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PRODUCTION OF HIGHER-VALUE TREATABLE SPF LUMBER

BY
P.I. MORRIS*, F. LAM* & J.F.G. MCKAY*

*Forintek Canada Corp.
6620 N.W. Marine Drive
Vancouver, B.C.
V6T 1X2

Departmental Representatives:

D. Haley, J. de Lestard & M. Heit
Forestry Canada
Pacific & Yukon Region
Pacific Forestry Centre
506 W. Burnside Road
Victoria, B.C. V8Z 1M5

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SUMMARY

Forintek has developed process technology to overcome the relatively low permeability of many Canadian wood species.

This report describes the results of experiments performed on western spruce-pine-fir (SPF) using the commercial prototype of a novel incisor. We investigated the effects of this incisor on the strength of the treated lumber, on degrade during drying and on the treatability of SPF. The variations in treatability between various sources of western SPF and between the individual species were also evaluated. Finally, in a supplementary study, the effect on treatment quality of increasing the duration of pressure treatment and using higher pressures were determined using one source of SPF.

The machine, developed by Forintek Canada Corp. and built by B.C. Cleanwood Preservers Ltd., uses synchronized pairs of incising rollers to lay down two superimposed patterns of incisions at a density of almost 12000 incisions per square metre (double-density incising). It has 12 mm-long thin sharp teeth which, when the lumber is incised green, separate rather than cut the wood fibers, leaving acceptable surface appearance and strength. Measured reductions of up to 23% in bending strength (fifth percentile modulus of rupture) and 7% in bending stiffness (mean modulus of elasticity) compared very favourably with those from other incisors, producing less than 6000 incisions/m^3, in previously published studies. The reductions from double-density incising were also less than the figures specified in the current Canadian building codes for incised and pressure treated lumber. Strength and stiffness reduction should therefore be no impediment to the commercial use of double-density green incising.

By incising the lumber before drying, the rate of drying was increased and the proportion of boards with checks was reduced from 11.6 to 1.1 %. Contrary to expectations, the spruce boards showed no more tendency to check than did lodgepole pine. These results should alleviate concerns about the influence of checking on the performance of treated spruce.

SPF from seven British Columbia sawmills showed no trend of increase or decrease in treatability with increasing latitude of origin. Thus, should spruce be included in Canadian or USA treated lumber standards no sources of spruce, within the western SPF area, need be excluded.

Further evaluation of this material with respect to variation between species showed, overall, equivalent penetration results for double-density incised spruce and lodgepole pine heartwood and even better penetration for alpine fir. Thus, there appears to be no technical reason why spruce and alpine fir should not be included in the American Wood Preservers' standards alongside lodgepole pine.

Where one species was much less treatable than the others, as in material obtained from Alberta, increasing the press time from two to six hours

brought the penetration and retention in spruce up to match that achieved in pine. The alpine fir in this experiment, and in material from across B.C., was more treatable than either of the other two species. Nevertheless, spruce, lodgepole pine and alpine fir could all be treated to meet Canadian and U.S. ground contact commodity standards by adjusting the duration of pressure treatment.

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1.0 OBJECTIVES

1. To improve the yields of higher value lumber by incising to reduce the down-grade caused by rapid drying.

2. To add value to the SPF resource by demonstrating a process for production of a pressure treatable SPF lumber product with minimal strength loss or change in surface appearance.

3. To provide access for SPF to the added value pressure treatment market in the USA by demonstrating the treatability of SPF from B.C.

2.0 INTRODUCTION

Forintek has developed process technology to overcome the relatively low permeability of many Canadian wood species. Species which yield predominantly heartwood lumber can be difficult to dry and difficult to pressure treat with preservatives. For example, the incising and pressure treating technology which is commercially available will not allow spruce, in particular, to be treated consistently to meet the 10 mm preservative penetration requirement in Canadian and USA treated lumber commodity standards. Consequently, white spruce (Picea glauca [Moench] Voss.) and alpine fir (Abies lasiocarpa [Hook] Nutt.) are not listed in the American Wood Preservation Commodity Standards and thus most Spruce-Pine-Fir (SPF) is excluded from the U.S.A. pressure treated wood markets. The work reported here is intended to enable sawmills to produce a lumber product which would be treatable by pressure processes. Such a treatable SPF would have added value and would be directed towards a market which is less dependent on housing starts than the untreated lumber market. This is because fifty percent of the treated lumber produced in North America is now used in residential remodelling and repair, rather than new housing.

The development of a treatable SPF product is mainly dependent on improvements in incising technology. Incising is required for pressure treatment of all Canadian heartwood lumber, either to meet CSA 080 or AWPA standards or to compete with U.S. southern pine and Chilean radiata pine sapwood lumber, both of which are readily treatable without incising. The Canadian pressure treating industry is already using close-spaced incising with thin sharp teeth on green-planed hem-fir. The incised lumber has an excellent surface appearance and can be dried to an ideal moisture content for pressure treatment. In contrast SPF is normally kiln dried and then incised, resulting in poor treatability and a poor surface appearance. Furthermore, the fine tooth incisors which can allow hem-fir to meet the standards still do not have a sufficiently close spacing to treat SPF. By adapting the procedure used for hem-fir and using a sufficiently high incision density a treatable SPF with an acceptable surface appearance might be produced.

During the early 1980's incisor development moved towards increased incision densities and smaller incisions. This work took place, in parallel, in research laboratories and in industry. At Forintek's Vancouver Laboratory, Ruddick (1980) increased the density of incisions from a conventional roller incisor by passing lumber through twice. From this work arose his concept of synchronized pairs of rollers laying down two superimposed patterns of incisions on each face of a board. Work on a laboratory prototype machine began in 1984 and in 1989 a patent was granted on this concept (Ruddick 1989).

Meanwhile, within the Canadian wood preservation industry, improvements in conventional roller incisors lead to two new designs of sharp-tooth high-density incisors (de Lissa 1987; Silcox 1987a). Silcox of B.C. Cleanwood Preservers Ltd.(1987a) designed a thin sharp 10 mm long tooth but his major concern was to increase the speed of processing, to eliminate downtime needed to clean rollers clogged with slivers of wood and to ensure a consistent incision depth. Consequently his major patented (Silcox 1987b) contribution to incisor development consisted of moveable spacer rings which are pushed away from the wood surface as the teeth penetrate the wood and consequently push off any slivers of wood caught between the teeth on the opposite side of the roller. The use of this "clean ring concept" and the process of sharpening the teeth limited the incision density to a maximum of $5860/m^2$.

During 1988 and 1989 collaboration between Forintek and BC Cleanwood Preservers Ltd. resulted in the construction of a commercial prototype machine incorporating the clean ring concept (Silcox 1987b), the synchronized paired roller concept (Ruddick 1989), longer (12 mm) teeth and the double parallel incisor pattern recommended by Ross and Morris (1988). This machine produces the ultra high density pattern illustrated in Figure 1 with 11720 incisions per square metre. This paper describes the results of investigations into the effect of this double-density incisor on properties of SPF lumber.

One major concern with such a high incision density is the effect on the strength of the lumber. The quantification of this effect has therefore been a major objective of this work.

In addition to the expected improvements in treatment from such an incisor, it was anticipated that the wood may dry faster and more evenly, leading to reduced degrade and allowing high temperatures to be used. These aspects have therefore been investigated.

In order to provide a green incised SPF product it will be necessary to plane the lumber in a green condition prior to incising otherwise some of the incision depth is removed by planing. The work described in this paper has therefore been performed on green-planed SPF. The size variation after drying has therefore been monitored.

When western white spruce and Engelmann spruce were proposed for inclusion in the American Wood Preservers' Association C2 Standard, one concern raised was that the treatability data presented concerned SPF from only one sawmill in B.C. This present study has therefore evaluated the treatability of SPF from 7 different sawmills covering a wide geographic distribution within B.C.

This report incorporates drying, strength and treatability data on SPF lumber from across B.C. subjected to various incising and treatment processes.

3.0 MATERIALS

Three thousand one hundred boards of rough-green 2.4 m (8') SPF, nominal 2 x 4 in lumber were donated by two sawmills in Mackenzie, two sawmills in Prince George and one sawmill in each of 100 Mile House, Kamloops and Grand Forks. These sawmills were judged to be representative of mills in their local area.

The proportions of lumber from each of the three lumber associations reflected their relative production rates thus about 50% of the material came from the Northern Interior Lumber Sector (NILS), 25% from the Cariboo Lumber Manufacturers Association (CLMA) and 25% from the Interior Lumber Manufacturers Association (ILMA). The lumber was shipped to Vancouver and custom planed to surfaced green size 39 x 90 mm.

Assignment of lumber to processing groups

On receipt at Forintek each piece of lumber was identified as to species and visually graded. The specimens were graded according to National Lumber Grading Authority grading rules as No. 3, No. 2, No. 1 and Select Structural. Only the No. 2 and better material was kept which resulted in a sample size of 1995 specimens. The species and grade controlling defects were monitored and clearly marked on each specimen. The dimensions at mid-length of each specimen were measured and recorded. A Cook-Bolinders SG-AF continuous lumber grading machine was used to estimate the flatwise Modulus of Elasticity (MOE) profile of each specimen. Each specimen was fed into the machine and forced to deform flatwise under a prescribed centre point deflection of 4.51 mm at a span of 910 mm. The machine continuously measured the load required to deform the specimen flatwise and converted the load readings to flatwise MOE estimates along the length of the lumber. To eliminate the effect of bow and kink in the lumber, each specimen was rotated 180^{o} about its longitudinal axis and fed through the machine a second time. The MOE estimates between the two passes were averaged to obtain the flatwise MOE estimates along the length of the lumber. A feed speed of 15 m/min. was used. Load readings were recorded at 102 mm intervals along the specimen.

The specimens from each grade were ranked according to the average flatwise MOE in ascending order. Specimens with the 7 lowest average flatwise MOE values were selected and randomly assigned to one of the seven matched groups. The specimens with the next 7 lowest average flatwise MOE values were then selected and assigned. This process was repeated for each mill until all the specimens were assigned to the 7 groups. This process resulted in 7 sample groups with matched flatwise MOE and representative numbers of boards from each mill. Six of the groups were processed as follows:

1. Not incised, pre-dried, no treatment, redried.
2. Not incised, pre-dried, pressure treated, redried.
3. Double-density - incised green, pre-dried, pressure treated, redried.
4. Pre-dried, double-density - incised dry, pressure treated, redried.
5. Pre-dried, single-density - incised dry, pressure treated, redried.
6. Double-density - incised green, pre-dried, no treatment, redried.

The seventh group was due to be incised with the Forintek high-speed, high-density incisor but preliminary studies showed that pressure treatment of this material would not meet the required standard. Further development of this incisor was therefore initiated and the group 7 lumber was kept in reserve.

Drying

Pre-drying and subsequent redrying were done in Forintek's kiln using a conventional schedule of 71^{o} C dry bulb and 60^{o} C wet bulb. The target moisture content (mc) for pre-drying was 25-30% mc and that for redrying was 8% mc.

The effect of incising on the drying process was investigated using groups 2 (unincised) and 3 (double-density green-incised). Each board was weighed before and after pre-drying and a moisture metre reading was also taken after the pre-drying process.

Groups 2 and 3 were also evaluated for checks, end-splits, crook, bow and twist before drying, after pre-drying and again after redrying.

Incising and Preservative treatment

The incising of groups 3-6 was done using the experimental incisor developed by Forintek and built by B.C. Cleanwood Preservers Ltd. at their plant in Surrey. Pressure treatment of groups 2-5 was done by B.C. Cleanwood Preservers Ltd. using 1.7% CCA and the following commercial schedule:

Schedule A

- 45 minute vacuum
- 2 hours at 1035 kpa pressure
- 15 minute final vacuum.

After the treatment data were obtained for groups 2-5, it was decided to try increasing the incision depth and lengthening the treating cycle in at B.C. Cleanwood Preservers Ltd. with a reduced gap between opposite incisor rollers. This resulted in an increase in incision depth from 8-9 mm to 9-10 mm. The lumber was then pre-dried at Forintek to 25-30% mc and half of these boards were pressure treated with 2.2% CCA using the following, longer schedule:

- 1/2 hour vacuum, 700 mm Hg
- pressure increased to 1035 kpa (150 psi) in 172 kpa increments with a 5 minute holding period after each increment.
- 6 hours at 1035 kpa pressure
- 15 minute clean-up vacuum 700 mm Hg

The treated boards were left for 4 days for fixation to take place then both the treated and the untreated incised groups were redried.

Increment core samples 6 mm in diameter were then removed from the heartwood face of each board and split in half along the grain. They were checked for copper penetration, using the chrome-azurol-S reagent on half of the split core (American Wood Preservers' Association 1989a) and for preservative retention using X-ray fluorescence spectroscopy (American Wood Preservers' Association 1986) on pellets made from the aggregated second halves of the core samples.

Strength measurement

All 7 groups were further air dried for a minimum period of 3 weeks to achieve a narrow range of moisture content. The dimensions at mid-length of each specimen were then remeasured and it was tested to failure in third point bending using a Forintek-designed hydraulically operated bending machine. The testing procedures conformed to those used in the Canadian Lumber Properties in-grade testing program (Lam, 1987). The machine was displacement controlled and operated at a rate of 2 mm/second which resulted in an average time-to-failure of between 30 to 60 seconds. A span-to-depth ratio of 17:1 was used. The specimen was positioned randomly such that the maximum strength reduction defect was randomly located between the supports. The machine stroke and load were recorded on a computer. The edgewise modulus of elasticity (MOE) and modulus of rupture (MOR) of each specimen were estimated from the data.

A moisture content sample was then cut from each specimen near the failure location. The moisture content and specific gravity of each specimen were determined following American Society for Testing and Materials D2395 method B (ASTM 1989).

During the incising and pressure treatment process approximately 50 specimens were damaged and discarded from the test samples. The final sample size and description of each sample group are shown in Table 13. For each sample group, the nonparametric point estimate of the fifth percentile bending strength (MOR_5) is given by:

$$MOR_5 = (1 + i - 0.05(n+1)MOR_1 + (0.05(n+1) - i)MOR_{i+1} \quad (1)$$

where n is the sample size, i is the greatest integer less than or equal to (0.05(n+1)), and MOR_1 is the observed value of the i^{th} order statistic of the sample.

The method for estimating the nonparametric 95% confidence intervals for the fifth percentile and median bending strength and the median MOE of each group is based on normal approximation to the incomplete beta function ratio and is given in detail by Gibbon (1971).

The difference between the strength properties of two groups at a particular percentile can be considered insignificant, when the nonparametric confidence intervals for the groups overlapped (Gibbon 1971). The nonparametric confidence intervals between groups 2-7b and group 1 (control) were compared.

4.0 RESULTS

Drying

During pre-drying the mean calculated moisture content of the unincised boards dropped from 48.9% to 30.7% in 8 hours; a rate of 2.3% per hour. The mean for the incised boards dropped from 51.3 to 28.1% in 8 hours, a rate of 2.9% per hour. Thus the incised boards dried faster than the unincised boards under identical conditions in the same kiln run.

With regard to drying defects there was no statistically significant difference after redrying between the incised and the unincised boards in crook (Table 1) Bow (Table 2) Twist (Table 3) or Ring-shake (Table 4). For end-splits (Table 5) the apparent difference between 2.8% (unincised) and 0% (incised) of the boards having end-splits was not statistically significant, however, further evaluation of end-splitting is warranted in further experiments.

There was, however, a statistically significant reduction in surface checks due to incising (Table 6). After redrying to 8%, 11.6% of the unincised and 1.1% of the incised boards had surface checks.

When the checking data was broken down by species (Table 7) there was no statistically significant difference in checking between spruce, pine and alpine fir when unincised. All three species exhibited the same reduction in percentage of checked boards when incised.

Preservative treatment

The most important result obtained from the treatment data for the commercially treated groups (2-5) was the similarity between the mean preservative penetrations and retentions from the NILS, CLMA and ILMA material (Table 8). This demonstrated no trend of increasing or decreasing treatability with latitude of origin. This held true for all three incising processes.

In comparison to unincised material, single-density dry-incising doubled the preservative retention and more than doubled the percentage of boards meeting the 10 mm penetration requirement. In comparison to single-density dry-incising, double-density dry-incising gave a further increase of 10% in retention and a further 40% increase in compliance with the penetration requirements. Double-density green incising gave similar results to single-density dry incising: 2.0 kg/m^3 retention and 32% of boards over 10 mm penetration.

The differences between the various incising processes were more noticeable when examining the percentage of samples meeting the 5 mm penetration requirement in the Canadian Institute of Treated Wood PSI Standard for residential lumber (Table 9). None of the unincised samples and less than a quarter of the single-density incised samples would have passed this standard. In contrast over two thirds of the double-density green-incised and all of the double-density dry-incised samples would have met the 5 mm penetration requirement. Tables 8 and 9 both present data on SPF grouped by mill of origin. Table 10 presents the same data with respect to the three individual species.

When the treatment data from all the mills were grouped together and broken down by species (Table 10), unincised pine proved to be significantly more treatable than either spruce or alpine fir. Single-density dry-incising made alpine fir the most treatable but double-density incising, green or dry, eliminated the differences in treatability between the three species.

None of this material came close to meeting the Canadian Standards Association ground contact standard (CSA 080.2) of 6.4 kg/m^3 retention and 80% over 10 mm penetration. Since previous, successful, experiments had used a minimum press time of 6 hours, group 7 was divided in two and half was subjected to a pressure treatment schedule of 6 hours duration. The mean retention in this material met the level required in CSA 080-2 for above ground exposure but not the ground contact requirement (Table 11). The mean percentage of boards again fell short of the requirement for 80% over 10 mm but came considerably closer than the material treated with a commercial 2 hour press. There was no statistically significant difference between the mean preservative penetration for the 7 mills.

As with the commercially treated material the data from group 7 was grouped together and then broken down by wood species. For this group, with double-density green-incising and a 6 hour pressure period, spruce and pine had almost identical percentages of boards with preservative penetration over 10 mm (Table 12). The one group of 20 alpine fir boards had a considerably higher percentage of boards with over 10 mm penetration, 90%. There was, however, no statistically significant difference between the mean preservative penetrations for the three species.

Since the lumber had still failed to pass the CSA 080.2 standard even with a 6 hour press time another explanation was sought for this unexpectedly poor performance. Examination of cross sections of double-density-incised and treated material revealed that one of the two superimposed patterns of incisions was not penetrating to the full depth of 10 mm. This had not been apparent from the surface appearance of the lumber or from the core samples and was only visible after the material had been broken (see below) and cross cut to remove a sample for moisture content determination. This machine fault was therefore rectified and further material, from a source in Alberta was incised and treated with various durations of pressure period and various pressures (see Appendix 1). This additional work demonstrated that double-density incised SPF at 25-30% mc could be successfully treated to meet above-ground, ground-contact, or Preserved Wood Foundation standards by varying the pressure treatment schedule.

Strength

None of the changes in mean MOE for any of the treated and untreated incised groups were statistically significant (Tables 14-16). However, the mean MOR values of groups 3-76 were all significantly different from the mean MOR of group 1 (the control group). The largest changes in mean MOR were 17.03% for the double-density dry incised and 20.83% for the double-density, green-incised 6 hour pressure treated group (group 7) (Table 16). The largest changes in fifth percentile MOR were 23.60% and 23.44% for the group 7 double-density, green-incised untreated and the double-density, green-incised 6 hour pressure treated group, respectively. The strength reduction for double-density dry-incising was not significantly different from that for single-density dry-incising or double-density green-incising.

The differences in MOE for all treated and untreated incised groups were not statistically significant. Compared to the control group, group 7b showed the largest change in mean MOE and mean MOR at approximately 16% and 21%, respectively. Both group 7a and 7b showed relatively large changes in MOR_5 when compared to the control group at 23.60% and 23.44%, respectively.

Size variation

The variation in dimensions of the green-planed SPF lumber after predrying, pressure treatment and redrying, were considerably larger than would be expected from planing dry lumber. The standard deviation for the mean dimensions of planed dry lumber has been estimated as 0.2 mm (Wang unpublished) whereas the standard deviations for the dried green-planed lumber in this study were 0.4 mm for thickness and 0.9 mm for width. Of the three species alpine fir showed the smallest shrinkage, presumably due to its lower density. The alpine fir lumber was, on average, 0.3 mm thicker and 0.4 mm wider than the spruce or pine lumber. Nevertheless, this amount of variation is not onerous and should not be an obstacle to the marketing of green-planed pressure-treated SPF in the same way that green-planed pressure-treated hem-fir is marketed now.

5.0 DISCUSSION

The benefits of double-density green-incising relate to drying rate, treatability and strength. The increase in drying rate due to incising may not, in itself, be sufficient to warrant incising of lumber which is not to be pressure treated since the 17% reduction in mean strength and a 25% reduction in allowable stress would likely negate any financial benefit in reduced drying time. However, if a mill were producing a green-planed, green-incised SPF product specifically for the treating industry the reduced drying time might help to offset the cost of incising the lumber making such an added-value product less costly to produce.

Similarly the only beneficial effect of incising on drying defects demonstrated so far, that of reduced checking, could not justify the incising of mill run lumber since surface checking does not affect grade and, in turn, lumber value.

The absence of any effect on defects such as crook, bow and twist caused by longitudinal stresses might be expected from the longitudinal orientation of the incisions. These would separate the fibers laterally but not longitudinally. Relief of lateral stresses would, however, effect surface checking and possibly end-splitting. Lateral stresses also cause cupping but this defect could not be quantified in such a small width of board. Further work should be done on 2 x 10 lumber to look for any influence of incising on cupping.

The mechanism for the reduction in checking was obvious from an examination of the incised material at the end of the experiment. The stresses which cause large checks had been distributed evenly across the board resulting in micro checks extending a few mm longitudinally in both directions from each incision (Figure 2). There was no indication that this micro-checking caused any deepening of the original incision during drying. This deepening during drying had been diligently searched for since it was hoped that it would permit improved penetration of preservative and reduce the depth to which incisions must be made. Although such a beneficial effect was not found, it did reduce the likelihood of checking from incisions exposing untreated wood on drying after treatment. One of the major concerns about preservative treatment of spruce was that its perceived tendency to check may lead to a direct pathway for decay fungi past the treated zone to the untreated interior of the lumber. Contrary to expectations the spruce boards showed no more tendency to check than the lodgepole pine.

Further work is underway to assess the long-term effect of incising on checking but this initial study suggests that, by reducing checking, incising may be beneficial to the long-term performance of treated wood over and above its effect on improving preservative penetration.

With regards to the effect of double-density incising on the treatability of SPF the ability to meet CSA Standards with SPF was finally demonstrated with material from Alberta (Appendix 1). Nevertheless, the data obtained from the B.C. material demonstrated two crucial points with respect to insertion of spruce into the Canadian and USA treated lumber commodity standards alongside lodgepole pine.

Firstly, although spruce heartwood may be less treatable than pine heartwood without incising, when double-density incised both species were similarly treatable with respect to preservative penetration. Secondly, there was no trend of increasing or decreasing treatability with latitude of origin, thus there should be no need to exclude from the standards SPF from particular regions within the geographic range of Western SPF. Such an exclusion is currently in place for Douglas fir (Pseudotsuga menziesii [Mirb.] Franco) from the interior of B.C.

When western white and Engelmann spruce were proposed for inclusion in the American Wood Preservers Association C2 Standard in 1988 the T2 Subcommittee concluded that "these species had previously been considered untreatable but technical advancements in incising can now provide for acceptable treatment" (Report of Subcommittee T2 Lumber and Timber). One concern raised was that the data presented concerned SPF from only one sawmill in B.C. and geographical variation in the species had not been addressed.

This concern has now been addressed at least for spruce separated from "western SPF" (Figure 3). Western SPF may best be defined as a Spruce-Pine-Fir mix in which the spruce is either white spruce or Engelmann spruce, the pine is lodgepole pine and the fir is alpine fir. Although white spruce grows all across North America, lodgepole pine and alpine fir are confined to areas west of the Rockies except for a zone in western Alberta (Hosie 1969). The above definition therefore covers the overwhelming majority of the lumber producing area of the Western SPF Association. Eastern SPF (Figure 3) comprises white spruce plus other minor spruce species, jack pine (Pinus banksiana Lamb.) and balsam fir (Abies balsamea [L.] Mill.), and is produced by sawmills east of the Alberta/Saskatchewan border.

The data presented here suggest that there is an acceptable variation in treatability with respect to preservative penetration, between different sources of Western SPF. Previous studies have also shown little or no difference between the treatabilities of white spruce and lodgepole pine from B.C. and from Alberta (Richards and Inwards 1989). The same cannot, however, be said of Eastern SPF. Although jack pine seemed to be reasonably consistent in its treatability, eastern white spruce and balsam fir appear to be rather more variable, with some sources being extremely refractory (Fox 1989, Richards and Inwards 1989). Nevertheless further work will be done to determine whether this refractory behaviour can be overcome using the Forintek double-density incisor and improved treatment process.

Turning finally to the question of the strength reduction from double-density incising, the results compare very favourably with those obtained for older types of incisor (Perrin 1978) despite using over twice the density of incisions. They are also less than the 10 and 30% reductions, for MOE and MOR respectively currently used in the building codes (Canadian Standards Association 086-1 1984). This degree of strength loss should therefore be no impediment to the commercial use of double-density incising for treated lumber.

7.0 CONCLUSIONS

The work reported here has demonstrated, on a commercial scale, that SPF can be provided with double the normal density of incisions while leaving an acceptable surface appearance and strength. The lumber also dried more rapidly and checking was virtually eliminated. Contrary to expectations spruce boards showed no more tendency to check than did lodgepole pine. These results should alleviate concerns about the influence of checking on the performance of treated spruce. Using this ultra-high incising density and lumber at 25-30% moisture content, SPF from one source in Alberta was treated to meet Canadian and U.S. commodity standards, using an appropriate treating schedule. There was no discernable variation in treatability related to the latitude from which the lumber was obtained. Furthermore, with regard to the component species of the SPF mix, the limited number of samples of alpine fir were more treatable than the other two species and white spruce was just as treatable as lodgepole pine. In consequence there seems to be no technical reason why white spruce, Engelmann spruce, and alpine fir from Western SPF should not be included in the AWPA lumber commodity standards alongside lodgepole pine.

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TABLE 1

EFFECTS OF DOUBLE-DENSITY INCISING ON CROOK IN SPF LUMBER

		Green	**Pre-dried to 25%**	**Treated & Dried to 8%**
Percentage of boards with crook >6 mm	Unincised	6.3 ± 2.9#	10.2 ± 3.6	9.5 ± 3.5
	Incised	3.9 ± 2.3	3.5 ± 2.2 *	6.7 ± 3.0
Mean crook (mm)	Unincised	13 ± 3	11 ± 2	11 ± 1
	Incised	12 ± 1	11 ± 2	15 ± 7

* Statistically significant difference between incised and unincised
\# 95% confidence limits

TABLE 2

EFFECTS OF DOUBLE-DENSITY INCISING ON BOW IN SPF LUMBER

		Green	**Pre-dried to 25%**	**Treated & Dried to 8%**
Percentage of boards with bow >6 mm	Unincised	4.2 ± 2.4	3.9 ± 2.3	3.2 ± 2.1
	Incised	3.9 ± 2.3	3.5 ± 2.2	6.7 ± 3.0
Mean bow (mm)	Unincised	10 ± 1	10 ± 2	19 ± 4
	Incised	13 ± 5	11 ± 2	13 ± 3

TABLE 3

EFFECTS OF DOUBLE-DENSITY INCISING ON TWIST IN SPF LUMBER

		Green	Pre-dried to 25%	Treated & Dried to 8%
Percentage of boards with twist >6 mm	Unincised	0.0	0.0	0.4 ± 0.7
	Incised	0.0	0.0	1.4 ± 1.4
Mean twist (mm)	Unincised	0	0	13[#]
	Incised	0	0	14 ± 13

[#] one sample only

TABLE 4

EFFECTS OF DOUBLE-DENSITY INCISING ON DEVELOPMENT OF RING-SHAKES IN SPF LUMBER

		Green	**Pre-dried to 25%**	**Treated & Dried to 8%**
Percentage of boards with ring shake	Unincised	0.7 ± 1.0	1.1 ± 1.2	2.8 ± 2.0
	Incised	0.7 ± 1.0	0.7 ± 1.0	1.1 ± 1.2
Mean length of shake in boards with ring shake	Unincised	1.53 ± 11.6	1.23 ± 2.6	1.4 ± 0.75
	Incised	1.53 ± 11.6	1.68 ± 9.7	2.13 ± 1.30

TABLE 5

EFFECTS OF DOUBLE-DENSITY INCISING ON DEVELOPMENT OF END SPLITS IN SPF LUMBER

		Green	**Pre-dried to 25%**	**Treated & Dried to 8%**
Percentage of boards with end-splits	Unincised	0.7 ± 1.0	0.4 ± 0.7	2.8 ± 2.0
	Incised	0.0	0.0	0.0
Mean split length (mm) in boards with end-splits	Unincised	0.09 ± 0.16	0.91#	0.32 ± 0.30
	Incised	0.0	0.0	0.0

one sample only

TABLE 6

EFFECTS OF DOUBLE-DENSITY INCISING ON DEVELOPMENT OF SURFACE CHECKS IN SPF LUMBER

		Green	Pre-dried to 25%	Treated & Dried to 8%
Percentage of boards with checks > 100 mm	Unincised	1.1 ± 1.2	7.0 ± 3.0	11.6 ± 3.8 *
	Incised	1.8 ± 1.6	2.5 ± 1.8	1.1 ± 1.2
Mean check length of checked boards (m)	Unincised	0.20 ± 0.53	1.25 ± 0.45	1.18 ± 0.33
	Incised	0.83 ± 1.20	1.00 ± 9.7	2.13 ± 1.30

* Statistically significant difference between incised and unincised

TABLE 7

COMPARISON OF CHECKING IN SPRUCE, PINE AND ALPINE FIR TREATED AND DRIED TO 8% MOISTURE CONTENT

		Spruce	Pine	Alpine Fir
Percentage of boards with checks > 100 mm long	Unincised	10.5 ± 6.6 *	12.1 ± 5.0 *	11.1 ± 12.1
	Incised	1.0 ± 2.0	1.2 ± 1.7	0.0
Mean check length of checked boards (m)	Unincised	0.94 ± 0.77	1.44 ± 0.41	2.23 ± 0.87
	Incised	2.43#	1.98 ± 5.80	0.0

* statistically significant difference between incised and unincised

\# one sample only

TABLE 8

TREATABILITY * OF SPF FROM ACROSS BRITISH COLUMBIA
WITH VARIOUS INCISING PROCESSES AND A 2-HOUR PRESS

		UNINCISED		SINGLE-DENSITY DRY**		FORINTEK DOUBLE-DENSITY DRY**		FORINTEK DOUBLE-DENSITY GREEN***	
MILL	SAMPLE	PENETRATION % > 10	RETENTION kg/m³	PENETRATION % > 10	RETENTION kg/m³	PENETRATION % > 10	RETENTION kg/m³	PENETRATION % > 10	RETENTION kg/m³
1	2	5	1.1	30	1.6	30	2.4	30	1.7
2	1	5	1.0	35	1.8	45	1.8	20	1.9
	2	20	1.0	60	3.0	50	2.3	50	2.1
	3	5	1.0	45	1.9	70	2.9	55	2.4
	4	30	1.5	30	1.7	50	2.5	35	1.5
3	1	25	1.4	25	1.8	30	1.9	20	1.7
	2	15	1.0	45	2.2	40	2.0	50	3.0
	3	10	0.6	30	2.1	35	2.0	25	1.8
4	1	10	0.8	35	2.4	45	2.7	25	2.2
5/6	1	10	0.8	10	1.7	30	2.4	15	1.7
7	1	10	0.7	15	1.4	20	1.7	40	1.6
8	1	0	1.1	35	2.0	40	2.0	20	2.1
	2	20	1.5	30	2.0	40	2.4	35	2.3
Mean NILS		12	1.0	32	1.9	42	2.3	35	1.8
Mean CLMA		17	1.0	33	2.0	35	2.3	32	2.1
Mean ILMA		10	1.0	33	2.1	52	2.3	27	2.2
Mean all samples		12	1.0	33	2.0	40	2.2	32	2.0

* Treated with a 1.7% solution of chromated copper arsenate at 1035 kPa for two hours at B.C. Cleanwood Ltd.
** Condition of lumber at time of incising. Dry= 25-30% moisture content.

TABLE 9

COMPLIANCE OF SPF WITH A 5 MM PENETRATION REQUIREMENT USING VARIOUS INCISING PROCESSES AND A 2-HOUR PRESS

Mill	Sample	Unincised % > 5 mm	Single-Density Dry % > 5 mm	Forintek Double-Density Dry % > 5 mm	Forintek Double-Density Green % > 5 mm
1	1	15	55	85	70
2	1	30	85	90	80
	2	35	80	95	90
	3	55	70	95	85
	4	50	60	90	90
3	1	30	75	85	65
	2	20	80	90	100
	3	25	65	85	95
4	1	15	65	90	90
5/6	1	10	60	95	70
7	1	15	35	85	85
8	1	15	65	90	90
	2	40	65	85	70
mean		24	66	89	82
% of samples passing		0	23	100	69

TABLE 10

COMPARISON OF PRESERVATIVE PENETRATION IN SPRUCE, PINE AND ALPINE FIR WITH VARIOUS INCISING PROCESSES AND A TWO-HOUR PRESS

	Unincised	Mean preservative penetration (mm)		
		Single-Density Dry	Double-Density Dry	Double-Density Green
Spruce	2.4 ± 0.8	5.9 ± 0.9	8.7 ± 0.7	7.1 ± 0.8
Pine	4.4 ± 0.8*	7.7 ± 0.8	9.2 ± 0.6	8.4 ± 0.6
Fir	2.3 ± 0.8	8.1 ± 1.9**	8.2 ± 1.2	7.1 ± 1.5

* Statistically significantly higher than spruce or fir
** Statistically significantly higher than spruce but not pine

TABLE 11

TREATABILITY OF DOUBLE-DENSITY GREEN-INCISED SPF FROM ACROSS B.C. WITH A 6-HOUR PRESS

Location	**Penetration** mean* (mm)	**Penetration** % ≥ 10 mm	**Retention** kg/m^3
Mackenzie	10 ± 2	65	4.7
Mackenzie	12 ± 2	70	4.8
Prince George	11 ± 2	74	5.0
Prince George	11 ± 2	50	4.3
100 Mile House	10 ± 2	65	3.5
Kamloops	12 ± 1	80	4.9
Grand Forks	10 ± 2	70	3.9
mean	**11 ± 2**	**68**	**4.4**

* The maximum penetration measured was 16 mm, the length of the core.

TABLE 12

TREATABILITY OF DOUBLE-DENSITY GREEN-INCISED SPRUCE, PINE AND ALPINE FIR WITH A 6-HOUR PRESS

	Spruce	**Pine**	**Fir**
mean penetration (mm)	11 ± 1	11 ± 1	12 ± 2
mean % > 10 mm	63	64	90
Number of sets of 20	2	4	1

TABLE 13

TEST GROUPS AND SAMPLE SIZE
FOR STRENGTH TESTING

GROUP	LUMBER CONDITION DURING INCISING	INCISION DENSITY ($/m^2$)	RANGE OF INCISION DEPTH (mm)	TREATMENT SCHEDULE	SAMPLE SIZE
1	-	-	-	-	385
2	-	-	-	A	281
3	Green	11720	8 - 10	A	275
4	Dry	11720	8 - 10	A	271
5	Dry	5860	7 - 11	A	283
6	Green	11720	8 - 10	-	285
7a	Green	11720	9 - 11	-	141
7b	Green	11720	9 - 11	B	128

TABLE 14

MODULUS OF ELASTICITY, MODULUS OF RUPTURE, FIFTH PERCENTILE MODULUS OF RUPTURE, MOISTURE CONTENT AND PRESERVATIVE TREATMENT DATA FOR ALL TEST GROUPS

GROUP	MOE MEAN ($x10^6$ kPa)	MOE STDV ($x10^6$ kPa)	MOR MEAN ($x10^3$ kPa)	MOR STDV ($x10^3$ kPa)	MOR_5	MEAN MC %	PENETRATION % > 10 mm	RETENTION kg/m^3
1	8.48	1.66	49.35	17.28	24.49	12.9	-	-
2	9.10	1.59	48.99	16.36	24.49	12.9	12	1.0
3	8.76	1.59	42.45	14.77	21.87	9.7	32	2.0
4	8.41	1.59	40.94	14.70	21.16	10.0	40	2.2
5	8.41	1.66	41.74	16.98	20.67	10.5	33	2.0
6	8.14	1.66	41.65	13.82	22.02	12.3	-	-
7a	8.34	1.66	41.10	15.23	18.71	10.0	68	4.4
7b	8.00	1.52	39.08	13.01	18.75	11.9	-	-

Note: STDV denotes standard deviation

TABLE 15

95% CONFIDENCE INTERVAL FOR MEDIAN MOE, MEDIAN MOR, AND MOR_5

GROUP	95% CONFIDENCE INTERVAL		
	MEDIAN MOE ($x10^6$ kPa)	MEDIAN MOR ($x10^3$ kPa)	MOR_5 ($x10^3$ kPa)
1	(8.07, 8.48)	(45.82, 49.16)	(21.89, 26.25)
2	(8.76, 9.17)	(44.68, 49.32)	(22.18, 27.00)
3	(8.48, 9.03)	(37.86, 44.35)	(20.02, 24.43)
4	(8.14, 8.69)	(36.99, 41.99)	(18.93, 22.38)
5	(8.20, 8.69)	(36.32, 40.66)	(17.86, 22.44)
6	(7.79, 8.27)	(38.66, 42.89)	(18.99, 23.45)
7A	(8.00, 8.62)	(35.83, 41.69)	(13.82, 21.52)
7B	(7.65, 8.20)	(33.80, 40.80)	(11.50, 23.40)

TABLE 16

COMPARISONS BETWEEN THE RESULTS FROM THE VARIOUS GROUPS AND THE RESULTS FROM GROUP 1

GROUP	PERCENTAGE DIFFERENCE FROM GROUP 1		
	MEAN MOE	MEAN MOR	MOR_5
2	-6,26%	0.75%	-0.01%
3	-3.69%	13.99%*	10.70%
4	0.46%	17.06%*	13.61%
5	0.48%	15.42%*	15.59%
6	4.25%	15.62%*	10.09%
7A	1.64%	16.73%*	23.60%*
7B	5.90%	20.83%*	23.44%

Note: Negative value denotes that group 1 (control) was weaker and * denotes significantly different from group 1 (control).

TABLE 17

SIZE VARIATION IN GREEN-PLANED SPF

	SPRUCE		PINE		FIR		TOTAL	
	THICKNESS	WIDTH	THICKNESS	WIDTH	THICKNESS	WIDTH	THICKNESS	WIDTH
mean dimension after planing (mm)	39.6	91.0	39.7	91.0	39.6	91.0	39.7	91.0
mean thickness after drying (mm)	38.5	88.1	38.5	88.2	38.8	88.6	38.6	88.2
standard deviation	0.4	0.9	0.4	0.8	0.3	0.8	0.4	0.9
shrinkage %	2.8	3.1	2.8	3.0	2.1	2.6	2.7	3.0

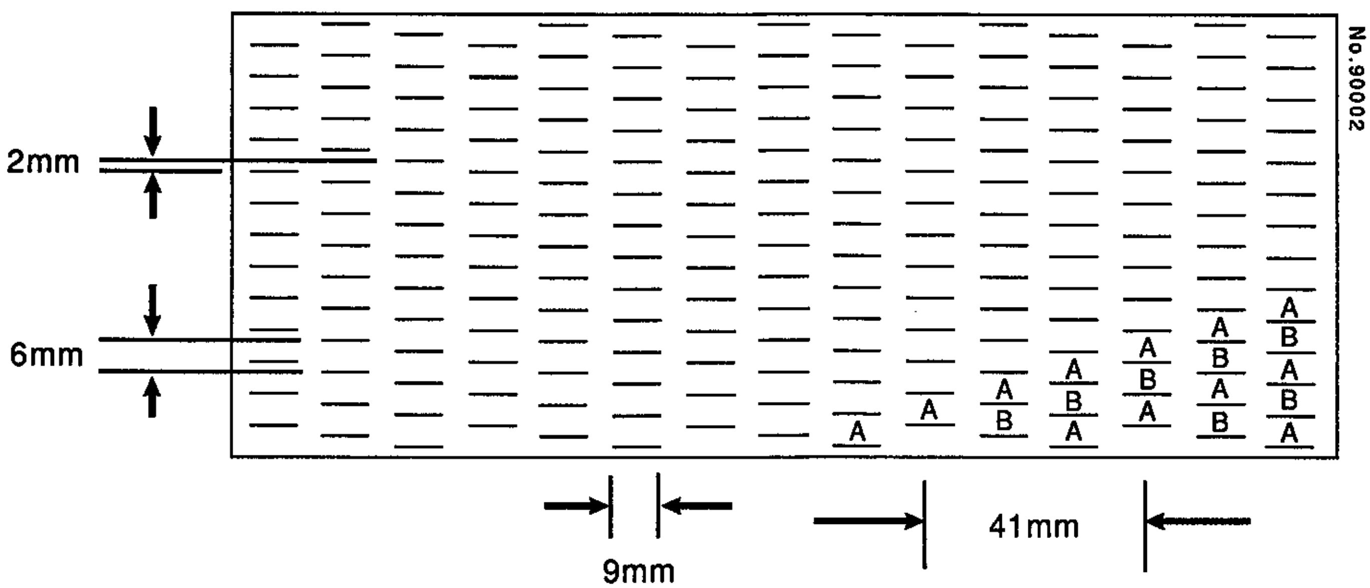

Figure 1. The double parallel incising pattern. Incisions labelled "A" were made by the first roller and incisions labelled "B" were made by the second roller.

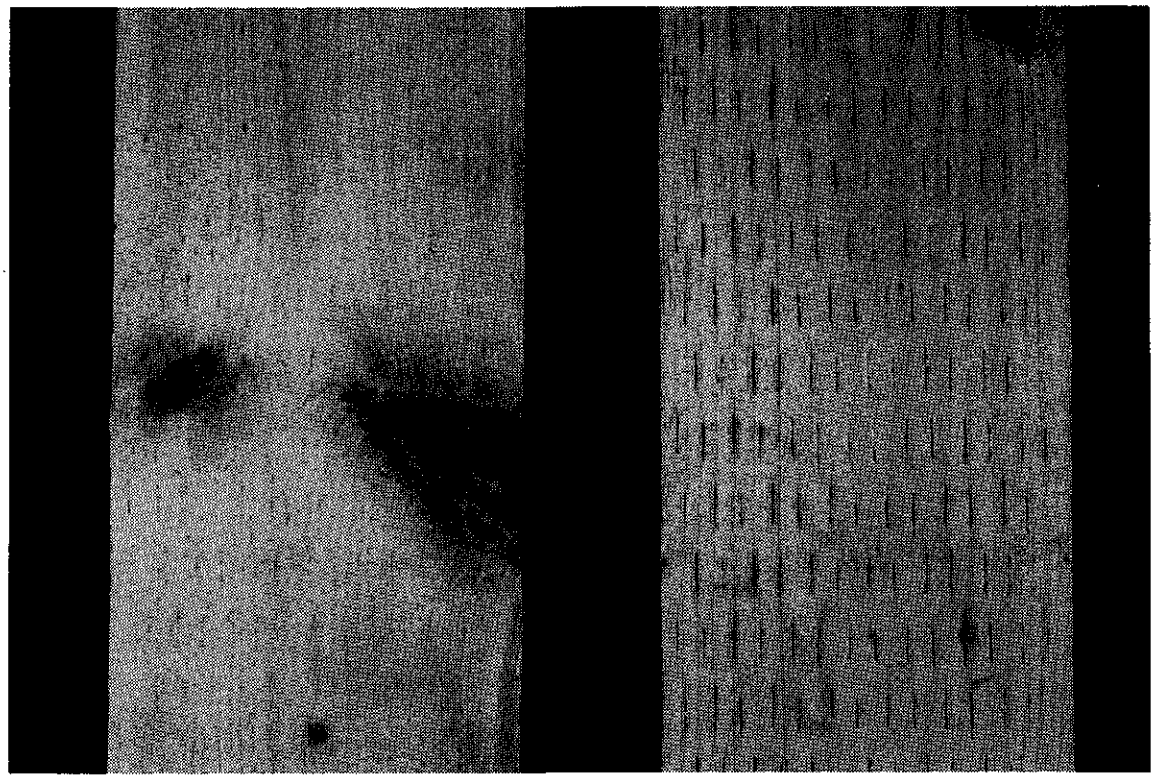

Figure 2. Spruce lumber incised with the double-density incisor in the dry (right) and green (left) condition, pressure-treated with CCA and air-dried.

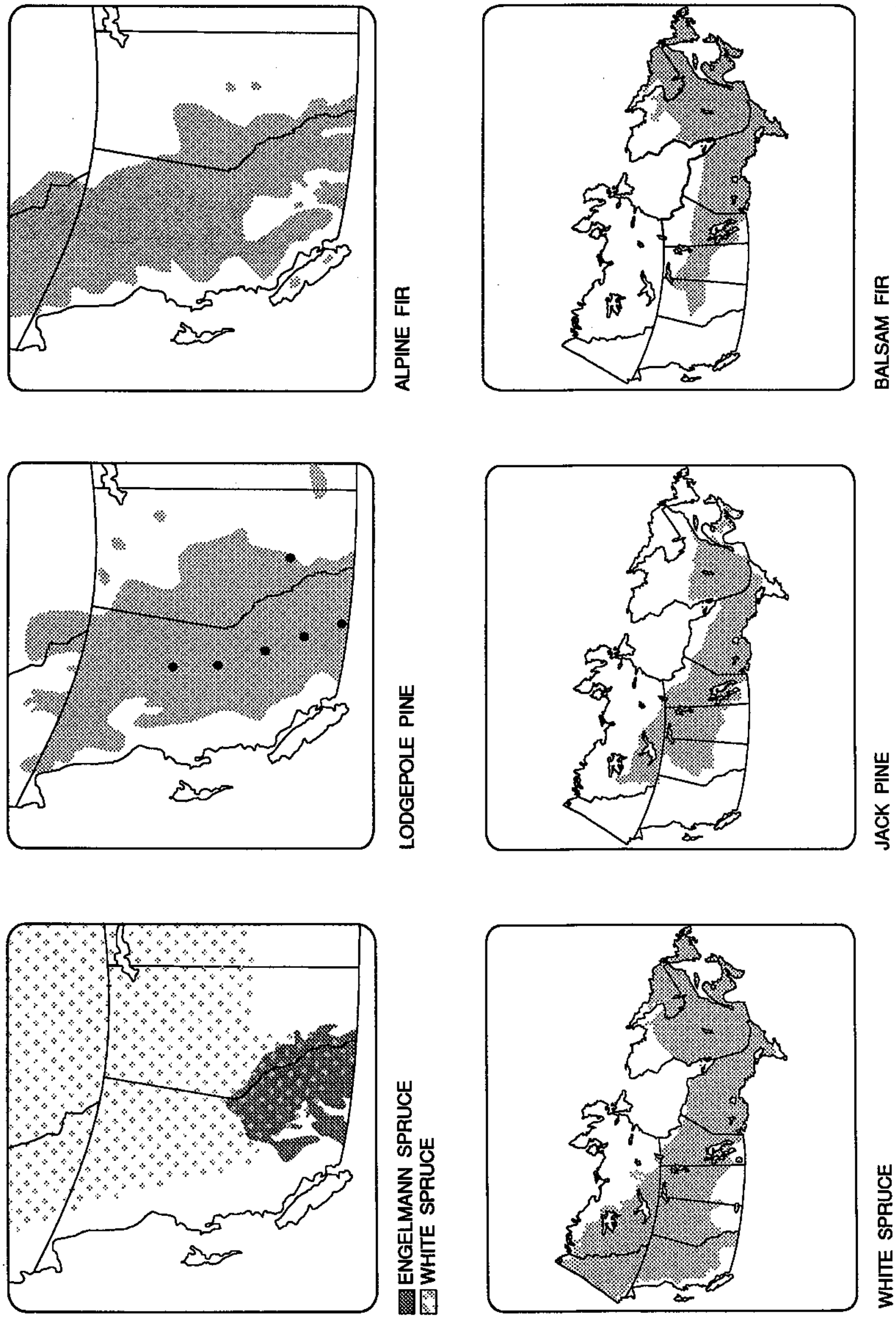

Figure 3. Distribution range of western (top) and eastern (bottom) SPF in Canada. The locations of the sawmills from which lumber was obtained are presented on the lodgepole pine distribution map.

APPENDIX 1

THE EFFECT OF PRESSURE AND ITS DURATION ON TREATABILITY OF ALBERTA SPF

Introduction

A considerable amount of work has been done recently within the wood preservation industry to determine the effect of incising and various treatment schedules on the treatability of Canadian species (Fox 1989; Richards and Inwards 1989). However, material with extremely close spaced incisions might be expected to respond differently to some of these schedule variations. This is particularly likely since Fox (1989) concluded that longer press times result in greater longitudinal penetration but no greater lateral penetration. The double-density incising pattern, due to its 2 mm lateral spacing and 40 mm longitudinal repeat, relies much less on lateral penetration than it does on longitudinal penetration to achieve a joining up of the areas treated from each individual incision.

A number of different press times and two different pressures were therefore tested on SPF from Cochrane, Alberta. This also provided information on treatability of western SPF from east of the Rockies.

Materials and methods

Twenty 2.5 m 2 x 4 boards each of white spruce, lodgepole pine and alpine fir were green-planed, then a 200 mm section was removed from one end. The remaining length was green-incised with the double-density incisor, now with a more even incision depth of 10-11 mm, and dried to 25-30% moisture content. Six 200 mm end-matched samples were cut from each board and end-sealed with a two part epoxy resin. Each set of 20 spruce, 20 pine and 20 alpine fir were treated with 2.5% CCA using one of the following schedules:

- 30 minute vacuum 700 mm Hg
- Release to atmosphere
- Flood cylinder
- Increase pressure to x kPa in 172 kPa increments with a 10 minute holding period between each increment
- Y hours at x kPa
- Release to atmosphere pressure
- Drain cylinder
- 15 minute clean-up vacuum 700 mm Mg

Where x = 1035 or 1240 kPa (180 psi 6 hours only)
Y = 2, 4, 6, 8, or 16 hours

Core sampling and analysis were done as described previously. The results are presented in Table A1.

Results and Discussion

In its natural state this material was not readily treatable. The unincised samples all failed to meet the CSA 080.2 ground contact standard and the unincised spruce was less treatable than the pine or the alpine fir. In contrast, when incised, only the spruce treated for 2 hours failed to meet the penetration requirements. Increasing the press time to 4 hours provided adequate penetration in spruce but 6 hours was needed to give an adequate retention in this species. The pine and alpine fir both met the standard with a 2 hour press time. Increasing the duration of pressure beyond 2 hours gave no further improvement in penetration in pine and alpine fir. Between 8 and 16 hours there was an increase in retention. After 16 hours at 1035 kPa spruce, pine and alpine fir all met the CSA 080.15 standard for preserved wood foundations: over 80% with 10 mm penetration and 8 kg/m^3 retention. Using 1240 kPa instead of 1035 kPa for 6 hours gave an improvement in penetration and, with pine and fir, in retention. No collapse was noted in any of these species. It appears that using this higher pressure can give as good, or better, results than longer press times.

The most impressive effect of double-density incising was observed with the extremely refractory spruce from this location. The unincised material pressure treated for 6 hours at 1035 kPa had a retention of only 1.7 kg/m^3, a mean penetration of only 2.2 mm and no pieces with over 10 mm penetration. When double-density incised, end-matched samples treated with the same schedule passed the CSA 080.2 ground contact standard with 6.7 kg/m^3 and 95% over 10 mm penetration. With a 16 hour pressure period (albeit unrealistic in practice) this refractory spruce passed the CSA 080.15 preserved wood foundation standard with 8.2 kg/m^3 and 95% over 10 mm penetration.

Conclusions

With the ultra-high incision density used in this work, spruce, pine and alpine fir could be treated to meet any CSA and AWPA commodity standards by manipulating pressure and duration of treatment.

TABLE A1

TREATABILITY OF UNINCISED AND DOUBLE-DENSITY INCISED SPF FROM ALBERTA USING VARIOUS TREATING PROCESSES

			Spruce		Pine		Fir	
Incising	Pressure kPa	Duration hrs	% > 10 mm	kg/m^3	% > 10 mm	kg/m^3	% > 10 mm	kg/m
-	1035	6	0	1.7	15	2.6	20	4.2
+	1035	2	75	4.2	95	7.0	90	6.4
+	1035	4	100	5.6	80	7.0	100	7.9
+	1035	6	95	6.7	85	7.6	90	8.7
+	1035	8	90	6.4	90	7.5	100	8.4
+	1035	16	95	8.2	90	9.5	85	10.9
+	1240	6	95	6.2	100	9.0	100	9.7