Wood Preservation--Preservative Treatment For Hardwood Glued-Laminated Bridges

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Abstract

Pressure-treating cycle guidelines were developed to obtain satisfactory penetration and retention of creosote preservatives in red oak, red maple and yellow poplar glued-laminated timbers. The creosote-treating cycle was used to treat a red oak glued-laminated timber bridge. A retention of 192.2 kg/m^3 (12.0 pcf) of creosote was obtained with penetration of more than 12.7 mm (0.5 inch). The treating cycle guidelines were slightly modified and used to treat a red maple glued-laminated timber bridge. Penetration ranged from 50.8 mm (2.0 inches) to completely through the cross section of the laminated beam with retention exceeding 240.3 kg/m^3 (15.0 pcf). Treatment of red maple bridge material also used a revised "post conditioning" cycle with a low-temperature/vacuum, post-creosote treatment cycle. The modified cycle resulted in an excellent creosote treatment of the red maple glued-laminated timber bridge and the post-treatment was successful in cleaning the surfaces and in controlling bleeding of the preservative.

Keywords: Bridges, Timber, Hardwood, Glued-Laminated, Preservative Retention, Preservative Penetration, Treating Cycle, Dimensional Stability

Background

Exterior use of hardwood glued-laminated timbers will require preservative treatment of the timbers. In general, hardwood species with low specific gravity values are usually treated at pressures and for durations similar to those treating cycles used for softwoods. Koch (1985) reports that hardwood species differ widely in their preservative treating cycle requirements. One caution in treating hardwoods, at least until the data are available, is that the effects of the treating process and/or the type of preservative may cause a reduction in the mechanical properties of the wood. Oil-type preservatives usually result in no appreciable reductions in mechanical properties after treatment since these preservatives apparently do not react with wood chemical constituents. Manbeck, et al. (1995) reports that the flexure properties are not reduced after creosote treatment of red oak, red maple and yellow poplar glued-laminated beams. However, reductions in mechanical properties may occur with oil-type preservatives if American Wood Preservers' Association (AWPA) recommended temperature-time combinations are exceeded during the preservative treatment cycle (Winandy, 1988; Barnes and Winandy, 1986).

The amount of preservative required to protect hardwoods depends on the wood species, service conditions, and type of preservative. Thompson and Koch (1981) have recommended 128.1 kg/m^3 (8.0 lbs/per cubic foot or pcf) retention of whole creosote in assay zones for protection of hardwoods placed in contact with the soil. While this level of retention is acceptable for railroad ties or other non-critical uses, AWPA recommends higher retention levels for bridge timbers and other structural members where failure or replacement is very impractical.

Data on the weatherability of preservative treated wood have been reported. Rietz (1961) reported that oil-type preservatives improved the weathering properties of red oak. The preservatives tested in his study included creosote and pentachlorophenol in various solutions. Baileys, et. al. (1994) reported on the gluebond and structural strength characteristics of hardwood glued-laminated beams treated with creosote. The creosote treated hardwood glued-laminated beams passed the American Institute of Timber Construction (1983, 1987) gluebond performance standards (Baileys, et. al., 1994).

Selbo (1967 and 1975) reported on the effects of eight preservatives, including creosote, on glueline strength for red oak, hard maple, southern pine, and Douglas fir glued-laminated specimens exposed for 20 years in an enclosed, unheated shed. The shear strengths of the resorcinol and phenol-resorcinol resins exposed to these eight preservatives used in the study, were similar to the strength of the wood. In another phase of this study, creosote provided the best protection for preventing checking and large amounts of shrinking and swelling for red oak after 20 years of exterior exposure. Water-borne preservative treatments provided little, if any improvement in protection against checking over the untreated wood. Douglas-fir, southern pine and red oak beams did not develop any appreciable delamination of glue joints after 20 years of exterior exposure. However, the hard maple untreated and water-borne preservative treated beams had appreciable glueline delamination. Study results identified creosote treatments, for glue-laminated beams subjected to exterior exposure, as providing enhanced weatherability along with desired protection against wood destroying organisms.

Data on the efficacy and service life of various hardwoods treated with several preservatives and exposed to the environment have been reviewed and published by Thompson and Koch (1981) and Koch (1985). All preservatives improved the service life over the untreated controls. However, creosote-treated hardwoods had the longest service life compared to the next best preservative treatment (usually pentachlorophenol). The waterborne metallic preservatives usually had the shortest service life compared to the other preservatives tested with hardwoods (Thompson and Koch, 1981).

Hardwoods are susceptible to degradation by soft rot fungi and, therefore, the preservative must be impregnated into the cell wall (Vick and Baechler, 1986; Gjovik and Gutzmer, 1989). The susceptibility to being degraded by soft rot fungi is directly related to the efficacy of wood preservatives. Certain salt solutions (e.g., copper sulfate, zinc sulfate, sodium chromate and arsenic acid) investigated as a wood preservative did not have a high efficacy in hardwoods. Zinc compounds are not effective in preventing soft rot in hardwoods. The lack of efficacy maybe associated with certain hardwood species that are difficult to treat. However, the exact reason zinc and copper compounds used as wood preservatives are ineffective in preventing soft rot in hardwoods is unknown (Vick and Baechler, 1986).

Based on the reports and a long history of success in treating railroad cross ties, creosote appeared to bean excellent choice as the preservative treatment for hardwoods. However, only a limited data base has been available on treatability and serviceability of hardwood glued-laminated timbers.

A number of researchers have summarized the effects of migration and mitigation of wood preservatives from treated wood products in the environment (Lamar and Kirk, 1994; Davis, Glasser, Evans and Lamar, 1993; Lamar, Evans and Glaser, 1993; Webb and Gjovik, 1988). Webb and Gjovik (1988) concluded that preservatives did not significantly migrate and/or accumulate in the environment after migration from the treated wood. Lamar and Kirk (1994) summarize the results of many research projects and conclude the microbiological treatments may be used as remediation of pentachlorophenol and creosote contaminated soils. Treated wood products and wood preservatives can be safely used with proper precautions (Lamar and Kirk, 1994; Davis, Glasser, Evans and Lamar, 1993 Lamar, Evans and Glaser, 1993; Webb and Gjovik 1988).

The purposes of this research were: 1) to determine the creosote treatability (penetration and retention) of three hardwood species glued-laminated timbers; 2) to develop guidelines for a pressure treating cycle to obtain satisfactory penetration and retention of three hardwood species glued-laminated beams; and 3) to demonstrate the applicability of the treating guidelines by treating red oak and red maple glued-laminated timber bridges. The data for this research were obtained and analyzed for red oak *(Quercus rubra),* red maple *(Acer rubrum),* and yellow poplar *(Liriodendron tulipiferu)* glued-laminated beams.

Experimental

Laboratory preservative treatment cycle studies used red oak, red maple, and yellow poplar glued-laminated specimens treated at Koppers Industries, Inc. These studies were used as the basis for forming the guidelines for the treating cycles used to treat the hardwood glued-laminated test specimens. After the preliminary laboratory studies, additional red oak, red maple, and yellow poplar were manufactured into glued-laminated beams and subsequently treated with creosote to determine if glued-laminated hardwoods maybe treated to the levels recommended in AITC 109-84. Each glued-laminated hardwood species was treated at Koppers Industries, Inc., using creosote at a selected treatment cycle with a minimum of 6 replications on 6-ply laminated beams produced from 25.4 mm (1.0 inch) ply beams 152.4 x 152.4 x 1828.8 mm (6.0 inches x 6.0 inches x 6.0 feet). Average gross retention and assay retention in kilograms per cubic meter or kg/m^3 (pounds per cubic feet or pcf) of each beam was determined. The depth of penetration was measured on each lamination. The individual tests sampled the three wood species, six beam treatment replications, and each lamination.

The preliminary treatment tests were used to develop recommended empty cell treatment cycle guidelines. These guidelines formed the basis for the treatment of the red oak and red maple glued-laminated timber bridges.

Results and Discussion

The treatability test samples were 6-ply laminated beams produced from 25.4 x 152.4x 1828.8 mm (1.0 inch x 6.0 inches x 6.0 feet) red oak, red maple and yellow poplar lumber. Three beams of each species, along with three additional incised yellow poplar beams, were treated with creosote solution meeting American Wood-Preservers' Association (AWPA) P2 Standard. These were treated in a charge of oak crossties at the Koppers Industries, Inc. Susquehanna Treating Plant located near Wllliamsport, PA.

Retention was determined by gauge, weight difference and assay for all 12 test pieces. Penetration and assay assessments were made by cutting each beam at the midpoint and removing a cross-sectional wafer 12.7 mm (0.5 inch) in thickness. Retention data for these samples are presented in Table 1 as average weight difference and assay under the standard treating cycle. Assay extraction followed the AWPA A6 procedures on an assay zone of the outer 15.2 mm (0.6 inch) of wood.

Baileys, et. al., (1994) reported that retention of preservative was acceptable in these initial samples but due to variable penetration in the beams, additional glued-laminated specimens were prepared. The extra samples would be treated by varying the treating cycle parameters of temperature, time and pressures to determine a cycle that would achieve improved penetration on the edges of the laminates. As a result, the following empty cell cycle guidelines were recommended to treat red oak, red maple and yellow poplar glued-laminated materials with creosote or creosote solution (Baileys, et. al., 1994):

- Initial air pressure should be between 137.9-206.9 kPa (20-30 psi);
- Creosote should be introduced into chamber and pressurized to 1034 .3-1379.0 kPa (150-200 psi). Actual pressure is species dependent;
- Treatment temperature should be between 87.8-98.9°C (19O-21OºF);
- Treatment temperature and pressure should continue until 192.2 kg/m^3 (12.0 pcf) retention (by gauge) is achieved;
- Following pressure cycle, the pressure should be released in a slow step-down manner over a one-hour period;
- During the "slow press release," an expansion bath should be used with an increase in temperature in the treating cylinder of 5.6°C (10°F);
- Remove the creosote and apply a minimum vacuum of 74.3 kPa (22.0 inches) of mercury for two hours;
- Release vacuum and, if possible, steam-clean the surface of the glued-laminated members for one hour; and
- A final minimum vacuum of 74.3 kPa (22.0 inches) of mercury is applied to treated members for two hours. Actual vacuum varies with altitude.

As a means to verify this proposed cycle, six replications of 6-ply glued-laminated beams for each hardwood species were again treated in a commercial operation. The previous performance of yellow poplar was not improved by incising; therefore, this test did not include incised yellow poplar test samples, The results using this adjusted treating cycle are also included in Table 1 (Baileys, et. al., 1994). Penetration was improved in both red maple and yellow poplar using the adjusted cycle. Red oak had exceptionally good penetration using both the preliminary and adjusted cycles.

Gluebond performance data including cyclic delamination, shear strength, percent wood failure, and end-joint performance are presented in Labosky, et al. (1993), Janowiak, et al. (1993), and Baileys, et al. (1994). The effects of creosote treatment on the performance of red oak, yellow poplar and red maple are presented by Manbeck, et al. (1995).

Table 1—Creosote Treatment of Glued-laminated Test Beams (Baileys, et. al., 1994)

SPECIES	CREOSOTE RETENTION: PRELIMINARY TREATMENT CYCLE: WEIGHT RETENTION pcf	kg/m³	ASSAY Combined[a] pcf	kg/m³	ASSAY Edge[b] pcf	kg/m³	ADJUSTED CYCLE: WEIGHT RETENTION pcf	kg/m³	ASSAY Edge[b] pcf	kg/m³
Red Oak	5.9	94.5	6.95	111.3	5.92	94.8	11.2	179.4	9.77	156.5
Red Maple	12.5	200.2	13.79	220.9	13.64	218.5	18.3	293.1	22.95	367.6
Yellow Poplar	10.6	169.8	10.76	172.4	12.94	207.3	16.1	257.9	16.22	259.8
I-Yellow Poplar[c]	10.0	160.2	10.74	172.0	10.55	169.0	NOT INCLUDED			

[a]Combined sample assay values are weighted average of edge and face laminates.
[b]Assay zone 0-15.2m (0-0.6") from edge of laminates only.
[c]I-Yellow Poplar = Incised Yellow Poplar.

Red Oak Glued-Laminated Bridge Preservative Treatment Summary

The northern red oak lamination materials used to construct the hardwood glulam demonstration bridge in Ferguson Township, Centre County, Pennsylvania, were treated with creosote solution at the Koppers Industries Susquehanna Treating Plant in Muncy, PA, using pressure process methods and P-2 creosote solution meeting the American Wood Preservers' Association Standards. The treating took place in two separate charges due to lamination assembly difficulties involving the bridge rail and post components. The beams, back walls, deck panels and diaphragms were treated on September 18, with the post and rail material arriving on October 4, 1991.

The lumber used to fabricate the bridge components had been kiln-dried below 16% average moisture content prior to gluing and the assembled pieces were wrapped and covered with water repellent paper to maintain this dry condition. One beam had a distinct separation along a glue line before treatment on one end and a few other minor separations were observed, but none were extensive enough to cause concern. The beam with the separated glue line was repaired at the construction site.

Lamination and fabrication were performed prior to preservative treatment and the preassembled components were loaded onto tram cars with 19.1 mm (0.75 inch) cable used as stickers to separate the layers. This allowed for better heat transfer and flow of the treating solution around and into the wood during pressure and vacuum cycles inside the retort cylinder.

There were 33.9 m^3 (1197.0 cubic feet) of bridge material in the first charge loaded on September 18 with the balance of this cylinder charge material consisting of air-dry oak industrial grade crossties. The treating cycle used included the following parameters:

• Initial air pressure . . . . 275.8 kPa (40 psi)
• Fi1l cylinder against initial
  air with preservative . . . 82.2°C (180°F)
Ž Pressure period . . . . 1275.6 kPa (185.0 psi)
  4 hrs.
• Cylinder temperature raised from 82.2°C to
  100°C (180°F to 212°F) during pressure
• Pressure release and maintain . 100°C (212°F)
  2 hrs.
• Preservative pumped back . . . . 50 minutes
• Final vacuum . . . . 91.2 kPa (27.0 in. Hg)
  3hrs.

Two core borings, 76.2 mm (3.0 inches) in length, were removed from each piece of bridge material to visually determine preservative penetration and provide samples for assay extraction to determine the level of retention.

Eighteen borings were taken from the beams with nine from face laminates and the other nine from inside laminates. All but two face laminate cores had 100% penetration of the annual rings in the 76.2 mm (3.0 inch) boring. Inner laminate cores obtained 51% (average) penetration of the annual rings in the 76.2 mm (3.0 inch) samples. Combining the penetration measurements of inner and face cores resulted in the beam samples having 83% of the annual ring count penetrated with preservative solution.

The deck panels were also bored and inspected for depth of penetration. Both face cores and inner laminate cores were again evaluated with face laminates exhibiting a more complete penetration of the wood by the creosote. The combined total ring count was 72% penetrated in the deck panel samples. Both the beam and deck panel borings meet the requirements for average penetration of 65% of annual rings in red oak as stated in the AWPA C2 Hardwood Lumber and C6 Crosstie Standards.

At the present time, hardwood retention of preservative using gross injection or gauge retention is determined by the total weight of preservative used to treat the volume of material. By this method, the retention of preservative in the deck and beam material was 205.0 kg/m^3 (12.8 pcf). However, an assay by solvent extraction was performed following the AWPA A6 Standard for determination of oil-type preservatives and water in wood. The deck and beam samples were assayed as two separate samples using the 0-25.4 mm (0-1.0 inch) zone from each boring. Results showed 262.7 kg/m^3 (16.4 pcf) in the beams and 241.9 kg/m^3 (15.1 pcf) in the deck panels. These levels easily meet the 192.2 kg/m^3 (12.0 pcf) soil contact retention requirements for softwood glulam structural members for highway construction specified in AWPA C14 Wood for Highway Construction Standard.

A second set of core borings were obtained from the post and bridge rail components treated in the later charge of material. Measured penetration was in a range of 19.1 to 63.5 mm (0.75 to 2.5 inches). The average was 38.1 mm (1.5 inches) for the 10 boring cores inspected. An assay was performed using the O-25.4 mm (0-1.0 inch) zone of wood resulting in a 145.8 kg/m^3 (9.1 pcf) retention, also meeting the specified creosote retention of 128.1 kg/m^3 (8.0 pcf) for sawn bridge (hand or guide) rails not in contact with ground or water as stated in C14.

The test bridge material of laminated red oak readily accepted preservative treatment with creosote solution in terms of both penetration and retention evaluations. Face lamination penetration was extremely good in all samples tested with acceptable but somewhat more variable penetration observed in the cores removed from inner laminates. Retention by gauge reading determination exceeded AWPA Standards for hardwood lumber in soil contact and using a 0-25.4 mm (0-1.0 inch) assay zone also gave results higher than specified for similar structural materials from softwood species.

The design of the red oak glued-laminated bridge included a 12.7 mm (0.5 inch) gap between deck panels. The gap would allow the deck panels to expand as they increased in moisture content from a average of 12% to approximately 20% during in-service. During treatment, the deck panels adsorbed moisture and expanded to between 3.2 and 19.1 mm (0.125 and 0.75 inches). The average expansion was 12.7 mm (0.5 inches).

Incidental preservative bleeding due to the kickback of the treating solution from the hardwood glulam was a cause of some concern at the construction site. This is common when treating kiln-dried materials which tend to trap initial air inside the wood cells and also retain a very heavy amount of preservative near the surface. Modification to the treatment cycle using additional cleanup cycle time with extended heat and vacuum to remove the initial air and clean excess creosote from the surface and/or use of a clean distillate creosote preservative may eliminate much of this problem.

Red Maple Glued-Laminated Bridge Preservative Treatment Summary

Red maple is considered an under-utilized source of hardwood lumber and timbers in many of the northeast states, especially Pennsylvania. The resource is plentiful, and one alternative to enable a utilization of this species is to manufacture glued-laminated materials. Although creosote preservatives are recognized as the primary treatment choice for hardwood timbers to be used in structural components, consideration must be given to alternative preservatives where there is human contact potential of the bridge (guide or hand) rail systems. Waterborne arsenical treatment chemicals are acceptable preservatives for softwood species when a clean, dry, nonoily surface is critical (such as backyard decks, porches, furniture and playground equipment). However, the experience in using these chemicals in hardwoods is limited because there is no water repellency provided to the treated hardwoods to prevent the development of moisture related defects. A recent development by Hickson Corp. and Koppers Industries, Inc. of an oil emulsion/waterborne system which injects an oil and wax combination into the outer 25.4 mm (1.0 inch) zone created the opportunity to test this new preservative system on the guide railings of this bridge.

The red maple bridge components were laminated from kiln-dried material (average 12% moisture content) prior to treatment. Creosote preservative treatment of the beams, deck panels, guide posts and diaphragms used as structural components 27.7 m^3 (977 cu ft) was conducted on June 13, 1995, at the Koppers Industries Susquehanna Plant located in Muncy, Pennsylvania. The glued-laminated bridge rail sections were shipped to the Koppers Industries treating plant in Montgomery, Alabama, to receive the two-step CCA/oil emulsion treatment available at that location.

Creosote Treatment — The treating cycle used with the red oak glued-laminated timber bridge was modified for the red maple girders and deck panels and included the following parameters:

- Initial air pressure . . . . 172.4 kPa (25.0 psi) for 0.16 hrs.
- Fill the cylinder . . . . 88.9°C (192°F) for 1.08 hrs.
- Pressure . . . . target retention 192.2 kg/m^3 (12.0 pcf gauge) 1275.6 kPa @ 95°C (185.0 psi @ 203°F) for 4.00 hrs.
- Blowback preservative . . . . 0.75 hrs.
- Vacuum . . . . 87.8kPa (26.0 inches Hg) for 5.00 hrs.
- Pump drips & break to atmospheric pressure 0.16 hrs.
- Final Vacuum . . . . 87.8kPa (26.0 inches Hg) for 2.00 hrs.
- Total time of treating . . . . 13.15 hrs.

The balance of the charge treated with the bridge components were crossties, and the gauge retention injected during this treating cycle was 205.0 kg/m^3 (12.8 pcf) which includes the amount of treatment in the crossties.

Assay retention analysis is required on all commodities except crossties in the American Wood-Preservers' Association Standards; therefore, the bridge material was bored for penetration and creosote assay retention. The retention was determined on the 0-25.4 mm (0-1.0 inch) zone of wood for both the deck panels and beams as separate units using 10 borings from each group for the AWPA A6 Toluene Extraction Assay. The results of these analyses were 338.0 kg/m^3 (21.1 pcf) for the deck panel samples and 339.6 kg/m^3 (21.2 pcf) for the beams.

Retention by assay is based on the actual volume of wood sample analyzed; whereas, the gauge retention is calculated using the total volume of wood in the charge and the total weight of preservative injected during treatment. There can be as much as 40 to 60 percent of the wood in the center of an individual piece that does not contain preservative, depending upon the species and moisture content. Also, the treated portion of wood has a gradient of preservative which decreases as the depth of penetration toward the center increases, and the greatest amount of preservative is contained in the outer 6.4 to 12.7 mm (0.25 to 0.50 inch). Therefore, this outer 25.4 mm (1.0 inch) zone will have the highest concentration of creosote when retention by assay is determined.

Kiln-dried material very often creates a problem in treating with any oil-type preservative because the potential exists to retain an excessive amount of oil in the outer extremely dry wood cells. This problem was experienced in this charge and caused an oil residue to collect on the treated material; therefore, all of the bridge components were pressure washed to remove the excess preservative from the surface. A concern remained and was supported by the high assay retention, that the material may have a potential to bleed preservative when put into service unless some of the creosote could be extracted. To address this concern, a post-conditioning low-temperature/vacuum steaming, cycle was developed and used to "clean" the surface and improve the overall condition of the material.

The low-temperature/vacuum steam, cycle subjects the material to a closed system steaming which raises the temperature to 65.6-68.3°C (150-155°F) by use of steam produced by covering the heating coils inside the cylinder with water. This eliminates the exposure of the material to any live or high temperature steam directly from the boiler. After reaching this temperature, a vacuum was applied at 74.3 -81.1 kPa (22.0-24.0 inches of Hg) with the temperature adjusted to allow a small amount of water to be pulled from the condenser unit indicating some vapors were being removed. This condition was held for 24 hours, then the remaining water and creosote extracted during the cycle was pumped from the cylinder followed by a three-hour final vacuum period to reduce the vapors and cool the material.

The low-temperature/vacuum steaming, cleanup cycle resulted in a lower assay retention of the bridge deck and beam components. The consistent original assay results on the outer 25.4 mm (1.0 inch) zone of these two groups, performed separately, allowed the assay of twelve borings following the low-temperature/vacuum steaming, cleanup cycle to be combined into one extraction sample. The results of this retention assay were 269.1 kg/m^3 (16.8 pcf) in the outer 25.4 mm (1.0 inch) zone with a 9.4 percent moisture content, indicating the success in reducing preservative retention while not increasing the moisture level of the wood in these components. The vacuum, low-temperature steaming, cleanup cycle was very successful in cleaning the surfaces of the red maple glued-laminated bridge components and removing the air trapped inside the components. The process eliminated all in-service bleeding of the creosote except for one component which had been accidentally dead-stacked preventing the cleanup of the surface.

Preservative penetration was determined using the requirements specified in *AWPA C28 Standard for Glued-Laminated Members.* Although the current Standard does not contain any hardwood species, proposals have been made to have red maple, red oak and yellow poplar included. All core borings of the deck panels and beams were taken from the edge of laminates in the center of the laminated component. After the original treatment, the twenty borings showed complete penetration of the creosote to a depth of 63.5 mm (2.50 inches) or more with some borings in excess of 76.2 mm (3 inches) in length.

The design of the red maple glued-laminated bridge included a 6.4 mm (0.25 inch) gap between deck panels. The purpose of the gap was to allow the panel to expand as the moisture content increased from an average of 12% to approximately 20% after installation of the bridge. During the creosote treatment process, the panels adsorbed moisture and expanded to between 3.2 and 6.4 mm (0.125 and 0.25 inches). Consequently, the edges of the deck panels were butted together during installation.

CCA/Oil Treatment — The bridge rail components to be treated with the CCA/oil emulsion system were shipped to the Koppers Industries plant located in Montgomery, Alabama. These four pieces were treated in a charge of southern pine poles with a target retention of 9.6 kg/m^3 (0.6 pcf) by assay with a follow-up treatment using the oil emulsion. Again, the AWPA C28 Standard was used as a guideline for the inspection after treatment.

Twenty borings were removed from the four units and used for both penetration and assay determinations. There were two borings taken from separate face laminates on each of the bridge rails with the remaining three from the inner laminates near the center of the piece. One boring of the twenty failed to meet the 12.7 mm (0.5 inch) penetration criteria, but two rejects are allowed in the Standard to accept the treatment. The reject boring had minimal surface penetration, but all other borings had 15.2 mm (0.6 inches) or deeper with the average penetration of the CCA treatment being 30.5 mm (1.2 inches).

Assay retention analysis was conducted using an LCA X-ray fluorescence analyzer to determine the amounts of the copper, chromium and arsenate in the wood. The assay zone used in CCA material was 0.0-15.2 mm (0.0-0.6 inch) as stipulated in the C28 Standard, and this material resulted in a 12.8 kg/m^3 (0.8 pcf) retention. This retention is higher than the amount recommended for in-soil contact of hardwoods treated with CCA in USDA (1981). Before continuing with the oil emulsion treatment, the materials were air dried for three weeks to remove excessive surface moisture and enhance penetration of the oil emulsion.

After surface checks began to develop, the oil emulsion treatment was performed. The decision had been made to avoid the larger diameter boring normally conducted to obtain the sample necessary to assess the retention of oil using this treatment system and to accept the material as satisfactory without an assay being conducted for the oil. However, the oil retention was determined to be 19.2 kg/m^3 (1.2 pcf) in the outer 12.7 mm (0.5 inch) on the southern pine poles treated in the emulsion charge with the red maple laminated bridge rails.

Recommended Guidelines Summary

The characteristics of treating cylinders vary and each treating plant may require slight modifications to the recommended guidelines. The ultimate objectives of these guidelines for treating hardwood glued-laminated timbers are to achieve a minimum retention of 192.2 kg/m^3 (12.0 pcf), to have a clean surface, and to eliminate in-service bleeding. The following empty cell treating guidelines are recommended to treat red oak, red maple and yellow poplar glued-laminated timbers with creosote or creosote solutions:

- Initial air pressure should be between 137.9-206.9 kPa (20-30 psi)
- Creosote should be introduced into chamber and pressurized to 1241.1 -1310.1 kPa (180-190 psi) at 82.2 - 87.8°C (180-190°F)
- Treatment temperature should be maintained at between 93.3 and 100°C (200 and 212°F)
- Treatment temperature and pressure should continue until 192.2 kg/m^3 (12 pcf) retention (by gauge) is achieved.
- Release pressure and maintain 100°C (212°F) for a minimum of 1 hour (expansion bath at 5.6°C (10°F) above treating temperature)
- Pump back preservative
- Vacuum at 87.8 -91.0 kPa (26-27 in Hg) for 4-5 hours
- Break to atmospheric pressure
- Vacuum at 87.8-91 kPa (26.0-27.0 in. Hg) for minimum of 2 hours

- Vacuum, low-temperature steam, treatment cycle:
  - a) Cover the heating coils inside the cylinder with water
  - b) Raise the temperature in the cylinder to 65.6 - 68.3°C (150-155°F)
  - c) After reaching the temperature apply a vacuum of 74.3 -81.1 kPa (22.0 to 24.0 in. Hg) for a minimum of 24 hours
  - d) Remove water and creosote from the cylinder
  - e) Final vacuum at 74.3 -81.1 kpa (22.0-24.0 in. Hg) for 3 hours
- Total minimum time in treating cylinder - 40 hours.

All glued-laminated timbers should have wood stickers placed between the components and should be securely attached using nylon straps or steel bands to the tram cars in order to minimize flotation of the timbers in the creosote solution. If the possibility exists that the outside of the timbers may be damaged due to bumping an object, wood bumper guards or similar material should be placed on critical edges or areas. Use of the recommended treating cycle guidelines along with proper handling procedures will produce undamaged glued-laminated timbers that meet the desired penetration and retention requirements.

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