CHAPTER 4

OVERHEAD DISTRIBUTION

Section I - ASSOCIATED OVERHEAD DISTRIBUTION GUIDANCE

4-1. Relevant overhead distribution guidance.

Maintenance work involving aerial line changes requires an understanding of the basic design premises of overhead construction requirements.

a. Location of electric circuits on poles. Where more than one electric circuit is carried on a pole, the highest voltage is at the top down to the lowest voltage above any communication circuits. Through wires of the same voltage level should be carried above local wires (those which are tapped frequently). The two or more wires of a circuit should always be carried in adjacent positions. To facilitate troubleshooting, wires of a circuit should always take the same positions on all poles, except where long lines have been provided with a transposition (change of line positions) to reduce electrostatic and electromagnetic unbalance.

b. Joint electric supply and communications circuits on poles. Electrical supply wires must be carried above communication circuits. Minimum clearances between supply wires and communication wires are specified in the NESC.

4-2. General construction guidance.

Rights-of-way for navigable water crossings and structure identification and climbing space free of obstructions must meet the following requirements.

a. Rights-of-way requirements. When the system is being extended across navigable waters within the United States, permission must be obtained from the nearest District Office of the U.S. Army Corps of Engineers. When crossings are made in waterways under the jurisdiction of other authorities, those authorities should be consulted.

b. Identification requirements. Poles, towers, and other supporting structures should be marked or numbered to facilitate identification by employees authorized to work on them. If the facility has no consistent identification method, it is recommended that such a system be implemented.

c. *Climbing space.* Despite the fact that, where practicable, nearly all pole work will be done from a bucket, the need for climbing space still exists. Sufficient space must be reserved for positioning the bucket to enable the linemen to perform their tasks; and actual climbing may be required on occasions. The recommended facility climbing space requirement is a square 30 inches (750 millimeters) on each side. Figures 4-l and 4-2 show details for various conditions. Any maintenance, repairs, replacement, or addition must be done in a way that maintains at least the minimum climbing space required by the NESC which may be less than the recommended space.

d. Obstructions. Poles and other structures should be kept free from posters, banners, nails, radio antennas, signs, or other devices that might interfere with safe working conditions.

Section II - DEFINING VOLTAGE NOMENCLATURE

4-3. Voltage terminology.

Voltage terminology can be very confusing, especially if there is no mutual understanding as to whether the term is defining a voltage level, a delivery usage, or an origination point.

4-4. Voltage level classification.

The accepted standard for voltage classifications is ANSI/IEEE 141. Low voltage is used for 600 volts or less, medium voltage is used for above 600 volts to 69,000 volts, high voltage is used for 115 to 230 kilovolts. Any voltage above this is called ultra-high voltage. The term high voltage is most often used when medium voltage is meant.

4-5. Voltage delivery usage.

There is no standard for delivery usage; but transmission system is used for high and ultra-high voltage systems; subtransmission system for 46- to 69-kilovolt systems; and distribution system is used for 35 kilovolt down to and including low-voltage systems. Utilization voltage is also used to describe the voltage from which the equipment directly operates, which may in some cases be a medium-voltage input.

4-6. Voltage origination point.

Input to a device which transforms voltage from one level to another is called a primary circuit, while the device’s output is called a secondary circuit. While most transformers are used to step down voltages, there are cases of step-up systems; so a primary circuit could have a lower voltage than a secondary circuit.

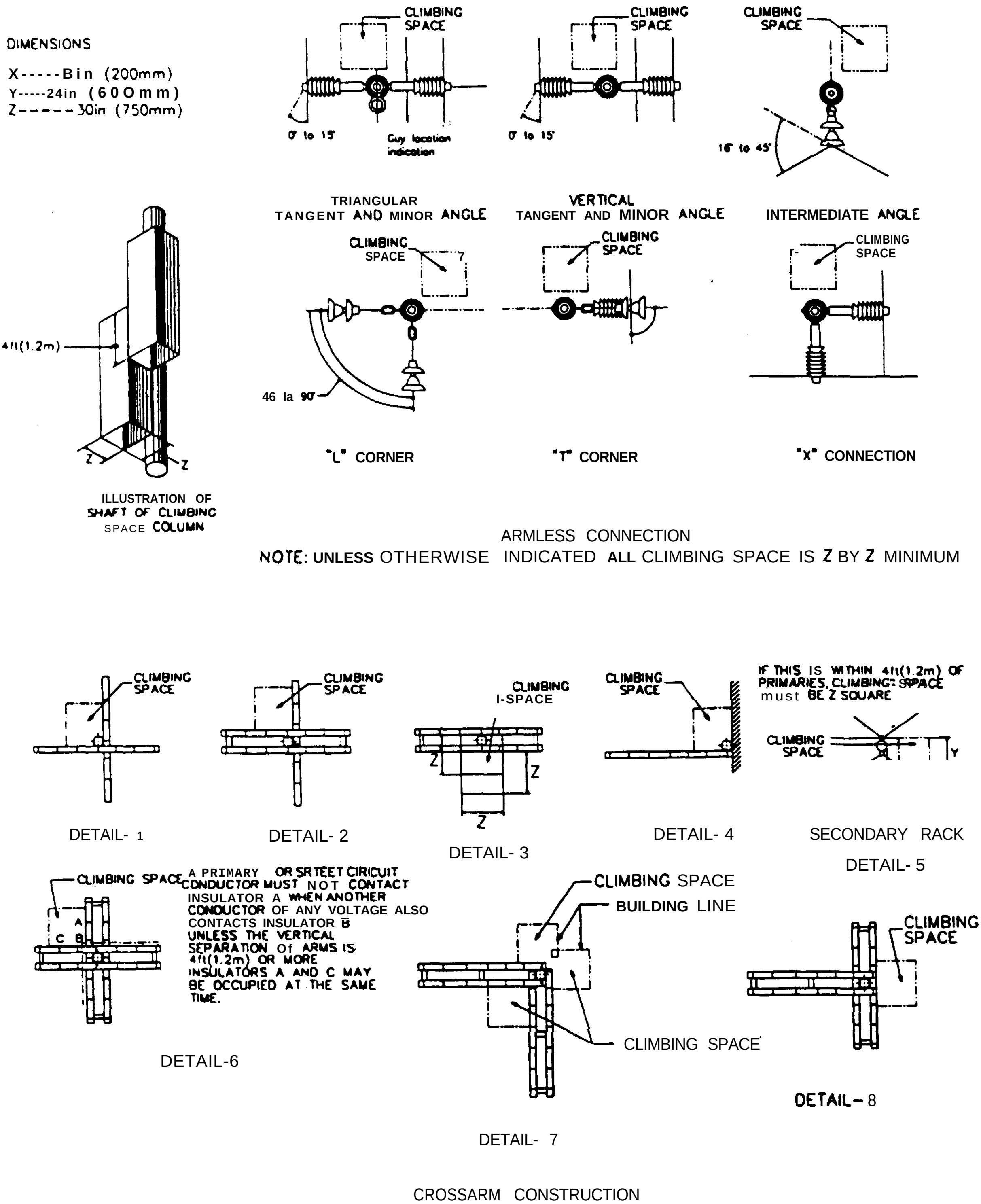


Figure 4-l. Details showing various horizontal dimensions necessary to provide recommended climbing space

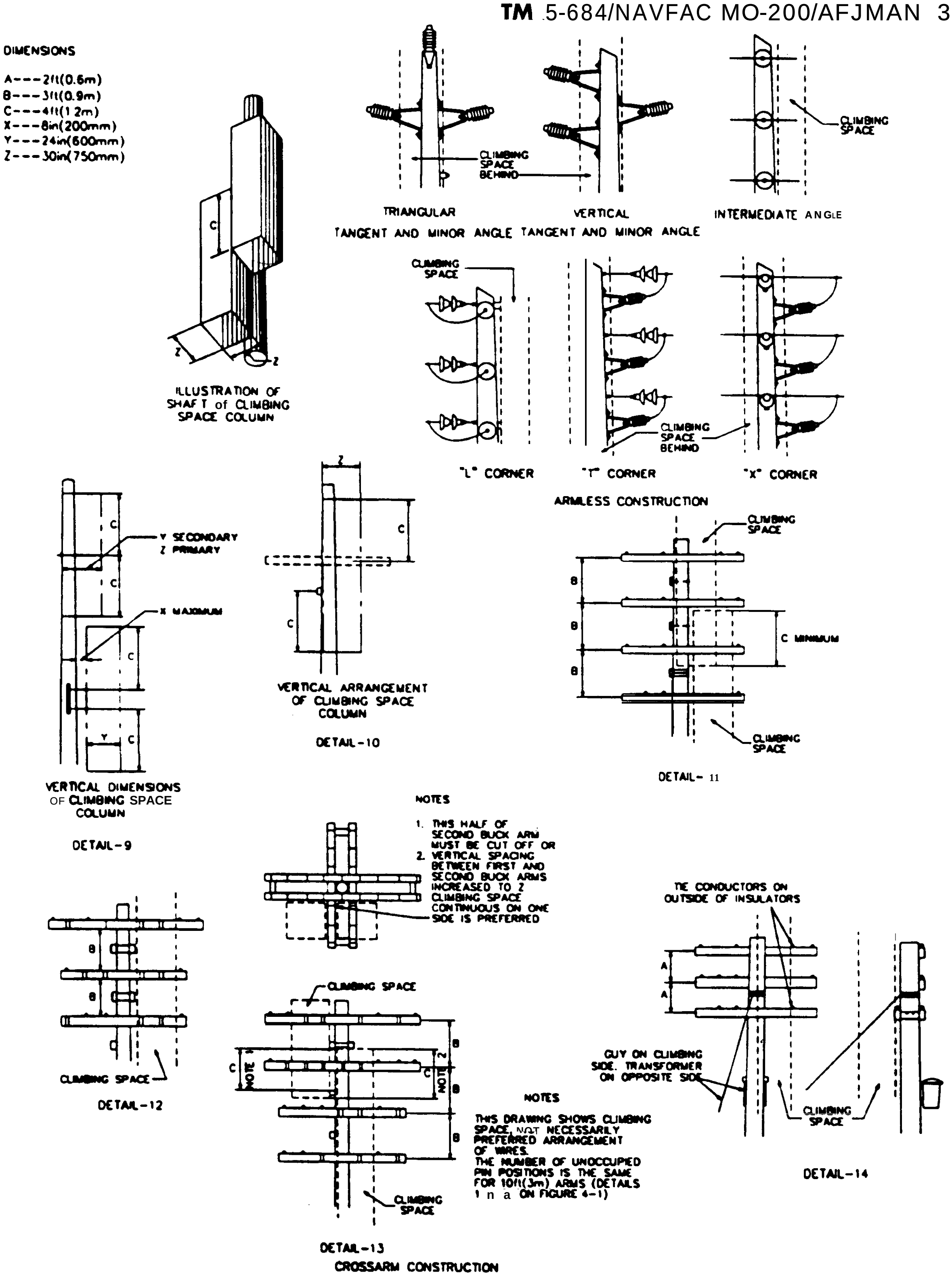


Figure 4-2. Details showing various vertical dimensions necessary to provide recommended climbing space

4-7. Voltage terminology usage in this manual.

The convention understood by most persons qualified to perform various electric line-work operations, that is, for aerial, underground, and at-grade work, is the one used in this manual, unless otherwise stated. Therefore, primary circuits have a medium-voltage rating; secondary circuits have a low-voltage rating.

Section III - TYPES OF MAINTENANCE

4-8. Component line maintenance.

The various components which make up an overhead line system include poles to carry and insulators to support the line, along with line connectors and guys. Most poles encountered will be wood, and most primary line conductors will be bare. There are conditions, though, which justify the increased cost of metal or concrete poles or primary overhead insulated lines or cables. Increasing use of armless construction will minimize, but not completely eliminate the use of crossarms. Pad-mounted, compartmental-type transformers are also replacing, to a large degree, many unaesthetic aerial platform-mounted, transformer installations. The discussion of maintenance necessary for the components mentioned assumes all work will be done on unenergized lines (unless specifically noted otherwise) and that all clearance procedures required to provide service, as mandated by TM 5-682, NAFVAC P-1060, or AFM 32-1078, have been followed.

4-9. Other types of line maintenance.

Trees adjacent to overhead lines pose a line clearance problem, requiring both checking for interferences and trimming on a planned time cycle. Maintenance methods on energized overhead power lines require special training and tools to meet safety requirements, but can reduce service interruption times where operational requirements do not permit the necessary outage period.

Section IV - WOOD POLES

4-10. Life span of wood poles.

The average life span of a full-length pressure-treated wood pole can be maintained and even extended another 10 to 20 years with a proper inspection, treatment, and reinforcement program.

4-11. Supplementary data on wood poles.

Pertinent information is covered in appendix C on why poles fail, initial installation, types of wood used for poles, influence of local conditions, and decay patterns.

4-12. Wood pole record keeping and inspections.

Proper record keeping is the basis for a systematic program of pole inspection and maintenance. These records will determine courses of actions based on actual examinations, eliminate much guesswork, extend actual pole life, and accumulate the historical data required to evaluate future pole maintenance costs.

a. Essential record data. The first point is to record the pole location, identification number, date of installation, and a manufacturer’s pole brand. Then poles should be rated based on the initial pole scheduling inspections. Ratings should indicate soundness of pole, any treatment provided during inspections, and any failed poles marked for safety because replacement or reinforcing is needed immediately. A sample format for recording data is shown in figure 4-3. The format shown should be revised as needed to meet local requirements.

(1) *Interpretation of pole brands.* An understanding of the brands on the side of a pole is necessary for proper inspection, record keeping, and reporting. An example is shown in figure 4-4. The brand is near eye level and is generally burned into the wood, though some pole suppliers use a countersunk aluminum disk.

(2) *Pole brand indications.* The codes for species and preservatives treatments are as follows:

(a) Timber species are coded as SP-southern pine; WC-western red cedar; DF-Douglas fir; WL-western larch; NP-northern (red or Jack) pine; LP-lodgepole pine; WP-ponderosa pine.

(b) Preservatives are the oil-borne type coded as A for pentachlorophenol; B for copper naphthenate; C for creosote, and the water-borne type coded as CCA for chromated copper arsenate and ACZA for ammoniacal copper zinc arsenate. Only copper naphthenate is a nonrestricted-use pesticide.

(c) Retentions are shown with a number for the pounds per cubic foot. On poles which show no retention figure, the pole was not pressure treated and should be rejected.

(3) *More data. See* AWPA M6 for more complete information on brands.

b. Initial pole scheduling inspections. Two types of initial pole scheduling inspections should be pro-

POLE INSPECTION AND MAINTENANCE RECORD

Inspector SPARKS, J Date 3 OCT 94

Map 78-1 Line Location SPRIGGS RD Starting Point SUBSTATION 2

Pole No.	Codes From Pole Brand: Length and class	Species	Supplier	City	Year	Preservative	Original treatment (code)	Inspection and maintenance (code)	Other Maintenance/Comments
7918	40-3	RD.CEDAR	POLES INC	TANK	84	TMI AA	BUTT	2	CK IN 6 MONTHS
7919	40-3	RD.CEDAR	POLES INC	TANK	86	TMI AA	10	1	

Code for Type of "Original Treatment"

Code	Explanation
8 (or 10)	Pressure treated--record pounds per cu. ft. shown on brand.
FLNP	Full-length non-pressure lreated (no pound shown on brand).
Butt	Butt treated

Code for "Inspection and Maintenance"

Code	Explanation
1	Pole ● ound, no evldence of decay or olher damage. groundline treatment applied. Relnspect In 7-10 years.
2	Some evidence of minor decay. Groundline treatment epplled. Relnspect lo S-7 years.
3	Moderately ● dvanced deca but pole well above minimum permissible groundline c rcumfemnce. Groundline treatment applied. Reinspect In 5-5 years.
4	Extensive decay. No groundline treatment applied. Relnepect. replace or stub within 1 year:
5	Failure. Replace or ● lub promptly.*

* Pole marked for safety.

Figure 4-3. Sample format for recording pole inspection and maintenance data

vided and will be used to determine future inspection frequencies.

(1) *Spot inspections.* Poles should be examined 8 to 10 years after a line is built. This spot inspection will decide courses of action as indicated below:

(a) When the examination of a representative number of poles (extended to the total number of similar poles in the line) shows there is advanced decay in 1 percent or more of the poles, or some minor decay in 5 percent or more of the poles in the line, a pole-by-pole maintenance program should be scheduled as soon as practicable.

(b) When the spot inspection shows there is only some minor softening of the wood in less than 5 percent of the poles in the line, the pole-by-pole maintenance program may be deferred 3 to 5 years.

(2) *Pole-by-pole inspections and maintenance.* This program should be planned for a line 13 to 15 years after construction, though the spot inspection will determine more precisely when it should be started.

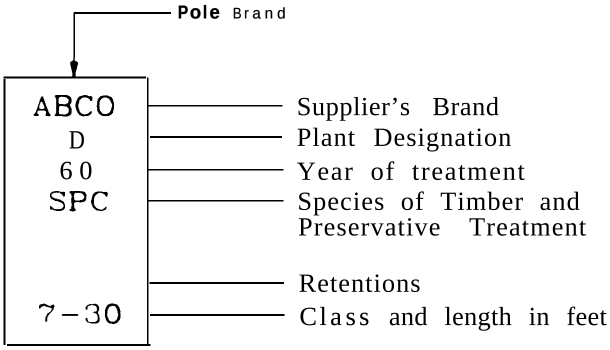


Figure 4-4. Typical pole brand and key

4-13. Wood pole maintenance crew instructions.

The crews used for pole inspections should be provided with instructions as to inspection precautions, duties, safety requirements, and use of equipment. Crews should always review any pole history available.

a. Spot examination crews. Crews of two or three people should be provided with an experienced crew leader.

b. Pole-by-pole crews. Crews of three to five people may be provided by the facility or work may be done by contract personnel. In either case, an experienced person employed by the facility should closely supervise the work.

c. Crew duties. The duties of the crew consist of observing the pole tops, crossarms, and attachments; inspecting the pole to a height that can be conveniently reached from the ground; excavating and inspecting the pole below the ground line; applying groundline treatment; keeping accurate records; and any other work, as appropriate.

d. Safety precautions. Follow all safety regulations described in TM 5-682, NAVFAC P-1060, or AFM 32-1078. Safety requires that any pole that has lost strength from decay or other cause to the point of being hazardous should be replaced or reinforced. Simple economy, however, requires that such condemnation be arrived at only after careful inspection, including measurement of groundline circumference when only groundline decay is involved. This means that lines may contain many poles that have lost a certain amount of their original strength and thus should be climbed only after taking proper precautions, such as guying. Pikes poles (a tool used in raising poles) are not permitted for support while personnel are working on poles. Before climbing a pole, the lineman should use spot examination methods to check a pole for which there is no recent inspection record. No inspection member who is not a lineman should be instructed to provide maintenance requiring a lineman's qualification.

e. Inspection equipment. For convenience, the following list shows the minimum amount of equipment usually needed. It may be added to according to type of soil, terrain, or extent of work to be undertaken.

(1) A shovel for digging around the pole and a tamper for use when the soil is backfilled.

(2) A flat-bladed spade, a suitable scraper, and a chipper to remove decayed wood.

(3) A wire brush for removing dirt and decayed wood.

(4) A pole prod or a small blunt tool for probing the pole for decay below ground line, such as a *dulled* ice pick or a screwdriver.

(5) An increment borer and wood plugs.

(6) A 1- to 2-pound (0.5 to 1-kilogram) hammer for sounding poles and for driving wood plugs.

(7) A tape for measuring the groundline circumference of the pole and a 6-inch (150-millimeter) rule.

(8) A flashlight and a binocular (6 x 30) for observing the upper portion of the pole above the inspector's groundline vision.

(9) Previous records and blank forms for recording all details of work.

(10) Dating nails to indicate year of inspection or groundline treatment and tags to indicate rejected poles and dangerous poles.

(11) Preservative and application equipment for groundline treatment.

(12) A first-aid kit to handle minor injuries.

f. Recommended time of year: If possible, inspect during the summer months when preservatives need not be heated, digging is easier, and the pole is drier. A dry pole makes examination for decay more positive, and ensures better penetration of preservatives.

4-14. Wood pole spot inspection procedures.

The spot inspection should not be confined to poles most convenient to reach, as this could give an absurd indication. A sufficient number of poles in a line should be sampled in arithmetical progression, checking every alternate pole or every third or fifth pole, depending upon the uniformity of conditions.

a. Visual. Make visual inspections from the ground using binoculars and flashlights to check for cracks, shell rot, knots, hollow spots, woodpecker holes, and burned spots.

b. Probing. A long probe or prod in the form of a 1-foot (0.3-meter) steel bar with a blunt point has been found useful in spot inspecting poles when a pattern of external decay is established. Such prodding should be done with care so as not to jab holes into the wood. As an improvement on this method, a special prod or impaction tool is now on the market.

This tool has a sleeve-like hammer; and, through vibrations carried to the hand, it is possible to detect decay below the ground line.

c. Sounding. Make a sound test to check for internal decay.

d. Nondestructive pole testing. The Electric Power Research Institute (EPRI) has developed a "PoleTest™" instrument that analyzes the sonic waves it sends through the pole to indicate the strength of the pole keyed to its wood species and diameter.

(1) *Components.* The complete testing setup consists of a programmed dedicated instrument, an input sensor, a pendulum impactor, output sensor, and impact nail. Specialized tools are provided to install pole-mounted items.

(2) *Operation.* The operator designates the wood species, diameter and length of the pole. After the correct input sequence and pendulum impacts, the unit will display the pole fiber strength, diameter, and species. From this information, the conformance of the pole's strength to NESC requirements can be determined by comparison with the required maximum fiber stresses for the various classes of poles given in ANSI 05.1.

(3) *Engineering judgement.* Interpreting the results requires engineering judgement. Testing should be made at the groundline unless there are more critical stress locations, that is points of damage or points of line loading. Since the existing bending strength of the pole determines whether the pole has adequate strength, the orientation of sensors should normally be perpendicular to the direction of the line.

e. Groundline inspection. If the soil is soft enough, probing through the soil at two or three places several inches (centimeters) below the ground line may reveal sound or decayed wood without excavation. Excavation should remove soil only where one or two major ground level separations (checks) are present in a pole.

(1) *Excavation.* Soil may be removed to a depth of 8 to 12 inches (20 to 30 centimeters) and the below-ground pole surface examined or probed.

(2) *Soil sterilization.* Excavation aerates the soil and encourages the growth of fungi. When new pressure-treated poles are first installed, some of the preservative diffuses into and sterilizes the soil immediately adjacent to the pole. When the soil around the pole is disturbed for any reason, or the pole is relocated, the soil must be sterilized. Use 2 or 3 gallons (8 to 12 liters) of an approved preservative solution and thoroughly mix with the backfill. Many effective pesticides that are easily applied in most soils prevent subterranean termite attack; kill fungi and weeds in the treated area; are very toxic; and must be approved for use. None of the preservative should be exposed when backfilling is completed. Personnel applying pesticides must be certified in accordance with applicable directives.

(3) *Backfilling.* Replace with sufficient resterilized soil tamped to avoid any water-collecting depressions.

f. Internal inspection. One or two borings should be taken above or below the ground line when sounding or other inspection methods cause a doubt as to the sturdiness of the interior pole condition.

g. Accuracy. When a reasonable accurate determination as to the condition of poles cannot be made by spot inspection methods, the more thorough procedures described for the pole-by-pole inspection should be followed. For these cases, the excavated poles should be groundline treated and so recorded.

4-15. Wood pole-by-pole inspection procedure.

Before any extensive inspection or maintenance work is begun, it should be known or ascertained that the line (or individual pole) can be expected to remain in the same position for several years without relocation. Before proceeding with the inspection, the upper portion of the pole should be observed from the ground to make sure it has not been badly damaged by woodpeckers, lightning, or other causes that would require replacement regardless of the groundline condition. Nondestructive pole testing may be used where "PoleTest" equipment is available. (See para 4-14.) Otherwise sounding and test boring may be necessary.

a. Sounding. If the pole condition appears good, then the pole should be sounded. This is a method of checking for interior decay above the ground line. It is not an infallible test and requires considerable practice to attune the ear to meaningful sounds. It should not be relied upon until considerable experience has been acquired.

(1) *Method.* With a l- or 2-pound (0.5 to l-kilogram) hammer, strike the pole squarely and firmly all around the pole from the ground line to as high as can be conveniently reached, while listening to the sound. A good pole has a solid ring, whereas one containing decay may give a hollow sound or dull thud. Often, however, such things as checks, separations, shakes (separation along the grain of the wood, usually occurring between the annual rings due to causes other than drying), loose slivers, loose molding, guys, load carried, wood density, moisture content, and the pole loading will affect or alter the resonance.

(2) *Purpose.* This method avoids needless excavation of poles found badly decayed internally above ground and assists in detecting the most likely

points for boring to determine the extent of any internal decay above ground.

b. Test boring. Whenever there is reason to suspect possible internal decay above or below the ground line, the pole should be bored with an increment borer as shown in figure 4-5. It is usually not necessary in cedar poles due to their decay resistant heartwood.

(1) *Increment borer. An* increment borer consists of three parts-the borer, the extractor, and the handle, which also serves as a receptacle for the other two parts when not in use. The tool is made of the highest-quality steel to withstand the force applied, though the borer has a cutting edge which must be protected from abuse. When boring below the ground line, the pole surface at the spot bored should be thoroughly cleaned of soil and grit by shaving or brushing. Bore toward the center of the pole, applying steady pressure to start, and in as nearly a horizontal line as possible. If any slant is necessary, it should always be upward to prevent any later water accumulation. The core is removed with the extractor by backing the borer a half turn after the extractor is shoved in, so as to break off the core before withdrawal.

(2) *Plugging bored holes.* All bored holes must be plugged by hammering in a tight-fitting treated wood plug as shown in figure 4-6, regardless of whether the pole needs to be replaced. Habitually and promptly drive a plug in each hole before boring another or before proceeding with other work. Otherwise, a bored hole may be overlooked, opening the way for future internal decay. The plugs, made of doweling, may be obtained from most pole suppliers. Those pointed on one end are preferable but not required. They should be 3 or 4 inches (80 to 100 millimeters) long with a diameter l/32 inch (0.8 millimeters) larger than the hole bored to provide a snug fit. The borer, an adequate supply of plugs, and a hammer should be kept together as a kit.

(3) *Evaluating test borings.* The extracted core should be carefully examined for wood integrity or evidence of decay, extent of any decay pocket, and the amount of original preservative in the wood. Decay will be evidenced by crumbly wood in part of the core. If a pole is badly decayed, a core may not be withdrawn intact. Borings may sometimes be soft and moist, but not decayed, if preservative is present and the wood fibers are strong.

(a) Preservative appearance. In sound poles, the preservative will be plainly visible, especially if it is creosote. In good original treatment, it extends the depth of the sapwood (table 4-l shows sapwood thickness). Some borings will show a heavy absorption of preservative, while in others it may appear in bands, giving the core a striped appearance. (Annual growth rings comprise hard dark summerwood and softer, sometimes spongy, springwood. 'Usually the summerwood absorbs more preservative in the timber species that are suitable for poles). In poles treated with pentachlorophenol (penta) solution, the oil carrier may not be visible, even though the penta itself is present in sufficient amount.

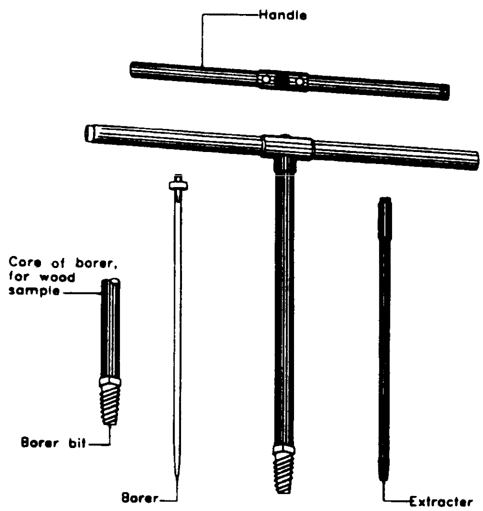


Figure 4-5. The increment borer

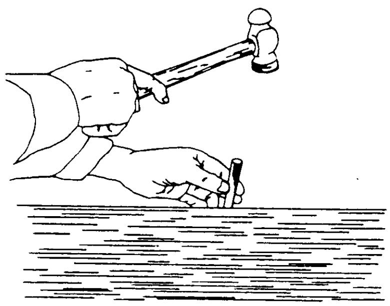


Figure 4-6. Sealing a test hole with a treated wooden plug

Table 4-l. Sapwood thickness in poles

Species	Sapwood thickness (inches)			Sapwood thickness (millimeters)			Natural heartwood decay resistance
Western red cedar	0.5	to	1.25	13	to	32	High
Douglas fir	0.75	to	2.5	19	to	64	Moderate
Western larch	0.5	to	1.5	13	to	38	Moderate
Jack pine.	0.75	to	2.0	19	to	51	Moderate
Red (Norway) pine..	2.0	to	4.0	51	to	102	Moderate

Table 4-l. Sapwood thickness in poles (continued)

Species	Sapwood thickness (inches)			Sapwood thickness (millimeters)			Natural heartwood decay resistance
Southern yellow pine.	2.0	to	4.25	51	to	108	Low to moderate
Lodgepole pine.	0.5	to	2.0	13	to	51	Low
Ponderosa pine	2.0	to	3.5	51	to	200	Low

(b) Condition rating. For practical purposes, the condition of a pole should be rated on its wood integrity or on the extent of any decay. While the amount of preservative present in one pole as compared with another should be taken into consideration in the rating, a high degree of accuracy in this respect requires laboratory methods or special apparatus.

(c) Effect of sapwood thickness. Table 4-l shows the average thickness of the sapwood in the timber species which are most often used for facility poles. It will be noted that the species with thin sapwood, which consequently receive a shallower penetration of preservative, generally have a more durable heartwood. However, long life in poles is more dependent upon effective preservative treatment. Since the thicker sapwood species are capable of a deeper treatment, they will often yield the longest average life.

c. Groundline inspection. If the inspection of the above-ground portion of the pole indicates that replacement is necessary, there is no need for below-ground inspection. However, if the above-ground portion is substantially intact or adequate for treatment in place, continue with the below-ground inspection. Sampling procedures may be used if the poles can be grouped by species and class, age, and conditions of exposure to damage. Every third or fourth pole should be inspected below the ground line. Any unsatisfactory conditions found during sampling will indicate the need for inspecting more or all of the poles in the group. Use the following method for below-ground inspections:

(1) *Excavation.* If the sound test indicates no serious internal decay above ground (verified by borings when in doubt), the next step is excavating the soil to about 18 inches (450 millimeters). It may be necessary to excavate deeper in dry or porous soils, and this can be determined as the work progresses. When there is danger of toppling the pole by digging, provide temporary propping of poles. The hole should be wide enough to permit use of the borer below the ground line. Care must be taken not to cut or disturb the ground wire.

(2) *Inspection.* With a blunt tool, probe the surface of the pole gently below the ground line to see if the wood is intact and firm or if decay is present as evidenced by soft, spongy wood. Close attention should be given to the vicinity of any separation checks. If the ground is wet, the wood may be soft but not decayed, so examine a sliver of the wood to see if it breaks easily or crumbles. Look and smell for preservative on the surface of the pole (a musty smell often indicates active decay). Remove as much decayed wood as possible with the spade and clean the surface with a wire brush. Open pockets of decay and determine their extent by probing. Interior decay at the ground line may be checked by taking borings.

(3) *Measuring pole circumference.* After removal of all decayed wood, the remaining circumference of the pole just below ground line should be measured. Deduction from this measured circumference is made for any external or internal decay pockets in order to determine whether the pole meets the minimum circumference permitted by the NESC.

(a) If the ground-line circumference is below the permissible minimum, the pole should be promptly replaced or reinforced.

(b) If the ground-line circumference is above the permissible minimum, the pole should be ground-line treated as covered in section VI.

4-16. Determination of wood pole adequacy.

When inspections reveal heart rot; splits; lightning, insect, bird, or vehicle damage; or other apparent weaknesses, these conditions should be reported so that the adequacy of the pole to sustain its loads may be evaluated by engineering personnel. Whenever the condition requires backfilling to any degree more than that for spot inspection, provide groundline treatment as covered in section VI. Test wood pole stubs, as required for the wood poles they help support. Steel stubs should be inspected to see that the installation is in good condition and holding properly.

a. Replacement. If the diameter of the pole has decreased more than about 15 percent due to damage or decay at the ground line, or if the diameter of the heart-rotted section as determined by boring is more than about 30 percent of the total diameter of the pole, it should be scheduled for replacement as soon as possible.

b. Reinforcement. In many cases, a pole will decay at the ground line but the wood above will be good. In such cases, especially if the pole contains several lines or equipment, pole reinforcing may be a more economical (and fully satisfactory) solution than providing a new pole. The pole must be sound from about 15 inches (400 millimeters) above the ground line to the pole top, and preservative should be applied under pressure to prevent spread of the groundline decay into healthy wood.

c. Pole treatment. Poles in place are exposed to weathering and decay, which is usually most severe at the ground line. In some cases, the upper part of the pole will have decayed to only a small degree, and preservative treatment to extend its useful life will be economical. Poles may have to be straightened because deterioration or replacement has caused them to be out of line. Guying, raking, or otherwise sustaining the pole load may permit line straightening, if the butt of the pole is kicked over while leaving the top of the pole in the same place, or if both the top and the butt of the pole are moved as necessary. Moving the butt means that groundline treatment will also be necessary. The cost of pole replacement, particularly of a large, heavily-loaded pole, can justify considerable effort and expense in extending the useful life of a pole in place. See section VI for information on treatment.

4-17. wood pole replacement.

It is recommended that new poles be fully treated with a NRECA WQC pressure treatment to ensure that the maximum service life potential is obtained. Butt treatment and similar partial treatment methods are not acceptable.

a. Installation. When a new pole does not have to be replaced in the same h.ole as the old one, setting the new pole near the old location, including ‘attachment of the equipment and conductors to the new pole before removing the old one, may be more convenient and safer.

(1) *Line wires.* Before any pole is cut off, the top of the pole must be held or guyed in four directions. In most cases, the line wires can be relied on to hold the pole in conformity with the line direction, while guys or pike poles are required to hold it in the other directions.

(2) *Service-drop conductors.* Free service-drop conductors; do not count on them to hold a pole because any strain might pull the service-drop brackets off the buildings.

(3) *Energized replacement.* If a pole must be replaced with conductors energized, the wire must be properly covered with rubber protective equipment designed for this purpose, so work on the pole can be done safely as covered in section XV

b. Pole setting. Poles need to be set in accordance with ground conditions. For normal firm ground, minimum pole-setting depths are given in table 4-2. In other types of soil, pole-setting depths need to be increased or decreased, in accordance with the local utility’s practice, dependent upon whether the ground tends to be swampy or rocky.

Table 4-2. Pole setting depth

Pole length. overall		Setting depths			
		Straight lines		Curves, corners and points of extra strain	
Feet	Meters	Feet	Meters	Feet	Meters
30	9.0	5.5	1.7	5.5	1.7
35	9.0	6.0	1.8	6.0	1.8
40	9.0	6.0	1.8	6.5	2.0
45	9.0	6.5	2.0	7.0	2.1
50	9.0	7.0	2.1	77.5	2.3
55	9.0	7.5	2.3	8.0	2.4
60	9.0	8.0	2.4	8.5	2.6
70	9.0	9.0	2.8	9.5	2.9

4-18. Wood pole reinforcement.

Pole reinforcement technology has developed several methods of pole repair which can restore poles to their original groundline strength. Engineering personnel should evaluate the selected method to ensure that the proposed installation is adequate.

a. Stub pole. A length of pole of the same size as the existing pole, and long enough to extend from the butt of the pole to about 5 feet (1.5 meters) above the ground line, is set flush alongside the existing pole. Follow criteria for setting a new pole and band it to the existing pole at the top and about 15 inches (400 millimeters) above the ground line. Figure 4-7 shows details for fastening the stub pole to an existing pole.

b. Steel reinforcing. If several poles need reinforcing, steel reinforcing may be more economical than the use of stub poles. The steel reinforcement consists of a “C” shaped galvanized steel section (as shown in figure 4-8), which is pneumatically driven to below the pole butt and then strapped to the existing pole. The equipment for driving the reinforcing is specifically designed for the purpose, but its use will be more economical than digging Holes for several stub poles. Although the steel reinforcing can be installed by in-house forces, it would probably be advantageous to have this work done by a firm specializing in this service. Steel reinforcing also provides extra protection from vehicles in congested areas. Engineering is required to ensure proper installation since the overall strength of the steel truss and pole combination depends on the strength of the banding system.

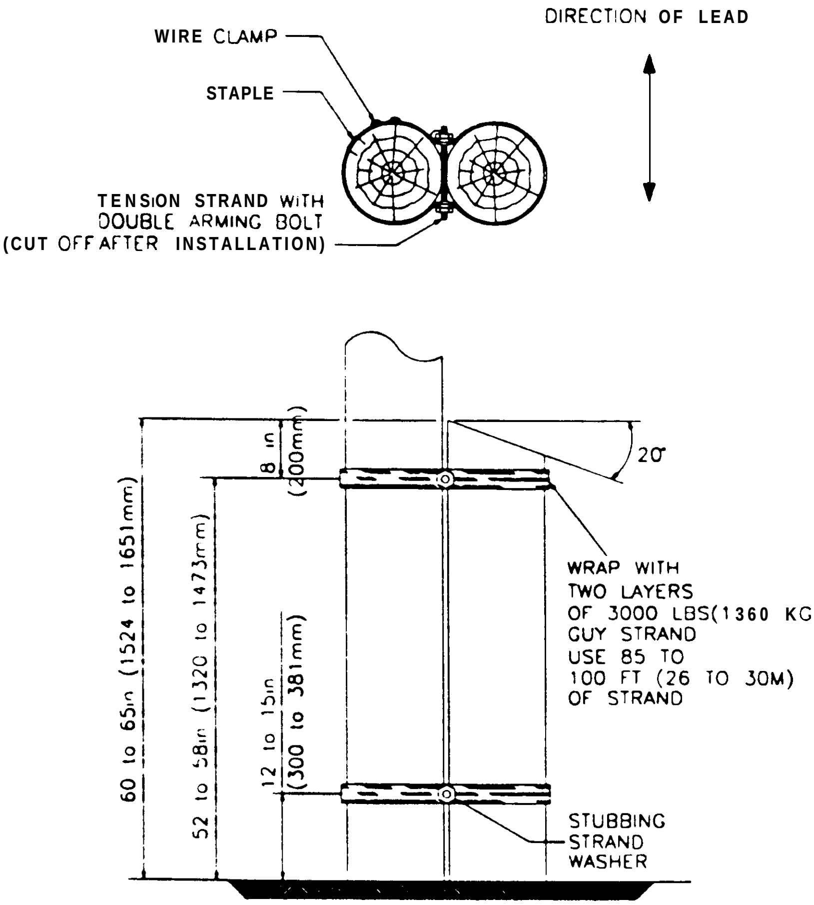


Figure 4-7. Wood stub pole

c. Compound set methods. There are a number of compound set methods. Engineering evaluation should select the appropriate method.

(1) *Compound.* The simplest method requires a compound (mixed in a completely self-contained mixing unit) which fills a hole slightly larger than the pole diameter. It is suitable also for straightening poles.

(2) *Compound and casing.* The decaying region is first treated with a liquid fumigant. A split-metal casing is driven below grade by rotary-driven equipment. The casing is filled with an epoxy-aggregate for stabilization and extra strength. The filler may also contain an approved preservative additive that migrates to the outside surfaces of the pole under a time-delay release action.

(3) *Compound, rebars, and collar.* This method requires a 2-foot (0.6-meter) deep trench to be excavated around the pole and several 4-foot (1.2-meter) long rebars to be stapled about the pole. An inert 3 to 4 foot (0.9 to 1.2 meter) collar descends to about 2 feet (0.6 meters) below the ground line and is filled by funnel with hand or electric mixed epoxy-resin compound. Periodic tamping is needed to ensure proper compound setting. The trench is then backfilled after the compound has cured.

Section V - CROSSARMS, BRACES, AND PLATFORMS

4-19. Pole crossarms.

All facility crossarms are fully treated and are usually of Douglas fir or yellow pine. The length and cross section of an arm is determined by the brace and strength requirements. Properly installed crossarms require little maintenance. Crossarms can decay; aging can cause separations such as checks or shakes; lightning can splinter crossarms; or they may twist or bend by overload. These occurrences may necessitate replacement. All crossarm attachments should be kept tight. If preservative treatment is applied to the pole, the crossarms should also be treated. Crossarms should be inspected visually from the ground whenever a pole is inspected. If the pole inspection indicates the pole may be climbed, a closer inspection should be made.

a. Decay. Crossarm decay usually starts at pinholes and can best be detected with a probe, if warranted by visual inspection. Probe the arm enough to determine the extent of the decay.

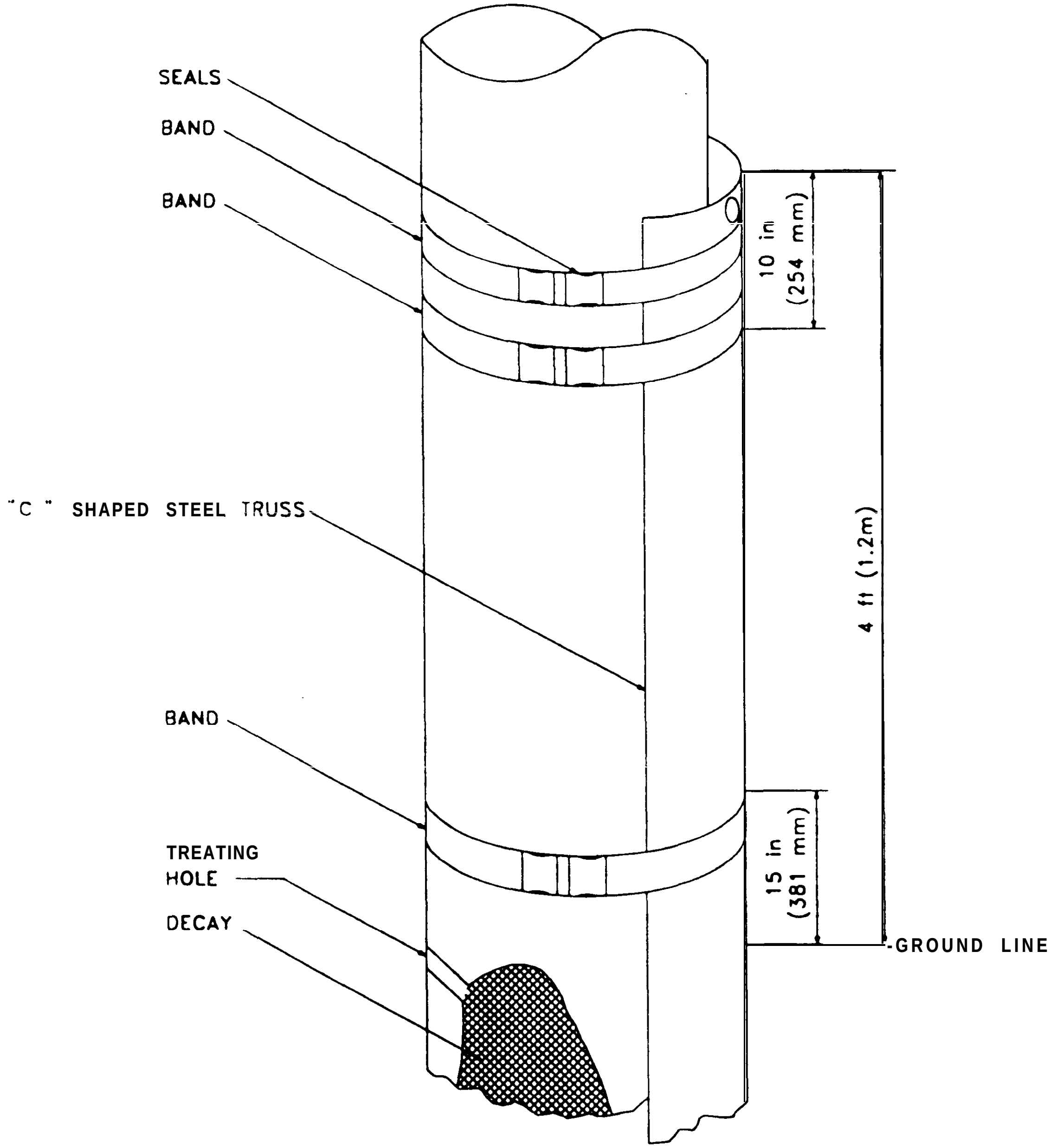


Figure 4-8. Steel reinforcing for a wood pole

b. Weathering. Crossarms may lose their strength because of cracks caused by weather separations. If cracks are near through-bolts or dead-end bolts, replace the arm because the crack may allow the bolt to pull through.

c. Twisting. Twisted arms may be caused by an unbalanced strain or insufficient guying. Where twisted arms impair the safety of the line, or create an unsightly appearance, the condition should be corrected.

4-20. Pole braces.

Braces are used to position crossarms in relation to the supporting structure. Only metal braces should be used. A crossarm brace should be maintained on the same schedule and in the same way as the crossarm it supports.

4-21. Pole platforms.

Platforms supported by one or more poles are used to mount transformers, regulators, or other heavy equipment above-ground. They are usually built with wooden stringers and flooring, or with wood flooring on steel beams. Many platforms now in use are composed of untreated timbers; these should be treated with suitable preservative to extend their useful life. When replacement is necessary, use fully treated timbers or consider installing ground-mounted equipment.

Section VI - MAINTENANCE WOOD PRESERVATION

4-22. Initial wood treatment.

For the best results, all wood used for maintenance should be fully treated as soon as practical after cutting and fabricating. Creosote and water-borne or oil-borne preservatives are all used. All of these can be used only by a certified pesticide applicator; only copper naphthenate does not require certification. Qualified applicators should meet the applicable agency requirements. The use of NRECA NQC treatment will ensure that best treatment practices are being employed, and that the treatment will produce desired results for the type of wood being treated. All personnel, either government or contractor, must be qualified for this specialized work. Engineering field support activities can provide assistance in training or obtaining qualified contractors. Factory-treated wood should always be used in the United States and elsewhere if available.

4-23. In-place wood pole treatment above ground.

Whenever wood poles, crossarms, or other pieces are cut or drilled, the freshly exposed wood should be given a preservative treatment immediately to prevent the entrance of fungi and insects to the inner wood area where treatment may not extend.

a. Treatment. An approved preservative should be used in accordance with AWPA recommended practices. It is recommended that a ready-to-use solution be purchased. Buying the proper formulation from a reliable supplier reduces the chances for error in mixing; eliminates the need for mixing equipment; establishes uniformity; and ensures that the preservative meets environmental directives. Test holes, and holes that are not to be used immediately, should be plugged at both ends with treated plugs as shown in figure 4-6.

b. Safety precautions. Treatment solutions can be irritating or harmful to skin and eyes. Full care must be exercised to prevent contact of any part of the body with spray or fumes from the solution. In addition to solvent-resistant gloves, boots, and clothing, a face shield should be worn to protect the eyes and face from any of the solution that may be splashed or blown toward the operator.

c. Treatment of pole top. Clean out all decayed wood. If heart rot is present, remove it to a depth of a foot (0.3 meters) or more. Flood the cavity with preservative paste or gel applied by trowel or spatula. Protect the top from weathering and leaching of the preservative with a cap of sheet metal or mineral-surfaced roofing felt, extending 1 inch (25 millimeters) or more down the sides, and securely fastened.

d. Treatment of exposed surfaces. Preservative solutions may be applied to exposed surfaces of wood poles and fixtures by either brush or powered equipment. Starting at the top and working down, the surface should be flooded with as much preservative as it will absorb. Special care should be taken to thoroughly flood all holes, splits, and check separations.

e. Brushing. A brush, a bucket, and a handline with snatch blocks are required for brush treatment. The brush should be as large as can be conveniently handled to minimize the number of dips. Care should be exercised to prevent splashing, spattering, or dripping the solution on nearby structures, vehicles, or pedestrians below.

f. Treatment of hollow heart. When hollow heart exists, locate the top of the damaged area and flood the cavity completely from this point. If no splits, checks, separations, or other openings from the surfaces to the cavity exist, apply the solution under pressure through the inspection hole. If other openings do exist, apply paste or gel under pressure.

g. Contact treatment. The above-ground portion of a pole is not subjected to the same conditions that promote decay at the ground line. Nevertheless, decay above-ground will develop sooner or later in all poles. In recent years, there has been increased use of spray, run-on, or brush treatments to the upper portion of poles.

(1) *Treatment* Use an approved remedial preservative. The pole surface should be dry, with the pole moisture content below 30 percent as determined with a moisture meter. The treatment should be applied in accordance with the preservative treatment manufacturer's recommendation, starting at the top of the pole. Immediately after the first treatment, a second application should be given the top 10 feet (3 meters) of the pole to ensure maximum absorption in the upper section and at points of attachments.

(2) *Safety.* Safety precautions must be carefully observed, especially when applying this treatment to poles in energized electric lines. Caution should also be used to avoid damage to freshly treated poles by grass fires.

4-24. Wood pole treatment at or below the ground line.

Groundline treatment should be provided whenever a pole is excavated during an inspection or resetting, and it has been determined the excavated pole need not be replaced. It is also required whenever a pole over 5 years old is moved. Such treatment involves excavation, cleaning of the surface, application of preservative, wrapping of the treated area, soil sterilization, and backfilling.

a. Excavation. The excavation should be deep enough to expose the affected area and wide enough to permit safe and efficient working conditions. The trench dug for the inspection will normally be satisfactory. When there is any possibility that digging will affect the stability of the pole, temporary guys or pikes should be installed. Remove all debris from the excavation.

b. Cleaning. The removal of all soft or decayed wood, at and below the ground line, with a spade and wire brush during inspection must be followed by wire brushing to expose a clean surface of sound wood. Treatment should immediately follow the inspection.

c. Preservative application. Several types of preservative available for groundline treatment of poles are compounds or liquid solutions applied to the pole and sterilization of the soil.

(1) *Compounds.* Preservative compounds in the form of approved pastes, gels, or greases can be applied in ¼ to ½-inch (6 to 13 millimeter) layers by means of a trowel or spatula. Start at the bottom of the trench and continue upward about 6 inches (150 millimeters) above the ground line. Power equipment consisting of a pump, hose and flattened nozzle, as shown in figure 4-9, will be a good investment if a large number of poles are to be treated. After the preservative has been applied, cover the treated area with a grease-resistant material to prevent the compound from diffusing into the soil. Cellophane, polyethylene film, or treated Kraft paper may be used, but care must be taken to prevent puncture or displacement by sharp stones, shovels, or tampers during backfill. The effectiveness of the treatment is dependent on the integrity of the covering.

(2) *Liquid solutions.* Treatment per pole will usually require 2 to 3 gallons (8 to 12 liters) of approved preservative solution.

(a) Initial backfill. Refill the excavation about half-way. With the blade of the shovel or spade make a V-shaped trench around the pole down to the original depth of the excavation. (This avoids using excess preservative by containing it close to the pole.) Then pour a liberal amount of the preservative all over and around the pole surface by placing the mouth of the container against the pole at several positions about 2 feet (0.6 meters) above the ground line. Allow the liquid to run slowly over the pole and into all crevices. Let the excess accumulate in the trench. All of the pole surface should be covered by the preservative, from the bottom of the excavation to about 2 feet (0.6 meters) above the ground line.

(b) Final backfill. Complete the backfill and tamp well. Then make another narrow trench 4 or 5 inches (100 to 130 millimeters) deep around the pole and fill this with more preservative. Use any remaining backfill to cover this trench. Tamp and mound to provide required bearing strength and avoid depressions. See section IV for methods and materials for providing extra pole-bearing strength.

(c) Active decay. In poles containing active decay, a desirable addition to the above treatment is to use an approved water-soluble pesticide as a first application. This will diffuse into the wood and is effective in killing or arresting internal decay that may not be reached by the preservative. A pesticide's usefulness is of short duration, however, as it is ineffective as a preservative alone. Sprinkle about one pound (0.5 kilograms) of dry pesticide against and all around the pole surface just before applying the preservative. Most of it should be applied below the ground line and none of it should be exposed after backfilling. Precautions are necessary to avoid any danger of poisoning persons or livestock by leaving pesticide lying about. Pesticide should be bought in l-pound (0.5 kilogram) cartons and each empty carton should be disposed of in the hole before backfilling.

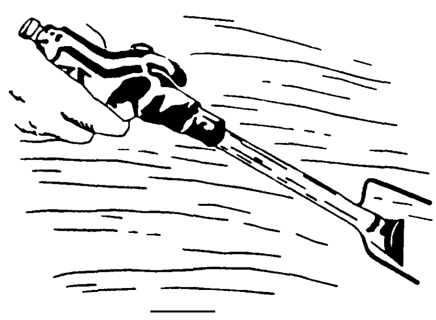


Figure 4-9. Nozzle for application of a compound preservative

Section VII - METAL POLES

4-25. Metal pole usage.

Some structures and most bolts and attachments are of metal. Steel is used where strength is the major requirement. Steel poles can be used in a rigid structure and thus eliminate the need for guys and anchors. Aluminum is used where its strength is adequate and where resistance to corrosion is important. See also chapter 3, section II.

4-26. Distribution line metal poles.

Metal poles are generally of tapered tubular construction with smooth or fluted surfaces. Attachments are made by bolting, clamping, or welding. Steel poles are subject to rusting on all surfaces. There is little that can be done to reduce rusting on the inaccessible inside surfaces, beyond requiring that new poles be treated with a rust inhibitor and sealed to keep out moisture. When rust appears on the outer surfaces, cleaning and painting are required. When corrosion at the ground line is severe, additional protection may be provided by welding a split ground sleeve over the affected area.

a. Aluminum poles. Aluminum alloy parts in contact with steel or other dissimilar metal require painting, as may the steel surfaces. Aluminum surfaces embedded in concrete ordinarily need not be painted, unless exposed to extremely corrosive conditions.

b. Self-weathering steel poles. It is important that all vegetation be kept away from these poles. Self-weathering steel, if kept moist, will corrode at a rate equal to plain carbon steel, unless protected with a high quality paint system. Salt fogs cause an accelerated corrosion because the salt residue remains on the pole. Self-weathering steel is not a completely maintenance-free material.

4-27. Transmission line metal towers.

Towers are assembled of various structural components that are bolted, riveted, or welded in place into a lattice type construction. All surfaces are more or less accessible for cleaning and painting. Most steel towers are galvanized to delay corrosion and rusting. Although galvanizing may provide good protection for many years, its effectiveness depends a great deal on the climate and area contaminants. Towers should be inspected for rusting and loose bolts. Spot painting is indicated for incidental rusting, but complete paint coverage is necessary where rusting is severe. Aluminum towers require no painting, but bolts should be checked for tightness. Tubular-type pole structures are preferred for transmission lines, because they are more aesthetically pleasing than the lattice type.

4-28. Pole-line metal hardware.

Pole-line hardware includes all metallic parts not intended to be part of the current-carrying system, except poles and other structures. This hardware is generally of galvanized steel, although some items may be aluminum alloy. The galvanized finish will resist corrosion for years under normal atmospheric conditions. Cleaning and painting may extend the useful life; but, in general, little attention is necessary except occasional checking for tightness. Because the condition of bolts passing through other items cannot be seen, replacement of a bolt is recommended if the head is rusted.

4-29. Painting of metal poles.

Preparation and painting of metal surfaces should comply with the SSPC painting manual, volume 1. Special finishes should be treated in accordance with the manufacturer's recommendations. The standard specifications for highway bridges of AASHTOP Division 11.13.2 also provides data on painting.

Section VIII - CONCRETE POLES

4-30. Concrete pole overview.

Reinforced and/or prestressed concrete poles have a projected life of 60 to 80 years and should require no attention, except for replacement when damaged. Concrete poles are preferred under conditions where the life of wood poles would be unduly shortened by decay or pests. When hauling concrete poles, they must be secured so they cannot bounce. Hard bouncing in transit will crack or chip the poles, especially when traveling over rough ground, roads, or railroad tracks. Concrete poles also require special attention if field drilling is required or there is a need for special banding or other attachment methods. Poles setting depths may in some cases be the same as wood poles, when the pole has been designed to be the equivalent of a wood pole of the same class and length. Engineering personnel should evaluate pole setting depths, guying, and foundation requirements.

4-31. Concrete pole foundations.

Other than for poles, the use of concrete in pole-line structures is limited almost entirely to the foundations. Where used for metal structures, the foundation may often be reinforced and extend above ground. Any small cracks should be filled with a high-strength grout. If substantial damage is found on existing foundations, remove loose concrete, clean surfaces, and restore the foundation to its original size. For wood and concrete pole-line structures, the backfill may be of concrete to provide better bearing in soft soils, and may or may not be visible at the surface. No maintenance is required. For distribution structures, replacement concrete should normally be 3,000 pounds per square inch (20,700 kilopascals) Class A.

Section IX - OVERHEAD OPEN WIRE CONDUCTORS

4-32. Overhead conductor construction.

Overhead electrical distribution at all voltages most often uses open wire construction, although aerial cables of various types are employed to some extent.

a. Open wire construction. The basic features of open wire construction are single conductors, insulated supports, and wide separation, with little or no conductor covering on the conductors. The air space around the conductors must be large enough to allow relative conductor movement without a flashover. Open wire construction is mounted on insulators, either as armless or crossarm construction.

(1) *Armless construction.* Armless construction consists of insulators on supporting brackets mounted directly on the pole. When possible, this construction is preferred for use on pole replacements because of its more attractive appearance and lower maintenance cost. Triangular tangent construction is preferred over vertical tangent construction, as it requires the least conductor space and is more economical. The difference between the two is shown in figure 4-l. Triangular construction is not suitable for configurations which require an overhead ground wire. It is not recommended except for the tangent and minor angle construction shown in figures 4-l and 4-2.

(2) *Crossarm construction.* Unless it conflicts with facility practice, crossarm construction should be phased out whenever possible, but may be necessary where equipment or line installations, utilizing armless construction, would result in excessive pole heights. Facility practice usually matches the local utility company's open wire construction.

b. Cables. Cables utilize conductors with covering which is sufficient to withstand the voltage at which the line is operating and, therefore, do not need insulators. Cables are discussed in section X.

4-33. Overhead conductor material.

Conductors used in open wire construction are usually copper, aluminum, or combinations of copper and steel or aluminum and steel. Specially designed connectors are required for splicing or otherwise connecting conductors of dissimilar metals.

a. Copper. Copper has high conductivity and is easily handled. Hard-drawn copper is desirable for distribution conductors because of its strength. Soldering will anneal copper and reduce a hard-drawn copper wire's tensile strength from 50,000 to 35,000 pounds per square inch (345,000 to 241,000 kilopascals). Splices and taps, therefore, should be made with connectors, clamps, or sleeves suitable for copper. Never make soldered splices. Use annealed or soft-drawn copper wire where it is necessary to bend and shape the conductor, such as for ground wires. Medium-hard-drawn copper is used for distribution, especially where wire sizes smaller than No. 2 AWG are needed.

b. Aluminum. An aluminum conductor has about 61 percent of the conductivity of copper of the same cross section but is lighter. Aluminum is relatively soft and, although low in tensile strength, is very durable. Some alloys are available with greater strength but less conductivity. Various combinations of steel and aluminum strands are available for use where both strength and good conductivity are required. Standard aluminum conductor steel-reinforced (ACSR) conductors should not be used in areas of severe corrosion. There are a variety of special aluminum alloy conductors some with special steel reinforcing, for use under conditions of corrosion, for greater strength requirements, and for self-damping to limit aeolian vibration. When replacing aluminum conductors, check to be sure the selection meets the requirements of the original design. Connectors used will conform to section XI.

c. Copper-clad steel. High-strength steel may be covered with copper to yield a conductor having 30 to 40 percent of the conductivity of pure copper. It is corrosion resistant and may be stranded in various combinations with copper to give various combinations of strength and conductivity. Its chief application is for use as an overhead ground wire.

4-34. Overhead conductor covering.

No covering is provided on open-wire primary circuit conductors. For open-wire secondary circuit conductors, a triple-braid weatherproof covering of impregnated cotton or layers of neoprene or polyethylene covering are provided. This covering is not sufficient to withstand the operating voltage and conductors must be mounted on secondary rack insulators. The covering is not to be considered as insulation, although when dry it will help prevent breakdowns at lower voltages if conductors swing together. The wires should always be treated as though they are bare. Because of both space requirements and unattractive appearance, this type of installation is being phased out in favor of insulated cable.

4-35. Overhead conductor sag.

Sag is the maximum droop of a wire in a given span, measured vertically from a straight line between the' two points of support. The amount of sag depends on the characteristics of the conductor, the temperature, and the tension. A properly sagged line will not be too tight in the cold of winter or too slack in summer heat. If the sag is insufficient, the tension will be too great and the conductor will stretch and might break. If the sag is too great, vertical clearances may be compromised and conductors may then blow together. Before adjusting the sag, check for a broken guy or pole, a tree limb lying on the wires, or twisted or leaning poles. All wires in any span should be sagged the same or with greater sag in the lower wires than in any above. This is important in maintaining midspan clearances.

a. Sag tables. Tables providing initial tension sag for most open wire conductors may be obtained from your local utility company. Line conductor manufacturers may also provide this data. TM 5-811-l/AFJMAN 32-1080 provides information on sag determination. As-built drawings, if available, may provide the initial tension sag at the time of construction. Resagging requirements should allow for the normal increase in sag caused by the unloaded weight of the conductors.

b. Measuring existing sag. Measuring existing sag can be done by following these instructions. Note that in both cases the line of sight is parallel to a line joining points of wire support. This may not be horizontal.

(1) *Line conductors. See* figure 4-10 for primary and secondary line conductor sag measurements.

(a) Estimate approximate sag in section and hold marker on each pole.

(b) Adjust marker equally on each support until A, B, and C shown in figure 4-10 are in line.

(c) Measure distances D and E shown in figure 4-10. If markers were adjusted properly, D and E will be the same, which is the amount of existing sag.

(2) *Service drop conductors. See* figure 4-11 for secondary service-drop procedures.

(a) Estimate approximate sag in service-drop conductors and hold marker on pole and building.

(b) Adjust markers equally at pole and building until A, B, and C are in line.

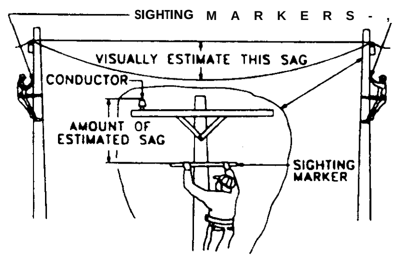
(c) Measure distances D and E. These distances should be equal. This is the amount of existing sag.

c. Clearances. Minimum clearances that should be maintained between conductors and other objects are contained in the NESC.

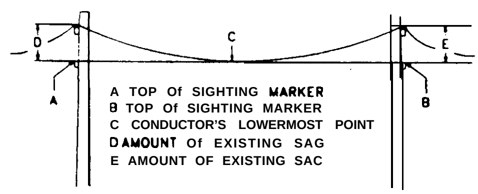
4-36. Overhead conductor damage.

Conductors can be damaged in many ways, and what appears initially to be superficial damage may in time cause a failure. Carelessness in installation may kink, nick, abrade, or overstress the conductor. Aeolian vibration, galloping, sway oscillation, unbalanced loading, lightning discharges, and short-circuit effects can be damaging to conductors in service. Poor connections cannot only cause damage, but are also possible sources of radio or television interference. An infrared scanning system is recommended over visual inspection. Equipment can be operated from the air or from the ground using aircraft or aerial equipment or vehicular-mounted or hand-held devices.

a. Damage signs. The following signs indicate that the conductor is probably being damaged.

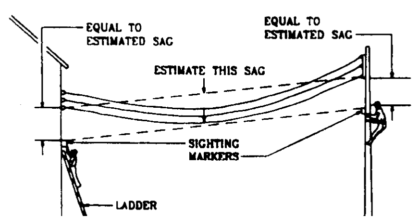


a. Showing position of sighting markers.

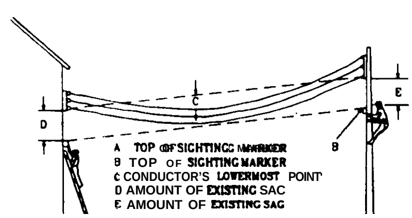


b. Showing how meosurement is mode.

Figure 4–10. Measuring sag on line conductors



a. Adjusting the markers.



b. Showing how measurement is made.

Figure 4-11. Measuring sag on service drop conductors

(1) *Abrasion.* Abrasion damage is a chafing, impact wear that accompanies relative movement between a loose tie, or other conductor hardware, and the conductor or armor rods. Abrasion is a surface damage and can be identified by black deposits on the conductor or tie wire.

(2) Fatigue. Prolonged periods of vibration will cause fatigue failure.

b. Line interference sources. Where radio or television interference complaints occur, check for possible sources of trouble covered in chapter 16, section II.

4-37. Overhead conductor repairs.

Installation of repair sleeves, preformed line splices, armor rods, or line guards; or replacing broken tie wire, may be the appropriate methods of maintaining conductivity and retarding additional damage. Preformed spiral vibration dampers should prevent conductor fatigue and scoring of insulators. Line replacement is indicated where more than two repair sleeves are required to cover the length of the damaged conductor.

Section X - OVERHEAD CABLE

4-38. Overhead cable construction.

The conductors of a cable, in contrast to open wire, are individually insulated so that they may be closely spaced or tightly bundled together. Except for some self-supporting cables (which are seldom used), all overhead cables consist of a messenger, which provides support, and one or more conductors attached to it by rings, wrappings, lashings, or insulating spacers. The cable messenger is attached to the pole. In the case of secondary circuits, the messenger may also provide the neutral wire.

4-39. Overhead cable repair requirements.

Aerial cable installations should be inspected for mechanical damage due to vibration and deteriorating supports, especially at suspension systems and dead-end supports. Check to see that cable insulation is not abraded, pinched, or bent too sharply.

a. Insulation. Insulation repair is covered in chapter 5, section VI.

b. Sheath. A sheath is sometimes applied to the insulated conductors to provide extra protection from moisture, mechanical damage, or atmospheric contaminants. The sheath may be metallic armor, lead, or another protective covering. Wear at points of support and cracks from vibration are the principal causes of sheath failure, although burns and mechanical damage are often contributing factors. Sheath repairs should be made as soon as the damage is discovered. If failure has not yet occurred, temporary repairs or protection may be desirable. Such temporary expedients may include providing weather shielding, taping, or spreading single conductors. Permanent repairs should be as extensive as necessary, from patching to replacement of the damaged length.

c. Messenger. The supporting messenger is usually of stranded galvanized steel or copper-clad steel. The initial design will provide adequate strength to support the cable under the maximum loading of ice and wind, and the temporary loads involved in installation and maintenance. Wear or rusting can reduce the messenger's strength. When it reaches the minimum safe value, then a messenger replacement should be made. Under these conditions, it is probable that other parts of the cable assembly will also require replacement.

d. Lashing. Metal rings are used with metallic-sheathed cables for field-assembled aerial cable. The disadvantage of this combination is the relatively rapid wear of the sheath at point of contact with the ring. Moving the rings periodically will alleviate this. When excessive wear occurs, lashing with a spiral wrap of metallic band or tape is recommended. This is the method used for factory-assembled cables, and it can also be used for field assembly, with little or no relative movement between conductors, messenger, and band.

e. Splices and taps. When making splices and taps on aerial cables, procedures specified elsewhere in this manual for overhead open wires in section XI or underground cables in chapter 5, section VI, as appropriate, should be followed.

Section XI - CONDUCTOR CONNECTIONS

4-40. Overhead line conductor requirements.

Line conductors must be joined together with full-tension splices, if the conductors are under tension. Bolted connectors can be used to join electric conductors at locations where the conductors are slack, such as between conductor dead-ends. Connectors should meet the requirements of ANSI C119.4 for aluminum lines or for connecting copper to aluminum lines. Only compression connectors will be installed on aluminum line conductors. Do not use screw clamps, split bolt connectors, or bolted connectors.

441. Overhead line conductor splices.

A splice is generally considered to be an end-to-end connection. It must be able to transmit the maximum electrical load without undue heating and should usually develop the full mechanical strength of the conductors. Because of different characteristics of copper and aluminum, connectors must be suitable for the specific materials of the conductors joined. Materials such as fluxes, inhibitors, and compounds should be of a type which will not adversely affect the conductors. See chapter 1, section III. Compression and automatic-type splices correctly join together conductors in tension and provide the strength and electrical conductivity required. Twist sleeve splices are no longer in use because they do not develop the strength of other connectors. Implosive-compression connectors are not recommended for use by facility personnel, as special training is required. Conductor connections should be kept to a minimum. Keep splices in transmission-line conductors at least 50 feet (15 meters) or more from dead-end connections. Do not make splices in lines crossing over railroads, rivers, canals, or freeways. Also try to avoid splices in spans crossing over communications circuits or electric transmission and distribution lines.

a. Compression sleeve splice. Compression sleeves provide full strength and conductivity and will produce the most trouble-free connection, but they cannot be salvaged. A compression connector may be used only for the size of conductor for which it is made. Neither the connector nor the conductor should be altered to fit a conductor for which the connector was not designed. Several types of compression sleeve splices are available:

(1) *Single sleeve.* This splice is used for copper, copper-clad, aluminum, and aluminum-clad conductors, as shown in figure 4-12. A sealant port and set screw or plug is provided for injecting filler paste before compressing the splicing sleeve with a hydraulically-powered compression tool. Some connectors may have a factory-applied sealant.

(2) *Double-sleeue.* This splice is used for ACSR conductors. In this type a steel sleeve is used to join the steel support stand, and an aluminum sleeve is used to join the aluminum conductors, as shown in figure 4-13. Both sleeves need to be compressed, and the aluminum strands need to be cut back from the steel core.

(3) *Single-sleeve and internal gripping unit.* This splice is used for ACSR. A gripping unit provides continuity for the steel core of the conductors being spliced and provides the required strength for the tension applied. The splice requires only one die in the compression tool, as the gripping unit replaces the double-sleeve's inner sleeve compressed on the steel core.

Figure 4-12. Single-sleeve compression splice (Courtesy of BURNDY Electrical)

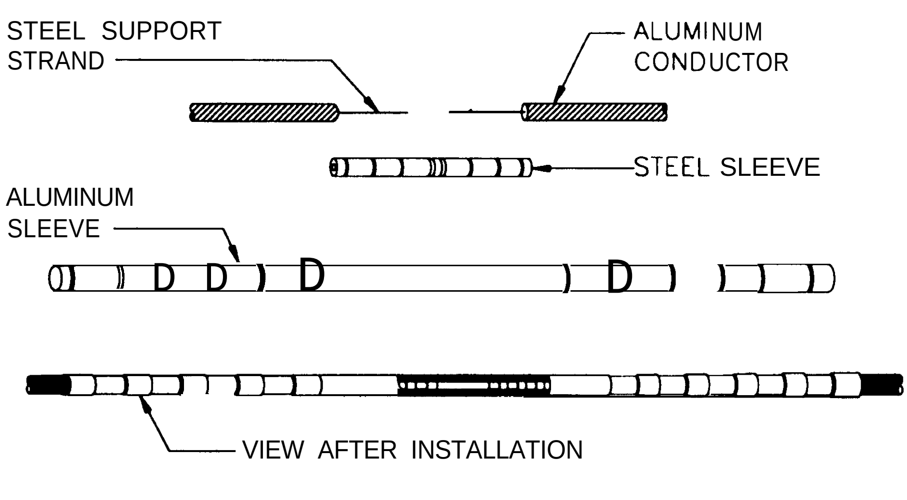


Figure 4-13. Double-sleeve compression splice (Courtesy of BURNDY Electrical)

(4) *Secondary and service cables.* Secondary and service cables can be spliced with bare or insulated compression connectors in a similar manner.

b. Automatic tension splice. Automatic tension or line splices with their single-bore sleeve as shown in figure 4-14 can only be used in any span where the wires are continually in tension. To install, force the gripping teeth of the splice jaws onto the conductor by imposing several severe jerks on the conductor or by pulling on the conductors to obtain a tension exceeding 15 percent of the rated breaking strength of the conductor. If an attempt is made to withdraw the conductor, the splice jaws will clamp down on the conductor because of a taper in the bore of the sleeve and on the jaws. The tension causes a wedging action which increases with the pull applied on the conductor. A loss of tension could cause the jaws to release their grip and allow the conductor to drop out. This type of splice is used where service must be restored quickly and is especially suited for live-line splicing.

(1) *Care.* Automatic line splices must be clean, as any contaminants will impair the proper operation of the internal jaws. Splices that have lost their original protective wrapping should be carefully inspected for any dirt. During installation and until the conductor reaches its final installed tension, automatic line splices should not be dragged through any element that could cause soiling. Any splice with a deformed or dented barrel will interfere with the proper seating of the internal jaws and should not be used.

(2) *Unsuitable Locations.* Splices should not be installed within 12 inches (300 millimeters) of a tie wire or armor rod. Splices cannot be used in taps and jumpers which have no tension, on conductors of dissimilar metals, or where there is severe vibration.

c. Clamp splices. Bolted-type connectors as shown in figure 4-15 are not recommended for wires under tension. Most clamps are designed primarily for conductivity and may not provide the required strength unless two or more are used.

d. Wires of different sizes. When the conductor size changes at a pole, special construction is usually necessary for conductor attachment. Some automatic line splices are available for use where this size difference is not great; but pins, insulators, and the line ties must be strong enough to hold the difference in tension between the two conductors. Under the worst loading conditions, when this tension difference exceeds 500 pounds (225 kilograms), automatic line splices are not recommended.

4-42. Overhead line connections.

Tap, jump, loop and secondary dead-end connections are generally considered to be tee connections. The connection must be able to transmit the required load current and have sufficient mechanical strength to support the connection and the connected conductors. In general, the connection should be suitable for installation without having to be joined to the main tension line conductor. Connectors are available in a wide range of sizes for connecting copper to copper, aluminum to aluminum, and copper to aluminum. It is essential that the proper size and type of connector be used. For tapping conductors over No. 2/0 AWG in size, a stirrup should be used on each conductor, with a hot line clamp, to avoid "burndown" of the feederline in the event of a heavy fault or "heated up" tap connector.

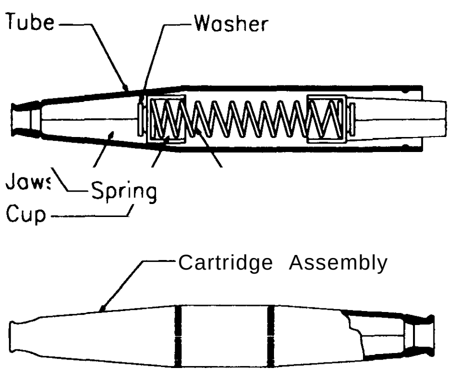


Figure 4-14. Automatic tension splice

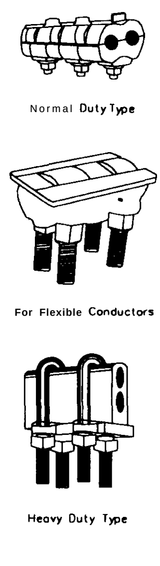


Figure 4-15. Clamp connectors (Courtesy of BURNDY Electrical)

a. Split-bolt connectors. Split-bolt connectors (bugs) are used extensively on lower voltage circuits, utilizing No. 2 AWG or smaller copper conductors, and are also available in larger sizes. Where vibration or twisting occurs, the contact pressure of a split-bolt connector will relax and may cause arcing, resulting in a burned-down conductor. Spacing two connectors about 6 inches (150 millimeters) apart will reduce this hazard. Never reuse a split-bolt connector, as it has probably been damaged in removal. Any bending or forming of the conductors should be made before final tightening of the connector. Never use split-bolt or similar type of connectors for medium-voltage splices under tension.

b. Bolted connectors. Bolted connectors are of various sizes and types, using one or more straight or U bolts to provide the contact pressure. The conductors may make contact with each other or they may be separated by spacers on the body of the clamp. Any bending or forming of the conductors should be completed before the final tightening of the connector.

c. Compression tap connectors. Compression-type tap connectors are available in such forms as T, L, and parallel. To fit over the main conductor without having to cut it, the connector has a U-shaped opening. This connection is not as strong as the full round splice connection, but if properly applied it is superior to any bolted connection. The connector is not reusable, and removal requires cutting the main conductor. If the tap is no longer needed, the tap wire may be cut off and the connector left on the main conductor.

d. Hot line clamps. Hot line clamps are used for either temporary or permanent connections in places where it is necessary or convenient to use hot sticks, and where the connection must be occasionally opened. Hot line clamps are prone to two types of trouble:

(1) Burning of the main conductor at the contact due to looseness and high resistance;

(2) Difficulty of removal due to freezing of the bolt in the body. The clamp should be located where vibration and flexing of the tap wire will be a minimum. To prevent burning from damaging and possibly dropping the main conductor, a hot line clamp should not be attached directly to the main conductor except in a nontension loop. The best method is to attach a suitable stirrup, either clamp or compression type, and apply the hot line clamp to the stirrup. In this way, any burning at contact or arcing during removal will burn the stirrup and not damage the main conductor. Hot line clamps can be applied over armor, if the contact between conductor and armor is thoroughly cleaned first. The problem of freezing threads is a matter of design, and the more modern hot line clamps are much less likely to have this trouble. Any hot line clamp that is not in good condition should be discarded.

e. Internally-fired taps. Internally-fired taps are used for a tee connection on transmission and distribution conductors of both copper and aluminum. The tap housing is made of a suitable alloy, tapered at the ends where the conductors enter. The application tool as shown in figure 4-16 contains a high-strength steel powder chamber that is loaded with a fast-burning propellant charge contained in a polyethylene cartridge. A simple hammer blow detonates the cartridge. Igniting the charge creates instantaneous high pressure in the chamber. This pressure drives cylindrical sets of wedge-shaped serrated aluminum jaws (into which the conductor ends have been inserted) at high velocity into the tapered ends of the housing. The jaws clamp and lock the conductor ends in position, providing the required holding strength and establishing a low-resistant current path across the housing. If correctly operated, a locking tab will verify the wedge

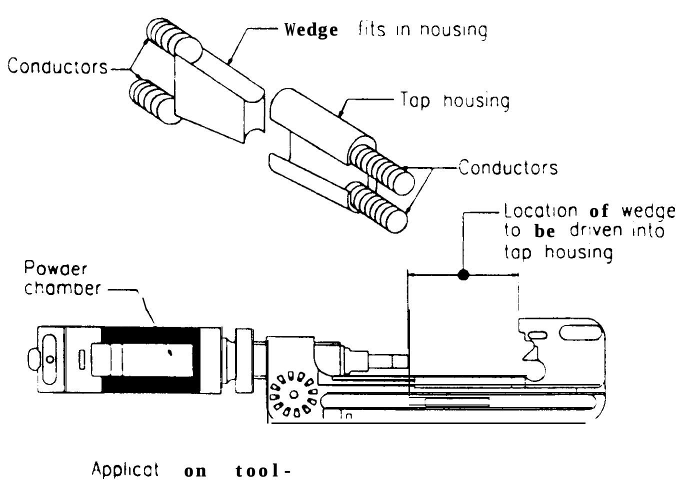


Figure 4-l 6. Internally-fired tap components

position is correct and will remain in position even under the most severe conditions. Use of a takeoff clip permits the tap to be removed as easily as it was installed, using the same application tool.

4-43. Overhead line armor rods.

Armor rods are required for all aluminum and ACSR cable supports except at dead ends. The rods provide threefold protection by preventing the breaking of strands due to vibration; the wearing of the conductor at its point of support; and the burning of the conductor from flashover or tap contact. Armor rods are sometimes used as a repair for broken or damaged strands. If damaged armor rods are found, replacement is recommended. Armor rods should be installed in accordance with manufacturer's instructions.

Section XII - POLE-LINE INSULATORS

4-44. Pole-line insulator related material.

Insulator use, inspection, repair, and cleaning are discussed in chapter 3, section IV, which also applies to pole-line insulators. Apparatus insulators used on substation equipment and to support buses are much heavier and more expensive than pole-line insulators. It may be more economical to replace pole-line insulators than to repair them. In many instances it is possible to wash energized pole-line insulators, as covered in section XV

4-45. Insulator operating performance.

Operating performance of aerial lines is dependent upon the quality of the line insulators. Pole-line inspection should reveal damage, even if visible corona or recognizable interference voltages have not already indicated some impairment.

a. Damaging conditions. Most pole-line insulator damage results from gun shots, lightning or contamination flashovers, and wind damage.

b. Understanding insulator provisions. Insulators provide mechanical and electrical performance values to meet requirements imposed by different applications. Mechanical performance dictates to a certain extent the type of insulator most suitable for the line being supported. Electrical performance requirements are mainly based on operating voltage and the degree to which area conditions affect the electrical performance.

4-46. Types of pole-line insulators.

Insulators used are the pin, post, and suspension type for primary lines; the spool, pin, and knob type for secondary lines; and the guy strain type for guys, as covered in section XIII. Figure 4-17 shows the different types normally used on facilities covered by this manual.

a. Pin insulators. This insulator gets its name from the fact it is supported on a pin. The pin is usually attached to a wood crossarm. Steel pins should always be used, as wood pins deteriorate rapidly from the leakage currents through the insulator. Where crossarm construction is being phased out, pin insulators are used less often on primary lines. They are available for secondary lines, but should only be used if the secondary line is mounted on crossarm construction. Conductors are fastened to pin insulators with wire ties.

b. Post insulators. Armless construction using post insulators is the preferable construction if practicable, as it is clean-looking and requires less space. Post insulators can also be used on crossarm construction. Line posts are stronger, more resistant to vandalism, and inherently more radio-interference free than pin insulators. Post insulators can be provided with clamp tops or tie tops. Tie tops cannot be used for angles of more than 15 degrees. For some mountings and loadings they can only be used for angles up to 2 degrees. Tie tops are less expensive, but clamp tops eliminate both tie wire material and labor costs, resulting in an easier installation.

c. Suspension insulators. Suspension insulators (dead-end bells) are used for primary lines, where pin or post insulators do not provide the required strength. They may also be referred to as strain insulators where lines are dead-ended at corners, where there are sharp curves or extra long spans, and at other places where a pull must be carried as well as insulation provided.

d. Spool insulators. Spool insulators are used on secondary racks or clevises, as required to support secondary cables, and require tie wires. Knob insulators should not be used, as they are not covered by an ANSI insulator standard and are manufactured for indoor installation.

e. Tie wires. Prefabricated ties are recommended for maintenance installation. They can be installed on energized line circuits, with proper protective equipment placed to insulate the tie from grounded equipment or other energized phase conductors. Hot line tools or rubber gloves and rubber sleeves are used, depending on the voltage of the conductor. Tie wire sizes should be in accordance with table 4-3. The wires should hold the line conductor tightly at all times to prevent chafing at the point of support. Never reuse a tie wire, as the kinks from the first use will prevent a satisfactory tie. A bare tie wire, of the same metal, should always be used on a bare

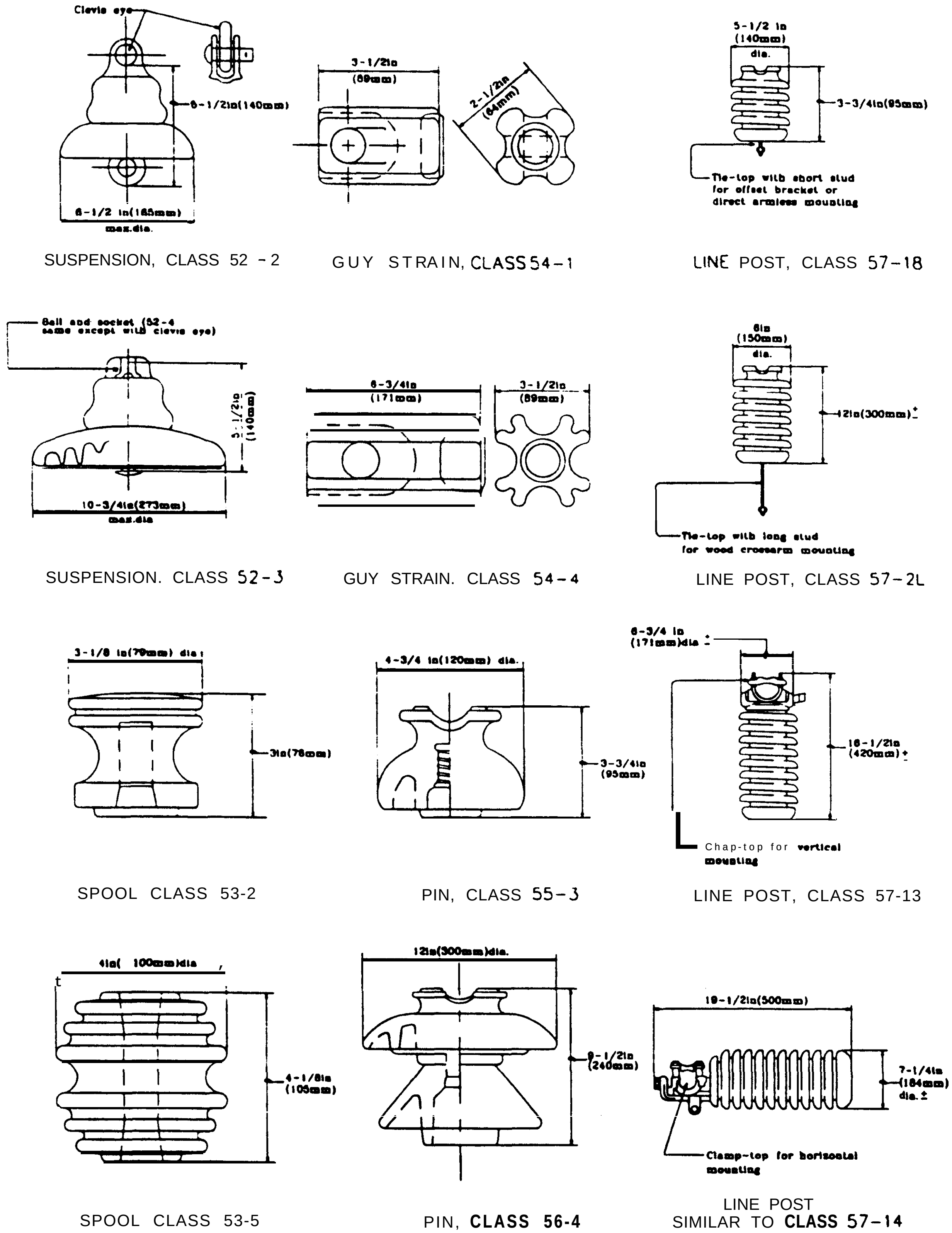


Figure 4-l 7. Types of insulators commonly installed

Table 4-3. Tie wire requirements

Conductor	Tie wire
Copper AWG.	Soft-drawn copper AWG
6	8
4 and 2	6
1 through 3/0	4
4/0 and larger	2
AAC,AAAC,orACSRAWG	AWG
Any size.	6 AAC or 4 AAC

conductor and likewise, a covered tie wire should always be used on a covered conductor. A loose or improper tie wire may be a source of radio interference.

4-47. Pole line insulator class requirements.

Insulator ratings are not specified by voltage but by ANSI C29 insulator classes. Manufacturers may indicate nominal line-voltage values but the NESC does not recognize voltage levels. Insulation level requirements are given in the NESC and do not relate directly to insulator classes. An understanding of the relations between insulator classes and insulation level requirements is helpful in understanding why each facility should have a recognized insulation level (class) for its various on-site distribution levels if they vary from requirements given in table 4-4.

a. Code requirements. The NESC spells out dry flashover requirements up to 230 kV These should be considered a minimum, even though a qualified engineering study could permit lower insulation levels. The NESC requires the use of insulators with higher dry flashover levels where severe lightning, high atmospheric contamination, or other unfavorable conditions exist. The NESC preparers recognized that dry flashover may not be the best test, but it has been used for many years with reasonable success. The desirability of using wet flashover as a basis has been recognized, but no consensus agreement has been reached.

Table 4-4. Relation of the NESC voltage levels to ANSI C29 class ratings

NESC (ANSI C2) requirement		ANSI C29 provision				
Nominal voltage (between phases)(kV)	Rated dry flashover voltage of insulators (kV)[1]	Rated dry flashover voltage of insulators (kV)	Area designation[2]	No. of insulators	ANSI class	Facility voltage level (kV)
ANSI C29.2—Suspension Insulators						
6.9	39	60	A	1	52–1	Up to 5
		115	B	2	52–1[2]	
13.2	55	130	A	2	52–2	6 to 15
		155	B	2	52¾	
23.0	75	155	A	2	52¾	16 to 25
		215	B	3	52¾	
34.5	100	215	A	3	52¾	26 to 35
		270	B	4	52¾	
ANSI C29.5 and C29.6—Pin Insulators						
6.9	39	55–3	A	1	55	Up to 5
		55–5	B	1	80	
13.2	55	55–5	A	1	80	6 to 15
		56–3	B	1	125	
23.0	75	56–3	A	1	125	16 to 25
		56–4	B	1	140	
34.5	100	56–4	A	1	140	26 to 35
		56–5	B	1	175	
ANSI C29.7—Line Post Insulators						
6.9	39	57–1	A	1	80	Up to 5
		57–1	B	1	80	
13.2	55	57–1	A	1	80	6 to 15
		57–2	B	1	110	
23.0	75	57–2	A	1	110	16 to 25
		57–3	B	1	125	
34.5	100	57–3	A	1	125	26 to 35
		57–4	B	1	150	

[1] The rated dry flashover voltage is based on manufacturer's tests where more than one insulator is required.
[2] Use the A value in areas where the atmosphere is dry (desert) or where fog occurs only to a limited degree and there is not more than moderate industry contamination. Use the B value in areas where medium-to-heavy fog is common occurrence and there is medium industrial contamination along a salt-water coast line.

b. Altitude derating. As altitude increases the insulation value of air decreases, so that an insulator at a high elevation will flashover at a lower voltage than the same insulator at sea level. The low frequency dry flashover value of an insulator at 7,000 feet (2,100 meters) is about 80 percent of the low frequency dry flashover at 1,000 feet (300 meters).

c. Cleaning. Insulators in severely contaminated atmospheres may require frequent cleaning. Pollutant buildup increases operating stresses and increasing the flashover level will help compensate for this. Such an increase does not eliminate the need for cleaning insulators.

Section XIII - GUYS

4-48. Guy functional requirements.

Guys are used whenever the line wires would tend to pull the pole out of its normal position because of unbalanced forces from dead-ended conductors, changing conductor sizes or material, or other conditions. The vertical forces of the line are resisted by the pole, while the guy counteracts the unbalanced horizontal components.

a. Inadequate guying. Inadequately guyed lines soon begin to sag, causing an unsightly installation, degrading line reliability, and possibly creating an unsafe supporting structure because the pole is overloaded.

b. Guy components. Guy installations usually include the guy wire (strand), the anchor assembly, attachments to poles and anchor rods from the guy strand, strain insulators, and sometimes guy markers.

c. Replacements or modifications. When any guy component becomes weakened due to corrosion or physical damage, that component should be replaced. Retension guy wires where any slack is observed. If a change is made in the number, size, or location of conductors, guys should be added or changed as required by the changed conditions. Guys should be checked whenever poles are checked.

4-49. Guy strand.

The major component in each guy installation is the guy strand or wire, whose rated breaking strength determines the requirements for all other components.

a. Wire types. Wire of either three or seven strands is commonly used. Each strand consists of a steel core having a protective coating of zinc or aluminum. Zinc coatings are available in standard ASTM coating weights, and a Class A coating weight is half of a Class B coating weight and a third of a Class C coating weight. The coating weight used is dependent upon atmospheric corrosion. Class A is used in dry or desert areas with little industrial contamination; Class C (or aluminum) is used in salt-laden or foggy areas or heavily contaminated locations; and Class B is used elsewhere. Copper-covered steel wire should be used only where specifically justified to meet an environmental requirement.

b. Wire replacement. Rated breaking strength used for replacement guys should not be less than 6,000 pounds (2,700 kilograms). Replacement guying should always be engineered. Because of corrosion or damage, the strength of existing guys on a pole may be less than for a new guy stranding of the same initially designed diameter. Existing guy strands may be overloaded, if it is assumed they have the same strength as new strands. Guy strands should not exceed the steepness and flatness limits of figure 4-18. If these limits cannot be maintained, then pole embedding may be necessary.

4-50. Anchor assemblies.

An anchor assembly with a rod and patent anchor buried in the ground is normally used to hold down the guy strand. Above-ground objects, such as trees or buildings, have sometimes been used for temporary guying, but only exceptional circumstances should justify any such interim use. Once installed, assemblies seldom require any maintenance except for inspection of the anchor rod for corrosion near the ground line, where repair should be provided as needed. In soils with a resistivity less than 30,000 ohm-centimeters and where corrosion of underground ferrous structures is a problem, galvanized steel anchors and guys should not be connected to copper grounding systems because severe corrosion may result. Instead, strain insulators need to be installed in the guy wire. When replacing an assem

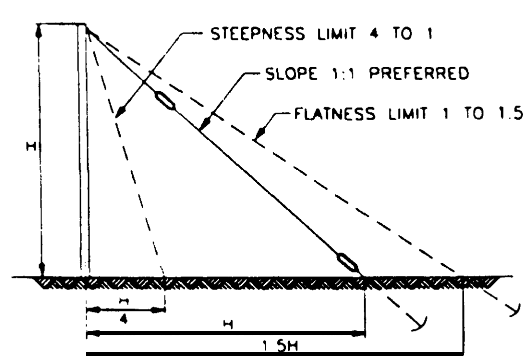


Figure 4-18. Steepness and flatness limits for guy strands

bly, be sure to provide adequate temporary support for the pole and to maintain clearances from energized lines. The anchor rod must be in line with the anchor guy. Try to attach only one guy to the eye of an anchor rod, but never more than two. If two guys are attached, the direction of the anchor rod must be the same as the resultant angle of the two guy strand angles.

a. Patent anchors. Patent or manufactured anchors, as shown in figure 4-19, are most often used because they are the easiest, quickest, and least expensive to install. If properly installed, there is no maintenance required as long as the anchor holds. If the anchor does not hold, then replacement, reduction of load, or positioning of one or more additional anchors that do not disturb the original installation (including the cone of earth above the anchor) will be required. Screw anchors in swampy soil may sometimes be screwed to a greater depth by means of an extension rod to restore holding power. The hole drilled for cone or expansion anchors should be no larger than necessary and the backfill firmly tamped.

b. Other anchors. Where patent anchors are not feasible, more expensive guying methods must be used.

(1) *Log anchors.* If the soil has little holding ability, the greatly increased bearing of a log anchor, sometimes called a log deadman, may be required. The log anchor is usually cut from a sound section of an old pole and should be thoroughly treated before installation. In the past, many deadmen consisted of logs or untreated pole sections and tended to deteriorate rather rapidly. When this happens, the anchor rod will pull free and a new anchor needs to be installed. Because of the extra labor required to install a log anchor, the replacement should be a patent anchor if soil conditions permit. Figure 4-20 shows the installation features of a log anchor.

(2) *Push brace.* On infrequent occasions, an anchor and guy may be impossible to install. In such cases, the proper support for the pole can be provided by a push brace applied to the pole at the inside of the corner. The push brace should be a pole the same length as the line pole being braced, and should support the line pole as near to its top as possible. Since the brace produces an uplift on the line pole, the line pole must be held down with cross cribbing bolted to its base. Details are shown in figure 4-21. Poles provided with push braces should be periodically inspected for uplift. If evidence indicates that this is happening, the pole may be held down by the installation of side anchors as shown in figure 4-22.

(3) *Self-supporting poles.* Where obstructions make guying difficult, self-supporting poles with hog guying, as shown in figure 4-23, can be used.

4-51. Guy attachments.

The guy strand is fastened to the pole hardware and the anchor rod with clips, clamps, or other devices. The guy is tightened by means of a chain jack and nonslip wire grips called come-alongs. The guy should be tightened until the pole leans slightly toward the anchor. Then the guy strand is firmly fastened and the chain jack released. When handling a guy strand, do not nick or scrape the surface; this breaks the protective coating and lets corrosion start. Guy guards should be installed in accordance with departmental safety requirements.

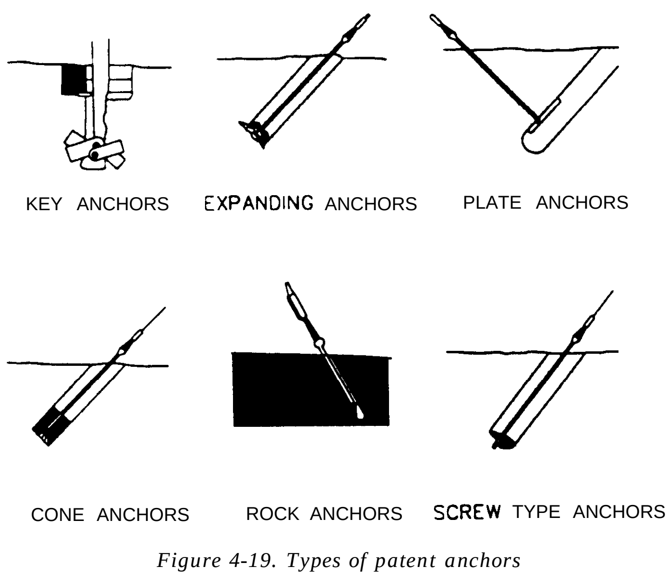
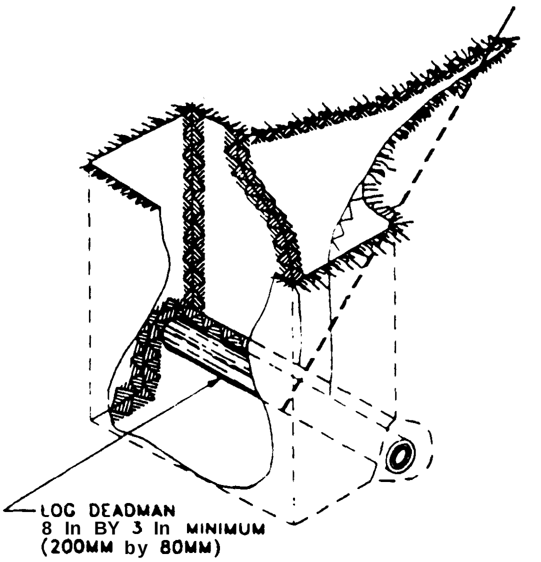


Figure 4-19. Types of patent anchors



SLOPE L/H	DEPTH M	DISTANCE K
0.5	5ft (1.5m)	2.5ft (0.75m)
1	4ft (1.2m)	4ft (1.2m)
1.5	3ft (0.9m)	4.5ft (1.35m)

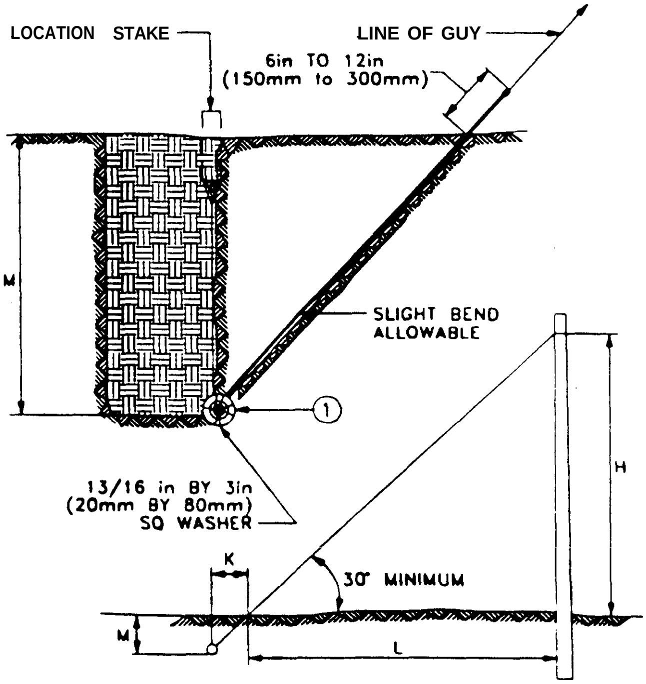


Figure 4-20. Log anchor

a. Guy clamps. Use three-bolt guy clamps which are made of steel with steel or malleable riders. All parts are galvanized to prevent rusting. The number of clamps used depends upon the breaking strength of the guy strand as shown in table 4-5. A two-bolt clamp is not recommended for use because of its limited strength. Little maintenance of the bolts will be required, if guy clamps are properly installed and the bolts are retightened after the load is applied. A loose guy can easily be tightened by repulling and clamping. The clamping surfaces should be free of oil or grease, but need not be cleaned to the extent necessary for electrical connectors. The end of the wire extending beyond the clamp is covered on the end with a guy clip or several wraps of wire.

b. Preformed grips. A preformed grip consists of a number of wires of suitable material and size, which are prefabricated to loop through a thimble or insulator and to wrap around the guy strand. The more the load is increased, the tighter the grip is drawn. Grips can be applied without tools and can be retensioned up to three times within 3 months after installation. Otherwise, they should not be considered salvageable for reuse. Due to the length of preformed grips, it may be necessary to use clamps where space is limited.

c. Serves. Instead of clamping, a method called serving may be used. This utilizes the guy strand end (on small-size or low-strength guy strands) to provide the necessary attachment to pole eyebolts, guy insulators, or ground rod thimbles. This method should not be used as a substitute for guy clamps or grips.

4-52. Guy strain insulators.

The NESC requires that ungrounded guys attached to supporting structures carrying open-supply conductors of more than 300 volts, or guys that are exposed to such conductors, be insulated. Otherwise, the guys must be effectively grounded. In guys that are effectively grounded, adequate electrical clearances and safe working space for the lineman may be maintained by installing insulators, if this is the facility's policy. A guy insulator installation must have a rated dry flashover voltage at least double, and a rated wet flashover voltage at least as high as, the nominal line voltage between conductors of the guyed circuit. A guy insulator installation may consist of one or more individual guy strain insulators. Linemen should be trained to recognize a grounded guy. When work is to be done on a grounded guy assembly, electrical continuity will need to be maintained and such guys should be treated as being an ungrounded device. Install proper protective equipment on adjacent grounded guys while the lineman is working on or near energized conductors. Ungrounded guys are insulated with porcelain, wood, fiberglass, or other materials of suitable mechanical and electrical properties.

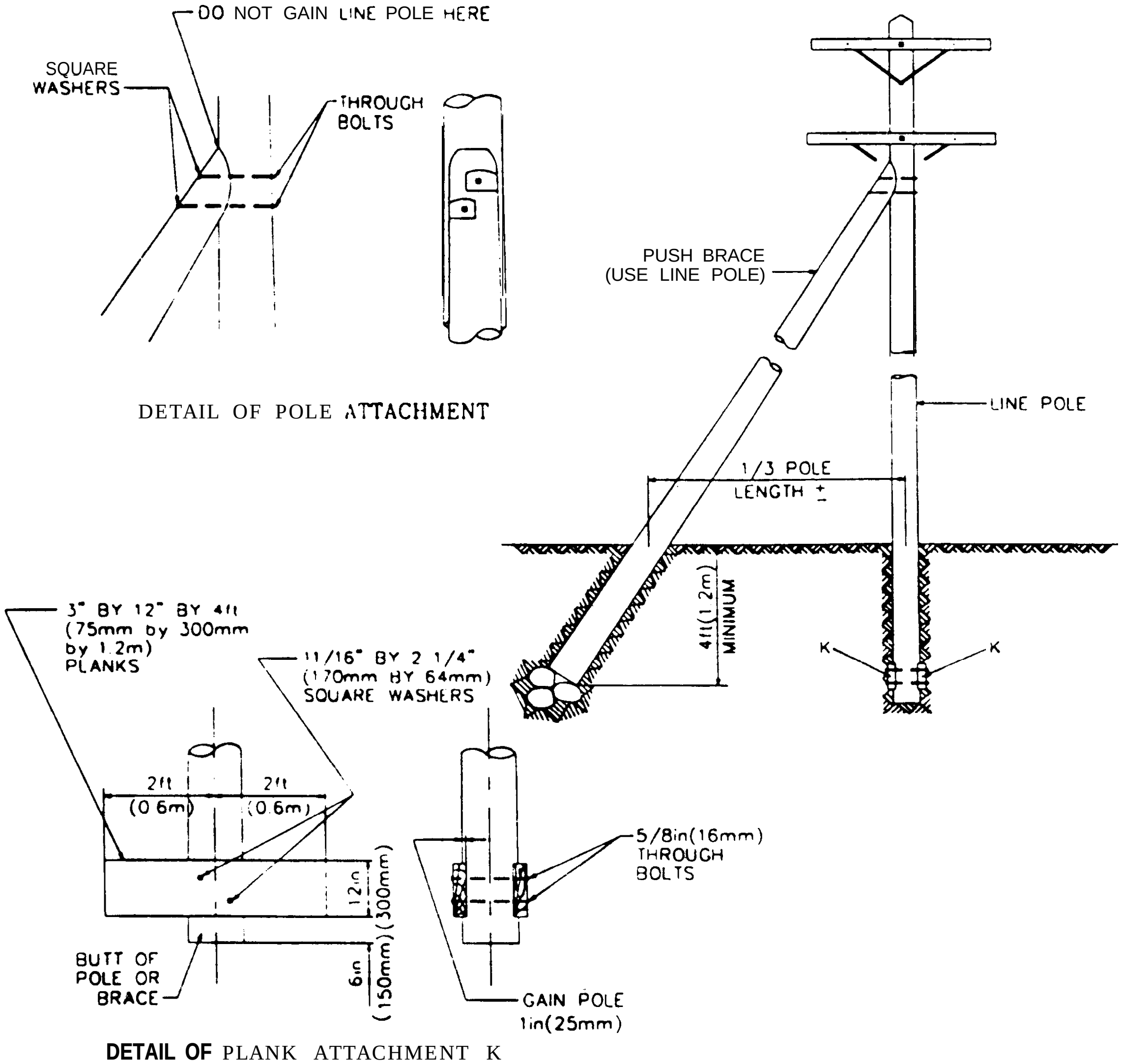


Figure 4-21. Wood-pole push brace

a. Porcelain. Porcelain guy strain insulators are usually of the interlocked (Johnny ball) type. The porcelain is in compression. If breakage occurs the guy is relaxed, but, due to the interlinkage, does not part. In replacing the insulator, consideration should be given to the cause of failure. If the broken insulator was too small, replace with a larger and stronger one.

b. Wood. Wood guy insulators may have been installed, particularly on higher voltage lines, because of their superior impulse resistance. The size and length of the wood member used would have depended on the strength required and the voltage of the circuit. The wood should have been treated with a nonconducting preservative. Arcing horns may have been set according to the need to bypass lightning strokes around the wood. The insulator should be replaced if deterioration or damage affects its strength. When a wood insulator replacement is needed, provide a fiberglass insulator instead.

c. Fiberglass. Fiberglass insulators should be used for guys in lieu of wood. Advantages are their indefinitely long life; their imperviousness to moisture; and their ability to withstand a direct stroke of lightning without bursting. They do not require arcing horns to bypass the lightning stroke. Fiberglass insulators are shorter than wood insulators, so they take up less space. Corrosion or rusting of the metal and fittings will ultimately be the reason for their replacement.

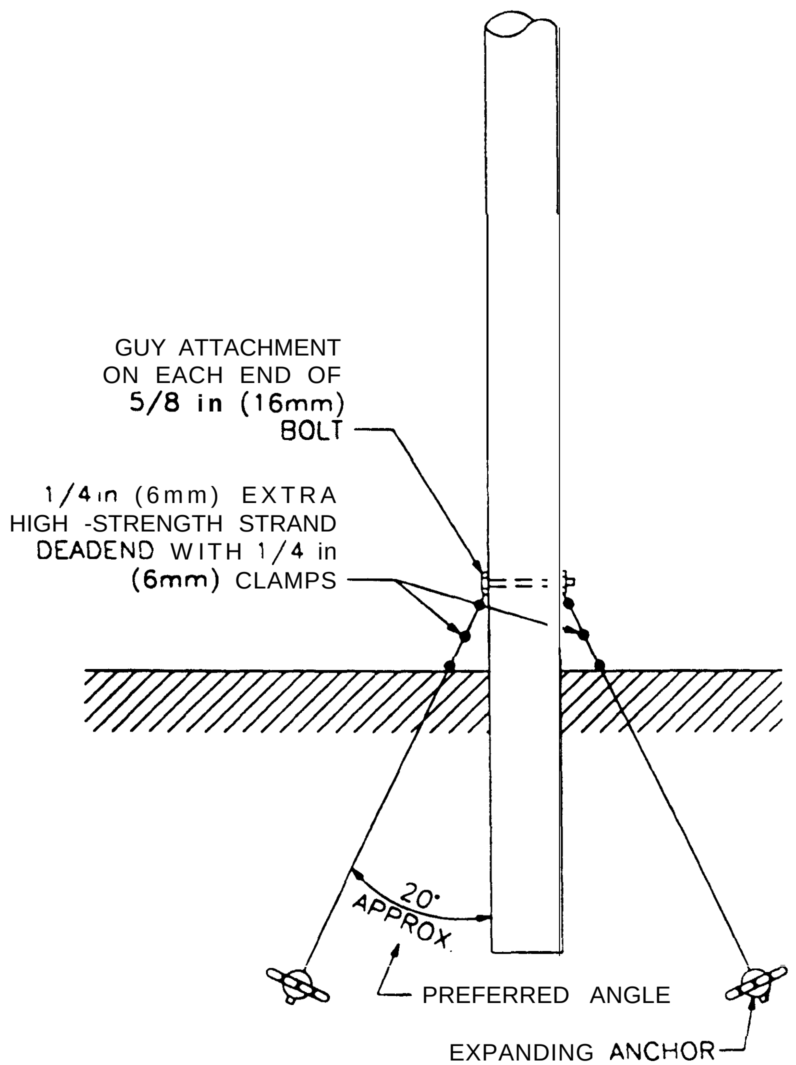


Figure 4-22. Side anchor

Section XIV - TREE TRIMMING

4-53. Tree trimming objectives.

Too much tree trimming impacts on environmental needs. Too little tree trimming impacts on line clearance requirements. The objective is to strike an acceptable balance between the two, considering both cost and safety considerations.

a. Environmental needs. Trees provide shade, reduce glare, keep the air fresh by supplying oxygen and consuming carbon dioxide, filter wind and noise, and satisfy human needs for beauty. They can also pose a hazard to electric service continuity in electric line rights-of-way.

b. Line clearance factors. The branches and limbs of trees growing near overhead lines are a potential source of trouble and service interruption. Trees near overhead lines may be broken off and blown across the line wires during a storm. Limbs may break wires, act as a conductor between wires, or force wires together to cause a short circuit. Limbs growing in contact with the wires provide a path for current to flow to ground, especially when wet. Wires and limbs rubbing together in the wind cause holes to be worn in the insulation, increasing the possibility of service failure.

c. Requirement. Tree trimming must be done before the trouble actually occurs. Although the reason for trimming is to protect the distribution circuits, the effect on the trees must not be overlooked. Trees must be left in as sound of a condition and appearance as possible. If leaving the tree in reasonable condition and appearance is incompatible with necessary clearance, consideration should be given to either raising or rerouting the line, or re moving the tree. Lines should be checked and

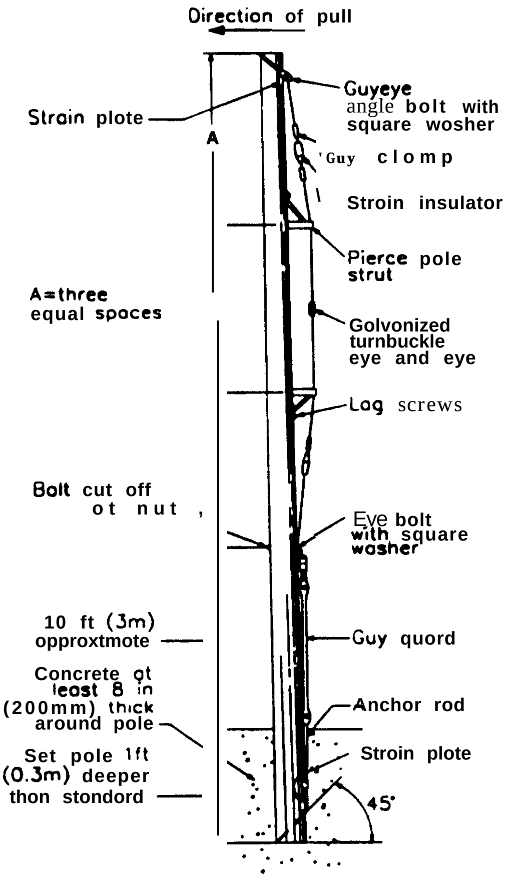


Figure 4-23. Self-supporting, hog-guyed pole

cleared on a planned time cycle and should provide hazard-free operation for at least 2 years to be cost-effective.

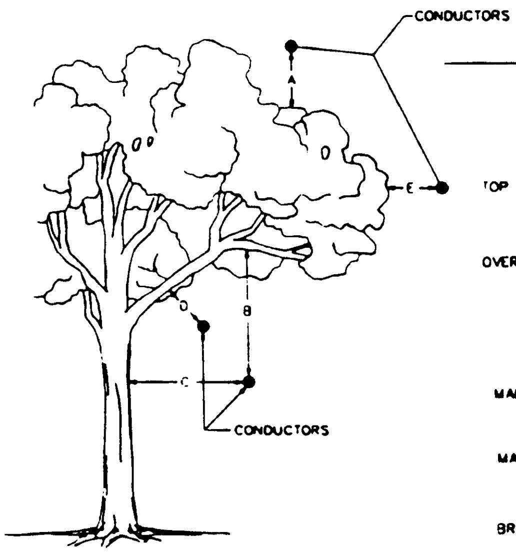
Table 4-5. Number of guy wire clamps

Breaking strength of guy stand: Pounds	Kilograms	Number of clamps	Type of clamp
4,000	1,800	1	Two-bolt
6,000	2,700	1	Three-bolt
10,000	4,500	2	Three-bolt
16,000	7,200	3	Three-bolt

d. Safety precautions. Tree trimming should be done from a bucket to the utmost extent possible. Even maximum use of buckets will not permit all work to be done without climbing the tree. When tree climbing is required, safety precautions must be observed. Refer to ANSI 2133.1 for tree care operations and safety requirements.

4-54. Tree trimming clearances and climbing space.

Minimum clearances to be maintained between conductors and any part of a tree are shown in figure 4-24. These distances may be increased as desired. Note that distances A and B are measured from the normal sagged position of the conductor, and that distance C, D, and E must be increased by the sag at that point. For tree trimming purposes, the 30-inch (750-millimeter) climbing space dimensions shown in figure 4-l should be increased to 40 inches (1,000 millimeters), and distances in figure 4-24 should be increased as required to maintain a 40-inch (1,000-millimeter) minimum climbing space.



	0 to 750 V and 13.2 Neutral	750 to 8700 V	13.2 Phase to 40 Kv	120 Kv
"A" TOP OF TREE	3ft(0.9m)	5ft(1.5m)	8ft(2.5m)	15ft(4 5m)
"B" OVERHANGING LIMB	15ft(1.5m)	10ft(3m)	AVOID	AVOID
SAG OF LINE PLUS				
"C" MAIN TRUNK	2ft(0.6m)	2ft(0.6m)	6ft(1.8m)	AVOID
"D" MAIN LIMB	4ft(1.2m)	4ft(1.2m)	7ft(2.1 m)	AVOID
"E" BRANCHES	5ft(1.5m)	5ft(1.5m)	8ft(2.5m)	12ft(3.7m)

Includes System Communication. Twigs or leaves shall not be allowed to touch System Communication bare wires.

Figure 4-24. Recommended minimum clearances for tree trimming

4-55. Tree trimming tools.

Only approved tools should be used for tree trimming. A 30-inch (750-millimeter) one-man crosscut saw, docking saw, forester saw, or pruning saw is used for cutting off any limbs within arm's reach. The type of saw to use depends on the size and location of the limbs to be removed. A pole saw or tree pruner is used for cutting off limbs beyond an arm's reach. If the saws become dull or lose their set, they should be repaired. Sharp tools make the job easier and safer. The first and second sections of the tree pruner are assembled on the ground and then raised carefully to a working position. If more than two sections of the pruner are to be used, the first two sections are assembled on the ground, and then raised and leaned against a limb, pole step, or other object while the third section is added. More than two sections must never be assembled on the ground and then raised, because the pruner is likely to break under the strain.

4-56. Types of tree trimming.

Different species of trees and their location with respect to overhead lines present varying problems of clearance and shaping. Tree-trimming jobs usually come under one of the following classifications, as shown in figure 4-25.

a. Center trimming. Center trimming, when necessary, requires that the limbs he cut away to leave a clear space around the wires. The cuts should be made at tree crotches to encourage the direction of limb growth away from the wires, thus avoiding the need for frequent trimming in the future.

b. Side trimming. Side trimming is necessary when the ends of the limbs on the side of a tree extend into or over the wires. In these cases, the limbs are cut off at a crotch so the limb can continue to grow, but in a direction parallel to or away from the line wires. The amount of trimming needed depends on the size and location of the limbs. Side trimming usually results in notches or an unbalanced tree that looks unsightly. When this is the case, branches or limbs not interfering with wires should be trimmed from the other side so that the tree is balanced.

c. Top trimming. Top trimming is necessary when a tree is growing into the wires. The ends of the

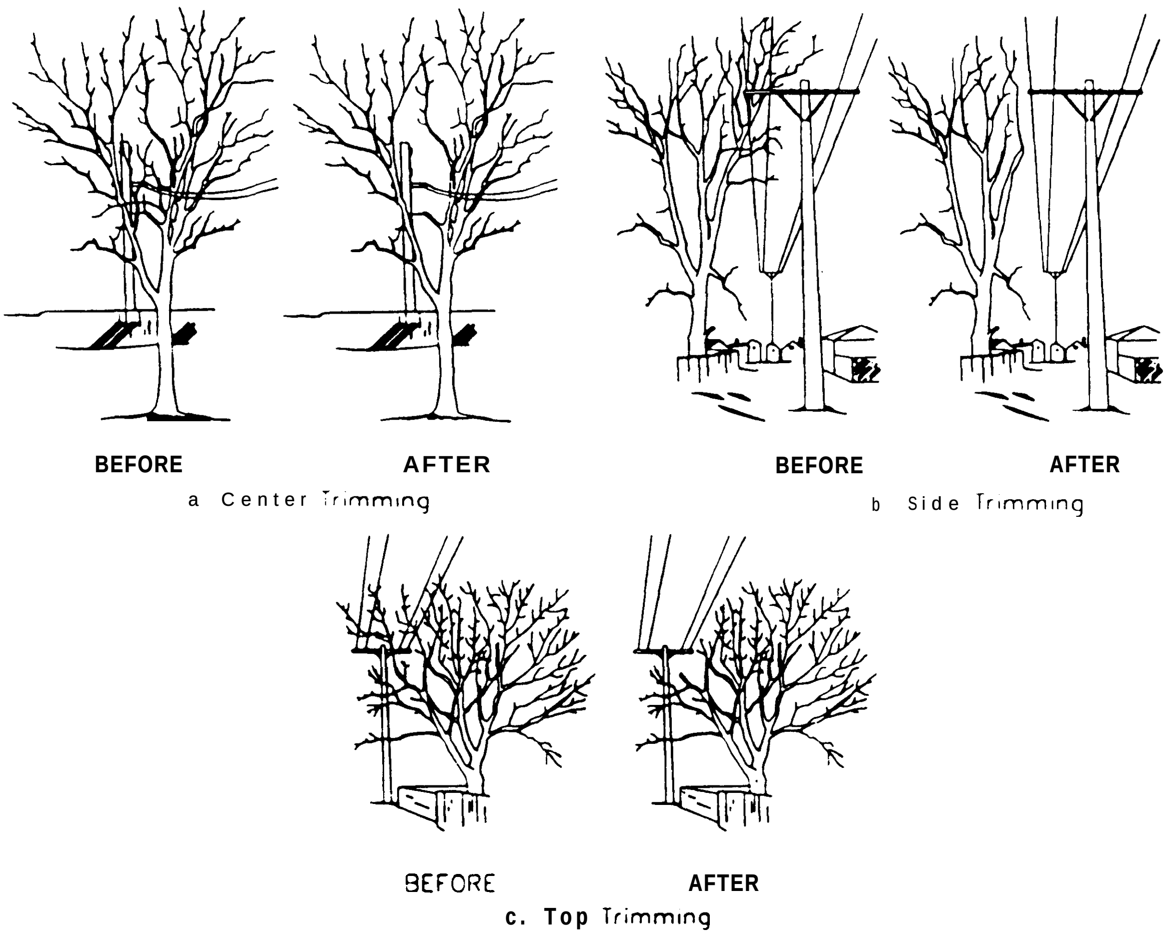


Figure 4-25. Tree trimming to clear electric wires

upper branches are cut off to form a well-shaped, low-spreading head below the wires. The natural shape of the tree should be retained as nearly as possible. For tall-growing trees, however, under-trimming or topping the tree is often necessary. Trees usually topped are willow, cottonwood, and poplar. These trees grow rapidly, even after being topped, and have branches more easily broken during storms. A tree topped in this manner usually grows a bushy or broomlike top, which will require more topping in a few years.

d. Undertrimming. Undertrimming is necessary when the under branches of a tree overhang or extend into wires. In some cases, tall trees growing adjacent to the line may be undertrimmed. The overhanging hazard should be relieved as much as possible by shortening or cutting off the tips of the overhanging branches. Sometimes a better remedy for the overhanging condition is to reshape and remove overhanging branches so that they do not grow toward the wires.

4-57. Tree trimming instructions.

The proper methods to use in trimming (pruning) trees requires considerable expertise. Instructions on pruning techniques are contained in the "Lineman's and Cableman's Handbook." This publication, or others which may be locally available, should be consulted before starting tree trimming operations.

a. Removing a limb overhanging wires. In addition to normal cutting and trimming, special handling instructions apply to prevent damage to wires. Two alternative methods, which may not be covered elsewhere, are shown in figure 4-26 and described below.

(1) *Method No. 1.* Use rope No. 1 to pull the center of the limb into the tree when the saw cut on the underside is about two-thirds through the limb. When the cut is completed, use rope No. 2 to prevent the butt of the limb from swinging out. Another rope may be used to guide the limb as it is being lowered.

(2) *Method No. 2.* Use rope No. 1 to prevent the limb from falling on the wires. After the limb is cut on the side away from which it is swung, use rope No. 2 to swing the limb clear of the wires and to pull the limb down after the cut is complete. Rope No. 3 is used to hold the butt of the limb.

b. Large vertical limbs. In removing large vertical limbs, a handline tied well up on the vertical limb is used to control the direction in which the limb is to fall. In some cases it may be necessary to make the limb fall in the direction opposite from which it is leaning. The fall of the limb is stopped by a butt rope. The butt rope should be pulled tight before the cut is completed to reduce the distance the limb will drop. If the limb is cut on only one side, completing the cut before it is lowered to the ground may be necessary. Heavy limbs should always be dropped in a snatch block.

4-58. Treating a tree trimming wound.

An asphalt-base tree paint should be painted or sprayed on every pruning cut larger than 1.5 inches (38 millimeters). This treatment should overlap the area around the cut and is necessary as a deterrent to disease organisms or insects whose entry would be harmful. The color serves to make the cut less noticeable. The paint can be sprayed, *or* brushed using a summer or winter grade type, as appropriate, for flowability. Paint with a growth inhibitor will reduce resprouting at the cut and make second-cycle trimming more economical.

4-59. Tree removal methods.

It is often preferable to remove a weak or diseased tree rather than to go to the trouble and expense of trimming and eventually having to remove it any

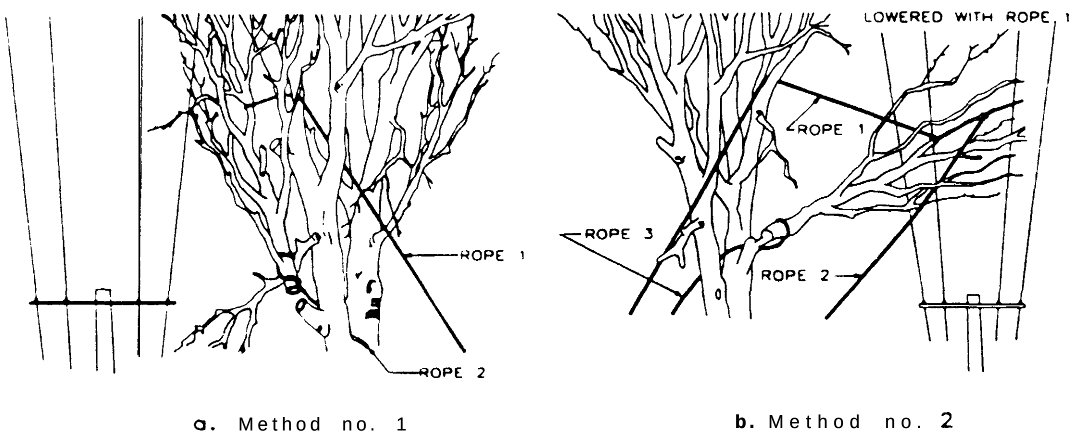


Figure 4-26. Removing a limb overhanging wires

way. Also, where the necessary trimming would result in an unsightly or depleted tree, and the distribution lines cannot be raised or rerouted, the tree should be removed.

a. Felling. Where space permits, the tree should be felled in one piece. It may then be cut up on the ground. To drop the tree in the exact spot desired requires experience and judgment on the part of the foreman. First, cut a notch near the ground line about one-third through on the side toward which the tree is to fall. Then cut from the opposite side with a saw, a few inches (several millimeters) above the previous notch. If there is any question as to the direction the tree will fall, use hand lines or a pulling line as insurance.

b. Piece-by-piece. Where adjacent structures, wire lines, highways, or other limitations prevent felling the tree, it may be taken down piece by piece. Starting on the lower limbs and working toward the crown, limbs are removed, one by one, as in trimming. If the trunk cannot be felled, it must also be removed in pieces.

c. Stumps. The usual practice is to cut the stump at the ground line. This can be done with a power saw or hand crosscut saw by excavating at the sides of the stump to provide clearance for operation of the saw. Power equipment of various types is available for removal of stumps or for cutting them to slightly below the ground line.

4-60. Tree killing chemicals.

Various chemicals are now available that will kill the plant or retard its growth. The installation agronomist, entomologist, or pest control officer should be consulted before any chemicals are used. Since misdirected or windblown spray can cause irreparable damage to plant life adjacent to the right-of-way, do not spray when there is appreciable wind. Protect personnel with rubber gloves and protective clothing when handling the chemicals. Manufacturer's instructions should be followed in mixing and applying chemicals. Local contractors are often available, who are experienced and equipped to do chemical clearing.

4-61. Posionous plants.

Poisonous plants are frequently encountered when trimming trees and removing brush. If the poisonous oily substance from these plants gets on the skin, it should be removed as soon as possible. Smoke, insects, clothing, and direct contact can spread the toxic effects, which are more likely to occur when the skin is covered with perspiration. A preventive cleanser is available which cleanses and decontaminates poisonous oils. Apply the cleanser to the exposed area of the skin for the recommended period and then rise off with cool running water. Other methods, which are not preventive treatments and do not alleviate the damage, are washing the exposed areas of the skin with warm water and brown laundry soap or with rubbing alcohol, then rinsing with clear water, and drying the skin. No brush should be used, as this would irritate the skin. Clothing exposed to the poison should also be thoroughly cleaned.

Section XV - LIVE-LINE MAINTENANCE

4-62. live-line maintenance requirements.

With the use of various types of aerial equipment and hot-line tools, many operations in the maintenance of overhead distribution lines may be performed while these lines are energized. Safety precautions are of utmost importance and personnel engaged in this type work must be thoroughly trained in the procedures and use of the tools and equipment. Departmental safety publications should be consulted for restrictions and certification requirements on live-line maintenance at various voltage levels. Also see requirements in chapter 1, section II. Trained personnel should be familiar with ANSI/IEEE 516 and ANSI/IEEE 935, which provide expanded guidance on energized power-line maintenance methods and live-line tool care. The "Lineman's and Cableman's Handbook" provides pictorial data on tools, equipment, and live-line operation techniques.

4-63. Categories of energized-line maintenance.

Energized-line maintenance means work on any line electrically connected to a source of potential difference, or electrically charged so as to have a potential difference from ground. Synonyms are alive, current carrying, hot, and live. Voltage is considered medium or high if it is over 600 volts up to 230,000 volts, see section II. The categories of work apply to the potential difference from ground at which the worker operates and specific precautions apply to each potential.

a. Workers at ground potential. Workers are located on the structure supporting the conductor or on other work platforms and remain essentially at ground potential using insulating tools and equipment.

b. Workers at intermediate potential. Workers are isolated from grounded objects by insulating means, such as an aerial lift or an insulating ladder or platform, and work with insulating tools and equipment.

c. Workers at line potential. Workers are bonded to the energized device on which work is to be performed and are insulated from grounded objects and other energized devices that are at a different potential. This is commonly known as the barehand technique and cannot be used by facility maintenance personnel.

4-64. Energized-line methods.

Most line maintenance utilizes insulated aerial lifts except where accessibility to the work area is impossible. Aerial lifts can be used for aerial inspections, unenergized line maintenance, tree trimming, streetlighting and lamp replacement; but an aerial lift will most often serve as the elevated platform for live-line maintenance.

a. Maintenance using rubber gloves and other protective equipment. Work is done directly on the lines using rubber gloves and other protective line equipment such as rubber sleeves; rubber insulating line hose and insulator hoods; and polyethylene conductor, insulator, crossarm, and pole covers. The lineman may be standing on a climber gaff, pole-attached insulated platform, or insulated aerial lift for the line maintenance voltage levels (low-voltage up to 15,000 volts medium-voltage) normally performed by facility personnel. Utilities normally use rubber gloves and climbers up to 7,500 volts and platforms or lifts above this voltage to 17,000 volts.

b. Maintenance using rubber gloves, other protective equipment, and hot-line tools. This procedure is normally used for all primary distribution lines maintained by facility personnel.

(1) Utilities use protective equipment and hot-line tools for voltages of 17,000 volts to 26,500 volts and work from insulated platforms or lifts. For voltages above 26,500 volts to 36,000 volts, utilities require aerial lifts.

(2) Approach distances and minimum tool insulation distance requirements must be observed. Rubber protective equipment comes in various voltage classes. Never use equipment rated at less than the maximum voltage involved.

c. Barehand maintenance. Barehand maintenance is done with the lineman at the same potential as the line being worked on. A conductive liner of metal-mesh in the aerial lift (the basket shielding) is brought to line potential using a bonding lead. This lead, which is permanently attached to the mesh, is hot-stick fastened to the energized line conductor. Barehand work can also be performed by linemen in special conducting suits working from special insulating ladders. The insulating suit is connected to the energized conductors to bring the lineman to line potential.

(1) *Policy.* Departmental policy must be complied with in the performance of “arehand” work. It is essential that any personnel involved in “hot-line” work be thoroughly trained and experienced. Barehand procedures require a knowledge of all three methods covered previously and dictate making periodic re-examinations of the worker’s ability to safely use the barehand technique. All tools and equipment must be in excellent condition and should be maintained solely for the purpose of performing live-line maintenance.

(2) *Qualified personnel.* Consideration should be given to having this type work done by a qualified contractor, unless the in-house personnel are fully qualified, adequately equipped, and perform this work frequently enough to maintain their proficiency.

4-65. Live-line operations.

All live-line operations require special tools and equipment to perform the variety of work procedures involves in hot-line maintenance.

a. Tools and equipment. The tools and equipment used in live-line maintenance are made specifically for this type of work. They are required to meet applicable acceptance test standards and they must be cared for and maintained to meet in-service standards. Chapter 15, section V discusses these requirements.

b. Operations. The most common live-line maintenance operations are as follows:

(1) Replacing poles.
(2) Replacing crossarms.
(3) Replacing insulators.
(4) Washing insulators.
(5) Cutting out and replacing live conductors.
(6) Tapping a hot line.
(7) Applying armor rods or vibration dampers.
(8) Phasing conductors.

c. Procedures for replacing poles, crossarms, and insulators. To replace any of these items requires that the conductors must be untied or unclamped from their insulators and temporarily supported.

(1) *Poles.* In overhead line maintenance, pole replacement is usually the result of deterioration or damage to the pole. The new pole should be set and the wire tongs, saddles, and other tools needed to support the existing line while moving it to the new pole should be provided. If the old pole must be used to support any tools, temporary bracing may need to be installed to strengthen the weakened pole.

(2) *Insulators.* The usual procedures in the replacement of insulators are as follows:

(a) Fasten the wire tongs to the conductor.

(b) Remove the tie or clamp from the conductor.

(c) Move the conductor clear of the work area and secure the wire tong.

(d) Remove old insulator.

(e) Mount new insulator.

(f) Return conductor to insulator.

(g) Tie or clamp conductor to insulator.

(h) Remove wire tongs.

(3) *Crossarms: In replacing crossarms, apply steps (a), (b), and (c) for all lines.* Then remove crossarm and insulators and replace with new crossarm with new insulators in place. Then apply steps *(f)*, *(g)*, and *(h)*.

d. Washing energized insulators. Hand cleaning of de-energized insulators is described in chapter 3, section IV ANSI/IEEE 957 provides a guide for cleaning insulators.

(1) *Facility procedures.* Each facility should develop procedures based on their level of voltages, contaminants, and available equipment. Using advice from the local utility concerning their energized insulator washing practices is recommended.

(2) *Energized cleaning methods.* Energized cleaning methods include the use of high pressure, medium-pressure, and low-pressure water; compressed air with abrasive dry cleaning compounds; and wiping with burlap cleaning hammocks using hot sticks. All of these procedures are covered in ANSI/IEEE 957.

(3) *Technical considerations of pressurized water cleaning.* Certain items influence the effectiveness of pressurized water cleaning performance and the leakage current that can pass to the operator's body from the water stream. These items are the nozzle conductor distance, the water's resistivity, the water pressure, and the nozzle-orifice diameter. Wind can interfere with the efficiency of the water spray. The washing interval must be such as to avoid flashover accidents during hot-line washing, which can occur when the acceptable limit of contamination has been exceeded. Some points, covered in more detail in ANSI/IEEE 957, are as follows:

(a) Water resistiuity. Water having a resistivity greater than 1500 ohm-centimeters can usually be obtained from city water system hydrants. This is an acceptable low-level resistivity. Water resistivity changes inversely with temperature and must be measured periodically during washing operations, especially in hot weather. In no case should water be used having a resistivity of below 1,000 ohm-centimeters. No soap, detergents, anti-freeze, or alcohol should be added.

(b) Nozzle type. A jet nozzle is more suited to transmission (high-voltage) systems because wind effects the spray less and the spray range is greater. The spray nozzle is suited for distribution (medium-voltage) systems.

(c) Apparatus. Consult manufacturers when washing nonceramic insulators. Bushings made of porcelain must be treated with great care and the effects of water pressure and volume and the mechanical support provided the bushing must be considered. Energized washing of surge arresters may impose severe electrical stresses on the arresters due to voltage imbalance and should not be done without the consent of the arrester manufacturer.

(4) *Safety.* Follow facility rules and general industry practices as covered in ANSI/IEEE 957. The OSHA safe working distance (from Table V-l of Subpart V, Section 1926.950) is the minimum distance recommended for personnel adjacent to energized objects at any time. This distance applies to the phase-to-phase voltage and is 2 feet (0.6 meters) for 2.1- to 15-kilovolt energized parts and 2.33 feet (0.71 meters) for 15.1- to 35-kilovolt energized parts.

e. Other procedures. Cutting out and replacing live conductors requires supporting the conductors and providing a temporary jumper to bypass the current while the splice is completed. The bypass uses hot-line clamps as 'does tapping a conductor. Installation of hot-line clamps, armor rods, and vibration dampers should follow manufacturer's hot-line instructions. Phasing-out requires a phase-tester, which should be connected in accordance with the manufacturer's instructions.

Section XVI-AERIAL LIFT REQUIREMENTS

4-66. Aerial lift construction.

Aerial lifts are required to be constructed to meet ANSI/SIA A92.2. Aerial lifts can be field modified for uses other than those intended by the manufacturer, provided the modification has been certified in writing by the manufacturer or other equivalent entity (such as a nationally-recognized testing laboratory) to conform with ANSI/SIA A92.2 and OSHA Subpart V Paragraph 1926.556 and to be at least as safe as the equipment was before modification.

4-67. Aerial lift specifics.

OSHA has defined equipment which must meet aerial lift rules and electrical tests.

a. Type of aerial lifts. Aerial lifts include the following types of vehicle-mounted aerial devices used singly or in combination to elevate personnel to job-sites aboveground.

(1) Extensible boom platforms.

(2) Aerial ladders.

(3) Articulating boom platforms.

(4) Vertical towers.

b. Manufacture. Aerial equipment may be made of metal, wood, fiberglass reinforced plastic (FRP), or other material; may be powered or manually operated; and is deemed to be an aerial lift whether or not the equipment is capable of rotating about a substantially vertical axis.

c. *Rules.* The following specific OSHA rules apply.

(1) Aerial ladders will be secured in the lower traveling position, by the locking device on top of the truck cab and the manually operated device at the base of the ladder, before the truck is moved for highway travel.

(2) Lift controls will be tested each day prior to use to determine that such controls are in safe working condition.

(3) Only authorized persons will operate an aerial lift.

(4) Belting off to an adjacent pole, structure, or equipment while working from an aerial lift will not be permitted.

(5) Employees will always stand firmly on the floor of the basket and will not sit or climb on the edge of the basket or use planks, ladders, or other devices for a work position.

(6) A body belt will be worn and a lanyard attached to the boom or basket when working from an aerial lift.

(7) Boom and basket load limits specified by the manufacturer will not be exceeded.

(8) The brakes will be set; and, when outriggers are used, they will be positioned on pads or a solid surface. Wheel chocks will be installed before using an aerial lift on an incline, provided they can be safely installed.

(9) Generally, an aerial lift truck will not be moved when the boom is elevated in a working position with men in the basket.

(10) Articulating boom and extensible boom platforms, primarily designed as personnel carriers, will have both platform (upper) and lower controls. Upper controls will be in *or* beside the platform, within easy reach of the platform operator. Lower controls will be in or beside the platform, within easy reach of the at-grade operator. Lower controls will provide for overriding the upper controls. Controls will be plainly marked as to their function. Lower level controls will not be operated unless permission has been obtained from workers in the lift, except in case of emergency.

(11) Climbers will not be worn while performing work from an aerial lift.

(12) The insulated portion of an aerial lift will not be altered in any manner that might reduce its insulating value.

(13) Before moving an aerial lift for travel, the boom(s) will be inspected to see that equipment is properly cradled and that outriggers are in stowed position.

d. Testing. Procedures for testing aerial-lift devices are described in chapter 15, section VIII.