing the tagout as well as the date of installation. The tag will be affixed to the individual lockout device. If it cannot be attached directly it will be placed as close as possible.

Lockout and Tagout devices will be standardized within the activity by color, shape and size. Tagout devices will also be standardized in print and format. An example of a Tagout Device is shown above.

Ground Set

Grounding is accomplished by using a grounding set. Grounding sets come in many styles, but all are designed to short the phases together and then take them to ground.

In the previous block you were introduced to grounding sets specifically designed for overhead distribution system grounding operations.

It is important for you to understand that those same grounding sets will not be used in support of underground distribution systems due to the differences in equipment design and the use of cable terminations verses open conductor.

Cable End Clamps

A quick way to identify an underground grounding set is by the end clamps. Underground grounding sets use clamp-type clamps or elbows on the end of the cable. Because of the importance of grounding, perform a visual inspection of any and all grounding sets prior to leaving the work center.

Make sure that you have the proper type of grounding set for the type of electrical system you are going to be working on. While doing the visual inspection, pay particular attention to the condition of the grounding set's cable and clamps.

Grounding Set Cable

The cable of any grounding set must be large enough to handle the induced current and maximum fault current that the source, such as a substation breaker, can deliver.

During a fault condition the cable can whip back and forth. Therefore, it must be made of a flexible, stranded conductor. The conductor will also have a 600 volt insulation rating. Most shops will have a ground set large enough to be used anywhere on the installation.

Clamps for Grounding Set

The clamps of an underground grounding set must be approved grounding clamps of the highest quality of construction designed for the specific purpose of grounding.

As is the case with the grounding cable, the grounding clamps must be of such size and construction as to carry the induced current and maximum fault current that could flow at the point of grounding for the time necessary to clear the line.

Clamps on the "hot" end of the cable may have insulated sticks permanently attached or be operated by using an insulated "shotgun" or rigid splice stick; see image.

Clamp-type Ground Set

The use of hot line clamps is not acceptable. Hot line clamps are not designed to handle large fault currents. The approved grounding clamp must also be permanently attached to the cable.

A live front transformer, shown in the left image, requires the use of a clamp type ground set, shown in the right image.

If grounding a dead front type transformer, the ground set may use elbows instead of clamps. Again, an approved elbow must be used as part of the ground set. As a general rule, if you purchase a ground set from a manufacturer, you are buying approved equipment.

If you make a ground set out of material you have laying around the shop, you are asking for trouble. Do not make your own grounding set. Buy an approved grounding set from a manufacturer.

Create a Procedural Plan to Isolate a Circuit

Isolating a circuit or system component requires careful planning. Even in an emergency, you will need to develop a plan prior to working on any circuit or high voltage equipment.

Any plan you develop will require you to refer to base distribution maps and draw on the knowledge of co-workers familiar with the distribution system in order to document the blocking and tagging procedures on the Lockout/Tagout Log.

The more detailed you make the locking and tagging instructions, the better off you are. When developing your plan, keep the customer in mind. Limit the isolation to areas that will have the least affect on customers.

Once you have finished developing your plan, have others review it and get their opinion. No matter how much knowledge you may have about the system, you may have left out important steps. Others may be able to fine-tune your plan, making it the best possible product.

Properly Communicate the Plan to all Team Members

Once you have devised a plan, it will be time to isolate the circuit or equipment. However, before the work actually starts it is common practice for the supervisor to brief every member that will take part in the job on all of the step-by-step procedures.

Steps required to accomplish the job, starting with the isolation procedures, through the procedures required to perform the installation, repair, or maintenance, and finally the procedures required to re-energize the circuit or equipment.

Everyone must know exactly what must be done and when, before any work begins. When working with electricity, safety must be the primary concern. After completing the required actions, make sure to record the time on the Lockout/Tagout Log.

Locking Out a Switch / Including Remote Access

Opening a switch does no good if you do not lock it out. Locking the switch in the open position and applying the appropriate tag to warn others will ensure your personal protection and that of your coworkers.

Make certain the tags are completely filled out with the correct information. Wrong information on a tag is just as bad as not tagging it at all. See image.

If a switch is operated by a motor, the motor must be disconnected from the system. Some switches can be operated from a remote location such as inside the blockhouse at the substation.

In this instance, the motor on the switch must be disconnected and tagged to prevent it from being inadvertently operated. Group maintenance requires a lockout device enabling each worker a place to position an individual lockout device.

Isolate the Circuit, Prior to Installing a Ground Set

Before installing the ground set, you obviously need to de-energize the system. That was the purpose of the detailed locking and tagging plan. Remember, your first priority when working on any high voltage circuit is the protection of personnel.

Use a high voltage phase tester to verify that the circuit or equipment you will be working on has been de-energized prior to installing a grounding set.

Beware of Stored Energy

One thing of which you need to be aware is that underground high voltage cable acts like a capacitor. It will store a charge even after the cable is de-energized. Because of this, do not make contact with any exposed conductor or elbow electrode prior to grounding it.

Know the System Voltage

Prior to testing, you must know the system voltage so that you will know what reading to expect during the test with the high voltage phase tester and that your tester is capable of reading the level of voltage on the system.

If the system voltage is higher than the rating of your high voltage phase tester, the meter may fail and cause you serious injury.

Using Feed-Thru Bushings

When testing dead front equipment, use adapters on the high voltage phase test set. Screw bushing adapters to the end of the phase tester to test the bushings on the equipment for voltage. Along with bushing adapters, you may need feed thru bushings (image).

Feed-thru bushings allow you to “park” a load-break elbow on one side of the bushing so you can test the other bushing of the feed thru for voltage. Remember to treat these cables as though they are energized. They are not safe until they have been grounded.

Using the High Voltage Phase Test Set

Always use universal hot sticks (image-left) when using the high voltage phase test set, (image-right). Do not use the phase test set with your bare hands or with just a set of rubber gloves on. If you detect voltage, leave the meter on long enough to get a clear meter indication.

This meter is not designed for continued contact with energized circuits for long periods of time. However, make sure you leave the meter on long enough to provide a clear and concise reading. This is no time to “think” you know what the meter indicated. You must be certain.

Testing Procedures

When you test cable or equipment for voltage, you must follow a very definite set of procedures. First, test the operation of the meter by measuring the voltage of a known "live" conductor.

Next, use the meter to test each phase of the cable that is supposed to be "dead". If no voltage was indicated on the de-energized cable, again test the meter on a "live" conductor to ensure it is still working properly. See image.

Other voltage meters may be used to test the cable. They are the digital voltage indicator and the high voltage audible indicator. Some phasing sticks use a glow lamp to indicate the presence of voltage instead of a meter reading

Install Ground Set

Once you have determined there is no voltage present on the cable or equipment, it is time to apply the grounding set. You must securely ground the grounding set before making connections the cable or equipment. Do this by firmly clamping the ground clamp to a good ground, such as a counterpoise, primary neutral or grounding electrode.

Temporary Grounding Sets

Most underground equipment has a grounding rod already installed and connected to the case. If for some reason there is not ready access to an established ground, you must install a temporary grounding rod. After you have done so, attach the free clamps of the grounding set to the conductor(s), (see image of a grounding set), using an approved and tested hot stick.

As a further safeguard, stand as far away as you safely can in the event an arc develops because the equipment is energized. Once all the phases have been grounded, the circuit or equipment is considered safe and ready to be worked. In removing grounds, the clamps must be detached from the conductors first.

Safety Concerns in using Grounding Sets

The task of isolating a circuit or equipment and installing grounding sets is filled with safety concerns. Of paramount importance is that you know your system voltages. Only by knowing these voltages will you know what to expect when taking voltage readings.

When taking readings using a phase test set or applying grounding leads, you will want to make sure you use hot sticks and personal rubber equipment. Never assume a cable or equipment is de-energized. Always check for voltage before installing a grounding set and only use ground sets that will handle the maximum fault current of the system you are working.

Pre-Use Inspection

Prior to installing a ground set, perform a pre-use inspection. Check the cables to see that none of the strands are broken. Make sure that all the cables are securely attached to the clamps and inspect the clamps to see that they operate freely.

You must strictly adhere to and 100% complete isolation procedures before attempting to work on any cable or line equipment without personal protective gear. Remember, if a cable or equipment has not been grounded, it is not dead!

Basic Measuring Equipment Precautions

When using measuring instruments, you must observe certain precautions. For example, it is especially important to be careful in using an ammeter because of its low internal resistance. If mistakenly placed across a voltage source, the meter can be damaged.

Always break the circuit and connect an ammeter in series, with one meter lead going to each point of the circuit breaker to measure an unknown quantity.

Be sure to de-energize the circuit before making or breaking the connections.

Start at the Highest Meter Range

When using either ammeters or voltmeters always start at the highest meter range. Then drop down to a lower scale range if necessary.

This practice protects the meter from injury if an attempt is made to read a high value in a low range.

You will also minimize damage to instruments if you form a habit of placing the range selector switch in the highest range position after you have finished using the instrument.

Observe Polarity

Observe polarity on all direct-current measurements. Take care to connect the positive terminal of the source to the positive terminal of the meter and the negative terminal of the source to the negative terminal of the meter.

This action ensures that the meter polarity matches the polarity of the circuit in which the meter is placed.

Be careful to avoid dropping a meter or subjecting it to excessive mechanical shock. Such treatment may damage the delicate mechanism or cause the permanent magnet to lose some of its magnetism.

Take care to avoid connecting the ohmmeter across circuits in which a voltage exists, since such connection can damage the instrument. Secure power first.

Discharge Capacitors

All capacitors must be discharged before the ohmmeter prods are connected in the circuit.

Charges remaining on capacitors after the applied voltage has been removed can severely damage the instrument.

Turn off when Finished

Always turn ohmmeters off when finished. This action will avoid discharge of the internal battery if the test leads are shorted inadvertently.

It is important that you remember to use a low voltage megger to test low-voltage insulation. Application of high voltage may initiate insulation breakdown.

Avoid…

Using low voltage meggers to test high voltage insulation, because an inaccurate reading may result from the comparatively small output voltages available from this instrument.

Be careful whether using high or low range meggers. Dangerous voltages exist at meter terminals and leads.

Test Equipment - Digital Multimeters

There are many different types and styles of autoranging digital multimeters designed for the professional at work in the field.

These instruments stand up to the use and abuse of everyday service and electrically insulate the user from potential shock hazards.

They have electronic overload protection against accidental application of voltage to resistance and continuity circuits. These characteristics, combined with their rugged construction, make them durable and reliable instruments.

Maintenance on Multitesters

Maintaining and cleaning these instruments is easy. Maintenance consists of periodic cleaning, battery replacement, fuse replacement, and recalibration. Perform calibration on these meters every year.

Clean the exterior of the instrument with a soft, clean cloth to remove any oil, grease, or grime from the exterior of the instrument.

Never use liquid solvents or detergents. If the instrument gets wet for any reason, dry it using low pressure "clean" air at less than 25 psi.

Use care and caution while drying around the display protector and areas where water or air could enter the interior of the instrument.

All resistance measurements should be taken on de-energized circuits only. When using compressed air for cleaning, wear chemical splash goggles. Do not direct the air toward eyes or skin.

Vibroground

The vibroground functions on the null balance principle. The current flows through a calibrated potentiometer that causes a voltage drop, which is fed to the primary of the ratio transformer, inducing a voltage drop in the secondary causing a current flow in the measuring circuit.

This current cancels the current in the measuring circuit due to the voltage drop across the ground resistance between the electrodes connected to terminals X and 1.

When the potentiometer and range switch are adjusted so that the two currents exactly cancel, the galvanometer needle will rest in the zero position.

Biddle Direct Reading Meter

The Biddle direct reading meter measures the resistance of ground connections to earth, thereby helping to determine the effectiveness and integrity of such grounding systems. It can also measure soil resistivity and determine optimum locations for earth electrodes. The resistance to earth ground should be less than 25 ohms and as close to 5 ohms as possible.

An AC test current, generated by the instrument, is passed between the ground under test and a current electrode (or reference ground). This potential drop to a separate electrode (or reference ground) is applied to a bridge circuit and nulled with a three-decade variable resistance. At balance, ground resistance in ohms is read instantly from the digital decade switches.

This null balance method means that at balance no current flows through the potential electrodes, and therefore, their resistance does not affect the reading.
The Biddle direct reading meter comes with 2 probes and 3 cables (red, green, and yellow,) in a carrying case.

Clamp on Ammeter

The Clamp On ammeter is used to check current on secondary distribution mains, service drops, and individual dwelling circuits.

The clamp on ammeter allows it to fit around a conductor to measure AC or DC current without breaking the circuit. See image.

Phase Rotation Meter

Phase rotation meters (image) are used to check for proper phase rotation of three-phase equipment being put into service for the first time.

It is also used to check phase rotation of alternators and generators that will be operated in parallel.

Maintenance of Distribution Systems

Overview

The elements, accidents, and willful vandalism cause most damage to power distribution equipment.

To repair these damages, the lineman requires experience, a total commitment to safety, and the knowledge repair the system as quickly and economically as possible.

Maintenance of Poles, Timbers, and Crossarms

The maintenance required on the poles, timbers, and crossarms in a power distribution system is minimal. Normally, this equipment lasts for 20 years or more.

The following problems may occur, however, and create a need for maintenance:

- A pole can settle and require straightening.
- Wood can shrink and cause all hardware to become loose and require tightening.

Wood Pole Maintenance

Wood poles are treated with preservatives to prevent decay, but small organisms, insects, and fungi all contribute to the breakdown of the wood preservatives.

The life of a pole can be extended by inspections and treatment, when necessary, to stop pole decay.

The inspection would normally include sounding the pole by hitting it with a hammer from belowground level to approximately 6 feet above ground to determine obvious defects. It also includes boring the pole to determine the presence of internal voids.

Poles with internal decay can be treated with insecticides. External decay is removed, and the area treated with preservatives and wrapped with a moisture-proof barrier.

Poles weakened excessively by internal or external decay must be reinforced or replaced.

Maintenance of Hardware, Conductors, Accessories, and Guys

Other items that may require maintenance are the hardware, conductors, accessories, and guys. Over time, guys can stretch and require re-tensioning.

Insulators get dirty and require cleaning, especially around the sea where there is salt in the air. They can also crack and require replacement.

Connections become loose with age and must be re-torqued to prevent hot spots, and in time, conductors stretch and require re-sagging.

Corona Discharge

“Corona” is defined as the luminous discharge due to ionization of the air in the vicinity of a conductor when the voltage gradient exceeds a certain critical value.

Interference Elimination

Another important area of maintenance is noise interference elimination in the power distribution system.

Power lines may be a source of interference with radio communications.

Conductors, insulators, and hardware contribute to this interference by spark discharges, localized corona discharge, and cross modulation.

Cross Modulation

Cross modulation (often the result of a corroded connection that causes nonlinear rectification of currents) may occur when splices are made by twisting the conductors, rather than using a tighter mechanical splice.

Additionally, when conductors of dissimilar metals are joined, corrosion occurs unless special connectors designed for the specific combination of metals are used.

Remedies for conductor, insulator, and hardware interference are relatively simple.

Remember, the condition for hardware interference exists whenever two pieces of hardware are not securely bonded to each other or are permanently separated by too short an air gap.

Transmission Line Inspections

Transmission lines should be inspected periodically, especially after construction or severe weather.

What to check for:

- Conductor condition.
- Conductor sag, clearance to ground, trees and structures.
- Condition of insulators.
- Line hardware, roughness and tightness.
- Excess inhibitor found should be removed from conductors to prevent corona discharges.
- Structure vibration and alignment.
- Guy anchors secure, guy wire condition, and missing or damaged guy guards.
- Ground wire connection and condition.
- Ground resistance for each structure.
- Structure footings for “washout” or other damage.
- Obstruction light operations if required for aircraft warnings.

Inspection Intervals

- Initial climbing inspection 1 year after initial entry into service.
- Climbing inspections are held approximately at 10 year intervals after that.
- Inspections by lineman walking the line are also completed at 10 year intervals in between the climbing inspections. This ensures a close look at the lines every 5 years.

Distribution Line Inspection

What to check for:

Poles - Broken or damaged, need replacement; Leaning poles, unstable soil; Poles in hazardous locations.

Guys - Slack, damaged or broken; too close to primary conductors or equipment; guy insulator improperly installed.

Pole Top assemblies - Broken, burned or damaged pins and/or crossarm, needs immediate replacement; broken skirt of pin type insulators.`

Line conductors - Too much slack in primaries; floating or loose conductors; conductors burning in trees; foreign objects on the line; insufficient vertical clearance over and/or horizontal clearance from other wires, buildings, parks, playgrounds, roads and spaces or ways accessible to pedestrians, waterways, boat launch areas.

Equipment installation - Leaking oil, arrestor blown or operation of the ground lead insolation device, blown fuses, switch contacts properly closed.

Inspection Intervals

A scheduled inspection should be completed every 5 years or more often if a circuit has a record of poor reliability.

These inspections must be done properly and as scheduled.

Failure to do so can cause complete equipment or electrical service breakdown. but most importantly could cause serious injury or death.

Capacitor Maintenance

Switched capacitors should be inspected annually, prior to the time they are automatically switched on and off.

Capacitor bank oil switches should be maintained on a schedule related to the type of on/off controls installed at each bank.

Capacitor switches are commonly removed from the line and replaced with a spare during the season they are not normally operated. The main switch is more effectively maintained in the shop.

The maximum number of open and close operations between inspections should not exceed 2500.

Recloser Maintenance

There are various types of reclosers and their maintenance schedules vary by type.

Hydraulically controlled reclosers - should be maintained after 50 operations or every 2 years.

Electronically controlled reclosers- should be maintained after 150 operations or 2 years.

Vacuum reclosers - require field testing every 3 years by high potential testing of the vacuum interrupter bottles.

All line reclosers will be installed with bypass provisions and a means for isolating the equipment for maintenance.

Pole Mounted Switch Maintenance

The lineman should check group mounted or single pole switches each time they are used.

What to check for:

- Burned contacts
- Damaged interrupters or arcing horns
- Proper alignment
- Worn parts
- Defective insulators
- Adequate lightning arrestor protection
- Proper ground connections
- Loose hardware

Inspection Intervals

Switches that have not been adequately inspected (rural areas) will be inspected at least every 5 years.

Underground Distribution Circuit Maintenance

Underground circuits originate at a substation or riser pole. Various components of these circuits, such as risers, switchgears, and cables must be inspected and the inspections properly documented.

Riser Maintenance

Risers should be inspected accomplished when overhead lines are being inspected and maintained.

What to inspect:

- Disconnect switches.
- Fused cutouts.
- Lightning arrestor.
- Operation of arrestor ground lead insulation devices.
- Riser cables and “potheads” or terminations.
- Support of the cables, conduit and/or “U” guard.

Switchgear Maintenance

Switchgears should be inspected annually.

What to inspect:

- Concrete pad cracked or tipping.
- Metal surfaces, peeling paint or traces of rust.
- Locks on doors work properly.
- Cleanliness of the switchgear area, to maintain the dialectic strength of the insulation.
- Equipment with insulating oil must be checked for moisture or contamination.
- Switches, fuses and other internal equipment in accordance with manufactures instructions.
- Cable grounds, terminations and other connections must be in good condition.
- Repairs

Records serve a vital function and are the basis for predicting equipment failure and for selecting future equipment needs.

De-energizing Lines for Maintenance

Prior to de-energizing a line for maintenance, you should make arrangements with the proper authority. You should also notify the affected customers prior to taking an apparatus out of service.

Before performing any maintenance, assure that:

- The breaker is open.
- The breaker is disconnected from the circuit on both sides.
- Disconnect switches are open.
- Drawer breaker is removed from the switchgear.
- All control circuits are open and potential transformer fuses removed.
- The supply to pneumatic/hydraulic operated breakers is shut off.
- Breakers and controls are properly tagged.
- The breaker is grounded.
- Barriers are installed between the breaker and adjacent apparatus that may be energized.

Summary

This course has addressed many of the basic components that make up both overhead and underground high voltage power distribution systems.

PPE - In this course we covered the commonly used gear and equipment required of personnel, to safely install and troubleshoot distribution systems.

Understanding these components is the fundamental knowledge needed, in order to effectively design and construct a power distribution system.

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This concludes our course on "Fundamentals of HV Electrical Power Distribution".
You may now proceed to the final exam.

Thank you for taking this Flashcard course!

Fundamentals of HV Electrical Power Distribution , 2019 Edition
Second Printing: April, 2019