IDENTIFICATION AND EVALUATION OF ASPEN DECAY AND STAIN IN CTMP PULPING

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ABSTRACT

Refiner mechanical pulping (RMP) was conducted on samples from Alberta of sound aspen and aspen decayed by the fungi *Phellinus tremulae* and *Peniophora polygonia*. All chips produced were used unscreened. Chips from aspen contained from 40 to 90% decay estimated by volume. The resulting RMP pulps were brightened with 1, 3, 5 and 7% H_2O_2 and the strength of the 7% H_2O_2-treated pulps were determined. Insufficient numbers of samples were available to show any trends other than that the pulp from the sample decayed (90% by volume) by *Phellinus tremulae* had lower brightness and strength parameters and a greater consumption of H_2O_2 than the other pulps.

ACKNOWLEDGEMENTS

Special thanks to S.S. Johal for his technical contribution to this study. I also thank P. Eng for his photographic work. Thanks to Y. Hirasuka, Forestry Canada, and the Alberta Forest Service for the aspen samples.

Keywords: aspen, Phellinus tremulae, Peniophora polygonia, RMP, hydrogen peroxide, brightness.

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INTRODUCTION

Decayed wood contains the highly coloured materials derived from fungal metabolism which are hard to remove or to bleach. Aspen tends to develop decay at a very early age, particularly in the heartwood. If the extended use of the *Populus* species present in Alberta for mechanical pulps is desirable, research is essential to determine the chemical characteristics of these coloured compounds and find means to negate their effects on the final pulp brightness. Quantification of the effects of the stain/decay on bleaching and pulp strength properties would be of great value to mechanical pulp producers using stained and decayed aspen. More importantly, the effects should be measured quantitatively on the basis of the well defined decays identified by the Alberta Forest Service (AFS) defect scheme (Hirasuka et al. 1990). The defect types are as follows:

Type	Cause of Decay	Defect
A	*Phellinus tremulae* (most prevalent decay fungus of aspen)	Wood friable
B	*Armillaria spp.* root rot	Wood stringy
C	*Peniophora polygonia*	Wood firm
D	Variety of agents (fungi, bacteria etc.)	Wood firm
E	Blue stain fungi which affect the sapwood only after felling	Wood firm

The previous work on the mechanical pulping of decayed and stained aspen (Becker and Briggs 1983; Jackson et al. 1985; Whitty et al. 1991) was mainly carried out on unidentified decays, the results of which are difficult to reproduce. Their results indicated that the presence of stain or decay in the aspen chips had an adverse effect on yield, brightness, strength and drainage of the resulting mechanical pulps. Recently a report (Araki and Lee 1991) on aspen decayed by *Peniophora polygonia* (Type C defect) indicated an increase in rejects during chip screening. A substantially increased amount of hydrogen peroxide was required to bleach pulps from the decayed aspen to the same brightness level as pulps from sound aspen.

The focus of this project is to provide complete information regarding the effects of decay and stain on yield, optical and strength properties of mechanical pulps produced from aspen wood. This information is needed to improve the current mechanical pulping processes and to produce better quality pulps at lower cost.

OBJECTIVES

1. To characterize the coloured compound(s) resulting from stain or decay in aspen and/or balsam poplar wood.

2. To find biological or chemical treatments to mitigate the effects of stain and decay on the brightness of mechanical pulps made from these woods.

3. To determine the effect of using stained and decayed wood on the bleaching and strength properties of the resulting pulps.

EXPERIMENTAL

Sample and Preparation

Ten bolts of trembling aspen (*Populus tremuloides*) wood from defect categories A and C as defined by the AFS (Hirasuka et al. 1990) and sound wood bolts were received from Alberta. The logs, ≈1.3 m long, were stored in the freezer until used. The bark from all samples was removed and two 2.5-3 cm thick discs were cut from both ends of each bolt. Average outside diameters of the bolts and the inner decay or stain core diameters at both ends of the bolts were measured. These data were used to estimate the total volume of decay/stain in each bolt. The bolts were then cut lengthwise into halves using a bandsaw. The cut bolts and discs were photographed (see Appendix 1). The halved bolts were then chipped in a six-knife chipper. The unscreened chips were thoroughly mixed and kept frozen until refined. The two sound bolts (W 92-10 and W 92-4) were chipped and mixed together as a single sample (W92-104).

Mechanical Pulping

The six chip mixtures were refined using multiple passes (2-4) in a laboratory Sprout Waldron 30 cm open discharge refiner to two levels of freeness, ≈ 200 and ≈ 100 mL, using plate type D2A507. The solids content of the chips ranged from 59 to 70% od wood. The refiner plate gap for the first pass was maintained at 0.51 mm while for subsequent passes the plate gap was adjusted from 0.08 to 0.25 mm to achieve the desired pulp freeness. The consistencies ranged from 13 to 18% and the refining temperatures from 90 to 96°C.

Pulp Brightening

The pulps were treated with 0.3% DTPA od pulp at 1% consistency and then pressed to 25% consistency before the peroxide stage. Silicate, 3.0% od pulp, followed by $MgSO_4$, 0.5% od pulp, was added before the addition of hydrogen peroxide 1, 3, 5 and 7% od pulp. Sodium hydroxide charges were 0.8, 2.8, 4.6 and 5.2% od pulp corresponding to the increasing peroxide charges. The peroxide stage was performed at 65°C for 100 minutes at 12% consistency. Final pH values were 7.7-8.0 for 1%, 7.5-7.9 for 3%, 8.5-9.6 for 5% and 9.7-10.4 for 7% peroxide charges od pulp. Peroxide consumptions and pulp brightnesses were determined after each bleaching test.

Pulp Physical and Optical Properties

All pulps had latency removed. Handsheets were made with white water recycle. The optical and physical properties of the unbleached pulps and pulps bleached with 7% peroxide od pulp were determined using standard CPPA methods for bulk, tear index, burst index, tensile index, brightness and scattering coefficient.

RESULTS AND DISCUSSION

The samples of decayed aspen (Table 1[1]) used in this study represent only two of the five defect classes as envisioned in the AFS classification, namely, Type A and Type C defects. All bolts were treated separately in order to encompass as wide a range of decay stages as possible. The fines and pin chips which could come from the most friable decayed material were not removed so that the worst case scenerio was studied. MacLeod et al. 1982, have shown that the "Paprifer" process can upgrade decayed aspen chips for kraft pulp production by removing the fines which largely constituted the badly decayed and friable material (Samples W 92-1 and W 92-9). The effect of the removal of the fines from the chips will be determined in subsequent investigations.

The required specific refining energies (SRE) at a given freeness for samples W 92-6, W 92-7, and W 92-9 are similar as listed in Table 2[1] and shown in Figure 1[2]. Samples W 92-8 and W 92-104 also have a similar relationship between SRE and freeness as shown in Figure 1. Sample W 92-1 contains the greatest amount of friable decay, Type A, and requires the least refining energy at a given freeness level as listed in Table 3[1].

Substantial brightness gains were achieved at relatively low peroxide consumptions as given in Table 4[1], particularly when the consumption was less than 2% peroxide od pulp. Brightness gains vary with different types and degrees of decay as in Figure 2[2]. For example, at about 2% peroxide consumed on od pulp, the brightness of all bleached pulps differed about four ISO units except for the W 92-1 pulp which showed a brightness of twelve ISO units less than the other pulps. The difference in brightness due to decays substantially decreased when the peroxide consumption was greater than 2% od pulp, except for samples W 92-1 and W 92-7. The bleached pulp from sample W 92-1 under the conditions employed never achieved 80% ISO brightness, which is considered minimum brightness for BCTMP market pulps, despite the large amount of peroxide consumed.

Pulps produced from decayed and stained aspen wood require additional bleaching chemical to remove the coloured matter. The estimated chemical cost for the W 92-7 pulp sample can be as high as $28.50/adt pulp over that for W 92-104 pulp at 80% ISO brightness as illustrated in Table 5[1]. The pulps from samples W 92-6, W 92-9, and W 92-8 required an additional $5.00, $6.50, and $19.00 chemical costs over the sound sample pulp. The cost of silicate, $MgSO_4$, and DTPA are the same for all pulps at $12.22/adt.

The mechanical properties of the twelve unbleached and six 7% hydrogen peroxide-bleached RMP pulps are presented in Tables 6[1] and 7[1] respectively. Plots of tear and tensile indexes vs. Canadian standard freeness (Csf), in mL, for the unbleached pulps are presented in Figures 3[2] and 4[2] respectively. The plots show a general trend for the tear index to increase slightly or remain

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[1]In Appendix 2.

[2]In Appendix 3.

unchanged and the tensile index to increase substantially as the Csf decreases. There are appreciable differences in tear and tensile strengths at the same Csf values for different decays and decay stages of bleached and unbleached pulps. The unbleached pulps from the sound aspen, sample, W 92-104, are consistently lower in mechanical strength than some of the pulps from the decayed or stained woods. The action of the fungal systems on the woods may have removed some lignin or in some way altered the fibres to be more collapsible or hydrophilic and, therefore, resulted in better bonding.

The mechanical strengths of the bleached pulps (Table 7[1]) were improved considerably over those of the corresponding unbleached pulps. The sound sample, W 92-104, displayed strength values in the middle of the range for all the decayed pulps tested, while the sample W 92-1 exhibited the lowest mechanical strength values of all the samples. Removal of the small sized material consisting of the most decayed and friable material would likely improve the results.

In general, when working with biological materials a sufficient number of samples are needed to overcome natural variability. It is premature to generalize on the effect of these defect types until several more samples of each type have been examined. Of the three samples of Type C defect, the order of decay appears to be W 92-8 < W 92-6 < W 92-7 based on strength parameters. Examination of the photos in Appendix 1 confirms that W 92-7 visually appears to be the most decayed.

The presence of 50-90% decay/stain by volume in the mill chip furnish is unlikely and the consequences of using 15-30% decay/stain by volume encountered in current industrial operations would be considerably less than in this study.

CONCLUSIONS

1. Advanced decay caused by *Phellinus tremulae* as exemplified by sample W 92-1 renders the fibre source unsuitable for mechanical pulps. Decay caused by *Peniophora polygonia* can be tolerated, but at a high bleaching chemical cost. The three pulp samples W 92-6, W 92-7 and W 92-8 produced from decayed aspen cost $6.50, $29 and $19/adt respectively over that of the sound wood to reach 80% ISO brightness, which is the minimum brightness required for bleached mechanical pulps.

2. The results of the strength tests on these single samples indicate that a larger number of samples will be required to counteract the sample variability so that meaningful conclusions can be drawn in reference to different decays and decay stages. This would best be determined by sampling from a single clone where sample difference is virtually eliminated.

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[1]In Appendix 2.

Future Research Work

Future sampling of the sound and defect Types A-E aspen wood should ensure that sufficient material is collected so that TMP/CTMP pulps can be made from each defect category. The amount of sample should include the possibility that different chemicals and chemical dosages will be tried to effect optimum conditions. The percentage of decay/stain for each sample should be kept to the value most frequently encountered in mills. Large numbers of samples should be available to compensate for the wide sample variations known for biological samples. Samples from a single clone would alleviate the variability problem.

Extractions with water and some organic solvents will be carried out on comminuted wood from the different defect types in an attempt to isolate the materials responsible for colouring the stained and decayed wood. Chemical treatments to the extracts will be carried out using a reducing agent, $NaBH_4$ and the oxidants, monoperoxysulphuric acid, dimethyldioxirane and H_2O_2. The chemical reactions will be characterized by IR, UV, GC/MS and NMR analysis in order to gain some insight into the changes of chemical composition of the colouring materials by the chemical treatments. Chemical treatments will be proposed for use in combination with the conventional bleaching process. The effects of fines and pin chips from decayed aspen wood on bleachability and mechanical strength of the pulps will be examined. General chemical analyses of the sound and decayed/stained woods for total extractives, lignin, 1% caustic extractive and sugar contents will be performed and compared with those from the literature (Antal and Micko 1992).

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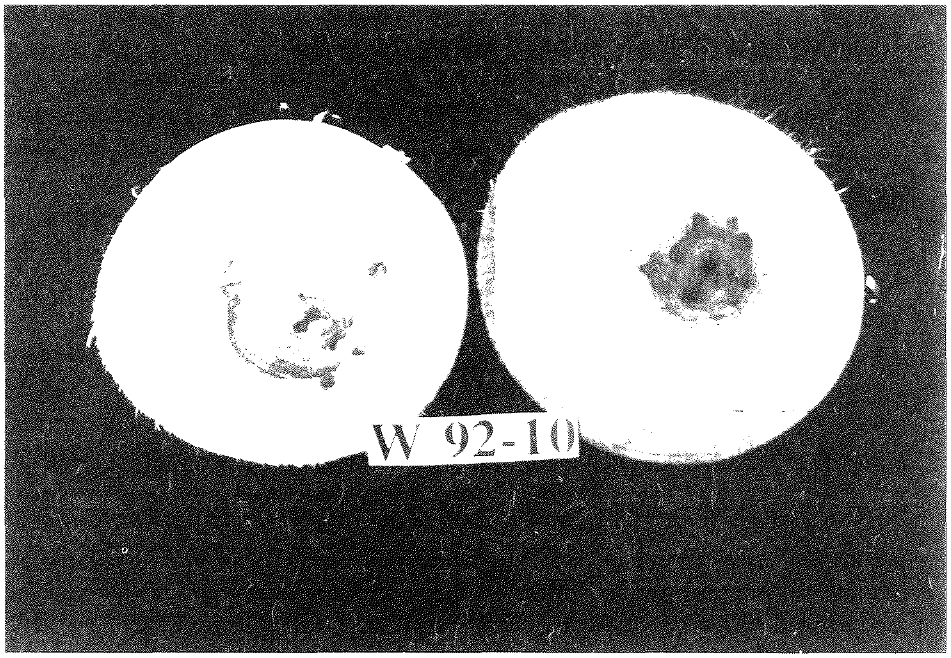
APPENDIX 1

Photographs of discs and split bolts of sound and decayed aspen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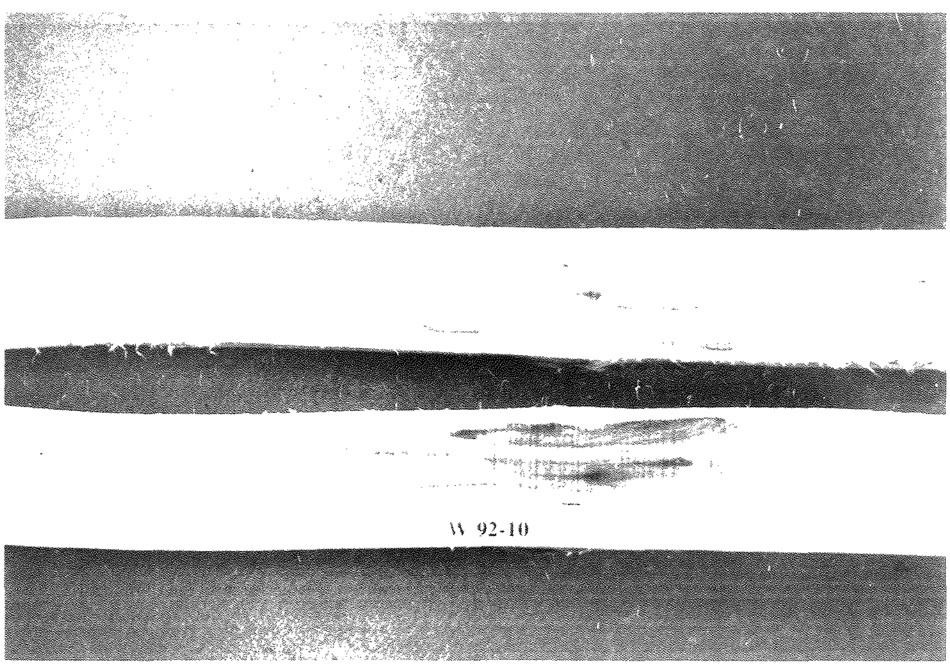
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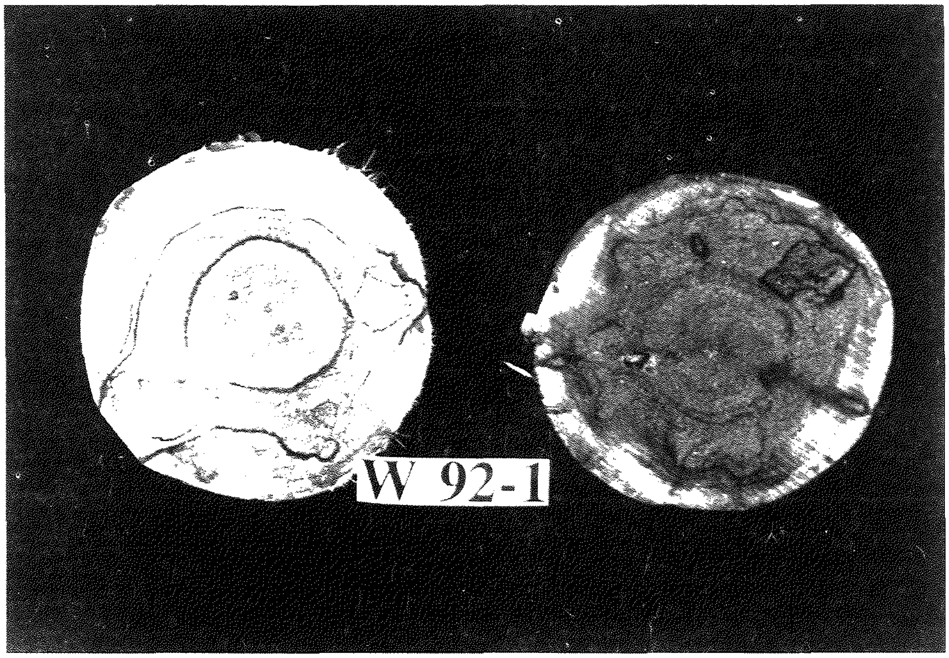
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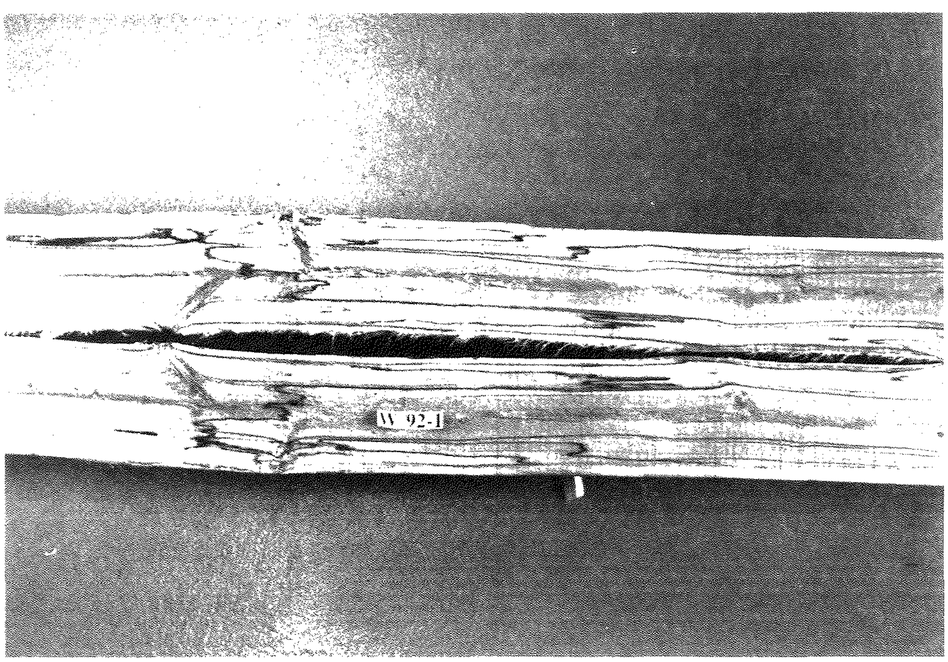
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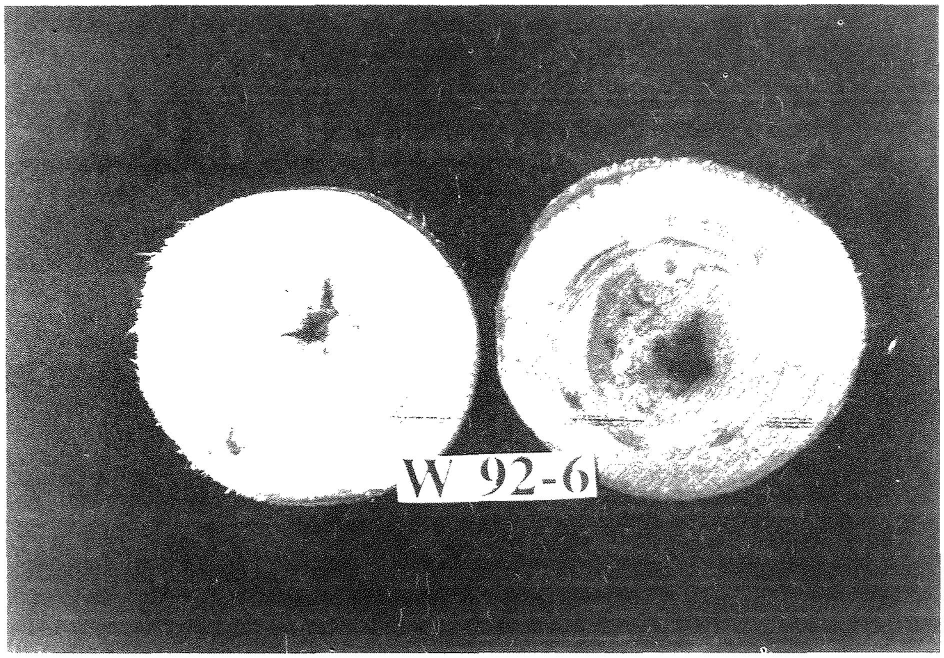
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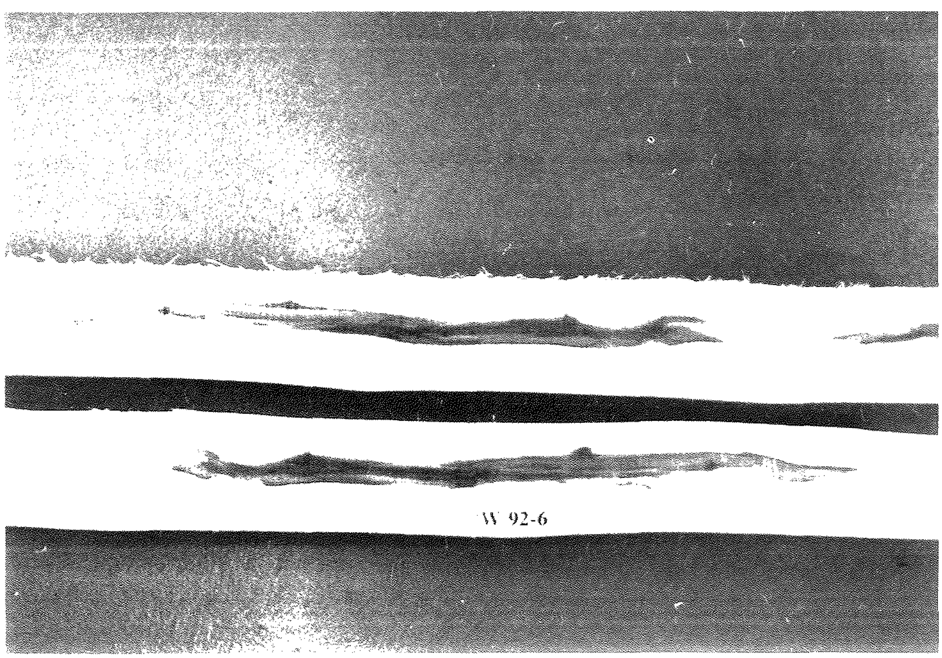
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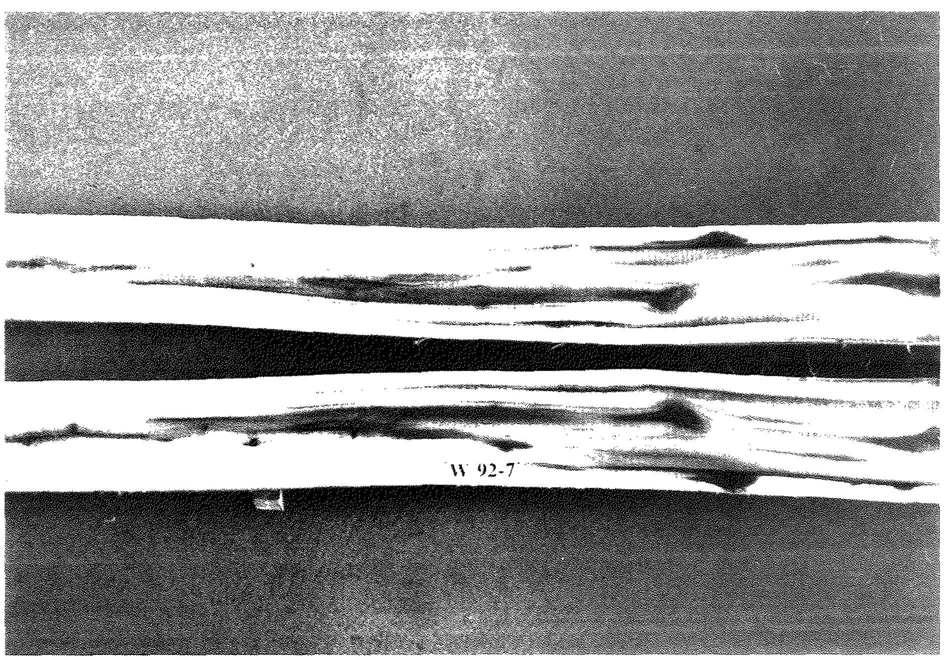
W 92-7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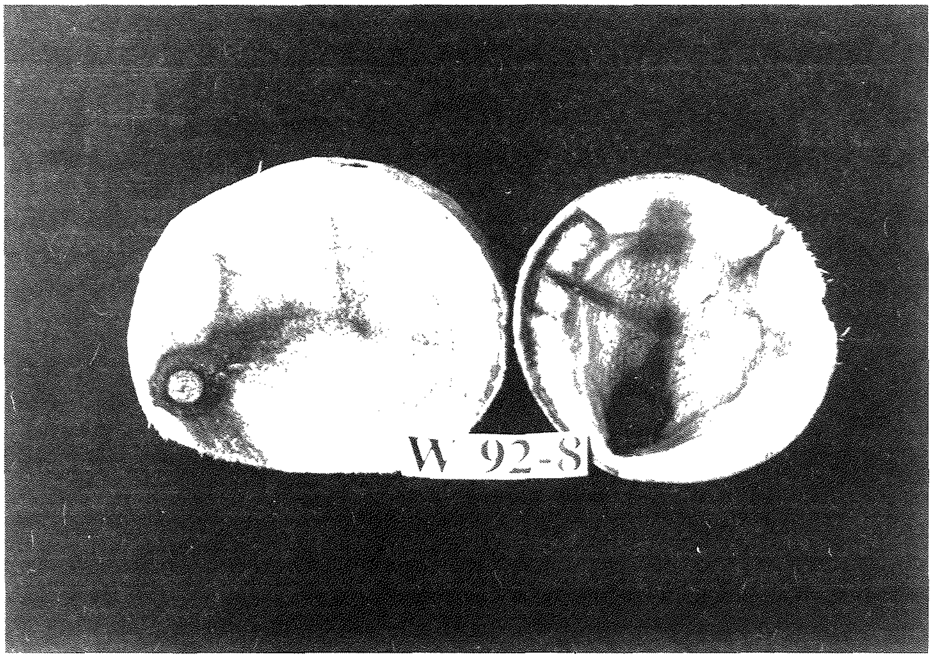
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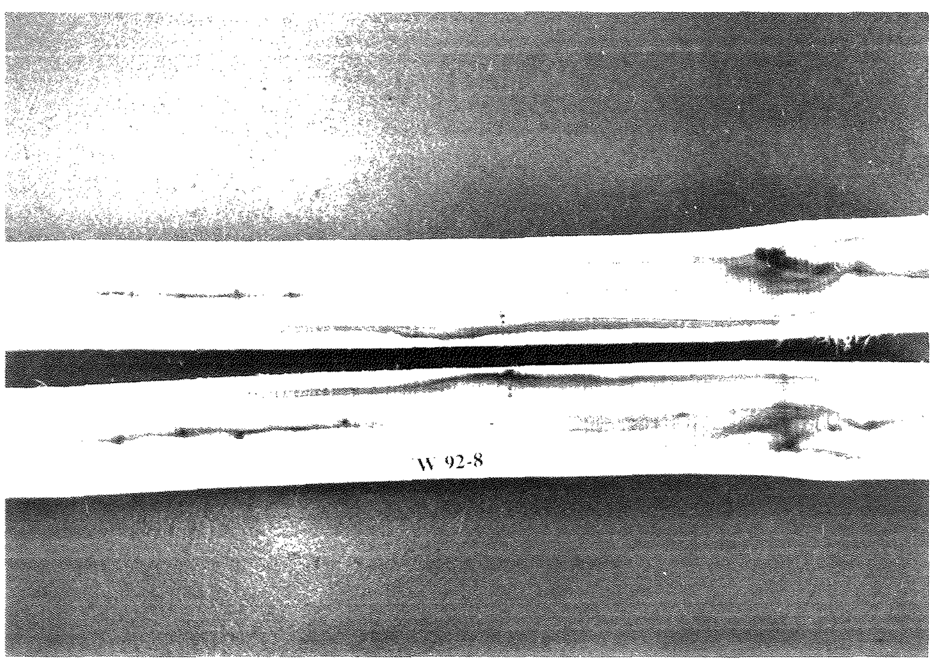
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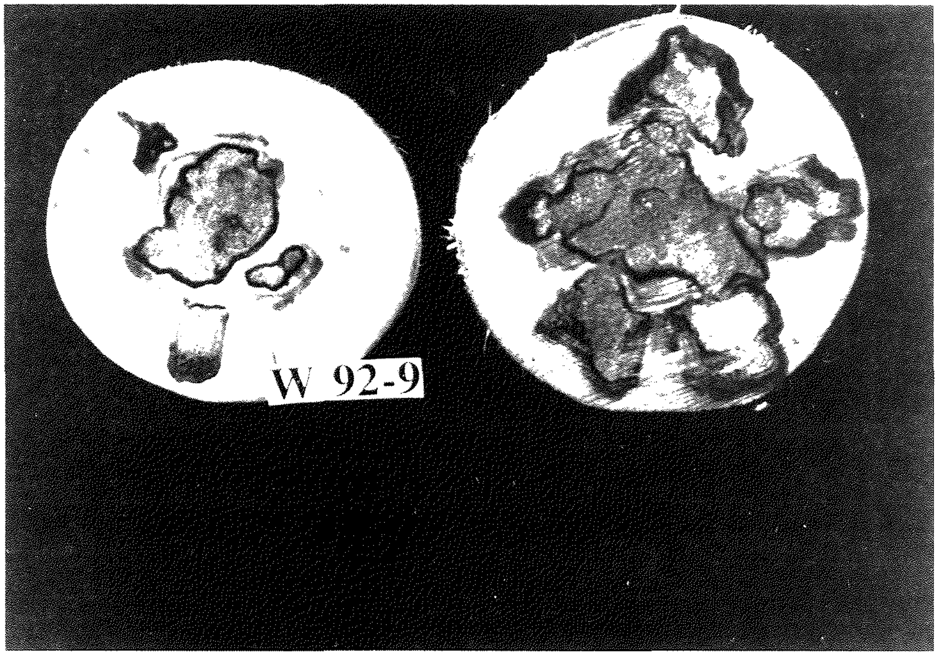
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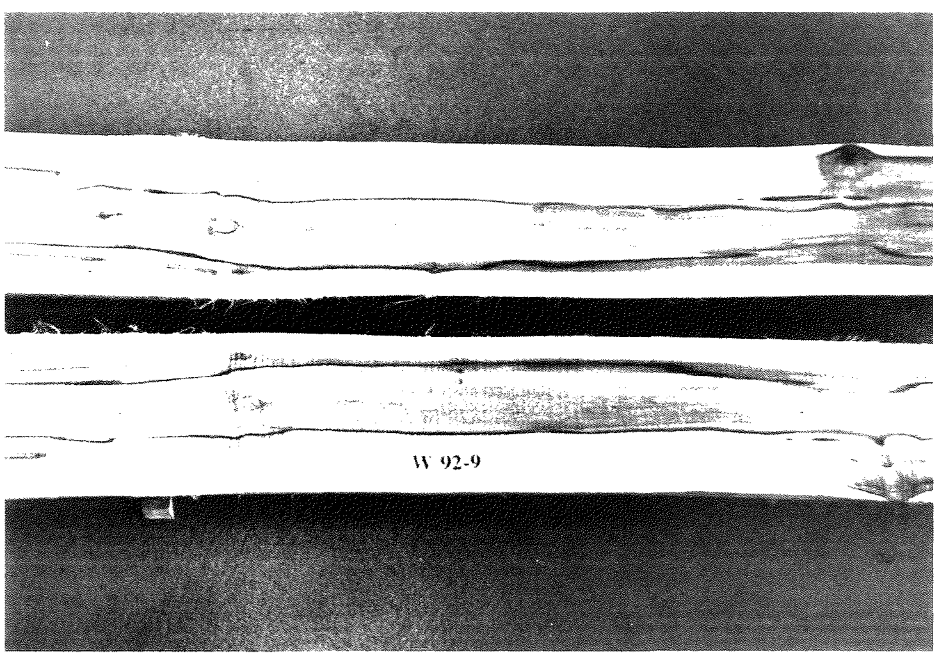
W 92-9

APPENDIX 2

Tables

Table 1. Decay/Stain Cores Diameters and Total Decay/Stain Volumes for Aspen Bolts.

Tree No.	Defect Type[1]	Av. Dia. (cm)	Av. Dia. Decay[2] Core (cm)	Decay[2], Vol. Basis (%)	Green Chips (kg)
W 92-1	A	15.5	14.5	87.5	13.20
W 92-6	C	13.0	9.0	48.0	14.85
W 92-7	C	15.5	10.5	46.0	15.15
W 92-8	C	14.0	10.0	51.0	14.30
W 92-9	A	22.0	15.0	46.5	31.05
W 92-4	Sound	9.0	0.0	0.0	[3]
W 92-10	Sound	17.5	7.0	16.0	27.55

[1] A denotes decay by *Phellinus tremulae* and C by *Peniophora polygonia.*
[2] Decay refers to both decay and stain.
[3] Combined with W 92-10 as a single sample.

Table 2. Specific Refining Energies (SRE) for Aspen RMP Pulps at Various Freeness Levels.

Tree No.	Defect Type	Specific Refining Energy (MJ/kg)				Csf (mL)			
		1[1]	2[2]	3[3]	4[3]	1[1]	2[2]	3[3]	4[3]
W 92-104	Sound	7.0	9.5	-	-	223.0	115.0	-	-
W 92-1	A	6.5	9.0	7.9	-	190.0	95.0	135.0	-
W 92-6	C	8.1	11.0	9.8	-	213.0	103.0	128.0	-
W 92-7	C	8.7	10.9	8.2	-	193.0	120.0	225.0	-
W 92-8	C	7.6	10.1	8.2	-	180.0	98.0	157.0	-
W 92-9	A	8.4	11.6	8.0	10.5	198.0	105.0	232.0	127.0

[1] Pulps used for bleaching and strength tests.
[2] Pulps used for strength tests only.
[3] Pulps not used for bleaching or strength tests.

Table 3. Interpolated Specific Refining Energies (SRE) for Aspen RMP Pulps at 100 and 200 mL, Csf.

Tree No.	Defect Type	Specific Refining Energy, MJ/kg	
		100 mL, Csf	200 mL, Csf
W 92-104	Sound	9.8	7.5
W 92-1	A	8.9	6.2
W 92-6	C	11.0	8.3
W 92-7	C	11.4	8.7
W 92-8	C	10.1	6.9
W 92-9	A	11.7	8.4

Table 4. Pulp Brightness and Hydrogen Peroxide Consumptions for Bleached Aspen RMP Pulps.

Tree No. (Defect)	Csf (mL)	Initial Brightness (% ISO)	Applied Hydrogen Peroxide, % od pulp							
			1		3		5		7	
			H_2O_2 Consumed (%)	Brightness (% ISO)	H_2O_2 Consumed (%)	Brightness (% ISO)	H_2O_2 Consumed (%)	Brightness (% ISO)	H_2O_2 Consumed (%)	Brightness (% ISO)
W 92-104[1] (Sound)	223	64.6	0.56	77.4	2.21	81.0	3.47	83.3	5.28	83.0
W 92-1 (A)	190	40.1	0.60	51.5	2.37	66.6	3.88	73.7	5.70	76.4
W 92-6 (C)	213	62.7	0.58	75.6	2.22	80.6	3.49	83.6	5.33	84.5
W 92-7 (C)	193	55.3	0.58	70.3	2.31	79.0	3.73	80.4	5.63	81.9
W 92-8 (C)	180	57.7	0.58	72.3	2.18	77.5	3.43	82.9	5.27	83.7
W 92-9 (A)	198	57.1	0.59	74.2	2.26	80.7	3.73	83.6	5.44	85.0

[1] W 92-104 = Chips from bolts 10 and 4 were combined to form the sound sample.

Table 5. Chemical Cost Difference Based on Estimated Peroxide Consumption for Bleached Pulps at 80% ISO Brightness.

Tree No.	Consumed H_2O_2 (% od pulp)	Difference to Sample 104	Cost/adt[2]
W 92-104	1.70	0.00	0.00
W 92-1	NA[1]	NA[1]	NA[1]
W 92-6	2.00	0.30	4.88
W 92-7	3.45	1.75	28.50
W 92-8	2.85	1.15	18.73
W 92-9	2.10	0.40	6.51

[1] Excessive amounts of peroxide required to achieve 80% ISO brightness.
[2] Additional chemical cost of peroxide and sodium hydroxide to attain 80% brightness compared to W 92-104 pulp based on listed peroxide price at $1.15/kg. Cost of silicate, $MgSO_4$ and DTPA fixed at ≈$12.

Table 6. Brightness and Strength Properties of Unbleached Aspen RMP Pulps.

Tree No. (Defect)	Csf (mL)	Initial Brightness (% ISO)	Bulk (cm^3/g)	Burst Index ($kPa.m^2/g$)	Tear Index ($mN.m^2/g$)	Tensile Index (N.m/g)	Scatter. Coeff. (m^2/kg)
W 92-104 (Sound)	115	65.5	2.74	0.71	1.79	17.3	745.0
W 92-1 (A)	95	41.8	2.74	0.91	2.17	22.3	607.0
W 92-6 (C)	103	65.4	2.78	0.95	2.91	22.8	746.0
W 92-7 (C)	120	56.4	2.82	0.74	2.01	19.2	698.0
W 92-8 (C)	98	58.5	2.82	0.98	2.24	24.3	701.0
W 92-9 (A)	105	56.8	2.59	0.87	2.07	20.8	689.0
W 92-104 (Sound)	223	64.6	2.98	0.46	1.74	11.6	667.0
W 92-1 (A)	190	40.1	3.25	0.68	2.29	15.7	507.0
W 92-6 (C)	213	62.7	3.17	0.70	2.34	16.1	696.0
W 92-7 (C)	193	55.3	3.06	0.59	1.84	13.4	645.0
W 92-8 (C)	180	57.7	3.01	0.78	2.23	16.7	659.0
W 92-9 (A)	198	57.1	2.86	0.66	1.96	14.1	610.0

Table 7. Strength Properties of Aspen RMP Pulps Bleached with 7% Hydrogen Peroxide on Od Pulp.

Tree No. (Defect)	Csf (mL)	Hydrogen Peroxide, 7% od pulp applied				
		Bulk (cm^3/g)	Burst Index ($kPa.m^2/g$)	Tear Index ($mN.m^2/g$)	Tensile Index (N.m/g)	Scatter. Coeff. (m^2/kg)
W 92-104 (Sound)	223	2.10	1.39	3.48	36.1	470
W 92-1 (A)	190	2.47	1.20	3.22	30.5	550
W 92-6 (C)	213	2.32	1.56	3.89	39.1	534
W 92-7 (C)	193	2.40	1.30	3.08	32.5	524
W 92-8 (C)	180	2.09	1.91	3.33	45.7	453
W 92-9 (A)	198	2.24	1.48	3.87	35.2	486

APPENDIX 3

Figures

Figure 1. Freeness vs. Specific Energy.

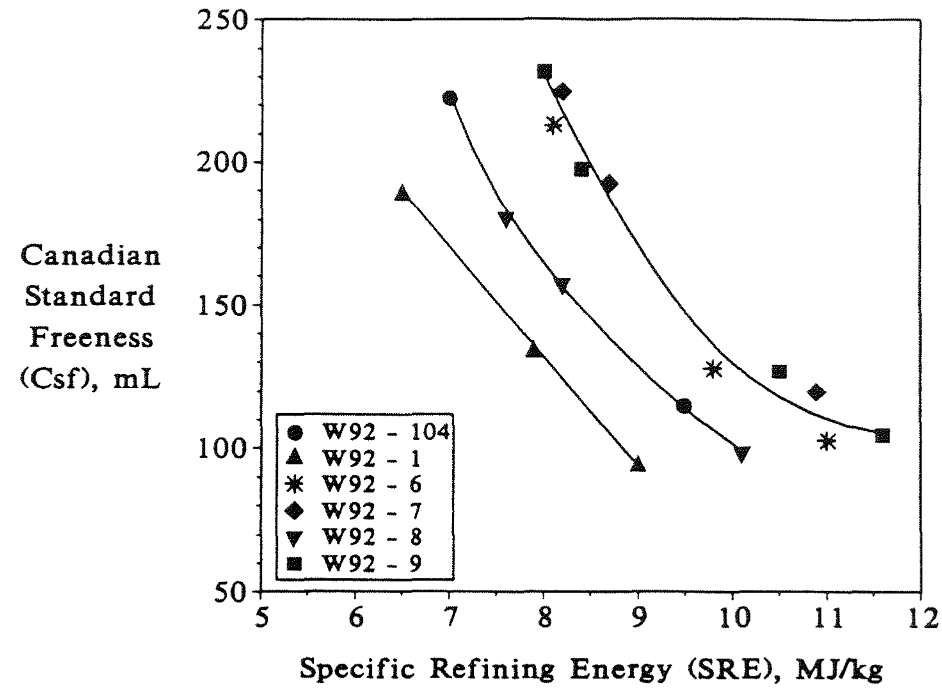

Figure 2. Brightness vs. Consumed H_2O_2.

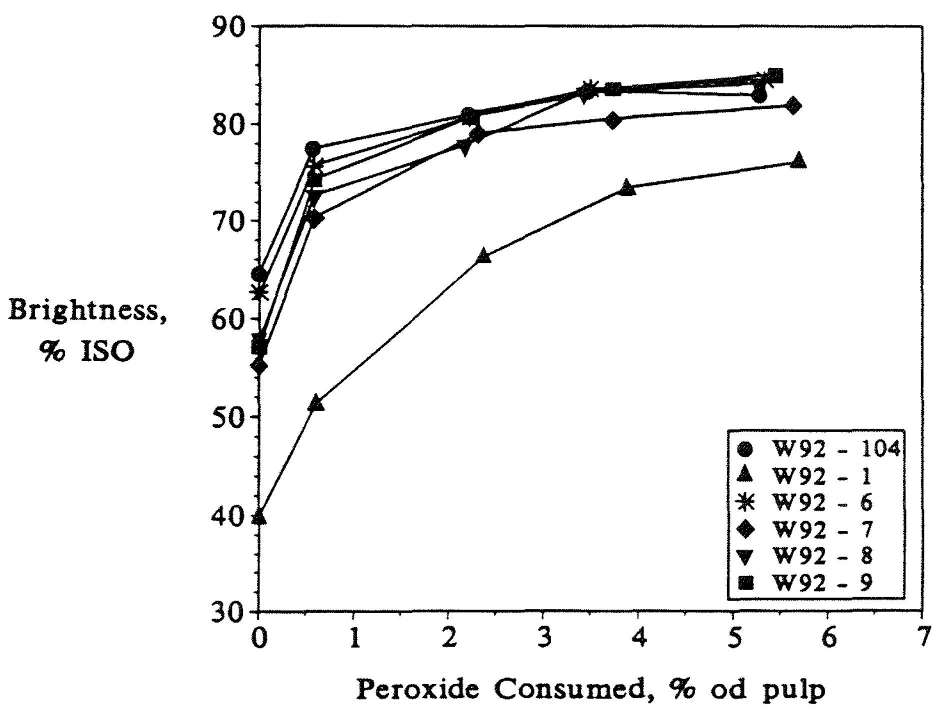

Figure 3. Tear Index vs. Freeness.

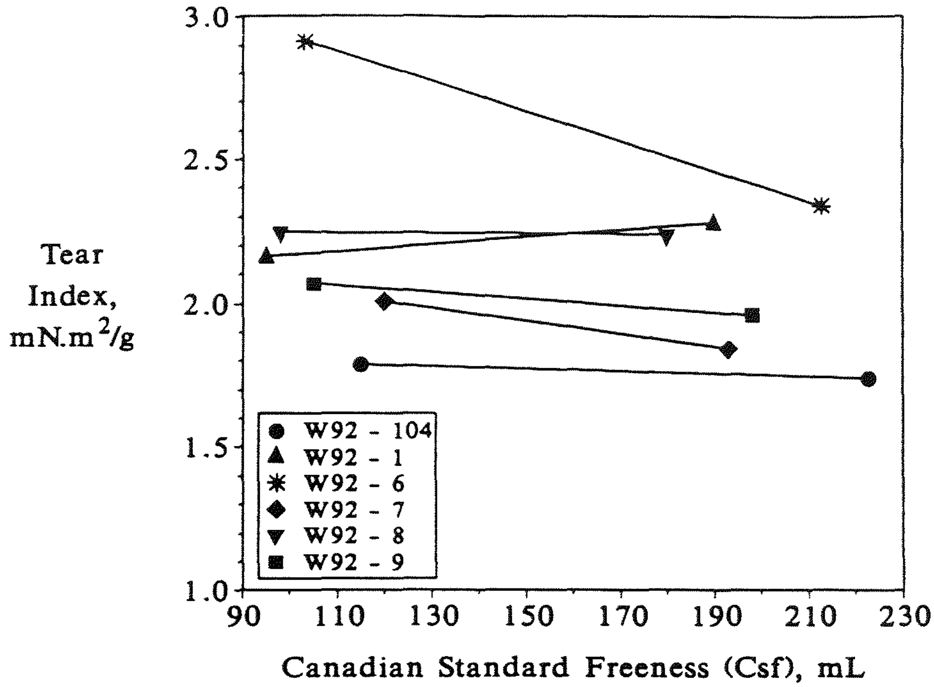

Figure 4. Tensile Index vs. Freeness.