Outside Plant Consulting Services, Inc.

A Comparison of Wood and Distribution Poles of Other Materials Relative to the Rules of the National Electrical Safety Code (NESC)

or

"Why is a Grade C Metal Pole Required to be Stronger than a Grade B Metal Pole?"

Prepared by:

Outside Plant Consulting Services, Inc.
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for Powertrusion International, Inc.

About Outside Plant Consulting Services, Inc. (OPCS)

Outside Plant Consulting Services, Inc. (OPCS) was established in the year 2002 to help meet the needs of the telecommunications and power industries in establishing standards, guidelines and practices for outside plant facilities and products. The OPCS Group provides related support services for field deployment, and product evaluation and analysis. Dr. Lawrence (Larry) M. Slavin, Principal of OPCS, has extensive experience and expertise in such activities, based upon his many years of service at AT&T/Lucent Bell Telephone Laboratories (Distinguished Member of Technical Staff) in telecommunications product design and development, followed by a career at Telcordia Technologies (Bellcore) in its research and professional service organizations.

As Principal Consultant and Manager/Director of the Network Facilities, Components, and Energy Group at Telcordia, Dr. Slavin was responsible for professional services related to the telecommunications industry. These activities include technical leadership in developing installation practices and "generic requirements" documents, introducing new construction methods, and performing analyses on a wide variety of technologies and products (poles, electronic equipment cabinets, flywheel energy storage systems, turbine-generators, …). Throughout his long career, he has had a leading role in the evolution of many telecommunications related fields and disciplines -- including aerial and buried plant design and reliability; advanced construction and cable placement techniques; copper pair, coaxial, and fiber-optic technology; flywheel energy storage systems; physical design and development of hardware and electronic and electro-optic systems ("SLC 96" digital loop carrier, …); cable media and equipment reliability studies; exploratory fiber-optic hardware development; and systems engineering.

Dr. Slavin is a member of several subcommittees of the National Electrical Safety Code Committee (NESC), responsible for specifying safety standards for aerial and buried telecommunications and power facilities in the United States. He is also an active member and participant on the Accredited Standards Committee ASC-O5 ("ANSI-O5") for wood poles and products. Dr. Slavin is a Charter Member of the North American Society for Trenchless Technology, has been instrumental in the development of directional drilling standards, and participates in training and certification activities for the directional drilling industry.

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Abstract

Although wood poles continue to be the primary choice for constructing power and telecommunications distribution lines, there are many applications for which alternate pole materials, typically engineered products (steel, concrete, fiber-reinforced composite,), represent an optimum solution. However, it is important to maintain the structural reliability of the non-wood poles relative to the existing wood poles, based upon the rules of the National Electrical Safety Code (NESC). The NESC strength and loading rules are specified as a function of "grade of construction" (reliability level), which will determine the appropriate size (strength) pole to withstand wind and ice storms, to meet the basic safety requirements. The different grades of construction will require a different capacity or strength. Since the utilities have experience and familiarity with the wood pole classification system ("pole class"), it is convenient for steel, concrete, … poles to be classified similarly, to facilitate their selection and use by the utility. However, due to the inherently different characteristics (statistical distributions, …) of naturally grown wood and engineered pole structures, the equivalency of a given non-wood pole size/strength (pole class number) for a Grade B construction application will, in general, not be the same for a Grade C construction application.

The present article attempts to clarify such issues, based upon the NESC strength reduction and overload factors. As explained herein, an engineered pole that is equivalent to a Class 4 wood pole (2400 lbs. average strength) for a Grade B application is required to have a minimum strength of 1560 lbs. In order to be equivalent to a Class 4 wood pole for a Grade C application, the engineered pole must have a significantly greater minimum strength of 2040 lbs. If the lower strength (1560 lbs.) Grade B equivalent pole, is used for a Grade C application (e.g., longer span length, more attachments,…), then the storm loading will result in a greater load (2040 lbs.) than it would be able to withstand to any appreciable degree. In this case, although the large majority of Class 4 wood poles would survive, the large majority of the non-wood, Grade B equivalent Class 4 poles would fail.

1. Introduction

Wood poles have historically been the mainstay of the utility distribution plant, for both power and telecommunications. Such poles have served well and provided reliable, economic service in the past, and will likely continue to be widely used in the future. Nonetheless, there are many applications for which alternate pole materials, typically engineered products (steel, concrete, fiber-reinforced composite, …), represent an optimum solution. Depending upon the specific alternate material, the advantages of such materials, include:

- Environmental (no chemical preservatives)
- Light weight (e.g., rear lot and other difficult access situations)
- Longevity (not vulnerable to water or insects)
- Appearance (colors, shapes, …)

However, it is important to maintain the structural reliability of the alternative non-wood poles relative to the existing wood poles. The National Electrical Safety Code has served to provide basic safety rules to ensure such reliability. Unfortunately, these rules are sometimes confusing to the general industry and public, and therefore not always properly understood or correctly interpreted when attempting to introduce the non-wood alternatives. The purpose of this article is to clarify these rules and their application, including to a non-technical audience.

The 2002 Edition of the National Electrical Safety Code (NESC), ANSI C2[1], provides basic safety requirements for the installation, operation or maintenance of outdoor communication and electric power facilities. It therefore complements the National Electrical Code (NEC) which provides requirements for indoor facilities. The NESC is intended to primarily focus on helping ensure the safety of employees and the public, and is not intended to be a design specification or instruction manual. Part 2 of the NESC addresses overhead lines, including clearances and strength and loading. In particular, Section 25 provides rules for defining the storm loadings to be withstood by the utility structures (poles, …). Section 26 provides the strength requirements based upon adjustment or de-rating, if necessary, of the industry-specified strength for various standard materials (wood, steel, concrete, ..) to provide acceptable basic margins for safety and survivability of the poles and supported facilities.

The NESC strength and loading rules are specified as a function of "grade of construction" (i.e., reliability level), which will determine the appropriate size (strength) pole to withstand wind and ice storms, to meet the basic safety requirements. Three grades of construction are defined relevant to pole lines:

- **Grade B** -- the highest grade; typically corresponds to crossings (highway, railroad, pole lines carrying varying power supply voltage levels, …)
- **Grade C** -- lower grade of construction than Grade B; typical power or joint-use (telecommunications and power) distribution pole applications

- Grade N -- lowest grade of construction; typical sole use telephony applications.[1]

The Grade B and Grade C construction are of primary interest to the utilities and is the focus of the present discussion, with most distribution lines built to Grade C standards.

Wood poles are classified by "pole class" (Class 1, Class 2, …, Class 10) that defines the size and strength of the pole. A lower class number pole is of larger diameter and stronger than a higher class number pole. The different grades of construction will require a different capacity or strength and therefore a different class pole. Since the utilities have experience and familiarity with the wood pole classification system, it is convenient for steel, concrete, … poles to be classified similarly, to facilitate their selection and use by the utility. However, due to the inherently different characteristics (statistical distributions, …) of naturally grown wood and engineered pole structures, the equivalency of a given non-wood pole size/strength (pole class number) for a Grade B construction application will, in general, not be the same as for a Grade C construction application[3,4].

2. Wood Pole Strength

Design criteria for telecommunications or power utility pole lines often directly relate to the forces resulting from transverse wind loads imposed during storm conditions. For this reason, wood pole strength is typically characterized by its lateral (horizontal) load bearing capacity, when subject to a horizontal force applied 2 ft. from the tip, in a cantilever configuration, as illustrated in **Figure 1**. Thus, the strengths of the wood poles, corresponding to the class sizes, are defined as their load capability with respect to such a lateral load. The dimensions (diameter or circumference) of a pole of a given class size will be a function of the pole length and wood species. The intention is that all pole members of a given pole class have the same nominal capacity when subject to the same (specified) lateral load, placed 2 ft. from the tip, regardless of the height or wood species of the pole. The dimensions (diameter) of the wood pole are specified accordingly, to account for different length poles and material properties.

This convention has been adopted by the by ANSI-O5.1[5] standard for wood poles and is reflected in the ASTM D 1036[6] test procedure. ANSI-O5.1 also provides the recommended depth of burial for the poles as a function of total length. For distribution poles of length 40 ft. or greater, the recommended depth is equal to 10% the pole length, plus 2 feet. (For poles shorter than 40 feet the recommendation is generally 10% the pole length, plus 2.5 ft.) Guidelines for the deployment of non-wood (steel, …) poles for utility applications are consistent with these recommendations. Thus, for a commonly used 40 ft. pole, the burial depth is 6 ft., and the applied load is located 32 ft. above the ground line -- i.e., 40 ft. length - 6 ft. depth - 2 ft. from tip = 32 ft. In general, non-wood

[1] The former "Bell System Practices"[2] define a range of construction grades dependent upon the type and quantity of telecommunications circuits supported, containing the equivalent of Grade B, Grade C, and below. It may be assumed that telecommunications companies utilize Grade C equivalent construction for most applications, including joint or sole use.

pole suppliers also attempt to test and characterize the strength of their poles in a manner consistent with that of Figure 1 and the wood standards.

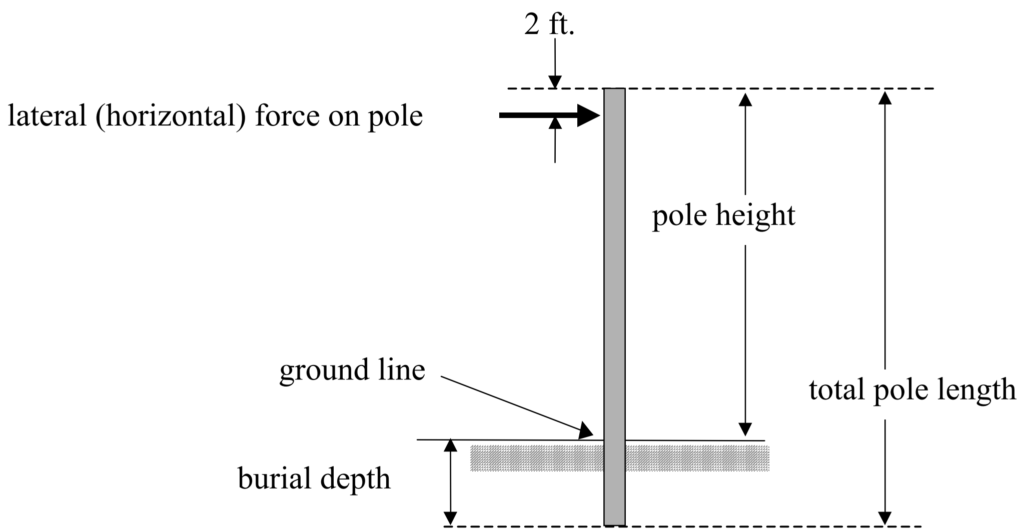

Figure 1
Lateral Force Applied to Installed Pole (Cantilever Configuration)

Table 1 provides the class strengths, as specified in the ANSI-O5.1 standard. The commonly used Class 4 pole, has a designated strength of 2400 lbs., when applied laterally 2 ft. from the top of the pole. These class strengths provide the basis for defining the minimum circumference (or diameter) of the pole at the ground line for a given class size. Poles within a class size actually display a range of diameters between the minimum required, consistent with the class strength, and that of the next larger class size.

The proper interpretation and significance of these class strength values has been the subject of much discussion in the industry. The common understanding has been that these are mean (average) values, and therefore require significant de-rating by a “strength factor”. That is, proper design of structures should not be based upon an average strength which will not be achieved by a significant number (50%) of poles. Rather, a somewhat reduced, or “minimum”, strength should be assumed to provide a conservative design and sufficient safety factor for the utility line, depending upon its importance -- i.e., grade of construction.

In order to clarify the significance of the wood class pole strengths, the 2002 edition of ANSI-O5.1 has explicitly stated that the designated stress (strength) levels of the primary used wood species (Southern Pine, Douglas Fir, Western Red Cedar) do correspond to the average strength. Furthermore, the material variability is also quantified for these species, allowing determination of a valid minimum design strength, and, equivalently, a technically valid de-rating or strength reduction factor to be calculated.

Table 1
Wood Pole Class Size (Nominal Strength)

Class Size	Lateral (Horizontal) Load, lbs. (applied 2 ft. from tip)	Class Size	Lateral (Horizontal) Load, lbs. (applied 2 ft. from tip)
H6	11,400	1	4,500
H5	10,000	2	3,700
H4	8,700	3	3,000
H3	7,500	4	2,400
H2	6,400	5	1,900
H1	5,400	6	1,500
		7	1,200
		9[2]	740
		10	370

Figure 2 illustrates the typical variability or strength distribution of a Class 4 wood pole. This wide range of strengths is due to several effects, including the material variability inherent in such a naturally-grown product, as well as the range of dimensions specified for that pole class number. The mean strength of 2400 lbs. reflects the various effects. Approximately half the poles have a capacity greater than the nominal 2400 lbs. and, conversely, half the poles are weaker. Some small percentage of poles are very weak -- e.g., less than 1600 lbs., while there is a similar percentage that may withstand more than 3200 lbs. -- greater than the nominal 3000 lbs. capacity of a Class 3 pole. Understanding that such a wide variation in pole strengths exists within a given class size is key to understanding the NESC treatment of wood poles and their associated strength factors in comparison to an engineered product, such as a steel pole, as discussed below.

[2] Class size "8" is not used.

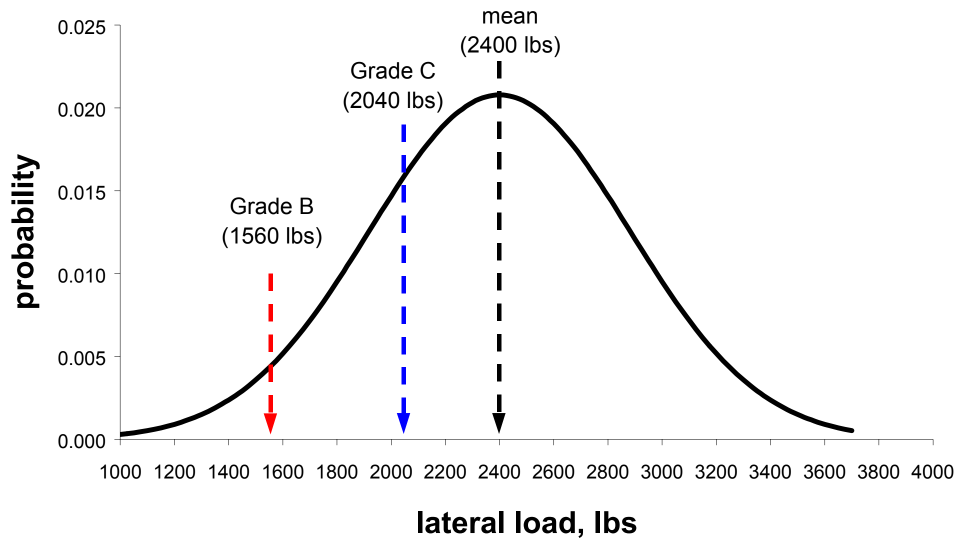

Figure 2
Strength Variation for Typical Class 4 Wood Pole

3. NESC

The NESC includes two types of storm loadings for overhead lines which utility structures must withstand. Rule 250B specifies storm loadings for combined ice and wind, which are applicable to all structures, and are based upon the historical Loading Districts ("heavy", "medium", "light") map for the United States, shown in **Figure 3**. Rule 250C specifies storm loadings for extreme wind (hurricanes, …). The NESC also specifies appropriate "safety factors" that must be taken into consideration in the implementation of these storm loadings. The NESC indicates that Rule 250C is not applicable to structures of less than 60 ft. height above ground. The vast majority of distribution structures are less than 60 ft. tall, and are therefore exempt from this rule.

3.1 NESC Strength Factors

Table 261-1A of the National Electrical Safety Code is reproduced as **Table 2**, and provides de-rating or "strength (reduction) factors" for various materials. Table 261-1A, and its companion "overload factor" NESC Table 253-1 (Table 3), is the preferred alternative to the older NESC Table 261-1B, and its companion "overload factor" Table 253-2, which apply to wood only, and will eventually be deleted from the NESC. The older Table 253-2 is the source of the familiar "4-to-1" and "2-to-1" overload/safety factors frequently referred to in the industry for Grade B and Grade C construction, respectively. These older tables, however, do not allow comparison between different structural materials and are not amenable to a discussion in this regard. The ability to distinguish between different materials and strengths is consistent with the widely accepted "reliability-based design" (RBD) concept[7], and is one of the original motives for the introduction of Tables 261-1A and 253-1 into the NESC. These newer tables may be shown to yield equivalent net design/safety factors for wood, but also provide appropriate factors for other materials. A discussion of the companion NESC overload factors and their implementation is provided in the next section (***NESC Overload Factors***).

PART 2. SAFETY RULES FOR OVERHEAD LINES

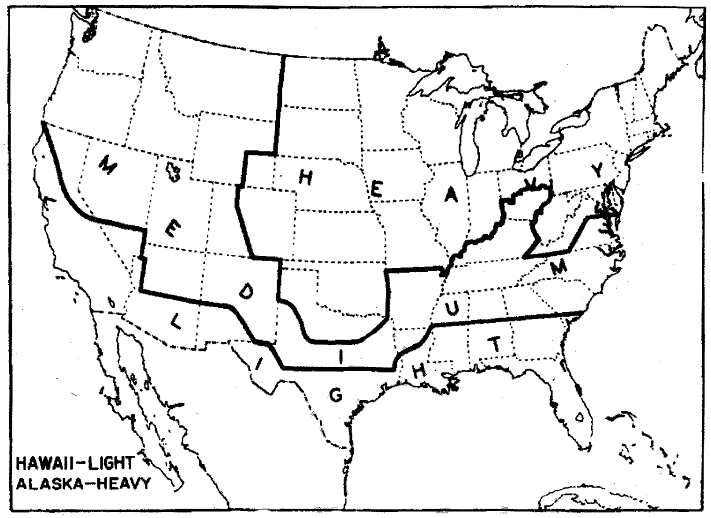

Fig 250-1
General Loading Map of United States
with Respect to Loading of Overhead Lines

Figure 3
Combined Ice and Wind Storm (NESC Loading Districts)

The strength factors corresponding to wood and metal (steel, …)[3] are highlighted in Table 2 below as applied to Rule 250B (Figure 3, combined ice and wind) of the NESC, applicable to structures of all heights. Thus, Table 2 indicates that there are two distinct strength reduction factors relevant to wood poles: 0.65 and 0.85, for Grade B and Grade C construction, respectively. These quantitative factors are based upon successful experience within the utility industry. The effective (assumed) strength of the wood pole is obtained by multiplying the appropriate strength factor by the industry-specified (ANSI-O5.1) nominal wood strength. For the Class 4 wood pole of 2400 lbs nominal (average) strength illustrated in Figure 2, the effective strengths are calculated as

[3] The NESC also considers concrete poles, but distinguishes between reinforced concrete and prestressed concrete. The former is treated similar to wood, while the latter is treated similar to metal and, for the present purposes, is considered to be an "engineered" product.

0.65 x 2400 lbs = **1560 lbs.** for **Grade B** construction

and

0.85 x 2400 lbs = **2040 lbs.** for **Grade C** construction

and are also indicated in Figure 2. Typical distribution pole design is subject to the Grade C construction and corresponding strengths.

The greater assumed strength allowed for the Grade C construction is consistent with the recognition that a somewhat less conservative reliability is acceptable for such applications. This may be implemented, for example, by allowing a significantly longer span length and/or more attachments than for a pole line subject to Grade B construction rules. The use of a longer span recognizes that most wood poles would still survive a storm of similar intensity applied to the longer span and resulting in higher loads on the pole -- albeit not as many as would survive if the span were shorter, consistent with the more conservative Grade B construction. This is a typical cost-risk trade-off.

Table 2
(NESC Table 261-1A)
Strength Factors for Structures, Crossarms, Support Hardware, Guys, Foundations, and Anchors for Use with Overload Factors of NESC Table 253-1

	Grade B	Grade C
Strength factors for use with loads of Rule 250B		
Metal and Prestressed-Concrete Structures	**1.0**	**1.0**
Wood and Reinforced-Concrete Structures	**0.65**	**0.85**
Support Hardware	1.0	1.0
Guy Wire	0.9	0.9
Guy Anchor and Foundation	1.0	1.0
Strength factors for use with loads of Rule 250C		
Metal and Prestressed-Concrete Structures	1.0	1.0
Wood and Reinforced-Concrete Structures	0.75	0.75
Support Hardware	1.0	1.0
Guy Wire	0.9	0.9
Guy Anchor and Foundation	1.0	1.0

Thus, the greater strength associated with the Grade C pole is not an indication of an inherently greater size or capacity -- but only of less conservative application rules, consistent with the recognition that most wood poles will survive significantly greater loads than assumed by the Grade B implementation rules. This is due to the wide variability of the naturally-grown wood poles. This larger assumed effective strength level (e.g., 2040 lbs. for a Class 4 wood pole) has been a confusing issue to many in the industry because it initially appears to suggest “a Grade C pole is stronger than a Grade B pole." But this statement is misleading and should more properly be stated as: "a pole deployed for a Grade C application is *assumed* to be stronger than a pole selected from the same class size and deployed for a Grade B application". That is, for Grade C construction, a steel pole is competing against an assumed stronger wood pole within the Class 4 wood population than is assumed for Grade B construction. This assumption and implementation for wood is accompanied by a greater, albeit acceptable, risk of failure in a given storm condition. This risk is minimal for the widely varying, naturally-grown wood pole.

This principle does not extend to engineered products (steel, FRC, …) of relatively narrow strength variability. Although a highly reproducible product (narrow variability) is obviously advantageous in providing a cost-effective design for each specific application, the low variability precludes the availability of poles with significantly greater strengths in the population, such as might be assumed for Grade C applications. Thus, Table 2 indicates the same strength factor for metal for both Grade B and Grade C construction, which is conservatively selected equal to 1.0 based upon an industry-specified nominal material and pole strength at a "minimum" level.

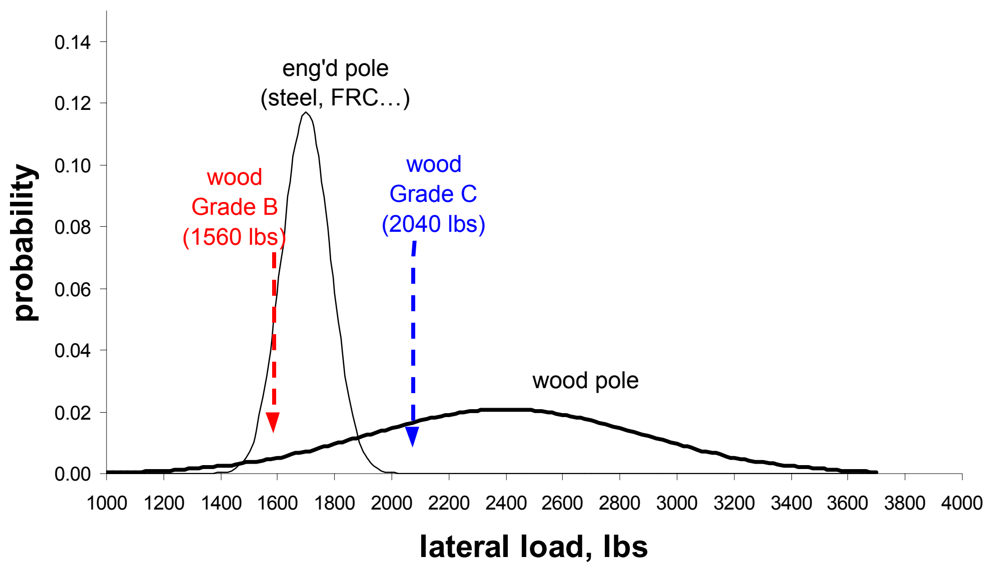

Figure 4
Strength Variation for Typical Class 4 Wood Pole and Comparable Engineered Pole (Grade B equivalent)

Figure 4 superimposes the strength characteristics of an engineered pole upon that of wood, as in Figure 2 (vertical scale changed). The engineered pole shown has a “minimum”strength of approximately 1560 lbs, equivalent to the minimum strength of that of a wood pole for Grade B construction, as required by the NESC. Thus, if a storm loading of this intensity is applied to a utility line (conductors, equipment, pole, …) supported by either the Class 4 wood or “equivalent” non-wood pole, there is a high reliability of survival -- i.e., the vast majority (e.g., typically 95%) of the poles will withstand the storm loading without breakage. For Grade C construction, the NESC specified allowable strength of 2040 lbs for the Class 4 wood pole is also indicated. The large majority of wood poles (e.g., 75 – 80%) will withstand this load, providing an acceptable level of reliability, albeit somewhat less than for the “more important” Grade B application. In order for a non-wood pole to survive the same storm loading (2040 lbs), at the same rate of survival, a likewise large majority of such poles must withstand this load. However, as seen in Figure 4, due to the low variability of the engineered product, essentially every such pole would fail. A significantly stronger non-wood pole, with a high survivability rate at the 2040 lbs level, would be required.

This phenomenon is illustrated in **Figure 5a**. The Grade B pole line illustrated is of a relatively short span length, consistent with the number of wires and cables present, that will result in an effective wind load of 1560 lbs. on a (wood or non-wood) pole of minimum strength equal to this load level. The condition of the pole line following a storm event that would produce this load is also indicated to show that little, if any, damage will occur -- i.e., essentially all poles survive this event. (Note: The slight “tilt” of the poles is a cartoon attempt to suggest that a minimal number of poles would be broken or damaged in some manner.)

Figure 5b is a similar sketch for a Grade C pole line, in which the non-wood pole is sized at the same strength as the Class 4 wood pole deployed in a Grade B application (1560 lbs), which is considerably less than that of the same Class 4 wood pole deployed in a Grade C application (2040 lbs). The assumed wood pole strength is now 2040 lbs, corresponding to the greater accepted risk for this application. Thus, a longer span length may be employed for the same given number of cables and attachments as for the Grade B line illustrated in Figure 5a. The slightly larger “tilt” for the wood pole following the same storm event, is a recognition that a somewhat greater number of wood poles will be damaged, but that the large majority will survive. The array of fallen non-wood poles acknowledges that almost all of these poles would fail when subjected to the load of 2040 lbs. load. A different, stronger non-wood pole is required to be equivalent to the Class 4 wood pole as deployed in a Grade C application -- essentially meeting the 2040 lbs. capability. As will be seen below, the 1560 lbs. engineered pole is only equivalent to a Class 5 wood pole, for a Grade C application.

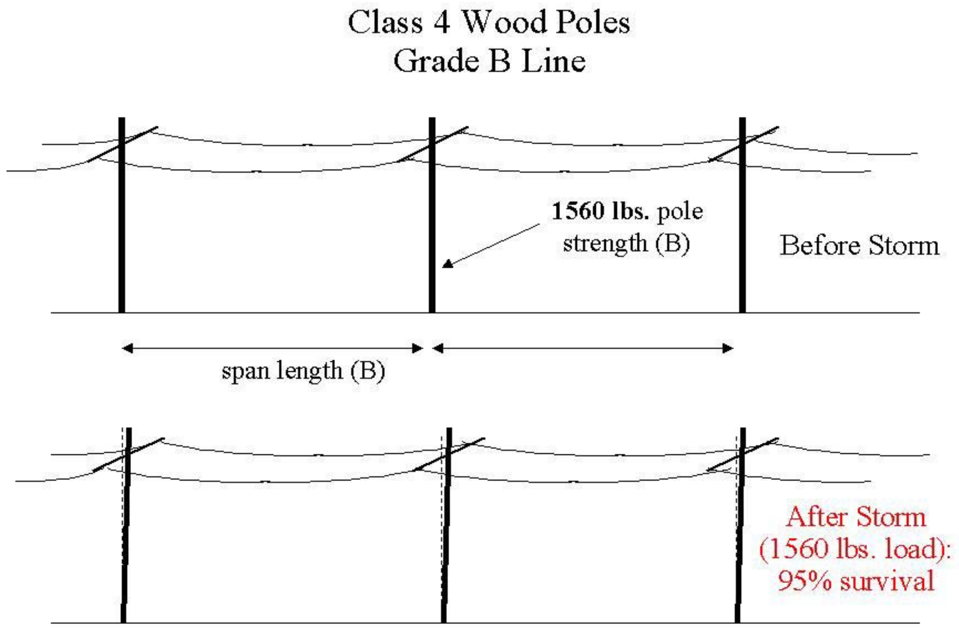

Figure 5a
Sample Utility Line for Grade B Construction, Short Span Length
(Class 4 Wood Pole and "Equivalent" Engineered Pole)

3.2 NESC Overload Factors

In order to provide a more complete understanding of the application of the NESC for strength and loading, it is necessary to discuss the concept of "overload factors". The NESC requires overload factors to be applied to the storm loadings specified in Rule 250B for combined ice and wind. This rule defines storm loadings based upon the familiar Loading Districts map for the United States -- corresponding to ½-in. radial ice buildup (plus horizontal wind pressure) in the heavy district, ¼ -in. ice buildup in the medium district, and no ice (but significantly greater wind pressure) in the "light" district. Since it is recognized that these specified loads significantly underestimate the severity of storms that may be experienced over the life of the utility lines -- e.g., during a 50-year period -- the calculated loads must be amplified or multiplied by an appropriate overload factor. Thus, the overload factors are used to simulate the effect of a more severe storm than otherwise indicated in a given storm map. (Rule 250C, for extreme wind, although not applicable to structures less than 60 ft. tall, is based upon very severe wind loadings and is generally not required to be further increased by an overload factor; equivalently, the corresponding overload factor is equal to 1.0.)

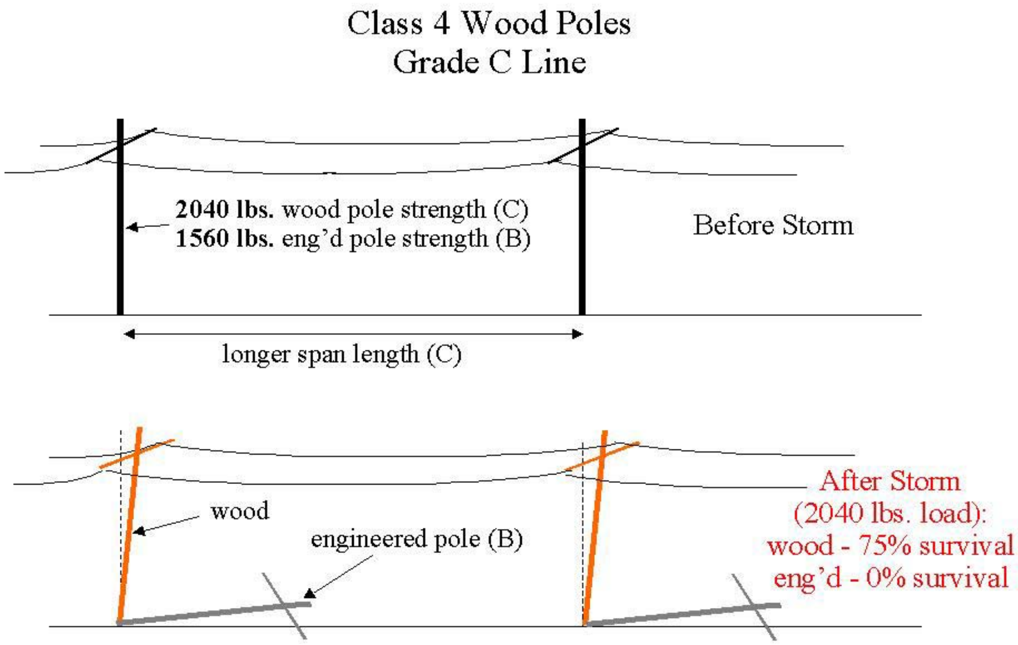

Figure 5b
Sample Utility Line for Grade C Construction, Longer Span Length
(Class 4 Wood Pole and Engineered Pole Meeting Grade B Strength)

The following formula defines the use of the overload factors in combination with the strength factors described in the previous section:

pole strength x **strength factor** ≥ calculated storm load x **overload factor**

This formula simply states that the reduced or minimum strength of the pole (as described above) must be at least as large as the amplified storm loads, as calculated from the specified storm loading map. The overload factor represents a "safety factor" applied to the storms loads, similar to as the strength factor represents a "safety factor" applied to the material or product strength.

Table 3 reproduces the applicable Table 253-1 of the NESC. The highlighted items refer to those that represent primary design considerations for a distribution structure -- i.e., transverse wind due to combined ice and wind. The overload factor for Grade B construction is 2.50. The overload factor for Grade C construction is 1.75, and applies to typical distribution applications. The overload factor for the Grade B application corresponds to a very severe storm -- such as a 50-year event. The somewhat lower Grade C overload factor corresponds to a somewhat less severe, more frequently occurring storm event.

Table 3
(NESC Table 253-1)
Overload Factors for Structures, Crossarms,
Support Hardware, Guys, Foundations, and Anchors to Be Used
with the Strength Factors of NESC Table 261-1A

Overload Factors		
	Grade B	**Grade C**
Rule 250B Loads		
Vertical Loads [3]	1.50	1.90 [6]
Transverse Loads		
Wind	**2.50**	**[1.75]**
Wire Tension	1.65 [2]	1.30 [5]
Longitudinal Loads		
At Crossings		
In general	1.10	no requirement
At deadends	1.65 [2]	1.30 [5]
Elsewhere		
In general	1.10	no requirement
At deadends	1.65 [2]	1.30 [5]
Rule 250C Loads	1.00	1.00

The two factors -- the overload factor and the strength factor -- may be combined into a single net factor defined as the overload factor divided by the strength factor, as seen in the above rearranged formula:

$$\text{pole strength} \geq \text{calculated storm load} \times \frac{\textbf{overload factor}}{\textbf{strength factor}}$$

This net factor is essentially equal to the overall factor for wood as provided in the older NESC Table 253-2, retained from earlier editions. For example, for a Grade B wood structure, the overload factor for transverse wind for the Rule 250B ice and wind storm (2.50) divided by the wood strength factor of Table 2 (0.65) is equal to 2.50/0.65, or 3.85 -- approximately equal to the familiar 4.0 safety factor for such wood applications. For a Grade C wood structure, the net factor is equal to 1.75/0.85, or 2.06 -- again, approximately equal to the familiar 2.0 factor for Grade C wood applications. It is not an accident that these factors are essentially the same values as that obtained from application of the previous method. The individual overload and wood strength factors were selected as a means of transitioning to the more technically correct, reliability-based design concept which utilizes separate factors for strength and loading. Applying this procedure to steel, … with a nominal strength corresponding to the minimum capacity, a net factor of 2.50/1.0 = 2.50 results for Grade B applications, and 1.75/1.0 = 1.75 for Grade C.

Since the overload factors are used to magnify or amplify the calculated loads on the structure, this further reduces (in addition to the strength reduction factor) the amount of load that a given size pole is considered to be able to support, as based upon the particular storm loading map employed. The net overall reduced load that the structure is assumed to be able to support is obtained from the nominal pole strength divided by the net overall factor. Thus, for a Grade B construction, the allowable design or "**working load**" for a Class 4 wood pole is determined as 2400 lbs divided by 3.85 (or 4.0), corresponding to approximately 600 lbs. In other words, the wood pole is assumed to be able to withstand only 600 lbs. for Grade B construction, with loadings determined from the relatively moderate storms indicated on the basic combined ice and wind map (Loading Districts) of Figure 2. For Grade C construction, the Class 4 wood pole is assumed to be able to withstand approximately 1200 lbs. (2400/2.05), based upon the same basic storm map loadings.

For steel, … the corresponding allowable working loads for a pole matching the effective Class 4, Grade B wood strength of 1560 lbs., would be 1560/2.50 -- approximately equal to 600 lbs., similar to wood. If this engineered pole is employed for a Grade C application, then its allowable working load is only 1560/1.75, or less than 900 lbs., in comparison to the 1200 lbs. allowable working load for wood under the same circumstances (same storm event). Thus, the engineered pole is not considered capable of withstanding the same working load as the Class 4 wood pole for Grade C applications; i.e., it is not equivalent to the Class 4 wood pole. This situation would again result in the failure of most of the Grade B equivalent steel, … poles in a storm that the Grade C consistent wood poles would survive to a high degree (similar to Figures 5a and 5b).

As an example, consider a Grade B line of a particular span length, utilizing a Class 4 wood pole with the 600 lbs. (2400/3.85) allowable working load. This pole is considered to be a conservative design to safely withstand that level of loads (600 lbs.) as determined from the ice map of Figure 3, as well as the corresponding significantly increased loads that will occur much less frequently (e.g., 50 year storm event). Similarly, a steel pole with approximately the same 600 lbs. allowable working load (1560/2.50) would support the same span at the same high level of reliability. Now consider a 50% longer span corresponding to a calculated storm load of 900 lbs., but constructed at the Grade C level of reliability. The same steel pole with the 1560 lbs. nominal strength has sufficient working load capability for this application. However, the allowable working load for the Class 4 wood pole is now almost 1200 lbs., which is unnecessarily high for this span length and Grade C application. Thus, a smaller size wood pole is acceptable. In particular, a Class 5 wood pole with a nominal strength of 1900 lbs. corresponds to a working load (1900/2.06 = 920 lbs.) exceeding the required 900 lbs. storm loading for the postulated Grade C application. Thus, in this case, the 1560 lbs. nominal strength steel pole would be equivalent to only a Class 5 wood pole.

4 Summary

Although wood poles continue to be the primary choice for constructing the utility distribution plant, for both power and telecommunications, there are many applications for which alternate pole materials, typically engineered products (steel, concrete, fiber-reinforced composite, …), represent an optimum solution. The advantages of such materials, include environmental, light weight, appearance, … However, it is important to maintain the structural reliability of the non-wood poles relative to the existing wood poles, based upon the rules of the National Electrical Safety Code (NESC).

The NESC strength and loading rules are specified as a function of "grade of construction" (i.e., reliability level), which will determine the appropriate size (strength) pole to withstand wind and ice storms, to meet the basic safety requirements. Grade B is the highest grade of constriction, for high reliability applications, while Grade C applies to most power distribution and joint use (power and telecommunications) applications, representing a somewhat lower grade of construction. Most distribution lines are built to Grade C standards.

Wood poles are classified by pole class (Class 1, Class 2, …) that defines the size and strength of the pole. The different grades of construction will require a different capacity or strength and therefore a different class pole. Since the utilities have experience and familiarity with the wood pole classification system, it is convenient for steel, concrete, … poles to be classified similarly, to facilitate their selection and use by the utility. However, due to the inherently different characteristics (statistical distributions, …) of naturally grown wood and engineered pole structures (steel, …), the equivalency of a given steel pole size/strength (pole class number) for a Grade B construction application will, in general, not be the same for a Grade C construction application.

The NESC provides de-rating or "strength (reduction) factors" for various materials as applied to NESC Rule 250B (combined ice and wind), applicable to all structures, based upon industry-specified specifications and characteristic product variability. There are two distinct strength reduction factors relevant to wood poles: 0.65 and 0.85, for Grade B and Grade C construction, respectively. These quantitative factors are based upon successful experience within the utility industry. The effective (assumed) strength of the wood pole is obtained by multiplying the appropriate strength factor by the industry-specified (ANSI-O5.1) nominal wood strength. For a Class 4 wood pole of 2400 lbs nominal (average) strength, the effective strengths are calculated as 0.65 x 2400 lbs = **1560 lbs.** for **Grade B** construction and 0.85 x 2400 lbs = **2040 lbs.** for **Grade C** construction.

The NESC requires a metal (steel, …) pole to have a "minimum"strength of approximately 1560 lbs, equivalent to the minimum strength of that of a wood pole for Grade B construction. Thus, if a storm loading of this intensity is applied to a utility lines (conductors, equipment, pole, …) supported by either the Class 4 wood or "equivalent" non-wood pole, there is a high reliability of survival -- i.e., the vast majority (e.g., typically 95%) of the poles would withstand the 1560 lbs. storm loading without breakage. However, for Grade C construction, the NESC recognizes that a somewhat lower reliability may be acceptable and therefore allows the wood pole to be used in a less conservative manner, taking advantage of the inherent reserve strength in this material of wide variability. For Grade C construction, the NESC specifies an allowable strength of 2040 lbs. for the Class 4 wood pole. The large majority of wood poles (e.g., 75 – 80%) will withstand this load, providing an acceptable level of reliability, albeit somewhat less than for the "more important" Grade B application. In order for the non-wood pole to survive the same storm loading (2040 lbs.), at the same rate of survival, a likewise large majority of such poles must withstand this load. However, due to the low variability of the engineered product, essentially every metal pole of 1560 lbs. capacity would fail. A significantly stronger non-wood pole, with a high survivability rate at the 2040 lbs. level, would be required.

The NESC also specifies "overload factors" to be applied to the storm loadings of Rule 250B for combined ice and wind. Since it is recognized that the Rule 250B loads significantly underestimate the severity of ice storms that may be experienced over the life of the utility lines, the calculated loads must be amplified or multiplied by the appropriate overload factor. The two factors -- the overload factor and the strength factor -- may be combined into a single net factor defined as the overload factor divided by the strength factor. For a wood structure, for transverse wind under Rule 250B for the combined ice and wind storm, the net factor is 3.85 or 2.06, for Grade B and Grade C construction, respectively. These values are approximately equal to the more familiar 4.0 and 2.0 factors for Grade B and C wood applications as determined by the older NESC method.

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