

NORTH AMERICAN WOOD POLE COALITION

TECHNICAL BULLETIN

*The Wood Pole 2005:
Design Considerations,
Service Benefits,
and Economic Reward*

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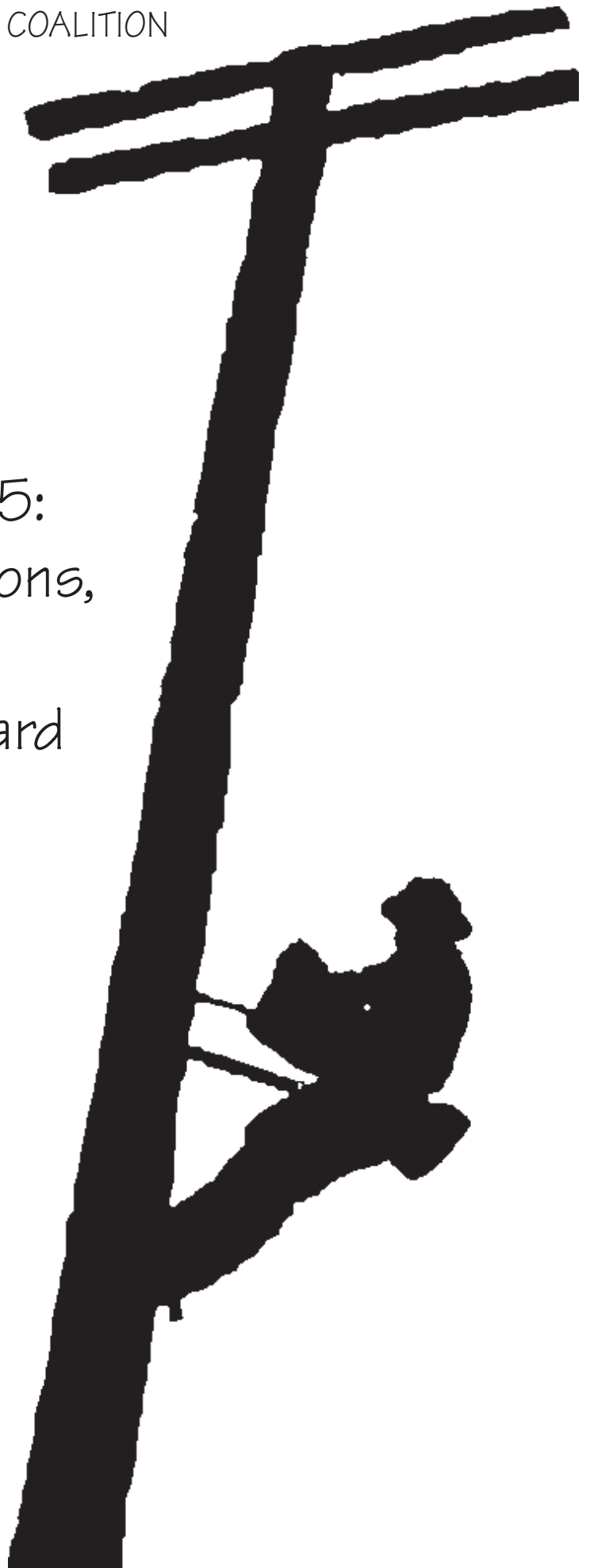


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INTRODUCTION

Since the beginning of electrification over a century ago, the wood pole has been at the heart of providing electrical service to the people of North America. Transmission and distribution lines deliver power to large cities, small towns, and remote outposts. Due to the continued advancements in wood preserving and engineering technology combined with its natural benefits and economics, the wood pole remains the foundation of power distribution in the 21st century. With over 130 million wood poles in service and millions of

new wood poles installed each year, it is little wonder the Utility Industry has stated that “TREATED WOOD IS THE ELECTRIC UTILITIES’ MATERIAL OF CHOICE” (1). Proper line design, pole selection and installation are the keys to the successful use of the wood pole. As an electrical distribution design and professional training consulting firm, Hi-Line Engineering is pleased to have been asked to provide its perspective on the design and use of the wood pole in 2005.

THE ABC’S OF STRUCTURE DESIGN

The fundamental building block in overhead electrical distribution line construction is the wood pole. It is abundant in nature, renewable, easy to handle, an excellent insulator, cost effective, and environmentally preferred. A finished wood power pole can be made from several types of trees. Common species of wood poles include southern yellow pine, Douglas fir, western red cedar, and northern red pine. The trees are harvested, milled to a length and class, and treated with a preservative. Utility engineers, staking technicians, and linemen must select the correct length and class poles to safely support the power line conductors and equipment. This Bulletin will discuss the basics of choosing a pole that will provide adequate strength to support the conductors used in electrical distribution pole-line construction. Wood poles are also used to support transmission lines, and while the design is somewhat more complex, the basic principals are the same.

Steel and pre-stressed concrete poles are also available for use on the distribution system. The designer must apply the correct analysis to these alternative materials to provide sufficient strength to adequately support conductors and

equipment. Since wood poles have been traditionally sized in length and class, the steel and concrete pole manufacturers produce an “equivalent” length and class so the designer can choose a pole based on his or her knowledge and experience using wood poles. To correctly select an equivalent size pole, the designer must understand what “equivalency” entails so accurate comparisons can be made.

An electrical distribution pole must support vertical, longitudinal, and transverse loads caused by weight, wind, and wire tension under design loading or worst case conditions. These conditions vary depending on the area of the United States where the pole-line is located. The *National Electrical Safety Code (NESC)* divides the USA into the three primary loading zones based on the expected ice and wind conditions over time. They are light, medium, and heavy and are shown in Figure 250-1 in the 2002 Edition of the *NESC*. For each loading district, the *NESC* describes specific wind and ice loads that distribution pole lines must support. Table 1 summarizes these values. A wood pole must have sufficient natural fiber mass and strength to support the conductors and equipment under the

Table 1: NESC Loading Districts and Applied Loads

NESC Loading District	Ice (Radial Thickness)	Wind (Transverse)
Light	0.00 inches	9 lbs (60 mph)
Medium	0.25 inches	4 lbs (40 mph)
Heavy	0.50 inches	4 lbs (40 mph)

Based on Table 250-1 of the 2002 Edition of the National Electrical Safety Code

selected design conditions. A steel or other non-wood pole can be manufactured with adequate material strength to handle the same parameters. The industry also recognizes that disastrous events exceeding the design conditions, such as hurricanes, tornadoes or catastrophic ice storms, may occur and result in structure failure, no matter what the pole material.

Vertical loads are caused by the weight of the attached equipment, the ice laden conductors, and the vertical component of guy tension. Longitudinal load is caused by the tension in the wire and is dependent on the sag and tension values used during installation. Transverse loads are caused by wind blowing on the bare or ice laden conductors and pole plus the tension produced by

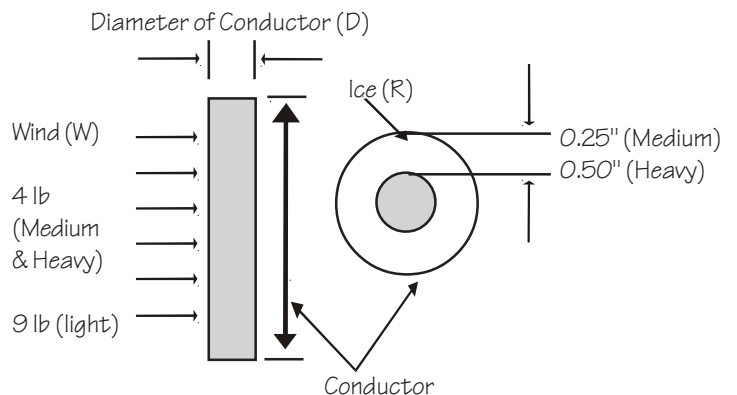
line angles. In all three cases, the pole must support the applied loading under the design conditions.

The first problem facing the designer is to select a pole class that will adequately support tangent (straight line) spans of wire in a line section for a particular NESC loading district. The best way to do this is to calculate the maximum span for a specific pole class and design each span in the line section to be less than the calculated maximum span. This one aspect of structure design will demonstrate the importance of scientifically evaluating a pole class selection in lieu of going with a standard class or an alternative material equivalent.

SELECTING A TANGENT POLE CLASS

The first step in choosing a pole length and class to support a designated set of conductors for a straight line section is to calculate the transverse ice and wind load on the wire. To determine the amount of transverse load on a span of conductor, the load is usually evaluated for 1-ft of a specified conductor and then applied to the total span length. Calculate the transverse load for one foot of conductor using the following procedure.

Using the equation at right, transverse wind loads can be calculated for any series of conductors. Values for four typical distribution conductors are shown at right in Table 2.



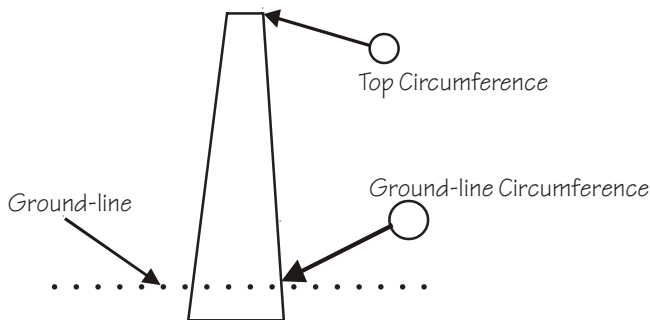
$$W_c = \frac{(D + 2R)W}{12}$$

- Wc = Transverse wind load for 1 ft of conductor in lbs/ft
- D = Diameter of the conductor in inches
- R = Radial thickness of ice in inches
- W = Magnitude of the wind force in pounds
- 12 = 12 inches or 1 ft of conductor

Table 2: Transverse wind load for 1-ft of specified conductor (Wc)

Conductor Physical Data			Transverse Wind Load (lbs/ft)		
Code Name	Size & Strand	Diameter	Light	Medium	Heavy
Sparate	2 ACSR, 7/1	0.325 in.	0.2438	0.2750	0.4417
Raven	1/0 ACSR 6/1	0.398 in.	0.2985	0.2993	0.4660
Penguin	4/0 ACSR 6/1	0.563 in.	0.4223	0.3543	0.5210
Merlin	336 ACSR 18/1	0.684 in.	0.51300	.3947	0.5613

The next step in choosing a tangent pole is to determine the breaking strength of a specified length and class pole. The ultimate resisting moment is the amount of force a pole can withstand at the ground-line before it breaks. The ultimate resisting moment is based on the fiber strength of the wood species and the dimensions of the pole at the ground-line and top. The pole classes are dependent on these dimensions and are specified in ANSI standard O5.1.



The fiber strength is dependent on the species of tree that the pole is produced from. Table 3 shows various tree species and the fiber strength of each.

Tree Species	Fiber Strength
Southern Yellow Pine	8,000 psi
Douglas Fir	8,000 psi
Northern Red Pine	6,600 psi
Ponderosa Pine	6,000 psi
Western Red Cedar	6,000 psi
Northern White Cedar	4,000 psi

The ultimate resisting moment of a wood pole is calculated using the following equations. To fully understand the process, an example problem will be worked to develop the ultimate resisting moment for a 45-ft class 4 southern yellow pine.

$$M_r = (K_r)(F_b)(C_g^3)$$

M_r = Ultimate resisting moment (ft-lbs)

K_r = Calculation constant = 0.000264

F_b = Designated pole fiber stress for wood species (psi)

C_g = Pole circumference at ground line (in)

Example 1: Calculate the ultimate resisting moment

Pole length and class = 45'- 4 southern yellow pine

Step 1: Calculate the pole circumference at ground-line (C_g).

$$C_g = \frac{(D_p - D_g)(C_b - C_t)}{(D_p - D_b)} + C_t$$

C_b = Pole circumference at 6' from butt = 35" (ANSI O5.1)

C_t = Circumference of pole at top = 21" (ANSI O5.1)

D_p = Distance from butt of pole to top of pole = 45'

D_g = Distance from pole butt to ground-line = 10%(45') + 2' = 6.5'

D_b = Distance from pole butt to classification point per ANSI O5.1 = 6'

Step 2: Calculate the ultimate resisting moment

$$C_g = \frac{(D_p - D_g)(C_b - C_t)}{(D_p - D_b)} + C_g = \frac{(45' - 6.5')(35'' - 21'')}{(45' - 6')} + 21'' = 34.82''$$

Table 4: Ultimate resisting moment of a 45-ft class 4 pole*

Tree Species	Fiber Strength	Pole Top Circumference	Ground-line Circumference	Ultimate Resisting Moment
Southern Yellow Pine Douglas Fir	8,000 psi	21 in.	34.82 in.	89,162 ft-lbs
Northern Red Pine	6,600 psi	21 in.	35.79 in.	86,764 ft-lbs
Ponderosa Pine Western Red Cedar	6,000 psi	21 in.	38.79 in.	88,853 ft-lbs
Northern White Cedar	4,000 psi	21 in.	43.71 in.	88,187 ft-lbs

* Pole set at 10% plus 2-ft deep

(Mr).

$$Mr = (Kr)(Fb)(Cg^3)$$

$$Kr = 0.000264$$

$$Fb = 8,000 \text{ psi (Table 3)}$$

$$Cg = 34.82 \text{ in. (calculated in Step 1)}$$

$$Mr = (0.000264)(8,000)(34.82^3) = 89,162.08 \text{ ft-lbs}$$

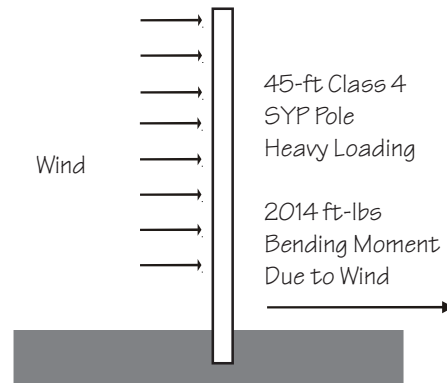
$$Mr = 89,162 \text{ ft-lbs}$$

Examples of the ultimate resisting moments for different species of 45-ft class 4 poles are shown in Table 4.

Table 4 points out that even though all the poles have approximately the same ultimate resisting moment, they vary in size at the ground-line circumference. In other words a 45'-4 northern white cedar pole is significantly larger in circumference at the ground-line than a 45'-4 southern yellow pine. Due to cedar's lower fiber strength, more wood mass (larger circumference) is needed to provide approximately the same overall strength or ultimate resisting moment as the southern yellow pine. The ultimate resisting moment values in Table 4 also show that the strength of a 45-ft class 4 wood pole is essentially the same for the different tree species.

A portion of the pole's inherent strength is needed to support the naked pole when it is subjected to wind. This portion of strength is

called the "bending moment due to wind". Once this value is calculated, the remainder of the pole strength can be used to support the conductors and equipment.



The bending moment due to wind can be calculated using the following equation. An example problem is used to illustrate the process for a 45'-4 SYP pole in NESCA heavy loading.

$$Mb = Lp \left[\frac{Lp 2Ct + Cg Kc}{Hp^2} \right]$$

Mb = Moment due to wind blowing on the pole (ft-lbs)

Lp = NESCA loading district wind per unit area of pole surface (lbs/ft²)

Ct = Circumference of pole at top (in)

Cg = Pole circumference at ground line (in)

Kc = Calculation constant = 72

Hp = Height of pole above ground (ft)

Example 2: Calculate the bending moment due to wind on the pole

Pole height and class = 45'- 4, southern yellow pine

NESC loading district = heavy

$$M_b = L_p \left[\frac{2C_t + C_g}{K_c} \right] H_p^2$$

$L_p = 4 \text{ lbs/ft}$ (Table 1, heavy loading, wind)

$C_t = 21''$ (Table 4)

$C_g = 34.82''$ (Table 4)

$K_c = 72 = 226.19$

$H_p = 38.5'$ (45' pole – 6.5' setting depth)

$$M_b = 4 \left[\frac{(2 \cdot 21) + 34.82}{226.19} \right] 38.5^2 = 2,014 \text{ ft-lbs}$$

Using the above values and a given set of conductors, the designer can calculate the maximum wind span that a 45-ft class 4 pole will support. Once the maximum wind span is known, the designer can use any combination of span lengths as long as the wind span for each of the 45' - 4 poles in the line section does not exceed the maximum. The wind span is the average of the lengths of the back-span and the forward span of a given pole. Any pole in a line section must

adequately support half of the back-span and half of the forward span.

The NESC requires that the designer use various overload factors when selecting a pole to support a given load. The NESC provides two different methods with separate sets of overload factors to calculate the strength of a wood pole. Method number one assumes the wood pole to be at 100% of its strength at installation and requires application of overload factors from NESC Table 253-2. Method number two reduces the wood pole ultimate resisting moment (strength) according to NESC Table 261.1A and then requires application of overload factors from NESC Table 253-1. Method number two is the only technique used to calculate loads for steel and pre-stressed concrete poles. For comparison purposes, it will be used here to calculate the wood pole size for a given set of conductors.

Table 5 lists the NESC overload factors from NESC Table 253-1 and the strength reduction factors from NESC Table 261-1A. These values will be used to determine the maximum wind span for the example 45-ft class 4 southern yellow pine.

Table 5: NESC Overload and Strength Reduction Factors		
Type Load	Grade B	Grade C
Transverse wind at crossing	2.50	2.20
Transverse wind elsewhere	2.50	1.75
Transverse wire tension	1.65	1.30*
Longitudinal at dead-ends	1.65	1.30*
Strength Reduction Factors		
Wood poles	0.65	0.85
Metal and pre-stressed concrete	1.00	1.00

* This value can be reduced to 1.10 for pre-stressed concrete and metal poles.

Example 3: Calculate the maximum wind span

Wood pole = 45' - 4 southern yellow pine set 10% + 2' deep

Conductors = (3) 336 ACSR 18/1 (Merlin) primary with (1) 4/0 ACSR 6/1 (Penguin) neutral

Pole top assembly = RUS VC1.11 assembly

NESC construction grade = C

NESC loading district = Heavy

The wind span is not at a crossing

$$S_m = \frac{M_r' - M_b'}{M_c}$$

S_m = Maximum wind span

M_r' = Reduced ultimate resisting moment

M_b' = Bending moment due to wind on the pole with applied overload factor

M_c = Moment due to wind on the conductors with applied overload factor

Step 1: Calculate the reduced ultimate resisting moment.

$$M_r' = M_r(S_{wf})$$

M_r' = Reduced ultimate resisting moment

M_r = Natural ultimate resisting moment of a 45'-4 SYP pole = 89,162 ft-lbs (Example 1)

S_{wf} = Strength reduction factor for wood poles at Grade C (Table 5) = 0.85

$$M_r' = 89,162 (0.85) = 75,788 \text{ ft-lbs}$$

The reduced ultimate resisting moment of the 45'-4 SYP is 75,788 ft-lbs

Step 2: Calculate the moment due to wind with the applied NESC overload factor.

$$M_b' = (M_b)(F_w)$$

M_b' = Moment due to wind blowing on the pole with applied NESC overload factor

M_b = Natural (no overload factor) bending moment due to wind = 2,014 ft-lbs (Example 2)

F_w = NESC overload factor, transverse wind elsewhere, Grade C = 1.75 (Table 5)

$$M_b' = (2,014)(1.75) = 3,525 \text{ ft-lbs}$$

The bending moment due to wind with applied overload factor on the 45'-4 SYP is 3,525 ft-lbs

Step 3: Calculate the moment due to wind blowing on the conductors.

$$M_c = \sum W_c \cdot H_c \cdot F_w$$

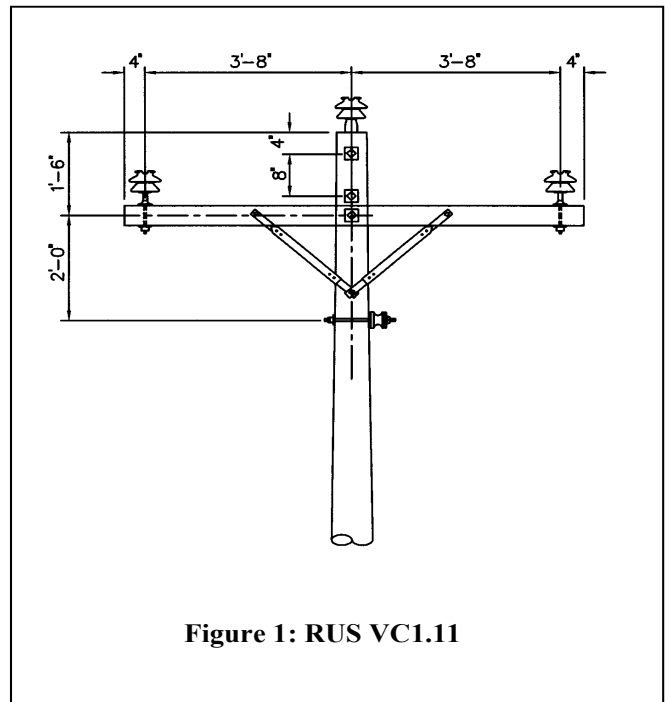


Figure 1: RUS VC1.11

M_c = Moment due to wind blowing on the conductors with applied NESC overload factor

W_c = Transverse wind load per unit area of conductor for heavy loading (Table 2)

$$336 \text{ ACSR} = 0.5613 \quad 4/0 \text{ ACSR} = 0.5210$$

H_c = Height of conductors above grade (VC1.11, assume 0.75' for pin & insulator height)

Referring to Figure 1 & pole set 6.5' deep, AØ & CØ (crossarm pins & insulators) = 37.75',

BØ (pole-top pin & insulator) = 39.25', neutral (single-upset bolt) = 35.00'

F_w = NESC overload factor for transverse wind elsewhere, Grade C (Table 5) = 1.75

The moment due to wind blowing on the ice laden conductors is 144.62 ft-lbs for 1-ft of each conductor tied to the pole top assembly.

Step 4: Calculate the maximum wind span for the (3) 336 ACSR primary and (1) 4/0 conductors on a 45'-4 SYP tangent pole in heavy loading built to Grade C construction.

$$S_m = \frac{M_r' - M_b'}{M_c}$$

S_m = maximum wind span

M_r' = Reduced ultimate resisting moment of the pole (Step 1) = 75,788 ft-lbs

Wire	Wc (lbs/ft)	x	Hc (ft)	x	Fw	=	Mc (ft-lbs)	
AÖ	0.5613	x	37.75	x	1.75	=	37.08	
BÖ	0.5613	x	39.25	x	1.75	=	38.55	
CÖ	0.5613	x	37.75	x	1.75	=	37.08	
N	0.5210	x	35.00	x	1.75	=	31.91	
$Mc = \sim Wc \cdot Hc \cdot Fw$							=	<u>144.62</u>

Mb' = Bending moment due to wind with applied overload factor (Step 2) = 3,525 ft-lbs
 Mc = Moment due to wind on the conductors with overload factor (Step 3) = 144.62 ft-lbs

$$S_m = \frac{75,788 - 3,525}{144.62} = 499.68$$

The 45-ft class 4 pole will support the (3) 336 ACSR primary and (1) 4/0 neutral conductors in the heavy loading district built to NESC Grade C for a maximum wind span of 499.68-ft. This is for a tangent (straight line) only. In many cases, clearance above grade will control the span length, and the actual wind span will be much shorter than the calculated maximum. If any line angle is present, the tension component of the conductors at a transverse line angle must be factored into the equation.

The example demonstrates the steps necessary to choose a length and class of wood pole to support a set of conductors for a specific loading district and grade of construction. This method can also be used for steel or pre-stressed concrete poles. In fact the designer should use this method instead of relying on equivalent size wood pole values to choose steel or concrete. The key is to determine the ultimate resisting moment and bending moment due to wind for wood,

steel, or concrete then calculate the maximum wind span. Since steel and concrete are manufactured poles, the strength reduction factor from NESC Table 261-1A is 1.00. In other words, the pole strength is not required to be reduced for steel or concrete.

Many times an advertised equivalent pole class for a steel or concrete pole is based on NESC Grade B. The Grade B strength reduction factor for wood poles is 0.65 (Table 5). If the line is being built to Grade C, the wood pole strength reduction factor increases to 0.85. Consequently, the Grade C wood pole will support a longer maximum wind span than the equivalent Grade B steel or concrete pole. At Grade C, the wood pole is stronger than the advertised equivalent steel or concrete pole. It is important to determine the pole loading based on scientific analysis rather than the "equivalent" pole class. In Table 6, a theoretical wood pole class with an ultimate resisting moment of 100,000 ft-lbs is compared to a steel or concrete pole that is manufactured to the equivalent Grade B wood pole class. As can be seen, if the line were built to Grade C, the wood pole would be stronger than the equivalent steel or concrete. The wood and equivalent steel/concrete poles are only equal at Grade B.

Pole	Ultimate Resisting Moment		
	Initial Moment	Grade B	Grade C
Natural wood class	100,000 ft-lbs	65,000 ft-lbs	85,000 ft-lbs
Equivalent class Grade B steel or pre-stressed concrete	65,000 ft-lbs	65,000 ft-lbs	65,000 ft-lbs

BASIC IMPULSE INSULATION LEVEL (BIL)

The basic impulse insulation level or BIL defines the ability of a structure to withstand a lightning impulse. A basic impulse insulation level of less than 300 kV can produce lightning flashovers where lightning strikes near the electric distribution line. A “BIL” equal to or greater than 300 kV (dry flashover) can be achieved on wood poles using standard pole-top assemblies rated for the operating voltage. The wood provides the additional insulation needed to achieve the required BIL. On metal or concrete poles, fiberglass links or extra insulators must be added to the standard pole-top assembly hardware to achieve the same BIL as the wood poles. The phase conductors, insulators, and neutral conductor in a

3-phase steel pole distribution line are all connected by a conductor (steel). In a wood pole distribution line, they are connected by an insulator (wood).

For areas of high lightning incidence, lightning arresters should be installed approximately every 1,200-ft along the line and at dead-ends. This will augment the natural insulation of the wood and minimize nuisance recloser operations and fuse blowing. This is more important for steel or concrete poles because of their lower lightning impulse withstand strength. Arrester intervals of 800-ft may be needed on steel or concrete poles to minimize momentary outages and damaged insulators.

RAPTOR PROTECTION

In many areas of the United States, utilities must provide raptor protection to comply with federal regulations. Wood pole and crossarm construction offers a distinct advantage because of the natural insulating properties of wood. For most raptors, including eagles, electrocution can be prevented using a 10-ft wood crossarm mounted 12” to 18” below the pole top. This will provide the required 60” spacing required for raptor protection. Steel poles act as their own

ground, thus decreasing the phase to ground clearance for raptors. It is recommended that 24” fiberglass pole-top pins, vinyl pole wraps, perch guards, and wood crossarms be installed on steel poles to achieve adequate raptor protection. As can be seen, standard wood pole crossarm construction will effectively prevent raptor electrocution without addition of special assemblies or perch guards. Wood provides a humane and economic advantage in protecting raptors.

INSTALLATION

Wood poles are easier to handle, store, and work with than alternative materials. They can be stacked in bundles in the pole yard without cribbing. Wood poles can be loaded onto the bare steel pole trailer using metal cables and standard rigging. No provision is needed to cushion the trailer rails or protect the exterior pole from scratches or scrapes. Standard utility digger-derrick trucks are adequate to handle and set wood poles up to 70-ft in height. In most cases, wood poles can be backfilled with the same material that was excavated from the pole hole. For additional strength, gravel backfill may be used to provide a more substantial foundation. Tamping can be done with hydraulic or hand tamps without worry over damaging the exterior surface of the pole. The larger butt section and rougher texture of wood provides substantial adhesion to the embedment soil. The smaller diameter and slicker surface of a directly embedded light steel pole offers little resistance to leaning unless special care is taken to adequately tamp the embedment

material.

Holes are easily bored in wood poles with conventional drills for any combination of assemblies. Newly bored holes can easily be field treated by swabbing with a preservative. Standard guy attachment hardware using lag bolts or cleats to anchor the lower end of the attachment to provide strength and prevent rotation can be used on wood poles. Steel or concrete poles require guy attachments with two machine bolts. No cleats can be present on the inside of the pole eye plate or a lag bolt used to anchor the attachment.

A significant number of poles on a utility's system can be worked more efficiently by a climbing lineman than with a bucket truck. Wood poles are easily climbed using traditional climbing tools. No special pole steps must be included in the design or purchase. This feature is not only beneficial for remote areas but also for subdivision back lot lines and yards that are not readily accessible to standard aerial lifts.

DUTY CYCLE

How long will wood poles last in service is a common and important question. With a continuing inspection and maintenance program, it has been shown that pole service life can reach 75 years or beyond (2). Steel and concrete claim life spans of 80 years, but the products have not been used long enough in direct burial installations to fully evaluate the impact of age and corrosion. However, the **duty cycle** (service life) of a pole depends largely on factors other than the condition of the pole. More often than not, a pole is

replaced not because it has deteriorated beyond its inherent strength to support the conductors, but because a line is upgraded, roads are widened, or land is developed. A significant number of poles are replaced due to these factors rather than to deterioration. These poles can be reused at other locations or recycled for non-utility applications. In fast growth areas with short duty cycles caused by frequent upgrades, development, or road widening, the lower cost of wood has a distinct economic advantage over the alternatives.

FLEXIBILITY

The wood pole is very flexible and can survive many adverse conditions caused by nature. When trees fall on conductors and guy wires, the wood pole will significantly deflect before breaking. Many times, the trees can be cut off the line and the pole will spring back into position. The wood pole is forgiving to the change in conductor tension

between spans. On very rigid poles such as concrete, the change in conductor tension brought about by expansion and contraction due to temperature change can bend crossarm pins. The wood pole will flex with the change in conductor tension and not damage the hardware.

ECONOMICS

The cradle to grave life cycle costs of pole materials is a key concern in design and purchasing decisions. Where duty cycles are short, wood has a clear advantage. Where longer service life is needed, the cost of inspection and maintenance must be incorporated into the decision as well as cost of disposal of the product at the end of its useful life. The most extensive review of this issue, undertaken by Engineering Data Management, Inc. (3) demonstrated that in terms of both initial cost and the full life cycle cost, wood has an advantage. The savings of lower initial cost of wood compared to alternative materials overcomes the discounted present value of potentially

higher maintenance, disposal and replacement costs for wood. In other words, the money saved by using wood today, invested at a modest return, will more than cover the costs associated with any disadvantage of wood, real or perceived, over the life of the power line. Averaging around 15% in 1997, the advantage for wood is no doubt much larger now with the explosion in steel costs in recent years. The utility industry has conducted its own review of wood verses alternatives and concluded that "Treated Wood Poles are preferred by utilities because they are more practical, functional, and economically acceptable than other alternatives."⁽¹⁾

CONCLUSION

Despite intense promotion by alternative materials and developments in engineered products, the fact is undisputable that now and for years to come, treated wood remains the best all around product for most utility applications. It is raptor friendly, easy to install, naturally insulating, and has a long duty cycle. These factors make the treated wood pole a leader in safety,

reliability, and efficiency. The key is to understand the design and application of wood poles. For more resources on wood poles the reader can access WOODPOLES.org on the internet. To learn about design and application, access the Hi-Line Engineering website at _____ for a schedule of nationwide seminars.

REFERENCES

- (1) Utilities Solid Waste Activities Group submission to EPA, Docket No. OPP-2004-0402, January 2005.
- (2) Western Wood Preservers Institute, Wood Pole Newsletter, Vol. 20, 1996.
- (3) Western Wood Preservers Institute, Wood Pole Newsletter, Vol. 23, 1997.

Disclaimer

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