IEEE Std 524-1992
(Revision of IEEE Std 524-1980)

IEEE Guide to the Installation of Overhead Transmission Line Conductors

Circuits and Devices

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IEEE Power Engineering Society

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Transmission and Distribution Committee

Industrial Applications

Signals and Applications

Standards Coordinating Committees

IEEE Std 524-1992

IEEE

Published by the Institute of Electrical and Electronics Engineers, Inc., 345 East 47th Street, New York, NY 10017, USA.

November 3, 1992

SH15479

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Transmission and Distribution Committee
of the
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Approved June 18, 1992

IEEE Standards Board

Abstract: General recommendations for the selection of methods, equipment, and tools that have been found to be practical for the stringing of overhead transmission line conductors and overhead groundwires are provided. The aim is to present in one document sufficient details of present day methods, materials, and equipment to outline the basic considerations necessary to maintain safe and adequate control of conductors during stringing operations.

The Institute of Electrical and Electronics Engineers, Inc.
345 East 47th Street, New York, NY 10017-2394, USA

ISBN 1-55937-241-9

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Foreword

(This foreword is not a part of IEEE Std 524-1992, IEEE Guide to the Installation of Overhead Transmission Line Conductors.)

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IEEE Guide to the Installation of Overhead Transmission Line Conductors

1. Introduction

1.1 Scope. This guide provides general recommendations for the selection of methods, equipment, and tools that have been found to be practical for the stringing of overhead transmission line conductors and overhead groundwires. The guide also includes a comprehensive list of definitions for equipment and tools used in stringing and for stringing terms commonly employed. This guide does not address special conductors such as those used for river and canyon crossing. These conductors may be custom designed and may often require special considerations.

1.2 Purpose. The purpose of this guide is to present in one document sufficient details of present day methods, materials, and equipment to outline the basic considerations necessary for maintaining safe and adequate control of conductors during stringing operations. References are given in Section 2 for those desiring more detailed information. Because the terminology used for many hardware items and for many stringing terms varies from place to place, a list of definitions is included to provide correlation and clarification of the terms most commonly employed.

1.3 Application. This guide is broad enough yet specific enough to be applicable to the stringing of conventional overhead transmission conductors and overhead groundwires (OHGW) of the following types: AAAC, AAC, AACSR, ACAR, ACSR, ACSR/TW, aluminum-clad steel OHGW, and galvanized steel OHGW. Since stringing practices for different projects will be strongly influenced by the magnitude and nature of each project and by local circumstances, alternate methods that have been successfully employed are presented. Information contained in this guide may not be sufficient for certain special cases, such as when stringing extremely long spans, severe line angles, high tensions, or special conductors and overhead ground wires such as T-2, SSAC, SDC, and OPGW. In these cases, the manufacturer should be consulted. The practices that are described in this guide provide for continuous control of the conductor from the initial setup to the ready-for-service condition. Any legal requirements of national, state, or local regulations must, of course, be observed.

The approach used within this guide is first to describe, in general terms, the stringing methods most commonly employed, then the specific requirements of the various tools and equipment used. Finally, the application of the methods and equipment to the process of stringing is described.

2. References

[1] IEEE Std 100-1984, IEEE Standard Dictionary of Electrical and Electronics Terms (ANSI).[1]

[2] IEEE P524A/D4, July 1992, *Draft Guide to Grounding During the Installation of Overhead Transmission Line Conductors.*[2]

[3] Boner, C. J., *Manufacture and Application of Lubricating Greases.* Robert E. Krieger Publishing Co. Inc., 1971.

[4] Clayton, J. M. and Powell, R. L., "Application of Arresters for Complete Lightning Protection of Substations," *AIEE Transactions*, vol. 77, pt. 3, 1958.

[5] "Grounding and Jumpering," Bulletin 9-7208, A. B. Chance Co., 1972.

[6] Hellstern, V. and Van Name, J. M., "A Study of Effective Temporary Grounding Techniques for Modern Transmission Lines," EEI Pub. No. 62-49.

[7] "Limitations on Stringing and Sagging Conductors," Paper TP64-146, Working Group of the IEEE Towers, Poles, and Conductors Subcommittee of the Transmission and Distribution Committee of the IEEE Power Engineering Society.

[8] "Live Line Maintenance Methods," Paper T73 157-5, Towers, Poles, and Conductors Subcommittee of the Transmission and Distribution Committee of the IEEE Power Engineering Society.

[9] Lummis, J. and Fischer, H. D., Jr., "Practical Application of Sag and Tension Calculations to Transmission Line Design," AIEE 54-501, Jun. 1955.

[10] Wagner, C. F. and Lloyd, B. L., "Corona Effects on Traveling Waves Determined by Field and Laboratory Tests," *Proceedings of the International Conference on Large Electric High-Voltage Systems (CIGRE)*, Paper No. 408, 1956.

[11] Winkelman, P. F., "Sag-Tension Computations and Field Measurements of Bonneville Power Administration," AIEE 59-900, 1959.

3. Definitions and Cross Reference of Terminology

Terminology for equipment and procedures associated with the installation of overhead transmission line conductors varies widely throughout the utility industry. Therefore, definitions (see 3.1) and a table of terminology cross references (see 3.2) have been included to provide a correlation between the terminology used in this guide and industry synonyms. Note that the synonyms are terms that are commonly used, although many are not necessarily good usage and should not be taken as equivalents to the guide terminology.

Many of the terms have additional meanings and usages that are defined in IEEE Std 100-1984 [1][3].

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[1]IEEE publications are available from the Institute of Electrical and Electronics Engineers, Service Center, 445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, USA.

[2]This authorized standards project was not approved by the IEEE Standards Board at the time this went to press. It is available from the IEEE Service Center.

[3]The numbers in brackets correspond to those of the references in Section 2.

3.1 Definitions and Terminology for Conductor Stringing Equipment

AAAC. Concentric-lay-stranded all aluminum alloy conductor.

AAC. Concentric-lay-stranded all aluminum conductor.

Aerex. See **explosives.**

alive. See **energized.**

all terrain vehicle (ATV). See **off-road vehicle.**

alligator. See **running board.**

aluminum conductor, steel reinforced (ACSR). A composite conductor made up of a combination of aluminum and coated steel wires. In the usual construction, the aluminum wires surround the steel.

aluminum alloy conductor, steel reinforced (AACSR). A composite conductor made up of a combination of aluminum alloy and coated steel wires. In the usual construction, the aluminum wires surround the steel.

aluminum conductor, aluminum alloy reinforced (ACAR). A composite conductor made up of a combination of aluminum and aluminum alloy wires. In the usual construction, the aluminum wires surround the aluminum alloy.

anchor. A device that serves as a reliable support to hold an object firmly in place. The general term "anchor" is normally associated with cone, plate, screw, or concrete anchors. The terms *snub, deadman*, and *anchor log* are usually associated with pole stubs or logs set or buried in the ground to serve as temporary anchors. The latter are often used at pull and tension sites. *Syn*: **anchor log, deadman, snub.**

anchor log. See **anchor.**

Baker board. See **platform, lineperson's.**

basket. See **bucket; grip, woven wire.**

bicycle. See **cable car.**

binder. See **load, binder.**

bird. See **running board.**

birdie. See **running board.**

block. A device designed with one or more single sheaves, a wood or metal shell, and an attachment hook or shackle. When rope is reeved through two of these devices, the assembly is commonly referred to as a *block and tackle.* A *set of fours* refers to a block and tackle arrangement utilizing two 4 in double sheave blocks to obtain four load-bearing lines. Similarly, a *set of fives* or a *set of sixes* refers to the same number of load-bearing lines obtained using two 5 in or two 6 in double sheave blocks, respectively. *Syn*: **set of fours, set of fives, set of sixes.**

block, hold-down. A device designed with one or more single groove sheaves to be placed on the conductor and used as a means of holding it down. This device functions essentially as a traveler used in an inverted position. It is normally used in midspan to control conductor uplift caused by stringing tensions, or at splicing locations to control the conductor as it is allowed to rise after splicing is completed. *Syn*: **block, splice release; roller, hold-down; traveler, hold-down.**

block, splice release. See **block, hold-down.**

block, snatch. A device normally designed with a single sheave, wood or metal shell, and hook. One side of the shell usually opens to eliminate the need for threading of the line. It is commonly used for lifting loads on a single line or as a device to control the position or direction, or both, of a fall line or pulling line. *Syn*: **Skookum, Washington, Western.**

boatswain's chair. A seat designed to be suspended on a line reeved through a block and attached to a pulling device to hoist a workman to an elevated position. *Syn*: **bosun's chair.**

bosun's chair. See **boatswain's chair.**

bonded. The mechanical interconnection of conductive parts to maintain a common electrical potential. *Syn*: **connected.**

boxing glove. See **hook, conductor lifting.**

brake. See **tensioner, bullwheel.**

bucket. A device designed to be attached to the boom tip of a line truck, crane, or aerial lift to support workers in an elevated working position. It is normally constructed of fiberglass to reduce its physical weight, maintain strength, and obtain good dielectric characteristics. *Syn*: **basket.**

buffalo. See **grip, conductor.**

bullet. See **link, connector.**

bull rope. See **line, bull.**

bullwheel. A wheel incorporated as an integral part of a bullwheel puller or tensioner to generate pulling or braking tension on conductors or pulling lines, or both, through friction. A puller or tensioner normally has one or more pairs of wheels arranged in tandem incorporated in its design. The physical size of the wheels will vary for different designs, but 17 in (43 cm) face widths and diameters of 5 ft (150 cm) are common. The wheels are power driven or retarded and lined with single or multiple groove neoprene or urethane linings. Friction is accomplished by reeving the pulling line or conductor around the groove of each pair.

bundle, two-conductor, three-conductor, four-conductor, multiconductor. A circuit phase consisting of more than one conductor. Each conductor of the phase is referred to as a *subconductor.* A two-conductor bundle has two subconductors per phase. These may be arranged in a vertical or horizontal configuration. Similarly, a three-conductor bundle has three subconductors per phase. These usually are arranged in a triangular configuration with the vertex of the triangle up or down. A four-conductor bundle has four subconductors per phase. These normally are arranged in a square configuration. Although other configurations are possible, those listed are the most common. *Syn*: **twin-bundle, tri-bundle, quad-bundle.**

cable. See **conductor.**

cable buggy. See **conductor car.**

cable car. A seat or basket-shaped device, designed to be suspended by a framework, and two or more sheaves arranged in tandem to enable a workman to ride a single conductor, wire, or cable. *Syn*: **bicycle, cable trolley, conductor car.**

cable trolley. See **cable car.**

cage. See **platform, aerial.**

cat. See **tractor, crawler.**

chain binder. See **load, binder.**

chain hoist. See **hoist.**

chain tugger. See **hoist.**

Chinese finger. See **grip, woven wire.**

choker. See **traveler sling.**

clip. See **clamp, cable.**

clamp, cable. A device designed to clamp cables together. It consists of a "U" bolt threaded on both ends, two nuts, and a base, and is commonly used to make temporary *bend back* eyes on wire rope. *Syn*: **clip, Crosby, Crosby clip.**

clamp, hose. See **clamp, strand restraining.**

clamp, plier. See **clamp, strand restraining.**

clamp, strand restraining. An adjustable circular clamp commonly used to keep the individual strands of a conductor in place and to prevent them from spreading when the conductor is cut. *Syn*: **block, cable binding; clamp, hose; clamp, plier; grip, vise.**

clamping-in. See **clipping-in.**

clearance. (1) The condition in which a circuit has been deenergized to enable work to be performed more safely. A clearance is normally obtained on a circuit presenting a source of hazard prior to starting work. *Syn*: **outage, permit, restriction.**

(2) The minimum separation between two conductors, between conductors and supports or other objects, or between conductors and ground or the clear space between any objects.

clipping. See **clipping-in.**

clipping-in. The transferring of sagged conductors from the travelers to their permanent suspension positions and the installing of the permanent suspension clamps. *Syn*: **clamping-in, clipping.**

clipping offset. A calculated distance, measured along the conductor from the plumb mark to a point on the conductor at which the center of the suspension clamp is to be placed. When stringing in rough terrain, clipping offsets may be required to balance the horizontal forces on each suspension structure.

clock. See **dynamometer.**

Coffing. See **hoist.**

Coffing hoist. See **hoist.**

come-along. See **grip, conductor.**

conductor. A wire, or combination of wires not insulated from one another, suitable for carrying an electric current. It may be, however, bare or insulated. *Syn*: **cable, wire.**

conductor car. A device designed to carry workmen and ride on sagged bundle conductors, thus enabling them to inspect the conductors for damage and install spacers and dampers where required. These devices may be manual or powered. *Syn*: **cable buggy, cable car, spacer buggy, spacer cart, spacing bicycle.**

conductor hook. See **hook, conductor lifting.**

conductor payout station. See **site, tension.**

conductor splice. See **joint, compression.**

connected. See **bonded.**

connector. See **link, connector.**

connector, rope. A special high strength steel link used to join two lengths of pulling rope by means of the eye splice at each end. Although designed to pass easily through the grooves of the bullwheels on the puller, it should not be passed under full load. *Syn*: **peanut.**

control span. See **sag span.**

counterpoise. See **ground grid.**

crawler. See **tractor, crawler.**

Crescent. See **grip, conductor.**

Crosby. See **clamp, cable.**

Crosby clip. See **clamp, cable.**

crossing structure. A structure built of poles and, sometimes, rope nets. It is used whenever conductors are being strung over roads, power lines, communications circuits, highways, or railroads, and is normally constructed in such a way as to prevent the conductor from falling onto or into any of these facilities in the event of equipment failure, broken pulling lines, loss of tension, etc. *Syn*: **guard structure, H-frame, rider structure, temporary structure.**

current carrying. See **energized.**

D-board. See **platform, lineperson's.**

dead. See **deenergized.**

deadend board. See **platform, lineperson's.**

deadend loop. See **jumper.**

deadend platform. See **platform, lineperson's.**

deadman. See **anchor.**

deenergized. Free from any electric connection to a source of potential difference and from electric charge; not having a potential different from that of the ground. The term is used only with reference to current-carrying parts that are sometimes alive (energized). To state that a circuit has been deenergized means that the circuit has been disconnected from all intended electrical sources. However, it could be electrically charged through induction from energized circuits in proximity to it, particularly if the circuits are parallel. *Syn*: **dead.**

diving board. See **platform, lineperson's.**

dolly. See **traveler.**

dolly car. See **rack, traveler.**

dynamite. See **explosives.**

dynamometer. A device designed to measure loads or tension on conductors. Various models of these devices are used to tension guys or sag conductors. *Syn*: **clock, load cell.**

earth wire. See **overhead groundwire.**

energized. Electrically connected to a source of potential difference, or electrically charged so as to have a potential different from that of the ground. *Syn*: **alive, current carrying, hot, live.**

equipotential. An identical state of electrical potential for two or more items.

explosives. Mixtures of solids, liquids, or a combination of the two that, upon detonation, transform almost instantaneously into other products that are mostly gaseous and that occupy much greater volume than the original mixtures. This transformation generates heat, which rapidly expands the gases, causing them to exert enormous pressure. Dynamite and Primacord are explosives as manufactured. Aerex, Triex, and Quadrex are manufactured in two components and are not true explosives until mixed. Explosives are commonly used to build construction roads, blast holes for anchors, structure footings, etc. *Syn*: **Aerex, dynamite, fertilizer, powder, Primacord, Quadrex, Triex.**

fertilizer. See **explosives.**

finger rope. See **line, finger.**

four bolt. See **grip, conductor.**

grip. See **grip, conductor.**

grip, Chicago. See **grip, conductor.**

grip, conductor. A device designed to permit the pulling of conductor without splicing on fittings, eyes, etc. It permits the pulling of a *continuous* conductor where threading is not possible. The designs of these grips vary considerably. Grips such as the Klein (Chicago) and Crescent utilize an open-sided rigid body with opposing jaws and swing latch. In addition to pulling conductors, this type is commonly used to tension guys and, in some cases, pull wire rope. The design of the come-along (pocket-book, suitcase, four bolt, etc.) incorporates a bail attached to the body of a clamp that folds to completely surround and envelope the conductor. Bolts are then used to close the clamp and obtain a grip. *Syn*: **buffalo; come-along; Crescent; four bolt; grip; grip, Chicago; Kellem; Klein; pocketbook; seven bolt; six bolt; slip-grip; suitcase.**

grip, vise. See **clamp, strand restraining.**

grip, wire mesh. See **grip, woven wire.**

grip, woven wire. A device designed to permit the temporary joining or pulling of conductors without the need of special eyes, links, or grips. *Syn*: **basket; Chinese finger; grip, wire mesh; Kellem; sock.**

ground, block. See **ground, traveler.**

ground, butt. See **ground, structure base.**

ground chain. See **ground, structure base.**

grounded. Connected to earth or to some extended conducting body that serves instead of the earth, whether the connection is intentional or accidental.

ground electrode. See **ground rod.**

ground grid. A system of interconnected bare conductors arranged in a pattern over a specified area either on or buried below the surface of the earth. Normally, it is bonded to ground rods driven around and within its perimeter to increase its grounding capabilities and provide convenient connection points for grounding devices. The primary purpose of the grid is to provide safety for workmen by limiting potential differences within its perimeter to safe levels in case of high currents that could flow if the circuit being worked became energized for any reason or if an adjacent energized circuit faulted. Metallic surface mats and gratings are sometimes utilized for this same purpose. When used, these grids are employed at pull, tension, and midspan splice sites. *Syn*: **counterpoise, ground gradient mat, ground mat.**

ground gradient mat. See **ground grid.**

ground, master. A portable device designed to short circuit and connect (bond) a deenergized circuit or piece of equipment, or both, to an electrical ground. Normally located remote from, and on both sides of, the immediate work site. Primarily used to provide safety for personnel during construction, reconstruction, or maintenance operations. *Syn*: **ground set, ground stick.**

ground mat. See **ground grid.**

ground, moving. See **ground, running.**

ground, personal. A portable device designed to connect (bond) a deenergized conductor or piece of equipment, or both, to an electrical ground. It is distinguished from a master ground in that it is utilized at the immediate site when work is to be performed on a conductor or piece of equipment that could accidentally become energized. *Syn*: **ground stick; ground, working; red head.**

ground rod. A rod that is driven into the ground to serve as a ground terminal, such as a copper-clad rod, solid copper rod, galvanized iron rod, or galvanized iron pipe. Copper-clad steel rods are commonly used during conductor stringing operations to provide a means of obtaining an electrical ground using portable grounding devices. *Syn*: **ground electrode.**

ground roller. See **ground, running.**

ground, rolling. See **ground, running; ground, traveler.**

ground, running. A portable device designed to connect a moving conductor or wire rope, or both, to an electrical ground. These devices are normally placed on the conductor or wire rope adjacent to the pulling and tensioning equipment located at either end of a sag section. They are primarily used to provide safety for personnel during construction or reconstruction operations. *Syn*: **ground, moving; ground roller; ground, rolling; ground, traveling.**

ground, sheave. See **ground, traveler.**

ground stick. See **ground, personal.**

ground, structure. See **ground structure base.**

ground, structure base. A portable device designed to connect (bond) a metal structure to an electrical ground. It is primarily used to provide safety for personnel during construction, reconstruction, or maintenance operations. *Syn*: **ground, butt; ground chain; ground, structure; ground, tower.**

ground, tower. See **ground, structure base.**

ground, traveler. A portable device designed to connect a moving conductor or wire rope, or both, to an electrical ground. It is primarily used to provide safety for personnel during construction or reconstruction operations. This device is placed on the traveler (sheave, block, etc.) at a strategic location where an electrical ground is required. *Syn*: **ground, block; ground, rolling; ground, sheave.**

ground, traveling. See **ground, running.**

ground, working. See **ground, personal.**

guard structure. See **crossing structure.**

H-frame. See **crossing structure.**

hoist. An apparatus for moving a load by the application of a pulling force and not including a car or platform running in guides. These devices are normally designed using roller or link chain and built-in leverage to enable heavy loads to be lifted or pulled. They are often used to deadend a conductor during sagging and clipping-in operations and during the tensioning of guys. *Syn*: **chain hoist; chain tugger; Coffing; Coffing hoist; puller, drum.**

hoist, double drum. See **puller, two drum, three drum.**

hoist, single drum. See **puller, drum.**

hoist, triple drum. See **puller, two drum, three drum.**

hook, conductor lifting. A device resembling an open boxing glove designed to permit the lifting of conductors from a position above them. It is normally used during clipping-in operations. Suspension clamps are sometimes used for this purpose. *Syn*: **boxing glove, conductor hook, lifting shoe, lip.**

hose clamp. See **clamp, strand restraining.**

hot. See **energized.**

hub. A reference point established through a land survey. A hub or point on tangent (POT) is a reference point for use during construction of a line. The number of such points that are established will vary with the job requirements. Monuments, however, are usually associated with state or federal surveys and are intended to be permanent reference points. Any of these points may be used as a reference point for transit sagging operations, provided that all necessary data pertaining to them is known. It is quite common to establish additional temporary hubs as required for this purpose. *Syn*: **monument, point on tangent.**

insulator saddle. See **lifter, insulator.**

isolated. (1) Physically separated, electrically and mechanically, from all sources of electrical energy. Such separation may not eliminate the effects of electrical induction.

(2) An object that is not readily accessible to persons unless special means for access are used.

Jacob's ladder. See **ladder, rope.**

joint, compression. A tubular compression fitting designed and fabricated from aluminum, copper, or steel to join conductors or overhead groundwires. It is usually applied through the use of hydraulic or mechanical presses. However, in some cases, automatic, wedge, and explosive-type joints are utilized. *Syn*: **conductor splice, sleeve, splice.**

joint, protector. A split sleeve that fits over a conductor compression joint used to protect the joint from bending or damage if the joint must pass through travelers. The joint protector usually has split rubber collars at each end to protect the conductor from damage where it exits at each end of the sleeve.

jumper. (1) The conductor that connects the conductors on opposite sides of a deadend structure. *Syn*: **deadend loop.**

(2) A conductor placed across the clear space between the ends of two conductors or metal pulling lines that are being spliced together. Its purpose, then, is to act as a shunt to prevent workers from accidentally placing themselves in series between the two conductors.

Kellem. See **grip, conductor; grip, woven wire.**

Klein. See **grip, conductor.**

ladder, hook. See **ladder, tower.**

ladder, rope. A ladder having vertical synthetic or manila suspension members and wood, fiberglass, or metal rungs. The ladder is suspended from the arm or bridge of a structure to enable workers to work at the conductor level, hang travelers, perform clipping-in operations, etc. *Syn*: **Jacob's ladder.**

ladder, tower. A ladder complete with hooks and safety chains attached to one end of the side rails. These units are normally fabricated from fiberglass, wood, or metal. The ladder is suspended from the arm or bridge of a structure to enable workers to work at the conductor level, to hang travelers, perform clipping-in operations, etc. In some cases, these ladders are also used as lineperson's platforms. *Syn*: **ladder, hook.**

leader. See **line, pilot.**

leader cone. A tapered cone made of rubber, neoprene, or polyurethane that is used to lead a conductor splice through the travelers, thus making a smooth transition from the smaller diameter conductor to the larger diameter splice. It is also used at the connection point of the pulling line and running board to assist in a smooth transition of the running board over the travelers, thus significantly reducing the shock loads. *Syn*: **nose cone, tapered hose.**

level. See **transit.**

lifter, insulator. A device designed to permit insulators to be lifted in a *string* to their intended position on a structure. *Syn*: **insulator saddle, potty seat.**

lifting shoe. See **hook, conductor lifting.**

line, bull. A high-strength line, normally synthetic fiber rope, used for pulling and hoisting large loads. *Syn*: **bull rope; line, pulling; line, threading.**

line, finger. A lightweight line, normally sisal, manila, or synthetic fiber rope, that is placed over the traveler when it is hung. It usually extends from the ground and passes through the traveler and back to the ground. It is used to thread the end of the pilot line or pulling line over the traveler and eliminates the need for workmen on the structure. These lines are not required if pilot lines are installed when the travelers are hung. *Syn*: **finger rope.**

line, hard. See **line, pulling.**

line, lead. See **line, pilot.**

line, life. See **line, safety life.**

line, light. See **line, pulling.**

line, pilot. A lightweight line, normally synthetic fiber rope, used to pull heavier pulling lines that, in turn, are used to pull the conductor. Pilot lines may be installed with the aid of finger lines or by helicopter when the insulators and travelers are hung. *Syn*: **leader; line, lead; line, straw; P-line; pilot rope.**

line, pulling. A high-strength line, normally synthetic fiber rope or wire rope, used to pull the conductor. However, on reconstruction jobs in which a conductor is being replaced, the old conductor often serves as the pulling line for the new conductor. In such cases, the old conductor must be closely examined for any damage prior to the pulling operations. *Syn*: **line, bull; line, hard; line, light; line, sock; pulling rope.**

line, safety. See **line, safety life.**

line, safety life. A safety device normally constructed from synthetic fiber rope and designed to be connected between a fixed object and the body belt of a worker working in an elevated position when his/her regular safety strap cannot be utilized. *Syn*: **line, life; line, safety; scare rope.**

line, sock. See **line, pulling.**

line, straw. See **line, pilot.**

line, tag. A control line, normally manila or synthetic fiber rope, attached to a suspended load to enable a worker to control its movement. *Syn*: **tag rope.**

line, threading. A lightweight flexible line, normally manila or synthetic fiber rope, used to lead a conductor through the bullwheels of a tensioner or pulling line through a bull wheel puller. *Syn*: **line, bull; threading rope.**

link. See **link, connector.**

link, connector. A rigid link designed to connect pulling lines and conductors together in series. It will not spin and relieve torsional forces. *Syn*: **bullet, connector, link, slug.**

link, swivel. A swivel device designed to connect pulling lines and conductors together in series or to connect one pulling line to the drawbar of a pulling vehicle. The device will spin and help relieve the torsional forces that build up in the line or conductor under tension. *Syn*: **swivel.**

lip. See **hook, conductor lifting.**

live. See **energized.**

load, binder. A toggle device designed to secure loads in a desired position. It is normally used to secure loads on mobile equipment. *Syn*: **binder, chain binder.**

load cell. See **dynamometer.**

logger. See **tractor, wheel.**

marker. See **pole, plumb marker.**

monkey tail. See **running board.**

monument. See **hub.**

nose cone. See **leader cone.**

O structure. See **snub structure.**

off-road vehicle. A vehicle specifically designed and equipped to traverse sand, swamps, muddy tundra, or rough mountainous terrain. Vehicles falling into this category are usually all wheel drive or tracked units. In some cases, units equipped with special air bag rollers having a soft footprint are utilized. *Syn*: **all terrain vehicle (ATV), swamp buggy.**

offset marker (pole). See **pole, plumb marker.**

OPGW. Concentric-lay-stranded composite conductor for use as overhead groundwire with telecommunication capability. The conductor is constructed with a central optical fiber core surrounded by helically laid aluminum-clad wires, aluminum alloy wires, galvanized steel wires, or combinations thereof.

outage. See **clearance.**

overhead groundwire (OHGW) (lightning protection). Multiple grounded wire or wires placed above phase conductors for the purpose of intercepting direct strokes in order to protect the phase conductors from the direct strokes. *Syn*: **earth wire, shield wire, skywire, static wire.**

P-line. See **line, pilot.**

payout site. See **site, tension.**

peanut. See **connector, rope.**

permit. See **clearance.**

pilot rope. See **line, pilot.**

platform. See **platform, aerial.**

platform, aerial. A device designed to be attached to the boom tip of a crane or aerial lift and support a worker in an elevated working position. Platforms may be constructed with surrounding railings that are fabricated from aluminum, steel, or fiber reinforced plastic. Occasionally, a platform is suspended from the load line of a large crane. *Syn*: **cage, platform.**

platform, lineperson's. A device designed to be attached to a wood pole or metal structure, or both, to serve as a supporting surface for workers engaged in deadending operations, clipping-in, insulator work, etc. The designs of these devices vary considerably. Some resemble short cantilever beams, others resemble swimming pool diving boards, and still others as long as 40 ft (12 m) are truss structures resembling bridges. Materials commonly used for fabrication are wood, fiberglass, and metal. *Syn*: **Baker board, D-board, deadend board, deadend platform, diving board.**

plumb mark. A mark placed on the conductor located vertically below the insulator point of support for steel structures and vertically above the pole center line at ground level for wood pole structures used as a reference to locate the center of the suspension clamp.

pocketbook. See **grip, conductor.**

point on tangent (POT). See **hub.**

pole, plumb marker. A small diameter, lightweight pole with a marking device attached to one end, having sufficient length to enable a worker to mark the conductor directly below him/her from a position on the bridge or arm of the structure. This device is utilized to mark the conductor immediately after completion of sagging. *Syn*: **marker, offset marker (pole).**

potty seat. See **lifter, insulator.**

powder. See **explosives.**

Primacord. See **explosives.**

puller. See **puller, bullwheel.**

puller, bullwheel. A device designed to pull pulling lines and conductors during stringing operations. It normally incorporates one or more pairs of urethane or neoprene-lined, power-driven, single or multiple groove bullwheels in which each pair is arranged in tandem. Pulling is accomplished by friction generated against the pulling line that is reeved around the grooves of a pair of the bullwheels. The puller is usually equipped with its own engine, which drives the bullwheels mechanically, hydraulically, or through a combination of both. Some of these devices function as either a puller or tensioner. *Syn*: **puller.**

puller, drum. A device designed to pull a conductor during stringing operations. It is normally equipped with its own engine, which drives the drum mechanically, hydraulically, or through a combination of both. It may be equipped with synthetic fiber rope or wire rope to be used as the pulling line. The pulling line is payed out from the unit, pulled through the travelers in the sag section, and attached to the conductor. The conductor is then pulled in by winding the pulling line back onto the drum. This unit is sometimes used with synthetic fiber rope acting as a pilot line to pull heavier pulling lines across canyons, rivers, etc. *Syn*: **hoist; hoist, single drum; tugger; winch, single drum.**

puller, reel. A device designed to pull a conductor during stringing operations. It is normally equipped with its own engine, which drives the supporting shaft for the reel mechanically, hydraulically, or through a combination of both. The shaft, in turn, drives the reel. The application of this unit is essentially the same as that for the drum puller. Some of these devices function as either a puller or tensioner. (See **puller, drum.**)

puller, two drum, three drum. The definition and application for this unit is essentially the same as that for the drum puller. It differs in that this unit is equipped with two or three drums and thus can pull one, two, or three conductors individually or simultaneously. (See **puller, drum.**) *Syn*: **hoist, double drum; hoist, triple drum; winch, double drum; winch, three drum; winch, triple drum; winch, two drum; tugger.**

pulley. See **sheave.**

pulling rope. See **line, pulling.**

pulling vehicle. Any piece of mobile ground equipment capable of pulling pilot lines, pulling lines, or conductors. However, helicopters may be considered as a pulling vehicle when utilized for the same purpose.

pull setting. See **sag section.**

Quadrex. See **explosives.**

rack, traveler. A device designed to protect, store, and transport travelers. It is normally designed to permit efficient use of transporting vehicles, spotting by helicopters on the line, and stacking during storage to utilize space. The exact design of each rack is dependent upon the specific travelers to be stored. *Syn*: **dolly car.**

reel setup. See **site, pull; site, tension.**

reel stand. A device designed to support one or more conductor or groundwire reels having the possibility of being skid, trailer, or truck mounted. These devices may accommodate rope or conductor reels of varying sizes and are usually equipped with reel brakes to prevent the reels from turning when pulling is stopped. They are used for either slack or tension stringing. The designation of reel trailer or reel truck implies that the trailer or truck has been equipped with a reel stand (jacks) and may serve as a reel transport or *payout* unit, or both, for stringing operations. Depending upon the sizes of the reels to be carried, the transporting vehicles may range from single-axle trailers to semitrucks with trailers having multiple axles. *Syn*: **reel trailer, reel transporter, reel truck.**

reel trailer. See **reel stand.**

reel transporter. See **reel stand.**

reel truck. See **reel stand.**

red head. See **ground, personal.**

restriction. See **clearance.**

retarder. See **tensioner, bullwheel.**

rider structure. See **crossing structure.**

roller. See **sheave.**

roller, hold-down. See **block, hold-down.**

ruling span. A *calculated span length* that will have the same changes in conductor tension due to changes of temperature and conductor loading as will be found in a series of spans of varying lengths between deadends.

running board. A pulling device designed to permit stringing more than one conductor simultaneously with a single pulling line. For distribution stringing, it is usually made of lightweight tubing with the forward end curved gently upward to provide smooth transition over pole crossarm rollers. For transmission stringing, the device is either made of sections hinged transversely to the direction of pull or of a hard nose rigid design, both having a flexible pendulum tail suspended from the rear. This configuration stops the conductors from twisting together and permits smooth transition over the sheaves of bundle travelers. *Syn*: **alligator, bird, birdie, monkey tail, sled.**

safety, conductor. A sling arranged in a vertical basket configuration, with both ends attached to the supporting structure and passed under the clipped-in conductor(s). These devices, when used, are normally utilized with bundled conductors to act as a safety device in case of insulator failure while workers in conductor cars are installing spacers between the subconductors, or as an added safety measure when crossing above energized circuits. These devices may be fabricated from synthetic fiber rope or wire rope.

sag. The distance measured vertically from a conductor to the straight line joining two points of support. Unless otherwise stated, the sag referred to is at the midpoint of the span.

sag board. See **target sag.**

sagger. See **tractor, wheel.**

sag section. The section of line between snub structures. More than one sag section may be required in order to sag properly the actual length of conductor that has been strung. *Syn*: **pull setting, stringing section.**

sag span. A span selected within a sag section and used as a control to determine the proper sag of the conductor, thus establishing the proper conductor level and tension. A minimum of two, but normally three, sag spans are required within a sag section in order to sag properly. In mountainous terrain or where span lengths vary radically, more than three sag spans could be required within a sag section. *Syn*: **control span.**

scare rope. See **line, safety life.**

scope. See **transit.**

self-damping conductor (SDC). ACSR that is designed to control aeolian vibration by integral damping. Trapezoidal aluminum wires and annular gaps are utilized.

set of fives. See **block.**

set of fours. See **block.**

set of sixes. See **block.**

seven bolt. See **grip, conductor.**

shaped wire compact conductor (TW). ACSR or AAC that is designed to increase the aluminum area for a given diameter of conductor by the use of trapezoidal shaped aluminum wires.

sheave. (1) The grooved wheel of a traveler or rigging block. Travelers are frequently referred to as sheaves. *Syn*: **pulley, roller, wheel, traveler.**
(2) A shaft-mounted wheel used to transmit power by means of a belt, chain, band, etc.

shield wire. See **overhead groundwire.**

site marker. See **transit.**

site, pull. The location on the line where the puller, reel winder, and anchors (snubs) are located. This site may also serve as the pull or tension site for the next sag section. Syn: **reel setup, tugger setup.**

site, tension. The location on the line where the tensioner, reel stands, and anchors (snubs) are located. This site may also serve as the pull or tension site for the next sag section. *Syn*: **conductor payout station, payout site, reel setup.**

six bolt. See **grip, conductor.**

skidder. See **tractor, wheel.**

Skookum. See **block, snatch.**

skywire. See **overhead groundwire.**

sled. See **running board.**

sleeve. See **joint, compression.**

sleeving trailer. See **splicing cart.**

slip-grip. See **grip, conductor.**

slug. See **link, connector.**

snub. See **anchor.**

snub structure. A structure located at one end of a sag section and considered as a *zero* point for sagging and clipping offset calculations. The section of line between two such structures is the sag section, but more than one sag section may be required in order to sag properly the actual length of conductor that has been strung. *Syn*: **O structure, zero structure.**

sock. See **grip, woven wire.**

spacer buggy. See **conductor car.**

spacer cart. See **conductor car.**

spacing bicycle. See **conductor car.**

splice. See **joint, compression.**

splice, wire rope. The point at which two wire ropes are joined together. The various methods of joining (splicing) wire ropes together include *hand tucked* woven splices, compression splices that utilize compression fittings but do not incorporate loops (eyes) in the ends of the ropes, and mechanical splices that are made through the use of loops (eyes) in the ends of the ropes held in place by either compression fittings or wire rope clips. The latter are joined together with connector links or steel bobs and, in some cases, are rigged *eye to eye*. Woven splices are often classified as short or long. A short splice varies in length from 7 to 17 ft (2 to 5 m) for 0.25 to 1.5 in (6 to 38 mm) diameter ropes, respectively, while a long splice varies from 15 to 45 ft (4 to 14 m) for the same size ropes.

splicing cart. A unit that is equipped with a hydraulic compressor (press) and all other necessary equipment for performing splicing operations on conductor. *Syn*: **sleeving trailer, splicing trailer, splicing truck.**

splicing trailer. See **splicing cart.**

splicing truck. See **splicing cart.**

static wire. See **overhead groundwire.**

steel supported aluminum conductor (SSAC). ACSR with the aluminum wires annealed.

step potential. See **step voltage.**

step voltage. The potential difference between two points on the earth's surface separated by a distance of one pace (assumed to be 1 m) in the direction of maximum potential gradient. This potential difference could be dangerous when current flows through the earth or material upon which a worker is standing, particularly under fault conditions. *Syn*: **step potential.**

stringing. The pulling of pilot lines, pulling lines, and conductors over travelers supported on structures of overhead transmission lines. Quite often, the entire job of stringing conductors is referred to as *stringing operations*, beginning with the planning phase and terminating after the conductors have been installed in the suspension clamps.

stringing block. See **traveler.**

stringing section. See **sag section.**

stringing sheave. See **traveler.**

stringing, slack. The method of stringing conductor slack without the use of a tensioner. The conductor is pulled off the reel by a pulling vehicle and is dragged along the ground, or the reel is carried along the line on a vehicle and the conductor is deposited on the ground. As the conductor is dragged to, or past, each supporting structure, the conductor is placed in the travelers, normally with the aid of finger lines.

stringing, tension. The use of pullers and tensioners to keep the conductor under tension and positive control during the stringing phase, thus keeping it clear of the earth and other obstacles that could cause damage.

stringing traveler. See **traveler.**

suitcase. See **grip, conductor.**

swamp buggy. See **off-road vehicle.**

switching surge. A transient wave of overvoltage in an electrical circuit caused by a switching operation. When this occurs, a momentary voltage surge could be induced in a circuit adjacent and parallel to the switched circuit in excess of the voltage induced normally during steady state conditions. If the adjacent circuit is under construction, switching operations should be minimized to reduce the possibility of hazards to the workmen.

swivel. See **link, swivel.**

T-2™[4]. A two-conductor twisted construction designed to control wind-induced motion.

tag rope. See **line, tag.**

takeup reel. See **winder, reel.**

tapered hose. See **leader cone.**

target. See **target sag.**

target, sag. A device used as a reference point to sag conductors. It is placed on one structure of the sag span. The sagger, on the other structure of the sag span, can use it as a reference to determine the proper conductor sag. *Syn*: **sag board, target**.

threading rope. See **line, threading.**

temporary structure. See **crossing structure.**

tensioner. See **tensioner, bullwheel.**

tensioner, bullwheel. A device designed to hold tension against a pulling line or conductor during the stringing phase. Normally, it consists of one or more pairs of urethane or neoprene-lined, power-braked, single or multiple groove bullwheels in which each pair is arranged in tandem. Tension is accomplished by friction generated against the conductor that is reeved around the grooves of a pair of the bullwheels. Some tensioners are equipped with their own engines, which retard the bullwheels mechanically, hydraulically, or through a combination of both. Some of these devices function as either a puller or tensioner. Other tensioners are only equipped with friction type retardation. *Syn*: **brake, retarder, tensioner.**

touch potential. See **touch voltage.**

touch voltage. The potential difference between a grounded metallic structure and a point on the earth's surface separated by a distance equal to the normal maximum horizontal reach, approximately 3 ft (1 m). This potential difference could be dangerous and could result from induction or fault conditions, or both. *Syn*: **touch potential.**

tractor. See **tractor, crawler; tractor, wheel.**

tractor, crawler. A tracked unit employed to pull pulling lines, sag conductor, level or clear pull and tension sites, and miscellaneous other work. It is also frequently used as a temporary anchor. Sagging winches on this unit are usually arranged in a vertical configuration. *Syn*: **cat, crawler, tractor.**

tractor, wheel. A wheeled unit employed to pull pulling lines, sag conductor, and miscellaneous other work. Sagging winches on this unit are usually arranged in a horizontal configuration. It has some advantages over crawler tractors in that it has a softer footprint, travels faster, and is more maneuverable. *Syn*: **logger, sagger, skidder, tractor.**

transit. An instrument primarily used during construction of a line to survey the route, to set hubs and point on tangent (POT) locations, to plumb structures, to determine downstrain

[4]T-2 Conductor is a registered trademark of CPI, Consumer Products, Inc., a wholly owned subsidiary of Reynolds Metals Company.

angles for locations of anchors at the pull and tension sites, and to sag conductors. *Syn*: **level, scope, site marker.**

traveler. A sheave complete with suspension arm or frame used separately or in groups and suspended from structures to permit the stringing of conductors. These devices are sometimes bundled with a center drum or sheave and another traveler, and are used to string more than one conductor simultaneously. For protection of conductors that should not be nicked or scratched, the sheaves are often lined with nonconductive or semiconductive neoprene or nonconductive urethane. Any one of these materials acts as a padding or cushion for the conductor as it passes over the sheave. Traveler grounds must be used with lined travelers in order to establish an electrical ground. *Syn*: **block, dolly, sheave, stringing block, stringing sheave, stringing traveler.**

traveler, hold-down. See **block, hold-down.**

traveler sling. A sling of wire rope, sometimes utilized in place of insulators, to support the traveler during stringing operations. Normally, it is used when insulators are not readily available or when adverse stringing conditions might impose severe downstrains and cause damage or complete failure of the insulators. *Syn*: **choker.**

tri-bundle. See **Bundle, two-conductor, three-conductor, four-conductor, multiconductor.**

Triex. See **explosives.**

tugger. See **puller, drum; puller, two drum, three drum.**

tugger setup. See **site, pull.**

twin-bundle. See **Bundle, two-conductor, three-conductor, four-conductor, multiconductor.**

quad-bundle. See **Bundle, two-conductor, three-conductor, four-conductor, multiconductor.**

uplift roller. A small single-grooved wheel designed to fit in or immediately above the throat of the traveler and keep the pulling line in the traveler groove when uplift occurs due to stringing tensions.

Washington. See **block, snatch.**

Western. See **block, snatch.**

wheel. See **sheave.**

winch, double drum. See **puller, two drum, three drum.**

winch, single drum. See **puller, drum.**

winch, three drum. See **puller, two drum, three drum.**

winch, triple drum. See **puller, two drum, three drum.**

winch, two drum. See **puller, two drum, three drum.**

winder, pilot line. A device designed to payout and rewind pilot lines during stringing operations. It is normally equipped with its own engine, which drives a drum or a supporting shaft for a reel mechanically, hydraulically, or through a combination of both. These units are usually equipped with multiple drums or reels, depending upon the number of pilot lines required. The pilot line is payed out from the drum or reel, pulled through the travelers in the sag section, and attached to the pulling line on the reel stand or drum puller. It is then rewound to pull the pulling line through the travelers. A pilot line winder can be a unit similar to a bullwheel puller and often has the reelwinder as an integral part of the machine.

winder, reel. A device designed to serve as a recovery unit for a pulling line. It is normally equipped with its own engine, which drives a supporting shaft for a reel mechanically, hydraulically, or through a combination of both. The shaft, in turn, drives the reel. It is normally used to rewind a pulling line as it leaves the bullwheel puller during stringing operations. This unit is not intended to serve as a puller, but sometimes serves this function where only low tensions are involved. *Syn*: **takeup reel.**

wire. See **conductor.**

zero structure. See **snub structure.**

3.2 Cross Reference of Terminology

Common Terminology	Guide Terminology	Common Terminology	Guide Terminology
Aerex	explosives	chain tugger	hoist
alive	energized	Chicago grip	conductor grip
alligator	running board	Chinese finger	woven wire grip
all terrain vehicle (ATV)	off road vehicle	choker	traveler sling
anchor log	anchor	clamping-in	clipping-in
Baker board	lineperson's platform	clip	cable clamp
basket	bucket	clipping	clipping-in
basket	woven wire grip	clock	dynamometer
bicycle	cable car	Coffing	hoist
binder	load binder	Coffing hoist	hoist
bird	running board	come-along	conductor grip
birdie	running board	conductor hook	conductor lifting hook
block	traveler	conductor payout station	tension site
block ground	traveler ground	conductor splice	compression joint
bosun's chair	boatswain's chair	connected	bonded
boxing glove	conductor lifting hook	connector	connector link
brake	bullwheel tensioner	control span	sag span
buffalo	conductor grip	counterpoise	ground grid
bullet	connector link	crawler	crawler tractor
bull line	pulling line	Crescent	conductor grip
bull line	threading line	Crosby	cable clamp
bull rope	bull line	Crosby clip	cable clamp
butt ground	structure base ground	current carrying	energized
cable	conductor	D-board	lineperson's platform
cable binding block	strand restraining clamp	dead	deenergized
cable buggy	conductor car	deadend board	lineperson's platform
cable car	conductor car	deadend loop	jumper
cable trolley	cable car	deadend platform	lineperson's platform
cage	aerial platform	deadman	anchor
cat	crawler tractor	diving board	lineperson's platform
chain binder	load binder	dolly car	traveler rack
chain hoist	hoist	dolly	traveler
double drum hoist	two drum puller	platform	aerial platform
double drum winch	two drum puller	pocketbook	conductor grip
dynamite	explosives	POT	hub
earthwire	overhead groundwire	potty seat	insulator lifter
fertilizer	explosives	powder	explosives

Common Terminology	Guide Terminology
finger rope	finger line
four bolt	conductor grip
grip	conductor grip
ground chain	structure base ground
ground electrode	ground rod
ground gradient mat	ground grid
ground mat	ground grid
ground roller	running ground
ground set	master ground
ground stick	master ground
ground stick	personal ground
guard structure	crossing structure
H-frame	crossing structure
hard line	pulling line
hold-down roller	hold-down block
hold-down traveler	hold-down block
hoist	drum puller
hook ladder	tower ladder
hose clamp	strand restraining clamp
hot	energized
insulator saddle	insulator lifter
Jacobs ladder	rope ladder
Kellem	woven wire grip
Klein	conductor grip
lead line	pilot line
leader	pilot line
level	transit
life line	safety life line
lifting shoe	conductor lifting hook
light line	pulling line
link	connector link
lip	conductor lifting hook
live	energized
load cell	dynamometer
logger	wheel tractor
marker	plumb marker pole
monkey tail	running board
monument	hub
moving ground	running ground
nose cone	leader cone
O structure	snub structure
offset marker (pole)	plumb marker pole
outage	clearance
P-line	pilot line
payout site	tension site
peanut	rope connector
permit	clearance
pilot rope	pilot line
spacer cart	conductor car
spacing bicycle	conductor car
splice	compression joint
splice release block	hold down block
splicing trailer	splicing cart

Common Terminology	Guide Terminology
Primacord	explosives
pull	sag section
puller	bullwheel puller
pulley	sheave
pulling rope	pulling line
quad-bundle	four conductor bundle
Quadrex	explosives
red head	personal ground
reel setup	pull site
reel setup	tension site
reel trailer	reel stand
reel transporter	reel stand
reel truck	reel stand
restriction	clearance
retarder	bullwheel tensioner
rider structure	crossing structure
roller	sheave
rolling ground	running ground
rolling ground	traveler ground
safety line	safety life line
sag board	sag target
sagger	wheel tractor
scare rope	safety life line
scope	transit
set of fours	block
set of fives	block
set of sixes	block
setting	sag section
seven bolt	conductor grip
sheave	traveler
sheave ground	traveler ground
shield wire	overhead groundwire
single drum hoist	drum puller
single drum winch	drum puller
site marker	transit
six bolt	conductor grip
skidder	wheel tractor
Skookum	snatch block
skywire	overhead groundwire
sled	running board
sleeve	compression joint
sleeving trailer	splicing cart
slip grip	conductor grip
slug	connector link
snub	anchor
sock	woven wire grip
sock line	pulling line
spacer buggy	conductor car
three drum winch	three drum puller
touch potential	touch voltage
tower ground	structure base ground
tractor	wheel tractor
tractor	crawler tractor

Common Terminology	Guide Terminology
splicing truck	splicing cart
static wire	overhead groundwire
step potential	step voltage
straw line	pilot line
structure ground	structure base ground
stringing block	traveler
stringing section	sag section
stringing sheave	traveler
stringing traveler	traveler
suitcase	conductor grip
swamp buggy	off-road vehicle
swivel	swivel link
tag rope	tag line
takeup reel	reel winder
tapered hose	leader cone
target	sag target
temporary structure	crossing structure
tensioner	bullwheel tensioner
traveling ground	running ground
tri-bundle	three conductor bundle
Triex	explosives
triple drum hoist	three drum puller
triple drum winch	three drum puller
tugger	three drum puller
tugger	drum puller
tugger setup	pull site
twin-bundle	two conductor bundle
two drum winch	two drum puller
Vise Grip plier clamp	strand restraining clamp
Washington	snatch block
Western	snatch block
wheel	sheave
wire	conductor
wire mesh grip	woven wire grip
working ground	personal ground
zero structure	snub structure

4. Conductor Stringing Methods

Unless specifically stated otherwise, all references to the term "conductor" in this document include overhead groundwires (OHGWs). Conductor stringing systems currently employed in the power industry are almost as numerous as the organizations that string conductors. Outlined below are the basic methods currently in use, but they are invariably modified to accommodate equipment readily available and the ideas and philosophies of the responsible supervisors. In addition to a description of the various methods being used are comments relative to application and a listing of equipment applicable to each method. This list is not all inclusive since, for example, a reel winder would not be necessary as a separate piece of equipment if this function is designed into the puller or tensioner being used, nor would a loader be required if the reel stand were self-loading.

4.1 Slack or Layout Method. Using this method, the conductor is dragged along the ground by means of a pulling vehicle, or the reel is carried along the line on a vehicle and the conductor is deposited on the ground. The conductor reels are positioned on reel stands or *jacks*, either placed on the ground or mounted on a transporting vehicle. These stands are designed to support the reel on an arbor, thus permitting it to turn as the conductor is pulled out. Usually, a braking device is provided to prevent overrunning and backlash. When the conductor is dragged past a supporting structure, pulling is stopped and the conductor is placed in travelers attached to the structure before proceeding to the next structure.

This method is chiefly applicable to the construction of new lines in cases in which maintenance of conductor surface condition is not critical and where terrain is easily accessible to a pulling vehicle. The method is not usually economically applicable in urban locations where hazards exist from traffic or where there is danger of contact with energized circuits, nor is it practical in mountainous regions inaccessible to pulling vehicles.

Major equipment required to perform slack stringing includes reel stands, pulling vehicle(s), and a splicing cart.

4.2 Tension Method. Using this method, the conductor is kept under tension during the stringing process. Normally, this method is used to keep the conductor clear of the ground and obstacles, which might cause conductor surface damage, and clear of energized circuits. It requires the pulling of a light pilot line into the travelers, which in turn is used to pull in a heavier pulling line. The pulling line is then used to pull in the conductors from the reel stands using specially designed tensioners and pullers. For lighter conductors, a lightweight pulling line may be used in place of the pilot line to directly pull in the conductor. A helicopter or ground vehicle can be used to pull or lay out a pilot line or pulling line. Where a helicopter is used to pull out a line, synthetic rope is normally used to attach the line to the helicopter and prevent the pulling or pilot line from flipping into the rotor blades upon release. The tension method of stringing is applicable where it is desired to keep the conductor off the ground to minimize surface damage or in areas where frequent crossings are encountered. The amount of right-of-way travel by heavy equipment is also reduced. Usually, this method provides the most economical means of stringing conductor. The helicopter use is particularly advantageous in rugged or poorly accessible terrain.

Major equipment required for tension stringing includes reel stands, tensioner, puller, reel winder, pilot line winder, splicing cart, and helicopter or pulling vehicle.

5. Grounding Equipment and Methods

5.1 Introduction. For any given situation, the bonding together of all equipment and electrical grounds in a common array is of major importance. However, such bonding offers no assurance that a hazardous potential will not exist between the bonded items and the earth. It is impractical to design a grounding system precisely around available fault currents or calculated effects. Such a design would require precise knowledge of many variables and would result in a different grounding scheme for each location.

The degree of grounding protection required for a given construction project is dependent upon the exposure to electrical hazards that exist within the project area. For a project remote from other lines and at a time of low probable thunderstorm activity, minimal grounding requirements are in order. Minimum grounding requirements include bonding and grounding of all machines involved in stringing of the conductor, pulling line, or pilot line. In addition, running grounds should be installed on all conductive lines in front of the pulling and tensioning equipment.

On the contrary, for a project in a congested area with exposure to numerous parallel lines and crossing situations, and with probability of thunderstorm activity and adverse weather conditions, extensive grounding requirements are called for. Historically, the most significant hazard results from work in proximity to energized lines. Specific procedures for grounding are discussed in Section 10.

Under any circumstance, in addition to open jumpers, grounding and other protective measures must be employed to ensure reasonable and adequate protection to all personnel. In addition to the grounding system, the best safety precaution is to respect all equipment as if it could become energized. The degree of protection provided for a specific project must be a decision of project supervision based on a clear understanding of the potential hazards, see [5] and [6].

5.2 Source of Hazards. Electrical charges may appear on a line due to one or more of the following factors:

(1) Charges induced on the line by a neighboring energized line
(2) A fault caused by an accidental contact or flashover between the line and a neighboring energized line
(3) Induced static charge due to atmospheric conditions
(4) An error in which the line is accidentally energized
(5) A lightning strike to the line (see [10] and [4])

5.3 Protection of Personnel. The means of providing personnel protection may take several forms. These forms may include the insulation or isolation of the workers, provision of an equipotential zone around the workers, or provision of a low resistance path to ground for induced charges or fault currents. The insulation or isolation of workers is usually not a practical approach for construction work other than on energized lines with bare hand work procedures, and, therefore, will not be further discussed, see [8]. The primary method of personnel protection is the establishment of equipotential work zones to limit touch and step voltages to a safe level. This may be accomplished by the proper use of low-resistance shunts and grounding devices. Low-resistance paths to ground are employed to limit the differences in potential between the various pieces of equipment, structures, and individual work zones. Despite grounding precautions, the best protection is to respect all equipment as if it could become energized.

5.4 Grounding Devices. All grounding devices must be sized to carry the largest fault current likely to be encountered for a time period long enough to allow the line protection system to operate.

Grounding devices include personal grounds, master grounds, structure base grounds, running grounds, traveler grounds, ground grids, and ground rods. Fig 1 shows a typical transmission type running ground.

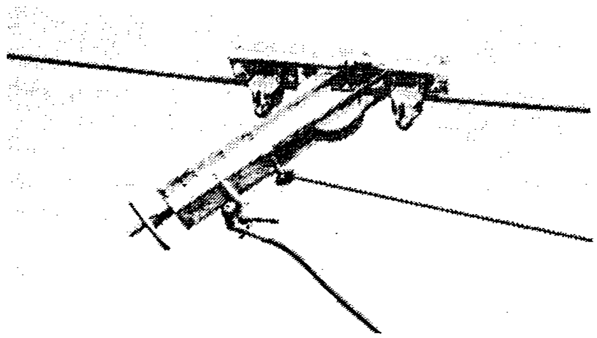


Fig 1
Running Ground

The clamps selected for grounding cables should be of high quality and should have a fault current capability equal to the cable. They should be capable of clamping positively on the object being grounded, as distinct from being spring loaded only. Table 1 is a listing of common grounding cable sizes with their fault carrying capabilities. Note that cables larger than 2/0 become heavy and might be difficult to handle, but may be necessary for high fault current values.

5.5 Grounding System Considerations

5.5.1 Care of the Grounding Equipment. Most grounding sticks are made of fiber-reinforced plastic and should be protected from physical damage and properly stored when not in use.

Each stick must be inspected before each use and wiped clean with a dry rag. Inspection should be made prior to use for loose or dirty connections, broken wire strands, and seized clamps. Some damaged sticks can be reconditioned. Rubber gloves should not be worn when using grounding sticks.

5.5.2 Grounding Conditions. Adverse grounding conditions (high electrical resistance) will exist in areas of dry sand or gravel and rock. In sand or gravel, rods with extensions or a cluster of two or more rods bonded together by grounding cables may be used as a ground

Table 1
Grounding Cable Capacities*

Cable Size	Fault Time	rms Amperes	
AWG	Cycles	Copper	Aluminum
	15	10 500	6500
2	30	7500	4600
	60	5300	3200
	15	16 500	10 500
1/0	30	11 500	7500
	60	8000	5300
	15	21 000	13 000
2/0	30	15 000	9000
	60	10 000	6500
	15	26 500	16 500
3/0	30	18 500	11 500
	60	13 000	8000
	15	30 000	21 000
4/0	30	21 000	15 000
	60	15 000	10 000
	15	35 000	25 000
250 kcmil	30	25 000	17 500

*Based on 30 °C ambient and a total temperature of 175 °C established by ICEA for short circuit characteristic calculations for power cables. Values are approximately 57.5% of fusing current for nominal lengths (<30 ft, 10 m). Higher values may be used based on tests. Cables should be regularly inspected. See 5.5.

source for portable grounding equipment. In rock, a rod or cluster may be employed at the best site within a reasonable distance.

Driven grounds are frequently restricted in their capability to effectively limit potential buildup, particularly if high currents are encountered. Block and running grounds may also be limited by the ground source to which they are connected. In addition to the grounding system, the best protection is provided by treating all devices and equipment as if they are energized. At the same time, the various grounding means should be used to ensure, as far as possible, that the devices and equipment are at an equipotential as near ground potential as possible.

The effectiveness of various available ground sources will vary. These sources would include station ground grids, grounded primary circuit neutrals, grounded towers, anchor rods, and ground rods. The preferred source must be determined for a particular system or area. Guy wires should not be used as a ground source.

5.5.3 Cleaning of Connections. Since the value of the grounding system depends on a low resistance path, all surfaces to which a grounding clamp is to be applied must be cleaned to ensure proper contact. The use of grub screws in some clamps may reduce the contact area of the clamp and may reduce grounding effectiveness.

5.5.4 Ground Application. Grounding cables *must* be connected to the ground source *first*, then to the object being grounded. When removing grounds, the ground *must* be removed from the grounded object *first* and then from the ground source. The object being grounded should not be teased with the ground clamp. The clamp must be poised by the object, snapped on quickly and firmly, and tightened. If an arc is drawn, the clamp should not be withdrawn, but should be kept on the conductor, thus grounding the line.

5.5.5 Ground Grid Application. Where ground grids are deemed necessary, adequate measures must be utilized to ensure effective contact with the earth. This may be accomplished by burying the grid conductors or placing metallic grid mats on the ground surface and by the use of ground rods. All grid conductors and ground rods must be interconnected, and all equipment, structures, anchors, metallic pulling lines, conductors, and overhead groundwires within the area should be bonded to the grid.

The area of the grid should be sufficient to enable all equipment to be placed and all work to be performed within its perimeter. In some instances, particularly in urban situations, it may be desirable to install temporary barriers to restrict access to the grid area.

6. Communications

Slack stringing requires a minimum of communications. It is, however, desirable to have communication between the pulling vehicle and the personnel at the reel location.

Tension stringing requires good communications between the personnel at the tensioner end and those at the puller end and at intermediate check points at all times during the stringing operation. During the stringing of bundled conductors with a running board, it is desirable to observe the running board as it passes through each traveler. The running board observer(s) should have reliable communications with both pulling and tensioning ends. When following the board from the ground is not practical, this can be accomplished with the aid of helicopters.

During helicopter stringing of the pilot line or conductor, reliable radio contact with all ground work sites is extremely important.

Dual or backup systems of communication, with a dedicated single-use frequency, should be available in case one system fails, particularly during the actual stringing operation.

7. Conductor Reels

7.1 Reel Types. Reels are supplied by the conductor manufacturer and can either be of the nonreturnable wooden (NR) or the returnable metal (RM, RMT) type. Table 2 shows the standard reel sizes and nominal dimensions as published by the Aluminum Association, including supplementary footnotes. Gross weight and type of reel can be obtained from the conductor manufacturer.

7.2 Reel Handling. The type and construction of the reel stand used and the type of reel determine the method and tools for handling. Reels are so constructed that they must be supported either on an axle through the arbor hole or by the reel flange. Returnable metal reels may be supported by a single-tree arrangement that clamps to the flange and is lifted from above. When the reels are lifted by an axle supported from above, a spreader bar must be employed to prevent damage to the conductor or reel, or both, by inward pressure on the reel flange. Proper equipment must be available to lift the reels.

Table 2
Dimensions of Standard Reels

ALUMINUM ASSOCIATION REEL DESIGNATION	TOTAL REEL VOLUME		NOMINAL REEL DIMENSIONS									
			FLANGE DIAMETER		DRUM DIAMETER		WIDTH				ARBOR HOLE DIAMETER	
							INSIDE		OUTSIDE			
	in^3	(m^3)	in	(m)	in	(m)	in	(m)	in	(m)	in	(mm)
NR 30.22	11 100	(.182)	30	(.76)	16	(.41)	22	(.56)	25	(.64)	3-3¼	(76-83)
NR 36.22	16 800	(.275)	36	(.91)	18	(.46)	22	(.56)	25	(.64)	3-3¼	(76-83)
NR 38.22	18 000	(.295)	38	(.97)	20	(.51)	22	(.56)	25	(.64)	3-3¼	(76-83)
NR 42.28	29 100	(.477)	42	(1.07)	21	(.53)	28	(.71)	32½	(.83)	3-3¼	(76-83)
NR 48.28	38 000	(.623)	48	(1.22)	24	(.61)	28	(.71)	32½	(.83)	3-3¼	(76-83)
NR 60.28	61 900	(1.014)	60	(1.52)	28	(.71)	28	(.71)	32½	(.83)	3-3¼	(76-83)
NR 66.28	76 000	(1.245)	66	(1.68)	30	(.76)	28	(.71)	32½	(.83)	3-3¼	(76-83)
RM 66.32	76 900	(1.260)	66	(1.68)	36	(.91)	32	(.81)	38	(.97)	3-3¼	(76-83)
RM 68.38	99 300	(1.627)	68	(1.73)	36	(.91)	38	(.97)	44	(1.12)	3-3¼	(76-83)
RMT 84.36	122 100	(2.001)	78-84	(1.98-2.13)	42	(1.07)	36	(.91)	43	(1.09)	5-5¼	(127-133)
RMT 84.45	152 700	(2.502)	78-84	(1.98-2.13)	42	(1.07)	45	(1.14)	52	(1.32)	5-5¼	(127-133)
RMT 90.45	187 000	(3.064)	84-90	(2.13-2.29)	42	(1.07)	45	(1.14)	52	(1.32)	5-5¼	(127-133)
RMT 96.60	298 600	(4.893)	90-96	(2.29-2.44)	42	(1.07)	60	(1.52)	67	(1.70)	5-5¼	(127-133)
RMT 108.74	422 400	(6.922)	102-108	(2.59-2.74)	56	(1.42)	74	(1.88)	83½	(2.12)	5-5¼	(127-133)

(1) Prefix NR denotes wooden nonreturnable reel, RM denotes metal returnable reel, and RMT denotes metal returnable reel with *I*-beam tires.
(2) Reels RM 66.32 and RM 68.38 have flat rims.
(3) Reels RMT 84.36, RMT 84.45, RMT 90.45, RMT 96.60, and RMT 108.74 have 3 in *I*-beam tires. Reels with similar dimensions except without *I*-beam tires are sometimes used.
(4) Pay off equipment for reels NR 48.28 and smaller should be a minimum of 2 in wider than the normal outside reel width to provide for extension of bolts and for possible flange distortion. For reels NR 60.28 and larger, either wood or metal, pay off equipment should be not less than 4 in wider than the reel width.
(5) Hub reinforcements will be provided for reels NR 60.28 and NR 66.28.
(6) Reels are not designed to withstand the forces required for braking during tension stringing operations.
(7) Where NR and RM reels are shown as alternatives, RM reels are preferred for more reliable conductor protection.
(8) The RMT 108.74 reel is not employed for any packages included in these standards. It is listed in this table, however, because it may be used for large sizes of conductors that may be added in the future.
(9) Total reel volume is the volume to the edge of the flange for NR and RM reels and to inside edge of *I*-beam for RMT reels.

8. Special Requirements for Mobile Equipment

8.1 Reel Stand. Reel stands are designed to be used with tensioners to supply the necessary back tension to the conductor. The stand(s) are selected to accommodate the conductor (or groundwire) reel dimensions and gross weight.

Some reels are not designed to withstand the forces developed by braking during tension stringing operations. Direct tension stringing from the reel at transmission line stringing tensions should not be attempted. The conductor may be pulled directly from the reel stand when employing slack stringing methods.

If the reel stand is not self-loading, a crane, forklift, or other suitable equipment is used to load the reel into the stand.

8.2 Helicopter. When pulling lines with a helicopter (see Fig 2), advantage in control and pulling capacity has been achieved with the use of special attachment devices that permit pulling from the side of the aircraft at a point near the center of gravity. These devices allow pulling of loads while maintaining normal operating attitude of the aircraft, thus increasing pulling capacity. The devices are equipped with quick release mechanisms and are subject to FAA approval. Braided or other nonrotating synthetic rope should be used to connect the line being pulled to the release mechanisms.

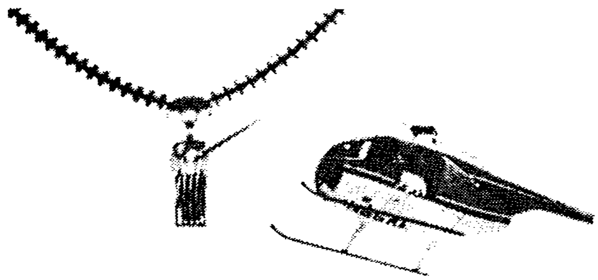


Fig 2
Helicopter Installing Pilot Line

8.3 Tensioner Bullwheel Characteristics. The depth, D_g, and flare of grooves in the bullwheels are not critical. Semicircular grooves with depths in the order of 0.5 or more times the conductor diameter and with flare angles in the order of 5° to 15° from the vertical generally have been found to be satisfactory.

The number of grooves in the bullwheel must be sufficient to prevent the outer layer of wires of multilayer conductors from slipping over underlying layers. The minimum diameter of the bottom of the grooves, D_b, should be in accordance with Fig 3.

Tandem bullwheels should be so aligned that the offset will be approximately one-half the groove spacing. For normal conductors having a right-hand direction of lay for the outer wires, bullwheels should be arranged so that, when facing in the direction of pull, the conductor will enter the bullwheel on the left and pull off from the right side. For any conductors having a left-hand direction of lay for the outer wires, the conductor should enter on the right and pull off from the left. This arrangement is necessary to avoid any tendency to loosen the outer layer of strands as the conductor passes over the bullwheels. See 10.4.2, Fig 11.

The material and finish of the grooves must be such as not to mar the surface of the conductor. Elastomer-lined grooves are recommended for all conductors, but are particularly important for nonspecular conductors. Should a semiconducting elastomer be used for lining the grooves, it should not be relied upon for grounding.

Difficulties have been experienced with single V-groove type bullwheels on some multilayer and special construction conductors. These types of bullwheels should only be used with the concurrence of the conductor manufacturer.

8.4 Puller and Tensioner Operating Characteristics. The pulling and braking systems should operate smoothly and should not cause any sudden jerking or bouncing of the conductor. Each system should be readily controllable and capable of maintaining a constant tension.

Pullers and tensioners may be mounted separately or in groups for bundled conductor installation. The controls should allow the independent adjustment of tension in each conductor. It is recommended that the tensioner have an independently operated set of bullwheels for each subconductor when stringing bundled conductor, particularly when more than two subconductors per phase are being installed. Pullers should be equipped with load indicating and limiting devices. The load limiting device should automatically stop the puller from acting further if a preset maximum load has been exceeded. Tensioners should be equipped with tension indicating devices.

Capacity selection of the puller and tensioner is dependent upon conductor weight, the length to be strung, and the stringing tensions. The capacities of the puller and tensioner should be based on the conductor, span length, terrain, and clearances required above obstructions. In general, stringing tensions will be about 50% of sag tensions. Sag tensions

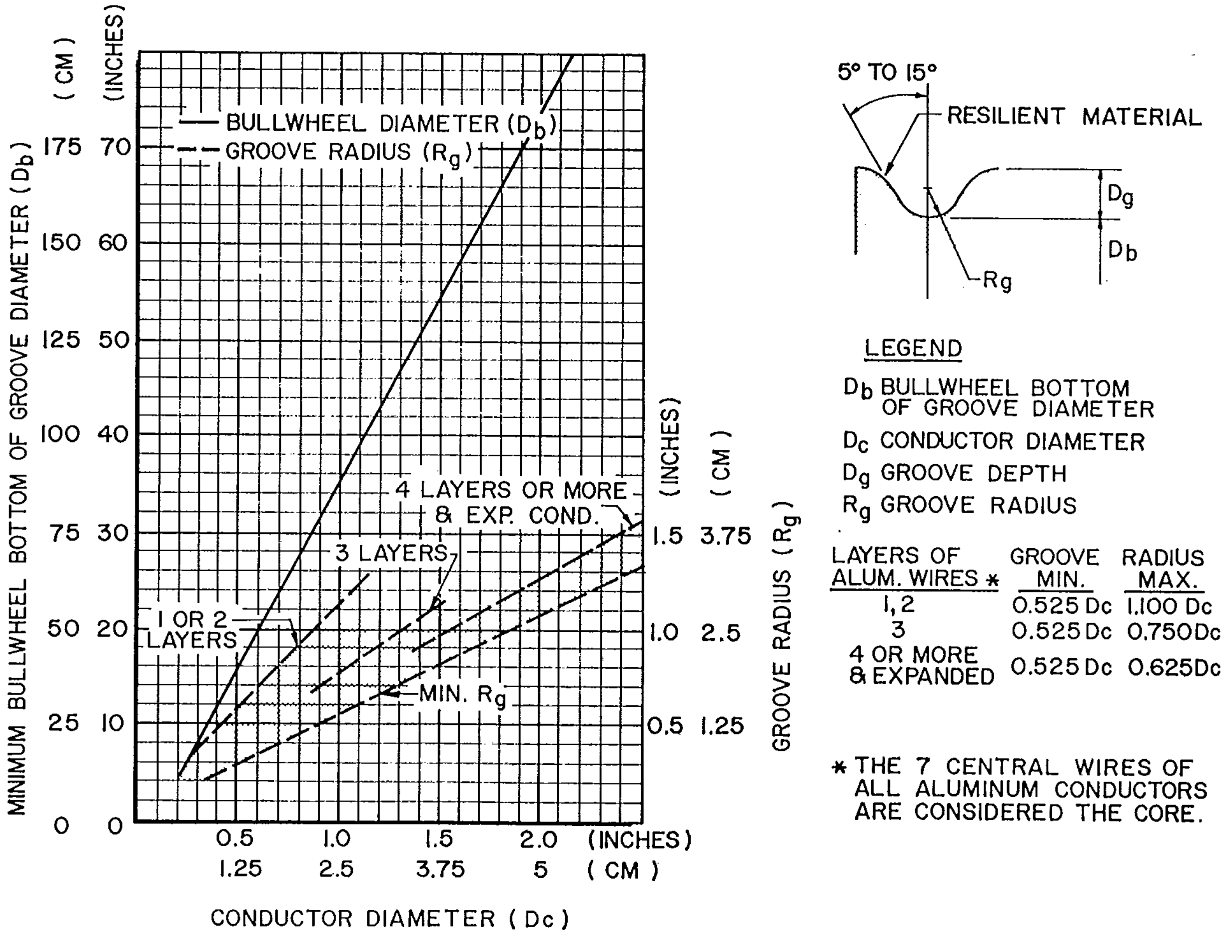


Fig 3
Recommended Bullwheel Dimensions

should never be exceeded during stringing. Required capacity for both puller and tensioner can be calculated by referring to Appendixes A, B, D, and E of this document.

Tensioner bullwheels must be retarded so that conductor tension may be maintained at various pulling speeds. Positive braking systems are required for pullers and tensioners to maintain conductor tension when pulling is stopped. Failsafe-type braking systems are recommended.

There are basically two types of pulling machines used in the construction of transmission lines being strung under tension. These are defined as bullwheel and drum-type or reel-type pullers. See Fig 4, which shows a drum-type puller. Some drum-type or reel-type pullers are available with level wind features to provide uniform winding of the line. Some drum-type and all reel-type pullers provide easy removal of the drum (or reel) and line to facilitate highway mobility. This feature also provides the advantage of interchangeability of drums. The control of payout tension of the pulling line is a desirable feature of many pullers. Mobility of the pullers and tensioners is important to minimize downtime between pulls. Also critical are the setup and leveling features of the units.

The overhead groundwire tensioner is normally a separate unit from the conductor tensioner as the requirements are independent of each other.

Fig 4
Drum Type Puller

8.5 Pilot Line Winder Operating Characteristics. Drum-type pilot line winders have operating characteristics similar to drum-type pullers. They usually have multiple drums to provide pilot lines for several phase or groundwire positions, or both. See Fig 5. Bullwheel-type pilot line machines have similar operating characteristics to bullwheel-type pullers, except that they normally have the reelwinder attached to the rear of the machine. This reel-winder is usually a self-loading type to facilitate the changing of reels of pilot line quickly. These units normally have the capability for high-speed operation. Retardation of the drum(s) is desirable in order to provide controlled payout of the pilot lines. These units are frequently employed to directly pull in overhead groundwire.

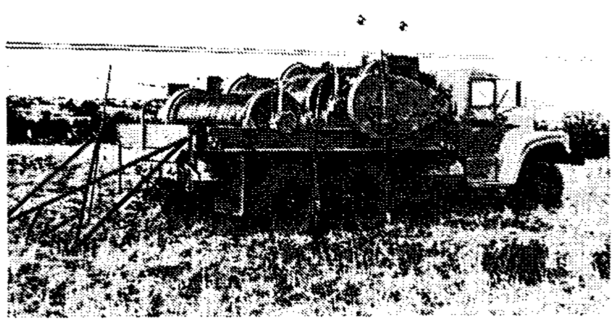


Fig 5
Pilot Line Winder

9. Travelers

9.1 Sheave Diameter. It is generally recognized that as sheave diameters are made larger, the following advantages are gained:

(1) The radius of bending of the conductor is increased, so the amount of strain and the amount of relative movement between individual wires in the conductor are reduced. This, in turn, reduces the amount of energy required to bend and straighten the conductor as it passes through the travelers. The force and energy required for such bending and straightening retards the passage of the conductor in much the same way as friction in the bearings of the travelers.
(2) The bearing pressures between conductor strand layers are reduced, thus reducing potential conductor internal strand damage. This is commonly known as strand notching.
(3) The force required to overcome friction in the bearings is reduced because of the greater moment arm for turning.
(4) The number of rotations and speed of rotation are reduced, so wear on the bearings and grooves is alleviated.
(5) The obvious disadvantages of larger sheaves are cost and added weight.

The minimum sheave diameter, D_s, at the bottom of the groove, as shown in Fig 6, should be satisfactory for typical conductor stringing operations. However, for stringing conductors in excess of approximately 2 mi (3.2 km) or over substantially uneven terrain, the recommended minimum bottom groove diameter of sheaves is $(20D_c - 4)$ in ($[20D_c - 10]$ cm) or larger, where D_c stands for conductor diameter. In exceptionally arduous circumstances, accurate sagging may sometimes be very difficult with sheaves having diameters of less than $19D_c$ or $20D_c$.

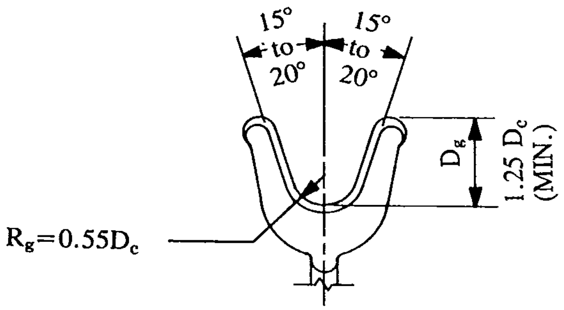
9.2 Configuration of Groove. The minimum radius at the base of the groove, R_g, is recommended to be 1.10 times the radius of the conductor as shown in Fig 6.

Sheaves having a groove radius as discussed above may, with limitations, be used with smaller conductors. The limitations relate to the number of layers of aluminum wires in the conductor. The more layers of aluminum wires, the more important it is to support the conductor with a well-fitting groove.

The depth of groove, D_g, should be a minimum of 25% greater than the diameter of the conductor. The sides of the groove should flare between 12° and 20° from the vertical to facilitate the passage of swivels, grips, etc., and to contain the conductor within the groove, particularly at line angles.

9.3 Bearings. The bearings should preferably be ball or roller type with adequate provisions for lubrication and shielding against contamination. The lubricant must be suitable for the temperature range involved; and, where sealed bearings are not used, care should be taken to ensure subsequent lubrication with the same type of grease. Mixing of greases of different types (that is, lithium base and calcium base) may cause degradation of the lubricant and subsequent bearing failure, see [3]. Bearings should have sufficient capacity to withstand running or static loads without damage. Proper maintenance is essential.

9.4 Material and Construction. Travelers may be of any suitable material, with due consideration given to weight. Unlined sheaves for stringing aluminum conductors should be made of aluminum or magnesium alloy, and the grooves should have a smooth, polished finish. It is recommended that the manufacturer's safe working load, or other identification to enable determination of such load, be permanently displayed on the traveler. Always ensure that the manufacturer's safe working load for the traveler is not exceeded. This is particularly important for situations in which travelers are used on heavy line angles or on the first or last towers at which the conductor comes to ground level. Maximum loads usually will result when the conductor is being pulled up to sag tensions.



D_s(min)—20 D_c - 8 inches or 20D_c-20 cm except that D_s shall not be less than 12 D_c
D_s—Sheave diameter at base of groove
D_c—Conductor diameter
R_g—Sheave groove radius
D_g—Groove depth

Number of Layers of Aluminum Wires*	R_g Minimum	R_g Maximum	D_g Minimum
1 or 2	0.55D_c	1.1 D_c	1.25D_c
3	0.55D_c	0.75 D_c	1.25D_c
4 or more & Expanded Conductors	0.55D_c	0.625D_c	1.25D_c

A sheave designed for a conductor of a given diameter, in accordance with this figure, may be used for stringing conductors of smaller diameters using above table or as follows:

Number of Layers of Aluminum Wires*	Minimum Diameter Conductor That May Be Used in a Sheave Designed for a Conductor of a Larger Diameter in Percent of the Diameter of the Larger Conductor
1 or 2	50%
3	75%
4 or more & Expanded Conductors	87.5%

*The 7 central wires of all-aluminum conductors shall be considered as a core.

Example: A sheave, with a groove radius of 0.825 inches and a diameter at the bottom of groove of 22 inches, designed for use with a conductor 1.5″ in diameter may be used for stringing a 2 layer conductor with a diameter as small as 0.75″.

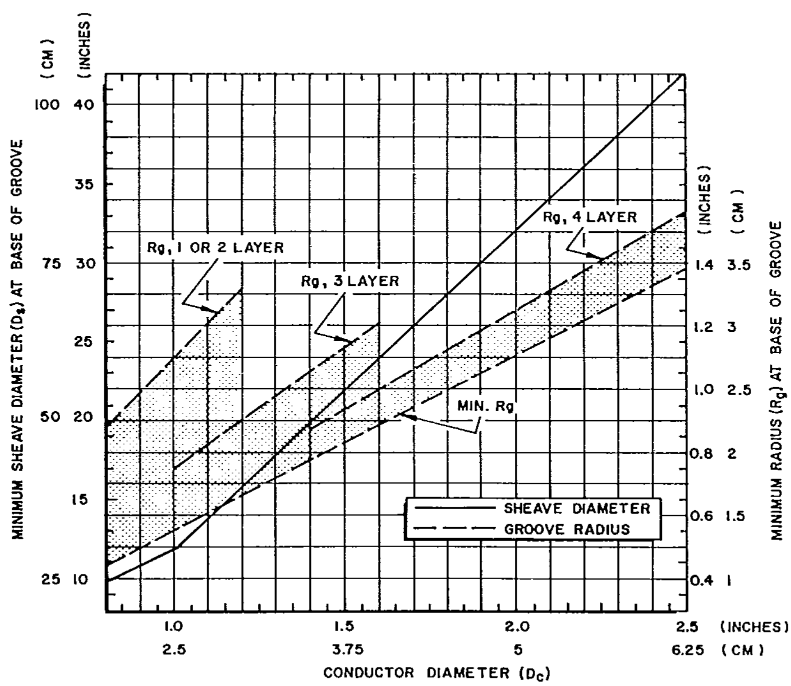


Fig 6
Recommended Sheave Configuration

It is recommended that clearances between the sheave(s) and frame, particularly in the traveler throat area, be kept as small as possible. This will prevent the pilot line from jamming should the pilot line come out of the pulling line sheave. It is recommended that the vertical throat opening of the stringing block be kept as small as possible while still allowing the safe passage of the pulling line, swivels, and the running board. This practice will minimize the distance the conductors need to be lifted during the clipping-in operation.

For bundle conductor configurations, the traveler frame and shaft should be sufficiently sized so that deflection due to load, particularly during the sagging operation, does not cause adjacent sheaves to contact. Excessive deflection can cause difficulty in sagging individual conductors.

9.5 Lining. While grooves may be unlined or lined, lining with elastomer provides cushioning to increase bearing area and precludes damage to the conductor from scratched or marred groove surfaces. Steel pulling lines are likely to scratch or mar the surface of unlined grooves; therefore, where such lines are to be used in the same groove as conductor, grooves definitely should be lined. It is generally recommended that all sheaves be lined. It is recommended that the total surface of the groove, including the top lip, be lined to give maximum protection to the conductor.

The elastomer used for sheave linings should be capable of withstanding all anticipated temperatures without becoming brittle or developing semipermanent flat areas. It should be sufficiently hard to prevent the conductor from climbing up the side of the groove. Bearing pressure limits for sheave linings are further discussed in Appendix C.

9.6 Electrical Characteristics. Neither lined nor unlined travelers should be relied on for grounding the conductor being installed. Greased bearings do not provide necessary conductivity and may be damaged by relatively small currents passing from the sheave to the body of the traveler. Semiconductive linings, commonly referred to as conductive linings, tested to date are reported burned with currents as low as 20 mA.

The induced electrical charges on conductor and pulling lines, particularly when stringing in the proximity of energized lines, must be drained off with traveler grounds that bypass the linings or greased bearings, or both. Traveler grounds provide a means to bypass electrically the sheaves and ground the conductor directly to a ground source.

After any grounding device has experienced fault current, it should not be used.

9.7 Bundled Configurations. Bundle conductor type travelers for stringing two or more subconductors simultaneously require special considerations. When even numbers of conductors are strung, a symmetrical arrangement may be used with an equal number of conductors on each side of the pulling line. An independent center sheave is provided only for the pulling line and should be of suitable material to withstand the abrasion of the pulling line.

When odd numbers of subconductors are strung, the center one could follow the pulling line in the center sheave. However, this is usually not desirable because of the material of the groove or because of contaminants deposited in this groove by the pulling line, or because of both. Offset-type bundle conductor travelers are used that balance the load by properly spacing the even and odd number(s) of conductors on each side of the pulling force. These travelers are directional and should be color-coded. Care should be taken to ensure their proper orientation.

When multiple conductors are strung in bundled conductor type travelers, reduced horizontal spacing between grooves can result in conductor oscillation, even in a very light crosswind, too severe to permit satisfactory sagging. (For example, groove spacing of 5.4 conductor diameters permitted sagging of conductors in a crosswind condition that repeatedly prevented sagging with a groove spacing of 2.7 conductor diameters because of very active conductor oscillation.)

When stringing multiple conductors around line angles in excess of 5°, bundle conductor travelers are required until the running board passes through the traveler, but should be replaced prior to sagging with single-type travelers to provide proper wire length in the clipped-in position. It is desirable during sagging for the horizontal spacing of the sheaves to match the final subconductor spacing to aid in preventing subconductor sag mismatch.

Some bundle conductor travelers may be converted to single conductor type travelers.

Multisheave bundle conductor type travelers and running boards must be designed to complement each other and work in unison. Running boards should only be used to pull in conductors. They should not be used to line up the conductors with an anchor (that is, running boards should not be pulled sideways). Running boards should have their safe working load displayed. It is recommended that all running boards and swivel links be proof tested to 50% over the safe working load. During stringing, normal pulling speeds should be maintained when the running board approaches a traveler.

9.8 Helicopter Travelers. Helicopter travelers utilize outrigger arms that guide the pilot line into the throat area of the traveler. These outriggers are usually brightly painted to be easily seen from the air. Spring-loaded gates are employed to contain the line. For bundle conductor travelers, additional guides may be utilized to funnel the lines into the proper groove. The design of helicopter travelers should be such that personnel are not required on the structure during placement of the pilot line. After initial placement of the line by helicopter, normal stringing practices are employed.

Helicopter travelers are directional, and care must be exercised to orient them properly on the structures. Due to the rotor wash of the helicopter, if the attachment method of travelers does not prevent twisting, yaw bars should be utilized for this purpose.

Some standard travelers may be converted to helicopter type by the addition of accessory parts.

9.9 Uplift Rollers and Hold-Down Blocks. Uplift rollers that attach to the traveler (see Fig 7) or hold-down blocks that are separate devices must be used at positions where uplift might occur. Uplift can occur with the pulling line during the stringing operation, due to its higher tension to weight ratio and, thus, much flatter sag. This condition is most likely to occur in hilly terrain at the towers in the low points of the pull. Hold-down blocks or uplift rollers should be used in these cases. Since the uplift condition will normally stop when the conductor(s) arrive, hold-down blocks that can be removed prior to the arrival of the conductor(s) without stopping the pulling should be used. Uplift devices that attach to bundle travelers are usually directional, and are usually positioned toward the pulling end. These devices should have a breakaway feature in the event of fouling of the pulling line or incorrect installation.

9.10 Traveler Suspension. The vertical location of sheaves should be considered for sagging purposes. For simplicity in marking and clipping procedures, it is desirable for the vertical position of the conductor in the sheave to be at the same elevation as when clamped in the final position in the suspension clamp.

Clearance required for running boards over the sheaves of the bundle conductor type traveler frequently prevents proper vertical positioning of conductors. The few inches of the drop of the conductor below its final position may be unimportant on tangent towers.

10. Typical Procedures for Stringing Operations

10.1 Pull, Tension, Anchor, and Splicing Sites

10.1.1 Site Selection. The selection of pull, tension, snub structure, and splicing sites should consider accessibility, terrain, angles in the pull section, location of usable deadends, length of conductor to be strung, available conductor and line lengths, puller capacity, snub structure loads, including placement of pullers, tensioners and conductor anchor locations,

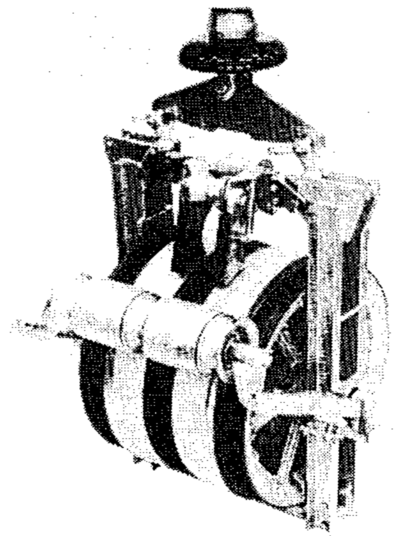


Fig 7
Bundle Conductor Traveler With Uplift Roller and Grounds

placement of reel stands, pilot line winder(s), reel winders, and the ability to provide an adequate grounding system.

10.1.2 Equipment Location. The location of the puller, tensioners, and intermediate anchor sites must be selected so that the snub structures are not overloaded. Where possible, a pulling line slope of three horizontal to one vertical from the traveler to the site is considered good practice. Refer to Appendix A for calculation of snub structure loads. It is also necessary that the puller be positioned so that the pulling line enters the machine at a minimum horizontal angle to minimize any possibility of damaging the line. When a bullwheel type puller is employed, the reel winder to recover the pulling line is located at the pulling site. The pilot line winder is located at the tension site. See Fig 8.

The arrangement of the tensioner and reel stands should be such that the lateral angle between the conductor as it approaches the bullwheel and the plane of rotation of the wheel is not great enough to cause the conductor to rub on the sides of the groove. As an example, birdcaging problems were eliminated with large conductors by using a maximum fleet angle of 1.5° from the plane normal to the conductor reel axis and a back tension of approximately 1000 lb (4.5 kN). For additional information on back tension considerations, see 10.4.2. The problems of birdcaging are normally more acute with large conductors of three or more aluminum layers.

The conductor reel should be aligned with the tail fairlead on the tensioner such that, during the payout of the conductor, it will not scrub on either of the flanges of the reel as it is being unwound.

10.1.3 Anchors. Anchors are normally required for holding equipment in place and snubbing conductors against tensions imposed. The type of anchor is dependent upon the soil conditions and sagging and stringing tensions. Portable equipment is often used for this purpose, as well as ground type anchors. Slack should be removed from all anchor lines prior to loading to minimize the possibility of equipment movement or impact loads to the anchors.

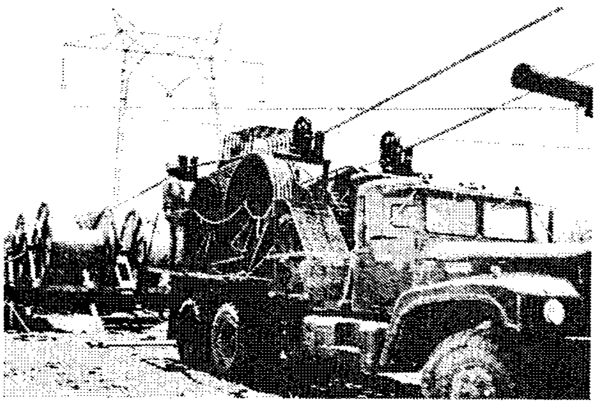


Fig 8
Tension Site

10.1.4 Equipment Grounding. Adequate grounding must be established at all sites. The methods required and equipment used will be determined by the degree of exposure to electrical hazards around the equipment as well as the pull section and the soil conditions at the site. All equipment, conductors, anchors, and structures within the work area must be bonded together and to the ground source.

Grounding and bonding is particularly important for protection of machinery and personnel where the new transmission line is being installed adjacent to, and parallel with, an existing energized transmission line. Hazardous voltages and currents can be encountered in such cases.

10.2 Section Between Snub Structures

10.2.1 Crossing Structures. When crossing roads, highways, railroads, energized lines, etc., some type of supplemental crossing structure should be employed. This can be guard poles erected in a football goalpost fashion of suitable height. In some cases, rope nets are strung between the poles to give more positive protection. A system of blocks can also be used to cradle the pulling lines and conductors. This is accomplished with support lines, space lines, and load lines to properly locate the special cradle blocks to afford protection should tension be lost during the stringing operation. See Fig 9.

10.2.2 Terrain Problems. The terrain must be analyzed to determine if there are areas of impaired ground clearance under stringing tensions. If such areas exist, precautions must be taken to protect the conductor. Locations of conductor or pulling line uplift must also be identified in order that hold-down blocks and uplift rollers can be provided. Other unusual terrain features may dictate special consideration.

10.2.3 Traveler Installation. Installation of travelers, including finger lines where used, requires consideration of traveler attachment methods and the need for and location of traveler grounds and uplift rollers. For single-conductor vertical insulator assemblies, the travelers are normally connected directly to the insulators and, with V-string insulator assemblies, to the yoke plate. For most bundled conductor lines, the travelers are connected to the yoke plate. With post-type insulators, the travelers are connected to the end of the insulators. Where travelers are installed to string through deadend towers, the travelers are normally

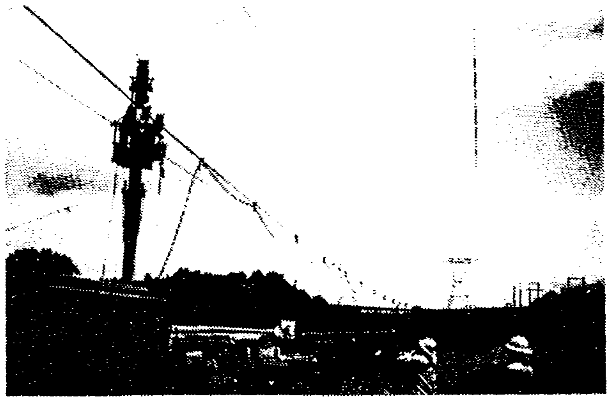


Fig 9
Cradle Block System

connected directly to the tower. If substantial line angles are involved, two travelers in tandem may be required to reduce the bending radius of the conductor or the load on each traveler, or both.

Where bundled conductor travelers are used at line angle locations of over 5°, it is advisable to change to individual single conductor travelers after the passage of the running board to facilitate accurate sagging.

When adequate quantities of travelers are available, it is common practice to install them at the same time that the insulators are installed. Under some situations, travelers may be attached to slings or rods in place of the normal insulator assembly.

The need for traveler grounds and required locations should be based on the degree of exposure to electrical hazards. When such hazards exist, traveler grounds should be installed, as a minimum, at the first and last tower between the tensioner and puller. When stringing in proximity to energized lines, additional grounds must be installed as required, but at a maximum distance not exceeding two miles. Additionally, grounds must be installed within a reasonable distance on each side of an energized crossing, preferably on the adjacent structures.

Travelers with grounds are usually sensitive to direction, and care should be exercised in hanging them. Usually, the grounds are oriented to the pulling end. Each traveler with grounds must be connected with temporary grounding sets to provide an electrical connection between the traveler and earth, or to some conductive medium that is at earth potential. Personnel should never be in series with a ground lead. Traveler grounds should have a suitable grounding stud located in an accessible position to enable placing and removing the ground clamps with hot sticks, when necessary. Traveler grounds will also help protect the sheave linings.

At the time the travelers are hung, finger lines, when used, should be installed and tied off at the base of the structures. If the helicopter method of pilot line installation is not to be used, the pilot line could be installed at this time in lieu of finger lines.

10.3 Conductor Splicing

10.3.1 Conductor Reel Lengths. Standard conductor reel lengths and dimensions are shown in Appendixes D and E. Normally, more than one conductor reel length will be required to obtain the total length of conductor to be strung at one time. Therefore, the conductor lengths must be spliced together at the tension site or midspan sites, or both. Regardless of the site; however, the required equipment and basic procedures are essentially the same and are applicable to conductors, overhead groundwires, and metal pulling lines.

10.3.2 Equipment. The major equipment required for splicing operations consists of a splicing cart equipped with a hydraulic pump and compressor, compression joints, strand restraining clamps, hold-down blocks, rope, conductor grips, hoists, ground rods, personal grounds, bonding cables, and bare conductor and clamps for a ground grid (when it is to be installed). All equipment must have adequate mechanical or electrical capabilities, or both, for the work involved.

10.3.3 Bonding and Grounding of Conductor Ends. It is extremely important that precautions be taken to prevent personnel from accidentally placing themselves in series between two conductors that are to be connected together, or in series to ground with either conductor. Accidents of this type can be prevented by providing an equipotential work area, by grounding and placing a jumper across the opening between the ends of the two conductors to serve as a shunt, or by a combination of both.

The following method is recommended when the line being strung might accidentally become energized; when it is adjacent, parallel, or both, to an existing energized transmission line; or when the possibility of high fault currents exists and the work is to be performed at ground level by personnel in direct contact with the earth.

(1) Install a ground grid if the splice is to be made in midspan. Ground grids installed at the pull and tension sites will suffice for splices made at those locations.
(2) Bond the splicing cart and all other mobile equipment, such as tractors, which may be holding the conductor ends, to the grid.
(3) Bond the two conductors to be spliced to a common ground using personal grounds connected within 10 ft (3 m) of each conductor end, then bond the conductor ends directly together using a jumper.
(4) Perform all splicing work within the grid perimeter.

In lieu of the ground grid, a metallic grounding mat may be used. The conductor ends and the mat must be bonded to a common ground. As before, a jumper should be installed directly between the conductor ends. If multiple ground rods are used, they should be bonded together. All splicing work should be performed on the mat.

If neither the grid nor the mat are used, all splicing work may be performed on an insulated platform. The conductor ends should be bonded to a common ground and directly together with a jumper as before. If multiple ground rods are used, they should be bonded together.

As a minimum, regardless of the level of exposure, a system of interconnected ground rods should be used, but the magnitude of potential electrical hazards must be thoroughly considered.

10.3.4 Compression Joint Application. The die or dies used to compress the compression joint must be of the correct size, and all presses must be made in the proper sequence specified by the manufacturer of the joint. Compounds that aid electrical contact, prevent corrosion, and ensure mechanical holding power should be used as specified by the compression joint manufacturer. Proper centering of joints on the conductor is very important. Failure to adhere to these requirements will result in defective splices, which, in turn, may become potential hazards.

10.3.5 Passing Compression Joints Over Travelers. The number of sites required for splicing conductors is dependent upon the number of conductor reel lengths required for the total length of conductor to be strung and the method used to join the conductor lengths as they are pulled out.

The most common stringing practice avoids pulling compression joints over the travelers. It consists of using woven wire grips to join the conductor lengths at the tension site until the total required length of conductor has been strung. The conductor is then lowered to the ground at each location of the woven wire grips, spliced, and later pulled up to sag.

Another stringing practice consists of splicing the conductor lengths together at the tension site with compression joints specifically designed to be pulled over travelers. This approach has the advantage of splicing being done at one location, thus reducing the total number of required operations when compared with the previous practice, particularly when ground grids are required. If this practice is to be employed, a preliminary study of the line to be strung should be made to determine the maximum stringing tensions and roll-over angles that would be encountered. Compression joint manufacturers should be consulted. If the splices are to be passed through the travelers, the groove of the conductor sheave should be designed to allow this. A groove that is too narrow to pass the splice could result in spreading of the sheave groove and breakage.

10.4 Stringing Procedures

10.4.1 Installation of Pulling Lines. When finger lines are installed, they are used to pull the pilot line or pulling line through the travelers as it is pulled out. The pilot line, when used, is then pulled back by use of the pilot line winder behind it, pulling the pulling line from a reel or drum puller, which can in turn be used to pull in the conductor. The initial pulling out of the pilot line or pulling line is usually done with any vehicle such as pickup truck or tractor, as appropriate.

In difficult or mountainous terrain, the pilot line is sometimes carried into position on the right of way by hand in short lengths and, after being stretched out, each length is joined to the other with special rope connectors. This technique is used particularly when the pilot line puller is a bullwheel-type machine.

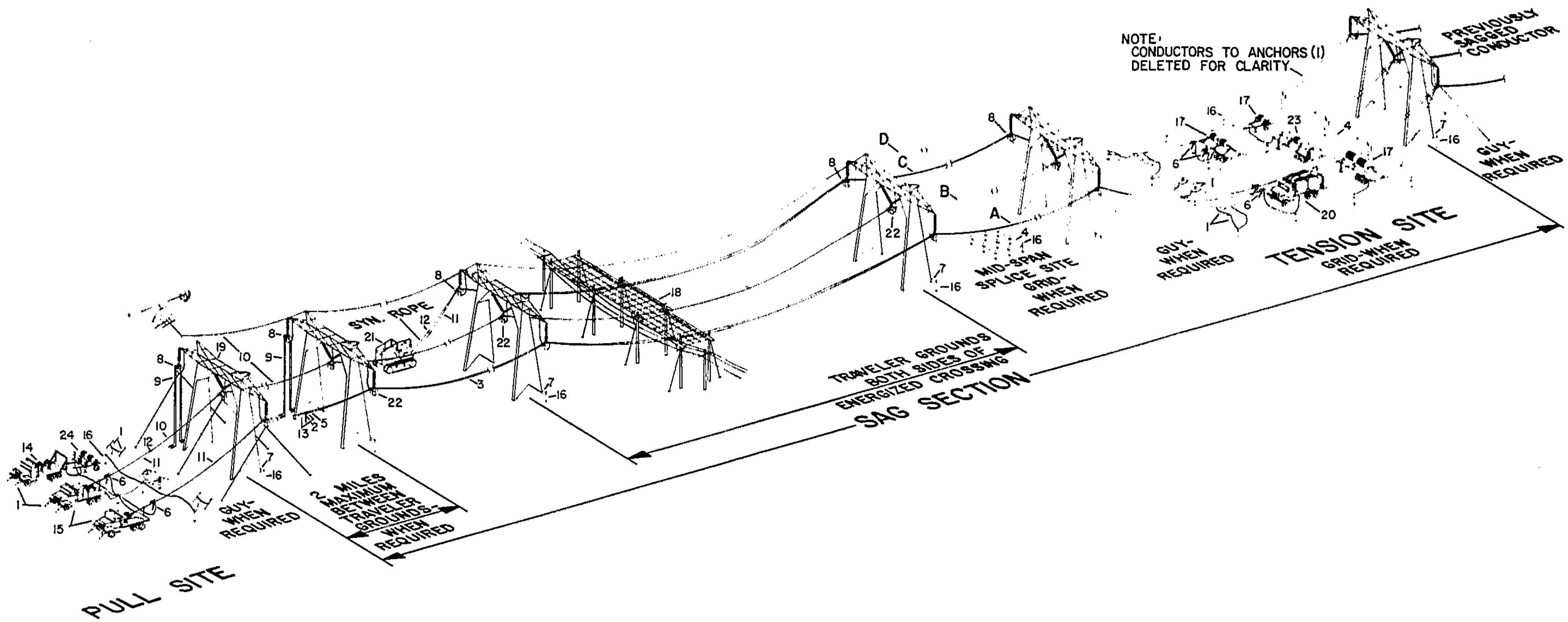
When helicopter methods are used, the pilot line is first pulled out by the helicopter (or from the helicopter) and directed by the helicopter pilot into travelers specially designed for this method. This initial line is usually small diameter synthetic rope, but could also be small steel line. This pilot line is then used to pull in the pulling line in the same manner as previously described. In cases in which it is necessary to string a line through the window of a structure, special devices are available to accomplish this stringing. These devices include the harpoon and the flytrap methods.

10.4.2 Installation of Conductor. See Fig 10. Once the rope pulling lines have been installed and prior to pulling in any conductor or conductive-type pulling lines, two running grounds should be installed: one between the reel stand or conductor tensioner for conductor and the first tower, and one between the puller for the pulling line and the last structure. These grounds must be bonded to the ground previously established at each site.

It is recommended that, in places where synthetic ropes are used as either a pilot line or a pulling line, they be installed under tension such that they do not contact the ground between towers. The outer surface of the synthetic rope can be easily abraded and damaged if it is pulled over the earth surface for any distance.

Pulling lines are usually pulled in under tension. The pulling line is then connected to a single conductor through a swivel link, or to bundle conductors through swivel links and a running board. Swivels must not be used to connect lengths of pulling line. A rope connector should be used for this purpose.

Pulling lines may be synthetic fiber or wire rope. Swivel links should not be used on a three-strand synthetic pulling line. When wire rope is used, it is recommended that the swaged type be used because it has less tendency to rotate under load, which minimizes most spinning problems. Swaged rope also has a much smoother outer surface. This smoother surface, plus low rotation, minimizes wear on traveler sheaves and bullwheel grooves on pullers. When synthetic pulling lines are used, a no-torque rope is recommended to minimize the problems



1. Anchor (see 10.1.3)
2. Running board
3. Bundled conductor
4. Ground grid (see 5.5.5)
5. Woven wire grip
6. Running ground
7. Structure base ground
8. Traveler ground (see 10.2.3)
9. Finger line
10. Pilot line
11. Pulling line
12. Connector link
13. Swivel link
14. Bullwheel puller
15. Drum puller
16. Ground rod
17. Reel stand
18. Crossing structure
19. Snub structure (see 10.2)
20. Bullwheel tensioner
21. Crawler tractor
22. Traveler
23. Pilot line winder
24. Reel winder

A. Typical stringing arrangement
B. Typical pulling line installation with pilot line winder
C. Typical installation of pulling lines with tractor and finger lines
D. Typical installation of pilot lines with helicopter

Fig 10
Composite for the Installation of Overhead Transmission Line Conductors

caused by kinking or twisting. This causes accelerated loss of strength of the pulling line, which results in a hazardous condition.

A specially designed steel reel should be used for the winding up of pulling line or pilot line. This is particularly true if the line is a synthetic rope that can generate large or very large crushing stresses on a reel when it is wound in multiple layers.

A ball-bearing swivel link is usually used for the connections between pulling lines, running boards, and conductors. Swivel links should be of sufficient rated working load to withstand loads placed on them during tension stringing. They should also be compatible with the travelers being used so that they can pass through without spreading or damaging the sheaves. These special line-stringing swivel links are clevis type and are compatible with woven wire grips and swaged steel pulling lines. It is recommended that swivel links not be passed over bullwheels under significant tension because they may be weakened or damaged due to bending.

When reeving the bullwheels of a tensioner with the conductor entering and leaving the wheel from the top facing in the direction of pull, the conductor should enter from the left and leave from the right for right-hand lay (standard for aluminum conductor) and enter from the right and leave from the left for left-hand lay (standard for groundwire, including OPGW). This procedure will avoid the tendency to loosen the outer layer of strands as the conductor passes around the bullwheels. (See Fig 11.)

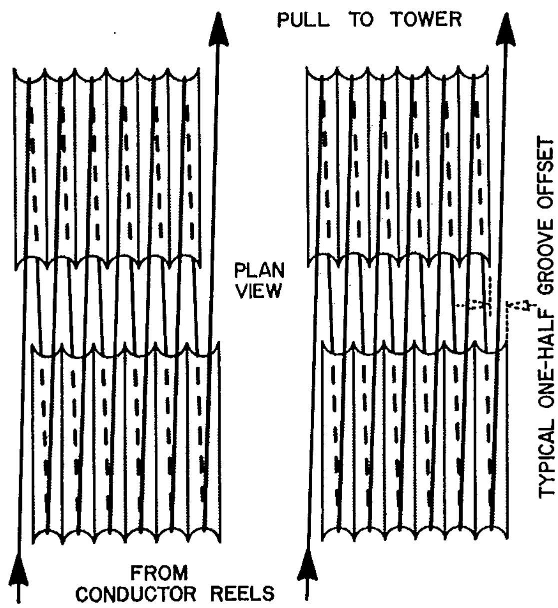


Fig 11
Bullwheel Reeving for Right-Hand Lay Conductor

It is recommended that conductor of only one manufacturer and one drawing stock (rod type cast or rolled) be used in a given pull, and preferably in any given sagging section. This precaution will help avoid significantly different conductor sag characteristics. Sets of reels with matched lengths are often specified to complement set-up locations and minimize scrap. A review of the conductor lengths available and selective grouping is a good practice.

Attachment of the conductor to the pulling line, to the running board, or to another reel of conductor to be pulled successively is accomplished by the use of woven wire grips. These grips should be of compatible strength and sized to the conductor or pulling line on which they are used. The overall diameter of the grip, when placed over the conductor or rope, should be small enough to pass over the sheaves without causing damage to the sheave or its lining. The grip should also be capable of connecting with a proper size swivel link.

Metal bands should be installed over the grip to prevent it from accidentally coming off and dropping the conductor. The open end of the grip should be secured with two bands. This should then be wrapped with tape to prevent accidentally stripping the grip off the conductor if the end were to snag or catch. This is particularly important when these grips are used between lengths of conductor when more than one reel is strung because the grips are passed through the travelers backwards. If the ends are not banded and taped, they could be stripped off.

Experience has shown that pulling speed is an important factor in achieving a smooth stringing operation. Speeds of 3–5 mi/h (5–8 km/h) usually provide a smooth passage of the running board or connecting hardware, or both, over the travelers; whereas slower speeds may cause significant swinging of the traveler and insulator-hardware assemblies. Higher speeds create a potential hazard of greater damage in case of a malfunction.

The maximum tension imposed on a conductor during stringing operations should not exceed that necessary to clear obstructions on the ground. It may be necessary under certain circumstances to string the conductor near sag tension to clear crossing structures such as poles over highways, roads, or existing distribution lines. This clearance should be confirmed by observation. If stringing tensions are greater than 10% of the conductor's breaking strength, consideration must be given to any possible prestressing of conductors that may result, based on the tension and time involved. Consideration must also be given to the fact that when long lengths of conductor are strung, the tension at the pulling end may exceed the tension at the tensioner by a significant amount. Differences in tension are caused by the length of conductor strung, number and performance of travelers, differences in elevation of supporting structures, etc. (See Appendix B.)

Light and steady back tension, sufficient to prevent over-run in case of a sudden stop, should be maintained on the conductor reels at all times. The tension must also be sufficient to cause the conductor to lie snugly in the first groove of the bullwheel and to prevent slack in the conductor between bullwheels. It may be necessary periodically to loosen the brake on the reel stand as the conductor is payed off. As the reel empties, the moment arm available to overcome the brake drag is reduced, and the tension therefore rises. This may cause the conductor to wedge into the underlying layers on the reel. The reel should be positioned so that it will rotate in the same direction as the bullwheels. Loosening of the stranding that often occurs between the reel and the bullwheels of the tensioner is caused to a great extent by coil memory in the conductor. As the conductor is unwound from the reel and straightens out, the outer strands become loose, a condition that is particularly noticeable in a large diameter conductor and can be best observed at the point at which it leaves the reel. As the conductor enters the bullwheel groove, the pressure of contact tends to push the loose outer strands back toward the reel where the looseness accumulates, leading to the condition commonly known as birdcaging, see Fig 12. If this condition is not controlled, the strands can become damaged to the extent that the damaged length of conductor must be removed. This problem can be remedied by allowing enough distance between the reel and tensioner to permit the strand looseness to distribute along the intervening length of conductor and simultaneously maintaining enough back tension on the reel to stretch the core and inner strands to sufficiently tighten the outer strands. It is recommended that the back tension or braking tension of the conductor reel not exceed 1000 lb (4.5 kN), since drawing down of the conductor into the lower layers on the reel may cause surface damage. For smaller diameters, the back tension should be considerably less.

The maximum time conductors may safely remain in the travelers depends upon wind-induced vibration or other motion of the conductors. Windblown sand can severely damage conductors in a few hours if clearance is less than about 10 ft (3 m) over loose sand with little vegetation. Damage from vibration at sagging tensions is quite possible and, when required, dampers should be installed promptly. However, at lower tensions generally used for initial

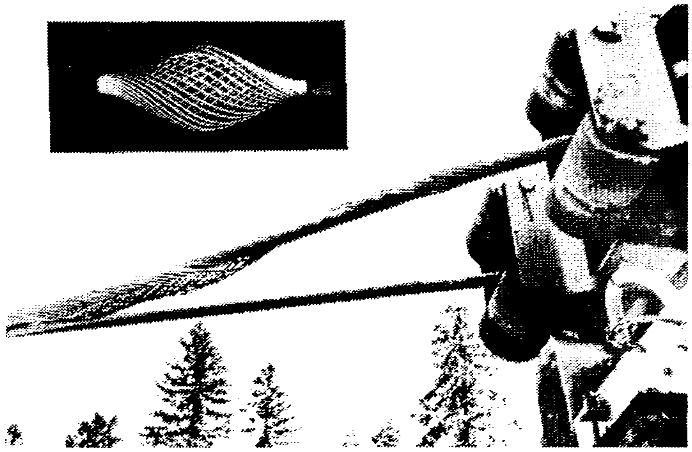


Fig 12
Birdcaging

stringing, damage to conductors or sheave bearings, or both, is not likely to occur from vibration. Even for travelers having lined sheaves with root diameters 20 times the conductor diameter, it is important to complete conductor stringing, sagging, plumb marking, clipping, spacing, and damping operations as soon as possible to prevent conductor damage from weather, particularly wind. Conductor should not be strung if adverse weather is predicted before the entire sequence can be completed.

Subconductor oscillation may occur in bundled conductor lines. Tie-down methods, temporary spacers, or other means may be required to prevent conductor surface damage prior to installation of spacers. Temporarily positioning one subconductor above another to prevent conductor clashing is undesirable because different tension history will later produce subconductor sag mismatch, unless the tensions are low and the duration is short enough so that creep is not a factor. Conductor clashing can mar the strands and produce slivers that can result in radio noise generation.

If a bullwheel-type puller is utilized, the pulling line should be recovered during the pulling operation on a separate piece of equipment. This function is usually performed by a reel winder that is placed behind the puller in an arrangement similar to the reel stand at the tension site. Some bullwheel pullers, particularly those used on smaller transmission lines, may have the reelwinder mounted on the rear frame of the puller itself. These reelwinders are usually self-loading for ease of removing full reels and installing empty ones. For these types of machines, typically two or three separate lengths of pulling line are used in a pull section.

Once the conductor has been pulled into place, one end is normally attached to the structure through a deadend insulator-hardware assembly or to a previously sagged section of conductor, and the other end is transferred from the puller or tensioner to the sagging unit. Attachment of the conductor to the sagging unit is accomplished by means of a properly designed conductor grip that should be capable of holding, without slipping, full sagging tension with appropriate safety factors. This must take into account possible impact loads that may be encountered as the sagging winch line wraps on the sagging winch drum, as well as overtension if the conductor is accidentally pulled above desired sag. In some cases, multiple grips will be required.

Extreme caution must be exercised when transferring a conductor from one holding device to another, or when connecting two conductors to ensure that the conductors are at all times adequately bonded together and to all equipment being used. This is essential to ensure that personnel cannot get in series with two items at different potentials, or with a conductor that could conduct induced potential to a grounded object.

Methods and procedures for the installation of overhead groundwires are the same as those indicated for conductors except that the loads and tensions involved are lighter. Groundwires are commonly pulled with lightweight pulling lines that are installed directly without the use of a pilot line. The groundwire(s) are normally installed prior to pulling the conductors due to their higher location on the structures and in order to prevent damage to the more easily damaged conductor when pulling groundwires up through them.

10.5 Sagging Procedures

10.5.1 Sagging and Clipping Offset Theories. Theoretically, conductor sagging is based upon hyperbolic functions describing a true catenary curve, see [9] and [11]. In practice, however, parabolic approximations of the catenary are often utilized.

In a series of suspension spans located in hilly terrain, wire in the sheaves will tend to run downhill. Gravity acting on the wire in the sheaves will cause excessive sag in the lower spans of the sagging section and too little sag in the upper spans. The unbalanced horizontal tensions will result in the insulators being pulled off from plumb in an uphill direction. To equalize the horizontal tensions, it is necessary to redistribute the wire between the spans. This process of pulling the wire uphill is known as "clipping offsets." The theory of clipping offsets is based upon the fact that, between snub structures, the total length of conductor at sag in the travelers is equal to the total length of conductor at sag in the suspension clamps. The distance that the clamp should be offset from the plumb position is calculated in order to pull slack from the lower spans and move it to the overly tight uphill spans.

There are several conditions that should be understood regarding the application of clipping offsets.

(1) Offsets must be calculated for the exact section being sagged. Insertion of a temporary snubbing position will change the offsets; therefore, offsets cannot be calculated until the sagging operation is determined.
(2) All offsets must be marked prior to any clipping-in of the wire.
(3) Offsets can be minimized by the judicious use of snubbing positions to separate line sections at different elevations.

Sags and clipping offsets are interrelated because sag corrections required for computing sags are dependent upon clipping offset computations. The application of sags and clipping offsets computed in this manner will produce balanced horizontal forces that will be the same for each structure within the sag section, see [7].

Figs 13 through 19 depict a basic analysis for clipping offsets and typical parabolic methods and computations required for sagging conductors. Where greater accuracy or more detailed information is required, see [9], [7], and [11].

10.5.2 Records and Forms. To assist in an accurate compilation of sag section data, a set of prepared forms should be devised to record accurately all field data, computations, drawing numbers, etc., as soon as they are obtained. Should questions arise while the work is in progress or at a later date, the availability of such records might greatly assist in providing the answers.

10.5.3 Design Criteria. A complete set of design criteria for the sag section should be available in the field. Included should be structure design data, stringing data, line profiles, conductor and pulling line sag templates, etc.

10.5.4 Equipment. Major equipment used for sagging could include transits (or similar viewing devices), portable radios, conductor thermometers, sagging watches, sagging platforms and targets, hand levels, stadia rods, dynamometers, measuring tapes, and miscellaneous marking devices.

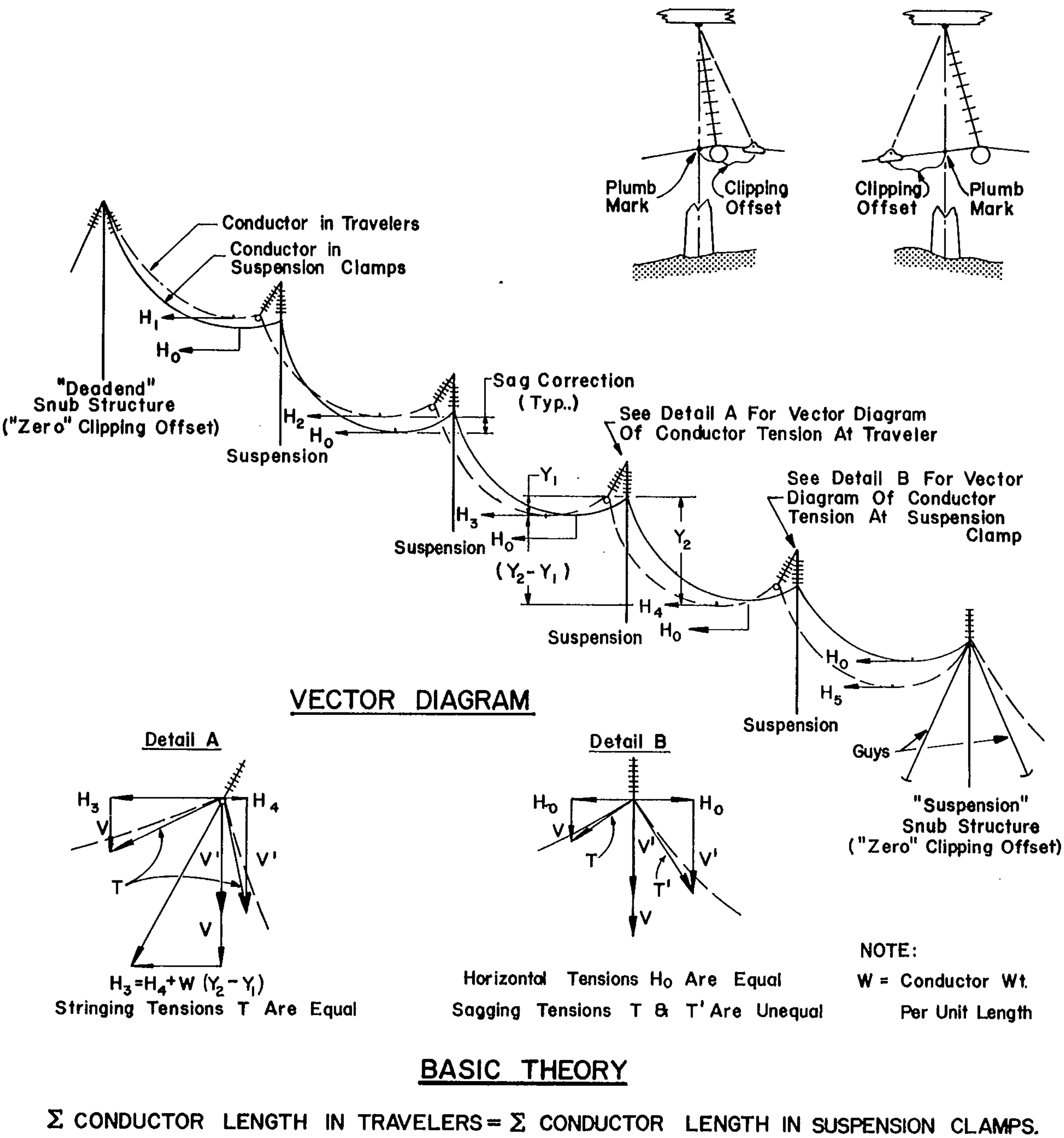


Fig 13
Example of Application of Clipping Offsets

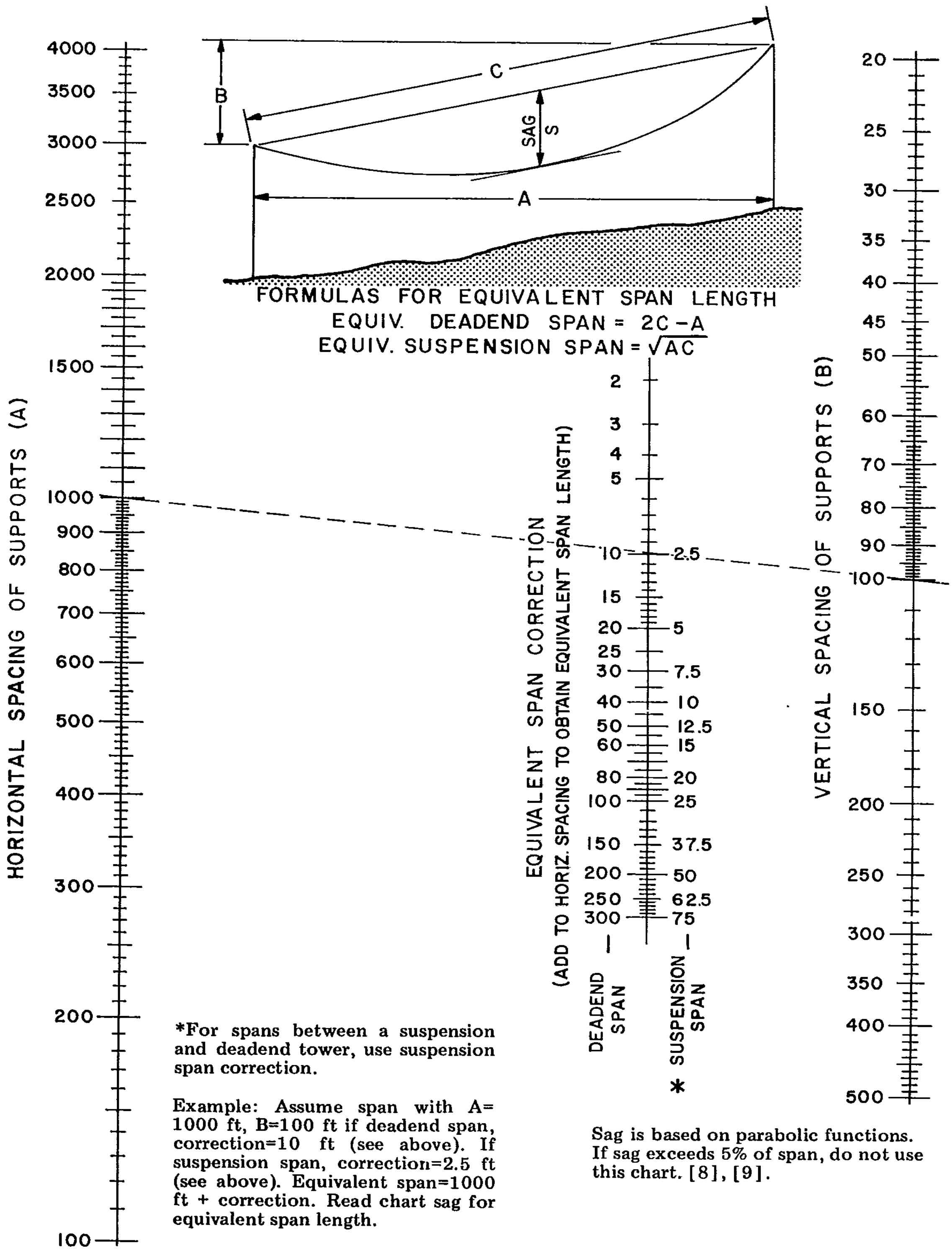
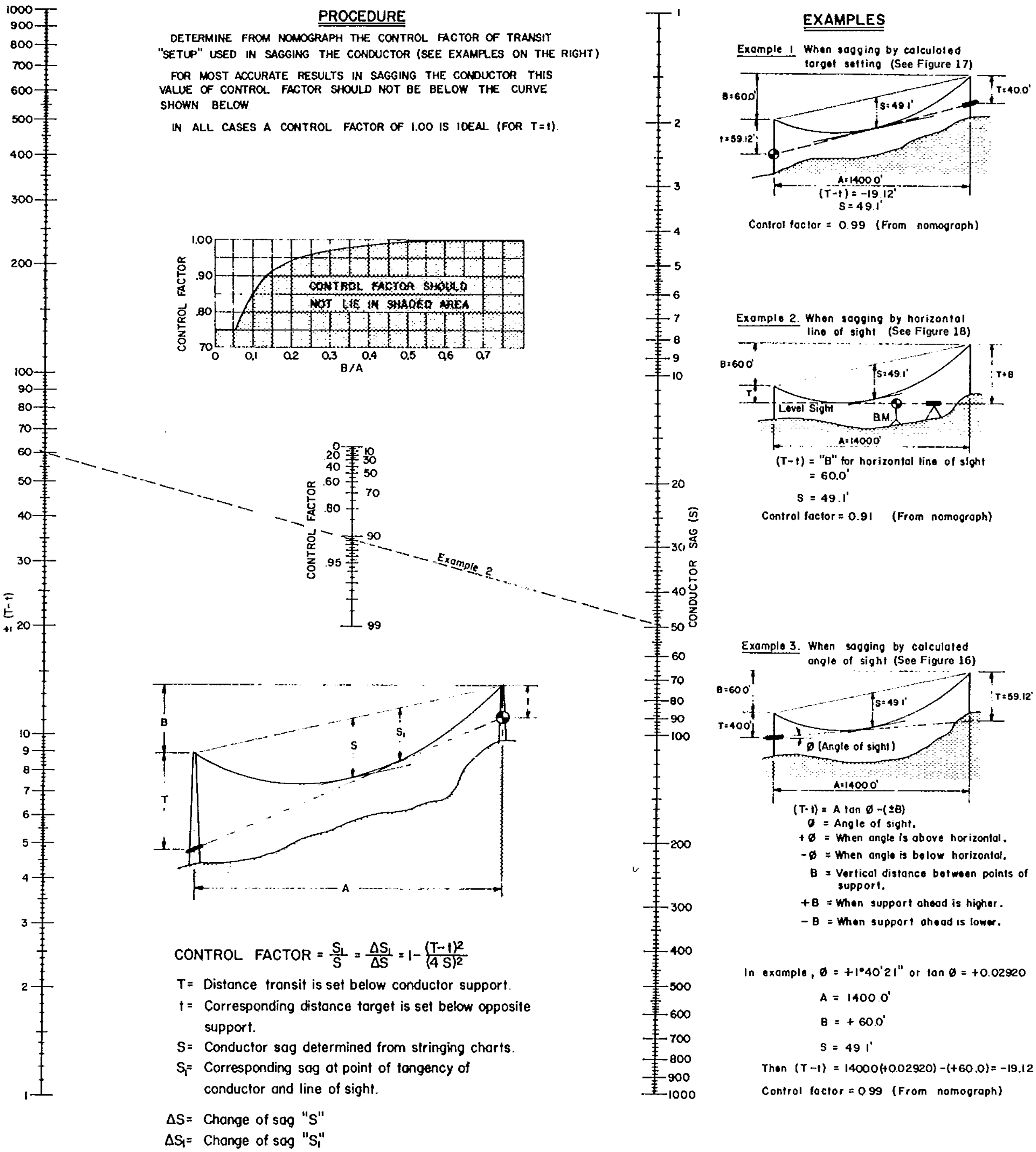
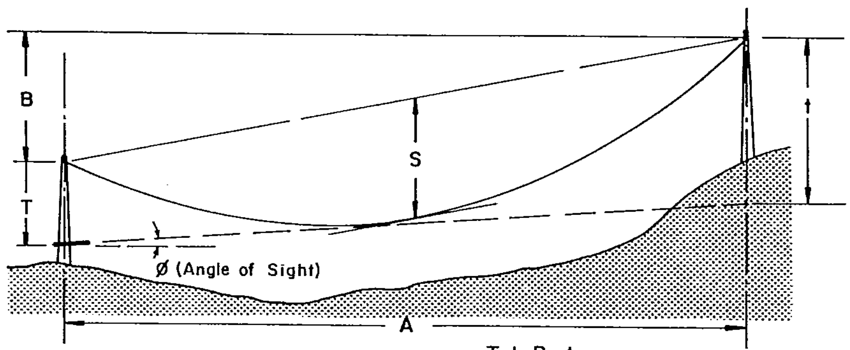


Fig 14
Nomograph for Determining Level Span Equivalents of Nonlevel Spans



Sag is based on parabolic functions. If sag exceeds 5% of span, do not use this chart. [8], [9].

Fig 15
Nomograph for Determining Control Factor for Conductor Sagging



METHOD 1: $\tan \phi = \frac{T \pm B - t}{A}$

METHOD 2: $\tan \phi = \frac{B + 2T - S(2+M)}{A}$

Ø = Angle of sight.
  + Ø When angle is above horizontal.
  − Ø When angle is below horizontal.

t = Vertical distance below support to line of sight. (See Figure 17)

T = Vertical distance below support for transit.

S = Sag.

A = Horizontal distance between points of support – obtained from structure list or plan & profile.

B = Vertical distance between points of support – obtained from plan & profile, tower site data sheets or field measurement.
  + B when support ahead is higher.
  − B when support ahead is lower.

M = Determined from curve on Figure 17.

EXAMPLES

GIVEN:

A = 1400.0'
B = + 60.0'
T = 40.0'

S = 49.1' @ 60°F
S = 51.2' @ 90°F
t = 59.12' @ 60°F
t = 63.76' @ 90°F

METHOD 1

$\tan \phi = \frac{T \pm B - t}{A}$

$\tan \phi_{60°F} = \frac{40.0 + 60.0 - 59.12}{1400.0} = 0.02920$

$\phi_{60°F} = +1° 40' 21''$

$\tan \phi_{90°F} = \frac{40.0 + 60.0 - 63.76}{1400.0} = 0.02589$

$\phi_{90°F} = +1° 28' 59''$

Change in angle Ø for 5°F =

$(1° 40' 21'' - 1° 28' 59'')(\frac{5}{30}) = 0° 1' 54''$

METHOD 2

$\tan \phi = \frac{B + 2T - S(2+M)}{A}$

$\tan \phi_{60°F} = \frac{60.0 + (40.0)(2) - (49.1)(2 + 0.019)}{1400.0} = 0.02919$

$\phi_{60°F} = +1° 40' 19''$

$\tan \phi_{90°F} = \frac{60.0 + (40.0)(2) - (51.2)(2 + 0.027)}{1400.0} = 0.02587$

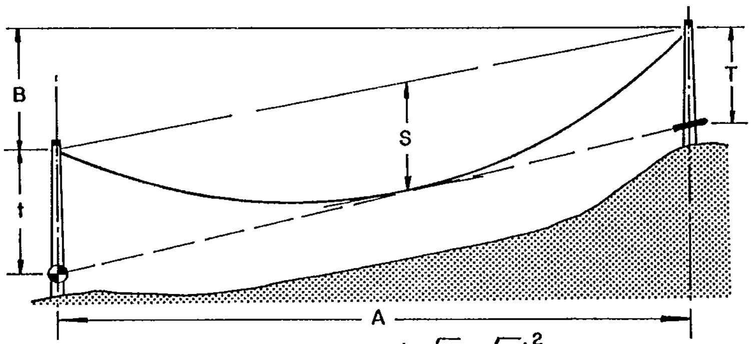
$\phi_{90°F} = +1° 28' 55''$

Change in angle Ø for 5°F =

$(1° 40' 19'' - 1° 28' 55'')(\frac{5}{30}) = 0° 1' 54''$

Sag is based on parabolic functions. If sag exceeds 5% of span, do not use this chart. [8], [9].

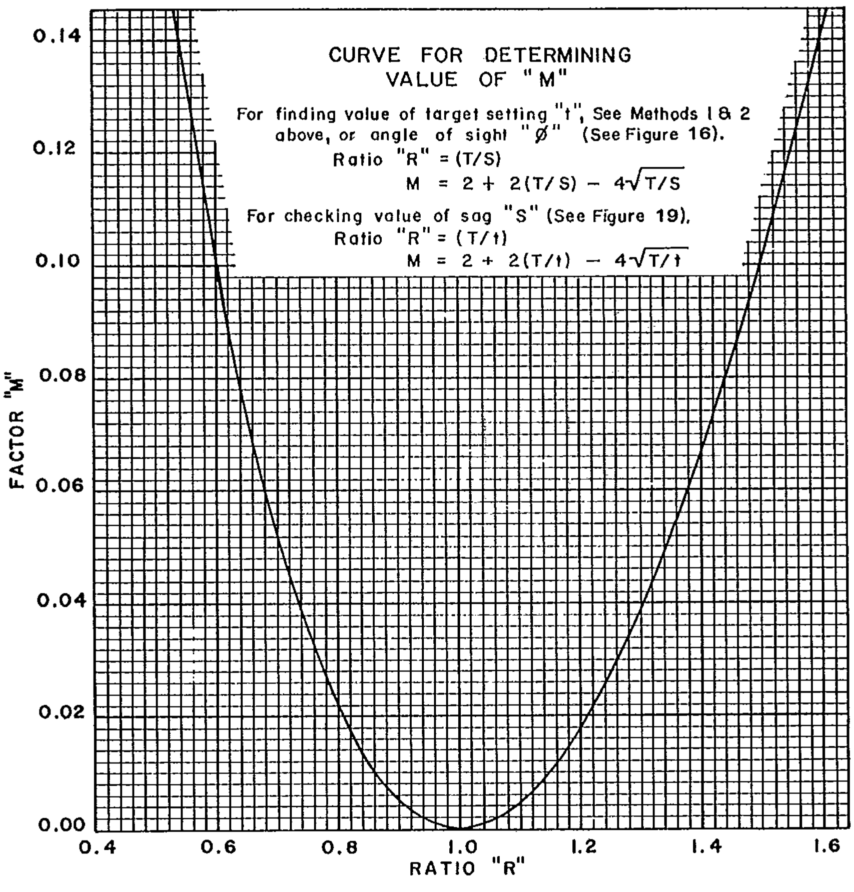
Fig 16
Conductor Sagging by Calculated Angle of Sight



METHOD 1: $t = (2\sqrt{S} - \sqrt{T})^2$

METHOD 2: $t = 2S - T + SM$

t = Vertical distance below support for target.
T = Vertical distance below support for transit.
S = Sag.
A = Horizontal distance between structures — obtained from structure list or plan & profile.
B = Vertical distance between points of support — obtained from plan & profile, tower site data sheets or field measurement.
M = Determined from curve below.



EXAMPLES

GIVEN:

A = 1400.0'
B = 60.0'
T = 40.0'
S = 49.1' @ 60°F
S = 51.2' @ 90°F

METHOD 1

$t = (2\sqrt{S} - \sqrt{T})^2$

$\sqrt{T}$ = 6.325

$\sqrt{S_{60°F}}$ = 7.007

$2\sqrt{S_{60°F}}$ = 14.014

$t_{60°F}$ = 59.12'

$\sqrt{S_{90°F}}$ = 7.155

$2\sqrt{S_{90°F}}$ = 14.310

$t_{90°F}$ = 63.76'

Change in "t" for 5°F

$= (63.76 - 59.12)(\frac{5}{30}) = 0.77'$

METHOD 2

$t = 2S - T + SM$

$T/S_{60°F}$ = 0.815

$M_{60°F}$ = 0.019

$2S_{60°F}$ = 98.2'

$t_{60°F}$ = 59.13'

$T/S_{90°F}$ = 0.781

$M_{90°F}$ = 0.027

$2S_{90°F}$ = 102.4'

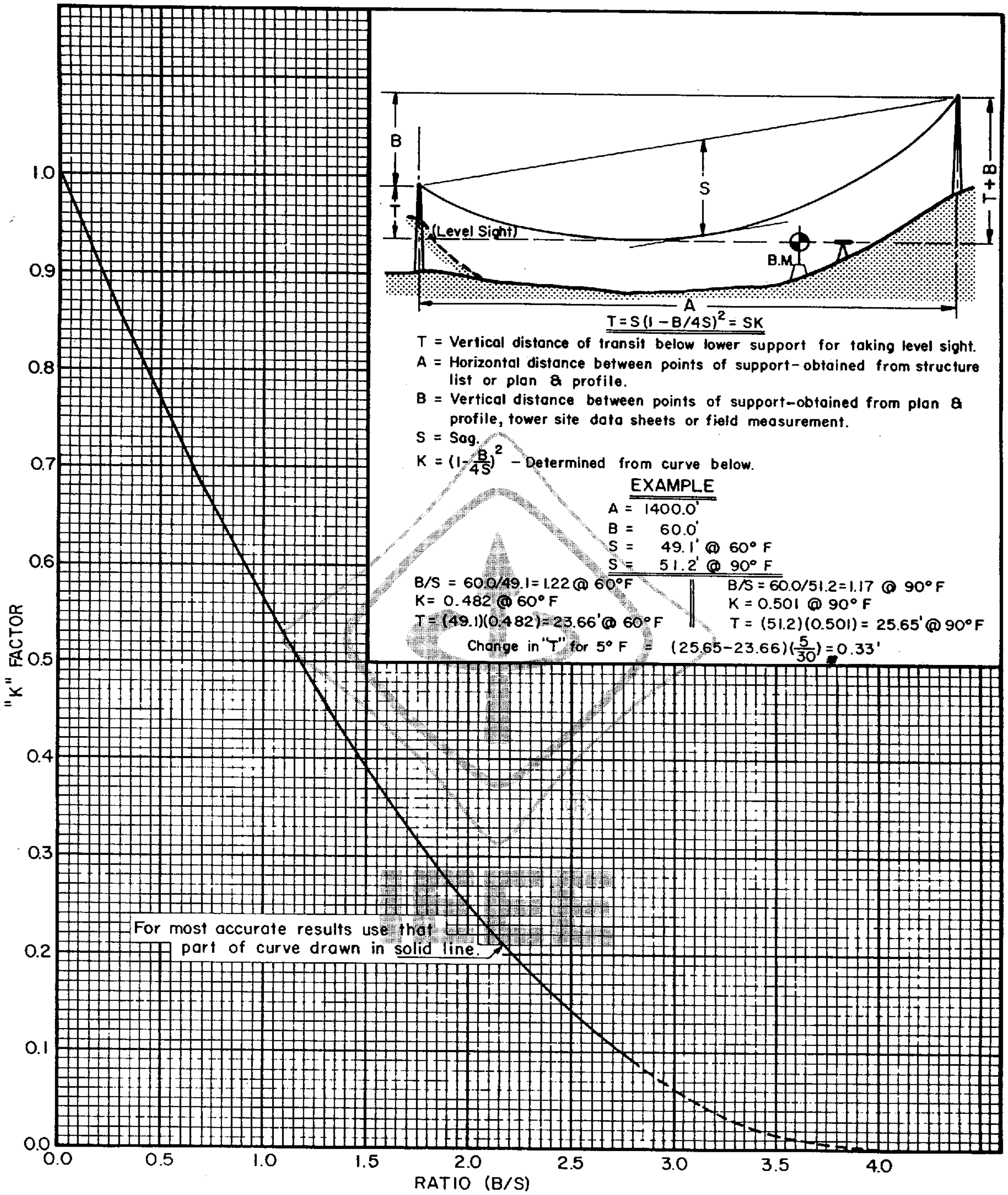
$t_{90°F}$ = 63.78'

Change in "t" for 5°F

$= (63.78 - 59.13)(\frac{5}{30}) = 0.78'$

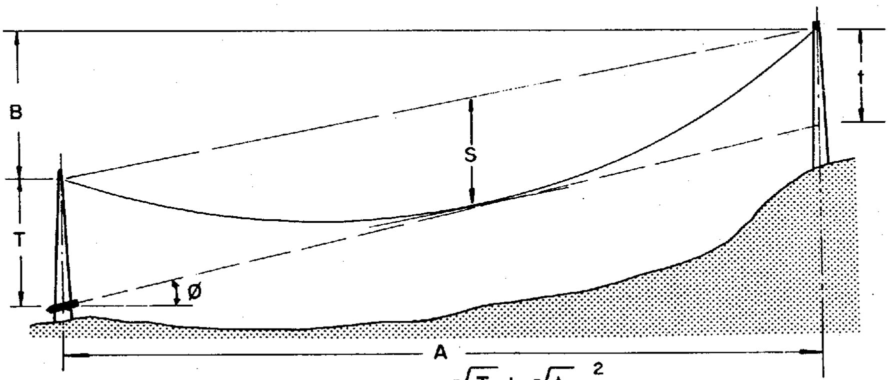
Sag is based on parabolic functions. If sag exceeds 5% of span, do not use this chart. [8], [9].

Fig 17
Conductor Sagging by Calculated Target Method



Sag is based on parabolic functions. If sag exceeds 5% of span, do not use this chart. [8], [9].

Fig 18
Conductor Sagging by Horizontal Line of Sight



METHOD 1: $S = \left(\frac{\sqrt{T} + \sqrt{t}}{2}\right)^2$

METHOD 2: $S = \frac{T}{2} + \frac{t}{2} - \frac{tM}{8}$

S = Sag.
t = Vertical distance below support for line of sight.
 = T ± B − A tan Ø when angle Ø is above horizontal.
 = T ± B + A tan Ø when angle Ø is below horizontal.
T = Vertical distance below support for transit.
B = Vertical distance between points of support — obtained from plan and profile, tower site data sheet or field measurement.
 +B when support ahead is higher.
 −B when support ahead is lower.
A = Horizontal distance between points of support — obtained from structure list or plan and profile.
Ø = Angle of sight.
M = Determined from curve on Figure 17.

EXAMPLES

GIVEN:

A = 1400.0' T = 40.0'
B = 60.0' Ø = + 1° 40' 21" @ 60°F
(Field Measured)

NOTE: When using Method 2, value of "T" should lie between 3/4"S" & 4/3"S"

METHOD 1

$S = \left(\frac{\sqrt{T} + \sqrt{t}}{2}\right)^2$

t = 40.0 + 60.0 − 1400.0 tan 1° 40' 21"
 = 59.12'

$\sqrt{t}$ = 7.689

$\sqrt{T}$ = 6.325

$S_{60°F}$ = 49.1'

METHOD 2

$S = \frac{T}{2} + \frac{t}{2} - \frac{tM}{8}$

t = 59.12'

t/2 = 29.56'

T/2 = 20.0'

M = 0.061

$S_{60°F} = 20.0 + 29.56 - \frac{(59.12)(0.061)}{8}$

$S_{60°F}$ = 49.1'

Sag is based on parabolic functions. If sag exceeds 5% of span, do not use this chart. [8], [9].

Fig 19
Conductor Sagging for Checking Sag *S*

10.5.5 Pull Site and Snub Structure Relationship. A pull site should be adjacent to the snub structure whenever possible. However, if a deadend structure is used as a snub structure, it could be located several spans away. When this occurs, the conductor between the pull site and the snub structure must be slacked down as much as possible at sag completion to minimize prestressing of the conductor. It is not a desirable situation since the next sag section will include the prestressed conductor together with unstressed conductor. Such situations should be avoided.

10.5.6 Conductor Uplift. Under certain conditions, conductor uplift within a sag section could occur at sag tension. Hold-down blocks or uplift rollers, or both, will be required to hold the conductor in the travelers to compensate for this condition.

10.5.7 Sag Section Length. A sag section should not exceed 4.5 miles (7 km), or approximately 20 spans, in length. Exceptions do occur but should be avoided, particularly in hilly or mountainous terrain. Excessive sag section length will usually result in sagging difficulties.

10.5.8 Sag Span Locations. Before sag spans are selected, a scale profile of the entire sag section should be reviewed to provide a complete, clear picture of the relationship between the terrain and the conductor. Such a profile is a valuable tool to be used in the selection of the sag spans and may emphasize locations of potential problems.

Sag spans should be at or near each end of the sag section. For sag sections over two miles long, additional sag span(s) near the center of the sag section should be utilized. Sag spans should be the longer, more level spans. If the sag span is not a level span, it is best if the transit is located at the lower structure since conductor control is increased. Sag spans should also be located on each side of line angles greater than 10°.

10.5.9 Tension Changes. Tension changes may occur at any point within a stringing section at which a strain structure is located. The most complicated situation occurs, however, when tension changes divide the stringing section into three or more separate parts, each of which must be sagged independently of the other. Under these conditions, two or more ruling spans, and hence two or more required tensions, exist within the stringing section. Although the conductor is continuous throughout the entire stringing section, the tension changes may be accomplished by deadending or the correct use of grips and hoists. Strain structures will always exist at any point where conductor tension changes, but the mere existence of a strain structure does not always imply a tension change.

10.5.10 Control Factors. The three basic sagging methods often used for sagging conductors are: transit method, dynamometer method, and stopwatch method.

10.5.10.1 Transit Method. The transit method is usually the most desirable method of checking sag because it can provide the most accurate control of conductor sag. There are three types of transit sagging methods used: calculated angle of sight method (see Fig 16), calculated target method (see Fig 17), and horizontal line of sight (see Fig 18). When choosing one of these three methods, it should be kept in mind that the point of tangency of the line of sight from the transit to the conductor should fall in the middle third of the span. Reference to the profiles will usually give an indication of the best transit sagging method to use. For example, tall structures on flat terrain and short spans indicate that the target or line of sight methods would probably provide the best control. Steep slopes, long spans, and large conductor sag indicate that the angle of sight method might be best. After the sag spans have been selected, they should be field checked for potential difficulties that might occur during sagging. At the same time, if required, sagging hubs should be established and sagging computation measurements obtained.

10.5.10.2 Dynamometer Method. The dynamometer or direct tension measurement method inserts a dynamometer in-line with the sagging equipment and displays the actual tension of the line. The dynamometer must be accurately calibrated and sized so that the anticipated readings will be approximately midscale. The location of the tension-measuring device on the conductor can be critical to the accuracy of this method due to efficiency loss from the sheaves. It is therefore best to locate the device as close as possible to the actual span with a minimum number of sheaves between the span and the dynamometer. A dynamometer can also be used as a sag check using a shunt dynamometer installed after the conductor has been secured. The dynamometer method works best on small conductors and shorter spans. It also is a good method of checking loads during the stringing operation.

10.5.10.3 Stopwatch Method. The stopwatch or sagwatch method is a quick and accurate means of checking sag. This method involves jerking or striking the conductor and measuring the time it takes the shock wave to be reflected back to the initial point. Usually, three or five return waves provide an accurate measurement of the tension in the span. This method is most effective on small conductors and shorter spans.

10.5.11 Preparation Prior to Sagging. Preparations for performing the mechanics of conductor sagging should be completed well in advance of the actual sagging operation. Otherwise, excessive costs and delay can be incurred.

When required, sag span transit hubs should be located and staked, transit height reference marks placed on the structures, and sagging platforms and transit mount brackets installed.

Sagging thermometers should be installed at or near the conductor prior to the actual sagging operation to allow temperature stabilization, and far enough above the ground to avoid the effect of ground heat radiation. Thermometers should be inserted in a container (sometimes a conductor section) to represent the internal conductor temperature. See Fig 20.

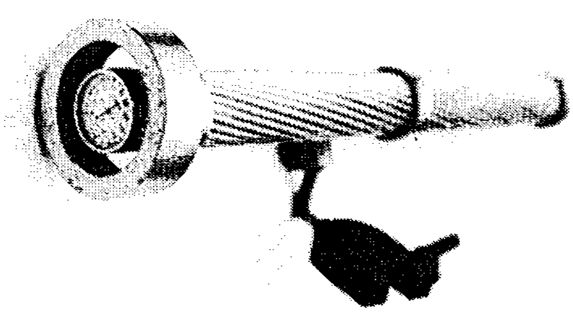


Fig 20
Sagging Thermometer and Container

The availability of sufficient portable radios should be ensured, and, if necessary, transportation should be arranged.

All sagging personnel should ensure that they have the proper equipment and sagging data in their possession. The person who controls the sagging should have in his/her possession a complete set of records pertaining to the entire sagging operation.

Due to adverse terrain conditions, sagging personnel will not always be able to observe all spans of the sag section. A study of the sag section profile will normally reveal such a situation. If the condition exists, additional help will be required to ensure that the conductors are sagging evenly in the blind spans.

10.5.12 Performance of Sagging Operation. After all preparations have been made and all personnel associated with the sagging operation are in position, the person who controls the sag should relay all last minute details to the puller operator.

Sagging personnel should obtain last minute thermometer readings and use the average of the two readings adjusted for an estimated increase or decrease in temperature at sag completion as the temperature for sagging the conductor. This information should be relayed to all persons involved in the sagging.

A conductor should never be sagged to the level of a previously sagged conductor. All conductors should be sagged based on temperature design criteria only. At the time of sagging conductors, the sag of any given phase should be within a tolerance of plus or minus 0.5 in (13 mm) sag of the theoretical value for each 100 ft (30 m) of span length, but not more than 6 in (152 mm) of sag in any one span. The sag of all phases of a circuit should have similar tolerances and direction from theoretical sag. Subconductors within a phase should have tolerances between each other of not over two conductor diameters with a maximum of 2 in. Due to the effects of solar radiation, vertical bundle conductors should not be sagged during midday if one subconductor is in the shadow of another subconductor. When checking sags at a time after original sagging, it should be remembered that creep will increase the sag and greater tolerance limits should be allowed for this and other unavoidable variations. Although it is desirable to check sags as soon as possible, it should be remembered that errors may be introduced during the clipping and deadending processes.

Communications and cooperation between the personnel who are sagging and the puller operator, and among the personnel themselves, are essential. The personnel should keep the puller operator constantly informed of the conductor movement, and, if bundled conductors are being sagged, they should also keep him/her advised of the state of evenness existing between the subconductors.

Conductor is sagged in progressive order from the tensioner end of the sag section to the puller end. Therefore, as the puller operator initiates conductor movement at the puller end, each person in a sag span, progressing from the puller end to the tensioner end, should inform the person who is actually sagging of the conductor movement as it moves through the sag section. Two benefits are derived by this method of communication. First, the person who is actually sagging knows when to expect conductor movement in his sag span, and, second, the puller operator knows when he/she should slow down or stop pulling.

Actual conductor sagging is initiated by the person who controls the sag and is first performed by that person in the sag span farthest from the puller working with persons who have spliced the conductor in the span containing the anchors for the previous sag. As the conductor is slowly released from the anchors, the person who is sagging should have the puller operator take the slack out of the conductor until it is slightly below sag. This condition should be maintained until the conductor is completely released from the hold-down blocks. Once the conductor is completely released, it can be pulled to sag.

If bundled conductors are being sagged, they should be brought to sag as evenly as possible. Should one of the subconductors be inadvertently pulled above sag in the sag span, severe difficulties can develop. In this situation, an attempt to slack one subconductor of the bundle down to sag usually results in unevenness in all of the other spans. Should this situation occur after an attempt to slack one subconductor down to sag, the sag should be stopped and the entire bundle should be slacked down below sag and evened. Another attempt to sag the conductors can then be made. Once the first sag span has been brought to sag, the subconductors of the bundle should be checked for evenness, and then the next sag span should be sagged. Unevenness in the sag spans in the middle or puller end of a sag section can usually be corrected by some manipulations of the conductors and, under normal conditions, will not result in starting the sag over again.

Attempts to sag conductor on excessively windy days should be avoided since serious errors can result due to conductor uplift caused by wind pressure on the conductor. Should severe wind conditions occur after a sag is in progress, allowances must be made for conductor uplift or the sag must be stopped.

10.5.13 Techniques for Checking Satisfactory Sag Progression. There are various techniques that are employed to determine if a conductor is sagging correctly. As stated before, conductor is sagged progressively toward the puller end of a sag section. As the first sag span comes to sag, the second person to sag should find that the conductor in his/her sag span is too high. This is to be expected and is normal, unless the conductor is excessively high. As the second person slacks his/her conductor down to sag, the third person should find the conductor too low in his/her sag span, and so on until the sag is completed. If any of the personnel who are sagging do not have the required conditions when the conductor is brought to sag in the preceding sag span, the entire sagging operation should be halted until the trouble is located.

If the conditions above are met, satisfactory sag progression is indicated. However, if an attempt to sag any sag span results in serious movement of a previously sagged span, trouble is again indicated, and the sagging operation should be halted until the trouble is located.

When the sag is completed, a tension reading should be recorded if a dynamometer has been used. The reading should be very close to the nominal tensions expected. Should the reading deviate excessively from the nominal tensions expected, the trouble should be located and any corrections should be made before the completed sag is accepted.

10.5.14 Conductor Reaction to Sagging Tensions. The reaction of conductor to tensions applied during sagging operations is similar to the wave created by dropping a stone in water. Once the wave is initiated, it continues for some period of time. Similarly, when tensions are applied to the conductor at the puller end of a sag section, the movement of the conductor is initiated at that point, and, although the tension may be held constant (puller stops), the movement of the conductor continues toward the other end at a decreasing rate. This movement must be dealt with when sagging conductor.

The travelers that are used to string conductor are not frictionless and, therefore, can cause problems during a sagging operation. If one or more of the travelers becomes jammed, sagging can become very difficult. A traveler that swings in the direction of the pull may be an indication of a defective traveler. Should unexplainable sagging difficulties occur, the travelers should be checked. Tensions applied to the conductor to overcome sticky or jammed travelers can cause sudden, abrupt movement of the conductor in the sag spans and quickly cause loss of sag, particularly if the conductor is already very close to sag.

10.6 Deadending Precautions

10.6.1 Electrical Hazards. The electrical hazards that exist when deadending work is being performed are analogous to those that exist during splicing operations. Therefore, precautions must be taken to prevent personnel from accidentally placing themselves in series with a potential electrical circuit.

10.6.2 Tension and Pull Sites. Continuity of grounding and bonding must be maintained when conductors or conductive pulling lines are transferred between pieces of equipment or between pieces of equipment and anchors. In the majority of cases, it will be necessary to move an existing ground on a conductor or pulling line before it can be transferred. Before removing the existing ground, the person must install his own personal ground to ensure that he/she will not place his or herself in series to ground with the conductor or line being transferred.

When two conductors or pulling lines, or any combination of them, are to be spliced or connected together in any way, the recommendations of 10.3.3 should be followed.

10.6.3 Deadend Structures. Prior to installing or removing deadend jumper on a metal structure, personal ground must be installed on the conductors on both sides of the intended work area and connected to the structure. If the structure is wood, they should be connected to a common ground source. In some cases, after one end of the jumper has been permanently attached to one conductor, electrical induction may be so severe that a third personal ground will be required to bond the loose end of the jumper to the other conductor in order that the jumper may be permanently attached.

10.7 Clipping-In. The clipping portion of the conductor stringing operations involves the work following sagging and plumb marking of the conductors. This entails removing the conductors from the travelers and placing them in their permanent suspension clamps attached to the insulator assemblies.

Clipping begins once the conductor has been brought to sag and is initiated by placing plumb marks on the conductor directly below the insulator attachment points on the structures with a plumb marker pole. This marking is done as soon as possible after reaching sag to minimize the effect of creep and possible movement of the conductor between spans. In rugged terrain, clipping offsets may be used whereby the suspension clamp, rather than being placed at the plumb marks, is offset a calculated distance from the mark to compensate for the unevenness of the terrain and to allow the insulator assemblies to hang vertically when all structures have been clipped in. When clipping is being done, care must be exercised to be certain that the conductors are grounded prior to clipping, despite the fact that the lines being clipped are not attached to any electrical source. This involves placing a personal ground upon the conductor at the location being worked.

After the conductors have been marked, personnel lift the weight of the conductors, allowing the travelers to be removed and the suspension clamps and armor rod, if used, to be placed on the conductors. Lifting is normally done by use of a hoist suspended from the structure and a conductor lifting hook that is designed so as not to notch or severely bend the conductors. This conductor lifting hook should have an elastomer cover so as not to damage the surface of the conductors. After placing the suspension clamps on the conductor, the hooks are lowered, thereby placing the weight of the conductor on the suspension clamp and completing the assembly. Where bundled conductors are used, the multiple conductors may be lifted simultaneously by the use of a yoke arrangement supporting the hooks and a single hoist or other lifting means.

It is recommended that conductors not be allowed to hang in the stringing blocks more than 24 h before being pulled to the specified sag. If this time is exceeded, the cable manufacturer should be consulted to determine if short time creep correction factors are required. The total time that the conductors are allowed to remain in the stringing blocks before being clipped should not be more than 72 h. If this time is exceeded, damage may occur to the conductors and/or sheaves.

10.8 Damper Installation. Dampers, if required, are normally placed on the conductors immediately following clipping to prevent any possible wind vibration damage. Damage can occur in a matter of a few hours at initial tensions.

10.9 Spacer and Spacer Damper Installation. When spacers are required for bundled lines with horizontal pairs of conductors, they should be installed immediately following the conductor clipping operations. Spacers can be installed using a bucket truck or by placing personnel on the conductors through the use of a conductor car. A conductor car is placed on the conductors and used to ride the conductors from structure to structure. Care should be exercised to ensure that the concentrated load of the person, car, and equipment does not increase the sag sufficiently to cause a hazard from obstructions over which the conductor car will pass. The installation and location of the spacers on the conductor varies with the type and manufacture of the spacer and is normally done is accordance with the manufacturer's recommendations. When unequal spacing is used, accuracy in spacer location is critical to protect the line against damage. Ground targets or car footage counters are necessary for accurately locating the spacers. Car footage counter accuracy should be verified to span length.

The load of the person, car, and equipment should be equally distributed to all subconductors of the phase. This is particularly important at the time each spacer is attached.

11. Special Conductors

Special conductors, for the purpose of this guide, consist of: SSAC, T-2, SDC, and OPGW. These conductors are considered special due to the fact that they require specialized installation and handling procedures. Each of the following sections on these conductors generally cover those procedures required by the existing manufacturers of these conductors. It is recommended that the manufacturer be consulted prior to installation and handling to be sure that further precaution is not required.

11.1 SSAC — Steel Supported Aluminum Conductor. SSAC is an aluminum-steel composite conductor that looks like conventional ACSR. The difference is that while the aluminum wires in conventional ACSR are hard drawn, those used in SSAC are softer and fully annealed. The annealed aluminum wires in SSAC, being softer, have much more ductility than hard drawn wires in ACSR. They are also more susceptible to damage through improper handling.

Although SSAC can be pulled in and sagged generally in the same manner as ACSR, particular attention should be given to the following paragraphs.

Additional emphasis should be placed on normal precautions to avoid scuffing of the surface. SSAC should not be dragged across any surface. Only tension stringing methods should be used. Pay-off should be straight from the reel in order to avoid scuffing of the conductor against adjacent turns of the reel. Kellem grips should be properly sized and double banded on the ends. Bolts on pocketbook type come-alongs and on bolted dead-end clamps should be clean and well lubricated. The bolts should be snugged-up and then tightened with at least five passes over them with full torque recommended by the manufacturer. Open-sided parallel jaw grips should be closely sized to the conductor diameter to minimize strand distortion. Tandem grips or core gripping methods may be required for certain high-tension applications. All stringing sheaves and bullwheels should be lined and sized according to this guide. Only multigroove tensioners should be used with SSAC because single V-groove tensioners may damage the conductor or cause it to birdcage excessively.

Conductor distortion and minor birdcaging with SSAC can often be repaired satisfactorily by hand reshaping with a small block of wood. Severed strands require armor rods or repair sleeves.

If the SSAC is to be prestretched prior to sagging, refer to the manufacturer for recommendations on the magnitude and the duration of the prestressing.

11.2 T-2 Conductor — Twisted Bare Conductors. T-2 Conductor consists of two standard concentric stranded conductors twisted around each other. T-2 Conductor may be installed using techniques and equipment similar to those used to install single concentric round wire conductors, with a few special procedures used to maintain equal tension between the two component conductors.

11.2.1 Handling. It is important to maintain the relationship of the conductor lengths established during manufacturing. Therefore, T-2 Conductor should not be rewound in the field from the shipping reel to another reel. Reels containing T-2 Conductor should be stored upright resting on the rims; never lay the reel on its side.

11.2.2 Tensioners and Sheaves. Most methods of installation used for standard round conductor can be used to install T-2 Conductor. However, tension methods of stringing are preferred.

Fig 21 illustrates two multigroove bullwheel tensioners that can be used to install T-2 Conductor.

Fig 21(a) represents a unit in which the alignment of the front and back bullwheels is offset by 1/2 the groove spacing. This design is satisfactory for installing smaller sizes of T-2 Conductor where the conductor will lay flat in the bottom of the groove. If improper equipment is used, the ridge between the grooves may separate the T-2 Conductor individual members.

Fig 21(b) illustrates another preferred type tensioner. In this design, one bullwheel is tilted slightly in relation to the other bullwheel. This allows the conductor to ride in the bottom of the grooves. This type of tensioner, properly sized, is preferred.

V-groove tensioners cannot be used.

Recommended bottom groove diameters for sheaves and bullwheels should be sized in accordance with this guide, except the bottom groove diameter for sheaves should not be less than 14 times the maximum diameter of the T-2 Conductor. See Fig 6. References to the conductor diameter, D, should be the maximum diameter for the T-2 Conductor (twice the diameter of one component conductor).

The groove radius of the sheave and bullwheel must be wide enough for the T-2 Conductor to pass through with the two component conductors laying side by side. The minimum groove radius must be 0.55 times the maximum diameter of the T-2 Conductor. (See Fig 6.)

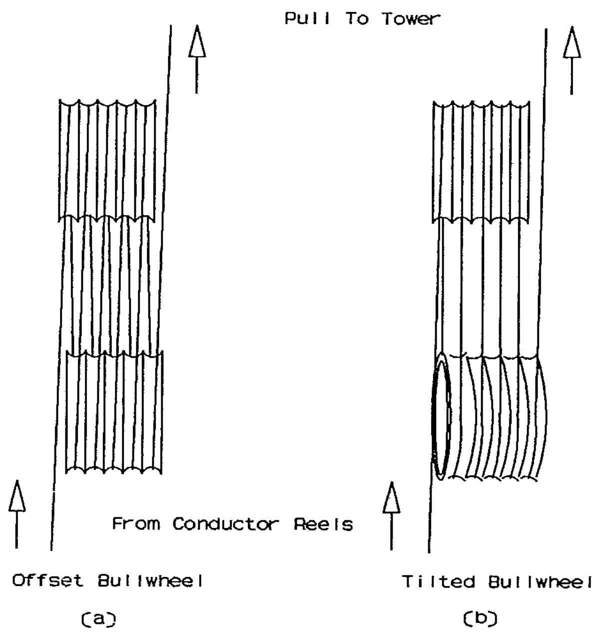


Fig 21
T-2 Bullwheel Tensioners

CAUTION: *Smaller than recommended diameter sheaves and/or high stringing tensions may cause a build-up of torsional stress into the conductor.*

11.2.3 Tensioning. T-2 Conductor is tensioned by placing a separate grip on each component conductor. The two grips are connected through a snatch block with a short pulling rope. Tension is applied to the snatch block. This arrangement will apply even tension between the component conductors.

11.2.4 Splicing. T-2 Conductors are joined by separately splicing each component conductor. Where possible, the individual conductor splices should be staggered about 5 ft (1.5 m). An additional twist may be needed before the second splice is made to remove any looseness between the component conductors. This will ensure that each component conductor carries an even share of line tension. Both splices should be made before tension is applied.

11.2.5 Repairs. Repairs to damaged component conductors can be made using the following procedure:

(1) Attach two wire grips facing each other approximately 15 ft (4.6 m) apart on the undamaged component conductor.
(2) Attach a chain hoist to the grips and take up tension. (As the tension increases, slack will appear in the damaged component conductor).
(3) Increase tension until there is enough slack to make repairs.

CAUTION: *If it is necessary to cut the damaged conductor to install a splice, a second set of grips and hoist should be installed on the damaged conductor before it is cut. The above procedure should be used to install the grips.*

Helically applied rods may be used for repair in accordance with utility policy, given the nature and severity of damage. Follow the above procedures to install the repair rods on the damaged conductor.

11.3 Self-Damping Conductor (SDC). The general recommendations for the installation of SDC are basically the same as for ACSR and are as given in this guide. There are, however, two major differences from normal practice that should be followed to prevent the steel core from being drawn inside the aluminum layers. They are

(1) *The installation of pulling sleeves on the pulling end of the conductor.* If two reels are pulled in tandem, pulling sleeves should also be installed on the drum end of the lead conductor. This is done just after the tail end is pulled off the reel with the conductor still held in the tensioner. As a precautionary measure, it is recommended that at least a two-bolt grip be placed on the conductor approximately 2 ft (0.6 m) from the end.
(2) *The use of bolted grips or come-alongs with elliptical grooves for holding the conductor during sagging or snubbing.* The elliptical groove is necessary in order for the aluminum layers to be deformed sufficiently into an oval shape to grip the steel core.

11.3.1 Preparation for Sagging. In preparation for transfer to the sagging unit or for temporarily snubbing-off prior to sagging, come-along(s) need only be attached to the conductor directly in front of the tensioner. The conductor can then be let out from the tensioner and handled like a conventional conductor. It is not necessary to install another come-along or two-bolt grip at the tail end of the conductor. The steel core may draw in approximately an inch as the conductor is let out of the tensioner. This is not detrimental and is no more than what, at times, happens with conventional ACSR.

When installing come-alongs on SDC, it may be necessary to retorque the nuts one or two more times than for conventional ACSR before uniform recommended torque readings are obtained. The nuts should be retorqued periodically when a come-along is used for snubbing over an extended period of time to be certain that relaxation has not occurred.

Upon removal of a come-along, SDC will retain an oval shape in the area under the come-along. Its original shape can be restored by hitting the major axis of the oval with a wood or rubber mallet or with a heavy piece of wood such as a 2 × 4.

A precautionary note: to insure that the required clamping force is always obtained, come-alongs should be properly maintained. The eyebolts should be kept cleaned and lubricated. The conductor groove should be clean and dry. This applies to all come-alongs, regardless of the type of conductor.

11.3.2 Sagging. The sagging procedure for SDC is the same as for any other type of conductor; however, SDC has a tendency to be slightly less free running than a conventional conductor. This is because that portion of SDC that rests in the sheaves between the time that it is strung and then pulled up to sag becomes slightly oval.

11.3.3 Clipping. Although not absolutely essential, it is advisable to let any conductor, after being pulled up to sag, sit in the stringing sheaves a minimum of two hours before being clipped in. This gives an opportunity for the conductor tension to equalize between spans.

11.3.4 Bullwheel Dimensions. The recommended bullwheel dimensions for stringing SDC are the same as those shown in Fig 3.

NOTE: Universal V-groove bullwheels should not be used with SDC.

11.3.5 Sheave Diameters. If too small a stringing sheave is used with SDC, the conductor becomes sufficiently oval while resting stationary in the sheaves to raise or pop a strand. Once a strand raises, it is extremely difficult, if not impossible, to get it back in place without taking the tension off the conductor in that area, Therefore, larger diameter sheaves are recommended with SDC than with conventional conductor.

A minimum sheave diameter at the bottom of the groove of 20 times the conductor diameter should be satisfactory for typical SDC stringing operations.

Extremely long vertical (weight) spans and large approach and snub angles may result in the conductor being sufficiently deformed in the sheaves to pop strands. At these locations, sheaves with diameters at the bottom of the grooves of greater than 20 times the conductor diameter, or larger, may be necessary.

11.4 Composite Overhead Groundwire With Optical Fibers (OPGW). OPGW was developed in order to provide large capacity telecommunication capabilities to utilities by utilization of their overhead power transmission lines. The product is one in which the central core of the overhead groundwire contains many fibers. Various manufacturers have different ways of enclosing the fibers. The balance of the OPGW is generally made of aluminum clad steel wires of varying conductivities but may be made up of galvanized steel or alloy aluminum in varying combinations to satisfy the strength/fault current requirements.

11.4.1 Stringing. Lined blocks are recommended for use with OPGW. The minimum stringing sheave diameter is $40D$ (i.e., $40 \cdot D$; D = diameter of the OPGW). The minimum bullwheel diameter for tensioners is $70D$. OPGW is typically left-hand lay, and the bullwheel must be reeved from right to left. The use of a swivel on the pulling line followed by an antirotation device should be used to minimize the tendency of the OPGW to twist during stringing.

Experience has shown that pulling speed, maximum tension imposed on the line during stringing, and the number of times the line passes through stringing blocks in one section are important factors in achieving a smooth operation. The maximum stringing tension should not exceed 20% of the rated breaking strength of the OPGW. Pulling speeds of 1.5–3 mi/h (2–5 km/h) are recommended; however, the manufacturer should be consulted.

11.4.2 Sagging. Sagging OPGW is the same as that used for normal overhead groundwires except that hardware tension clamps and stringing tools should have conductor grooves closely matching the diameter of the OPGW. Sag/tension data is normally supplied by the OPGW manufacturer.

11.4.3 Splicing. There is one primary difference between OPGW and normal overhead groundwires. Normal overhead groundwires are typically spliced midspan with a compression type connector. OPGW, on the other hand, is typically spliced at a tower. A 30–65 ft (9–20 m) tail is therefore required to make up the connection, depending on the particular splice box arrangement being used.

Appendixes

(These appendixes are not a part of IEEE Std 524-1992, IEEE Guide to the Installation of Overhead Transmission Line Conductors, but are included for information only.)

Appendix A
Travelers or Snub Structure Load Calculation

The following is a method for calculating the actual load on travelers and snub structures when tension stringing. If structures are at the same elevation and there are no angles in the line, only the first and last travelers need to be considered. However, in rough terrain and situations in which angles are encountered, the load at these points should also be calculated. For snub structure loading, the weight of insulator assemblies and travelers must also be considered.

A = distance of tensioner or puller from structure
B = height of structure arm from elevation of tensioner or puller
D = sag during stringing operation
E = difference in elevation between points of attachment
$F°$ = angle of conductor from tensioner or puller to horizontal
$G°$ = angle tangent to conductor and horizontal
$K°$ = azimuth angle of departure in line
L = length of span
R_H = horizontal load on traveler
R_V = vertical load on traveler
R_{max} = total load on traveler
T = line tension

Example: Stringing tension is 5000 lb (T) and the tensioner is located 300 ft (A) from the first structure. Height from the point of attachment of the traveler to the elevation of the tensioner is 100 ft (B). The first span is 1000 ft (L), and sag during stringing is to be 50 ft (D). The angle of departure from the lead-in from the tensioner is 16° (K). The difference in elevation from the first to the second structure is 98 ft (E). The resultant load on the traveler is calculated as follows:

A = 300 ft
B = 100 ft
D = 50 ft
E = 98 ft
L = 1000 ft

$$\text{Tan } F = \frac{B}{A} = \frac{100}{300} = 18.4°$$

$$\text{Tan } G = \frac{E + 4D}{L} = \frac{98 + 4 \cdot 50}{1000} = \frac{298}{1000} = 16.6°$$

The lead-in angle is 18.4° from horizontal, and the lead-out angle is 16.6°. The traveler will bisect the total angle of 35°, actually giving a 17.5° angle on either side.

T = 5000 lb
K = 16°

To solve for R_V,

$$R_V = 2T \sin \frac{F° + G°}{2}$$
$$R_V = 2 \cdot 5000 \cdot \sin 17.5°$$
$$R_V = 3000 \text{ lb}$$

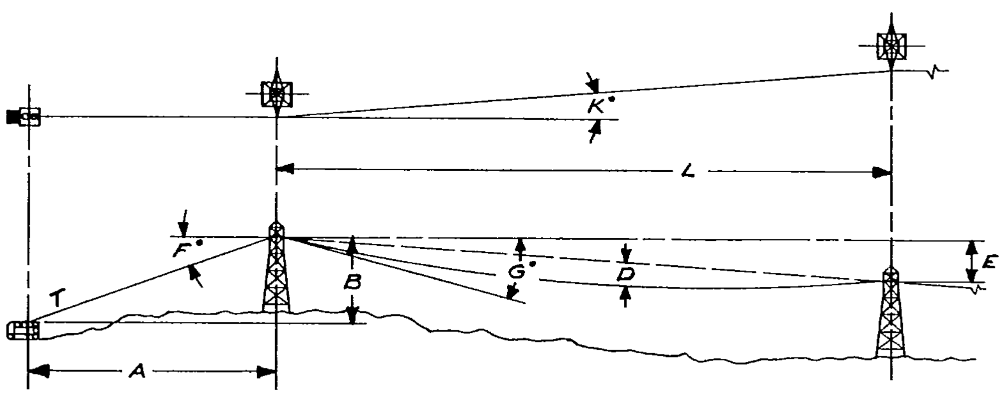
To solve for R_H,

$$R_H = 2T \sin \frac{K°}{2}$$
$$R_H = 2 \cdot 5000 \cdot \sin 8°$$
$$R_H = 1390 \text{ lb}$$

To solve for R_{max},

$$R_{max} = \sqrt{3000^2 + 1390^2}$$
$$R_{max} = 3307 \text{ lb}$$

Therefore, the total load on the traveler is 3307 lb. This value is approximate because the above formulas are based on parabolic rather than catenary equations, and sag is disregarded between the tensioner and first traveler. However, this method gives slightly less than actual load.



Appendix B
Efficiency of Travelers During Tension Stringing

The question of the efficiency of travelers often arises when planning overhead line construction jobs. Before this can be determined, the amount of force, holding power, or tension needed to support the wire in the span must be calculated. For a level span, this can easily be done with the following formula.

$$T_1 = \frac{WL^2}{8D}$$

where

W = weight per unit length of conductor
D = sag (sag during stringing, not final sag)
L = span length
T_1 = tension to support wire in span (static condition)

Once the tension required to support the wire in a static condition is known, the next consideration is the amount of tension needed to pull the wire across the supports, which, in this case, are the travelers. The additional tension required here is primarily the work needed to bend the wire, not to overcome the friction on the bearings of the travelers.

If a solid round metal bar is bent around a radius, the metal on the inside of the bend must compress and the metal on the outside of the bend must stretch. It takes a considerable amount of force acting through an appreciable distance to bend such a rigid bar. Force acting through a distance is called work.

Wire rope or cable strand or conductor is made much more flexible than a solid bar by taking round wires and forming them into a helix. The greater flexibility of such a structure is due to the fact that the wire, at any point on the inside of the bend, does not have to compress, nor does it have to stretch on the outside of the bend. Instead, the wire simply slips around the helix so as to adjust for the shortening on the inside and the lengthening on the outside of the bend.

However, these wires are pressed together with considerable pressure. The pressure is due to and is proportional to the tension in the cable (the pull on the cable). Thus, the slipping of the wire around the helix when the cable is bent is accompanied by considerable friction. Therefore, while it takes a great deal less work to bend a cable than it does to bend a solid bar, it still involves an appreciable amount of work. Friction is proportional to the tension in the cable. Thus, the higher the tension, the more work is required to bend the cable around a radius.

At each point of support, as the cable or conductor is being pulled, the cable or conductor must bend to the sheave radius of the traveler at the entering side and then must be straightened out again at the leaving side. Thus, an appreciable amount of work (or resistance to pull) is developed at each sheave. The amount of work (resistance to pull) is proportional to the tension and is inversely proportional to the diameter of the sheave because it obviously takes more to bend around a smaller arc than around a larger arc.

From this, it is apparent that the tension becomes greater because each traveler is passed since this tension builds up progressively at each support.

If we assume a 2% loss at each block, then the efficiency is 98% at each support. To solve for the total loss or the total efficiency, the number of travelers must be an exponent of the efficiency. The efficiency will vary depending on the size of the wire, the size of the block, and the other factors discussed above. Efficiency at 98% is used as representative under normal conditions encountered.

From this, if the initial tension before entering the first sheave = T_1, and the final tension after passing over N number of supports = T_{max}, then,

$$T_{max} = \frac{T_1}{0.98^N}$$

where

T_1 = tension to support first span
0.98 = the efficiency at each traveler
N = number of supports

Example:

D = 50 ft (sag in ft during stringing)
W = 2 lb (weight of conductor per ft)
L = 1000 ft (span length in ft)
T_1 = tension to support first span
N = 8 (number of supports)
0.98 = assumed efficiency at each traveler
T_{max} = tension to pull conductor

$$T_1 = \frac{WL^2}{8D} = \frac{2 \cdot 1000^2}{8 \cdot 50}$$

T_1 = 5000 lb

then

$$T_{max} = \frac{T_1}{0.98^N} = \frac{5000}{0.98^N} = \frac{5000}{0.8508} = 5877 \text{ lb}$$

This formula, explanation, and example are published in this form as a guide. Many factors affect the value being sought; however, this is an acceptable figure in most instances. In the case of actual varying field conditions encountered, an allowance should be considered.

Many variables will affect the assumed 98% efficiency of the travelers. Should very small sheaves be used, the efficiency of the travelers will be much less. On the other hand, cases of large sheaves, over 20 times conductor diameter at bottom of groove, have resulted in efficiency of over 99%. This is important as it must be considered in the selection of pulling and tensioning equipment and pulling lines.

Appendix C
Recommended Bearing Pressure on Sheave Linings

Considering bearing pressure between conductors and stringing sheaves, it should be noted that the pressure per unit of length between the conductor and sheave groove is a function of the tension (T) in the conductor, the diameter of the sheave to the bottom of the groove (D_s), and the diameter of the conductor (D_C). The pressure is independent of the angle of radial contact around the sheave and the resulting load on the traveler. The bearing pressure is therefore expressed by the following equation:

$$P = \frac{3T}{D_s D_c}$$

where

P = bearing pressure
T = conductor tension
D_s = diameter of sheave to bottom of groove
D_c = diameter of conductor or pulling line

Limits or guidelines for conductors have been 500–700 psi for lined sheaves, less for unlined ones. To obtain reasonable wear on sheave linings, maximum allowable unit bearing pressure for steel pulling lines is 2000 psi for neoprene, 3500 psi for urethane.

Examples:

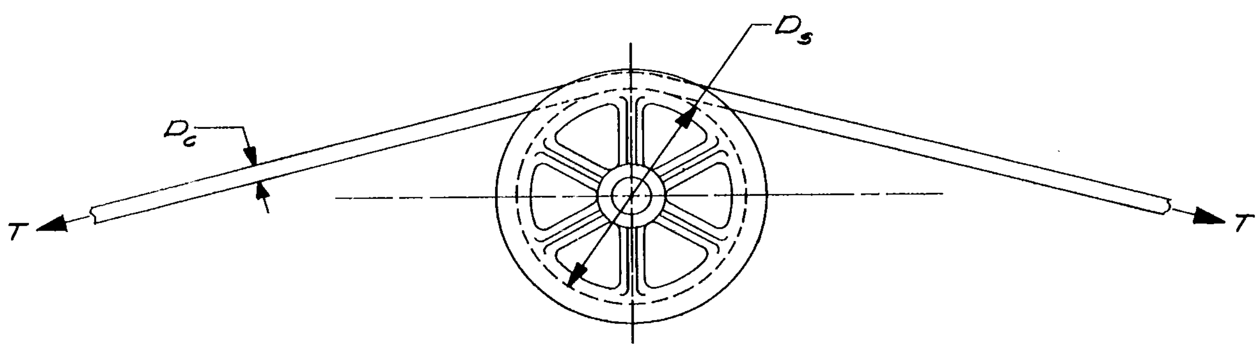
T = 12 000 lb for pulling line
T = 6000 lb for each conductor
D_s = 24 in (diameter of sheave to bottom of groove)
D_c = 0.625 in (diameter of pulling line)
D_c = 1.502 in (diameter of conductor)

$$P = \frac{3 \cdot 12\,000}{24 \cdot 0.625}$$

P = 2400 psi representing unit bearing pressure for the 5/8 in OD pulling line

$$P = \frac{3 \cdot 6000}{24 \cdot 1.502}$$

P = 500 psi representing unit bearing pressure for the 1.502 in OD conductor



Appendix D
All Aluminum 1350* Alloy Conductor Standard Packages

Code Word	SIZE		Strands	No ** of Layers	Conductor Diameter		Rated Strength	Wt Per 1000 ft	Wt. Per km	Reel Design	Standard Packaging Weight		Standard Packaging Length	
	kcmil	(mm²)			Inches	(mm)	lb	lb	(kg)		lb.	(kg)	ft.	(m)
Orchid	636	322	37	2	.918	23.32	11 400	598.9	888.4	RMT 84.45	7 400	3 355	12 400	3 780
										NR 66.28	3 700	1 680	6.200	1 890
										RM 68.32	3 700	1 680	6 200	1 890
										RM 68.38	3 700	1 680	6.200	1 890
										NR 48.28	1 850	840	3 100	945
Violet	715.5	363	37	2	.974	24.74	12 800	672.0	1000	RMT 84.45	7 400	3 355	11 020	3 360
										NR 66.28	3 700	1 680	5 510	1 680
										RM 68.32	3 700	1 680	5 510	1 680
										RM 68.38	3 700	1 680	5,510	1 680
										NR 48.28	1 850	840	2,755	840
Arbutus	795	403	37	2	1.026	26.06	13 900	746.4	1111	RMT 84.45	7 400	3 355	9 920	3 025
										NR 66.28	3 700	1 680	4 960	1 510
										RM 66.32	3 700	1 680	4,960	1 510
										RM 68.38	3 700	1 680	4,960	1 510
										NR 48.28	1 850	840	2 480	755
Lilac	795	403	61	3	1.028	26.11	14 300	746.8	1111	RMT 90.45	9 760	4 425	13 080	3 985
										RM 68.38	4 880	2 215	6 540	1 995
Magnolia	954	483	37	2	1.124	28.55	16 400	895.8	1333	RMT 84.45	7 400	3 355	8,260	2 520
										NR 66.28	3 700	1 680	4,130	1 260
										RM 66.32	3 700	1 680	4,130	1 260
										RM 68.38	3 700	1 680	4,130	1 260
										NR 48.28	1 850	840	2 065	630
Goldenrod	954	483	61	3	1.126	28.60	16 900	896.1	1333	RMT 90.45	9 760	4 425	10 900	3 320
										RM 68.38	4 880	2 215	5 450	1 660
Bluebell	1033.5	524	37	2	1.170	29.72	17 700	971.0	1444	RMT 84.45	7 400	3 355	7 630	2 325
										NR 66.28	3 700	1 680	3 815	1 165
										RM 66.32	3 700	1 680	3 815	1 165
										RM 68.38	3 700	1 680	3 185	1 165
										NR 48.28	1 850	840	1 910	580
Larkspur	1033.5	524	61	3	1.172	29.77	18 300	970.7	1444	RMT 90.45	9 760	4 425	10 060	3 065
										RM 68.38	4 880	2 215	5 030	1 535
Marigold	1113	564	61	3	1.216	30.89	19 700	1045	1555	RMT 90.45	9 760	4 425	9 340	2 845
										RM 68.38	4 880	2 215	4 670	1 425
Hawthorn	1192.5	604	61	3	1.258	31.95	21 100	1119	1665	RMT 90.45	9 760	4 425	8 720	2 660
										RM 68.38	4 880	2 215	4 360	1 330
Narcissus	1272	645	61	3	1.300	33.02	22 000	1194	1777	RMT 90.45	9 760	4 425	8,170	2 490
										RM 68.38	4 880	2 215	4 085	1 245
Columbine	1351.5	685	61	3	1.340	34.04	23 400	1269	1888	RMT 90.45	9 760	4 425	7 690	2 345
										RM 68.38	4 880	2 215	3 845	1 170
Carnation	1431	725	61	3	1.379	35.03	24 300	1344	1999	RMT 90.45	9 760	4 425	7 270	2 215
										RM 68.38	4 880	2 215	3 635	1 110
Gladiolus	1510.5	765	61	3	1.417	35.99	25 600	1419	2110	RMT 90.45	9 760	4 425	6 880	2 095
										RM 68.38	4 880	2 215	3 440	1 050
Coreopsis	1590	806	61	3	1.454	36.93	27 000	1493	2222	RMT 90.45	9 760	4 425	6 540	1 995
										RM 68.38	4 880	2 215	3 270	995
Jessamine	1750	887	61	3	1.525	38.74	29 700	1643	2445	RMT 90.45	9 760	4 425	5 940	1 810
										RM 68.38	4 880	2 215	2 870	905
Cowslip	2000	1013	91	4	1.630	41.40	34 200	1876	2793	RMT 90.45	9 100	4 130	4 850	1 480
Sagebrush	2250	1140	91	4	1.729	43.92	37 700	2132	3174	RMT 90.45	9 100	4 130	4 270	1 300
Lupine	2500	1267	91	4	1.823	46.30	41 900	2368	3527	RMT 90.45	9 100	4 130	3 840	1 170

*Alloy 1350 was formerly designated as EC.
**The number of aluminum layers does not include the 7 central wires which are considered as a core.
( ) Denote approximate value.

Appendix E
ACSR Conductor Standard Packages

Code Word	Size		Strands Al/stl	No of Layers	Conductor Diameter		Rated Strength	Wt. Per 1000 ft	Wt. Per km	Reel Design	Standard Packaging			
											Weight		Length	
	kcmil	(mm²)			Inches	(mm)	lb	lb	(kg)		lb.	(kg)	ft.	(m)
Kingbird	636	322	18/1	2	.940	23.88	15 700	691	1027	RM 66.32	4 160	1 885	6,020	1,835
										NR 66.28	4 160	1 885	6,020	1 835
										RM 68.38	4 160	1 885	6 020	1,835
										NR 48.28	2 080	945	3 010	915
										NR 42.28	1 385	630	2 005	610
Rook	636	322	24/7	2	.977	24.82	22,000	819	1219	RMT 84.36	6 550	2 970	8 000	2 440
										RMT 84.45	6 550	2 970	8,000	2 440
										NR 60.28	3 275	1 485	4 000	1 220
Grosbeak	636	322	26/7	2	.990	25.15	25 200	875	1302	RMT 84.36	7 590	3 445	8 670	2 645
										RMT 84.45	7 590	3 445	8 670	2 645
										NR 60.28	3 795	1 720	4 335	1 320
Egret	636	322	30/19	2	1.019	28.88	31 500	988	1470	RMT 84.45	9 860	4 470	9 980	3 040
										RM 66.32	4 930	2 235	4 990	1 520
										NR 66.28	4 930	2 235	4 990	1 520
										RM 68.38	4,930	2 235	4 990	1 520
Flamingo	666.6	338	24/7	2	1.000	25.40	23 700	859	1277	RMT 84.36	6 550	2 970	7 630	2 325
										RMT 84.45	6 550	2 970	7 630	2 325
										NR 60.28	3 275	1 485	3 815	1 165
Starling	715.5	363	26/7	2	1.051	26.70	28 400	985	1466	RMT 84.36	7 590	3 445	7,710	2 350
										RMT 84.45	7 590	3 445	7 710	2 350
										NR 60.28	3 795	1 720	3 855	1 175
Redwing	715.5	363	30/19	2	1.081	27.46	34 600	1,111	1653	RMT 84.45	9 860	4 470	8 880	2 705
										RM 66.32	4 930	2 235	4 440	1 355
										NR 66.28	4 930	2 235	4 440	1 355
										RM 68.38	4 930	2.235	4 440	1 355
Cuckoo	795	403	24/7	2	1.092	27.74	27 900	1 024	1522	RMT 84.36	6,550	2,970	6 400	1 950
										RMT 84.45	6 550	2 970	6 400	1 950
										NR 60.28	3 275	1 485	3 200	975
Drake	795	403	26/7	2	1.108	28.14	31 500	1 094	1628	RMT 90.45	11 380	5 160	10 400	3 170
										RMT 84.36	7 590	3 445	6 940	2 115
										RMT 84.45	7 590	3 445	6 940	2 115
										NR 60.28	3 795	1 720	3 470	1 060
Tern	795	403	45/7	3	1.063	27.00	22 100	896	1333	RMT 90.45	10 750	4 875	12 000	3,660
										RM 68.38	5 375	2 440	6 000	1 830
										NR 60.28	3 585	1 625	4 000	1 220
Condor	795	403	54/7	3	1.093	27.76	28,200	1 024	1524	RMT 90.45	11 800	5 350	11 520	3 510
										RM 68.38	5 900	2,675	5 760	1 755
Mallard	795	403	30/19	2	1.140	28.96	38 400	1 235	1838	RMT 84.45	9 860	4 470	7 980	2 430
										RM 66.32	4 930	2 235	3 990	1 215
										NR 66.28	4 930	2 235	3 990	1 215
										RM 66.28	4 930	2 235	3 990	1 215
Canary	900	456	54/7	3	1.162	29.51	31.900	1 159	1725	RMT 90.45	11 800	5 350	10 180	3 105
										RM 68.38	5 900	2 675	5 090	1 550
Rail	954	483	45/7	3	1.165	29.59	25 900	1.075	1600	RMT 90.45	10 750	4 875	10,000	3 050
										RM 68.38	5 375	2 440	5 000	1 525
										NR 60.28	3 585	1 625	3 335	1 015
Cardinal	954	483	54/7	3	1.196	30.38	33 800	1,229	1829	RMT 90.45	11 800	5 350	9 600	2 925
										RM 68.38	5 900	2 675	4 800	1 465
Ortolan	1033.5	524	45/7	3	1.212	30.78	27 700	1 164	1734	RMT 90.45	10 750	4 875	9 230	2 815
										RM 68.38	5 375	2 440	4 615	1 405
										NR 60.28	3 585	1 625	3 075	935
Curlew	1033.5	524	54/7	3	1.244	31.60	36 600	1 330	1981	RMT 90.45	11 800	5 350	8 870	2 705
										RM 68.38	5 900	2 675	4 435	1 350

Code Word	Size		Strands Al/stl	No of Layers	Conductor Diameter		Rated Strength	Wt Per 1000 ft	Wt Per km	Reel Design		Standard Packaging			
												Weight		Length	
	kcmil	(mm²)			Inches	(mm)	lb	lb	(kg)			lb	(kg)	ft	(m)
Bluejay	1113	564	45/7	3	1.259	31.98	29 800	1 255	1868	RMT	90.45	10 750	4 875	8 570	2 610
										RM	68.38	5 375	2 440	4 285	1 305
										NR	60.28	3 585	1 625	2 855	870
Finch	1113	564	54/19	3	1.293	32.84	39 100	1 431	2130	RMT	90.45	11 720	5 315	8 200	2 500
										RM	68.38	5 860	2 660	4 100	1 250
Bunting	1192.5	604	45/7	3	1.302	33.07	32 000	1 344	2000	RMT	90.45	10 750	4 875	8 000	2 440
										RM	68.38	5 375	2 440	4 000	1 220
										NR	60.28	3 585	1 625	2 665	810
Grackle	1192.5	604	54/19	3	1.333	33.86	41 900	1 533	2281	RMT	90.45	11 720	5 315	7 650	2 330
										RM	68.38	5 860	2 660	3 825	1 165
Bittern	1272	645,	45/7	3	1.345	34.16	34 100	1 434	2134	RMT	90.45	10 750	4 875	7 500	2 285
										RM	68.38	5 375	2 440	3 750	1 145
										NR	60.28	3 585	1 625	2 500	760
Pheasant	1272	645	54/19	3	1.382	35.10	43 600	1 635	2433	RMT	90.45	11 720	5 315	7 175	2 185
										RM	68.38	5 860	2 660	3 585	1 095
Dipper	1351.5	685	45/7	3	1.385	35.18	36 200	1 523	2266	RMT	90.45	10 750	4 875	7 060	2 150
										RM	68.38	5 375	2 440	3 530	1 075
										NR	60.28	3 585	1 625	2 355	720
Martin	1351.5	685	54/19	3	1.424	36.17	46 300	1 737	2585	RMT	90.45	11 720	5 315	6 755	2 060
										RM	68.38	5 860	2 660	3 375	1 030
Bobolink	1431	725	45/7	3	1.427	36.25	38 300	1 613	2400	RMT	90.45	10 750	4 875	6 665	2 030
										RM	68.38	5 375	2 440	3 335	1 015
										NR	60.28	3 585	1 625	2 220	675
Plover	1431	725	54/19	3	1.465	37.21	49 100	1,840	2738	RMT	90.45	11 720	5 315	6 375	1 945
										RM	68.38	5 860	2 660	3 190	970
Nuthatch	1510.5	765	45/7	3	1.466	37.24	40 100	1 702	2533	RMT	90.45	10 750	4 875	6 320	1 925
										RM	68.38	5 375	2 440	3 160	965
										NR	60.28	3 585	1 625	2 110	645
Parrot	1510.5	765	54/19	3	1.505	38.23	51 700	1 940	2890	RMT	90.45	11 720	5 315	6,040	1 840
										RM	68.38	5 860	2 660	3,020	920
Lapwing	1590	806	45/7	3	1.504	38.15	42 200	1 792	2667	RMT	90.45	10 750	4 875	6 000	1 830
										RM	68.38	5 375	2 440	3 000	915
										NR	60.28	3 585	1 625	2 000	610
Falcon	1590	806	54/19	3	1.545	39.24	54 500	2 044	3042	RMT	90.45	11 720	5 315	5 740	1 750
										RM	68.38	5 860	2 660	2 870	875
Chukar	1780	902	84/19	4	1.602	40.69	51 000	2 075	3086	RMT	96.60	19 080	8 655	9 200	2 805
Bluebird	2156	1092	84/19	4	1.762	44.75	60 300	2 511	3737	RMT	96.60	18 830	8 540	7 500	2 285
Kiwi	2167	1098	72/7	4	1.737	44.12	49 800	2 303	3427	RMT	96.60	16 120	7 310	7 000	2 135
Thrasher	2312	1172	76/19	4	1,802	45.77	56 700	2 526	3761	RMT	96.60	17 690	8 025	7 000	2 135
Joree	2515	1274	76/19	4	1.880	47.75	61 700	2 749	4091	RMT	96.60	17 325	7 860	6 300	1 920

( ) Denote approximate value

Appendix F
Drum or Reel Winding

Stranded members should be wound on a drum or reel according to the lay and the direction of travel.

Note the convenient thumb rule. Clench the hand into a fist, with the thumb and index finger protruding. Use the *right hand* for *right lay* and the *left hand* for *left lay*. The clenched fingers represent the barrel and the index finger the direction of pull-off. The thumb points to the proper attachment site.

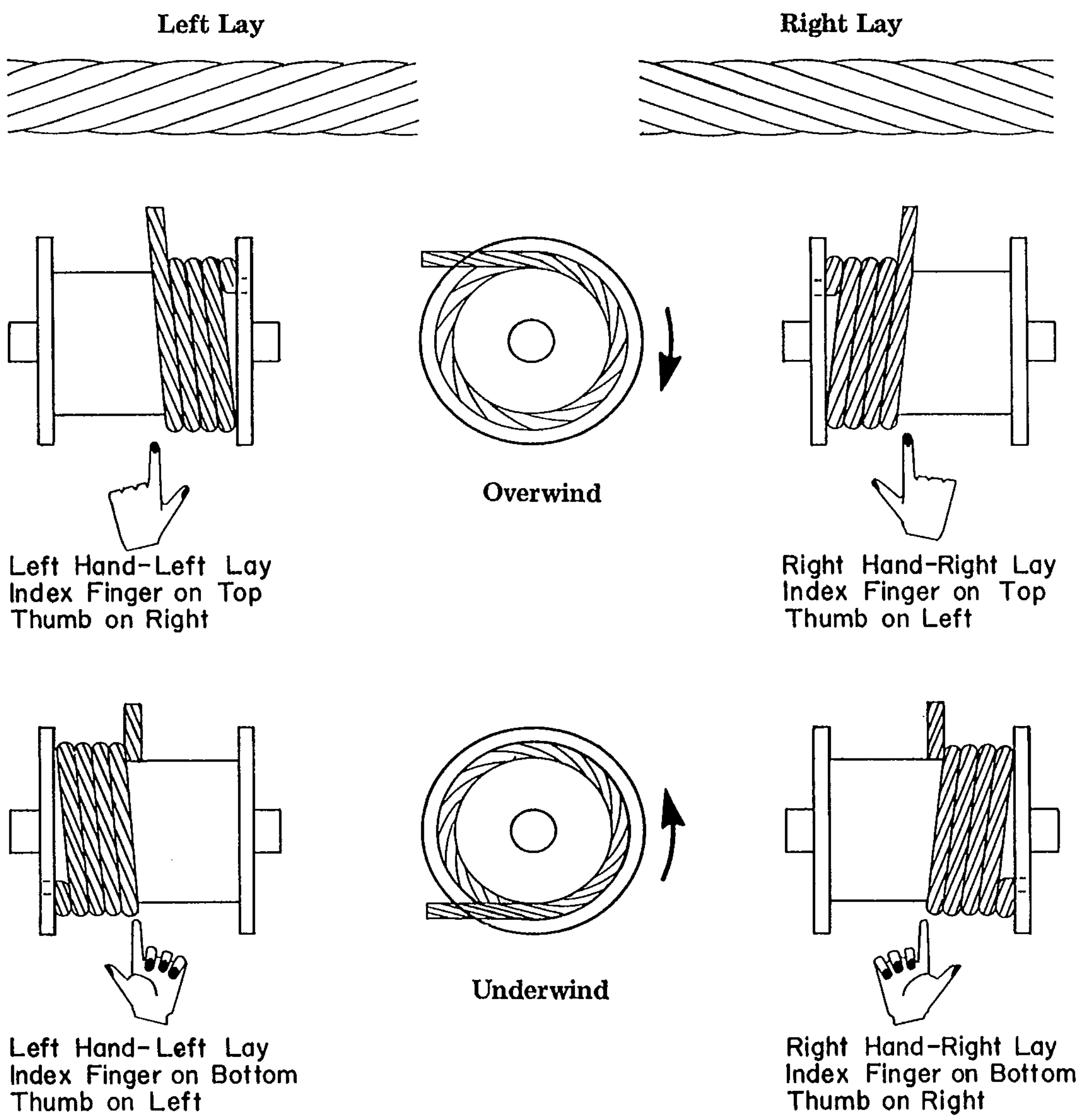


Fig F1

Appendix G
Drum or Reel Capacities

Wire rope

L = $(A + D) A B K$ (ft)
K = constant as tabulated below and as obtained by dividing 0.2618 ft/in^3 by the oversize wire diameter squared*

Fiber rope

$$L = \frac{B(H^2 - D^2)}{15.2d^2} \text{ (ft)}$$

d = rope diameter
A, B, D, H and d are in inches

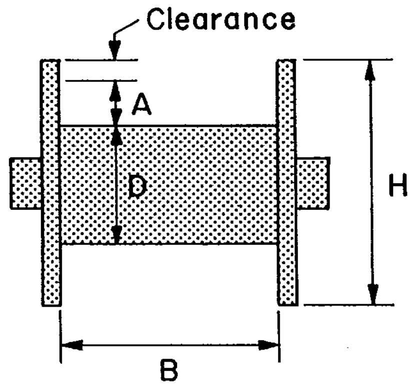


Fig G1

Table G1

Nominal Wire Diam In	K, ft/in³*	Nominal Wire Diam, In	K, ft/in³*	Nominal Wire Diam, In	K, ft/in³*
1/16	49.8	1/2	.925	1 3/8	.127
3/32	23.4	9/16	.741	1 1/2	.107
1/8	13.6	5/8	.607	1 5/8	.0886
5/32	8.72	11/16	.506	1 3/4	.0770
3/16	6.14	3/4	.428	1 7/8	.0675
7/32	4.59	13/16	.354	2	.0597
1/4	3.29	7/8	.308	2 1/8	.0532
5/16	2.21	1	.239	2 1/4	.0476
3/8	1.58	1 1/8	.191	2 3/8	.0419
7/16	1.19	1 1/4	.152	2 1/2	.0380

*Values of K allow for normal oversize. Clearance shown on Fig G1 should be 2 inches unless fittings require greater clearance.

The formula is based on uniform winding and will not give correct results if wound nonuniformly. It is based on the same number of wraps in each layer which is not strictly correct but which does not result in appreciable error unless the traverse of the reel is quite small compared with the flange diameter (H).

ISBN 1-55937-241-9