7-1-1976

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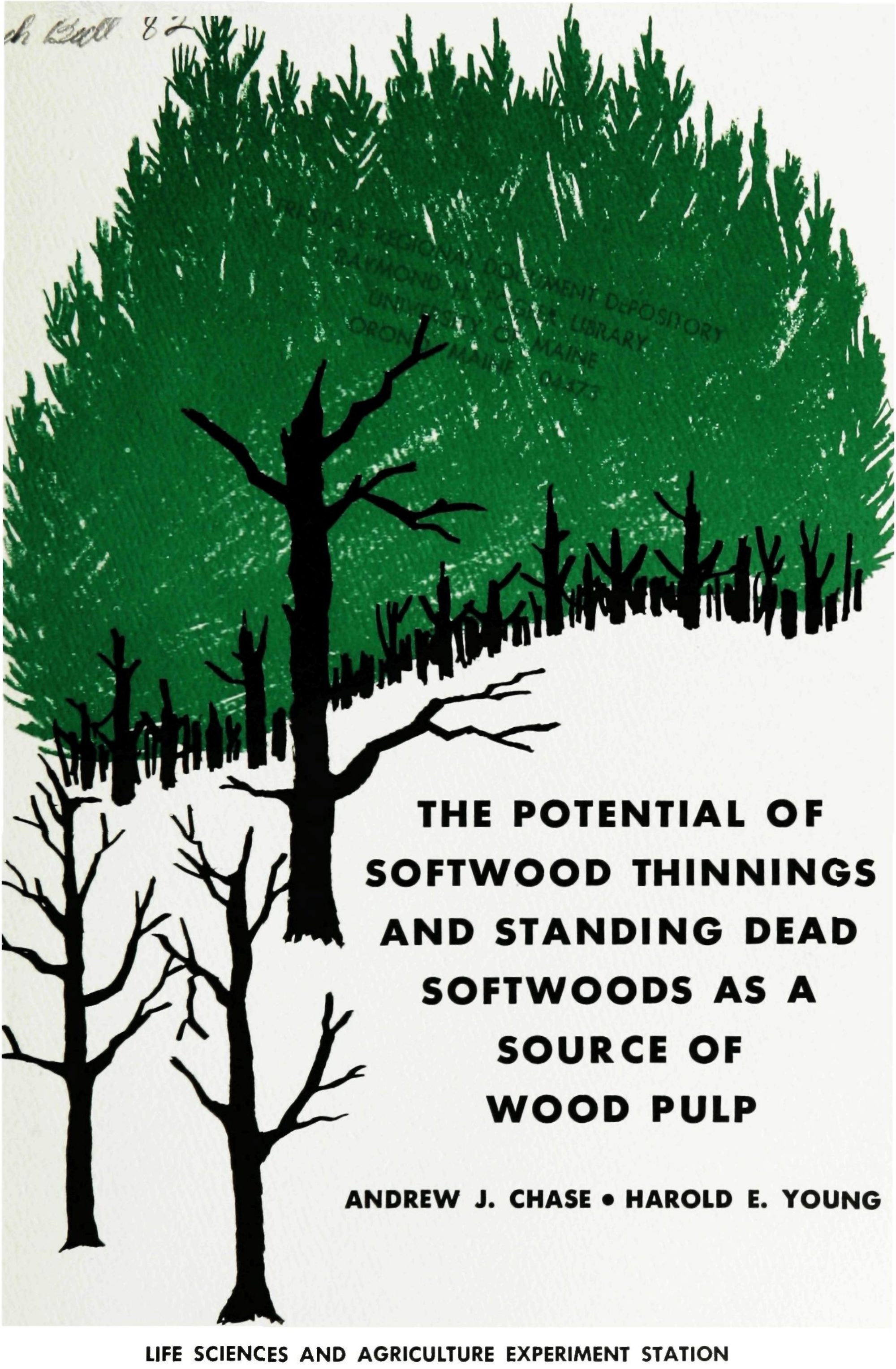

THE POTENTIAL OF SOFTWOOD THINNINGS AND STANDING DEAD SOFTWOODS AS A SOURCE OF WOOD PULP

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LIFE SCIENCES AND AGRICULTURE EXPERIMENT STATION

JULY 1976

The Potential of Softwood Thinnings and Standing Dead Softwoods as a Source of Wood Pulp

By

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ACKNOWLEDGMENTS

The authors wish to acknowledge the support of the Seven Islands Land Company, the J. D. Irving family of New Brunswick, Morbark Industries Incorporated and the Life Sciences and Agriculture Experiment Station (McIntire-Stennis Funds). This support made it possible for Michael Young, Len Paulozzi and Alan Kimball to harvest and prepare the tree material and for Mr. and Mrs. A. Krishnagopalan to conduct the pulping studies.

The contribution of the Chemical Engineering Department of the University of Maine is gratefully acknowledged for the use of its facilities and equipment.

ABSTRACT

This study was made to determine the potential of softwood thinnings and standing dead softwood as a source of wood pulp, employing the kraft process. In the thinning studies, the seven softwood species used were: eastern white pine, eastern hemlock, balsam fir, norway spruce, red pine, eastern larch and northern white cedar. The stem (wood and bark) and the top (wood, bark and needles) as well as the stem and top combined were pulped. When compared with pulp from a commercial size softwood species, the thinnings provided pulps of good strength that were slightly undercooked and that had significantly lower yields. The stem portion pulps were superior in all cases to those made from the top portion. This is attributed to the foliage and higher bark content of the branches of the top which resulted in relatively low yields. The brief study of the characteristics of standing dead softwood trees, either killed by fire

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or natural attrition, indicated that they compare favorably with the live thinnings as a source of pulp when yield and physical properties are the criteria.

It was concluded from this study that 35-40 percent of the thinnings material is available as a good grade of wood pulp. The bark and foliage in this material will create problems in the pulping and subsequent pulp mill operations mainly in the area of pulp cleaning. These are not insurmountable problems, however, and future economic and material conservation requirements of the pulp and paper industry will dictate common use of such materials — softwood thinnings and standing dead softwoods.

INTRODUCTION

Mankind had despoiled vast forested areas a thousand years before Christ (1). The continuation of such practices and the rapid expansion of the human race resulted in the establishment of some conservation methods and forestry practices long before the first forestry schools were established in the eighteenth century. Silviculture, the art of producing and tending the forest, was a matter of considerable concern in those early forestry schools and continues to be today since the total area in forests continues to shrink while the population continues to increase.

Natural seeding may produce a fully stocked stand of 100,000 or more seedlings, yet at industrial maturity there will seldom be more than 100 trees per acre. Forest scientists have studied the phenomenon which brings about the rapid reduction in stand density and have repeatedly demonstrated that periodic thinnings will increase growth of the remaining crop trees.

At this point the economics of the practice of forestry becomes an important factor. When labor costs are low and stumpage prices of the final crop are very high, it is economically feasible to thin without any industrial use of the thinned material. When the reverse is true, the more usual case, thinnings cannot be made. It is for this reason that there has been very little thinning in the United States.

The writers are advocates of the Complete Tree Concept: biological and technological investigation of the entire tree from the root tips to the leaf tips inclusive (2). This has been expanded into the Complete Forest Concept to include all tree and woody shrub species. Although not explicitly stated in the definition we believe that every silvicultural practice should be conducted so that the forest land owner will have a net profit or, at the very least, break even. This philosophy demands utilization of virtually all components of every tree and shrub regardless of size.

Within the framework of this basic philosophy we (3, 4, 5) have conducted a series of pulping studies on tree species currently used commercially as well as on puckerbrush species, successional hardwood tree and shrub species seldom used commercially. The results of these studies indicate that the forest residuals, tops and stump-root systems, and the puckerbrush species constitute a sizable potential source of pulp. These studies have silvicultural implications. The former could be a big factor in reducing the cost of site preparation for the next crop and the latter could be an effective means of removing less desirable species in order to increase the growth of preferred species.

Natural spruce-fir stands tend to be quite dense. Epidemic spruce budworm attacks or fire may result in large areas of spruce-fir that are extremely dense. The spruce budworm epidemic that occurred during World War I resulted in several million acres of spruce-fir that now (a) have 1500-7500 trees per acre one inch and larger, (b) have few trees of commercial size, and (c) have a sizable number of standing dead trees. The purpose of this study is to determine the pulping potential of thinnings and standing dead in very dense spruce-fir stands. A companion study that will be published separately will determine (1) the amount of standing dead per acre, (2) the total biomass of the standing crop and (3) the amount that should be removed in a thinning operation. In the event that the pulping studies are negative the results of the companion study will provide useful information as to the amount of material available for the production of energy or for a variety of products that can be made from the needles, such as MUKA, animal fodder and vitamin supplement.

EXPERIMENTAL PROCEDURE

The work may be divided into two parts, the first being the pulping of softwood thinnings and the second the pulping of wood from standing dead trees. The sulfate process was used throughout.

(a) *Softwood thinnings.*

Seven species of softwood thinnings were pulped. They were eastern white pine (Pinus strobus L.), eastern hemlock (Tsuga canadenis (L.) Carr.), balsam fir (Abis balsamea (L.) Mill.), norway spruce (Picea abies (L.) Karst), red pine (Pinus resinosa Ait.), eastern larch (Larix laricina (Du Roi) K. Koch.), and white cedar (Thuja occidentalis L.).

Three components of each species were used. They were the stem, the top, and the entire above ground portion of the tree, and are defined as follows. *Stem* is the wood and bark of the bole from the stump to the first live branch. *Top* is the wood, bark, and needles from the first live branch to the tip. *Entire* is the wood, bark and needles from stump to tip. Data on the ages, dimension, and weight proportions of bark and wood in the entire tree, stem, and top are shown, for each species, in Appendices A, B, and C.

All materials were chipped as received from the forest. The chips were immediately stored in air-tight containers so they would not dry and could be pulped in the "green" condition.

Portions of the chips from the entire tree component were allowed to dry under ambient conditions and were pulped as "dry" chips.

Pulping conditions were first established, using a "standard" wood, such that the permanganate number of the resulting pulp was in the range of 22-24. This required several exploratory cooks in which the active chemical, sulfidity, and maximum temperature were kept constant and the time of cooking was varied until the prescribed permanganate number was realized. The "standard" wood was from the debarked bole of a large Norway Spruce. All materials were then pulped under nearly identical conditions as shown in Table I.

Table I.
Cooking Conditions

Alkali (as Na_2O) to wood ratio	0.2	
Sulfidity, %	25	
Maximum temperature, °F	337	
Time to temperature, hrs.	3/4	
Time at temperature, hrs.	4	
Liquor to wood ratio	7	approximately
Liquor concentration, $\frac{\#Na_2O}{ft^3}$	1.8	

Equipment consisted of a stainless steel digester having a capacity of approximately two pounds of chips, on a bone dry basis. The chips were contained in a stainless steel wire basket within the digester to minimize carry-over of fines into the liquor circulation system. Liquor was continuously circulated through an external electric heater. Maximum temperature and the time-temperature cooking cycle were automatically controlled. At the conclusion of a cook, digester pressure was slowly reduced to ambient and the chips were transferred to a slushmaker where they were defibered for five minutes. The resulting pulp was then screened on a slotted vibrating screen and the yield of acceptable fiber was determined.

Samples of the acceptable pulp were taken for determination of Permanganate Number in accordance with TAPPI Standard Method T-214. The remaining pulp was mechanically refined in accordance with T-200, Beater Processing of Pulp, and handsheets were made and tested according to T-205, Forming Handsheets for Physical Tests of Pulp, and T-220, Physical Testing of Pulp Handsheets.

(b) *Standing Deadwood.*

The same procedure was used in preparing the chips, cooking and pulp evaluation, as for the softwood thinnings. In this case, however, the entire tree was used. Chips were allowed to dry prior to cooking.

RESULTS AND DISCUSSION

(A) *Pulping of Softwood Thinnings.*

Information on the pulp obtained from green softwood thinnings is shown in Table II.

Table II.
Pulp from Softwood Thinnings (Green).
Pulp Yield and Chemical Consumption

Species	Permanganate Number			Pulp Yield (Percent)			Percent of Chemical Consumed		
	Stem	Top	Entire	Stem	Top	Entire	Stem	Top	Entire
Standard	23.5	—	—	46.1	—	—	65	—	—
Norway Spruce	30.4	36.2	31.5	39.8	29.0	34.9	73	80	78
Red Pine	22.6	22.6	27.7	40.1	28.8	35.5	73	78	79
White Pine	29.5	35.5	28.5	40.6	27.6	35.4	82	85	80
Balsam Fir	33.2	37.2	34.8	40.8	33.1	33.8	82	84	82
Eastern Hemlock	32.1	35.0	32.7	40.4	32.4	37.5	73	80	74
Eastern Larch	30.7	35.6	30.3	38.3	29.5	35.5	78	82	79
White Cedar	29.1	34.2	33.4	42.0	34.4	39.6	73	80	80

Permanganate number. This property of the pulp is related to the degree to which the wood has been delignified in the cooking operation. It would be expected that the stem portion would be delignified most, the top portion least because of the higher percentage of bark and foliage, whereas the degree of cooking of the entire tree would be intermediate. The results, as indicated by the permanganate numbers, do not support these expectations in three cases, Red Pine, White Pine, and Eastern Larch, although for the latter two the discrepancies are sufficiently small to be within the reproducibility limits. With the single exception of the Red Pine all top portions had the highest permanganate numbers. This can be attributed to the higher proportion of bark to wood and the higher proportion of non-carbohydrate, or non-cellulosic materials in the bark and needles. The effect of the softwood bark is clearly apparent if the permanganate number of the standard pulp which was produced from debarked stemwood, is compared with those of the pulps from the thinnings stem portions, Red Pine being the exception.

Pulp yield. Screened pulp yields are shown for the three portions of each species. In all cases the highest yield was obtained from the stem portions, the lowest from the tops, the entire tree giving intermediate yields. In all cases the yields were lower than that of the standard, averaging 5.8 percentage points lower for the stem portions and 15.4 points lower for the tops. The lower yields compared with that of the standard, are attributable to the bark and needles, the former having a relatively low fiber content and the needles containing essentially no fiber.

Chemical consumption. All portions of all species consumed more of the pulping chemicals than did the standard wood. This is due to the bark and needles. Generally the top portion consumed the most chemical, the stem portion the least. It may be theorized that the bark and needle constituents are generally more reactive than the wood portion. Thus, a significant portion of the chemicals is rapidly consumed reducing the concentration of the liquor and reducing the rate of pulping. This could account, in large part for the higher permanganate numbers of the thinnings pulps, compared with those of the standard pulp.

Comparison of the seven species shows no great differences in pulp yields. If only stem portions were used, there would be no significant differences, with the possible exception of the cedar at 42% and the larch at 38.3%. Cedar shows a significantly higher yield when the entire tree is pulped.

Results of pulping the thinnings after they had been air-dried are shown in Table III. In this case (only) the entire tree was pulped. Comparison of the permanganate numbers with those shown in Table II showed little difference of significance as a result of drying prior to pulping. There were only minor changes in pulping yield, although the hemlock replaced cedar as giving the highest yield. With respect to chemical consumption there was no detectable trend as a result of drying. Consumption decreased for some species and increased for others with the changes being minor, two to four percentage points.

Table III.
Pulp from Softwood Thinnings*
Pulp Yield and Chemical Consumption for Entire Tree

Species	Permanganate Number	Pulp Yield (%)	Percent of Chemical Consumed
Standard	23.5	46.1	65
Norway Spruce	31.7	34.8	77
Red Pine	28.3	32.5	80
White Pine	28.1	36.5	76
Balsam Fir	34.3	34.9	78
Eastern Hemlock	32.4	39.9	76
Eastern Larch	31.6	35.5	81
White Cedar	34.0	36.5	80

*Thinnings dried to moisture equilibrium with ambient conditions before processing.

PULP PHYSICAL PROPERTIES

It was explained previously that beater tests were made on each of the pulps. Handsheets were made of pulps beaten for several different time intervals for each species. The sheets were then tested for several physical characteristics. The detailed results of strength property versus beating time are shown in Appendix D.

Tables IV, V, and VI show only the *maximum* values of burst and tensile strength and the sheet bulk corresponding to the maxima. It should be noted that the several species generally attained their maximum strength at different beating times because their responses to the beating action differed. *The strength values in parentheses* are those of the pulp from air-dried thinnings, all other values are for the pulps produced from green (fresh) thinnings.

Sheet bulk. Results of bulk measurement are contained in Table IV.

Table IV.
Bulk (cc./gm.)
(Pulp from Softwood Thinnings)

Species	Stem	Top	Entire Tree
Standard	1.45	—	—
Norway Spruce	1.67	1.65	1.69 (1.65)
Red Pine	1.52	1.46	1.54 (1.52)
White Pine	1.35	1.33	1.34 (1.31)
Balsam Fir	1.73	1.77	1.75 (1.81)
Eastern Hemlock	1.74	1.70	1.72 (1.70)
Eastern Larch	1.79	1.72	1.74 (1.80)
White Cedar	1.40	1.56	1.51 (1.59)

These were determined on those handsheets which had the highest values of burst and tensile strength. Values are shown for all three portions of the seven species when pulped in green condition and for the entire tree only (parentheses) when material was air-dried prior to pulping. This property of paper, being the reciprocal of sheet density, is generally well correlated with sheet strength properties. Lower bulk, indicating a compact, well-bonded sheet, usually means good burst and tensile strength. In general this is true for the thinnings pulps, although there are exceptions. Larch which produced the bulkiest sheet also was weakest in burst and tensile strength as shown in Tables V and VI. The red and white pines produced a more dense sheet and were superior in tensile strength.

Table V.
Breaking Length (Meters)
(Pulp from Softwood Thinnings)

Species	Stem	Top	Entire Tree
Standard	14,700	—	—
Norway Spruce	13,400	10,200	12,800 (12,100)
Red Pine	14,200	13,000	14,200 (12,200)
White Pine	14,300	11,500	14,200 (13,200)
Balsam Fir	13,000	10,700	12,000 (12,300)
Eastern Hemlock	12,700	13,400	13,100 (12,000)
Eastern Larch	12,100	12,000	11,500 (12,100)
White Cedar	14,100	10,600	12,700 (11,100)

Table VI.
Burst Factor
(Pulp from Softwood Thinnings)

Species	Stem	Top	Entire Tree
Standard	99	—	—
Norway Spruce	92	66	85 (88)
Red Pine	106	80	92 (90)
White Pine	96	69	93 (95)
Balsam Fir	104	85	99 (93)
Eastern Hemlock	93	91	93 (94)
Eastern Larch	83	82	85 (83)
White Cedar	100	76	95 (82)

With the exception of the white pine, all thinnings pulps had higher bulk than the standard. This could be attributed to the presence of relatively bulky fibrous elements produced from the barks of the thinnings.

Burst and tensile strength. Strength properties as the maximum values attained in beater processing of the pulps are shown in Tables V and VI. In general the thinnings compare favorably with the standard pulp, the most important exception being larch which is consistently weaker. Of course the top portions, containing more material from the bark and shorter fibers, gave the weakest pulps in all cases.

The effect of drying of the chips before cooking was inconclusive and minor although some decrease in strength resulted for most of the species.

Three characteristics of pulps from the green, entire tree portions are shown as a function of beating time. (Figs. 1, 2, and 3). Fig. 1 shows that even though there were significant differences in the freenesses of the unbeaten pulps, they all responded much the same to the beating action as indicated by the similarity of the slopes of the resulting curves.

The response of sheet bulk to beating, Fig. 2, is similar, qualitatively, to that of freeness. There were significant differences in the bulk of the unbeaten pulps and these *differences* changed very little during the beating treatment. The rate of bulk decrease was nearly the same for all species after the first few minutes of beating.

Burst strength versus beating time curves were typical, Fig. 3. Most of the pulps developed stength rapidly during the first 10 to 20 minutes of beating and appeared to attain maximum burst around the 40 minute time.

Tensile strength was not plotted but inspection of the tensile versus beating time data in the Appendix shows that the rate of development was similar to that of burst strength.

(B) *Pulping of Dead Trees.*

Two categories of standing dead trees were pulped using the same conditions as were used for the softwood thinnings (Table I). These were trees that had been exposed to fire and subsequently had died, and trees

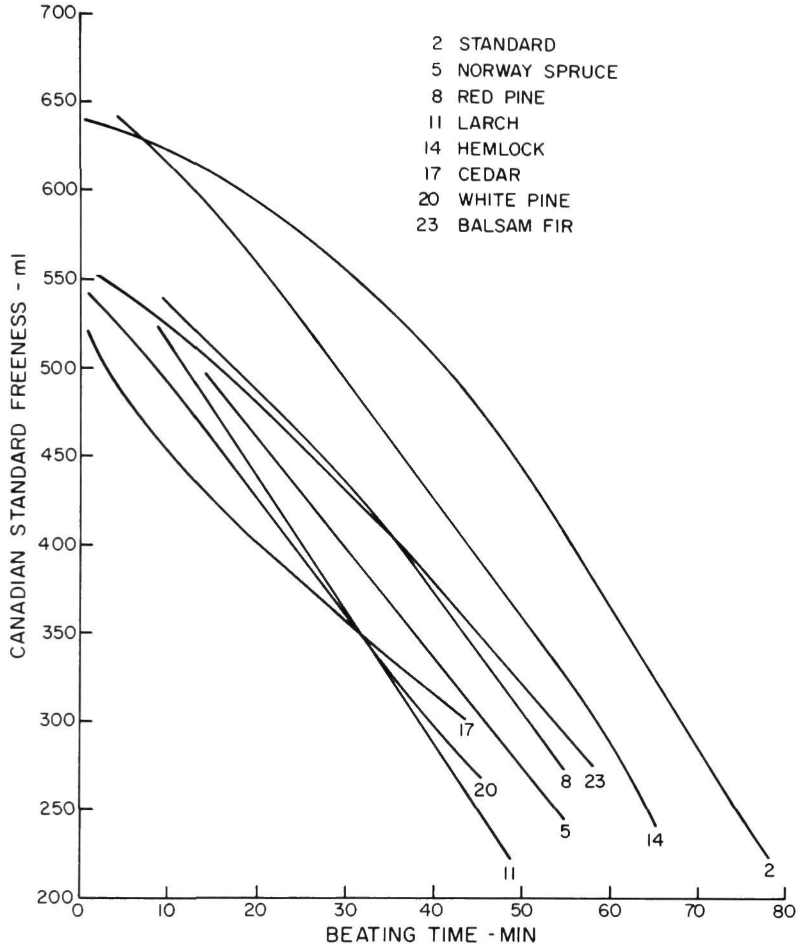

FIGURE 1

that had died of causes (natural) other than fire. Only the "entire tree" portions were pulped. The amount of bark was less than that in the thinnings study and there was no foliage.

(a) *Fire killed trees.*

Table VII shows the permanganate numbers and pulping yields for three species, Norway Spruce, White Pine, and Balsam Fir, that had been exposed to fire and had subsequently died. The year of exposure is indicated in parentheses. The "standard" for a particular species is the entire tree portion of the green thinnings described in part (A). Thus the results for "standing dead wood" pulps are compared with those of "live wood" pulps from the same species.

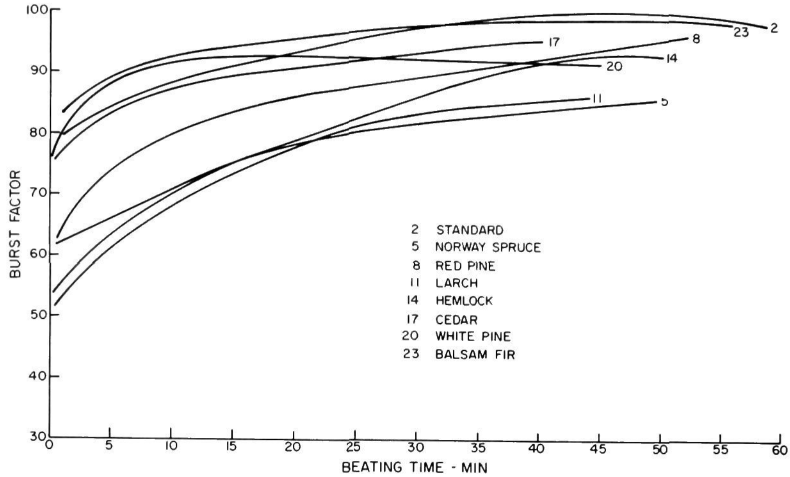

FIGURE 2

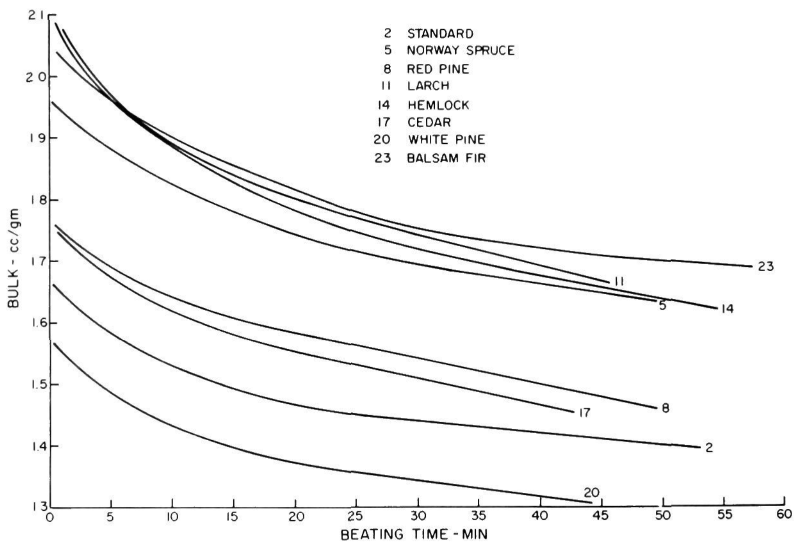

FIGURE 3

The yields from standing dead wood were greater than those of the standards with one exception, that of the 1957 Norway Spruce. In that case the wood may have suffered considerable deterioration, particularly in the cellulosic materials. The percent of rejected material, 6.8% was

Table VII.
Pulp from Dead Softwoods (Fire killed).
Permanganate Number and Pulp Yield

Species (Year of Kill)	Permanganate Number	Screened Yield (%)	Rejects (%)
Norway Spruce (Standard)	31.5	34.9	1.7
Norway Spruce (1957)	35.9	29.1	6.8
Norway Spruce (1961)	27.6	44.1	1.2
Norway Spruce (1974)	33.2	42.0	2.2
White Pine (Standard)	28.5	35.4	1.3
White Pine (1952)	35.8	36.0	2.7
Balsam Fir (Standard)	34.8	33.8	1.5
Balsam Fir (1965)	34.8	39.2	1.3

also very high for this pulp. This is further indication of deterioration, and formation of materials resistant to the pulping chemicals.

The increased yields of pulp from all the other dead trees can be attributed in large measure to the absence of bark, at least in amounts comparable to those on green, unbarked, trees. It appears that the natural shedding of bark from standing dead trees can be an advantage, insofar as pulping is concerned. Other effects, such as insect damage and natural decay, will offset this advantage in time.

Table VIII shows the bulk, burst strength, and tensile strength, of pulps from the fire-killed wood. Properties of the standard pulps are included for comparison.

Table VIII.
Physical Properties of
Pulp from Dead Trees (Fire killed).

Species (Year of Kill)	Bulk (cc./gm.)	Burst Factor	Breaking Length (Meters)
Norway Spruce (Stnd)	1.69	85	12,800
Norway Spruce (1957)	1.42	74	12,800
Norway Spruce (1961)	1.40	105	15,600
Norway Spruce (1974)	1.43	107	15,100
White Pine (Stnd)	1.34	93	14,200
White Pine (1952)	1.35	83	14,900
Balsam Fir (Stnd)	1.75	99	12,000
Balsam Fir (1965)	1.36	95	15,800

With the exception of the white pine the bulk values were significantly lower for the dead wood pulps than for the standards. Correspondingly, the strength properties were higher.

(b) *Standing dead wood (natural causes).*

Results of the pulping study of these trees are shown in Tables IX and X. The values in parentheses are those for the pulps from entire trees green thinnings, as shown in Tables IV, V, and VI, and are included here for purposes of comparison. It appeared that the pulps from the standing dead wood were not quite as well cooked (higher permanganate numbers), but were produced in higher yield than pulps from live thinnings of the same species. They were stronger in tensile, have lower bulk, and show no definite trend in burst strength. In this respect their physical characteristics were similar to those of pulps from the fire-killed trees.

Table IX.
Permanganate Number and Pulp Yield
Pulp from Dead Trees

Species	Permanganate Number	Screened %	Rejects %
Red Pine	33.0 (27.7)	38.0 (35.5)	0.7
Eastern Hemlock	37.2 (32.7)	33.2 (37.5)	2.2
Eastern Larch	34.0 (30.3)	35.9 (35.5)	2.5
White Cedar	33.2 (33.4)	40.7 (39.6)	0.6

Table X.
Physical Properties.
Pulp from Dead Trees

Species	Bulk (cc./gm.)	Burst Factor	Breaking Length (Meters)
Red Pine	1.49 (1.54)	80 (92)	14,300 (14,200)
Eastern Hemlock	1.69 (1.72)	81 (93)	13,700 (13,100)
Eastern Larch	1.69 (1.80)	87 (85)	13,300 (11,500)
White Cedar	1.30 (1.51)	103 (95)	15,400 (12,700)

CONCLUSIONS

(1.) Pulp from softwood thinnings, is not as well delignified as most commercial pulps as indicated by higher permanganate numbers. It probably would not bleach as easily.

(2.) Lower pulping yields may be expected, ranging from 5 to 15 percentage points lower depending upon the relative proportions of bark and foliage to wood in the thinnings material.

(3.) Chemical consumption is higher for the thinnings primarily because of the bark and foliage. This is not necessarily a negative factor in the kraft process because of the chemical recovery process.

(4.) If the thinnings are dried under atmospheric conditions before pulping, very small differences result in yield, chemical consumption and the physical properties of the resulting pulp.

(5.) Pulp from the thinnings generally compared favorably with the standard pulp in strength properties. However it is important to note that the top portions produced a relatively weaker pulp. This is to be expected, considering the higher proportion of bark, and the foliage, in this part of the tree.

(6.) There is good evidence from this work that standing dead softwoods can be pulped with results comparable to those for live wood. This particular conclusion should be tested by further study, however, because the rate of deterioration of standing dead trees may depend on factors that were not considered in this work.

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APPENDIX A.

Data on Softwood Thinnings Used in Study.

The following Table shows the diameter breast high, height, and age of the trees.* The weight percentages of total material (fresh weight) represented by the stem and top portions, bark and foliage included, are also shown.

Species	D.B.H. (inches)	Height (feet)	Age (years)	Stem (% of total weight)	Top (% of total weight)
Norway Spruce	4.0/4.3	27/29	39/39	68.5	31.5
Red Pine	3.0/4.0	25/32	23/23	56.3	43.7
White Pine	2.9/3.5	28/28	21/21	77.7	22.3
Balsam Fir	3.0/4.0	21/31	31/40	45.4	54.6
Eastern Hemlock	3.4/3.7	34/32	103/101	48.1	51.9
Eastern Larch	3.9/3.6	34/36	25/25	66.3	33.7
White Cedar	3.7/4.4	23/29	46/52	42.5	57.5

*Two trees of each species were used.

APPENDIX B.

Weight Percent of Bark and Wood In the Stem and Top Portions of Softwood Thinnings.

	Fresh Weight Basis				Dry Weight Basis			
	Stem		Top		Stem		Top	
Species	Wood	Bark	Wood	Bark	Wood	Bark	Wood	Bark
Norway Spruce	87.8	12.2	74.0	26.0	88.9	11.1	79.3	20.7
Red Pine	87.3	12.7	75.0	25.0	82.8	17.2	76.9	23.1
White Pine	83.4	16.6	66.1	33.9	81.6	18.4	69.8	30.2
Balsam Fir	85.6	14.4	65.7	34.3	82.5	17.5	68.6	31.4
Eastern Hemlock	84.8	15.2	72.3	27.7	83.5	16.5	77.2	22.8
Eastern Larch	79.3	20.7	61.8	38.2	82.1	17.9	68.6	31.4
White Cedar	87.1	12.9	77.9	22.1	87.1	12.9	78.3	21.7

APPENDIX C.

Weight Percent of Bark and Wood in The Combined Stem and Top Portions of Softwood Thinnings.

This Table shows the proportions of wood and bark in the *entire* portion as defined in this report. The values were determined, on a fresh weight basis only, from the data in Appendices A and B.

Species	Weight % Wood	Weight % Bark
Norway Spruce	83.4	16.6
Red Pine	81.9	18.1
White Pine	79.5	20.5
Balsam Fir	74.8	25.2
Eastern Hemlock	78.3	21.7
Eastern Larch	73.3	26.7
White Cedar	81.8	18.2

APPENDIX D

Strength Property vs. Beating Time

Data Sheet 1
Wood Species: Standard (Norway Spruce)
Tree Portion: Stem

Standard Beater Test — Strength Development

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	641	1.67	77	11,700	39
20	595	1.47	92	—	112
40	510	1.45	99	13,600	286
60	367	1.39	97	14,700	>300
80	208	1.35	91	13,500	—

Data Sheet 2
Wood Species: Norway Spruce, Green
Tree Portion: Stem

Standard Beater Test — Strength Development

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	502	1.94	61	10,000	24
15	484	1.75	81	11,800	75
25	415	1.73	83	12,800	154
40	299	1.62	94	13,200	>300
45	256	1.60	91	13,400	—

Data Sheet 3
Wood Species: Norway Spruce, Green
Tree Portion: Top

Standard Beater Test — Strength Development

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	550	2.01	47	7,800	23
10	411	1.76	60	8,900	70
20	313	1.71	64	9,500	166
30	232	1.65	66	10,200	>300

Data Sheet 4
Wood Species: Norway Spruce, Green
Tree Portion: Whole

Standard Beater Test — Strength Development

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	557	1.95	61	9,100	23
10	520	1.83	71	10,800	51
25	431	1.72	80	11,000	143
40	332	1.68	80	10,600	>300
50	270	1.63	87	10,900	

Data Sheet 5 Standard Beater Test — Strength Development
Wood Species: Red Pine, Green
Tree Portion: Stem

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	622	1.71	65	10,500	35
15	540	1.54	90	—	102
35	446	1.51	96	12,200	230
50	363	1.46	106	14,000	>300
65	249	1.39	103	14,000	

Data Sheet 6 Standard Beater Test — Strength Development
Wood Species: Red Pine, Green
Tree Portion: Top

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	500	1.65	58	9,200	149
10	375	1.55	70	11,000	>300
25	291	1.48	80	12,300	
35	253	1.43	78	13,000	

Data Sheet 7 Standard Beater Test — Strength Development
Wood Species: Red Pine, Green
Tree Portion: Whole

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	612	1.76	59	10,500	33
10	535	1.65	81	11,900	76
15	509	1.60	82	13,100	98
30	436	1.54	89	13,100	257
50	307	1.46	96	14,200	>300

Data Sheet 8 Standard Beater Test — Strength Development
Wood Species: White Pine, Green
Tree Portion: Stem

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	560	1.56	80	10,400	176
10	491	1.44	92	—	>300
20	436	1.38	96	13,900	
32	360	1.34	95	14,300	
45	303	1.32	93	12,700	

Data Sheet 9
Wood Species: White Pine, Green
Tree Portion: Top

Standard Beater Test — Strength Development

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	431	1.58	57	10,200	>300
5	345	1.43	64	—	
15	294	1.35	69	11,500	
21	256	1.35	67	10,300	

Data Sheet 10
Wood Species: White Pine, Green
Tree Portion: Whole

Standard Beater Test — Strength Development

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	592	1.58	75	11,800	149
7	510	1.45	90	12,300	>300
14	463	1.42	92	14,200	
30	355	1.35	93	14,000	
45	269	1.30	92	11,500	

Data Sheet 11
Wood Species: Balsam Fir, Green
Tree Portion: Stem

Standard Beater Test — Strength Development

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	622	2.03	80	10,400	21
15	555	1.83	101	11,900	57
30	507	1.73	100	12,700	118
50	375	1.68	102	13,000	279
68	273	1.63	108	11,600	>300

Data Sheet 12
Wood Species: Balsam Fir, Green
Tree Portion: Top

Standard Beater Test — Strength Development

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	550	2.06	65	9,900	38
8	478	1.93	75	10,700	79
22	396	1.81	87	10,300	152
35	295	1.75	80	9,800	>300

Data Sheet 13 — Standard Beater Test — Strength Development
Wood Species: Balsam Fir, Green
Tree Portion: Whole

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	598	2.04	75	11,200	29
14	508	1.87	94	12,000	75
28	443	1.77	94	—	163
45	347	1.71	99	13,300	>300
58	278	1.68	98	11,400	

Data Sheet 14 — Standard Beater Test — Strength Development
Wood Species: Eastern Hemlock, Green
Tree Portion: Stem

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	680	2.33	42	7,700	2
20	616	1.80	75	11,200	10
40	487	1.69	86	11,300	31
55	368	1.63	93	12,700	112
65	257	1.60	95	12,700	282

Data Sheet 15 — Standard Beater Test — Strength Development
Wood Species: Eastern Hemlock, Green
Tree Portion: Top

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	612	2.09	57	9,000	7
15	514	1.83	75	11,200	21
30	427	1.70	87	11,300	57
45	366	1.68	87	12,500	100
60	276	1.60	93	13,400	211

Data Sheet 16 — Standard Beater Test — Strength Development
Wood Species: Eastern Hemlock, Green
Tree Portion: Whole

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	662	2.14	53	9,000	4
20	553	1.79	80	11,600	19
40	424	1.67	—	12,700	61
55	330	1.62	89	13,100	129
65	237	1.58	96	12,300	294

Data Sheet 17
Wood Species: Eastern Larch, Green
Tree Portion: Stem

Standard Beater Test — Strength Development

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	643	2.19	46	8,700	4
15	541	1.91	71	11,100	16
30	441	1.78	72	11,300	39
45	319	1.74	86	12,100	103

Data Sheet 18
Wood Species: Eastern Larch, Green
Tree Portion: Top

Standard Beater Test — Strength Development

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	553	2.03	48	8,600	14
10	449	1.86	66	—	38
20	370	1.80	72	10,100	66
30	320	1.72	79	11,300	153
35	247	1.68	83	12,000	218

Data Sheet 19
Wood Species: Eastern Larch, Green
Tree Portion: Whole

Standard Beater Test — Strength Development

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	610	2.10	50	9,100	7
10	516	1.89	68	10,700	21
20	446	1.80	78	11,000	39
35	322	1.72	83	11,500	112
45	249	1.67	87	11,200	229

Data Sheet 20
Wood Species: White Cedar, Green
Tree Portion: Stem

Standard Beater Test — Strength Development

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	565	1.63	83	11,800	289
10	470	1.49	93	12,700	>300
25	405	1.44	100	13,800	
40	329	1.38	98	14,100	
50	273	1.26	95	13,400	

Data Sheet 21 Standard Beater Test — Strength Development
Wood Species: White Cedar, Green
Tree Portion: Top

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	480	1.84	60	9,000	191
5	411	1.72	73	10,000	279
15	350	1.64	72	—	>300
30	278	1.56	75	10,600	

Data Sheet 22 Standard Beater Test — Strength Development
Wood Species: White Cedar, Green
Tree Portion: Whole

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	536	1.77	75	10,600	206
5	487	1.67	84	11,700	>300
12	430	1.61	87	12,600	
24	379	1.54	91	12,700	
40	315	1.47	96	12,500	

Data Sheet 23 Standard Beater Test — Strength Development
Wood Species: Norway Spruce, Dried
Tree Portion: Whole

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	576	1.97	66	9,400	24
15	463	1.75	84	11,200	85
30	350	1.65	83	12,000	225
42	288	1.66	89	12,100	>300

Data Sheet 24 Standard Beater Test — Strength Development
Wood Species: Red Pine, Dried
Tree Portion: Whole

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	585	1.78	65	9,900	49
10	502	1.64	82	11,400	114
30	390	1.52	86	10,600	290
45	296	1.51	91	12,200	>300

Data Sheet 25
Wood Species: White Pine, Dried
Tree Portion: Whole

Standard Beater Test — Strength Development

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	479	1.55	74	12,100	>300
10	404	1.38	88	12,400	
20	353	1.34	95	13,200	
35	266	1.29	91	12,600	

Data Sheet 26
Wood Species: Balsam Fir, Dried
Tree Portion: Whole

Standard Beater Test — Strength Development

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	550	2.09	68	11,000	37
13	473	1.90	86	11,300	101
28	372	1.82	94	12,300	214
45	272	1.73	85	10,100	>300

Data Sheet 27
Wood Species: Eastern Hemlock, Dried
Tree Portion: Whole

Standard Beater Test — Strength Development

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	650	2.22	57	8,000	3
15	565	1.81	84	11,200	15
30	477	1.70	93	12,000	37
45	378	1.65	91	11,900	106
55	287	1.61	95	11,900	201

Data Sheet 28
Wood Species: Eastern Larch, Dried
Tree Portion: Whole

Standard Beater Test — Strength Development

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	591	2.14	53	9,200	7
15	473	1.91	77	10,700	30
27	353	1.83	78	11,500	60
40	300	1.76	83	12,100	123

Data Sheet 29 Standard Beater Test — Strength Development
Wood Species: White Cedar, Dried
Tree Portion: Whole

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)	Porosity (seconds) Gurley Densometer
0	516	1.85	69	9,100	180
8	445	1.71	78	11,000	>300
18	380	1.63	—	10,400	
38	290	1.57	81	11,100	

Data Sheet 30 Standard Beater Test — Strength Development
Wood Species: Red Pine, Dead Wood
Tree Portion: Stem

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)
0	521	1.70	58	11,200
10	464	1.61	74	13,100
20	403	1.51	78	14,400
30	324	1.49	78	14,300
40	277	1.48	82	14,100
50	206	1.43	90	14,500

Data Sheet 31 Standard Beater Test — Strength Development
Wood Species: Eastern Hemlock, Dead Wood
Tree Portion: Stem

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)
0	540	2.23	63	10,500
10	438	1.90	75	12,600
20	347	1.70	79	13,200
30	284	1.68	86	13,300
40	229	1.63	85	13,500

Data Sheet 32 Standard Beater Test — Strength Development
Wood Species: Eastern Larch, Dead Wood
Tree Portion: Stem

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)
0	588	2.10	54	9,900
10	492	1.95	69	12,100
20	434	1.72	74	12,900
30	348	1.70	86	13,400
40	289	1.68	89	13,800
50	214	1.65	91	14,300

Data Sheet 33 — Standard Beater Test — Strength Development
Wood Species: White Cedar, Dead Wood
Tree Portion: Stem

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)
0	511	1.54	82	13,400
10	439	1.42	94	14,900
20	385	1.31	101	15,300
30	322	1.33	107	15,400
40	261	1.26	103	13,600

Data Sheet 34 — Standard Beater Test — Strength Development
Wood Species: Norway Spruce, Live
Tree Portion: Stem

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)
0	560	2.04	65	11,600
10	497	1.68	78	13,100
20	425	1.62	85	14,200
30	374	1.61	88	14,400
40	314	1.53	92	14,500
50	251	1.48	99	14,900

Data Sheet 35 — Standard Beater Test — Strength Development
Wood Species: Norway Spruce, Fire Kill 1957.
Tree Portion: Stem

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)
0	579	1.98	50	9,800
10	484	1.66	62	12,100
20	402	1.49	71	12,000
30	319	1.42	74	13,100
40	242	1.40	74	13,200

Data Sheet 36 — Standard Beater Test — Strength Development
Wood Species: Norway Spruce, Fire Kill 1961
Tree Portion: Stem

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)
0	652	1.80	70	12,300
10	600	1.61	88	14,100
20	552	1.56	94	15,100
30	493	1.48	99	14,800
40	414	1.43	103	15,600
50	337	1.41	103	15,300
60	240	1.38	108	15,900

Data Sheet 37 — Standard Beater Test — Strength Development
Wood Species: Norway Spruce, Fire Kill 1974
Tree Portion: Stem

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)
0	621	1.98	73	13,500
10	577	1.63	93	13,400
20	524	1.56	100	14,300
30	458	1.46	106	14,600
40	369	1.43	110	14,900
50	295	1.43	107	15,100
60	211	1.36	110	15,400

Data Sheet 38 — Standard Beater Test — Strength Development
Wood Species: White Pine, Live
Tree Portion: Stem

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)
0	522	1.72	69	12,600
10	468	1.49	78	14,100
20	414	—	81	14,500
30	348	1.33	86	15,500
40	300	1.28	90	16,200
50	248	—	92	15,800

Data Sheet 39 — Standard Beater Test — Strength Development
Wood Species: White Pine, Fire Kill 1952
Tree Portion: Stem

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)
0	565	1.92	59	10,500
10	500	1.76	69	12,500
20	429	1.52	73	14,000
30	360	1.35	81	14,700
40	290	1.35	81	—
50	228	1.33	86	15,200

Data Sheet 40 — Standard Beater Test — Strength Development
Wood Species: Balsam Fir, Live
Tree Portion: Stem

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)
0	601	2.26	63	11,900
10	533	2.05	74	14,100
20	477	1.99	78	14,300
30	393	1.90	85	15,300
40	318	1.79	90	14,500
50	231	1.68	88	—

Data Sheet 41
Wood Species: Balsam Fir, Fire Kill 1965
Tree Portion: Stem

Standard Beater Test — Strength Development

Beating Time (minutes)	Freeness Canadian Standard	Bulk (cc./gm.)	Burst Factor	Breaking Length (meters)
0	561	1.70	70	12,900
10	516	—	82	14,300
20	468	1.47	81	15,400
30	425	1.42	88	—
40	356	1.41	90	15,600
50	299	1.36	95	15,500
60	237	1.35	91	16,100