A COMPARISON OF NEEDLE INCISING AND CONVENTIONAL NORTH AMERICAN INCISING PROCESSES FOR IMPROVING PRESERVATIVE TREATMENT

by

J.N.R. Ruddick*

FORINTEK CANADA CORP.
Western Region
6620 N.W. Marine Drive
Vancouver, B.C.

Abstract

The objective of the study was to compare the improvement in chromated-copper-arsenate (CCA) treatment of spruce and lodgepole pine lumber due to needle incising with that produced by a conventional North American incisor (producing a staggered incising pattern).

Fifty spruce and fifty lodgepole pine kiln-dried boards, 4.9 m in length were sawn into three pieces, two of which were 2 - 2.3 m long, while the third (a reference sample) was ca 0.3 m in length. After labelling, one of the longest samples from each board was sent to J. Benker KG, Hörgertshausen to be needle incised. The matching piece was incised at B.C. Clean Wood Preservers Ltd., Surrey. The incised boards were returned to Forintek Canada Corp. where they were sorted into two groups, by wood species, and pressure treated with CCA using a commercial treating schedule. The preservative retentions were measured by X-ray analysis. The penetrations were determined for each test sample by both a boring method, for comparison with the Canadian Wood Preservation Standard, and by an alternative mapping procedure which provided a measurement of the integrity of the envelope of treated wood.

For the spruce lumber the needle incising significantly enhanced both the CCA retention and the penetration. The rentention exceeded that required by the standard whereas the corresponding conventionally incised boards did not. Although the penetration of neither group of incised lumber met the specifications for preserved wood foundation lumber, the improvement provided by the needle incising was readily apparent.

The corresponding evaluation of the lodgepole pine also showed a major improvement due to needle incising. Although neither CCA retention exceeded the standard requirement the 1.74 percent solution strength used was slightly lower than that currently used by industry. Increasing the concentration to 2 - 2.6 percent would have ensured adequate retentions were achieved. Again the CCA penetration, although markedly improved in the needle incised wood, was insufficient to meet that demanded by the Canadian standard.

It was concluded from the study that needle incising provided a significant improvement in the CCA treatment of the three wood species compared to the conventional incising process. It was recommended that a slight increase in the needle incision depth to 11 - 13 mm and an increase in the density of the incisions (by a reduction of the longitudinal separation) would allow all three wood species to be successfully treated.

Introduction

While the sapwood of Canadian softwoods is easily treated with both oilborne and waterborne preservatives, the heartwood is much more variable in permeability, ranging from moderately easy to treat to completely impermeable. Unfortunately, it is not possible to identify those wood species which are easy to treat, since the climatic conditions of the tree source can influence the permeability of the wood. For example, Cooper and Ross (8) observed that western hemlock (Tsuga heterophylla (Ref.) Sarg.) from the interior of British Columbia was more difficult to treat with either chromated-copper-arsenate (CCA) or ammoniacal copper arsenate (ACA) preservative than corresponding coastal material. A similar conclusion was made by Bramhall (2) with respect to the permeability of Douglas-fir (Pseudotsuga menziesii Mirb. Franco). In recognition of this, the Canadian standard for wood preservation (4) has eliminated interior (sometimes known as inter-mountain) Douglas-fir from the lumber standard (5). Lodgepole pine (Pinus Contorta Dougl.) and white spruce (Pinea glauca (Moench) Voss) from the interior of British Columbia have both been shown to be moderately resistant to impregnation (15; 7). While similar problems are not experienced in much of the U.S.A. due to the widespread availability of treatable southern pine, studies on western U.S. wood species have produced comparable results to those found in Canada (9; 16).

Recognizing this difficulty in treating heartwood, the Canadian Wood Preservation Standard (5) requires that lumber be incised in order to ensure adequate preservative penetration to produce an effective

envelope of treated wood (Figure 1). Traditionally, incisors producing a diamond arrangement of incisions have been used. More recently a staggered incising pattern has been found to be more effective in producing an integral treated envelope in lumber (15; 1; 10). The staggered incising patterns generally have a high number of incisions per unit area, with longitudinal and lateral separation of neighboring incisions ranging from 20 to 30 mm and 3 to 15 mm respectively.

However, despite the introduction of commercial incisors with thin ($\leq$1 mm) teeth located on rings spaced relatively close together, it is still often impossible to produce lumber with the desired uniform (ca 10 mm) envelope of treated wood. Further reduction in the separation of adjacent rings on the incisor is considered to be impractical for several reasons. Firstly, there is the problem of stripping the outer wood during the incising process. Secondly, even with the current incising patterns, concern has been expressed over the loss in strength due to incising. This topic has been reviewed by Perrin (14), who noted that reductions in bending strength of spruce lumber of approximately 16 percent had been reported. More recently, Nunomura and Saito (13) have observed a lowering of the MOR of Douglas-fir lumber by 25 percent (Table 1). Clearly, further strength reductions resulting from an increased density of incisions would be unacceptable.

A third factor, previously not considered to be significant, is the final appearance of the treated product. With the dramatic increase in the use of preservative treated wood in domestic house construction and renovation, the incising requirement in the CSA standard is often waived on account of the surface appearance of the wood.

As a consequence of the increasing interest in improved treatments for refractory woods such as spruce, attention in North America and Europe has been focussed on alternative methods of incising sawn wood. Three techniques have been identified, any one of which could form the basis of an alternative industrial process. Two of these, the use of lasers and fluid jets, do not require teeth to physically create the incisions. They therefore have an advantage over current techniques in that breakage of incising teeth (due to knots or grain deviation) would be eliminated. However, both laser and fluid-jet incisors are still in the developmental stage. The third method, the use of needles, while having limitations due to needle life, offers distinct advantages of high surface quality of the incised wood, and the current status of the technology. Some of the principal advantages and disadvantages of each of the techniques are listed in Table 2 while a comparison of some of the key parameters, (e.g., the incising rate, machine cost, etc.) is provided in Table 3.

Following initial discussions with researchers at the Bundesanstalt für Materialprufung in 1982, it was decided to undertake an evaluation of the novel needle (or perforation) incising process developed by PHB Weserhütte in West Germany.

In this process, small holes are made in the wood using fine needles. Because of the small diameter of the needles, the holes produced by the incisor are barely visible after incising, and are generally invisible after treatment with a waterborne preservative since the wood tends to expand due to the increase in moisture content during treatment. A study of the strength losses of European spruce lumber (3) produced during perforation incising failed to detect any strength losses, (Table 4). A prototype needle incisor has been undergoing industrial evaluation by J.H. Benker, a German wood treating company, for the treatment of spruce lumber and siding.

The current study was undertaken to compare the improvement in the CCA preservative treatment of spruce and pine lumber, incised using a needle incisor and a conventional North American incisor (producing a staggered incising pattern).

Material and Methods

Sample Preparation

One hundred kiln dried boards (nominally 5 x 10 cm), each 4.9 m long and labelled as 50 western white spruce and 50 lodgepole pine, were supplied by Weyerhaeuser Canada Ltd. from Kamloops, B.C. Upon arrival at Forintek, the test material was numbered sequentially and each board sawn into three matched samples. Two of the samples were 2 to 2.3 m in length and were subsquently incised and treated. The third piece, which was ca 0.3 m long, was retained for reference purposes and was later used to confirm the wood species.

The 2 to 2.3 m long sawn material was divided into two matching groups, each comprised of 50 spruce and 50 pine samples. One of these lumber groups was carefully packaged and shipped by air to J.H. Benker KG, Hörgertshausen, for needle incising. All shipment between Germany and Canada was by air to minimize risk of fungal infection in transit. The needle incising pattern used (Figure 2) was that employed by Benker in the commercial treatment of spruce lumber and siding, and described previously by Burmester (3). After needle incising, a small piece 0.6 m in length was removed from the lumber and retained by Professor M. Gersonde, Bundesanstalt für Materialprüfung, for testing. The packaged lumber was then returned to Forintek.

The matching spruce and pine boards retained by Forintek were commercially incised by B.C. Clean Wood Preservers Ltd., Surrey, B.C. with a staggered pattern (Figure 3) normally used on preserved wood foundation lumber.

Following incising, all the lumber was stored at Forintek under cover for a minimum of 10 days to allow their moisture contents to equilibrate.

Preservative Treatment of Test Material

The needle and conventionally incised boards were assembled into two charges for CCA preservative treatment, based on wood species. Prior to treatment, each board was measured, weighed, and its moisture content determined using a resistance type moisture meter. They were

then treated with CCA-type C using a full cell pressure cycle, the details of which were based on commercial schedules currently employed for pressure treatment of lodgepole pine from the interior of B.C. The initial vacuum phase of 98 kPa was maintained for one hour, after which the 1.74 percent (w/w) CCA solution was introduced into the retort while retaining the vacuum. Once full of solution, the pressure in the retort was increased to 1040 kPa (150 psi). After 27 hours the pressure was reduced to atmospheric pressure and the preservative solution drained from the retort. A final vacuum of 78 kPa was drawn on the retort for 45 minutes to minimize the amount of solution dripping from the treated lumber. The boards were individually weighed to determine the gross preservative solution uptake.

Analysis of the Treated Lumber

Following treatment, the lumber was allowed to air-dry for five to six days, at the end of which a small section ca 15 cm long was sawn from the center of each board. This section was oven dried and then sampled to determine preservative penetration and retention.

Determination of CCA Retention

A sample, extending into the wood 16 mm from the surface, was removed from the heartwood face of each analytical section. The selection of 16 mm as the assay zone conforms to the corresponding requirements of the CSA standards for lumber for use in ground contact (5) and in the preserved wood foundation system (15). The sampling was done using a router equipped with a sawdust collector to ensure maximum recovery of fine sawdust (particle size less than 40 mesh). Care was taken to avoid sampling the wood directly adjacent to the incisions, although this was not always possible due to the small distances separating the incisions. A 0.4 g sample of the sawdust was thoroughly mixed with 0.1 g of cellulose powder and compressed at 300 MPa for two minutes to form a disc for analysis using energy dispersive X-ray spectrometry. The X-ray counts for each sample were processed by computer to allow correction for interelement interference and matrix effects. The results were converted from a weight-per-weight basis to weight-per-volume basis using a conversion factor that included the wood specific gravity (SG). An SG value of 0.48 was used for the lodgepole pine (this being the value assigned by the CSA for lodgepole pine preserved wood foundation lumber). A corresponding SG for spruce is not available in the CSA standard, so that a literature value of 0.37 was used (11).

Determination of CCA Penetration

The effectiveness of the needle incising in improving the CCA penetration in the lumber was assessed by two methods. In the first, a thin cross-sectional slice was removed from each block and cut in two with a knife at the approximate centerpoint of each long dimension to form a core. The only critera used in selecting the location of the knife-cuts were that they did not pass either through any incisions or through defects such as knots. The newly exposed surface was then sprayed with chrome azurol S to determine the CCA penetration (based on that of the copper) from the heartwood face of the board.

This method of core sampling was considered to be analogous to the standard boring of test samples, but is much more rapid, suiting the conditions of the investigation*. The penetration results for the needle and conventionally incised lumber were compared with each other and with the requirements of the appropriate CSA standards (5, 6).

The second method of assessing the improvement in the CCA penetration was based on the measurement of the continuity of the treatment in the outer shell of treated wood. Since the heartwood lumber will be difficult to treat, the maximum preservative penetration should generally correspond to the depth of the incisions produced by the two incisors, i.e., 11 mm. Upon examination of the test samples, it was discovered that the penetrations of the two incising processes were not only less than the anticipated 11 mm, but were also not equal, being ca 9 mm for the needle incised material and 6 to 8 mm for the North American incisor. Clearly, measurement of the percent of treated wood in the outer 10 mm envelope (the CSA penetration requirement) would unfairly bias the results in favor of the needle incisor. Consequently, the following strategy was developed. A uniform channel 4 mm deep and 13 mm wide was created across the

*For ease of discussion in the paper, the method will be described as measurement on "cores".

heartwood face of each analytical section using a router. After spraying this channel with chrome azurol S to enhance the visibility of CCA-treated wood, the percentage of treated wood was measured (with the aid of a grid) over a standard area extending across the full width of the sample. In this way the percentage integrity of the envelope of treated wood at a depth of 4 mm was recorded and used to compare the effectiveness of the two incising processes.

Wood Identification

In order to confirm the identity of the wood used in the study, a microscopic examination was done of all samples not positively identified as pine. This showed that five boards previously considered to be spruce were in fact amabilis fir (Abies amabilis). The data for these boards were therefore extracted and considered separately. Thus the study was actually done on test material prepared from 50 pieces of lodgepole pine, 45 pieces of western white spruce, and 5 pieces of amabilis fir.

Results and Discussion

Needle incising enhanced both the preservative retention and penetration during pressure treatment in all three wood species studied. To determine the extent of this improvement, the results for each wood species are considered separately (Tables 5 to 7).

The successful treatment of spruce lumber has been the subject of much research, so that it is appropriate to discuss the results of this

wood species first. From the retention data in Table 5, it is obvious that the needle incising has increased the gross retention and preservative assay. The mean assay for the needle incised boards is about 40 percent higher than that for the matching conventionally incised material. Such an increase would be consistent with an overall improvement in the treatment of the boards, but could also arise if just some of the boards were very well treated. Examination of the histogram showing the number of boards with each increment of retention for the two incising processes (Figure 4) clearly shows that there has been an overall improvement in the treatment due to needle incising. Further, the population distribution for both types of incised material is normal, with no evidence of an unusually high number of samples with a high retention.

While the CCA assay for the needle incised lumber exceeded the 8 kg/m^3 required by the standard for preserved wood foundation lumber, that determined for the conventionally incised material did not. However, the CCA solution concentration of 1.74 percent used in the study was slightly lower than the 2 to 2.5 percent solution strength usually employed by the wood preserving industry. Increasing the solution strength in the present study to 2.2 percent would presumably have produced a concomitant increase in the retention of the conventionally incised lumber to a level in excess of that shown in the standard.

One of the most challenging aspects of the Canadian Wood Preservation Standard, with respect to treatment of "difficult to treat wood", is the penetration requirement specified for the various commodities and wood species. For example, of 20 cores removed from a charge of preserved wood foundation lumber, 16 (i.e., 80 percent) must have a minimum penetration of 10 mm, and no core can have less than 6 mm of CCA penetration (6). These penetration requirements are the same for all wood species currently listed in the standard, so that presumably they would also apply to spruce were it to be allowed for this end use.

To determine whether the spruce lumber in the current study meets the penetration criteria described above, the data for the core sampling was examined (Table 5). The mean penetration of 9.5 mm for the 45 pieces of needle incised lumber is slightly below the standard (10 mm) requirement, whereas the corresponding penetration of the conventionally incised material is markedly less than this value.

Examination of the individual results showed that cores from four (or nine percent) of the needle incised boards did not have the minimum 6 mm penetration, and only 21 (or 47 percent) had a penetration of 10 mm or more. The corresponding results for the matching conventionally incised material were 18 (or 40 percent) less than 6 mm and 10 (or 22 percent) with 10 mm or more penetration. The histogram of the number of boards with each penetration increment (Figure 5) confirmed that the needle incised samples as a group had a higher penetration than the conventionally incised material, but that neither group met the CSA standard requirement of 80 percent samples with a minimum penetration of 10 mm.

In order to understand why the 10 mm penetration was not achieved, a detailed examination of the boards was made. In the most difficult to treat material, penetration of the CCA into wood adjacent to the needle incisions was minimal, and an increase in the density of incisions would be needed if an integral envelope of treated wood was to be formed. For most of the needle incised samples, however, a complete (or almost complete) shell of treated wood was created. This was not the case for the conventionally incised lumber.

An important observation made during the analysis of the boards was the fact that the depth of the incisions of the two patterns differed. Although both incisions are designed to produce 11 mm deep incisions in lumber and timber, the needle incising pattern had an incision depth of ca 9 mm, while the incisions from the conventional incising process penetrated the wood 6 to 8 mm. Thus, while the use of "core" measurements of the CCA penetration provides a basis for comment on the acceptability of the treatment relative to the standard specification, it does not allow comment to be made on the relative effectiveness of the two incising techniques, since the incision depths differed. The key to assessing the relative merits of the two incising processes is the extent to which an integral envelope of treated wood is created, and this should form the basis for the comparison. After considering the incision depths produced by the needle and conventional incisor, together with the profile of the treated wood surrounding each incision, it was decided to monitor the percentage of treated wood in an 11 cm^2 area at a depth of 4 mm from the heartwood face of each board. The 4 mm depth selected was less than the incision depth of either process but was much greater than CCA penetration would be in an unincised board. The results are shown in Table 5.

For the needle incised samples at the 4 mm depth, 90 percent of the 11 cm area examined was treated. This was significantly better (at the 99 percent confidence level) than the 70 percent recorded for the matching conventionally incised material. Clearly, the needle incising has greated improved the quality of the CCA treatment of the spruce compared with the conventional staggered incising process. Even so, it is concluded that both the number and depth of the incisions must be increased slightly if the penetration requirements of the standard are to be achieved.

Although spruce is widely acknowledged as being refractory, lodgepole pine from the interior of British Columbia has also been shown to be difficult to treat. As with the spruce, the needle incising provided a significant improvement in the gross solution retention and preservative assay (Table 6). The preservative assay for the needle incised lodgepole pine increased by almost 40 percent over that recorded for the conventionally incised boards. The histograms of the number of boards with each increment of retention show normal distribution (Figure 6), with the needle incised samples centered at a higher retention than the conventionally incised material. This is indicative of the overall improvement in the treatment produced by the needle incising. However, unlike the spruce, the preservative assay for both groups of incised material failed to exceed the 8 kg/m^3

demanded by the standard. To achieve this retention in the needle incised boards, a slight increase in the solution concentration to 1.9 percent would have been required, whereas for the conventionally incised material a 2.6 percent CCA solution would have been needed. Since both solution concentrations are within the range of those in normal use, it may be concluded that the preservative retention requirement could easily be achieved for the lodgepole pine.

The mean penetration of the needle incised lumber of 8.4 mm is significantly greater (at the 95 percent confidence level) than the 5.9 mm recorded for the equivalent conventionally incised samples. However, examination of the individual penetration results, based on analysis using "cores", showed that seven (or 14 percent) of the needle incised lodgepole pine boards did not have 6 mm, and only 10 (or 20 percent) had more than 10 mm of penetration. The corresponding figures for the conventionally incised boards were 33 (or 66 percent) with less than 6 mm, and 10 (or 20 percent) with more than 10 mm. The needle incising has obviously improved the penetration in most samples, but has not increased the number of boards with 10 mm (or more) penetration (Figure 7). Inspection of the well-treated boards provided an explanation for this observation. A few of the well treated boards contained some fungal infection which enhanced the permeability of the wood and masked the beneficial effects of the incising.

The range of penetrations recorded for the lodgepole pine lumber is shown in Figure 7.

The potential of each incising process to produce a uniform penetration in the test samples was assessed (as described earlier) over an 11 cm area, at a 4 mm depth from the heartwood face. The improvement in the treatment due to needle incising when assessed in this way was highly significant (at the 99 percent confidence level). The mean percent penetration (at the 4 mm depth) was 81 percent for the needle incised lumber and 55 percent for the matching conventionally incised samples. Thus once again the needle incising has markedly improved the quality of the treatment, but further refinement of the incising pattern will be needed if the penetration requirements of the standard are to be achieved.

Although not originally intended to be included in the study, five of the boards supplied as spruce were in fact amabilis fir. Since the sample size is small, the results (Table 7) should be considered only as an indication of the potential improvement in the treatability of this wood species as a result of needle incising. In agreement with the result for the other two wood species, needle incising enhanced the gross solution uptake (significant at the 99 percent level) but the variability in the preservative assay over the five samples did not allow the CCA retention for the needle incised boards to be considered an improvement (at the 95 percent confidence level) over that recorded for the conventionally incised boards. However, the mean penetrations (based on the "core" sampling) for the lumber incised by the two processes were significantly different (Table 7), with the needle incising again producing the better treatment. As with the other two wood species, although the needle incising clearly

improved the uniformity of the penetration into the heartwood over that achieved by conventional incising, further improvement in the incising pattern was still required.

Reviewing the results for all three wood species, the needle incising clearly has improved the quality of the treatment based not only on the preservative retentions and penetrations achieved, but also on the appearance of the treated wood. Although visible in the untreated wood, the needle incisions are closed during treatment with CCA so that they are not visible in the treated wood, even after drying. The difference in the incision depths was an unexpected finding. Following discussion with the personnel from the two wood treating facilities who carried out the incising, it was concluded that a combination of incorrect machine setting and variation in board thickness led to the slight reduction in the needle incision depth, whereas inadequate roller pressure was thought to have caused this corresponding (and more noticeable) reduction for the conventional process. The latter observation highlights the importance of monitoring the depth of the incision during modification of the incising pattern, particularly when the number of incising teeth is increased in order to improve the effectiveness of the process. However, even with the differences in the incision depths, the enhancement of the treatment due to needle incising is readily apparent.

Conclusions

1. Needle incising greatly enhanced the CCA treatment of spruce, lodgepole pine and amabilis fir lumber. The improvement in the treatment achieved by needle incising was significantly better (at a 99 percent confidence level) than that produced by current conventional incisors using a closely spaced staggered pattern.

2. Only the retention of the needle incised spruce lumber exceeded the 8 kg/m^3 assay requirement of the Canadian standard for preserved wood foundation lumber. However, increasing the solution concentration would allow the retention specified to be attained for all the wood species tested. Because of the better treatments achieved by the needle incising, the solution concentrations calculated (or used) to produce 8 kg/m^3 retention were lower than those required for the conventionally incised lumber.

3. None of the treatments provided 10 mm penetration in 80 percent of the test samples for any wood species. The principal reasons for this were (a) the incision depth was inadequate; (b) the spacing of the incising pattern was too great.

4. Following CCA preservative treatment of the boards, the incisions produced by the needle incisor are generally invisible. This feature will offer a tremendous potential for improving the marketing of wood sold through lumber retail outlets, since much material is currently not incised because the conventional incising process is considered to make the appearance of the product unacceptable to the consumer.

Acknowledgements

The assistance and advice provided by Professor M. Gersonde, Bundesanstalt für Materialprüfung, during the design and needle incising phases of the project is gratefully acknowledged. The author is pleased to acknowledge the generous financial support for the study provided by Timber Specialties Ltd., Mississauga, Ontario, Weyerhaeuser Company, Tacoma, Washington, and Pacific Wood Preservation Services Ltd., Surrey, B.C. Forintek would also like to thank J. Benker KG, Hörgertshausen, and B.C. Clean Wood Preservers Ltd., Surrey, B.C., for excellent cooperation during the incising of the lumber.

Literature Cited

(1) Banks, W.B. 1973. Preservative penetration of spruce - close-spaced incising an improvement. Timber Trades Journal. 285 (supplement):251-53.

(2) Bramhall, G. 1966. Permeability of Douglas-fir heartwood from various areas of growth in B.C. British Columbia Lumberman 50(1):98, 100, 102.

(3) Burmester, A. 1983. Influence of incising on the bending strength of spruce wood. Holz als Roh- und Werkstoff 41:331-332.

(4) Canadian Standards Association. 1983. CSA 080-M1983. Wood Preservation. CSA, Rexdale, Ontario.

(5) Canadian Standards Association. 1983. CSA 080.2-M1983. Preservative Treatment of Lumber, Timber, Bridge Ties and Mine Ties by Pressure Processes. CSA, Rexdale, Ontario.

(6) Canadian Standards Association. 1983. CSA 080.15-M1983. Preservative Treatment of Wood for Building Foundation Systems, Basements, and Crawl Spaces by Pressure Process. CSA, Rexdale, Ontario.

(7) Cooper, P.A. 1973. Effect of species, precompression and seasoning on heartwood preservative treatability of six western conifers. Forest Products Journal. 23(7):51-59.

(8) Cooper, P.A. and N.A. Ross. 1977. Treatability of western hemlock lumber from coastal and interior British Columbia regions with waterborne preservatives. Forest Products Journal. 27(12):36-39.

(9) Graham, R.D. 1956. The Preservative Treatment of Eight Oregon Conifers by Pressure Processes. Proc. Amer. Wood Preser. Assoc., 52:118-139.

(10) Henshaw, B.G. and N. Williams. 1976. The effect of incising on penetration of organic solvent wood preservatives. J. Inst. Wood Sci. 7(4):14-23.

(11) Jessome, A.D. 1977. Strength and Related Properties of Wood Grown in Canada. Tech. Rep. No. 21. 37pp. Eastern Forest Products Laboratory, Ottawa.

(12) Miller, D.J. and R.D. Graham. 1963. Treatability of Douglas-fir from Western United States. Proc. Amer. Wood Preser. Assoc. 59:218-222.

(13) Nunomura, A. and M. Saito. 1983. Effects of incising on the strength and permeability of Hokkaido softwood. (II.) Incising processing and material strength. J. Hokkaido Forest Prod. Res. Inst. 378:12-16.

(14) Perrin, P.W. 1978. Review of incising and its effects on strength and preservative treatment of wood. Forest Products Journal. 28(9)27-33.

(15) Ruddick, J.N.R. 1980. Treatability of lodgepole pine lumber with ACA and CCA. Forest Products Journal. 30(2):28-32.

(16) Weaver, F.W. and M.P. Levi. The treatability of southern pine and Douglas-fir heartwood with creosote, modified creosote, chromated-copper-arsenate, and ammoniacal-copper-arsenate. Proc. Amer. Wood Preser. Assoc. 75:176-187.

TABLE 1

STRENGTH REDUCTION IN DOUGLAS-FIR

ision Density per m^2	Wood Cross Section (mm^2)	Control Bending Strength (kg/cm^2)	Incised Bending Strength (kg/cm^2)	Percent Reduction (%)
3,300	85 X 85	430	380	11.6
6,600	85 X 85	480	360	25.0

Table 3

Comparison of Incising Process

	Conventional	Needle	Fluid-Jet	Laser
Speed (m/min.)	~100	20-30	5-10	~4
No. of Surfaces Incised	4	1-2	1-2	1
Depth of Incision (mm)	< 20	<15	<20	~10
Machine Cost	$20-30,000	$80-100,000	$40-70,000	> $200,000

Table 2

Advantages and Disadvantages of Needle, Laser, Fluid-Jet and Conventional Incising Techniques

NEEDLE INCISING

Advantages	Disadvantages
• No Surface Degrade	• Moderate - High Capital Cost
• A Very Small Loss in Strength	• Only Two Faces Incised With One Pass
• Enhanced Treatment of Refractory Woods	• Needle Life
• Easy Needle Replacement	• Moderate Throughput
• Low-Moderate Operating Cost	

LASER INCISING

Advantages	Disadvantages
• Small Surface Degrade	• High Capital Cost
• Minimal Loss in Strenth	• Skilled Operator Required
• Low Maintenance Requirements	• Moderate Speed
• Low-Moderate Operating Cost	• High Energy Requirement
	• "State of the Art" Lasers Have Insufficient Power

FLUID-JET INCISING

Advantages	Disadvantages
• No Surface Degrade	• Control of Fluid Jet
• No or Very Little Loss in Strength	• Separation of Earlywood - Latewood
• Possible to Use Preservative to Create Incision	• Slow Speed
	• Moderate-High Capital Cost
	High Operating Cost

CONVENTIONAL INCISING

Advantages	Disadvantages
• Low Capital Cost	• Surface Degrade
• High Throughput	• Significant Loss in Strength
• Low Maintenance	• Inadequate for Refractory Wood
• Low Operating Cost	• Difficult to Replace Teeth

TABLE 4

STRENGTH REDUCTION IN GRADE I SPRUCE

Wood Cross Section (mm^2)	Control Bending Strength (N/mm^2)	Needle Incised Bending Strength (N/mm^2)	Percent Reduction (%)
50X80	59.8	60.0	+0.3*
80X80	60.4	62.5	+3.5*
50X100	57.8	55.8	-3.5*

*Not significant   Incision density = $13,888/m^2$

Table 5

Summary of Results for Incised Spruce Lumber[1]

Incising	Gross Retention (kg/m^3)	Assayed CCA Retention (kg/m^3)	Penetration By Boring (mm)	Penetration at 4 mm Depth (%)
Conventional Staggered	390*	6.41**	7.3**	70**
Needle	496*	8.87**	9.5**	90**

* Differences significant at the 95 percent level
**Differences significant at the 99 percent level

[1] Number of samples - 45