cient distribution of warm air in the winter and cool air in
the summer from a centrally located unit. This building
technique is often referred to as the Plen-Wood System.

Pile (piling): Round timbers or poles that are driven into
the ground to support a load, as a foundation for structure,
or as part of a dock or moorage. Sawn timbers are some-
times used as piling.

Plywood: A flat panel made up of a number of thin sheets,
or veneers, of wood in which the grain direction of each ply,
or layer, is at right angles to the one adjacent to it. The veneer
sheets are united, under pressure, by a bonding agent.

Pole: A long, usually round piece of wood, often a small
diameter log with the bark removed, used to carry utility
wire or for other purposes; often treated with preservative.

Post: A piece of lumber, less than 16 feet in length, used in
a vertical position to support a beam or other structural
member in a building, or as part of a fence. Although 4 by 4s
are often referred to as posts, most grading rules define a
post as having dimensions of 5 inches or more in width, with
the width not more than 2 inches greater than the thickness.

Post frame construction: A construction system using
vertical members (posts, columns, poles, timbers, or oth-
ers) that may be embedded in the ground or surface-
mounted to a concrete or masonry foundation to form the
building’s frame.

Retaining wall: A structure designed to keep a bank of
ground from collapsing or eroding.

Structural composite lumber: A family of engineered
wood products that combine wood fiber and exterior-type
adhesives to form lumber products of virtually any cross-
sectional size. The wood fibers may be in the form of ve-
neers, strand, or a combination thereof bonded together
with wet-use structural adhesives.

Stringer: A horizontal timber used to support floor joists
or other cross members. A stair stringer.

Subject to saltwater splash: Any member of a marine
structure which is positioned above mean high tide, but is
subject to frequent wetting from wave action or wind, which
supports intermittent degradation by marine organisms.

Timber: A size classification of lumber that includes
pieces that are at least 5 inches in their smallest dimension;
also classified as beams, stringers, and girders.

Wale/waler: Planking placed horizontally across a
structure to strengthen it. Horizontal bracing used to stiffen
concrete form construction.

References
(adapted for use in this document).
The Southern Pine Council. www.southernpine.com

This table is reprinted for the convenience of the reader. It is
posted at www.epa.gov/pesticides/factsheets/chemicals/
awpa_table.htm.

Performance of Zinc-Based Preservative Systems
in Ground Contact

H. M. Barnes, T. L. Amburgey, and M. G. Sanders

Abstract
Zinc naphthenate and its analogs were investigated as
potential ground contact preservatives in field stake tests. A
water-dispersible formulation, a solvent-borne formula-
tion, and an oilborne system were investigated. Perfor-
mance of the water-dispersible and solvent-borne systems
was poor in ground contact. However, when carried in a
heavy oil, performance was markedly improved and was
comparable to a similar copper naphthenate system. The re-
placement of some copper by zinc in naphthenic systems
showed promise but requires additional study.

Introduction
For about two decades, metal carboxylate systems have
been investigated as wood preservatives. Predominate
among these systems has been copper naphthenate. Num-
erous papers have shown it to be an efficacious ground contact
system (Merichem 2004, Barnes et al. 2003). Less informa-
tion is available for zinc naphthenate (ZN), an analogous sys-
tem. Barnes (1986) reported on the treatment of log home
logs with the zinc system. ZN yields a colorless treatment, an
obvious advantage over copper naphthenate. Subsequently,
ZN was marketed for above-ground applications. Zinc-based
systems are attractive because they are cheaper than copper naphthenate. Additionally, there is less environmental concern with zinc than with other heavy metals. Previous work has shown wood treated with water-dispersible formulations of ZN or copper naphthenate to be no more corrosive to metals than untreated wood (Barnes et al. 1984). This paper reports our results with ground contact testing of ZN systems. The objectives of this research were to determine how ZN systems would perform in ground contact, to ascertain the impact of additives on performance, to determine performance differences due to the carrier system, and to compare the performance of zinc systems to a similar one based on copper.

Methods and Materials

End-matched southern pine (Pinus spp.) stakes measuring 0.75 by 0.75 in. in cross section by 18 in. long were pressure treated with ZN solutions using a full-cell treating cycle. The cycle consisted of a full intensity vacuum (28 in Hg) for 30 minutes followed by a 1 hour pressure cycle at 150 psig. Retention was varied by varying treating solution strength. Retention was calculated by weight gain. Four different systems were evaluated. The first was a water-dispersible formulation diluted with water. The second formulation was an oilborne formulation diluted with toluene to make a light organic solvent preservative (LOSP) system. The same oilborne system also was diluted with an AWPA P9 Type A oil to yield a heavy oil system (AWPA 2003). The oil carrier was a 1:3 mixture of Base Oil L2-toluene which yielded an oil retention of 6 to 8 pcf, an oil retention range commonly found with oilborne preservative systems such as pentachlorophenol. An LOSP zinc neodecanoate system was also evaluated. Ten replicate stakes per combination of preservative formulation, carrier system, and retention were treated for evaluation.

To test the effect of various additives on performance, additional stakes were treated with insecticide added to water-dispersible (WD) ZN to see if the addition would improve the performance against termites. For one set of stakes, chlorpyrifos [Dursban®-(O,O-diethyl-O-(3,5,6-trichloro-2-pyridyl)phosphorothioate) at 0.01 percent and 0.1 percent (w/w) was added to the treating solution prior to treatment. In a second stake test, permethrin [Pounce®, (3-phenoxybenzyl(1RS)-cis-trans-3-(2,2-dichlorovinyl)-2,2-dimethylcyclopropanecarboxylate] at 0.2 percent (w/w) was added to the treating solution. An additional set of stakes were treated with a commercial water repellent (approximately 1% w/w) was added to ZN carried in water, toluene, or AWPA P9 Type A oil to see if the decay resistance of wood was improved.

After treatment, end-matched stakes were placed in ground contact in our Dorman Lake test site (AWPA Deterioration Zone 4) and our Saucier, MS test site (AWPA Deterioration Zone 5). Stakes were evaluated annually using the 10-point rating scale (10 = no deterioration, 0 = complete failure) given in the AWPA E7 standard (AWPA 2003). For the purposes of this paper, only the data from our Dorman Lake test site will be reported as the results from the Saucier site were very similar. The Dorman Lake site is located on the Starr Memorial Forest, Oktibbeha County, 10 miles south of Starkville, MS. The soil is characterized as acidic (pH = 4.8) heavy clay (Falkner) on a poorly drained site. This site is known to have copper-tolerant fungi and is very active for decay and termites. A detailed description can be found in the literature (Schultz et al. 2002).

Results and Discussion

Results are presented in the form of dose-response curves with a logarithm fit of the Index of Condition (IC) vs. preservative retention. IC is obtained by summing the results from the ten replicate stakes to yield a 100 point scale (100 = no deterioration).

Effect of Insecticide Addition

Figure 1 shows the 5-year exposure dose-response curve for termite attack on stakes for both levels of added Dursban®. At higher retentions, a slight improvement with the added insecticide was noted. The data for Pounce® addition indicates a slight, but non-significant, improvement in termite resistance (Fig. 2). The addition of insecticides used in these studies for improving the resistance of wood treated with WD ZN to termite attack cannot be recommended.

Effect of Water-Repellent Addition

Figure 3 shows at best a marginal, non-significant improvement after 5 years of exposure for the WD and LOSP systems. No improvement was noted for the oilborne system. Perhaps the addition of higher concentrations of water repellent would have increased the efficacy of one or more of these systems.

Carrier Effects

Performance of the water-dispersible system in ground contact was poor as is shown in Figure 4. After 5 years of exposure, only the highest retentions were above an IC of 70, the lowest level of performance generally considered acceptable. A decay grade of 70 indicates that 10 to 30 percent of the cross section is decayed. After 5 years of exposure, no retention in this study was acceptable. These data would indicate that water-dispersible ZN would not qualify as a ground contact system at anything approaching a reasonable economic retention. The same is true, only more so, for LOSP ZN or zinc neodecanoate systems (Fig. 5). For the LOSP systems, no retention studied was effective after 3 years of exposure.

When ZN is carried in a heavy oil (AWPA P9 Type A solvent), the performance was tremendously improved. An IC of 70 or below was reached only after 7 to 10 years of exposure, as is clear from Figure 6. These data would indicate

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2 A medium aromatic petroleum oil obtained from Lillyblad Petroleum, Inc., Bellevue, WA.
Figure 1.—Effect of chlorpyrifos (Dursban® = CPF) addition on the performance of wood treated with water-dispersible zinc naphthenate after 5 years of exposure in ground contact.

Figure 2.—Effect of permethrin (0.2% Pounce®) addition on the performance of wood treated with water-dispersible zinc naphthenate after 5 years of exposure in ground contact.

Figure 3.—Effect of the addition of water repellant (WR) on the performance of wood treated with water-dispersible (WD), solvent-borne (LOSP), and oilborne (P9A) zinc naphthenate after 5 years of exposure in ground contact.

Figure 4.—Dose-response curves after 1, 3, or 5 years of exposure for wood treated with water-dispersible zinc naphthenate (data from two different stake tests).

Figure 5.—Dose-response curves after 1, 3, and 5 years of exposure for wood treated with solvent-borne (LOSP) zinc naphthenate (solid lines) and zinc neodecanoate (NEO-dashed lines).

Figure 6.—Dose-response curves at 3, 5, 7, and 10 years of exposure for wood treated with oilborne zinc naphthenate in an AWPA P9 type A solvent.
Figure 7.—A comparison of dose-response curves for water-dispersible zinc naphthenate and copper naphthenate after 5 years of exposure.

Figure 8.—A comparison of dose-response curves for solvent-borne (LOSP) zinc naphthenate and copper naphthenate after 5 years of exposure.

Figure 9.—A comparison of dose-response curves for zinc naphthenate (solid lines) and copper naphthenate (dashed lines) in heavy oil (AWPA P9 type A) after 5 or 10 years of exposure.

Figure 10.—Dose-response curves for a 2.67:1 Zn:Cu LOSP system compared to zinc- and copper naphthenate systems after 5 years of exposure. (Zn:Cu system is based on the Zn retention.)

that ZN might qualify as a ground-contact preservative when carried in a heavy oil solvent. The data suggest that performance in above-ground usages would certainly be adequate.

Comparison with Copper Naphthenate

Copper naphthenate (CN) was evaluated in parallel studies as has been reported previously (Barnes et al. 2003). Comparison between the two preservative systems generally shows the copper-based system to be superior as can be seen in Figures 7, 8, and 9 for 5 years of exposure of the water-dispersible, solvent-borne (LOSP), and heavy oil (AWPA P9 Type A) systems, respectively. After 10 years of exposure, the performance of both the Zn and Cu systems is similar (Fig. 9), with CN showing better performance. Care should be exercised in interpreting data on small stakes after 7 years of exposure. This is in part due to the “reservoir”

effect being small in small-sized samples as compared to that for wood in larger structural sizes.

Figure 10 compares the dose-response curves for a combination zinc/copper (2.67:1 Zn:Cu) naphthenate LOSP system with both copper naphthenate and ZN LOSP systems after 5 years of exposure. The significant improvement in performance of the Zn/Cu system as compared to ZN alone can be attributed to the addition of the copper. The extent to which zinc could replace copper in a combination system from both a performance and economic standpoint requires additional study.

Summary and Conclusions

This paper reports on the effectiveness of ZN in ground contact in various carriers and with different additives. The addition of insecticides or water repellants did little to improve the performance of ZN systems at the concentrations
tested. As has been shown with other systems, the carrier system used had the greatest effect on performance (Nicholas et al. 1994). When formulated as a water-dispersible or LOSP system, performance would not qualify ZN as a ground-contact preservative. However, in a heavy oil (AWPA P9 Type A) carrier performance was greatly improved, suggesting that ZN might be effective in some ground-contact applications such as deck structural members, glulam beams, agricultural and highway uses. Performance lagged slightly behind that for copper naphthenate in heavy oil. The replacement of copper with zinc in a naphthenic system showed some promise but will require additional study.

References

H. M. Barnes, Professor; T. L. Amburgey, Professor; and M. G. Sanders, Research Associate III, Mississippi Forest Products Laboratory, Mississippi State University, Mississippi State, MS. Approved as Journal Article FP-315, Forest & Wildlife Research Center, Mississippi State University, Mississippi State, MS. This paper was presented at the 2004 Annual Meeting of the Forest Products Society. The use of trade names is for the convenience of the readers only and does not imply endorsement by Mississippi State University over similar products which may be equally suitable.

Recent Trends in Preservative Treatments for Timber Bridges
James P. Wacker

Abstract
An overview of wood preservatives currently used for timber bridges is presented through a series of case studies from different regions of the United States. New wood species and preservative treatment options for timber bridges have made choosing the appropriate preservative more complicated. The compatibility of wood species and preservative treatment is often overlooked but can be very important to the durability of timber bridge components. More technical guidance is needed for bridge designers who are not familiar with wood preservative treatments. The current trend is toward the use of waterborne preservatives and untreated decay-resistant wood species in opposition to current American Association of State Highway and Transportation Officials design specifications.

Introduction
Timber bridge designers are faced with an increasingly complicated decision when choosing an appropriate preservative treatment. Preservative treatment information guides are available (Lebow and Makel 1995), but bridge designers need more specific information addressing compatibility issues between wood species and preservatives. Several new wood species (both hardwoods and softwoods) have been adopted for timber bridge applications through efforts of the National Wood in Transportation Program (USDA 2004). Widespread use of these non-traditional wood species in timber bridges has highlighted the importance of wood species and preservative compatibility for the durability of treated bridge components. In many cases, compatibility issues between wood species and pre-