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Through-Treating Post-MPB Lumber: Technical Feasibility and Process Development

by

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Summary

Preservative treatment to achieve termite and decay resistance has potential to develop new products and markets for post-MPB lumber. The objective of this work was to determine the feasibility of through treating post-MPB lumber to reduce Canada's competitive disadvantage versus US southern pine and New Zealand radiata pine in markets where termite and decay resistance is important. Post-MPB sapwood has increased permeability but the heartwood is unchanged from its normal low permeability. There is an opportunity to take advantage of the increased permeability of the sapwood in treated lumber with minimal heartwood content. Another potential advantage of treating is the ability to mask bluestain discolouration. Post-MPB lumber was sorted into a heavy stain group (stain across three sides) and a non-sorted group of mixed proportions of heartwood and sapwood. Both non-dried (ND) and kiln-dried (KD) lumber, the latter with planed or combed surface, was pressure treated with borate using a conventional process then stored to allow moisture equilibration. Additional KD lumber was pressure treated with borate at a higher solution temperature and with alkaline copper quaternary (ACQ). Further material, stained and mixed, planed and combed, was treated with a novel accelerated process involving a dip followed by 72 hrs kiln conditioning.

The stained sort, either pressure treated with DOT or with the dip plus 72hr kiln conditioning gave through treatment (over 85% cross section) after one week storage, comparable to requirements for Southern Pine. Lumber sorted for heavily stained sapwood content resulted in about twice the uptake from pressure treatments. ACQ treatment gave substantial penetration only in sapwood, with a very thin shell in the heartwood. A higher temperature DOT solution did not increase uptake from pressure treatment. Pressure treatment uptakes were lower in non-dried wood than in kiln-dried wood. Pressure treatment of kiln-dried lumber with DOT at 20°C met penetration and retention targets only with stained sort combed samples. Pressure treatment of kiln-dried lumber with DOT at 35°C met penetration and retention targets only with stained sort planed (combed not tested) samples. None of the pressure treatments had heartwood penetrations with 80% at or over 10mm even after 2 weeks storage whereas dip-plus-kiln-conditioning treatment met this requirement for mixed sort planed and combed with Treatment 1 and mixed sort combed with Treatment 2 after one week.

Dip-plus-kiln-conditioning uptake was greater on combed surfaces but, strangely, this was not reflected in increased borate loading. Dip-plus-kiln-conditioning Treatment 2 uptakes and retentions were greater than in dip-plus-kiln-conditioning Treatment 1. The dip-plus-kiln-conditioning process increased the wood moisture content to 20% to 30% MC, with the greater increases resulting from dip-plus-kiln-conditioning Treatment 2. Process modifications will be needed to reduce the moisture uptake or bring the moisture content down to below 20% before shipping to prevent problems with stain and mold.

The dip-plus-kiln-conditioning process met penetration and retention targets with stained sort planed or stained sort combed samples treated with dip-plus-kiln-conditioning Treatment 2. Targets were met immediately after treatment. None of the data adequately reflects the difference in uniformity of treatment between the pressure treatment and the dip-plus-kiln-conditioning treatment. Dip-plus-kiln-conditioning treatment gave a much more uniformly penetrated shell around the whole cross section, though this was not reflected in the analyzed heartwood retentions.

Further refinements are needed to the dip-plus-kiln-conditioning process, but these will likely be customized for each sawmill depending on whether spray or dip is used to apply the formulation and the type of kiln used for conditioning. The lack of relationship between analysed retentions, uptakes and penetrations in the dip-plus-kiln-conditioning process requires further investigation.

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1 Objective

To determine the feasibility of through treating post-MPB lumber to reduce Canada's competitive disadvantage versus US southern pine and New Zealand radiata pine in markets where termite and decay resistance is important.

2 Introduction

British Columbia is faced with harvesting large volumes of mountain pine beetle (MPB) affected lodgepole pine (*Pinus contorta* Dougl.) trees and funneling products made from these trees into existing or new markets. It is almost as if the industry were forced to shift to a new tree species with very different properties. With the support of Forest Innovation Investment and the Canadian Forest Service Mountain Pine Beetle Initiative, Forintek has put considerable effort into characterizing this new resource in terms of challenges in processing and properties that will affect certain end uses (Byrne 2003, Lum 2003, McFarling and Byrne 2003, Williams and Mucha 2003). This project capitalizes on documented properties of post-MPB wood, such as low moisture content, coloured sapwood and increased permeability (Byrne 2004, McFarling and Byrne 2003, Oliveira, et al 2005).

Currently Post-MPB lumber is going to existing markets in the US south and new markets in Asia, both areas where termites are a major issue. Production of termite-resistant framing may prove key to maintaining the existing 6 billion FBM (US$1.75 billion) market for SPF framing in the US South (Baker *et al.* 2001) and to developing new markets in China, India, Taiwan and elsewhere in Asia (Cartwright *et al.* 1998, Iverson and Jahraus 2004). The Formosan subterranean termite, now expanding its activities in the US south, was introduced from southern China and Taiwan by way of Hawaii where it has been established for 150 years. This termite species is regarded as one of the most aggressive in the world, and consequently, treated wood framing has been mandatory in Hawaii for decades (Manning 2004). This market saw a shift towards steel framing, 40% in 2002, which has since receded due to the increased cost of steel. However, the Steel Framing Alliance is targeting a 25% share of the US residential construction market and using termite resistance as a key marketing tool. The Portland Cement Association in association with the US National Home Builders Association is promoting concrete homes as termite resistant.

It is estimated that preservative treatment adds approximately US$3,000 to the cost of a 2000 sq ft house. According to data from the Louisiana State University Agricultural Center (http://www.lsuagcenter.com/en/environment/insects/Termites/formosan_termites/), using steel framing adds US$9,000, fumigating once costs US$5,000 and has no residual effect, so the termites can come back shortly thereafter. Repairing typical Formosan termite damage costs US$15,000. Despite these numbers, builders cite cost as the major reason for not using treated framing (Gaston and Vlosky 2004). This objection would be easier to overcome if the cost of treating could be reduced by two thirds by shifting from conventional pressure process to a novel accelerated process.

In areas of Asia where the Formosan termite or related species (*Coptotermes spp.*) are endemic, termite-resistant framing may be the only way to ensure performance comparable to concrete and steel, currently the preferred construction materials (Cartwright *et al.* 1998, Iverson and Jahraus 2004). In China, "FII had identified business opportunities for BC wood products in three key areas 1) Building products 2) Value added products and 3) Components or products for further remanufacture in China" (FII Strategy 2004). Termites are a major concern for buildings in China, particularly in Guangdong and Hainan where 90% of residential property is infested with Formosan termites. In Guangxi, Hunan, Fujian, Hubei, and

Anhui about 60% are infested (Zhong and Liu 1994). Termite resistant framing lumber represents an added value building product for these areas (Cartwright *et al*. 1998).

This work may also help to reduce the cost of treated wood used in repairing leaky condominiums in southwestern BC (Towslager 2004).

A major benefit of producing preservative treated product from MPB-killed lumber is that the colour of wood preservatives or added colourants may mask the bluestain (Byrne 2004, Chow 2005). The copper-based alternatives to Chromated Copper Arsenate are green, and blue dye is added to borates for inventory control.

Turning post-MPB lumber into preservative treated framing effectively turns a resource problem into a solution for a market access problem. The resource problem with post-MPB lumber is the amount of bluestained sapwood considered visually undesirable in certain markets (Chow 2005). The problem for BC industry in markets that require treated wood is that our commercially important wood species consist primarily of difficult to treat heartwood whereas our competition, southern pine and radiata pine sapwood, can be readily through treated (Morris 1999). This translates into increased treating costs attempting to meet standards and a disadvantage in the marketplace where our competitors point to the limited depth of preservative penetration in our species. The Southern Pine Council is aggressively promoting treated framing (http://www.southernpine.com/whatisptlumber.shtml) because it believes this will shift the market away from SPF, which requires incising (perforation) for most treated applications. Borate treatment does not require incising (Baker *et al.* 2001) and is preferred due to its low mammalian toxicity, cost effectiveness against termites and decay, lack of VOCs and ability to penetrate BC wood species. Forintek also identified a novel accelerated treating process that had not yet been commercialized in North America and that showed promise for a lower cost treatment method for post-MPB wood.

Post-MPB sapwood has increased permeability but the heartwood is unchanged from its normal low permeability (Byrne 2004, McFarling and Byrne 2003, Oliveira et.al. 2005). If we are to take advantage of the increased permeability in the sapwood, we need to minimize the heartwood content of the material. MPB attack larger trees that may have wider sapwood thus it may be possible to produce boards high in sapwood (Byrne 2004). Normally it is difficult to distinguish sapwood from heartwood, but the stain fungi carried by the beetle stain the sapwood, making it easily identifiable (Byrne 2004). Selecting boards stained on three sides will maximize treatable sapwood. Research at Forintek has shown air-drying is the best method of reducing wood moisture content prior to preservative treatment (Morris *et al.*1998). Logs from MPB-killed trees are already dried on the stump to moisture contents between 20 and 40% (Obermajer and Zaturecky 2005), ideal for treating (Morris 1991). By avoiding kiln drying prior to treatment we may be able to maximize treatability. Pressure treatment of framing lumber normally requires kiln drying both before and after treatment, substantially adding to the cost of this product. Eliminating one of the initial kiln drying steps could make the product more competitive. By using a combination of processes that improve penetration into heartwood (Baker *et al.* 2001) we aimed to produce through treated lumber, directly competitive with southern pine and radiata pine. By using the accelerated treatment process we hoped to dramatically reduce the two-week storage time currently required for SPF and thereby reduce inventory costs. This process is also designed to eliminate the post-treatment re-drying step, thus reducing costs. It had been found to be effective on New Zealand plantation grown Douglas fir. A visit to New Zealand by the senior author (see appendix) resulted in several recommendations to improve the research plan. Chief among these was the addition of combed surface material to improve initial preservative uptake.

3 Staff

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4 Materials and Methods

4.1 Materials

The source material for this test was non-dried (rough) post-MPB 8 ft 2 x 6 inch lumber supplied by Canfor's Isle Pierre Sawmill. Three packages were shipped to Forintek where pieces appropriate for production of four end-matched 0.46 meter long samples were labeled and separated into two sets, "A" and "B". Each set consisted of sixty pieces selected with stained sapwood on one wide face and 90% of the two edges (stain sort), and sixty non-selected (mix sort) pieces with varying amounts of stained sapwood, unstained sapwood, and heartwood. All pieces were sawn in half, with a 50mm section removed from the centre of each piece for gravimetric determination of moisture content (MC). The average moisture content of the lumber supplied from the mill was 60% (standard deviation of 36). One 0.46-meter sample was removed from each piece of set B for treatment in the non-dried state. The remaining lumber of both sets was kiln-dried at Forintek to a target of 14% MC, using the previously determined MC as a guide for the drying schedule. Moisture meter measurements of the dried lumber coming out of the kiln was typically about 12% MC.

The dried lumber was planed on four sides or "combed" on four sides before being cut into 0.46 meter samples in preparation for treating, as shown in Figures 1 and 2. Treatments consisted of two preservatives used commercially in Canada, Disodium Octaborate Tetrahydrate (DOT) and alkaline copper quaternary carbonate (ACQ-D carbonate), both applied using a pressure process, and a novel borate formulation proposed for use in Canada using a dip-plus-kiln-conditioning process.

The "combed" surface was prepared using a special cutting head manufactured to produce small grooves on the wood surface to increase surface area. The grooves produced were cut lengthwise and were 1.0 mm peak to valley and 1.7 mm peak to peak. The ridges between the grooves were rounded for ease of handling the lumber. All samples were end-sealed with two (for dip treatments) or three (for pressure treatments) coats of a two-part epoxy. Each treatment consisted of sixty samples. The distribution of samples into sets, groups and treatments is shown in Figures 1 and 2.

Alkaline copper quaternary carbonate (ACQ-D carbonate) was supplied by Chemical Specialties Inc. Treating solution was prepared at Forintek and the concentration was verified by analysis.

Disodium Octaborate Tetrahydrate (DOT) was supplied by Timber Specialties Co. The treating solution was mixed at Forintek and verified by analysis.

The novel borate formulation ingredients were sourced by Kop-Coat Inc. Kop-Coat staff prepared the formulation and were present during treatment.

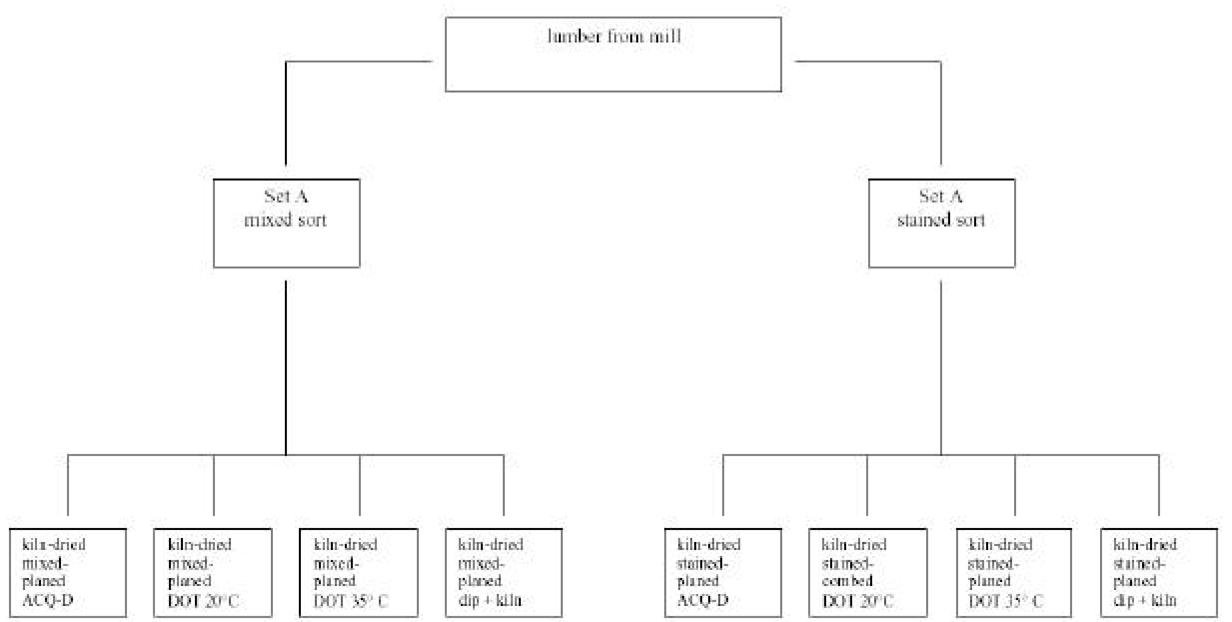

Figure 1. Distribution of Samples - Set A

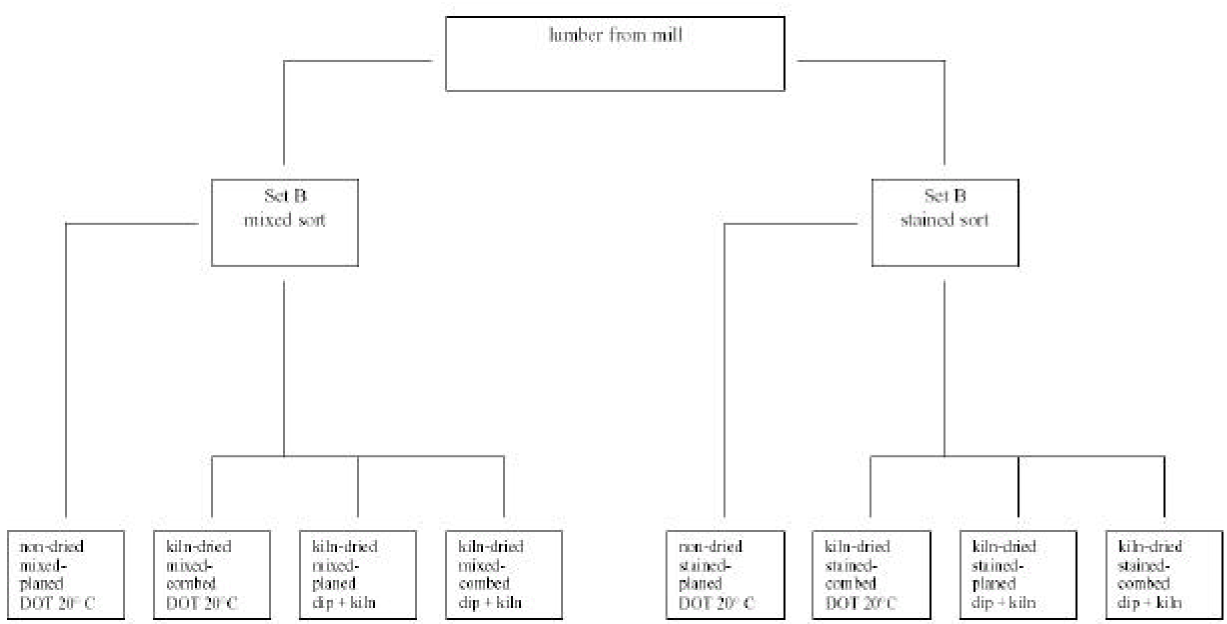

Figure 2. Distribution of Samples - Set B

4.2 Pressure Treatments

Two treatments were done with ACQ-D at 20°C using a standard pressure schedule targeting above ground retention (4 kg/m^3) in sapwood. A 30-minute vacuum was followed by a 2-hour press at 1035 kPa and a final vacuum for 15 minutes using a 1.8% ACQ-D solution. Samples were weighed before and after treatment. Immediately after treatment the samples were close piled and wrapped on six sides with plastic sheet. After one week of storage, a 50mm sub-sample was removed from each sample. The 50 mm sub-samples were dried in an oven at 50°C. A 5mm slice was removed from within the sub-sample. Simulated cores, 10mm wide and 16mm deep, were cut from one edge and from the heartwood face of each 5mm slice for determination of ACQ-D retention. The sixty samples of each treatment were divided into three groups of 20. Simulated cores were pooled for analysis of edge and heartwood faces in each group of 20. A fresh-sawn surface of the remaining sub-sample was sprayed with chrome-azurol indicator to assess penetration measured three ways: from one edge, from the heartwood face, and percent total cross-section.

A standard pressure schedule targeting Formosan borate retention (2% BAE sampled from board edges and 0.7% BAE sampled from the heartwood face) was used for the DOT treatments at 20 and 35°C. A 30-minute vacuum was followed by a 2-hour press at 1035 kPa and a final vacuum of 15 minutes using a 4.8% BAE solution. Samples were weighed before and after treatment. Immediately after treatment the samples were close piled and wrapped on six sides with plastic sheet. Samples were removed for assessment after 24 hours, one week, and two weeks storage. At each time period, a 50mm sub-sample was removed for retention and penetration assessments. After 24 hours and one week, fresh cuts on the samples were sealed with one coat of a two-part epoxy and the samples were once again close piled and the pile rewrapped on six sides. The 50 mm sub-samples were dried in an oven at 50°C. A 5mm slice was removed from within each sub-sample. Simulated cores, 10mm wide and 16mm deep, were cut from one edge and from the heartwood face of each 5mm slice for determination of boron retention. The sixty samples in each treatment were divided into three groups of 20; the simulated cores from one group of 20 samples were analysed individually and the simulated cores from each of the other two groups of 20 were pooled for single edge and heartwood face analyses. A fresh-sawn surface of the remaining sub-sample was sprayed with boron indicator to assess penetration measured three ways: from one edge, from the heartwood face, and percent total cross-section.

4.3 Dip-plus-kiln-conditioning Treatment

Under supervision of Kop-Coat staff, one-half (30 samples) of two treatment groups from set A (mixed sort, planed; stained sort, planed) and four treatment groups from set B (mixed sort, planed; mixed sort, combed; stained sort, planed; stained sort, combed) were treated with the dip-plus-kiln-conditioning process (Dip-plus-kiln-conditioning Treatment 1). The remaining 30 samples of each treatment were used for similar treatments with dip-plus-kiln-conditioning Treatment 2. Unfortunately, an error was made by the local supplier of one of the components, thus the formulation for Treatment 1 was not up to specifications. Kop-Coat staff used a new batch of that formulation component and a slightly different mix of ingredients to prepare the formulation for Treatment 2. Ingredients were mixed at 80-90°C with pre-heated water in a tank equipped to maintain the liquid at 85°C for the duration of dip treatment. Each pre-weighed sample was submerged in the liquid for one minute. Upon removal from the liquid the samples were lightly shaken to remove some excess liquid and immediately weighed, then close piled and kept covered with plastic sheet to prevent drying. Once all samples were treated they were transferred to a small kiln where the close-piled samples were covered on five sides with lumber wrap, leaving the bottom of the pile uncovered.

The kiln was operated with constant steam input at 86°C with minimum wet bulb depression (near 100% relative humidity) for 72 hours. The equilibrium moisture content of wood in such conditions would be about 22% MC. The kiln, with samples still inside, was then turned off and the door kept closed overnight. The following morning the samples were removed from the kiln and weighed. Ten samples from each sample set were randomly selected and sawn to remove a 50mm sub-sample for assessment of boron retention and penetration, and a 25mm piece for determination of moisture content. The remaining sample was end-sealed on the fresh cut and, with the other 20 samples from each sample set, were repackaged (close piled) and wrapped on five sides and stored indoors at 20°C for one week.

After one-week storage, all samples were sawn to remove a 50mm sub-sample. After drying the 50 mm sub-samples in an oven at 50°C, a 5mm slice was removed from the centre of the dried sub-sample. Simulated cores, 10mm wide and 16mm deep, were cut from one edge and from the heartwood face of each 5mm slice for determination of boron retention. Simulated cores were pooled for edge and heartwood face analyses of 10 samples and assessed before and after the one-week storage. For the other 20 samples, simulated cores were individually analysed. A fresh-sawn surface of the remaining sub-sample was sprayed with boron indicator to assess preservative penetration measured three ways: from one edge, from the heartwood face, and percent total cross-section.

The process was repeated (Dip-plus-kiln-conditioning Treatment 2) for the remaining 30 samples of each of the six sets using the modified novel borate formulation mixture.

4.4 Treatment with Dye

Twenty boards of post-MPB lumber were treated by Futura Forest Products using a borate solution containing the standard blue dye (Premium Blue Wood Stain, PF3516-37, from Valspar – formerly from Associated Chemists Inc.) used by all treaters where required for identification of treated stock. A brown dye (Everlan Brown ESR, from Everlight Chemical Industrial Corporation) was used in a pressure treatment of post-MPB lumber at Forintek.

4.5 Data Processing

For each treatment process, the solution uptake, preservative retention (by analysis of individual or pooled simulated cores), and preservative penetration (percent of samples achieving 10mm and percent of cross-section treated) were determined. For dip-plus-kiln-conditioning process-treated samples, post-treatment moisture contents were determined. Statistical comparisons were made using paired t-tests for end-matched samples, and unpaired t-tests for sets which were not end-matched.

Treatments are considered successful if the following penetration and retention targets are met:

- ACQ-D retention of 4 kg/m^3, when sampled from the edge
- Retentions of 2% BAE, sampled at the edge, and 0.7% BAE, sampled from the heartwood face
- 80% of samples are penetrated 10mm or greater, sampled at the edge
- An average of 85% cross-section treated

Typically lumber is inspected by sampling at the edge, where there is more treatable sapwood, but it is also important to achieve adequate loadings on the heartwood faces. An ACQ retention of 4.0 kg/m^3 is required for framing lumber. A retention of 2% BAE is equivalent to the 4.5 kg/m^3 B_2O_3 specified in the AWPA standards for resistance to Formosan subterranean termites (AWPA 2005). A retention of 0.7%

BAE provides adequate protection against Formosan subterranean termites in laboratory tests but provides no factor of safety for field exposure. A target of 0.7% BAE was selected for the heartwood face since the uneven distribution of borate is expected to even out under service conditions. The penetration requirements for lodgepole pine pressure treated with borates are 80% at or over 10mm (AWPA 2005) and this same requirement was used for the dip-plus-kiln-conditioning process. Southern pine is required to have 85% penetration of sapwood (AWPA 2005) and dimension lumber is almost entirely sapwood. Thus to be more competitive with southern pine, lodgepole pine could be treated to a target of 85% cross-section.

Since the non-dried sort was largely eliminated from the experiment and the results indicated no better treatment with non-dried material than KD material the effect on moisture sort of removing high sapwood content boards from the mix was not determined.

5 Results

5.1 Treatment Uptakes

Liquid uptake was similar for ACQ-D and DOT, at both 20 and 35°C (Table 1). For kiln-dried samples, uptakes in the stained sort were more than double and significantly different ($p<0.05$) from, the mixed sort (approximately 470 and 170 kg/m^3, respectively). Uptake of DOT was less in the non-dried samples; almost one-third less in the mixed sort and about one-half less in the stained sort and these differences were statistically significant. This was not consistent with previous work in which higher moisture content (~30% mc) material treated better (Morris 1991). This is probably due to the much higher than expected moisture content in the non-dried material (60% mc) taking up space that would have been occupied by treating solution.

For the dip-plus-kiln-conditioning Treatment 1, combed samples showed greater uptakes (35 and 38 kg/m^3, Table 2) than for the planed, stained sort (27 and 30 kg/m^3, Table 2), or the mixed sort (23 and 21 kg/m^3, Table 2). Similar uptake differences occurred in dip-plus-kiln-conditioning Treatment 2 samples, but with even larger (confirmed statistically) uptakes (ranging from 26 to 59 kg/m^3, Table 3).

5.2 Preservative Retentions

Table 4 shows ACQ-D pooled retentions for the three groups of twenty samples in each treatment. The target ACQ retention of 4 kg/m^3 was closely met in the mixed sort treatment sampled on the edge. Samples in the stained sort (edge sampled) were about double the target retention (8 to 10 kg/m^3), and were statistically different than the mixed sort ($p<0.05$). Sampling from the heartwood face resulted in retentions of 0.6 to 2 kg/m^3.

There was no statistical significant difference in DOT retentions between treatments at 20°C and 35°C (Tables 5 and 6). As expected from the DOT uptakes, pressure treatment combed surfaces did not affect retentions, with edge results of 1.4 % BAE for the mixed sort and 3.2 % BAE for the stained sort similar to the 1.1%BAE and 3.6% BAE found in the planed samples (Table 5). Retentions of non-dried samples were slightly lower (0.9 and 2.4 % BAE for the mixed and stained sort, Table 5). Only the stained combed KD lumber pressure treated at 20° C and the stained planed KD lumber pressure treated at 35 °C met a target of over 2% boric acid equivalent (BAE) in the edge and over 0.7% BAE in the heartwood.

Dip-plus-kiln-conditioning Treatment 1, gave edge sampled retentions ranging from 1.2 to 5.6% BAE, and heartwood face sampled retentions ranging from 0.6 to 6.6 % BAE (Table 7). The material showing 6.6% was re-analysed and gave 6.3% but this data point is considered unreliable. No conclusions can be drawn regarding the effect of the mixed or stained sort or of planed or combed surfaces since there was no consistent pattern of differences among them.

Retentions for dip-plus-kiln-conditioning Treatment 2 were greater (confirmed statistically) than Treatment 1 for edge sampled analyses with 3.2 to 4.7 %BAE for mixed sort and 7.1 to 9.2 %BAE for the stained sort (Table 8). All the material from the second treatment of this accelerated process met loading targets of 2% BAE from edge sampling and 0.7% BAE from heartwood face sampling.

Strangely, in neither dip-plus-kiln-conditioning treatment did the increased uptake from comb surfacing result in increased preservative retentions. This was confirmed statistically. This anomaly needs to be further investigated.

When retentions found in the DOT and dip-plus-kiln-conditioning Treatment 2 were compared, while the edge retention was significantly higher in Treatment 2 (mean of 5.7 vs. 2.5), heartwood retentions showed no difference ($p<0.05$).

5.3 Preservative Penetration

For the ACQ pressure treatment, only the stained sort sampled from the edge met the target of 80% or more samples with 10mm or greater penetration (Table 9). The target average of 85% of cross-section treated was not met.

For the DOT pressure treatments, only the stained sort sampled from the edge met the target of 80% or more with 10mm or greater penetration of DOT, regardless of temperature of treatment (Tables 10 and 11). This was achieved in both kiln-dried and non-dried samples. Contrary to the results of previous work (Baker *et al*. 2001), additional storage time did not make a difference to the penetration.

For both treatments, only samples from the stained sort, planed or combed, achieve the target of cross-section averaging 85% or greater treated (Tables 12 and 13). Storage time had little effect.

The percent of samples with 10mm or greater penetration treated with dip-plus-kiln-conditioning Treatment 1 are shown in Table 14. For this novel borate formulation, one-week storage generally improved penetration in sapwood and heartwood. After one week, all treatments sampled from the edge had more than 80% of samples with 10mm or greater penetration. In some cases, sampling from the heartwood face also resulted in greater than 80% of samples with 10mm or more penetration.

For dip-plus-kiln-conditioning Treatment 1, only the mixed sort combed group met the target of an average 85% cross-section treated (Table 16).

For dip-plus-kiln-conditioning Treatment 2, all but one treatment (stained sort, combed) achieved 80% of samples with 10mm or greater penetration (sampled from the edge) immediately after treatment (Table 15). All achieved the target after one-week storage. In some cases, sampling from the heartwood face also resulted in greater than 80% of samples with 10mm or more penetration.

For dip-plus-kiln-conditioning Treatment 2, all of the stain sort treatments achieved the target of an average 85% cross-section treated immediately after treatment (Table 17). The mixed sort treatments did not make the target even after one week.

For both dip-plus-kiln-conditioning treatments there was poor correlation of preservative penetration with analysed preservative retention. This anomaly needs further investigation.

5.4 Moisture Contents at End of Dip-plus-kiln-conditioning Process

The dip-plus-kiln-conditioning treatment process increased the wood moisture content to between 20% and 30% MC, with the higher moisture contents occurring in dip-plus-kiln-conditioning Treatment 2 samples (Tables 18 and 19). This may have been partly due to leaving the samples in the kiln to cool overnight. With Treatment 1, the doors were opened allowing the steam to escape, with Treatment 2, the doors were kept closed which would have allowed the steam to condense inside the kiln. Removing the samples from the kiln at the end of the kiln conditioning may have allowed some of the surface moisture to flash off. If this does not work, process modifications will be needed to reduce the moisture uptake or bring the moisture content down to below 20% before shipping.

5.5 Pressure Treatment with Dye

Since the treating solution was taken up to a much greater extent by the sapwood than by the heartwood both dyes accentuated the colour difference. Neither dye successfully masked the bluestain discolouration inherent in post-MPB lumber. Use of a pigment may be more successful but this should be carefully tested since it might reduce preservative penetration.

6 Conclusions

The stained sort, either pressure treated with DOT or with the dip plus 72hr kiln conditioning gave through treatment (over 85% cross section) after one week storage, comparable to requirements for Southern Pine.

Lumber sorted for heavily stained sapwood content resulted in about twice the uptake from pressure treatments.

ACQ treatment gave substantial penetration only in sapwood, with a very thin shell in the heartwood.

A higher temperature DOT solution did not increase uptake from pressure treatment.

Pressure treatment uptakes were lower in non-dried wood than in kiln-dried wood.

Pressure treatment of kiln-dried lumber with DOT at 20°C met penetration and retention targets only with stained sort combed samples. Pressure treatment of kiln-dried lumber with DOT at 35°C met penetration and retention targets only with stained sort planed (combed not tested) samples.

None of the pressure treatments had heartwood penetrations with 80% at or over 10mm even after 2 weeks storage whereas dip-plus-kiln-conditioning treatment met this requirement for mixed sort planed and combed with Treatment 1 and mixed sort combed with Treatment 2 after one week.

Dip-plus-kiln-conditioning uptake was greater on combed surfaces but, strangely, this was not reflected in increased borate loading.

Dip-plus-kiln-conditioning Treatment 2 uptakes and retentions were greater than in dip-plus-kiln-conditioning Treatment 1.

The dip-plus-kiln-conditioning process increased the wood moisture content to 20% to 30% MC, with the greater increases resulting from dip-plus-kiln-conditioning Treatment 2. Process modifications will be needed to reduce the moisture uptake or bring the moisture content down to below 20% before shipping to prevent problems with stain and mold.

The dip-plus-kiln-conditioning process met penetration and retention targets with stained sort planed or stained sort combed samples treated with dip-plus-kiln-conditioning Treatment 2. Targets were met immediately after treatment.

None of the data adequately reflects the difference in uniformity of treatment between the pressure treatment and the dip-plus-kiln-conditioning treatment. Dip-plus-kiln-conditioning treatment gave a much more uniformly penetrated shell around the whole cross section, though this was not reflected in the analyzed heartwood retentions.

7 Recommendations

Further refinements are needed to the dip-plus-kiln-conditioning process, but these will likely be customized for each sawmill depending on whether spray or dip is used to apply the formulation and the type of kiln used for conditioning. The lack of relationship between analysed retentions, uptakes and penetrations in the dip-plus-kiln-conditioning process requires further investigation.

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Table 1. Pressure Treatment Uptakes

Material					**Average Uptake**	
Set[1]	**MC[2]**	**Treatment**	**Sort**	**Surface**	**Active Ingredient (kg/m^3)**	**Liquid (kg/m^3)**
A	KD	ACQ-D	mix	plane	2.9 (2.4)	168 (140)
			stain	plane	8.8 (2.8)	466 (145)
A	KD	DOT 20° C	mix	plane	9.3 (7.0)	189 (142)
			stain	plane	22.2 (7.1)	459 (148)
A	KD	DOT 35° C	mix	plane	8.4 (7.0)	176 (148)
			stain	plane	22.0 (6.7)	465 (141)
B	KD	DOT 20° C	mix	comb	8.3 (4.6)	177 (99)
			stain	comb	23.2 (7.0)	486 (147)
B	ND	DOT 20° C	mix	plane	5.9 (4.6)	121 (94)
			stain	plane	11.2 (5.8)	234 (123)

[1] matched

[2] KD = kiln-dried, ND = non-dried

Note: standard deviations are shown in parentheses

Table 2. Dip-plus-kiln-conditioning Treatment 1 Uptakes

Material					**Average Uptake**
Set[1]	**MC[2]**	**Treatment**	**Sort**	**Surface**	**Liquid (kg/m^3)**
A	KD	dip + kiln	mix	plane	23.3 (4.8)
			stain	plane	29.8 (6.8)
B	KD	dip + kiln	mix	comb	35.3 (8.2)
			mix	plane	21.1 (4.1)
			stain	comb	38.3 (5.6)
			stain	plane	26.5 (5.8)

[1] matched

[2] KD = kiln-dried, ND = non-dried

Note: standard deviations are shown in parentheses

Table 3. Dip-plus-kiln-conditioning Treatment 2 Uptakes

Material					Average Uptake
Set[1]	**MC[2]**	**Treatment**	**Sort**	**Surface**	**Liquid (kg/m^3)**
A	KD	dip + kiln	mix	plane	36.1 (9.0)
			stain	plane	39.8 (8.9)
B	KD	dip + kiln	mix	comb	51.8 (10.0)
			mix	plane	25.7 (7.4)
			stain	comb	58.9 (11.6)
			stain	plane	34.8 (8.3)

[1] matched
[2] KD = kiln-dried, ND = non-dried
Note: standard deviations are shown in parentheses

Table 4. Pressure Treatment ACQ-D Retentions

Material							Average Retention
Set[1]	**MC[2]**	**Treatment**	**Sort**	**Surface**	**Sample Face**	**Sample Pool**	**(kg/m^3 ACQ-D)**
A	KD	ACQ-D	mix	plane	edge	1	4.3
						2	5.8
						3	3.2
A	KD	ACQ-D	mix	plane	heart	1	0.6
						2	1.3
						3	0.8
A	KD	ACQ-D	stain	plane	edge	1	9.5
						2	7.8
						3	10
A	KD	ACQ-D	stain	plane	heart	1	1.3
						2	1
						3	2.3

[1] matched
[2] KD = kiln-dried, ND = non-dried

Table 5. Pressure Treatment DOT 20° C Retentions

Material						Average Retention
Set[1]	**MC[2]**	**Treatment**	**Sort**	**Surface**	**Sample Face**	**(% BAE)**
A	KD	DOT 20° C	mix	plane	edge heart	1.1 (1.2) 0.7 (1.2)
A	KD	DOT 20° C	stain	plane	edge heart	3.8 (2.7) 0.5 (0.6)
B	KD	DOT 20° C	mix	comb	edge heart	1.4 (1.1) 0.7 (0.8)
B	KD	DOT 20° C	stain	comb	edge heart	3.2 (0.7) 0.9 (1.0)
B	ND	DOT 20° C	mix	plane	edge heart	0.9 (1.1) 0.4 (0.7)
B	ND	DOT 20° C	stain	plane	edge heart	2.4 (0.6) 0.3 (0.4)

1 matched
2 KD = kiln-dried, ND = non-dried
Note: standard deviations are shown in parentheses

Table 6. Pressure Treatment DOT 35° C Retentions

Material						Average Retention
Set[1]	**MC[2]**	**Treatment**	**Sort**	**Surface**	**Sample Face**	**(% BAE)**
A	KD	DOT 35° C	mix	plane	edge heart	1.6 (1.1) 0.7 (0.7)
A	KD	DOT 35° C	stain	plane	edge heart	3.6 (1.1) 0.7 (0.7)

[1] matched
[2] KD = kiln-dried, ND = non-dried
Note: standard deviations are shown in parentheses

Table 7. Dip-plus-kiln-conditioning Treatment 1 Retentions

Material						**Average Retention**
Set[1]	**MC**[2]	**Treatment**	**Sort**	**Surface**	**Sample Face**	**(% BAE)**
A	KD	dip + kiln	mix	plane	edge heart[3]	2.7 (3.0) 0.9
A	KD	dip + kiln	stain	plane	edge heart[3]	5.6 (3.3) 1
B	KD	dip + kiln	mix	plane	edge heart[3]	1.8 (0.8) 1
B	KD	dip + kiln	mix	comb	edge heart[3]	1.9 (0.8) 1.1
B	KD	dip + kiln	stain	plane	edge heart[3]	3.9 (2.2) 0.6
B	KD	dip + kiln	stain	comb	edge heart[3]	1.2 (1.2) 6.6

[1] matched
[2] KD = kiln-dried, ND = non-dried
[3] pooled analysis
Note: standard deviations are shown in parentheses

Table 8. Dip-plus-kiln-conditioning Treatment 2 Retentions

Material						**Average Retention**
Set[1]	**MC**[2]	**Treatment**	**Sort**	**Surface**	**Sample Face**	**(% BAE)**
A	KD	dip + kiln	mix	plane	edge heart	3.2 (4.4) 0.8 (0.3)
A	KD	dip + kiln	stain	plane	edge heart	7.1 (4.7) 0.7 (1.2)
B	KD	dip + kiln	mix	plane	edge heart	4.7 (6.0) 1.0 (1.2)
B	KD	dip + kiln	mix	comb	edge heart	4.2 (4.2) 0.8 (0.4)
B	KD	dip + kiln	stain	plane	edge heart	7.6 (4.8) 0.7 (0.5)
B	KD	dip + kiln	stain	comb	edge heart	9.2 (6.2) 1.8 (2.6)

[1] matched
[2] KD = kiln-dried, ND = non-dried
Note: standard deviations are shown in parentheses

Table 9. Pressure Treatment ACQ-D Penetrations

Material							% = 10mm	Average % Cross-section Treated
Set[1]	**MC[2]**	**1 Week**	**Sort**	**Surface**	**Sample Face**	**Sample Pool**	**1 Week**	**1 Week**
A	KD	ACQ-D	mix	plane	edge	1	40	
						2	40	53 (23)
						3	40	36 (12)
					heart	1	15	38 (13)
						2	5	
						3	10	
A	KD	ACQ-D	stain	plane	edge	1	100	
						2	100	75 (14)
						3	90	78 (17)
					heart	1	0	68 (15)
						2	15	
						3	10	

[1] matched
[2] KD = kiln-dried, ND = non-dried
Note: standard deviations are shown in parentheses

Table 10 Pressure Treatment DOT 20° C Penetrations

Material							% = 10mm		
Set[1]	MC[2]	Treatment	Sort	Surface	Sample Face	Sample Pool	Time 0	1 Week	2 Week
A	KD	DOT 20° C	mix	plane	edge	1	50	65	70
						2	65	65	65
						3	74	68	74
					heart	1	25	20	25
						2	25	25	35
						3	16	21	58
A	KD	DOT 20° C	stain	plane	edge	1	90	100	100
						2	100	100	100
						3	95	100	100
					heart	1	40	20	50
						2	45	32	45
						3	45	35	35
B	ND	DOT 20° C	mix	plane	edge	1	75	75	80
						2	65	65	55
						3	65	95	85
					heart	1	25	20	35
						2	30	25	45
						3	10	30	20
B	ND	DOT 20° C	stain	plane	edge	1	100	95	95
						2	95	100	100
						3	80	95	95
					heart	1	10	55	40
						2	20	55	60
						3	20	20	45
B	KD	DOT 20° C	mix	comb	edge	1	45	60	45
						2	50	78	78
						3	91	70	75
					heart	1	25	40	40
						2	6	6	17
						3	27	25	25
B	KD	DOT 20° C	stain	comb	edge	1	100	100	95
						2	100	100	100
						3	100	100	100
					heart	1	40	40	45
						2	21	42	37
						3	42	26	37

[1] matched

[2] KD = kiln-dried, ND = non-dried

Table 11. Pressure Treatment DOT 35° C Penetrations

Material							% = 10mm		
Set[1]	**MC[2]**	**Treatment**	**Sort**	**Surface**	**Sample Face**	**Sample Pool**	**Time 0**	**1 Week**	**2 Week**
A	KD	DOT 35° C	mix	plane	edge	1	55	60	65
						2	47	68	58
						3	65	40	65
					heart	1	10	40	25
						2	16	32	42
						3	10	10	20
A	KD	DOT 35° C	stain	plane	edge	1	100	100	100
						2	100	100	100
						3	95	90	95
					heart	1	10	26	30
						2	25	40	35
						3	15	25	25

[1] Matched
[2] KD = kiln-dried, ND = non-dried

Table 12. Pressure Treatment DOT 20° C Cross-sections

Material						Average % Cross-section Treated		
Set[1]	**MC[2]**	**Treatment**	**Sort**	**Surface**	**Sample Pool**	**Time 0**	**1 Week**	**2 Week**
A	KD	DOT 20° C	mix	plane	1	60 (20)	66 (19)	71 (18)
					2	62 (16)	64 (18)	74 (18)
					3	58 (14)	63 (13)	75 (14)
A	KD	DOT 20° C	stain	plane	1	88 (11)	86 (12)	89 (10)
					2	91 (10)	88 (12)	89 (13)
					3	85 (16)	83 (16)	83 (13)
B	ND	DOT 20° C	mix	plane	1	65 (20)	74 (17)	76 (15)
					2	70 (17)	75 (17)	76 (12)
					3	70 (13)	84 (12)	74 (12)
B	ND	DOT 20° C	stain	plane	1	75 (18)	85 (16)	83 (13)
					2	81 (17)	91 (13)	91 (11)
					3	74 (17)	83 (13)	87 912)
B	KD	DOT 20° C	mix	comb	1	63 (22)	75 (18)	73 (17)
					2	67 (12)	65 (13)	71 (14)
					3	76 (13)	72 (12)	76 (12)
B	KD	DOT 20° C	stain	comb	1	90 (10)	90 (10)	92 (9)
					2	83 (13)	89 (11)	90 (10)
					3	84 (16)	83 (15)	88 (13)

[1] matched
[2] KD = kiln-dried, ND = non-dried
Note: standard deviations are shown in parentheses

Table 13. Pressure Treatment DOT 35° C Cross-sections

Material							Average % Cross-section Treated		
Set[1]	MC[2]	Treatment	Sort	Surface	Sample Face	Sample Pool	Time 0	1 Week	2 Week
A	KD	DOT 35° C	mix	plane	edge	1	58 (17)	68 (17)	62 (18)
						2	58 (19)	64 (20)	63 (21)
						3	51 (16)	57 (16)	56 (17)
A	KD	DOT 35° C	stain	plane	edge	1	84 (14)	86 (13)	84 (14)
						2	86 (14)	85 (13)	84 (15)
						3	81 (15)	83 (15)	83 (17)

[1] Matched
[2] KD = kiln-dried, ND = non-dried
Note: standard deviations are shown in parentheses

Table 14. Dip-plus-kiln-conditioning Treatment 1 Penetrations

Material						% = 10mm	
Set[1]	MC[2]	Treatment	Sort	Surface	Sample Face	Time 0	1 Week
A	KD	dip + kiln	mix	plane	edge	60	90
					heart	70	67
A	KD	dip + kiln	stain	plane	edge	80	97
					heart	20	38
B	KD	dip + kiln	mix	plane	edge	89	86
					heart	67	97
B	KD	dip + kiln	stain	plane	edge	100	96
					heart	0	56
B	KD	dip + kiln	mix	comb	edge	70	90
					heart	80	100
B	KD	dip + kiln	stain	comb	edge	100	96
					heart	13	78

[1] Matched
[2] KD = kiln-dried, ND = non-dried

Table 15. Dip-plus-kiln-conditioning Treatment 2 Penetrations

Material						% = 10mm	
Set[1]	MC[2]	Treatment	Sort	Surface	Sample Face	Time 0	1 Week
A	KD	dip + kiln	mix	plane	edge	100	86
					heart	100	64
A	KD	dip + kiln	stain	plane	edge	100	94
					heart	67	41
B	KD	dip + kiln	mix	plane	edge	100	83
					heart	82	47
B	KD	dip + kiln	stain	plane	edge	100	100
					heart	64	74
B	KD	dip + kiln	mix	comb	edge	67	79
					heart	67	89
B	KD	dip + kiln	stain	comb	edge	100	100
					heart	55	46

[1] Matched
[2] KD = kiln-dried, ND = non-dried

Table 16. Dip-plus-kiln-conditioning Treatment 1 Cross-sections

Material					Average % Cross-section Treated	
Set[1]	MC[2]	Treatment	Sort	Surface	Time 0	1 Week
A	KD	dip + kiln	mix	plane	71 (11)	75 (12)
A	KD	dip + kiln	stain	plane	74 (14)	76 (10)
B	KD	dip + kiln	mix	plane	63 (4)	76 (10)
B	KD	dip + kiln	stain	plane	68 (12)	72 (10)
B	KD	dip + kiln	mix	comb	73 (10)	86 (8)
B	KD	dip + kiln	stain	comb	75 (12)	82 (12)

[1] matched
[2] KD = kiln-dried, ND = non-dried
Note: standard deviations are shown in parentheses

Table 17. Dip-plus-kiln-conditioning Treatment 2 Cross-sections

Material					Average % Cross-section Treated	
Set[1]	**MC[2]**	**Treatment**	**Sort**	**Surface**	**Time 0**	**1 Week**
A	KD	dip + kiln	mix	plane	82 (11)	78 (9)
A	KD	dip + kiln	stain	plane	89 (12)	85 (9)
B	KD	dip + kiln	mix	plane	72 (8)	76 (8)
B	KD	dip + kiln	stain	plane	88 (13)	85 (14)
B	KD	dip + kiln	mix	comb	78 (9)	80 (10)
B	KD	dip + kiln	stain	comb	89 (12)	88 (9)

[1] matched
[2] KD = kiln-dried, ND = non-dried
Note: standard deviations are shown in parentheses

Table 18. Dip-plus-kiln-conditioning Treatment 1 Moisture Contents

Material					Average %MC
Set[1]	**MC[2]**	**Treatment**	**Sort**	**Surface**	**Time 0**
A	KD	dip + kiln	mix	plane	20 (5)
			stain	plane	24 (6)
B	KD	dip + kiln	mix	comb	19 (5)
				plane	19 (4)
			stain	comb	22 (5)
				plane	22 (4)

[1] matched
[2] KD = kiln-dried, ND = non-dried
Note: standard deviations are shown in parentheses

Table 19. Dip-plus-kiln-conditioning Treatment 2 Moisture Contents

Material					**Average %MC**
Set[1]	**MC2**	**Treatment**	**Sort**	**Surface**	**Time 0**
A	KD	dip + kiln	mix	plane	22 (5)
			stain	plane	30 (8)
B	KD	dip + kiln	mix	comb	24 (7)
				plane	22 (6)
			stain	comb	27 (9)
				plane	29 (10)

[1] matched

[2] KD = kiln-dried, ND = non-dried

Note: standard deviations are shown in parentheses

Appendix I

Notes on the Tru-Core ä Process From a Visit to New Zealand
9th- 17th December 2005

Notes on the Tru-Core™ Process From a Visit to New Zealand 9th- 17th December 2005

Note:
The Tru-Core™ process and chemistry are patented and patent pending with Kop-Coat and its development partners.

Observations

The Tru-Core™ process is designed to treat kiln-dried lumber with borates plus other biocides to provide decay, termite and mold resistance. Repellant termiticides can be added to eliminate nibbling. Estimated treatment costs are less than half of pressure treatment. Water repellency can also be added.

The process is essentially a flood coat or dip with a hot solution followed by a period of in-kiln activation with minimal wet bulb depression.

The process adds a very small amount of moisture to the wood so it has to be over-dried (target average14%) prior to treatment but the kiln activation is likely to relieve any stresses thus created and kiln drying after treatment is not necessary.

Forintek has previously evaluated dip treatment in hot concentrated borate followed by hot storage and pressure treatment with hot solutions followed by warm storage. Neither achieved penetration as rapidly as Tru-Core™ indicating that the penetration enhancing additives are key to this process.

The ingredients have to be added in a specific order and allowed to react. The mixing in and reaction of these additives require specialized apparatus, made highly compact through a number of proprietary technologies.

Kop-Coat provides a technician to operate the treating system in each mill.

Currently (December 2005) New Zealand sawmills are treating to 0.4% BAE cross-section retention for beetle and decay resistant framing. They may also be soon able to treat to 0.8% BAE for painted outdoor applications such as siding. They are evaluating formulation and process improvements that may achieve 2.0% BAE cross-section retention for termite resistant framing.

Surface modification by impressing, i.e. shallow incising, or comb surfacing may be required to achieve this higher loading. Impressing apparently does not reduce the strength of Radiata pine but this may be because the large knots are still the strength-limiting factor. Alternatively it may be because the lumber was incised on the faces only and tested on edge. SPF takes a 25% strength reduction from incising so the Canadian industry would not want to go this route.

The comb surfacing might make a distinctive product. It is already used on glulam here and increases uptake of coatings, improving their performance.

The spray booths have elegantly simple nozzles with no moving parts and are not prone to clogging. Mist elimination systems would be required for Canadian sawmills.

One sawmill is taking lumber from a transverse conveyor (on an existing de-stickering unit) down a linear conveyor flipping it to a linear conveyor back the other way through a spray booth back to the transverse conveyor. The lumber is then stacked, wrapped and taken to the kiln. Solution is absorbed rapidly and drippage is minimal.

Another plant is dipping packages using a sophisticated automated dip system capable of running anti-stain (or anti-mold) treatment and Tru-Core™ or two types of Tru-Core™. Which process a package goes through is determined by a remote control operated by the forklift driver. The stage in the process the package is at is shown by a series of lights on the outside of the building. The estimated cost of this unit is $1.0 million but a cheaper system could probably be designed. The packages are immersed with a down-up-down motion to facilitate liquid penetration for 30 seconds then pulled up and tilted for 2 minutes to drip. The lumber moves down a long conveyor with a drip tray but such is the nature of the process that only the first two meters of the drip tray shows signs of drippage. The lumber is then wrapped and taken to the kiln.

Care is required with the kiln activation to avoid condensation and moisture uptake in the packages. Care may also be required with the choice of wrapping.

Given the number of pressure treating plants with pre-staining lines and CCA fixation chambers they are not using, if the sawmills are not interested, treaters could do this.

Marking of treated product uses the pink dye that indicates a specific standard for through treatment with borates in New Zealand. However, several plants also use a branding wheel that imprints the plant name and treatment type every meter. This would allow avoidance of the dye for N. America and other markets.

The coarse chop saw created less saw drag of borate than the fine band saw and is therefore less likely to cause false indication of penetration.

Quality assurance procedure at Red Stag overestimates penetration due to the use of a dropper to apply parts A and B of reagent and rapid application of part B after part A. This surface wetting allows diffusion of borate. Independent labs use a spray as we do at Forintek. We also allow part A to dry before applying part B.

Opinions

Mick Hedley: It works if done properly but not if they cut corners. It is too fast to be diffusion.

Jeanette Drysdale: It works but not sure how. Thinks, like me, there may be gas- phase movement.

Treating Trial – MPB Affected Pine

A package of Post-MPB 8ft nominal 2 x 6 inch pine was shipped by Tolko to Kop-coat in New Zealand together with all necessary phytosanitary documentation.

The lumber was inspected by Paul prior to treatment and pieces with stain across all three sides (almost entirely sapwood) were marked on both ends.

All the lumber was run through the spray booth at Red Stag using a solution temperature of 83° C. Half was run with the incisor operational, half with the incisor removed.

Incised and non-incised packages were 5-sides wrapped separately and stored overnight in a warm room.

Both packages were placed into the kiln and subjected to a 36 hr kiln schedule at 75° C with a 2° C wet bulb depression for the first 20 hrs (due to boiler problems) and 85° C with no wet bulb depression for the remaining 16 hrs. They were then subjected to a second 36 hr kiln schedule at 85° C with a 2° C wet bulb depression for the first 24 hrs and no wet bulb depression for the remaining 12 hrs.

Immediately after removal from the kiln, the packages were opened (normally they would stay hot longer and penetration would continue). Ten stain-three-sides boards and ten other boards were selected from each of the incised and non-incised batches.

Electrical resistance moisture meter measurement showed readings from 19% to 60%, however the high readings were likely due partly to the conductivity of borates and partly due to condensation on the wood surface from the temperature fluctuations within and between kiln schedules. Cross cutting showed the interior of the boards appeared dry.

All boards were cut at least 600mm from one end. After removal of the original cut end, a slice 7-10mm thick was cut from each board. All slices were oven dried and cooled.

All slices were evenly sprayed with a light application of part A of the curcumin reagent. They were allowed to dry then sprayed with a light application of part B of the reagent. After 30 minutes the cross-sections were photographed.

All stain-three-sides boards were virtually fully penetrated. All other boards were penetrated to a minimum depth of 10mm on all four sides. There was no substantial effect on penetration from incising. Without the boiler problems a 48 hr schedule might have done the same job.

Analysis of these samples will be done in the New Year to determine if cross-section loading of borate is sufficient to prevent *Coptotermes* attack. [*Note: subsequent analysis showed loadings just below the 2% BAE required. It was anticipated that substituting a dip treatment for the spray used in this trial would provide the increased uptake required.*]

Recommendations

Bring the application of the curcumin reagent for QA at Red Stag in line with that at analytical labs.

If loadings do not meet H2 requirements for *Coptotermes*, consider conducting commercial trials of beetle-killed lumber 1. with combed surface and 2. with longer immersion.

Provide sample of penetration enhancing additive to Forintek to test ancillary properties.

Modify work plan for treating trial in Vancouver to

1. Add combed surface by drying some of the "green" material and surfacing
2. Drop some of the "green" moisture content material to compensate
3. Split each group into two runs, one 48hrs and one 72 hrs, 30 replicates each.
4. Drop assessment at 24 hrs to compensate for extra comb surfacing and 2 runs.