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**UNITED STATES DEPARTMENT OF AGRICULTURE
Rural Utilities Service**

**BULLETIN 1724E-153
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SUBJECT: Electric Distribution Line Guys and Anchors

TO: RUS Electric Borrowers and RUS Electric Staff

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AVAILABILITY: This bulletin is available on the Rural Utilities Service website at page at <http://www.usda.gov/rus/electric/index.htm>.

PURPOSE: This guide bulletin provides information needed to properly design guying for conductors attached to wood distribution poles. To this end, the bulletin contains data, equations, and sample calculations. The bulletin also contains information regarding standard RUS anchor and guying assemblies and their component parts to assist the user in the proper selection and installation of these assemblies.



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MATERIALS AND EQUIPMENT:

Guys and Anchors Design Guide

ABBREVIATIONS

ACSR	Aluminum conductor, steel reinforced
ANSI	American National Standards Institute
BIL	Basic Impulse Insulation Level
IEEE	Institute of Electrical and Electronic Engineers, Inc.
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^{-6} square meters)
g	gram or grams (metric base unit of weight)
kg	kilogram or kilograms (1,000 grams = 1 kilogram)
lbs	pounds (1 pound = 0.45359 kilograms)
ft-lbs	foot-pounds (feet x pounds), (a measure of torque or angular force)

ELECTRIC DISTRIBUTION LINE GUYS AND ANCHORS

1. INTRODUCTION

1.1 Guyed Structures: Guys and anchors are installed at distribution line deadends, 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. RUS highly discourages the use of push-brace poles in lieu of downguys and anchors.

1.2 Scope of Bulletin: This guide bulletin lists all of the standard RUS distribution guy and anchor assemblies and their permitted loads and holding power, respectively. The bulletin also discusses the component parts of guy assemblies and their strengths. Installation guidelines are provided for guy and anchor assemblies.

Within this bulletin are the derivation 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.

1.3 National Electrical Safety Code: The bulletin references rules and presents selected strength and overload factors required by the 1997 Edition of the National Electrical Safety Code (NESC) for certain guy calculations. At the time this bulletin was written, the 1997 Edition was the latest edition of the NESC. Periodically the NESC is updated and revised. Users of this bulletin 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 Electronic Engineers, Inc., (IEEE) at the following address:

IEEE Customer Service
445 Hoes Lane, PO Box 1331
Piscataway, NJ 08855-1331

2. ANCHORS, ANCHORING, AND SOILS

2.1 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 2-2: Soil Classification). 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 2-1: RUS Standard Distribution Anchor Assemblies

Anchor Type	RUS Designation	Minimum Area (square inches)	Designated Maximum Holding Power (lbs) *
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.

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.

2.1.1 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.

2.1.2 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, 34.5kV through 69 kV.”

2.2 Anchor Strength Requirements: Table 261-1A of the 1997 NESC specifies strength factors (equal to 1.0 for both Grade B and Grade C construction) with which the established holding power of anchors are to be multiplied. Rule 264 of the 1997 NESC requires that an anchor and rod assembly have an ultimate strength not less than that of the guy(s) attached to it.

2.3 Soil Classifications: The following table defines the commonly accepted soil classes and their descriptions.

Table 2-2: 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

The following table 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 261-1A of the 1997 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 overload factors found in Section 25 of the 1997 NESC.

Table 3-1: Guy Wire Strength Data

Type Strand	Size	Breaking Strength (lbs)	Permitted Load (0.9 x Rated Strand Breaking Strength) (lbs)
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

4.1 RUS Guy Assemblies: Standard RUS distribution guying assemblies include both the guy wire and the hardware to connect the guy wire to the pole. For analysis purposes, this bulletin discusses the guy wires and the pole attachment hardware separately and refers to the pole attachment hardware as the guying assembly. Table 4-1: RUS Guying Assembly Units presents the RUS standard distribution guy assemblies included in Bulletin 1728F-803, “Specifications and Drawings for 24.9/14.4 kV Line Construction.” Multiple downguys consist of two or more guy assemblies installed in parallel and attached to one or more anchors as may be needed. The last two columns on the right side of Table 4-1 itemize the permitted loads allowed by RUS standards on each guy assembly. The permitted loads shown are the calculated strengths of the assemblies, as designated by RUS, multiplied by the strength factor of 0.85 as required in the 1997 NESC. 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 1997 NESC.

Table 4-1: RUS Guying Assembly Units

Guying Assembly Type	RUS Designation	Permitted Loads (lbs) *	
		Horizontal	@ 45 Degrees
Single Down Guy (Through Bolt)	E1.1	5,000	7,100
Single Overhead (Through Bolt)	E1.02	6,600	-
Single Down Guy – Heavy Duty (Through Bolt)	E2.1	7,400	10,500
Single Down Guy (Wrapped Type)	E3.1	11,900	16,800
Single Down Guy – Large Conductors (Pole Band Type)	E4.1L	8,500	12,000

* Permitted load is the lesser of loads shown or permitted load of guy wire (See Table 3-1: Guy Wire Strength Data).

Permitted loads are designated capacities multiplied by 0.85, the 1997 NESC strength factor.

Greater permitted loads (strengths) are required for guy angles less than 45 degrees.

4.2 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), or thimble eye bolts and/or thimble eye nuts;
- Guy attachments (guy hook or pole band type, or guy hooks and guy plates); and
- Guy deadends (types include: 3-bolt clamp, U-bolt clamp, offset guy clamp, and automatic and formed deadends).

4.3 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 4-2: 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 4-2: Standard Washers – Loads Allowed

Washer Size and Type	Approximate Area (square inches)	Load Allowed Abutting Pole (lbs)
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

5. LOADING ON POLES AND GUY ASSEMBLIES

5.1 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 top of pole is 60 feet or more above ground),
- 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 overload factor as specified in Section 25 of the 1997 NESC. The tables in Exhibit A and Exhibit B at the end of this bulletin provide the information required to calculate wind/ice loading for each NESC loading district and on bare conductors commonly installed on distribution lines. The greater of either the (1) wind/ice loads or, (2) extreme wind loads, but not both, need to be added to the sum of the loads. The wind load on materials and equipment attached to a pole can usually be ignored.

5.2 NESC Overload Factors: The following table of overload factors has been adapted from Table 253-1 of the 1997 NESC:

Table 5-1: Overload Factors for Poles, Guys, Anchors, Etc.
(Use with Table 261-1A Strength Factors)

	Overload Factors	
	Grade B	Grade C
Rule 250B Loads		
Vertical Loads	1.50	1.50
Transverse Loads		
Wind	2.50	2.20
Wire Tension	1.65	1.30
Longitudinal Loads		
In General	1.10	No Requirement
At Deadends	1.65	1.30
At Deadends (for guys)	1.65	1.10

5.3 Pole Loading: Guyed poles may be considered to act as struts and need to support the vertical component of the loads cited in Section 5.1 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 (sideguys) may be desirable.

5.4 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.

5.4.1 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 conductor tension loads and the maximum wind/ice (or extreme wind) loads on the conductors. 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 and the attached equipment and material is not added to the sum of the loads.

5.4.2 Double dead-end assemblies consist of two dead-end assemblies that are each guyed in the opposite direction of the conductors. The tension and wind/ice loads 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. In the case of tangent dead-end assemblies, only the difference of the two loads needs to be guyed. Thus, the calculations assume guy assemblies in two directions, however only (preferably) one guy assembly needs to be installed.

5.4.3 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 are performed independently for each set of conductors attached to the pole using the same methodology and assumptions discussed in Section 5.4.2.

5.4.4 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 have to be applied to all of the above loads.

6. NESC (1997 EDITION) GUYING REQUIREMENTS

6.1 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 (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 1997 NESC sets forth the requirements and exceptions for grades of construction.

6.2 Strength Requirements: Section 26 of the 1997 NESC sets forth the strength requirements and strength factors for guys and anchors. Table 261-1A (to be used with the overload factors of Table 253-1) requires a strength (multiplication) factor of 0.85 be applied to the pole attachment hardware and 0.9 be applied to guy wires for Grade C construction.

7. DETERMINE WEAKEST COMPONENT PART

Determination of the weakest component part of a guying-anchoring system, as may be derated by application of the necessary NESC strength factors (and perhaps age), is essential in proper line design and the use of guys and anchors. The strength or holding power of the combined guy and anchor is only as strong as its weakest component part. Each factor listed below needs to be analyzed separately and compared to ascertain that even the weakest component part of the guying system is stronger than the induced load.

- Holding power of anchors (see Sections 2.1 and 2.2)
- Soil classification (see Sections 2.3 and 8.3)
- Strength of guy wires (see Section 3)
- Maximum permitted load for guy assemblies, hardware and washers (see Sections 4.1, 4.2, and 4.3, respectively)

8. INSTALLATION OF GUY AND ANCHOR ASSEMBLIES

8.1 Guy Assemblies: Guy and anchor assemblies need to be installed before conductors are installed. These assemblies should be located as far as possible from highways, driveways and paths where they might pose an obstacle to expected traffic. If possible, guy wires should be installed such that the angle formed between the guy and the pole is 45 degrees or more. (45 degrees occurs when the height of guy attachment is equal to the length of the guy lead [the distance from the pole to the anchor rod], i.e., a 1 to 1 ratio.)

8.2 Guy Markers: Rule 264E of the 1997 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, a guy marker be installed on all down guys.

8.3 Anchor Assemblies: In RUS Bulletin 1728F-803, under “Construction Specifications for Anchoring,” RUS specifies the following for standard 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 backfill of all anchor holes must be thoroughly tamped the full depth.
- 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 overload 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.
- When the anchor is used in poorer soils, the holding power of the anchor should 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.”

8.4 Grounding of Guy Wires: Rules 92C2, 93C5, and 215C2 of the 1997 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 non-standard 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.

8.5 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 the above objectives can be achieved with the installation of guy strain insulators, when needed, as shown on RUS standard construction drawing “E5.1G”. 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-lbs), 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. Thus:

$$M_g = S_h M_c + M_t + M_p + M_e \quad \text{EQ 9-A}$$

Where:

S_h = 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)

$$= F_{ow} \{ \Sigma (W_c H_c) \} \cos(\theta/2) \quad \text{EQ 9-B}$$

M_t = Summation of moments due to the tension in each conductor, if there is a line angle (ft-lb)

$$= 2F_{ot} \{ \Sigma (T_c H_c) \} \sin(\theta/2) \quad \text{EQ 9-C}$$

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

$$= F_{ow} W_p \left(\frac{2C_t + C_g}{K_c} \right) H_p^2 \quad \text{EQ 9-D}$$

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

And where:

F_{ow} = NESC overload factor for wind loads

F_{ot} = NESC overload 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/ft²)

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 9-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

10.1 Total Horizontal Load: The total horizontal load on a guy assembly is determined by dividing the total ground line moment M_g (see EQ 9-A) by the height of the guy attachment above the ground using the following equation:

$$G_h = \frac{M_g}{H_g} \quad \text{EQ 10-A}$$

Where:

- G_h = Horizontal component of loads on guy assembly (lbs)
- M_g = Summation of ground line moments of load forces (ft-lbs) (EQ 9-A)
- H_g = Height of guy attachment (or average of multiple guy attachments) above the groundline (ft)

Substituting EQ 9-A for M_g into Equation EQ 10-A yields:

$$G_h = \left[\frac{S_h M_c + M_t + M_p + M_e}{H_g} \right] \quad \text{EQ 10-B}$$

The terms use in EQ 10-B are defined in Section 9. The computation is simplified and the results are conservative if, in the calculation of M_c (EQ 9-B), the cosine of $\theta/2$ is set at 1.0 for all values of θ . This practice is recommended for manual calculations. Also, if insignificant, the wind loading on the pole's material and equipment, M_e , can be deleted.

10.2 Horizontal Loads on Bisector Guy Assemblies: Equation 10-B is used to calculate the horizontal loads exerted on bisector guy assemblies. Note that the NESC overload factors have been applied. The horizontal permitted load of the guy assembly to be used (see Table 4-1: RUS Guying Assembly Units) needs to be greater than the total horizontal loads of G_h calculated in EQ 10-B. The angle θ , (used when substituting EQ 9-B and EQ 9-C into M_c and M_t above, respectively), is the line angle. It is assumed that the wind blows in a direction parallel to the bisector guy.

10.3 Horizontal Loads on Dead-End Guy Assemblies: Equation 10-B is used as the basis to calculate the horizontal loads exerted on dead-end guy assemblies. As explained in Section 5.4.1, 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

on (perpendicular to) the conductors. This methodology simulates the worst case condition. Thus, the $\cos(\theta/2)$ in Equation EQ 9-B and the $\sin(\theta/2)$ in EQ 9-C are each set to unity (1.0). The equation used to calculate the horizontal loads on a single dead-end guy assembly is:

$$G_h = \left[\frac{S_h M_c + M_t}{H_g} \right] \quad \text{EQ 10-C}$$

Where:

$$M_c = F_{ow} [\Sigma(W_c H_c)] \quad \text{EQ 10-D}$$

$$M_t = F_{ot} [\Sigma(T_c H_c)] \quad \text{EQ 10-E}$$

$$S_h = \frac{1}{2} \text{ the span length of the conductor deadending on the pole (ft)}$$

(The remaining terms are defined in Section 9 in Equation EQ 9-A)

However, under some circumstances, the wind (only) loading on the pole and the attached material and equipment may be greater than the wind/ice loading on the conductors. In such cases it is assumed that the wind direction is the same as the conductor longitudinal tension. Therefore, the following equation is used to calculate the horizontal loads on a single dead-end guy assembly.

$$G_h = \left[\frac{M_t + M_p + M_e}{H_g} \right] \quad \text{EQ 10-F}$$

The terms in the above equation are also defined in Section 9. The horizontal permitted load of the guy assembly to be used (see Table 4-1: RUS Guying Assembly Units) needs to be greater than the total horizontal load, G_h , calculated by either method above.

10.4 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 and Equation EQ 10-C or Equation EQ 10-F for each dead-end assembly.

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.

$$G_r = \frac{G_h}{\sin \phi} \quad \text{EQ 11-A}$$

Where:

G_r = Total guy load (lbs) (on guy assembly, guy wire, and anchor assembly)

G_h = Total horizontal load on guy assembly (lbs) (Equation EQ 10-A)

ϕ = Guy wire angle with respect to pole (degrees)

The loads applied to the guy and anchor assembly have previously been multiplied by the appropriate NESC overload factors in the calculation of G_h in Equation EQ 10-B.

However, the NESC strength factors have not been applied in Equation EQ 11-A.

According to Table 261-A of the 1997 NESC, the load, G_r , calculated in Equation EQ 11-A should be multiplied by 0.85, 0.9, and 1.0 to yield the permitted loads for guy assemblies, guy wires, and anchor assemblies, respectively. Note that RUS has already multiplied the designated loads for anchors, guy wires, and guy assemblies by the above strength factors and listed the resulting permitted loads in Table 2-1: RUS Standard Distribution Anchor Assemblies, Table 3-1: Guy Wire Strength Data, and Table 4-1: RUS Guying Assembly Units, respectively.

The permitted loads (capacities) of guy assemblies and guy wires and the holding power of anchors each need to be greater than total load, G_r , calculated in Equation EQ 11-A, to adequately support the conductor tension and wind loads and meet the requirements of the 1997 NESC.

Since the down guy assembly forms a right triangle:

$$F_g^2 = H_g^2 + L_g^2 \quad \text{and} \quad \sin\phi = \frac{L_g}{F_g}$$

Where:

L_g = Guy lead, or distance from pole to anchor rod (ft)

H_g = Height of guy attachment above ground (ft)

F_g = Length of guy wire (ft)

Then:

$$\sin\phi = \frac{L_g}{\sqrt{H_g^2 + L_g^2}}$$

And Equation EQ 11-A can also be written as:

$$G_r = G_h \frac{\sqrt{H_g^2 + L_g^2}}{L_g} \qquad \text{EQ 11-B}$$

Assuming a 1:1 guy slope, or ϕ is equal to 45° , the resultant guy load or tension is:

$$G_r = 1.414 G_h \quad \text{EQ 11-C}$$

12. CALCULATION OF MINIMUM GUY LEAD

While it is recommended that a 1:1 guy slope be used wherever possible, in some instances it is necessary to determine the minimum allowable guy lead for various guy and anchor arrangements.

The minimum allowable guy lead to the average anchor position is given by:

$$L_{ga} = H_g \tan \left[\arcsin \left(\frac{G_h}{G_u F_g} \right) \right] \quad \text{EQ 12-A}$$

Where:

L_{ga} = Minimum allowable guy lead (ft)

H_g = Guy attachment height (ft)

G_h = Horizontal load at guy attachment point (lbs) (Equation EQ 10-A)

G_u = Least of: guy wire breaking strength, designated strength of guy assembly, or total anchor holding power (each in lbs)

F_g = NESC strength factor (Table 261-A of 1997 NESC)

If the permitted loads of RUS anchors, guy wires, and guy assemblies are used (Table 2-1: RUS Standard Distribution Anchor Assemblies, Table 3-1: Guy Wire Strength Data, and Table 4-1: RUS Guying Assembly Units, respectively), then F_g should be set to 1.0 because RUS has already included the 1997 NESC strength factors in the aforementioned tables.

Minimum guy leads should be used only when it is not possible to obtain a 1:1 or greater guy slope. Always use the longest possible guy wire lead length to obtain the maximum strength from the guy assembly. It is common practice to increase calculated minimum leads from six inches to one foot to allow for wind loading on structure accessories and for construction tolerances. Short guy leads and the resulting greater downward loads on the bolt holding the guy assembly to the pole may cause the pole to split.

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 two 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.

Multiple guy attachments on a pole are relatively short distances apart for most distribution structures. If this is the case, then the simplest method for calculating guy loads is to assume that all of the guys are just one assembly, attached to the pole at one point and attached to one anchor. The pole attachment is assumed to be the average height above ground of all of the actual guy attachments. The anchor is assumed to be the average distance from the pole of all of the actual anchor locations. The calculations are then made for a single guy and anchor using the equations given previously.

To determine the minimum guy leads required for multiple guys, calculate the total load at the average guy attachment point. Then divide this load by the number of guys and calculate the required guy lead to the average anchor location.

14. EXAMPLE GUY ASSEMBLY CALCULATION

14.1 Given Information: Assume that a RUS standard VC3.2L (25 kV, Suspension Angle, Large Conductors), three-phase, pole-top assembly needs to be constructed at a line angle (θ) of 30 degrees. The assembly is installed on a class 40-5 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 (S_h) is 400 feet. Four (4) standard RUS down guy assemblies and two (2) standard RUS anchor assemblies are to be used to hold the conductor loads. NESC Grade C construction is to be used and the pole is situated in the NESC light loading district.

14.2 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 the above theoretical construction.

14.3 Tabulation of Data:

Pole Data:

L_p	= 40 ft	(height 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)

(1997) NESC Data: (See Section 9)

$$\begin{aligned} W_p &= 9 \text{ lbs/ft}^2 \text{ (Table 250-1)} \\ F_{ow} &= 2.2 \text{ (Table 253-1)} \\ F_{ot} &= 1.3 \text{ (Table 253-1)} \\ F_g &= 0.9 \text{ (Table 261-1A)} \end{aligned}$$

Conductor Data

<u>Conductor</u>	<u>W_c (lbs/ft)</u>	<u>W_v, (lbs/ft)</u>	<u>T_c lbs (40 % Ultimate Strength)</u>
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)

Average guy attachment height:

$$H_g = \frac{31.5 + 27.5 + 23.5 + 19.5}{4}$$

$$H_g = 25.5 \text{ ft}$$

14.4 Wind Moment Load on the Pole Surface:

(Use Equation EQ 9-D)

$$\begin{aligned} M_p &= (F_{ow}) \left(W_p \right) \left[\frac{(2C_t + C_g)}{K_c} \right] H_p^2 \\ &= (2.2)(9) \left[\frac{((2)(19) + 31)}{72\pi} \right] (34)^2 \\ &= 6,982 \text{ lb-ft} \end{aligned}$$

14.5 Wind Moment Load on the Conductors:

(Use Equation EQ 9-B)

$$M_c = F_{ow} [\Sigma(H_c W_c)] \cos \theta/2$$

<i>Phase</i>	<i>H_cW_c</i>
<i>A</i>	(33.0)(0.4815) = 15.89 <i>ft-lb / ft</i>
<i>B</i>	(29.0)(0.4815) = 13.96 <i>ft-lb / ft</i>
<i>C</i>	(25.0)(0.4815) = 12.04 <i>ft-lb / ft</i>
<i>N</i>	(21.0)(0.2985) = 6.27 <i>ft-lb / ft</i>
	$\Sigma(H_c W_c) = 48.16 \text{ ft-lb / ft}$

$$M_c = (2.2)(48.16)(\cos 15^\circ)$$

$$= 102.34 \text{ ft-lb/ft}$$

14.6 Total Horizontal Moment Load Due to Conductor Tensions:

(Use Equation EQ 9-C)

$$M_t = (2)(F_{ot})[\Sigma(H_c T_c)]\sin(\theta/2)$$

<i>Phase</i>	<i>H_cT_c</i>
<i>A</i>	(33.0) (4500) = 148,500 <i>ft-lb</i>
<i>B</i>	(29.0) (4500) = 130,500 <i>ft-lb</i>
<i>C</i>	(25.0) (4500) = 112,500 <i>ft-lb</i>
<i>N</i>	(21.0) (1750) = 36,750 <i>ft-lb</i>
	$\Sigma H_c T_c = 428,250$

$$M_t = (2)(1.3)(428,250)(\sin 15^\circ)$$

$$= 288,182 \text{ ft-lb}$$

14.7 Total Horizontal Load on Guy Assemblies:

(Use Equation 10-B)

$$G_h = \frac{(400)(102.34) + 288,182 + 6,982}{25.5}$$

$$= 13,180 \text{ lbs.}$$

14.8 Total Load on Guy Assemblies: The total load on the guy assemblies, assuming an average 1:1 guy slope, is calculated with Equation EQ 11-C.

$$G_r = (1.414)(13,180) = 18,639 \text{ lbs}$$

14.9 Average Load on Each Guy Assembly: The average load on each guy assembly, using 4 down guys and assuming each has a 1 to 1 guy slope is:

$$\frac{18,639}{4} = 4,660 \text{ lbs}$$

14.10 Permitted Loads on, and Required Strength of Guy Assemblies: The average load calculated above (which has been previously multiplied by the appropriate NESC overload factors), should not exceed the permitted load on each guy assembly. The permitted load on a guy assembly is determined by multiplying its designated strength by its appropriate NESC strength factor of 0.85 as found in Table 261-1A of the 1997 NESC. (See Section 4.1.) Conversely, the required strength of the guy assembly is determined by dividing the total (in this case, average) load by the appropriate NESC strength factor. Thus, for this example,

required (or designated) strength is: $\frac{4,660}{0.85} = 5,482 \text{ lbs (at 45 degrees)}$

14.11 Selection of Guy Assembly: Based on the calculations above, the guy assembly has to have a permitted load (strength) of 4,660 pounds at 45 degrees or equivalently, a designated strength of 5,482 pounds. Any of the standard RUS down guy assemblies, as listed in Table 4-1: RUS Guying Assembly Units, 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 with a permitted load of 10,5000 pounds at 45 degrees.

14.12 Permitted Loads on, and Strength of Guy Wires: Similar to guy assemblies, the permitted load (strength) of each guy wire also has to be equal to or greater than the average load of 4,660 pounds at 45 degrees calculated above. The designated strength of the guy wire is also determined by dividing the (average) total load by the NESC strength factor of 0.90 as found in Table 261-1A of the 1997 NESC. Therefore, for the guywires;

required (or designated) strength is: $\frac{4,660}{0.90} = 5,178 \text{ lbs.}$

14.13 Selection of Guy Wires: 3/8 inch Siemens-Martin Steel guy wires, with a permitted load of 6,255 pounds (see Table 3-1: Guy Wire Strength Data) would be adequate for the loads calculated above. Because the guy wires are holding large conductors, RUS recommends that 7/16 inch Siemens-Martin Steel guy wire (permitted load equals 8,415 pounds) be used.

14.14 Permitted Load on Anchors: The required holding power of each anchor is 9,320 pounds (18,639 pounds divided by 2) assuming that the total load is equally split between the anchors. The permitted loads on anchors is equal to their designated maximum holding power because the strength factor (Table 261-1A of the 1997 NESC) for anchor is 1.0.

14.15 Selection of Anchors: Any of the standard RUS anchor assemblies rated at 10,000 pounds or more (see Table 2-1: RUS Standard Distribution Anchor Assemblies) may be used. However, anchors rated at 12,000 pounds or more are recommended in this case as a measure of safety and to better match the larger guy assemblies and guy wires that are recommended.

14.16 Minimum Average Guy Lead: Determine the minimum average guy lead, assuming the following recommended RUS standard assemblies are used:

- Guy assemblies – E2.1 (permitted load = 4 x 10,500 = 42,000 lbs)
- Guy wire – 7/16 inch Siemens-Martin (permitted load = 4 x 8,415 = 33,660 lbs)
- Plate anchors – F3.12 (permitted load = 2 x 12,000 = 24,000 lbs)

From the calculations, the anchors are the limiting component part of this example guying arrangement, and thus is used in the design calculations. Use Equation EQ 12-A to determine the minimum average guy lead.

$$L_{ga} = (25.5) \tan \left[\arcsin \left(\frac{13,182}{24,000} \right) \right] = 16.76 \text{ ft}$$

Note that the average guy attachment height of 25.5 feet was previously calculated in Section 14.3. Also, the NESC strength factor was not used in the denominator in the above equation because it had already been applied to the anchor to yield its permitted load. After adding 0.5 foot tolerance and rounding up the next whole foot, the minimum lead becomes:

$$L_{ga} = 18 \text{ ft}$$

The spacing between anchors should not be less than 5.0 feet, i.e., each anchor should be 2.5 feet from the average lead length calculated above and in line with the line angle bisector. If the guy lead lengths need to be further reduced, then select guy assemblies, guy wires, and/or anchor assemblies with greater permitted loads, or increase the number of anchors. The calculation is then repeated. However, RUS does not recommend guy lead lengths of less than 15 feet because of the tendency of the pole to split where the through bolt holds the guy assembly.

15. DETERMINATION OF POLE CLASS TO SUPPORT VERTICAL LOADS

15.1 Column Strength of Poles: 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. 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.

15.2 Assumptions and Safety Factor: The American Institute of Timber Construction suggests that the critical section of a guyed pole is one-third the distance from the point of guy attachment to the groundline. In column strength calculations this section is assumed to be where the pole strength is most critical. A *minimum* factor of safety of 1.5 (based on Table 253-1 of the 1997 NESC) should be applied to the loads in the computations because of the various assumptions that need to be made.

15.3 Critical Vertical Load: In general, the critical axial load for a pole acting as a column is calculated by using the following formula:

$$P_{cr} = \frac{\pi EA^2}{F_v K_a (K_u H_{gb})^2} \quad \text{EQ 15-A}$$

Where:

- P_{cr} = Critical buckling axial load (lbs)
- E = Modulus of elasticity of wood (= 1,800,000 lbs/in²)
- A = Cross section area of pole at two-thirds of the distance from the groundline to the bottom guy attachment (in²)
- K_a = Conversion constant (= 576 /ft²)
- H_{gb} = Height of bottom guy attachment above ground (ft)
- K_u = The theoretical coefficient of unbraced length
 - = 0.7 for bisector guying
 - = 2.0 for dead-end guying
- F_v = Safety Factor (= 1.5 minimum)

To determine the area of the pole at the critical point, A, solve the following equation:

$$A = \frac{1}{4\pi} \left(\frac{(C_b - C_t)(H_p - 0.667H_{gb}) + C_t}{L_p - L_b} \right)^2 \quad \text{EQ 15-B}$$

Where:

- C_b = Circumference of pole 6 feet from the butt (in)
- C_t = Circumference of pole at top, (in)
- H_{gb} = The distance from groundline to the bottom guy (ft)

H_p = Pole height above ground, (ft)

L_b = Bottom of pole to ANSI classification point (= 6 ft)

L_p = Pole height (ft)

15.4 Actual Vertical Loads: The actual vertical loads on the pole are the vertical (vector) component of the loads on the guy wire(s) plus the weight of the conductors plus the weight of the material and equipment installed on the pole. G_v , the vertical component of the load contributed by guy wire is calculated using the following equation:

$$G_v = \frac{(S_h)(M_c) + M_t + M_p + M_e}{L_g} \quad \text{EQ 15-C}$$

Where:

M_c , M_t , M_p and M_e are groundline moments as defined in Section 9 (ft-lb)

L_g = Length of guy lead (ft)

S_h = 1/2 the sum of adjacent spans (ft)

All overload factors should be set equal to 1.0 when performing the calculations to determine G_v in Equation EQ 15-C. (If groundline moments have previously been calculated using overload factors, such as in Equation EQ 10-A, then it is only necessary to divide these previously calculated moments by the overload factors.) The moment due to wind on the material and equipment on the pole, M_e , is included in the calculations only if the material and equipment has sufficient cross-section area to have appreciable impact on the wind moment.

W_c , the vertical load (lbs) due to the weight of the conductors is calculated using the following equation:

$$W_c = (S_v)(\Sigma W_v) \quad \text{EQ 15-D}$$

Where:

S_v = Distance between the low point of sags of the adjacent spans (ft)

W_v = Loaded vertical force (weight) of conductors per unit length (lb/ft)

Where spans are relatively short, the error will be small if the horizontal wind span, S_h , is substituted for S_v . The weight of crossarms, braces, insulators, and the pole above the bottom guy attachment point can usually be neglected in calculations for distribution poles.

15.5 Required Pole Class: P_{cr} was defined in Section 15.3 as the critical buckling axial load of a pole. If $(G_v + W_c) \leq P_{cr}$, then the selected pole class is adequate; otherwise the pole class needs to be increased until $(G_v + W_c) \leq P_{cr}$ is true.

15.6 Example Calculation for Vertical Loads: Determine the critical axial load for the guyed pole in the example problem in Section 14. Use the previous data provided, the results of the previous calculations and the following data regarding a standard 40 foot, Class 5, Southern Yellow Pine pole.

Pole Data:

$F_b =$	8,000 lb/in ²	(designated fiber stress)
$H_p =$	34 ft	(height above ground)
$H_{gb} =$	19.5 ft	(height to bottom guy attachment)
$L_g =$	6 ft	(bottom to ground line)
$L_b =$	6 ft	(bottom to ANSI classification point)
$C_t =$	19 in	(circumference at top)
$C_b =$	31 in	(circumference at ANSI classification point)
$C_g =$	31 in	(circumference at ground line)

Using Equation EQ 15-B:

$$A = \frac{1}{4\pi} \left(\frac{(C_b - C_t)(H_p - 0.667H_{gb})}{L_p - L_b} + C_t \right)^2$$

$$A = \frac{1}{4\pi} \left(\frac{(31 - 19)(34 - 0.667 \times 19.5)}{40 - 6} + 19 \right)^2$$

$$= 55.49 \text{ in}^2$$

Using Equation 15-A:

$$P_{cr} = \frac{\pi E A^2}{F_v K_c (K_u H_{gb})^2}$$

$$P_{cr} = \frac{(\pi)(1,800,000)(55.49)^2}{(1.5)(576)(0.7 \times 19.5)^2}$$

$$= 108,161 \text{ lbs}$$

Use Equation EQ 15-D, substitute S_h for S_v , and solve for W_c :

$$W_c = (400) [(3 \times 0.367) + (1 \times 0.145)] = 498 \text{ lbs}$$

Use Equation 15-C and solve for G_v . Use the values of M_c , M_t and M_p previously used in the guy strength calculations, but divide each value by the appropriate overload capacity factor to reduce the factor to one.

$$G_v = \left[\frac{(400)(102.43)}{2.2} + \frac{288182}{1.3} + \frac{6982}{2.2} \right] \div 6$$

$$G_v = 40,579 \text{ lbs}$$

$$G_v + W_c = 40,579 + 498 = 41,077 \text{ lbs}$$

Therefore, the pole has adequate strength for vertical axial loads.

The calculations immediately above will demonstrate that for most distribution guy designs, axial loading will not be a problem if a 1:1 guy slope is used and the poles are equal to or one class larger than the normal tangent pole class. Computations should be made where unusually tall poles require guying. Generally, reducing a guy lead by one-half will approximately double the axial load; using one-fourth of the normal guy lead will increase the pole's axial load by a factor of approximately four.

EXHIBIT A: CONDUCTOR LOADINGS (1997 NESC)

Name	Size	Strand	Light			Medium			Heavy			Ultimate Strength	Diam. In.	X-Area Sq. In.
			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			
ACSR Conductors														
Swanate Sparrow Sparate Raven Quail	4 2 2 1/0 2/0	7/1 6/1 7/1 6/1 6/1	0.0670 0.0913 0.1067 0.1452 0.1831	0.1928 0.2370 0.2438 0.2985 0.3353	0.1622 0.1934 0.2060 0.3819 0.4320	0.2247 0.2673 0.2855 0.3467 0.3998	0.2523 0.2720 0.2750 0.2993 0.3157	0.5379 0.5814 0.5964 0.6580 0.7094	0.5379 0.5989 0.6199 0.7036 0.7719	0.4190 0.4387 0.4417 0.4660 0.4823	0.9818 1.0423 1.0611 1.1439 1.2102	2,360 2,850 3,640 4,380 5,310	0.257 0.316 0.325 0.398 0.447	0.0411 0.0608 0.0654 0.0968 0.1221
Pigeon Penguin Waxwing Partridge Merlin Linnet Pelican Hawk Osprey Dove Kingbird Grosbeak Drake Tern	3/0 4/0 266.8 266.8 336.4 336.4 477.0 477.0 556.5 556.5 636.0 636.0 795.0 795.0	6/1 6/1 18/1 26/7 18/1 26/7 18/1 18/1 26/7 26/7 18/1 26/7 26/7 45/7	0.2309 0.2911 0.2894 0.3673 0.3653 0.4630 0.5180 0.6570 0.6040 0.7660 0.6910 0.8750 1.0940 0.8960	0.3765 0.4223 0.4568 0.4815 0.5130 0.5408 0.6105 0.6435 0.6593 0.6953 0.7050 0.7425 0.8310 0.7973	0.4917 0.5629 0.5907 0.6556 0.6798 0.7619 0.8506 0.9696 0.9441 1.0845 1.0372 1.1976 1.4238 1.2493	0.4647 0.5439 0.5565 0.6446 0.6557 0.7649 0.8488 1.0015 0.9550 1.1319 1.0610 1.2605 1.5162 1.3042	0.3340 0.3543 0.3697 0.3807 0.3947 0.4070 0.4380 0.4527 0.4597 0.4757 0.4800 0.4967 0.5360 0.5210	0.7723 0.8491 0.8681 0.9486 0.9653 1.0664 1.1551 1.2990 1.2599 1.4278 1.3645 1.5548 1.8081 1.6044	0.8539 0.9520 0.9789 1.0774 1.1015 1.2222 1.3350 1.5014 1.4614 1.6533 1.5864 1.8014 2.0938 1.8678	0.5007 0.5210 0.5363 0.5473 0.5613 0.5737 0.6047 0.6193 0.6263 0.6423 0.6467 0.6633 0.7027 0.6877	1.2899 1.3853 1.4162 1.5084 1.5363 1.6501 1.7656 1.9241 1.8900 2.0737 2.0131 2.2197 2.5086 2.2904	6,620 8,350 6,880 11,300 8,680 14,100 11,800 19,500 13,700 22,600 15,700 25,200 31,500 22,100	0.502 0.563 0.609 0.642 0.684 0.721 0.814 0.858 0.879 0.927 0.940 0.990 1.108 1.063	0.1537 0.1939 0.2210 0.2436 0.2789 0.3070 0.3955 0.4354 0.4612 0.5083 0.5275 0.5808 0.7264 0.6674
6201 Aluminum Alloy Conductors														
Azusa Anaheim Amherst Alliance Butte Canton Darien Elgin Flint Greeley	123.3 155.4 195.7 246.9 312.8 394.5 559.5 652.4 740.8 927.2	7 7 7 7 19 19 19 19 37 37	0.1157 0.1459 0.1857 0.2318 0.2936 0.3703 0.5252 0.6124 0.6754 0.8704	0.2985 0.3353 0.3765 0.4223 0.4815 0.5408 0.6435 0.6953 0.7433 0.8310	0.3701 0.4156 0.4689 0.5317 0.6140 0.7054 0.8806 0.9765 1.0543 1.2534	0.3172 0.3626 0.4175 0.4846 0.5709 0.6722 0.8697 0.9783 1.0612 1.2926	0.2993 0.3157 0.3340 0.3543 0.3807 0.4070 0.4527 0.4757 0.4970 0.5360	0.6361 0.6807 0.7347 0.8003 0.8862 0.9858 1.1804 1.2878 1.3718 1.5993	0.6741 0.7347 0.8067 0.8927 1.0037 1.1295 1.3696 1.4997 1.6025 1.8702	0.4660 0.4823 0.5007 0.5210 0.5473 0.5737 0.6193 0.6423 0.6637 0.7027	1.1195 1.1789 1.2495 1.3337 1.4432 1.5668 1.8031 1.9314 2.0345 2.2979	4,460 5,390 6,790 8,560 11,000 13,330 18,800 21,800 24,400 30,500	0.398 0.447 0.502 0.563 0.642 0.721 0.858 0.927 0.991 1.108	0.0968 0.1221 0.1537 0.1939 0.2456 0.3099 0.4394 0.5124 0.5818 0.7282

EXHIBIT B: EXTREME WIND LOADINGS (1997 NESC)

Name	Size	Strand	Vert. Lb/Ft	13 Lbs		16 Lbs		21 Lbs		26 Lbs		31 Lbs		6 Lbs	
				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	Swing Angle
ACSR Conductors															
Swanate	4	7/1	0.0670	0.2784	0.2864	0.3427	0.3492	0.4498	0.4547	0.5568	0.5608	0.6639	0.6673	0.1285	78.35
Sparrow	2	6/1	0.0913	0.3423	0.3543	0.4213	0.4311	0.5530	0.5605	0.6847	0.6907	0.8163	0.8214	0.1580	59.98
Sparate	2	7/1	0.1067	0.3521	0.3679	0.4333	0.4463	0.5688	0.5787	0.7042	0.7122	0.8396	0.8463	0.1625	65.71
Raven	1/0	6/1	0.1452	0.4312	0.4550	0.5307	0.5502	0.6965	0.7115	0.8623	0.8745	1.0282	1.0384	0.1990	53.88
Quail	2/0	6/1	0.1831	0.4843	0.5177	0.5960	0.6235	0.7823	0.8034	0.9685	0.9857	1.1548	1.1692	0.2235	50.67
Pigeon	3/0	6/1	0.2309	0.5438	0.5908	0.6693	0.7080	0.8785	0.9083	1.0877	1.1119	1.2968	1.3172	0.2510	47.39
Penguin	4/0	6/1	0.2911	0.6099	0.6758	0.7507	0.8051	0.9853	1.0274	1.2198	1.2541	1.4544	1.4833	0.2815	44.04
Waxwing	266.8	18/1	0.2894	0.6598	0.7204	0.8120	0.8620	1.0658	1.1043	1.3195	1.3509	1.5733	1.5996	0.3045	46.46
Partridge	266.8	26/7	0.3673	0.6955	0.7865	0.8560	0.9315	1.1235	1.1820	1.3910	1.4387	1.6585	1.6987	0.3210	41.15
Merlin	336.4	18/1	0.3653	0.7410	0.8262	0.9120	0.9824	1.1970	1.2515	1.4820	1.5264	1.7670	1.8044	0.3420	43.11
Linnet	336.4	26/7	0.4630	0.7811	0.9080	0.9613	1.0670	1.2618	1.3440	1.5622	1.6293	1.8626	1.9193	0.3605	37.90
Pelican	477.0	18/1	0.5180	0.8818	1.0227	1.0853	1.2026	1.4245	1.5158	1.7637	1.8382	2.1028	2.1657	0.4070	38.16
Hawk	477.0	26/7	0.6570	0.9295	1.1383	1.1440	1.3192	1.5015	1.6389	1.8590	1.9717	2.2165	2.3118	0.4290	33.14
Osprey	556.5	18/1	0.6040	0.9523	1.1277	1.1720	1.3185	1.5383	1.6526	1.9045	1.9980	2.2708	2.3497	0.4395	36.04
Dove	556.5	26/7	0.7660	1.0043	1.2630	1.2360	1.4541	1.6223	1.7940	2.0085	2.1496	2.3948	2.5143	0.4635	31.18
Kingbird	636.0	18/1	0.6910	1.0183	1.2306	1.2533	1.4312	1.6450	1.7842	2.0367	2.1507	2.4283	2.5247	0.4700	34.22
Grosbeak	636.0	26/7	0.8750	1.0725	1.3842	1.3200	1.5837	1.7325	1.9409	2.1450	2.3166	2.5575	2.7030	0.4950	29.50
Drake	795.0	26/7	1.0940	1.2003	1.6241	1.4773	1.8383	1.9390	2.2263	2.4007	2.6382	2.8623	3.0643	0.5540	26.86
Tern	795.0	45/7	0.8960	1.1516	1.4591	1.4173	1.6768	1.8603	2.0648	2.3032	2.4713	2.7461	2.8886	0.5315	30.68
6201 Aluminum Alloy Conductors															
Azusa	123.3	7	0.1157	0.4312	0.4464	0.5307	0.5431	0.6965	0.7060	0.8623	0.8701	1.0282	1.0347	0.1990	59.83
Anaheim	155.4	7	0.1459	0.4843	0.5058	0.5960	0.6136	0.7823	0.7957	0.9685	0.9794	1.1548	1.1639	0.2235	56.86
Amherst	195.7	7	0.1857	0.5438	0.5740	0.6693	0.9641	0.8785	0.8975	1.0877	1.1031	1.2968	1.3098	0.2510	53.80
Alliance	246.9	7	0.2318	0.6099	0.6525	0.7507	0.7856	0.9853	1.0122	1.2198	1.2417	1.4544	1.4728	0.2815	50.53
Butte	312.8	19	0.2936	0.6955	0.7549	0.8560	0.9050	1.1235	1.1612	1.3910	1.4216	1.6585	1.6843	0.3210	47.55
Canton	394.5	19	0.3703	0.7811	0.8644	0.9613	1.0302	1.2618	1.3150	1.5622	1.6055	1.8626	1.8990	0.3605	44.23
Darien	559.5	19	0.5252	0.9295	1.0676	1.1440	1.2588	1.5015	1.5907	1.8590	1.9318	2.2165	2.2779	0.4290	39.24
Elgin	652.4	19	0.6124	1.0043	1.1762	1.2360	1.3794	1.6223	1.7340	2.0085	2.0998	2.3948	2.4718	0.4635	37.12
Flint	740.8	37	0.6754	1.0736	1.2684	1.3213	1.4839	1.7343	1.8611	2.1472	2.2509	2.5601	2.6477	0.4955	36.27
Greeley	927.2	37	0.8704	1.2003	1.4827	1.4773	1.7147	1.9390	2.1254	2.4007	2.5536	2.8623	2.9917	0.5540	32.48

EXHIBIT C: CONTRIBUTORS

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