Maximizing value recovery from mountain pine beetle-killed pine for veneer products

Brad Wang and Chunping Dai-Forintek Canada Corp.

Mountain Pine Beetle Initiative
Working Paper 2005–9

Natural Resources Canada, Canadian Forest Service,
Pacific Forestry Centre 506 West Burnside Road, Victoria, BC V8Z 1M5
(250) 363-0600 • www.pfc.cfs.nrcan.gc.ca

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Forintek Canada Corp.
2665 East Mall
Vancouver, British Columbia, Canada
V6T 1W5

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506 West Burnside Road
Victoria, British Columbia, Canada
V8Z 1M5

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Abstract

Laboratory, pilot plant and mill tests were conducted to quantify the impact of using mountain pine beetle (MPB)-killed logs on veneer manufacture, and to determine optimum manufacturing strategies for conditioning, peeling, and drying to recover higher veneer value from this resource. It was found that: Proper log conditioning is key to improving veneer recovery from MBP logs. Conditioning MBP logs at 120 ~ 135^{0}F (49 ~ 57^{0}C) pond temperature with a target core temperature of about 80^{0}F (27^{0}C) helps reduce ribbon breakage, and therefore reduces the volume percentage of random veneer. In addition, the veneer breakage is caused by cracks and splits in the radial and longitudinal directions due to log dry-out: Lathe settings also have a pronounced effect on veneer quality and veneer recovery. A proper lathe setting with a compression ratio (CR) of about 13% is recommended to help peel higher quality veneer and reduce the breakage of the veneer ribbon: Compared to the control green veneer, MBP green veneer has lower moisture content (MC) and smaller MC variation. In general, MBP veneer can be clipped narrower with an equivalent of 1% increase in recovery because of smaller width shrinkage, and be sorted more accurately requiring only two green sorts: heart and light sap. In particular, the MBP light sap sort is comparable to the control heart sort. MBP veneer can further be dried faster with a reduction in drying time by about 25% for the heart veneer and about 35% for the light sap veneer. Despite about 1% increase in recovery from veneer clipping and about 27.5% increase in productivity from veneer drying, the recovery of MBP logs is about 8% lower than that of control logs due to higher percentage of narrower random sheets and waste from peeling, and increased manual handling and composing. As well, the color of bluestain in MBP veneer is lightened after drying, but it still causes interference with the visual grading systems. Since MBP wood is drastically different from non-mountain pine beetle wood in terms of MC and subsequent processing characteristics, it is recommended that the MPB wood be sorted in the log yard. Such sorting is warranted with significant savings from increased recovery and productivity as the proportion reaches about 10% of the logs procured.

Résumé

Des essais en laboratoire, en usine pilote et en scierie ont été effectués afin de quantifier les incidences de l'utilisation des billes de pins tués par le dendroctone du pin ponderosa dans la fabrication des placages et de déterminer des stratégies de fabrication optimales pour le conditionnement, le déroulage et le séchage afin de récupérer la valeur la plus élevée en bois de placage pour cette ressource. Le conditionnement approprié des billes est, selon ces essais, un facteur clé pour améliorer la récupération du bois de placage issu des billes attaquées par le dendroctone du pin ponderosa. Le conditionnement des billes diminue l'assèchement et contribue à réduire les bris du ruban et le pourcentage en volume du placage pour plis intérieurs. Les réglages de la dérouleuse influent sur la qualité et la récupération du bois de placage. En règle générale, le bois de placage attaqué par le dendroctone peut être massicoté plus finement du fait qu'il subit moins de retrait sur la largeur, avec une augmentation de la récupération équivalant à 1 %, et il peut être trié avec une plus grande précision, avec seulement deux catégories de bois : coeur et aubier à faible teneur en humidité. En outre, ce bois sèche plus vite.
En dépit d'une augmentation de la récupération de 1 % liée au massicotage et d'un accroissement de la productivité d'environ 27,5 % lié au séchage, la récupération pour les billes attaquées par le dendroctone est inférieure d'environ 8 % à celle obtenue avec les billes témoins en raison des feuilles pour plis intérieurs plus étroites et des déchets issus du déroulage, ainsi que d'un accroissement du travail manuel (manutention et assemblage). En outre, bien que le bleuissement s'atténue après le séchage, il constitue tout de même un problème dans le classement visuel. Le triage dans les parcs à grumes peut faire réaliser des économies notables en améliorant la récupération et la productivité puisque la proportion des billes attaquées par le dendroctone atteint environ 10 % des billes obtenues.

Table of Contents

Objectives

The general objectives for this study were the following:

- To quantify the impact of using Mountain Pine Beetle (MPB)-killed logs on veneer manufacture, and
- To determine the optimum manufacturing strategies for plywood products using Mountain Pine Beetle (MBP)-killed logs.

The work performed consisted of laboratory studies, a pilot plant veneer manufacturing trial, and a mill manufacturing trial.

Specifically, the objectives for the laboratory tests were to:

1) determine the wood quality pertaining to veneer processing,
2) compare veneer quality of MBP wood to control wood species, and
3) explore means of maximizing the value of MBP wood for veneer.

The objective for the pilot plant trial was to validate the optimum conditioning parameters and lathe settings for MBP veneer. The objective of the mill trial was to confirm the laboratory and pilot plant results.

Introduction

Currently, softwood plywood is the dominant wood panel industry in British Columbia with 14 mills producing 1.2 billion square feet of plywood on a 3/8" basis per year. Lodgepole pine is the predominant softwood species in B.C., accounting for almost 24% of the province's total growing stock and half of the growing stock in the central/interior parts of the province. This species has been traditionally used to make plywood and structural lumber (Byrne 2003). During the past few years, a large outbreak of mountain pine beetle in interior forests has resulted in an increased percentage of dry and stained logs entering wood-products manufacturing facilities (Figures 1 and 2). Dry wood can be thawed more easily in wintertime and dried faster than normal wood, -- presenting an opportunity to reduce costs by using different log conditioning, veneer peeling, and drying parameters.

The purpose of this study is to determine if it makes economic sense to sort and process MBP logs separately from normal logs. Laboratory tests, pilot plant and mill trials were conducted to quantify the impact of using MBP logs in veneer manufacture and determine the optimum manufacturing strategies for conditioning, peeling and drying to recover maximum veneer value from this resource.

Figure 1: A glance at the MBP forest
(Source: http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/)

Figure 2: Mountain pine beetle and bluestained log
(Source: http://www.for.gov.bc.ca/hfp/mountain_pine_beetle/ and Amman et al. 1997)

Staff

Chunping Dai	Group Leader
Brad Wang	Composites Research Scientist
Kevin Groves	Composites Research Scientist
Heng Xu	Composites Research Scientist
Peter Ens	Senior Composites Technologist
George Bartz	Senior Composites Technologist
Axel Andersen	Senior Composites Technologist
Gordon Chow	Industry Advisor

Material and Methods

Laboratory Testing

For the laboratory and pilot plant tests, a total of 60 logs (8 ft/2.4 m long) consisting of 30 blocks of typical MBP and 30 blocks of control wood (a typical whitewood mix including western white spruce, lodgepole pine, and balsam fir) were acquired from the cooperating mill Riverside, Armstrong, B. C. All the tests were performed in Forintek's composites pilot plant.

Figure 3 shows the pile of 60 logs acquired for this study. To differentiate the logs, before testing, the MBP logs were marked with numbers whereas control logs were marked with letters. For peeling with a mini-lathe, twenty logs each were randomly selected from the MBP and control log categories, respectively. Each log was then cut into six 13-inch (0.33-m) long blocks and marked in sequence. The diameter of each block was measured. Meanwhile, a 2" (5 cm) thick disk was cut from the middle part of each log for measurement of moisture content MC) and specific gravity. For MBP logs, the average depth of bluestain in each block was also measured. For peeling with a 4-ft (1.2-m)lathe, the remaining 10 logs each from the MBP and control log categories were cut into 4-ft (1.2-m) long blocks, respectively. The diameter of each block was also measured.

Figure 3: Logs acquired for this study

Figure 4: The cross-section of MBP logs

Log conditioning

To find the optimum conditioning temperature for veneer peeling, we conducted a first trial to heat blocks in two steps to achieve uniform temperature through the log cross-section. Three different levels of temperature at 70^{0}F (21.1^{0}C), 80^{0}F (26.7^{0}C), and 90^{0}F (32.2^{0}C) were targeted. As shown in Figure 5, Forintek's log-conditioning computer program Logcon® was used to estimate the heating time needed at different pond temperatures and target log temperatures. The weather temperature was estimated at 65^{0}F (18.3^{0}C). The average log diameter was about 11.5″ (29.2 cm) after debarking with a standard deviation of 1 (2.5 cm). Table 1 summarizes the pond temperature and heating time for achieving different levels of isothermal heating. Six replicates were used with blocks from three different logs.

A second trial was conducted with one-step heating. As shown in Table 2, six blocks each from MBP and control logs were conditioned at different combinations of heating time and pond temperature to achieve different target core temperatures.

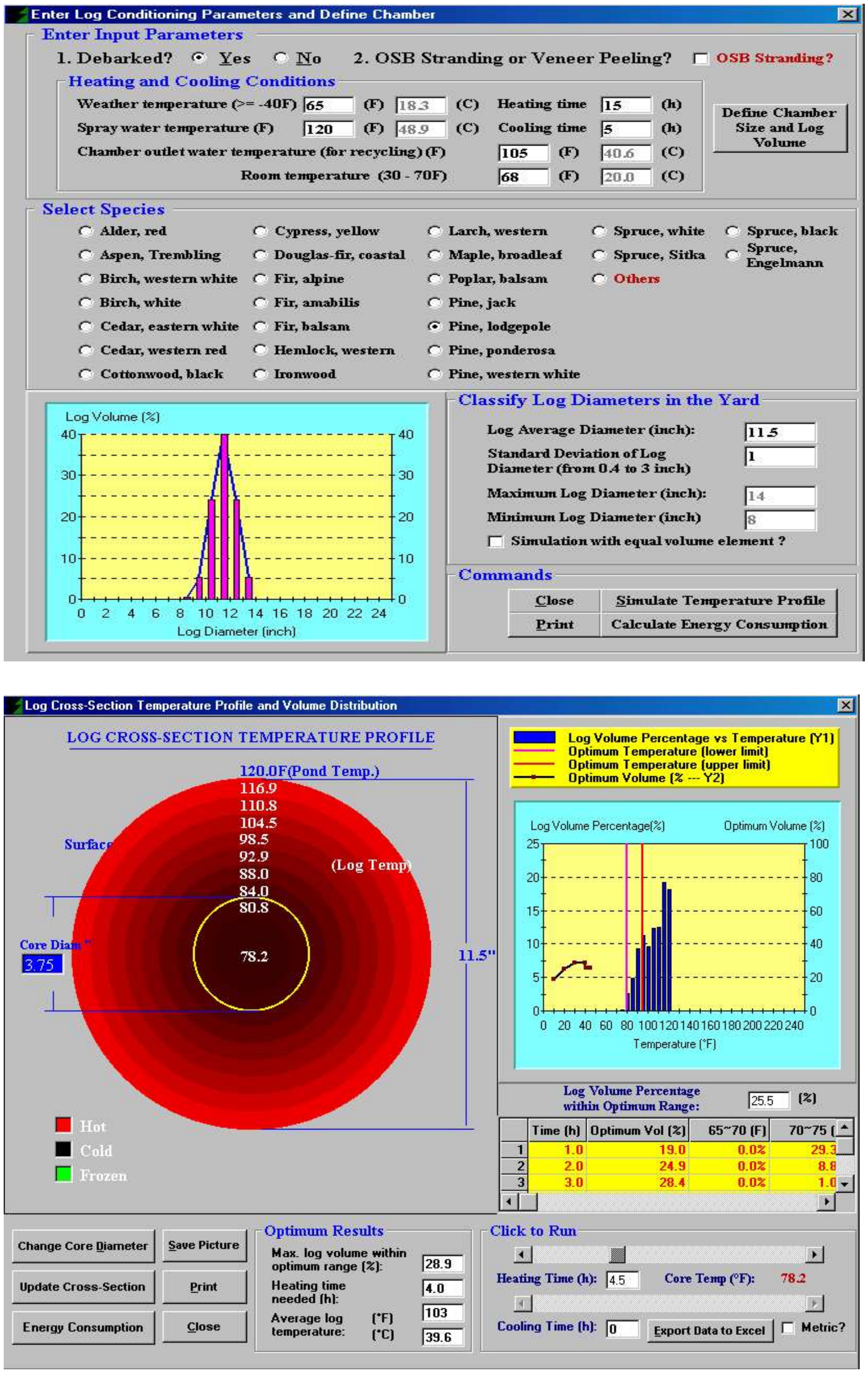

Figure 5: Estimating heating time needed at different pond temperatures

Table 1: Parameters for log isothermal conditioning

Case	Target log (core) temperature ^{0}F (^{0}C)	Set pond temperature ^{0}F (^{0}C)	Heating time (h)	Total time needed (h)	Replicates (Block number)	
					MBP	Control
1	70 (21.1)	80 (26.7)	3	6	6	6
		70 (21.1)	3			
2	80 (26.7)	90 (32.2)	6	9	6	6
		80 (26.7)	3			
3	90 (32.2)	100 (37.8)	8	11	6	6
		90 (32.2)	3			

Table 2: Log conditioning parameters for different target core temperatures

Case	Target (core) temperature ^{0}F (^{0}C)	Set pond temperature ^{0}F (^{0}C)	Heating time (h)	Replicates (Block number)	
				MBP	Control
4	81 (27.2)	120 (49)	4.5	6	6
5	96 (35.6)	120 (49)	8.0	6	6
6	90 (32.2)	150 (66)	4.5	6	6
7	113 (45.0)	150 (66)	8.0	6	6

Veneer peeling

The mini-lathe equipped with a 2.56″ smooth roller bar was used to peel the loop at a speed of 300 ft/min (1.5 m/s) with a core drop size of 3.75″ (9.5 cm). The target veneer thickness was 1/8″ (3.175 mm). Conditioning temperature and time varied in the trial, based on Tables 1 and 2. As shown in Table 3, we tried three lathe settings to peel veneer at different target log (core) temperature for both MBP logs and control logs. These lathe settings were determined through the Forintek's computer simulation program VPeel®, as shown in Figure 6, to achieve different levels of compression during peeling (Dai and Wang, 2003). Figure 7 shows the 15″ (38 cm) veneer mini-lathe.

Table 3: Three lathe settings with different compression ratios

Lathe settings	Pitch angle (PA) (degree)	Horizontal gap (HG) (cm)	Vertical gap (VG) (cm)	Compression ratio (CR) at 11.5" (29.2 cm) (%)	Conditioning cases
1	89.5	0.1 (0.25)	0.475 (1.20)	10.5	1, 2, 3, 4
2	89.5	0.1 (0.25)	0.425 (1.08)	13.0	4, 5, 6, 7
3	89.5	0.1 (0.25)	0.375 (0.95)	15.5	4, 5, 6, 7

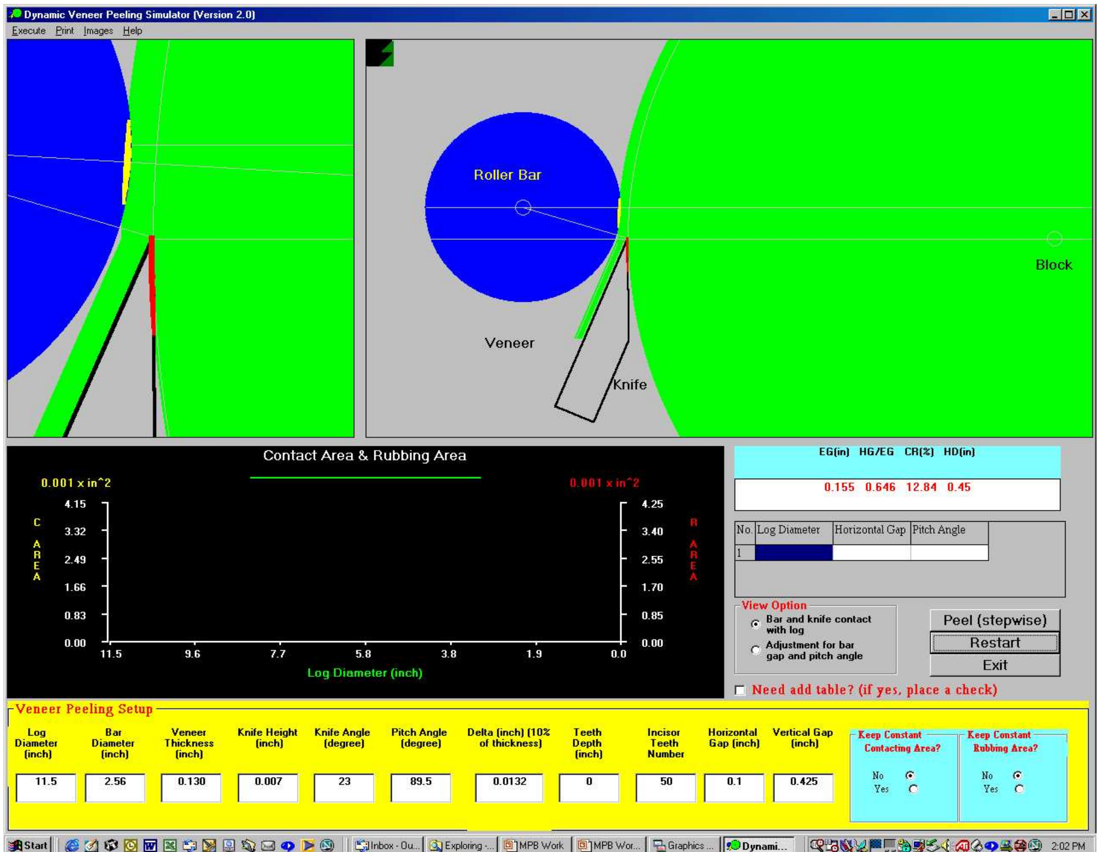

Figure 6: Determination of lathe settings with VPeel® computer simulation program

Figure 7: Peeling veneer with 15” (38 cm) mini-lathe

We also conducted peeling tests to investigate the effect of pitch angle (PA) on veneer quality and ribbon continuity, as shown in Table 4. Before peeling, the round-up diameter of each block was recorded. During peeling, the temperature of each block was carefully monitored with an infrared gun.

Table 4: Lathe settings for comparison tests

Lathe settings	Pitch angle (PA) (degree)	Horizontal gap (HG) (cm)	Vertical gap (VG) (cm)	Compression ratio (CR) at 11.5" (29.2 cm) (%)	Conditioning case
2	89.5	0.1 (0.25)	0.425 (1.08)	13.0	135 ^{0}F (57^{0}C) for 8h
3	89.5	0.1 (0.25)	0.375 (0.95)	15.5	150^{0}F (66^{0}C) for 4h then 70^{0}F (21^{0}C) for 2 h
4	90.0	0.1 (0.25)	0.425 (1.08)	13.0	4
5	89.0	0.1 (0.25)	0.425 (1.08)	13.0	4

Veneer property measurement

After each peel, the core drop diameter was measured and the veneer ribbon was laid on the floor. The veneer quality was evaluated in terms of veneer thickness, veneer curl-up and roughness. Meanwhile, veneer ribbon continuity was monitored to assess veneer recovery. Ten 13-inch-wide (33-cm-wide) veneer samples were cut from the ribbon representative of sap (3 sheets), heart (4 sheets), and core (3 sheets) woods to measure veneer thickness (9 points), roughness grade, moisture content (MC), and density. The final 80-inch-long (about 2-m-long) veneer towards the core was used to evaluate the veneer curl-up in terms of peak number and peak height. All data were entered into a Microsoft Excel® sheet template for analysis.

Pilot Plant Trial

Log conditioning and veneer peeling

To validate the conditioning and peeling parameters obtained from the small-scale tests, a scale-up test was performed using Forintek's 4-ft (1.2-m) lathe, as shown in Figure 8. We cut the remaining ten 8-ft (2.4-m) logs each into 4-ft (1.2-m) logs with a 2″-thick (5-cm-thick) disk being trimmed in the middle part of the log to measure the average log moisture content (MC). These logs were conditioned with 120 ~ 130^{0}F pond temperature for 4.5 hours and peeled with the optimum peeling parameters identified in tables 3 and 4. After peeling, veneer sheets were clipped into 25″ (63.5 cm) widths and stacked in piles. These veneer sheets were then passed through Forintek's pilot scale veneer dryer to test veneer shrinkage.

Veneer drying and width shrinkage

To investigate the effect of MBP veneer on drying rate, we used Forintek's mini-dryer with accurate control of drying temperature and humidity (Dai et al. 2003). Three 13″ x 13″ (33 cm x 33 cm) sapwood and heartwood veneer sheets were each randomly sampled from MBP veneer and control veneer. During drying, the weight and temperature of each sheet were continuously monitored. The drying temperature was set at 180^{0}C with an air velocity of 5 ~ 7 m/s and a relative humidity of 1 ~ 2%.

To investigate the width shrinkage of MBP veneer, we used Forintek's pilot-scale jet dryer. The drying temperature was set at 175^{0}C. The drying time was 6.5 min for heartwood veneer and 8.5 min for sapwood veneer.


Figure 8: Scale-up peeling test with 4-ft (1.2 m) lathe

Mill Trials

The mill trials were planned with staff at the cooperating mill. The mill trial was based on testing opportunities for manufacturing cost savings identified using the results of the laboratory tests and pilot plant trial. The trials were conducted in two major sub-tests. A total of approximately 100 m^3 of 8-ft (2.44-m) raw logs were used in each test to process plywood. Data were collected on-line and off-line in terms of veneer quality, grades, recovery, and productivity. The species used in each test were: 1) 100% MBP logs, and; 2) a mix of MBP and other white wood including western white spruce and balsam fir (MBP logs account for about 10%).

For log conditioning, the inlet and outlet water temperature, conditioning time, and block diameter distribution were recorded: The block surface temperature and core temperature at the lathe were measured using an infrared sensor.

For veneer peeling, the vertical gap (VG), horizontal gap (HG) profile and pitch angle (PA) profile were checked. The spin-out rate and number of full sheets and random sheets were recorded.

For veneer clipping, the clipping width of green veneer was measured for different sorts.

For green veneer sorting, the volume percentage of each sort was recorded. The green veneer MC distribution for each sort was measured.

For veneer drying, the final MC of dry veneer was checked. The drying temperature, drying speed (drying time), and volume percentage of dry, stacking, and redry sheets were recorded from the dryer control screen.

For MBP veneer, 60 4'x 8' (1.2 m x 2.4 m) full-size sheets were randomly selected from two sorts: heart and light-sap, respectively. For control veneer (a typical whitewood mix), 60 4'x 8' (1.2 m x 2.4 m) full-size sheets were randomly selected from three sorts: heart, light-sap, and sap, respectively. For each green veneer sheet, the weight, width, and three-point thickness (left, middle, and right) were measured. Then each sort of veneer was put through the one-zone longitudinal dryer and recovered to measure the dry veneer weight, width, and thickness. In doing so, the green veneer MC and shrinkage in veneer width can be obtained.

Figure 9 shows the ribbon of MBP veneer coming off the 8' (2.44m) lathe. Figure 10 shows the sampled veneer sheets for weight, thickness, and width measurement.

Figure 9: Ribbon of MBP veneer coming off the 8-ft (2.44 m) lathe

Figure 10: Sampled 4'x 8'(1.2 m x 2.4 m) veneer sheets

Results and Discussion

The results are summarized based on wood and veneer properties, and are presented under the headings of results for laboratory and pilot plant testing and mill trials.

Laboratory Results

Wood properties

As shown in Table 5, log diameter was measured for both MBP logs and control logs before roundup. For MBP logs, the bluestained (infestation) depth was also measured. Figure 11 compares the distribution of log diameter between MBP and control logs. The results show that compared to the control logs, the diameter of MBP logs was larger. The average bluestained depth for the MBP logs was 1.65″ (4.2 cm), accounting for 51.2% of total log volume. The results also indicate that almost all MBP sapwood was bluestained.

Table 5: Comparing log diameter between MBP and control logs

Log category	Number of logs	Log diameter (cm)		Average bluestained depth (cm)	Average bluestained volume (%)	Average diameter of heartwood (cm)	Sapwood volume (%)
		Average	Std. Dev.				
MBP logs	30	11.6 (29.5)	1.2 (3.0)	1.65 (4.2)	51.2%	8.3 (21.1)	51.2%
Control logs	30	10.3 (26.1)	1.5 (3.8)	N. A.*	N. A.	7.3 (18.5)	50.0%

: * N. A. refers to not applicable

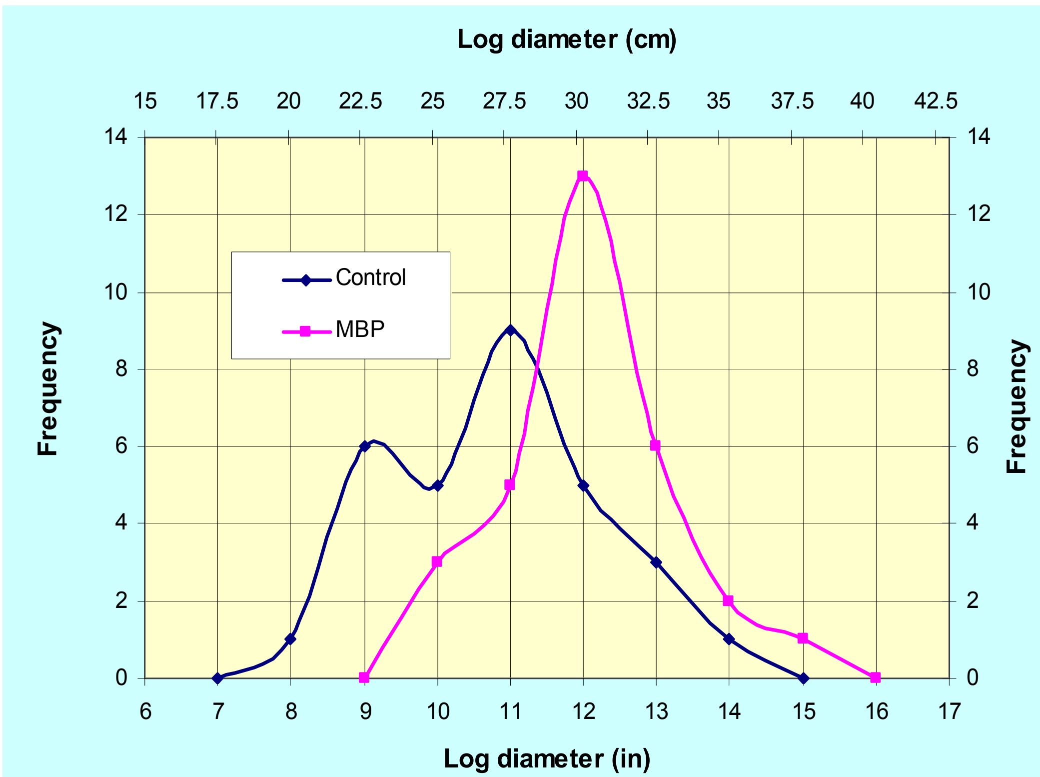

Figure 11: Log diameter distribution for MBP and control logs

Table 6 and Figure 12 show the wood density, specific gravity, and MC of sapwood and heartwood veneer of the MBP and control logs. The results demonstrate that:

1) compared to the control sapwood veneer, the MC of the MBP sapwood veneer is significantly lower with a smaller MC variation due to log dry-out. The average MC of sapwood is only 47.7% for MBP logs compared to 106.8% for control logs;
2) the MC of the MBP heartwood veneer is lower than that of the control heartwood veneer with a smaller MC variation;
3) the MC of the MBP sapwood veneer is very close to that of the control heartwood veneer, and;
4) the specific gravity of MBP logs is significantly higher than that of control logs. This is probably due to the fact that most of the control logs are western white spruce.

Table 6: Wood density, specific gravity and MC of sapwood and heartwood veneer

Log category	Number of logs	Sapwood MC (%)		Heartwood MC (%)		Wood density (kg/m^3)		Specific gravity	
		Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.	Average	Std. Dev.
MBP logs	30	47.7	14.8	29.2	4.5	570	32	0.429	0.034
Control logs	30	106.8	30.0	43.6	13.9	605	57	0.368	0.019

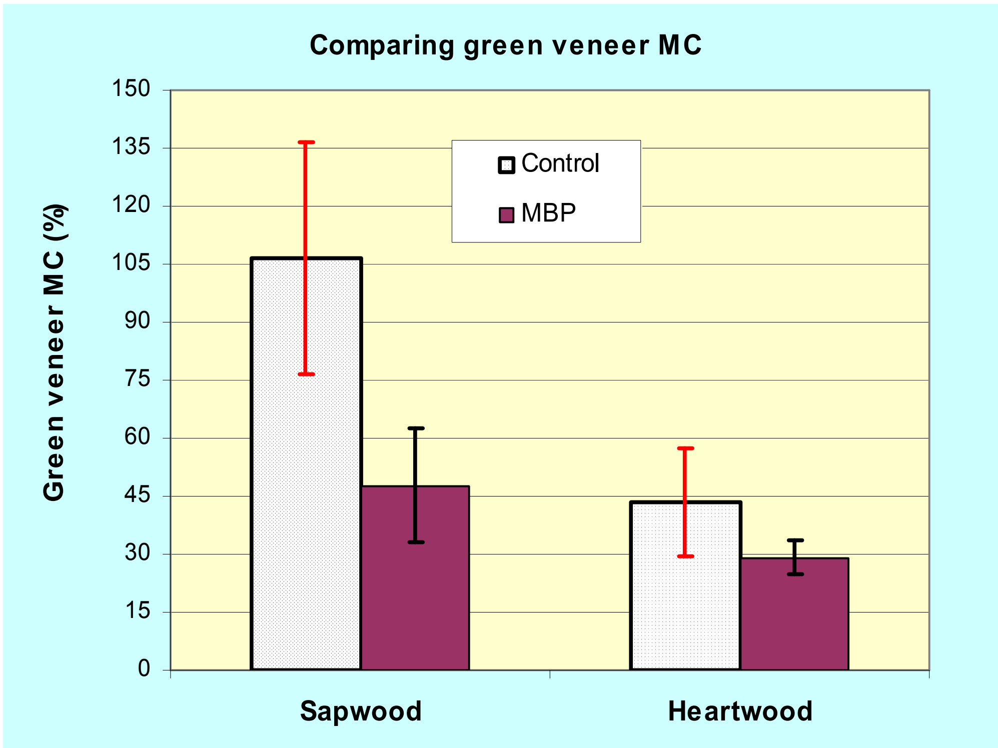

Figure 12: Comparison of green veneer MC between sapwood and heartwood
(error bar represents one standard deviation)

Veneer properties

For MBP logs, as shown in Figure 13, cracks appeared in the block after round up. After peeling, the breakage of the sap veneer ribbon occurred regardless of how the blocks were conditioned. In practice, this discontinuity will cause difficulty in handling, sorting, and drying, and will result in an increase in random-width veneer and a reduction in veneer recovery.

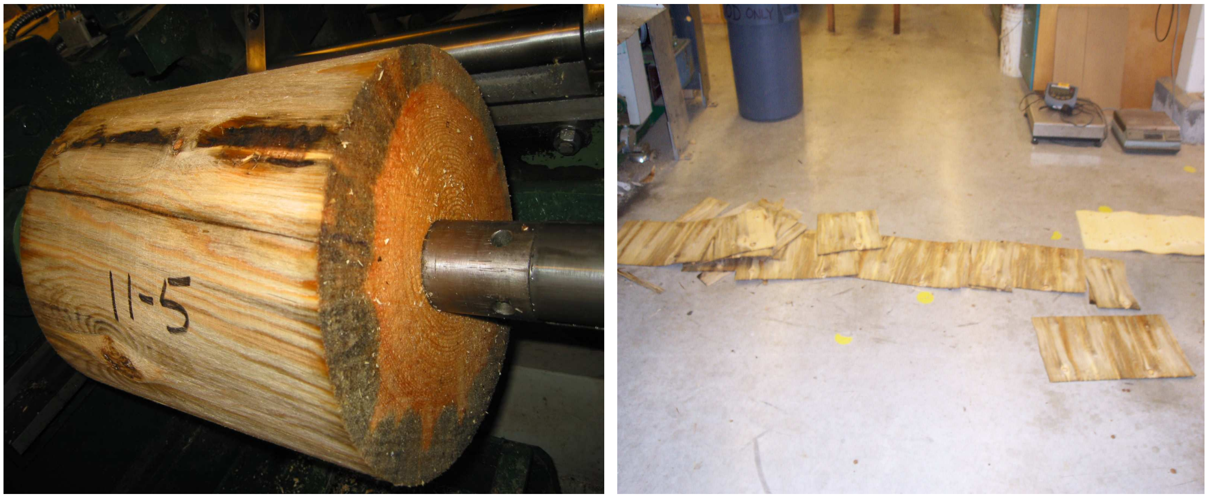

Figure 13: Peeling MBP blocks with cracks

As shown in Figure 14, if there were no serious cracks, veneer ribbons peeled from some MBP blocks were continuous from sap to heart if parameters of conditioning and peeling were appropriate. In contrast, veneer ribbons peeled from control blocks generally did not break.

Figure 14: Veneer ribbon continuity

Table 7 summarizes the testing results in terms of green veneer thickness and thickness variation. Table 8 summarizes the testing results in terms of roughness grade, curl-up, and ribbon continuity, as well as of veneer specific gravity and MC for sap, heart, and core. For the lathe setting 1, as shown in testing No. 1, 2, and 3, isothermal conditioning at below 90^0F (32.2^0C) was not effective because the ribbon of the MBP sap veneer was fully or severely broken. Meanwhile, the variation of green veneer thickness was above the control limit generally set at 0.005″ (0.127

mm) for either sap, heart, or the core part of veneer. Further, as shown in testing No. 4, conditioning blocks at 120^{0}F (49^{0}C) for 4.5 hours improved the ribbon continuity. Based on the above peeling results, we discontinued to use the isothermal conditioning for the MBP blocks. The reasons for the ribbon breakage are probably due to: 1) lack of wood plasticity in improperly conditioned blocks, and; 2) cleavage of veneer ahead of the knife with larger VG.

To increase the wood plasticity, the laboratory results demonstrate that it is advisable to use a higher conditioning temperature and a longer conditioning time. To reduce the knife cleavage, the lathe setting 2 with a reduced VG was used. As shown in testing No. 5, 6, 7, 8, and 13, we tried different combinations of log-conditioning temperatures and times in order to improve veneer ribbon continuity. The results show that conditioning at 120^{0}F (49^{0}C) for 4.5 hours with a target core temperature of 81^{0}F (27.2^{0}C) satisfactorily improved the ribbon continuity with the least veneer curl-up and thickness variation: Conditioning at 120^{0}F (49^{0}C) or higher than 120^{0}F (49^{0}C) for a longer time did not show any further improvement in ribbon continuity: on the contrary, veneer became rougher and had larger thickness variation and curl-up.

To investigate the effect of the VG on veneer quality and ribbon continuity, the lathe setting 3 was used with a further reduced VG. As shown in testing serial No. 9, 10, 11, and 12, we tried the same conditioning parameters as used by lathe setting 2. The results show that compared to the lathe setting 2, the ribbon continuity was worsened, probably due to the larger compression ratio (CR). Further, as shown in testing No. 14, conditioning blocks at 150^{0}F (66^{0}C) for 4 hours and then placing blocks into a pond with water temperature at 70^{0}F (21^{0}C) for 2 hours brought sapwood MC up to 68%, but veneer quality and ribbon continuity were not improved noticeably. We concluded that conditioning blocks at 120^{0}F for 4.5 hours was encouraging. This implies that by just heating the sap part of MBP blocks to about 100^{0}F (37.8°C), the higher plasticity of wood improves the ribbon continuity.

As shown in testing No. 15 and 16, the effect of pitch angle on veneer quality and ribbon continuity was studied with the optimum conditioning (120^{0}F for 4.5 hours). The results show that compared to the lathe setting 2 (PA = 89.5^{0}), both lathe settings 4 (PA = 90°) and 5 (PA = 89°) did not show any improvement in the ribbon continuity, and the lathe setting 5 was relatively better than the lathe setting 4. In addition, the lathe setting 4 resulted in a larger thickness variation in the sap veneer. Therefore, it is recommended that for peeling MBP logs, the PA be chosen from 89.5° to 89°.

Table 7: Experimental results of green veneer thickness

Testing serial No.	Lathe setting	Block conditioning	Block category	Green veneer thickness (in)						Green veneer thickness (mm)					
				Core		Heart		Sap		Core		Heart		Sap	
				Avg	Std dev	Avg	Std dev	Avg	Std dev	Avg	Std dev	Avg	Std dev	Avg	Std dev
1	1	Case 1	MBP	0.139	0.005	0.136	0.005	0.134	0.005	3.522	0.135	3.463	0.120	3.408	0.125
			Control	0.137	0.004	0.132	0.004	0.135	0.006	3.467	0.106	3.364	0.091	3.435	0.159
2	1	Case 2	MBP	0.138	0.007	0.135	0.005	0.132	0.004	3.504	0.180	3.428	0.116	3.342	0.106
			Control	0.136	0.005	0.134	0.004	0.130	0.005	3.449	0.117	3.398	0.100	3.312	0.135
3	1	Case 3	MBP	0.137	0.005	0.136	0.006	0.134	0.005	3.480	0.122	3.462	0.142	3.402	0.139
			Control	0.136	0.005	0.135	0.004	0.132	0.005	3.458	0.119	3.417	0.102	3.345	0.125
4	1	Case 4	MBP	0.136	0.004	0.135	0.004	0.135	0.006	3.459	0.100	3.434	0.101	3.416	0.158
			Control	0.136	0.004	0.135	0.003	0.131	0.004	3.443	0.105	3.416	0.085	3.321	0.113
5	2	Case 4	MBP	0.135	0.002	0.134	0.002	0.131	0.004	3.427	0.060	3.405	0.063	3.335	0.110
			Control	0.135	0.002	0.133	0.003	0.128	0.004	3.421	0.061	3.389	0.065	3.258	0.091
6	2	Case 5	MBP	0.135	0.005	0.133	0.004	0.132	0.005	3.439	0.117	3.377	0.093	3.360	0.122
			Control	0.134	0.004	0.132	0.004	0.127	0.004	3.411	0.109	3.359	0.098	3.236	0.105
7	2	Case 6	MBP	0.135	0.005	0.133	0.005	0.133	0.007	3.437	0.119	3.374	0.134	3.378	0.168
			Control	0.136	0.005	0.133	0.004	0.128	0.005	3.443	0.131	3.374	0.103	3.261	0.138
8	2	Case 7	MBP	0.135	0.005	0.133	0.003	0.131	0.006	3.424	0.130	3.390	0.086	3.323	0.152
			Control	0.133	0.004	0.133	0.004	0.130	0.005	3.383	0.095	3.369	0.093	3.293	0.119
9	3	Case 4	MBP	0.131	0.006	0.131	0.004	0.130	0.005	3.336	0.150	3.335	0.091	3.308	0.128
			Control	0.135	0.005	0.131	0.003	0.130	0.004	3.437	0.132	3.330	0.075	3.299	0.094
10	3	Case 5	MBP	0.135	0.004	0.134	0.004	0.130	0.005	3.442	0.101	3.400	0.090	3.298	0.133
			Control	0.135	0.004	0.133	0.004	0.128	0.005	3.435	0.102	3.372	0.095	3.254	0.114
11	3	Case 6	MBP	0.137	0.005	0.133	0.003	0.130	0.003	3.470	0.133	3.372	0.067	3.296	0.067
			Control	0.136	0.004	0.135	0.005	0.131	0.004	3.462	0.109	3.421	0.117	3.327	0.099
12	3	Case 7	MBP	0.130	0.003	0.128	0.003	0.124	0.004	3.302	0.088	3.258	0.068	3.151	0.112
			Control	0.131	0.004	0.129	0.004	0.125	0.005	3.339	0.107	3.283	0.110	3.176	0.118
13	2	*	MBP	0.135	0.004	0.134	0.004	0.130	0.005	3.433	0.093	3.412	0.104	3.306	0.131
			Control	0.136	0.004	0.135	0.005	0.130	0.004	3.444	0.104	3.434	0.119	3.311	0.114
14	3	**	MBP	0.134	0.004	0.132	0.003	0.127	0.003	3.399	0.109	3.364	0.074	3.218	0.071
			Control	0.135	0.004	0.136	0.004	0.130	0.005	3.439	0.095	3.449	0.109	3.308	0.124
15	4	Case 4	MBP	0.134	0.004	0.132	0.004	0.124	0.007	3.415	0.113	3.341	0.090	3.155	0.175
			Control	0.132	0.003	0.130	0.003	0.122	0.006	3.359	0.079	3.307	0.075	3.091	0.164
16	5	Case 4	MBP	0.134	0.003	0.133	0.003	0.130	0.004	3.409	0.086	3.368	0.082	3.311	0.104
			Control	0.132	0.002	0.131	0.003	0.125	0.004	3.361	0.059	3.332	0.066	3.172	0.100

Note:

* *Indicates conditioning at 135 ^{0}F (57^{0}C) for 8 h;*
** *Indicates conditioning at 150 ^{0}F (66^{0}C) for 4 h, then at 70 ^{0}F (21^{0}C) for 2 h.*

Table 8: Experimental results of veneer roughness, curl-up and ribbon continuity

Testing serial No.	Lathe setting	Block conditioning	Block category	Roughness grade Average	Specific gravity			Green veneer MC			Curl-up		Ribbon continuity
					Core	Heart	Sap	Core (%)	Heart (%)	Sap (%)	Total peak height: in (cm)	Number of peaks	
1	1	Case 1	MBP	3.5	0.398	0.425	0.415	27	28	38	1.1 (2.7)	2	Fully or severely broken
			Control	3.2	0.316	0.356	0.372	34	51	135	1.7 (4.4)	2	
2	1	Case 2	MBP	3.5	0.399	0.438	0.420	27	26	43	1.3 (3.3)	3	Fully or severely broken
			Control	3.1	0.322	0.354	0.370	35	62	131	1.3 (3.3)	2	
3	1	Case 3	MBP	2.9	0.400	0.434	0.425	27	26	39	0.9 (2.4)	2	Fully or severely broken
			Control	2.7	0.318	0.357	0.374	34	46	122	1.8 (4.5)	2	
4	1	Case 4	MBP	3.2	0.426	0.434	0.441	29	28	31	1.2 (3.0)	3	Fully broken
			Control	2.7	0.324	0.351	0.358	45	63	140	2.5 (6.4)	3	
5	2	Case 4	MBP	2.8	0.382	0.417	0.431	32	32	40	0.5 (1.3)	1	Good ribbon
			Control	2.9	0.331	0.350	0.359	47	91	90	0.4 (1.1)	1	
6	2	Case 5	MBP	2.9	0.399	0.424	0.438	29	29	46	1.6 (4.0)	2	Broken at intervals
			Control	2.7	0.322	0.350	0.365	38	59	89	2.5 (6.2)	3	
7	2	Case 6	MBP	3.3	0.396	0.431	0.443	30	29	36	2.1 (5.4)	3	Slightly broken
			Control	2.9	0.331	0.357	0.368	33	57	92	1.5 (3.8)	3	
8	2	Case 7	MBP	3.1	0.405	0.423	0.434	29	28	45	2.9 (7.4)	3	Slightly broken at intervals
			Control	3.1	0.343	0.357	0.353	34	42	93	2.7 (6.8)	2	
9	3	Case 4	MBP	2.7	0.398	0.422	0.422	28	29	53	0.5 (1.3)	1	Broken at intervals
			Control	3.2	0.353	0.350	0.364	33	40	97	0.4 (0.9)	1	
10	3	Case 5	MBP	2.8	0.390	0.409	0.398	26	38	63	0.8 (2.1)	2	Fully broken
			Control	2.9	0.331	0.341	0.339	38	74	92	1.2 (2.9)	3	
11	3	Case 6	MBP	3.2	0.363	0.380	0.367	29	38	65	1.6 (4.1)	3	Fully broken
			Control	3.5	0.334	0.324	0.342	33	36	62	2.1 (5.3)	2	
12	3	Case 7	MBP	2.4	0.396	0.427	0.408	28	31	67	0.6 (1.5)	2	Broken at intervals

			Control	3.0	0.345	0.352	0.354	49	73	103	1.3 (3.4)	2	
13	2	*	MBP	3.4	0.399	0.421	0.425	29	28	47	1.8 (4.6)	2	Broken at intervals
			Control	3.2	0.334	0.348	0.357	33	45	97	2.5 (6.3)	3	
14	3	**	MBP	3.0	0.393	0.413	0.414	26	30	68	0.4 (1.0)	1	Fully broken
			Control	3.3	0.333	0.339	0.347	41	73	88	0.9 (2.2)	2	
15	4	Case 4	MBP	2.8	0.386	0.426	0.409	27	31	51	0.2 (0.4)	1	Broken at intervals
			Control	2.6	0.331	0.347	0.385	36	90	103	0.5 (1.4)	2	
16	5	Case 4	MBP	2.5	0.366	0.403	0.405	31	32	51	0.3 (0.7)	1	Slightly broken at intervals
			Control	2.3	0.327	0.340	0.350	39	120	117	0.8 (2.0)	1	

Note:

* *Indicates conditioning at 135 ^{0}F (57^{0}C) for 8 h;*
***Indicates conditioning at 150 ^{0}F (66^{0}C) for 4 h, then at 70 ^{0}F (21^{0}C) for 2 h.*

In summary, the breakage (splitting) of veneer ribbon due to dryout and cracks was found to be the main issue for peeling MBP logs due to dryout and cracks. For the laboratory testing with 13″ (33 cm) blocks, a schedule of 120^{0}F (49^{0}C) water temperature and 4.5-hour soaking time helped improve the ribbon continuity. Compared to the shorter blocks used in the laboratory, longer blocks would have slightly slower heat conduction to the centre of the blocks. Therefore, in the pilot plant trial with 4' (1.2 m) blocks and the mill trial with 8' (2.4 m) blocks, a schedule of 120 ~ 135^{0}F (49 ~ 57^{0}C) pond temperature with a target core temperature of about 80^{0}F (27^{0}C) could be applied to increase wood plasticity. Among the lathe settings tested with the mini-lathe, the lathe setting 2, namely, pitch angle (PA) = 89.5°, HG = 0.1″ (2.5 mm) and VG = 0.425″ (10.8 mm) with 13% CR, was recommended for peeling MBP logs to achieve smoother veneer, better ribbon continuity, less curl-up, and less thickness variation.

Pilot Plant Trials

Before applying the optimum conditioning and peeling parameters to the mill trials, scale-up tests from the laboratory trials were conducted using Forintek's veneer pilot plant. Four MBP blocks and three control blocks were used in the pilot plant test. The blocks were conditioned at 120 ~ 130^{0}F (49 ~ 54^{0}C) for 4.5 hours. The lathe setting 2 was used to peel the veneer. Figure 15 shows the veneer ribbon coming off the 4' (1.2 m) lathe. Figure 16 shows a MBP sap veneer sheet with splits due to natural cracks in the block. Table 9 shows the results of green veneer thickness and roughness grade. In general, with the lathe setting recommended, the ribbon continuity was good without running-through natural cracks, and both MBP and control veneer exhibited acceptable roughness and thickness variation.

Figure 15: Veneer ribbon coming off the 4' (1.2m) lathe

Figure 16: Splits in the MBP sap veneer sheet

Table 9: Green veneer thickness and roughness

Peeling test	Block No.	Green veneer thickness (in)						Green veneer thickness (mm)						Roughness grade
		Core		Heart		Sap		Core		Heart		Sap		
		Avg	Std dev	Avg	Std dev	Avg	Std dev	Avg	Std dev	Avg	Std dev	Avg	Std dev	
MBP	Block 1	0.136	0.005	0.130	0.005	0.123	0.005	3.447	0.124	3.312	0.122	3.117	0.134	2.4
	Block 2	0.136	0.005	0.133	0.005	0.129	0.005	3.454	0.127	3.372	0.127	3.282	0.138	2.7
	Block 3	0.133	0.005	0.132	0.004	0.127	0.005	3.376	0.125	3.355	0.106	3.221	0.137	2.9
	Block 4	0.134	0.004	0.134	0.004	0.130	0.005	3.402	0.112	3.403	0.103	3.303	0.128	2.6
Control	Block 1	0.132	0.004	0.130	0.002	0.129	0.005	3.365	0.091	3.302	0.051	3.268	0.127	3.7
	Block 2	0.135	0.004	0.132	0.003	0.129	0.004	3.419	0.097	3.346	0.081	3.267	0.090	2.4
	Block 3	0.130	0.005	0.134	0.004	0.134	0.003	3.314	0.138	3.416	0.112	3.404	0.086	2.6

Figure 17 shows stacked MBP veneer after clipping. Figure 18 shows drying of MBP veneer with the pilot-scale dryer. The results show that after peeling, the MBP sap veneer can be clipped in the same way as the control veneer, but special caution is needed to handle veneer sheets in the stacking and drying to prevent crack-led splitting.

Figure 18: Drying MBP veneer with pilot-scale dryer

Veneer drying characteristics

For the control veneer sheets, as shown in Figure 19, the drying curves of sapwood and heartwood veneer are quite apart. Because sapwood veneer displays larger variation in MC, the green veneer MC sorting is critical to achieve more uniform veneer drying and better drying quality.

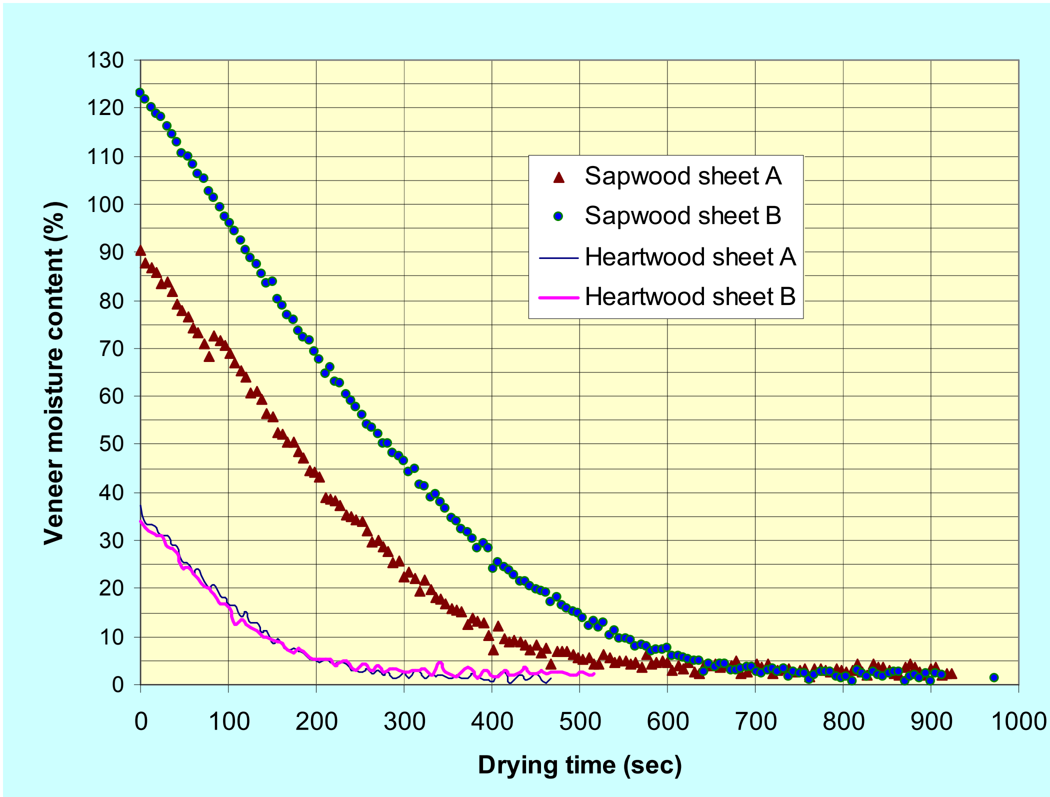

Figure 19: Typical drying curves of sapwood and heartwood veneer from control western white spruce logs

Figure 20 shows the drying curve of MBP sapwood veneer obtained through the mini-dryer. Based on Figure 20, we estimated that the drying time was about 7.5 min (450 sec) for drying MBP sapwood veneer down to a target MC of 3%. This drying time is close to the drying time used for the heartwood veneer in the mill.

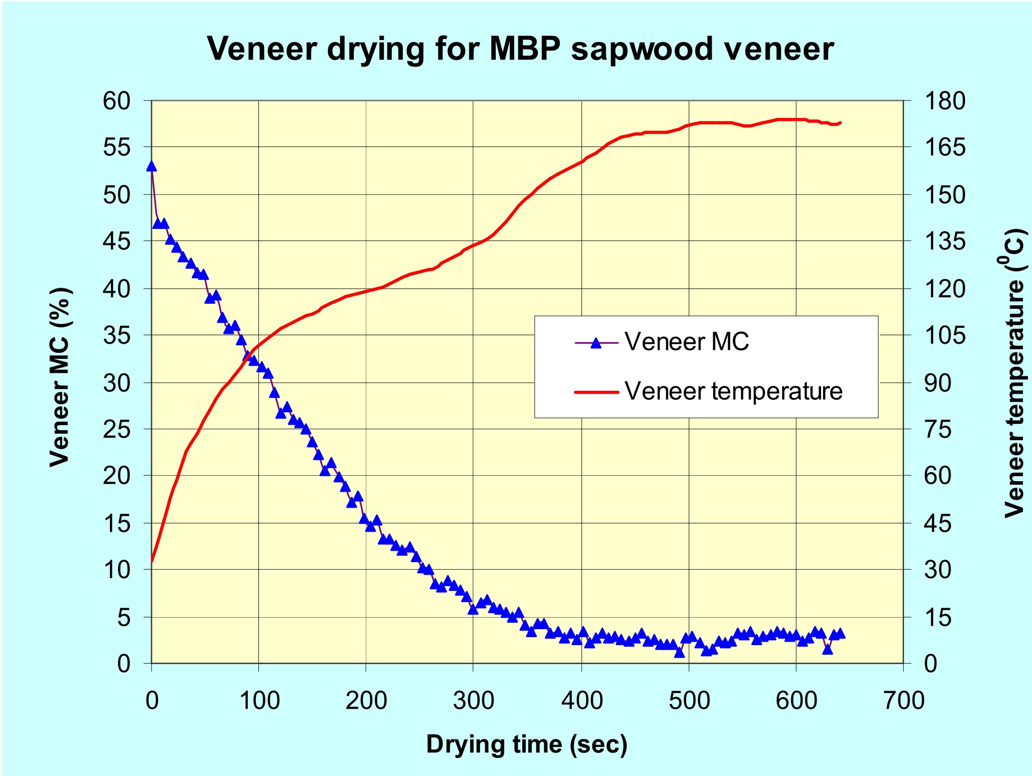

Figure 20: Drying curve for MBP sapwood veneer

Figure 21 shows the comparison of drying curves between sapwood veneer from a MBP log and a control log. The results demonstrate that the MCs of MBP sapwood sheets were very consistent and lower compared to those of control sheets. This implies that drying time can be reduced for MBP sap veneer. It is estimated from Figure 21, the average drying time for control sap veneer is 11.5 min (690 sec) whereas the average drying time for MBP sap veneer is only 7.5 min (450 sec), a reduction in drying time of about 35%.

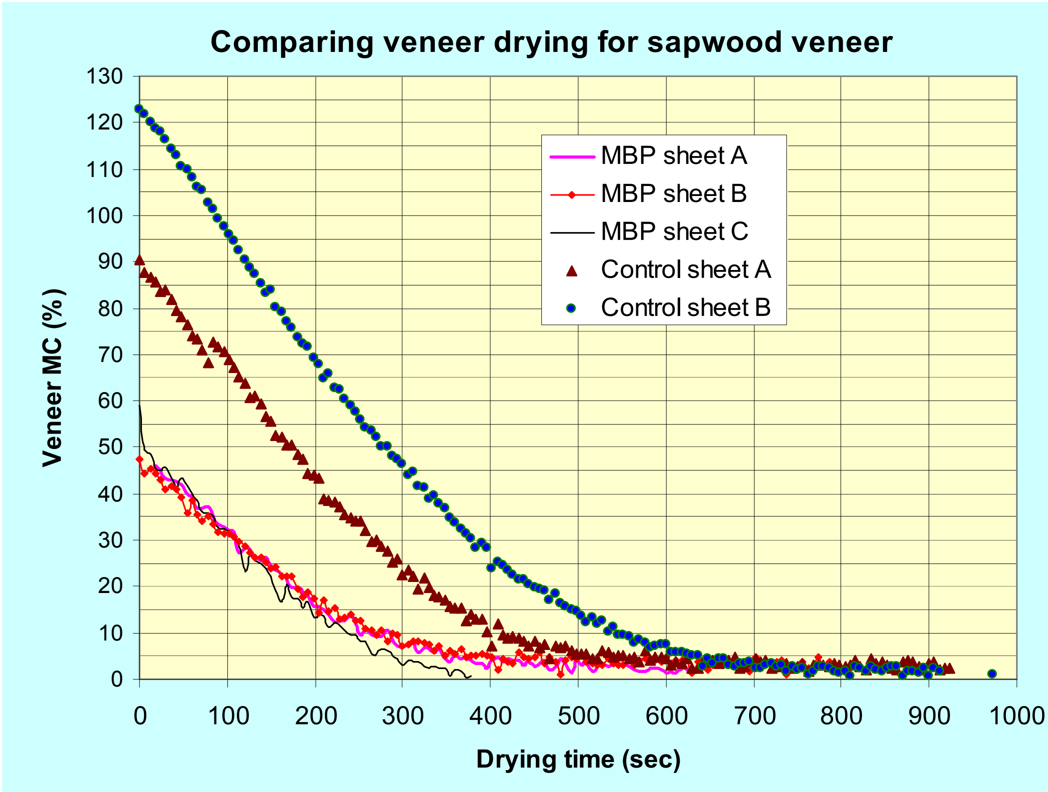

Figure 21: Comparison of drying curves between MBP and control sapwood veneer

Figure 22 shows the comparison of drying curves between heartwood veneer from a MBP log and a control log. The results demonstrate that the MCs of MBP heartwood sheets were also very consistent and lower compared to those of control sheets. The implication is that for MBP heartwood veneer, drying time can also be reduced. It is estimated from Figure 22, the reduction in drying time is about 25%.

Overall, when drying MBP veneer, productivity can be increased by about 35% for sapwood veneer and about 25% for heartwood veneer, and more consistent drying schedules can be applied. In general, MBP veneer can be sorted into about 70% heart and 30% light sap/sap (Wharton 2004). Therefore, the drying productivity of the MBP veneer can be increased by about 27.5% compared to the control veneer. Assuming the volume ratio of MBP logs is 10% in the mill, the overall drying production increase will be 2.75%. Since 1% productivity increase means annual profit of about $150,000 per mill, the bottom-line benefit from veneer drying is estimated at $412,500.

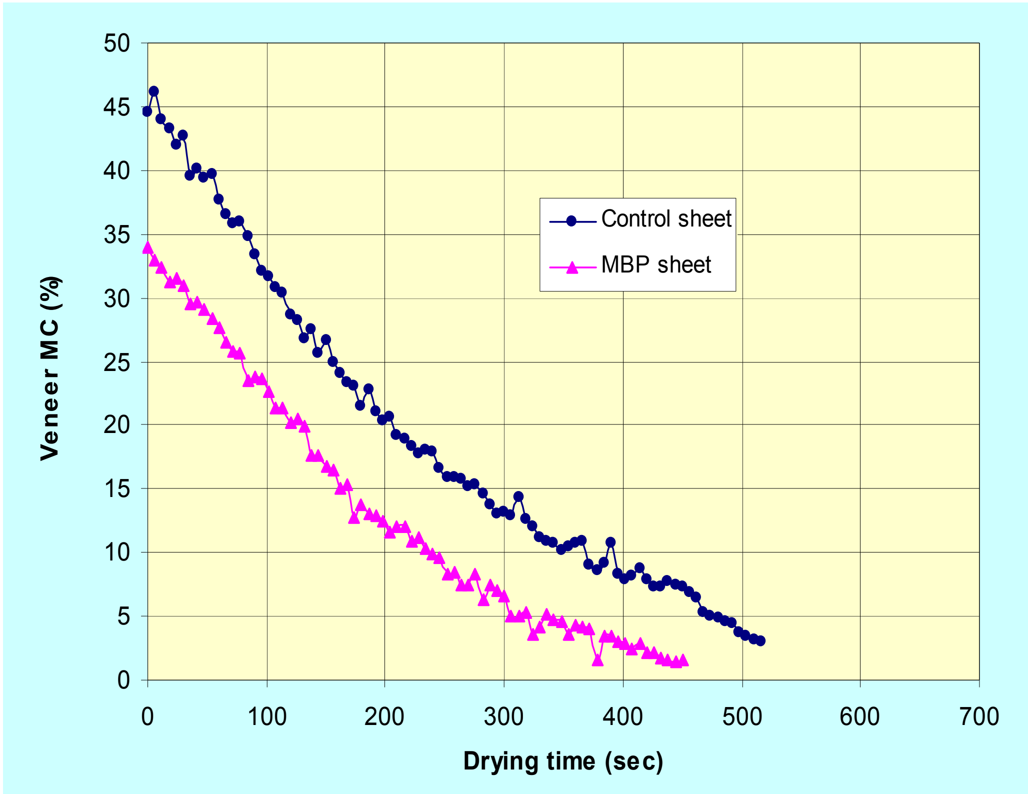

Figure 22: Comparison of drying curves between MBP and control heartwood veneer

Table 10 shows the results of veneer-width (tangential) shrinkage after drying with the pilot-scale dryer. We found that:

1) MBP veneer shrank less than control veneer;
2) The difference in width shrinkage between control logs and MBP logs was 1.4% for sapwood veneer and 0.7% for heartwood veneer, and;
3) The difference in width shrinkage between sapwood and heartwood veneer was only 0.3% for MBP logs compared to 1.0% for control logs.

In practice, the pilot plant results suggest that MBP sapwood veneer can be clipped about 0.75″ (about 2 cm) narrower than control sapwood veneer, and MBP heartwood veneer can be clipped about 0.38″ (about 1 cm) narrower than control heartwood veneer. This will translate to a recovery increase of about 1%. Assuming the volume ratio of MBP logs is 10% in the mill, the annual profit from veneer clipping will be about $30,000 (1% increase in recovery means $300,000).

Table 10: Comparison of veneer width shrinkage between MBP and control logs

Veneer drying tests		Control logs		MBP logs	
		Sapwood veneer	**Heartwood veneer**	**Sapwood veneer**	**Heartwood veneer**
Green veneer MC (%)	Average	119.6	40.3	51.2	32.9
	Std. Dev.	35.8	11.9	12.7	3.7
Veneer width shrinkage (%)	Average	6.7	5.7	5.3	5.0
	Std. Dev.	0.3	0.4	0.3	0.2
Difference in shrinkage (%)		1.0		0.3	

In summary, the pilot plant trials suggest that processing MBP veneer separately could result in approximately $442,500 annual savings from 0.1% increase in veneer recovery through clipping and 2.75% increase in drying productivity assuming that MBP logs account for 10% of total log volume in the mill. However, compared to the control logs, processing MBP logs will generate more random veneer and waste from veneer handling and composing. As a result, plywood mills need to conduct their own complete evaluation of the net benefit based on their actual volume percentage of MBP logs.

Mill Trials

Log conditioning

The water pond temperature was 140^{0}F (60^{0}C). The logs were conditioned for approximately 6 hours before peeling. The surface temperature and core temperature of about 70 blocks were monitored using an infrared gun. Figures 23 and 24 show the frequency distribution of block surface temperature after loading onto the lathe and core temperature right after peeling, respectively. The results demonstrate that:

1) due to the energy loss, the actual block surface temperature was lower than the pond temperature. Also the block surface temperature was not uniform with an average temperature of 105^{0}F (standard deviation = 11.7^{0}F);
2) the core temperature varied significantly from 30^{0}F to 115^{0}F, which is normal in log conditioning without diameter sorting, and;
3) the average core temperature was 79^{0}F (standard deviation = 23^{0}F), which was very close to the optimum target core temperature 81^{0}F (27.2^{0}C) obtained through the laboratory tests.

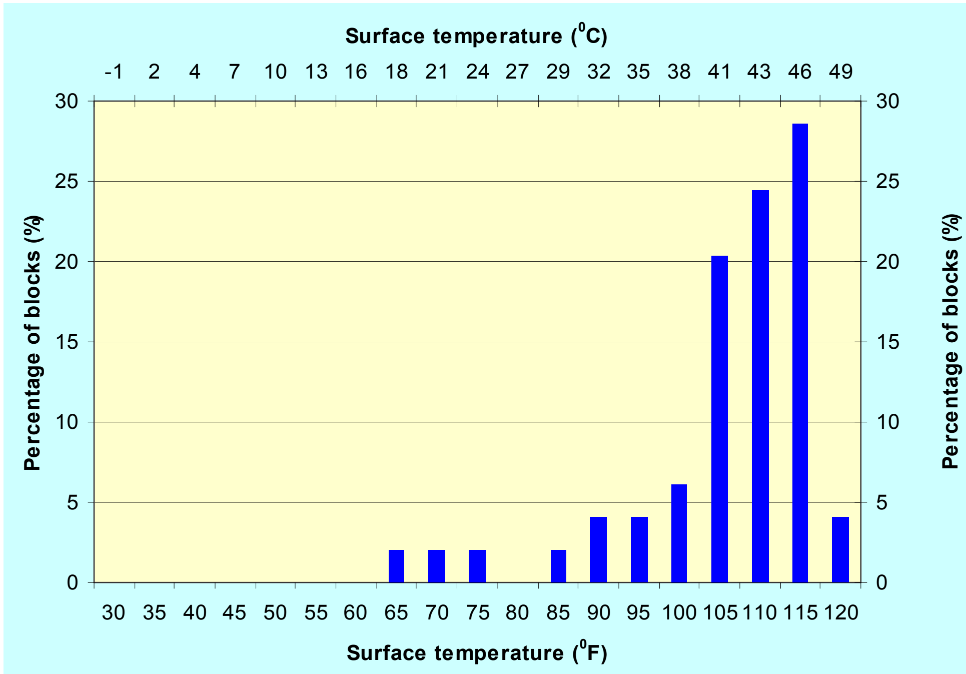

Figure 23: The frequency distribution of block surface temperature

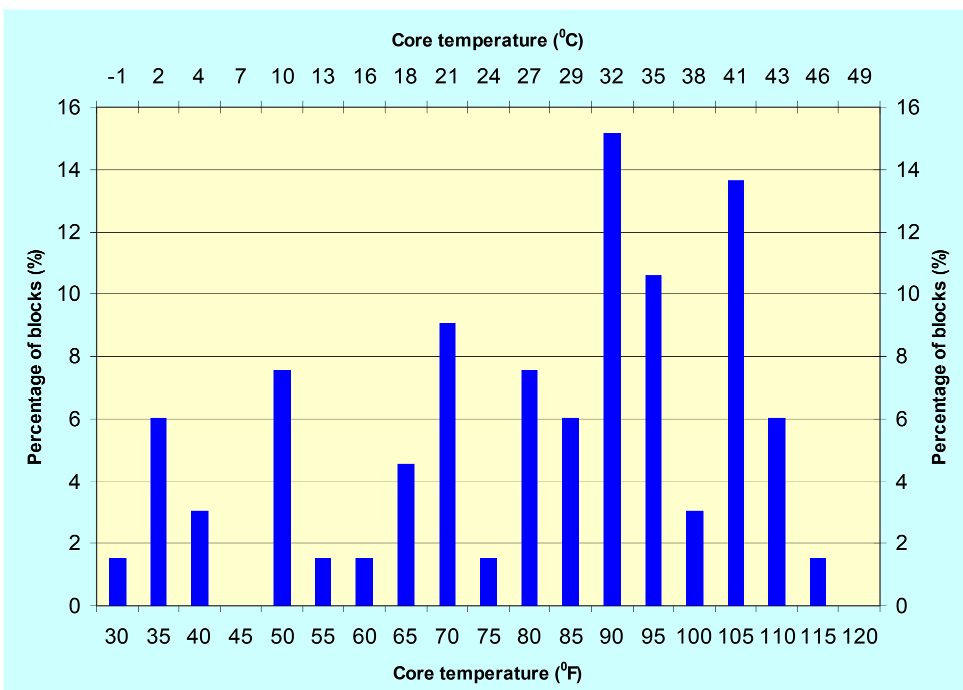

Figure 24: The frequency distribution of block core temperature

Veneer peeling

In general, the veneer ribbon of the MBP veneer produced during the mill trials was continuous due to the close-to-optimum block conditioning. The peeling speed was 1500 ft/min. This speed was considered to be too fast since the head ribbon of veneer was flipped and rolled up, resulting in substantial waste in veneer clipping. The lathe settings used for veneer peeling were: roller bar diameter = 3.75″, VG = 0.655″ and knife height = 0.019″. The PA and HG changed during the peeling. To check the lathe settings, the gap opening and pitch angle were measured at the following four carriage positions: 10.76″, 9.05″, 6.00″, and 1.64″. The measured gap openings were 0.101″, 0.096″, 0.085″, and 0.058″, respectively. Using Forintek's VPeel® computer program, the actual CR between roller bar and block was determined as: 14.5%, 16.1%, 18.1%, and 11.4%, respectively. Figure 25 shows the relative position of the roller bar, knife, and block with 18.1% CR when carriage position is 6.00″ (15.2 cm).

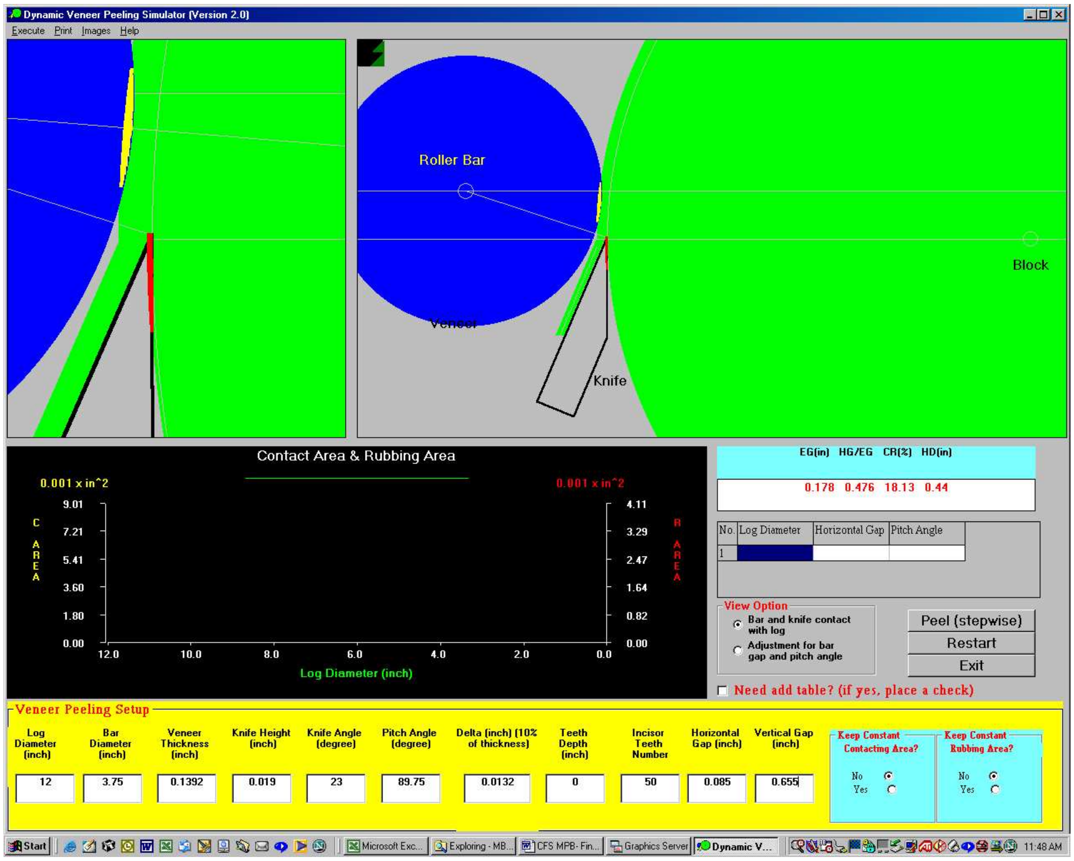

Figure 25: Lathe settings used in the mill trial for a 12" log diameter

Table 11 summarizes the results of green and dry veneer thickness, volume breakdown of each green veneer sort, and volume percentage of random veneer for both MBP veneer and control veneer. The results demonstrate that:

1) the thickness variation of both green and dry veneer was slightly higher than (or equal to) 0.005″ (0.127 mm). To control veneer thickness, the current pitch angle and gap profiles in the mill need to be adjusted. Compared to the optimum compression ratio (CR=13%) obtained through the laboratory tests, the CR used in the mill lathe was considered too high. This could be the main reason why the veneer ribbon in the mill was tighter, easier to roll up and larger in thickness variation;
2) 2) due to the low veneer MC, there was 69.6% of heart veneer, but only 6.8% of heavy sap for MBP veneer. In contrast, there was only 46.5% of heart veneer but 32.7% of heavy sap for the control veneer;
3) 3) the volume percentage of random veneer (composer stock) was 17.9% for MBP logs, which was 2% higher than control logs, and;

4) 4) the average width of random veneer was 18.5″ (470 mm) for MBP veneer, which was considerably narrower than 30.0″ (762 mm) for the control veneer. This indicates that MBP veneer requires more manual handling and is more labor intensive.

Based on the data collected from the lathe in this mill (Wharton 2004), the average diameter was 11.7″ (29.7 cm) for MBP logs and 10.3″ (26.1 cm) for control logs. The data were consistent from those obtained from the laboratory measurement. Using Forintek's veneer recovery simulation program VYield® (Wang and Dai 1999), as shown in Figure 26, the effect of log diameter on volume percentage of random veneer can be predicted. Assuming the same accuracy of centering error, control logs would generate about 3.0% more random veneer than MBP logs due to the smaller diameter. In reality, due to the dry out and cracks, peeling MBP logs would generate more random veneer. If the log diameter is the same, as that of control logs, MBP logs will generate at least 5.0% more random veneer during peeling. Further, according to the mill data from the peeling lathe, peeling MBP logs generated 1.6% spin-outs compared to 1.2% for peeling control logs, which indicates another source of loss in recovery with MBP logs.

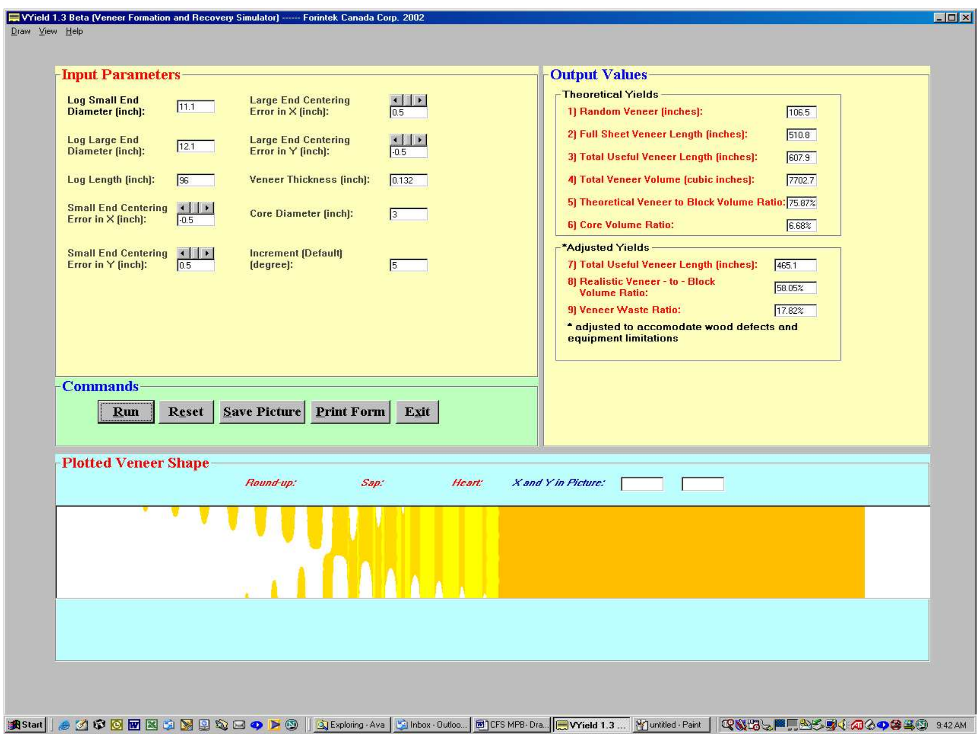

Figure 26: Prediction of volume percentage of random veneer with VYield®

Table 11: Green and dry veneer thickness and veneer recovery

Logs	Veneer sorts	Green veneer thickness (mm)		Dry veneer thickness (mm)		Volume percentage	Volume percentage of random veneer	Average width of random veneer (mm)
		Average	Std. Dev.	Average	Std. Dev.			
MBP	Heart	0.141 (3.591)	0.007 (0.187)	0.128 (3.251)	0.006 (0.152)	69.6%	17.9%	18.5 (470)
	Light sap/sap	0.140 (3.548)	0.007 (0.176)	0.123 (3.125)	0.005 (0.128)	23.6% / 6.8%		
Control (Mix)	Heart	0.142 (3.595)	0.008 (0.212)	0.125 (3.163)	0.006 (0.152)	46.8%	15.9%	30.0 (762)
	Light sap	0.137 (3.481)	0.008 (0.202)	0.122 (3.109)	0.006 (0.164)	20.5%		
	Sap	0.136 (3.463)	0.007 (0.178)	0.129 (3.281)	0.005 (0.138)	32.7%		

Veneer clipping, sorting, and drying

Table 12 summarizes the results of veneer drying settings and drying output collected from the dryer control software for different sorts of MBP veneer and control veneer. All dryers were one-zone longitudinal type. The final average MC was about 3% for the usable dry veneer. The dryers ran well with all sorts. After drying, the colour of bluestain in MBP veneer is lightened, but it still interferes with the visual grading. This is an additional challenge when using MBP logs since operators have to override the scanners to extract the maximum grade possible. Since the MC of MBP veneer was low, only two green sorts were generated: heart and light sap/sap. The mill results also show that compared to the control veneer, the drying time of MBP veneer was much shorter. On average, the reduction in drying time was about 29% for the MBP heart veneer and 36% for the MBP light sap/sap veneer. For the light sap/sap veneer, the reduction in drying time was consistent with that obtained through the laboratory drying test. For the heart veneer, the reduction in drying time was slightly higher in the mill compared to 25% obtained in the laboratory. The reason is mainly due to the sorting accuracy of the control heart veneer. The mill should be able to estimate the exact improvement in productivity by taking into account the volume breakdown of the species mix and the sorting accuracy.

Table 12: Veneer drying settings and drying output

Logs	Veneer sorts	Veneer drying settings		Dryer output (volume ratio)			Note
		Drying temperature ^{0}F (^{0}C)	Drying time (min)	Dry veneer (%)	Stacking (%)	Redry (%)	
MBP	Heart	351 (177)	5.7	71.6	26.0	2.4	No.3 dryer
	Light sap/sap	352 (178)	9.1	77.6	21.0	1.4	No.3 dryer
Control (Mix)	Heart	338 (170)	8.0	75.6	17.4	7.0	No.2 dryer
	Light sap	352 (178)	11.5	76.8	18.6	4.6	No.2 dryer
	Sap	339 (171)	16.8	77.4	11.9	10.7	No.4 dryer

Table 13 summarizes the results of green veneer MC, green veneer clipping width, dry veneer width, and width shrinkage. The results show that:

1) the MC of the MBP heart veneer was the lowest with the smallest variation, and the MC of the MBP light sap veneer was very close to that of the control heart veneer;
2) overall, the width shrinkage of the MBP veneer was smaller than that of the control veneer. The average difference was about 0.7%;
3) the data of width shrinkage for both MBP heart veneer and light sap veneer were consistent with those obtained through the tests in the pilot plant as shown in Table 10, as were the data for the width shrinkage of the heart veneer for the control veneer;
4) for the control veneer, the difference in shrinkage between the heart veneer and sap veneer was only 0.3% compared to 1.0% obtained through the pilot plant test. The reasons could be due to the species mixture and the less accurate sorting for the control veneer, and;
5) the reason why the control light sap veneer shrank less than the heart veneer was probably due to the significant MC overlapping between the two sorts, as shown in Figure 27.

Table 13: Green veneer MC, clipping width and width shrinkage

Logs	Veneer sorts	Green veneer MC (%)		Green veneer clipping width (mm)		Dry veneer width (mm)		Width shrinkage (%)	
		Avg	Std. Dev.	Avg	Std. Dev.	Avg	Std. Dev.	Avg	Std. Dev.
MBP	Heart	33.2	3.1	52.7 (1339)	0.22 (5.6)	50.0 (1271)	0.27 (6.9)	5.0	0.4
	Light sap/sap	45.9	8.5	52.8 (1340)	0.23 (5.8)	49.9 (1267)	0.27 (6.9)	5.4	0.5
Control (Mix)	Heart	47.4	9.6	52.7 (1338)	0.30 (7.6)	49.6 (1260)	0.34 (8.6)	5.8	0.5
	Light sap	51.1	12.7	53.0 (1345)	0.61 (15.5)	50.1 (1271)	0.40 (10.2)	5.6	0.4
	Sap	105.4	28.8	53.5 (1359)	0.17 (4.3)	50.3 (1278)	0.30 (7.6)	6.1	0.4

Figure 28 shows the MC distribution of the heart and light sap veneer for the MBP veneer. It demonstrates that overall, the sorting of the MBP veneer was more accurate than that of the control veneer, but some overlapping occurred between these two sorts of veneer.

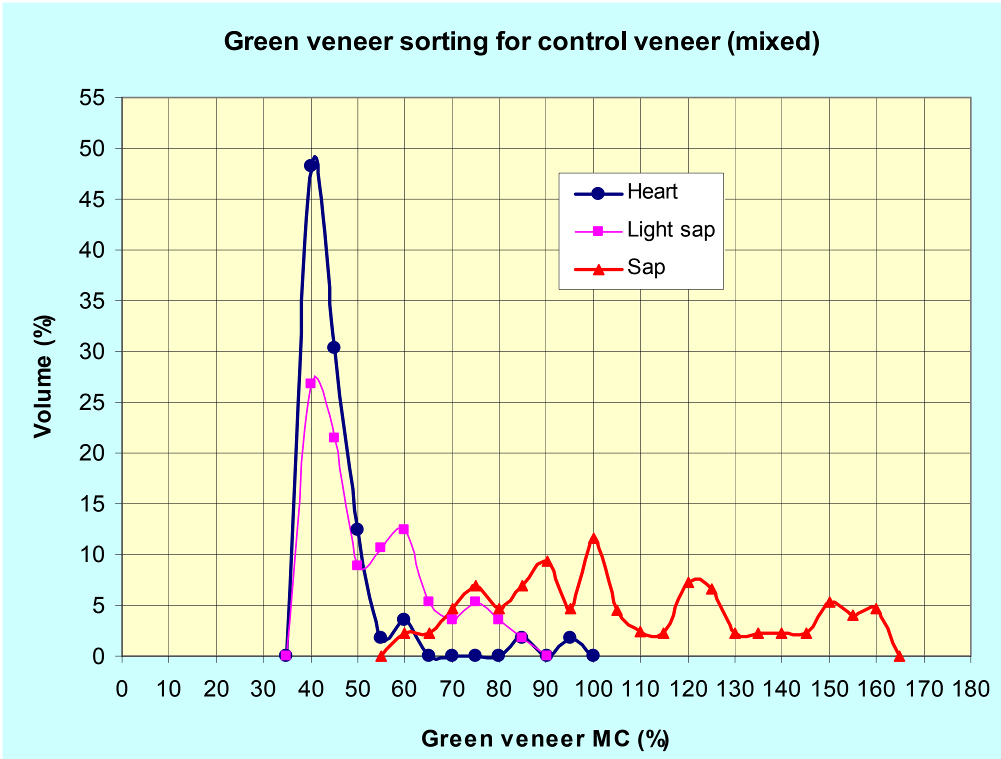

Figure 27: The green veneer sorting accuracy for the control veneer (mixed)

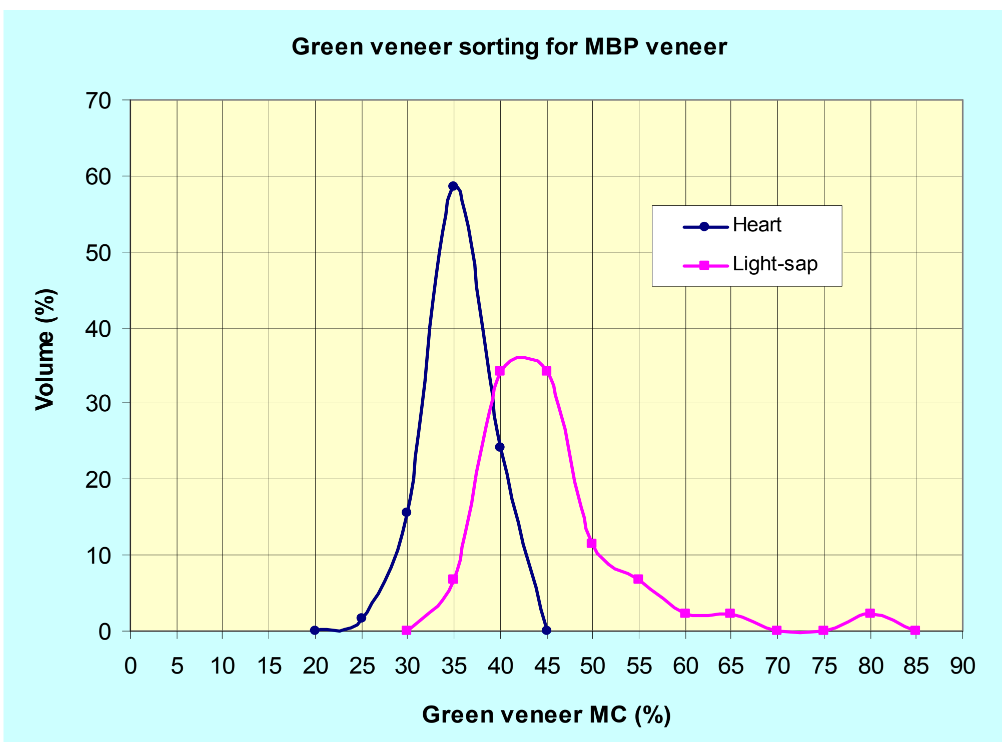

Figure 28: The green veneer sorting accuracy for MBP veneer

Veneer recovery

Table 14 summarizes the veneer recovery data at log yard, green end, dry end, and ?? for MBP logs and control logs (mill shift average). The results demonstrate that:

1) due to the larger diameter of MBP logs, only about 4.5% of MBP logs were sorted for saw logs (Wharton 2004). Hence, the recovery of MBP logs at the log yard/wood room was higher compared to control logs;
2) at the green end, the recovery of MBP logs was about 6% lower than that of control logs, and;
3) the overall veneer recovery with MBP logs was only 42.4%, which was about 8% lower than that with control logs.

In summary, since the volume percentage of MBP logs is about 10% in this mill, the total value loss in recovery from log yard to composer for processing MBP veneer is estimated at $240,000 (1% loss in recovery means $300,000). However, as demonstrated in the pilot plant and mill trials, processing 10% of MBP logs could result in approximately $442,500 annual savings from a 0.1% increase in recovery from veneer clipping and a 2.75% increase in productivity from veneer drying. As a result, there could be a net profit estimated at $202,500 when processing the 10% MBP log volume in the mill.

Table 14: Veneer recovery from mill trials

Veneer recovery	MBP logs		Mill shift average (control logs)	
	Square ft of veneer on 3/8" basis per m^3 log	Recovery	Square ft of veneer on 3/8" basis per m^3 log	Recovery
Log yard/wood room		95.5%		86.0%
Green end	572	50.6%	638	56.5%
Dry end	539	47.7%	N. A	N. A
Overall after composer	479	42.4%	N. A	>= 50%

Note: * N. A refers to not available

Conclusions

Proper log conditioning is key to improving veneer recovery from MBP logs. Conditioning MBP logs at 120 ~ 135^{0}F (49 ~ 57^{0}C) pond temperature with a target core temperature of about 80^{0}F (27^{0}C) helps reduce ribbon breakage, and therefore reduce the volume percentage of random veneer. In addition, the veneer breakage could also be attributed to the dry-out of MBP logs causing cracks and splits in radial and longitudinal directions.

Lathe settings have a pronounced effect on veneer quality and veneer recovery. A proper lathe setting with a CR of about 13% produces the highest quality veneer and reduces breakage of the veneer ribbon.

Compared to the control veneer, MBP green veneer has lower moisture content (MC) and smaller MC variation. In general, MBP veneer can be clipped narrower with an equivalent of 1% increase in recovery because of less width shrinkage, and be sorted more accurately requiring only two green sorts: heart and light-sap. In particular, the MBP light sap sort is comparable to the control heart sort. MBP veneer can also be dried faster with a reduction in drying time of about 25% for the heart veneer and about 35% for the light sap veneer. Despite about 1% increase in recovery from veneer clipping and 27.5% increase in productivity from veneer drying, the recovery of MBP logs is about 8% lower than that of control logs due to higher percentages of narrower random sheets and waste from peeling, and increased manual handling and composing. As well, although the bluestain in MBP veneer is lightened after drying, it still interferes with the visual grading.

Recommendations

Since Mountain Pine Beetle-killed Pine (MBP) logs are drastically different from other kinds of logs in terms of moisture content (MC) and subsequent processing characteristics, it is recommended that the species be sorted in the log yard. Such sorting allowed us to take advantage of the shorter drying time, and reduce the amount of over-dried veneer. Logyard sorting brings about significant savings from increased recovery and productivity as the proportion reaches about 10% of the logs procured. To achieve uniform target core temperature during log conditioning, sorting of MBP logs based on diameter is recommended. Furthermore, it is recommended that proper lathe settings with a CR of about 13% be adopted by the mill, and new visual grading recipes be developed to handle MBP veneer on the production line. Finally, as a follow-up to this study, the effect of MBP veneer on panel lay-up and hot pressing, product grade, panel stiffness, and bonding strength needs to be examined and quantified. By implementing the above recommendations, substantial savings can be realized by the B.C. plywood industry.

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Contacts:
Brad Wang or Chunping Dai
Forintek Canada Corp.
2665 East Mall, Vancouver, B. C. V6T 1W5
Tel: 604 222 5737 Fax: 604 222 5690
Email: wang@van.forintek.ca or dai@van.forintek.ca

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Contact:

For more information on the Canadian Forest Service, visit our web site at:
www.nrcan.gc.ca/cfs-scf

or contact the Pacific Forestry Centre
506 West Burnside Road
Victoria, BC V8Z 1M5
Tel: (250) 363-0600 Fax: (250) 363-0775
www.pfc.cfs.nrcan.gc.ca