Effects of incising on preservative treatment of Douglas-fir lumber

J. J. Morrell, S. M. Smith. Department of Forest Products, Oregon State University, Corvallis, OR and J. E. Winandy U.S. Forest Products Laboratory, Madison, WI

Abstract

Incising is widely used to improve the depth and uniformity of preservative treatment, but incising practices vary widely. As a result, it is difficult to assess the effects of various incising practices on wood treatment or wood strength. In this paper, we describe a method for non-destructively assessing the effects of incising on preservative distribution in Douglas-fir heartwood lumber. Incisions had small effects on radial preservative distribution relative to longitudinal distribution. A comparison of zones of treatment with different incision teeth indicated a need for incision densities ranging from 1,975 to 16,667 incisions/m^2 depending on tooth shape. Increased tooth size reduced the number of incisions required, but increased wood damage. Further tests are underway with white spruce and southern pine heartwood to develop systems for predicting treatment with varying incision types and densities.

Introduction

The preservative treatment of wood species containing high percentages of heartwood poses an extreme challenge to wood treaters, and in some instances, severely limits the development of markets for the products. To help overcome these problems, the Canadian Standards Association and the American Wood Preserver's Association Standards both require incising prior to treatment of wood species with large percentages of heartwood including Douglas-fir, hem-fir, and the spruces. Incising drives metal teeth into the wood, parallel to the grain and serves to increase the amount of more easily treated end grain exposed to preservative treatment. This process improves the uniformity of treatment to the depth of the incisions. Incising depth may range from 5 to 20 mm.

While incising has been widely used since the 1920's, there are no standards for incising and the process has developed empirically. As a result, different manufacturers produce incisors with differently shaped teeth and widely divergent incision densities. A survey of wood treaters revealed that incision density varied from 753 to 5813/m^2 (Morrell and Winandy, 1987), reflecting the fact that the AWPA and CSA Standards are results, not process, oriented. Thus, the variations in incising practices do not adversely affect treated wood that is adequately treated; however, this variation does pose difficulties when incised, preservative treated wood is used structurally. Each incision removes a portion of the cross-sectional area of the board. Larger teeth or more frequent incisions remove correspondingly more material, adversely affecting wood strength to a greater degree. Previous studies suggest that mechanical property effects due to incising vary widely, (Perrin, 1978; Nunomura and Saito, 1983; Nunomura et al., 1982; Kass, 1975; Kamke and Peralta, 1990). This variation makes it difficult to precisely design with incised, treated wood.

Incising practices are continually changing and include the use of double density incising (Morris, 1991), needle incising (Ruddick, 1985, 1986; Keith and Chauret, 1988), and laser incising (Ruddick, 1987; Goodell et al., 1991; Kamke and Peralta, 1990). These techniques, however, are still heavily dependent on increasing the cross-sectional area exposed to treatment, albeit using many smaller incisions to reduce the visual impact of the process.

There are two approaches to developing reliable material properties for incised treated wood. The effects of all incising patterns on wood strength could be assessed in a large scale study on full sized species; however, the scope of such a study would be enormous and its value would be negated by subsequent changes in incising practices. As an alternative we can study the effects of various incising variables on treatment results to identify the most effective processes and develop predictive models to optimize incising patterns. These patterns can then be evaluated in mechanical tests and also modeled. The result is a series of predictive systems from which a treater can determine the effects on various incision parameters on both preservative treatment and mechanical properties.

The first step in this process is to identify treatment patterns around incisions. The distribution of preservative around incisions has been estimated visually with the aid of chemical indicators or chemically by grinding and analysis of zones around the incision (Nakamura and Nishimoto, 1987a,b; Ruddick, 1987; Keith and Chauret, 1988). Indicators provide no means for determining the relative amounts of chemical away from the incision, while grinding produces an average chemical retention, but no information on preservative gradients around the incision. Ideally, preservative distribution should be studied non-destructively in situ. Direct scan X-ray densitometry represents a method for non-destructively studying preservative distribution. In previous studies, this method has been found to be closely related to preservative retention (Smith et al., 1990) and has been used to develop preservative distribution maps around incisions of differing geometries (Smith and Morrell, 1990). In this report, we describe results of comparative X-ray densitometry studies of 5 different incisor teeth in Douglas-fir heartwood and sapwood.

Materials and Methods

Freshly sawn, coastal Douglas-fir heartwood and sapwood boards (5x10x90 cm long) were obtained from a mill located near Philomath, OR. The boards were conditioned to _ 13% mc and end-sealed using an epoxy resin. Incisions were made at 10 cm intervals along the center line of one wide face of each board. Each board received one incision each of the following shapes: flared, tapered, straight, mini or needle (Figure 1). The boards were then pressure treated with 1% chromated copper arsenate (oxide basis), using a modified full cell process with a 30 minute vacuum (880 mb), followed by a 16 hour pressure period (880 kPa). The treated samples were then blotted dry, wrapped, and stored for 24 hours to permit fixation. The boards were then reconditioned to 13%.

A 26 mm wide by 80 mm long by 10 mm deep zone was cut around each incision and this sample was further split into two (Figure 2). The specimens were reconditioned to ambient room conditions (approximately 8%) prior to direct-scan X-ray densitometry examination using previously described procedures (Figure 3)(Smith and Morrell, 1990). Briefly, a series of 15 transverse scans were made at 5 mm intervals perpendicular to the longitudinal axis, extending 35mm on each side of the centerline of the incision (Figure 4). X-ray attenuation values were converted into preservative retention values using a previously developed curve of X-ray attenuation vs. retention. This curve was constructed by scanning Douglas-fir samples treated to known chemical loadings. These chemical levels were determined after scanning by grinding the wood and analyzing the wood using an ASOMA 8620 X-ray fluorescence analyzer (ASOMA Instruments, Austin, TX) (Smith et al., 1990).

The results were then plotted using SAS Graphics (SAS, 1987) and overlays were used to identify the incision densities which produced a minimum retention of 6.4 kg/m^3 along the entire board.

RESULTS AND DISCUSSION

X-ray intensity was highly correlated with CCA retention, as measured with the ASOMA fluorescence analyzer (R^2= 0.945 for heartwood and R^2= 0.950 for sapwood) indicating that direct X-ray scanning provided an accurate assessment of preservative retention within the wood (Figure 5). The ability to directly determine chemical levels has significant advantages over previous methods employed for studying chemical distribution in which samples were ground and composited for analysis (Nakamura and Nishimoto, 1988) or those which measured chemical distribution using indicators (Nakamura and Nishimoto, 1987a, b; Ruddick, 1987; Keith and Chauret, 1988). As expected, treatment results were consistently better in Douglas-fir sapwood, reflecting the greater permeability of this wood.

Incision geometry had significant effects on distribution of preservative around each incision, but the incision effect was largely limited to the longitudinal direction (Figure 6). The zone of incision effect, defined as the area with a minimum CCA retention of 3.2 kg/m^3, was greatest with the flared tooth, followed by the tapered, straight, mini- and needle teeth. This level was chosen since a combination of overlapping incision zones would produce an minimum retention of 6.4 kg/m^3, the level required for ground contact exposure. Preservative retentions around incisions declined rapidly in the direction perpendicular to the incision direction, and tapered more gradually in the longitudinal direction. This effect reflects the exposure of tracheid lumens within the incision, but the effect extended beyond the 3.5 mm average length of an individual Douglas-fir tracheid.

In general, the flared incisions produced the largest zone of treatment around the incision. This tooth, however, was associated with extensive pulling and crushing of the wood which, while exposing more transverse area to treatment, also caused increased wood damage. The wood incised with the flared tooth also tended to have more checks around the incision. The tapered tooth was associated with the next best treatment without the wood damage or degree of associated checking. The zones associated with the mini tooth and straight tooth were similar, but smaller than those found with the larger teeth, while the needle incisions were associated with the smallest zones of treatment. The mini-tooth and needle incisions were not associated with any significant checking.

The goal of this research was to identify treatment patterns which would achieve the desired retention and penetration results to satisfy the requirements of the American Wood Preserver's Association Standard C2. These requirements include a minimum penetration of 10 mm and a minimum retention of 6.4 kg/m^3 in a 0 to 15 mm deep assay zone. The zone around the incision where treatment was observed to the required depth and which contained a retention of at least 3.2 kg/m^3 was identified for each incision type. The zones were then overlaid to identify the minimum incision density to achieve the required treatment results. Because preservative distribution followed a relatively steep gradient away from the incision and the goal was to identify a pattern which resulted in at least 6.4 kg of CCA/m^3, the overall retention of a given board will far exceed the minimum target. Maps of the five incision types clearly show the relative differences between teeth as well as the tendency towards longitudinal penetration (Figure 7).

Map overlays of the various incision types suggest that, for our material and processing conditions, incisions from needle teeth should be spaced 1.5 mm apart radially and 40 mm apart longitudinally, while those from the largest teeth need be placed 7.5 mm apart radially and 67.5 mm apart longitudinally to deliver the required chemical loadings into the wood (Figure 8). These patterns result in incision density requirements ranging from 1,975 to 16,667 incisions/m^2 for flared and needle type teeth, respectively (Table 1). Previous studies suggest that incision densities as high as 12,000/m^3, delivered via double density incising, are required for adequate treatment of spruce incised using the straight tooth (Morris, 1991); however, there is no comparative data on incision densities required for Douglas-fir. A preliminary survey indicated that commercial incision densities employed in the Pacific Northwest ranged from 753 to 5,813 incisions/m^3 (Morrell and Winandy, 1987), well below the levels which our study suggests are necessary for adequate heartwood treatment. It is readily apparent that the wide range of incision densities will produce materials which drastically differ in appearance and mechanical properties. Previous studies have suggested that increasing incision density will produce a corresponding reduction in wood properties (Lam and Morris, 1991; Perrin, 1978; Nunomura and Saito, 1983). Further research is planned to model the relationship between incision geometry and treatment and to utilize this data to produce incising patterns whose effects on treatability and mechanical properties can then be predicted.

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Table 1. Incision densities required for treatment of Douglas-fir heartwood with CCA using incisor teeth of varying geometries.

INCISOR (size, mm)	INCISION (spacing, mm)		INCISION DENSITY (incisions/meter^2)
	Radial	Long.	
Flared (3 x 15)	7.5	67.5	1,975
Tapered (2.4 x 11.5)	5.0	30.0	6,667
Straight (1.8 x 13)	3.5	33.0	8,658
Mini (1.3 x 3)	2.5	35.0	11,428
Needle (0.6 dia.)	1.5	40.0	16,667

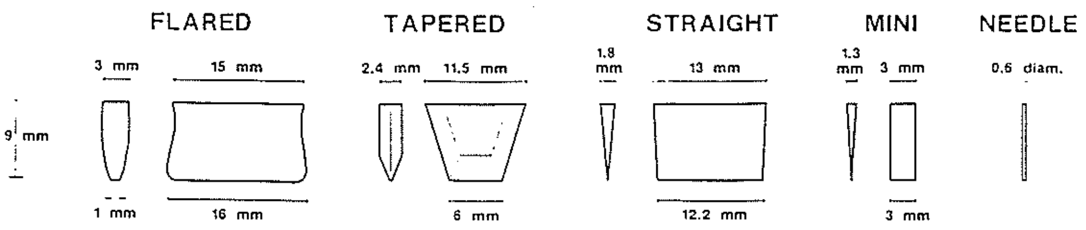


Figure 1. Tooth types employed to evaluate CCA distribution around incisions.

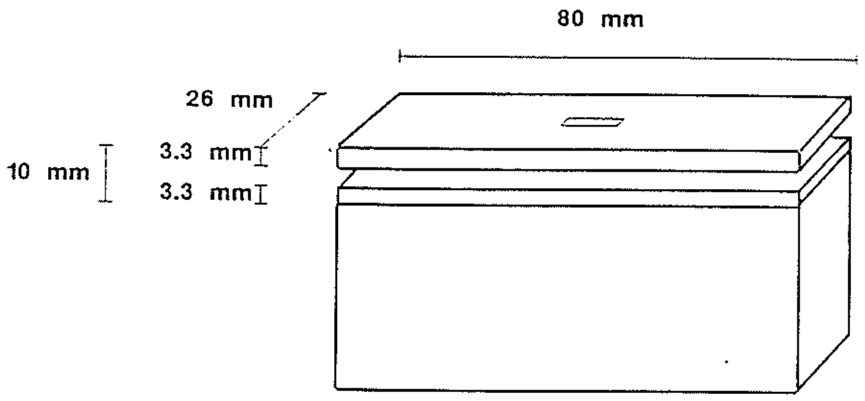


Figure 2. Sampling pattern employed to remove two 26 mm wide by 80 mm long by 3.3 mm thick specimens for direct-scan X-ray densitometry.

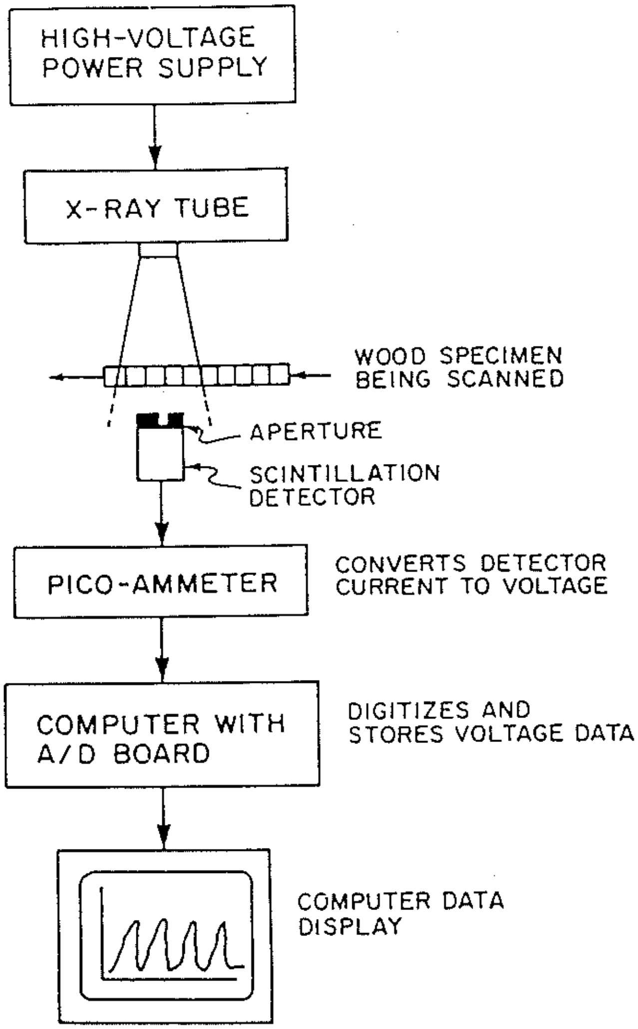


Figure 3. Schematic of procedures employed to evaluate CCA distribution around incisions using direct-scan X-ray densitometry (from Hoag and McKimmy, 1988).

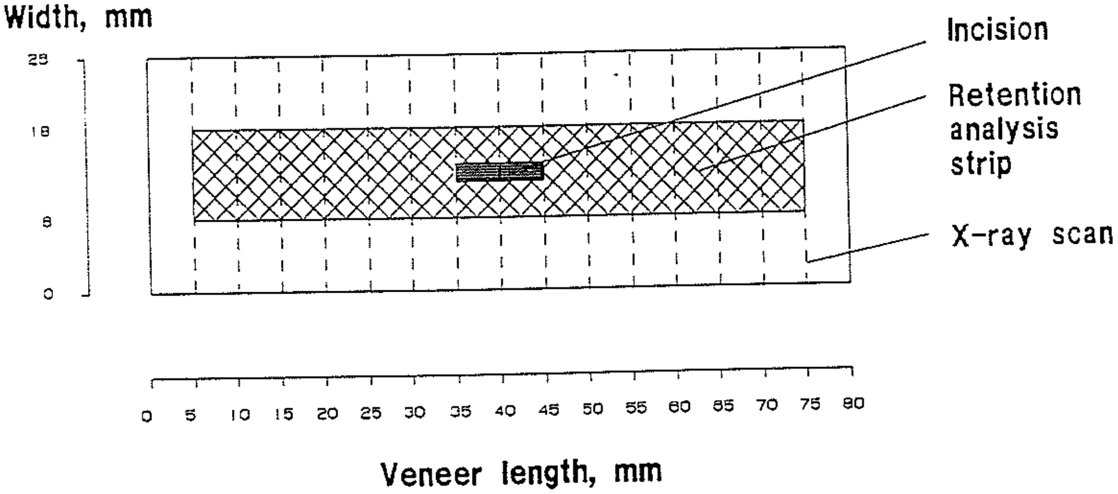
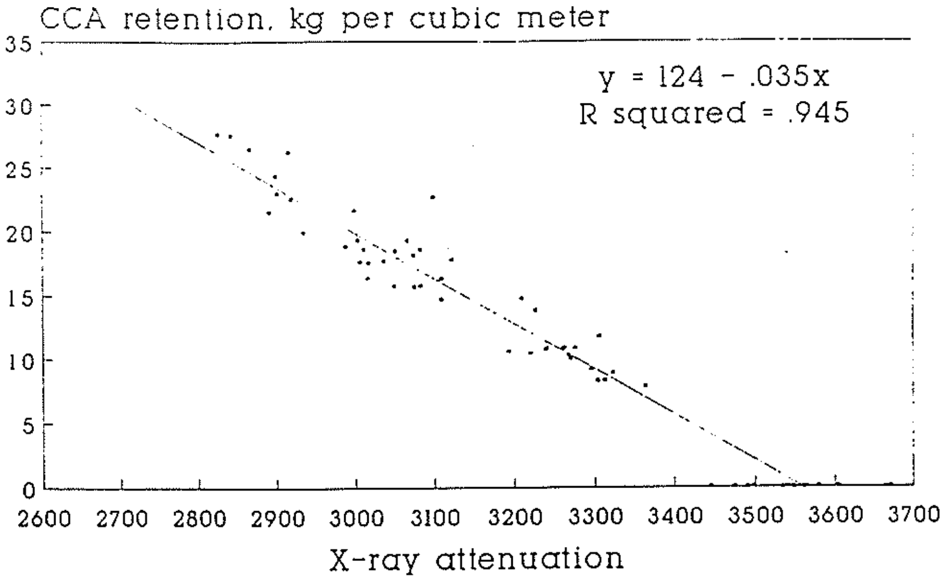


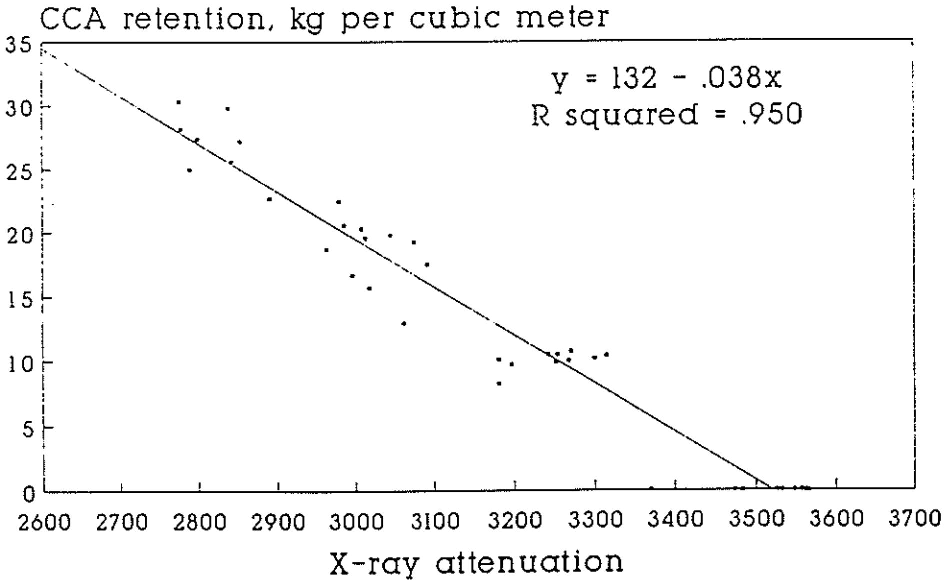
Figure 4. Locations of multiple X-ray scans measuring CCA distribution in 0.5 mm steps across the test veneers.

Douglas-fir heartwood



CCA retention measured by ASOMA

Douglas-fir sapwood



CCA retention measured by ASOMA

Figure 5. Comparison between actual chemical loading and X-ray attentuation values obtained by direct-scan X-ray densitometry of Douglas-fir heartwood and sapwood wafers.

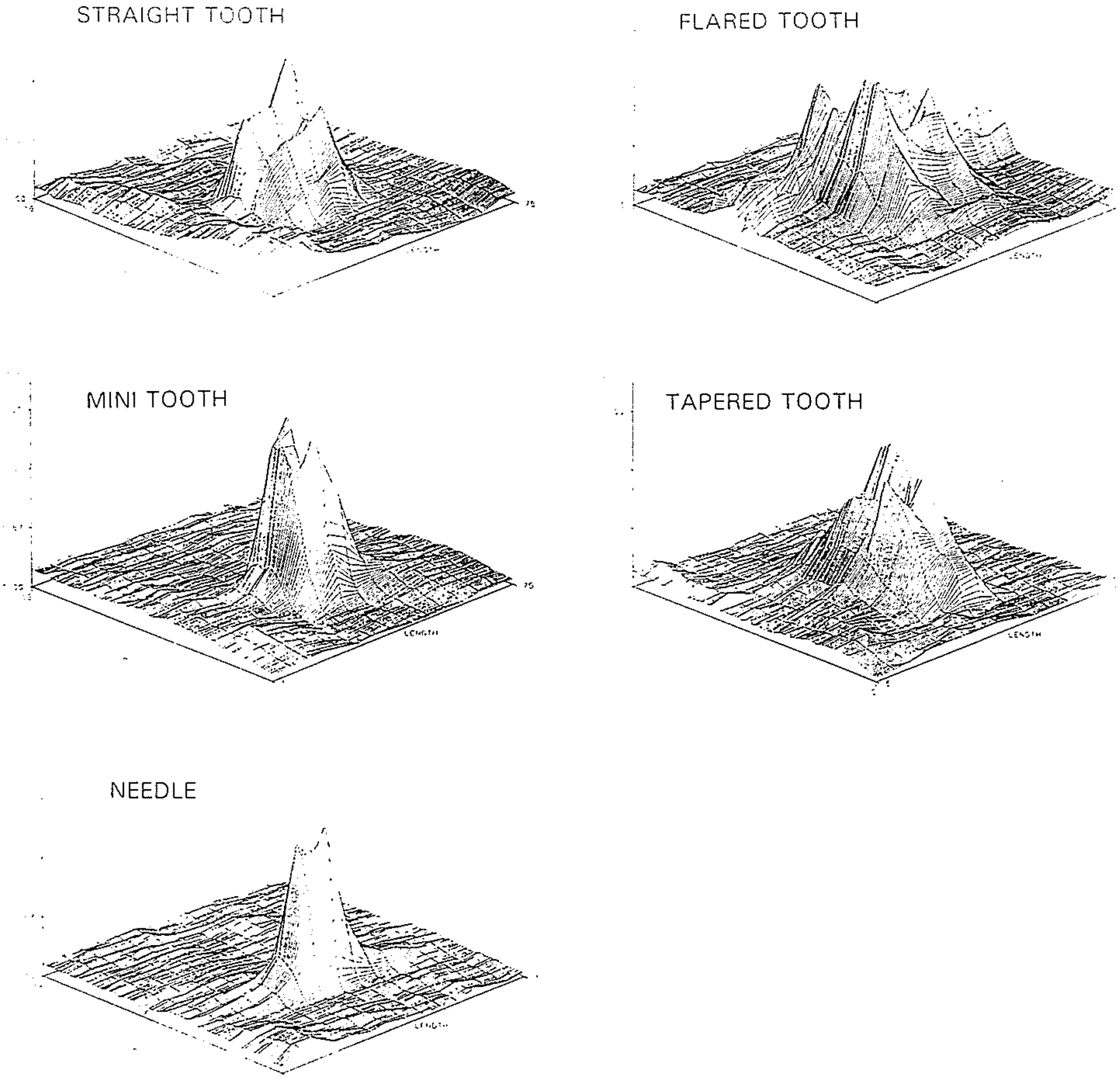


Figure 6. Three-dimensional mean CCA retention levels (kg/m^3) 0 to 15 mm from the wood surface in 10 mm wide by 70 mm long retention analysis samples cut from around incisions in Douglas-fir heartwood or sapwood.

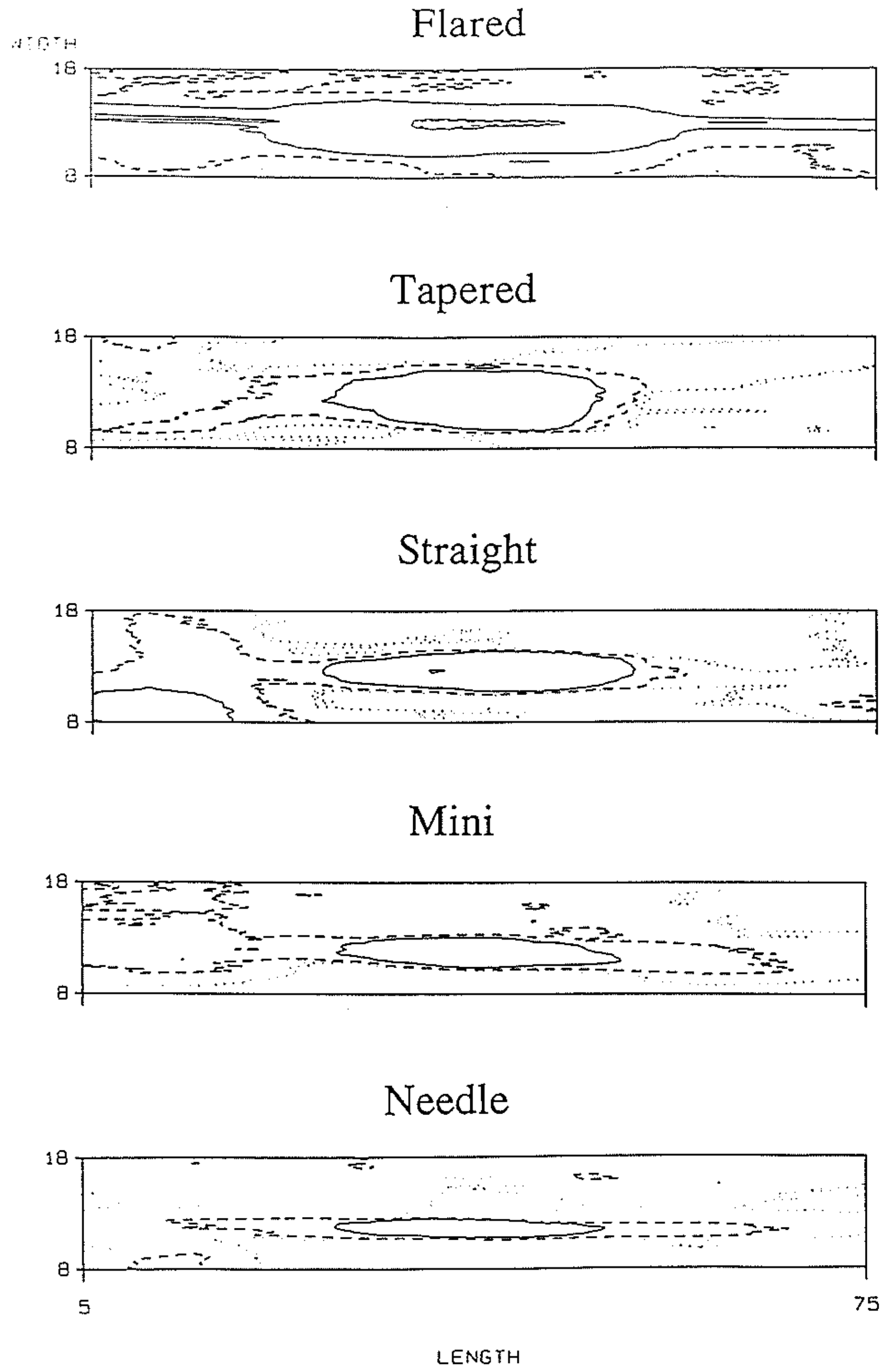
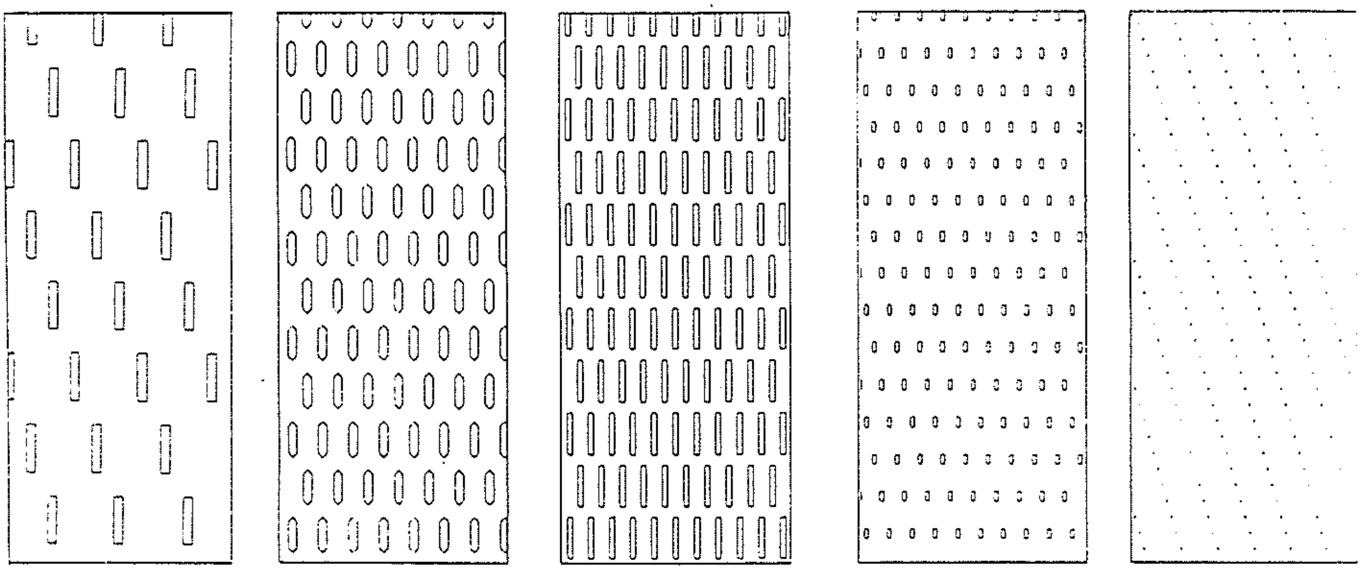


Figure 7. Two dimension maps of CCA retention 0 to 15 mm from the treated wood surface in 10 mm wide by 70 mm long samples cut from around incisions in Douglas-fir heartwood or sapwood where (——)= 6.4 kg/m^3, (-----)= 3.2 kg/m^3, and (·····)=2.0 kg/m^3 of CCA.



Flared Tapered Straight Mini Needle

Figure 8. Examples of potential incising patterns to deliver 6.4 kg CCA/m^3 into Douglas-fir heartwood lumber using flared, tapered, straight, mini, or needle incisions.