# Effect of Koppers Pole Additive Technology on the Resistance To Gaff Penetration in Southern Pine Utility Poles

Wood Durability Laboratory
IAS TL-350

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**TABLE OF CONTENTS**

SIGNATORIES……………………………………………………..………...……...….3

INTRODUCTION….……………………………………..…………..…...……..4

MATERIALS & METHODS………...………………………..…………….….……..….4

RESULTS AND DISCUSSION....   …………………………………… ………..……8

SUMMARY OF RESULTS…..…………………..……………..…………………..……15

WDL IAS Certificate of Accreditation ………..………...…..…………………...…..….16

END OF REPORT…………………………………………………………………….19

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## INTRODUCTION

The Wood Durability Laboratory (WDL) at Louisiana State University AgCenter was contracted by Koppers, Griffin, GA to perform gaff hardness testing on southern pine pole sections treated with CCA, Pentachlorophenol and CCA plus two pole additive systems, Koppers Oil Emulsion and Wolman ET™. The additive systems are designed to improve the climbing characteristics of CCA treated utility poles.

Surface hardness was assessed by means of gaff penetration testing using two different lineman gaffs. One gaff selected for testing was recommended for general pole climbing, while the second gaff was specifically recommended by the supplier for climbing CCA treated poles. In addition to gaff hardness testing, surface hardness was measured with a Pilodyn 6J.

## MATERIALS AND METHODS

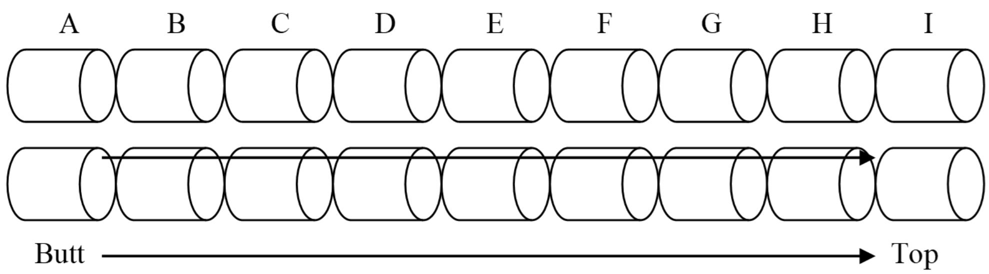
### A. Pole Sections

Thirty six, 3 foot long pole sections were received from Koppers for gaff and Pilodyn hardness testing at the WDL. The pole sections and associated treatments are summarized in Table 1 below. The letter designations associated with each pole number represent the location within each parent pole, with the "A" sections being cut from the butt of the respective poles and the "I" sections being cut from 24 to 27-feet along the length of the pole (Figure 1).

**Table 1.** Pole section treatment identification.

| Treatment | Pole Section ID |
|---|---|
| CCA-C (control group) | 8B, 8E, 8H<br>9B, 9E, 9H<br>10B, 10E, 10H |
| CCA/Koppers Oil Emulsion | 8C, 8F, 8I<br>9C, 9F, 9I<br>10C, 10F, 10I |
| Pentachlorophenol | 11B, 11E, 11H<br>12B, 12E, 12H<br>13B, 13E, 13H |
| CCA/Wolman ET™ | 14B, 14E, 14H<br>15B, 15E, 15H<br>16B, 16E, 16H |

**Figure 1.** Cutting of full-length utility poles into 3 foot long test sections.




B. <u>Conditioning and Drying</u>

Upon receipt from Koppers, the pole sections were placed outdoors under an open-sided overhang for conditioning to constant moisture contents (MC). This overhang was designed to protect the sections from the weather while allowing maximum air flow. The sections were kept upright during this stage of drying and were evenly spaced to promote uniform drying.

A Delmhorst RDM-3 resistance type moisture meter was used to periodically monitor the moisture content of each pole section at a depth of 1 inch. The pole sections were also weighed periodically to monitor moisture loss. Total drying time for the pole sections ranged from 3 to 5 months.

C. <u>Gaff Hardness Testing</u>

Gaff hardness testing was performed using LSU's Instron Universal Testing machine (Model #5582) (See Figure 2). The test setup used was designed to reproduce the principal movement of the gaff in penetrating a wood pole.

**Figure 2.** Gaff hardness testing.

The equipment consisted of a jig mounted to the Instron base that held the pole sections at a 20 degree angle from vertical direction. Lineman gaffs were attached using threaded pins to a steel billet that was affixed to the load cell of the Instron Testing Machine. The gaffs were mounted to the billet so that they were perfectly in line with one another.

Two different lineman gaffs were used to evaluate the effectiveness of the Koppers Oil Emulsion treatment when compared to CCA only, Pentachlorophenol (Penta) and Wolman ET (ET). The gaffs were identified as follows:

- Buckingham T9106A – Screw Style Replaceable CCA Pole Gaff.
- Buckingham T9206A – Screw Style Replaceable Pole Gaff.

The T9106A gaff is designed to penetrate hard CCA poles, while the T9206A gaff is designed for general pole climbing. A total of 5 gaffs of each type were used and were randomly assigned to each pole section to smooth out any variation caused by dulling.

In addition to the pole sections being mounted at a 20 degree angle from vertical direction, both gaff styles used in this study were designed with a 16 degree angle between the upper and lower shafts of the gaff. The combination of these two angles resulted in a penetration angle of approximately 36 degrees to the central axis of the test specimens, which corresponds to the average angle measured on a lineman climbing the pole.

The pole stubs were carefully positioned on the test bench so as to avoid knots and other wood defects (e.g., split). Once the test stubs were mounted on the Instron machine, the load head was lowered until the gaff was in contact with the pole surface. A force of 5 pounds was applied to the pole sections prior to testing to ensure that the gaff was fully seated. The load head was then displaced 0.475 inches at a rate of 0.50 in./min. A load sensor/cell was used to measure the applied force in the axis of the gaff. A total of 10 replicate readings were taken for each treatment/gaff combination.

D. Pilodyn Hardness Testing

In addition to gaff hardness testing, surface hardness of the pole sections was measured with a 6 joule Pilodyn with a 2.5 mm diameter blunt end probe (Pilodyn 6 J, Proceq SA, Zurich, Switzerland). Five measurements were taken at an angle of 90 degrees in the vicinity of the gaff hardness tests (See Figure 3).

**Figure 3.** Pilodyn hardness testing.

The test consists of injecting a spring-loaded steel striker pin into the wood. The penetration of the pin depends on the hardness of the wood. A scale on the instrument gives the depth of penetration. Generally, the deeper the penetration, the softer the wood.

E. Moisture Content

Prior to physical testing, 3 electronic moisture readings were taken from each pole section at a 1-inch depth. As with the Pilodyn, moisture readings were taken in the vicinity of the gaff hardness tests.

In addition, 3 core borings, 4 inches in length and 0.2 inches in diameter were removed from each pole section for determination of moisture content by the oven-dry method. Each boring was cut into one-inch increments, to a depth of 3 inches. The respective zones from each of the 3 borings were combined and immediately weighed to the nearest 0.01 gram. To reduce volatilization or drippage of the additives, the borings were dried at 49°C for 24 hours followed by 2 hours at 100°C. The weight after the 100°C exposure was used for the moisture content calculation.

F. Density Determination

The density values for each of the full-length parent poles were established by Koppers prior to shipment to LSU AgCenter's WDL. The reported procedure for determining weight density consisted of the following:

> "Three-inch long discs were cut out of each full-length pole at 9, 18 and 27 feet along the length for determination of density. A small block was

accurately machined from the outer 1-inch of each disc. The blocks were accurately measured and weighed. The blocks were then dried at 49°C for 24 hours followed by 2 hours at 100°C. The weight after the 100°C exposure was used for the moisture content calculation."

G. Pole Section Assay

For the pole sections treated with the experimental additives, a drill bit 0.5-inch in diameter was used to collect wood shavings from the outer ½-inch of each section. To ensure sufficient material for analysis, a total of 40 locations were assayed per section. The shavings were collected and returned to Koppers for determination of percentages and ratios of the respective additives.

## RESULTS AND DISCUSSION

The data collected for this evaluation is summarized in Tables 4 through 7 and visually displayed in corresponding Figures 4 through 7. The following is a summation of the data presented in each;

- Table 4, Figure 4 – Gaff Hardness for Buckingham CCA Pole Gaff.
- Table 5, Figure 5 – Gaff Hardness for Buckingham General-Purpose Gaff.
- Table 6, Figure 6 – Pilodyn Hardness.
- Table 7, Figure 7 – Moisture Content.

A. Pole Section Assay

The average assay results for the 9 pole sections from each respective treatment are presented in Table 2 below.

**Table 2.** Summary of pole section retention results.

| Retention, PCF | | | | | |
|---|---|---|---|---|---|
| **Treatment** | **Replicate Pole Sections** | **CCA by Gauge** | **CCA by Assay** | **Oil by Gauge** | **Oil by Assay[1]** |
| CCA-C (control group) | 9 | 0.68 | 0.59 | N/A | N/A |
| CCA/ Koppers Oil Emulsion | 9 | 0.61 | 0.57 | 0.69 | 1.02 |
| Pentachlorophenol | 9 | N/A | N/A | 0.45 | 0.40 |
| CCA/Wolman ET™ | 9 | 0.60 | N/A | Not Provided | 1.20 |

[1] The assay zone for the Koppes Oil Emulsion, Wolman ET™ and Penta treated pole sections was 0.0 to 0.5" from the pole surface.

B. Density

The density values as calculated by the Koppers Researchers are summarized in the following Table. The density values for the CCA and CCA/Koppers Oil Emulsion treated pole sections were the same as they were end-matched sections from the same full-size poles.

**Table 3.** Summary of pole section density results.

| **Calculated Oven-dry Density[1], PCF (Distance from Butt-End)** | | | | |
|---|---|---|---|---|
| **Treatment** | **Replicate Pole Sections** | **9 feet** | **18 feet** | **27 feet** |
| CCA-C (control group) | 9 | 34.7 | 31.5 | 27.9 |
| CCA/Koppers Oil Emulsion | 9 | 34.7 | 31.5 | 27.9 |
| Pentachlorophenol | 9 | 46.1 | 42.2 | 40.2 |
| CCA/Wolman ET™ | 9 | 40.0 | 37.2 | 35.5 |

[1] Density was determined for the outer 1-inch of the respective test sections in the oven-dry condition. The weight of chemical in the CCA-Wolman ET and Penta treated poles was not factored into the density calculation.

C. Moisture Content

A review of the data in Table 4 and Figure 4 showed that the CCA control pole sections equilibrated near 15% moisture content (MC) or less. There was also a good correlation between the meter and oven-dry values in the outer inch. Very little gradient was observed from the shell to a depth of 3 inches indicating that the CCA control poles had in fact equilibrated.

When compared to the CCA controls, treatment of the pole sections with the CCA/ Koppers Oil Emulsion additive resulted in an increase in MC near the surface of the pole sections that became more pronounced deeper in the pole. This moisture gradient was also noted in the CCA/Wolman ET treated pole sections and to a lesser degree in the Penta treated pole sections.

The shell MC's (oven-dry basis) of the pole sections treated with the Koppers Oil Emulsion were comparable to or slightly lower than those found in the Wolman ET and Penta treated pole sections at the time of testing. The correlation between the meter and oven-dry MC in the outer inch tended to be more variable for the Koppers Oil Emulsion additive treatment and was most variable with the Wolman ET treated pole sections.

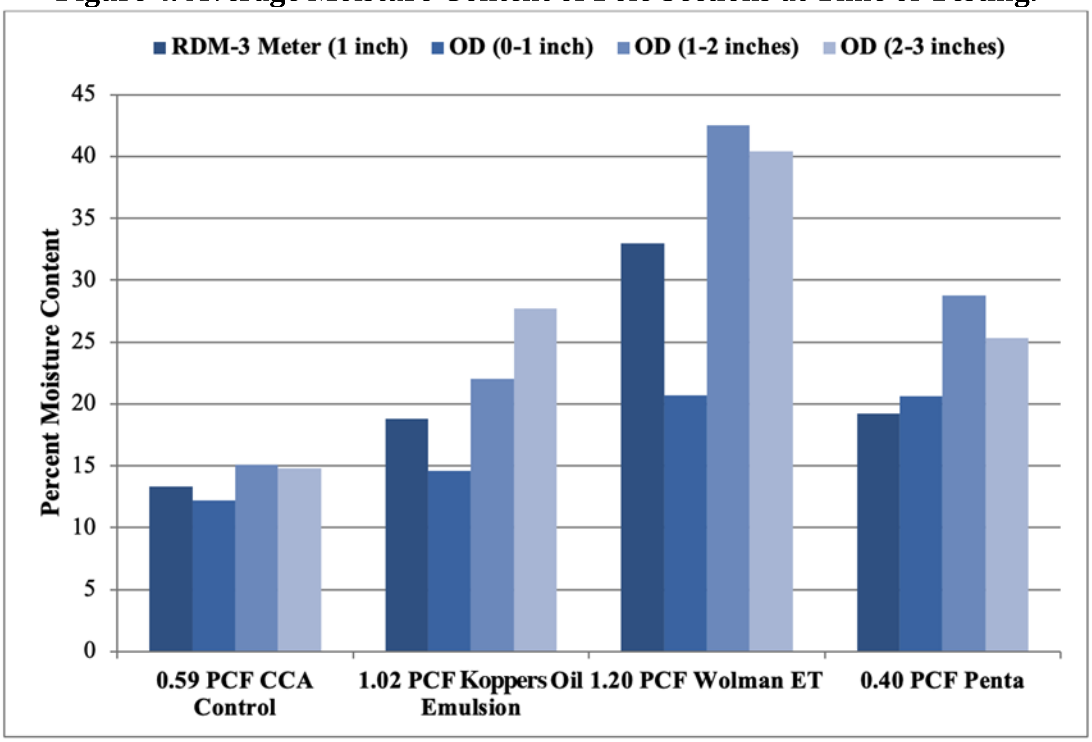
The presence of the moisture gradients in the pole sections provides evidence that they had not yet completely dried or equilibrated at the time of testing. This indicates that the Koppers Oil Emulsion additive retards the drying rate considerably much like that seen with the Wolman ET additive.

**Table 4. Average Moisture Content of Pole Sections at Time of Testing.**

| | | Moisture Content[1] Oven-Dry Method | | |
|---|---|---|---|---|
| **Treatment** | **RDM-3 Meter (1 inch)** | **0-1 inch** | **1-2 inches** | **2-3 inches** |
| `0.59 PCF CCA Control | 13.3 | 12.2 | 15.1 | 14.8 |
| 1.02 PCF Koppers Oil Emulsion | 18.8 | 14.6 | 22.0 | 27.7 |
| 1.20 PCF Wolman ET™ | 33.0 | 20.7 | 42.5 | 40.4 |
| 0.40 PCF Penta | 19.2 | 20.6 | 28.8 | 25.3 |

[1] Average of 9 pole sections, 10 readings per section.

**Figure 4. Average Moisture Content of Pole Sections at Time of Testing.**



A. Gaff Hardness Testing

As moisture content and density are known to have an effect on the surface hardness of utility poles, both variables must be considered when evaluating the softening effect of the test formulations. Density was not considered a contributing factor to changes in gaff hardness for the test poles treated by Koppers as the experimental design evenly distributed density across the entire population of test poles. Comparisons to commercial controls were somewhat more difficult as the pole densities did vary somewhat.

Gaff hardness testing of southern pine pole sections treated with the Koppers Oil Emulsion treating system at a loading of 1.02 pcf in the outer 0.5 inch, showed a pronounced reduction in surface hardness over the CCA treated controls. The shell MCs of the CCA control pole sections were generally lower than those for the additive systems. Thus, some degree of surface hardness can be attributed to the low moisture content in the control poles. This contribution is thought to be minor given the relatively large separation in gaff hardness between the additive treatments and controls.

When comparing the effect on gaff hardness of the Koppers Oil Emulsion treating system to the Wolman ET and Penta treatments, the oil retention level, surface MC and density must be reviewed carefully as these poles were commercially treated, thus the test sections did not come from the same parent poles.

The average oil retention level for the Wolman ET treated pole sections was 1.20 pcf while the oil loading for the Koppers Oil Emulsion was 1.02 pcf. The shell MC for the Koppers Oil Emulsion treated pole sections tended to be slightly lower on average than the Wolman ET and Penta treated sections. The average density for the pole sections treated with CCA and the Koppers Oil Emulsion was 31 pcf. The average density of the Wolman ET and Penta pole sections was 38 and 43 pcf, respectively.

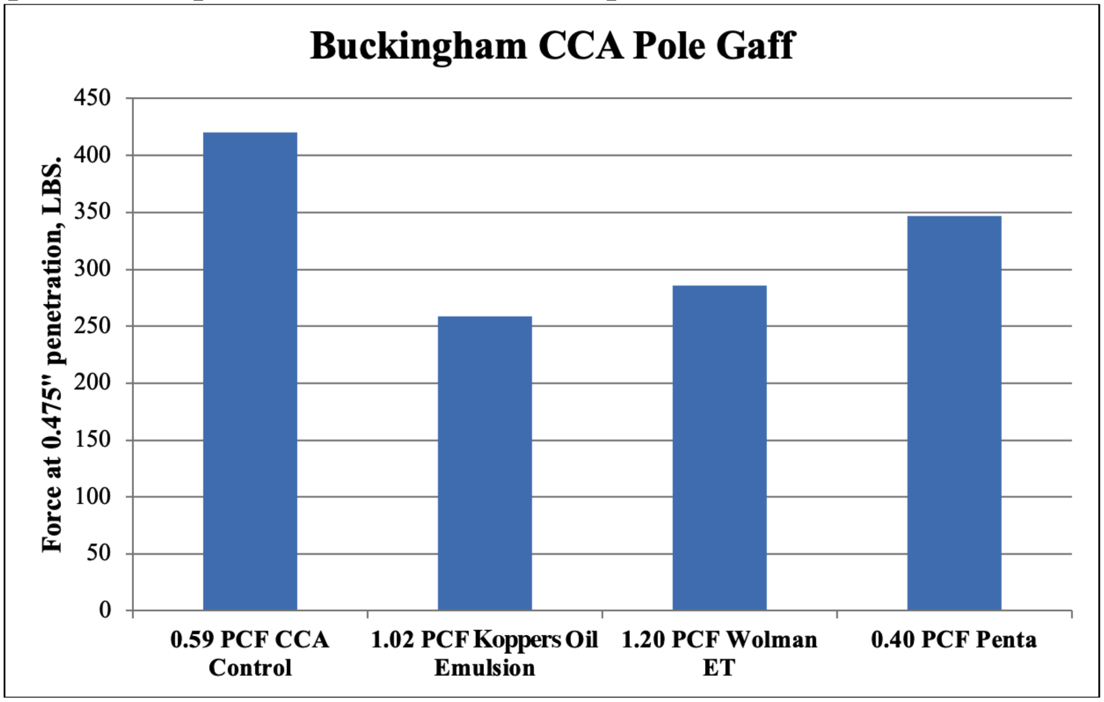
A review of the gaff hardness data summarized in Tables 5-6 and associated Figures 5-6, showed that the Koppers Oil Emulsion treated poles sections were comparable to Wolman ET treated pole sections and slightly better than Penta. The higher density values of the Wolman ET and Penta pole sections may have had a negative impact on surface hardness, but the degree of impact is unknown. In contrast, the higher oil loading of the Wolman ET test poles likely had a positive influence on gaff hardness. Again the degree of impact is unknown.

**Table 5. Average Gaff Hardness with Buckingham CCA Pole Gaff.**

| Treatment | Force at 0.475" Penetration, LBS.[1] |
|---|---|
| 0.59 PCF CCA Control | 420 (97) |
| 1.02 PCF Koppers Oil Emulsion | 259 (56) |
| 1.20 PCF Wolman ET™ | 286 (41) |
| 0.40 PCF Penta | 347 (68) |

[1] Average of 9 pole sections, 10 readings per section. Data in parenthesis represent standard deviations.

**Figure 5. Average Gaff Hardness with Buckingham CCA Pole Gaff.**



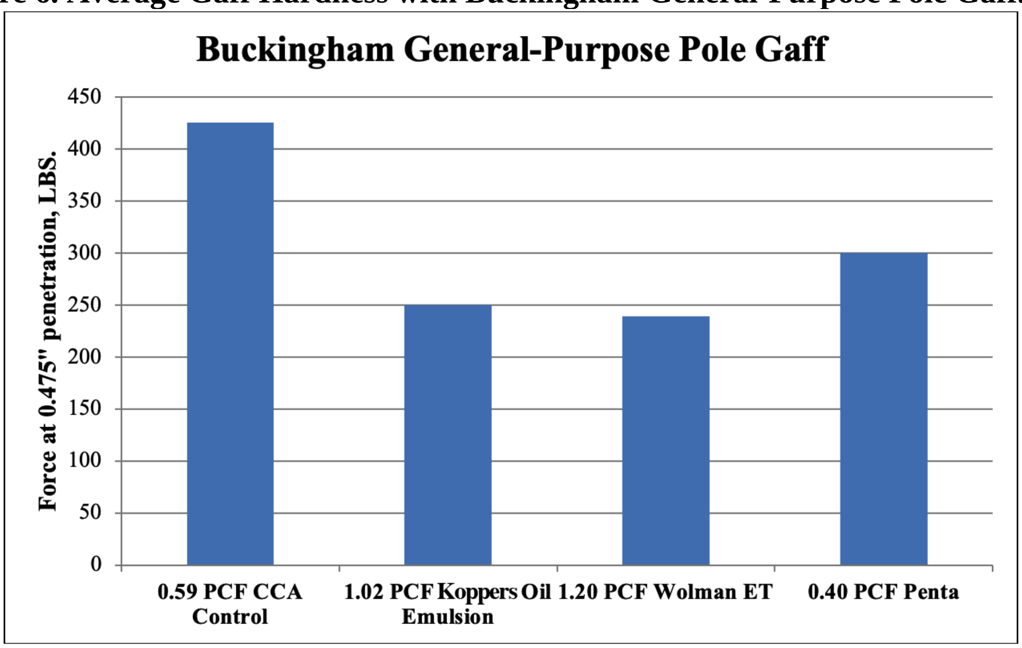

**Note: The data depicted in the chart represents the force required to drive the Gaff 0.475 inches into the pole section. The lower the force, the softer the pole surface.**

**Table 6. Average Gaff Hardness with Buckingham General-Purpose Pole Gaff.**

| Treatment | Force at 0.475" Penetration, LBS.[1] |
|---|---|
| 0.59 PCF CCA Control | 426 (117) |
| 1.02 PCF Koppers Oil Emulsion | 250 (42) |
| 1.20 PCF Wolman ET™ | 239 (44) |
| 0.40 PCF Penta | 300 (63) |

[1] Average of 9 pole sections, 10 readings per section. Data in parenthesis represent standard deviations.

**Figure 6. Average Gaff Hardness with Buckingham General-Purpose Pole Gaff.**




**Note: The data depicted in the chart represents the force required to drive the Gaff 0.475 inches into the pole section. The lower the force, the softer the pole surface.**

B. Pilodyn Hardness Testing

When interpreting Pilodyn penetration data, it is important to note that deeper the penetration of the striker pin, the softer the wood. As with gaff hardness testing, the inclusion of the Koppers Oil Emulsion in the CCA treated pole sections showed an improvement in Pilodyn hardness over the CCA control pole sections, with a marked increase in pin penetration (Table 7, Fig. 7). Again, some degree of surface hardness may be attributed to the low moisture content in the control poles.

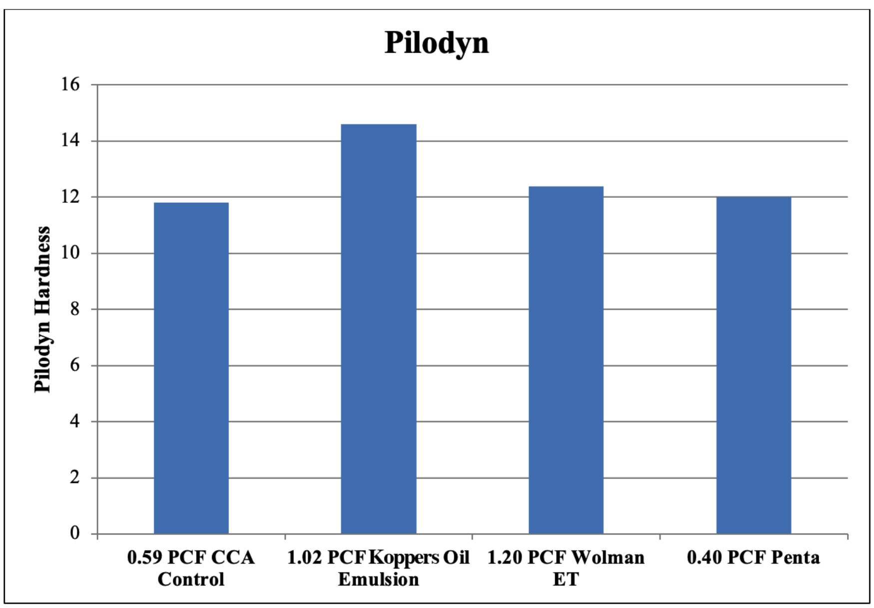
The average Pilodyn penetration was found to be the greatest for the pole sections treated with the Koppers Oil Emulsion, indicating that this treatment afforded the greatest reduction in surface hardness. The Pilodyn penetrations for the Wolman ET and Penta treated sections were similar and slightly less than that for the Koppers Oil Emulsion treated sections. Similar to gaff hardness testing, the higher density values of the Wolman ET and Penta pole sections may have had a negative impact on Pilodyn hardness, but the degree of impact is unknown. However, the fact that the pole sections treated with the Koppers Oil Emulsion had lower moisture levels and lower oil loadings than the Wolman ET treated sections, provides evidence that the Koppers additive system performs similarly.

**Table 7. Average Pilodyn Hardness.**

| Treatment | Pilodyn[1] |
|---|---|
| 0.59 PCF CCA Control | 11.8 (1.6) |
| 1.02 PCF Koppers Oil Emulsion | 14.6 (2.2) |
| 1.20 PCF Wolman ET™ | 12.4 (1.1) |
| 0.40 PCF Penta | 12.0 (1.0) |

[1] Average of 9 pole sections, 10 readings per section. Data in parenthesis represent standard deviations.

**Figure 7. Average Pilodyn Hardness.**




**Note: The data depicted in the chart represents the penetration of the striker pin into the pole section. The higher the Pilodyn Hardness (deeper the penetration), the softer the pole surface.**

## SUMMARY OF RESULTS

A review of the gaff hardness and Pilodyn penetration data obtained from this testing showed that the Koppers Oil Emulsion, at a loading of 1.02 pcf, provided a pole surface hardness that was comparable to Wolman ET at a loading of 1.20 pcf. The surface hardness of the pine poles treated with the Koppers Oil Emulsion was also slightly improved over that of the Penta treated southern pine pole sections.

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**Testing Laboratory TL-350**

has met the requirements of AC89, *IAS Accreditation Criteria for Testing Laboratories*, and has demonstrated compliance with ISO/IEC Standard 17025:2017, *General requirements for the competence of testing and calibration laboratories*. This organization is accredited to provide the services specified in the scope of accreditation.

Effective Date July 9, 2020

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## WOOD DURABILITY LABORATORY

**Contact Name** Dr. Qinglin Wu **Contact Phone** +225 578-8369

*Accredited to ISO/IEC 17025:2017* *Effective Date July 9, 2020*

| **Physical** | |
|---|---|
| ASTM D143 | Standard test methods for small clear specimens of timber |
| ASTM D1037 | Standard test methods for evaluating properties of wood-base fiber and particle panel materials (compression parallel to surface, section 12, excluded) |
| ASTM D2395 | Standard Test Methods for Density and Specific Gravity (Relative Density) of Wood and Wood-Based Materials |
| ASTM D2481 | Standard test method for accelerated evaluation of wood preservatives for marine services by means of small size specimens |
| ASTM D3043 | Standard test methods for structural panels in flexure (methods A and D only) |
| ASTM D3273 | Standard test method for resistance to growth of mold on the surface of interior coatings in an environmental chamber |
| ASTM D3345 | Standard test method for laboratory evaluation of wood and other cellulosic materials for resistance to termites |
| ASTM D4442 | Standard Test Methods for Direct Moisture Content Measurement of Wood and Wood-Based Materials |
| ASTM D4445 | Standard test method for fungicides for controlling sapstain and mold on unseasoned lumber (laboratory method) |
| ASTM D5456 | Standard specification for evaluation of structural composite lumber products (test methods referenced in annex A3 and A4 only) |
| ASTM D5516 | Standard test method for evaluating the flexural properties of fire-retardant treated softwood plywood exposed to elevated temperatures |
| AWPA E1 | Laboratory methods for evaluating the termite resistance of wood-based materials: choice and no-choice tests |
| AWPA E5 | Standard test method for evaluation of wood preservatives to be used in marine applications (UC5A, UC5B, UC5C); panel and block tests |
| AWPA E7 | Standard field test for evaluation of wood preservatives to be used in ground contact (UC4A, UC4B, UC4C); stake test |
| AWPA E9 | Standard field test for the evaluation of wood preservatives to be used above ground (UC3A and UC3B); L-joint test |

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| | |
|---|---|
| AWPA E10 | Laboratory method for evaluating the decay resistance of wood-based materials against pure basidiomycete cultures: soil/block test |
| AWPA E11 | Standard method for accelerated evaluation of preservative leaching |
| AWPA E12 | Standard method of determining corrosion of metal in contact with treated wood |
| AWPA E16 | Standard field test for evaluation of wood preservatives to be used above ground (UC3B); horizontal lap-joint test |
| AWPA E18 | Standard field test for evaluation of wood preservatives to be used above ground (UC3B); ground proximity decay test |
| AWPA E20 | Standard method of determining the depletion of wood preservatives in soil contact |
| AWPA E21 | Standard field test method for the evaluation of wood preservatives to be used for interior applications (UC1 and UC2); full-size commodity termite test |
| AWPA E22 | Laboratory method for rapidly evaluating the decay resistance of wood-based materials against pure basidiomycete cultures using compression strength: soil/water test |
| AWPA E23 | Laboratory method for rapidly evaluating the decay resistance of wood-based materials in ground contact using static bending: soil jar test |
| AWPA E24 | Laboratory method for evaluating the mold resistance of wood-based materials: mold chamber test |
| AWPA E26 | Standard field test for evaluation of wood preservatives intended for interior applications (UC1 and UC2): ground proximity termite test |
| AWPA E29 | Antisapstain field test method for green lumber |
| ICC ES AC257 | Corrosion-resistant fasteners and evaluation of corrosion effects of wood treatment chemicals (test methods referenced in section 4.0, excluding sections 4.3.1.1, 4.3.1.2, 4.3.1.4 and 4.3.2.2) |
| ICC ES AC380 | Termite physical barrier systems (test methods referenced in sections 3, 4.1, 4.2 and 4.3, excluding 4.4.1 through 4.4.9) |
| WDL-SOP-25 | Field evaluation of termiticide against subterranean termites |
| WDMA T.M. 1 | Soil block test method |
| WDMA T.M. 2 | Swellometer test method |

*AWPA: American Wood Preservers' Association*

*WDMA: Window and Door Manufacturer Association*

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