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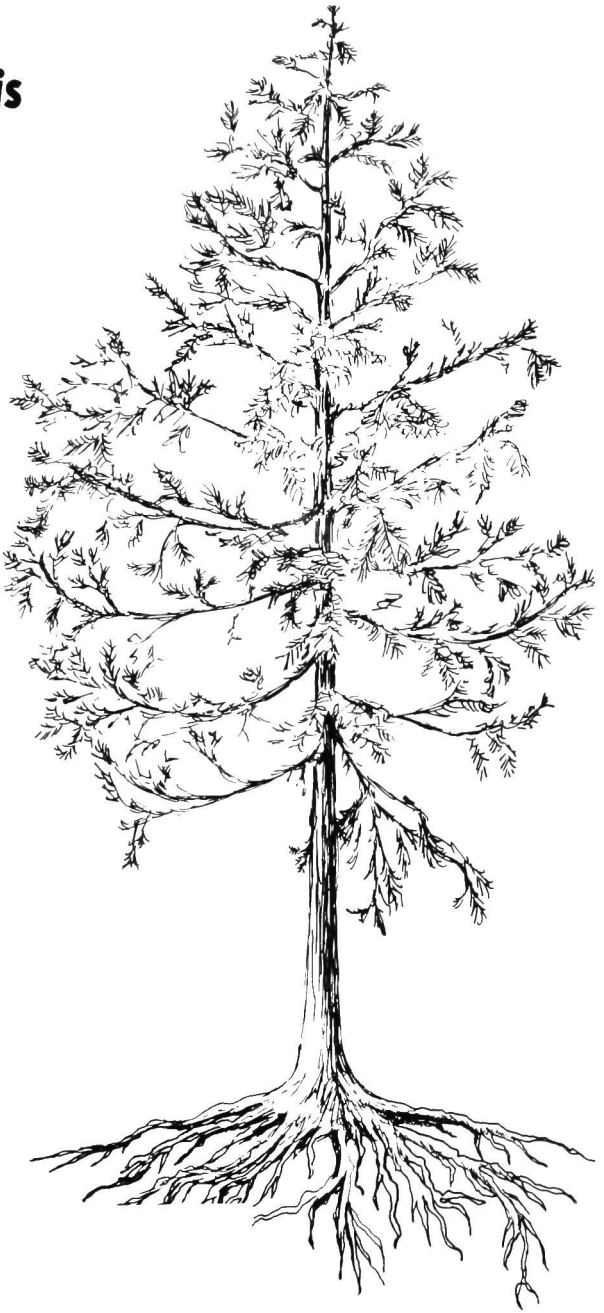
TB27: Fresh and Dry Weight, Nutrient Elements and Pulping Characteristics of Northern White Cedar, Thuja occidentalis

Richard F. Dyer

FRESH AND DRY WEIGHT, NUTRIENT ELEMENTS AND PULPING CHARACTERISTICS OF NORTHERN WHITE CEDAR

Thuja occidentalis



RICHARD F. DYER

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CONTENTS

FRESH AND DRY WEIGHT, NUTRIENT ELEMENTS AND PULPING CHARACTERISTICS OF NORTHERN WHITE CEDAR, *THUJA OCCIDENTALIS*

RICHARD F. DYER[1]

Introduction

A series of complete tree studies of commercial size red spruce, balsam fir, white pine, eastern hemlock, white birch, red maple and aspen have been conducted in Maine. These culminated in fresh and dry weight tables (Tech. Bul. No. 12), nutrient element tables (Tech. Bul. No. 20) and pulping characteristics (Tech. Bul. No. 17) published by the Maine Agricultural Experiment Station.

There are more than 30 tree species in Maine of which only about one-third are of major commercial importance. Northern white cedar was selected as the eighth species for complete tree investigation of weight, nutrient elements and pulping characteristics because it comprises approximately 13% of the total softwood growing stock in Maine, but only amounts to about 2% of the total softwood timber cut for all purposes. It is hoped that the information in this bulletin will provide basic information permitting northern white cedar to become a more meaningful segment of the Maine forest economy.

All of the tables presented must be considered preliminary in nature because they are based on a limited amount of information from a restricted portion of the state. If properly used, they can provide first estimates as guides until more extensive data are available.

Fresh Weight, Dry Weight and Nutrient Elements Studies

These were accomplished in two phases based on tree size. Phase one consisted of 21 trees of commercial size (5.6 inches Dbh and larger) obtained on the University of Maine Forest, Stillwater, Maine. The field and laboratory procedures in the weight and nutrient element studies on these trees did not deviate from those previously reported on the first seven species. Phase two consisted of 36 trees of seedling and sapling size ranging from 1 to 35 feet in height above ground obtained on the same forest. In the second phase only four components were recognized: leaves or needles, branches, stem and stump and roots combined because of the comparatively small size of the trees. The field and laboratory procedures on the second phase were similar, ex-

[1]This study was conducted while the author was a graduate assistant in the School of Forestry, University of Maine. He is now employed by the Northwest Paper Company, Cloquet, Minnesota.

cept that shovels were used to remove the trees from the ground and the wood and bark were not separated in any component.

The composition of a typical commercial size northern white cedar is presented in table 1. The bole wood represents less than 40% of the complete tree, on a dry weight basis, and the branches and roots have a notably high percent of bark.

Regression equations relating fresh and dry weight separately to diameter and height for the trees of commercial size with their R^2 values appear in tables 2 and 3. The R^2 are similar to those reported for the first seven species. Tables based on these equations are presented and are limited to the range of diameters and heights of the basic data.

Table 1 Dry weight of wood and bark of components as a percentage of dry weight of a complete cedar tree and bark as a percentage of dry weight of each component.*

Component	Dry weight of wood as % of dry weight of complete tree	Dry weight of bark as % of dry weight of complete tree	Dry weight of bark as % of dry weight of component
Merchantable stem	36.8	5.3	12.6
Unmerchantable stem	5.0	1.1	18.5
Stump	9.1	1.2	11.9
Roots 4"+	3.5	0.6	14.8
Roots 1–4"	3.4	0.6	14.3
Branches 1"+	1.8	0.6	26.0
Branches ¼–1"	11.2	3.8	25.6
Branches less than ¼"	3.2		
Leaves	9.5		
Roots ¼–1"	1.1	0.7	39.5
Roots less than ¼"	1.5		
Total	100%		

*The data in this table is based on one cedar tree 8.4 inches in diameter and 37.3 feet in height.

Table 2 Regression equations relating fresh weight of components of large cedar trees to tree dimensions, in pounds.

Component(s)	Equation	R^2
Complete tree	$\log Y = -2.07+1.59 \log X_1+1.29 \log X_2$	90
Roots over 4 inches and aerial portion	$\log Y = -2.04+1.62 \log X_1+1.25 \log X_2$	91
Total stem plus total branches	$\log Y = -2.63+1.53 \log X_1+1.41 \log X_2$	90
Total stem	$\log Y = -3.94+1.46 \log X_1+1.71 \log X_2$	93
Merchantable stem	$\log Y = -5.44+1.56 \log X_1+2.01 \log X_2$	95
Stump, large and medium roots	$\log Y = -1.96+1.90 \log X_1+0.61 \log X_2$	89
Large and medium roots	$\log Y = -4.39+1.78 \log X_1+1.18 \log X_2$	77
Roots less than 1 inch	$\log Y = -7.96+1.31 \log X_1+2.06 \log X_2$	55

Where Y is the weight in pounds, X_1 the Dbh in inches, X_2 the height above ground in feet and R^2 the coefficient of determination.

Table 3 Regression equations relating dry weight of components of large cedar trees to tree dimensions, in pounds of dry wood.

Component(s)	Equation	R^2
Complete tree	$\log Y = -3.29+1.53 \log X_1+1.40 \log X_2$	92
Roots over 4 inches and aerial portion	$\log Y = -3.30+1.53 \log X_1+1.39 \log X_2$	93
Total stem plus total branches	$\log Y = -3.97+1.41 \log X_1+1.59 \log X_2$	91
Total stem	$\log Y = -4.62+1.29 \log X_1+1.79 \log X_2$	92
Merchantable stem	$\log Y = -6.02+1.39 \log X_1+2.06 \log X_2$	95
Stump, large and medium roots	$\log Y = -2.81+2.00 \log X_1+0.54 \log X_2$	90
Large and medium roots	$\log Y = -5.70+1.96 \log X_1+1.51 \log X_2$	79
Roots less than 1 inch	$\log Y = -8.82+1.84 \log X_1+1.52 \log X_2$	51

Where Y is the weight in pounds, X_1 the Dbh in inches, X_2 the height above ground i[illegible] R^2 [illegible] on.

COMPLETE TREE

FRESH WEIGHT (POUNDS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	175.	254.			
7	224.	325.			
8		402.			
9		484.			
10		573.	764.		
11		667.	890.		
12		766.	1022.		
13					
14					
15					

NO. WHITE CEDAR

COMPLETE TREE

DRY WEIGHT (POUNDS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	67.	101.			
7	85.	127.			
8		156.			
9		187.			
10		220.	301.		
11		255.	349.		
12		291.	398.		
13					
14					
15					

TOTAL STEM PLUS TOTAL BRANCHES

FRESH WEIGHT (POUNDS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	137.	206.			
7	173.	261.			
8		320.			
9		383.			
10		451.	618.		
11		522.	715.		
12		596.	817.		
13					
14					
15					

NO. WHITE CEDAR

TOTAL STEM PLUS TOTAL BRANCHES

DRY WEIGHT (POUNDS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	53.	84.			
7	66.	104.			
8		126.			
9		149.			
10		173.	247.		
11		198.	283.		
12		224.	320.		
13					
14					
15					

TOTAL STEM

FRESH WEIGHT (POUNDS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	90.	147.			
7	113.	185.			
8		224.			
9		267.			
10		311.	456.		
11		357.	524.		
12		406.	595.		
13					
14					
15					

NO. WHITE CEDAR

TOTAL STEM

DRY WEIGHT (POUNDS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	43.	72.			
7	52.	88.			
8		105.			
9		122.			
10		140.	209.		
11		158.	236.		
12		177.	264.		
13					
14					
15					

MERCHANTABLE STEM

FRESH WEIGHT (POUNDS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	66.	119.			
7	84.	151.			
8		186.			
9		224.			
10		264.	415.		
11		307.	481.		
12		352.	552.		
13					
14					
15					

NO. WHITE CEDAR

MERCHANTABLE STEM

DRY WEIGHT (POUNDS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	32.	59.			
7	40.	73.			
8		88.			
9		104.			
10		121.	192.		
11		138.	219.		
12		156.	247.		
13					
14					
15					

TOTAL BRANCHES

FRESH WEIGHT (POUNDS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	46.	55.			
7	61.	73.			
8		92.			
9		113.			
10		136.	156.		
11		160.	184.		
12		187.	214.		
13					
14					
15					

NO. WHITE CEDAR

TOTAL BRANCHES

DRY WEIGHT (POUNDS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	9.	10.			
7	12.	14.			
8		19.			
9		25.			
10		31.	35.		
11		39.	43.		
12		47.	52.		
13					
14					
15					

BRANCHES SMALLER THAN ONE INCH

FRESH WEIGHT (POUNDS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	46.	54.			
7	59.	69.			
8		86.			
9		105.			
10		124.	141.		
11		145.	164.		
12		167.	189.		
13					
14					
15					

NO. WHITE CEDAR

BRANCHES SMALLER THAN ONE INCH

DRY WEIGHT (POUNDS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	8.	10.			
7	11.	13.			
8		17.			
9		21.			
10		25.	28.		
11		30.	33.		
12		36.	39.		
13					
14					
15					

ROOTS OVER 4 INCHES AND AERIAL PORTION

FRESH WEIGHT (POUNDS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	164.	234.			
7	210.	301.			
8		374.			
9		452.			
10		536.	709.		
11		626.	827.		
12		721.	952.		
13					
14					
15					

NO. WHITE CEDAR

ROOTS OVER 4 INCHES AND AERIAL PORTION

DRY WEIGHT (POUNDS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	64.	95.			
7	81.	121.			
8		148.			
9		178.			
10		209.	285.		
11		242.	330.		
12		277.	377.		
13					
14					
15					

STUMP. LARGE AND MEDIUM ROOTS

FRESH WEIGHT (POUNDS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	33.	40.			
7	45.	53.			
8		69.			
9		86.			
10		105.	120.		
11		126.	144.		
12		149.	170.		
13					
14					
15					

NO. WHITE CEDAR

STUMP. LARGE AND MEDIUM ROOTS

DRY WEIGHT (POUNDS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	13.	15.			
7	18.	21.			
8		27.			
9		35.			
10		43.	49.		
11		52.	59.		
12		62.	70.		
13					
14					
15					

LARGE AND MEDIUM ROOTS

FRESH WEIGHT (POUNDS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	16.	23.			
7	21.	30.			
8		38.			
9		47.			
10		57.	74.		
11		67.	88.		
12		79.	103.		
13					
14					
15					

NO. WHITE CEDAR

LARGE AND MEDIUM ROOTS

DRY WEIGHT (POUNDS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	5.	8.			
7	7.	10.			
8		14.			
9		17.			
10		21.	28.		
11		26.	34.		
12		31.	40.		
13					
14					
15					

ROOTS LESS THAN ONE INCH

FRESH WEIGHT (POUNDS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	4.	7.			
7	4.	9.			
8		10.			
9		12.			
10		14.	22.		
11		16.	25.		
12		18.	28.		
13					
14					
15					

NO. WHITE CEDAR

ROOTS LESS THAN ONE INCH

DRY WEIGHT (POUNDS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	0.	1.			
7	0.	1.			
8		1.			
9		2.			
10		2.	3.		
11		3.	4.		
12		3.	5.		
13					
14					
15					

Table 4 presents the parts per million of 12 nutrient elements in the large trees. Ca, N, K and Mg were present in much larger proportions than the other elements. By multiplying these by the dry weight of the merchantable bole and the complete tree, tables estimating the amount of these elements in grams were prepared.

Regression equations relating fresh and dry weight separately, of seedling and sapling size cedar trees, to height above ground for 36 trees obtained on the university Forest are shown in table 5. Their R^2 values are uniformly high for all components.

Fresh and dry weight for ten height classes are presented in tabular form. The values for the complete tree in the table are the values of the four components added together. The complete tree equation would have provided results slightly different due to the statistical methods used.

Table 6 shows the parts per million for each of the 12 nutrient elements in the seedling and sapling size trees for each of the four tree components. The leaves have the highest proportion of all elements except for Al and Cu which are highest in the roots. These percentages of the nutrient elements were multiplied by the dry weight of each of the four components for each of ten size classes as shown in the same table with the weight of the small trees.

Table 4 Estimated nutrient element content in large cedar trees based on data from 3 trees.

Element	Tree component	
	Merchantable bole	Complete tree
	Parts per million	
Al	5	17
Mn	3	14
Mo	2	4
Ca	4650	6010
P	34	150
Mg	177	307
Zn	4	8
Cu	0.4	0.(
Fe	34	49
B	5	6
K	146	375
N		

COMPLETE TREE

NITROGEN (GRAMS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	48.	72.			
7	60.	91.			
8		111.			
9		133.			
10		156.	214.		
11		181.	247.		
12		206.	282.		
13					
14					
15					

NO. WHITE CEDAR

MERCHANTABLE BOLE

NITROGEN (GRAMS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	11.	19.			
7	13.	24.			
8		29.			
9		34.			
10		39.	62.		
11		45.	71.		
12		51.	80.		
13					
14					
15					

COMPLETE TREE

CALCIUM (GRAMS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	184.	276.			
7	233.	349.			
8		428.			
9		512.			
10		602.	823.		
11		696.	952.		
12		795.	1087.		
13					
14					
15					

NO. WHITE CEDAR

MERCHANTABLE BOLE

CALCIUM (GRAMS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	69.	126.			
7	86.	156.			
8		187.			
9		221.			
10		255.	405.		
11		292.	462.		
12		329.	522.		
13					
14					
15					

COMPLETE TREE

POTASSIUM (GRAMS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	11.	17.			
7	15.	22.			
8		27.			
9		32.			
10		38.	51.		
11		43.	59.		
12		50.	68.		
13					
14					
15					

NO. WHITE CEDAR

MERCHANTABLE BOLE

POTASSIUM (GRAMS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	2.	4.			
7	3.	5.			
8		6.			
9		7.			
10		8.	13.		
11		9.	15.		
12		10.	16.		
13					
14					
15					

COMPLETE TREE

MAGNESIUM (GRAMS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	9.	14.			
7	12.	18.			
8		22.			
9		26.			
10		31.	42.		
11		36.	49.		
12		41.	56.		
13					
14					
15					

NO. WHITE CEDAR

MERCHANTABLE BOLE

MAGNESIUM (GRAMS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	3.	5.			
7	3.	6.			
8		7.			
9		8.			
10		10.	15.		
11		11.	18.		
12		13.	20.		
13					
14					
15					

COMPLETE TREE

PHOSPHORUS (GRAMS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	4.6	6.9			
7	5.8	8.7			
8		10.7			
9		12.8			
10		15.0	20.5		
11		17.4	23.7		
12		19.8	27.1		
13					
14					
15					

NO. WHITE CEDAR

MERCHANTABLE BOLE

PHOSPHORUS (GRAMS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	.5	.9			
7	.6	1.1			
8		1.4			
9		1.6			
10		1.9	2.9		
11		2.1	3.4		
12		2.4	3.8		
13					
14					
15					

COMPLETE TREE

MANGANESE (GRAMS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	.43	.65			
7	.55	.82			
8		1.00			
9		1.20			
10		1.41	1.93		
11		1.63	2.23		
12		1.86	2.55		
13					
14					
15					

NO. WHITE CEDAR

MERCHANTABLE BOLE

MANGANESE (GRAMS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	.04	.07			
7	.05	.09			
8		.10			
9		.12			
10		.14	.23		
11		.16	.26		
12		.18	.29		
13					
14					
15					

COMPLETE TREE

IRON (GRAMS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	1.5	2.2			
7	1.9	2.8			
8		3.5			
9		4.2			
10		4.9	6.7		
11		5.7	7.8		
12		6.5	8.9		
13					
14					
15					

NO. WHITE CEDAR

MERCHANTABLE BOLE

IRON (GRAMS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	.5	.9			
7	.6	1.1			
8		1.4			
9		1.6			
10		1.9	3.0		
11		2.1	3.4		
12		2.4	3.8		
13					
14					
15					

COMPLETE TREE

ALUMINUM (GRAMS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	.5	.8			
7	.7	1.0			
8		1.2			
9		1.5			
10		1.7	2.3		
11		2.0	2.7		
12		2.3	3.1		
13					
14					
15					

NO. WHITE CEDAR

MERCHANTABLE BOLE

ALUMINUM (GRAMS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	.1	.1			
7	.1	.2			
8		.2			
9		.2			
10		.3	.4		
11		.3	.5		
12		.3	.5		
13					
14					
15					

COMPLETE TREE

MOLYBDENUM (GRAMS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	.11	.17			
7	.14	.21			
8		.26			
9		.31			
10		.36	.49		
11		.42	.57		
12		.48	.65		
13					
14					
15					

NO. WHITE CEDAR

MERCHANTABLE BOLE

MOLYBDENUM (GRAMS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	.03	.06			
7	.04	.08			
8		.09			
9		.11			
10		.13	.20		
11		.14	.23		
12		.16	.26		
13					
14					
15					

COMPLETE TREE

ZINC (GRAMS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	.2	.3			
7	.3	.4			
8		.5			
9		.6			
10		.8	1.0		
11		.9	1.2		
12		1.0	1.4		
13					
14					
15					

NO. WHITE CEDAR

MERCHANTABLE BOLE

ZINC (GRAMS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	.1	.1			
7	.1	.1			
8		.1			
9		.2			
10		.2	.3		
11		.2	.4		
12		.3	.4		
13					
14					
15					

COMPLETE TREE

COPPER (GRAMS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	.02	.02			
7	.02	.03			
8		.04			
9		.04			
10		.05	.07		
11		.06	.08		
12		.07	.09		
13					
14					
15					

NO. WHITE CEDAR

MERCHANTABLE BOLE

COPPER (GRAMS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	.01	.01			
7	.01	.01			
8		.02			
9		.02			
10		.02	.03		
11		.03	.04		
12		.03	.04		
13					
14					
15					

COMPLETE TREE

BORON (GRAMS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	.2	.3			
7	.2	.3			
8		.4			
9		.5			
10		.6	.8		
11		.7	.9		
12		.8	1.0		
13					
14					
15					

NO. WHITE CEDAR

MERCHANTABLE BOLE

BORON (GRAMS)

D.B.H. (IN.)	TOTAL HEIGHT (FEET) 30	40	50	60	70
6	.1	.1			
7	.1	.2			
8		.2			
9		.2			
10		.3	.4		
11		.3	.5		
12		.3	.5		
13					
14					
15					

Table 5 Regression equations relating fresh and dry weight of components of small cedar trees to tree height, in grams.

Component(s)	Equation	R^2
Leaves:		
Fresh weight	$\log Y = 2.58+2.03 \log X$	94
Dry weight	$\log Y = 1.59+2.07 \log X$	94
Branches:		
Fresh weight	$\log Y = 1.20+2.40 \log X$	90
Dry weight	$\log Y = 0.59+2.37 \log X$	89
Stem:		
Fresh weight	$\log Y = 0.59+2.98 \log X$	97
Dry weight	$\log Y = -0.32+3.07 \log X$	95
Roots:		
Fresh weight	$\log Y = 1.31+2.46 \log X$	94
Dry weight	$\log Y = 0.60+2.40 \log X$	93
Complete tree:		
Fresh weight	$\log Y = 3.02+2.41 \log X$	96
Dry weight	$\log Y = 2.21+2.42 \log X$	96

Where Y is the weight in grams, X the height above ground in feet and R^2 the coefficient of determination.

Table 6 Estimated nutrient element content in small tree components based on data from 5 tree size classes.

Element	Tree component			
	Leaves	Branches	Stems	Roots
	Parts per million			
Al	74	54	17	130
Mn	265	39	31	82
Mo	11	9	6	6
Ca	14,700	11,400	7,300	8,100
P	890	250	120	290
Mg	1,070	450	280	360
Zn	44	23	10	14
Cu	2	2	3	5
Fe	134	92	44	168
B	13	7	6	7
K	2,100	470	210	550
N	8,300	2,400	1,500	1,700

Pulping Studies

To conform with the studies published in Technical Bulletin 17, pulp was made from the same tree components by the same pulping equipment and accepted laboratory practices and tests of the chemical engineering department of the University of Maine. In addition, a sample consisting of each of the tree components (except the leaves) in proportion to their percentage of the complete tree was pulped to simulate pulp that might be obtained from chips produced by a complete tree harvester, a machine that is still only an idea.

Inasmuch as northern white cedar is not being used commercially for pulp, certain aspects of its pulping should be mentioned. The sulfate liquor was prepared according to conditions used by Standard Packaging Corporation in some of their laboratory testing. This included a chemical to wood ratio of 0.3:1 (the chemical being expressed as equivalent Na_2O and a 25% sulfidity). The liquor concentration

Table 7
NORTHERN WHITE CEDAR (grams)

Height (feet)	Component	Fresh Weight	Dry Weight	Al	Mn	Mo	Ca	P	Mg	Zn	Cu	Fe	B	K	N	Component
	Needles	13.2	4.9	0.000	0.001	0.000	0.072	0.004	0.005	0.000	0.000	0.001	0.000	0.010	0.041	Needles
	Branches	3 3	1.8	.000	.000	.000	.021	.000	.001	.000	.000	.000	.000	.001	.004	Branches
	Stem	1.8	.7	.000	.000	.000	.005	.000	.000	.000	.000	.000	.000	.000	.001	Stem
	Roots	3.7	1.9	.000	.000	.000	.015	.001	.001	.000	.000	.000	.000	.001	.003	Roots
	Complete Tree	22.0	9.3	0.000	0.001	0.000	0.113	0.005	0.007	0.000	0.000	0.001	0.000	0.012	0.049	Complete Tree
	Needles	122.	48.	0.004	0.013	0.001	0.706	0.043	0.051	0.002	0.000	0.006	0.001	0.101	0.398	Needles
	Branches	47.	24.	.001	.001	.000	.278	.006	.011	.001	.000	.002	.000	.011	.058	Branches
	Stem	48.	21.	.000	.001	.000	.155	.003	.006	.000	.000	.001	.000	.004	.032	Stem
	Roots	55.	26.	.003	.002	.000	.207	.007	.009	.000	.000	.004	.000	.014	.043	Roots
	Complete Tree	272.	119.	0.008	0.017	0.001	1.346	0.059	0.077	0.003	0.000	0.013	0.001	0.130	0.531	Complete Tree
	Needles	344.	138.	0.010	0.037	0.001	2.034	0.123	0.148	0.006	0.000	0.019	0.002	0.291	1.149	Needles
	Branches	160.	82.	.004	.003	.001	.932	.020	.037	.002	.000	.008	.001	.038	.196	Branches
	Stem	221.	102.	.002	.003	.001	.746	.012	.029	.001	.000	.004	.001	.021	.153	Stem
	Roots	193.	87.	.011	.007	.001	.706	.025	.031	.001	.000	.015	.001	.048	.148	Roots
	Complete Tree	918.	409.	0.027	0.050	0.004	4.418	0.180	0.245	0.010	0.000	0.046	0.005	0.398	1.646	Complete Tree
	Needles	679.	278.	0.021	0.074	0.003	4.086	0.247	0.297	0.012	0.001	0.037	0.004	0.584	2.307	Needles
	Branches	359.	182.	.010	.007	.002	2.070	.045	.082	.004	.000	.017	.001	.085	.436	Branches
	Stem	605.	288.	.005	.009	.002	2.100	.035	.081	.003	.001	.013	.002	.060	.431	Stem
	Roots	441.	195.	.025	.016	.001	1.583	.057	.070	.003	.001	.033	.001	.108	.332	Roots
	Complete Tree	2084.	943.	61	0.106	0.008	9.839	0.384	0.530	0.022	0.003	0.100	0.008	0.837	3.506	Complete Tree
	Needles	1399.	582.	0.043	0.154	0.006	8.557	0.518	0.623	0.026	0.001	0.078	0.007	1.222	4.831	Needles
10	Branches	845.	423.	.023	.017	.004	4.824	.106	.190	.010	.001	.039	.003	.199	1.016	Branches
	Stem	1754.	861.	.015	.027	.005	6.287	.103	.241	.009	.003	.038	.005	.181	1.292	Stem
	Roots	1059.	460.	.060	.038	.003	3.727	.133	.166	.006	.002	.077	.003	.253	.782	Roots
	Complete Tree	5057.	2326.	0.141	0.236	0.018	23.395	0.860	1.220	0.051	0.007	0.232	0.018	1.855	7.921	Complete Tree
	Needles	3182.	1349.	0.100	0.357	0.014	19.828	1.200	1.443	0.059	0.003	0.181	0.017	2.833	11.195	Needles
15	Branches	2240.	1107.	.060	.043	.010	12.618	.277	.498	.025	.003	.102	.008	.520	2.657	Branches
	Stem	5885.	2995.	.051	.093	.017	21.867	.359	.839	.030	.009	.132	.017	.629	4.493	Stem
	Roots	2866.	1218.	.158	.100	.008	9.862	.353	.438	.017	.006	.205	.009	.670	2.070	Roots
	Complete Tree	14173.	6669.	0.369	0.593	0.049	64.175	2.189	3.218	0.131	0.021	0.620	0.051	4.652	20.415	Complete Tree
	Needles	5701.	2448.	0.181	0.649	0.026	35.993	2.179	2.620	0.108	0.005	0.328	0.031	5.142	20.323	Needles
20	Branches	4472.	2190.	.118	.085	.020	24.963	.547	.985	.050	.005	.201	.015	1.029	5.225	Branches
	Stem	13892.	7254.	.123	.225	.041	52.952	.870	2.031	.073	.022	.319	.042	1.523	10.881	Stem
	Roots	5809.	2429.	.316	.199	.015	19.671	.704	.874	.034	.012	.408	.017	1.336	4.129	Roots
	Complete Tree	29874.	14321.	0.738	1.158	2.102	133.579	4.300	6.510	0.265	0.044	1.256	0.105	9.030	40.558	Complete Tree
	Needles	8959.	3888.	0.288	1.030	0.041	57.158	3.461	4.161	0.171	0.008	0.521	0.050	8.165	32.273	Needles
25	Branches	7647.	3717.	.201	.145	.033	42.375	.929	1.673	.085	.009	.342	.026	1.747	8.921	Branches
	Stem	27046.	14404.	.245	.447	.081	105.151	1.729	4.033	.144	.045	.634	.084	3.025	21.606	Stem
	Roots	10048.	4149.	.539	.340	.026	33.607	1.203	1.494	.058	.020	.697	.029	2.282	7.053	Roots
	Complete Tree	53700.	26158.	1.273	1.962	0.181	238.291	7.322	11.361	0.458	0.082	2.194	0.189	15.222	69.853	Complete Tree
	Needles	12964.	5674.	0.420	1.504	0.060	83.405	5.050	6.071	0.250	0.011	0.760	0.073	11.915	47.093	Needles
30	Branches	11852.	5728.	.309	.223	.052	65.296	1.432	2.577	.132	.014	.527	.040	2.692	13.747	Branches
	Stem	46613.	25230.	.429	.782	.161	184.170	3.028	7.064	.252	.078	1.110	.146	5.298	37.845	Stem
	Roots	15722.	6426.	.835	.527	.040	58.057	1.864	2.314	.090	.031	1.080	.046	3.535	10.925	Roots
	Complete Tree	87151.	43058.	1.993	3.036	0.293	384.837	11.374	18.026	0.724	0.134	3.477	0.305	23.440	109.610	Complete Tree
	Needles	17717.	7810.	0.578	2.070	0.083	114.801	6.951	8.356	0.344	0.016	1.046	0.100	16.400	64.820	Needles
35	Branches	17168.	8255.	.446	.322	.074	94.113	2.064	3.715	.190	.020	.760	.058	3.880	19.813	Branches
	Stem	73858	40526.	.689	1.256	.227	295.838	4.863	11.347	.405	.126	1.783	.235	8.510	60.789	Stem
	Roots	22953.	9304.	1.210	.763	.038	75.363	2.698	3.349	.130	.045	1.563	.066	5.117	15.817	Roots
	Complete Tree	131698.	65895.	2.923	4.411	0.442	580.115	16.567	26.767	1.069	0.207	3.152	0.459	33.907	161.239	

could not be determined in advance because the amount of liquid necessary to cover the chips was not known. It was later found to be about 19.7 grams per liter with a liquor to wood ratio of 15:1. The chemicals, NaOH and Na_2S were dissolved in water. Either caustic or sulfide was added as necessary until the test showed 25% sulfidity (as Na_2O). The concentration of the liquor was also determined and the amount necessary to give a chemical to wood ratio of 0.3:1 was calculated. An estimated cooking time of 4.5 hours was used in the first trial. Inasmuch as this yielded the desired permanganate number of 18, it was used in each subsequent cook.

The permanganate numbers as shown in table 8 indicate that lignin is less easily removed from the branches and roots and that pulp from these components will require more bleaching than pulp from the bole. Pulps from the composite samples had permanganate numbers only slightly higher than those from the bole.

Table 8 Permanganate numbers in pulping study of northern white cedar.

Component	Tree #1 6″ Dbh	Tree #2 8″ Dbh	Tree #3 12″ Dbh
Unmerchantable bole	18.9	19.0	18.6
Merchantable bole	19.4	——	18.5
Branches	23.3	23.6	22.8
Roots	20.8	21.6	20.7
Composite	20.6	19.9	19.8

Table 9 Screened yield of cedar pulp as percent of bone dry chips charged.

Component	Tree #1	Tree #2	Tree #3
Unmerchantable bole	42.1	43.4	42.4
Merchantable bole	42.6	——	42.9
Branches	39.1	38.5	41.2
Roots	40.0	40.1	43.6
Composite	42.0	43.6	44.4

The screened yields based on bone dry weight of wood charged are shown in table 9. The branches and roots had lower yields than the other components. Variation in tree size was not found to affect permanganate numbers or screened yields. So few rejects were found from all samples that they were considered to be insignificant.

All structural and strength data were plotted with respect to Canadian Standard Freeness instead of refining time because CSF is a better measure of the actual conditions of the fibers. This is true because all pulps do not react the same to refining. Strength curves are presented only for the 8.4 inch Dbh tree as there were no real differences between trees of different size and age. This fact would be significant in considering cedar for commercial pulping.

Figure 1 is a graph of the relationship between CSF and refining time. The pulps from all components reacted to refining at about the same rate. The branches were lower in freeness than the other components.

Bulk curves are shown in figure 2. The curves show that the branch pulps definitely have higher bulk than pulps from other components.

Graphs of the tear factors are shown in figure 3. In general the roots and branches are a little higher in tear strength than the other components.

Curves representing the burst factors are presented in figure 4. The branch and root pulps are inferior to the bole pulp in burst strength. Pulps from the composite samples are intermediate in burst strength between pulps from the bole and pulps from the roots and branches.

Tensile strength in terms of breaking length is plotted in figure 5 for each component and the composite. The branch and root pulps were inferior to the bole pulp.

Stretch as a percent is presented in figure 6. Pulp from the branches has superior stretching properties. Figure 7 shows bulk and strength curves for a typical sulfate spruce pulp and for pulp from the bole wood of cedar as a means of comparing a species that is commercially favored with cedar which is not used in the northeast at the present time. Table 10 shows fiber dimensions for pulps from four tree components.

Due to limited material and lack of confidence in the accuracy of the M.I.T. fold tester, this test was not performed. Recent informal discussions with Benjamin Hoos of the Brown Company brought new light on this characteristic of cedar pulp. Prior to World War II he was able to make extensive pulping studies of a number of species for which considerable material was on hand and there was a sizable staff to perform the standard tests. By making a large number of fold tests with the M.I.T. fold tester he was able to note distinct average differences between species native to the northeast. Northern white cedar shows a much greater fold test value than any other species. In fact, it was several times greater than that for spruce which, in turn, was larger than any other eastern species tested. For certain products some western pulp mills are now adding as much as 15-20% cedar to the furnish to increase the fold capacity of the final product. This possibility may become of industrial value in the northeast.

Figure 1. Relationship of freeness to refining time for pulps from tree #3.

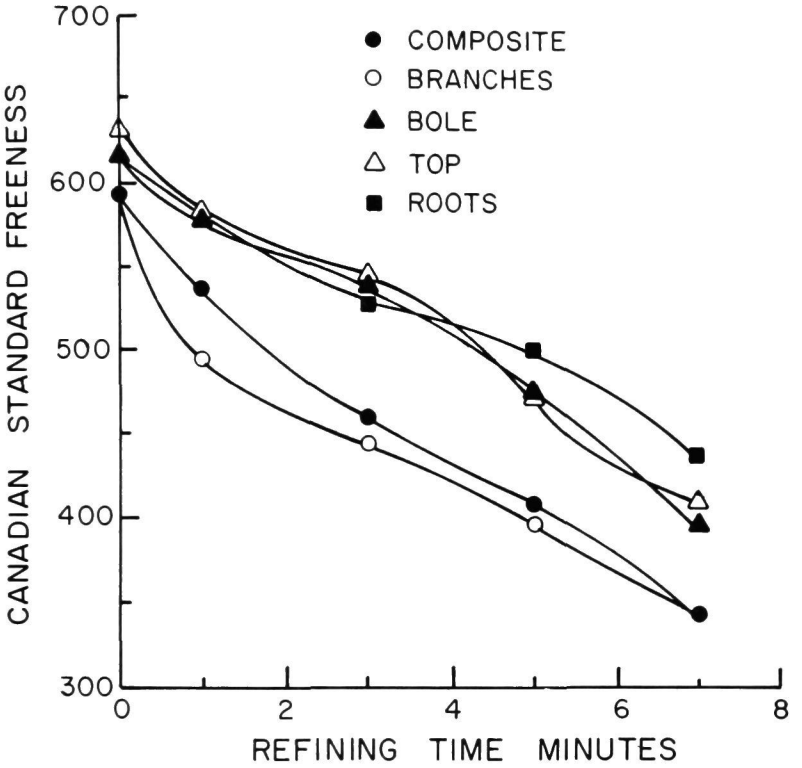


Figure 2. Relationship of bulk to freeness for pulps from tree #3.

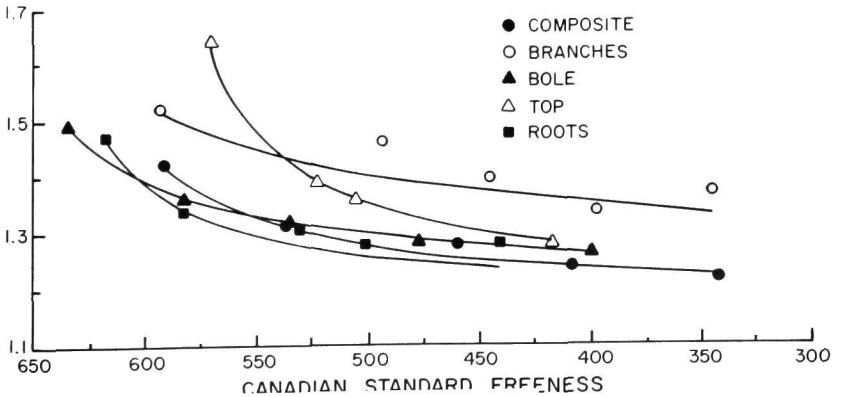


Figure 3. Relationship of tear factor to freeness for pulps from tree #3.

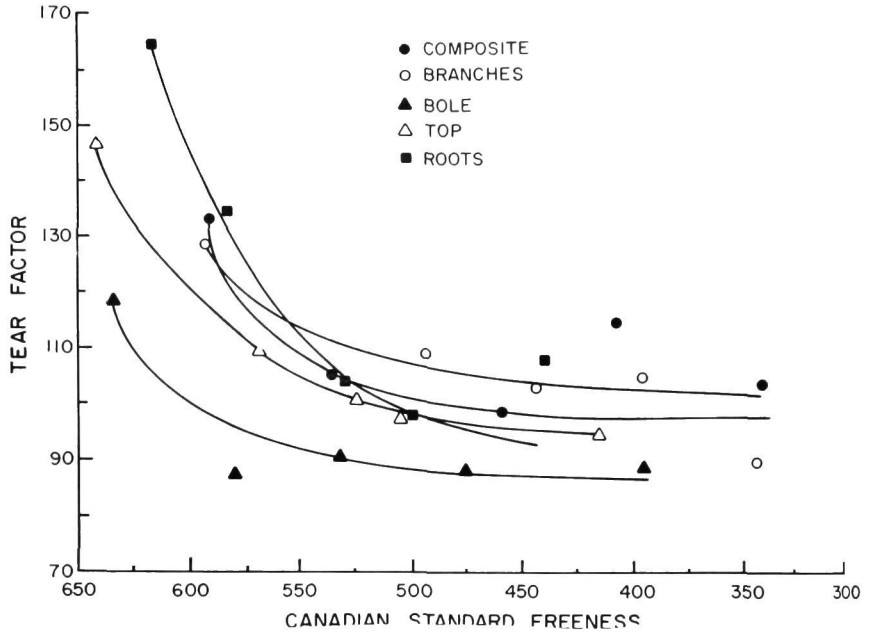


Figure 4. Relationship of burst factor to freeness for pulps from tree #3.

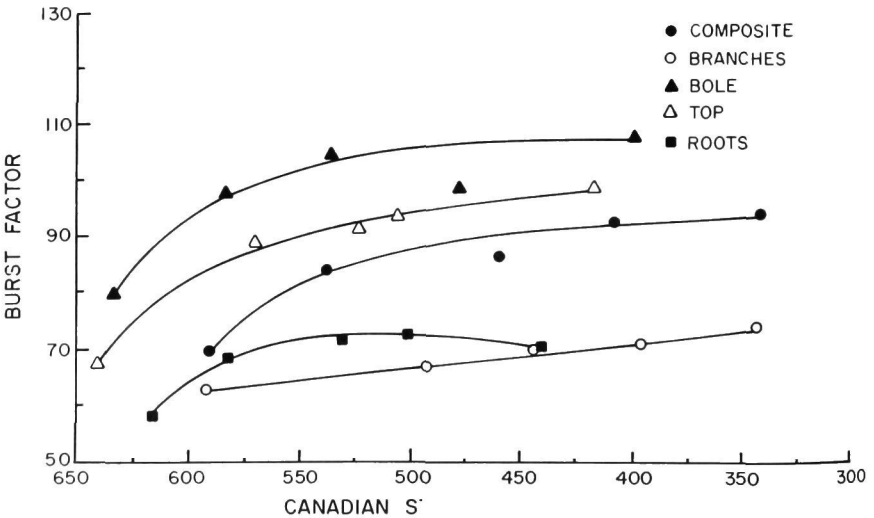


Table 10 Fiber dimensions for pulps from 4 tree components.

Component	Tree #1	Tree #3
Average fiber diameters:		
Unmerchantable top	0.02 mm	0.01 mm
Branches	0.01 mm	0.01 mm
Roots	0.02 mm	0.02 mm
Bole	0.02 mm	0.02 mm
Average fiber lengths: Component		
Unmerchantable top	2.55 mm	2.65 mm
Branches	1.81 mm	1.62 mm
Roots	2.26 mm	2.03 mm
Bole	2.56 mm	2.78 mm

Figure 5. Relationship of breaking length to freeness for pulps from tree #3.

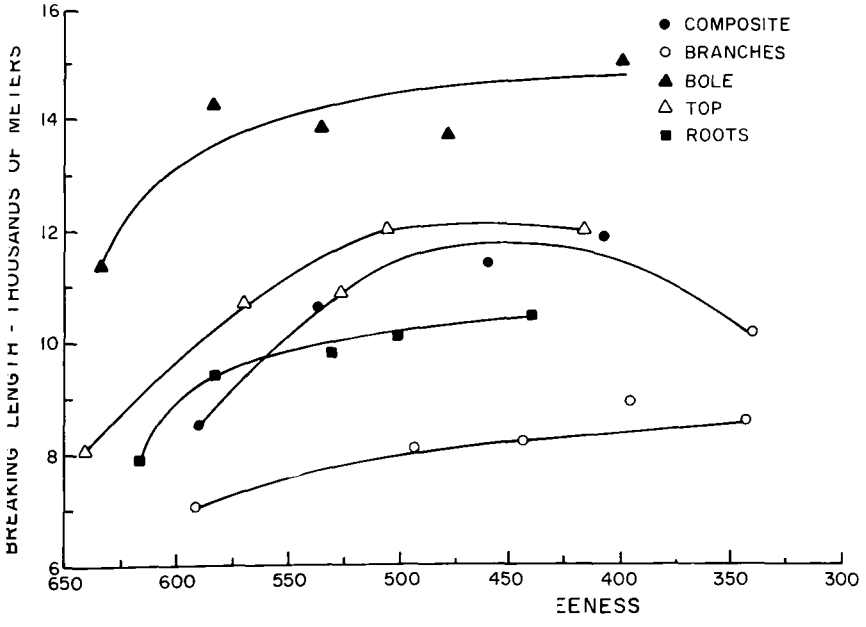


Figure 6. Relationship of stretch percent to freeness for pulps from tree #3.

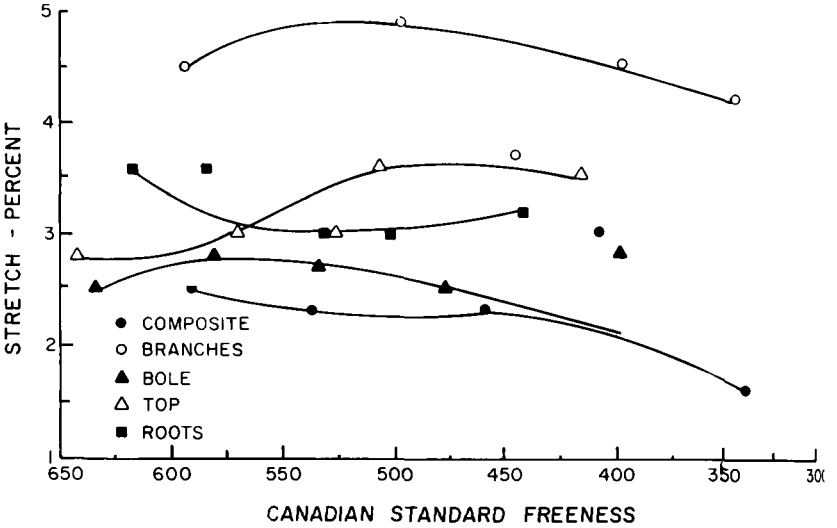
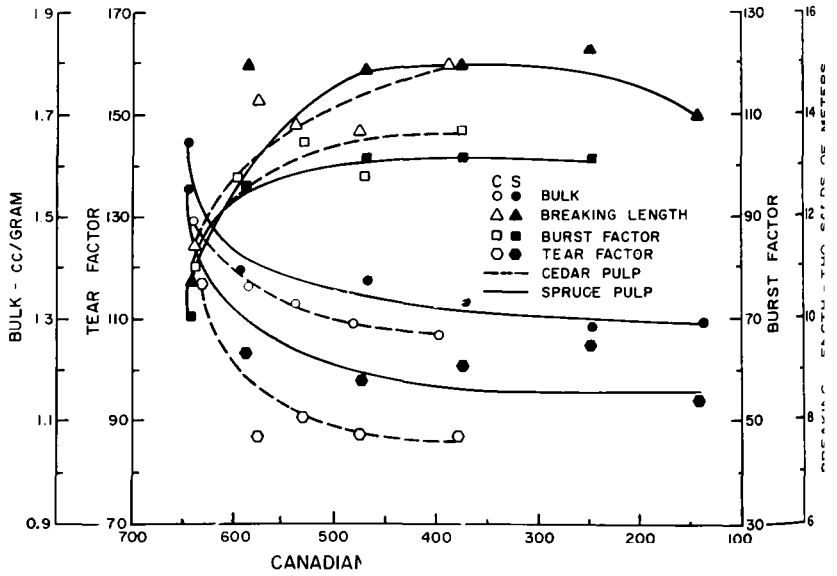


Figure 7. Bulk and strength curves for a typical sulfate spruce pulp and for pulp from the bole wood of cedar.



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