DOUBLE DENSITY INCISING -- THE CCA-C TREATABILITY AND FIELD PERFORMANCE TESTING OF REFRACTORY SOFTWOODS

Michael J. Richards
Osmose Wood Preserving, Inc., 980 Ellicott Street, Buffalo, NY 14209

1. Introduction

It is well known that incising is required for most softwood species of lumber from Canada and the Northern United States to meet the North American wood preservation standards for pressure treatment of waterborne preservatives. Historically, lumber incisors have been fabricated using large blunt teeth which are forced into the wood under great pressure, causing tearing and splintering of the wood surface. Incising lumber with these traditional machines typically resulted in unacceptable consumer products such as decks and fencing where appearance is extremely important. In addition, conventional incisors have been shown to cause strength losses in lumber of up to 28% (9).

In 1985, a new type of incisor with an improved tooth design was developed by B. C. Clean Wood Preservers (12). The Gen II Permacisor incorporated many new concepts, but the major improvement was the closely spaced, small, thin teeth. This tooth was reported to produce a uniform treatment envelope with greatly improved surface appearance.
In 1986, the Osmose Research Division initiated an extensive study to evaluate the treatability and field performance of CCA-C treated refractory softwoods incised with the Gen II Permacisor (10). The results from this study showed that, in general, none of the species/geographic sources, incising patterns or pressure periods consistently produced CCA treated material which would meet CSA or AWPA penetration requirements. The major reason for the non-conforming penetration results was the lack of lateral movement of the preservative between incisions. However, it should be noted that the treated material included in this study continues to show excellent field performance after 5 years exposure in Florida and Ontario.

In order to improve the lateral movement of preservative between incisions, Forintek developed a roller incising technology capable of doubling the incision density while preventing tearing of the wood surface. The double density incising is accomplished by the use of two offset synchronized heads instead of one. Work on small prototype machines began in 1984 and a patent was granted on this technology in 1989 (11). This new incising system is compatible with the "clean ring" technology which is one of the major advantages to the Gen II Permacisor (12). B. C. Clean Wood Preservers, Surrey, British Columbia, has modified a Gen II incisor to include two synchronized rollers so that the Forintek double density incising technology can be performed on a commercial scale (8).

As was the case with the Gen II Permacisor, a Research project was conducted by Osmose in 1991 to evaluate the results of treating and the field performance of treated material when double density incised.

2. Purpose

The purpose of this study was to evaluate the treatability and field performance of western hemlock, western white spruce, lodgepole pine and coastal Douglas-fir when double density incised using the commercially modified Gen II Permacisor at B. C. Clean Wood Preservers. Data from this project will be used to:

1. Compare treatment results from incised vs. unincised material.
2. Compare treatment results from 3 hour and 8 hour pressure periods.
3. Determine if the results of treatments are in conformance with CSA Standard 080 (6) or AWPA Standard C2 (3).

In addition, the results from this study can be compared to the results, for the same species, of the previous Gen II incising study (10) to determine if double density incising improves penetration. However, this paper will not address this comparison.

In addition to evaluating treatability, 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 and Hagersville, Ontario.

3. Materials and Methods

A. Wood.

Approximately 130 pieces of nominal 2" x 6" x 16' each of western hemlock, western white spruce, lodgepole pine and coastal Douglas-fir were obtained. 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 as measured by an electrical resistance type moisture meter.

All the lumber was specified to be S4S and No. 2 or better. The western hemlock and coastal Douglas-fir were specified surfaced green, while the western white spruce and lodgepole pine were acquired surfaced dry. All material was graded by an agency certified by the Canadian Lumber Standards Division of the Canadian Standards Association. The Douglas-fir obtained in the United States was graded in accordance with the American Softwood Lumber Standard. Lumber was graded by one of the following associations:

Council of Forest Industries
West Coast Lumbermans Bureau

The 130 pieces of wood from each species was divided into the following categories:

80 pieces -- double density incised
40 pieces -- unincised
10 pieces -- unincised, untreated

B. Incising.

All incising for this project was performed at B. C. Clean Wood Preservers Ltd. under the supervision of their personnel. The incising was done using a commercial Gen II incisor which was modified to perform double density incising. It was reported that an incision depth of 0.4" (10 mm) could be obtained by using the Gen II 16ST incising ring equipped with 1/2" (12.5 mm) teeth. A typical Gen II 16ST incising pattern will result in 6,000 incisions per M^2, however, by utilizing the Forintek technology for double density incising, the pattern will produce approximately 12,000 incisions per M^2. The double density incising pattern is shown in Figure I (7,8).

The incisor was run at a speed rate of 470 feet per minute when incising the material. Periodically, the incisor was stopped and the incision pattern and depth was checked. The equipment was also checked and adjusted for each species.

C. Sample Preparation.

After incising, 70 pieces were selected for treating from each species group based on physical condition and visual appearance. The 70 pieces were made up of 35 pieces each of incised and unincised material. An additional 10 unincised pieces from each species were selected for use as untreated controls for field tests.

Each of the 70 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.

Following cutting, the western hemlock and Douglas-fir, which were S-GRN, were stickered and kiln dried to a moisture content of 30% or less.

Just prior to treatment, each piece of the 560 pieces to be treated was weighed to the nearest 0.1 pound and the moisture content measured by electrical resistance type moisture meter. Average moisture contents are shown in Table III for each treatment group.

D. Treatment.

The material was treated by a standard full-cell schedule in two commercial charges (one 3 hour and one 8 hour) using a 2.1% CCA-C oxide solution conforming to AWPA Standard P5-92 (5). Treating schedules are shown in Table II.

E. Post-Treatment Procedure.

Following treatment, each piece was weighed to the nearest 0.1 pound. For each species, incised/unincised, and each pressure period, a 0.2" diameter increment core boring was taken from 20 randomly selected pieces. The borings, 1" in length, were taken from the heartwood face at a point midway from the ends. In addition, all borings were taken from the wide face of the board at a point between incisions. These core borings were used for retention assay and penetration determination according to applicable CSA or AWPA Standards.

The material was then stickered and air-dried for several weeks prior to packaging and shipment to Osmose, Buffalo, New York, for further evaluation.

F. Evaluation Procedure.

Evaluation of Retention: Retentions for each piece of wood treated was determined on a weight gain basis. The average retentions, solution and oxide for each species, incised/unincised, and each pressure period are given in Table III. In addition, the 20 core borings taken randomly from the pieces of each project variable were analyzed for chemical retention in accordance with AWPA Standard A9-90 using a 0.0-0.6" assay zone (2).

Evaluation of Penetration: Figure 2 shows the cutting scheme for the evaluation of penetration. Cross sectional penetration was measured on a section cut 18-20" from the end of a piece. Radial penetration was measured on a section cut 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 A3-91, Method 2 (1).

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" (10 mm) zone (depth of penetration required by CSA and AWPA Standards) penetrated was determined.

In addition, the random core borings which were taken after treatment were sprayed with Chrome Azurol S and their depth of penetration measured.

A photographic record was made of all cross and radial section penetrations, as well as for all core borings.

Initiation of Field Performance Tests: Soil contact and above ground exposure tests were established at the Osmose/Timber Specialties Gainesville, Florida and Hagersville, Ontario test plots. Field performance samples were cut from selected boards as shown in Figure 2, Diagram B. The cut end of each field performance sample was coated with a 9% solution of CCA-C in accordance with AWPA Standard M4-91 (4). Ten nominal 2" x 6" x 18" stakes for each species, incised/unincised, and each pressure period were placed in the soil, with the uncut end down, to a depth of about 9". Ten untreated controls for each species were also placed in the test. A total of 200 soil contact stakes were installed in February (Florida) and May (Ontario) of 1992.

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 2, Diagram B). Cut ends were 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 ends of the boards to CCA treated stringers using two 10d hot dipped galvanized spiral nails. The deck modules were placed directly on the ground, resulting in the deck boards being approximately 5½" above the ground. Untreated boards were installed as controls. A total of 100 test pieces were installed at each site. Each test deck was carefully photographed prior to exposure. The above ground decks and soil contact samples were placed in test at the same time.

4. Results and Discussion

Average CCA-C retentions on a weight gain basis for each species, incised/unincised, and each pressure period are given in Table III. Also given in Table III are the retention assay results for the 20 core borings taken for each project variable. Table IV presents the average results of the cross sectional and radial penetration evaluation for each species, incised/unincised, and each pressure period. The results of penetration for the 20 core borings are given in Table V. Figures 3 to 12 show graphically the influence of incising and pressure period on the average solution retentions, penetration and standards conformance for each species.

A separate, in-depth discussion of the results of this study will be presented for each species. In order to determine the statistical significance of the differences in retentions and penetrations, an Analysis of Variance was conducted at the 95% confidence level. Conclusions drawn on differences in solution absorption and penetration are based upon the results of this statistical analysis.

Douglas-fir (Refer to Figures 3, 5, and 6, and Table V)

Solution Retention:

-- Coastal Douglas-fir, when treated for 8 hours, had increased solution absorptions for both incised and unincised material when compared to material treated for 3 hours.

-- Incising increased solution retentions when compared to unincised material at each pressure period.

-- Incised Douglas-fir treated for 3 hours had solution absorptions not significantly different than unincised material treated for 8 hours.

Penetration:

-- Incising significantly improved cross sectional penetration for both pressure periods.

-- Both incised and unincised material had greater cross sectional penetration when treated for 8 hours then for 3 hours.

-- Penetration for Douglas-fir as measured on core borings was greater for incised material for both pressure periods. Penetration for incised material treated for 8 hours was greater than for 3 hours.

-- There was no significant difference in core boring penetration at 8 hour or 3 hour pressure periods for unincised material.

Standards Conformance:

-- For Douglas-fir, penetration in both the radial and cross sectional directions was similar with regards to standards conformance. Material incised and treated for 8 hours was considered acceptable (>80%), while material incised and treated for 3 hours was slightly less than acceptable. All unincised material was well below acceptable levels.

-- Standards conformance as determined by core borings showed that Douglas-fir incised and treated for 8 hours conformed to AWPA/CSA Standards (3,6). Incised material treated for 3 hours failed conformance by one boring. The unincised material treated with either pressure period was well below conformance levels.

Western Hemlock (Refer to Figures 3, 7 and 8, and Table V)

Solution Retention:

-- Regardless of pressure period duration, incised western hemlock had greater solution absorptions than did unincised material.

-- Both incised and unincised material had greater solution retentions when treated for 8 hours than did material treated for 3 hours.

Penetration:

-- Incised western hemlock had significantly greater cross sectional and core boring penetration regardless of pressure period when compared to unincised material.

-- There was no significant difference in cross sectional penetration for incised material treated at either pressure period. The same was true for unincised material. This trend for both incised and unincised material was also found in the core boring evaluation.

Standards Conformance:

-- Incised western hemlock produced similar standards conformance results for each pressure period in both cross sectional and radial evaluations. Similar results were also found between each of the unincised groups.

-- All groups of incised material had values significantly greater than the unincised.

-- Neither the cross sectional or radial evaluations produced results which would be considered acceptable for standards conformance. This was true for both incised and unincised material and for each pressure period. However, the results on incised western hemlock were close to acceptable levels.

-- Penetration measurements on core borings indicated that no material was in conformance with AWPA/CSA Standards. Incised western hemlock treated for 8 hours failed conformance by one boring, while 3 hours failed by two borings. The unincised material from this species was well below conformance. Even though none of the western hemlock met standard, the difference between incised and unincised material was quite significant.

<u>Western White Spruce</u> (Refer to Figures 4, 9 and 10, and Table V)

Solution Retention:

-- Western white spruce, both incised and unincised, when treated for 8 hours had greater solution absorptions than corresponding material treated for 3 hours.

-- Incised material, regardless of pressure period, had significantly greater solution retention than did unincised material.

Penetration:

-- When compared to unincised material, the cross sectional and core boring penetration of incised material was significantly greater, regardless of pressure period.

-- There was no significant difference in cross sectional penetration for incised material treated at either pressure period. This same trend held true when core borings were evaluated.

-- There was no significant difference in cross sectional penetration of unincised western white spruce regardless of treatment duration. Unincised material had greater core boring penetration when treated for 8 hours compared to 3 hours.

Standards Conformance:

-- There was no significant difference in penetration standards conformance in cross sectional and radial directions for incised western white spruce, regardless of pressure period. All incised material was considered acceptable, while all unincised material was well below conformance.

-- Incised western white spruce treated for 8 hours met AWPA/CSA Standards for penetration requirements when measured by core borings. Material treated for 3 hours failed by only one boring. The single non-conforming boring had a depth of penetration of .37" (9.4 mm) as compared to the requirement of .40" (10 mm). All unincised material was well below conformance levels.

Lodgepole Pine (Refer to Figures 4, 11 and 12, and Table V)

Solution Retention:

-- Solution absorptions for lodgepole pine, when treated for 8 hours, were greater for both incised and unincised material when compared to material treated for 3 hours.

-- Incised material had significantly greater solution retentions than did unincised material at both pressure periods.

Penetration:

-- There was no significant difference in cross sectional or core boring penetration for incised material regardless of pressure period. This was also true for core borings of unincised material. Cross sectional penetration for unincised material was greater at 8 hours than it was at 3 hours.

-- Incising significantly improved penetration over unincised material, regardless of pressure period or evaluation procedure.

Standards Conformance:

-- There was no significant difference in penetration standards conformance in cross sectional and radial directions for incised lodgepole pine, regardless of pressure period. All material incised and treated was considered acceptable, while no unincised material was considered acceptable.

-- Penetration as determined by core borings resulted in incised material treated for 8 hours meeting AWPA/CSA Standards, while the material treated for 3 hours failed by three borings. All unincised lodgepole pine was well below conformance levels.

5. Conclusions

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

1. Double density incising significantly increases the ability of the wood to absorb CCA solution.
2. Solution absorptions are increased when treatment pressure periods are extended from 3 hours to 8 hours. This increase was proportionally greater for incised material then it was for unincised material.
3. Double density incising significantly increased the penetration in all species.

4. Increasing the pressure periods from 3 hours to 8 hours significantly improved penetration of incised coastal Douglas-fir. The penetration of incised western hemlock, western white spruce and lodgepole pine was not significantly improved by extended pressure periods.

5. Penetration of unincised Douglas-fir and lodgepole pine was improved by increasing the pressure period, while penetration results for unincised western hemlock and western white spruce did not change substantially.

6. There appeared to be a reasonably close correlation between the average penetration values as determined by cross sectional evaluation of 35 samples and those determined by measuring the penetration on 20 core borings taken randomly in accordance with the applicable AWPA/CSA Standards. This correlation was particularly noticeable for the incised wood.

7. When conformance to standards was determined on a cross sectional and radial basis, western hemlock was the only species which did not meet the criteria at either pressure period. However, the results for both pressure periods were slightly below the acceptance level of 80%. Coastal Douglas-fir, western white spruce and lodgepole pine all met the conformance criteria when treated for 8 hours and came very close at 3 hours.

8. When core borings were evaluated to determine conformance with the applicable AWPA/CSA Standards, incised Douglas-fir, western white spruce and lodgepole pine treated for 8 hours met the Standards. Although none of the incised material treated for 3 hours met the standards, in all cases this was the result of only 1 or 2 non-conforming borings.

9. Penetration results for unincised material of all four species were well below conformance levels of appropriate AWPA/CSA Standards. This was true regardless of pressure period duration or penetration evaluation procedure.

In general, double density incising does improve the treatability of difficult-to-treat species. The results of this study indicate that the existing AWPA/CSA Standards can be met with the utilization of this incising technology. Although western hemlock used in this study did not meet the appropriate standards, it only failed by a small margin. Historically, western hemlock has been reasonably easier to treat than the other species included in this study (8).

The penetration of CCA in all the incised species evaluated came close to, met, or exceeded the existing requirements. In addition, the lateral movement of the preservative between incisions was complete, resulting in a uniform, continuous envelope of CCA. It is the opinion of the author that dimensional lumber, double density incised and treated to the results of this study, will provide excellent long term performance. Field tests have been established to verify this.

6. Acknowledgments

The author wishes to express his appreciation to all those who cooperated with this project. To our lumber suppliers: B. C. Clean Wood Preservers; Jasper Wood Treating; Prince George Wood Preserving.

Special appreciation goes to Cam Smith and the entire staff at B. C. Clean Wood Preservers for providing the use of the facilities for incising and treating of the wood used for this study. Their technical assistance throughout this project is also appreciated.

Literature Cited

(1) American Wood Preservers' Association. 1992. Standard methods for determining penetration of preservatives and fire retardants. AWPA Standard A3-91. AWPA, Woodstock, MD.

(2) _________. 1992. Standard method for analysis of treated wood and treating solutions by x-ray spectroscopy. AWPA Standard A9-90. AWPA, Woodstock, MD.

(3) _________. 1992. Lumber, timbers, bridge ties and mine ties -- Preservative treatment by pressure processes. AWPA Standard C2-92. AWPA, Woodstock, MD.

(4) _________. 1992. Standard for the care of preservative-treated wood products. AWPA Standard M4-91. AWPA, Woodstock, MD.

(5) _________. 1992. Standards for waterborne preservatives. AWPA Standard P5-92. AWPA, Woodstock, MD.

(6) Canadian Standards Association. 1989. Preservative treatment of lumber, timber, bridge ties and mine ties by pressure processes. CSA 080.2 M. CAN/CSA - 080 Series M89, Wood Preservation. CSA, Rexdale, Ontario, Canada.

(7) Morris, P. I. 1990. Recent developments in incising. Proceedings. Canadian Wood Preservation Association. CWPA, Mississauga, Ontario, Canada.

(8) Morris, P. I., J. N. R. Ruddick and R. Silcox. 1991. Development, design and construction of a double density incisor. Forest Products Journal 41(2):15-20.

(9) Perrin, P. W. 1978. Review of incising and its effects on strength and preservative treatment of wood. Forest Products Journal 29(9):P27-33.

(10) Richards, M. J. and R. D. Inwards. 1989. Treatability with CCA-C and initiation of field performance testing of refractory softwoods. Proceedings. Canadian Wood Preservation Association. CWPA, Mississauga, Ontario, Canada.

(11) Ruddick, J. N. R. 1989. Multi-head incisor for lumber, timber and the like. United States Patent No. 4,836,254.

(12) Silcox, R. 1987. Mechanical incising and the clean ring concept. Proceedings-Incising Workshop. Special Publication No. SP-28. Forintek Canada Corp., Vancouver, B. C.

TABLE I

Species	Geographic Location	Grade	Condition of Seasoning	Moisture Content at Time of Incising
Douglas-fir Pseudotsuga menziessii	N.W. Coastal United States	No. 1 or No. 2, S4S	S-GRN	35.4%
W. Hemlock Tsuga heterophylla	British Columbia	No. 1 or No. 2, S4S	S-GRN	42.5%
W. White Spruce Picea spp.	British Columbia	No. 1 or No. 2, S4S	S-DRY	20.1%
Lodgepole Pine Pinus contorta	British Columbia	No. 2 Sel. Str., S4S	S-DRY	23.1%

TABLE II

TREATING SCHEDULES

Charge #1

Treating Schedule:

30 minutes full initial vacuum (26" Hg)
3 hours high pressure (125-150 psi)
15 minute final vacuum

Solution Concentration:

1.0185 @ 70°F = 2.1%
Assay - 2.06%

Charge #2

Treating Schedule:

30 minutes full initial vacuum (26" Hg)
8 hours high pressure (125-150 psi)
15 minute final vacuum

Solution Concentration:

1.0185 @ 70°F = 2.1%
Assay - 2.01%

TABLE III

Species	Incised	Pressure Period (Hours)	Retention, pcf Weight Gain Solution	Retention, pcf Weight Gain Oxide	Retention, pcf Assay Oxide	Moisture Content (%)
Douglas-fir	Yes	3	24.49	.50	.51	14.6
	No	3	14.53	.30	.26	16.4
	Yes	8	29.43	.59	.71	17.7
	No	8	22.77	.46	.33	18.7
W. Hemlock	Yes	3	18.98	.39	.36	18.0
	No	3	8.10	.17	.15	21.5
	Yes	8	22.10	.44	.49	17.1
	No	8	9.66	.19	.16	20.1
W. White Spruce	Yes	3	17.86	.37	.38	18.1
	No	3	8.57	.18	.17	16.5
	Yes	8	20.96	.42	.51	18.0
	No	8	10.93	.22	.23	16.5
Lodgepole Pine	Yes	3	17.66	.36	.30	22.2
	No	3	7.80	.16	.22	22.6
	Yes	8	19.69	.40	.38	20.3
	No	8	10.71	.22	.26	21.1

TABLE IV

Species	Incised	Pressure Period (Hours)		Penetration: Cross Section: Depth of Minimum Face (") *	Penetration: Cross Section: Depth of Maximum Face (") *	Penetration: Cross Section: Percent of Standard	Penetration: Radial: Percent of Standard
Douglas-fir	Yes	3	Average	0.25	0.54	67.1	66.9
			(Range)	(0.00-0.75)	(0.19-0.75)	(40.0-100.0)	(25.0-100.0
	No	3	Average	0.04	0.31	29.9	31.5
			(Range)	(0.00-0.75)	(0.00-0.75)	(0.00-100.0)	(0.0-100.0)
	Yes	8	Average	0.44	0.67	88.3	88.8
			(Range)	(0.05-0.75)	(0.05-0.75)	(35.0-100.0)	(30.0-100.0
	No	8	Average	0.09	0.48	49.1	46.3
			(Range)	(0.00-0.75)	(0.00-0.75)	(2.0-100.0)	(5.0-100.0)
W.Hemlock	Yes	3	Average	0.25	0.39	67.9	69.4
			(Range)	(0.05-0.38)	(0.19-0.50)	(20.0-98.0)	(40.0-95.0)
	No	3	Average	0.01	0.11	9.1	12.0
			(Range)	(0.00-0.06)	(0.00-0.75)	(0.0-65.0)	(0.0-55.0)
	Yes	8	Average	0.22	0.38	70.4	69.4
			(Range)	(0.05-0.38)	(0.19-0.75)	(25.0-98.0)	(25.0-98.0)
	No	8	Average	0.02	0.11	10.1	7.7
			(Range)	(0.00-0.13)	(0.00-0.25)	(2.0-30.0)	(0.0-40.0)
W. White Spruce	Yes	3	Average	0.25	0.52	89.7	90.1
			(Range)	(0.13-0.50)	(0.31-0.75)	(75.0-100.0)	(75.0-100.0
	No	3	Average	0.06	0.33	28.3	22.2
			(Range)	(0.00-0.38)	(0.06-0.75)	(2.0-95.0)	(2.0-95.0)
	Yes	8	Average	0.23	0.49	92.3	94.2
			(Range)	(0.13-0.50)	(0.31-0.75)	(65.0-100.0)	(60.0-100.0
	No	8	Average	0.05	0.28	23.6	26.8
			(Range)	(0.00-0.19)	(0.00-0.75)	(1.0-65.0)	(0.0-80.0)
Lodgepole Pine	Yes	3	Average	0.38	0.54	94.2	94.8
			(Range)	(0.25-0.75)	(0.44-0.75)	(80.0-100.0)	(80.0-100.0
	No	3	Average	0.04	0.20	27.2	46.4
			(Range)	(0.00-0.25)	(0.00-0.75)	(0.0-85.0)	(5.0-100.0)
	Yes	8	Average	0.37	0.56	93.9	95.2
			(Range)	(0.25-0.75)	(0.38-0.75)	(80.0-100.0)	(80.0-100.0
	No	8	Average	0.06	0.41	32.7	53.3
			(Range)	(0.00-0.25)	(0.13-0.75)	(5.0-70.0)	(5.0-100.0)

* Value of .75" indicates penetration of .75" or greater.

TABLE V

Species	Incised	Pressure Period (Hours)		Penetration — Twenty Random Core Borings: Depth (")	Number Meeting .40" Standard	Percent Meeting Standard
Douglas-fir	Yes	3	Average	0.46	15/20	75.0
			(Range)	(0.20-0.75)		
	No	3	Average	0.19	5/20	25.0
			(Range)	(0.02-0.70		
	Yes	8	Average	0.60	17/20	85.0
			(Range)	(0.30-0.75)		
	No	8	Average	0.20	3/20	15.0
			(Range)	(0.02-0.61)		
W.Hemlock	Yes	3	Average	0.41	14/20	70.0
			(Range)	(0.29-0.55)		
	No	3	Average	0.13	1/20	5.0
			(Range)	(0.05-0.50)		
	Yes	8	Average	0.43	15/20	75.0
			(Range)	(0.25-0.62)		
	No	8	Average	0.07	0/20	0.0
			(Range)	(0.02-0.20)		
W. White Spruce	Yes	3	Average	0.44	15/20	75.0
			(Range)	(0.30-0.75)		
	No	3	Average	0.12	1/20	5.0
			(Range)	(0.02-0.42)		
	Yes	8	Average	0.47	19/20	95.0
			(Range)	(0.35-0.62)		
	No	8	Average	0.20	4/20	20.0
			(Range)	(0.05-0.58)		
Lodgepole Pine	Yes	3	Average	0.43	13/20	65.0
			(Range)	(0.22-0.75)		
	No	3	Average	0.28	8/20	40.0
			(Range)	(0.02-0.75)		
	Yes	8	Average	0.46	16/20	80.0
			(Range)	(0.31-0.75)		
	No	8	Average	0.30	6/20	30.0
			(Range)	(0.04-0.75)		

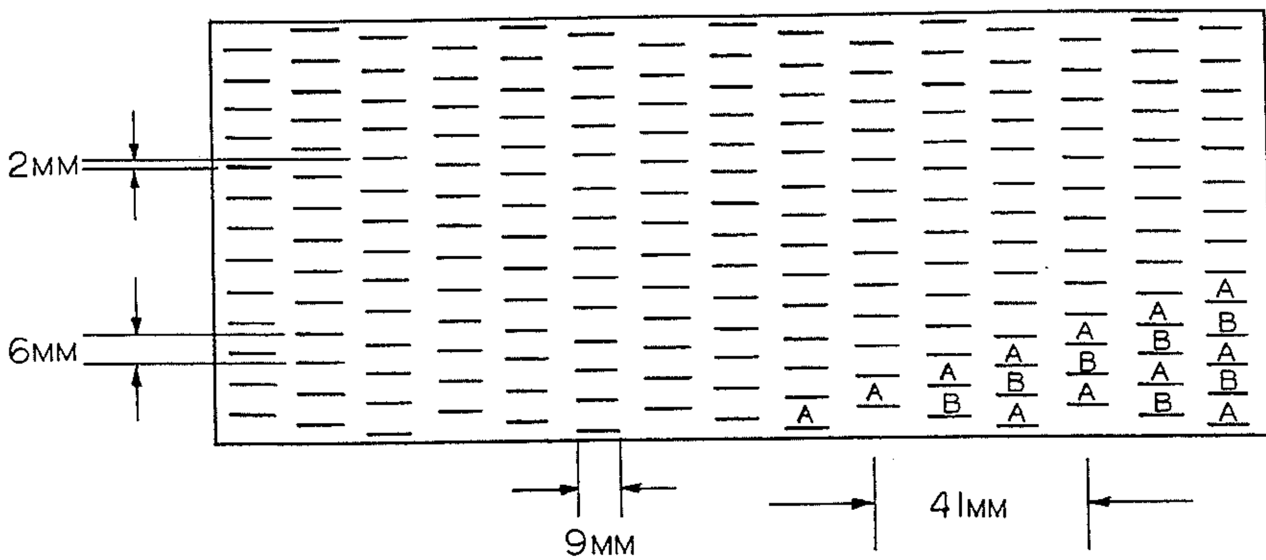

FIGURE 1. THE DOUBLE-DENSITY INCISING PATTERN. INCISIONS LABELED "A" AND "B" WERE MADE BY THE FIRST AND SECOND ROLLERS, RESPECTIVELY (7).

Figure 2.

DIAGRAM A - PENETRATION EVALUATION

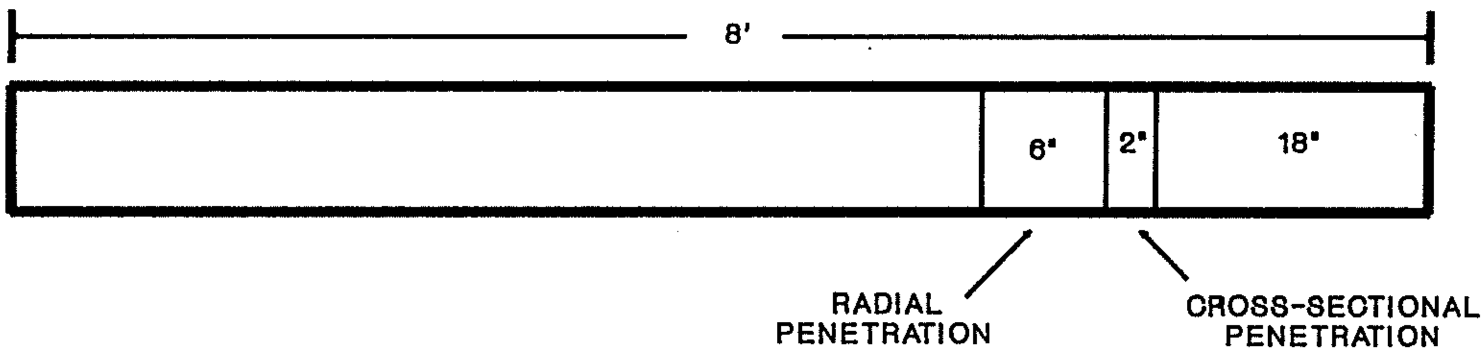

DIAGRAM B - PENETRATION EVALUATION AND FIELD PERFORMANCE

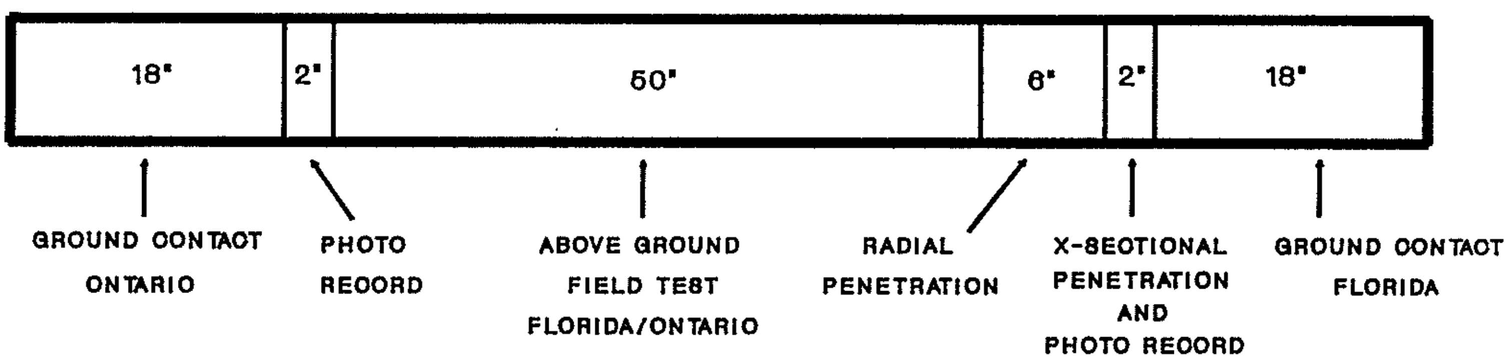

Figure 3

Influence of Double Density Incising and Pressure Period on Solution Retention

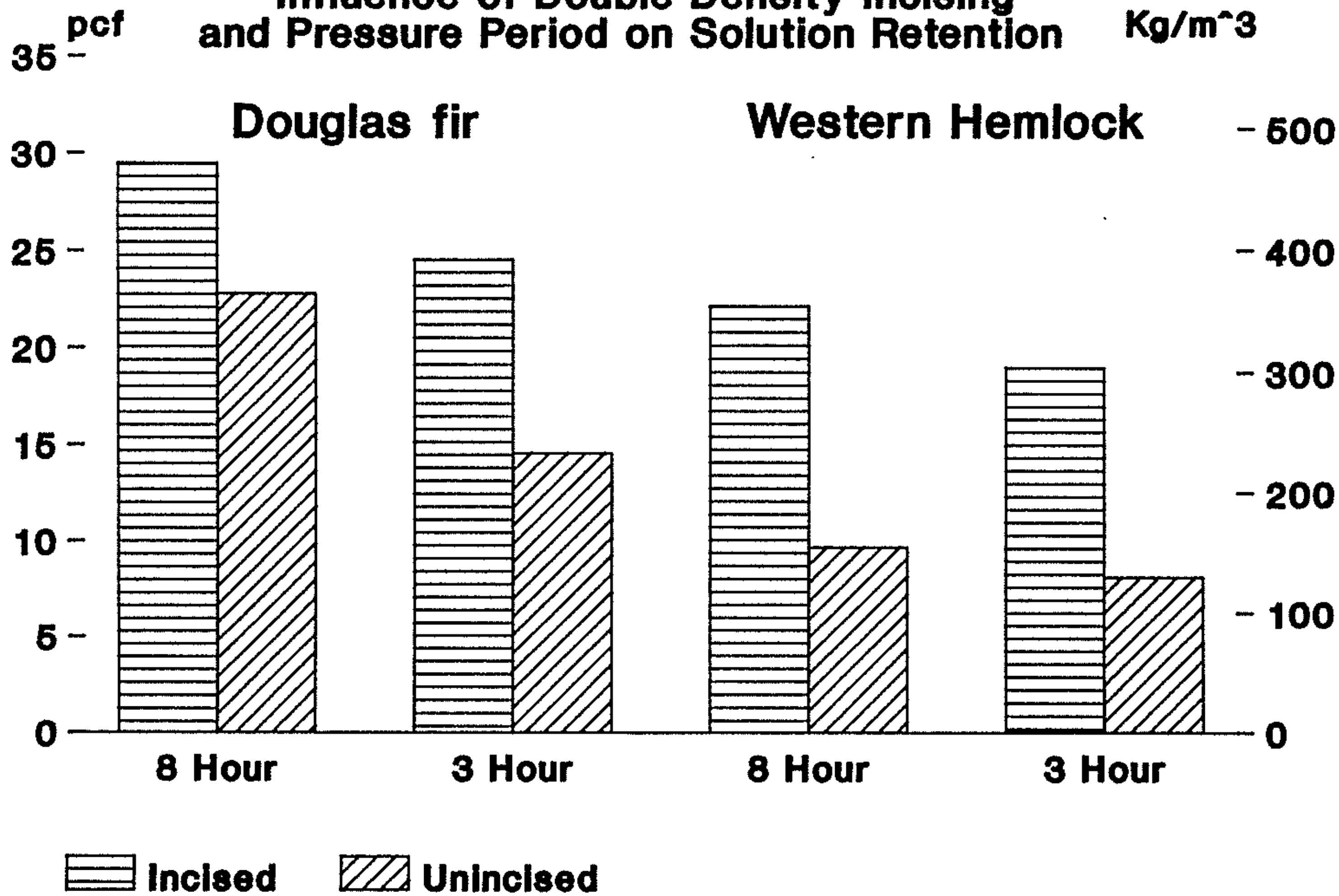

Figure 4

Influence of Double Density Incising and Pressure Period on Solution Retention

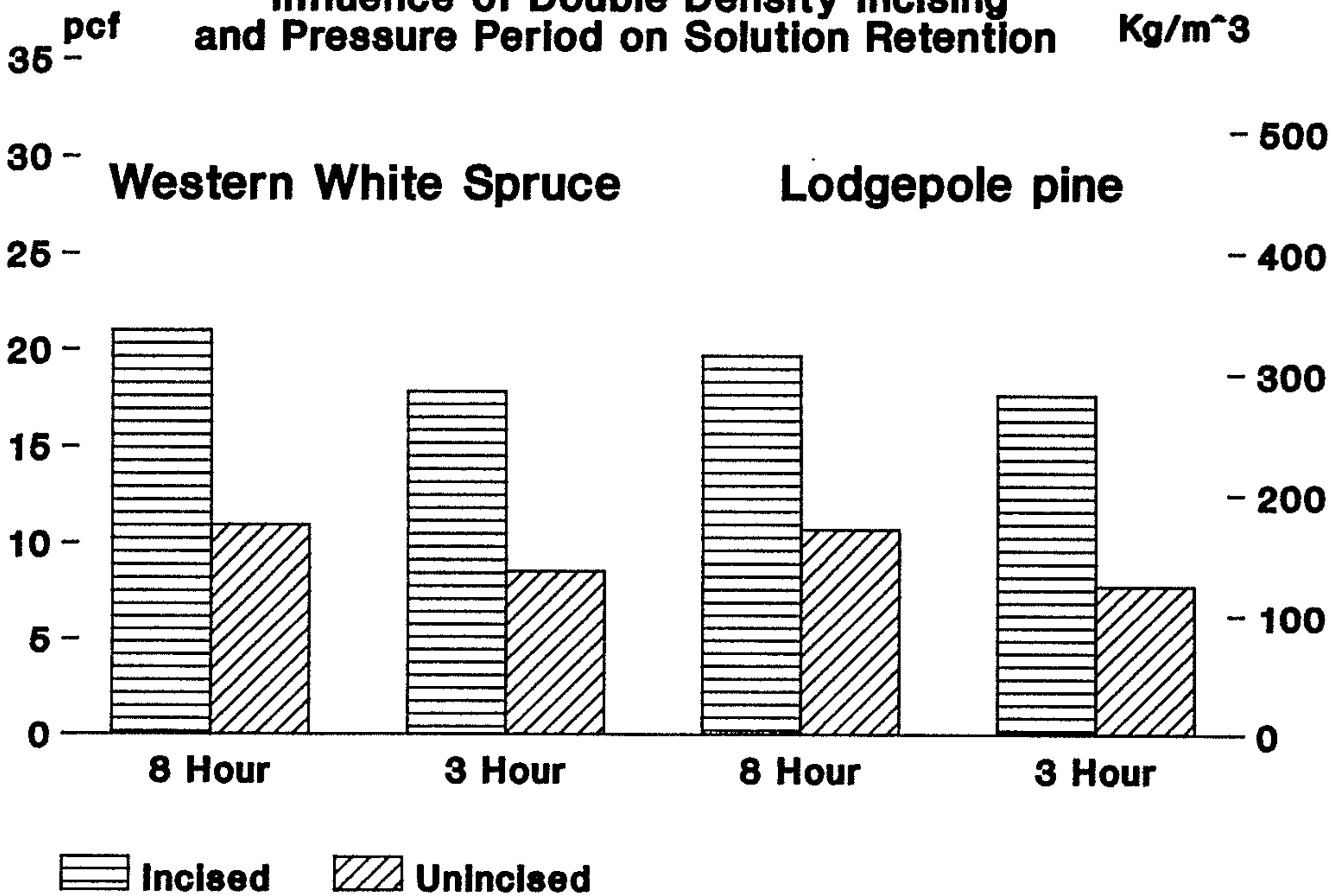

Figure 5: Douglas fir

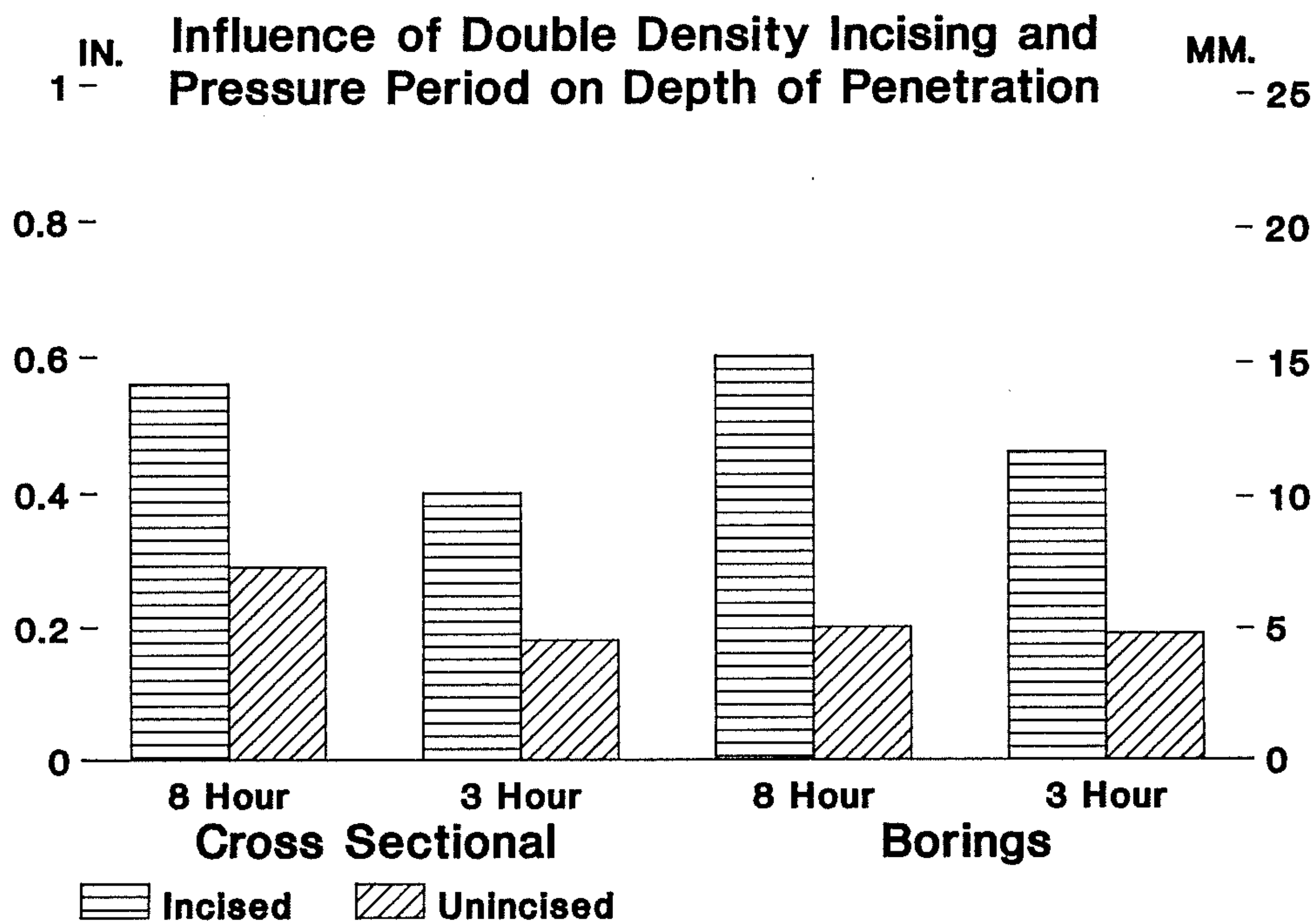

Figure 6: Douglas fir

Influence of Double Density Incising and Pressure Period on Standards Conformance

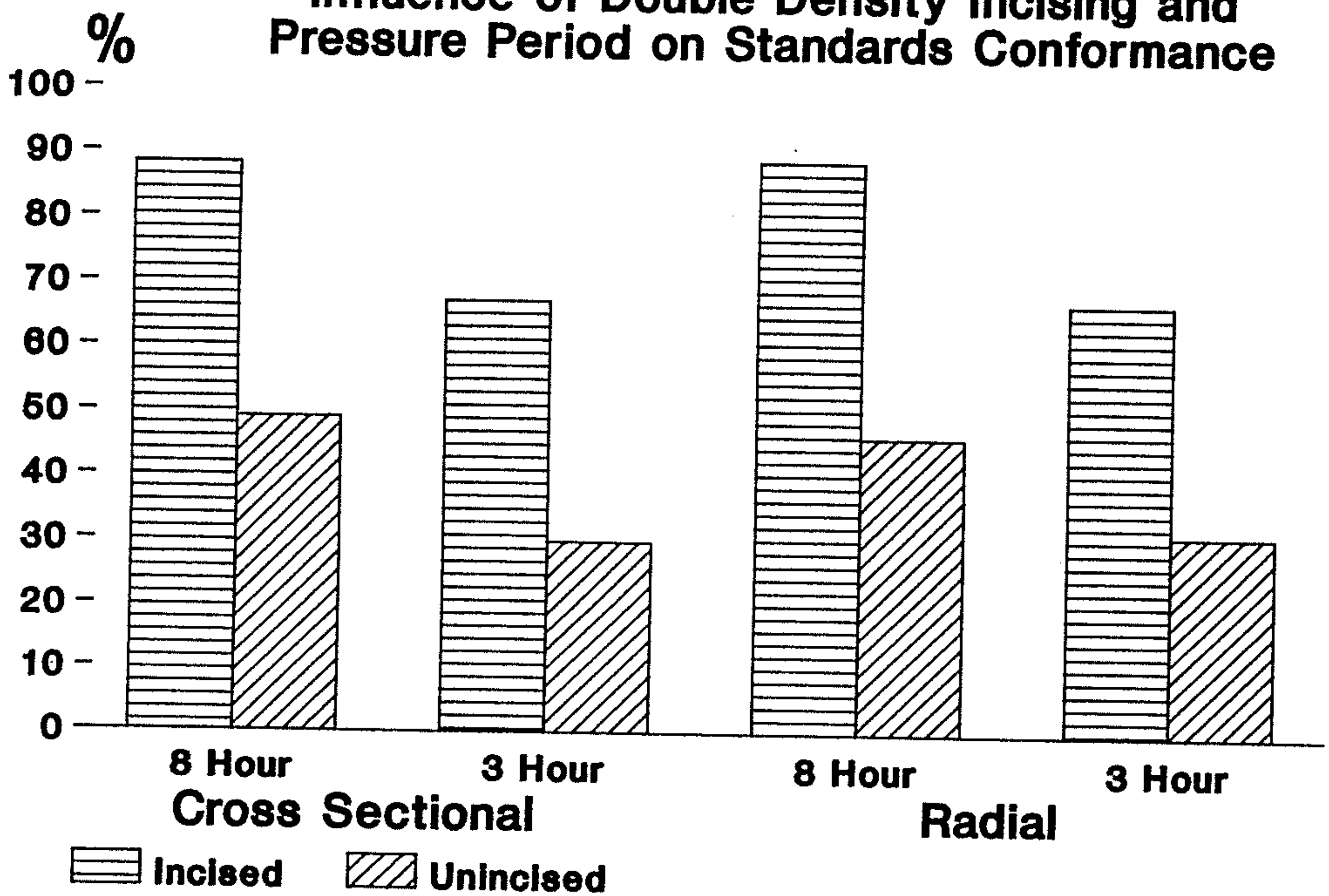

Figure 7: Western hemlock

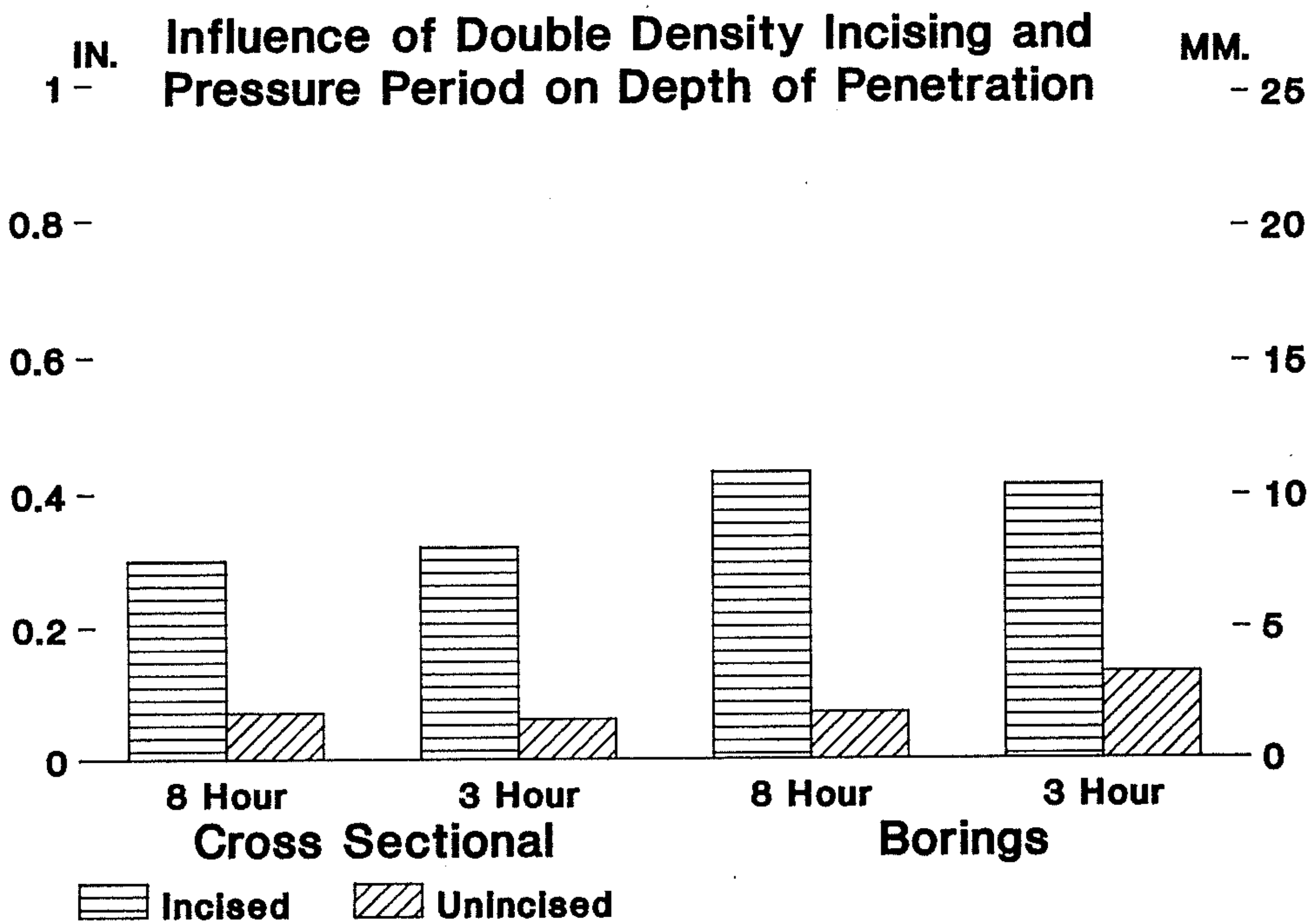

Figure 8: Western hemlock

Influence of Double Density Incising and Pressure Period on Standards Conformance

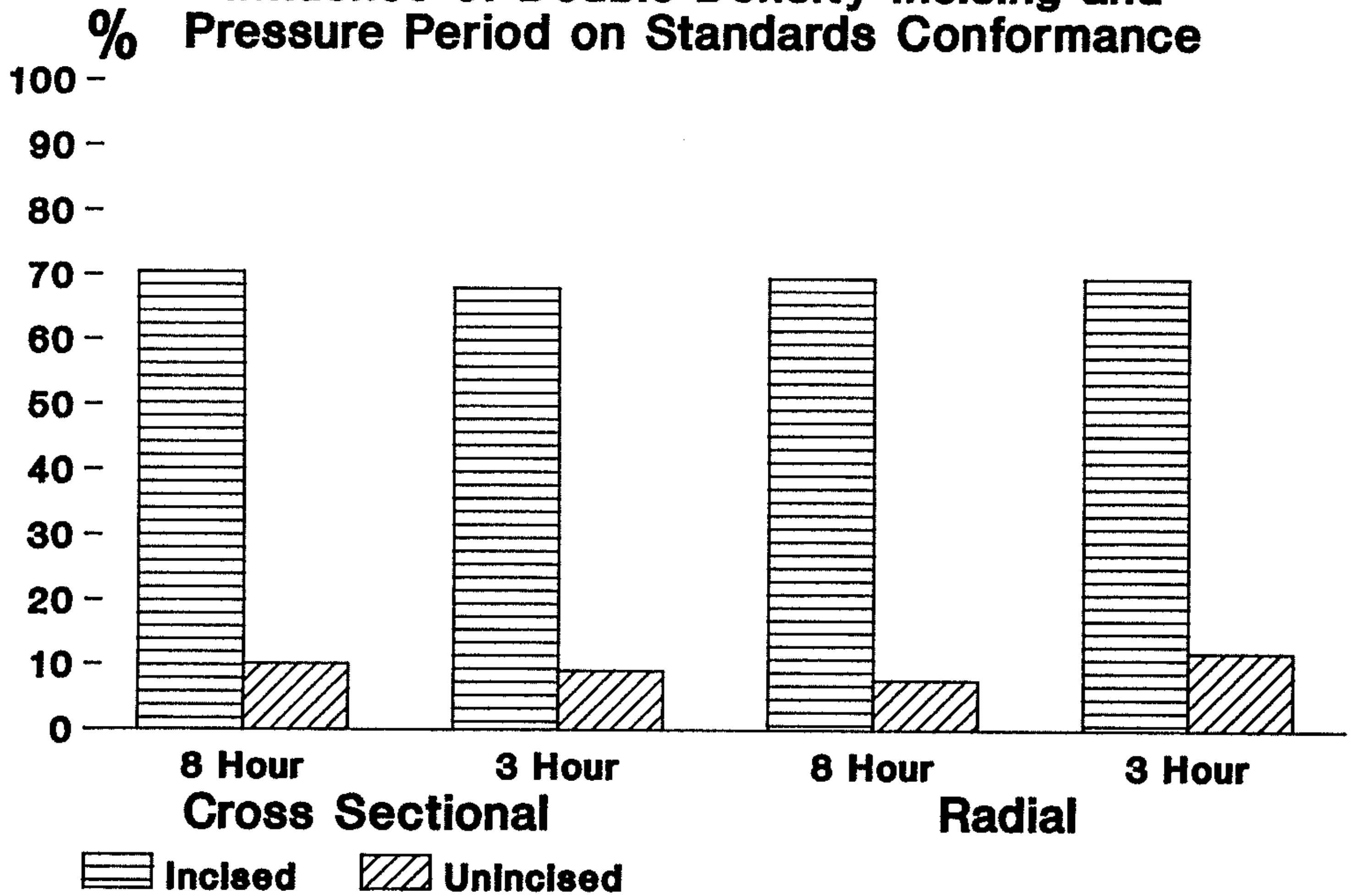

Figure 9: Western white spruce

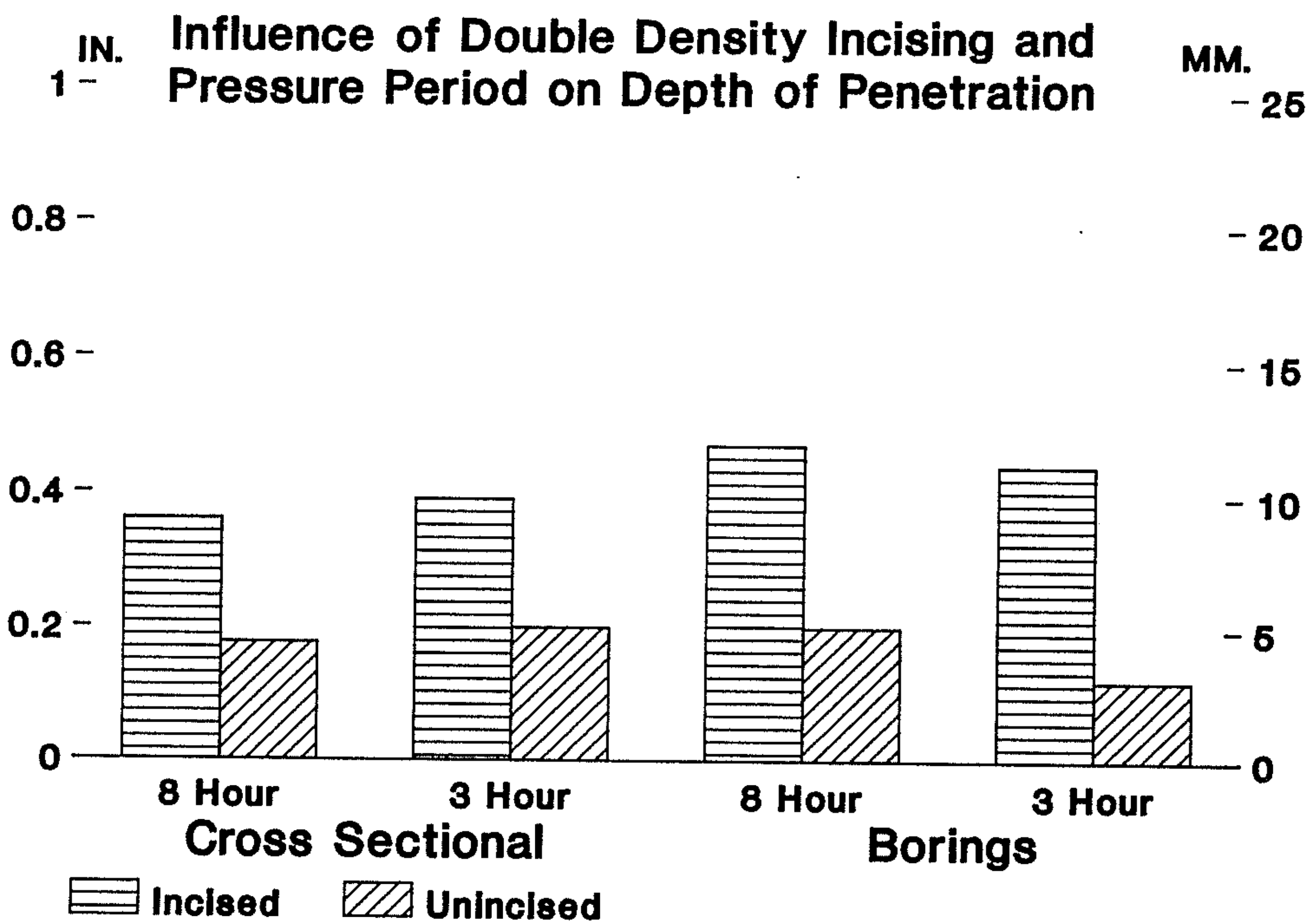

Figure 10: Western white spruce

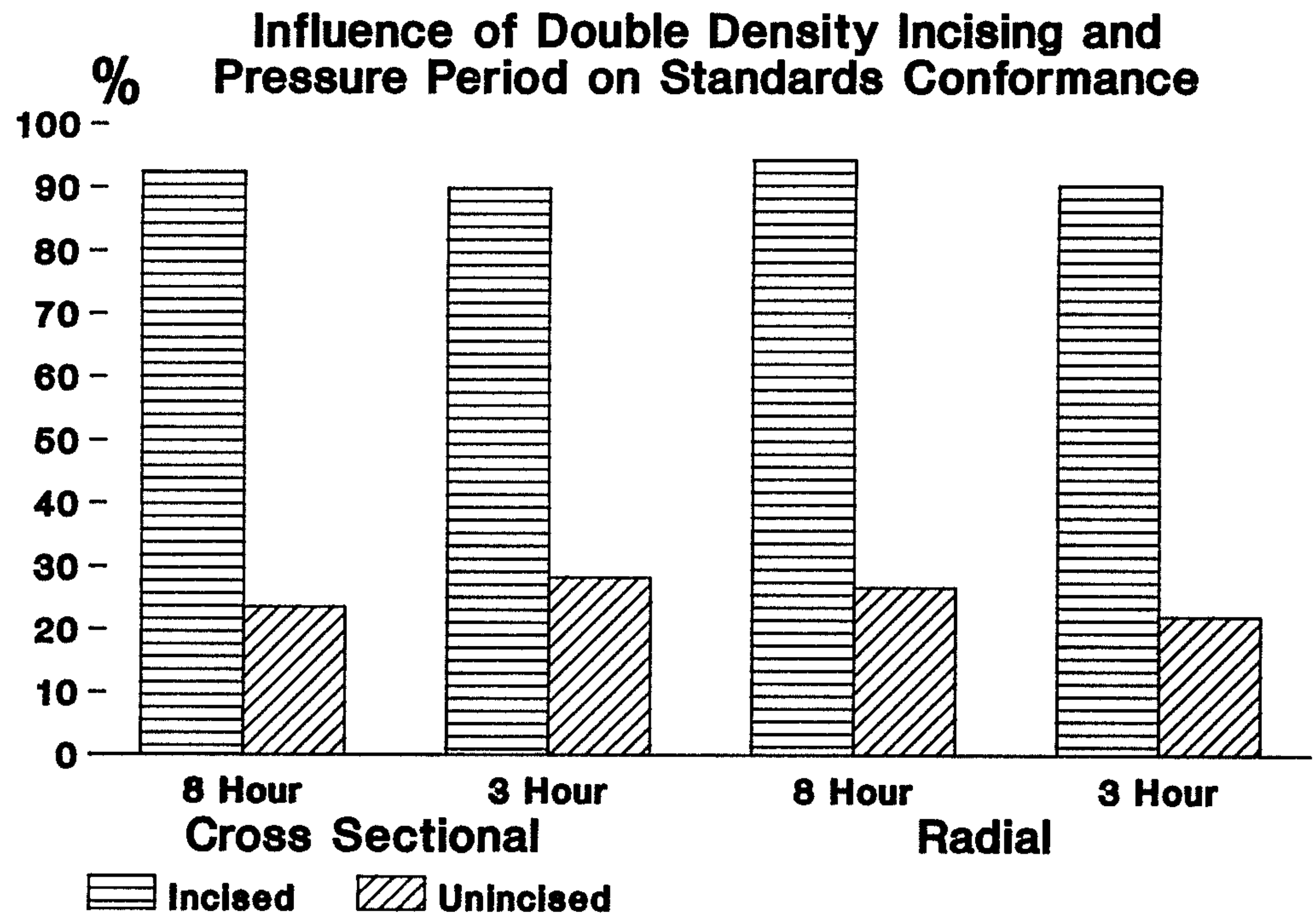

Figure 11: Lodgepole Pine

Influence of Double Density Incising and Pressure Period on Depth of Penetration

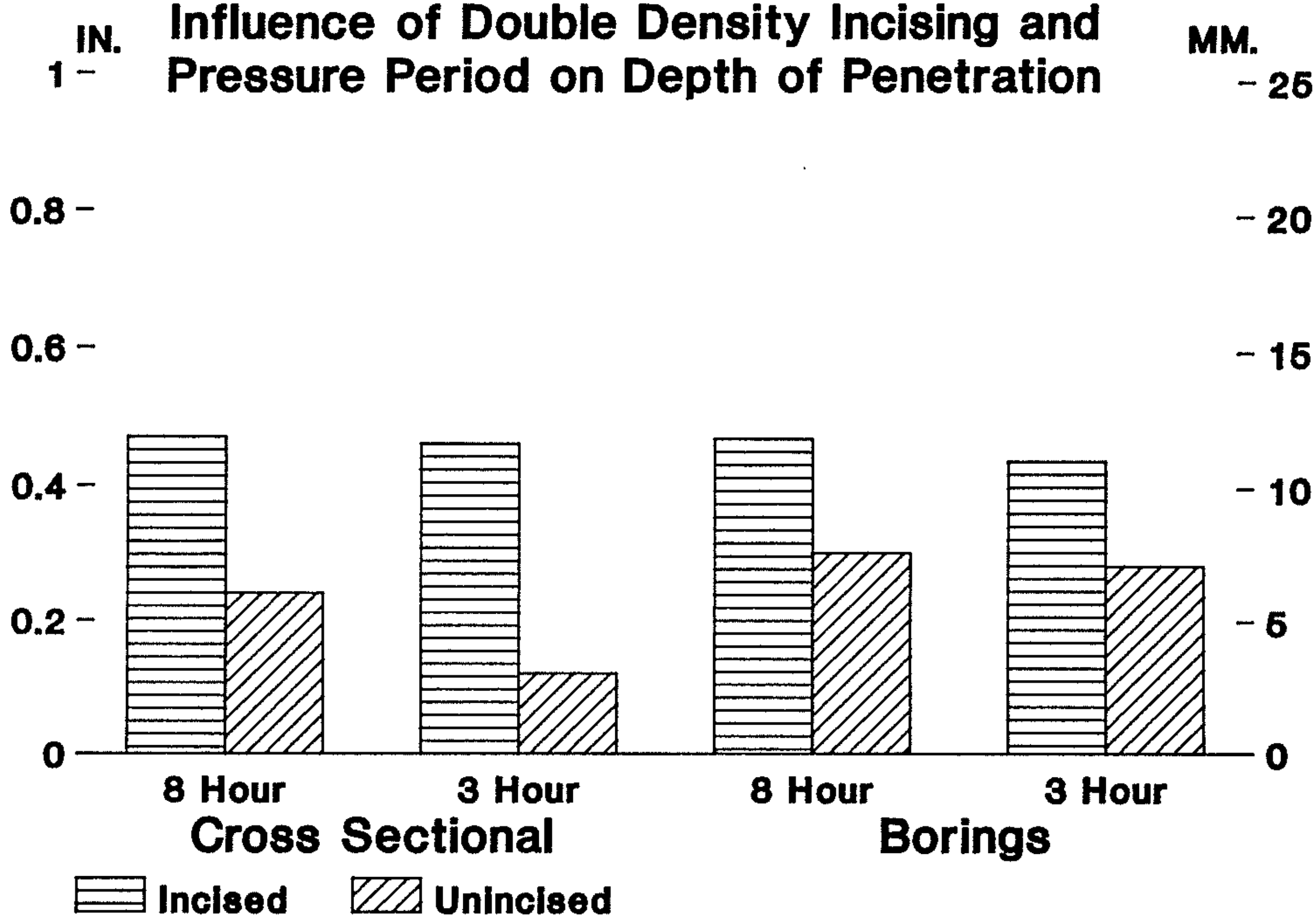

Figure 12: Lodgepole pine

Influence of Double Density Incising and Pressure Period on Standards Conformance