Pacific Gas & Electric

Live-Line Procedures Manual

Live-Line Hot Stick Work Methods

Pacific Gas & Electric (pge.com)

PG&E refers to **Pacific Gas and Electric Company**, a subsidiary of PG&E Corporation.

Dedication

Pacific Gas and Electric is dedicated to the safety and well-being of all employees and makes all best efforts to educate and inform each and every employee of safe work practices.

Acknowledgments

Thanks to all the various committee members, Electrical Safety Consultants International, and all other persons involved in preparing this document.

Foreword

This manual has been completely revised for 2014. Here in the Front section you will find a full table of contents, showing what is in all sections. Thereafter each section will show the table of contents for that section alone.

Live-Line Procedures Manual
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Part 1:

Live-Line Rigging Introductory Material

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Foreword

This manual has been prepared as a guide for Live-Line work on PG&E's transmission system. It is not the object of this manual to provide detailed instructions covering the procedure of every hot-line tool Live-Line maintenance job. This would be impossible due to the great variety of jobs and types of line construction and special conditions. Every pole is unique. This manual is intended to be used as a guide to general concepts and methods employed in the most fundamental operations of Live-Line maintenance work with hot sticks and a hydraulic power arm.

Scope

This Live-Line hot-stick work methods manual covers the replacement of insulators, cross arms, or a total structure replacement of PG&E's overhead transmission infrastructure. The complexity of PG&E's transmission system requires that these procedures be performed in a uniform and highly disciplined manner. Anyone working on PG&E's transmission system shall follow all procedures detailed in this manual. These procedures have been developed in accordance with Cal/OSHA Title 8, Subchapter 5, Group 2, Article 36, 2941 "Work Procedures and Operating Procedures."

References

Cal/OSHA Title 8, Subchapter 5, Group 2, Article 36, 2941
"Work Procedures and Operating Procedures"

PG&E Switching and Clearance Procedures

IEEE 516—2009 Guide for Maintenance Methods of Energized Power Lines

ASTM F478-09 Standard Specification for In-Service Care of Insulating Line Hose and Covers

ASTM F479-06 (2011) Standard Specification for In-Service Care of Insulating Blankets

1. Introduction

Live-Line maintenance has been made possible by the development of special tools and procedures for the work. The demand for performing maintenance operations using Live-Line methods is constantly increasing due to an ever increasing distribution and transmission network and the necessity of maintaining continuous electric service. Continuity of service is very important to the customers of PG&E. Continuous service is possible through the use of Live-Line maintenance.

The maintenance of energized or “hot” high-voltage lines may appear to be hazardous, especially when compared to working on “dead” or de-energized and properly grounded lines. Actually, the work is completed safely when the lineman is continually conscious of the fact that the lines are “hot” and the need to be careful to follow correct procedures. There is no possibility of the line being “hot” when it was thought to be dead, as there is when working on de-energized lines. Also, there is no possibility of confusion with live duplicate circuits, in Live-Line work methods, every conductor is worked “hot” and every operation is planned and worked accordingly.

The most common of these Live-Line operations are:

- Replacing insulators
- Replacing cross arms
- Replacing poles
- Tapping an energized line
- Cutting in or removing conductor slack
- Splicing conductors
- Installing armor rods
- Installing vibration dampers

1.1. How Live-Line Tools Are Manufactured

Live-Line tools made of Epoxiglas are superior to wood and laminated wood tools. They are stronger both mechanically and dielectrically and are more resistant to impacts and abrasion. Moisture does not materially affect the insulating quality of epoxiglas tools.

Epoxiglas tools are produced by a patented process which positions epoxy resin-impregnated electrical grade fiberglass strands parallel to and around a polyurethane foam core. The epoxy resin is then cured by heat and pressure.

The rigid polyurethane foam core performs three functions. It serves as a precise diameter mandrel for the fiberglass strands of the outer shell. It increases the overall hot stick strength. It also permanently seals out moisture.

Thousands of small unconnected cells make up the core. Since each cell is closed, condensation cannot form. Moisture cannot travel from one cell to another. Moisture cannot migrate through the hot stick.

The high glass and low resin content of the stick shell develops maximum strength with minimum weight. The fiberglass strands are laid in spiral and longitudinal layers under tension on the core for the highest strength and surface uniformity. Maximum adhesion between strands and to the foam core is achieved by bathing the fiberglass strands in an epoxy resin before wrapping.

Avery tough fiberglass surface coating has greater resistance to impact and abrasion than other finishes. This helps to prevent fracture of the fiberglass fibers. The smooth high gloss finish resists solvents and is easy to keep clean.

Every inch of Epoxiglas pole is electronically monitored during the manufacturing process to assure dielectric consistency. The dielectric value of a new pole is 100 kV per foot. Each run of pole is also tested mechanically to ensure quality and consistency.

Epoxiglas Live-Line tools will retain indefinitely their dielectric and mechanical strength if given the proper care.

1.2. Care of Live-Line Tools

Extreme care is exercised in the manufacturing process of Live-Line tools. Care should be used to protect these tools. Proper care will result in not only longer tool life, but will contribute to the safety and confidence of the user.

Care of the tools begins with storage and transportation. The hot sticks should be stored and transported to the job site in a hot stick trailer. The hot sticks should be mounted on racks and securely strapped in place to avoid damage to the tool surface. These racks should be well padded.

The hot stick trailer is equipped with a heater so that it may serve as a drying cabinet when the tools are being stored between jobs. Saddles, lever lifts, clamps, hoists, rope blocks, hot rope and cover up equipment should be stored carefully in bins or containers in the tool trailer. Jack screws should be padded so that their threads are protected.

One of the most important factors in the care of Live-Line tools is to keep them clean and dry. They should never be laid on the ground. The hot sticks always should be placed on the tool racks or leaned against a truck. All conductor covers, hoists, rope blocks and Live-Line tool components should be placed on tarpaulins to keep them clean.

Care should be exercised when removing and storing tools in the tool trailer. A dirty tool should never be placed into the trailer. All hot sticks should be wiped down before returning them to their proper place in the trailer. If the tools are carelessly stored in the hot stick trailer, they can be damaged during transport.

1.3. Daily Inspection and Cleaning of Live-Line Tools

All Live-Line tools should be inspected and cleaned before and after each use. Field repair or modification of tools is not permitted. If after inspection, there is any doubt about the condition of a tool, it should not be used and be removed from service. The tool should be repaired and tested before being used on the job.

The hot sticks should be placed on tool racks and their surface inspected for dirt, creosote, grease or any other foreign contaminating material. If surface contamination is found, the stick must be cleaned with an approved hot stick cleaner and wiped down with a silicone cloth. If the hot stick has a clean glossy sheen clean and no surface contamination is found, the stick may be wiped down with a silicone cloth to remove dust.

- Inspect all hot stick attachment points for indications that the tool may have been overstressed. Check all metal parts for excessive wear and damage. Cracked, bent, broken or missing rivets or bolts indicate excessive strain or stress. Excessive strain will overstress the parts and weaken them, and weakened parts may cause the tool to fail.
- Inspect all saddles, lever lifts, clamps, etc., for bent or missing parts. Ensure that all rivets and bolts are in place, tight, and not damaged or deformed.
- Inspect all slings and rope for excessive wear. Look for small cuts or abrasions that can compromise the ultimate strength of the rigging equipment.
- Inspect rope blocks for damaged rope or sheaves. Sheaves can be cracked or missing parts.
- Inspect hoists for bent or missing parts. Inspect straps for contamination and small tears and abrasion.
- Inspect wire grips for proper alignment of the jaws and bent or missing parts. The grip should be clean and free of any residue of any kind.
- Inspect hot rope for abrasions and overall cleanliness. Hot rope should be stored in its own clean, dry container.
- Never lay any Live-Line tool directly on the ground. Always use tool racks and a clean plastic or vinyl tarpaulin to stage tools for use.

1.4. Care of Cover-Up

Thorough Visual Inspection. Visual inspection of each piece of cover just prior to use is required and important. Each cover should be inspected inside and out for cracks, deep gouges and contamination. Check to make sure that each grip-all adapter is secure and that all fasteners are in place. If there is any question that a cover is not suitable for use, it should be immediately be set aside for later cleaning, electrical testing, or discarding. Plastic cover cannot be repaired.

Careful Handling During Installation And Removal. Line workers should become acquainted with any unfamiliar cover-up equipment before actually using it up on a pole. The line worker needs to know how each piece of cover is installed, coupled, adjusted and removed. Rough handling can damage and shorten the life of hard plastic cover.

Cleaning. Proper and frequent cleaning of cover-up equipment is required. Dirt, creosote and conductor wire residue can be conductive and needs to be removed from the cover regularly. Covers are regularly slid along a conductor, cross arm or pole during installation and removal. This sliding action picks up contamination that can compromise the dielectric properties of the cover and cause scratches and gouges. Cover-up should be cleaned when it appears dirty. Mild soap and water are recommended for cleaning all cover-up materials. Strong household and industrial cleaners can cause permanent damage to some cover-up materials. Always follow manufacturer's recommended cleaning procedures.

Proper Use. Cover-up is designed and rated to provide safety protection for momentary incidental or brush contact only. Cover-up should never be intentionally used in continuous direct contact between line and ground voltage, or phase-to-phase voltage. MWD must always be maintained, even when using 69 kV line guard. Cover-up should not be left on conductors or structures for extended periods. Corona and UV damage may occur. Cover-up can be safely left up overnight if necessary.

Proper Storage. Store cover-up in a clean, dry location. The hot stick trailer is ideal for this. Prolonged exposure to sunlight is detrimental to cover-up. Cover-up equipment should always be stored in such a way that the original intended shape is preserved. Line guards are designed to have specific air gaps and flashover distances in order to achieve a specific electrical rating. Distortion can alter the electrical characteristics of the cover-up.

2. Definitions

Affected worker—An employee whose job duties require them to work in areas (Zone 1 & 2) during the operation, maintenance and construction of exposed energized conductors and equipment.

Energized—Electrically connected to a source of potential difference, or electrically charged so as to have a potential significantly different from that of ground.

Exposed—Not isolated or guarded

NOTE: **Rated insulated cover-up or insulated rubber gloves do not eliminate exposure. If energized conductors and equipment are exposed, a minimum of two qualified electrical workers shall be present at the work site.**

Extended reach—The distance a worker can reach with a conductive object in an unprotected hand (screw driver, tape measure, armor rod, etc.)(See Figure 5.1).

NOTE: **Unprotected hand is defined as a worker not wearing rated insulated gloves, or gloves and sleeves, and not using the rubber glove work method.**

Insulated Cover-up—An insulating device rated for the voltage involved (line hose, plastic cover-up, blankets, etc.).

Inadvertent movement—An industry-accepted safety factor distance added to the MAID. If the worker was to accidently enter this area with any part of their body, there would not be an arc flash. The inadvertent movement from 750V to 72.5 kV is two feet, and one foot from 72.5 kV and above.

Live-Line Hot-Stick Work Method—A work procedure which uses insulated Live-Line tools to install, move, remove and repair exposed energized conductors and equipment. Live-Line tools are often used as an extension of qualified electrical workers' arms, allowing them to position themselves where they will not reach into the MWD, and provide adequate insulating capability. Live-Line tools are typically constructed from fiberglass rods and, when in good condition, are rated for 100 kV per foot.

Mechanical equipment—Vehicles and equipment, including un-insulated manlifts, digger/derricks, boom trucks, cranes, directional boring equipment, trailers, and pulling and tensioning equipment used in stringing conductors, cable pulling, etc.

Minimum air insulation distance (MAID)—The shortest distance in air between an exposed energized conductor or equipment and a grounded surface (cross arm, pole, worker, pole ground, etc.), where the air's insulation will not allow an arc flash from the exposed energized conductor or equipment and the grounded surface. The MAID is dependent on humidity, altitude, air contaminants, smoke, impressed voltage, and transients.

Minimum approach distance (MAD)—The minimum air insulation distance (MAID) plus a factor for inadvertent movement.

Minimum Work Distance (MWD)—Minimum distance that must be maintained from energized lines and apparatus.

Non-Reclose—The certification by the system operator that a specified conductor, cable, or equipment, controlled by the system operator, has had the automatic reclosing disabled, and a non-reclose tag has been placed next to a reclose control switch. A non-reclose order ensures the specified conductor, cable, or equipment will not be re-energized without approval from the clearance holder holding the non-reclose order.

Reach—The distance a worker can reach with hand and fingers fully extended.

System Operator—An authorized employee designated to operate PG&E's T&D system. The system operator has the authority and responsibility for all switching and clearances on distribution and transmission conductors, cables, stations, and equipment, operating at 600 volts and above, owned and operated by PG&E. The system operator issues orders to open and close switches, to place and remove tags, and to de-energize or clear conductors, cables, stations, and equipment on which personnel will work.

Qualified Electrical Worker—One who is knowledgeable in the operation, maintenance and construction of the electric power generation, transmission, and distribution equipment, along with the associated hazards. With proper training they may work in Zones 2 & 3.

Qualified Safety Watch—One whose has been assigned the task of observing the safe work practices of qualified electrical worker(s) performing Live-Line hot-stick work methods. They shall attend a minimum of five days training in Live-Line hot-stick work methods before performing this task. They shall be knowledgeable in the operation, maintenance and construction of the electric power generation, transmission, and distribution equipment involved, along with associated hazards.

3. General Requirements

3.1 A job briefing shall be held with all affected workers involved with Live-Line hot-stick work methods before the work begins. It shall include:

- A detailed discussion of the Live-Line work procedure to be used.
- Identification of all exposed energized conductors and equipment, and the voltages involved at the work site.
- Hazards involved in the planned work.
- The minimum work distance (MWD) for workers and mechanical equipment.
- The required Personal Protective Equipment (PPE).
- The required Live-Line tools, insulating rubber goods, and insulating cover-up equipment.
- The proper set-up location of mechanical equipment.

3.2 All qualified electrical workers shall have a minimum of five days of Live-Line hot-stick work methods training before being allowed to perform Live-Line hot-stick work methods.

3.3 All anticipated conductor loading and weight, dead-end tension, conductor angles, and guying information shall be assembled. Calculations shall be performed to identify how much stress the structure and Live-Line tools must withstand during Live-Line work methods. All Live-Line tools, safety equipment, blocks, ropes, slings, and other associated tools shall be rated, including the proper safety factors, for the anticipated workloads.

3.4 Before beginning any Live-Line hot-stick work procedure, the condition of the structures on either side of the specific work location shall be inspected. The inspection shall include a visual assessment of the condition of the structures, arms, insulators, conductor, tie wires, and hardware. These structures must be capable of withstanding the stress and strain involved with the planned work. If either structure and/or its components are found to be in questionable condition, appropriate measures shall be taken to correct the identified weakness before the planned work begins.

3.5 All Live-Line tools required to perform the planned energized work shall be identified, inventoried, inspected, cleaned, and laid on tool racks or a tarpaulin before work begins. All energized Live-Line hot-stick work shall be performed using the proper length and load rated Live-Line tools and equipment. Any Live-Line tool found to be damaged shall be tagged and removed from service.

3.6 During the performance of Live-Line hot-stick work methods, a qualified safety watch shall be positioned where they can AT ALL TIMES:

- Observe the work and position of the qualified electrical worker(s) performing Live-Line hot-stick work methods;
- Warn the qualified electrical workers if they are about to perform an unsafe act;
- Provide rescue of the worker(s).

The qualified safety watch can be located on the ground if they can perform the duties listed above. However, the qualified safety watch cannot engage in any work or task that would take their total undivided attention away from the qualified electrical worker(s) performing line-line hot-stick work methods.

They must position themselves in a location where they have a clear view of the Live-Line hot-stick work being performed. If the safety watch must leave their position, Live-Line hot-stick work methods shall stop until the qualified safety watch returns to the designated position.

3.7 Live-Line hot-stick work methods shall not be started during inclement weather, including rain, sleet, snow, smoke, fog, and/or heavy winds. If the weather changes after Live-Line hot-stick work methods have begun, the work should continue, if safe, until an appropriate stopping point is reached.

3.8 All Live-Line work methods shall be performed with reclosing disabled.

3.9 If exposed energized distribution conductors and equipment are located within the specific work location, the exposed energized distribution conductors, and equipment shall be covered with rated cover-up and/or relocated to extension arms, depending on the planned work. The energized distribution conductors and equipment must be covered or relocated to:

- Ensure workers can safely climb through the distribution space;
- Allow for any planned rigging and Live-Line tool location set-up;
- Allow the installation of a new structure, if applicable.

3.10 When replacing insulators on energized transmission lines certain safety precautions are required.

- The decision to replace ceramic (porcelain or glass) insulators is usually based on visible damage, such as broken or cracked skirts and/or flashovers.
- When working on or near insulators on energized 60 – 115 kV transmission structures a thorough visual inspection of each insulator is required. Insulators that are heavily contaminated, broken, chipped, cracked, gunshot damaged or that have evidence of flashover damage should be worked around or removed from service with extreme caution. Since energized transmission work is limited to dry conditions and no lightning in the area and the line is on non-test (non-reclose), the maximum switching overvoltage possible is very low. If the line is energized and the insulator or insulators supporting the conductor show no sign of leaking (buzzing or arcing) it can be assumed that the insulator unit is good or healthy and retains all of its dielectric strength. If the visual inspection leaves a concern as to the dielectric strength of the insulator unit, electrical testing of the unit or circuit de-energization may be required.
- When removing a conductor from a pin type “flower pot” insulator that could be damaged, the conductor support tools and equipment should be installed so that the conductor will “float” off the insulator when the tie wire is cut or removed. This will ensure that the conductor does not fall on the arm or arc to the arm pin if the insulator is being held together by the tie wire.
- When removing or replacing post type insulators that could be damaged, the same conductor support strategy should be employed.

- When removing or replacing suspension or dead end ceramic insulators or strings utilizing the hot stick method, the required minimum number of good or not visibly damaged units per insulator string is 4 when working on 60–70 kV structures, and 7 when working on 115 kV structures.
- When removing or replacing nonceramic insulators, a thorough visual inspection of the insulator is required. In addition to the standard insulator inspection criteria, missing or cut sheds should be noted. PG&E has a policy in place that requires electrical testing of all NCI's prior to being used in live line work.

4. Work Zones

PG&E's transmission work areas have been broken into three zones (Zone 1, Zone 2 & Zone 3).

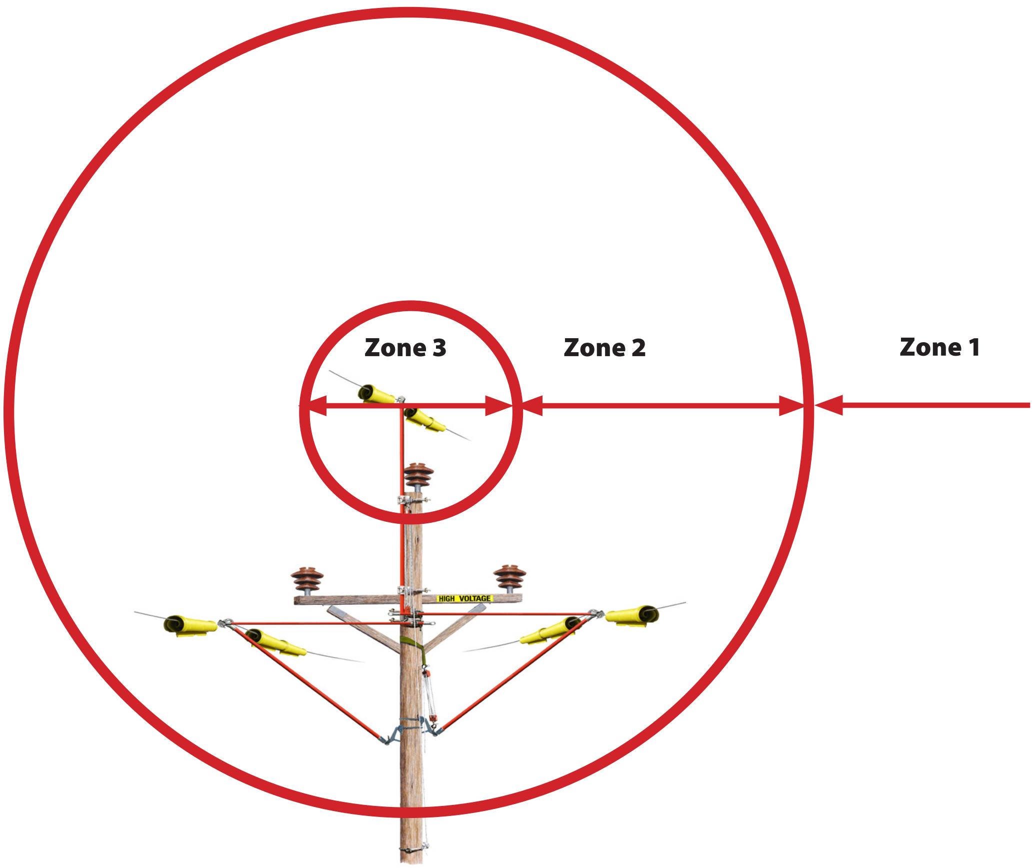

Figure 4.1.

Zone 1

The work area ten feet (10') or more from exposed energized conductors and equipment, energized up to 50 kV. For exposed energized conductors and equipment energized at more than 115 kV the ten foot distance is increased by 0.4 feet/kV (see Table 4.1). If work is to be performed in Zone 1, no workers, mechanical equipment or materials shall come within Zone 2 or Zone 3 without the required additional protection from exposed energized conductors and equipment (see Figure 4.1).

Table 4.1.

kV	Distance (feet)
60	10' 4"
69	10' 7.6"
115	12' 2"

Zone 2

The work area between Zone 1 (the ten foot distance, plus 0.4 feet/kV above 50 kV, and Zone 3, the minimum work distance (MWD). If work is to be performed in Zone 2, workers shall be considered qualified electrical workers, and mechanical equipment or materials shall not enter Zone 3 (the MWD) without additional specifications required for work within Zone 3, the MWD (see Figure 5.1).

Zone 3

The work area inside the MWD. If work is to be performed in Zone 3 the exposed energized conductors and equipment shall be covered with rated cover-up before workers enter the MWD. For voltages where rated cover-up is not available, no workers, mechanical equipment or materials shall enter Zone 3 (see Figure 5.1).

5. Work Positioning

5.1 While performing Live-Line hot stick work methods, workers shall position themselves where they cannot reach into the MWD, or where they will not extend their reach into the MWD. The term "reach" is defined by the distance a worker can reach with hand and fingers fully extended (see Table 5.1). The term "extended reach" is defined by the distance a worker can reach with a conductive object in their hand (screw driver, tape measure, armor rod, etc.) (see Figure 5.1).

Table 5.1

MWD and MWD + Reach		
Nominal Voltage (kV)	MWD Ø – GND with tools	MWD + Reach
46 – 72.5	3' 0"	6' 0"
72.5 – 121	3' 4"	6' 4"

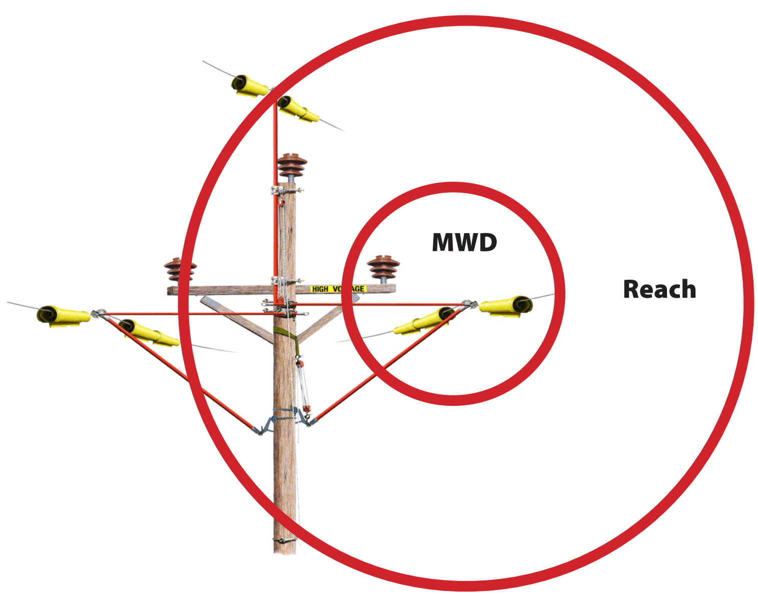

Figure 5.1.

5.2 While performing Live-Line hot stick work methods and procedures, workers will maintain MWD for the voltage class of the structure being worked on from all electrically bonded hardware and apparatus until, or unless the following has been completed:

- The bond wire has been cut with hot stick cutters and the ends separated a minimum of 12".
- The bond wire voltage is tested using an approved voltage tester to be below 1,000 volts. After testing below 1,000 volts, the bond wire may be disconnected or cut and separated by the worker wearing class 2 rubber gloves.
- The bond wire is tested and grounded following approved grounding methods and procedures.
- A cut and separated bond wire cannot be left overnight. It must be reconnected or jumpered using class 2 rubber gloves.

Part 2:

Live-Line Rigging Calculations

Contents

1. Calculate Conductor Weight

Conductor Weight is the weight of the conductor at the support point either on the insulator or in the shoe on suspension insulators. For Live-Line work on tangent structures, you will need to know the weight of a conductor to be lifted or supported. (See **6. PG&E Wire Data**.)

Theoretically the conductor weight consists of half the weight of the two spans adjacent to the structure being worked. To allow for other variables such as wind loading and peakers a safety factor is used. The safety factor is 2 for short spans (250 feet or less) and 1.5 for long spans (250 feet or more). One must not forget that as the conductor is raised from its existing position the weight at the support point increases.

The Calculation

To calculate the conductor weight you take half the length of **Span A** and half of **Span B** or **Span A + Span B** divided by 2, multiply it by the weight of the conductor per foot (see PG&E Wire Data) and multiply it by the **safety factor** (1.5 or 2 depending on span length). This can be stated in the formula:

$$\textbf{Conductor Weight} = \frac{\textbf{Span A + Span B}}{\textbf{2}} \times \textbf{Weight per foot} \times \textbf{Safety Factor}$$

SAFETY FACTOR = 1.5 for spans greater than 250 feet
= 2 for spans less than 250 feet

For example: What is the conductor weight on an H-frame tangent structure, using 477 Hawk conductor, a span of 640 feet one way and 550 feet the other?

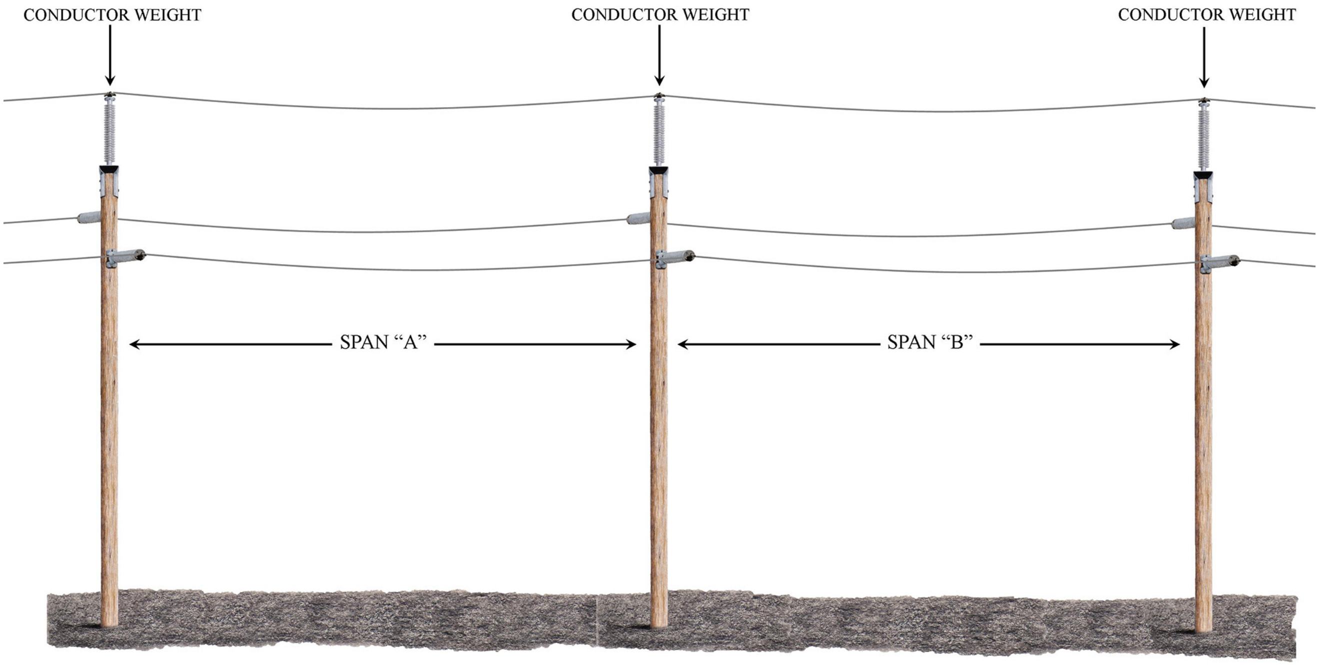

Figure 1.1. Conductor Weight.

Using the formula:

$$\textbf{Conductor Weight} = \frac{\textbf{Span A + Span B}}{\textbf{2}} \times \textbf{Weight per foot} \times \textbf{Safety Factor}$$

From the information given, we can calculate the conductor weight by applying the formula. Span A = 640, span B = 55, Weight per foot = 0.655 (from conductor table in the Live Line Manual), and the Safety Factor = 1.5 because the spans are more than 250 feet.

$$\textbf{Conductor Weight} = \frac{640 + 550}{2} \times 0.655 \times 1.5$$

$$= 595 \times 0.655 \times 1.5 \quad = 584.6 \text{ or } 585 \text{ lbs.}$$

Example: What is the conductor weight on a three-phase lift used to support three 2/0 Quail conductors, with span lengths of 180 feet and 220 feet?

$$\textbf{Conductor Weight} = \frac{180 + 220}{2} \times 0.1831 \times 2$$

$$= 200 \times 0.1831 \times 2 = 73.24 \text{ lbs. per phase}$$
$$= 73.24 \times 3 \text{ (phases)} = 219.72 \text{ or } 220 \text{ lbs.}$$

2. Calculate Conductor Tension

Conductor Tension or **Line Tension** is the pull of the conductor or the force acting on the conductor, which tends to stretch it. When performing Live Line Maintenance on deadend structures, vertical corners, running angles, etc., the conductor tension must be known. In many cases this tension or weight must be supported, and the mechanical load to be imposed on tools must be known.

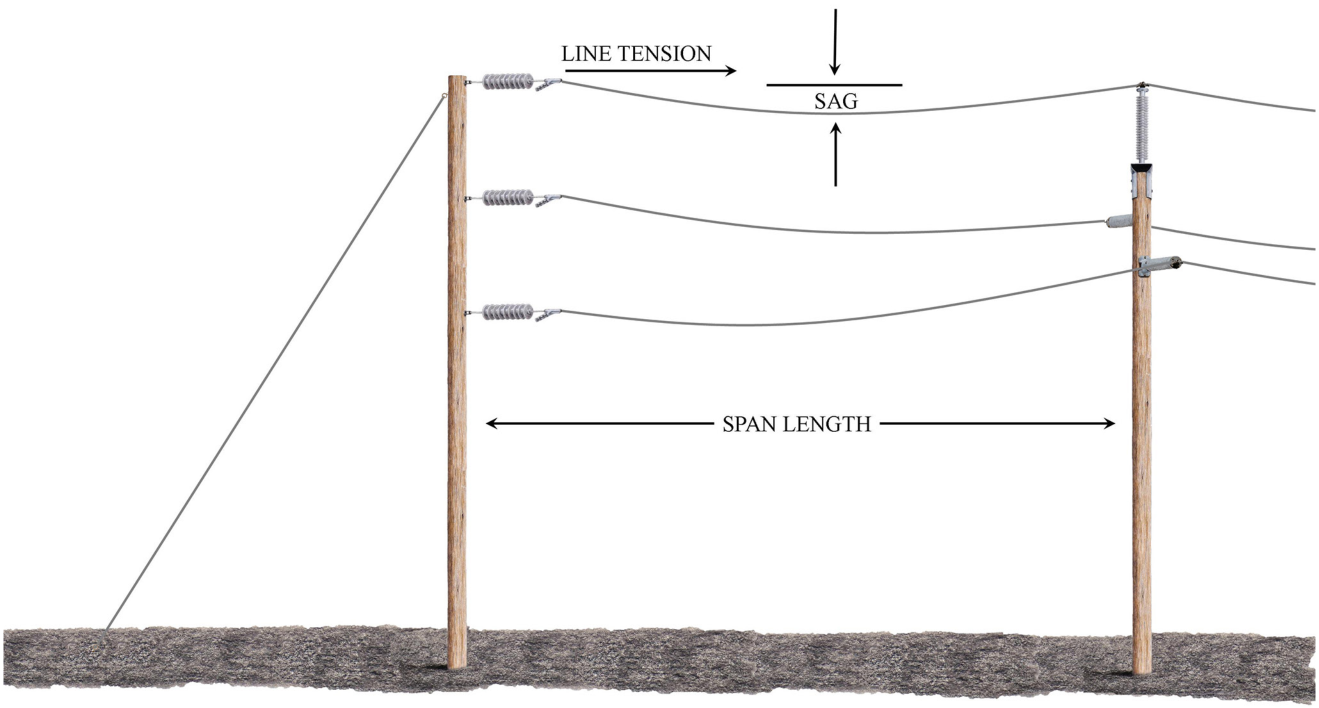

Figure 2.1. Calculate Conductor Tension.

The Calculation

To calculate the conductor tension, you take the **weight of the conductor per foot (W)** (see PG&E Wire Data), multiply it by the **Span Length^2**
(Span Length x Span Length), and divided this by **8** (constant) times the **Sag in feet**. This can be stated by the formula:

$$\textbf{Conductor Tension} = \frac{\mathbf{W \times (Span\ Length)^2}}{\mathbf{8 \times Sag\ in\ Feet}}$$

For Example: What is the Conductor Tension that must be supported to change out a set of broken deadend insulators on a structure where the conductor is 2/0 Quail (weight of conductor per foot is 0.1831 lbs.), the Span Length is 320 feet, and the sag in that span is 6.5 feet?

By applying this information to the formula, we can calculate the Conductor Tension.

$$\text{Conductor Tension} = \frac{W \times (\text{Span Length})^2}{8 \times \text{Sag in Feet}}$$

$$= \frac{0.1831 \times (320)^2}{8 \times 6.5}$$

$$= \frac{18749}{52}$$

Conductor Tension = 360.5 lbs.

Example: What is the Conductor Tension that has to be supported to change the insulators on a transmission deadend where the conductor is 0.477 MCM Hawk (conductor weight per foot is 0.655 lbs.), the Span Length is 1275 feet, and the sag in the span is 35 feet ?

$$\text{Conductor Tension} = \frac{0.655 \times (1275)^2}{8 \times 35}$$

$$= \frac{1064784}{280}$$

Conductor Tension = 3802.8 lbs.

For the second example, it can be seen that the Conductor Tension is more than 3800 lbs., which would require that the rigging and tools be selected carefully in order to support the greater tension. This emphasizes the importance for calculating the forces that will have to be supported. One must also take into consideration the effects of conductor loading. Ice loaded or rain soaked conductors may be considerably heavier than calculated. Also heavily loaded (amperage) conductors could be somewhat lighter than calculated because the increased load heats the conductor and increases the sag. In these cases, rig for heavier anticipated tension to allow for decrease in load as the job progresses.

3. Calculate the Compressive Force on a Deadend Pole

To choose the correct rigging method and apparatus, it is important to understand the forces acting on a deadend pole.

Compressive Force is the downward force on a pole resulting from the addition of a down guy to support the line tension. The tension in the guy and the line tension wants to straighten the conductor out, so the pull is in a straight line as shown below. If the pole was guyed horizontally, the tension in the guy would equal the tension in the conductor. There would be no compressive force acting down on the pole, other than conductor weight. However, guys increase the compressive force by pulling down on the pole.

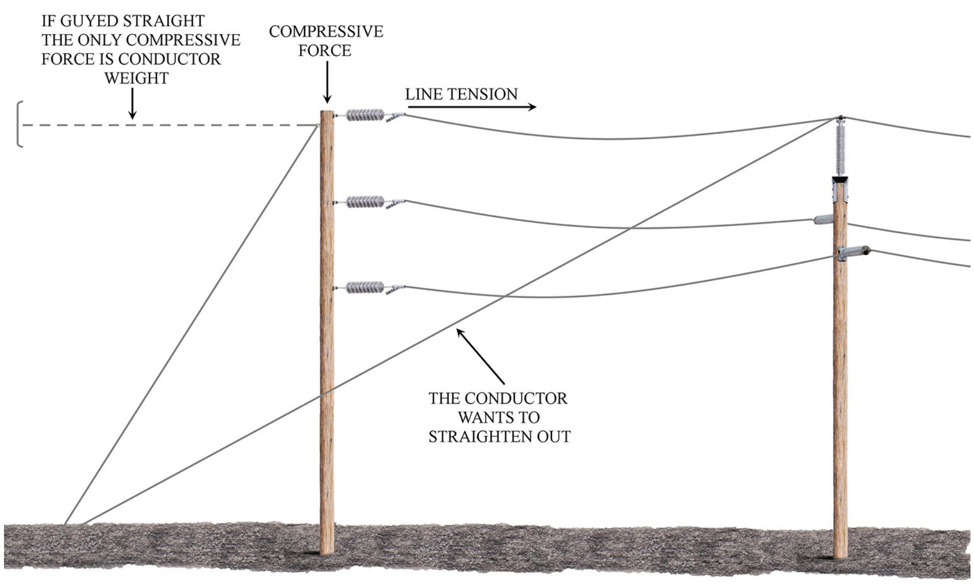

Figure 3.1. Compressive Forces.

The Calculation

To calculate the compressive force of a pole, you take the line tension, divide it by the distance from the anchor head to the butt of the pole (anchor distance), and multiply it by the height of the pole. This can be stated by the formula:

$$\textbf{Compressive Force} = \frac{\textbf{Line Tension}}{\textbf{Anchor Distance}} \times \textbf{Pole Height}$$

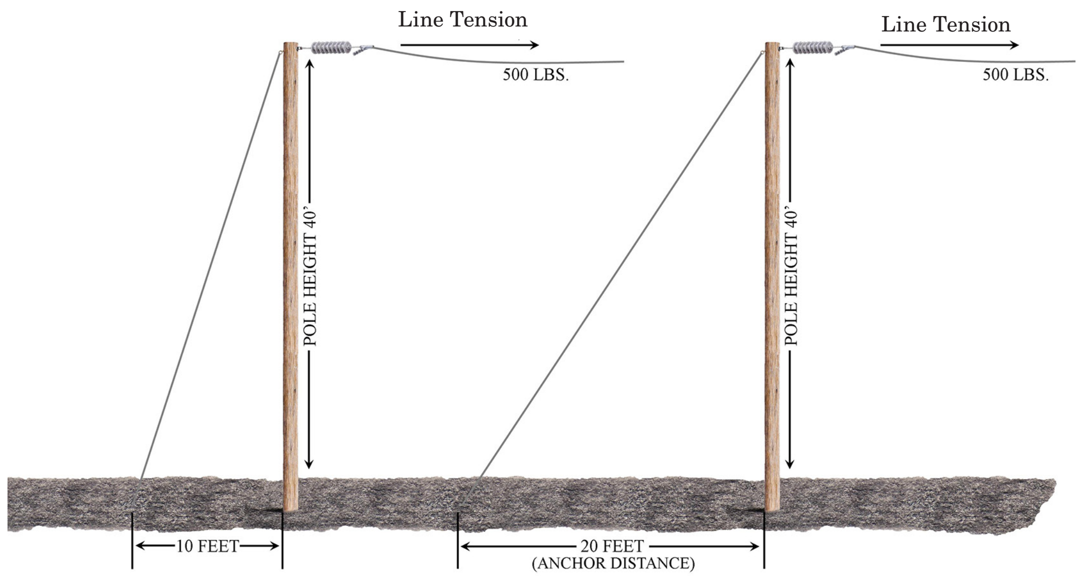

Figure 3.2. Anchor Distance. Figure 3.3.

For example: What is the compressive force of the pole in Figure 3.2 above?

By applying the formula:

$$\textbf{Compressive Force} = \frac{\textbf{Line Tension}}{\textbf{Anchor Distance}} \times \textbf{Pole Height}$$

$$\textbf{Compressive Force} = \frac{500}{10} \times 40 = 50 \times 40 = 2000 \text{ lbs.}$$

Example: What is the compressive force on the pole in Figure 3.3 above?

$$\textbf{Compressive Force} = \frac{500}{20} \times 40 = 25 \times 40 = 1000 \text{ lbs.}$$

It can be seen from the two examples, that by increasing the anchor distance the compressive force is reduced. In this case by doubling the anchor distance, the compressive force is cut in half.

Example: What is the compressive force on a three-phase deadend pole, given three conductors with a line tension of 475 lbs. each, an anchor distance of 12 feet and a pole height of 38 feet?

$$\textbf{Total Line Tension} = 3 \times 475 = 1425 \text{ lbs.}$$

$$\textbf{Compressive Force} = \frac{1425}{12} \times 38 = 118.75 \times 38 = 4512.5 \text{ lbs.}$$

4. Working Loads for Principal Hot Line Tools

The maximum load any hot line tool will support without danger of breaking, depends upon the position of the tool on the structure and its relation to other tools used in conjunction with it.

The following tables and accompanying figures show the maximum loads that can be applied to wire tongs when used as pictured. In the case of link sticks and miscellaneous tools, the load values given in the tables refer to the normal direct loads that can be applied. Loading for certain variations can be readily calculated; however, caution should be exercised when loading a tool near the limit given in the tables.

The maximum working load given in the wire tong table represents the actual breaking load as determined by tests, less 15 percent for possible variations in the structure, and the result divided by a safety factor of 2. When it becomes necessary to use wire tongs to handle larger wire sizes or larger spans than the ones mentioned in the table, double tongs should be employed. Where small diameter tongs are listed, a larger diameter tong should be selected.

It should be remembered that loading increases considerably at hilltop structures, the extra weight depending upon the steepness of the line grade. It is possible that this force may exceed the weight of the conductor; therefore, hilltop and other unusual problems require special analysis in the selection of wire tongs.

LINK STICKS — WORKING LOADS		
Type	**Pole Diameter (In inches)**	**Max. Work. Load (in Pounds)**
Strain	1-1/4	3500
Strain	1-1/2	6500
Roller	1-1/4	1000

MISCELLANEOUS TOOLS —WORKING LOADS	
Tool	**Max. Working Load (in Pounds)**
Wire Tong Saddle	1000
Wire Tong Saddle Ext.	800
Extension Chain	2500
Rope Snubbing Bracket	1000
Single Lever Lift	1500
Double Lever Lift	750 (each trunnion)
Two-Pole Strain Carrier	15,000 (Epoxiglas)
Aerial Platform	500
Rope Blocks	3500

WIRE TONGS — WORKING LOADS									
Fig. No.	**Diameter (in inches)**			**TYPE SUPPORT**	**Max. Working Load (lbs. Per Conductor)**	**Max. Wire Size and Span (in Feet / Level Ground)**			
						ACSR		**CPR**	
	“A”	**“B”**	**“C”**			**Size**	**Span**	**Size**	**Span**
4.1	1-1/2 x 10	2 x 12		Saddle	275	4/0	700	4/0	300
	1-1/2 x 10	2-1/2 x 12		Lever Lift	475	4/0	1200	4/0	500
	1-1/2 x 10	3 x 12		Saddle	600	2 in.	—	2 in.	—
	1-1/2 x 10	3 x 12		Lever Lift	850	2 in.	—	2 in.	—
	1-1/2 x 10	3 x 14		Saddle	600	2 in.	—	2 in.	—
	1-1/2 x 10	3 x 14		Lever Lift	700	2 in.	—	2 in.	—
	1-1/2 x 12	3 x 16		Saddle	600	2 in.	—	2 in.	—
	1-1/2 x 12	3 x 16		Lever lift	550	2 in.	—	2 in.	—
				Saddle	275	4/0	700	4/0	300
				Lever Lift	475	4/0	1200	4/0	500
4.2	1-1/2	2 x 12		Lever Lift	350	4/0	850	4/0	375
	1-1/2	2-1/2 x 12		Lever Lift	1000	397.5	1150	250	850
	1-1/2	3 x 12		Lever Lift	1000	2 in.	—	2 in.	—
	1-1/2	3 x 14		Lever Lift	1000	2 in.	—	2 in.	—
	1-1/2	3 x 16		Lever Lift	1000	2 in.	—	2 in.	—
4.3	2 x 8	2-1/2 x 12		Saddle	225*	4/0	550	4/0	230
4.4	2-1/2	—	—	Saddle	500	4/0	1250	4/0	525

* With maximum lift of 5 feet above saddle, Max. unbalance of 225 lbs. on one side.

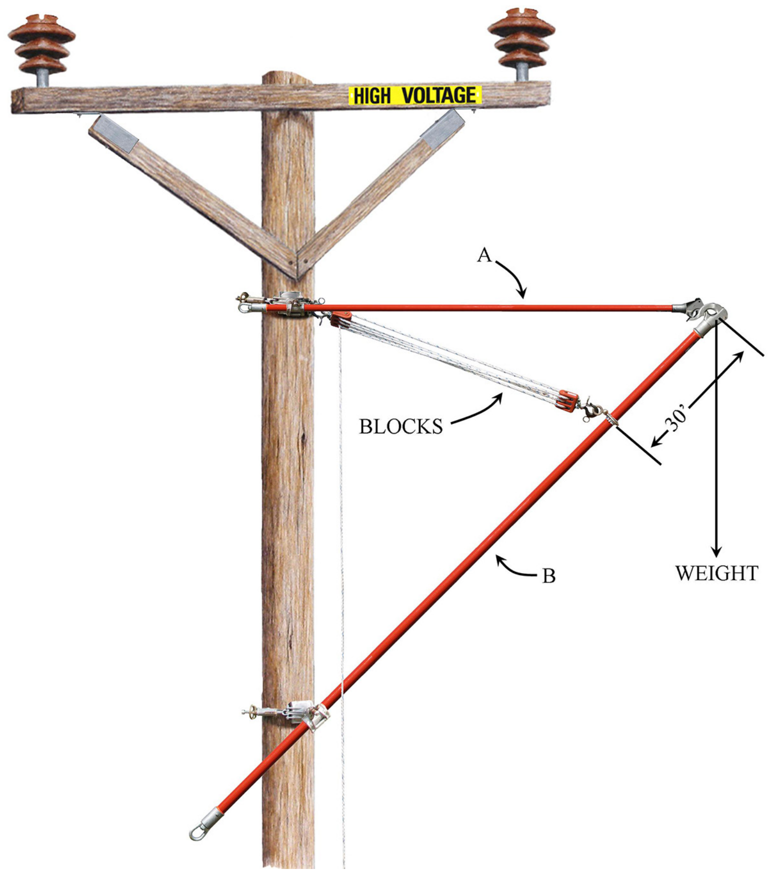

Figure 4.1. Wire tong working loads.

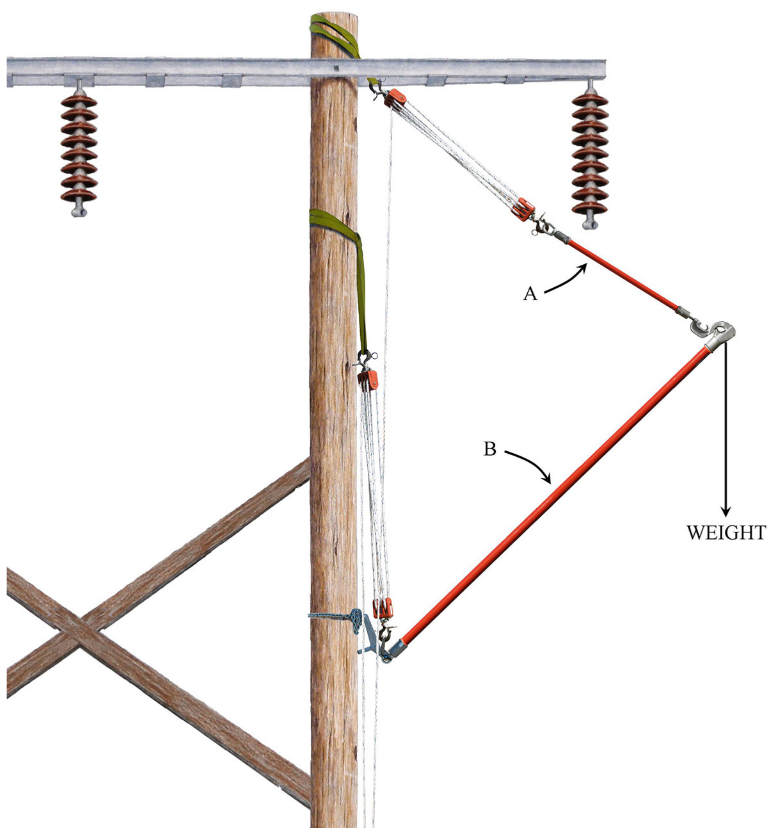

Figure 4.2. Wire tong working loads.

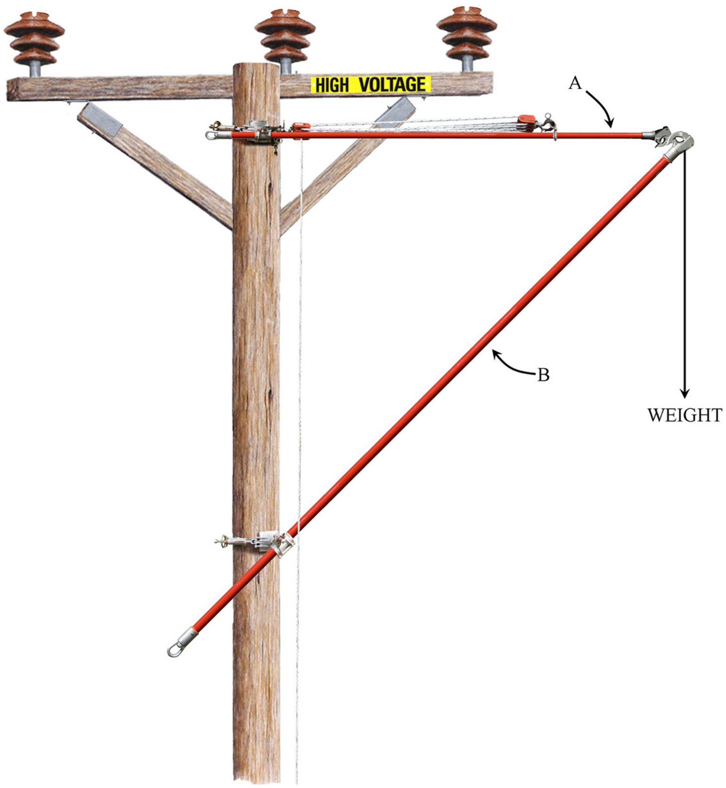

Figure 4.3. Wire tong working loads.

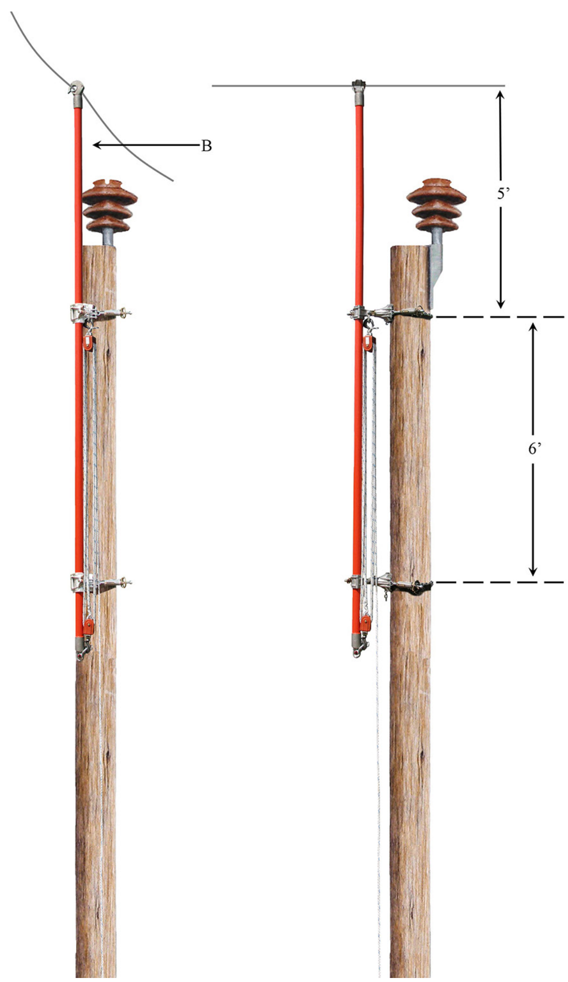

Figure 4.4. Wire tong working loads.

5. Calculate Weights & Forces on Live Line Tools

Calculating the demands placed upon live line tools, the lineman must know and be able to apply all the calculations for weights and forces previously discussed. Each job will require careful consideration of all weights and forces present that will have to be moved or supported. In some cases the calculations (compressive force for example) can be used to find the force applied to a tool instead of a pole and will be shown here. The following are examples of typical live line jobs and will illustrate different rigging methods and the weights and forces present for each situation.

Single Ø Tangent Insulator Change

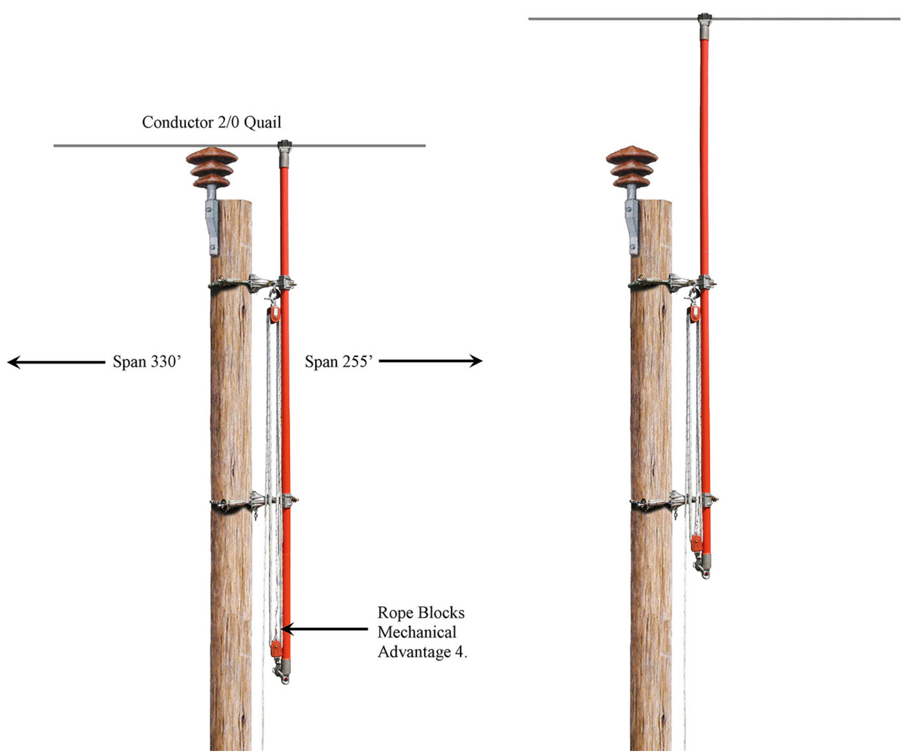

Figure 5.1.

Figure 5.1 illustrates the moving of a single phase conductor using a 2-1/2" wire tong and a set of rope blocks with a mechanical advantage of 4. The weights and forces involved in this job are: conductor weight,; compressive force on the wire tong; the pull on the fall line of the rope blocks; and the weight on the saddles.

- What is the conductor weight to be lifted with the wire tong?

$$\textbf{Conductor Weight} = \frac{\textbf{Span A + Span B}}{\textbf{2}} \times \textbf{Weight Cond. per ft.} \times \textbf{S.F.}$$

$$\textbf{Conductor Weight} = \frac{330 + 255}{2} \times 0.1831 \times 1.5 = \frac{525}{2} \times 0.1831 \times 1.5$$

$$= 292.5 \times 0.1831 \times 1.5 = 53.56 \times 1.5 = 80.34 \text{ lbs.}$$

- What is the compressive force (weight) on the wire tong?

Compressive Force = Conductor Weight = 80.34 lbs.

- What is the pull on the fall line required to lift the wire tong?

The weight to be lifted with the rope blocks is 80.34 or 80 lbs., and the mechanical advantage of the blocks is 4.

$$\textbf{Pull on Fall Line} = \frac{\textbf{Weight to be Lifted}}{\textbf{Mechanical Advantage}} + \textbf{10\% of weight}$$

$$\textbf{Pull on Fall Line} = \frac{80}{4} + 8 = 20 + 8 = 28 \text{ lbs.}$$

- What is the weight on the saddle if the rope blocks were attached to the shackle?

Weight on Saddle = Conductor Weight + Pull on Fall Line

Weight on Saddle = 80 + 28 = 108 lbs.

It can be seen that the weights involved in this job are within the ratings of all tools. The weight of 108 lbs. on the saddle is well within the rating of the saddle (1000 lbs., or 800 lbs. with extension). To reduce the weight on the saddle a recommended practice is to attach the blocks to a sling installed around the pole.

Tangent X-arm Insulator Change

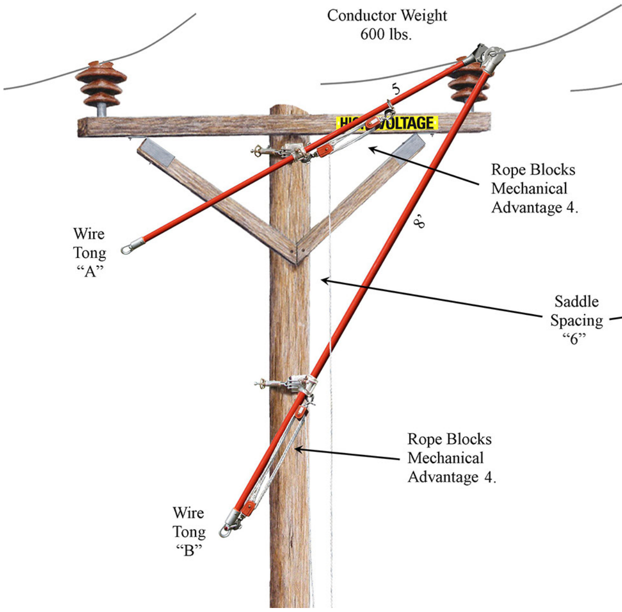

Figure 5.2.

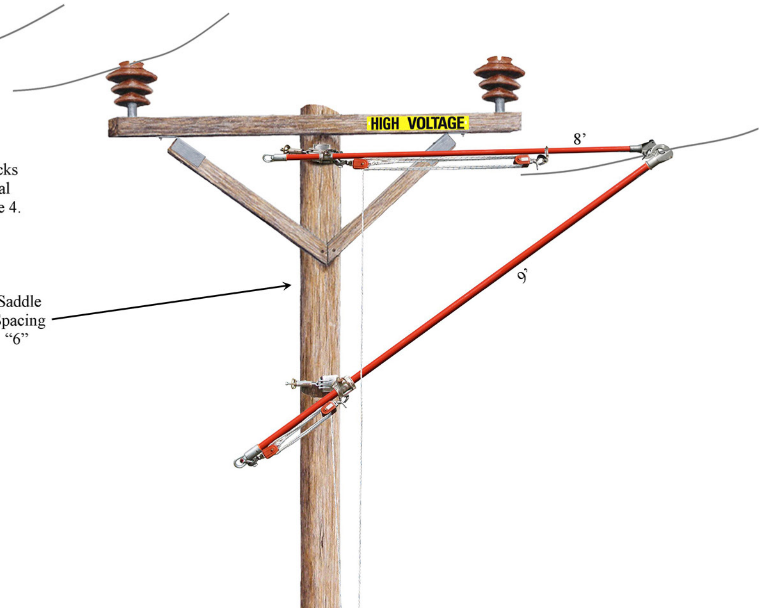

Figure 5.3.

Figures 5.2 and 5.3 show the rigging used to change the insulator on an X-arm using a 1-1/2" wire tong "A", and a 2-1/2" wire tong "B". The rope blocks used to support wire tong "A" have mechanical advantage of 4; and the blocks on wire tong "B" have a mechanical advantage of 4. The conductor weight is 600 lbs., which applies tension to wire tong "A" and compressive force to wire tong "B".

To calculate the tension on wire tong "A" in Figure 5.2, remember how you calculated guy tension previously and apply the same formula here. Consider wire tong "A" to be the guy wire; wire tong "B" to be the pole; the saddle spacing to be the anchor distance; and the conductor weight to be the line tension. By substituting these into the guy tension formula, the tension on wire tong "A" can be calculated.

$$\textbf{Guy Tension} = \frac{\textbf{Line Tension}}{\textbf{Anchor Distance}} \times \textbf{Guy Length}$$

$$\textbf{Tension Wire Tong "A"} = \frac{\textbf{Conductor Weight}}{\textbf{Saddle Spacing}} \times \textbf{Length Wire Tong "A"}$$

$$\textbf{Tension Wire Tong "A"} = \frac{600 \times 5}{6} = 100 \times 5 = \textbf{500 lbs. Tension}$$

To calculate the compressive force on wire tong "B" in Figure 5.2, remember how you calculated compressive force on a pole previously and apply the same formula here. Consider wire tong "A" to be the guy wire; wire tong "B" to be the pole; the saddle spacing to be the anchor distance; and the conductor weight to be the line tension.
By substituting these into the compressive force formula, the compressive force on wire tong "B" can be calculated.

$$\textbf{Compressive Force} = \frac{\textbf{Line Tension}}{\textbf{Anchor Distance}} \times \textbf{Pole Height}$$

$$\textbf{Compression Wire Tong "B"} = \frac{\textbf{Conductor Weight}}{\textbf{Saddle Spacing}} \times \textbf{Length Wire Tong "B"}$$

$$\textbf{Compression Wire Tong "A"} = \frac{600}{6} \times 8 = 100 \times 8 = \textbf{800 lbs. Compression}$$

- What is the tension on wire tong "A" in Figure 5.3?

$$\textbf{Tension Wire Tong "A"} = \frac{\textbf{Conductor Weight}}{\textbf{Saddle Spacing}} \times \textbf{Length Wire Tong "A"}$$

$$\textbf{Tension Wire Tong "A"} = \frac{600}{6} \times 8 = 100 \times 8 = \textbf{800 lbs. Tension}$$

- What is the compressive force on wire tong "B" in Figure 5.3?

$$\textbf{Compression Wire Tong "B"} = \frac{\textbf{Conductor Weight}}{\textbf{Saddle Spacing}} \times \textbf{Length Wire Tong "B"}$$

$$\textbf{Compression Wire Tong "A"} = \frac{600}{6} \times 9 = 100 \times 9 = \textbf{900 lbs. Compression}$$

- What is the pull on the fall line of the rope blocks required to move wire tong "A" in Figure 5.2?

$$\textbf{Pull on Fall Line} = \frac{\textbf{Weight to be Lifted}}{\textbf{Mechanical Advantage}} + \textbf{10\% of weight}$$

$$\textbf{Pull on Fall Line} = \frac{500}{4} + 50 = 125 + 50 = \textbf{175 lbs.}$$

- What is the pull on the fall line of the rope block required to move wire tong "B" in Figure 5.2?

$$\text{Pull on Fall Line} = \frac{\text{Weight to be Lifted}}{\text{Mechanical Advantage}} + 10\% \text{ of weight}$$

$$\text{Pull on Fall Line} = \frac{800}{5} + 80 = 160 + 80 = 240 \text{ lbs.}$$

- What is the pull on the fall line of the rope blocks required to move wire tong "A" in Figure 5.3?

$$\text{Pull on Fall Line} = \frac{\text{Weight to be Lifted}}{\text{Mechanical Advantage}} + 10\% \text{ of weight}$$

$$\text{Pull on Fall Line} = \frac{800}{4} + 80 = 200 + 80 = 280 \text{ lbs.}$$

- What is the pull on the fall line of the rope block required to move wire tong "B" in Figure 5.3?

$$\text{Pull on Fall Line} = \frac{\text{Weight to be Lifted}}{\text{Mechanical Advantage}} + 10\% \text{ of weight}$$

$$\text{Pull on Fall Line} = \frac{900}{5} + 90 = 180 + 90 = 270 \text{ lbs.}$$

It can be seen from the above examples that as the conductor is moved out away from the pole the tension and compressive force on the wire tongs increases. If the saddle spacing was reduced to 3 feet, the weight per foot on the triangle would double to 200 lbs., and therefore the tension and compressive force on the wire tongs would double. This demonstrates the importance of spacing the saddles as far apart as possible to reduce the loads placed upon tools.

H-Frame Insulator Change

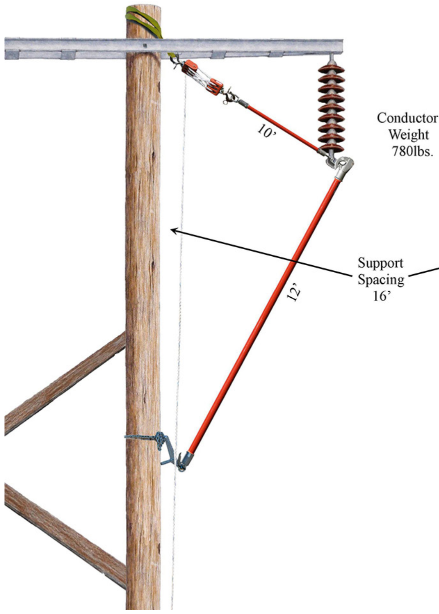

Figure 5.4.

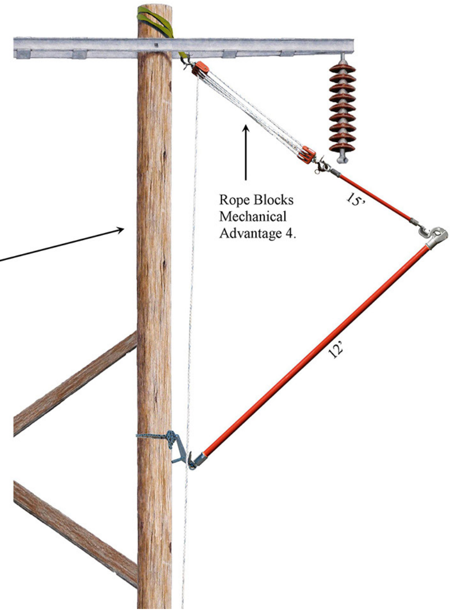

Figure 5.5.

Figures 5.4 and 5.5 show the rigging used to change a set of insulators on an H-frame structure using a 2-1/2" x 12-inch wire tong and a 1-1/2" link stick attached to a set of rope blocks with a mechanical advantage of 4. The conductor weight to be supported is 780 lbs., which applies a tension to the rope blocks and link stick, and compressive force to the wire tong.

To calculate the tension on the rope blocks and link stick in Figure 5.4, remember how you calculated guy tension previously and apply the same formula here. Consider the rope blocks and link stick to be the guy wire; the wire tong to be the pole; the support spacing to be the anchor distance; and the conductor weight to be the line tension.
By substituting these into the guy tension formula, the tension on the rope blocks and link stick can be calculated.

$$\textbf{Guy Tension} = \frac{\textbf{Line Tension}}{\textbf{Anchor Distance}} \times \textbf{Guy Length}$$

$$\textbf{Tension Link Stick} = \frac{\textbf{Conductor Weight}}{\textbf{Support Spacing}} \times \textbf{Length Blocks \& Link Stick}$$

$$\textbf{Tension Link Stick} = \frac{780}{16} \times 10 = 48.75 \times 10 = \textbf{487.5 lbs. Tension}$$

To calculate the compressive force on the wire tong in Figure 5.4, remember how you calculated compressive force on a pole previously and apply the same formula here. Consider the rope blocks and link stick to be the guy wire, the wire tong to be the pole, the support spacing to be the anchor distance, and the conductor weight to be the line tension. By substituting these into the compressive force formula, the compressive force on the wire tong can be calculated.

$$\text{Compressive Force} = \frac{\text{Line Tension}}{\text{Anchor Distance}} \times \text{Pole Height}$$

$$\text{Compression Wire Tong} = \frac{\text{Conductor Weight}}{\text{Support Spacing}} \times \text{Length Wire Tong}$$

$$\text{Compression Wire Tong} = \frac{780}{16} \times 12 = 48.75 \times 12 = 585 \text{ lbs. Compression}$$

- What is the tension on the rope blocks and link stick in Figure 5.5?

$$\text{Tension Link Stick} = \frac{\text{Conductor Weight}}{\text{Support Spacing}} \times \text{Length Blocks \& Link Stick}$$

$$\text{Tension Link Stick} = \frac{780}{16} \times 15 = 48.75 \times 15 = 731.25 \text{ lbs. Tension}$$

- What is the compressive force on the wire tong in Figure 5.5?

  The compressive force on the wire tong remains the same as the length on the wire tong, support spacing and conductor weight remains the same.

- What is the pull on the fall line of the rope blocks required to move the conductor in Figure 5.4?

$$\text{Pull on Fall Line} = \frac{\text{Weight to be Lifted}}{\text{Mechanical Advantage}} + 10\% \text{ of weight}$$

$$\text{Pull on Fall Line} = \frac{487.5}{4} + 48.75 = 121.88 + 48.75 = 170.63 \text{ lbs.}$$

- What is the pull on the fall line of the rope block required to move the conductor in Figure 5.5?

$$\text{Pull on Fall Line} = \frac{731.25}{4} + 73.12 = 182.81 + 73.12 = 255.93 \text{ lbs.}$$

Single Ø Angle Insulator Change

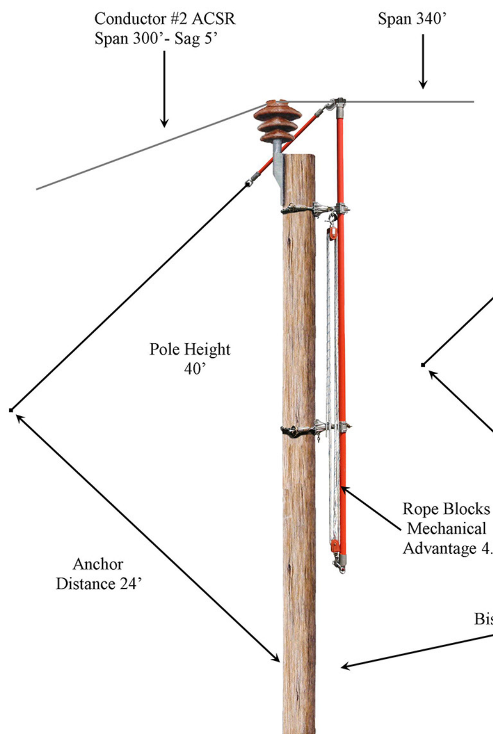

Figure 5.6.

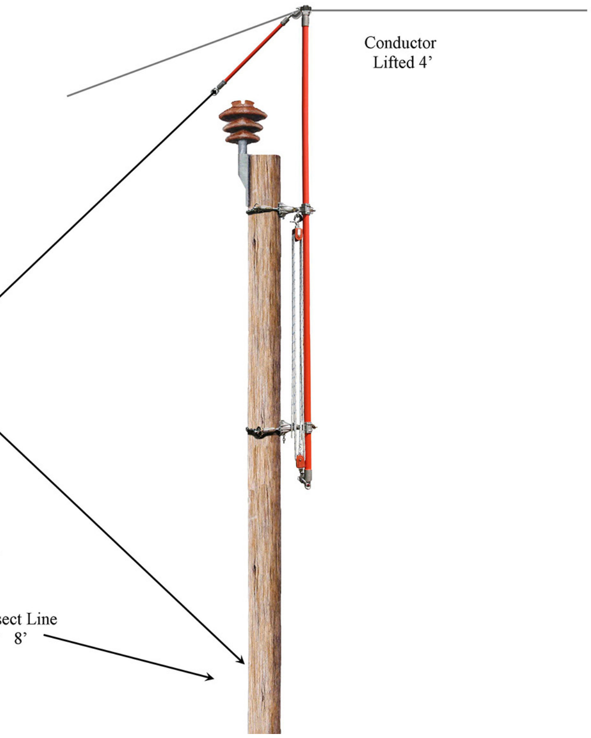

Figure 5.7.

Figures 5.6 and 5.7 illustrate a single phase angle insulator change using a 2-1/2" x 12-foot wire tong, a roller link stick with a guy rope, and a set of rope blocks with a mechanical advantage of 4. In this job the weights and forces involved are: conductor weight; line tension; bisect tension; tension on the roller link stick and guy rope; the compressive force on the wire tong; pull on the fall line of the rope blocks; and the weight on the saddles. As the conductor is moved up 4 inches to allow for working clearance the forces change on the equipment.

- What is the weight of the conductor at the point of lifting?

$$\text{Conductor Weight} = \frac{\text{Span "A"} + \text{Span "B"}}{2} \times \text{Weight of Cond. per ft.} \times \text{S.F.}$$

$$\text{Conductor Weight} = \frac{300 + 340}{2} \times 0.0913 \times 1.5 = \frac{640}{2} \times 0.0913 \times 1.5$$

$$= 320 \times 0.0913 \times 1.5 = 29.2 \times 1.5 = 43.9 \text{ lbs.}$$

- What is the line tension that has to be calculated to find the bisect tension?

$$\textbf{Line Tension} = \frac{\textbf{Weight of Cond. per ft. x (Span)}^2}{\textbf{8 x Sag in ft.}}$$

$$\textbf{Line Tension} = \frac{0.0913 \times (300)^2}{8 \times 5} = \frac{0.0913 \times 90000}{40} = \frac{8217}{40} = 205.4 \text{ lbs.}$$

- What is the bisect tension of the angle shown in Figures 5.6 and 5.7?

$$\textbf{Bisect Tension} = \frac{\textbf{Line Tension}}{\textbf{50}} \times 2 \times \textbf{Bisect Line}$$

$$\textbf{Bisect Tension} = \frac{205.4}{50} \times 2 \times 8 = 4.1 \times 2 \times 8 = 8.2 \times 8 = 65.6 \text{ lbs.}$$

- What is the tension on the roller link stick and guy rope used to support the bisect tension in Figure 5.6?

  In order to find the tension on the roller link and guy rope the length must first be calculated.

$$\textbf{Guy Length} = \sqrt{\textbf{Anchor Distance}^2 + \textbf{Pole Height}^2}$$

$$\textbf{Guy Length} = \sqrt{24^2 + 40^2} = \sqrt{576 + 1600} = \sqrt{2176} = 46.65 \text{ feet}$$

$$\textbf{Guy Tension} = \frac{\textbf{Line Tension}}{\textbf{Anchor Distance}} \times \textbf{Guy Length}$$

In this case the roller link stick and guy rope are supporting only the bisect tension and therefore, we substitute bisect tension for line tension in the guy tension formula.

$$\textbf{Guy Tension} = \frac{\textbf{Bisect Tension}}{\textbf{Anchor Distance}} \times \textbf{Guy Length}$$

$$\textbf{Guy Tension} = \frac{65.6}{24} \times 46.65 = 2.73 \times 46.65 = 127.35 \text{ lbs.}$$

- What is the tension on the roller link stick and guy rope used to support the bisect tension in Figure 5.7?

  Because the conductor was lifted 4 feet, the guy length increased and has to be recalculated.

$$\text{Guy Length} = \sqrt{\text{Anchor Distance}^2 + \text{Pole Height}^2}$$

$$\text{Guy Length} = \sqrt{24^2 + 44^2} = \sqrt{576 + 1936} = \sqrt{2512} = 50.12 \text{ feet}$$

$$\text{Guy Tension} = \frac{\text{Bisect Tension}}{\text{Anchor Distance}} \times \text{Guy Length}$$

$$\text{Guy Tension} = \frac{65.6}{24} \times 50.12 = 2.73 \times 50.12 = 136.8 \text{ lbs.}$$

- What is the total compressive force on the wire tong in Figure 5.6?

$$\text{Compressive Force} = \frac{\text{Bisect Tension}}{\text{Anchor Distance}} \times \text{Pole Height}$$

$$\text{Compressive Force} = \frac{65.6}{24} \times 40 = 2.73 \times 40 = 109.2 \text{ lbs.}$$

The 109.2 lbs. is the compressive force applied to the wire tong supporting the bisect tension. To find the total compressive force on the wire tong, we add the compressive force and the conductor weight.

$$\text{Total Compressive Force} = \text{Compressive Force} + \text{Conductor Weight}$$

$$\text{Total Compressive Force} = 103.2 + 43.9 = 153.1 \text{ lbs.}$$

- What is the total compressive-force on the wire tong after the conductor has been moved up 4" as shown in Figure 5.7?

$$\text{Compressive Force} = \frac{\text{Bisect Tension}}{\text{Anchor Distance}} \times (\text{Pole Height} + 4)$$

$$\text{Compressive Force} = \frac{65.6}{24} \times (40 + 4) = 2.73 \times 44 = 120.12 \text{ lbs.}$$

$$\text{Total Compressive Force} = \text{Compressive Force} + \text{Conductor Weight}$$

$$\text{Total Compressive Force} = 120.1 + 43.9 = 164 \text{ lbs.}$$

- What is the pull required on the fall line of the rope blocks to lift the wire with the wire tong in Figure 5.6?

$$\textbf{Pull on Fall Line} = \frac{\textbf{Weight to be Lifted}}{\textbf{Mechanical Advantage}} + \textbf{10\% of Weight}$$

$$\textbf{Pull on Fall Line} = \frac{153}{4} + 15.3 = 38.25 + 15.3 = 53.55 \textbf{ lbs.}$$

- What is the pull on the fall line of the rope blocks in Figure 5.7?

$$\textbf{Pull on Fall Line} = \frac{\textbf{Weight to be Lifted}}{\textbf{Mechanical Advantage}} + \textbf{10\% of Weight}$$

$$\textbf{Pull on Fall Line} = \frac{164}{4} + 16.4 = 41 + 16.4 = 57.4 \textbf{ lbs.}$$

- What is the weight on the saddles in Figure 5.6 if the rope blocks were attached to the saddle clevis?

Weight on Saddle = Compression on Wire Tong + Pull on Fall Line

Weight on Saddle = 120.1 + 57.4 = 177.5 lbs.

- What is the weight on the saddles in Figure 5.7 if the rope blocks were attached to the saddle clevis?

Weight on Saddle = Compression on Wire Tong + Pull on Fall Line

Weight on Saddle = 164 + 57.4 = 221.4 lbs.

From the above examples, it can be seen that as the conductor is moved up for working clearance the weights and forces on all the equipment increases. It is important, when calculating the weights and forces to be handled, that they are calculated for both the conductor in the original position and for the conductor at the moved position. If in this job the weights and forces were heavier, they may exceed equipment ratings in the moved position.

Cross Arm Angle Insulator Change

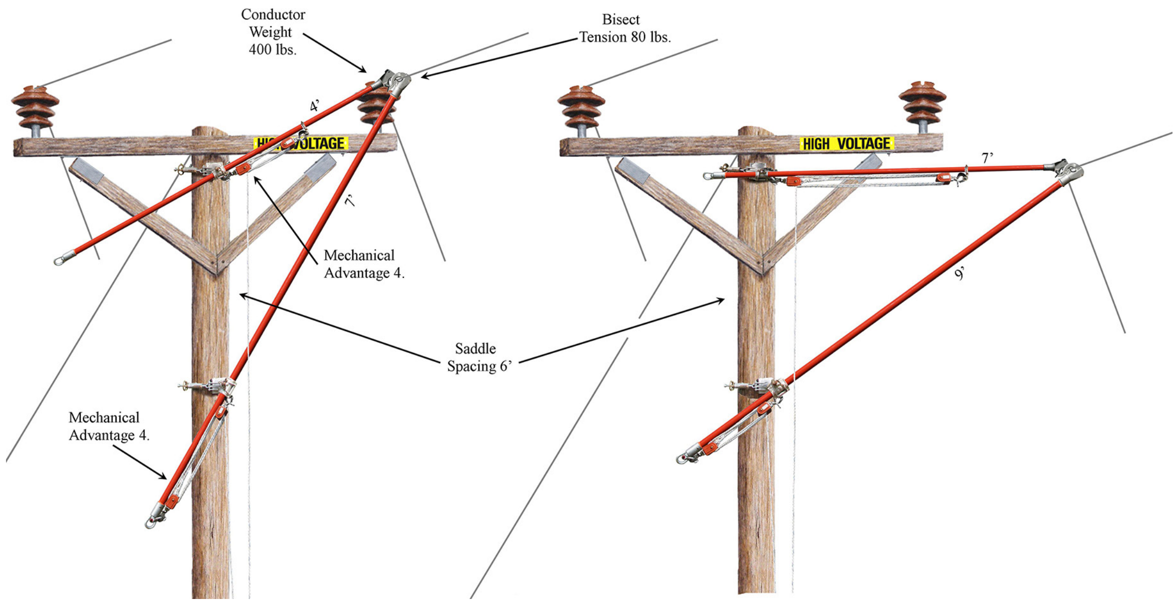

Figure 5.8. Figure 5.9.

Figures 5.8 and 5.9 show the rigging used to change the insulator on the cross arm of an angle structure, using a 1-1/2" x 10-foot wire tong ("A") with a set of rope blocks supporting the tension having a mechanical advantage of 4; and a 2-1/2" x 12-foot wire tong ("B") under compression of the conductor weight. A set of rope blocks with a mechanical advantage of 4 is used to support this weight.

The saddle spacing is 6 feet, the conductor weight is 400 lbs., and the bisect tension of the corner is 80 lbs. For this job we need to know the tension on wire tong "A" in Figure 5.8; the pull on the fall line of the rope blocks supporting this tension; the compression on wire tong "B" to Figure 5.8; the pull on the fall line of the rope blocks on wire tong "B" in Figure 5.8; and the weights on the saddles of both wire tongs in Figure 5.8 if the rope blocks are attached to the saddle clevis. Finally, we need to know how all these weights and forces will change when the conductor is moved out to provide working clearance as shown in Figure 5.9.

- What is the tension on the wire tong "A" in Figure 5.8?

$$\textbf{Tension} = \frac{\textbf{Conductor Weight}}{\textbf{Saddle Spacing}} \times \textbf{Wire Tong Length}$$

$$\textbf{Tension} = \frac{400}{6} \times 4 = 66.7 \times 4 = 266.7 \textbf{ lbs.}$$

- Wire tong "A" is also supporting the bisect tension, so this must be added to the tension on the wire tong from the conductor weight to find the total tension on the wire tong.

$$\textbf{Tension Wire Tong "A"} = 266.7 + 80 = 346.7 \text{ lbs.}$$

- What is the pull on the fall line of the rope blocks on wire tong "A" in Figure 5.8?

$$\text{Pull on Fall Line} = \frac{\text{Weight to be Lifted}}{\text{Mechanical Advantage}} + \text{10\% of Weight}$$

$$\text{Pull on Fall Line} = \frac{347}{4} + 34.7 = 86.75 + 34.7 = 121.45 \text{ lbs.}$$

- What is the compressive force on wire tong "B" in Figure 5.8?

$$\text{Compression} = \frac{\text{Conductor Weight}}{\text{Saddle Spacing}} \times \text{Wire Tong Length}$$

$$\text{Compression} = \frac{400}{6} \times 7 = 66.7 \times 7 = 466.9 \text{ lbs.}$$

- What is the pull on the fall line of the rope blocks on wire tong "B" in Figure 5.8?

$$\text{Pull on Fall Line} = \frac{\text{Weight to be Lifted}}{\text{Mechanical Advantage}} + \text{10\% of Weight}$$

$$\text{Pull on Fall Line} = \frac{467}{4} + 46.7 = 116.75 + 46.7 = 163.45 \text{ lbs.}$$

- What is the weight on the saddle of wire tong "A" in Figure 5.8, if the rope blocks were attached to the clevis on the saddle?

$$\text{Weight on Saddle} = \text{Tension} + \text{Pull on Fall Line}$$

$$\text{Weight on Saddle} = 346.7 + 121.45 = 468.15 \text{ lbs.}$$

- What is the weight on the saddle of wire tong "B" in Figure 5.8, if the rope blocks were attached to the clevis on the saddle?

$$\text{Weight on Saddle} = \text{Tension} + \text{Pull on Fall Line}$$

$$\text{Weight on Saddle} = 466.9 + 163.45 = 630.35 \text{ lbs.}$$

- What is the tension on wire tong "A" in Figure 5.9?

$$\textbf{Tension} = \frac{\textbf{Conductor Weight}}{\textbf{Saddle Spacing}} \times \textbf{Wire Tong Length}$$

$$\textbf{Tension} = \frac{400}{6} \times 7 = 66.7 \times 7 = 466.9 \textbf{ lbs.}$$

Total Tension = Tension + Bisect Tension

Total Tension = 46&9 + 80 = 546.9 lbs.

- What is the pull required on the fall line of the rope blocks on wire tong "A" to move the conductor back into position as shown in Figure 5.9?

$$\textbf{Pull on Fall Line} = \frac{\textbf{Weight to be Lifted}}{\textbf{Mechanical Advantage}} + \textbf{10\% of Weight}$$

$$\textbf{Pull on Fall Line} = \frac{546.9}{4} + 54.7 = 136.7 + 54.7 = 191.4 \textbf{ lbs.}$$

- What is the compressive force on wire tong "B" in Figure 5.9?

$$\textbf{Compression} = \frac{\textbf{Conductor Weight}}{\textbf{Saddle Spacing}} \times \textbf{Wire Tong Length}$$

$$\textbf{Compression} = \frac{400}{6} \times 9 = 66.7 \times 9 = 600.3 \textbf{ lbs.}$$

- What is the pull on the fall line of the rope blocks on wire tong "B" in Figure 5.9?

$$\textbf{Pull on Fall Line} = \frac{\textbf{Weight to be Lifted}}{\textbf{Mechanical Advantage}} + \textbf{10\% of Weight}$$

$$\textbf{Pull on Fall Line} = \frac{600}{4} + 60 = 150 + 60 = 210 \textbf{ lbs.}$$

- What is the weight on the saddle of wire tong "A" in Figure 5.9, if the rope blocks were attached to the clevis on the saddle?

Weight on Saddle = Tension + Pull on Fall Line

Weight on Saddle = 546.9 + 191.4 = 738.3 lbs.

- What is the weight on the saddle of wire tong “B” in Figure 5.9, if the rope blocks were attached to the clevis on the saddle?

Weight on Saddle = Tension + Pull on Fall Line

Weight on Saddle = 600 + 210 = 810 lbs.

It can be seen that when the conductor is moved, the weight on the wire tongs, pull on the fall lines, and the weight on the saddles increase as the conductor is laid out. The weight on the saddle is getting near the rating of a saddle with an extension (800 lbs.), and it is advised to put the blocks on a sling around the pole in this example to remove the pull of the fall lines from the saddles.

Running Angle Insulator Change

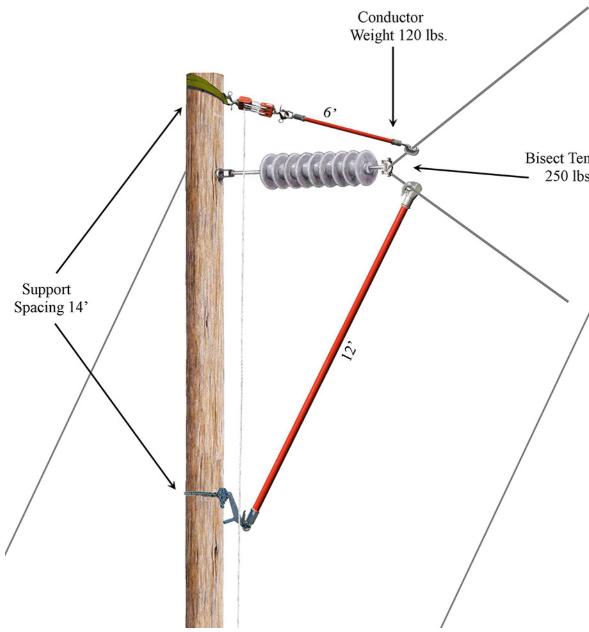

Figure 5.10.

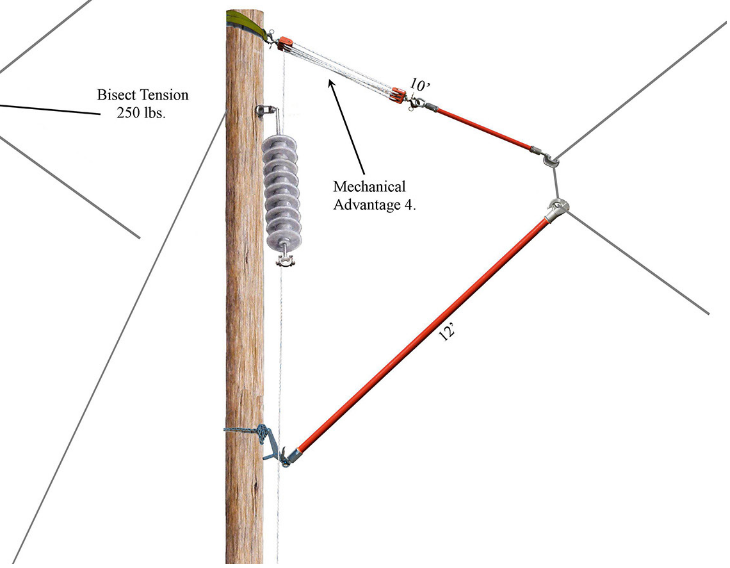

Figure 5.11.

Figures 5.10 and 5.11 show the rigging used to change the insulators on a running angle structure, using a 1-1/2" x 4-foot strain link stick with a set of rope blocks with a mechanical advantage of 5. A lever lift with a 2-1/2" x 12-foot wire tong is used to support the weight of the conductor. The conductor weight is 120 lbs., the bisect tension is 250 lbs., and the spacing between the support points is 14 feet. In this job we need to calculate the tension on the rope blocks and link stick, the pull on the fall line of the rope blocks, and the compression on the wire tong in Figure 5.10. We must also calculate these weights and forces for Figure 5.11 where the wire has been moved out for working clearance.

- What is the tension on the rope blocks and link stick in Figure 5.10?

$$\textbf{Tension} = \frac{\textbf{Conductor Weight}}{\textbf{Support Spacing}} \times \textbf{Length Link Stick and Blocks}$$

$$\textbf{Tension} = \frac{120}{14} \times 6 = 8.6 \times 6 = 51.6 \textbf{ lbs.}$$

$$\textbf{Total Tension} = \textbf{Tension} + \textbf{Bisect Tension}$$

$$\textbf{Total Tension} = 51.6 + 250 = 301.6 \textbf{ lbs.}$$

- What is the pull on the fall line of the rope blocks on the link stick in Figure 5.10?

$$\textbf{Pull on Fall Line} = \frac{\textbf{Weight to be Lifted}}{\textbf{Mechanical Advantage}} + \textbf{10\% of Weight}$$

$$\textbf{Pull on Fall Line} = \frac{301.6}{4} + 30.2 = 75.4 + 30.2 = 105.6 \textbf{ lbs.}$$

- What is the compression on the wire tong and lever lift in Figure 5.10?

$$\textbf{Compression} = \frac{\textbf{Conductor Weight}}{\textbf{Support Spacing}} \times \textbf{Length of Wire Tong}$$

$$\textbf{Compression} = \frac{120}{14} \times 12 = 8.6 \times 12 = 103.2 \textbf{ lbs.}$$

- What is the tension on the rope blocks and link stick after the conductor is moved out for working clearance as shown in Figure 5.11?

$$\textbf{Tension} = \frac{\textbf{Conductor Weight}}{\textbf{Support Spacing}} \times \textbf{Length Link Stick and Blocks}$$

$$\textbf{Tension} = \frac{120}{14} \times 10 = 8.6 \times 10 = 86 \textbf{ lbs.}$$

$$\textbf{Total Tension} = \textbf{Tension} + \textbf{Bisect Tension}$$

$$\textbf{Total Tension} = 86 + 250 = 336 \textbf{ lbs.}$$

- What is the pull required on the fall line of the rope blocks in Figure 5.11 to move the conductor back into its original position?

$$\textbf{Pull on Fall Line} = \frac{\textbf{Weight to be Lifted}}{\textbf{Mechanical Advantage}} + \textbf{10\% of Weight}$$

$$\textbf{Pull on Fall Line} = \frac{336}{4} + 33.6 = 84 + 33.6 = 117.6 \textbf{ lbs.}$$

Vertical Corner Insulator Change

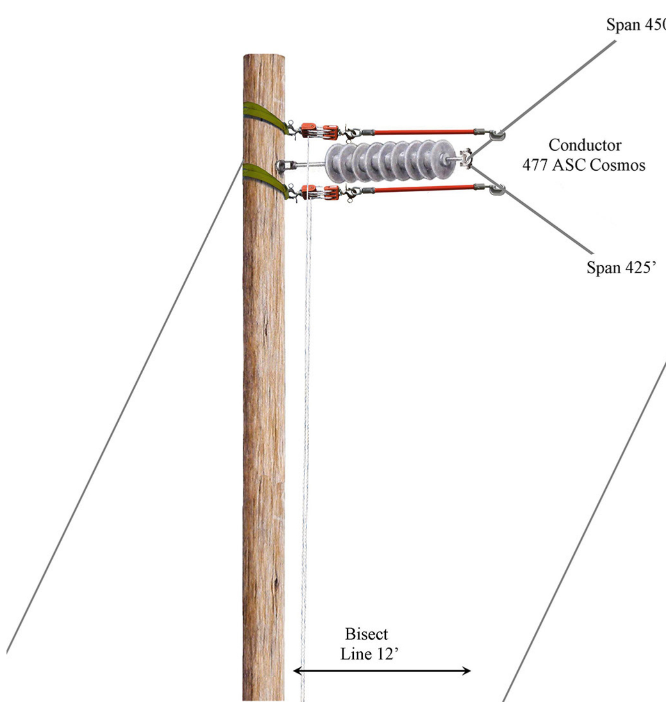

Figure 5.12.

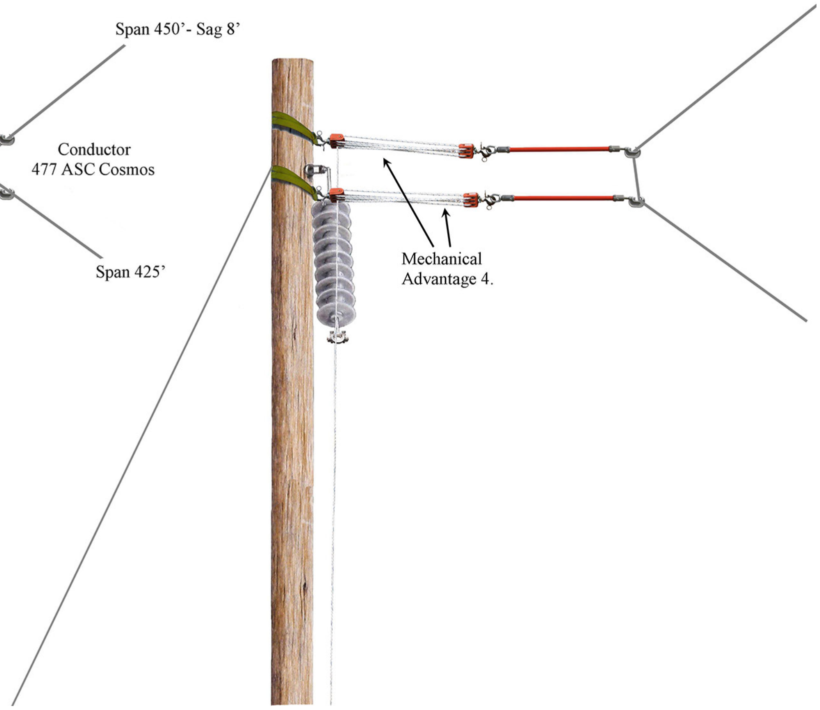

Figure 5.13.

Figures 5.12 and 5.13 illustrate the rigging used to change the insulators on a vertical corner. The conductor is supported by two 1-1/2" x 42-inch spiral link sticks, each attached to a set of rope blocks with a mechanical advantage of 5. The span lengths are 450 feet and 425 feet, the sag in the 450-foot span is 8 feet, the conductor is 477 ASC Cosmos, and the bisect line has been measured at 12 feet. For this job we need to calculate the line tension, the bisect tension that has to be supported, the conductor weight, and the pull on the fall lines of the rope blocks in Figure 5.12.

- What is the line tension that has to be calculated in order to find the bisect tension?

$$\textbf{Line Tension} = \frac{\textbf{Conductor Weight/ft} \times (\textbf{Span Length})^2}{8 \times \textbf{Sag in feet}}$$

$$\textbf{Line Tension} = \frac{.446 \times 450^2}{8 \times 8} = \frac{.446 \times 202500}{64} = \frac{90315}{64} = 1411 \text{ lbs.}$$

- What is the bisect tension that has to be supported?

$$\text{Bisect Tension} = \frac{\text{Line Tension}}{50} \times 2 \times \text{Bisect Line}$$

$$\text{Bisect Tension} = \frac{1411}{50} \times 2 \times 12 = 28.22 \times 2 \times 12 = 56.44 \times 12 = 677.28 \text{ lbs.}$$

- What is the conductor weight at the point of attachment to the insulators?

$$\text{Conductor Weight} = \frac{\text{Span “A”} + \text{Span “B”}}{2} \times \text{Cond. Weight/ft.} \times \text{SF.}$$

$$\text{Conductor Weight} = \frac{450 + 425}{2} \times .446 \times 1.5 = \frac{875}{2} \times .446 \times 1.5$$

$$= 437.5 \times 446 \times 1.5 = 195.1 \times 1.5 - 292.7 \text{ lbs.}$$

- What is the total tension that must be supported by the rope blocks and link sticks?

$$\text{Total Tension} = \text{Conductor Weight} + \text{Bisect Tension}$$

$$\text{Total Tension} = 292.7 + 677.3 = 970 \text{ lbs.}$$

- What is the pull on the fall lines of the rope blocks?

  The way this job is rigged splits the tension that must be supported in half between each set of rope blocks and link sticks.

$$\text{Weight} = 970 / 2 = 485 \text{ lbs.}$$

$$\text{Pull on Fall Line} = \frac{\text{Weight to be Lifted}}{\text{Mechanical Advantage}} + 10\% \text{ of Weight}$$

$$\text{Pull on Fall Line} = \frac{485}{4} + 48.5 = 121.25 + 48.5 = 169.75 \text{ lbs.}$$

In Figure 5.13 the weights and forces that have to be supported when the Conductor is let out for working clearance will be less than those calculated in Figure 5.12. As the conductor is let into the comer, the bisect and line tensions will decrease as slack is added to the line. If the conductor had to be moved away from the corner the weights and forces would increase,

Deadend Insulator Change

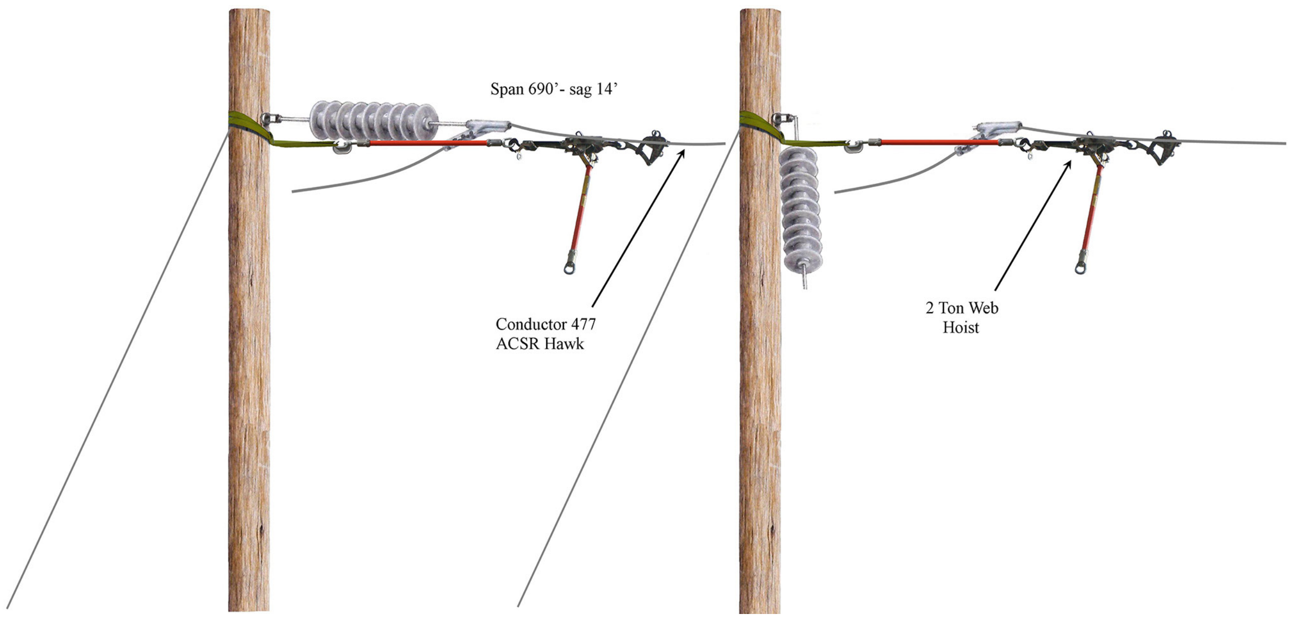

Figure 5.14.

Figure 5.14 shows the rigging used to change the insulators on a deadend structure, the span length is 690 feet, the sag in the span is 14 feet, and the conductor is 477 ACSR Hawk. The rigging used on this job is a 1-1/2" x 42-inch spiral link stick and a 2-ton web hoist, the only force to deal with on this job is line tension. We must calculate it to make sure all the rigging (slings, link stick, and web hoist) is capable of handling the line tension.

- What is the line tension that has to be supported to change the deadend insulators in Figure 5.14?

$$\textbf{Line Tension} = \frac{\textbf{Conductor Weight/ft} \times (\textbf{Span Length})^2}{8 \times \textbf{Sag in feet}}$$

$$\textbf{Line Tension} = \frac{.655 \times 690^2}{8 \times 14} = \frac{.655 \times 476100}{112} = \frac{311845.5}{112} = 2784.3 \textbf{ lbs.}$$

It can be seen that the line tension of 2785 lbs. can be safely handled by the 2-ton web jack (4000 lbs.) and the link stick (3500 lbs.). A sling must be chosen to ensure that it is capable of supporting this weight.

6. PG&E Wire Data

Table 1. Bare Aluminum Conductor (AAC)

Size-Stranding	Code Word	Class	Diameter	Weight	AC Resistance At 25° C.	AC Resistance At 75° C	Heat Capacity
AWG or kcmil			(in.)	(lbs./ft.)	(Ohms\1000 ft.)	(Ohms\1000 ft.)	(Watts-S/ft.-C)
1/0 - 7	Poppy*	A,AA	0.368	0.099	0.1670	0.2000	42.9
2/0 - 7	Aster*	A,AA	0.414	0.125	0.1330	0.1590	54.1
3/0 - 7	Phlox*	A,AA	0.464	0.157	0.1050	0.1260	68.0
4/0 - 7	Oxlip*	A,AA	0.522	0.198	0.0835	0.1000	85.7
250 - 19	Valerian**	A	0.574	0.235	0.0709	0.0849	101.8
266.8 - 7	Daisy*	AA	0.586	0.250	0.0663	0.0793	108.3
266.8 - 19	Laurel*	A	0.593	0.250	0.0663	0.0793	108.3
300 - 19	Peony**	A	0.629	0.282	0.0591	0.0707	122.1
336.4 - 19	Tulip*	A	0.666	0.316	0.0526	0.0630	136.8
350 - 19	Daffodil*	A	0.679	0.328	0.0506	0.0605	142.0
397.5 - 19	Canna*	A,AA	0.723	0.372	0.0446	0.0534	161.1
477 - 37	Syringa*	A	0.795	0.447	0.0373	0.0445	193.6
500 - 37	Hyacinth*	A	0.813	0.468	0.0356	0.0425	202.6
715.5 - 37	Violet*	AA	0.974	0.671	0.0251	0.0299	290.5
954 - 37	Magnolia*	AA	1.124	0.895	0.0191	0.0226	387.5
954 - 61	Goldenrod*	A	1.126	0.895	0.0191	0.0226	387.5
1113 - 61	Marigold*	A,AA	1.216	1.044	0.0165	0.0195	452.1
1431 - 61	Carnation*	A,AA	1.379	1.342	0.0132	0.0155	581.1
2300 - 61	Pigweed*	A	1.749	2.177	0.0090	0.0103	942.6

Lt. Gray	Not Approved For Purchase

* REYNOLDS METALS COMPANY — PROJECT DATA SHEET, NOVEMBER 1991.

** ALCOA CONDUCTOR PRODUCTS COMPANY — T&D CONDUCTORS, SUMMER 1994.

9/3/96 — FINAL REVISION — ALL VALUES VERIFIED AND CHECKED.

Table 2. Bare Aluminum Conductor Steel Reinforced (ACSR)

Size-Stranding	Code Word	Diameter	Weight	AC Resistance At 25° C.	AC Resistance At 75° C	Heat Capacity
AWG or kcmil		(in.)	(lbs./ft.)	(Ohms\1000 ft.)	(Ohms\1000 ft.)	(Watts-S/ft.-C)
4 - 6/1	Swan*	0.250	0.057	0.4120	0.5220	20.8
2 - 6/1	Sparrow*	0.315	0.091	0.2590	0.3360	33.1
2 - 7/1	Sparate*	0.325	0.107	0.2560	0.3300	36.6
80 - 8/1	Grouse*	0.367	0.149	0.2110	0.2610	48.5
1/0 - 6/1	Raven*	0.398	0.145	0.1630	0.2160	52.6
2/0 - 6/1	Quail*	0.447	0.183	0.1300	0.1760	66.4
3/0 - 6/1	Pigeon*	0.502	0.231	0.1030	0.1450	84.0
4/0 - 6/1	Penguin*	0.563	0.291	0.0822	0.1160	105.4
266.8 - 26/7	Partridge*	0.642	0.367	0.0651	0.0780	133.7
336.4 - 30/7	Oriole*	0.741	0.526	0.0513	0.0615	182.8
397.5 - 26/7	Ibis*	0.783	0.547	0.0438	0.0524	199.1
452.3 - 30/7	**	0.861	0.710			
518 - 42/19	***	1.000	1.117	0.0320	0.0383	354.0
518 - 42/19	****	1.000	1.117	0.0320	0.0383	346.8
605 - 30/19	Teal*	0.994	0.939	0.0287	0.0343	326.7
795 - 54/7	Condor*	1.092	1.023	0.0222	0.0273	383.5
954 - 54/7	Cardinal*	1.196	1.227	0.0186	0.0228	460.3
804.5 - 38/19	*****	1.213	1.570			
1113 - 54/19	Finch*	1.292	1.429	0.0161	0.0197	537.2
1272 - 45/7	Bittern*	1.345	1.432	0.0144	0.0171	569.3
1852 - 51+12/7	******	1.600	1.940			800.7
1855-69/37	*******	1.753	2.951			

Lt. Gray	Not Approved For Purchase

* DATA FROM REYNOLDS METALS COMPANY — PROJECT DATA SHEET, NOVEMBER 1991.

** PG&E CONDUCTOR DATA SHEET, GREAT WEST. PWR CO, 4/12/20, CARIBOU-GOLDEN GATE T/L.

*** PG&E CONDUCTOR DATA SHEET, ALCOA COMPANY OF AMERICA, 6/6/30, PIT #3 T/L.

**** PG&E CONDUCTOR DATA SHEET, ALCOA COMPANY OF AMERICA, TIGER CREEK-NEWARK T/L.

***** PG&E SAG TEN PROGRAM, ALCOA COMPANY OF AMERICA.

****** PG&E CONDUCTOR DATA SHEET, ROME CABLE CORPORATION, 11/8/62.

******* PG&E SAG AND TENSION PROGRAM.

9/3/96 — FINAL REVISION — ALL VALUES VERIFIED AND CHECKED.

Table 3. Bare Aluminum Conductor Steel Supported (ACSS)

Size-Stranding	Code Word	Diameter	Weight	AC Resistance At 25° C.	AC Resistance At 75° C	Heat Capacity
AWG or kcmil		(in.)	(lbs./ft.)	(Ohms\1000 ft.)	(Ohms\1000 ft.)	(Watts-S/ft.-C)
477 - 24/7	Flicker/SSAC*	0.846	0.614	0.0357	0.0429	229.8
954 - 54/7	Cardinal/SSAC*	1.196	1.227	0.0181	0.0223	460.3
1113 - 54/19	Finch/SSAC*	1.292	1.429	0.0157	0.0193	537.2
2156 - 90/37	**	2.012	4.406	0.0085	0.0104	1395.2

* DATA FROM REYNOLDS METALS COMPANY — PROJECT DATA SHEET, NOVEMBER 1991.

** PG&E CONDUCTOR DATA SHEET, REYNOLDS METALS COMPANY, 7/29/81, LAKEVILLE-SOBRANTE 230KV T/L.

9/3/96 — FINAL REVISION — ALL VALUES VERIFIED AND CHECKED.

Table 4. Bare MHD Concentric Stranded Copper Conductor

Size-Stranding	ASTM Class	Diameter	Weight	AC Resistance At 25° C.	AC Resistance At 75° C	Heat Capacity
AWG or kcmil		(in.)	(lbs./ft.)	(Ohms\1000 ft.)	(Ohms\1000 ft.)	(Watts-S/ft.-C)
4 - 7	A	0.232	0.129	0.2670	0.3184	24.8
3 - 3	AA	0.285	0.161	0.2099	0.2495	30.9
2 - 7	A	0.292	0.205	0.1670	0.1992	39.4
2 - 3	AA	0.320	0.203	0.1660	0.1979	39.0
1 - 7	A	0.328	0.258	0.1330	0.1586	49.5
1/0 - 7	AA	0.368	0.326	0.1052	0.1254	62.6
2/0 - 7	AA	0.414	0.411	0.0836	0.0997	78.9
3/0 - 7	AA	0.464	0.518	0.0662	0.0789	99.5
4/0 - 7	AA	0.522	0.653	0.0525	0.0626	125.4
250 - 19	A	0.574	0.772	0.0447	0.0533	148.2
500 - 37	A	0.813	1.544	0.0227	0.0270	296.4
500 - 37/7	G	0.922	1.585	0.0232	0.0277	304.3
1000 - 37	AA	1.151	3.088	0.0119	0.0142	592.9

Lt. Gray	Not Approved For Purchase

ANACONDA WIRE AND CABLE COMPANY, SECTION 16, CONDUCTORS FOR WIRE AND CABLE, PUBLICATION C-79, 1951.

9/3/96 — FINAL REVISION — ALL VALUES VERIFIED AND CHECKED

Table 6. Bare Solid MHD Copper Conductor

Size-Stranding	Class	Diameter	Weight	AC Resistance At 25° C.	AC Resistance At 75° C	Heat Capacity
AWG or kcmil		(in.)	(lbs./ft.)	(Ohms\1000 ft.)	(Ohms\1000 ft.)	(Watts-S/ft.-C)
6 - 1	MHD	0.162	0.079	0.4155	0.4954	15.2
4 - 1	MHD	0.204	0.126	0.2608	0.3110	24.2

Lt. Gray	Not Approved For Purchase

COPPER WIRES AND CABLES, CATALOG 490-CUWC, 1949 EDITION, GENERAL CABLE CORPORATION.

9/3/96 — FINAL REVISION — ALL VALUES VERIFIED AND CHECKED.

Table 7. Bare Stranded Copperweld-Copper Conductor

Size-Stranding	Type	Diameter	Weight	AC Resistance At 25° C.	AC Resistance At 75° C	Heat Capacity
AWG or kcmil		(in.)	(lbs./ft.)	(Ohms\1000 ft.)	(Ohms\1000 ft.)	(Watts-S/ft.-C)
4A - 2/1	A	0.290	0.162	0.2686	0.3184	32.4

Lt. Gray	Not Approved For Purchase

ALCOA CONDUCTOR PRODUCTS COMPANY DATA SHEET, BIMETALLIC PRODUCTS, TABLE 1, PAGE 12.

9/3/96 - FINAL REVISION-ALL VALUES VERIFIED AND CHECKED