NORTH AMERICAN WOOD POLE COUNCIL

No. 19-D-204

TECHNICAL BULLETIN

Unique Overload Capacity of Wood Poles

Prepared by:

H. Martin Rollins, P.E.
H.M. Rollins Company, Inc.

About NAWPC

The North American Wood Pole Council (NAWPC) is a federation of three organizations representing the wood preserving industry in the U.S. and Canada. These organizations provide a variety of services to support the use of preservative-treated wood poles to carry power and communications to consumers.

The three organization are:

Western Wood Preservers Institute
With headquarters in Vancouver, Wash., WWPI is a non-profit trade association founded in 1947. WWPI serves the interests of the preserved wood industry in the 16 western states, Alberta, British Columbia and Mexico so that renewable resources exposed to the elements can maintain favorable use in aquatic, building, commercial and utility applications. WWPI works with federal, state and local agencies, as well as designers, contractors, utilities and other users over the entire preserved wood life cycle, ensuring that these products are used in a safe, responsible and environmentally friendly manner.

Southern Pressure Treaters' Association
SPTA was chartered in New Orleans in 1954 and its members supply vital wood components for America's infrastructure. These include pressure-treated wood poles and wood crossarms, and pressure-treated timber piles, which continue to be the mainstay of foundation systems for manufacturing plants, airports, commercial buildings, processing facilities, homes, piers, wharfs, bulkheads or simple boat docks. The membership of SPTA is composed of producers of industrial treated wood products, suppliers of AWPA-approved industrial preservatives and preservative components, distributors, engineers, manufacturers, academia, inspection agencies and producers of untreated wood products.

Wood Preservation Canada
WPC is the industry association that represents the treated wood industry in Canada. WPC operates under Federal Charter and serves as a forum for those concerned with all phases of the pressure-treated wood industry, including research, production, handling, use and the environment. WPC is dedicated to promoting and supporting a stronger Canadian wood treating industry; informing the public on the benefits to be gained from the use of quality wood products; and preserving the integrity of the environment through the promotion of responsible stewardship of our resources.

Unique Overload Capacity of Wood Utility Poles

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Introduction

Today, the words “reliability,” “resilience” and “hardening” are often heard in the context of electric power transmission and distribution systems. Some of these terms, such as reliability, may have different meanings to different groups.

A utility may view reliability in the context of their requirement to track and report reliability metrics in terms of the frequency and duration of outages. But a residential utility customer may associate reliability with the long-term outages caused by extreme weather events.

The public has raised their concerns with the length of time that it has taken to restore power after these storm events. To address these customer concerns, public utility regulatory bodies in many states have required studies to be performed concerning the “hardening” of the electrical distribution system.

In some cases the lines serving critical infrastructure have been hardened by increasing the design loads and improving right-of-way clearances by requiring tree trimming at a set frequency. In other cases, utilities have opted to use non-wood poles for these hardened lines. This is based on the incorrect belief that non-wood poles are somehow superior to wood poles.

In fact, wood poles have a much greater overload capacity than poles manufactured from alternate materials, and therefore will exhibit a much higher reliability in extreme weather events.

Pole Loading

The National Electrical Safety Code (NESC) provides minimum safety loads for a variety of loading conditions. The NESC has requirements for:

- District Loads in Rule 250B, which include combinations of ice and wind loads to which load factors are applied;.
- Extreme Wind Loads in Rule 250C; and
- Extreme Ice and Concurrent Wind Loads in Rule 250D.

The most severe loading condition applies at a particular geographic location. The NESC does not require the designs for structures less than 60 feet in height to consider either the Rule 250 C Extreme Wind or the Rule 250D Extreme Ice and Concurrent Wind loads.

The reason for this is that the very long history of observations of the results of extreme weather events has shown that most damage to distribution structures is associated with secondary damage effects. There is significant debate on this issue, but the NESC itself provides some basis to support the belief that secondary damage effects are the cause of the catastrophic damage often associated with extreme weather events.

First, it should be understood that wholesale failures of the overhead line system will not occur unless the line components experience actual loads that are higher than the design loads. The net effect of the application of load factors and strength factors in the NESC provides for a “safe” design such that mass failures should not occur in the system under the specified loads.

Some involved in the debate concerning the application of the extreme load cases in Rules 250C and 250D to shorter structures have suggested that the old District Loading criteria in Rule 250B should be removed from the NESC. They contend the criteria are antiquated and are not a true application of Load and Resistance Factor Design (LRFD) principles.

It must be understood that for most of the country the Rule 250B effective loads of combined ice and wind exceed the Rule 250D Extreme Ice and Concurrent Wind loads.

So, if the present exclusion from the consideration of Rule 250D loads for structures 60 feet or less in height was removed, and the District Load case of Rule 250B was removed, the combined ice and wind loading criteria of structures 60 feet or less in height would actually be reduced at most locations.

Obviously, lowering the required design load would not improve system performance. This does prove, however, that not requiring the application of Rule 250D loads to structures 60 feet and less in height is not responsible for the fact that massive failures do sometimes occur during ice storms that do not exceed the Rule 250B and Rule 250D weather conditions.

Even though distribution systems are generally designed to combined ice and wind loads higher than the extreme ice and wind loads of Rule 250D, widespread failures still occur in ice storm conditions due to secondary damage effects.

Most involved in the 60-foot exclusion debate appear to be willing to acknowledge that secondary damage effects are the primary cause of failures in ice storm situations. But they fail to acknowledge the same primary cause in distribution system failures during coastal extreme weather events such as hurricanes.

It is more difficult to directly observe the secondary damage effects in hurricanes because it is unsafe for personnel to be outside and patrolling the system during the height of the storm. Knowledgeable and experienced utility personnel have continued to state that secondary damage is the primary cause of failures during hurricane events.

Given that distribution systems experience failures in ice storms, in spite of the fact the systems are typically designed for loads higher than the Extreme Ice and Concurrent Wind loads of Rule 250D, it becomes questionable whether simply designing distribution systems to extreme wind loads in coastal areas would significantly change the outcome.

Certainly, any potential benefit to be gained by increasing design loads is unquantifiable. Perhaps the financial resources would be better spent on improving right-of-way clearance and thereby reducing the likelihood of secondary damage.

This discussion is presented to illustrate that electric distribution systems sometimes experience catastrophic damage when the observed weather conditions are not more severe than those for which the lines were designed. It should be clear that for widespread failures to occur, the actual loads experienced by the system components were higher than the design load.

The loads that cause these failures cannot be reliably quantified, but there is no doubt that they occur. Engineers need to consider the fact that loads exceeding the design load are likely to occur and they need to consider how the installed system will respond to these overload conditions.

That leads to the primary focus of this paper, the extraordinary and unique overload capacity of wood poles.

Reliability in Overload Situations

Today's engineering graduates are taught very little about wood design in school. The educational focus at engineering schools is on manufactured products engineered in their design to perform a certain function and exhibit a specific strength.

If good manufacturing process controls are in place, a utility pole made of steel, pre-stressed concrete or fiberglass can be designed and manufactured to a specific Lower Exclusion Limit (LEL) strength with little variance in strength from piece to piece.

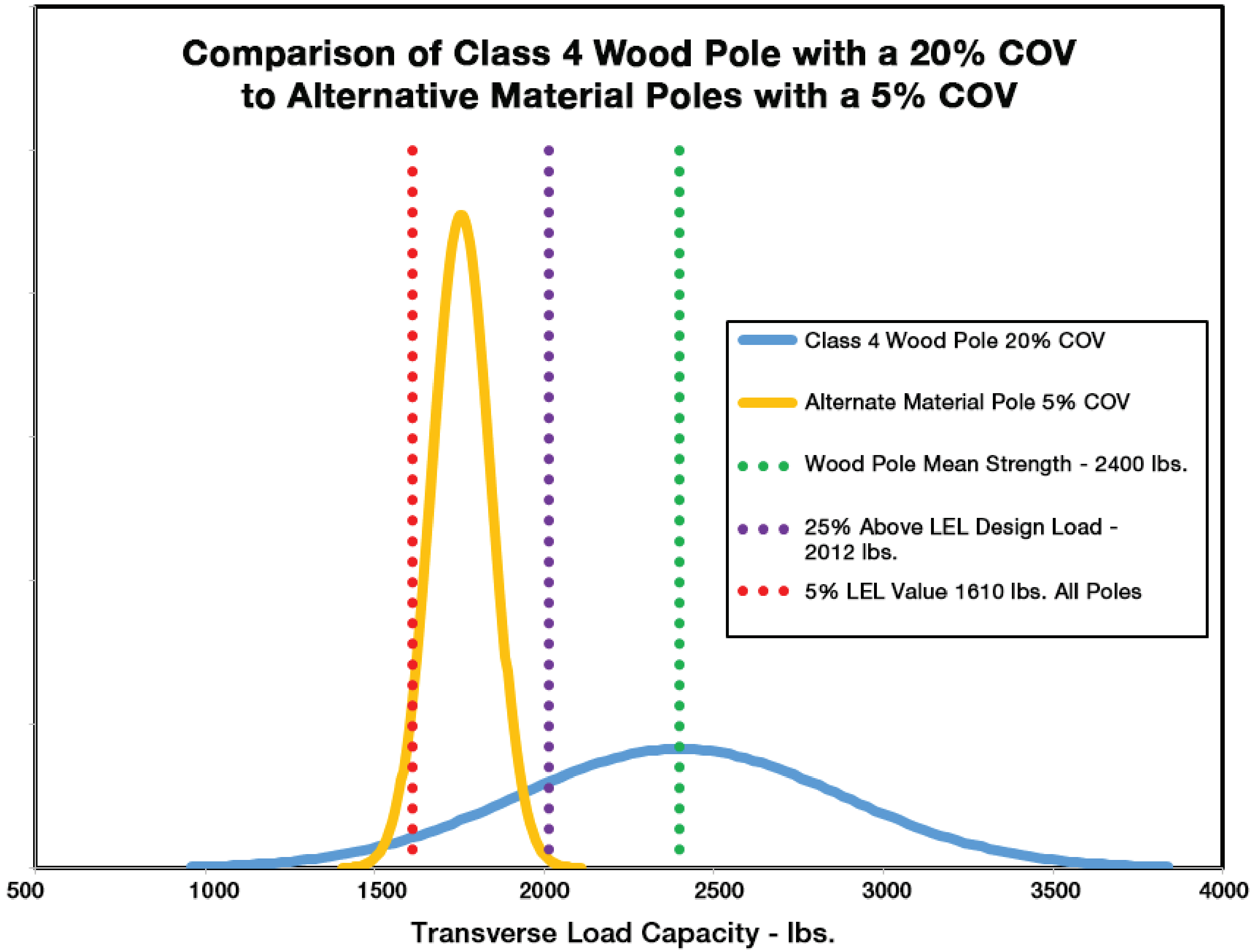

Figure 1

For engineered products, the LEL strength is typically 5%, meaning it is expected that 95% of a population of these products will exceed the specified strength. Engineers today employing Load and Resistance Factor Design (LRFD) want to design all materials to the same 5% LEL design point and assume that those designs are essentially equivalent.

That assumption is reasonably correct, if all of the materials under consideration have similar coefficients of variation (COV) in their strengths. But it is not correct when comparing materials or products that have a significantly different COV.

In the case of utility poles, for instance, steel, pre-stressed concrete, or composite poles are expected to have low COVs, in the 5% range. However, because of natural variations, wood poles are expected to have a COV in the 20% range.

If poles of all of these materials are designed to the same load at the 5% LEL strength value of the poles, wood poles will have substantially higher reliability when exposed to expected weather loads.

This concept was fully investigated and presented in ASCE Manual of Practice No. 111, ***Reliability-Based Design of Utility Pole Structures***.

Figure 1 shows the expected strength distributions of an engineered pole with a COV of 5% vs. the strength distribution of a wood pole having a COV of 20%. Both distributions have the same 5% LEL strength.

In this case, the wood pole shown is a Class 4 pole, which has a mean transverse strength of 2,400 lbs. applied 2 feet from the tip, and a 5% LEL strength of 1,610 lbs.

The 5% LEL design would be how today's engineer would want to design for "equivalent" design. This also closely represents the design equivalency in Grade B of the NESC, which applies a strength factor to wood of 65%, close to the 67.1% that would be computed as the 5% LEL for a material whose published strength is a mean strength with a COV of 20%.

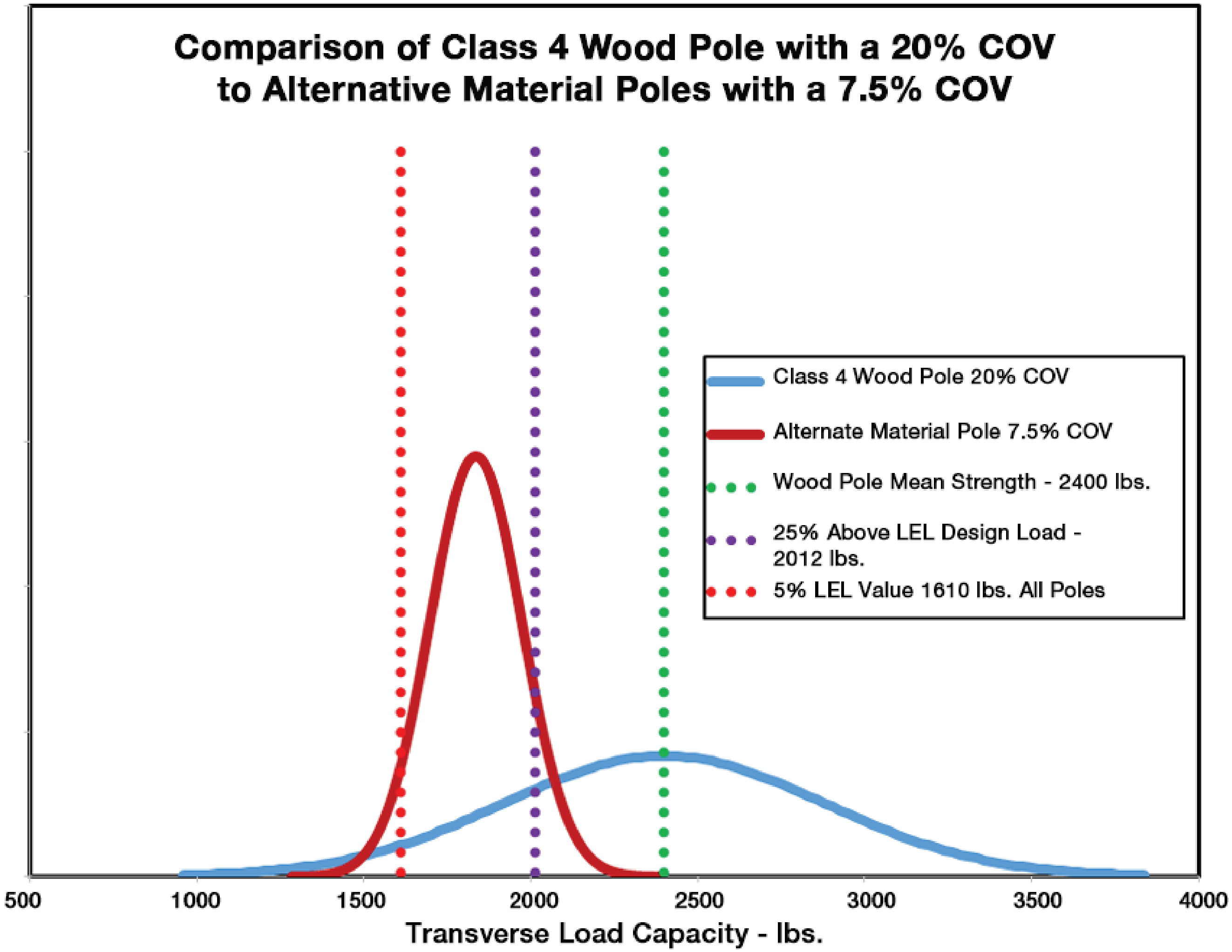

Figure 2

It should be obvious from observing Figure 1 that alternate material poles are somewhat less likely to fail than the wood pole at loads below the 5% LEL value. However, it should be even more evident that at loads above the 5% LEL strength, the wood pole is far less likely to fail than the alternate material pole.

There is a vertical line on Figure 1 at a point 25% above the 5% LEL strength, or 2,012 lbs. of load. This shows that virtually all of the alternate material poles would be expected to fail at this load, while most of the wood poles easily carry this load.

Performing the statistical calculations provides an expected failure rate at this load of 99.8% for the alternate material pole and only 20.9% for the wood pole. So, an overload of 25%, whether caused by secondary damage effects or by an actual weather load, will destroy virtually 100% of the structures manufactured with a COV of 5%.

The design of utility structures should consider the probability of an overload. It is not like designing a bridge where the maximum load is well defined and limited by highway vehicle weight limitations.

Figure 2 provides the same comparisons for an alternate material pole having a COV of 7.5%. In this instance, the predicted failure rate of the alternate material pole at a load that is 25% above the 5% LEL value is 90%. Most of the wood poles will survive an overload that destroys all of the 7.5% COV alternate material poles.

Some utilities are adopting NESC Grade B loading for lines serving critical infrastructure as a "hardening" activity. Others are changing from wood to alternate material poles on these "hardened" lines.

However, it should be clear that moving to non-wood poles is a mistake. The failures they are trying to prevent are not failures that occur at or below the design loads. Instead, they are trying to prevent those failures that cause severe long-term outages following ice storms or hurricanes, and those failures occur because some system components experienced loads substantially above their design loads.

In those situations, wood poles are the far superior choice because of their unique overload capacity.

Summary

Damage to the overhead electrical distribution system in extreme weather events such as ice storms, hurricanes or tornados is both undesirable and unpopular for both utilities and their customers. However, absent the ability of a utility company to clear all vegetation within striking distance of the line, future outages will continue to occur.

In areas prone to ice storms, lines typically are already being designed to loads above the Extreme Ice and Concurrent Wind loads in Rule 250D of the NESC. In these cases, secondary damage effects are creating loads substantially higher than the design loads.

Few are calling for "hardening" of lines in areas subject to ice storms, as it is acknowledged there may be little improvement in system performance. History supports a similar logic in coastal areas subject to hurricanes. But political pressure is forcing utilities to consider "hardening" some or all of their lines in hurricane-prone areas.

Widespread failure is not going to occur unless the actual load exceeds the design load. Overload condition can be caused by secondary damage effects such as fallen trees or windblown debris or it can be an actual weather event more intense than expected. In either instance, it does not matter.

With the understanding that failures occur due to overloads and that overload conditions will occur, it becomes very important to understand the capabilities of individual system components to withstand that overload. As noted above, wood utility poles have far superior overload capacity when compared to alternate materials.

For overall reliability, wood should be the material of choice in areas subject to extreme weather events. If utilities are going to harden their systems, the use of wood poles designed to the higher loads – rather than alternate material poles – will result in a more reliable system due to the greater inherent overload capacity of wood poles.

North American Wood Pole Council

NAWPC 19-D-204
10-2019