Treatability with CCA and Initiation of Field Performance Testing of Refractory Softwoods

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INTRODUCTION

The treatability of "difficult to treat" softwood species from Canada and the Northern United States can be improved by incising. However, conventional incisors improve treatment at the expense of the appearance of wood. Conventional incisors have large blunt teeth which are forced into the wood under great pressure, causing tearing and splintering of the surface of the wood. This results in unacceptable consumer products such as decks and fencing where appearance is extremely important.

In 1985, a new type of incisor with an improved tooth design was developed by the Permacisor Corporation. The Gen II Permacisor utilized many new concepts, but the major improvement was the closely spaced, narrow and thin teeth. Treatment results were said to be a uniform treatment envelope with greatly improved surface appearance. This new technology set the stage for incising material that was previously not incised due to appearance degradation. This material was also most likely poorly treated. Additionally, the Gen II could make possible the treatment of species not previously treated due to poor penetration.

Another aspect of the Gen II incising technology is the field performance of the product after treatment with CCA-C. This subject is important because the primary emphasis of Gen II incising is on the creation of a uniform and continuous envelope of preservative penetration and not a maximum (and possibly discontinuous) depth of penetration. Accordingly, the length of the incising tooth for 2" dimensional decking is slightly shorter than the penetration depth specified in CSA or AWPA Standards. This new approach to incised treated lumber required the initiation of a project to evaluate the results of treating and the field performance of treated material using this technology.

PURPOSE

The primary purpose of this study is to evaluate the CCA-C treatment of Canadian softwood species incised with the Gen II incisor and field performance of this treated material. Data from this project will be used to compare treatment results from: (1) incised and unincised material, (2) 6mm incision and 10mm incision depths, (3) 3 hour and 8 hour treatment pressure periods, and (4) penetration of material in relation to CSA Standard 080 or AWPA Standard C2. Wood species to be evaluated are western white spruce, eastern white spruce, jack pine, lodgepole pine, balsam fir, Coastal Douglas-fir and the species grouping hem-fir from the Western United States. Two geographic sources are to be evaluated for eastern white spruce, western white spruce, lodgepole pine and jack pine. In addition, treatability is to be evaluated for jack pine from one geographic location for material incised either S-Grn (wet) or S-Dry.

In addition to treatability data, above ground and soil contact field performance will be evaluated for representative material associated with different pressure periods for incised and unincised material. Field test sites are located near Gainesville, Florida (Osmose plot) and Hagersville, Ontario. Above ground and ground contact exposures will be evaluated at these test sites.

MATERIALS AND METHODS

A. Wood

Fourteen sets of approximately 144 pieces of nominal 2" x 6" x 16' were obtained for each species/geographic location/seasoning combination. Table I provides information on species, geographic sourcing and lumber grade. Also shown is the seasoning condition at the time of acquisition and the moisture content when incised.

Unless otherwise noted in Table I, all the lumber was specified to be S4S, No. 2 or better and surfaced green. Surfaced dry material was used for eastern white spruce and one source of jack pine because surfaced green material was unavailable. All material was graded by an agency certified by the Canadian Lumber Standards Division of the Canadian Standards Association. Species obtained in the United States were graded in accordance with the American Softwood Lumber Standard. Lumber was graded by one of the following associations:

National Lumber Grades Authority
Council of Forest Industries
Alberta Forest Products Association
Ontario Lumber Manufacturers Association
Quebec Lumber Manufacturers Association
Western Wood Products Association
West Coast Lumbermans Bureau

B. Incising

The incising was done under the supervision of engineers from Timber Specialties, Ltd., with a commercial Gen II incisor manufactured by Permacisor Manufacturing Corporation. Wood originating from Western Canada and the Northwestern United States was incised at B. C. Clean Wood Preservers Ltd., Surrey, British Columbia, while the Eastern Canadian species were incised at Toronto Wood Treating, Acton, Ontario.

The 16ST and 15ST incising rings for the Gen II were intended to give incision depths of 6mm and 10mm, respectively. The 144 pieces of wood from each unit were divided into the following categories:

1. 60 pieces incised with 16ST tooth ring.
2. 60 pieces incised with 15ST tooth ring.
3. 24 pieces unincised.

The average moisture content for each group of 144 was determined by electrical resistance type moisture meter and is shown in Table I.

Following incising, the wood was stickered using 3/4" stickers, then shipped to Buffalo, New York.

C. Air Drying

All dimensional lumber was air dried for 2½-3½ months at Wood Treaters of Buffalo, Buffalo, New York during the months of July through mid-October. All lumber groups reached a moisture content of 20% or less.

D. Preparation for Treatment

After air drying, 72 pieces were selected for treating from each group based on physical condition and visual appearance. The 72 pieces were made up of 30 pieces each incised with the 15ST or 16ST tooth and an additional 12 unincised pieces. An additional 5 unincised pieces from each species/source were selected for use as untreated controls for field tests.

Each of the 72 pieces was cut in half to give end-matched pieces 8 feet long which were labeled A or B, to be treated by a 3 or 8 hour pressure period, respectively. Just prior to treatment, each piece of the 2016 pieces was weighed to the nearest ~~0.1~~ 0.25 pound and the moisture content determined by electrical resistance type moisture meter. Average moisture contents are shown in Table III for each treatment group.

E. Treatment

The material was treated at Wood Treaters of Buffalo by a standard full cell schedule in four commercial charges (two 3 hour and two 8 hour) using a 2.3-2.5% CCA-C oxide solution conforming to AWPA Standard P5-86. Treating schedules are shown in Table II and the treating reports are shown in Appendix 1. After treatment, the material was kiln dried to a moisture content of 25% or less using a moderate drying schedule.

F. Evaluation Procedure

Sample Selection:

After treatment, the retention for each piece was determined by weighing to the nearest 0.1 pound. Average retentions for each category of species/source, incising tooth and pressure period are shown in Table III. The individual piece retentions were used to select 20 pieces from each of the two groups of 30 incised pieces and 10 pieces from the 12 unincised pieces which were representative of each category. These representative pieces were used for evaluation of penetration. Ten of the twenty pieces evaluated for penetration were randomly selected from each group for field testing.

Evaluation of Penetration:

Figure 1 shows the cutting scheme for the evaluation of penetration. Cross sectional penetration was observed on a section 18-20" from the end of a piece. Radial penetration was examined on a section 20-28" from the end of a piece which was ripped at its center to expose the radial surface. To measure CCA penetration, Chrome Azurol S (copper detecting reagent) was used in accordance with AWPA Standard A3-84.

For each piece, both the minimum and maximum depth of cross section penetration from any of the four surfaces was recorded and for both cross section and radial sections, the percent of the outer 0.40" zone (depth of penetration required by CSA and AWPA Standards) penetrated was determined.

A photographic record was made of all cross and radial section penetrations.

Initiation of Field Performance Tests:

Soil contact and above ground exposure tests were installed at the Osmose Gainesville, Florida test plot and in a newly established test plot located in Hagersville, Ontario. Field performance samples were cut from selected boards as shown in Figure I, Diagram B. The cut end of each field performance sample was end coated with a 9% solution of CCA-C in accordance with AWPA Standard M4-84. Ten nominal 2" x 6" x 18" stakes for each species/ source, incising tooth and pressure period were placed in the soil, with the uncut end down, to a depth of about 9". Ten untreated controls for each species/source were also placed in the test. A total of 980 soil contact stakes were installed at each of the plots during 1988.

Above ground test samples were selected from the remaining 48" sections from the center of each board after the removal of soil contact and penetration evaluation sections (Figure I, Diagram B). Cut ends were end coated using the same procedure used with the soil contact sections. Deck-type modules containing 5 test boards for each treatment variable were constructed by nailing the boards to CCA treated stringers using two 10d hot dipped galvanized spiral nails at each end of a board. The deck modules were placed directly on the ground resulting in the deck undersurface being approximately 5½" above the ground. Untreated boards will be installed as controls. A total of 540 test pieces will be installed at each site. The Hagersville above ground tests were started in August 1988, while the Gainesville test site will be started in February 1989.

RESULTS AND DISCUSSION

Average CCA-C retentions on a weight gain basis for each species, geographic source, incising tooth and pressure period are given in Table III. Table IV presents the average results of the cross sectional and radial penetration evaluation for each species/ source, incising tooth and pressure period. Figures 2 - 13 show graphically the influence of incising and pressure period on the solution retentions and average depth of cross sectional penetration for each species and geographic location.

The in-depth results of this study will be presented by addressing each species separately. In order to determine the statistical significance of the differences in retentions, a Students T-Test was conducted at the 95% confidence level. Conclusions drawn on differences in solution absorption are based upon the results of this statistical analysis.

Western White Spruce (Refer to Figures 2 and 3)

British Columbia:

Western white spruce from British Columbia, when treated for 8 hours, had increased solution absorptions for all incising groups over that of material treated for 3 hours. Incising improved penetration of the western white spruce when treated for both 3 and 8 hour pressure periods. Additional observations:

- Eight hour pressure period with 15ST tooth gave greater solution absorption than the 16ST tooth. Not seen with 3 hour pressure period.

- When compared to unincised material, the 15ST tooth is necessary to get a significant increase in solution retention for both 3 and 8 hour pressure periods.

- Penetration was improved by incising, especially with the 15ST tooth treated for 8 hours.

Alberta:

Western white spruce from Alberta, when incised and treated for 8 hours, had increased solution uptakes compared to material treated for 3 hours, but no difference was observed in unincised material. Penetration was improved by incising for both 3 and 8 hour pressure periods.

- For the 15ST and 16ST incising teeth, no significant difference in absorption of material was observed for 3 or 8 hour pressure periods.

- For 8 hour press, both the 15ST and 16ST teeth significantly increased loadings compared to unincised material. For the 3 hour press, neither tooth significantly increased loadings over unincised material.

- No substantial difference was noted in penetration between the 15ST and 16ST teeth for either pressure period.

Geographic Source Comparison:

When comparing the treatability of western white spruce from British Columbia and Alberta, there appears to be no significant differences in solution absorption or penetration in the material from these two geographic regions.

Eastern White Spruce (Refer to Figures 4 and 5)

Northern Ontario:

Eastern white spruce from Northern Ontario had the greatest solution absorption for both pressure periods when incised with the 16ST tooth. Material incised with the 15ST tooth had higher solution loadings than the unincised material, but not as great as with the 16ST tooth. Incising improved penetration. The spruce incised with the 16ST tooth had the greatest penetration for 3 and 8 hour pressure periods.

Quebec:

An 8 hour pressure period increased solution absorptions for all incising groups of eastern white spruce from Quebec. Incising has little or no effect on the average penetration.
Additional comments:

- Both the 15ST and 16ST teeth had essentially the same solution retention for 3 and 8 hour pressure periods.

- Incising increased solution absorptions of material for both 3 and 8 hour pressure periods.

Geographic Source Comparison:

Eastern white spruce from Northern Ontario had significantly greater solution retentions and greater penetrations in all material when compared to eastern white spruce from Quebec. This indicates a significant effect of geographic location on treatability.

Western Hemlock (Refer to Figures 6 and 7)

Solution retentions for western hemlock from British Columbia increased for all incising groups and unincised material when a pressure period of 8 hours was compared to 3 hours. Both the 15ST and 16ST incising teeth improved penetration over unincised western hemlock for both 3 and 8 hour pressure periods. Additional observations:

- No significant difference in solution absorption for 15ST and 16ST teeth was noted for either 3 or 8 hour pressure periods.

- Incising did not significantly improve solution retentions in either the 3 or 8 hour pressure period.

Hem/Fir (Refer to Figures 6 and 7)

The hem/fir species grouping from the Northwestern United States, when incised, had greater solution absorptions than unincised hem/fir for both 3 and 8 hour pressure periods. The 15ST and 16ST incising teeth also improved penetration into the wood for both pressure periods. Other observations:

- 8 hour pressure period increased the solution retentions for all incising groups and for unincised material compared to a 3 hour pressure period.

- No significant difference in solution absorption for 15ST or 16ST tooth in either pressure period.

- Penetration with the 15ST tooth was greater when compared to the 16ST tooth when using an 8 hour pressure period. There was very little difference in penetration between the incising teeth for a 3 hour pressure period.

Douglas-fir (Refer to Figures 6 and 7)

Increasing the pressure period from 3 to 8 hours had little effect on solution absorption of Douglas-fir from the Northwestern United States. Incising improved penetration of the material treated for both 3 and 8 hours. Additional comments:

- The 15ST and 16ST teeth did not result in improved solution absorption with either pressure period.

- When compared to unincised material, incising had no effect on solution absorptions.

- A greater improvement in penetration was noted for both the 15ST and 16ST teeth for 3 hours pressure, rather than 8 hours.

It was noted that Douglas-fir supplied for this study contained unusually high amounts of sapwood. For this reason, we believe the incising had little or no relative effect on the solution absorptions of this material, regardless if treated for 3 or 8 hours. The apparent failure of solution absorption to parallel increased penetration may also be due to the inconsistent influence of widely varying sapwood content.

Jack Pine (Refer to Figures 8 and 9)

Western Ontario:

Jack Pine from Western Ontario was used to compare the treatability of material incised surfaced green to that of material surfaced dry. There was no significant difference in solution absorption for material incised green or dry, regardless of pressure period. However, there appeared to be a very slight improvement in penetration for the S-Dry pine when compared to the S-Grn pine for both pressure periods. Additional observations:

- For S-Grn, increasing the pressure period from 3 to 8 hours improved solution absorption for all incising groups.

- For S-Grn, there was no significant difference in the solution pickups between the 15ST and 16ST teeth for either pressure period.

- For S-Grn, incising did not significantly increase solution retentions for either the 3 or 8 hour pressure period.

- For S-Dry, 15ST tooth gave greater solution loadings than did the 16ST tooth with both pressure periods.

- For S-Dry, in general, very little difference in solution absorptions between incised and unincised material.

- No clear difference between incising teeth was noted for penetration.

- Increase in press time generally resulted in improved penetration.

Quebec:

Increasing the press time from 3 to 8 hours for jack pine from Quebec resulted in increased solution absorptions for incised material, but not for unincised material. Penetration was improved by incising for both pressure periods. Additional observations:

- For both pressure periods, the 16ST tooth had greater solution absorptions than did the 15ST tooth.

- Incised material had greater solution retentions than did unincised material.

Geographic Source Comparison:

There was no appreciable difference in the solution absorptions between incised jack pine from either Western Ontario or Quebec. However, there was a considerable difference in the absorptions of the unincised material, with the Western Ontario material having the larger absorptions. This may be attributed to a higher sapwood content. There was no clear difference in penetration for the Western Ontario and Quebec material.

Lodgepole Pine (Refer to Figures 10 and 11)

British Columbia:

Increasing the press time from 3 to 8 hours for lodgepole pine from British Columbia increased solution absorptions for incised but not unincised material. Improved penetration was observed for material incised and treated for 8 hours. Additional observations:

- At 8 hours, the 15ST tooth increased solution absorptions more than the 16ST tooth. This did not occur at 3 hours.

- Incising significantly increased solution retentions at 8 hours, but not at 3 hours.

- Material incised and treated for 3 hours did not show an improvement in penetration.

Alberta:

Increasing the press time from 3 to 8 hours for incised and unincised lodgepole pine from Alberta resulted in increased solution absorptions. For 3 and 8 hour press times, improved penetration was noted when the material was incised. Additional observations:

- Solution absorptions were increased when material was incised. Differences in solution retention for the 15ST or 16ST tooth was not significant for either press period.

- The 15ST tooth treated for 3 hours showed the greatest penetration. Increased penetration for 3 hours as opposed to 8 hours may be due to the inconsistent influence of widely varying sapwood content.

- Increasing the pressure period from 3 to 8 hours appears not to have had an effect on the penetration.

Geographic Source Comparison:

Lodgepole pine from Alberta had higher solution absorptions than the pine from British Columbia. This effect appeared to be more pronounced in the incised material than in the unincised material.

Eastern Hemlock (Refer to Figures 12 and 13)

When incised, the solution absorption of eastern hemlock from Quebec increased significantly when treated for either 3 or 8 hours. Incising also improved penetration substantially, regardless of the pressure period. Additional observations:

- Increasing the press period from 3 to 8 hours increased solution absorption for incised and unincised material.

- The 15ST tooth increased solution absorption over the 16ST tooth for both pressure periods.

- An 8 hour pressure period with incised material increased penetration over that of incised material treated for 3 hours.

- There was no significant difference in penetration between the 15ST and 16ST teeth for either pressure period.

Balsam Fir (Refer to Figures 12 and 13)

Increasing the press period from 3 to 8 hours for incised and unincised balsam fir from Ontario increased solution absorptions. For both pressure periods, penetration was improved by incising. Additional observations.

- The 15ST and 16ST teeth are not significantly different in solution absorption for either pressure period.

- Incised material, treated for either 3 or 8 hours, had increased solution absorptions compared to unincised material.

- There is essentially no difference in penetration of incised balsam fir for either pressure period.

- Penetration was improved to a greater extent when incised with the 16ST tooth regardless of pressure period.

CONCLUSIONS

Based on the results of this study, the following specific conclusions can be made:

1. Incising significantly increases the ability of the wood to absorb CCA solution.

2. When pressure periods are extended from 3 to 8 hours, solution absorptions are increased. This increase was proportionally greater for incised material compared to unincised material.

3. Generally, the 15ST tooth gave higher solution loadings compared to the 16ST tooth.

4. Incising substantially increased the penetration in all species/sources, except for eastern white spruce from Quebec.

5. Increasing the pressure periods from 3 to 8 hours did not result in a clear trend of improved penetration.

6. There was no strong trend to indicate increased average penetration due to the 15ST tooth compared to the 16ST tooth.

7. For the only single species/source evaluated with incising at different moisture contents, there was no significant difference in solution absorptions, whether incised green or dry. There did appear to be a slight improvement in penetration for dry material.

In general, none of the species/sources, incising patterns or pressure periods would appear to consistently produce CCA treated material which would meet CSA or AWPA penetration requirements. However, it is the opinion of the authors that dimension lumber treated to the results presented in this study will provide positive performance. Field tests, in both above ground and ground contact exposure, have been established to verify this opinion.

RECOMMENDATIONS

On the basis of this study, the following recommendations are made:

1. Incising with the Gen II incisor with either the 15ST or 16ST incising tooth improves treatability. The 15ST tooth in general gave better retentions and penetrations, while the 16ST tooth produced a superior appearance.

2. Eight hour pressure periods were superior to three hour pressure periods.

3. For these specific treatments and incising patterns, the species that appeared to be the most treatable were:

    Hem/Fir - N.W. Coastal United States
    Western Hemlock - British Columbia
    Eastern Hemlock - Quebec
    Eastern White Spruce - Northern Ontario

Species of moderate treatability were:

    Douglas-fir - N.W. Coastal United States
    Jack Pine - Western Ontario

Jack Pine - Quebec
Lodgepole Pine - Alberta
Lodgepole Pine - British Columbia

Species which were the most difficult to treat were:

Balsam Fir - Ontario
Eastern White Spruce - Quebec
Western White Spruce - Alberta
Western White Spruce - British Columbia

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Toronto Wood Treating
Great West Timber
Mathews Lumber Co.
Goodfellow Inc.

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TABLE I.

Species: Common Name	Species: Scientific Name	Geographic Location	Grade	Condition of Seasoning	Moisture Content at Time of Incising
Western white spruce	Picea Spp.	Brit. Columbia	No.2, Sel. Str. S4S	S-GRN	25.8%
Western white spruce	Picea Spp.	Alberta	No.1, No.2 S4S	S-GRN	19.7%
Eastern white spruce	Picea Spp.	N. Ontario	No.2 S4S	S-DRY	21.8%
Eastern white spruce	Picea Spp.	Quebec	No.1 S4S	S-DRY	15.9%
Western hemlock	Tsuga heterophylla	Brit.Columbia	No.1 S4S	S-GRN	41.6%
Eastern hemlock	Tsuga canadensis	Quebec	No.1 S4S	S-GRN	44.8%
Jack pine	Pinus banksiana	W. Ontario	No.1 S4S	S-GRN	27.3%
Jack pine	Pinus banksiana	W. Ontario	No.2 S4S	S-DRY	14.8%
Jack pine	Pinus banksiana	Quebec	No.2, S4S.	S-DRY	16.5%
Lodgepole pine	Pinus contorta	Brit. Columbia	No.2. Sel. Str. S4S	S-GRN	25.5%
Lodgepole pine	Pinus contorta	Alberta	No.1 S4S	S-GRN	29.7%
Balsam fir	Abies balsamea	Ontario	No.2 S4S	S-GRN	53.0%
Douglas-fir	Pseudotsuga menziessii	N.W. Coastal United States	No.1 S4S	S-GRN	23.8%
Hem/Fir	*	N.W. Coastal United States	No.1 S4S	S-GRN	37.5%

* Species grouping which may include the species of western hemlock, California red fir, grand fir, noble fir, Pacific silver fir and white fir.

TABLE II.

Charge #1

Treating Schedule:

30 minutes full initial vacuum (22"Hg)
3 hours high pressure (125-145 psi)

Solution Concentration:

1.0202 @ 65°F = 2.3%
Assay - 2.37%

Charge #2

Treating Schedule:

30 minutes full initial vacuum (22"Hg)
8 hours high pressure (125-145 psi)

Solution Concentration:

1.0202 @ 65°F = 2.3%
Assay - 2.27%

Charge #3

Treating Schedule:

30 minutes full initial vacuum (22"Hg)
3 hours high pressure (125-145 psi)

Solution Concentration:

1.0224 @ 65°F = 2.4%
Assay - 2.48%

Charge #4

Treating Schedule:

30 minutes full initial vacuum (22"Hg)
8 hours high pressure (125-145 psi)

Solution Concentration:

1.0224 @ 65°F = 2.4%
Assay - 2.48%

Figure 1.

DIAGRAM A - PENETRATION EVALUATION

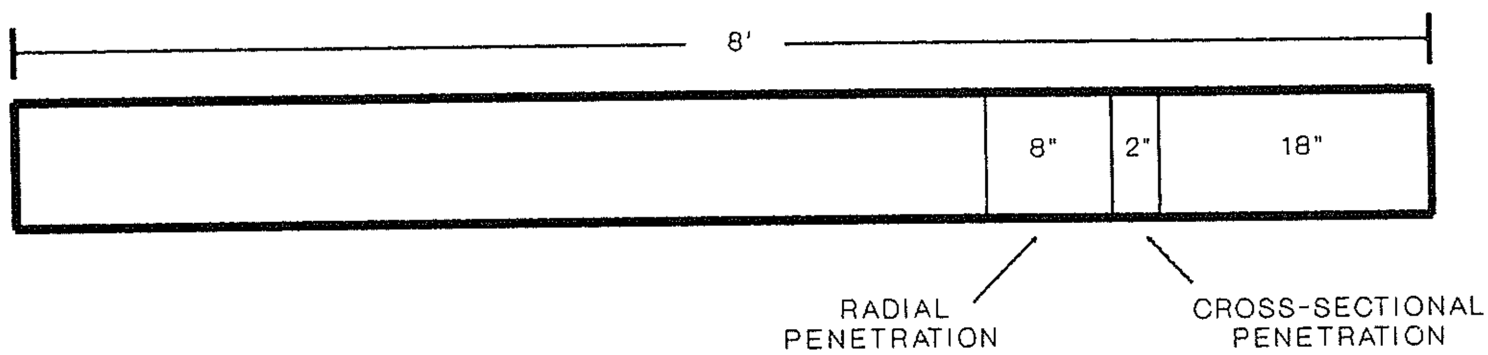

DIAGRAM B - PENETRATION EVALUATION AND FIELD PERFORMANCE

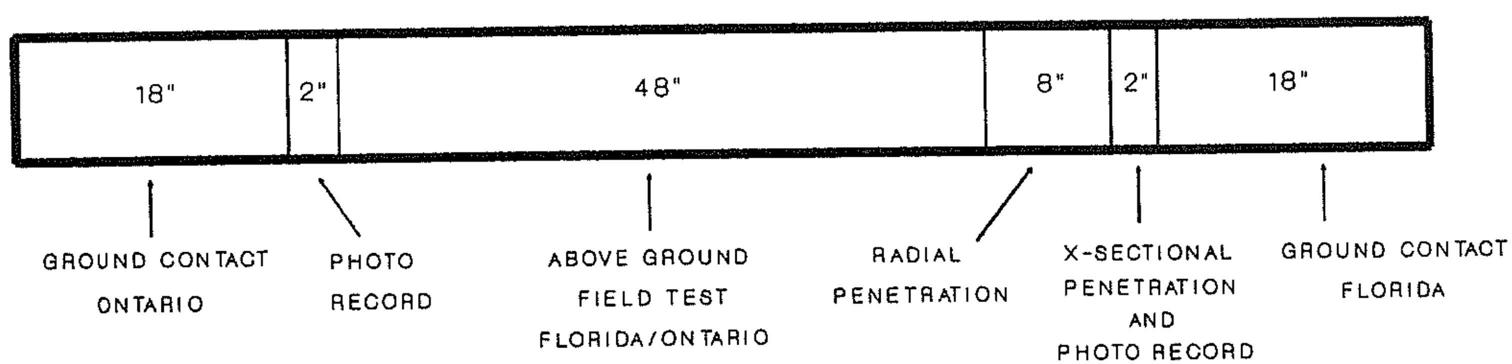

TABLE III.

Species/Source	Incising Tooth	Pressure Period (Hrs.)	Retention, Kg/m^3		Moisture Content (%)
			Solution	Oxides	
Western White Spruce British Columbia	15ST	3	187.7	4.5	13.6
	16ST	3	165.9	4.0	14.8
	None	3	128.5	3.0	16.9
	15ST	8	260.5	5.9	13.3
	16ST	8	201.6	4.6	14.9
	None	8	179.8	4.2	17.0
Western White Spruce Alberta	15ST	3	206.7	5.0	15.7
	16ST	3	193.4	4.6	16.7
	None	3	161.9	3.8	15.3
	15ST	8	234.4	5.3	13.6
	16ST	8	211.2	4.8	16.3
	None	8	156.5	3.5	14.0
Eastern White Spruce Northern Ontario	15ST	3	269.4	6.7	13.2
	16ST	3	347.7	8.6	12.7
	None	3	218.6	5.4	13.5
	15ST	8	281.3	7.0	14.0
	16ST	8	393.9	9.8	12.9
	None	8	249.3	6.2	14.1
Eastern White Spruce Quebec	15ST	3	143.5	3.4	13.3
	16ST	3	153.8	3.7	13.5
	None	3	75.4	1.8	14.0
	15ST	8	188.0	4.3	14.2
	16ST	8	181.9	4.2	14.6
	None	8	102.6	2.4	15.0
Western Hemlock British Columbia	15ST	3	278.1	6.6	18.7
	16ST	3	265.4	6.2	17.3
	None	3	233.0	5.6	18.4
	15ST	8	321.4	7.4	19.1
	16ST	8	305.6	6.9	17.6
	None	8	283.0	6.4	17.2

TABLE III. cont.

Species/Source	Incising Tooth	Pressure Period (Hrs.)	Retention, Kg/m^3 Solution	Retention, Kg/m^3 Oxides	Moisture Content (%)
Eastern Hemlock Quebec	15ST	3	294.1	7.0	19.6
	16ST	3	241.3	5.8	20.1
	None	3	157.0	3.7	21.5
	15ST	8	344.3	7.8	19.0
	16ST	8	306.2	6.9	19.6
	None	8	203.2	4.6	21.8
Jack Pine (S-Grn) Western Ontario	15ST	3	191.5	4.5	15.5
	16ST	3	217.6	5.1	14.9
	None	3	190.2	4.5	15.7
	15ST	8	237.3	5.4	15.7
	16ST	8	241.4	5.4	15.3
	None	8	222.1	5.1	15.1
Jack Pine (S-Dry) Western Ontario	15ST	3	249.8	6.2	12.1
	16ST	3	178.1	4.5	13.9
	None	3	234.7	5.8	12.5
	15ST	8	279.7	6.9	13.1
	16ST	8	244.6	6.1	15.4
	None	8	245.4	6.1	12.9
Jack Pine Quebec	15ST	3	210.7	5.0	13.7
	16ST	3	268.3	6.4	13.9
	None	3	144.8	3.4	14.7
	15ST	8	243.0	5.4	13.9
	16ST	8	295.5	6.7	14.0
	None	8	149.4	3.4	14.8
Lodgepole Pine British Columbia	15ST	3	160.6	4.0	15.0
	16ST	3	149.0	3.7	13.6
	None	3	141.3	3.5	13.7
	15ST	8	200.3	5.0	15.1
	16ST	8	173.6	4.3	13.2
	None	8	147.0	3.7	13.1

TABLE III. cont.

Species/Source	Incising Tooth	Pressure Period (Hrs.)	Retention, Kg/m3 Solution	Oxides	Moisture Content (%)
Lodgepole Pine Alberta	15ST	3	205.8	5.1	14.0
	16ST	3	238.6	5.9	14.4
	None	3	154.4	3.8	14.2
	15ST	8	264.6	6.6	14.0
	16ST	8	272.5	6.7	14.5
	None	8	185.8	4.6	14.0
Balsam Fir Ontario	15ST	3	206.9	5.1	17.7
	16ST	3	214.4	5.3	18.7
	None	3	122.2	3.0	15.8
	15ST	8	254.4	6.2	15.8
	16ST	8	276.2	6.9	17.3
	None	8	170.9	4.2	16.0
Hem/Fir N.W. Coastal United States	15ST	3	356.6	8.8	14.1
	16ST	3	335.5	8.3	13.4
	None	3	201.9	5.0	14.3
	15ST	8	391.5	9.8	14.0
	16ST	8	364.6	9.1	13.7
	None	8	259.7	6.4	13.4
Douglas-fir N.W. Coastal United States	15ST	3	250.4	6.2	15.2
	16ST	3	239.8	5.9	16.1
	None	3	249.1	6.2	14.7
	15ST	8	271.0	6.7	14.7
	16ST	8	257.0	6.4	15.8
	None	8	253.0	6.2	14.1

TABLE IV.

Species/Source	Incising Tooth	Pressure Period (Hrs.)	Penetration: Cross Section: Depth of Minimum Face (mm) Avg.	Range	Depth of Maximum Face (mm) Avg.	Range	Percent of Standard Avg.	Range	Radial: Percent of Standard Avg.	Range
Western White Spruce British Columbia	15ST	3	2.3	(1.3-6.4)	5.8	(1.3-12.7)	28.6	(20.0-60.0)	34.6	(2.0-75.0)
	16ST	3	1.5	(1.3-4.8)	5.3	(1.3-22.4)	27.8	(10.0-65.0)	24.8	(5.0-50.0)
	None	3	0.5	(0.0-1.3)	3.3	(1.3-7.9)	15.5	(5.0-40.0)	13.0	(0.0-40.0)
	15ST	8	1.8	(1.3-3.3)	8.1	(1.3-22.4)	43.5	(20.0-70.0)	46.3	(10.0-70.0)
	16ST	8	1.3	(1.3-3.3)	4.8	(1.3-9.7)	26.0	(15.0-45.0)	25.5	(5.0-65.0)
	None	8	1.0	(0.0-3.3)	4.1	(1.5-9.7)	22.0	(10.0-50.0)	28.9	(1.0-100.0)
Western White Spruce Alberta	15ST	3	2.3	(1.3-4.8)	7.1	(1.5-25.4)	27.3	(15.0-45.0)	30.0	(10.0-75.0)
	16ST	3	1.8	(1.3-3.3)	7.4	(3.3-31.8)	29.5	(20.0-50.0)	39.3	(15.0-60.0)
	None	3	0.8	(0.0-1.5)	5.3	(1.5-19.1)	12.5	(5.0-40.0)	9.8	(0.0-50.0)
	15ST	8	2.5	(1.3-3.3)	5.8	(1.5-19.1)	28.8	(15.0-60.0)	34.8	(10.0-60.0)
	16ST	8	1.8	(1.3-3.3)	5.1	(3.3-12.7)	26.3	(15.0-45.0)	35.0	(15.0-55.0)
	None	8	0.5	(0.0-1.5)	3.6	(0.0-12.7)	9.6	(0.0-20.0)	5.8	(2.0-15.0)
Eastern White Spruce Northern Ontario	15ST	3	2.5	(1.3-4.8)	8.6	(4.8-25.4)	41.0	(15.0-60.0)	50.5	(15.0-95.0)
	16ST	3	5.8	(1.3-38.1)	17.3	(3.3-38.1)	69.3	(40.0-100.0)	71.9	(30.0-100.0)
	None	3	0.8	(0.0-3.3)	7.1	(1.5-25.4)	25.5	(5.0-65.0)	17.7	(0.0-60.0)
	15ST	8	3.3	(1.3-4.8)	8.6	(4.8-25.4)	40.8	(20.0-80.0)	44.5	(20.0-90.0)
	16ST	8	3.0	(0.0-4.8)	11.7	(4.8-25.4)	76.0	(45.0-95.0)	88.7	(65.0-100.0)
	None	8	1.0	(0.0-1.5)	6.1	(1.5-12.7)	21.0	(5.0-40.0)	15.1	(2.0-45.0)
Eastern White Spruce Quebec	15ST	3	1.0	(0.0-1.3)	1.5	(1.3-3.3)	14.0	(5.0-35.0)	33.3	(15.0-55.0)
	16ST	3	1.3	(0.0-1.5)	1.8	(1.3-3.3)	17.0	(10.0-40.0)	20.5	(5.0-45.0)
	None	3	0.0	(0.0-0.0)	2.3	(0.0-4.8)	7.7	(2.0-15.0)	6.1	(2.0-10.0)
	15ST	8	1.3	(0.0-1.5)	2.3	(1.3-6.4)	21.3	(10.0-45.0)	39.8	(15.0-60.0)
	16ST	8	1.3	(0.0-1.5)	3.0	(1.3-6.4)	17.9	(10.0-40.0)	38.0	(10.0-50.0)
	None	8	0.0	(0.0-0.0)	2.3	(0.0-4.8)	8.2	(2.0-15.0)	5.5	(2.0-15.0)

TABLE IV. cont.

Species/Source	Incising Tooth	Pressure Period (Hrs.)	Penetration: Cross Section: Depth of Minimum Face (mm) Avg.	Range	Depth of Maximum Face (mm) Avg.	Range	Percent of Standard Avg.	Range	Radial: Percent of Standard Avg.	Range
Western Hemlock	15ST	3	4.3	(1.3-6.4)	6.9	(3.3-12.7)	53.3	(20.0-80.0)	53.8	(15.0-85.0)
British Columbia	16ST	3	4.3	(1.3-6.4)	7.1	(3.3-12.7)	62.0	(25.0-90.0)	60.5	(20.0-90.0)
	None	3	1.0	(0.0-3.3)	3.6	(1.5-4.8)	29.0	(10.0-60.0)	39.5	(20.0-70.0)
	15ST	8	4.1	(1.3-6.4)	7.1	(4.8-12.7)	48.8	(30.0-80.0)	57.0	(35.0-80.0)
	16ST	8	3.3	(1.3-4.8)	7.1	(4.8-12.7)	48.3	(25.0-80.0)	60.3	(20.0-85.0)
	None	8	1.5	(0.0-3.3)	5.1	(3.3-9.7)	34.0	(10.0-60.0)	35.2	(2.0-75.0)
Eastern Hemlock	15ST	3	3.3	(1.5-4.8)	6.9	(4.8-11.2)	61.8	(30.0-80.0)	78.8	(55.0-98.0)
Quebec	16ST	3	3.0	(1.3-6.4)	7.1	(4.8-11.2)	50.5	(20.0-90.0)	66.8	(40.0-95.0)
	None	3	0.3	(0.0-1.5)	2.8	(1.5-6.4)	15.5	(10.0-30.0)	21.7	(2.0-45.0)
	15ST	8	4.3	(1.3-6.4)	9.4	(6.4-25.4)	78.0	(45.0-90.0)	85.4	(30.0-100.0)
	16ST	8	4.3	(1.5-6.4)	8.4	(4.8-12.7)	65.0	(20.0-95.0)	74.8	(35.0-100.0)
	None	8	0.5	(0.0-1.5)	3.3	(1.5-4.8)	20.5	(10.0-45.0)	27.5	(10.0-40.0)
Jack Pine (S-Grn)	15ST	3	1.5	(1.3-3.3)	8.9	(1.3-25.4)	31.8	(5.0-60.0)	50.8	(15.0-90.0)
Western Ontario	16ST	3	2.0	(1.3-4.8)	8.1	(3.3-25.4)	39.3	(15.0-70.0)	59.0	(30.0-95.0)
	None	3	0.3	(0.0-1.5)	6.9	(1.5-16.0)	32.0	(10.0-65.0)	48.0	(10.0-75.0)
	15ST	8	1.5	(0.0-4.8)	11.4	(3.3-25.4)	36.8	(15.0-90.0)	56.7	(15.0-98.0)
	16ST	8	1.5	(1.3-3.3)	10.4	(1.5-38.1)	36.8	(10.0-75.0)	62.0	(25.0-95.0)
	None	8	0.8	(0.0-3.3)	11.7	(1.5-31.8)	29.5	(15.0-50.0)	61.0	(2.0-98.0)
Jack Pine (S-Dry)	15ST	3	3.0	(1.3-4.8)	11.7	(4.8-25.4)	52.5	(15.0-95.0)	60.0	(15.0-99.0)
Western Ontario	16ST	3	3.0	(1.3-4.8)	9.7	(3.3-25.4)	36.0	(15.0-65.0)	35.3	(15.0-95.0)
	None	3	0.8	(0.0-3.3)	8.1	(1.3-25.4)	41.0	(5.0-75.0)	66.5	(10.0-100.0)
	15ST	8	3.0	(1.3-6.4)	10.9	(4.8-25.4)	45.5	(15.0-80.0)	67.8	(35.0-100.0)
	16ST	8	3.3	(0.0-6.4)	12.4	(4.8-31.8)	48.8	(15.0-75.0)	61.2	(15.0-100.0)
	None	8	1.0	(0.0-3.3)	12.2	(4.8-22.4)	38.5	(15.0-85.0)	47.5-	(10.0-100.0)

TABLE IV. cont.

Species/Source	Incising Tooth	Pressure Period (Hrs.)	Penetration: Cross Section: Depth of Minimum Face (mm) Avg.	Range	Depth of Maximum Face (mm) Avg.	Range	Percent of Standard Avg.	Range	Radial: Percent of Standard Avg.	Range
Jack Pine	15ST	3	2.5	(1.3-4.8)	11.4	(4.8-25.4)	53.3	(25.0-85.0)	64.0	(20.0-95.0)
Quebec	16ST	3	2.5	(1.3-6.4)	11.4	(1.3-25.4)	60.8	(15.0-95.0)	77.3	(30.0-100.0)
	None	3	0.5	(0.0-1.5)	8.4	(1.3-19.1)	19.5	(5.0-30.0)	17.5	(5.0-25.0)
	15ST	8	2.8	(1.3-6.4)	7.4	(1.3-12.7)	59.3	(20.0-90.0)	75.0	(30.0-100.0)
	16ST	8	3.0	(0.0-4.8)	11.7	(3.3-25.4)	72.3	(35.0-95.0)	80.0	(30.0-100.0)
	None	8	1.0	(0.0-3.3)	7.4	(1.3-19.1)	22.0	(5.0-40.0)	27.9	(2.0-85.0)
Lodgepole Pine	15ST	3	2.5	(1.3-4.8)	7.6	(4.8-25.4)	50.0	(25.0-80.0)	57.8	(5.0-100.0)
British Columbia	16ST	3	1.8	(1.3-4.8)	9.1	(3.3-25.4)	34.3	(15.0-50.0)	41.8	(10.0-90.0)
	None	3	0.3	(0.0-1.5)	10.7	(1.5-25.4)	21.7	(2.0-60.0)	15.3	(2.0-45.0)
	15ST	8	2.5	(1.3-6.4)	9.9	(3.3-25.4)	46.5	(30.0-80.0)	60.4	(20.0-98.0)
	16ST	8	2.3	(1.3-4.8)	8.1	(3.3-19.1)	36.5	(25.0-50.0)	46.3	(20.0-70.0)
	None	8	0.5	(0.0-1.5)	7.1	(1.5-19.1)	23.5	(5.0-50.0)	42.9	(2.0-90.0)
Lodgepole Pine	15ST	3	2.0	(1.3-4.8)	12.7	(3.3-25.4)	39.5	(15.0-75.0)	48.5	(15.0-100.0)
Alberta	16ST	3	3.0	(0.0-6.4)	9.7	(1.3-25.4)	47.3	(20.0-90.0)	51.2	(20.0-100.0)
	None	3	0.5	(0.0-1.5)	7.9	(1.3-12.7)	23.5	(10.0-55.0)	27.9	(0.0-60.0)
	15ST	8	2.3	(1.3-4.8)	8.9	(1.5-25.4)	43.0	(20.0-70.0)	62.5	(25.0-100.0)
	16ST	8	3.3	(1.3-4.8)	8.9	(3.3-25.4)	51.5	(25.0-80.0)	66.9	(25.0-100.0)
	None	8	0.8	(0.0-3.3)	6.6	(1.5-14.2)	26.5	(10.0-75.0)	38.7	(2.0-85.0)
Balsam Fir	15ST	3	1.8	(0.0-3.3)	4.1	(1.5-6.4)	27.6	(10.0-50.0)	47.5	(25.0-75.0)
Ontario	16ST	3	2.8	(1.3-4.8)	5.1	(1.5-7.9)	28.8	(15.0-65.0)	51.5	(15.0-80.0)
	None	3	0.8	(0.0-1.5)	3.3	(1.5-6.4)	12.0	(5.0-20.0)	17.6	(1.0-55.0)
	15ST	8	1.5	(0.0-3.3)	3.8	(1.5-12.7)	22.3	(10.0-40.0)	45.5	(15.0-75.0)
	16ST	8	3.0	(1.3-4.8)	5.8	(1.5-12.7)	33.9	(25.0-70.0)	53.3	(20.0-95.0)
	None	8	0.5	(0.0-1.5)	2.0	(1.5-3.3)	11.0	(5.0-20.0)	20.7	(2.0-35.0)

TABLE IV. cont.

Species/Source	Incising Tooth	Pressure Period (Hrs.)	Penetration: Cross Section: Depth of Minimum Face (mm) Avg.	Range	Depth of Maximum Face (mm) Avg.	Range	Percent of Standard Avg.	Range	Radial: Percent of Standard Avg.	Range
Hem-Fir	15ST	3	4.6	(1.3-6.4)	12.7	(6.4-25.4)	78.4	(65.0-98.0)	84.2	(65.0-100.0)
N.W. Coastal	16ST	3	4.3	(1.3-9.7)	12.2	(3.3-31.8)	58.8	(25.0-95.0)	64.5	(30.0-90.0)
United States	None	3	0.8	(0.0-1.5)	5.3	(1.3-25.4)	25.0	(5.0-70.0)	26.9	(2.0-80.0)
	15ST	8	5.1	(1.3-9.7)	12.7	(6.4-25.4)	79.5	(55.0-100.0)	84.0	(35.0-100.0)
	16ST	8	3.8	(1.3-6.4)	8.4	(4.8-25.4)	60.5	(30.0-90.0)	61.3	(25.0-95.0)
	None	8	1.8	(0.0-4.8)	6.6	(1.3-12.7)	38.0	(5.0-80.0)	38.2	(2.0-85.0)
Douglas-Fir	15ST	3	2.3	(1.3-6.4)	10.7	(3.3-38.1)	41.5	(15.0-65.0)	43.1	(15.0-85.0)
N.W. Coastal	16ST	3	1.8	(1.3-6.4)	10.7	(1.3-25.4)	27.0	(10.0-80.0)	34.3	(10.0-80.0)
United States	None	3	0.8	(0.0-1.3)	5.1	(0.0-19.1)	20.4	(5.0-60.0)	22.2	(2.0-45.0)
	15ST	8	1.5	(1.3-6.4)	6.9	(1.5-25.4)	34.5	(20.0-65.0)	38.8	(20.0-70.0)
	16ST	8	1.3	(0.0-3.3)	8.6	(4.8-25.4)	39.5	(20.0-65.0)	33.0	(15.0-65.0)
	None	8	0.0	(0.0-0.0)	6.9	(0.0-25.4)	19.7	(2.0-50.0)	13.4	(0.0-55.0)

Figure 2.
INFLUENCE OF INCISING AND
PRESS PERIOD ON RETENTION

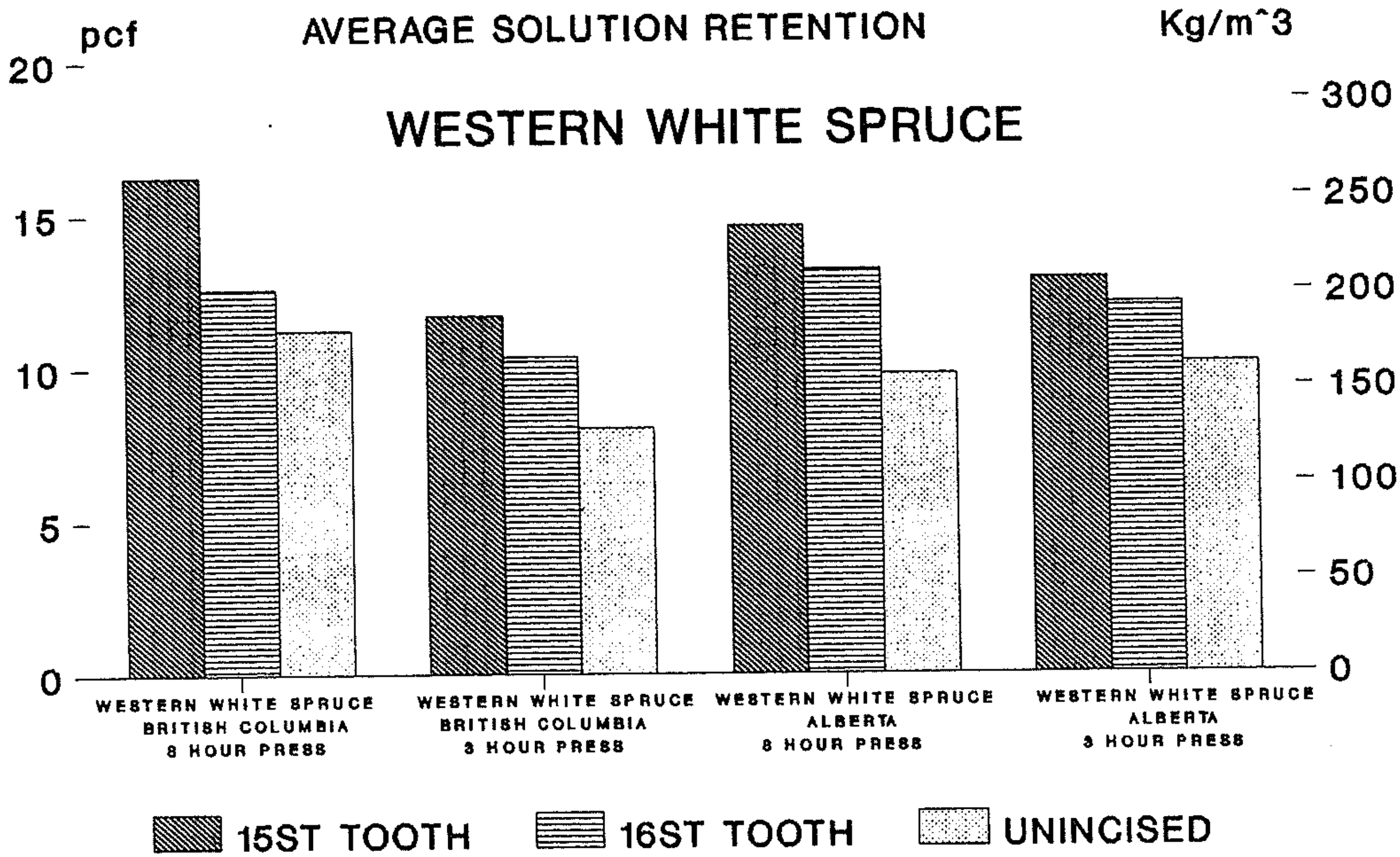

Figure 3.
INFLUENCE OF INCISING AND PRESS PERIOD ON DEPTH OF PENETRATION

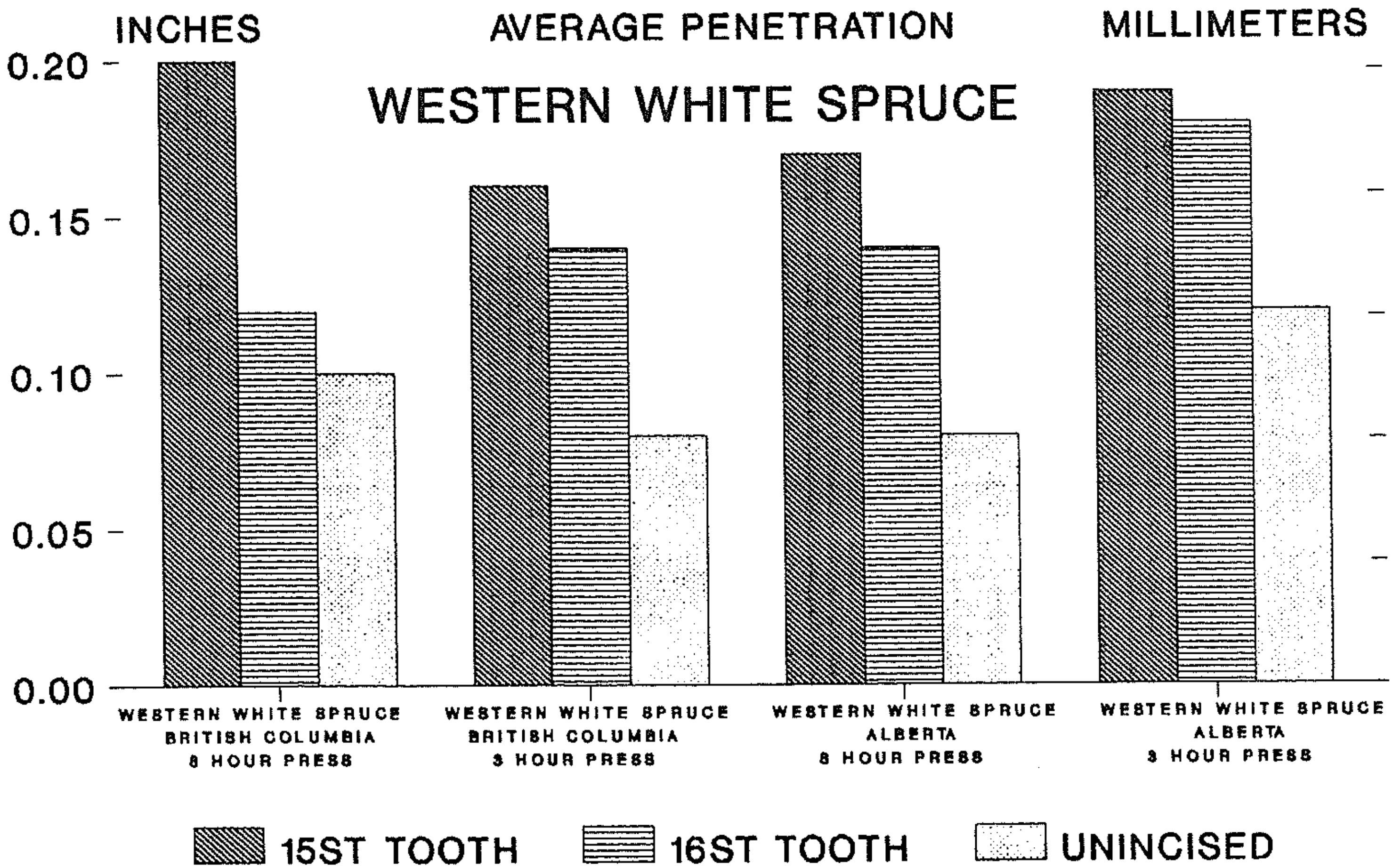

Figure 4.

INFLUENCE OF INCISING AND
PRESS PERIOD ON RETENTION

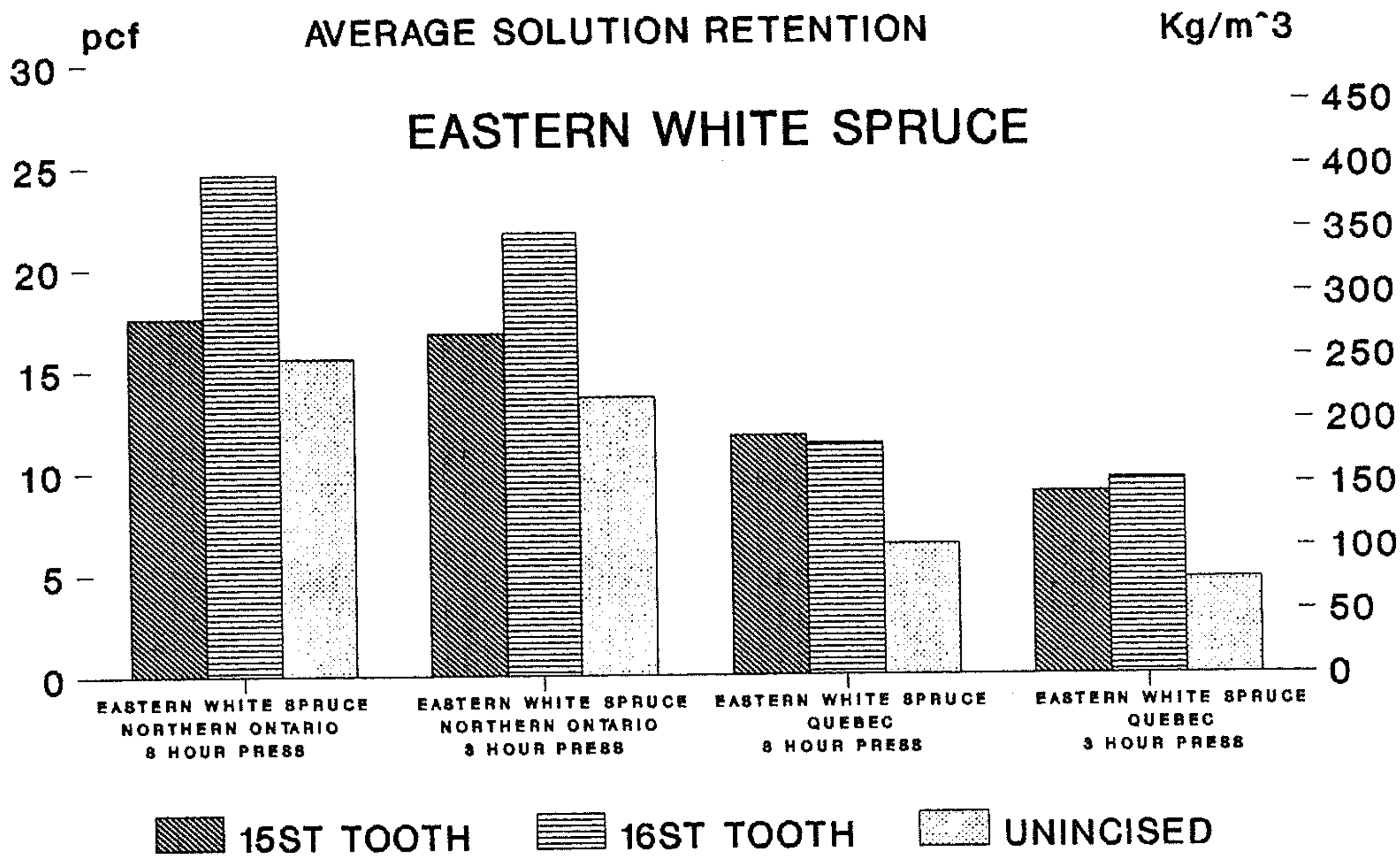

Figure 5.
INFLUENCE OF INCISING AND PRESS
PERIOD ON DEPTH OF PENETRATION

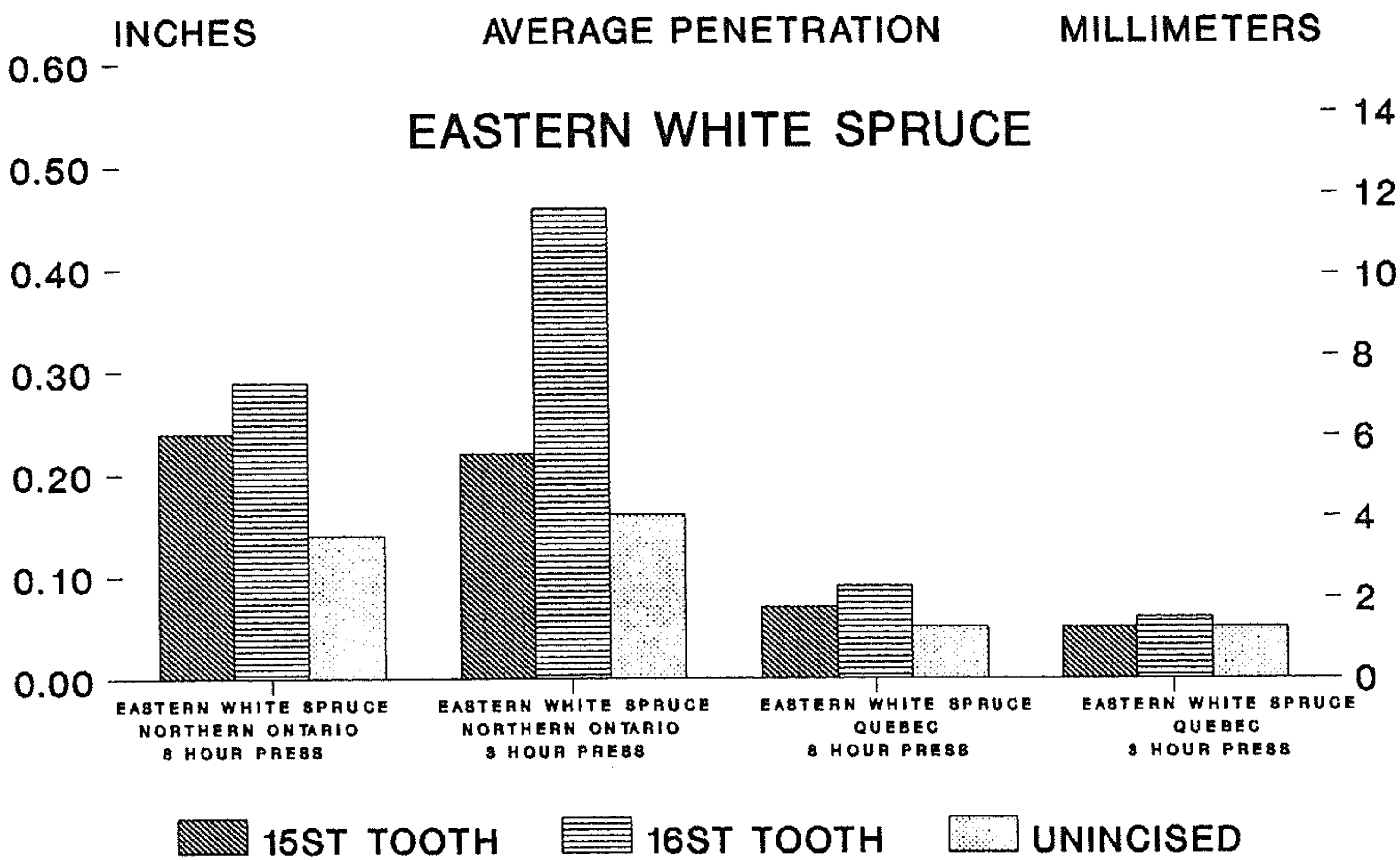

Figure 6.

INFLUENCE OF INCISING AND PRESS PERIOD ON RETENTION

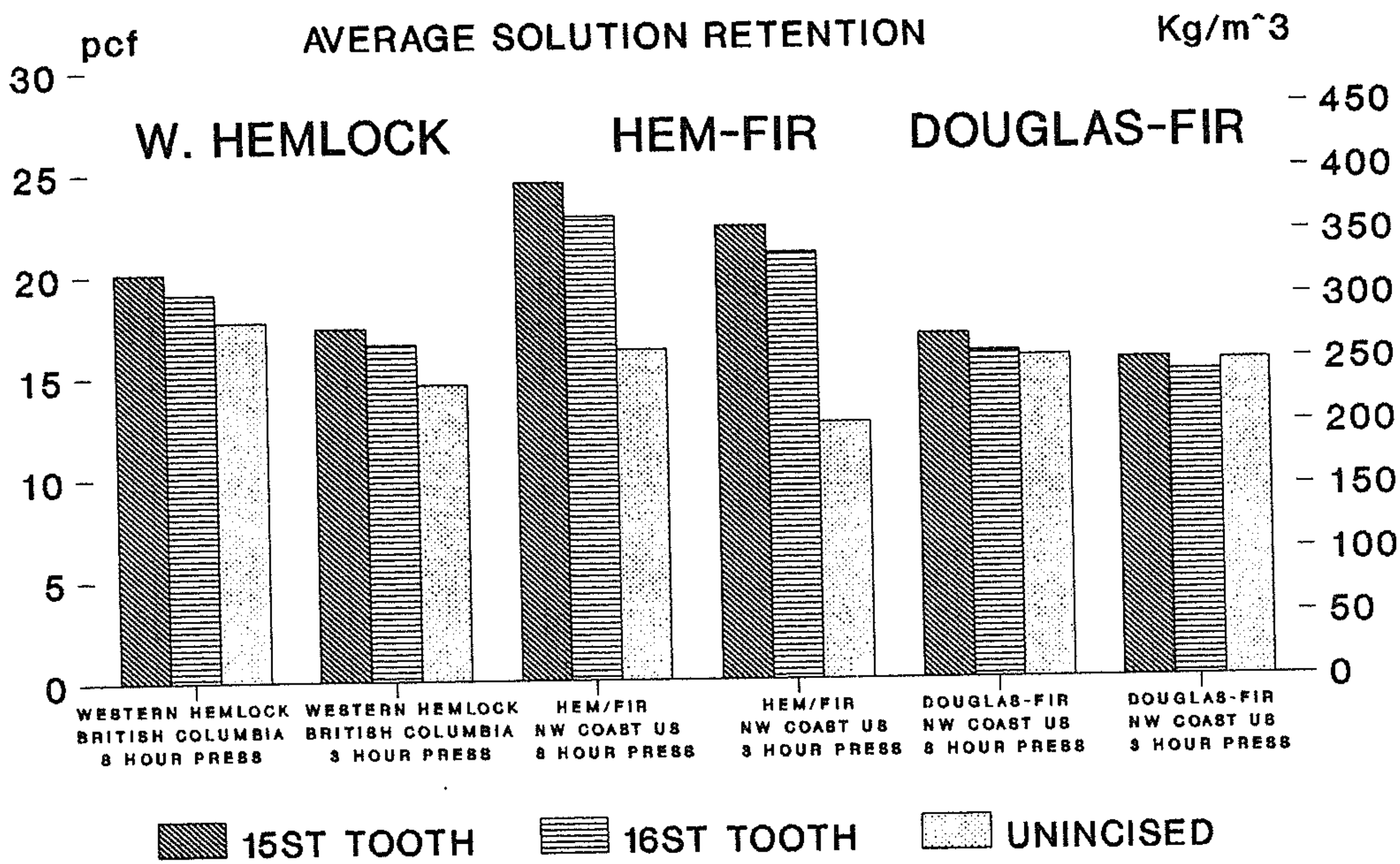

Figure 7.

INFLUENCE OF INCISING AND PRESS PERIOD ON DEPTH OF PENETRATION

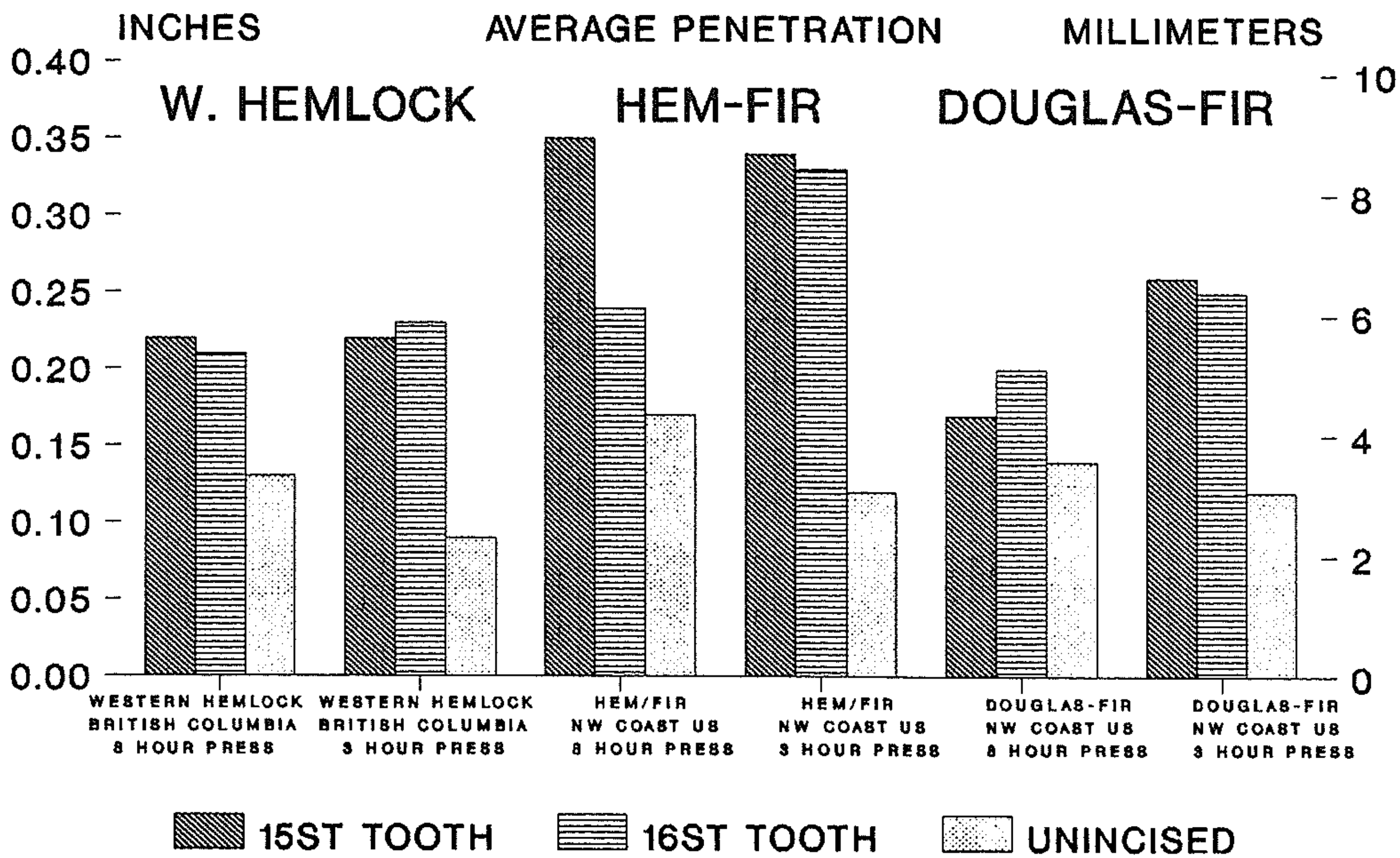

Figure 8.
INFLUENCE OF INCISING AND PRESS PERIOD ON RETENTION

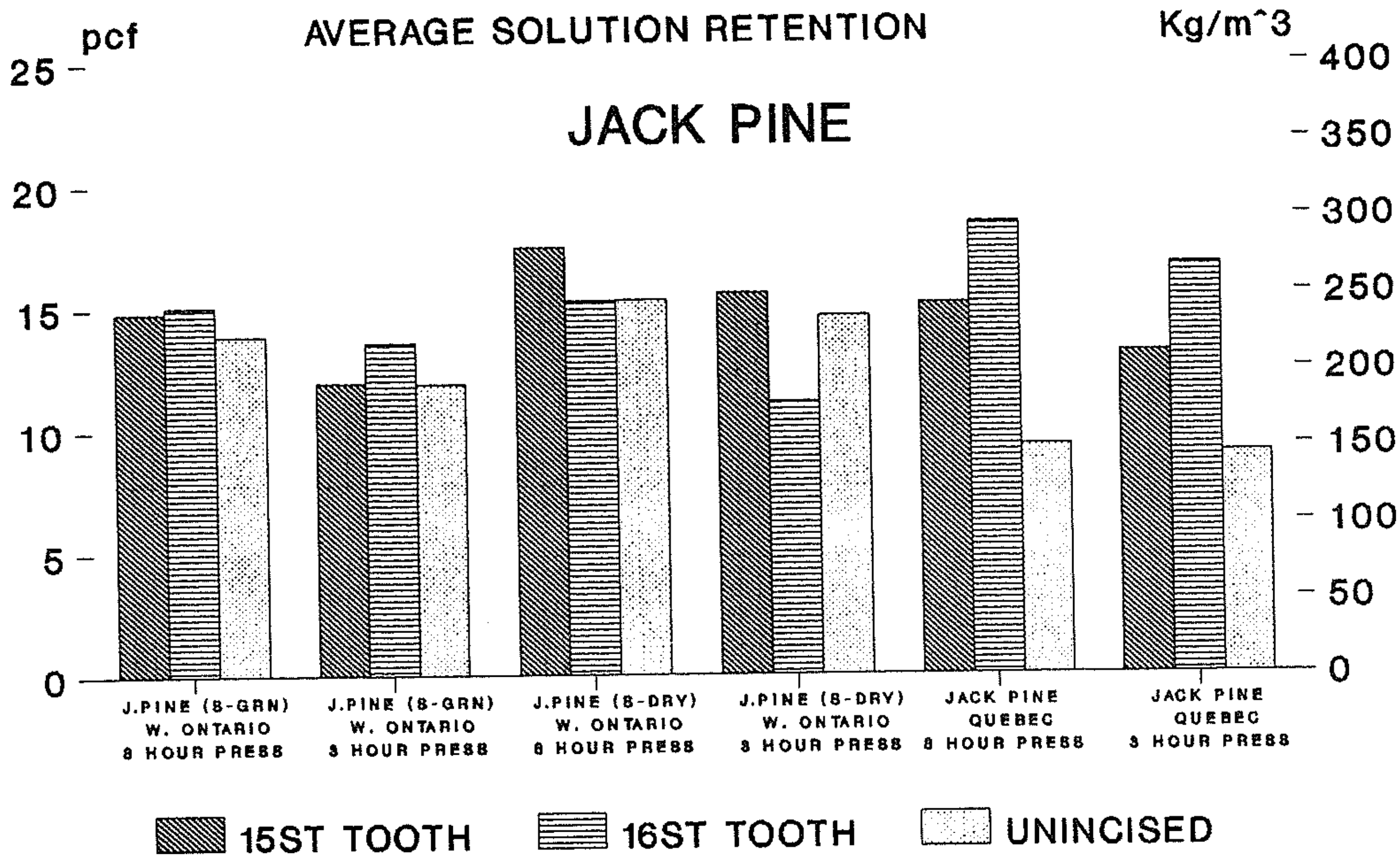

Figure 9.

INFLUENCE OF INCISING AND PRESS PERIOD ON DEPTH OF PENETRATION

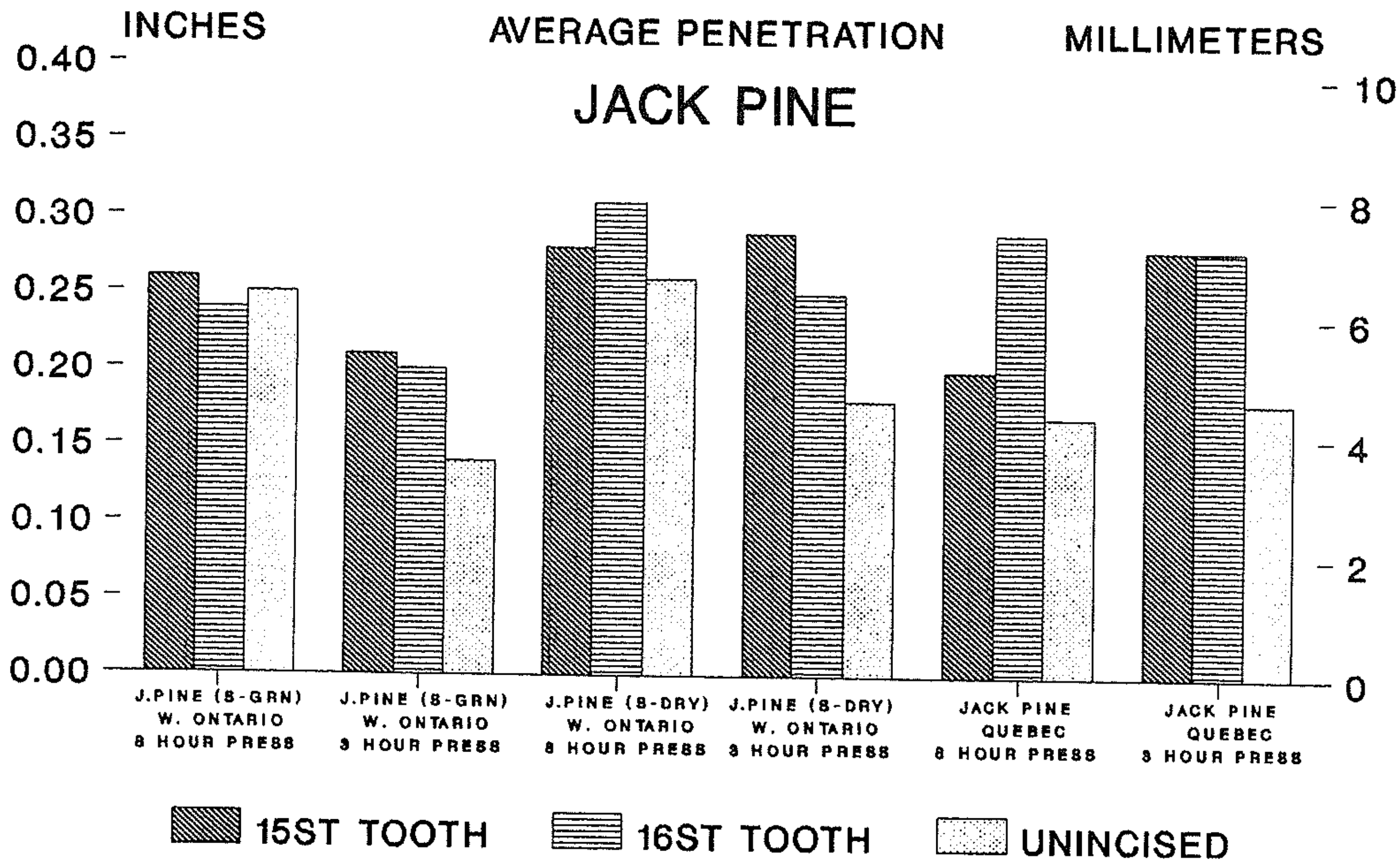

Figure 10.
INFLUENCE OF INCISING AND
PRESS PERIOD ON RETENTION

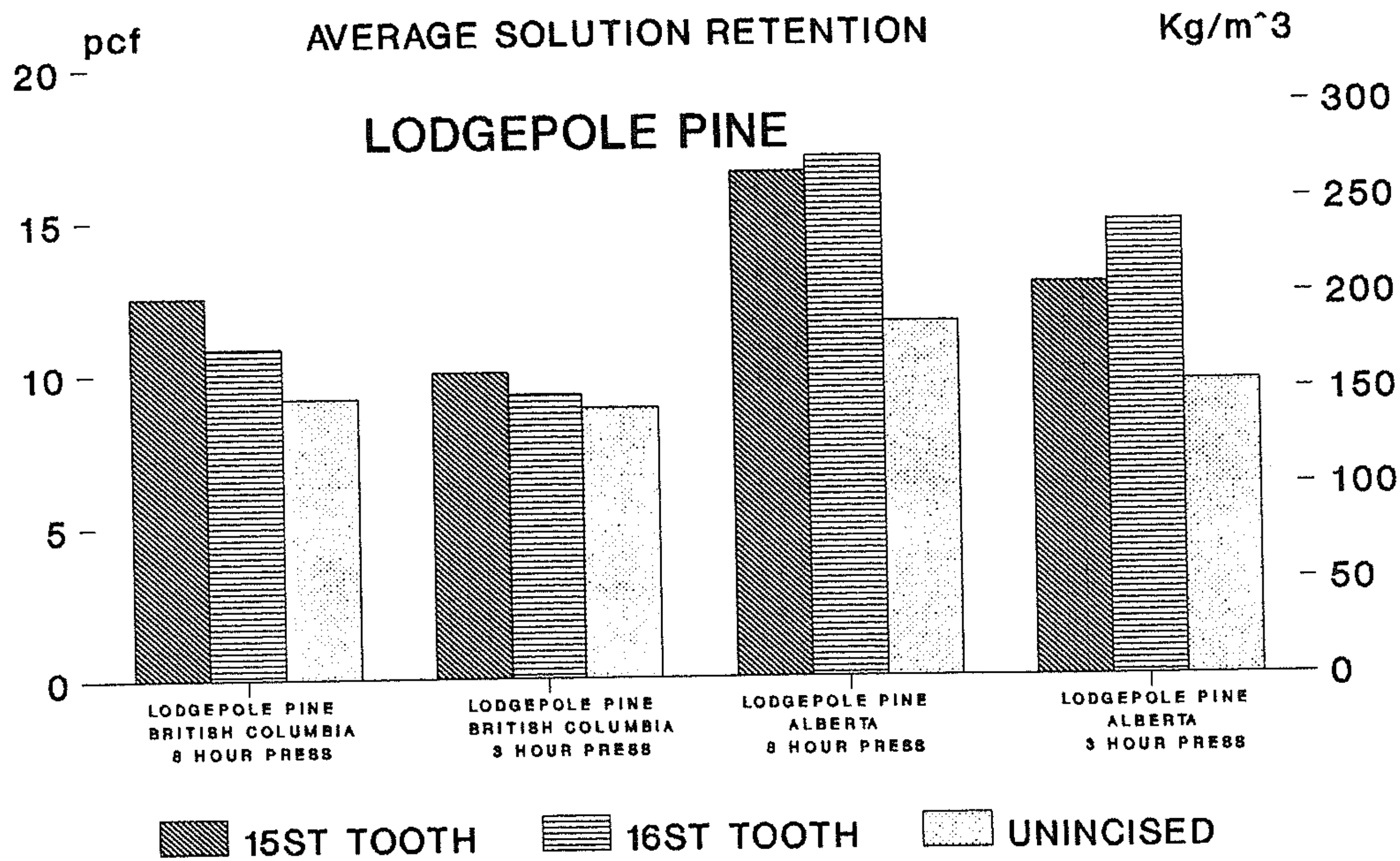

Figure 11.
INFLUENCE OF INCISING AND PRESS
PERIOD ON DEPTH OF PENETRATION

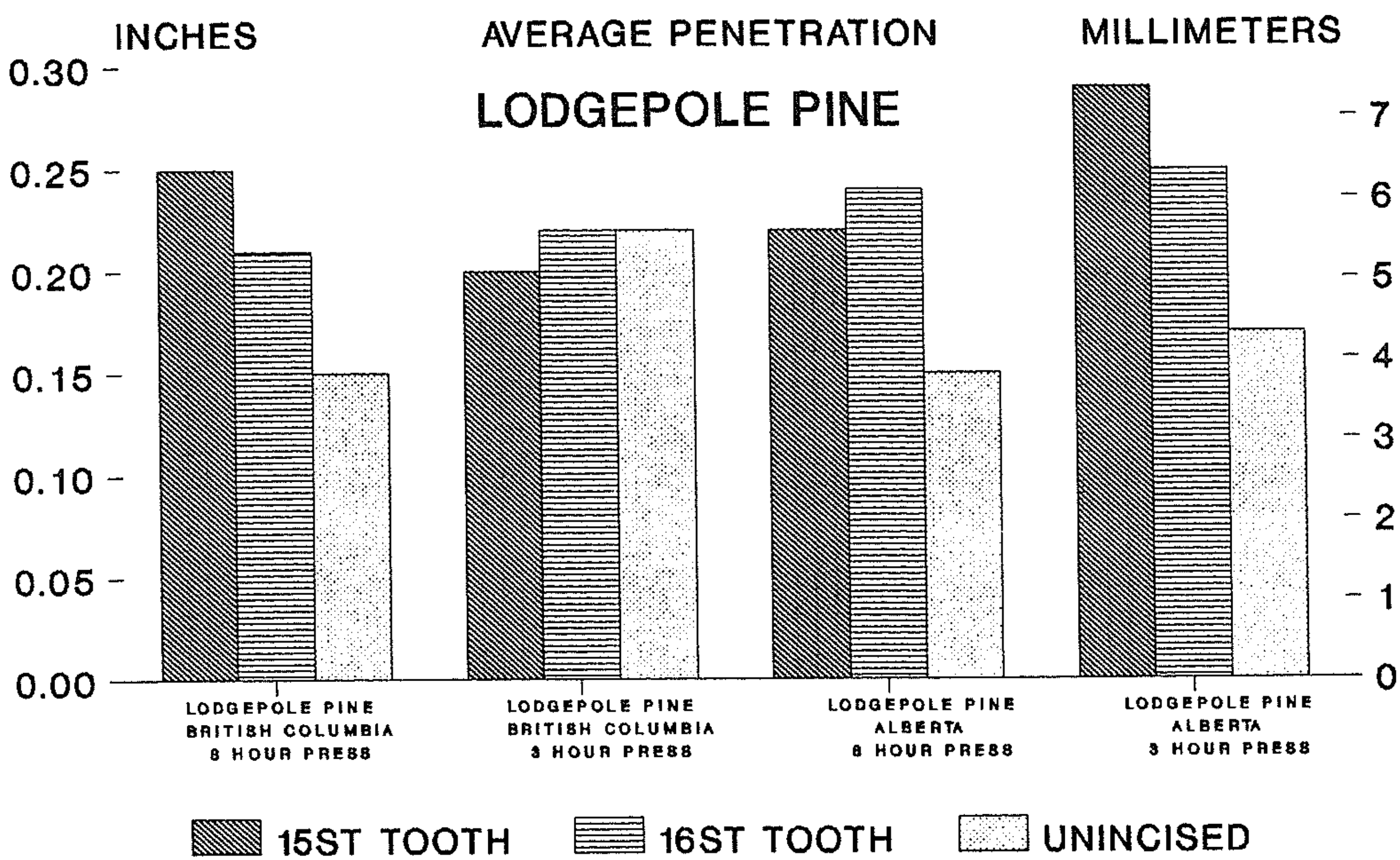

Figure 12.
INFLUENCE OF INCISING AND
PRESS PERIOD ON RETENTION

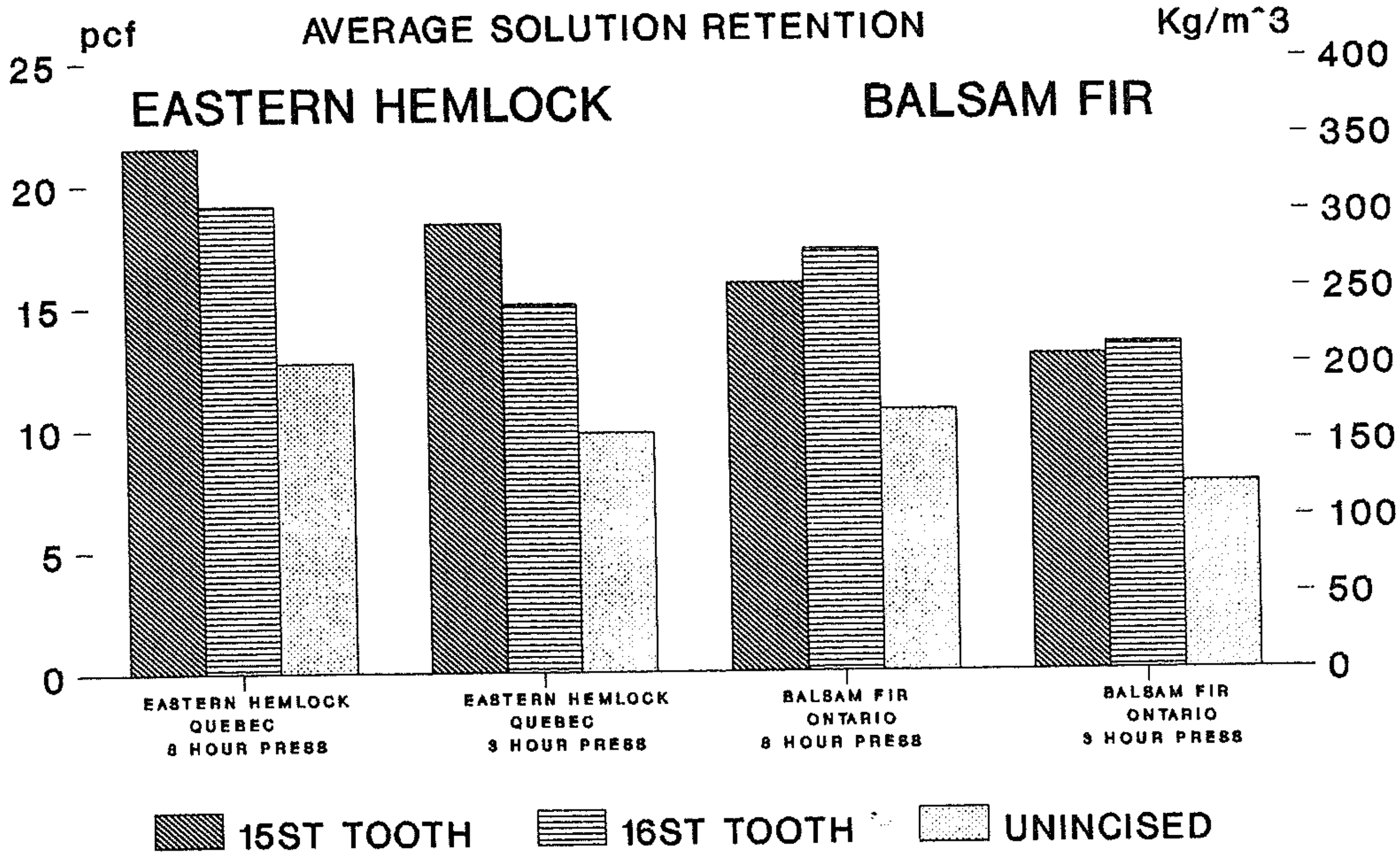

Figure 13.

INFLUENCE OF INCISING AND PRESS
PERIOD ON DEPTH OF PENETRATION