Synergy and Diffusion with a Borax–Copper Hydroxide Groundline Preservative: 20 Year Update

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ABSTRACT

A groundline remedial treatment containing 3.1% copper hydroxide (2% elemental copper) and 40% sodium tetraborate decahydrate (borax) was applied to unseasoned pine posts prior to placement in a test site in southern Mississippi. The soundness of the posts was periodically evaluated using a push test. After 3.5, 6.5, 10, 15 and 20 years, sections were taken from two posts to determine retention of borax and copper hydroxide as a function of vertical position above ground and distance from the wood surface. Within 3.5 years of exposure all untreated control posts had failed. The upper portion of the treated posts became severely decayed after 6.5 – 10 years, but assay sections removed from posts were sound for 15 years. After 20 years one post remained sound through-out the assay area, while the other post was exhibiting some decay at groundline and above. Borax retentions were greatest in the above-ground sampling zones, and generally declined over time. The overall overage borax retention in the assay zones was 21.3, 15.0, 9.7, 11.5 and 1.6 kg/m^3 (1.33, 0.93, 0.60, 0.72 and 0.10 lb/ft^3) after 3.5, 6.5, 10, 15 and 20 years, respectively. Copper hydroxide retentions were less affected by vertical position in the post, and remained more stable over time. Although copper retentions were greatest in the outer assay zone, copper was also detected in the inner assay zones. The overall average copper hydroxide retention across all assay zones was 3.0, 3.5, 2.9, 2.5 and 2.9 kg/m^3 (0.19, 0.22, 0.18, 0.16 and 0.18 lb/ft^3) after 3.5, 6.5,10, 15 and 20 years, respectively. Although retentions varied among posts, after 20 years above-ground borax retentions were still above the threshold needed for protection, while copper remained above the protection threshold in the groundline and below ground areas.

Keywords: posts, groundline treatment, borax copper hydroxide, permanence, diffusion

INTRODUCTION

Exterior groundline preservative treatments are often applied to utility poles to supplement the initial pressure treatment and prevent surface decay (DeGroot, 1981; Freeman, 2007). They are also intended to protect untreated sapwood and heartwood in poles that fail to meet the original pressure treatment penetration specifications. These treatments may also be applied to other types of vertical supports, such as building poles and posts. Although application techniques vary, typically soil is excavated from around the pole to a depth of approximately 0.46 m (18 in.) and the formulation is brushed or troweled onto the exposed wood to form a thick layer that extends 51 – 76 mm (2 – 3 in.) above the ground line. The layer of preservative is then covered with a water-impervious wrap to hold the chemical against the wood, and the excavated area is refilled.

Evaluation of the efficacy of groundline remedial treatments is challenging because they are applied to poles in a range of conditions and with varying types and contents of residual pressure treatment. Perhaps the simplest approach is to evaluate the remedial treatments on untreated posts (Abbott et al., 2001; Amburgey and Freeman, 1993; DeGroot, 1981; Morrell et al., 1994). In one of the earliest studies of this type, established in 1957, the Forest Products Laboratory (FPL) compared the ability of remedial preservatives to protect unseasoned pine posts exposed at the Harrison Experimental Forest near Saucier, Mississippi (DeGroot, 1981). That trial led to commercial products that have performed well in service. However, use of untreated posts does not account for the potential effects of the original pressure treatment on the remedial treatments penetration or efficacy. Other studies have attempted to evaluate groundline remedial treatments under more representative conditions by treating in-service utility poles that had been initially treated with oil-type preservatives (Morrell, et al., 2013).

A variety of preservative have been used in groundline remedial treatments. Some products contained only one active ingredient (i.e. pentachlorophenol, copper naphthenate or sodium fluoride) while others contain multiple components (Freeman, 2007). Although creosote, pentachlorophenol were once components of several formulations, these actives have been phased-out of products used in North America. Groundline treatments may be most effective if they are mobile enough to penetrate into the wood and yet sufficiently leach resistant to provide long-term protection. One approach to achieving both diffusion and permanence is to use a formulation that contains one active ingredient that "fixes" in the wood and another that diffuses. The diffusible component moves with the water in the pole and may penetrate deeply into the sapwood. In most groundline treatments the less mobile active is copper, typically applied in the form of copper hydroxide, copper naphthenate or copper-8-quinolinolate. The diffusible component is typically some form of boron, although fluoride was used in previous formulations. Other components such as azoles and insecticides may also be incorporated into these groundline treatments.

This paper reports on a study conducted with a remedial treatment formulation containing borax and copper hydroxide complexed with ethanolamine. A paste was applied to unseasoned and otherwise untreated southern pine posts which were then installed in FPL's test site near Saucier, MS. The retention and diffusion of copper and borax in the posts after 3.5, 6.5 and 10 years of exposure were reported previously (Abbott et al., 2001; Crawford et al., 2005). Here we provide additional results after 15 and 20 years of exposure.

MATERIALS AND METHODS

The remedial preservative evaluated in this study contained 3.1% copper hydroxide (2% elemental copper) and 40% sodium tetraborate decahydrate as active ingredients. The inert ingredients were ethanolamine, water, and thickeners. Borax is a well-known diffusible preservative, and ethanolamine complexes of copper have become familiar fixed active ingredients in wood preservatives. Use of borax with ethanolamine–copper buffers the alkalinity of the amine and facilitates production and sale of the formulation as a remedial preservative. The test method was similar to that reported previously (Degroot 1981). The posts were cut and peeled within 1 week prior to treatment and installation. Average circumference of the posts was 48 cm (18.9 in.) at the base. A 0.6-cm (0.25-in.) layer of borax–copper hydroxide paste was applied to a vinyl sheet 46 cm (18 in.) long and equal in circumference to the base of the post. This "bandage" was tightly pressed around the base of the post. In June 1993, shortly after treatment, the posts were installed in 41-cm- (16-in.-) deep post holes.

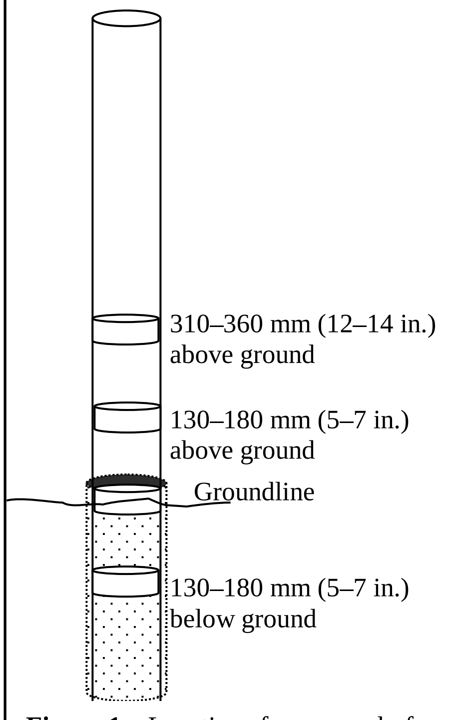

Figure 1—Locations for removal of cross-sections**.**

Each year for the first 5 years the posts were given a push test and the results recorded. Subsequent durability evaluations were made at 2 or 3 year intervals. After 3.5, 6.5, 10, 15 and 20 years, two posts were removed for analysis. Cross sections were cut from the following locations on the posts: 130 to 180 mm (5 to 7 in.) below ground; 25 mm (1 in.) below ground to 25 mm (1 in.) above ground; 130 to 180 mm (5 to 7 in.) above ground; and 310 to 360 mm (12 to 14 in.) above ground (Figure 1). The sections were cut into three assay zones relative to the post surface: outer (0–13 mm (0–0.5 in.)), middle (13–25 mm (0.5–1.0 in.)), and inner (25–50 mm (1.0–2.0 in.)). These assay samples were dried ground, mixed, and assayed for copper and boron. The percentages of borax and copper hydroxide were calculated and converted to a weight per unit volume basis using AWPA Standard A12–03 density for southern yellow pine of 512 kg/m^3 (32 lb/ft^3) (AWPA 2013).

RESULTS AND DISCUSSION

All untreated controls had failed within 3.5 years of exposure. Within 6.5 years, the tops of groundline-treated posts were also essentially destroyed by decay. Some decay had extended 450 to 600 mm (18 to 24 in.) down the posts but had remained well above the treated zone. For up to 15 years, there was no visible evidence of termite attack or decay where the assay cross sections were cut from the treated posts (up to 360 mm above the groundline). After 20 years one of the posts removed had substantial decay 130 mm above ground and a small decay pocket in the groundline and below ground areas. In general, the groundline treatment provided excellent protection to the groundline area of these posts despite the lack of initial pressure treatment and their exposure in a site with severe exposure hazard.

Results for average copper hydroxide and borax concentrations in the sampled sections are shown in Figures 2 and 3. Although the variability between replicates makes it difficult to form definitive conclusions, some trends are apparent. The greatest borax retentions were generally in the cross section removed 130 to 180 mm (5 to 7 in.) above ground, regardless of assay zone (Figure 2). Substantial diffusion of boron occurred, with the average retention in the middle assay zone typically only slightly lower that in the outer assay zone. Boron concentrations were typically highest after 3.5 years and decreased over time, although in two cases boron concentrations were greater at 15 than 10 years. With only two replicate posts removed at each time point, results are sensitive to concentration differences between posts. Although boron concentrations were initially highest in outer assay zone, after 20 years boron concentrations were sometimes greatest in inner assay zone. This trend is likely a result of greater boron depletion from the outer assay zone. The overall overage borax retention in the assay zones was 21.3, 15.0, 9.7, 11.5 and 1.6 kg/m^3 (1.33, 0.93, 0.60, 0.72 and 0.10 lb/ft^3) after 3.5, 6.5, 10, 15 and 20 years, respectively.

For the first 15 years of exposure, concentrations of borax detected in the posts generally exceeded published threshold values for inhibiting attack by decay fungi and termites. Fahlstrom (1964) evaluated the toxicity of borax to five decay fungi and reported toxic thresholds ranging from 0.8 to 2.9 kg/m^3 (0.05 to 0.18 lb/ft^3). There have been numerous other reports on the concentration of boron needed to prevent colonization by decay fungi, as summarized in an article by Freitag and Morrell (2005). Depending on the fungus evaluated and the methodology used, threshold concentrations have been reported to vary from as low as 0.4 kg/m^3 (0.02 lb/ft^3) to as high as 7.1 kg/m^3 (0.45 lb/ft^3) when expressed on a borax basis. In their article, which reported on a method intended to simulate wood used above ground, Freitag and Morrell concluded that the threshold retention was in the range of 0.6 to 0.7 kg/m^3 (approximately 0.04 lb/ft^3) when expressed on a borax basis. Published values of the concentration of boron needed to prevent termite attack also vary. Researchers have reported effective borate concentrations (when expressed as borax) ranging from below 2.0 to over 19.2 kg/m^3 (0.12 to 1.20 lb/ft^3) (Drysdale, 1994; Freeman, et al., 2009; Peters and Fitzgerald 2006), with most laboratory studies indicating efficacy at retentions of around 3.8 kg/m^3 (0.24 lb/ft^3). In some cases, and particularly after 15 and 20 years of exposure, borax concentrations in samples removed at and below groundline had fallen below reported threshold values for preventing decay or termite attack (Figure 2). However, these areas remained sound, probably as a result of copper hydroxide remaining in the wood.

Trends in copper hydroxide retention differed from those of borax. The effect of vertical sampling location appeared to depend on assay zone, with higher retentions occurring above ground in the outer (0–13 mm, 0–0.5 in.) assay zone and higher retentions occurring below ground in the inner assay zones (Figure. 3). Substantial upward movement of copper was observed. Inward movement of copper hydroxide was more limited than that of borax, but did occur. Not surprisingly, copper also appeared to be more permanent than boron. Average copper hydroxide retention across all assay zones was 3.0, 3.5, 2.9, 2.5 and 2.9 kg/m^3 (0.19, 0.22, 0.18, 0.16 and 0.18 lb/ft^3) after 3.5, 6.5,10, 15 and 20 years, respectively. In other research on the efficacy of groundline treatments, the efficacy threshold for copper has been identified as approximately 0.6 kg/m^3 (0.04 lb/ft^3) (Morrell, et al., 2010) which equates to 0.9 kg/m^3 (0.06 lb/ft^3) when expressed as copper hydroxide. In this study, copper hydroxide concentrations detected in the outer assay zone were well above this threshold, and concentrations in the middle and inner assay zones often exceed this threshold as well (Figure 3). The high copper hydroxide concentrations noted in the outer assay zone at and below the groundline appears to compensate well for the relatively low boron concentrations in those areas.

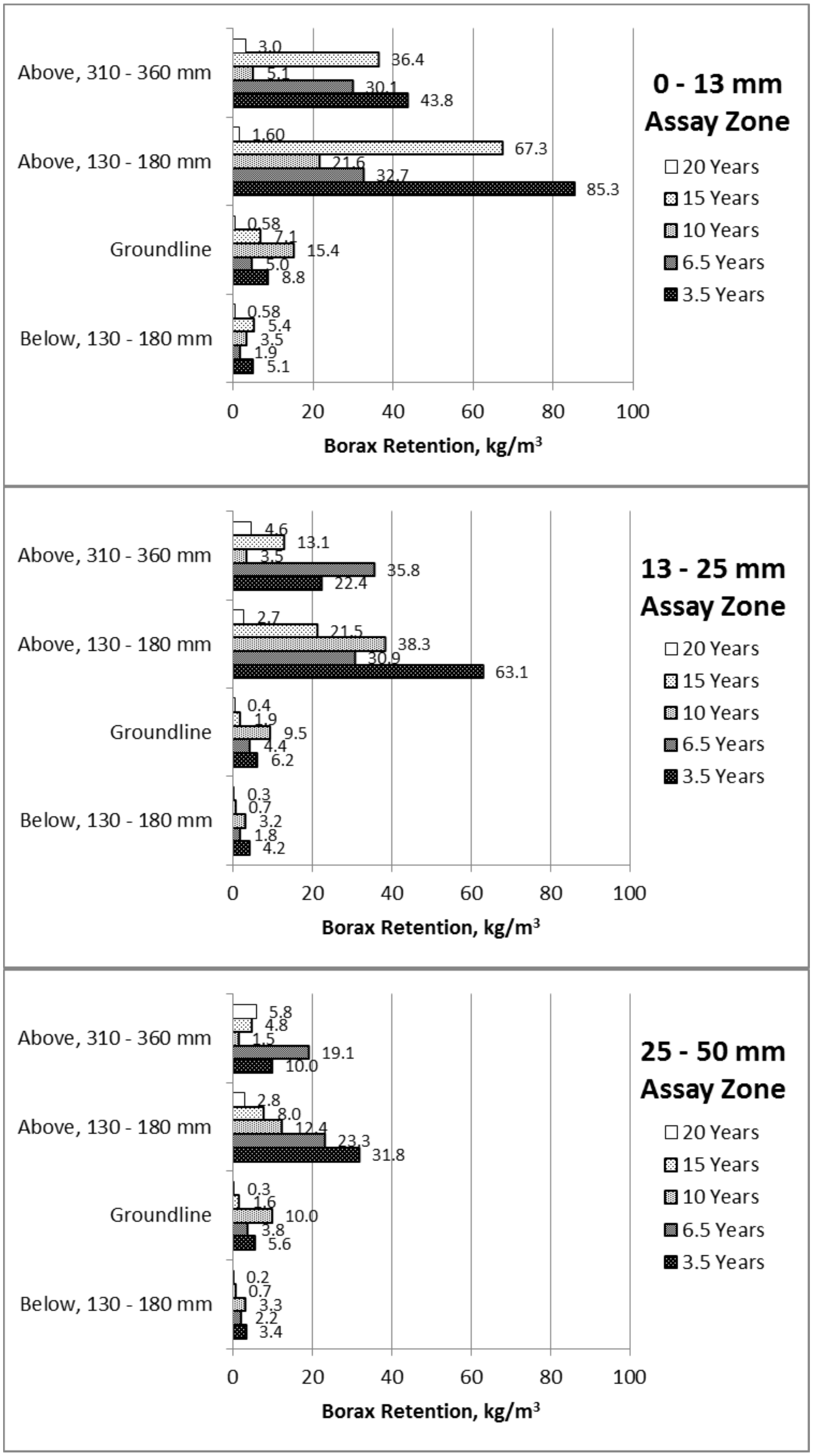

Figure 2. Borax retentions by assay zone, vertical position, and years in test. Each value is the average of two posts, except for 310 – 360 mm above ground at 20 years. That value is for a single post.

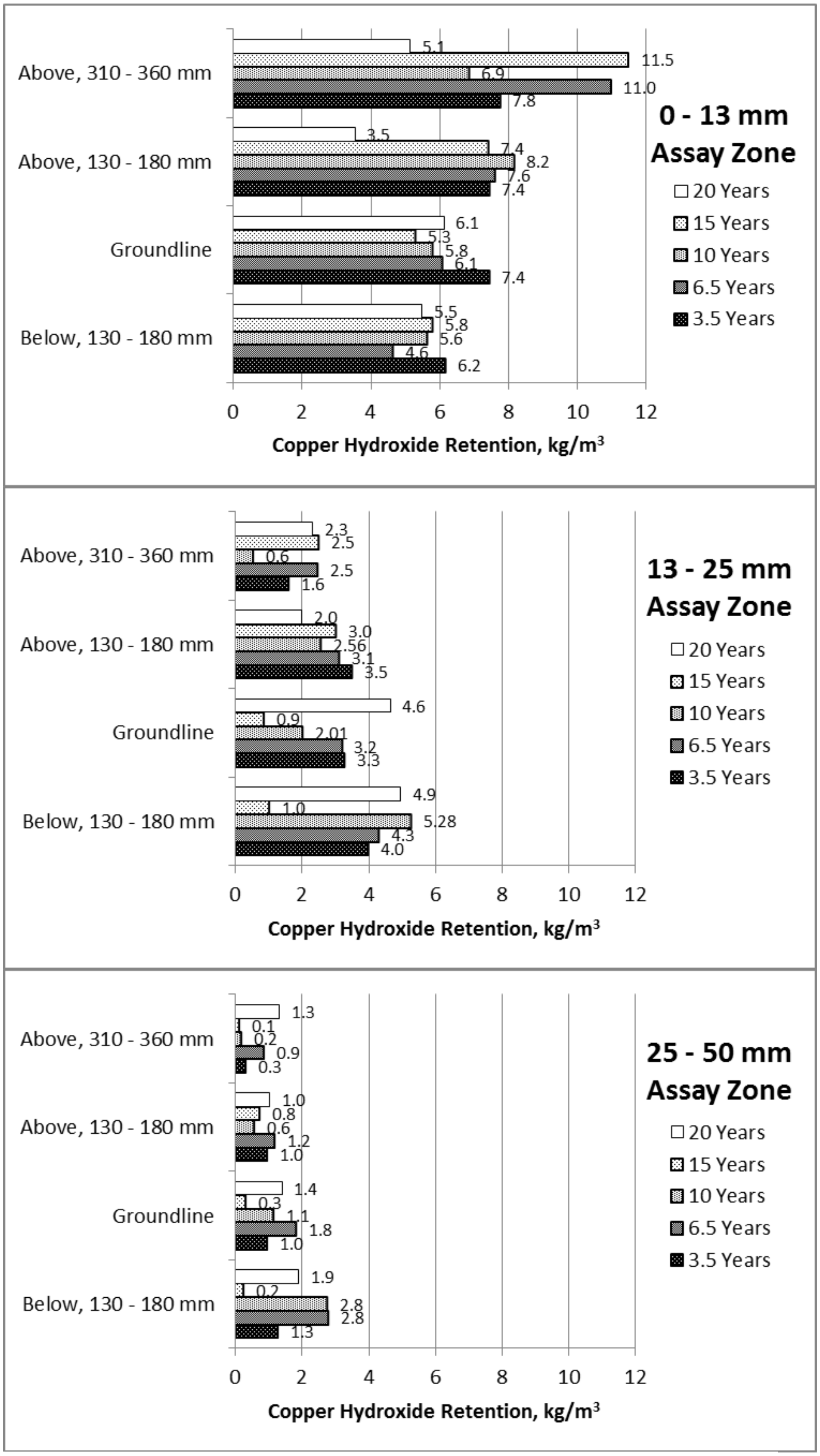

Figure 3. Copper hydroxide retentions by assay zone, vertical position, and years in test. Each value is the average of two posts, except for 310 – 360 mm above ground at 20 years. That value is for a single post.

The boron and copper concentrations noted in this study tend to be greater than those noted in two subsequent studies with the same formulation (Morrell et al., 2010; Morrell et al., 2013). In a study conducted in Georgia, the preservative paste was applied to in-service southern pine utility poles that had initially been pressure-treated with an oil-type preservative, and previously remedially treated with a creosote/fluoride groundline paste (Morrell, et al., 2010). After 1, 2, 3 and 5 years assay samples were removed at depth of 150 mm (6 in.) below the groundline and distances of 0-13, 13-25 and 25-50 mm from the wood surface. Boron concentrations were greatest after the first year, at which time they were similar to those noted in the current study after 3.5 years. However, in subsequent years the boron concentrations noted by Morrell et al. (2010) declined below those noted in the current study. Although copper concentrations reported by Morrell et al. (2010) increased during the course of the study, they were generally less than half of those found in the current study. The lower concentrations found by Morrell et al. (2010) may be a result of application of a thinner layer of the preservative paste. In that study paste thickness was limited to 1.6 mm to provide uniformity between preservatives evaluated, while in the current study the paste was applied to 6 mm thickness. It is also possible that the oil-based pressure treatment and previous applications of a creosote paste interfered with diffusion of boron into the poles evaluated by Morrell et al. (2010) relative to the untreated posts evaluated in the current study.

In a subsequent Arizona study the preservative paste was applied to Douglas-fir, western redcedar or western pine poles that had initially been treated with creosote or pentachlorophenol (Morrell et al., 2013). After 17 months, assay samples were removed from the poles at a depth of 150 mm (6 in.) below the groundline, and distances of 0-13, 13-25 and 25-50 mm from the wood surface. When expressed on the basis of southern pine density (512 kg/m^3), borax retentions varied from 4.1 - 8.1 kg/m^3 (0.26 – 0.51 lb/ft^3) in the 0 - 13 mm assay zone, 1.6 - 3.2 kg/m^3 (0.10 – 0.20 lb/ft^3) in the 13 - 25 mm assay zone, and 0.3 - 1.1 kg/m^3 (0.02 – 0.07 lb/ft^3) in the 25 - 50 mm assay zone. The concentrations noted by Morrell et al. (2013) in the outer assay zone are similar to those found in in this study after 3.5 years, but we observed higher concentrations in the inner assay zones. This may reflect the longer exposure time of the current study, the effect of initial pressure treatment, differences in wood species, and/or differences in wood moisture content.

The post durability and movement of copper observed in this study is in agreement with a previous study using a copper naphthenate/borax paste (Freeman, 2013). In that study the paste was also applied to otherwise untreated pine posts, which were installed at a test site near Dorman Lake, MS. After 10 years no decay was observed within 457 mm (18 in.) of the groundline in the unseasoned posts or within 310 mm (12 in.) of the groundline in seasoned posts. Some decay was observed in the groundline posts after 15.5 years, but no failures had occurred. Substantial movement of copper both along and across the grain was observed, possibly in the form of a copper-borate complex (Freeman, 2013).

It is possible that the use of untreated posts in the current study allowed greater penetration of both copper and boron than might be observed when the paste is applied to wood pressure treated with creosote or heavy oil carriers. Conversely, the lack of initial pressure treatment may have presented an exaggerated decay hazard. Research has indicated that the copper–borax formulation evaluated in this report is effective in combination with either creosote or pentachlorophenol. Fahlstrom (1964) reported synergism for borax and creosote, noting that wood treated with sub-threshold creosote levels could resist attack by creosote-tolerant fungi with the addition of as little as 0.32 kg/m^3 (0.02 lb/ft^3) anhydrous borax. The synergy of combinations of borax and pentachlorophenol has been reported (Chapman 1940), and combinations of copper and pentachlorophenol have also been reported to perform well (Hochman and Amundsen 1980). An earlier laboratory study also concluded that amine copper complexes from copper hydroxide are highly synergistic with creosote for controlling *Neolentinus lepedius*, a creosote-tolerant fungus (Woodward et al., 2002).

CONCLUSIONS

A borax–copper groundline treatment has protected the lower half of otherwise untreated pine posts for over 15 years. Borax concentrations were highest above-ground, and were generally greatest after 3.5 years. Borax concentrations were generally above thresholds needed to prevent biodeterioration, although by 20 years, borax concentrations in the outer 0 – 13 mm (0 – 0.5 in.) assay zone were below effective thresholds. Copper concentrations were more stable over time, and in the outer assay zone, remained at effective concentrations after 20 years. In most samples, copper concentrations in the 13 – 25 mm (0.5 – 1.0 in.) assay zone were also sufficient to provide protection. Although copper movement through the posts was not a great as that of boron, substantial movement occurred, especially parallel to the grain. It is possible that the use of untreated posts allowed greater movement of copper and boron than might be observed for wood pressure-treated with oil-type preservatives, but conversely, pressure-treated posts would also be less reliant on the groundline treatment for protection. The long-term protection observed appears to be primarily attributable to copper in the groundline and below-ground areas, and to both boron and copper above-ground. This study indicates that the evaluation of untreated posts can be a valuable part of the overall assessment of the efficacy of a groundline treatment.

LITERATURE CITED

Abbot, W., D.M. Crawford, and M. West. 2001. Permanence of a borax-copper hydroxide remedial preservative when applied to unseasoned pine posts. Proc., American Wood-Preservers Assoc. 97:190–193.

Amburgey, T.L. and M.H. Freeman. 1993. Ten year field test with a copper-borate ground line treatment for poles. International Research Group on Wood Preservation, Document No. IRG/WP93-30017.

AWPA. 2013. Book of Standards. American Wood-Preservers' Association. Selma, Alabama.

Chapman, A.D. 1940. Preservative Composition. U.S. Patent No. 2,186,134.

Crawford, D., Lebow, S., West, M. and W. Abbott. 2005. Permanence and diffusion of borax-copper hydroxide remedial preservative applied to unseasoned pine posts: 10 year update. Proc., American Wood-Preservers' Assoc. 101:94-102.

Degroot, R.C. 1981. Groundline treatments of southern pine posts. Res. Paper FPL–RP–409. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 9 p.

Drysdale, J. A. 1994. Boron treatments for the preservation of wood—A review of efficacy data for fungi and termites. International Research Group on Wood Preservation. Document No. IRG/WP 94-30037.

Fahlstrom, G.B. 1964. Threshold values for wood preservatives. Forest Prod. J. XIV(11):529–531.

Freeman, M.H. 2007. Wood pole and crossarm maintenance and remedial treatment: A state of the industry review. Proc., American Wood Protection Assoc. 103:151-177.

Freeman, M.H. 2013. The concept of copper and boron synergy: Why copper naphthenate and borates are a couple made in heaven. International Research Group on Wood Preservation. Document No. IRG/WP 13-30622. 19p.

Freeman, M.H., McIntyre, C.R. and D. Jackson. 2009. A critical and comprehensive review of boron in wood preservation. Proc., American Wood-Preservers' Assoc. 105:279-274.

Freitag, C. M. and J. J. Morrell. 2005. Development of threshold values for boron and fluoride in non-soil contact applications. Forest Prod. J. 55(4): 97–101.

Hochman, H. and J. Amundsen. 1980. New waterborne preservative systems PTC (Penta-tetra-copper). Proc., American Wood-Preservers' Assoc. 76:56–60.

Morrell, J. J., M. A. Newbill, and C. M. Freitag. 1994. Capacity of surface and internal groundline treatments to protect untreated Douglas-fir posts. Holzforschung. 48(2):113-116.

Morrell, J.J., C. Love, C. Freitag, L. Bell and S. Leavengood. 2010. Oregon State University Utility Pole Research Cooperative, 30th Annual Report. November 4th, 2010. Department of Wood Science & Engineering Oregon Wood Innovation Center. 128p. http://www.cof.orst.edu/coops/utilpole/pdf/2010.pdf

Morrell, J.J., C. Love, C. Freitag, J. Schindler and S. Leavengood. 2013. Oregon State University Utility Pole Research Cooperative, 30th Annual Report. October 9, 2013. Department of Wood Science & Engineering Oregon Wood Innovation Center. 135p.
http://www.cof.orst.edu/coops/utilpole/pdf/2013.pdf

Peters, B. C. and C. J. Fitzgerald. 2006. Borate protection of softwood from Coptotermes acinaciformis (Isoptera: Rhinotermitidae) damage: Variation in protection thresholds explained. J. Econ. Entomol. 99(5):1749–1756.

Woodward, B., W. Abbot, and M. West. 2002. Retreatment of spent creosote-treated wood with copper hydroxide and sodium tetraborate. Proc., American Wood-Preservers’ Assoc. 98:58–61.