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Title: Treatability of Plywood Panels Containing Western Wood Species from Different Geographic Regions of the Pacific Northwest

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Plywood panels collected from thirty seven mills located throughout the Pacific Northwest they were treated with chromated copper arsenate Type C (CCA-C) or ammoniacal copper zinc arsenate (ACZA) using modified full cell and full cell processes respectively. Preliminary tests were performed to determine plywood sample size, replication, and treating schedule.

ACZA produced better preservative treatment than CCA in plywood from all regions. For both treatments, outer veneers had higher preservative penetration than inner veneers. Plywood panels from Washington, Oregon, or Idaho were similar in treatability and were better treated than plywood from Montana.

Differences in plywood treatability between Washington, Oregon, Idaho and Montana differed from those previously found in lumber. Species composition and veneer distribution also influenced plywood treatability. Within a geographic region log source was linked to plywood treatability in panels containing only one species.

Treatability of Plywood Panels Containing Western Wood Species from Different Geographic Regions of the Pacific Northwest

by

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DEDICATED TO

My Parents

George and Alta Mitchoff

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LITERATURE REVIEW

Introduction

The use of treated plywood in residential and commercial construction has continually risen. This material is increasingly used where exposure to weather, water, or soil make it susceptible to decay fungi, marine borers, and insects. To ensure long service life, these panels should be pressure-treated with an oil or waterborne preservative.

Although residential housing construction is declining, the use of treated products is expected to rise by 50% between 1986 and 2000 (Gogolski, 1987). For example, the volume of treated plywood rose by 49% between 1984 and 1986 (Micklewright 1986; 1987; 1988). Fifty three percent of this plywood was treated with waterborne preservatives (Micklewright, 1987). The demand for treated plywood reflects its favorable cost, excellent strength characteristics, workability, and availability.

Background and Problem

The rise in production of treated plywood reflects the use of plywood to replace traditional cement construction such as marine decking, freeway sound barriers, crawl space foundations under residential houses, and the Permanent Wood Foundation (PWF).

Preservative treated plywood used in a marine environment must withstand high moisture contents without delaminating, while retaining high levels of toxicity to prevent marine borer attack. Crawl spaces such as the Plen-Wood System (PW) are built with pressure-treated plywood and lumber and are typically exposed to moist soils (Gogolski, 1987).

The development of the PWF has had a major, favorable impact on the treated plywood market. Since its introduction in 1969, 40,000 PWF homes have been built in 43 states (Camarano, 1980). All plywood used in the PWF must conform to American Plywood Association (APA) standard for foundation grade plywood (APA, 1983) and must be treated with one of the inorganic arsenicals to the standards of the American Wood Preservers' Association (AWPA) (AWPA, 1989).

APA standards for foundation grade plywood refer to panel quality and species, but do not address the more difficult problem of treatability. Many of the species listed in the standard for foundation grade plywood differ widely in their degree of treatability. For example, the treatability of a plywood panel containing Inter-mountain Douglas-fir (Pseudotsuga menziesii (Mirb)Franco) var. glauca) veneers was evaluated by the Forest Research Laboratory at Oregon State University (Morrell and Lebow, 1987). The panels were obtained from logs grown in the eastern Washington - western Idaho region. Heartwood veneers could not be treated to the required retention and had incomplete preservative penetration patterns. Despite this difficulty, Inter-mountain Douglas-fir is included in APA list of species allowed in foundation grade plywood.

Treatability of Western Wood Species

Historically, the retention and penetration patterns of western species have shown wide variability between and within species (Graham 1954; 1956; Cooper, 1972; Gjovik, 1983). Previous studies have demonstrated the difficulty of treating heartwood of many of the western species listed in the APA foundation grade when the material originates from certain geographic regions (Miller, 1961; Miller and Graham 1963; Cooper and Ross, 1977).

A. Treatability with oil-borne preservatives: Studies of creosote treatability of dimension lumber, as measured by retention and penetration of Oregon conifers indicated that white-fir (Abies concolor (Gord. and Glend)Lindl) and coastal western hemlock (Tsuga heteropylla (Raf)Sarg) were easily treated, while Douglas-fir, California red fir (Abies magnifica (A Murr.)), and Sitka spruce (Picea sitchenesis (Bong.)Carr.) were difficult to treat (Graham 1954; 1956). A more intensive study of Oregon-grown Douglas-fir heartwood indicated that penetration of creosote into heartwood was better in material from western Oregon and varied widely with heartwood from northeastern areas of the state (Miller, 1961). A subsequent study of treatability of Douglas-fir heartwood from Washington, Oregon, northern California, Idaho and Montana indicated that material along the Pacific coast and in some areas of the Cascade range contained a larger percentage of permeable samples than material obtained from east of the Cascades (Miller and Graham, 1963). The latter material was almost impermeable. These treatability differences led to the recognition of two types of

Douglas-fir, Pacific Coast and Inter-mountain, within the AWPA standards (AWPA, 1989).

A similar treatability study performed on western hemlock collected from 3 regions in British Columbia, found that lumber from coastal regions achieved retentions that were twice then retentions in western hemlock collected further inland (Cooper and Ross, 1977). These studies indicate that geographic source presents a reasonably reliable basis for predicting lumber treatability of some western wood species, and most commercial wood preserving operations source their material in this manner.

B. Treatability with waterborne preservatives: Western wood species are increasingly treated with waterborne preservatives, but it is sometimes difficult to treat these species with some waterborne preservatives. Several pretreatments have been applied to western wood species to improve retention and penetration including kiln drying, air seasoning below the fiber saturation point (30% moisture content), incising, and precompression (Cooper, 1972). Kiln drying, air seasoning and incising produced the greatest improvements in treatability of western wood species. Preliminary studies also suggest that kiln-drying can improve treatability of some species with waterborne salts (Kumar and Morrell, 1989).

Treatability differences between species and within species have also been noted with waterborne preservatives (Blew et al. 1967; Gjovik, 1983). Gjovik (1983) found that treatment of western hemlock and Sitka spruce lumber from Oregon with ammoniacal copper arsenate (ACA) produced higher retentions and penetrations than the same species from Alaska, while Douglas-fir from Colorado was inadequately treated. Blew et al. (1967) pressure-treated lumber with chromated copper arsenate Type C (CCA-C) and achieved adequate retentions and penetrations in silver fir (Abies amabilis (Dougl.)Forbes), western hemlock and Pacific Coast Douglas-fir, while white spruce (Picea glauca (Moench) Voss) and interior Douglas-fir were poorly treated.

Before treated plywood composed of western wood species can be extensively used in the Pacific Northwest (PNW), acceptable preservative treatment must be achieved.

Treatability of Plywood

Little research has been done on the treatability of plywood. This lack of information may reflect the historical use of plywood for interior uses or in siding, where weather resistance and durability against microorganisms were of little concern.

Compared to lumber, plywood has more features which can influence treatability (Anonymous, 1986). Panel characteristics such as discontinuous glue-lines, lathe checks, veneer discontinuities and variations in veneer thickness can affect preservative treatment. Panels may also contain different species with varying degrees of treatability and veneers may contain varying amounts of more easily treated sapwood.

Glue-lines of high-solids glues are more likely than low-solids glues to limit preservative penetration in plywood, but small lathe checks in the veneers allow any penetrating chemical to migrate further in the panel (Miller and Currier, 1964). Plywood from regions containing refractory timber has also been proven difficult to treat. Examination of a Douglas-fir-spruce panel commercially treated with CCA-B (Fahlstrom, 1982) revealed that the Douglas-fir veneers were well treated, but preservative penetration in the thick crossband spruce veneers was confined to lathe check surfaces. Chemical analysis of the panel revealed that adequate retentions were achieved. Treatment of panels containing Douglas-fir heartwood from Oregon or Engelmann spruce heartwood (*Picea engelmannii* Parry ex Engelm.) from Montana with ACA or CCA-C resulted in uniform preservative penetration in both species at high retentions of ACA, but poor penetration when the material was treated with CCA (Gjovik, 1983).

Current AWPA standards require that 90% of the veneers in a plywood panel be penetrated (AWPA, 1989); however this requirement does not refer to the degree of penetration for each veneer, making it difficult to distinguish between easily treatable material and panels in which penetration is confined to the lathe checks. For example, some commercially treated plywood panels had high retentions, but only 43% of the veneers were completely penetrated and only 70% of the face veneers where penetrated (Morris, 1988).

Durability of Plywood

There are relatively few studies on the durability of treated plywood. Furthermore, the effects of incomplete preservative penetration on panel performance are poorly defined. Fahlstrom (1982) found that stakes cut from one commercially treated panel, in which the cross band veneers were poorly treated and the face and core veneers were well treated, were free of fungal and termite attack after 8 years of exposure. CCA treated plywood panels were also decay resistant in laboratory soil block tests if the treated edges were not cut after preservative treatment, while panels in which the edges were cut after treatment and not treated experienced decay (Anonymous, 1986).

The existing test data suggests that high chemical loadings in some veneers may be as effective as even loading of chemical through each veneer; however, no controlled studies have explored this possibility.

Species composition of preservative-treated plywood panels can also influence plywood performance. Panels containing white spruce or Inter-mountain Douglas-fir veneers were difficult to treat with ACA or CCA and were susceptible to fungi attack in standard soil block tests (Smith and Balcean, 1978). Panels containing western hemlock, silver fir, or Pacific Coast Douglas-fir in the inner plies were characterized by good preservative treatments and decay resistance.

Field exposures of preservative-treated plywood indicate that pentachlorophenol treated plywood remains serviceable after 37 years in the ground, while Douglas-fir plywood stakes treated with another formulation of pentachlorophenol only achieved 15.4 years of service life (Gjovik and Gutzmer, 1986). No sign of decay or termite attack was found in ACA or CCA-C treated Douglas-fir or Engelmann spruce plywood after 9 years in service (Gjovik and Gutzmer, 1986).

Foundation grade plywood pressure-treated with CCA had performance ratings of 90 (100=sound, 0=failed) after 9 years of exposure at Vancouver Island in British Columbia (Morris, 1988).

Justification

The treated plywood market in the forest products industry is large and will continue to experience excellent growth. At present, the growth of treated plywood containing western wood species is limited by uncertainties over achieving adequate preservative penetration. The efforts that have been undertaken to improve lumber treatability of western wood species also need to be applied to plywood. A key step towards improving treatment is to evaluate the treatability of panels manufactured from western species to provide guidelines for obtaining plywood that can be treated to meet current standards. This information should help maintain confidence in the use of preservative-treated panels, contribute to the increased application of these products, and provide a baseline for further improvements in treatment practices.

Objective

The objective of this study was to determine the treatability of plywood composed of western wood species by:

1.) Determining the effect of geographic source on plywood treatability
2.) Determining the effect of wood species on plywood treatability.

CHAPTER I. Effect of Panel Size and Geographic Source on Retention and Penetration of Chromated Copper Arsenate Following 2, 4, 6, or 8 Hour Pressure Periods: A Preliminary Study.

INTRODUCTION

Plywood is a heterogenous material, creating the potential for wide retention and penetration variability in the same panel. Preliminary tests were conducted to identify which variables most affected plywood treatability. These tests were designed to determine the extent of variability within and between samples cut from the same panel, the optimum sample size, replication, and the optimum solution strength required to achieve the target retention. This information was used to perform a larger scale plywood treatment study.

MATERIALS AND METHODS

Sample Preparation

Two panels each from Libby, Montana (Mill A), Pierce, Idaho (Mill B), and Springfield, Oregon (Mill C) were examined (Table 1). The veneers in each panel were anatomically identified to genus and, where possible, species (Harlow et al., 1979) by cutting a small (0.5 cm by 0.5 cm) square from each panel, softening the square in water, and cutting a thin slice from the radial side of each veneer. These sections were mounted in water on a glass slide and examined using a light microscope equipped with 100X and 400X lenses. Where more information was needed, the squares were split at the glue-line and thin slices were cut from the tangential side of each veneer.

Four samples of each of four dimensions (2 cm x 15 cm, 4 cm x 15 cm, 7.5 cm x 15 cm, and 15 cm x 15 cm) were cut from each panel. The samples were stickered and conditioned in a controlled room at 23 C and 68 % relative humidity until their moisture contents stabilized. An additional sample (7.5 cm x 15 cm) was cut from each panel and used to determine initial panel moisture content (MC). These MC samples were weighed, oven-dried for 48 hours at 65 C, and weighed again to determine MC. Randomly chosen test samples (15 cm x 15 cm) in the conditioning room were weighed at the start of conditioning and at regular intervals thereafter to record MC changes during the conditioning period. At the end of the conditioning period, the samples equilibrated to 5 % to 6 % MC after 6 days.

The conditioned samples were edged-sealed with a waterproof epoxy resin (Gluvit Epoxy Waterproof Sealer and Gluvit Catalyst, Chelsea Massachusetts) to prevent end-grain preservative penetration. Two coats of epoxy were applied 24 hours apart, then the samples were cured an additional 24 hours and weighed (nearest 0.01 g) prior to pressure treatment. Additional samples (7.5 cm x 15 cm or 15 cm x 15 cm) were epoxied on all sides but one end-grain face to evaluate maximum longitudinal or tangential preservative penetration through the sample, with orientation of the desired direction based on the face veneer, during 2, 6 or 8 hour pressure periods. The preservative could move a maximum distance of 15 cm from the opening to the end of the sample.

Preservative Treatment

Chromated copper arsenate Type C (CCA-C) was prepared at a concentration of 2.5 % (oxide basis) (AWPA Standard P5-86), a level which previous research suggested would produce a target retention of 9.6 kg/m^3 (Morrell and Lebow, 1987). The samples were treated by drawing a 71.12 cm vacuum for 1 hour, then releasing the vacuum and raising the pressure to 0.827 MPA over a 20 minute period and holding the pressure for 2, 4, 6, or 8 hours. The system required 10 minutes to reach the desired vacuum. Samples from panel 2 were used in the 2 and 6 hour pressure periods, while samples from panel 1 were used in the 4 and 8 hour periods. After the first treating charge, the 2 smallest sample dimensions were eliminated because the variability between the different dimensions were small. Samples epoxied on all faces but one end-grain side were treated using a 2, 6, or 8 hour pressure period.

After the appropriate pressure period, the samples were removed from solution, drained of excess preservative, blotted on paper towels, and weighed (nearest 0.01 g).

Preservative Retention and Penetration

Preservative retention was determined for each sample using the following equation:

$$\text{Retention (kg/m}^3\text{)} = \frac{\text{Post wt - Pre wt (kg) X Conc.}}{\text{Wood Volume (m}^3\text{)}}$$

Post wt = After treatment weight (kg)

Pre wt = Before treatment weight (kg)

Conc. = Preservative concentration (0.025)

Preservative penetration was evaluated by cutting a 5 cm x 5 cm square from the corner of each test sample. Chrome azurol S, a copper indicator which turns blue in the presence of copper (AWPA Standard A3-84), was sprayed on the cut surface, and the depth and degree of copper penetration in each veneer was visually rated on a scale of 0.0 to 4.0 (0.0 = no penetration, 4.0 = complete preservative penetration). Both transverse and radial faces of each veneer were examined. Preservative penetration measurements of both faces of each veneer were averaged for each sample and these values were averaged for each panel.

Samples that were epoxied on all but one edge were sectioned into fifteen 1 cm thick slices cut progressively back from the uncoated edge and perpendicular to the direction of allowable preservative flow. Each 1 cm sample was sprayed with chrome azurol S and the percent of section area penetrated by copper penetration was measured. Penetration measurements for the veneers were averaged for each sample and these values were averaged for each panel.

RESULTS AND DISCUSSION

Effect of Sample Dimension on Plywood Treatability

A. Preservative Retention: Sample dimension had little effect on retention of CCA-C in the test samples (Table 2). Variability between the samples of different sample from panels from the same mill was low, and the 2 smallest sample dimensions were eliminated after the first charge (4 hour pressure period). The larger sample dimensions provided the material needed for subsequent preservative analysis and future biodegradation tests. Variability between the 7.5 cm x 15 cm and the 15 cm x 15 cm dimensions treated using 2, 6, 4, or 8 hour pressure periods is shown in Table 3. Differences in preservative retention between the 2 sample dimensions over 2, 4, 6, or 8 hour pressure periods appeared to be largest in panels from Mill A (1.75) and Mill B (1.45) (Figure I.1). These differences may reflect the variable treatability of the geographic regions from which these panels originated.

B. Preservative Penetration: Penetration was not measured on the 2 smallest sample dimensions. Differences in copper penetration between the 7.5 cm x 15 cm and the 15 cm x 15 cm samples for each mill were similar to those found with retention (Figure I.2), with larger differences between the 2 dimensions occurring in panels from Mill A and Mill B (1.45 cm), where copper penetration was low.

Effect of Pressure Period

A. Preservative Retention: CCA-C retention of panels from the same mill did not vary widely over the 2, 4, 6, or 8 hour pressure periods (Table 3), except in Mill B (1.1 cm) where the two panels contained different species mixtures. Preservative retentions in panels from different mills and geographic regions exhibited differences in preservative retention over all pressure periods (Figure I.3).

Preservative retentions of panels from Mill A increased over the pressure periods and were generally below or just slightly above the target retention (9.6 kg/m^3) (Table 3). The larger dimension samples cut from the 1.5 cm thick panel never achieved the target retention with increasing pressure period. In the smaller dimension samples, panels exposed to the 2 or 6 hour pressure periods had higher retentions than the panels treated using 4 or 8 hour periods. Panels used in the 4 and 8 hour pressure periods contained western larch in the inner plies, while panels treated using 2 or 6 hour periods contained western larch in the face and back veneers.

The larger dimension samples cut from 1.45 cm thick panels from Mill B had retentions above the target retention following 2, 4, or 8 hour pressure periods, while the smaller dimension samples required an 8 hour press to achieve the target retention. Large fluctuations in retention were noted in the 1.1 cm thick panels due to species differences between the two panels. Panel 2 contained an apparently highly permeable true-fir core veneer, and was treated to retentions far above the target level. Samples from panel 1 (Mill B, 1.1 cm) were composed entirely of Douglas-fir veneers. These samples were treated to the target retention in large sample dimensions following 4 or 8 hour pressure periods and the smaller dimension after an 8 hour pressure period.

Panels from Mill C were also treated to similar retentions over the pressure period tested (Table 3), but were consistently over-treated. While differences in retention were observed between smaller dimension samples from the two panels, these differences may reflect different percentages of sapwood and heartwood.

Samples that were epoxied on all but one side did not show large differences in CCA retention when longitudinal or tangential faces were exposed (Figure I.4). Chemical retentions were also similar to those found in samples which were only edged-sealed.

B. Preservative Penetration: Preservative penetration exhibited little variation with increasing length of the pressure period, except where species differed between individual panels (Figure I.5). Copper penetration ratings in panels from Mill C were consistently between 3.0 and 4.0 (Table 3). Panels from Mill B (1.45 cm) and Mill A also did not exhibit increases in copper penetration following longer pressure periods, except in panels from Mill A (1.1 cm), where larch inner plies were associated with increased penetration.

Samples epoxied on all sides but one end-grain surface edge showed differences in preservative penetration over the three pressure periods, particularly between mills due to species composition of the panels (Figure I.6). Only the smaller dimension samples (7.5 cm x 15 cm) were examined. Preservative penetration in samples from Mill A, which contained western larch in the 2 and 4 veneer positions, exhibited a wide degree of variability (Figure I.7). In the 2 and 6 hour pressure periods, tangentially orientated western larch veneers exhibited higher degrees of preservative penetration than longitudinally oriented Douglas-fir veneers. Similar penetration patterns were noted in the samples treated using an 8 hour pressure period, although the larch veneers in these samples were in the 1 and 5 positions (the face and back veneers)

Panel samples from Mill B also exhibited wide differences in preservative penetration which were dependent on the species composition (Figure I.8). The true-fir inner ply in the 1.1 cm thick panels treated using 2 or 6 hour pressure periods exhibited consistently higher degrees of preservative penetration than the Douglas-fir outer veneers.

Conversely, the inner ply of the 1.45 cm thick panel also exhibited a higher degree of preservative penetration than the outer plies; however, all of the veneers were Douglas-fir. The nature of these differences is unclear, although they may reflect the presence of more treatable sapwood in some plies.

Samples from Mill C exhibited uniformly high degrees of copper penetration through all veneers over the 3 pressure periods when the face veneers were oriented to allow longitudinal preservative flow (Figure I.9). There were only slight differences in preservative penetration between veneers or between longitudinal and tangential preservative penetration. In the 2 and 6 hour pressure periods, inner plies in the tangential direction had higher penetration than outer plies in the same direction. In samples where the face and back veneers were orientated in the tangential direction (Figure I.9), there were wide differences between tangential and longitudinal direction. Longitudinal preservative penetration was much greater than tangential over the 2 and 6 hour pressure periods, but these differences were less substantial in the 8 hour pressure period.

Large differences in the degree of copper penetration were evident between the three species present in the test panels (Figure I.10). The degree of copper penetration was highest in true-fir veneers, and was sometimes twice as high as that found in Douglas-fir veneers. In some cases, tangential preservative penetration of one species exceeded longitudinal preservative penetration of another species.

CONCLUSION

Since panels used in the preliminary tests varied in thickness and ply number, it is difficult to make definitive conclusions. Panels received from western Oregon were easily treated to the target retention using a 2 hour pressure period, while panels from Idaho and Montana were less easily treated. Different species from the same location showed great differences in preservative retention. The position of individual species in the panel also affected treatability, but position did not alter relative treatability in relation to the other species in the panel.

Samples that were epoxied to orient preservative flow through the longitudinal or tangential direction never achieved complete longitudinal preservative penetration. Depending on species, tangential flow was sometimes better than longitudinal flow, independent of veneer position. Panels containing true-fir veneers had consistently higher degrees of preservative penetration, but the number of panels containing true-fir veneers was small compared to those with western larch or Douglas-fir veneers. These results illustrate the geographic differences in veneer treatability and the need for a more comprehensive survey of panel treatability.

RECOMMENDATIONS

The CCA-C concentration chosen for this preliminary study was subsequently found to be approximately two-thirds higher than that used in industry practice. Further studies will use a CCA-C concentration of of 1.5%, based upon the retention achieved in samples from Mill C using a 6 hour pressure period. All samples in the subsequent large scale study will be treated using a 6 hour pressure period.

Measuring preservative penetration in individual veneers was time consuming and highly subjective. In the final study, diagonal cuts will be made to expose the same orientation in each veneer to increase the accuracy of individual measurements and reduce the need for subjective judgements. Penetration will be assessed as percent area of copper penetration of each veneer. Variability between samples cut from the same panel was small, replication of 4 subsamples will be randomly chosen from each panel and a sample size of 7.5 cm x 15 cm will be used. The dimensions are representative of full-size plywood panels which are rectangular and provides enough material for penetration and retention analyses.

Table I.1. Description of panels collected from 3 plywood mills used in preliminary treating studies.

Mill	Panel Number	Panel Thickness (cm)	Veneer Species[a] V1	V2	V3	V4	V5[b]	Geographic Region[c]
A	1	1.5	L	DF	DF	DF	L	Montana
A	2	1.5	DF	L	DF	L	DF	Montana
A	1	1.75	L	DF	DF	DF	L	Montana
A	2	1.75	DF	L	DF	L	DF	Montana
B	1	1.1	DF	DF	DF			Idaho
B	2	1.1	DF	TF	DF			Idaho
B	1	1.45	DF	DF	DF			Idaho
B	2	1.45	DF	DF	DF			Idaho
C	1	1.1	DF	DF	DF	DF		Oregon
C	2	1.1	DF	DF	DF	DF		Oregon
C	1	1.1	DF	DF	DF			Oregon

[a] DF=Douglas-fir, L=western larch, TF=true-fir

[b] Veneer order is from face to back. Panels were marked to retain orientation for later analysis.

[c] Geographic region of mills from which the panels were obtained.

Table I.2. Gross CCA retention of plywood panels cut to 4 different sample dimensions and treated with CCA-C using a 4 hour pressure period.

Mill	Panel Thickness (cm)[a]	Sample Dimension (cm)	Retention (std)[b] (kg/m^3)
A	1.5	15.0 x 15.0	7.38 (0.53)
A	1.5	7.5 x 15.0	7.38 (0.51)
A	1.5	4.0 x 15.0	6.90 (0.56)
A	1.5	2.0 x 15.0	7.55 (0.63)
A	1.75	15.0 x 15.0	6.44 (0.57)
A	1.75	7.5 x 15.0	7.11 (1.10)
A	1.75	4.0 x 15.0	6.01 (1.18)
A	1.75	2.0 x 15.0	6.51 (0.85)
B	1.1	15.0 x 15.0	10.02 (0.40)
B	1.1	7.5 x 15.0	8.59 (0.65)
B	1.1	4.0 x 15.0	8.78 (0.54)
B	1.1	2.0 x 15.0	9.39 (0.71)
B	1.45	15.0 x 15.0	10.86 (1.89)
B	1.45	7.5 x 15.0	7.57 (1.05)
B	1.45	4.0 x 15.0	5.59 (0.62)
B	1.45	2.0 x 15.0	7.73 (1.30)
C	1.1*	15.0 x 15.0	16.80 (0.29)
C	1.1*	7.5 x 15.0	17.44 (0.72)
C	1.1*	4.0 x 15.0	17.21 (0.80)
C	1.1*	2.0 x 15.0	16.41 (0.90)
C	1.1**	15.0 x 15.0	16.67 (0.20)
C	1.1**	7.5 x 15.0	17.51 (0.30)
C	1.1**	4.0 x 15.0	16.38 (1.20)
C	1.1**	2.0 x 15.0	15.69 (1.13)

[a] *4-ply, **3-ply

[b] Values represent means of 4 samples. Values in parentheis represent one standard deviation.

Table I.3. Preservative retention and penetration of samples cut from plywood panels and treated with CCA-C using 2, 4, 6, or 8 hour pressure periods[a].

Table I.3

				Preservative Retention (kg/m^3)				Preservative Penetration			
				Pressure Period (Hours)							
Mill Number	Sample Dimension (cm)	Number of Plies	Panel Thickness (cm)	2	4	6	8	2	4	6	8
A	15 x 15	5	1.50	7.73(0.64)	7.38(0.53)	8.45(1.77)	8.90(1.54)	2.30(1.13)	2.35(1.27)	2.15(0.75)	2.35(1.46)
A	15 x 15	5	1.75	6.63(0.55)	6.44(0.57)	7.24(1.52)	8.38(2.21)	2.45(0.88)	2.35(1.31)	2.3 (0.66)	2.15(1.35)
B	15 x 15	3	1.10	15.05(0.90)	10.02(0.40)	16.12(0.22)	12.34(0.60)	3.16(0.94)	2.17(0.58)	3.25(0.96)	2.50(0.52)
B	15 x 15	3	1.45	10.17(0.43)	10.85(1.89)	9.10(1.93)	10.15(0.73)	2.67(0.98)	2.25(0.62)	2.17(0.72)	2.41(0.67)
C	15 x 15	4	1.10	14.78(1.45)	16.80(0.29)	14.09(1.09)	17.12(0.21)	3.56(0.72)	3.94(0.25)	3.31(0.87)	3.81(0.40)
C	15 x 15	3	1.10	-	16.67(0.20)	-	15.65(3.86)	-	4.00(0.00)	-	3.67(0.89)
A	7.5 x 15	5	1.50	8.70(1.21)	7.38(0.51)	9.80(2.75)	8.37(0.84)	2.35(1.04)	2.45(0.19)	2.35(1.08)	2.35(1.49)
A	7.5 x 15	5	1.75	8.83(0.60)	7.11(1.05)	9.94(1.09)	7.17(1.20)	2.55(0.88)	2.25(1.29	2.85(0.58)	2.10(1.49)
B	7.5 x 15	3	1.10	14.19(0.59)	8.59(0.65)	16.46(0.41)	10.63(1.07)	3.25(0.87)	2.50(0.52)	3.33(0.98)	2.42(0.67)
B	7.5 x 15	3	1.45	7.77(1.06)	7.57(1.05)	7.94(1.45)	11.12(0.30)	2.25(0.45)	2.17(0.58)	1.75(0.86)	2.42(0.52)
C	7.5 x 15	4	1.10	14.49(0.45)	17.44(0.72)	16.20(0.60)	16.83(0.69)	3.50(0.52)	3.81(0.40)	3.93(0.25)	3.81(0.54)
C	7.5 x 15	3	1.10	-	17.51(0.30)	-	17.16(0.37)	-	3.92(0.28)	-	4.00(0.00)

[a] Values represent means of 4 replications. Values in parentheses represent one standard deviation.

Figure I.1. Gross CCA-C retention of 7.5 cm x 15 cm and 15 cm x 15 cm samples from panels collected from various geographic regions following treatment using 2 (A), 4 (B), 6 (C), or 8 (D) hour pressure periods.

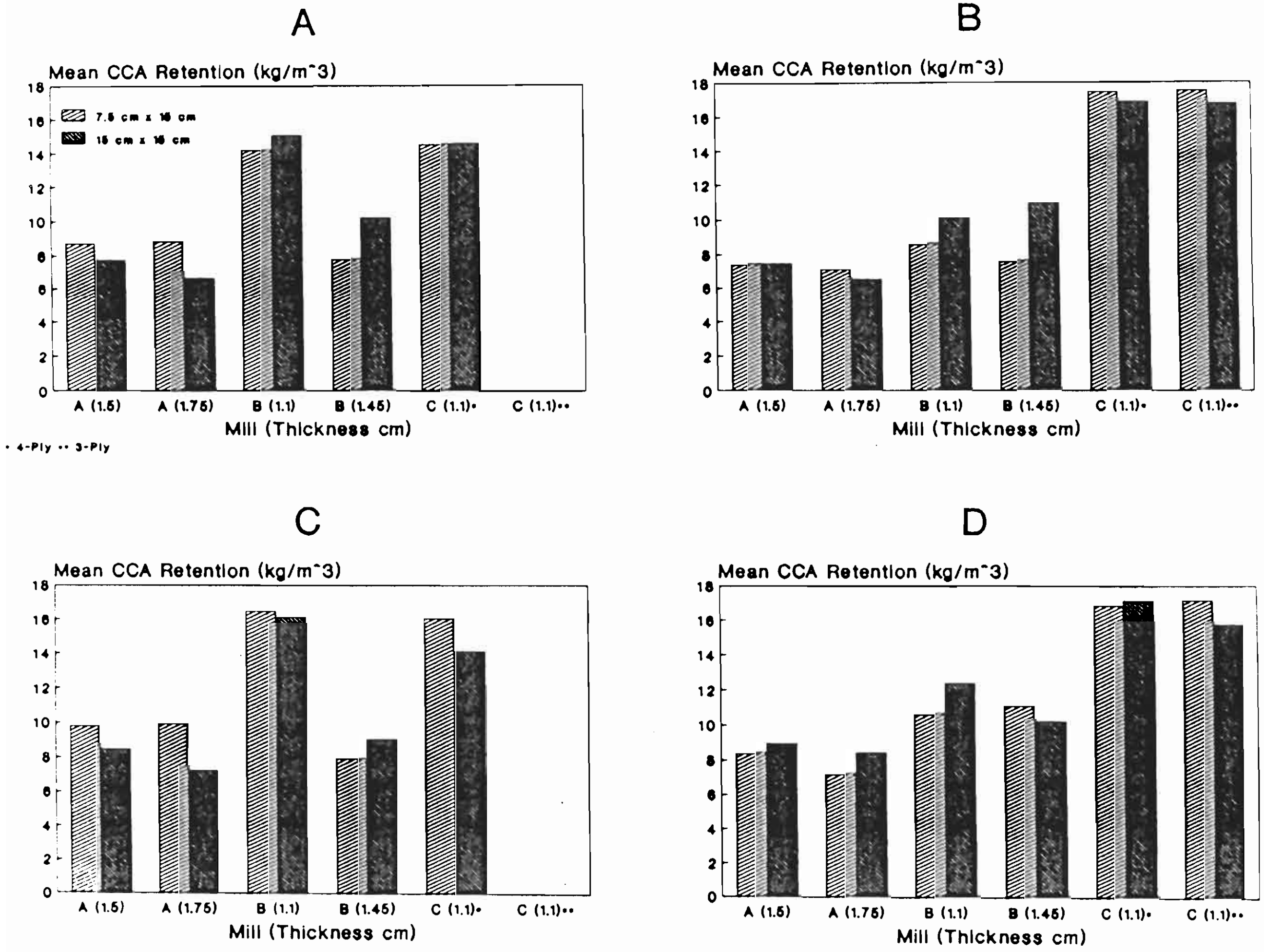

A
Mean CCA Retention (kg/m^3)
18
16
14
12
10
8
6
4
2
0
▨ 7.5 cm x 15 cm
▩ 15 cm x 15 cm
A (1.5)
A (1.75)
B (1.1)
B (1.45)
C (1.1)*
C (1.1)**
Mill (Thickness cm)
* 4-Ply ** 3-Ply
B
Mean CCA Retention (kg/m^3)
18
16
14
12
10
8
6
4
2
0
A (1.5)
A (1.75)
B (1.1)
B (1.45)
C (1.1)*
C (1.1)**
Mill (Thickness cm)
C
Mean CCA Retention (kg/m^3)
18
16
14
12
10
8
6
4
2
0
A (1.5)
A (1.75)
B (1.1)
B (1.45)
C (1.1)*
C (1.1)**
Mill (Thickness cm)
D
Mean CCA Retention (kg/m^3)
18
16
14
12
10
8
6
4
2
0
A (1.5)
A (1.75)
B (1.1)
B (1.45)
C (1.1)*
C (1.1)**
Mill (Thickness cm)

Figure I.1

Figure I.2. Mean copper penetration through face veneers (0 = no penetration, 4 = complete penetration), as measured using chrome azurol S, of 7.5 cm x 15 cm and 15 cm x 15 cm samples from panels collected from various geographic regions and treated with CCA-C using 2 (A), 4 (B), 6 (C), or 8 (D) hour pressure periods.

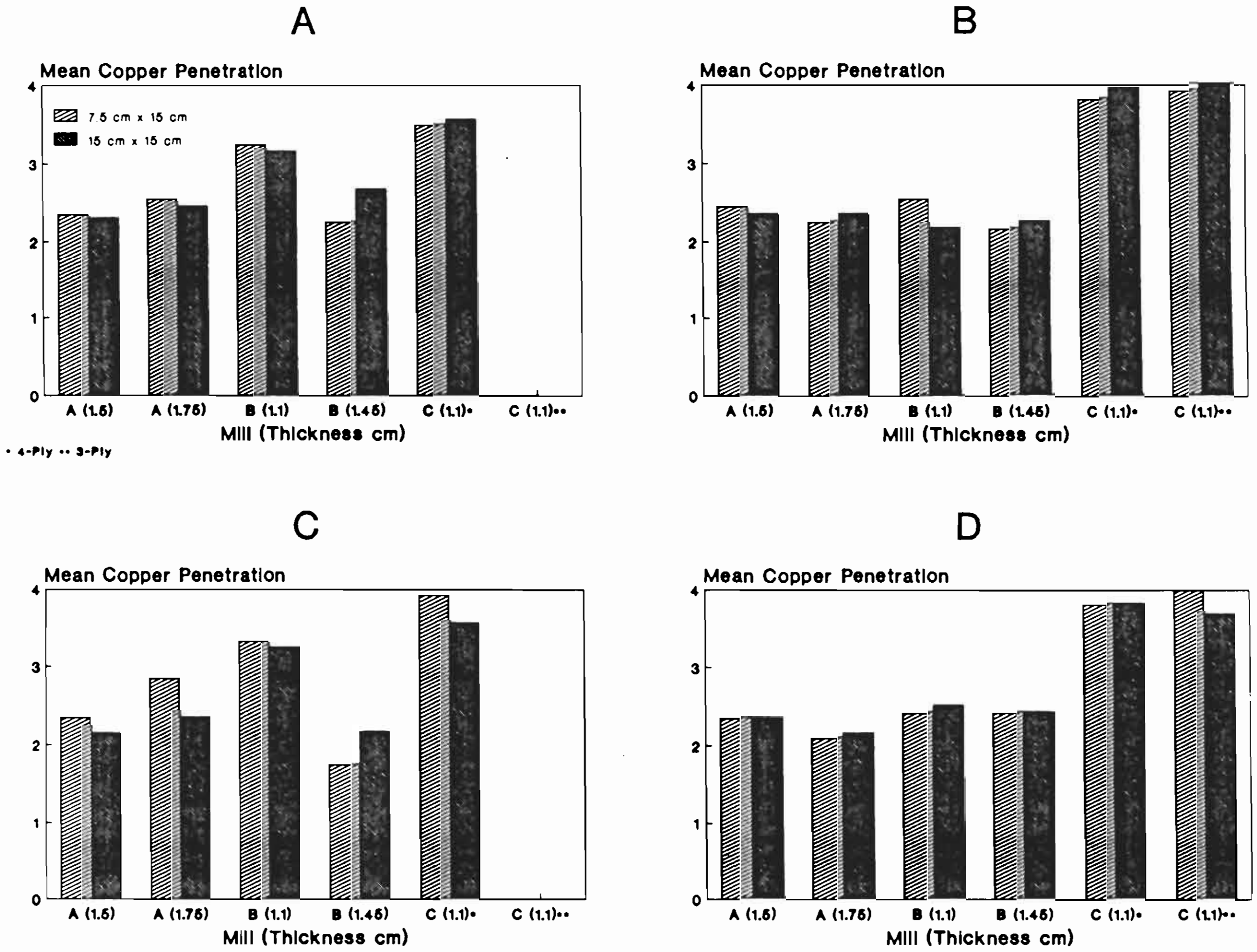
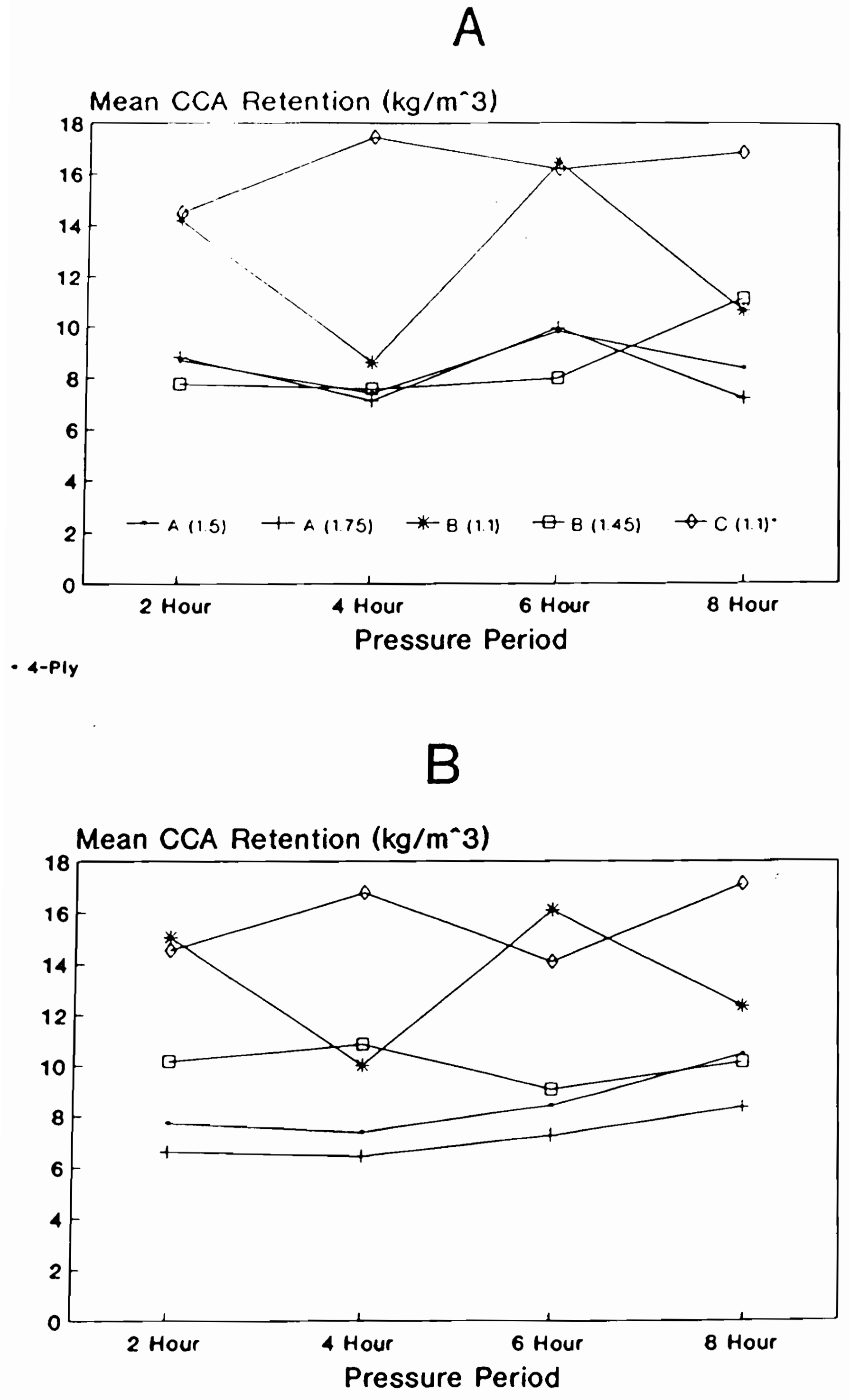

A
Mean Copper Penetration
7.5 cm x 15 cm
15 cm x 15 cm
0
1
2
3
4
A (1.5)
A (1.75)
B (1.1)
B (1.45)
C (1.1)•
C (1.1)••
Mill (Thickness cm)
• 4-Ply •• 3-Ply
B
Mean Copper Penetration
A (1.5)
A (1.75)
B (1.1)
B (1.45)
C (1.1)•
C (1.1)••
Mill (Thickness cm)
C
Mean Copper Penetration
A (1.5)
A (1.75)
B (1.1)
B (1.45)
C (1.1)•
C (1.1)••
Mill (Thickness cm)
D
Mean Copper Penetration
A (1.5)
A (1.75)
B (1.1)
B (1.45)
C (1.1)•
C (1.1)••
Mill (Thickness cm)

Figure I.2

Figure I.3. Gross CCA-C retention of 7.5 cm x 15 cm (A), or 15 cm x 15 cm (B) samples treated with CCA-C using 2, 4, 6, or 8 hour pressure periods.



* 4-Ply

Figure I.3

Figure I.4. Gross CCA-C retention in the longitudinal (A) or tangential (B) directions of samples cut from panels from various geographic regions following treatment with CCA-C using 2, 6, or 8 hour pressure periods. Panel specimens were sealed on all faces but one, with the orientation of the desired direction based on the face veneer (veneer #1).

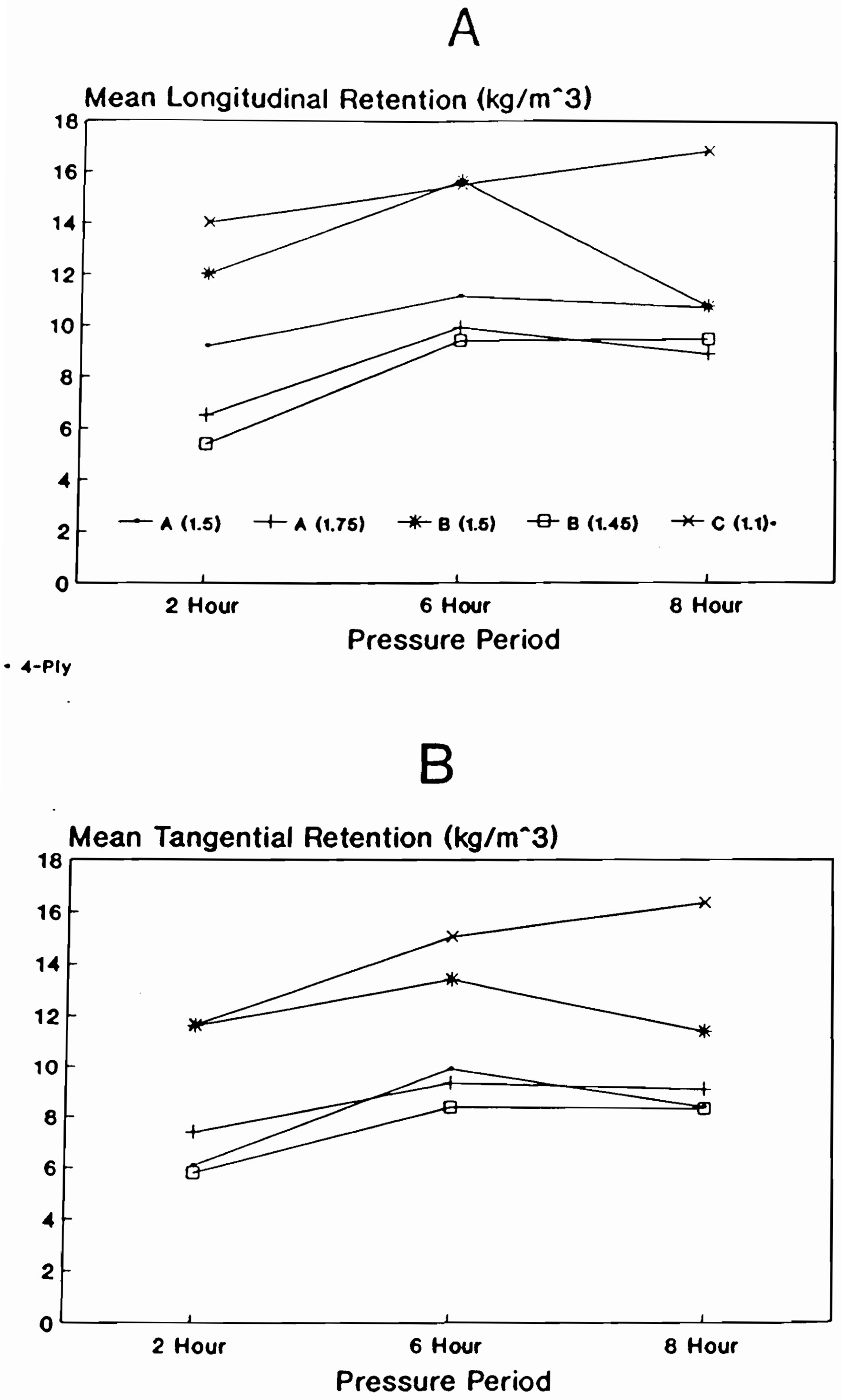
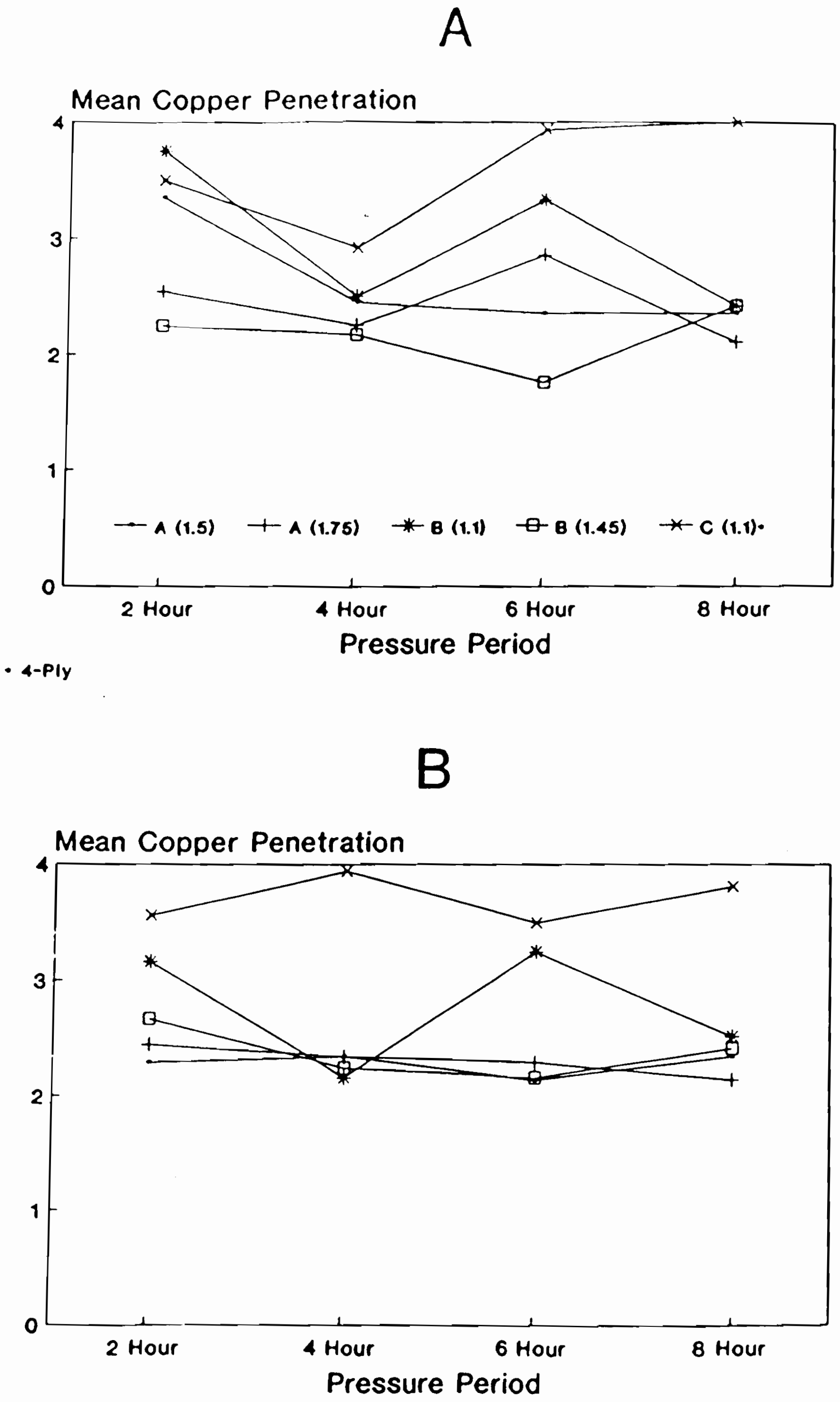

A
Mean Longitudinal Retention (kg/m^3)
18
16
14
12
10
8
6
4
2
0
A (1.5)
A (1.75)
B (1.5)
B (1.45)
C (1.1)•
2 Hour
6 Hour
8 Hour
Pressure Period
• 4-Ply
B
Mean Tangential Retention (kg/m^3)
18
16
14
12
10
8
6
4
2
0
2 Hour
6 Hour
8 Hour
Pressure Period

Figure I.4

Figure I.5. Mean copper penetration through face veneers, as measured using chrome azurol S, of 7.5 cm x 15 cm (A) and 15 cm x 15 cm (B) samples cut from panels collected from various geographic regions treated with CCA-C using a 2, 4, 6, or 8 hour pressure period.



• 4-Ply

Figure I.5

Figure I.6. Mean copper penetration, as measured using chrome azurol S, in the longitudinal (A) and tangential (B) directions following CCA-C treatment of samples cut from panels from various geographic regions using 2, 6, or 8 hour pressure periods. Samples were sealed on all faces but one, with the desired orientation based on the face veneer (veneer #1).

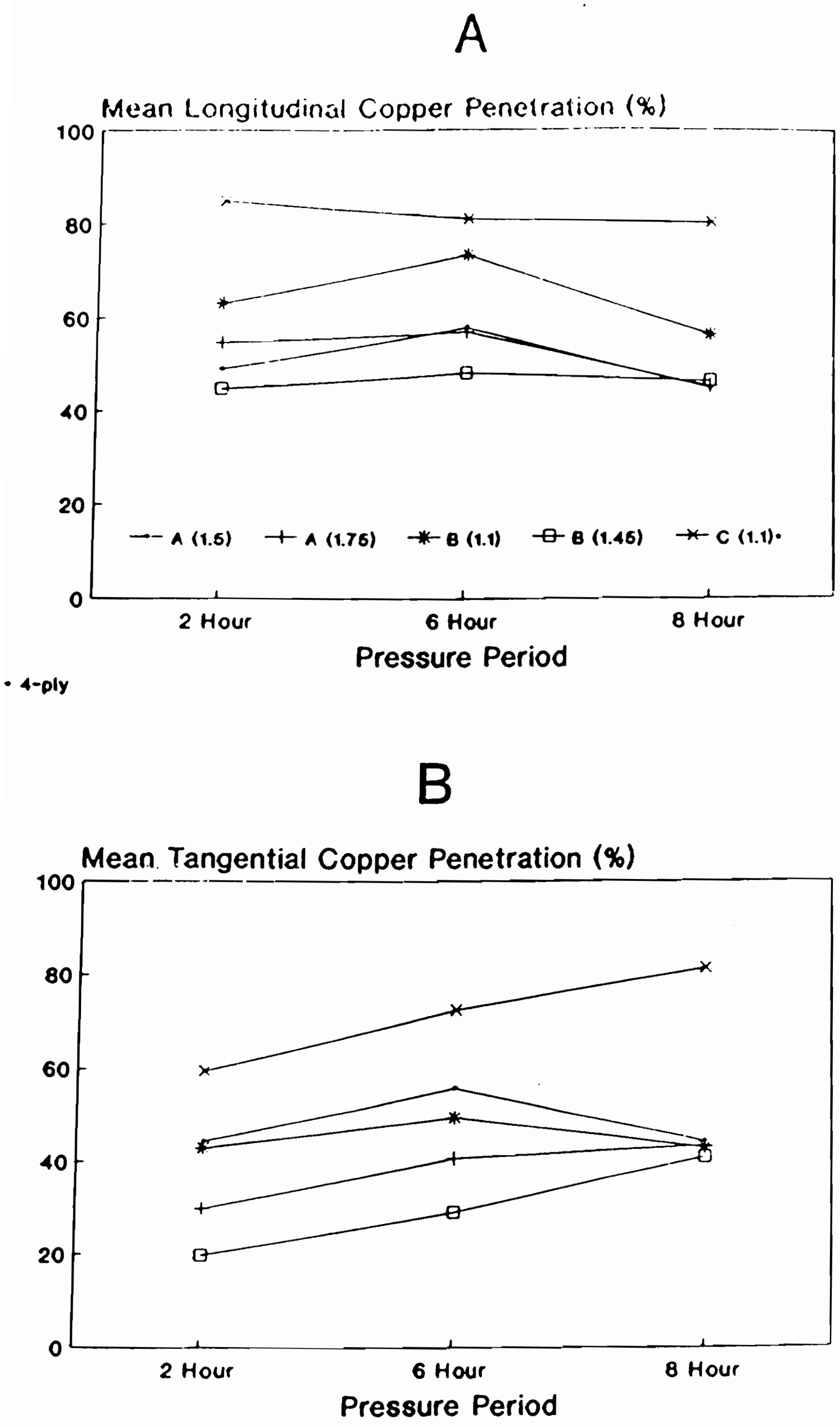

A
Mean Longitudinal Copper Penetration (%)
100
80
60
40
20
0
A (1.5)
A (1.75)
B (1.1)
B (1.45)
C (1.1)•
2 Hour
6 Hour
8 Hour
Pressure Period
• 4-ply
B
Mean Tangential Copper Penetration (%)
100
80
60
40
20
0
2 Hour
6 Hour
8 Hour
Pressure Period

Figure I.6

Figure I.7. Mean copper penetration, as measured using chrome azurol S, of samples cut from panels obtained from Mill A which were epoxied to allow preservative flow through the veneers in the longitudinal (L) (A,C,E) or tangential (T) (B,D,F) directions and treated with CCA-C using 2 (A,B), 6 (C,D), or 8 (E,F) hour pressure periods.

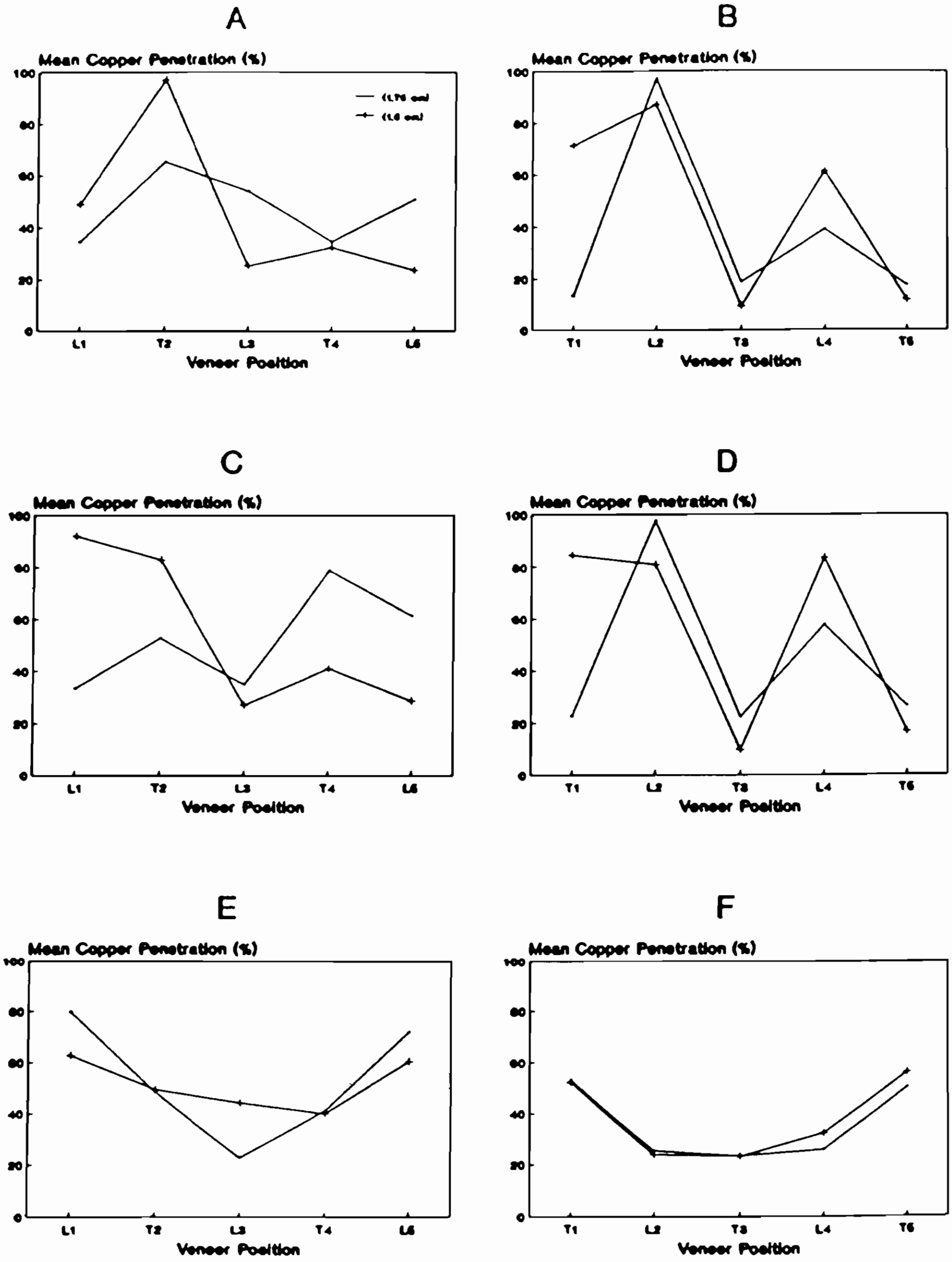

A
Mean Copper Penetration (%)
(1.75 cm)
(1.6 cm)
100
80
60
40
20
0
L1
T2
L3
T4
L5
Veneer Position
B
Mean Copper Penetration (%)
T1
L2
T3
L4
T5
Veneer Position
C
Mean Copper Penetration (%)
Veneer Position
D
Mean Copper Penetration (%)
Veneer Position
E
Mean Copper Penetration (%)
Veneer Position
F
Mean Copper Penetration (%)
Veneer Position

Figure I.7

Figure I.8. Mean copper penetration, as measured using chrome azurol S, of samples cut from panels obtained from Mill B which were epoxied to allow preservative flow through the veneers in the longitudinal (L) (A,C,E) or tangential (T) (B,D,F) directions and treated with CCA-C using 2 (A,B), 6 (C,D), or 8 (E,F) hour pressure periods.

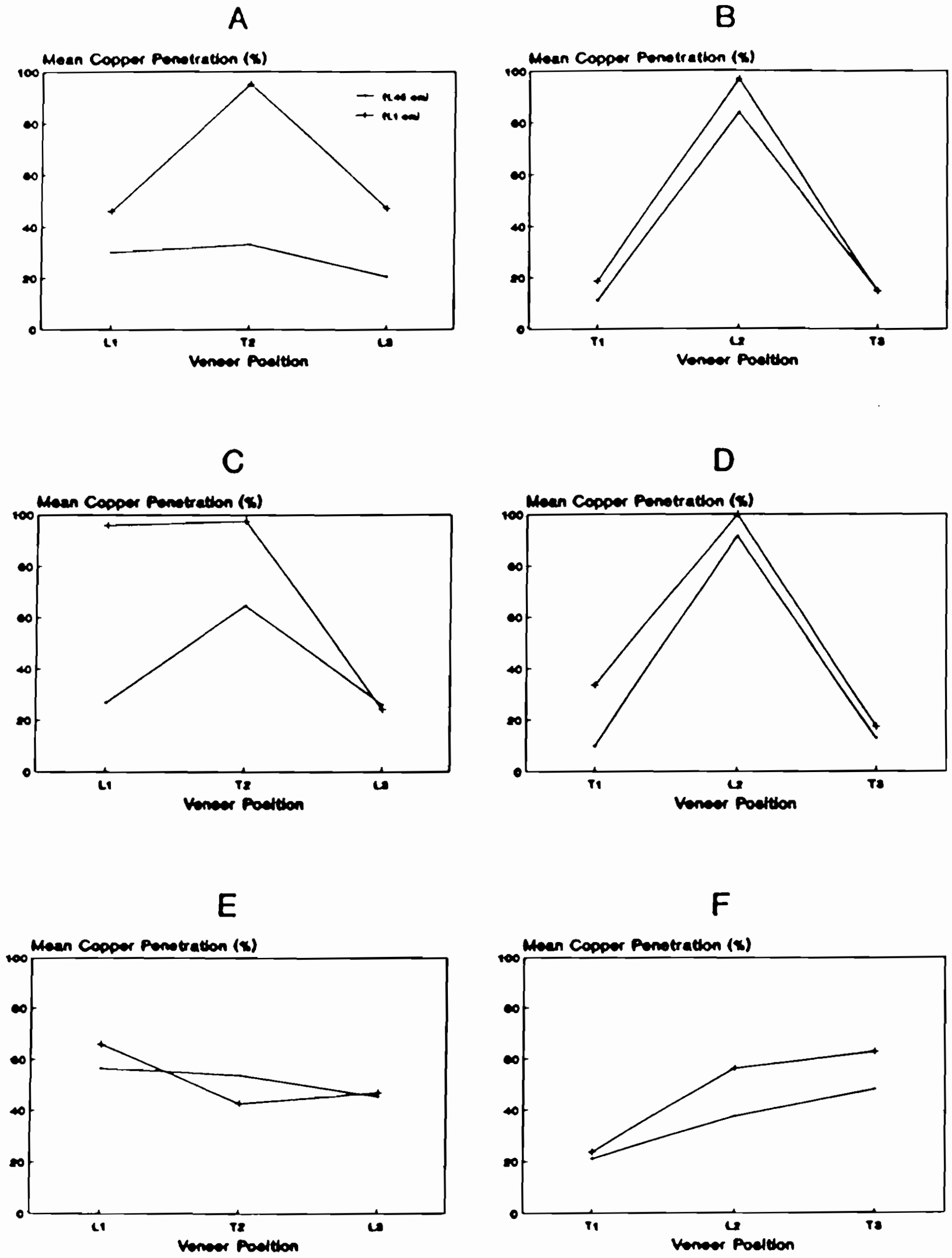

A
Mean Copper Penetration (%)
100
80
60
40
20
0
(1.46 cm)
(1.1 cm)
L1
T2
L3
Veneer Position
B
Mean Copper Penetration (%)
T1
L2
T3
Veneer Position
C
Mean Copper Penetration (%)
L1
T2
L3
Veneer Position
D
Mean Copper Penetration (%)
T1
L2
T3
Veneer Position
E
Mean Copper Penetration (%)
L1
T2
L3
Veneer Position
F
Mean Copper Penetration (%)
T1
L2
T3
Veneer Position

Figure I.8

Figure I.9. Mean copper penetration, as measured using chrome azurol S, of samples cut from panels obtained from Mill C which were epoxied to allow preservative flow through the veneers in the longitudinal or tangential (A and B) and treated with CCA-C using 2, 6, or 8 hour pressure periods.

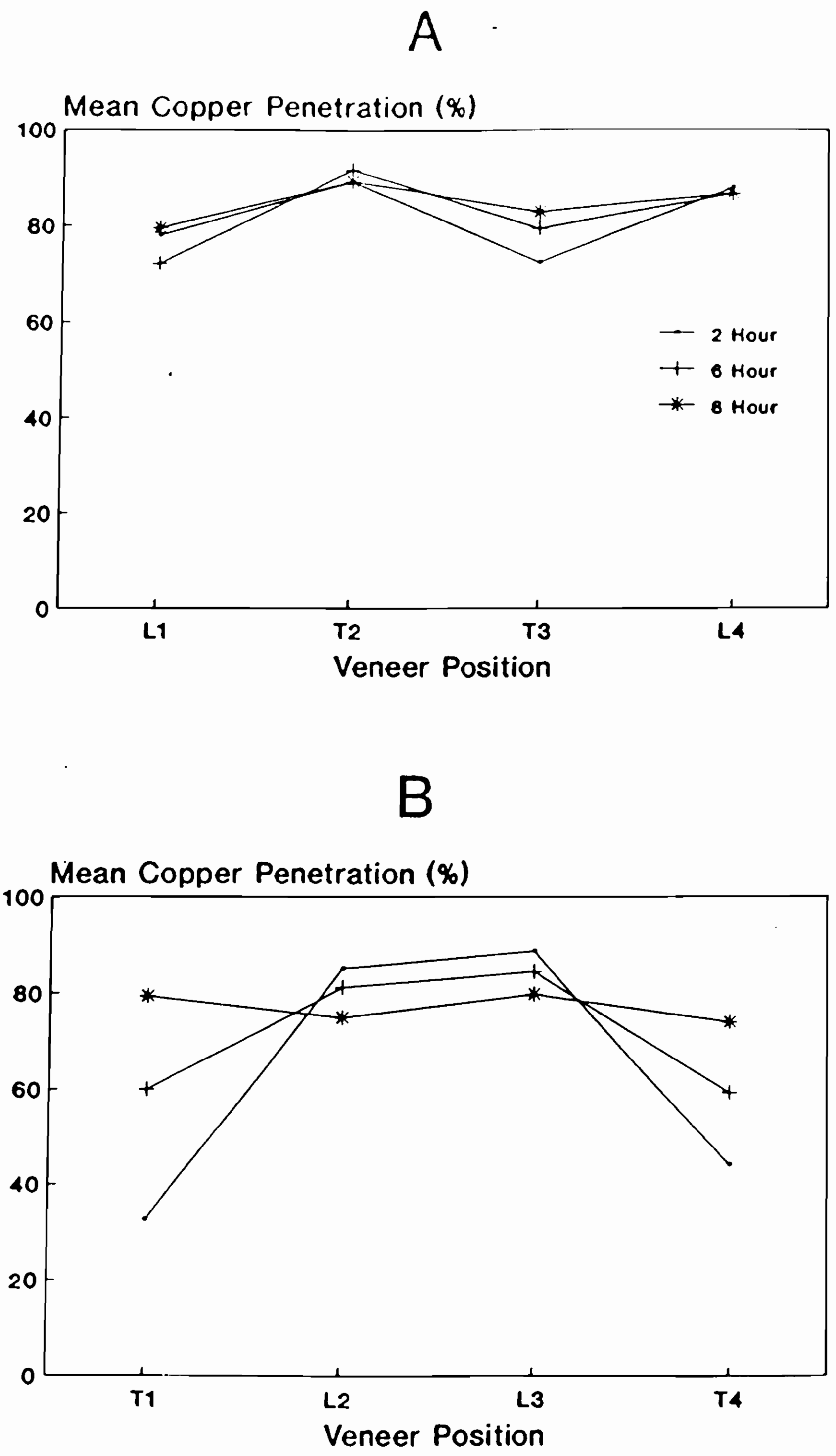

A
Mean Copper Penetration (%)
100
80
60
40
20
0
L1
T2
T3
L4
Veneer Position
2 Hour
6 Hour
8 Hour
B
Mean Copper Penetration (%)
100
80
60
40
20
0
T1
L2
L3
T4
Veneer Position

Figure I.9

Figure I.10. Mean copper penetration, as measured using chrome azurol S, of veneers of different species in samples cut from panels from different geographic regions following treatment with CCA-C using a 2, 6, or 8 hour pressure period.

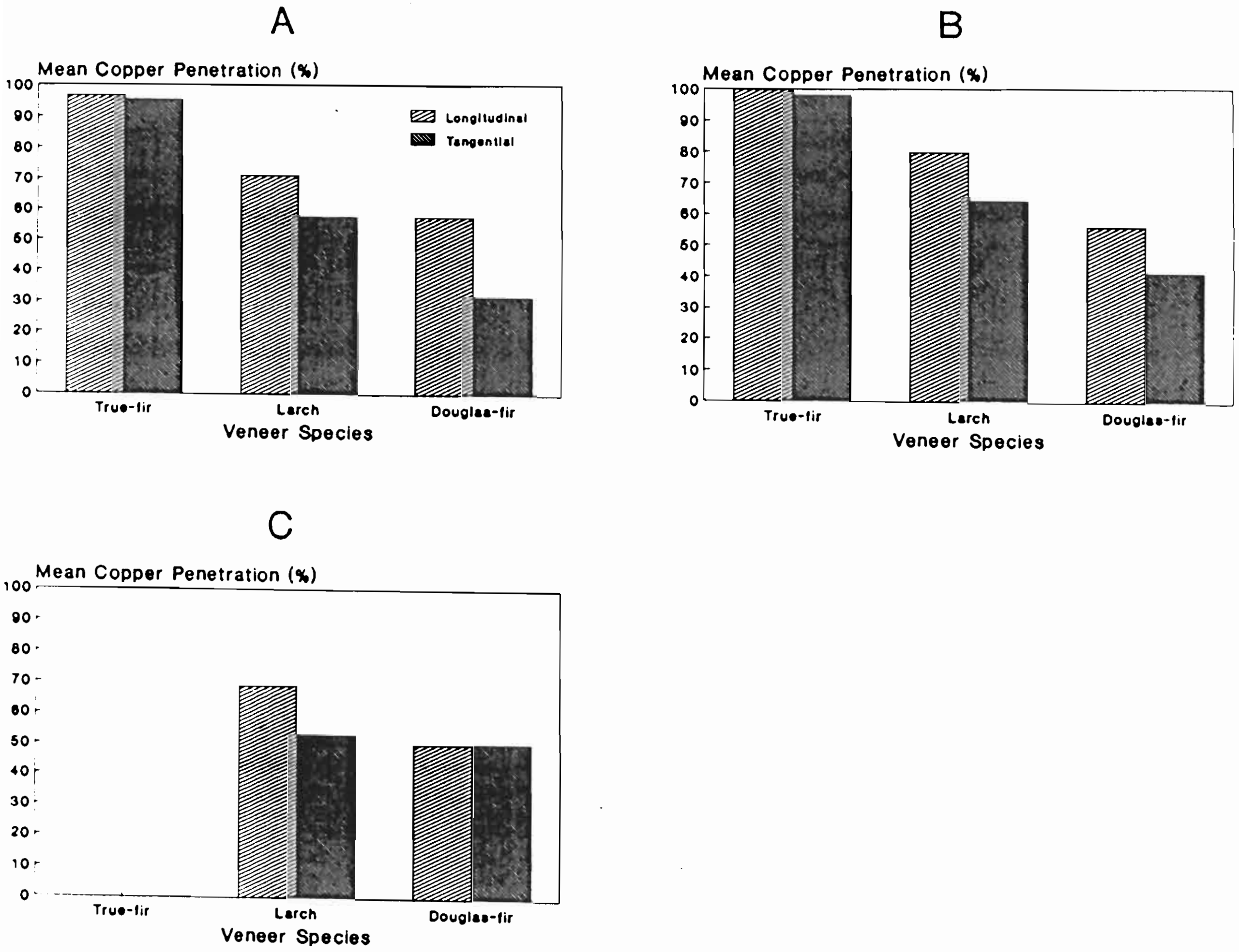
A
Mean Copper Penetration (%)
100
90
80
70
60
50
40
30
20
10
0
▨ Longitudinal
▧ Tangential
True-fir
Larch
Douglas-fir
Veneer Species
B
Mean Copper Penetration (%)
100
90
80
70
60
50
40
30
20
10
0
True-fir
Larch
Douglas-fir
Veneer Species
C
Mean Copper Penetration (%)
100
90
80
70
60
50
40
30
20
10
0
True-fir
Larch
Douglas-fir
Veneer Species

Figure I.10

CHAPTER II. Treatment of Plywood Panels with Chromated Copper Arsenate Type C and Ammoniacal Copper Zinc Arsenate.

INTRODUCTION

Plywood is assumed to be highly treatable with a number of panel characteristics, including species composition, veneer thickness, the presence of heartwood, glue-lines, or plywood grade that may influence treatability (Anonymous, 1986). Previous studies indicate that lathe checks aid in preservative flow through the veneers in plywood (Miller and Currier, 1964); however, incomplete preservative penetration is often noted with plywood containing certain wood species (Fahlstrom, 1982, Morris, 1988).

Many western wood species are difficult to treat (Graham, 1954; 1956; Cooper, 1971; Gjovik 1983), suggesting that treatability patterns of solid wood may also occur in plywood made from these species.

Achieving complete treatment of plywood is essential for insuring long service life of panels in systems such as the Permanent Wood Foundation (PWF). The effects of geographic source on plywood treatability are poorly defined. In this study, the effects of plywood source on treatability were explored using pressure treatments with chromated copper arsenate and ammoniacal copper zinc arsenate.

MATERIALS AND METHODS

Sample Preparation

Plywood panels measuring 0.305 by 1.219 meters were obtained from thirty seven mills in Oregon, Washington, Idaho, and Montana (Figure

II.1). Each mill supplied four panels cut from different full size-panels (1.2 by 2.4 meters). Three mills supplied 2 sets of 4 panels. Panels from two of these mills had different species compositions and the 8 panels from the third mill were divided into two set of 4 panels. All panels were numbered and the structural grade of each panel was recorded. Veneers in each panel were also numbered, with highest grade face receiving number one. For example, in a C-D panel, veneer number one would be assigned to the C veneer. If a mill sent more than four panels, four panels were randomly chosen. If the grade stamp was not visible, a grade estimate was assigned to the panel.

Based on previous studies of the treatability of western wood species from different geographic regions (Cooper and Ross, 1977; Miller 1961), the plywood mills were assigned to one of four geographic regions (Figure II.1). The regions were western Washington, western Oregon, Idaho (including eastern Washington and eastern Oregon), and Montana.

A small (0.5 cm by 0.5 cm) square was cut from each panel, softened in water, and a thin slice was cut from the radial side of each veneer. These sections were mounted in water on a glass slide and examined using a light microscope with 100X and 400X lenses to determine species composition of each panel. Where necessary, the squares were split at the glue-line and thin slices were cut from the tangential side of each veneer. Veneers were identified to genus and where possible, species using the appropriate keys (Panshin and DeZeeuw, 1980). The panels were composed of Douglas-fir (Pseudotsuga menziesii (Mirb.) Franco), western hemlock (Tsuga heterophylla (Raf.) Sarg), true-fir (Abies sp. Mill.), or Redwood (Sequoia sempervirens (D.Don) Endl.)

(Table II.1).

The panels were cut into 7.5 cm by 15 cm samples. Four samples were randomly selected from each panel for each preservative used. The samples were stickered and conditioned at 68 % relative humidity and 70 C° until the moisture content stabilized. An additional sample, randomly chosen from each panel, was used to determine initial panel moisture content (MC). These samples were weighed, oven-dried for 48 hours at 65 C° (0 % MC), and weighed again to determine MC.

Ten samples in the conditioning room were randomly chosen from any panel, and weighed periodically to record MC changes during the conditioning period. The samples conditioned to approximately 7 % MC after 2 months. The thickness of one sample from each panel, as well as the thickness of each veneer in the panel, was measured using a micrometer. These values were used as the panel thickness and veneer thickness for every sample in a given panel.

The conditioned samples were then randomly numbered to reflect mill, panel number, sample number, and preservative treatment respectively. The samples were then end-coated on all four edges with a water-proof epoxy resin (Gluvit Epoxy Waterproof Sealer and Gluvit Catalyst, Chelsea, Massachusetts) to protect the end-grain from penetration of the preservative. Two coats of epoxy were applied 24 hours apart, then the samples were cured an additional 24 hours and weighed (nearest 0.1 g) to obtain pre-treatment wood weight.

Preservative Treatments

The samples were treated with one of two preservatives: chromated copper arsenate Type C (CCA-C) or ammoniacal copper zinc arsenate (ACZA). The samples treated with CCA-C were randomly placed on stickers in a 25.4 cm diameter by 101.6 cm long treating tank and held down with coated lead weights. The preservative was then poured over the samples until they were covered with the treating solution. CCA-C was used at a concentration of 1.5% (oxide basis) in a modified full cell process which involved drawing an initial 1 hour vacuum (71.12 cm) followed by a 6 hour pressure period (0.827 MPA).

After the first treating charge, the epoxy failed as an effective edge-coating. Stresses at each glue-line caused the epoxy to crack, opening pathways for the preservative to penetrate the veneers. A less viscous epoxy was found (West System 105 Epoxy Resin and 206 Hardener, Bay City, MI) and the old epoxy was cut off of each sample, reducing the sample dimension to 6.7 cm by 17.2 cm. Preliminary studies showed that sample dimension did not influence treatability. Five coats of epoxy were required to completely coat the end-grain of the samples, which were then treated with CCA-C under the same conditions previously described. After each charge, the samples were drained of excess preservative, blotted on paper towels, and weighed (nearest 0.1 g). The samples were stickered and air-dried 24 hours to allow fixation reaction to proceed in the wood. After the fixation period, the samples were dried at 50 C° for 48 hours.

The samples treated with ACZA were coated with a polyurethane adhesive (Sikaflex 240 Polyurethane marine adhesive/sealant, Sika Corporation, Des Plaines, Illinois). Preliminary tests showed that the West System epoxy used with the CCA-C treated samples could not withstand the swelling associated with the ammonia in the ACZA. One moderately thick coat of the polyurethane adhesive was applied to the edges of each sample. The samples were treated at the University of California Forest Products Laboratory in Richmond, CA. The coated samples were placed in a basket, separated between layers by a screen, and held down on the top to prevent samples from floating. The samples were then treated using a full cell process. An initial 71.12 cm vacuum was drawn over a 1 hour period, then the solution was dropped into the cylinder under vacuum. The pressure was then increased over a 40 minute period to 0.827 MPA and held for 6 hours. Steam coils in the bottom of the cylinder were used to raise and maintain the treating solution between 40 C° and 52 C°. Solution temperature was monitored using thermocouples placed inside the cylinder door. The thermocouples were positioned above the solution and gave only approximate solution temperatures. Solution temperature was difficult to control since the steam coils were on the bottom of the cylinder and thermocouples were at the top of the cylinder. At the end of the pressure period, the solution was drained and pressure was released. The samples were left in the cylinder overnight to cool and then each sample was weighed (nearest 0.1 g). The samples were not blotted since the ammonia helped drive off moisture on the surface as pieces came in contact with air. After weighing, the samples were air-dried for 1 week.

Analysis of Preservative Retention and Penetration

Gross preservative retention of each sample was determined using the following equation:

$$\text{Retention (kg/m}^3\text{)} = \frac{\text{Post wt - Pre wt (kg) X Conc.}}{\text{Wood Volume (m}^3\text{)}}$$

Conc. = Chemical concentration (%) / 100
Post wt = Post treatment weight (kg)
Pre wt = Pre-treatment weight (kg)

The concentration of CCA differed in each charge. A concentration factor was calculated by dividing the desired concentration of 1.5 % by the actual concentration and the concentration factor was multiplied by the concentration in the above equation.

The dried samples of both treatments were cut diagonally. One half of the sample was used for retention analysis using an ASOMA X-ray Fluorescence Analyzer (ASOMA) and the other half was used to evaluate penetration. The diagonal cut exposed all veneers on the same face and simplified penetration readings.

Preservative penetration was determined by spraying the cut surface of each sample half with Chrome Azurol S (AWPA, 1989) an indicator, which turns blue in the presence of copper. Each veneer in a sample was visually evaluated for the percent of copper penetration. A panel average was obtained by averaging penetration values for each veneer in a sample, then averaging the 4 samples from each panel.

The remaining sample half was prepared for the ASOMA analysis by first removing the epoxy so only chemical in the wood was measured. The effect of resin content on the ASOMA results was considered to be negligible. Samples halves containing only one species were analyzed by cutting a single strip back from the diagonal side. This strip was cut into smaller pieces which were ground using a Wiley mill to pass a 20 mesh screen. Three strips were cut from samples containing more than one wood species. These strips were then split at the glue-line to separate the veneers by species. Several strips were necessary to obtain sufficient material of each veneer species (1 g of ground wood) for ASOMA analysis. The separated veneers were ground using a Wiley mill to pass a 20 mesh screen. Wood densities (at 4% MC) of Douglas-fir (500 kg/m^3), western hemlock (458 kg/m^3), true-fir (407 kg/m^3), western larch (540 kg/m^3), and redwood (416 kg/m^3) were used to obtain retention in kilograms of preservative per volume of wood (kg/m^3) (USDA, 1988).

The gross preservative retention data, ASOMA retention data, and penetration data for each sample were analyzed using SAS for microcomputers (SAS Institute, 1987). Statistical analysis subjected the data to an analysis of variance (ANOVA) for a completely randomized design, and Fischer's Protected Least Significant Difference Multiple Comparison t-test (alpha=0.05). Comparisons were made on the means of the panels collected from each mill for gross retention, ASOMA retention, and the penetration. Transformation of the penetration data used an arc sine square root transformation since proportional data usually does not follow the normal distribution curve required for ANOVA (Little and Hills, 1978).

Comparisons of preservative penetration distribution through the samples between veneer positions of outer, inner, and core veneers were performed. Veneer positions were assigned as follows: Five ply panels, veneers 1 and 5 (face and back veneers) were assigned to the outer position, veneers 2 and 4 the inner position and veneer 3 the core. For four ply panels, veneers were 1 and 4 assigned the outer position and veneers 2 and 3 inner position. Means were taken at each position for each geographic region for comparisons of preservative penetration.

Veneers in the panels were grouped by species for comparison of preservative penetration and ASOMA retention within one geographic region and between regions. The effect of species and position on penetration was compared between and within each geographic region.

RESULTS AND DISCUSSION

Plywood treated with CCA or ACZA showed significant differences in retention and penetration between the two preservatives ($p<=0.0001$) (Table II.2). The ACZA treatment produced higher means in Oregon, Washington, Idaho, and Montana. The differences between CCA and ACZA were greatest in Idaho and Montana, indicating that plywood with lowest CCA retention and penetration experienced the greatest improvement when treated with ACZA. It appears the treatment cycle used for ACZA, which involved heating under pressure and an ammonia based solution which swelled the pit openings in the wood improved movement of ACZA especially in the difficult to treat species.

As with treatment differences, retention values measured by x-ray fluorescence (ASOMA) were consistently higher than gross absorption measurements of both CCA and ACZA. In addition, the variability in retention means measured by ASOMA was smaller than that measured by gross absorption. As a result, statistical tests produced different results.

Gross absorption probably under-estimated retentions because it assumes no depletion of preservative elements from the solution into the wood. The difference between the two measurements suggested that at least some selective chemical absorption into the plywood occurred during the treatment cycles.

Effect of Geographic Source on Plywood Treatability

Plywood treatability differences were found between panels collected from different regions in the Pacific Northwest (Table II.2). Mean CCA retentions of plywood from Washington, Oregon, and Idaho were significantly higher than those from Montana ($p<=0.0001$) (Figure II.2), but no region achieved the required retention of 9.6 kg/m^3 (AWPA 1989). Plywood from Washington, Oregon, or Idaho treated with ACZA had significantly higher mean gross retention values than panels from Montana ($p<=0.0001$) (Figure II.2), while mean retentions measured by ASOMA showed no significant differences between regions ($p>=0.05$). Acceptable retentions were achieved in ACZA treated plywood from all regions when measured by ASOMA, but only in plywood from Washington, Oregon, and Idaho when measured by gross absorption.

CCA or ACZA preservative penetration in plywood from Washington, Oregon, and Idaho differed significantly from Montana ($P<=0.0001$)(Table II.3). Penetration of CCA in plywood from Oregon was significantly higher than that found in panels from Washington, Idaho, or Montana (Figure II.3), while ACZA treated plywood from Idaho had penetration values which were significantly higher than the other regions.

One reason for differences between regions might be that veneer position in a panel affected treatability and distribution of preservative through the panel. CCA penetration in outer veneers in plywood from Washington, Oregon, and Idaho was significantly higher than inner and core veneers ($P<=0.0001$ (Figure II.4). ACZA penetration showed significant differences between outer, inner, and core veneer positions ($P<=0.0001$)(Figure II.4). ACZA penetration was greatest in outer veneers, and preservative penetration fell off sharply in the inner and core positions. This decline may reflect the greater effects of heat and ammonia near the surface.

Plywood from Idaho treated with CCA showed higher penetration measurements in inner veneers, but these penetration values were not significantly different from those in the outer veneers ($P>=0.05$). These results indicated that position did not influence penetration in plywood from Idaho, although species composition may have influenced treatability.

Plywood from Idaho showed similar treatability patterns to plywood from Washington and Oregon. Miller and Graham (1963) found that Douglas-fir heartwood lumber from Idaho was very difficult to treat compared to similar material from western Oregon and Washington. In the present study, plywood obtained from Idaho contained a mixture of Douglas-fir, western hemlock, true-fir, and western larch. Previous studies have indicated that there is wide range in treatability between these species, and that western hemlock and true-firs are more treatable than Douglas-fir (Graham 1956; Blew et al. 1967). The results in the current study suggest that plywood composed of a mixture of species can achieve higher preservative retention and penetration than would be expected for panels containing only one species.

In summary, gross absorption retention, ASOMA retention, and preservative penetration of CCA or ACZA treated plywood followed the same general trends for the four geographic regions (Figure II.5). Plywood from Oregon was most treatable with CCA followed by Idaho, Washington, and Montana. Plywood from Idaho was the most treatable with ACZA.

While previous studies found that geographic region was a reliable basis for determining treatability of lumber (Miller and Graham, 1963; Copper, 1977) the present study suggests that geographic source is not a sufficient indicator of plywood treatability. It is, however, useful to examine treatability of panels by region.

A. Washington: Mills in Washington were grouped into two areas: Puget Sound and Columbia River. In general, CCA treated plywood from mills in the Puget Sound area was associated with high retention and penetration measurements (Figure II.6). Improved treatability may reflect log sources from low elevation Olympic and Cascade Mountain sites. Previous studies on the effect of geographic distribution on treatability suggest that increasing elevation may adversely affect treatability (Graham and Miller, 1963; Cooper, 1977).

Plywood from mills in the Columbia River area had adequate retention, but poor penetration (Figure II.6). This pattern of high preservative retention and poor penetration (preservative loading) has been noted in other treating studies (Fahlstrom, 1982). High preservative loadings in the more permeable veneers may reflect species differences or the percent of sapwood; however, penetration only measures the presence of copper and could not quantify the levels of preservative present.

ACZA gross retentions in plywood from mill locations in Washington were not significantly different from each other (P>=0.05) (Table II.3), indicating that the ACZA treatment was not affected by plywood panel source (Figure II.7).

In both preservative treatments, the one mill located along the Olympic Peninsula had low retention and penetration measurements. The poor treatability and mill location suggests that the logs for these panels were obtained from high elevation sites in the Olympics.

B. Oregon: Oregon mills were grouped in three areas: The Pacific Coast, Willamette Valley, and southwest Oregon. ACZA gross and ASOMA retention of plywood from these mills did not differ significantly from each other (P>=0.05) (Table II.3). Plywood from mills in the Pacific Coast area generally had high retention and penetration values with both preservatives (Figures II.8, II.9), with the exception on one mill on the southern coast. Miller (1961) consistently found permeable Douglas-fir heartwood lumber from locations on the Pacific Coast. Mills along the coast generally obtain logs from the westside of the Coast Range, which helps explain the high preservative retention and penetration measurements. However, mills may buy veneers from sources some distance away. As a result mill location is not always a reliable indication of treatability. This factor might explain the poor treatability of the mill in the southern part of the Pacific Coast area.

Mean retention and penetration measurements from mills located in the Willamette Valley were very diverse (Figures II.8, II.9). Variability in retention and penetration between mill locations probably reflects variability in log source. Mills in this area may obtain logs from the Coast Range or Cascades at a variety of elevations. While log source should be considered as a factor in panels destined for preservative treatment, it is unlikely that mills could afford to sort logs to this degree.

In general, higher retention and penetrations values were found in plywood from mills located in southwest Oregon then in other areas in Oregon (Figures II.8, II.9). The lowest retention and penetration values for plywood in southern Oregon were found in plywood composed of redwood, true-fir, and Douglas-fir. As in the Willamette Valley, treatability varied among mills possibly reflecting log source. Possible log sources for these mills include the Cascades, the Siskiyous, and the eastside of the Coast Range. Mills closest to the Cascades probably buy logs from both high and low elevation sites in the Cascades, producing high variability in treatability. Mills located between the Cascades and the Coast Range probably buy most of their logs from low elevations in the Cascades or the Coast Range. Plywood from these mills had higher, more uniform mean retentions and penetrations.

C. Idaho and Montana: Treatability of plywood from mill locations within Idaho or Montana with CCA or ACZA, as measured by retention and penetration, were not significantly different from each other ($P>=0.05$) (Table II.3). Treatment of panels from these regions was uniform and specific location was not necessarily an accurate predictor of treatability.

Effect of Species on Plywood Treatability

In general, preservative penetration decreased from outer to inner veneers in most species (Figures II.10, II.11); however, reverse gradients were present in Douglas-fir and western hemlock from Idaho, and western hemlock from Washington when treated with CCA (Figure II.10). These exceptions may reflect the presence of more easily treated sapwood.

Most species were not randomly distributed within a panel making it difficult to accurately assess the effects of species and veneer location. These factors prevented statistical analysis of species effects. Instead, the relative differences between species from the different regions will be discussed.

A. Douglas-fir: In general, there was little variation in retention and penetration of Douglas-fir veneers from Washington, Oregon, or Idaho when panels were treated with CCA or ACZA (Figures II.12, II.13), with the exception of high ACZA penetration values found in Douglas-fir veneers from Idaho (Figure II.13). Douglas-fir from Montana had low retention and penetration measurements compared to the other regions.

Previous studies on the treatability of Douglas-fir from different geographic regions established the differences in treatability between coastal and interior locations (Blew et al. 1967; Miller and Graham 1963). These studies found that coastal Douglas-fir was more treatable than interior, while the present study failed to detect these differences. Douglas-fir from Idaho had similar treatability to material from Washington and Oregon. This discrepancy may reflect the small sample size (n=38) of Douglas-fir veneers from Idaho as well as the benefits of lathe checks or glue-lines. Veneer position of Douglas-fir veneers in panels from Idaho (11=inner veneer, 27=outer veneers) and the presence of sapwood content might have also affected treatability. Douglas-fir was represented evenly in all veneer positions in panels from Washington and Oregon, permitting more accurate comparisons.

B. Western hemlock: Western hemlock veneers were only present in plywood from Washington, Oregon, and Idaho. ACZA or CCA treated plywood containing western hemlock veneers showed similar retention or penetration measurements between regions (Figures II.12, II.13). ACZA penetration of western hemlock veneers was nearly twice as great as that found with CCA, while differences between the two treatments was not as large for retention.

Western hemlock has been found to be more easily treatable than other western wood species (Graham 1954, 1956; Blew et al., 1967). In the present study, CCA treated plywood containing western hemlock veneers within Washington, Oregon, and Idaho had the lowest retention and penetration measurements of the species present. (Figures II.14, II.15). The differences between previous results and those in the present study may reflect small sample size of western hemlock veneers (n=14), or the absence of western hemlock veneers in the outer veneer where penetrations were highest.

C. Western larch: Idaho and Montana were the only regions with plywood containing western larch veneers. CCA and ACZA retentions and penetrations were higher in western larch from Idaho (Figures II.12, II.13).

Western larch primarily grows in the Inter-mountain region between the Oregon Cascade Mountain Range and the Rocky Mountains, making treatability comparisons between coastal and interior regions unnecessary. The results suggest that western larch from intermountain locations can be treated to retentions and penetrations similar to those in other species from the western areas of Washington and Oregon, especially with ACZA.

D. True-firs: True-fir veneers were present in plywood from Washington, Oregon, and Idaho. In both treatments, the variation in retention and penetration of true-fir veneers between regions was small (Figures II.12, II.13). ACZA treatment of panels from Washington and Oregon produced slightly higher retentions, while ACZA retentions in panels from Idaho were lower than those found with CCA. Similar to western hemlock, true-fir veneers were better and more evenly treated with ACZA (Figure II.13).

True-fir veneers had lower CCA and ACZA retentions than those found in Douglas-fir, but penetration measurements were equal or better than those in Douglas-fir (Figures II.14, II.15). Previous treatability studies have shown that true-firs treat better than interior Douglas-fir (Graham 1954, 1956; Blew et al. 1967); however, Douglas-fir veneers from Idaho in the present study were treated to higher mean retentions than true-fir veneers. This variation may reflect small sample sizes, rather than real treatability differences.

In summary, the results suggest that plywood species composition plays a major role in plywood treatability. Treatability between species from Washington, Oregon and Idaho exhibited little overall difference, but species from Montana were more difficult to treat. Since the plywood was not randomly selected from locations within each region, unequal sample numbers of each species may have affected the results. In addition, variables such as sapwood content and sample size could influence results, and might explain differences between this study on plywood and previous lumber studies.

CONCLUSION

Throughout the study, preservative treatment with ACZA provided higher retentions and better penetration in plywood than CCA. In general, outer veneers were penetrated to a higher degree than inner and core veneers. CCA and ACZA treated plywood from Oregon, Washington, and Idaho were similar in treatability and were consistently better treated than plywood from Montana.

The results indicated that differences in plywood treatability between geographic regions differed from those found in previous lumber studies. Other considerations such as species composition, veneer distribution and minor variations in log source may have influenced these results.

In Washington, plywood from the low elevation Puget Sound area was generally more treatable than plywood from other areas in the state. In Oregon, plywood from southwest Oregon was generally more treatable than material along the coast and Willamette Valley. Plywood from mills in the Willamette Valley showed a wide diversity in treatability, suggesting a range of log sources from low elevation Coast Range to high elevation Cascades. For these plywood mills, specific log source should be considered when purchasing material which will be treated; however, it is doubtful that mills could afford to sort logs to the degree necessary.

The results illustrate the variability of panel treatability among the potential sources. While some of this variation can be minimized by the use of ACZA; the results indicate that panels from Montana pose the greatest treatability challenge. Variations in treatability of panels from the other three regions reflect species composition and log source, making it difficult to reliably source treatable material. Reliable sourcing of panels must then depend upon treatment trials and previous experiences with panel manufactures. While this appears tedious, many treatment plants already operate in this fashion for dimension lumber sources.

The results suggest that more controlled studies of panels composed of single species and collected from the same mills over a period of time are necessary to determine the effects of wood species, geographic region, and veneer position on treatability. Furthermore, the effects of incomplete treatment on performance must be more fully investigated before restrictive treatment requirements are proposed.

Table II.1. Species composition of panels collected from thirty seven plywood locations in Washington, Oregon, Idaho, or Montana.

Geographic Region	Mill	Panel Number	Species Composition
Washington	A	1	DF DF H H DF
	A	2	DF DF H H DF
	A	3	DF DF H H DF
	A	4	DF DF H H DF
	B	1	DF DF DF DF DF
	B	2	DF DF DF DF DF
	B	3	DF DF DF DF DF
	B	4	DF DF DF DF DF
	D	1	DF DF DF DF DF
	D	2	DF DF DF DF DF
	D	3	DF DF DF DF DF
	D	4	DF DF DF DF DF
	F	1	DF DF DF DF DF
	F	2	DF DF DF DF DF
	F	3	DF DF DF DF DF
	F	4	DF DF DF DF DF
	K	1	DF DF DF DF DF
	K	2	DF DF DF DF DF
	K	3	DF DF DF DF DF
	K	4	DF DF DF DF DF
	P	1	DF DF DF DF DF
	P	2	DF DF DF DF DF
	P	3	DF DF DF DF DF
	P	4	DF DF DF DF DF
	O	1	DF DF DF DF DF
	O	2	DF DF DF DF DF
	O	3	DF DF DF DF DF
	O	4	DF DF DF DF DF
	R	1	TF TF TF DF
	R	2	TF TF TF DF
	R	3	DF TF TF DF
	R	4	TF TF TF DF
	S	1	TF DF DF TF
	S	2	TF DF DF DF
	S	3	TF DF TF DF
	S	4	TF DF DF DF
Oregon	C	1	DF DF DF DF
	C	2	DF DF DF DF
	C	3	DF DF DF DF
	C	4	DF DF DF DF
	E	1	DF TF DF TF
	E	2	DF TF DF TF
	E	3	DF TF DF TF

Table II.1 (continued)

Geographic Region	Mill	Panel Number	Species Composition
	E	4	DF TF DF TF
	H	1	RW TF RW RW RW
	H	2	RW DF RW DF RW
	H	3	RW WF RW WF RW
	H	4	RW DF RW WF RW
	I	1	DF TF DF TF DF
	I	2	DF TF DF TF DF
	I	3	DF TF DF TF DF
	I	4	DF TF DF TF DF
	J	1	DF DF DF DF DF
	J	2	DF DF DF DF DF
	J	3	DF DF DF DF DF
	J	4	DF DF DF DF DF
	L	1	DF DF DF DF DF
	L	2	DF DF DF DF DF
	L	3	DF DF DF DF DF
	L	4	DF DF DF DF DF
	Q	1	DF DF DF DF DF
	Q	2	DF DF DF DF DF
	Q	3	DF DF DF DF DF
	Q	4	DF DF DF DF DF
	T	1	DF DF DF DF DF
	T	2	DF DF DF DF DF
	T	3	DF DF DF DF DF
	T	4	DF DF DF DF DF
	Z	1	DF DF DF DF DF
	Z	2	DF DF DF DF DF
	Z	3	DF DF DF DF DF
	Z	4	DF DF DF DF DF
	AA	1	DF DF DF DF DF
	AA	2	DF DF DF DF DF
	AA	3	DF DF DF DF DF
	AA	4	DF DF DF DF DF
	BB	1	DF DF DF DF DF
	BB	2	DF DF DF DF DF
	BB	3	DF DF DF DF DF
	BB	4	DF DF DF DF DF
	DD	1	DF H DF H DF
	DD	2	DF H DF H DF
	DD	3	DF H DF H DF
	DD	4	DF H DF H DF
	EE	1	DF DF DF DF DF
	EE	2	DF DF DF DF DF
	EE	3	DF DF DF DF DF
	EE	4	DF DF DF DF DF

Table II.1 (continued)

Geographic Region	Mill	Panel Number	Species Composition
	GG	1	DF DF DF DF DF
	GG	2	DF DF DF DF DF
	GG	3	DF DF DF DF DF
	GG	4	DF DF DF DF DF
	HH	1	DF DF DF DF DF
	HH	2	DF DF DF DF DF
	HH	3	DF DF DF DF DF
	HH	4	DF DF DF DF DF
	II	1	DF H DF H DF
	II	2	DF H DF H DF
	II	3	DF H DF H DF
	II	4	DF H DF H DF
	JJ	1	DF DF DF DF DF
	JJ	2	DF DF DF DF DF
	JJ	3	DF DF DF DF DF
	JJ	4	DF DF DF DF DF
Idaho	G	1	L DF DF L
	G	2	L L L DF
	G	3	L L DF L
	G	4	DF TF TF L
	M	1	DF TF DF TF
	M	2	DF TF DF TF
	M	3	DF TF DF TF
	M	4	DF TF DF TF
	N	1	DF DF DF DF
	N	2	DF DF DF DF
	N	3	DF DF DF DF
	N	4	DF DF DF DF
	X	1	DF H H DF
	X	2	DF TF DF TF
	X	3	DF TF DF TF
	X	4	DF TF DF TF
Montana	U	1	L L L L
	U	2	L L L L
	U	3	L L L L
	U	4	L L L L
	V	1	DF DF DF DF
	V	2	DF DF DF DF
	V	3	DF DF DF DF
	V	4	DF DF DF DF
	Y	1	L DF DF DF L
	Y	2	L L L DF L
	Y	3	L L L DF L
	Y	4	L L DF L L
	FF	1	L DF L L L

Table II.1 (continued)

Geographic Region	Mill	Panel Number	Species Composition
	FF	2	L L L L L
	FF	3	L L DF L DF
	FF	4	L DF L DF DF
	CC	1	DF DF DF DF
	CC	2	DF DF DF L
	CC	3	DF DF DF DF
	CC	4	DF DF DF DF

Table II.2. Mean gross retention, ASOMA retention, and preservative penetration (as copper) of plywood panels from four geographic regions treated with chromated copper arsenate (CCA) or ammoniacal copper zinc arsenate (ACZA). Values in parentheses represent two standard errors.

Treatment	Geographic Region	Gross Retention (kg/m^3)	ASOMA (kg/m^3)	Penetration (%)
CCA	Washington	7.80(0.40)	6.76(0.48)	57.03(4.32)
CCA	Oregon	8.17(0.32)	9.16(0.36)	64.23(3.44)
CCA	Idaho	8.00(0.30)	8.88(0.46)	56.45(5.06)
CCA	Montana	5.55(0.46)	6.72(0.70)	37.10(6.02)
ACZA	Washington	9.86(0.18)	10.41(0.36)	71.63(3.96)
ACZA	Oregon	9.98(0.14)	10.54(0.26)	69.97(3.24)
ACZA	Idaho	9.60(0.24)	10.64(0.34)	84.80(4.74)
ACZA	Montana	8.74(0.32)	10.27(0.40)	60.15(4.72)

Table II.3. Mean gross retention, ASOMA retention, and preservative penetration (as copper) of panels from mills located in Washington, Oregon, Idaho, or Montana treated with CCA or ACZA. Values in parentheses represent one standard error.

Table II.3

Geographic Region	Mill	CCA			ACZA		
		Gross Retention (kg/m^3)	ASOMA Retention (kg/m^3)	Penetration (%)	Gross Retention (kg/m^3)	ASOMA Retention (kg/m^3)	Penetration (%)
Washington	A	6.93(0.90)	8.33(1.01)	50.03(8.24)	9.98(0.25)	11.80(0.25)	80.50(3.53)
	B	6.06(0.63)	6.23(0.63)	43.54(8.02)	9.38(0.54)	9.04(0.15)	49.06(4.25)
	D	8.93(0.21)	9.54(0.27)	63.48(2.50)	10.25(0.16)	11.46(0.09)	71.19(3.08)
	F	7.46(0.60)	8.72(0.82)	57.44(5.68)	9.63(0.10)	10.73(0.10)	65.56(3.49)
	I	8.87(0.24)	9.57(0.11)	71.23(4.83)	10.29(0.05)	10.29(0.05)	68.85(3.72)
	M	7.78(0.40)	9.55(0.30)	49.86(7.59)	9.60(0.32)	10.85(0.10)	70.55(3.89)
	N	7.86(0.31)	8.72(0.42)	57.25(3.63)	9.68(0.34)	10.06(0.11)	68.46(3.90)
	P	6.84(0.47)	7.69(0.31)	47.58(3.54)	9.78(0.13)	9.04(0.41)	87.94(2.95)
	Q	9.18(0.13)	9.96(0.40)	72.81(2.75)	10.53(0.09)	10.29(0.16)	78.36(4.55)
	JJ	8.12(0.41)	9.26(0.86)	54.11(3.66)	9.93(0.23)	10.55(0.20)	75.85(7.38)
Oregon	C	8.26(0.28)	8.95(0.40)	60.47(5.59)	10.18(0.24)	10.66(0.20)	73.11(2.53)
	E	8.91(0.24)	10.02(0.42)	78.84(3.13)	10.13(0.19)	10.66(0.20)	77.97(4.63)
	CC	5.46(0.55)	6.56(0.63)	48.14(4.55)	9.76(0.29)	9.85(0.27)	52.85(2.52)
	G	8.13(0.15)	9.24(0.12)	63.63(3.94)	9.57(0.05)	10.62(0.33)	85.91(2.97)
	H	8.88(0.29)	10.30(0.55)	74.55(5.29)	9.75(0.14)	10.39(0.12)	60.10(4.63)
	J	9.17(0.77)	10.27(1.05)	66.39(6.72)	10.01(0.07)	10.69(0.07)	82.85(7.11)
	O	7.67(0.21)	8.39(0.30)	58.89(4.39)	10.10(0.12)	10.38(0.11)	64.33(2.63)
	R	7.14(0.19)	7.78(0.42)	48.43(3.51)	10.10(0.04)	10.40(0.15)	60.35(5.96)
	U	7.73(0.50)	8.53(0.32)	59.97(3.95)	10.18(0.31)	10.56(0.10)	64.61(7.10)
	X	8.79(0.19)	10.32(0.22)	73.44(7.11)	10.10(0.13)	10.25(0.13)	75.69(5.33)
	Y	8.89(0.33)	11.14(0.38)	75.51(7.43)	10.41(0.06)	11.71(0.07)	76.00(3.62)
	Z	6.22(0.54)	7.26(0.81)	45.14(7.38)	8.96(1.02)	9.52(0.22)	55.91(5.63)
	BB	8.87(0.29)	9.33(0.28)	60.88(4.25)	10.26(0.06)	10.82(0.19)	83.19(6.60)
	DD	9.81(0.24)	9.99(0.32)	77.44(6.61)	10.12(0.18)	11.17(0.08)	84.79(3.88)
	FF	8.05(0.53)	8.65(0.45)	65.95(6.58)	10.09(0.18)	10.37(0.09)	62.13(4.67)
	GG	8.67(0.68)	9.15(0.62)	63.89(8.45)	10.14(0.07)	10.36(0.11)	77.29(5.54)
	HH	9.17(0.14)	11.21(0.37)	74.69(6.56)	10.49(0.12)	11.81(0.12)	70.81(2.86)
	II	7.17(0.77)	7.88(0.75)	59.98(8.86)	9.33(0.49)	9.57(0.17)	51.75(2.74)
Idaho	KK	7.82(0.13)	8.84(0.65)	58.05(4.90)	9.20(0.37)	10.90(0.30)	77.94(3.20)
	K	8.36(0.15)	8.98(0.31)	60.08(3.52)	9.82(0.16)	10.05(0.42)	88.59(1.21)
	L	7.66(0.47)	8.55(0.61)	51.28(6.91)	9.55(0.16)	10.69(0.08)	82.18(7.94)
	V	8.19(0.31)	9.19(0.37)	56.41(5.48)	9.85(0.12)	10.92(0.51)	90.47(2.00)
Montana	S	5.78(0.50)	6.90(0.68)	42.16(4.14)	8.26(0.40)	9.96(0.13)	56.25(6.04)
	T	4.95(0.68)	5.59(0.64)	24.28(4.87)	8.63(0.33)	10.38(0.09)	56.94(6.74)
	W	6.43(0.70)	8.14(0.94)	43.40(8.81)	9.12(0.35)	10.75(0.23)	63.60(3.02)
	AA	5.28(0.71)	6.28(0.80)	31.30(4.48)	9.12(0.12)	10.36(0.16)	63.00(4.51)
	EE	5.30(0.54)	6.68(0.60)	44.35(6.60)	8.59(0.44)	9.92(0.16)	60.94(7.15)

Figure II.1. Mill locations from which plywood panels were collected. Mill locations were divided into four geographic regions: Washington, Oregon, Idaho (including northeastern Washington and northeastern Oregon), and Montana.

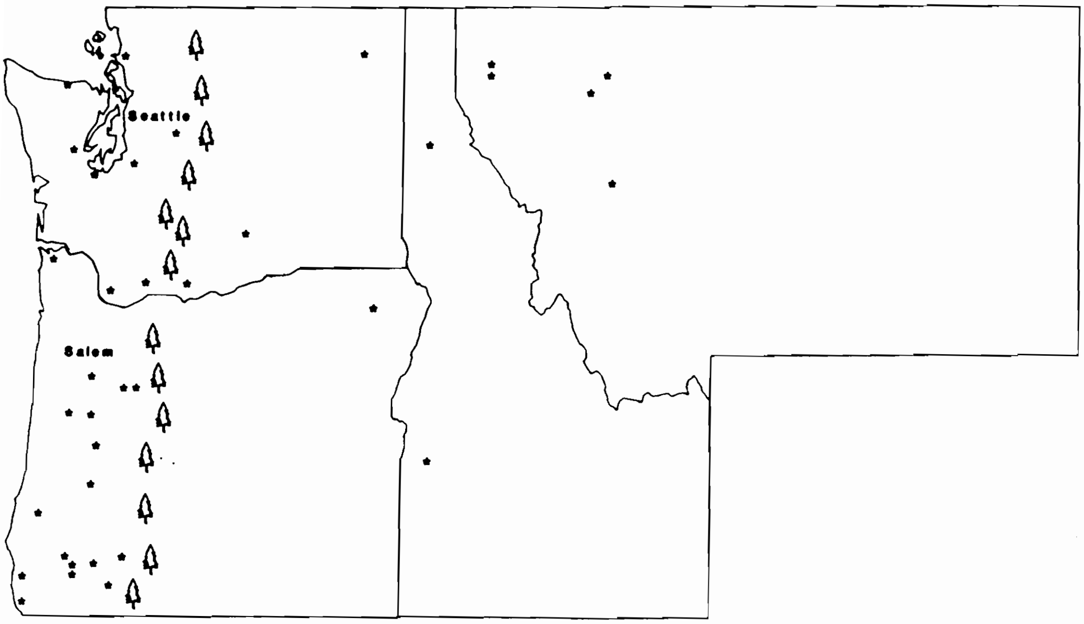


Figure II.1

Figure II.2. Mean gross or ASOMA retention of panels collected from Washington, Oregon, Idaho, or Montana treated with CCA (A), or ACZA (B).

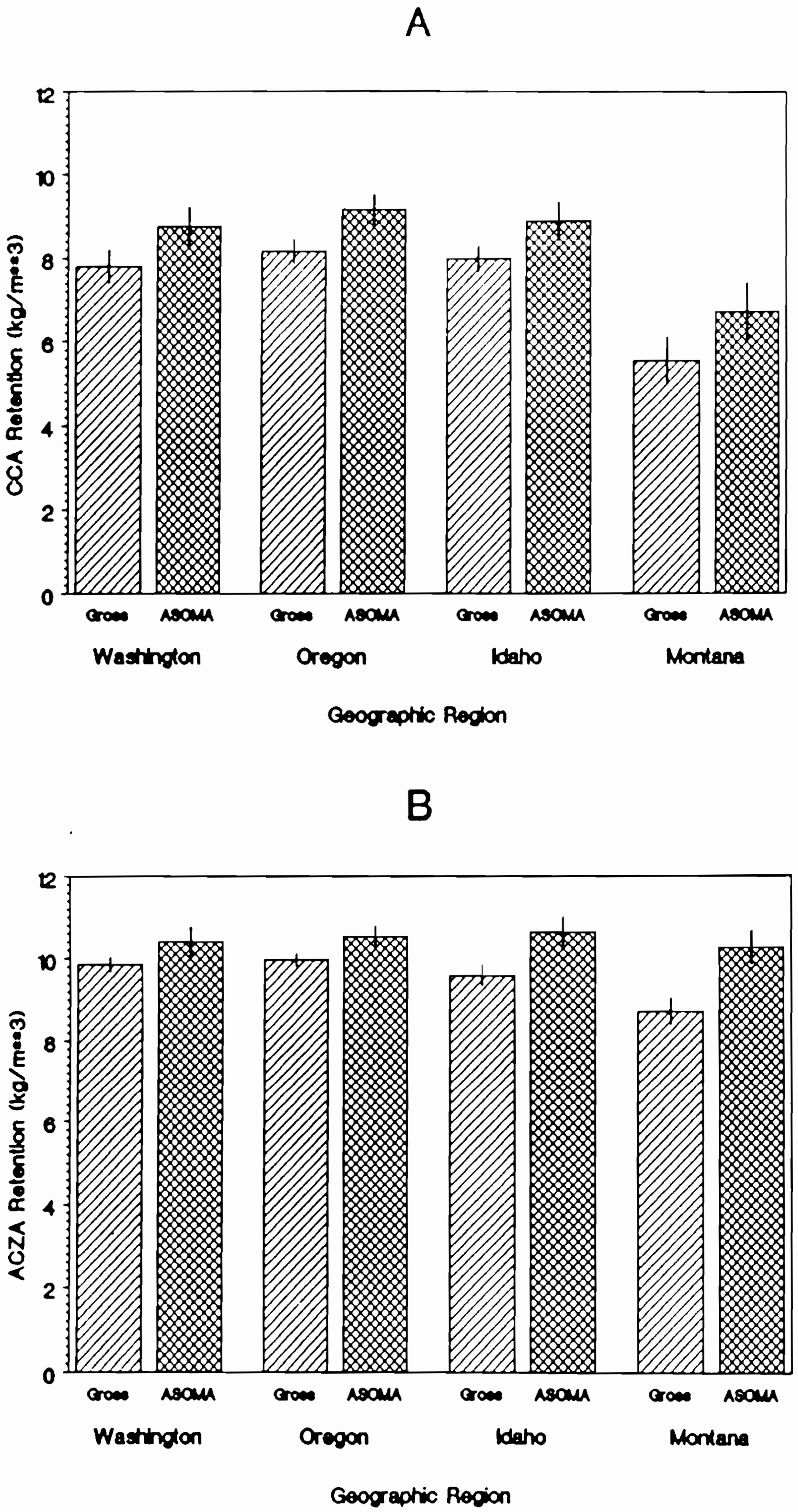

A
12
10
8
6
4
2
0
CCA Retention (kg/m**3)
Gross
ASOMA
Gross
ASOMA
Gross
ASOMA
Gross
ASOMA
Washington
Oregon
Idaho
Montana
Geographic Region
B
12
10
8
6
4
2
0
ACZA Retention (kg/m**3)
Gross
ASOMA
Gross
ASOMA
Gross
ASOMA
Gross
ASOMA
Washington
Oregon
Idaho
Montana
Geographic Region

Figure II.2

Figure II.3. Mean preservative penetration (as copper), measured using a copper indicator, in relation to veneer position in panels obtained from Washington, Oregon, or Montana and treated with CCA (A) or ACZA (B).

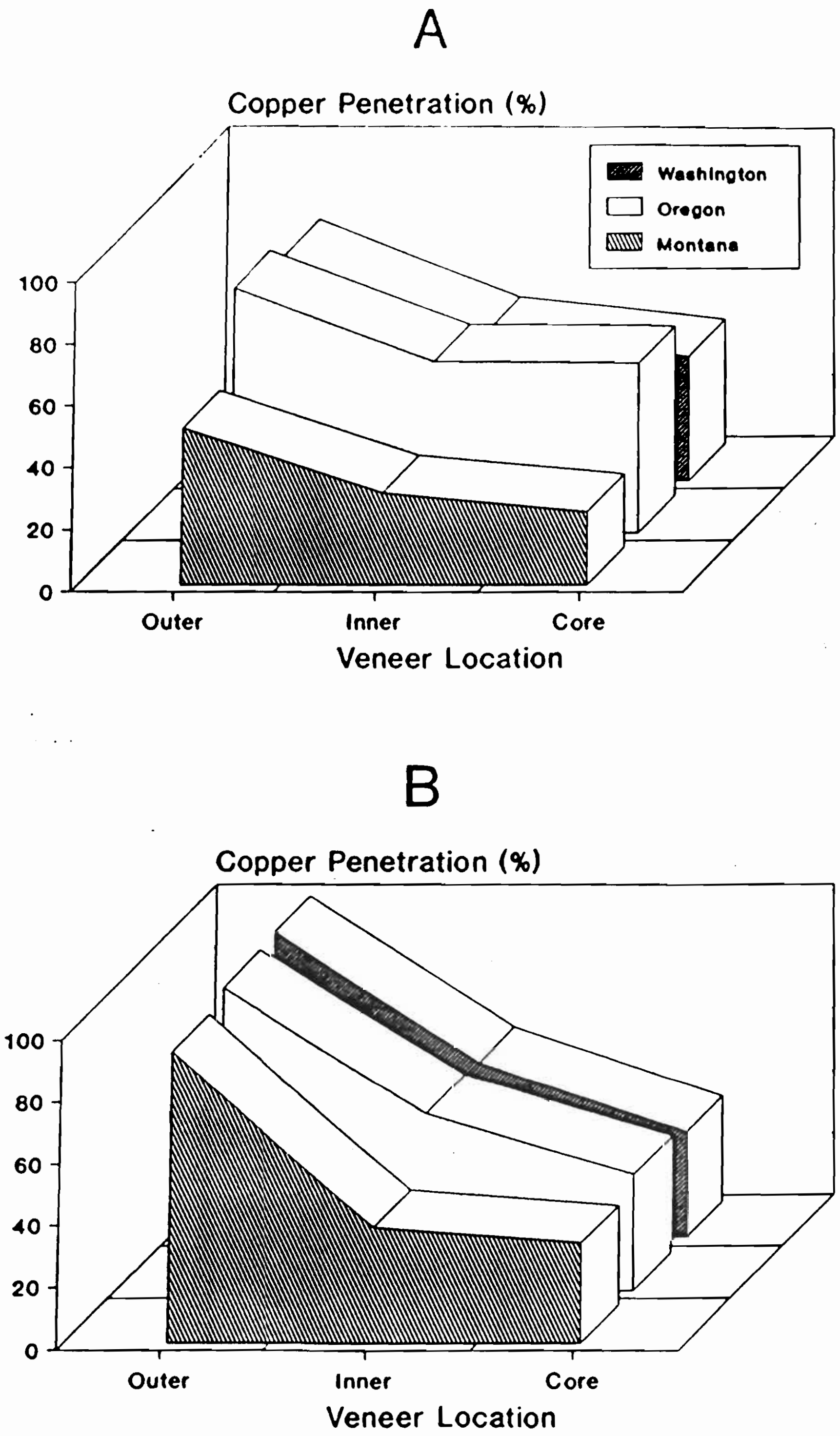

A
Copper Penetration (%)
Washington
Oregon
Montana
100
80
60
40
20
0
Outer
Inner
Core
Veneer Location
B
Copper Penetration (%)
100
80
60
40
20
0
Outer
Inner
Core
Veneer Location

Figure II.3

Figure II.4. Mean preservative penetration as measured using a copper indicator, of panels collected from Washington, Oregon, Idaho, or Montana, and following treatment with CCA or ACZA.

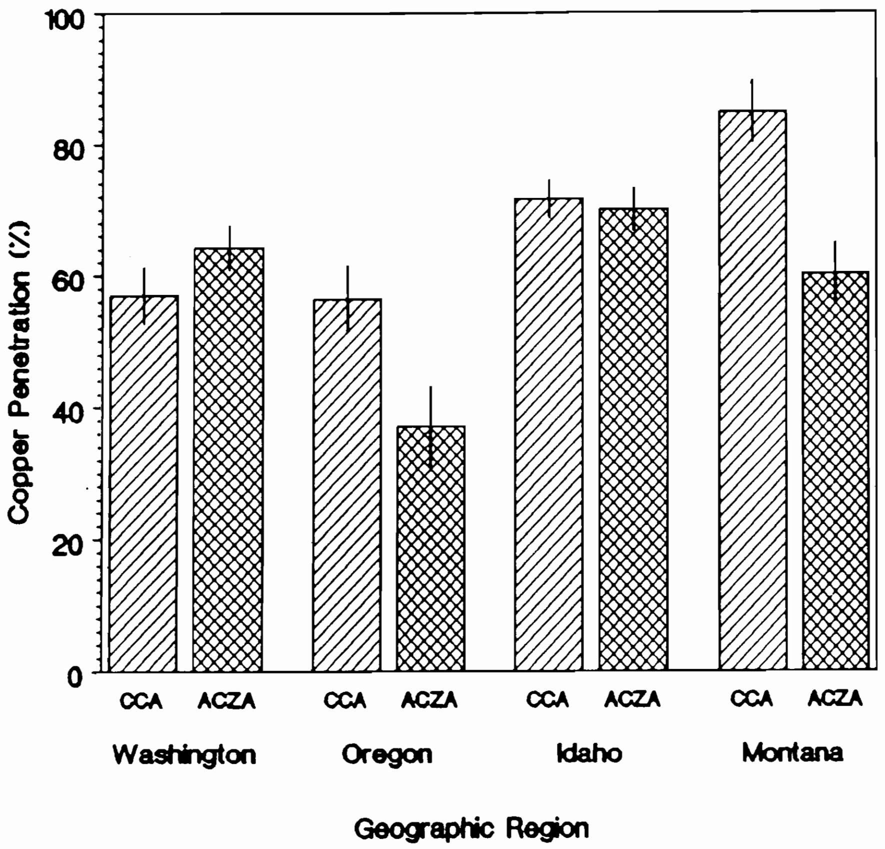

100
80
60
40
20
0
Copper Penetration (%)
CCA
ACZA
CCA
ACZA
CCA
ACZA
CCA
ACZA
Washington
Oregon
Idaho
Montana
Geographic Region

Figure II.4

Figure II.5. Mean preservative penetration (as copper), gross retention and ASOMA retention of panels from Washington, Oregon, Idaho, or Montana following treatment with CCA (A) or ACZA (B). Bar graph represents copper penetration, while the two lines represent gross and ASOMA retention.

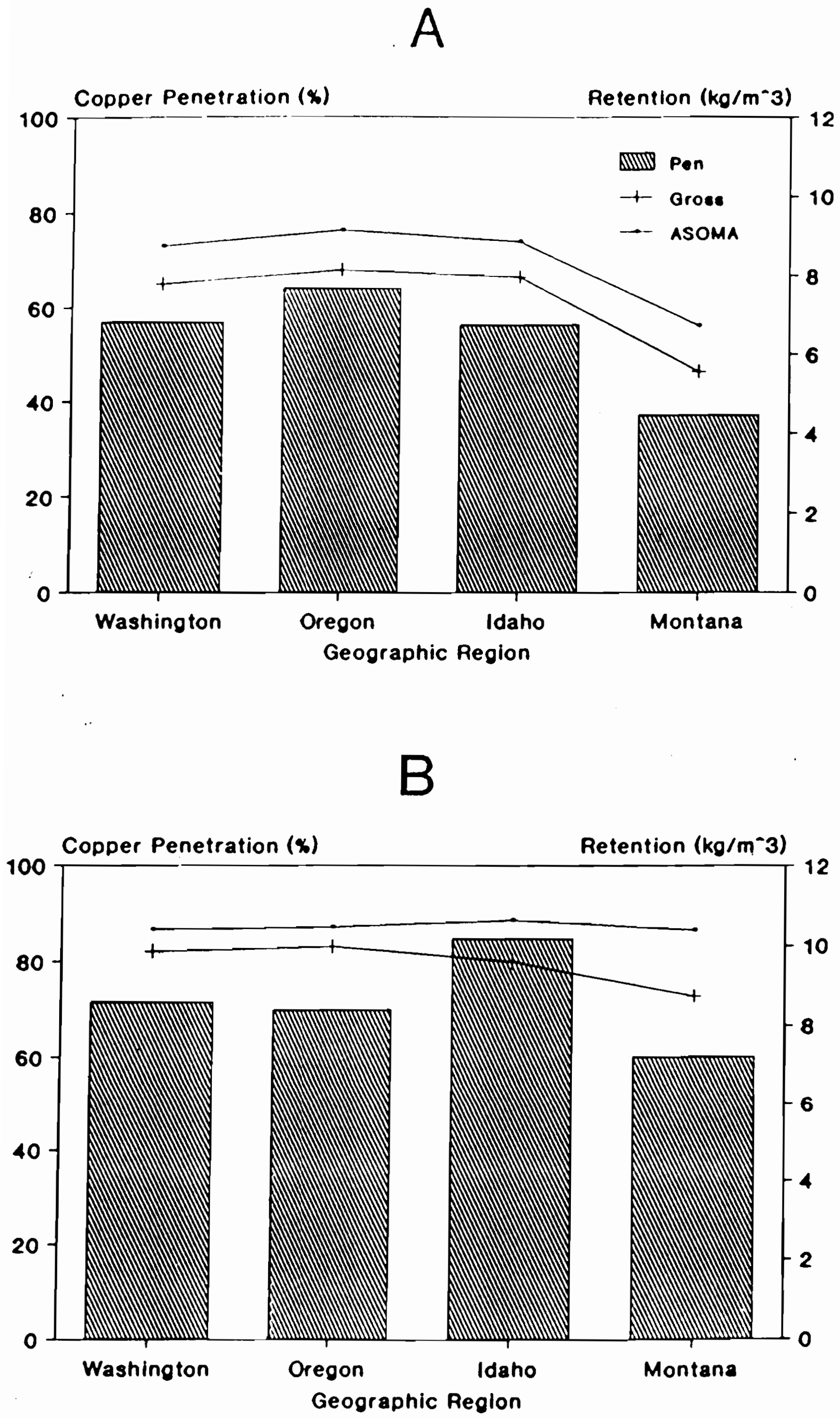

A
Copper Penetration (%)
Retention (kg/m^3)
100
80
60
40
20
0
12
10
8
6
4
2
0
Pen
Gross
ASOMA
Washington
Oregon
Idaho
Montana
Geographic Region
B
Copper Penetration (%)
Retention (kg/m^3)
100
80
60
40
20
0
12
10
8
6
4
2
0
Washington
Oregon
Idaho
Montana
Geographic Region

Figure II.5

Figure II.6. Comparisons between mills in Washington of A) CCA gross retention, B) CCA ASOMA retention, or C) CCA penetration as determined using Fischer's Protected Least Significant Difference test at a significance level of alpha=0.05. Mill locations with same group letters are not significantly different. A=high, values D=low values.

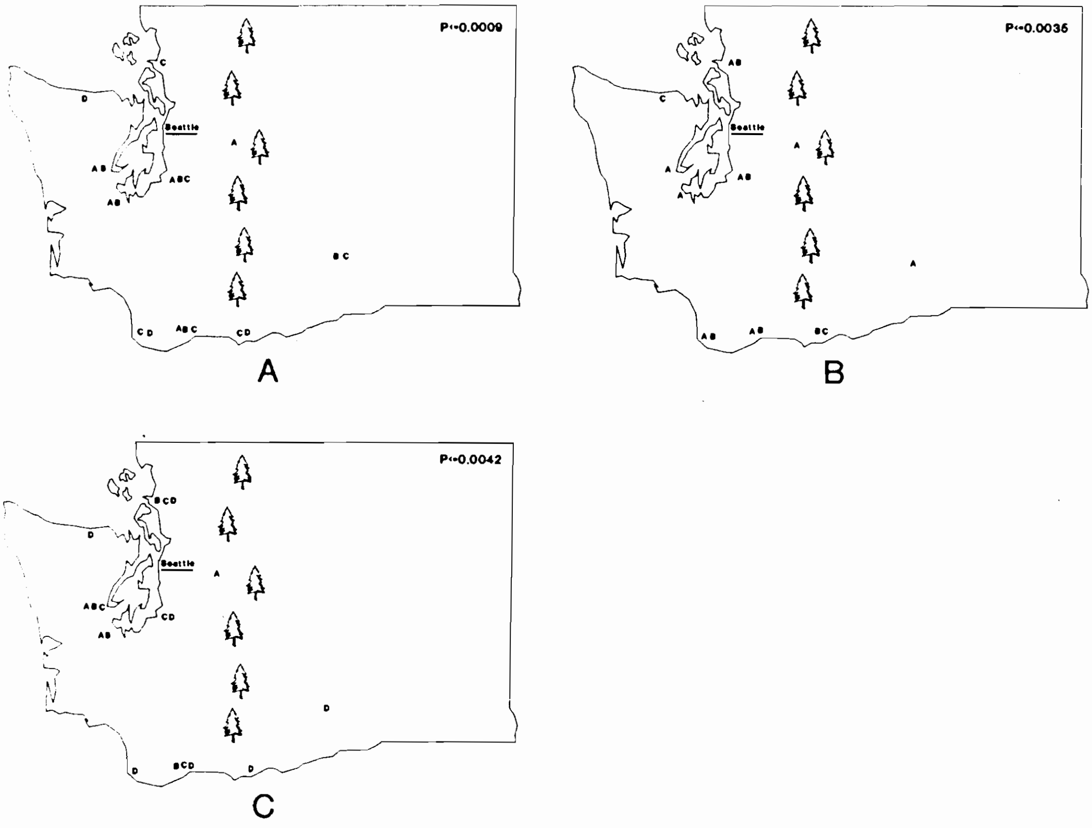

P<=0.0009
C
D
Seattle
A
AB
ABC
AB
BC
CD
ABC
CD
A
P<=0.0036
AB
C
Seattle
A
A
AB
A
A
AB
AB
BC
B
P<=0.0042
BCD
D
Seattle
A
ABC
CD
AB
D
D
BCD
D
C

Figure II.6

Figure II.7. Comparisons between mills in Washington of A) ACZA ASOMA retention, or B) ACZA penetration as determined using Fischer's Protected Least Significant Difference test at a significance level of alpha=0.05. Mill locations with same group letters are not significantly different. A=high values, D=low values.

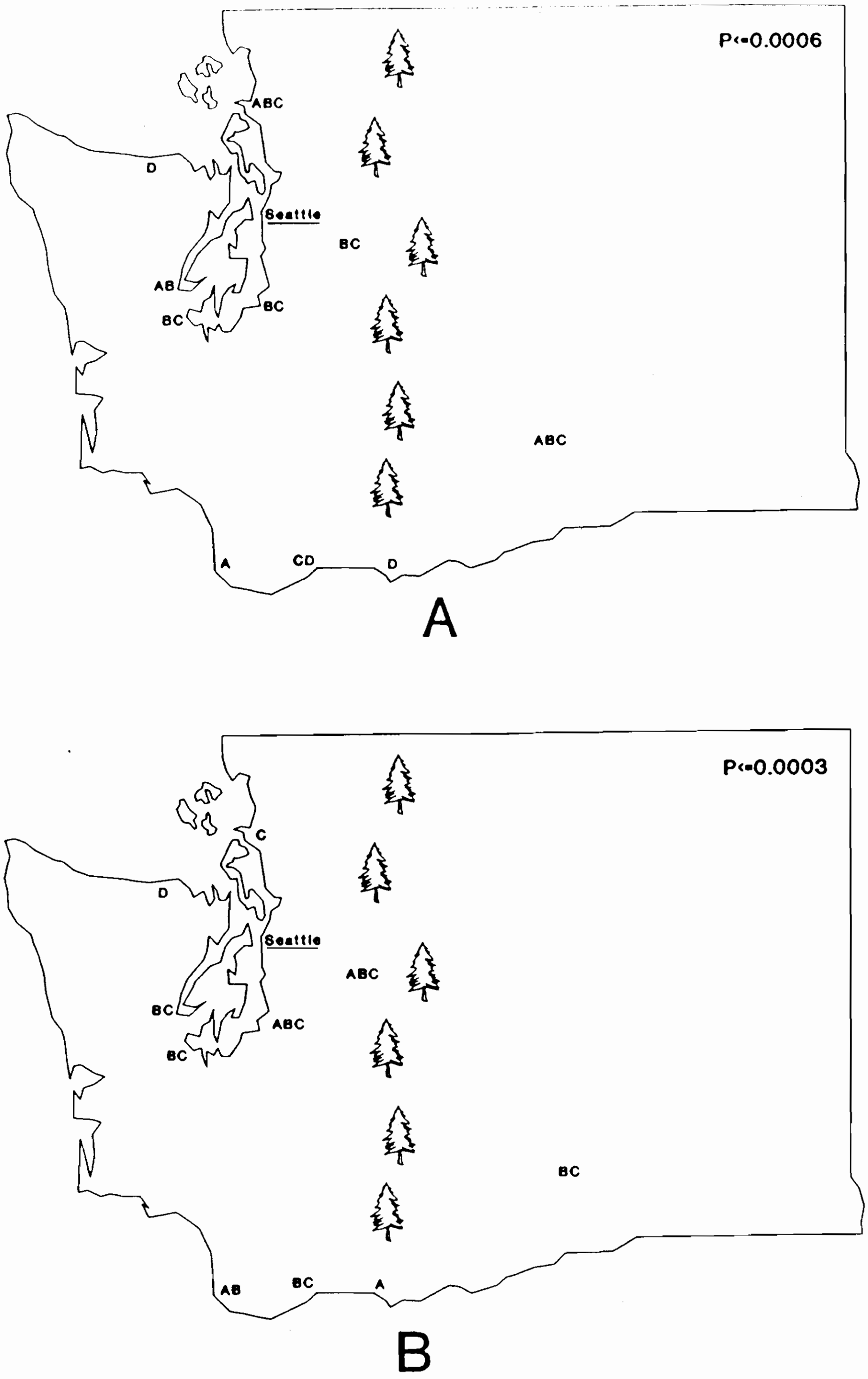

P<=0.0006
ABC
D
Seattle
BC
AB
BC
BC
ABC
A
CD
D
A
P<=0.0003
C
D
Seattle
ABC
BC
ABC
BC
BC
AB
BC
A
B

Figure II.7

Figure II.8. Comparisons between mills in Oregon of A) CCA gross retention, B) CCA ASOMA retention, or C) CCA penetration as determined using Fischer's Protected Least Significant Difference test at a significance level of alpha=0.05. Mill locations with same group letters are not significantly different. A=high values, H=low values.

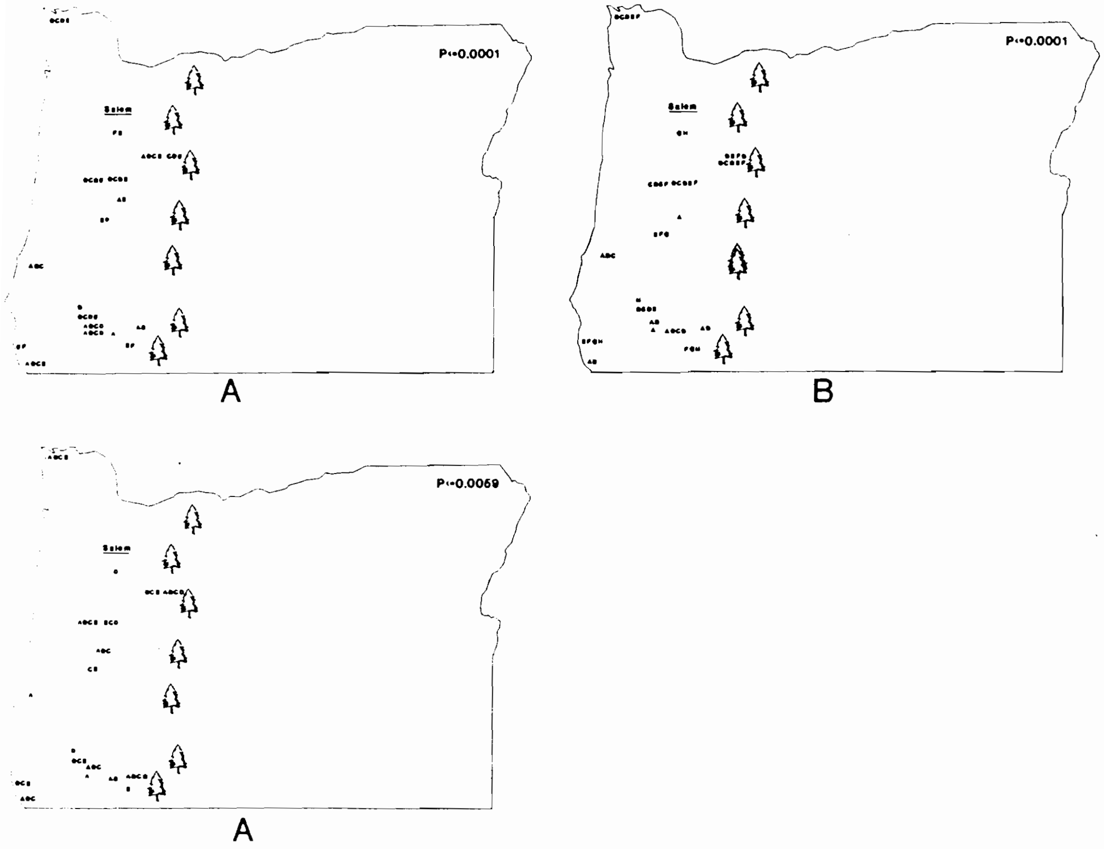

A B A

Figure II.8

Figure II.9. Comparisons between mills in Oregon of ACZA penetration as determined using Fischer's Protected Least Significant Difference test at a significance level of alpha=0.05. Mill locations with same group letters are not significantly different. A=high values, G=low values.

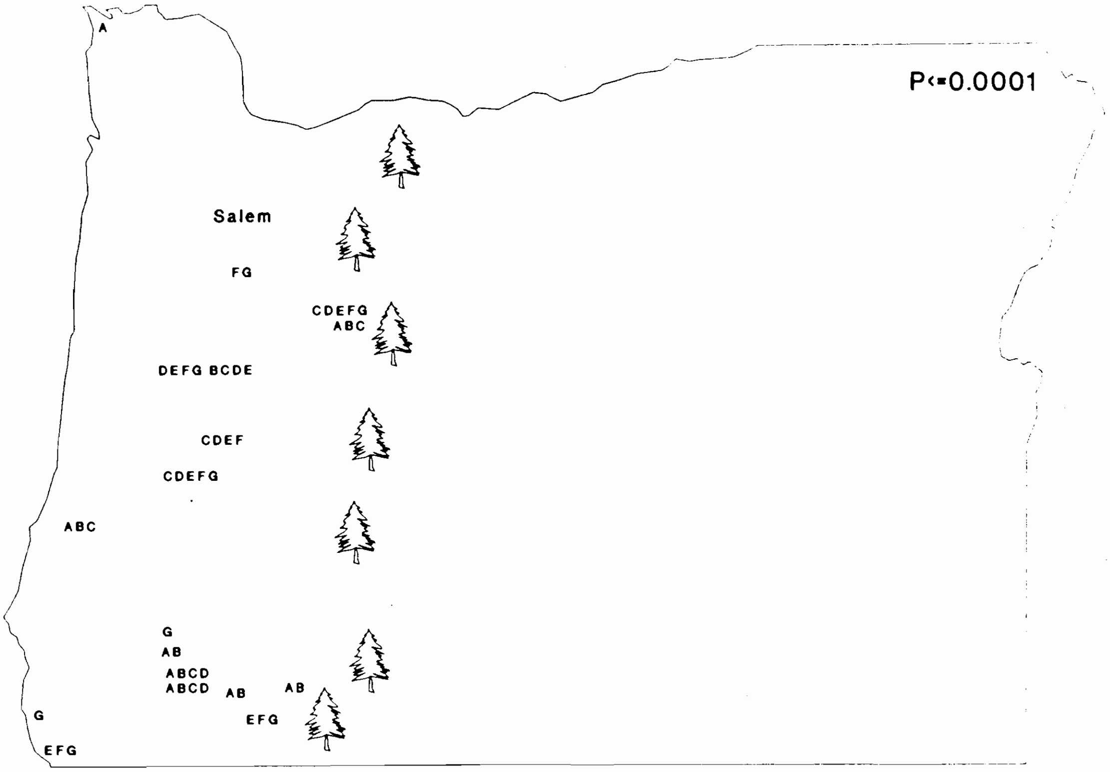

A
P<=0.0001
Salem
FG
CDEFG
ABC
DEFG BCDE
CDEF
CDEFG
ABC
G
AB
ABCD
ABCD
AB
AB
EFG
G
EFG

Figure II.9

Figure II.10. Mean preservative penetration (as copper) of wood species by veneer position in panels collected from Washington (A), Oregon (B), Idaho (C), or Montana (D) following treatment with CCA.

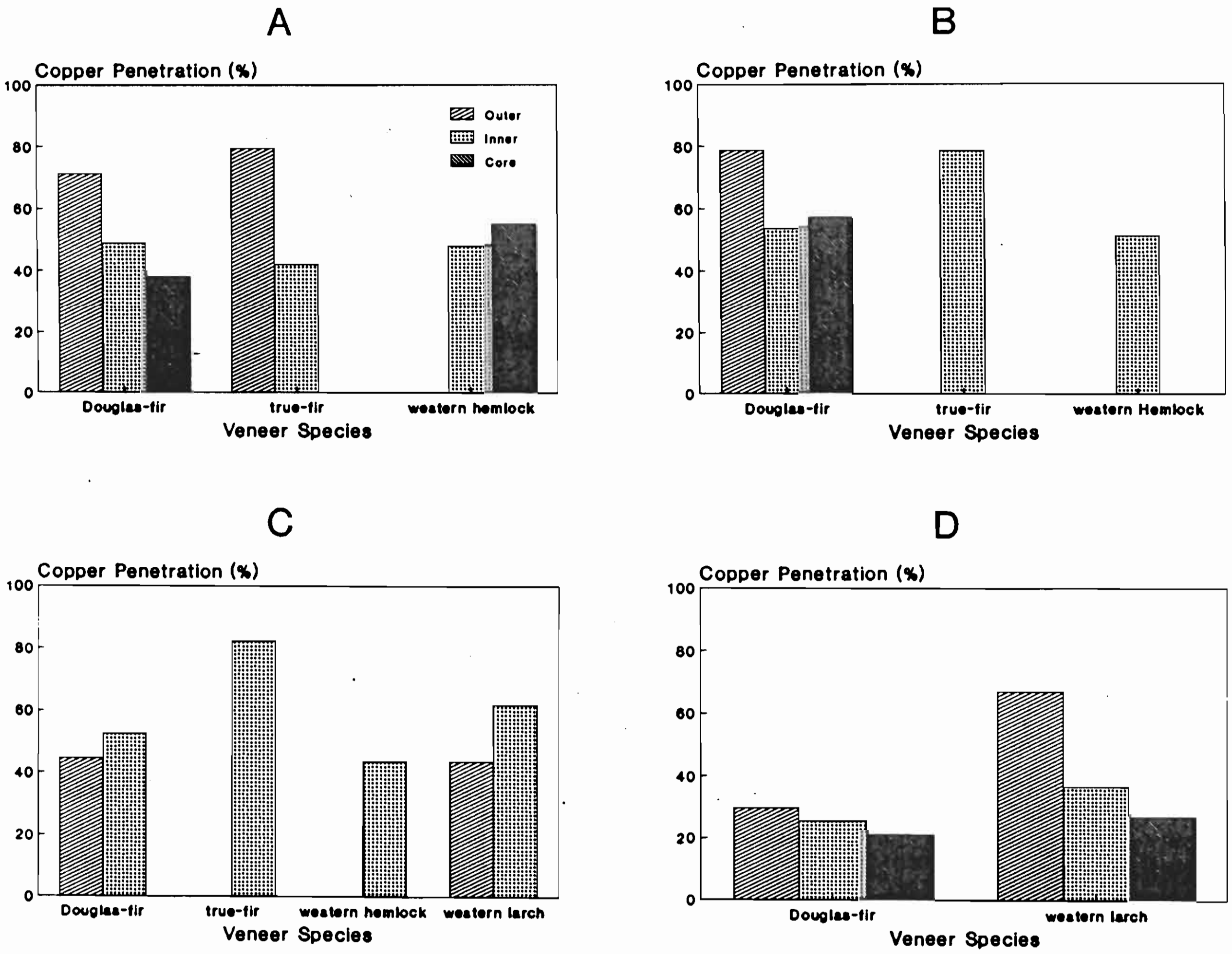

A
Copper Penetration (%)
100
80
60
40
20
0
Outer
Inner
Core
Douglas-fir
true-fir
western hemlock
Veneer Species
B
Copper Penetration (%)
100
80
60
40
20
0
Douglas-fir
true-fir
western Hemlock
Veneer Species
C
Copper Penetration (%)
100
80
60
40
20
0
Douglas-fir
true-fir
western hemlock
western larch
Veneer Species
D
Copper Penetration (%)
100
80
60
40
20
0
Douglas-fir
western larch
Veneer Species

Figure II.10

Figure II.11. Mean preservative penetration (as copper) of wood species by veneer position in panels collected from Washington (A), Oregon (B), Idaho (C), or Montana (D) following treatment with ACZA.

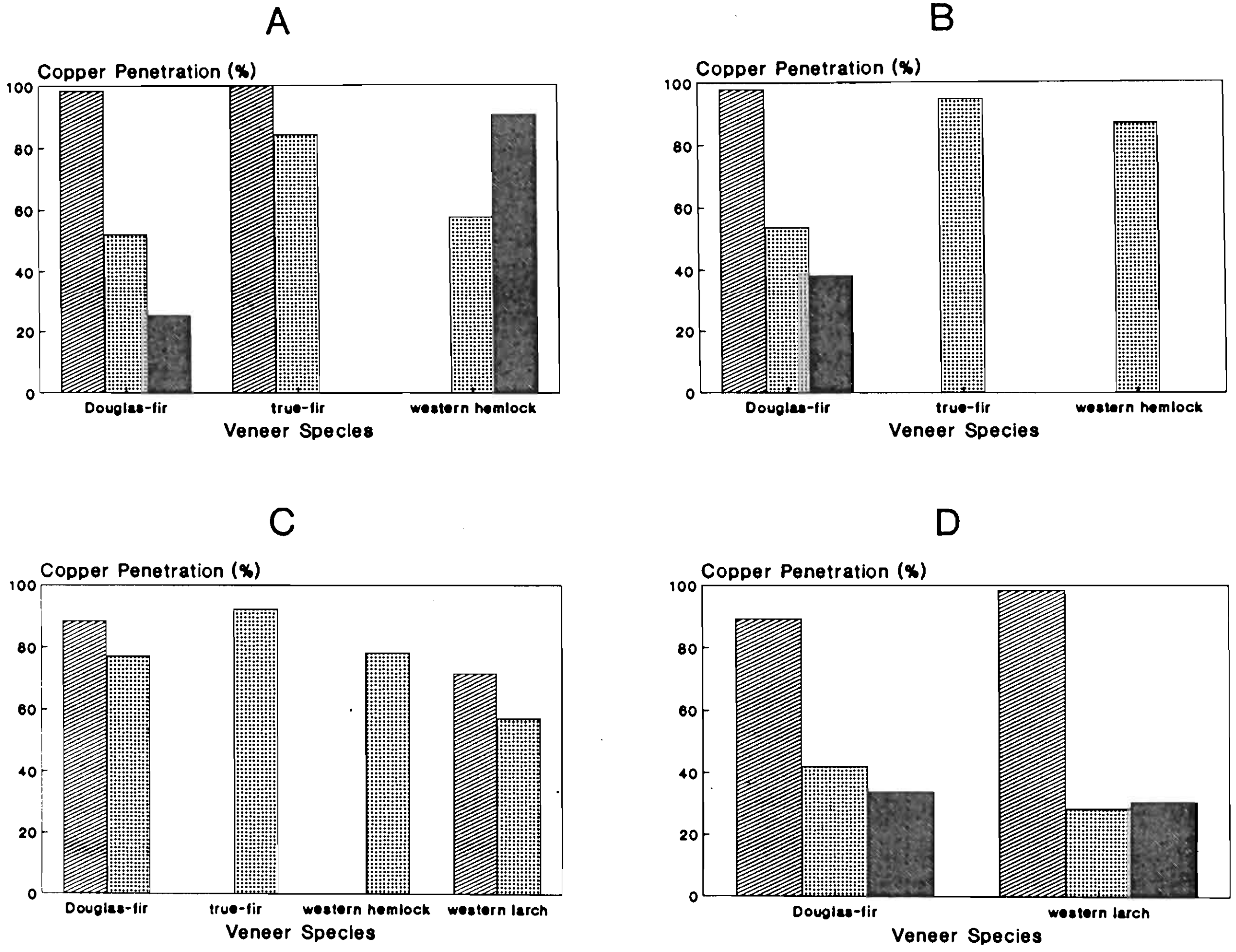

A
Copper Penetration (%)
100
80
60
40
20
0
Douglas-fir
true-fir
western hemlock
Veneer Species
B
Copper Penetration (%)
100
80
60
40
20
0
Douglas-fir
true-fir
western hemlock
Veneer Species
C
Copper Penetration (%)
100
80
60
40
20
0
Douglas-fir
true-fir
western hemlock
western larch
Veneer Species
D
Copper Penetration (%)
100
80
60
40
20
0
Douglas-fir
western larch
Veneer Species

Figure II.11

Figure II.12. Mean ASOMA retention of Douglas-fir (A), western hemlock (B), western larch (C), and true-fir (D) veneers in panels collected from Washington, Oregon, Idaho, or Montana following treatment with CCA or ACZA.

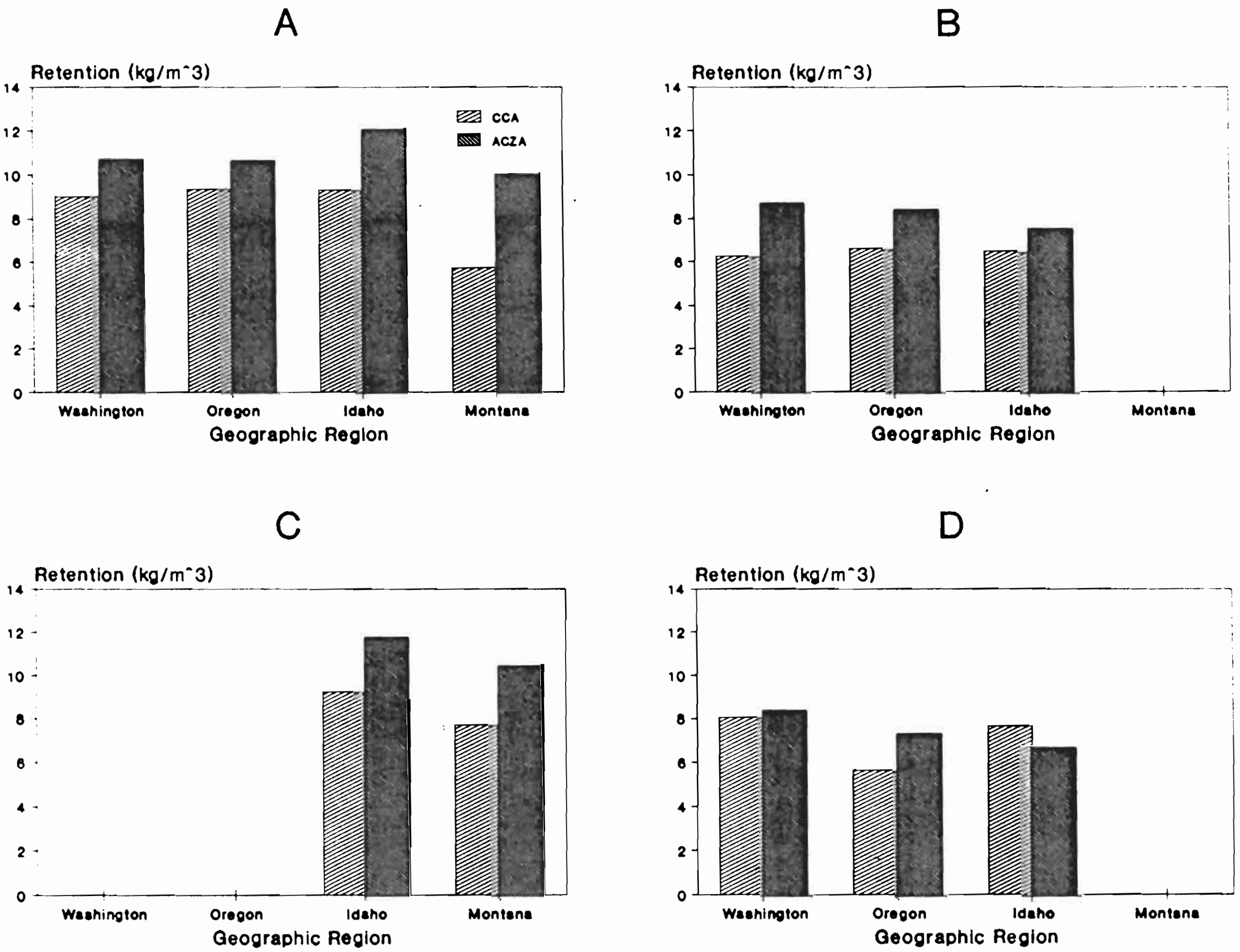

A
Retention (kg/m^3)
14
12
10
8
6
4
2
0
CCA
ACZA
Washington
Oregon
Idaho
Montana
Geographic Region
B
Retention (kg/m^3)
14
12
10
8
6
4
2
0
Washington
Oregon
Idaho
Montana
Geographic Region
C
Retention (kg/m^3)
14
12
10
8
6
4
2
0
Washington
Oregon
Idaho
Montana
Geographic Region
D
Retention (kg/m^3)
14
12
10
8
6
4
2
0
Washington
Oregon
Idaho
Montana
Geographic Region

Figure II.12

Figure II.13. Mean preservative penetration (as copper) of Douglas-fir (A), western hemlock (B), western larch (C), and true-fir (D) veneers in panels collected from Washington, Oregon, Idaho, or Montana following treatment with CCA or ACZA.

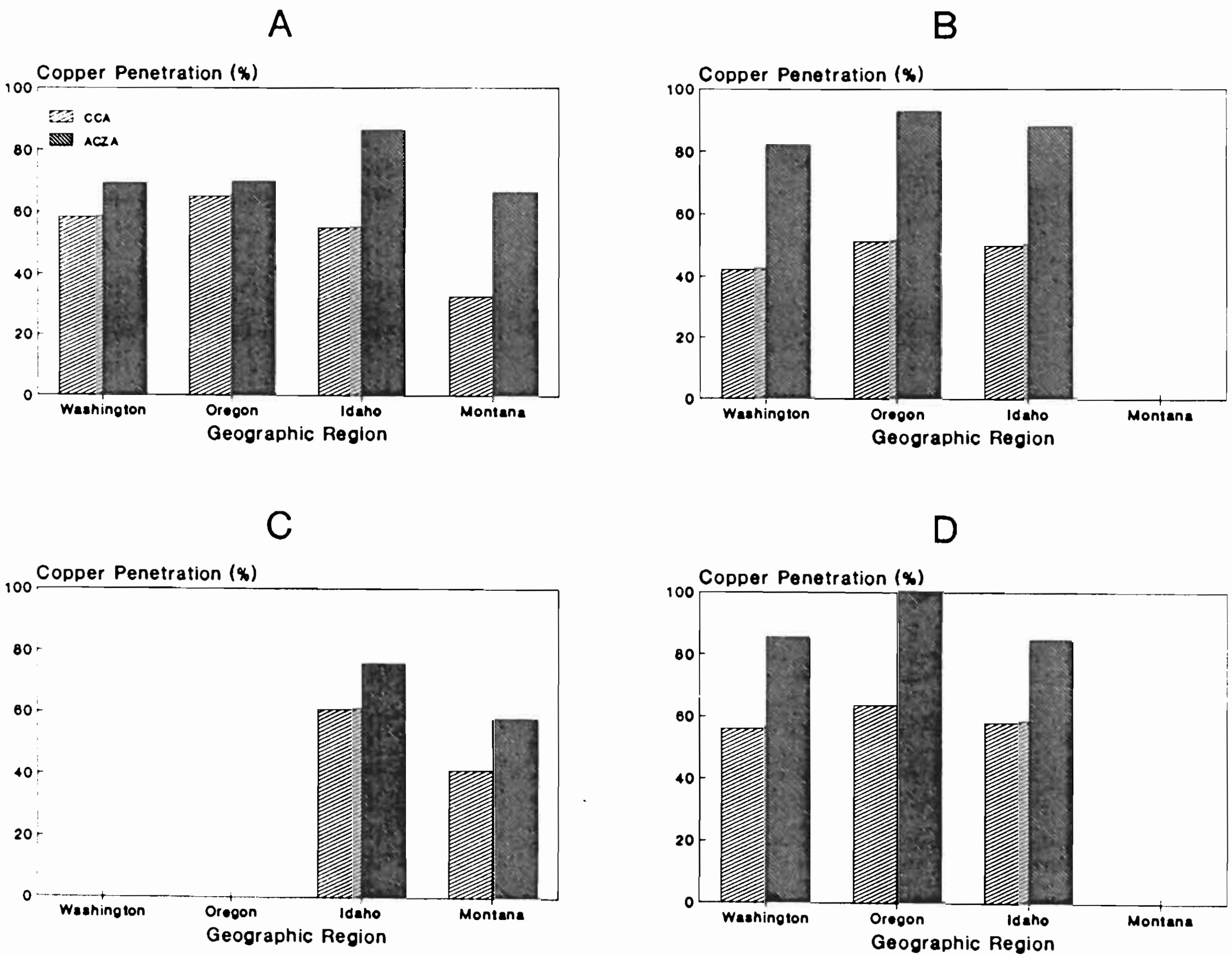

A
B
C
D
Copper Penetration (%)
CCA
ACZA
0
20
40
60
80
100
Washington
Oregon
Idaho
Montana
Geographic Region

Figure II.13

Figure II.14. Mean ASOMA retention of Douglas-fir, western hemlock, western larch or true-fir veneers in panels collected from Washington (A), Oregon (B), Idaho (C), or Montana (D) following treatment with CCA or ACZA.

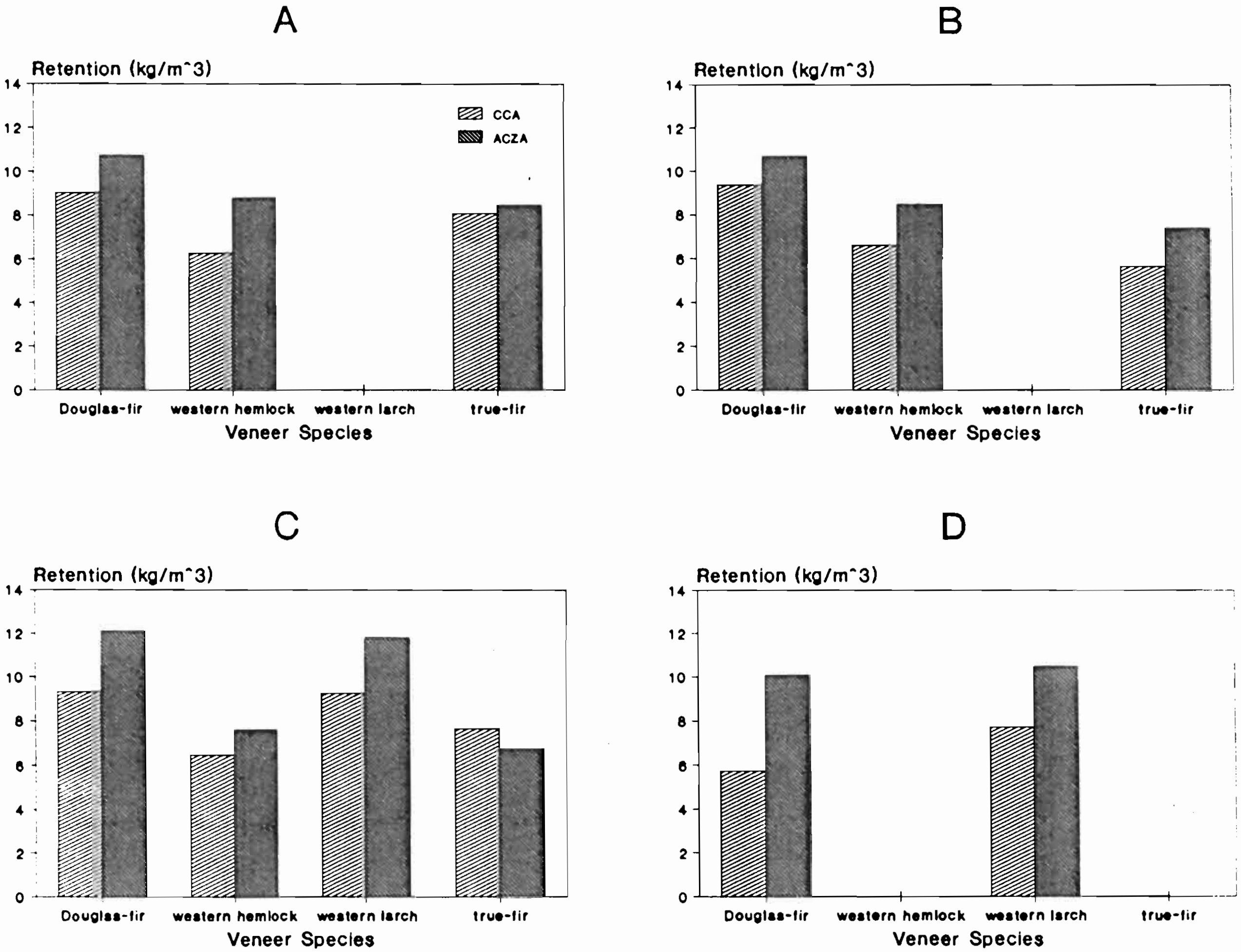

A
B
C
D
Retention (kg/m^3)
0
2
4
6
8
10
12
14
▨ CCA
▧ ACZA
Douglas-fir
western hemlock
western larch
true-fir
Veneer Species

Figure II.14

Figure II.15. Mean preservative penetration (as copper) of Douglas-fir, western hemlock, western larch or true-fir veneers in panels collected from Washington (A), Oregon (B), Idaho (C), or Montana (D) following treatment with CCA or ACZA.

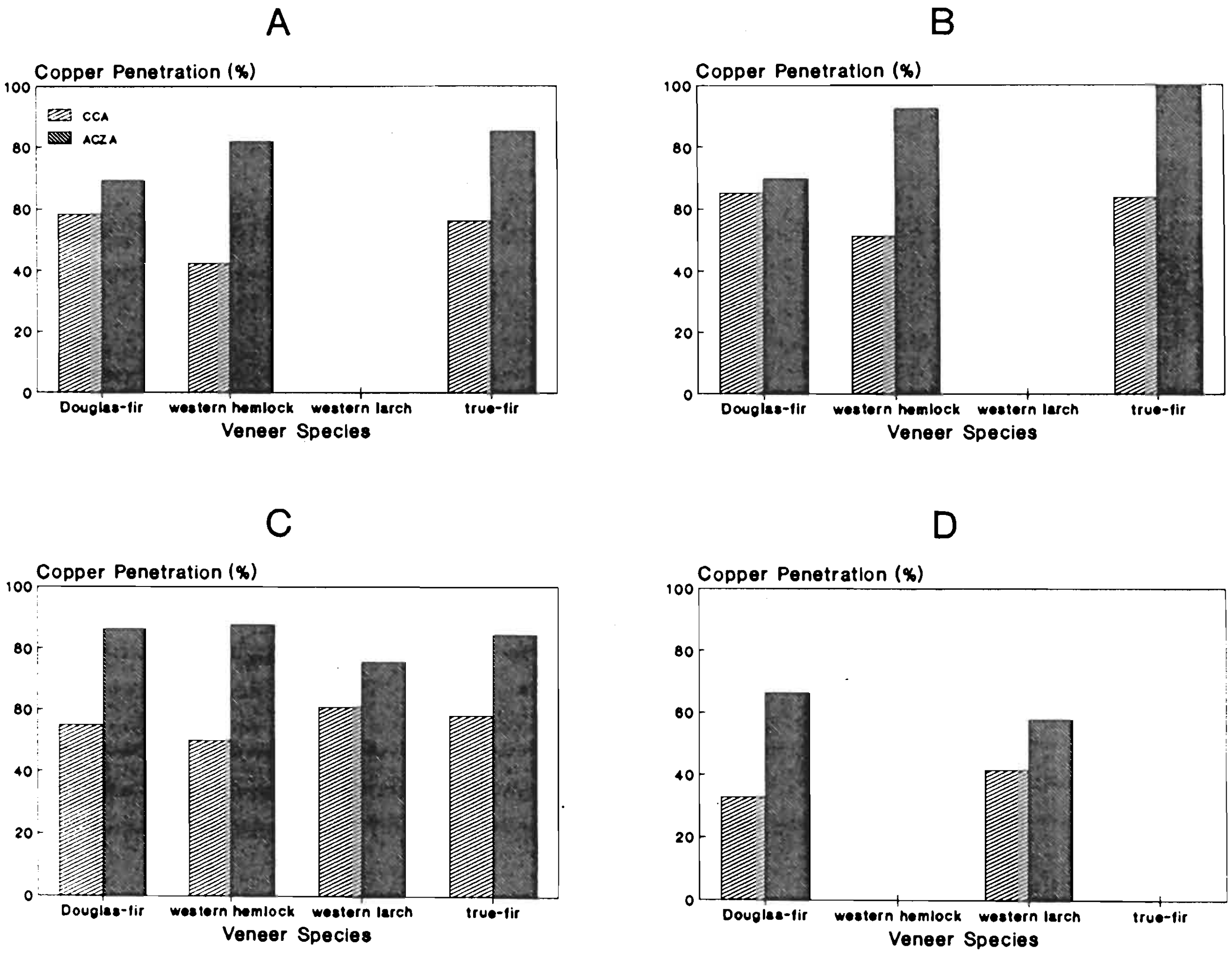

A
B
C
D
Copper Penetration (%)
100
80
80
40
20
0
CCA
ACZA
Douglas-fir
western hemlock
western larch
true-fir
Veneer Species
100
80
60
40
20
0

Figure II.15

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