Permanence and Diffusion of Borax–Copper Hydroxide Remedial Preservative Applied to Unseasoned Pine Posts: 10 Year Update

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Abstract: In 1993, unseasoned pine posts were treated with groundline remedial treatment containing 3.1% copper hydroxide and 40% sodium tetraborate decahydrate (borax). The soundness of the posts was periodically evaluated using a push test. After 3.5, 6.5, and 10 years, sections were taken from two posts to determine retention of borax and copper hydroxide below ground to 36 cm (14 in.) above ground. By 3.5 years of exposure, all untreated control posts had failed. After 6.5 and 10 years, the remedially treated posts were generally sound at the groundline but most suffered top decay. Average borax retention was 24.2, 15.8, and 10.6 kg/m^3 (1.51, 0.99, and 0.66 lb/ft^3) after 3.5, 6.5, and 10 years, respectively. Average copper hydroxide retention was 3.7, 4.2, and 3.5 kg/m^3 (0.23, 0.26, and 0.22 lb/ft^3) after 3.5, 6.5, and 10 years, respectively. Although retentions varied among posts, in most cases the borax retentions were still above the threshold needed to prevent attack by decay fungi even 10 years after treatment.

Introduction: After many years in service, the preservative in the groundline area of utility poles may become sufficiently depleted to allow surface attack by some types of decay fungi. To combat this surface decay and to extend the useful life of the pole, remedial preservatives may be applied to the groundline area. The components in a remedial formulation must be compatible with as well as complement the original pressure treatment preservatives such as creosote and pentachlorophenol. Remedial treatments are designed to protect wood containing below-threshold levels of creosote or pentachlorophenol. They are also intended to protect untreated sapwood and heartwood in poles that fail to meet the original pressure treatment penetration specifications. To be effective, remedial treatments must be mobile enough to penetrate the wood and yet 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 the heartwood. This component should he capable of preventing both decay and insect attack. The fixed component should be capable of moving well into the sapwood before becoming immobile. It is important that the fixed component be able to control decay fungi that are tolerant to creosote and pentachlorophenol.

The remedial treatment formulation reported here contains borax and copper hydroxide complexed with ethanolamine. Borax is a well-known diffusible preservative. In recent years, 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 permits production and sale of the formulation as a remedial preservative.

Considerable research data support the performance of a combination of copper and borate compounds for general wood preservation. It is known that borate compounds leach readily from wood in contact with the ground whether or not borate is combined with copper. To minimize borax losses in remedial groundline treatments, impermeable sheets are used to cover the preservative and contain borax in the pole. These impermeable liners ("bandages") also help to prevent movement of creosote and pentachlorophenol out of the poles.

Evaluation of the efficacy of remedial treatments is challenging because they are applied to poles in a range of conditions and with varying types and contents of residual preservative treatment. The American Wood-Preservers' Association (AWPA) has considered standardizing a test for evaluating these systems but has been unable to reach consensus on an appropriate method (AWPA 1999). Perhaps the simplest approach is to evaluate the remedial treatments on untreated posts. In 1957, the Forest Products Laboratory established a trial comparing 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, performance on untreated posts should not be the sole indicator of the effectiveness of remedial preservatives. Active ingredients of remedial treatments must have the ability to penetrate into wood that has been treated with oil-type preservatives. The active ingredients may also be synergistic with, or at least complementary to, the original pressure treatment preservative.

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 synergism 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). A recent study concludes that amine copper complexes from copper hydroxide are highly synergistic with creosote for controlling *Neolentinus lepedius*, a creosote-tolerant fungus (Woodward et al. 2002). Similarly, combinations of creosote and copper have a long history of successful wood protection. This historical data, in combination with other permanence and penetration studies on in-service utility poles, complements this report on the performance of remedial borax–copper treatment on untreated posts. The retention and diffusion of copper and borax in the posts after 3.5 and 6.5 years of exposure was reported previously (Abbott et al. 2001). Here we provide the results after 10 years of exposure.

Materials and Methods

The remedial preservative used in this study contained 3.1% copper hydroxide and 40% sodium tetraborate decahydrate as active ingredients. The inert ingredients were ethanolamine, water, and thickeners. The test method was that reported previously (Degroot 1981), except that six additional posts were treated and installed. The posts were cut and peeled within 1 week prior to treatment and installation. Average circumference was 48 cm (18.9 in.) at the base. A 0.6-cm (0.25-in.) layer of borax–copperhydroxide 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.

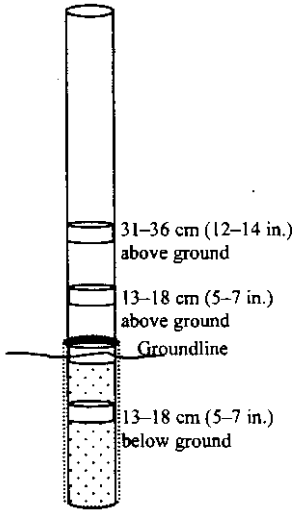

Figure 1–Sampling locations for assays.

Each year the posts were given a push test and the results recorded. After 3.5, 6.5, and 10 years, two posts were removed. Cross sections were cut from the following locations on the posts: 13 to 18 cm (5 to 7 in.) below ground; 2.5 cm (1 in.) below ground to 2.5 cm (1 in.) above ground; 13 to 18 cm (5 to 7 in.) above ground; and 31 to 36 cm (12 to 14 in.) above ground (Fig. 1). The sections were cut into three assay zones relative to the post surface: outer (0–1.3cm, 0-0.5 in.), middle (1.3–2.5cm, 0.5–1.0 in.), and inner (2.5–5 cm, 1.0-2.0 in.). The samples were sent to an independent laboratory where they were oven-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-A03 density for southern yellow pine of 512 kg/m^3 (32 lb/ft^3) (AWPA 2003).

Results and Discussion

All untreated controls had failed by 3.5 years of exposure. After 6.5 years, the top of each remedially treated post was essentially destroyed by decay. Some decay had extended 45 to 60 cm (18 to 24 in.) down the posts hut had remained above the treated zone. After all exposure periods (3.5, 6.5, and 10 years), there was no visible evidence of insect attack or decay where the cross sections were cut from the treated posts. Results for copper hydroxide and borax concentrations in the sampled sections are given in Table 1 and Figures 2 and 3. Chemical levels in the two posts removed at each time point vary greatly. Visual examination of post growth rings suggests that this variability was caused by density differences.

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 13 to 18 cm (5 to 7 in.) above ground, regardless of assay zone (Fig. 2). Borax evidently diffused into the posts, as the average retention in the middle assay zone (18.6 kg/m^3, 1.16 lb/ft^3) was only slightly lower that in the outer assay zone (21.6 kg/m^3, 1.35 lb/ft^3). Some depletion of borax from the posts has apparently occurred over time. Average borax retention was 24.2, 15.8, and 10.6 kg/m^3 (1.51, 0.99, and 0.66 lb/ft^3) after 3.5, 6.5, and 10 years, respectively. However, even after 10 years, the average borax concentration in assay samples removed from most posts was greater than the toxic threshold for decay fungi. 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 to0.18 lb/ft^3).

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 aboveground in the outer (0-l.3-cm, 0–0.5-in.)assay zone and higher retentions occurring below ground in the inner assay zones (Fig. 3). Diffusion of copper hydroxide into the wood was also more limited than that of borax. Average copper hydroxide retention in the middle assay zone (3.0 kg/m^3, 0.19 lb/ft^3) was less than half that in the outer assay zone (7.0 kg/m^3, 0.44 lb/ft^3). Not surprisingly, copper hydroxide also appeared to be more permanent than borax. The duration of exposure did not have a noticeable effect on average copper hydroxide retention; retention was 3.7, 4.2, and 3.5 kg/m^3 (0.23, 0.26, and 0.22 lb/ft^3) after 3.5, 6.5, and 10 years, respectively.

Conclusions

A borax-copper groundline treatment has protected the lower half of otherwise untreated pine posts for 10 years. The diffusion of borax has been more effective than that of copper; copper appears to be less mobile but more permanent. Although variability between replicates makes definitive conclusions difficult, it appears that the retentions of borax and copper remaining in the wood are sufficient to prevent attack by decay fungi and termites. This study indicates that the evaluation of untreated posts can be a valuable part of the overall assessment of the efficacy of groundline treatment.

Literature Cited

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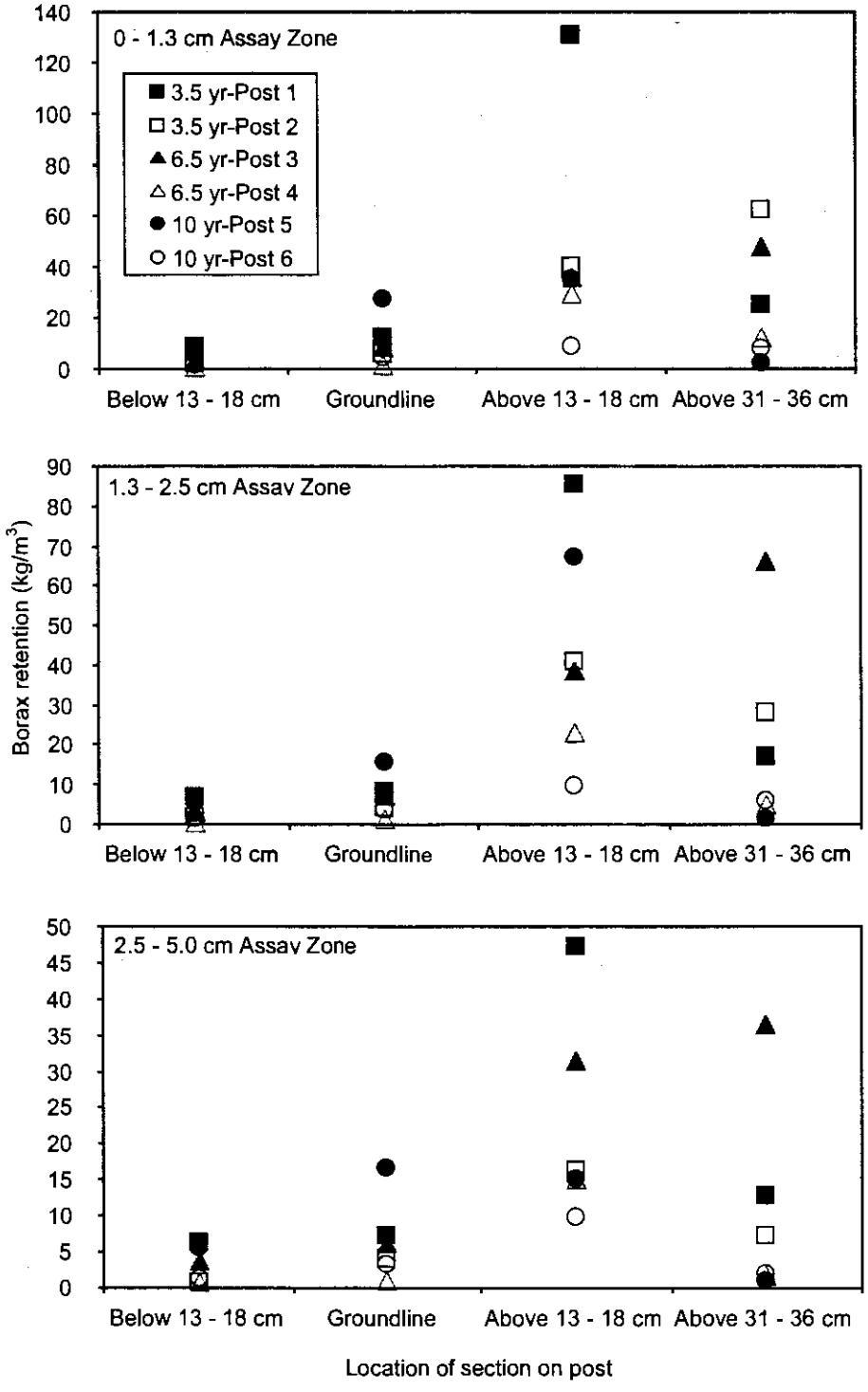

Figure 2–Borax retentions in three assay zones as function of location on post and years of exposure.

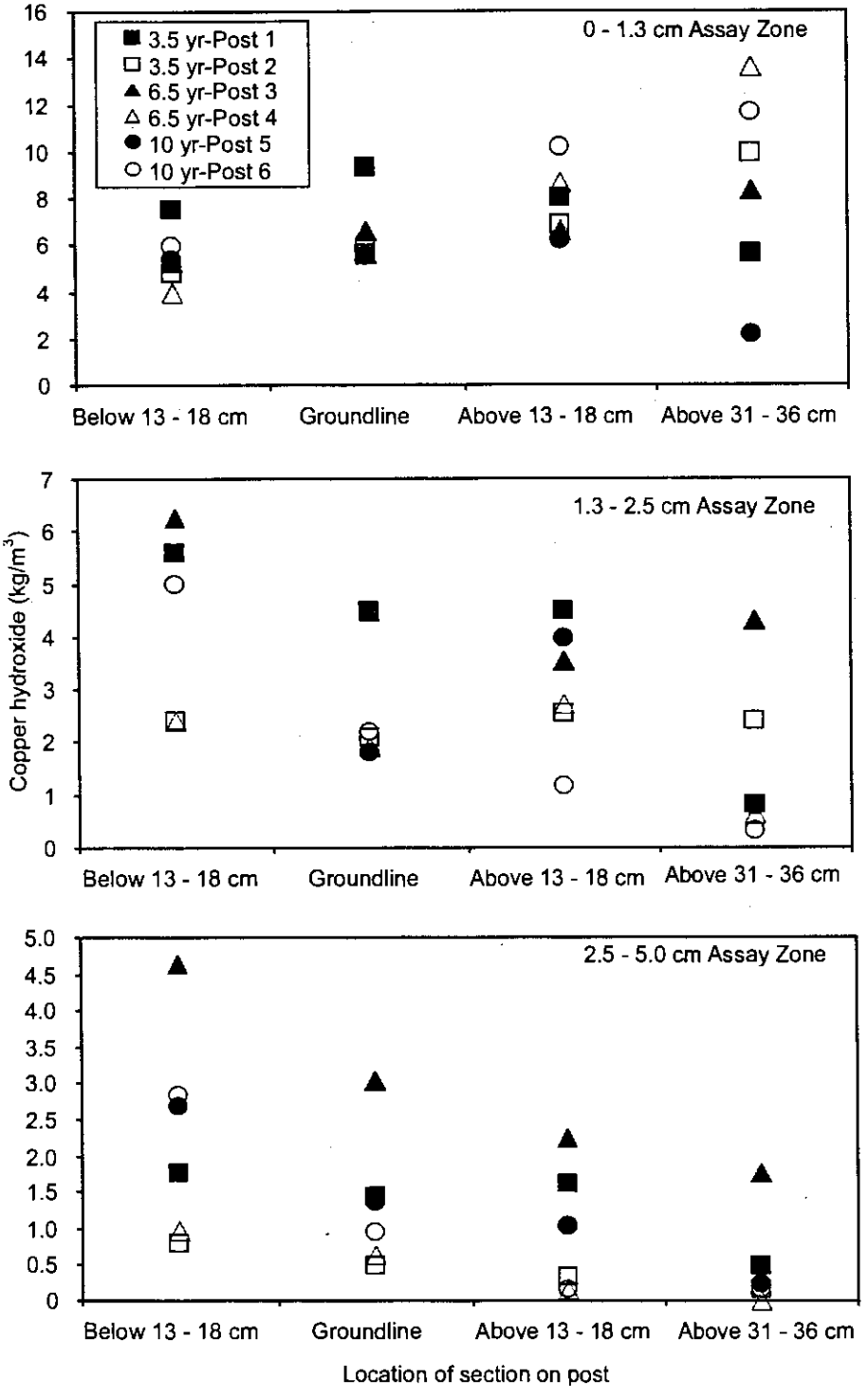

Figure 3–Copper hydroxide retentions in three assay zones as function of location on post and years of exposure.

Table 1a. Borax and copper hydroxide retentions in three assay zones as a function of location on post and years of exposure–metricunits

Years in test	Post	Vertical location above ground (AG) or below ground (BG)	Assay zone (cm)	Borax (kg/m^3)	Copper hydroxide (kg/m^3)
3.5	1	13–18 cm BG	0–1.3	8.3	7.5
	2	13–18 cm BG	0–1.3	1.9	4.8
6.5	3	13–18 cm BG	0–1.3	3.4	5.3
	4	13–18 cm BG	0–1.3	0.5	4.0
10	5	13–18 cm BG	0–1.3	5.8	5.4
	6	13–18 cm BG	0–1.3	1.1	5.9
3.5	1	2.5 cm BG–2.5 cm AG	0–1.3	12.2	9.3
	2	2.5 cm BG–2.5 cm AG	0–1.3	5.4	5.6
6.5	3	2.5 cm BG–2.5 cm AG	0–1.3	8.5	6.6
	4	2.5 cm BG–2.5 cm AG	0–1.3	1.4	5.6
10	5	2.5 cm BG–2.5 cm AG	0–1.3	26.8	5.5
	6	2.5 cm BG–2.5 cm AG	0–1.3	4.0	6.1
3.5	1	13–18 cm BG	0–1.3	130.6	8.0
	2	13–18 cm BG	0–1.3	40.0	6.9
6.5	3	13–18 cm BG	0–1.3	36.0	6.6
	4	13–18 cm BG	0–1.3	29.4	8.6
10	5	13–18 cm AG	0–1.3	35.0	6.2
	6	13–18 cm AG	0–1.3	8.2	10.2
3.5	1	31–36 cm AG	0–1.3	25.3	5.6
	2	31–36 cm AG	0–1.3	62.4	9.9
6.5	3	31–36 cm AG	0–1.3	47.8	8.3
	4	31–36 cm AG	0–1.3	12.3	13.6
10	5	31–36 cm AG	0–1.3	2.2	2.1
	6	31–36 cm AG	0–1.3	8.1	11.6
3.5	1	13–18 cm BG	1.3–2.5	6.7	5.6
	2	13–18 cm BG	1.3–2.5	1.8	2.4
6.5	3	13–18 cm BG	1.3–2.5	3.2	6.2
	4	13–18 cm BG	1.3–2.5	0.5	2.4
10	5	13–18 cm BG	1.3–2.5	5.3	5.6
	6	13–18 cm BG	1.3–2.5	1.2	5.0
3.5	1	2.5 cm BG–2.5 cm AG	1.3–2.5	8.5	4.5
	2	2.5 cm BG–2.5 cm AG	1.3–2.5	4.0	2.1
6.5	3	2.5 cm BG–2.5 cm AG	1.3–2.5	7.5	4.5
	4	2.5 cm BG–2.5 cm AG	1.3–2.5	1.3	1.9
10	5	2.5 cm BG–2.5 cm AG	1.3–2.5	15.6	1.8
	6	2.5 cm BG–2.5 cm AG	11–2.5	3.5	2.2

Table 1a. Borax and copper hydroxide retentions in three assay Zones as a function of location on post and years of exposure–metric units, continued

Years in test	Post	Vertical location above ground (AG) or below ground (BG)	Assay zone (cm)	Borax (kg/m^3)	Copper hydroxide (kg/m^3)
3.5	1	13–18 cm AG	1.3–2.5	85.4	4.5
	2	13–18 cm AG	1.3–2.5	40.8	2.6
6.5	3	13–18 cm AG	1.3–2.5	38.7	3.5
	4	13–18 cm AG	1.3–2.5	23.0	2.7
10	5	13–18 cm AG	1.3–2.5	67.0	3.9
	6	13–18 cm AG	1.3–2.5	9.6	1.2
3.5	1	31–36 cm AG	1.3–2.5	16.8	0.8
	2	31–36 cm AG	1.3–2.5	28.0	2.4
6.5	3	31–36 cm AG	1.3–2.5	66.2	4.3
	4	31–36 cm AG	1.3–2.5	5.3	0.6
10	5	31–36 cm AG	1.3–2.5	1.3	0.8
	6	31–36 cm AG	1.3–2.5	5.8	0.3
3.5	1	13–18 cm BG	2.5–5	6.2	1.8
	2	13–18 cm BG	2.5–5	0.6	0.8
6.5	3	13–18 cm BG	2.5–5	3.7	4.6
	4	13–18 cm BG	2.5–5	0.6	1.0
10	5	13–18 cm BG	2.5–5	5.4	2.7
	6	13–18 cm BG	2.5–5	1.1	2.8
3.5	1	2.5 cm BG–2.5 cm AG	2.5–5	7.2	1.4
	2	2.5 cm BG–2.5 cm AG	2.5–5	4.0	0.5
6.5	3	2.5 cm BG–2.5 cm AG	2.5–5	6.4	3.0
	4	2.5 cm BG–2.5 cm AG	2.5–5	1.1	0.6
10	5	2.5 cm BG–2.5 cm AG	2.5–5	16.7	1.3
	6	2.5 cm BG–2.5 cm AG	2.5–5	3.3	0.9
3.5	1	13–18 cm AG	2.5–5	47.4	1.6
	2	13–18 cm AG	2.5–5	16.3	0.3
6.5	3	13–18 cm AG	2.5–5	31.5	2.2
	4	13–18 cm AG	2.5–5	15.0	0.2
10	5	13–18 cm AG	2.5–5	15.2	1.0
	6	13–18 cm AG	2.5–5	9.7	0.2
3.5	1	31–36 cm AG	2.5–5	12.8	0.5
	2	31–36 cm AG	2.5–5	7.2	0.2
6.5	3	31–36 cm AG	2.5–5	36.5	1.8
	4	31–36 cm AG	2.5–5	1.8	0.0
10	5	31–36 cm AG	2.5–5	1.0	0.2
	6	31–36 cm AG	2.5–5	2.1	0.2

Table 1b. Borax and copper hydroxide retentions in three assay zones as a function of location on post and years of exposure–inch–pound units

Years in test	Post	Vertical location above ground (AG) or below ground (BG)	Assay zone (in.)	Borax (lb/ft^3)	Copper hydroxide (lb/ft^3)
3.5	1	5–7 in. BG	0–0.5	0.52	0.47
	2	5–7 in. BG	0–0.5	0.12	0.30
6.5	3	5–7 in. BG	0–0.5	0.21	0.33
	4	5–7 in. BG	0–0.5	0.03	0.25
10	5	5–7 in. BG	0–0.5	0.36	0.34
	6	5–7 in. BG	0–0.5	0.07	0.37
3.5	1	1 in. BG–1 in. AG	0–0.5	0.76	0.58
	2	1 in. BG–1 in. AG	0–0.5	0.34	0.35
6.5	3	I in. BG–1 in. AG	0–0.5	0.53	0.41
	4	1 in. BG–1 in. AG	0–0.5	0.09	0.35
10	5	I in. BG–1 in. AG	0–0.5	1.67	0.34
	6	1 in. BG–1 in. AG	0–0.5	0.25	0.38
3.5	1	5–7 in. BG	0–0.5	8.16	0.50
	2	5–7 in. BG	0–0.5	2.50	0.43
6.5	3	5–7 in. BG	0–0.5	2.25	0.41
	4	5–7 in. BG	0–0.5	1.84	0.54
10	5	5–7 in. BG	0–0.5	2.19	0.38
	6	5–7 in. BG	0–0.5	0.51	0.64
3.5	1	12–14 in. AG	0–0.5	1.58	0.35
	2	12–14 in. AG	0–0.5	3.90	0.62
6.5	3	12–14 in. AG	0–0.5	2.99	0.52
	4	12–14 in. AG	0–0.5	0.77	0.85
10	5	12–14 in. AG	0–0.5	0.13	0.13
	6	12–14 in. AG	0–0.5	0.50	0.72
3.5	1	5–7 in. BG	0.5–1.0	0.42	0.35
	2	5–7 in. BG	0.5–1.0	0.11	0.15
6.5	3	5–7 in. BG	0.5–1.0	0.20	0.39
	4	5–7 in. BG	0.5–1.0	0.03	0.15
10	5	5–7 in. BG	0.5–1.0	0.33	0.35
	6	5–7 in. BG	0.5–1.0	0.07	0.31
3.5	1	1 in. BG–1 in. AG	0.5–1.0	0.53	0.28
	2	1 in. BG–1 in. AG	0.5–1.0	0.25	0.13
6.5	3	1 in. BG–1 in. AG	0.5–1.0	0.47	0.28
	4	1 in. BG–1 in. AG	0.5–1.0	0.08	0.12
10	5	1 in. BG–1 in. AG	0.5–1.0	0.97	0.11
	6	1 in. BG–1 in. AG	0.5–1.0	0.22	0.14

Table 1b. Borax and copper hydroxide retentions in three assay zones as a function of location on post and years of exposure–inch–pound units, continued

Years in test	Post	Vertical location above ground (AG) or below ground (BG)	Assay zone (in.)	Borax (lb/ft^3)	Copper hydroxide (lb/ft^3)
3.5	1	5–7 in. BG	0.5–1.0	5.34	0.28
	2	5–1 in. BG	0.5–1.0	2.55	0.16
6.5	3	5–7 in. BG	0.5–1.0	2.42	0.22
	4	5–7 in. BG	0.5–1.0	1.44	0.17
10	5	5–7 in. BG	0.5–1.0	4.19	0.25
	6	5–7 in. BG	0.5–1.0	0.60	0.07
3.5	1	12–14 in. AG	0.5–1.0	1.05	0.05
	2	12–14 in. AG	0.5–1.0	1.75	0.15
6.5	3	12–14 in. AG	0.5–1.0	4.14	0.27
	4	12–14 in. AG	0.5–1.0	0.33	0.04
10	5	12–14 in. AG	0.5–1.0	0.08	0.05
	6	12–14 in. AG	0.5–1.0	0.36	0.02
3.5	1	5–7 in. BG	1.0–2.0	0.39	0.11
	2	5–7 in. BG	1.0–2.0	0.04	0.05
6.5	3	5–7 in. BG	1.0–2.0	0.23	0.29
	4	5–7 in. BG	1.0–2.0	0.04	0.06
10	5	5–7 in. BG	1.0–2.0	0.34	0.17
	6	5–1 in. BG	1.0–2.0	0.07	0.18
3.5	1	1 in. BG–1 in. AG	1.0–2.0	0.45	0.09
	2	1 in. BG–1 in. AG	1.0–2.0	0.25	0.03
6.5	3	1 in. BG–1 in. AG	1.0–2.0	0.40	0.19
	4	1 in. BG–1 in. AG	1.0–2.0	0.07	0.04
10	5	1 in. BG–1 in. AG	1.0–2.0	1.04	0.08
	6	1 in. BG–1 in. AG	1.0–2.0	0.20	0.06
3.5	1	5–7 in. BG	1.0–2.0	2.96	0.10
	2	5–7 in. BG	1.0–2.0	1.02	0.02
6.5	3	5–7 in. BG	1.0–2.0	1.97	0.14
	4	5–7 in. BG	1.0–2.0	0.94	0.01
10	5	5–7 in. BG	1.0–2.0	0.95	0.06
	6	5–7 in. BG	1.0–2.0	0.61	0.01
3.5	1	12–14 in. AG	1.0–2.0	0.80	0.03
	2	12–14 in. AG	1.0–2.0	0.45	0.01
6.5	3	12–14 in. AG	1.0–2.0	2.28	0.11
	4	12–14 in. AG	1.0–2.0	0.11	0.00
10	5	12–14 in. AG	1.0–2.0	0.06	0.01
	6	12–14 in. AG	1.0–2.0	0.13	0.01

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