

UNITED STATES DEPARTMENT OF AGRICULTURE
Rural Utilities Service

BULLETIN 1724E-150

SUBJECT: Unguyed Distribution Poles – Strength Requirements

TO: RUS Electric Borrowers and RUS Electric Staff

EFFECTIVE DATE: Date of Approval

OFFICE OF PRIMARY INTEREST: Distribution Branch, Electric Staff Division

FILING INSTRUCTIONS: This bulletin replaces Chapter V-4, “Pole Strength Calculations and Guides,” of RUS Bulletin 160-2, “Mechanical Design Manual for Overhead Distribution Lines,” dated April 1982.

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

PURPOSE: This guide bulletin presents equations, data, and other information needed to determine: (1) the loads applied to unguyed wood distribution poles; (2) a pole’s strength requirements to sustain applied loads; and (3) maximum horizontal spans based on pole strengths. Sample solved problems are included in this bulletin to help the reader understand and apply the presented equations. At the end of this bulletin is a table of calculated ground line moments caused by wind on various species of wood poles and also a table of permitted moments at the ground line of various species of wood poles commonly used for distribution construction.



July 30, 2003

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ABBREVIATIONS

ACSR Aluminum conductor, steel reinforced
ANSI American National Standards Institute
CFR Code of Federal Regulations
EQ Equation
IEEE Institute of Electrical and Electronics Engineers
MOR Modulus of rupture
NESC National Electrical Safety Code
RUS Rural Utilities Service
SYP Southern Yellow Pine (a type of wood pole)

UNITS OF MEASURE

in inch or inches (1 inch = 2.54 centimeters = 0.0254 meters)
in-lb inch-pounds (inch x pounds) (1 inch-pound = 0.370685 newtons)
ft foot or feet (1 foot = 0.3048 meters)
ft-lb foot-pounds (feet x pounds) (1 foot-pound = 4.448222 newtons)
kcmil 1,000 circular mils (1 kcmil = 5.067075×10^{-6} square meters)
kV kilovolts [1 kilovolt = 1,000 volts]

UNGUYED DISTRIBUTION POLES – STRENGTH REQUIREMENTS

1. INTRODUCTION

1.1 Purpose of Bulletin: This guide bulletin presents equations, data, and other information needed to determine:

- The loads applied to unguyed wood distribution poles,
- A pole's strength requirements to sustain applied loads, and
- Maximum horizontal spans based on pole strengths.

Sample solved problems are included in this bulletin to help the reader understand and apply the presented equations. A table of calculated ground line moments caused by wind on wood poles and a table of calculated permitted moments at the ground line of commonly used wood poles are included in Exhibit A at the end of this bulletin.

1.2 Scope of Bulletin: The presentation in this bulletin is limited to the horizontal loading of unguyed wood distribution poles acting as simple cantilever beams or slender columns. Unguyed poles, according to RUS distribution construction standards, have a maximum line angle of 5 degrees. (The determination of the strength requirements of guyed poles is presented in Section 15 of RUS Bulletin 1724E-153, "Electric Distribution Line Guys and Anchors.")^{1/} The loading effect of transformers and other heavy equipment on poles is not included in this bulletin.

1.3 National Electrical Safety Code (NESC): Throughout this bulletin are references to rules and selected data contained specifically in the 2002 Edition of the NESC. At the time this bulletin was written, the 2002 Edition was the latest edition of the NESC. Users of this bulletin should use the rules and data, as may be periodically updated, revised and renumbered, from the most recent edition of the NESC. The NESC is published by the Institute of Electrical and Electronics Engineers, Inc., (IEEE).^{2/}

1.4 American National Standards Institute (ANSI): This bulletin also references ANSI 05.1-2002, Specifications and Dimensions for Wood Poles.^{3/} This standard provides specifications for quality and dimensions of wood poles that are to be used in single-pole utility structures.

^{1/} Copies available from: RUS-USDA, Publications Office – PDRA
STOP 1522, Washington DC 20250-1522, Telephone (202) 720-8674

^{2/} Copies may be purchased from: IEEE Customer Service
445 Hoes Lane, P.O. Box 1331, Piscataway, NJ 08855-1331, Telephone 1-800-678-4333

^{3/} Copies may be purchased from: American National Standards Institute, Inc.
1430 Broadway, New York, New York 10018, Telephone: (212) 354-3300

2. CLASSIFICATION AND STRENGTH OF WOOD POLES

2.1 Classification of Wood Poles: ANSI 05.1-2002 designates the fiber stress and dimensions of natural wood poles and also classifies poles by wood species, length, and class. Usually a pole's height and classification are abbreviated. For example, a pole identified as "35-6" indicates a 35-foot, (ANSI) Class 6 pole.

2.2 Strength of Wood Poles by Class: Annex B of ANSI 05.1-2002 defines pole classes so that poles of various species and lengths will have approximately equal load-carrying capability. The minimum circumferences specified at 6 feet from the butt, (shown in Tables 3 through 10) have been calculated such that each species in a given class will not exceed the groundline stresses tabulated in Annex B, when a given horizontal load is applied 2 feet from the top of the pole. For example, all Class 6 poles are capable of holding a 1,500-pound load applied transversely 2 feet from the top of the pole. The ground line circumferences of different species of poles in the same class will deviate because of the differences in allowable fiber stress.

3. EXPLANATION OF APPLIED LOADS AND MOMENTS

3.1 NESC Loading Requirements: Section 25 of the NESC requires that wind and ice loads on conductors and poles be determined according to the location (Heavy, Medium, or Light loading district) of construction. Assumed ice and wind loads have to be increased if they are expected to be greater than the minimum requirements of the NESC. Extreme wind loading has to be considered if any part of a pole or the conductors attached to it is 60 feet or more above the ground. Extreme wind loading has to be applied, using the formulas and data of Rule 250C of the NESC, if it is greater than the otherwise calculated wind and ice loading based on loading districts. Loads applied to wood poles have to be multiplied by the appropriate overload factors of NESC Table 253-1.

3.2 Combined Loading Equation: All of the loads that can be expected to be applied to a pole have to be considered in order to determine the pole's strength requirements to sustain the loads. Loads are simultaneously applied to poles in both the horizontal and vertical directions. Poles need to have sufficient strength such that the following relationship is satisfied:

$$\frac{M_{applied}}{S} + \frac{P_{applied}}{A} \leq MOR \quad \text{EQ 3.1}$$

Where,

$M_{applied}$	= Moments induced in the pole (in-lb)
$P_{applied}$	= Vertical loads on the pole (lbs)
S	= Section of modulus (in ³)
A	= Cross section area of pole (in ²)
MOR	= Modulus of rupture (lb/in ²)

Usually the P/A portion of Equation 3.1 is negligible in comparison with the M/S portion of the equation and thus is ignored in the distribution pole strength calculations of this bulletin.

3.3 Direction of Critical Loading: By using vector algebra, all horizontal loads applied to a pole can be calculated in 2 component directions: *longitudinal* (parallel to the direction of the line) and *transverse* (perpendicular to the line). Usually there is only one direction of loading that dictates the minimum class of pole required to sustain all of the loads expected to be applied. This direction is called the *direction of critical loading*. Computations for pole strength requirements only need be made for the direction of critical loading when that direction is known. The direction of critical loading for unguyed poles is in the transverse direction.

4. HORIZONTAL MOMENTS ON A POLE

4.1 Equations for Applied Moments: In this bulletin, an applied moment is the multiplication product of an applied load or force times the distance from its centroid to the ground line of the pole. The unit of measure used in this bulletin for moments is foot-pounds (ft-lb). The sum of all of the applied moments multiplied by the appropriate NESC overload factors, has to be determined before a pole of sufficient strength (i.e., class) can be selected. The total of all the ground line moments induced in a pole, M_g , is expressed as follows:

$$M_g = S_h M_{wc} + M_{wp} + M_{we} + M_{tc} + M_{vo} + M_{p-\delta} \quad \text{EQ 4.1}$$

Where:

S_h = Horizontal wind span (= the sum of 1/2 the lengths of the adjacent spans) (ft)
 M_{wc} = Summation of moment loads due to wind on each conductor expressed as moment per unit length of conductor (ft-lb/ft)

$$= F_{ow} \{ \Sigma(W_c H_c) \} \cos(\theta/2) \quad \text{EQ 4.2}$$

M_{wp} = The moment due to wind on the pole (ft-lb)

$$= F_{ow} W_p \left(\frac{2C_t + C_g}{K_c} \right) H_p^2 \quad \text{EQ 4.3}$$

Note: M_{wp} is calculated for several commonly used poles and tabulated in Table 1 in Exhibit A at the end of this bulletin.

M_{we} = The moment due to wind on the material and equipment attached to the pole (ft-lb)

M_{tc} = Summation of moments due to the tension of the conductors (ft-lb)

$$= 2F_{ot} \{ \Sigma(T_c H_c) \} \sin(\theta/2) \quad \text{EQ 4.4}$$

M_{vo} = The moment due to unbalanced vertical loads (ft-lb)

$M_{p-\delta}$ = The moment due to pole deflection (ft-lb)

And where:

F_{ow} = NESC (Table 253-1) overload factor for wind loads

F_{ot} = NESC (Table 253-1) overload factor for longitudinal (tension) loads

H_p = Height of pole above ground (ft)

H_c = Height of each conductor attachment above ground line (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 (degrees)
- C_t = Pole circumference at top (in)
- C_g = Pole circumference at ground line (in)
- K_c = Calculation constant = 72π

4.2 Simplification of Applied Moment Equation: The following force moment terms of Equation 4.1 can usually be omitted for the following reasons:

4.2.1 M_{we} can usually be ignored because the transverse moment due to wind on pins, insulators and the ends of crossarms is typically less than 500 ft-lb. However, M_{we} should be considered for attached transformers or other large equipment. Throughout this bulletin it is assumed that no large equipment is attached to the pole.

4.2.2 M_{tc} is zero on tangent poles where the line angle $\theta = 0$ because the sine of $(\theta/2) = 0$ and thus $M_{tc} = 2F_{ot}\{\Sigma(T_c H_c)\}\sin(\theta/2) = 0$. The nearly equal and opposite longitudinal conductor tensions essentially cancel each other.

4.2.3 M_{vo} is usually small and can be ignored. RUS standard crossarm assemblies are symmetrical (looking in the longitudinal direction). Thus, the moments induced in the pole by conductor weights supported by crossarms cancel one another. The remaining conductors are attached directly to the pole. Therefore, the moment induced in the pole due to offset conductor weights is negligible. (Vertical conductor weights alone seldom dictate the required pole class.)

4.2.4 $M_{p-\delta}$ are small ground line moments. Transverse loads cause an unguyed pole to deflect a small distance. Vertical loads on the pole times this deflection distance cause additional moments to be induced in the pole. These additional moments are small compared to the other moments of Equation 4.1 and compensated for in Equation 5.2.

4.3 Simplified Equation for Applied Moments: After applying the assumptions and omissions of paragraph 4.2 of this bulletin, Equation 4.1 can be simplified to:

$$M_g = S_h M_{wc} + M_{wp} + M_{tc} \tag{EQ 4.5}$$

4.4 Example Problem 1: Total Horizontal Moment: Given the following information and data, calculate the moment, M_g , at the ground line of a 35-foot unguyed pole adjacent to a highway crossing span that supports a 3-phase, crossarm assembly. The horizontal wind span (S_h) is 300 feet. The line angle (θ) is 2 degrees.

4.4.1 Given pole data:

Pole: Southern Yellow Pine (SYP); 35-foot (set 6 foot deep); Class 5

$$C_t = 19 \text{ in} \quad C_g = 29 \text{ in} \quad H_p = 29 \text{ ft}$$

4.4.2 Given conductor data:

3 Primary Conductors; 266.8 kcmil ACSR (“Waxwing”), $W_c = 0.5363 \text{ lb/ft}$

1 Neutral Conductor: #1/0 ACSR (“Raven”), $W_c = 0.4660 \text{ lb/ft}$

Conductor attachment heights above ground line:

$$H_c \text{ (ft)} = \begin{array}{c} \text{A phase} \\ \text{B phase} \\ \text{C phase} \\ \text{Neutral} \end{array} \begin{array}{c} 28.25 \\ 29.87 \\ 28.25 \\ 25.50 \end{array}$$

Phase conductor design tension: $T_c = 2,408 \text{ lb}$

Neutral conductor design tension: $T_c = 1,731 \text{ lb}$

4.4.3 Given NESC data:

NESC Heavy Loading District; NESC Grade C construction (crossing span)

$$F_{ow} = 2.20 \quad F_{ot} = 1.30 \quad W_p = 4 \text{ lbs/ft}^2$$

4.4.4 The summation of moments per unit length of conductor, M_{wc} , due to wind on each conductor can be tabulated as follows:

Phase	$W_c H_c$	
A	$(0.5363)(28.25)$	= 15.15
B	$(0.5363)(29.87)$	= 16.02
C	$(0.5363)(28.25)$	= 15.15
N	$(0.4660)(25.50)$	= 11.88
Total	$\Sigma(W_c H_c)$	= 58.20

$$M_{wc} = F_{ow} \{ \Sigma(W_c H_c) \} \cos(\theta/2) = (2.20)(58.20)(0.999) = 127.91 \text{ ft-lb/ft}$$

4.4.5 The moment due to wind on the pole is calculated using Equation 4.3 as shown below, or alternatively determined from Table 1 in Exhibit A at the end of this bulletin.

$$M_{wp} = F_{ow} W_p \left(\frac{2C_t + C_g}{K_c} \right) H_p^2$$

$$M_{wp} = (2.20)(4) \left(\frac{(2)(19) + 29}{72\pi} \right) (29^2) = 2,192 \text{ ft-lb}$$

4.4.6 The summation of moments due to the tension of each conductor, M_{tc} , can be calculated as follows:

<u>Phase</u>	<u>$T_c H_c$</u>		
A	(2,408)(28.25)	=	68,026
B	(2,408)(29.87)	=	71,927
C	(2,408)(28.25)	=	68,026
N	(1,731)(25.50)	=	44,141
Total	$\Sigma(T_c H_c)$	=	252,120

$$M_{tc} = 2F_{ot} \{ \Sigma(T_c H_c) \} \sin(\theta/2) = 2(1.30)(252,120)(0.01745) = 11,440 \text{ ft-lb}$$

4.4.7 The total moment on the pole is calculated using Equation 4.5 as follows:

$$M_g = S_h M_{wc} + M_{wp} + M_{tc}$$

$$M_g = 300 \text{ (ft)} \times 127.91 \text{ (ft-lb/ft)} + 2,192 \text{ (ft-lb)} + 11,440 \text{ ft-lb} = 52,004 \text{ ft-lb}$$

5. POLE STRENGTH AND REQUIREMENTS

5.1 NESC Strength Requirements of Poles: The NESC requires that a support structure be able to withstand a load equivalent to all of the expected applied loads (multiplied by the appropriate NESC overload factors) without exceeding the *permitted load* of the support structure. The *permitted load* is the designated strength of the support structure multiplied by the appropriate NESC strength factor of NESC Table 261-1A. In this bulletin “support structure” means a single, wood distribution pole. For purposes of this bulletin, the NESC strength requirement for a support structure means: the permitted moment, M_r , for a pole at the ground line has to be equal to or exceed the total ground line moment, M_g , induced in the pole. This relationship is expressed in the following equation:

$$M_g \leq M_r \tag{EQ 5.1}$$

5.2 RUS Increased Moment Recommendation: RUS recommends that moment, M_g , in Equation 5.1 be increased by a minimum of 5 percent to compensate for the approximations and omissions presented in paragraph 4.2 of this bulletin. Thus, RUS recommends the following relationship be satisfied:

$$1.05 \times M_g \leq M_r \tag{EQ 5.2}$$

5.3 Pole Circumference at the Ground Line: The permitted moment, M_r , for a pole at the ground line can be calculated if the pole’s circumference at the ground line is known. However, pole tables tabulate pole circumferences at a fixed distance (usually 6 feet as per ANSI 05.1) from the bottom of each pole which may not be at the ground line. A pole’s circumference at its ground line, based on its circumference 6 feet from its bottom, can be calculated by using following Equation 5.3:

$$C_g = \frac{(L_p - L_g)(C_b - C_t)}{(L_p - L_b)} + C_t \quad \text{EQ 5.3}$$

Where:

- C_g = Pole circumference at ground line (in)
- L_p = Length of pole (ft)
- L_g = Distance from pole bottom to ground line (ft)
- L_b = Distance from pole bottom to classification point per ANSI 05.1-2002 (6 feet)
- C_b = Pole circumference at distance L_b from bottom per ANSI 05.1-2002 (in)
- C_t = Pole circumference at top (in)

The calculated ground line circumferences (C_g) for several commonly used distribution poles are tabulated in Table 1 in Exhibit A at the end of this bulletin.

5.4 Permitted Moment of Pole at the Ground Line: The permitted moment of a pole at its ground line can be calculated using the following equation:

$$M_r = S_f K_r F_b C_g^3 \quad \text{EQ 5.4}$$

Where:

- M_r = Permitted moment at ground line (ft-lb)
- K_r = Calculation constant = 2.64×10^{-4} (ft/in)
- F_b = Designated fiber stress (lb/in²)
- S_f = NESC strength factor (NESC Table 261-1A)

The calculated permitted ground line moments (M_r) for several commonly used distribution poles are tabulated in Table 2 in Exhibit A at the end of this bulletin.

5.5 Example Problem 2: Determine Pole Resisting Moment: Given the following pole data, determine if a 35-foot, Class 5, Southern Yellow Pine pole (35-5 SYP) is adequate to sustain the total moment of 52,004 ft-lb calculated in Example Problem 1 in paragraph 4.4 of this bulletin multiplied by 1.05 as recommended by RUS (equals 54,604 ft-lb).

5.5.1 Given pole and NESC data:

$$\begin{array}{lll} C_b = 29 \text{ in} & L_p = 35 \text{ ft} & F_b = 8,000 \text{ lb/in}^2 \\ C_t = 19 \text{ in} & L_g = 6 \text{ ft} & S_f = 0.85 \\ & L_b = 6 \text{ ft} & \end{array}$$

5.5.2 The pole circumference at the ground line (C_g) does not need to be calculated for this particular pole height because $L_g = L_b = 6$ feet and therefore $C_g = C_b = 29$ in. Normally, for other

pole heights and classes, C_g needs to be calculated using Equation 5.3 or determined using Table 1 in Exhibit A at the end of this bulletin.

5.5.3 The permitted moment at the ground line of a 35-5 SYP pole can be calculated using Equation 5.4 as follows (or determined using Table 2 in Exhibit A at the end of this bulletin):

$$\begin{aligned}M_r &= S_f K_r F_b C_g^3 \\ &= (0.85)(0.000264 \text{ ft/in})(8,000 \text{ lb/in}^2)(29^3 \text{ in}^3) \\ M_r &= 43,780 \text{ ft-lb}\end{aligned}$$

Since the induced moment of 54,604 ft-lb is greater than the resisting moment of a SYP 35-5 pole, a pole of greater strength (higher class) needs to be selected to sustain the given loads and conditions of Example Problem 1 in paragraph 4.4 of this bulletin.

5.6 Repeat Comparison Procedure: If calculations show that a selected pole does not have adequate strength to sustain the calculated loads, then another, stronger pole needs to be selected. The permitted moment (M_r) of any (new) selected pole needs to be determined and ascertained that the M_r of the new selected pole is greater than the total moment expected to be induced in the pole. Use the equations and procedure included in paragraphs 5.1 through 5.4 of this bulletin.

5.7 Moments Above Guy Attachments: Where horizontal loads are applied at some distance above a guy attachment, it is advisable to check for the pole strength at the guy attachment location. The portion of a pole below a guy attachment is considered to be a strut with only vertical loads applied. The loads above the top guy attachment and the strength of the pole at the guy attachment location are calculated in the same manner as an unguyed pole with the following two modifications.

5.7.1 The moments above a guy attachment can be calculated and summed using the same equations and procedure presented in Section 4 of this bulletin. However, the distances from the applied loads to the pole's ground line, H_c in Equation 4.2, has to be replaced with the distances from the applied loads to the top guy attachment location on the pole.

5.7.2 The circumference of the pole at the top guy attachment location can be calculated by replacing the distance L_g in Equation 5.3 with the distance from the bottom of the pole to the guy attachment location. Thus M_r , in Equation 5.4 becomes the permitted moment at the guy attachment location and can be calculated and compared to the calculated moment at the guy attachment location.

6. DETERMINATION OF MAXIMUM HORIZONTAL SPANS

6.1 Maximum Horizontal Span: The maximum permitted horizontal span for an unguyed pole based on a pole's species, height, and class span can be calculated by essentially reversing the procedure presented in Sections 4 and 5 of this bulletin. Usually the pole height and class are known or given. When unknown, the pole's species should be assumed to be the type with the lowest fiber stress for calculation purposes.

6.2 Equation for the Maximum Horizontal Span: The (simplified) equation for the total ground line moment induced in an unguyed pole with no large or heavy equipment attached was presented in paragraph 4.1 in this bulletin as:

$$M_g = S_h M_{wc} + M_{wp} + M_{tc} \quad (\text{EQ 4.5})$$

Equation 4.5 can be rearranged as follows to determine the horizontal span, S_h , as a function of the induced moments in the pole:

$$S_h = \frac{M_g - M_{wp} - M_{tc}}{M_{wc}} \quad \text{EQ 6.1}$$

By replacing M_g in EQ 6.1 with M_r , the permitted moment of the pole at its ground line, the equation becomes an expression for the maximum horizontal span, $S_{h(max)}$, as follows:

$$S_{h(max)} = \frac{M_r - M_{wp} - M_{tc}}{M_{wc}} \quad \text{ft} \quad \text{EQ 6.2}$$

The definitions of the moment terms in Equation 6.2 are provided in paragraphs 4.1 and 5.3 of this bulletin. M_{tc} is zero where the line angle $\theta = 0$, because the sine of $(\theta/2) = 0$ and thus $M_{tc} = 2F_{ot}\{\Sigma(T_c H_c)\}\sin(\theta/2) = 0$.

6.3 Example Problem 3: Determination of Maximum Span: Determine the maximum horizontal span, $S_{h(max)}$, for a 35-5 SYP pole using the moments calculated in Example Problem 1 in paragraph 4.4 of this bulletin.

6.3.1 Given (previously calculated) moments:

M_{wp}	= 2,192 ft-lb	See paragraph 4.4.5 of this bulletin
M_{tc}	= 11,440 ft-lb	See paragraph 4.4.6 of this bulletin
M_{wc}	= 127.91 ft-lb/ft	See paragraph 4.4.4 of this bulletin
M_r	= 41,695 ft-lb	See paragraph 5.5.3 of this bulletin and note below.

Note that M_r has been reduced by 5 percent (previously calculated at 43,789 ft-lb) in accordance with the RUS recommendation presented in paragraph 5.2 of this bulletin.

6.3.2 Maximum horizontal span:

$$S_{h(\max)} = \frac{M_r - M_{wp} - M_{tc}}{M_{wc}} \quad (\text{EQ 6.2})$$

$$S_{h(\max)} = \frac{41,695(ft - lb) - 2,192(ft - lb) - 11,440(ft - lb)}{127.91(ft - lb / ft)}$$

$$S_{h(\max)} = 219 \text{ ft}$$

TABLE 1: GROUND LINE MOMENTS CAUSED BY WIND ON WOOD POLES

NESC Medium and Heavy Loading Districts (See Note 1)
 NESC Grade C Construction - Non Crossing Spans (See Notes 2 and 3)

Length (ft)	GL (ft)	C _T (in)	Southern Yellow Pine & Douglas Fir		Lodgepole Pine & Red Pine		Western Larch		Western Red Cedar	
			C _{GL} (in)	M _{WP} (ft-lb)	C _{GL} (in)	M _{WP} (ft-lb)	C _{GL} (in)	M _{WP} (ft-lb)	C _{GL} (in)	M _{WP} (ft-lb)
Class 1		27								
35	6.0		39.0	2,430	41.5	2,490	38.0	2,400	42.5	2,520
40	6.0		41.0	3,410	44.0	3,520	40.0	3,370	45.0	3,550
45	6.5		42.8	4,450	45.8	4,590	41.8	4,410	47.2	4,660
50	7.0		44.6	5,660	47.5	5,820	43.6	5,600	49.0	5,910
55	7.5		45.9	6,990	48.8	7,200	44.9	6,920	50.8	7,330
60	8.0		47.2	8,490	50.6	8,770	46.3	8,410	52.5	8,930
Class 2		25								
35	6.0		36.5	2,260	38.5	2,310	35.5	2,230	40.0	2,350
40	6.0		38.5	3,180	41.0	3,270	37.5	3,140	42.5	3,320
45	6.5		40.3	4,150	42.8	4,270	39.3	4,110	44.3	4,340
50	7.0		41.6	5,260	44.5	5,420	40.6	5,200	46.0	5,510
55	7.5		42.9	6,510	45.8	6,710	42.0	6,440	47.8	6,840
60	8.0		44.3	7,910	47.1	8,150	43.3	7,830	49.1	8,310
Class 3		23								
35	6.0		34.0	2,090	36.0	2,140	33.0	2,060	37.5	2,180
40	6.0		36.0	2,940	38.0	3,020	35.0	2,910	39.5	3,070
45	6.5		37.3	3,830	39.8	3,950	36.8	3,810	41.3	4,010
50	7.0		38.6	4,860	41.6	5,020	38.1	4,830	43.0	5,110
55	7.5		40.0	6,020	42.9	6,220	39.5	5,980	44.3	6,320
60	8.0		41.3	7,320	44.2	7,560	40.3	7,240	45.6	7,690
Class 4		21								
35	6.0		31.5	1,920	33.5	1,970	31.0	1,910	34.5	2,000
40	6.0		33.5	2,710	35.5	2,780	32.5	2,670	36.5	2,820
45	6.5		34.8	3,530	36.8	3,630	33.8	3,490	38.3	3,690
50	7.0		36.1	4,480	38.6	4,620	35.2	4,430	39.6	4,680
55	7.5		37.5	5,560	39.9	5,730	36.5	5,500	41.4	5,840
60	8.0		38.3	6,740	41.2	6,980	37.9	6,700	42.7	7,100
Class 5		19								
35	6.0		29.0	1,750	31.0	1,800	28.5	1,740	32.0	1,830
40	6.0		31.0	2,480	33.0	2,550	30.0	2,440	34.0	2,590
45	6.5		32.3	3,240	34.3	3,330	31.3	3,190	35.8	3,400
50	7.0		33.7	4,110	35.6	4,220	32.7	4,060	37.1	4,310
Class 6		17								
35	6.0		27.0	1,600	28.5	1,630	26.5	1,580	30.0	1,670
40	6.0		28.5	2,240	30.5	2,320	28.0	2,230	31.5	2,350
45	6.5		29.8	2,940	31.8	3,030	28.8	2,890	32.8	3,070

GL = Distance from bottom of pole to ground line (feet)

C_T = Circumference of pole at top (inches)

C_{GL} = Circumference of pole at ground line (inches)

M_{WP} = Ground line moment induced by wind on pole (foot-pounds)

(1) Multiply M_{WP} by 2.25 for NESC Light loading district.

(2) Multiply M_{WP} by 1.43 for NESC Grade B construction (Crossing and non-crossing spans)

(3) Multiply M_{WP} by 1.25 for crossing spans

TABLE 2: PERMITTED⁽¹⁾ MOMENTS AT GROUND LINE OF WOOD POLES

NESC Grade C Construction (Multiply M_{R-GL} by 0.75 for Grade B construction)

Length (ft)	DFS = GL (ft)	Southern Yellow Pine	Douglas Fir	Lodgepole Pine	Red Pine	Western Larch	Western Red Cedar
		M_{R-GL} (ft-lb))	M_{R-GL} (ft-lb))	M_{R-GL} (ft-lb))	M_{R-GL} (ft-lb))	M_{R-GL} (ft-lb))	M_{R-GL} (ft-lb))
		8,000	8,000	6,600	6,600	8,400	6,000
Class 1							
35	6.0	106,400	106,400	105,800	105,800	103,400	103,300
40	6.0	123,700	123,700	126,100	126,100	120,600	122,600
45	6.5	140,700	140,700	142,200	142,200	137,600	141,500
50	7.0	159,200	159,200	158,700	158,700	156,200	158,400
55	7.5	173,600	173,600	172,100	172,100	170,600	176,500
60	8.0	188,700	188,700	191,800	191,800	187,000	194,800
Class 2							
35	6.0	87,200	87,200	84,500	84,500	84,300	86,100
40	6.0	102,400	102,400	102,000	102,000	99,400	103,300
45	6.5	117,400	117,400	116,100	116,100	114,400	117,000
50	7.0	129,200	129,200	130,500	130,500	126,100	131,000
55	7.5	141,700	141,700	142,200	142,200	139,600	147,000
60	8.0	156,000	156,000	154,700	154,700	153,000	159,300
Class 3							
35	6.0	70,500	70,500	69,000	69,000	67,700	71,000
40	6.0	83,700	83,700	81,200	81,200	80,800	82,900
45	6.5	93,100	93,100	93,300	93,300	93,900	94,800
50	7.0	103,200	103,200	106,600	106,600	104,200	107,000
55	7.5	114,800	114,800	116,900	116,900	116,100	117,000
60	8.0	126,400	126,400	127,800	127,800	123,300	127,600
Class 4							
35	6.0	56,100	56,100	55,600	55,600	56,100	55,200
40	6.0	67,400	67,400	66,200	66,200	64,700	65,400
45	6.5	75,600	75,600	73,800	73,800	72,700	75,600
50	7.0	84,400	84,400	85,100	85,100	82,200	83,600
55	7.5	94,600	94,600	94,000	94,000	91,600	95,500
60	8.0	100,800	100,800	103,500	103,500	102,600	104,800
Class 5							
35	6.0	43,700	43,700	44,100	44,100	43,600	44,100
40	6.0	53,400	53,400	53,200	53,200	50,800	52,900
45	6.5	60,400	60,400	59,700	59,700	57,800	61,700
50	7.0	68,700	68,700	66,800	66,800	65,900	68,700
Class 6							
35	6.0	35,300	35,300	34,200	34,200	35,000	36,300
40	6.0	41,500	41,500	42,000	42,000	41,300	42,000
45	6.5	47,500	47,500	47,600	47,600	45,000	47,500

(1) "Permitted" means strength factor of NESC Table 261-1A has been factored in values of M_{R-GL}

GL = Distance from bottom of pole to ground line (feet)

M_{R-GL} = Resistive moment of pole at ground line (foot-pounds)

DFS = Designated fiber stress of poles (pounds/square inch)

EXHIBIT B: CONTRIBUTORS

The following members of the Overhead Distribution Lines Subcommittee of the National Rural Electric Cooperative Association, Transmission and Distribution Engineering Committee provided invaluable assistance in preparing this document:

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