GUIDE FOR ELECTRIC DISTRIBUTION LINE GUYS AND ANCHORS

Distribution Subcommittee

Overhead Work Group



Transmission and Distribution
Engineering Committee

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ABBREVIATIONS

ACSR	Aluminum Conductor, Steel-Reinforced
ANSI	American National Standards Institute
BIL	Basic Impulse Insulation Level
IEEE	Institute of Electrical and Electronics Engineers
NESC	National Electrical Safety Code

RUS Rural Utilities Service

UNITS OF MEASURE

m meter or meters (metric base unit of length)

in inch or inches (1 inch = 0.0254 meters)

in^2 square inches (1 square inch = 0.0006452 square meters)

ft foot or feet (1 foot = 0.3048 meters)

ft^2 square feet (1 square foot = 0.092903 square meters)

cmil circular mils (1 circular mil = 5.067075×10^{-10} square meters)

kcmil 1,000 circular mils (1 kcmil = 5.067075×10^{-7} square meters)

g gram or grams (metric base unit of weight)

kg kilogram or kilograms (1,000 grams = 1 kilogram)

lb pound or pounds (1 pound = 0.45359 kilograms)

ft-lb foot-pounds (feet × pounds), a measure of torque or angular force

CONTRIBUTORS

The Distribution Subcommittee Overhead Work Group of the Transmission and Distribution Engineering Committee (TDEC) provided invaluable assistance in preparing this document.

DISCLAIMER

This guide is meant to provide a general overview for the installing guys and anchors on distribution lines. Users of this guide must verify independently of this document that they are meeting all applicable requirements, including, but not limited to, the current National Electrical

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1 INTRODUCTION

A GUYED STRUCTURES

Guys and anchors are installed at distribution line dead-ends, line angles, and at points of unbalanced conductor tensions. Unbalanced conductor tensions occur where the conductor size is changed or where there is an appreciable change in the ruling span. A guy assembly needs to be designed to hold the entire horizontal component of the load being applied on the structure in the opposite direction of the guy assembly. A wood pole is used as a strut and supports the vertical components of all loads on the pole including the vertical forces due to the tension contributed by the guy.

While a pole may have sufficient strength to withstand side strain of angles up to 5 degrees for small conductors, it is usually advisable to install a guy and anchor to prevent the pole from leaning. The use of pole keys in place of guys should be avoided wherever possible. The use of push-brace poles in lieu of down guys and anchors is discouraged.

B SCOPE OF GUIDE

This guide lists the standard RUS distribution guy and anchor assemblies and their permitted loads and holding power along with installation guidelines. The guide also discusses the component parts of guy assemblies and their strengths.

Within this guide are the derivations of the equations required to calculate loading moments, guy resisting forces for several guying situations, guy loads, minimum guy leads, and required pole class to support vertical loads. Example problems using these equations are also presented.

C NATIONAL ELECTRICAL SAFETY CODE

This guide references rules and presents selected data contained in the 2023 Edition of the National Electrical Safety Code (NESC). At the time this guide was written, the 2023 Edition was the latest edition of the NESC. Periodically, the NESC is updated and revised. Users of this guide should use the rules and data, as may be revised and renumbered, from the most recent edition of the NESC. Copies of the NESC may be obtained from the Institute of Electrical and Electronics Engineers, Inc., (IEEE) at the following address:

IEEE Customer Service

445 Hoes Lane, P.O. Box 1331

Piscataway, NJ 08855-1331

Telephone: 1-800-678-IEEE (1-800-678-4333)

Throughout this guide, references to the NESC pertain specifically to the 2023 Edition of the National Electrical Safety Code.

2 ANCHORS, ANCHORING, AND SOILS

A TYPES OF ANCHOR ASSEMBLIES

Selection of the proper type of anchor assembly depends upon the soil conditions where the anchor is to be installed. (See Table 2: Soil Classifications.) Many utility systems standardize on one or two sizes of anchors of the types most suitable for the soil conditions found in their service areas. The surface area and holding power of the anchor assemblies depicted in RUS specifications and drawings for distribution line construction are shown in the following tables.

Table 1: RUS Standard Distribution Anchor Assemblies

Anchor Type	RUS Designation	Minimum Area (square inches)	Designated Maximum Holding Power (lb) *
Expanding	F1.6	90	6,000
	F1.8	100	8,000
	F1.10	120	10,000
	F1.12	135	12,000
Screw (Power Installed)	F2.6	90	6,000
	F2.8	100	8,000
	F2.10	120	10,000
	F2.12	135	12,000
Plate	F3.6	90	6,000
	F3.8	100	8,000
	F3.10	120	10,000
	F3.12	135	12,000
Swamp		Helix Diameter (inches)	
	F6.6	10	6,000
	F6.8	12	8,000
	F6.10	15	10,000
Service		Anchor Type	
	F4.1	Expanding	2,500
	F4.2	Screw	2,500

** Note: The "designated maximum holding power" assumes the use of the proper anchor rod type and diameter and proper installation in Class 5 soils. For locations where soils have less holding capacity than Class 5 soils, anchor holding power should be evaluated.*

Expanding anchors are the most commonly used anchors on rural distribution lines. Screw (power-installed) anchors are most commonly used when loose soils are known to be prevalent near the ground line with firmer soil underneath. Likewise, swamp anchors are needed to penetrate firm soil under swamps and wetlands. Plate anchors are most commonly used when heavy conductors are installed on rural distribution lines. Service anchors are usually used to guy service drops and secondary conductors.

(1) Rock anchors are to be installed and used where solid rock is encountered. Only one guy is to be attached to a rock anchor. Where more than one guy is required, separate anchors are to be installed for each guy at a minimum of 2 feet apart and, where practical, in a direct line with the conductors. The holding power of rock type anchors is highly variable and depends on type of rock, installation procedures, and the grout used.

(2) Log-type anchors are acceptable for use on RUS distribution systems. The materials and construction details for these types of anchors can be found in RUS Bulletin 1728F-810, "Electric Transmission Specifications and Drawings, 34.5 kV through 69 kV."

B ANCHOR STRENGTH REQUIREMENTS

Table 261-1 of the 2023 NESC specifies strength factors (equal to 1.0 for both Grade B and Grade C construction) by which the established holding power of anchors are to be multiplied. Rule 264 of the 2023 NESC requires that an anchor and rod assembly have an ultimate strength not less than that of the guy(s) attached to it.

The designated holding powers shown on the anchor assembly drawings are based on the maximum holding power of average, Class 5 soil. When the anchor is installed in poorer soils, the holding power of the anchor shall be derated. A suggested guide is to derate by 25 percent in Class 6 soil and by 50 percent in Class 7 soil. For Class 8 soil, it is usually necessary to use swamp anchors or power-driven screw anchors which can penetrate the poor soil into firmer soil. See the "Soil Classifications" table (Table 2, below) for soil classes.

C SOIL CLASSIFICATIONS

The following table defines the commonly accepted soil classes and their descriptions.

Table 2: Soil Classifications

Class	Engineering Description
0	Sound hard rock, unweathered
1	Very dense and/or cemented sands; coarse gravel and cobbles
2	Dense fine sand; very hard silts and clays
3	Dense clayed sand, sand, gravel; very stiff to hard silts and clays
4	Medium-dense sandy gravel; very stiff to hard silts and clays
5	Medium-dense coarse sand and sandy gravels; stiff to very stiff silts and clays
6	Loose to medium-dense fine to coarse sand; firm to stiff clays and silts
7	Loose fine sand; alluvium; loess; soft-firm clays; varved clays; fill
8	Peat; organic silts; inundated silts; fly ash

3 GUY WIRES

Table 3 illustrates the most common sizes and types of stranded guy wire used for guying conductors on distribution lines. The last column of the table shows the maximum load permitted on a guy wire, which is 90 percent of its rated breaking strength per the strength factors (for both Grade B and Grade C construction) specified in Table 261-1 of the 2023 Edition of the NESC. Guy wires and guy assemblies need to be able to hold all of the horizontal forces (loads) acting on the pole multiplied by the appropriate load factors found in Table 253-1 of the 2023 NESC.

Table 3: Guy Wire Strength Data

Type Strand	Size	Rated Breaking Strength (lb)	Permitted Load (0.9 × Rated Strand Breaking Strength) (lb)
Siemens Martin Steel	1/4 in	3,150	2,835
	3/8 in	6,950	6,255
	7/16 in	9,350	8,415
High Strength Steel	1/4 in	4,750	4,275
	3/8 in	10,800	9,720
	7/16 in	14,500	13,050
Aluminum Clad Steel	6 M	6,000	5,400
	8 M	8,000	7,200
	10 M	10,000	9,000
	12 M	12,500	11,250

A more complete list of stranded guy wires is included in section “y” of RUS Information Publication 202-1, “List of Materials Acceptable for Use on Systems of RUS Electrification Borrowers.”

4 RUS GUY ASSEMBLIES AND HARDWARE

A RUS GUY ASSEMBLIES

Standard RUS distribution guying assemblies include both the guy wire and the hardware to connect the guy wire to the pole. The guying assembly, for this guide, refers to the pole attachment hardware. Guy wires are evaluated separately (see Section 3, above). Table 4, RUS Guying Assembly Units, presents the RUS standard distribution guy assemblies included in RUS Bulletin 1728F-804, “Specifications and Drawings for

12.47/7.2 kV Line Construction" and Table 5 presents guy assembly information included in RUS Bulletin 1728F-803, "Specifications and Drawings for 24.9/14.4 kV Line Construction."

Multiple down guys consist of two or more guy assemblies installed in parallel and attached to one or more anchors as may be needed. The far right columns of both Tables 4 and 5 itemize the permitted loads allowed by RUS standards on each guy assembly. The permitted loads shown are either the designated capacities multiplied by 0.85 or loads allowed for the square washers. All wind and conductor tension loads acting on guy assemblies need to be multiplied by the appropriate overload factors as found in Section 25 of the 2023 NESC.

Table 4: RUS Guying Assembly Units (RUS Bulletin 1724F-804 – 12.47/7.2 kV)

Guy Type	Machine Bolt			Square Washer		Guy Attachment Load Rating (lb)	Permitted Load * (lb)	
	Diameter (in)	Tensile Strength (lb)	Tensile Strength × 0.85 (lb)	Side Dimension (in)	Load Allowed (lb)	Horizontal Permitted Load	Horizontal	@ 45°
E1.1 (E1-2)	5/8	13,050	11,100	3	7,800	8,500	7,800	11,030
E1.1L (E1-3)	3/4	20,050	17,050	4	14,200	8,500	8,500	12,019
E1.2 (E3-3)	X	X	X	X	X	8,500	8,500	12,019
E1.3L	X	X	X	X	X	8,500	8,500	12,019
E1.4 (E2-2)	thimble eye bolt 5/8	13,050	11,100	3	7,800	thimble eye nut 5/8" diam. 13,050 × 0.85 = 11,100 lb	Lesser of 7,800 lb horizontal or 90% of guy wire RBS	

Guy Type	Machine Bolt			Square Washer		Guy Attachment Load Rating (lb)	Permitted Load * (lb)	
	Diameter (in)	Tensile Strength (lb)	Tensile Strength × 0.85 (lb)	Side Dimension (in)	Load Allowed (lb)	Horizontal Permitted Load	Horizontal	@ 45°
E1.4L (E2-3)	thimble eye bolt 3/4	20,050	17,050	4	14,200	thimble eye nut 3/4" diam. 20,050 × 0.85 = 17,050 lb	Lesser of 14,200 lb horizontal or 90% of guy wire RBS	

**Permitted Load is the limiting hardware load for the guy type shown. Limiting hardware loads are either designated capacities multiplied by 0.85 or loads allowed for the square washers. Greater limiting strengths (and possibly different pole attachment hardware) are required for guy angles (ϕ - relative to the pole) less than 45 degrees.*

Table 5: RUS Guying Assembly Units (RUS Bulletin 1724F-803 – 24.9/14.4kV)

Guy Type	Machine Bolt			Square Washer		Guy Attachment Load Rating (lb)	Permitted Load * (lb)	
	Diameter (in)	Tensile Strength (lb)	Tensile Strength × 0.85 (lb)	Side Dimension (in)	Load Allowed (lb)	Horizontal Permitted Load	Horizontal	@ 45°
E1.1	5/8	13,050	11,100	2-1/4	4,200	5,200	4,200	5,940
E2.1	3/4	20,050	17,050	3	7,800	8,500	7,800	11,030
E3.1	X	X	X	X	X	8,500	8,500	12,019
E4.1L	X	X	X	X	X	8,500	8,500	12,019
E1.01	thimble eye bolt 5/8	13,050	11,100	2-1/4	4,200	thimble eye nut 5/8" diam. 13,050 × 0.85 = 11,100 lb	Lesser of 4,200 lb horizontal or 90% of guywire RBS	
E2.01	thimble eye bolt	20,050	17,050	3	7,800	ab – thimble eye nut 3/4" diam.	Lesser of 7,800 lb horizontal or 90% of guywire RBS	

	3/4					20,050 × 0.85 = 17,050 lb	

**Permitted Load is the limiting hardware load for the guy type shown. Limiting hardware loads are either designated capacities multiplied by 0.85 or loads allowed for the square washers. Greater limiting strengths (and possibly different pole attachment hardware) are required for guy angles (ϕ - relative to the pole) less than 45 degrees.*

B HARDWARE

The following hardware is needed, in certain specific combinations, to attach guy wires to distribution poles:

- Machine bolts and washers (with nuts and locknuts), thimble eye bolts, thimble eye nuts;
- Guy attachments (guy hook or pole band type, or guy hooks and guy plates); and
- Guy dead-ends (types include: 3-bolt clamp, U-bolt clamp, offset guy clamp, and automatic and formed dead-ends).

C WASHERS

An area of concern with guy attachment hardware is the crushing of wood pole fibers where the washer under the bolt head is in contact with the pole. This washer usually carries the full horizontal component of the working load of the guy assembly. RUS standards allow no more than 910 pounds per square inch of compression for washers abutting wood poles and crossarms. Table 6, Standard Washers–Loads Allowed, shows the maximum compression load allowed by RUS standards for washers abutting wood poles. (The area of the bolt hole is subtracted from the total surface area of the washer.)

Table 6: Standard Washers–Loads Allowed

Washer Size and Type	Approximate Area (square inches)	Load Allowed Abutting Pole (lb)
2-1/4 in. Square, Flat	4.6	4,200

3 in. Square, Curved	8.6	7,800
4 in. Square, Curved	15.6	14,200

D GUY STRAIN INSULATORS

NESC 279.A.1.c states that, "the rated ultimate strength of the guy insulator shall be at least equal to the required strength of the guy in which it is installed." Guy strain insulators vary in ultimate strength by manufacturer and design. Check with the manufacturer or the RUS List of Materials for its rating.

5 LOADING ON POLES AND GUY ASSEMBLIES

A CONDUCTOR TENSION AND WIND/ICE LOADING

Guy-anchor assemblies, in conjunction with poles, need to support the sum of the following loads:

- Conductor tension loads,
- Maximum wind/ice loads on the conductors (as defined by NESC Loading Districts),
- Extreme wind loads (only when a structure or its supported facilities exceed 60 ft above ground or water level,
- Extreme ice with concurrent winds loads (only when a structure or its supported facilities exceeds 60 ft above ground or water level,
- Wind loads on the supporting structure (pole), and
- Wind loads on the material and equipment attached to the structure.

All of the above-calculated loads need to be multiplied by the appropriate load factor as specified in Section 25 of the 2023 NESC. The tables in Exhibits A, B, and C at the end of this guide provide the information required to calculate wind/ice loading for each NESC loading district and on bare conductors commonly installed on distribution lines. The required loading should be the one that has the greatest effect of either the:

(1) district (conductor) loads—Exhibit A;
(2) extreme wind loading—Exhibit B; or
(3) extreme ice with concurrent wind condition—Exhibit C.

Extreme load cases apply to a structure or its supported facilities that exceed 60 ft above ground or water level. The wind load on materials and equipment attached to a pole can usually be ignored. However, wind loading and weight of conductor marker balls that are often used at airports and water crossings should be considered.

It should be noted that cables, conductors, equipment, and other attachments are sometimes added to poles after initial installation by either the borrower or other entities. Before any additions are made to structures, the increased loading should be evaluated and arrangements made for strengthening or replacement of the structure that may be required.

B NESC LOAD FACTORS

The following table of load factors is taken from Table 253-1 of the 2023 NESC.

Table 7: Load Factors for Poles, Crossarms, Guys, Foundations, and Anchors

(Use with NESC Table 261-1 Strength Factors)

Load Factors			
	Grade B	**Grade C**	
Rule 250B Loads		At Crossings	Elsewhere
Vertical Loads	1.50	1.90 [3]	1.90 [3]
Transverse Loads			
Wind	2.50	2.20	1.75
Wire Tension	1.65 [1]	1.30 [2]	1.30 [2]

Longitudinal Loads			
In General	1.10	No Requirement	No Requirement
At Dead-ends	1.65 (1)	1.30 (2)	1.30 (2)
Rule 250C Loads (Extreme Wind)			
Wind Loads	1.00	1.00	1.00
All Other Loads	1.00	1.00	1.00
Rule 250D Loads (Extreme ice with concurrent wind)			
	1.00	1.00	1.00

1. *For guys and anchors associated with structures supporting communication conductors and cables only, this factor may be reduced to 1.33.*
2. *For foundations and guy anchors, use a value of 1.10. For structures, portions of structures, crossarms, and guys made from metal, prestressed concrete, or fiber-reinforced polymer, use a value of 1.10.*
3. *For foundations and guy anchors use a value of 1.50. For structures, portions of structures, crossarms, and guys made from metal, prestressed concrete, or fiber-reinforced polymer, use a value of 1.50.*

C POLE LOADING

Guyed poles may be considered to act as struts and need to support the vertical component of the loads cited in Section 5A above on Conductor Tension and Wind/Ice Loading, plus any additional vertical component of forces that may be induced by the guys. It is assumed that a pole will adequately hold transverse (horizontal) loads not in line with the guy(s). However, unguyed transverse loads may cause the pole to lean, thus, the installation of additional guys (side guys) may be desirable.

D APPLICATION OF LOADING PER TYPE OF GUY ASSEMBLY

Standard RUS distribution construction utilizes dead-end, line angle bisector, and, occasionally, overhead types of guys. The loads that guy assemblies need to hold for the different types of guying arrangements are discussed below.

Single dead-end guy assemblies are installed in line with the conductors they (horizontally) support on the opposite side of the pole. Dead-end guy assemblies need to support both conductor tension loads and the maximum wind/ice (or extreme wind and extreme ice) loads on the conductors and pole. These loads are calculated and then multiplied by the appropriate NESC overload factors. For calculation purposes:

- Wind loads are assumed to be horizontal and perpendicular to the conductors (which is considered to be the worst case wind/ice loading condition),
- Wind/ice loads are added to the conductor tension loads in line with the guy assembly, and
- Wind loading on the pole is added to the sum of the loads.

Double dead-end angle and tangent assemblies consist of two dead-end assemblies that may be guyed in the opposite direction of the conductors. The loads and guying requirements are calculated independently for each guying assembly using the same procedure as discussed for single dead-end assemblies. Likewise, at double dead-end assemblies on tangent poles, the loads and guying requirements are determined independently for each set of conductors attached to the pole.

Junction poles and tap poles usually have one or more single dead-end guy assembly(s). The calculations required to determine the loading and strength requirements for the guys and the structure are performed independently for each set of conductors attached to the pole using the same methodology and assumptions discussed in the preceding paragraphs.

Bisector guy assemblies are installed at line angles where there is no change in conductor tension. The conductor may be attached to the pole with a pole-top angle assembly or a double dead-end assembly up to approximately 30 degrees. The guy assembly(s) is installed in line with the bisector of the line angle. The total loading on a bisector guy assembly is the vector sum of the following:

- The transverse conductor loading tension,
- The wind/ice (or extreme wind) loading on all attached line conductors, and
- The wind loading on the pole, and, if critical, the wind loading on the materials and equipment on the pole.

The wind direction is assumed to be parallel with the direction of the line angle bisector. The appropriate NESC overload factors must be applied to all of the above loads.

6 2023 NESC GUYING REQUIREMENTS

A GRADE OF CONSTRUCTION

As a minimum, guys and anchors are to be of the same grade of construction as the conductors which they horizontally support. For standard RUS distribution construction, a minimum of NESC Grade C construction is required in accordance with 7 CFR Part 1724. However, guys and anchors which support distribution lines and communications circuits attached to or underbuilt on transmission line structures and poles are to be designed and constructed to Grade B construction requirements. The NESC may also require Grade B construction for other specific situations and locations. Section 24 of the 2023 NESC sets forth the requirements and exceptions for grades of construction.

B STRENGTH REQUIREMENTS

Section 26 of the 2023 NESC sets forth the strength requirements and strength factors for guys and anchors. The strength factors of NESC Table 261-1 are to be used with the load factors of Table 253-1 to calculate the allowable loads for guys and anchors. The NESC requires a strength multiplication factor of 0.9 be applied to guy wires for Grade C construction. RUS uses a strength factor of 0.85 as an additional safety factor to be applied to the guying assemblies.

7 DETERMINE WEAKEST COMPONENT

Determination of the weakest component part of a guying-anchoring system, as determined by application of the appropriate NESC strength factors, is essential in proper line design, pole class selection, and the use of guys and anchors. See Section 15 for information on selecting pole class to support vertical loads. The strength or holding power of the combined guy and anchor is only as strong as its weakest component. Each factor listed below needs to be analyzed separately and compared to loading requirements to determine if each component of the guying system is stronger than the required load:

- Holding power of anchors (see Section 2),
- Soil classification (see Section 2 and Section 8),
- Strength of guy wires (see Section 3),
- Maximum permitted load for guy assemblies, hardware and washers (see Section 4, Section 5, and Section 6), and
- Vertical capacity of pole.

8 INSTALLATION OF GUY AND ANCHOR ASSEMBLIES

A GUY ASSEMBLIES

Guy and anchor assemblies need to be installed before conductors are installed. The location of the guy assemblies should avoid traveled ways and, if installed in parking areas, should be marked as required by the NESC. If possible, guy wires should be

installed such that the angle formed between the guy and the pole is 45 degrees. A 45-degree angle is formed when the height above ground of the guy attachment on the pole is equal the distance from the pole to the anchor rod. An angle of less than 26 degrees (2-to-1 guy attachment height to guy lead ratio) should be reviewed for vertical loading on the pole.

B GUY MARKERS

Rule 217C of the 2023 NESC requires a conspicuous guy marker be installed where a guy is exposed to vehicle or pedestrian traffic. RUS specifies, on the assembly drawings in Bulletin 1728F-803, that a guy marker be installed on all down guys.

C ANCHOR ASSEMBLIES

The following excerpts from RUS Bulletin 1728F-803, under "Construction Specifications for Anchoring," describe the RUS standard for anchor assemblies for distribution line construction:

- All anchors and rods shall be in line with the strain and shall be installed so that approximately 6 inches of the rod remains out of the ground. In cultivated fields or other locations, as deemed necessary, the projection of the anchor rod above earth may be increased to a maximum of 12 inches to prevent burial of the rod eye. The full depth of backfill of all anchor holes must be thoroughly tamped.
- After a cone anchor has been set in place, the hole shall be backfilled with coarse crushed rock for 2 feet above the anchor and tamped during the filling. The remainder of the hole shall be backfilled and tamped with dirt.
- The maximum load with load factors transferred to the anchor should not exceed the designated maximum holding power given in the design parameters on the anchor assembly drawing. The rating is coordinated with the maximum holding power of average, Class 5, soil conditions.

D GROUNDING OF GUY WIRES

Rules 92C2, 93C5, and 215C2 of the 2023 NESC specify the requirements for the grounding of guy wires. With only a few exceptions, all guy wires are required to be grounded by being bonded to each other and bonded to the system neutral. RUS specifies that an anchor-bonding clamp be installed between all down guys and anchors. RUS considers it to be nonstandard construction when guy wires are not effectively bonded and grounded. RUS recommends the installation of stainless steel or galvanized steel ground rods, or the replacement of existing copper ground rods with stainless steel or galvanized steel ground rods, instead of isolating down guys to mitigate the cathodic corrosion of anchors.

E BIL LEVELS AND RAPTOR PROTECTION

RUS strongly recommends that a minimum basic impulse insulation level (BIL) of 300 kV be maintained on all distribution pole tops to mitigate the possibility of lightning flashovers. Furthermore, RUS recommends that a minimum of 24 inches of vertical separation be maintained between energized conductors and (grounded) guys to lessen the danger of electrocution to raptors. Both of these objectives can be achieved with the installation of guy strain insulators, when needed, as shown on RUS standard construction drawing E5.1G or E1.5. Guys still need to be grounded by bonding them to one another and to the system neutral below the guy strain insulator.

9 EQUATIONS FOR LOADING MOMENTS ON POLE

The total ground line moment, M_g (measured in ft-lb), on a pole equals the sum of all the load moments applied to the pole due to wind on the conductors, the pole, and the equipment, plus tension loads imposed by the conductors. Equation A forms the basis for calculating guying loads. It is the function of the guying system to support the structure and resist these overturning loads.

M_g = $HSM_c + M_t + M_p + M_e$ **EQ A**

Where:

HS = Horizontal wind span (1/2 the sum of adjacent spans) (ft)

M_c = Summation of moment loads due to wind on each conductor expressed as moment

per unit length of span (ft-lb/ft)

= $F_w\{\Sigma(W_cH_c)\}\cos(\theta/2)$ **EQ B**

M_t = Summation of moments due to the tension in each conductor, if there is a line angle

(ft-lb)

= $2F_t\{\Sigma(T_cH_c)\}\sin(\theta/2)$ **EQ C**

M_p = The moment due to wind on the pole (ft-lb)

= $F_w W_p \left(\frac{2C_t + C_g}{K_c}\right) H_p^2$ **EQ D**

M_e = The moment due to wind on the material and equipment on the structure (ft-lb)

And where:

F_w = NESC load factor for wind loads

F_t = NESC load factor for longitudinal (tension) loads

H_p = Height of pole above ground (ft)

H_c = Height of each conductor attachment above groundline (ft)

W_c = Wind load per unit length of each conductor (lb/ft)

W_p = Wind load per unit area surface of pole (lb/ft^2)

T_c = Tension in each conductor (lb)

θ = Line angle at pole

C_t = Pole circumference at top (in)

C_g = Pole circumference at ground line (in)

K_c = Calculation constant = 72π

One or more of the force moment components may be omitted from Equation EQ A if its contribution is insignificant as compared to the other force components. The moment due to wind on the material and equipment on the pole, M_e, can usually be omitted because the cross-sectional area of the equipment and material multiplied by the wind force is very small compared to the other forces acting on the pole. Other legitimate omissions are discussed in Section 10.

10 CALCULATION OF HORIZONTAL LOADS ON GUY ASSEMBLIES

A TOTAL HORIZONTAL LOAD

The total horizontal load on a guy assembly is determined by calculating the load on that guy assembly due to wind on conductor, conductor tensions, wind on pole, and wind on material and equipment. The example problems that follow show how loads are

calculated and guying assembly and anchors chosen based on loads supported by each guying attachment.

B HORIZONTAL LOADS ON BISECTOR GUY ASSEMBLIES

NESC load factors are used in calculating the horizontal loads supported by the guying assemblies. The permitted horizontal load of the guy assembly to be used (Tables 4 and 5: RUS Guying Assembly Units) must be greater than the horizontal load calculated for each guying assembly. The angle θ is the line angle. It is assumed that the wind blows in a direction parallel to the bisector guy.

C HORIZONTAL LOADS ON DEAD-END GUY ASSEMBLIES

As explained in Section 5D, Application of Loading per Type of Guy Assembly, the calculated loads acting on a guyed dead-end pole consist of the longitudinal conductor tension linearly added to the wind/ice (or extreme wind) loading perpendicular to the conductors. This methodology simulates the worst case condition. The horizontal permitted load of the guy assembly to be used (Tables 4 and 5: RUS Guying Assembly Units) needs to be greater than the total calculated horizontal load.

D OTHER DEAD-END GUY ASSEMBLIES

At double dead-ends, multiple dead-ends, junction poles, and tap poles, the total horizontal loads—and, subsequently, the guying requirements—need to be determined independently for each dead-end assembly on the pole. The horizontal loads acting on each guy assembly are calculated using the above assumptions.

11 CALCULATION OF PERMITTED LOADS ON GUY ASSEMBLIES

The total load on the guy attachment hardware, the guy wire, and the anchor assembly is calculated by using the following equation.

$$\frac{G_h}{\sin \phi}$$

$$G = G_h/\cos \beta \qquad \textbf{EQ E}$$

Where:

G = Total guy load (lb) (on guy assembly, guy wire, and anchor assembly)

G_h = Total horizontal load on guy assembly (lb)

β = Guy wire angle with respect to ground (degrees)

The loads applied to the guy and anchor assembly are to be multiplied by the appropriate NESC load factors in the calculation of G_h. NESC and RUS strength factors must be applied to the rated strength of the guy assemblies, guy wires, and anchors to determine the permitted load. The permitted loads must be greater than the required loads. See Table 1: Anchors; Table 3: Guy Wire; and Tables 4 and 5: Guy Assembly Units, for permitted load information.

12 CALCULATION OF MINIMUM GUY LEAD

It is recommended that a 1:1 guy slope, or 45-degree guy angle with respect to the ground, be used whenever possible. However, field conditions or easement restrictions sometimes require the guy leads to be reduced by moving the guy anchors to be installed closer to structures, which increases the angle of the guy wire relative to the ground. In such cases, the calculated force on the guy increases and the vertical loads on the guy attachment and the pole will also increase. All elements of the guying system—including the pole, anchors, guy wires, and guy assemblies—must be evaluated to determine if the permitted loads are greater than the applied loads with load factors. See Section 15 for calculation of vertical load limits on the pole and selection of pole class.

Guy leads should only be reduced when it is not possible to obtain a 1:1 or greater guy slope. As a general rule, use the longest possible guy wire lead length that is practical to obtain the maximum strength from the guy assembly. It is common practice to increase calculated minimum leads from 6 inches to one foot to allow for wind loading on structure accessories and for construction tolerances. Shorter guy leads created by moving anchors toward the pole result in greater downward loads on the bolt holding the guy assembly to the pole and may cause the pole to split. Because of this, guy lead lengths of less than 15 feet from the pole to the closest anchor are not recommended. In any case, the loads must be evaluated for the guy leads to determine if permitted loads are exceeded for all components of the guying system.

13 METHODOLOGY FOR MULTIPLE GUYS

Multiple guys and anchors are required where the strength of one guy assembly or one anchor is not adequate for the load. Multiple guys may be placed 2 or more in line with the longitudinal tension according to RUS construction specifications, or, if required by field conditions, spread apart with the anchors installed side-by-side. The recommended minimum separation between anchors is 5 feet in soils and 2 feet in rock.

The same design process should be followed for multiple guy attachments as previously shown for single guy wire attachments, including evaluation of permitted loads of the guy assemblies and pole.

14 GUY ASSEMBLY CALCULATION EXAMPLE 1

A GIVEN INFORMATION

Assume that an RUS standard VC3.2L (25 kV, Suspension Angle, Large Conductors), three-phase, pole-top assembly needs to be constructed at a crossing with a line angle (θ) of 30 degrees. The assembly is installed on a 40 ft., Class 5 Southern Yellow Pine

pole. The phase conductors are 266.8 kcmil (26/7) ACSR with a 1/0 (6/1) ACSR neutral. One-half the sum of the adjacent spans (*HS*) is 400 feet. For purposes of illustration for this example, calculations will be shown for 4 standard RUS down guy assemblies used with 4 standard RUS anchor assemblies. As an alternative—and to show the effect of moving anchors in toward the pole—calculations will also be shown using 2 standard RUS anchor assemblies to hold the structure loads with 4 guys. NESC Grade C construction is to be used and the pole is located in the NESC light loading district.

B STATEMENT OF PROBLEM

Determine the loads that the guy and anchor assemblies need to hold and, subsequently, determine the adequate standard RUS assemblies that should be used for this example. In addition, determine if the buckling capacity of the pole is adequate.

Tabulation of Data

Pole Data:

L_p = 40 ft (length of pole)

H_p = 34 ft (height above ground)

L_g = 6 ft (bottom to ground line)

C_t= 19 in (circumference at top)

C_g = 31 in (circumference at ground line)

K_c = 72π (calculation constant)

2023 NESC Data:

W_p = 9 lb/ft^2 (Table 250-1)

F_w = 2.2 (Table 253-1)

F_t = 1.3 (Table 253-1)

F_v = 1.9 (Vertical Load Factor, Table 253-1)

Conductor Data:

Conductor	W_c (lb/ft)	W_v (lb/ft)	T_c (lb) (40 % Ultimate Strength)
266.8 kcmil	0.4815	0.3673	4,500

1/0	0.2985	0.1452	1,750

Conductor Attachment Heights:		(VC3.2L)	(Center of brackets from top of pole)
Top (A) Phase	=	1.0 ft	(= 33 ft from groundline)
Middle (B) Phase	=	5.0 ft	(= 29 ft from groundline)
Bottom (C) Phase	=	9.0 ft	(= 25 ft from groundline)
Neutral	=	13.0 ft	(= 21 ft from groundline)

Guy Assembly Attachment Heights:		(VC3.2L)	(From top of pole)
Top Phase	=	2.5 ft	(= 31.5 ft from groundline)
Middle Phase	=	6.5 ft	(= 27.5 ft from groundline)
Bottom Phase	=	10.5 ft	(= 23.5 ft from groundline)
Neutral	=	14.5 ft	(= 19.5 ft from groundline)

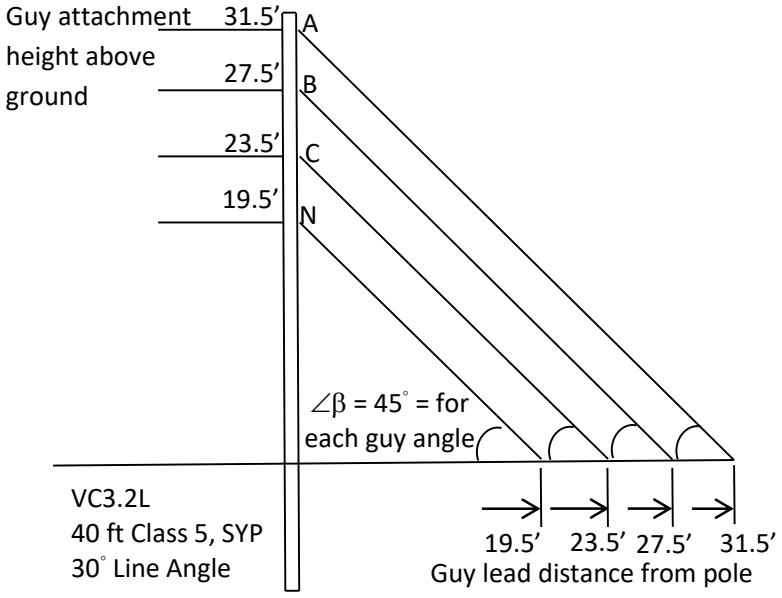


Figure 1: Structure VC3.2L – 40 ft/Class 5 Pole

Note: The recommended minimum separation between anchors in soils is 5 feet.

This problem is for mathematical demonstration purposes only.

(1) Wind Load on the Pole Surface (b)

Use Equation EQ D:

$$M_p = (W_p)\left[\frac{(2C_t + C_g)}{K_c}\right] H_p{}^2$$

$$= (9)\left[\frac{((2)(19)+31)}{72\pi}\right](34)^2$$

= 3,174 ft-lb

Determine wind load per guy attachment (divide wind moment load for the pole by the number of guy attachments):

3,174 ft-lb/4 guys = 794 ft-lb per guy

Determine force on each guy (b) due to wind on pole moment by dividing wind pole moment by height of guy attachment above ground:

b_A = 794 ft-lb/31.5 ft = 25.2 lb

b_B = 794 ft-lb/27.5 ft = 28.9 lb

b_C = 794 ft-lb/23.5 ft = 33.8 lb

b_N = 794 ft-lb/19.5 ft = 40.7 lb

(2) Transverse wind load on conductor and neutral (a)

$a = (W_c)(HS)(\cos \theta/2)$

$a_A = a_B = a_C = (0.4815 \text{ lb/ft})(400 \text{ ft})(\cos 15°) = 186 \text{ lb}$

$a_N = (0.2985 \text{ lb/ft})(400 \text{ ft})(\cos 15°) = 115 \text{ lb}$

(3) Transverse wire tension (c)

$c = 2 (T_c)(\sin \theta/2)$

$c_A = c_B = c_C = 2 (4{,}500 \text{ lb})(\sin 15°) = 2{,}329 \text{ lb}$

$c_N = 2 (1{,}750 \text{ lb}) (\sin 15°) = 906 \text{ lb}$

(4) Calculate horizontal guying load at each guy attachment, assuming β = 45°

$G_h = F_w (a + b) + F_t c = G (\cos \beta)$

Where:

G = Guy load; G_A = load in guy A, for example

G_h = Horizontal guy load

G_{hA} = Horizontal guy load at attachment A, for example

β = Guy angle relative to the ground

F_w = 2.2 = Wind load factor

F_t = 1.3 = Tension load factor

Note: NESC Load Factors for Grade C construction are included in these calculations.

G_{hA} = 2.2 (186 lb + 25.2 lb) + 1.3 (2,329 lb) = 3,493 lb = G_A (cos β)

G_{hB} = 2.2 (186 lb + 28.9 lb) + 1.3 (2,329 lb) = 3,501 lb = G_B (cos β)

G_{hC} = 2.2 (186 lb + 33.8 lb) + 1.3 (2,329 lb) = 3,512 lb = G_C (cos β)

G_{hN} = 2.2 (115 lb + 40.7 lb) + 1.3 (906 lb) = 1,521 lb = G_N (cos β)

Cosine of Guy angle relative to ground = Horizontal guy force ÷ Force in guy or:

cos β = G_h/G *or* G = G_h/cos β

As an example, the force in Guy A = Horizontal guy force at A ÷ cos β.

*Note: Because angle β = 45° **in this example**, horizontal forces = vertical forces at the guy attachment. If anchors are moved closer to the pole, angle β increases, guy angle at the pole (ϕ) decreases, vertical forces at the guy attachments increase, and the load in the guy increases.*

G_A = G_{hA}/cos β; G_A = 3,493 lb/cos 45° = 4,940 lb

G_B = 3,501 lb/cos 45° = 4,952 lb

G_C = 3,512 lb/cos 45° = 4,967 lb

G_N = 1,521 lb/cos 45° = 2,151 lb

(5) Select Anchor, Guy Wire, and Guy Assembly

Anchor Capacity (A_U), Guy Wire Capacity (G_W), and Guy Assembly Capacity must all be greater than guy force (G).

(6) Selection of Guy Assembly

Based on the calculations above, the horizontal loads at the guy attachments on the pole are the following:

G_{hA} = 3,493 lb
G_{hB} = 3,501 lb
G_{hC} = 3,512 lb
G_{hN} = 1,521 lb

Since these calculated loads include the appropriate load factors, they can be compared to the permitted loads of the guy assemblies. The permitted loads must be greater than the calculated loads.

Any of the standard RUS down guy assemblies, as listed in Table 5, are adequate to hold the conductor tension and wind loads as calculated above. However, for large conductor applications, such as used in this example, RUS recommends the use of heavy-duty guy assemblies, specifically E2.1 for this example, with a permitted guy load at 45 degrees of 11,030 lb for guys A, B, and C. For the neutral guy, N, guy assembly E1.1 with a permitted guy load at 45 degrees of 5,940 lb could be used. To simplify construction practice, E2.1 could be used for the neutral guy.

(7) Selection of Guy Wires

Based on the calculations above, the loads in the guys are the following:

G_A = 4,940 lb
G_B = 4,952 lb

G_C = 4,967 lb
G_N = 2,151 lb

Since these calculated loads include the appropriate load factors, they can be compared to the permitted load of the guy wire. The permitted load must be greater than the calculated load. As indicated in Table 3, the permitted load of the guy wire is obtained by multiplying the breaking strength by 0.9.

3/8-inch Siemens-Martin Steel guy wire with a permitted load of 6,255 lb would be adequate for the guy loads for Guys A, B, and C. Because the guy wires are holding large conductors in this example, RUS recommends, for this example, 7/16-inch Siemens-Martin Steel guy wire with a permitted load of 8,415 lb for the conductor guys. For the neutral guy, N, ¼-inch Siemens-Martin Steel guy wire with a permitted load of 2,835 lb could be used. However, for simplified construction practice using only one size guy wire at the structure, the 7/16-inch guy wire could be used.

(8) Selection of Anchors

Repeating the guy loads used above:

G_A = 4,940 lb
G_B = 4,952 lb
G_C = 4,967 lb
G_N = 2,151 lb

Since these calculated loads include the appropriate load factors, they can be compared to the permitted load of the anchors. The permitted load for an anchor assembly is equal to the Designated Maximum Holding Power from Table 1 because the strength factor for anchors (NESC 2023, Table 261-1) is 1.0. In addition, NESC 2023, 264F requires that the anchors have an ultimate strength not less than that required of the guys.

For this example, any of the standard RUS anchor assemblies rated at 6,000 lb or more (see Table 1) may be used for the conductor guys. Anchors rated at 8,000 lb or more, such as Screw Anchor F2.8, are recommended in this example as a measure of safety and to better match the large guy assemblies and guy wires. Anchor F2.6, rated at 6,000 lb, could be used for the neutral guy. To simplify construction, Anchor F2.8 could also be used.

(9) Selection of Pole Class

The column strengths of poles at guyed locations should be examined for their ability to sustain loads due to the vertical weight of the conductors, equipment, and the vertical component of the load supported by the guys. The vertical axial capacity of a pole increases as the size and strength of the pole increases. A guyed pole acts as a column sustaining these axial loads. A pole acting as a column becomes unstable when the axial force becomes large enough to cause large lateral deflections which might significantly add to the moment loads contributed by conductors, ice, and equipment installed on the pole.

In order to evaluate the vertical load capacity of a guyed pole, it is necessary to determine the critical buckling axial load, or P_{cr}. P_{cr} calculation assumptions and procedures established in Chapter 14 of RUS Bulletin 1724E-200, Design Manual for High Voltage Transmission Lines, are used here.

There are three formulas based on column configurations which can be used to calculate P_{cr}.

Table 8: Three Formulas to Calculate Critical Buckling Axial Load

Conditions	Fixed – Free End	Fixed – Pinned End	Pinned – Pinned End

For a tapered column (circular cross section)	$P_{cr} = \frac{\pi^2 EI_A}{4\ell^2}\left(\frac{d_g}{d_a}\right)^{2.7}$	$P_{cr} = \frac{2\pi^2 EI_A}{\ell^2}\left(\frac{d_g}{d_a}\right)^{2.0}$	$P_{cr} = \frac{\pi^2 EI_A}{\ell^2}\left(\frac{d_g}{d_a}\right)^{2.0}$

Fixed-Free End P_{cr} equation normally used for in-line tangent dead-ends with no side guys. Formula developed using shape factor, k = 2:

$(k\ell)^2 = (2\ell)^2 = 4\ell^2$

Fixed-Pinned End P_{cr} equation normally used for in-line guyed poles at medium and large angle dead-ends. Formula developed using k = 0.7:

$(k\ell)^2 = (0.7\ell)^2 = 0.49\ell^2$

Thus giving the "2" in the numerator.

Pinned-Pinned End P_{cr} equation normally used for bisector guys. Formula developed using

k = 1.0:

$(k\ell)^2 = (1\ell)^2 = \ell^2$

Where:

E = Modulus of Elasticity
I_A = Moment of Inertia at the guy attachment, in^4
d_g = Diameter at the groundline, in
d_a = Diameter at the point of lowest guy attachment
ℓ = Distance from the groundline to the point of lowest guy attachment, in

Assuming the pinned-pinned column condition for bi-sector guys, for this example use:

$$P_{cr} = \left[\frac{\pi^2 EI}{l^2}\right] \cdot \left[\frac{d_g}{d_a}\right]^{2.0}$$

Determine the weight of the conductors:

W_{VT} = Weight of conductors and neutral = F_V [HS(3(W_{VC}) + 1(W_{VN}))]
W_{VT} = 1.9[400(3 (0.3673) + 1 (0.1452))]
W_{VT} = 948 lb

Note: NESC Vertical Load Factor (F_V) for Grade C construction is included in this calculation.

Table 9: Calculate Guying Vertical Load on Pole

Guy Attachment	Load in Guy, G, lb	Horizontal Guy Load at Attachment, G_h, lb	*Vertical Guy Load at Attachment, G_v, lb
A	4,940	3,493	3,493
B	4,952	3,501	3,501
C	4,967	3,512	3,512
N	2,151	1,521	1,521
			12,027 = Total Vertical Guying Load

** Vertical guy load at attachment equals horizontal load at attachment in this example because b = 45°.*

Total Vertical Load on Pole = W_{VT} + Total Vertical Guying Load
Total Vertical Load on Pole = 948 lb + 12,027 lb = 12,975 lb

Calculate critical buckling axial load (P_{cr}) of 40 ft, Class 5 Southern Yellow Pine Pole in this guying configuration:

$$P_{cr} = \left[\frac{\pi^2 EI}{l^2}\right] \cdot \left[\frac{d_g}{d_a}\right]^{2.0}$$

Where:

E = 1,800,000 psi

$I = \frac{\pi d_a^4}{64}$ = 171 in^4

d_g = 9.87 in

d_a = 7.68 in

ℓ = 19.5 ft = 234 in

$$P_{cr} = \left[\frac{\pi^2(1.8)(10^6)(171)}{(234)^2}\right] \cdot \left[\frac{(9.87)}{(7.68)}\right]^{2.0}$$

P_{cr} = 91,632 lb

So:

Total Vertical Load on Pole < P_{cr}

12,975 lb < 91,632 lb

Vertical capacity of 40 ft, Class 5 Southern Yellow Pine is sufficient

15 GUY ASSEMBLY CALCULATION EXAMPLE 2

A COMBINING TWO GUYS ON ONE ANCHOR AND GUY ANGLES GREATER THAN 45 DEGREES

This example problem will assume the same given information used in the previous example. Some changes will be made in order to illustrate the effect of combining two guys on one anchor and also the impact of moving anchors closer to the pole so that angle β, the guy angle relative to the ground, is greater than 45 degrees for some of the guys.

For purposes of this example, the anchor for the neutral conductor will remain at a distance of 19.5 feet from the pole, or an angle with the ground, β, equaling 45°. The guy for conductor C will be combined with the neutral guy on the same anchor at 19.5 ft

from the pole. The guys for conductors A and B will be combined on an anchor at 25 feet from the pole.

Horizontal loads at the guy attachments on the pole will be the same as the previous example.

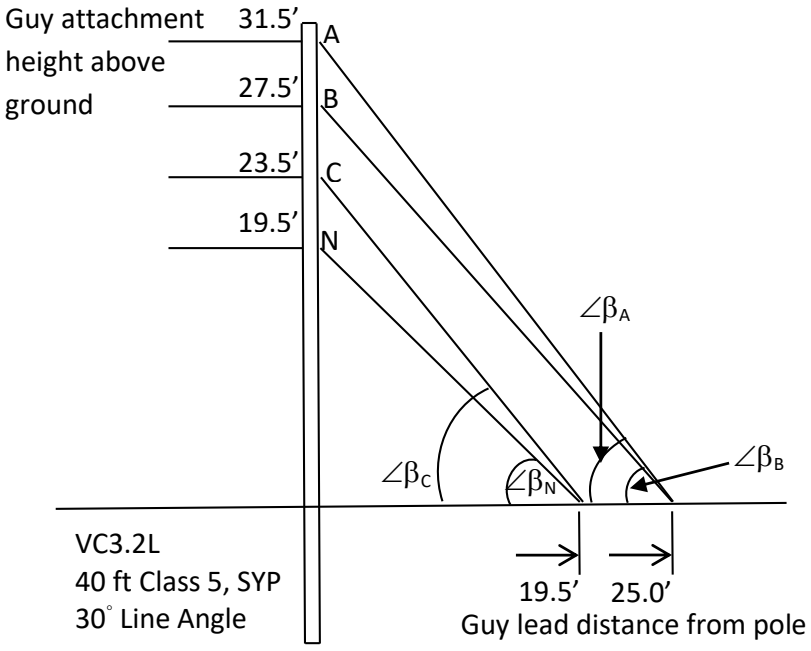


Figure 2: Structure VC3.2L – Two Anchors

Table 10: Calculate Guying Vertical Load for Two Guys on One Anchor

Guy Attachment	Horizontal Guy Load at Attachment, G_h, lb	Guy Angle, b Degrees	Load in Guy, G, lb	Vertical Guy Load at Attachment, G_V, lb
A	3,493	51.6	5,624	4,408
B	3,501	47.7	5,202	3,848
C	3,512	50.3	5,498	4,231
N	2,151	45	2,151	1,521
				14,008 = Total Vertical Guying Load

Note: NESC Load Factors for Grade C construction are included in the calculations of Horizontal Guy Loads, G_h, from the previous example problem.

(1) Calculate Guy Angle, β, for Each Guy

Tan β_A = 31.5'/25' β_A = 51.6°
Tan β_B = 27.5'/25' β_B = 47.7°
Tan β_C = 23.5'/19.5' β_C = 50.3°
β_N = 45°

(2) Calculate Load in Guy, G, for Each Guy

$G_A = G_{hA}/\cos \beta$, so:
G_A = 3,493 lb/cos 51.6°= 5,624 lb
G_B = 3,501 lb/cos 47.7°= 5,202 lb
G_C = 3,512 lb/cos 50.3°= 5,498 lb
G_N = 1,521 lb/cos 45° = 2,151 lb

(3) Calculate Vertical Guy Load, G_V, in Each Guy

$G_{VA} = G_A/\sin \beta_A$ = 5,624 (sin 51.6°) = 4,408 lb
$G_{VB} = G_B/\sin \beta_B$ = 5,202 (sin 47.7°) = 3,848 lb
$G_{VC} = G_C/\sin \beta_C$ = 5,498 (sin 50.3°) = 4,231 lb
$G_{VN} = G_N/\sin \beta_N$ = 2,151 (sin 45°) = 1,521 lb

(4) Select Anchor, Guy Wire, and Guy Assembly

Anchor capacity (A_U), guy wire capacity (G_W), and guy assembly capacity must all be greater than guy force (G).

(5) Selection of Guy Assembly

As shown above, the horizontal loads at the guy attachments on the pole are the following and are the same as the previous example:

G_{hA} = 3,493 lb
G_{hB} = 3,501 lb
G_{hC} = 3,512 lb
G_{hN} = 1,521 lb

However, the anchor attachments have been moved in closer to the structure for guys A, B, and C in this example. The angle of the guy wire with the ground, β, for guys A, B, and C is greater than 45 degrees and the angle of the guy wire with respect to the pole is less than 45 degrees. As a result, the vertical loads at the pole attachment and the loads in the guy wires are greater than in the previous example. When this occurs, the guy assembly must be selected based on its permitted load and compared to the calculated loads.

In this case, the calculated guy loads are still significantly less than the 45 degrees permitted load for the guy attachment for E 2.1 from Table 5.

G_A = 5,624 lb
G_B = 5,202 lb
G_C = 5,498 lb
G_N = 1,521 lb

(6) Selection of Guy Wires

Based on the calculations above, the loads in the guys are the following:

G_A = 5,624 lb
G_B = 5,202 lb
G_C = 5,498 lb
G_N = 2,151 lb

Since these calculated loads include the appropriate load factors, they can be compared to the permitted load of the guy wire. The permitted load must be greater than the calculated load. As indicated in Table 3, the permitted load of the guy wire is obtained by multiplying the breaking strength by 0.9.

3/8 inch Siemens-Martin Steel guy wire, with a permitted load of 6,255 lb would be adequate for the guy loads for Guys A, B, and C. Because the guy wires are holding large conductors in this example, RUS recommends for this example that 7/16 inch Siemens-Martin Steel guy wire with a permitted load of 8,415 lb for the conductor guys. For the neutral guy, N, ¼ inch Siemens-Martin Steel guy wire with a permitted load of 2,835 lb could be used. However, for simplified construction practice to use only one size guy wire at the structure, the 7/16 inch guy wire could be used.

(7) Selection of Anchors

Repeating the guy loads used above:

G_A = 5,624 lb
G_B = 5,202 lb
G_C = 5,498 lb
G_N = 2,151 lb

Since these calculated loads include the appropriate load factors, they can be compared to the permitted load of the anchors. The permitted load for an anchor assembly is equal to the Designated Maximum Holding Power from Table 1, because the strength factor for anchors (NESC 2023, Table 261-1) is 1.0. In addition, NESC 2023, 264F, requires that the anchors have an ultimate strength not less than that required of the guys.

For this example, any of the standard RUS anchor assemblies rated at 6,000 lb or more (see Table 1) may be used for the conductor guys. Anchors rated at 8,000 lb or more, such as Screw Anchor F2.8, are recommended in this example as a measure of safety and to better match the large guy assemblies and guy wires. Anchor F2.6, rated at 6,000 lb, could be used for the neutral guy. To simplify construction, Anchor F2.8 could also be used.

(8) Selection of Pole Class

The pole in this example is the same pole as the previous example, a 40 ft, Class 5 Southern Yellow Pine. Since the guying attachment on the pole is the same as the previous example problem, the P_{cr} value for the vertical capacity of the pole is the same, P_{cr} = 91,632 lb. This value should be compared to the new vertical loads on the pole created by moving the anchors in towards the pole.

- Total Vertical Load on Pole = W_{VT} + Total Vertical Guying Load
- W_{VT} = 948 lb from previous example
- Total Vertical Load on Pole = 948 lb + 14,008 lb = 14,956 lb

Note that the W_{VT} and the Total Vertical Guying Load all contain the load factors required by NESC 2023.

Total Vertical Load = 14,956 lb, which is less than P_{cr} = 91,632 lb. Therefore, the pole selected is adequate for this example also.

Note: Even though the loads in this example did not increase by a large amount when compared to the previous example, attention is called to process that must be used when evaluating the strength of the various components of a guying system. This is particularly important when moving guys in toward the pole and the guy angle with respect to the ground is greater than 45 degrees.

EXHIBIT A: CONDUCTOR LOADINGS

STRUCTURES 60 FEET OR LESS (ABOVE GROUND OR WATER)

EXHIBIT A: CONDUCTOR LOADINGS 2023 NESC Rule 250B							Light		Medium			Heavy		
							0.0" Ice		0.25" Ice			0.50" Ice		
							9 lb Wind		4 lb Wind			4 lb Wind		
	Manufacturer's Data						K = 0.05		K=0.20			K=0.30		
Name (ACSR Cond.)	Size	Strand	Cable OD (In)	X-Area Sq. In.	Ultimate Strength	Vert. lb/ft	Trans. lb/ft	Total lb/ft	Vert. lb/ft	Trans. lb/ft	Total lb/ft	Vert. lb/ft	Trans. lb/ft	Total lb/ft
Swanate	4	7/1	0.257	0.0411	2360	0.0670	0.1928	0.2541	0.2219	0.2523	0.5360	0.5294	0.4190	0.9752
Sparrow	2	6/1	0.316	0.0608	2850	0.0913	0.2370	0.3040	0.2642	0.2720	0.5792	0.5898	0.4387	1.0350
Raven	1/0	6/1	0.398	0.0968	4380	0.1452	0.2985	0.3819	0.3431	0.2993	0.6553	0.6938	0.4660	1.1357
Quail	2/0	6/1	0.447	0.1221	5310	0.1831	0.3353	0.4320	0.3960	0.3157	0.7064	0.7616	0.4823	1.2015
Pigeon	3/0	6/1	0.502	0.1537	6620	0.2309	0.3765	0.4917	0.4606	0.3340	0.7689	0.8430	0.5007	1.2805
Penguin	4/0	6/1	0.563	0.1939	8350	0.2911	0.4223	0.5629	0.5394	0.3543	0.8454	0.9404	0.5210	1.3751
Waxwing	266.8	18/1	0.609	0.2210	6880	0.2894	0.4568	0.5907	0.5518	0.3697	0.8642	0.9668	0.5363	1.4056
Partridge	266.8	26/7	0.642	0.2436	11300	0.3673	0.4815	0.6556	0.6397	0.3807	0.9444	1.0649	0.5473	1.4973
Merlin	336.4	18/1	0.684	0.2789	8680	0.3653	0.5130	0.6798	0.6506	0.3947	0.9609	1.0886	0.5613	1.5248
Linnet	336.4	26/7	0.721	0.3070	14100	0.4630	0.5408	0.7619	0.7596	0.4070	1.0617	1.2089	0.5737	1.6381
Pelican	477	18/1	0.814	0.3955	11800	0.5180	0.6105	0.8506	0.8430	0.4380	1.1500	1.3207	0.6047	1.7525
Hawk	477	26/7	0.858	0.4354	19500	0.6570	0.6435	0.9696	0.9954	0.4527	1.2935	1.4866	0.6193	1.9104
Osprey	556.5	18/1	0.879	0.4612	13700	0.6040	0.6593	0.9441	0.9488	0.4597	1.2543	1.4464	0.6263	1.8762
Dove	556.5	26/7	0.927	0.5083	22600	0.7660	0.6953	1.0845	1.1255	0.4757	1.4219	1.6377	0.6423	2.0592
Kingbird	636	18/1	0.940	0.5275	15700	0.6910	0.7050	1.0372	1.0545	0.4800	1.3586	1.5706	0.6467	1.9986
Grosbeak	636	26/7	0.990	0.5808	25200	0.8750	0.7425	1.1976	1.2537	0.4967	1.5485	1.7852	0.6633	2.2044
Drake	795	26/7	1.108	0.7264	31500	1.0940	0.8310	1.4238	1.5088	0.5360	1.8012	2.0763	0.7027	2.4919

CELL FORMULAS, FOR USE IN BUILDING OTHER WIRE SIZES DATA

H8 = (D8*9)/12

I8 = SQRT((G8^2)+(H8^2))+0.05

J8 = G8+(((PI()*((D8+0.25+0.25)^2)*12)/4)*(56/(12*12*12)))-(((PI()*(D8^2)*12)/4)*(56/(12*12*12)))

K8 = ((D8+0.25+0.25)*4)/12

L8 = SQRT((J8^2)+(K8^2))+0.2

M8 = G8+(((PI()*((D8+0.5+0.5)^2)*12)/4)*(56/(12*12*12)))-(((PI()*(D8^2)*12)/4)*(56/(12*12*12)))

N8 = ((D8+0.5+0.5)*4)/12

O8 = SQRT((M8^2)+(N8^2))+0.3

Ice & Wind loading shown is from 2023 NESC Table 250-1

K factor shown is from 2023 NESC Table 251-1

CONSTANTS USED:
Assumed weight of ice [lb/ft^3]: 56

EXHIBIT B: EXTREME WIND LOADING

EXHIBIT B: Extreme Wind Loading 2023 NESC Rule 250C					STRUCTURES < = 60' ONLY												
	Manuafacturer's Data				70 mph, 12.5 lbs/ft^2		80 mph, 16.4 lbs/ft^2		90 mph, 20.7 lbs/ft^2		100 mph, 25.6 lbs/ft^2		110 mph, 31 lbs/ft^2		50 mph, 6.4 lbs/ft^2		
Name (ACSR Cond.)	Size	Strand	Cable OD (In)	Vert. lb/ft	Trans. lb/ft	Total lb/ft	Trans. lb/ft	Total lb/ft	Trans. lb/ft	Total lb/ft	Trans. lb/ft	Total lb/ft	Trans. lb/ft	Total lb/ft	Trans. lb/ft	Total lb/ft	Swing Angle
Swanate	4	7/1	0.257	0.0670	0.2677	0.2760	0.3512	0.3576	0.4433	0.4484	0.5483	0.5523	0.6639	0.6673	0.1371	0.1526	63.95
Sparrow	2	6/1	0.316	0.0913	0.3292	0.3416	0.4319	0.4414	0.5451	0.5527	0.6741	0.6803	0.8163	0.8214	0.1685	0.1917	61.55
Raven	1/0	6/1	0.398	0.1452	0.4146	0.4393	0.5439	0.5630	0.6866	0.7017	0.8491	0.8614	1.0282	1.0384	0.2123	0.2572	55.63
Quail	2/0	6/1	0.447	0.1831	0.4656	0.5003	0.6109	0.6377	0.7711	0.7925	0.9536	0.9710	1.1548	1.1692	0.2384	0.3006	52.47
Pigeon	3/0	6/1	0.502	0.2309	0.5229	0.5716	0.6861	0.7239	0.8660	0.8962	1.0709	1.0955	1.2968	1.3172	0.2677	0.3535	49.22
Penguin	4/0	6/1	0.563	0.2911	0.5865	0.6547	0.7694	0.8227	0.9712	1.0139	1.2011	1.2358	1.4544	1.4833	0.3003	0.4182	45.89
Waxwing	266.8	18/1	0.609	0.2894	0.6344	0.6973	0.8323	0.8812	1.0505	1.0897	1.2992	1.3310	1.5733	1.5996	0.3248	0.4350	48.30
Partridge	266.8	26/7	0.642	0.3673	0.6688	0.7630	0.8774	0.9512	1.1075	1.1668	1.3696	1.4180	1.6585	1.6987	0.3424	0.5021	42.99
Merlin	336.4	18/1	0.684	0.3653	0.7125	0.8007	0.9348	1.0036	1.1799	1.2352	1.4592	1.5042	1.7670	1.8044	0.3648	0.5163	44.96
Linnet	336.4	26/7	0.721	0.4630	0.7510	0.8823	0.9854	1.0887	1.2437	1.3271	1.5381	1.6063	1.8626	1.9193	0.3845	0.6019	39.71
Pelican	477	18/1	0.814	0.5180	0.8479	0.9936	1.1125	1.2272	1.4042	1.4967	1.7365	1.8121	2.1028	2.1657	0.4341	0.6759	39.97
Hawk	477	26/7	0.858	0.6570	0.8938	1.1093	1.1726	1.3441	1.4801	1.6193	1.8304	1.9447	2.2165	2.3118	0.4576	0.8007	34.86
Osprey	556.5	18/1	0.879	0.6040	0.9156	1.0969	1.2013	1.3446	1.5163	1.6321	1.8752	1.9701	2.2708	2.3497	0.4688	0.7646	37.82
Dove	556.5	26/7	0.927	0.7660	0.9656	1.2326	1.2669	1.4805	1.5991	1.7731	1.9776	2.1208	2.3948	2.5143	0.4944	0.9117	32.84
Kingbird	636	18/1	0.940	0.6910	0.9792	1.1984	1.2847	1.4587	1.6215	1.7626	2.0053	2.1210	2.4283	2.5247	0.5013	0.8537	35.96
Grosbeak	636	26/7	0.990	0.8750	1.0313	1.3524	1.3530	1.6113	1.7078	1.9189	2.1120	2.2861	2.5575	2.7030	0.5280	1.0220	31.11
Drake	795	26/7	1.108	1.0940	1.1542	1.5903	1.5143	1.8681	1.9113	2.2022	2.3637	2.6046	2.8623	3.0643	0.5909	1.2434	28.38

CELL FORMULAS, FOR USE IN BUILDING OTHER WIRE SIZES &/OR ICE THICKNESS DATA

F7 = (D7*12.5)/12
G7 = SQRT((E7^2)+(F7^2))
P7 = (D7*6.4)/12
Q7 = SQRT((E7^2)+(P7^2))
R7 = (ATAN(P7/E7))*180/PI()

Wind loading is from Table 250-4

EXHIBIT C: EXTREME ICE WITH CONCURRENT WIND CONDITION

EXHIBIT C:

EXTREME ICE WITH CONCURRENT WIND LOADING

2023 NESC Rule 250D

					0.5" ice thickness, structures with total height <= 60'									0.75" ice thickness, structures with total height <= 60'								
	Manuafacturer's Data					30 mph wind 2.3 lb/ft^2		40 mph wind 4.0 lb/ft^2		50 mph wind 6.4 lb/ft^2		60 mph wind 9.2 lb/ft^2			30 mph wind 2.3 lb/ft^2		40 mph wind 4.0 lb/ft^2		50 mph wind 6.4 lb/ft^2		60 mph wind 9.2 lb/ft^2	
Name (ACSR Cond.)	Size	Strand	Cable OD (In)	Vert. lb/ft	Vert. lb/ft	Trans. lb/ft	Total lb/ft	Trans. lb/ft	Total lb/ft	Trans. lb/ft	Total lb/ft	Trans. lb/ft	Total lb/ft	Vert. lb/ft	Trans. lb/ft	Total lb/ft	Trans. lb/ft	Total lb/ft	Trans. lb/ft	Total lb/ft	Trans. lb/ft	Total lb/ft
Swanate	4	7/1	0.257	0.0670	0.5294	0.2409	0.5817	0.4190	0.6752	0.6704	0.8542	0.9637	1.0995	0.9897	0.3368	1.0454	0.5857	1.1500	0.9371	1.3629	1.3470	1.6715
Sparrow	2	6/1	0.316	0.0913	0.5898	0.2522	0.6414	0.4387	0.7350	0.7019	0.9168	1.0089	1.1687	1.0681	0.3481	1.1234	0.6053	1.2277	0.9685	1.4418	1.3923	1.7548
Raven	1/0	6/1	0.398	0.1452	0.6938	0.2680	0.7437	0.4660	0.8357	0.7456	1.0184	1.0718	1.2767	1.1971	0.3638	1.2512	0.6327	1.3540	1.0123	1.5677	1.4551	1.8843
Quail	2/0	6/1	0.447	0.1831	0.7616	0.2773	0.8105	0.4823	0.9015	0.7717	1.0842	1.1094	1.3456	1.2799	0.3732	1.3332	0.6490	1.4350	1.0384	1.6482	1.4927	1.9663
Pigeon	3/0	6/1	0.502	0.2309	0.8430	0.2879	0.8908	0.5007	0.9805	0.8011	1.1629	1.1515	1.4271	1.3781	0.3837	1.4305	0.6673	1.5312	1.0677	1.7433	1.5349	2.0628
Penguin	4/0	6/1	0.563	0.2911	0.9404	0.2996	0.9870	0.5210	1.0751	0.8336	1.2567	1.1983	1.5233	1.4942	0.3954	1.5456	0.6877	1.6448	1.1003	1.8556	1.5816	2.1758
Waxwing	266.8	18/1	0.609	0.2894	0.9668	0.3084	1.0148	0.5363	1.1056	0.8581	1.2927	1.2336	1.5673	1.5346	0.4042	1.5870	0.7030	1.6880	1.1248	1.9027	1.6169	2.2292
Partridge	266.8	26/7	0.642	0.3673	1.0649	0.3147	1.1104	0.5473	1.1973	0.8757	1.3787	1.2589	1.6489	1.6428	0.4106	1.6933	0.7140	1.7912	1.1424	2.0010	1.6422	2.3228
Merlin	336.4	18/1	0.684	0.3653	1.0886	0.3228	1.1354	0.5613	1.2248	0.8981	1.4112	1.2911	1.6887	1.6793	0.4186	1.7307	0.7280	1.8303	1.1648	2.0437	1.6744	2.3714
Linnet	336.4	26/7	0.721	0.4630	1.2089	0.3299	1.2531	0.5737	1.3381	0.9179	1.5178	1.3194	1.7895	1.8109	0.4257	1.8602	0.7403	1.9564	1.1845	2.1639	1.7028	2.4857
Pelican	477	18/1	0.814	0.5180	1.3207	0.3477	1.3657	0.6047	1.4525	0.9675	1.6371	1.3907	1.9179	1.9511	0.4435	2.0009	0.7713	2.0980	1.2341	2.3086	1.7741	2.6371
Hawk	477	26/7	0.858	0.6570	1.4866	0.3561	1.5286	0.6193	1.6104	0.9909	1.7866	1.4245	2.0589	2.1304	0.4520	2.1778	0.7860	2.2708	1.2576	2.4739	1.8078	2.7941
Osprey	556.5	18/1	0.879	0.6040	1.4464	0.3601	1.4905	0.6263	1.5762	1.0021	1.7596	1.4406	2.0414	2.0966	0.4560	2.1457	0.7930	2.2416	1.2688	2.4507	1.8239	2.7789
Dove	556.5	26/7	0.927	0.7660	1.6377	0.3693	1.6788	0.6423	1.7592	1.0277	1.9335	1.4774	2.2056	2.3026	0.4652	2.3491	0.8090	2.4406	1.2944	2.6415	1.8607	2.9605
Kingbird	636	18/1	0.940	0.6910	1.5706	0.3718	1.6141	0.6467	1.6986	1.0347	1.8808	1.4873	2.1631	2.2395	0.4677	2.2879	0.8133	2.3827	1.3013	2.5902	1.8707	2.9180
Grosbeak	636	26/7	0.990	0.8750	1.7852	0.3814	1.8255	0.6633	1.9044	1.0613	2.0769	1.5257	2.3483	2.4694	0.4773	2.5151	0.8300	2.6051	1.3280	2.8038	1.9090	3.1212
Drake	795	26/7	1.108	1.0940	2.0763	0.4040	2.1152	0.7027	2.1919	1.1243	2.3611	1.6161	2.6311	2.7965	0.4999	2.8408	0.8693	2.9285	1.3909	3.1233	1.9995	3.4378

CELL FORMULAS, FOR USE IN BUILDING OTHER WIRE SIZES &/OR ICE THICKNESS DATA

F7 = E7+(((PI()*((D7+0.5+0.5)^2)*12)/4)*(56/(12*12*12)))-(((PI()*(D7^2)*12)/4)*(56/(12*12*12)))

G7 = ((D7+(0.5+0.5))*2.3)/12

H7 = SQRT((F7^2)+(G7^2))

R7 = ((D7+(0.75+0.75))*4)/12

Ice loading is from Figure 250-3 of Rule 250D

Wind loading is from Table 250-4

CONSTANTS USED:
Assumed weight of ice [lb/ft^3]: 56