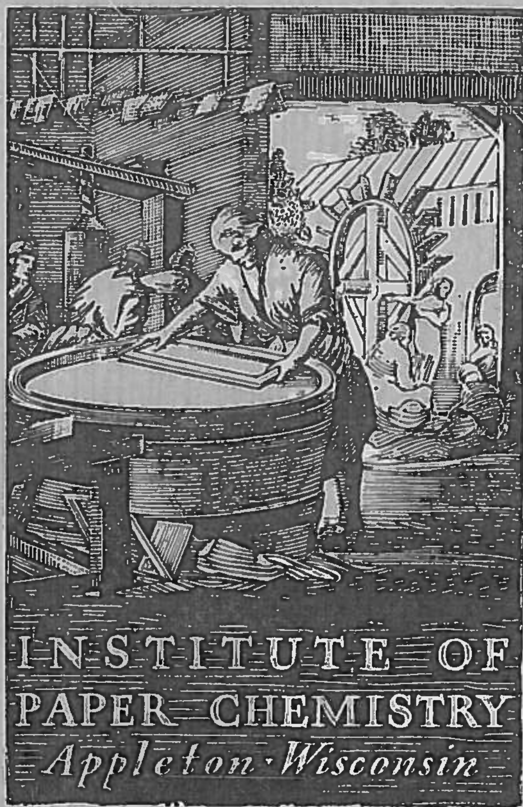

GENETIC INPROVEMENT OF LARCH

Project 3409

Report Eight
A Progress Report
to
MEMBERS OF GROUP PROJECT 3409

February 15, 1988

MATERIALS AND METHODS

WOOD PROPERTIES

The trees selected for this study consisted of three 26-year-old pulpwood-sized trees from a plantation in northern Wisconsin (Oneida County) and three 69-year-old, well-formed, dominant/codominant trees growing in a nearby unmanaged stand. The plantation trees were growing on a well-drained sandy site and the unmanaged stand was located on a low, poorly-drained soil typical of the sites presently supporting tamarack stands in north central Wisconsin.

The size of the experimental trees, along with information on wood specific gravity, percent bark, heartwood, and compression wood are summarized in Table 7. As can be noted from the data plantation tamarack on a well-drained site grew considerably faster than the mature tamarack in a low, poorly drained site typical of where most tamarack are found; another indication that tamarack can occupy upland sites. After collection, the trees were sampled by taking disks at the base, 4-1/2 ft (1.37 m), and every 6 ft (1.83 m) to a 4-inch (10.2 cm) top inside diameter. The bolts were then manually debarked and chipped. Chips were screened and those passing the one-inch (25.4 mm) screen and retained on the 1/2- and 1/4-inch (12.7 and 6.4 mm) screens were the fractions pulped. Oversize reject chips were rechipped and rescreened once prior to discarding the rejects and fines. The accepted chips were air dried prior to pulping.

Pulps were evaluated for their usefulness as bag papers by kraft cooking to a kappa number of approximately 50 and for use as part of a furnish of bleachable-grade pulps by cooking to a kappa 30. The pulping conditions used were the same as for earlier studies conducted by Project 3409 on red pine,

Table 7. Tamarack tree size and wood quality.

Tree No.	Type of Material	Age, years	DBH, inches	Total Height, feet	Whole Tree sp.gr.	Age-15 Fiber Length, mm	Bark, %	Heartwood, %	Compression Wood, %
I	Mature	71	10.0	67	0.464	2.1	7.4	49.4	6.5
II	Mature	72	9.9	72	0.453	2.6	9.8	49.9	6.4
III	Mature	63	9.7	74	0.498	2.5	7.9	52.5	6.2
	Av.	69	9.9	71	0.472	2.4	8.4	50.6	6.4
IV	Young	26	7.0	50	0.423	2.5	11.8	39.8	11.4
V	Young	26	7.0	50	0.411	2.2	10.6	37.6	9.4
VI	Young	26	7.9	50	0.397	2.8	9.4	26.8	7.4
	Av.	26	7.3	50	0.410	2.5	10.6	34.7	9.4

European larch, Japanese larch, and European x Japanese hybrid larch pulpwood-sized thinnings. Fifty-five-year-old jack pine wood was also included in the earlier studies as a source of control pulp.

The data on percent bark are the weighted average values and were estimated from disk samples by removing the bark and comparing wood and bark oven-dry weights. Tree specific gravity is the dry weight divided by green volume, with the green volume being determined by a maximum-moisture, water-displacement procedure using disks located at six-foot intervals up the tree to a four-inch top diameter. Compression wood and heartwood levels were determined using disk samples taken at six-foot intervals. Moist disks were examined using a light box to help distinguish heartwood and compression wood areas. The levels presented are weighted average whole-tree values to a four-inch top diameter for both the thinnings and the mature wood samples.

Fiber measurements were made on representative unbeaten mature wood and young wood pulps and on breast high (4-1/2 ft) disk samples. Appropriate annual ring samples were taken from each of the six trees used in the study and fiber length/age curves prepared for each tree. Six hundred plus intact fibers were measured for each sample. Fiber length data were generated for annual rings 5, 15, 25, 42, and 63 to 72 for the mature trees. Fiber length values were determined for annual rings 5, 15, 20, and 26 for the young wood trees. Duplicate pulp samples were measured for the kappa 30 young wood, kappa 50 young wood, kappa 30 mature wood, and 50 mature wood pulps using the Kjanni automatic fiber length measuring procedure.

CHEMICAL DETERMINATIONS

Chemical determinations were made on representative air-dried chip samples that were prepared for analysis in a Wiley mill. The finely ground wood samples were considered to be representative of the entire bark-free bole to a 4-inch top for the three trees that make up each sample. Determinations included lignin using the Tappi Journal method,[10] alcohol-benzene extractives (TAPPI Method T 204 os-76), and hot water extractives (TAPPI Method T 207 os-75).

PULPING AND BLEACHING CONDITIONS

The chips from the three trees representing each of the two sources of tamarack wood (young wood and mature wood) were thoroughly mixed and air dried prior to pulping. Pulping runs were carried out in an M&K digester using the cooking conditions given in Table 8 to obtain pulps with kappa numbers of approximately 30 and 50. The cooking liquors were prepared from solutions of sodium hydroxide and sodium sulfide of known concentration and density, together with the appropriate amount of dilution water. A microcomputer was used to control the system and acquire temperature, H-factor, and conductivity data. Spent liquor samples were taken to determine the residual alkali. Kappa number, yield, viscosity, and brightness were measured on the pulps produced.

Table 8. Pulping conditions.

Wood charge, kg o.d.	4.0
Water-to-wood ratio, cm^2/g	4.0
Effective alkali, % o.d. wood	16.0
Sulfidity, %	25.0
Ramp rate, °C/min	1.8
Pulping temperature, °C	172.0
H-factors	1000-1700

The chips were fiberized in a Williams disintegrator, and the pulp was screened through a 0.009-inch (0.15 mm) cut screen plate in a small Valley flat screen. The rejects were oven dried, weighed, and discarded. The accepted fiber was then used to determine the physical properties of the pulps using TAPPI methods after beating in a PFI mill at a 10% consistency. Handsheets were prepared from the kappa 30 and kappa 50 pulps after beating in the PFI mill to CSF freeness intervals that varied from 340 to 730 (see table on handsheet strength properties). Handsheets were evaluated for burst, tear, tensile, zero-span tensile, tensile energy absorption (TEA), stretch, porosity, scattering coefficient, and adsorption coefficient. The strength properties of tear, burst, tensile, and TEA are discussed in detail in this report.

Two 50 gram samples of the kappa 30 pulps were bleached using a C_DEHDED sequence. Chlorination was carried out in a stirred tank reactor. The E, H, and D stages were carried out in plastic bags immersed in a constant temperature bath. Kappa number was measured after the E1 stage. Cuene viscosity, G.E. brightness, and pH were measured on pulps at several of the bleaching stages, and this information, along with chemical requirements, was used to compare pulp sources.

RESULTS AND DISCUSSION

WOOD PROPERTIES

The two sources of tamarack were from northern Wisconsin. All trees were straight dominant and codominant trees. Despite the straightness, the young wood had greater levels of compression wood. Additionally, the young wood had higher amounts of juvenile wood, lower levels of heartwood (35 vs. 51%), and lower specific gravity (0.41 vs. 0.47). The wood quality differences between wood sources were much as anticipated with the exception that the differences in heartwood levels were less than anticipated.

The chemical properties of wood (lignin, extractives, etc.) are important in the evaluation of wood species for pulping because of the influence they have on pulp yield, pitch properties, pulping chemical requirements, and pulp bleaching chemical requirements. Lignin levels were similar for young wood and mature wood, and both sources had levels that were lower than jack pine and *Larix* species (Table 9). The level of extractives, both alcohol-benzene and hot water, in the young wood were about twice as high as anticipated in view of the earlier results obtained with plantation grown European and hybrid larch.

No problems were encountered in chipping the two wood sources. After chipping, the material was screened and the rejects (chips retained on the one-inch screen) were rechipped once. The rejects shown are the chips retained on the one-inch screen after one rechipping. Prior to pulping, the chips were air dried. Moisture contents were taken after chipping and prior to air drying. The chip size distribution (Table 10) for the two sources of wood were very similar and, as might be expected because of the higher levels of heartwood and lower juvenile wood, the mature wood chips were a little lower in moisture content.

Table 9. Chemical properties of wood.

Type of Material	Lignin, %	Extractives, %	
		Alcohol-Benzene	Hot Water
Mature tamarack	25.6	3.9	10.0
Young tamarack	26.5	4.2	9.3
23-Year-old hybrid larch	27.9	2.5	4.2
18-Year-old European larch	27.6	1.8	3.9
Jack pine control (55 yr)	27.4	3.5	2.3

Table 10. Characteristics of chips prepared for pulping.

Wood Sample	Percent of Chips on Each Screen[a]				Moisture Content,[c] %
	On 1/4-Inch	On 1/2-Inch	Fines	Rejects[b]	
Young tamarack	24.7	67.7	4.3	3.4	48
Mature tamarack	28.7	61.5	6.2	3.6	41

[a]Based upon oven dry weight measurements.
[b]Rejects from first screening were rechipped once and rescreened.
[c]Moisture content of On 1/4 and On 1/2-inch chips, determined on a fresh weight basis.

PULPING CHARACTERISTICS

The pulping times required to produce kappa 50 (bag paper) and kappa 30 (bleachable grade) pulps were established and then used to obtain pulps that could be used in strength comparisons. Table 11 summarizes the results of varying pulping conditions on kappa number and pulp yield. Pulping time has been replaced by the generally more useful H-factor.[11] Differences between the two sources of chips were further clarified by plotting kappa number *vs.* H-factor, as illustrated in Fig. 8.

Table 11. Pulping conditions, kappa number, Cuene viscosity, and pulp yield.

Material	H-Factor	Kappa Number	Cuene Viscosity	Unscreened Yield, % o.d. wood	Screened Rejects,[a] % o.d. wood
Young tamarack	1000	53.4	48.4	45.7	0.1
	1080	50.1	48.4	46.1	0.1
	1700	31.5	34.5	44.0	0.1
Mature wood	1005	49.7	43.8	45.9	0.1
	1650	30.2	35.2	42.9	0.1

[a]Pulps were run through a refiner at 1/12,000-inch gap prior to screening.

As can be seen from the regression line in Fig. 8, there appear to be only minor differences in the pulping rates for the two sources of wood. The overall rate of pulping for tamarack, as will be commented on later, was more rapid than for the earlier evaluated sources of larch and jack pine, but not as rapid as red pine.

Obtaining the maximum yield of pulp from each oven dry pound of wood is extremely important. Figure 9 illustrates the lack of differences that existed between the two sources of wood when they were evaluated at comparable kappa numbers. The degree of polymerization of the pulps, as measured by Cuene viscosity, were about 3 units higher for the kappa 50 young wood pulp, and this indicates a lower level of cellulose degradation during pulping. However at kappa

30, the mature wood pulps had a slight viscosity advantage. Levels of screen rejects were not influenced by wood source. Rejects were only 0.1%, even for the pulps cooked to the higher kappa numbers (49 to 53). However, the procedure used, which involved passing the pulp through a refiner with a 1/12,000-inch gap prior to screening rejects, probably reduced any differences that existed between pulps before refining.

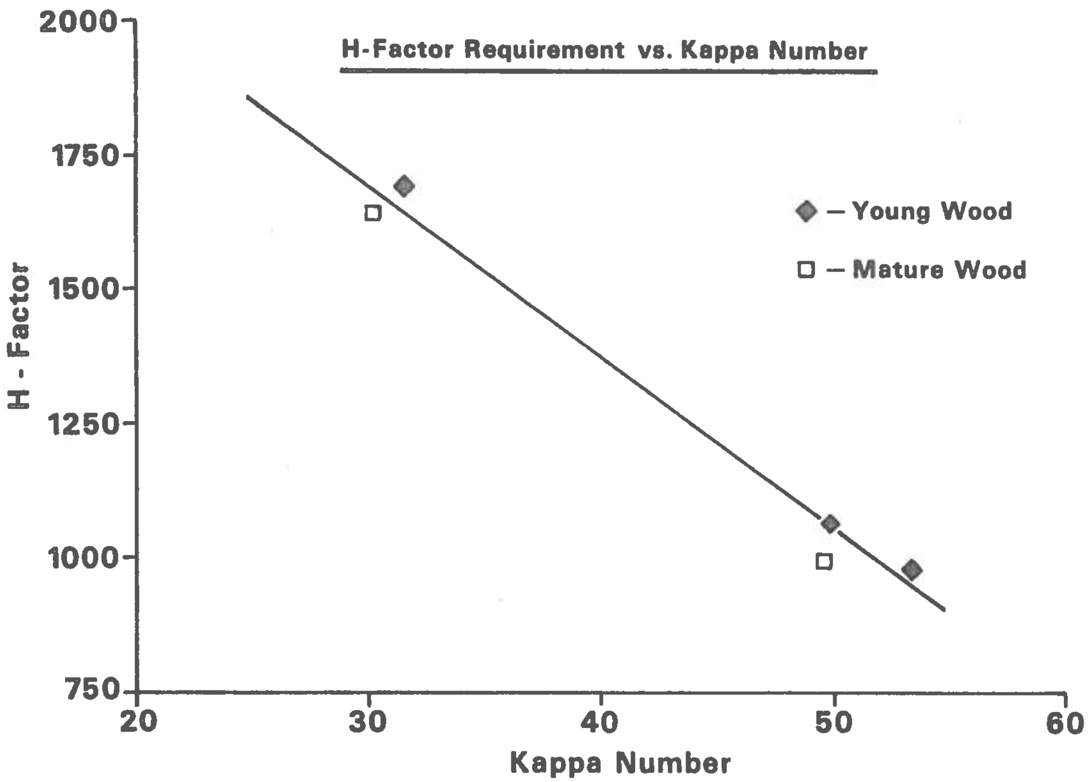

Figure 8. H-factor requirement vs. kappa number for tamarack. The regression line is based on the equation kappa no. = 82.93 + (-0.031 • H factor), R = 0.99.

PULP BLEACHING RESULTS

Mature wood kappa 30.2 and young wood kappa 31.5 pulps were bleached using the C_DEHDED bleaching sequence. Duplicate samples of each pulp source were evaluated. The chlorination stage involved substitution of 15% of the estimated chlorine requirements with chlorine dioxide. The starting chlorine requirements were determined from the formula % Cl_2 = 0.22 x kappa number. Chemical requirements, pulp viscosity, and pulp brightness were used to evaluate the bleached pulps (Table 12).

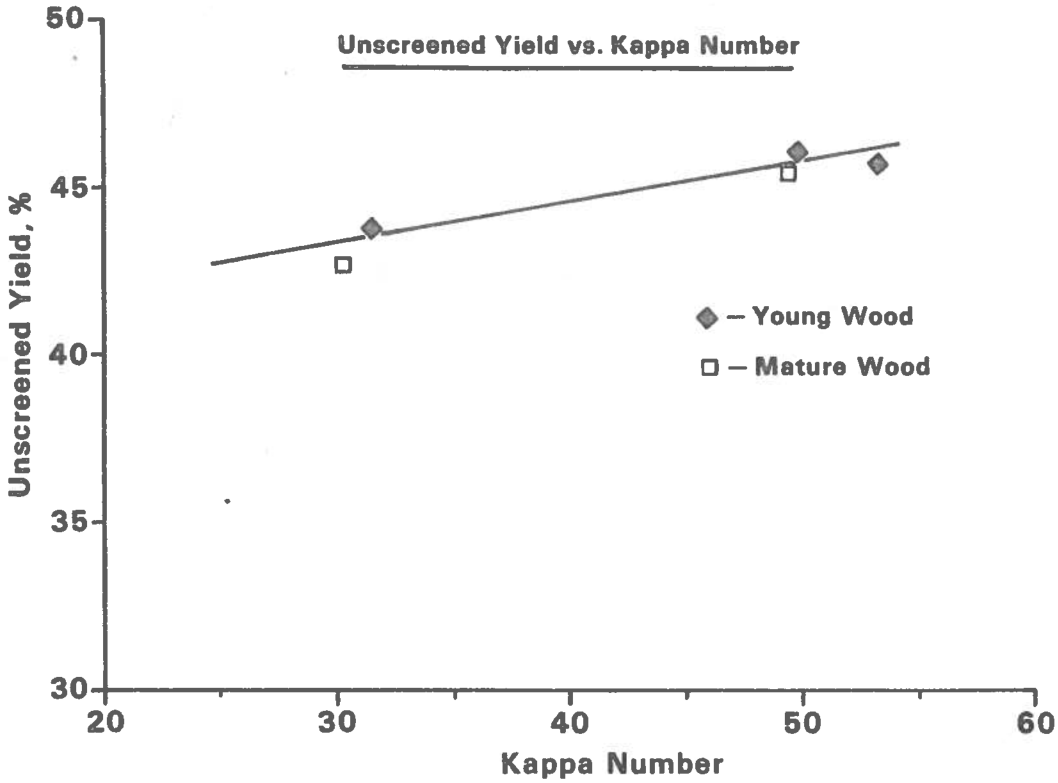

Figure 9. Unscreened yield vs. kappa number for tamarack. The regression line is based on the equation unscreened yield = 39.8 + (0.119 • kappa no.), R = 0.95.

The young wood pulps had a little higher starting kappa number (1.3 units) and as a result had about 0.3% greater starting chlorine level. The young wood tamarack consumed a little higher chlorine in the chlorination stage than the mature wood pulp. Chlorine consumption in the hypo-stage was identical for the pulp sources. Chlorine dioxide consumption was less for the young wood pulps in the dioxide stage (D1) and the same in the D2 stage. The Cuene viscosity, which is a measure of the degree of polymerization of the pulps and reflects pulp degradation, was similar for young and mature wood pulps. The

Table 12. Tamarack bleaching results.

Bleaching Stage	Pulp Source: Young Wood[a]	Pulp Source: Mature Wood[a]
C_D Chlorination: % Cl_2 = 0.22 x kappa no., 15% substitution of Cl_2 by ClO_2		
Cl_2 consumed, %[b]	6.9	6.6
Exit pH	1.52	1.51
E_1 Extraction: % NaOH = Cl_2 • 0.55, 60 min reaction time, 60°C, 10% consistency		
CE kappa no.	6.2	6.4
CE viscosity	33.0	29.4
Exit pH	12.2	12.6
H Hypo-Stage: 1.0% active Cl_2 as NaOCl, 0.4% NaOH, 60 min, 35°C, 10% consistency		
Residual NaOCl, %[b]	0.05	0.05
Exit pH	10.6	10.4
D_1 Dioxide-Stage: 0.8% ClO_2, 0.4% NaOH, 180 min, 70°C, 10% consistency		
Exit pH	2.5	2.4
Residual ClO_2, %[b]	0.22	0
CEHD viscosity	28.9	28.2
G.E. brightness, %	83.8	83.2
E_2 Extraction: 0.4% NaOH, 60 min, 60°C, 10% consistency		
Exit pH	11.8	11.8
D_2 Dioxide: 0.4% ClO_2, 0.07% NaOH, 180 min, 70°C, 10% consistency		
Exit pH	3.5	3.5
Residual ClO_2, %[b]	0.14	0.14
Final viscosity	27.1	25.2
G.E. brightness, %	88.2	88.6

[a]Average values of duplicate samples.
[b]% based on o.d. pulp.

final brightness levels were essentially the same for the two sources of pulp (88.2 vs. 88.6).

Both tamarack pulps bleached without difficulty and had very similar bleaching chemical requirements when compared with bleached jack pine control pulps and 18-year-old European and 23-year-old hybrid larch pulps, when a CEDED bleaching sequence was used (Project 3409, Progress Report One, p. 56). Jack pine 55-year-old control pulps, for example, consumed 7.0% Cl_2 in the chlorination stage, 1.2% ClO_2 in the D1 stage, 0.4% ClO_2 in the D2-stage, and achieved a 90.3 G.E. brightness. It should be noted, however, the bleaching results from the two studies are not strictly comparable because hypochlorite stage was added to the sequence for the tamarack study.

Unpublished data are also available on the C_DEHDED bleaching of the red pine pulps that were evaluated in Project 3409, Progress Report Seven, 1987. When the tamarack bleaching results are compared with bleaching results for mature red pine, the tamarack pulps had about 1.0% higher chlorine consumption in the chlorination stage and very similar chemical requirements in all other bleaching stages. The bleached tamarack pulps were 4 to 7 units higher in Cuene viscosity (degraded less) and had very similar G.E. brightness (88.4 vs. 89.2). Bleaching does not appear to be a problem for the kappa 30 kraft tamarack pulps evaluated in this study.

PULP STRENGTH

The strength properties of the pulps obtained from plantation grown tamarack (young wood) and mature wood are summarized in Table 13. Conifer pulps are refined to improve formation, increase bonding, and improve tensile strength

Table 13. Physical properties of unbleached kappa 50 and kappa 30 tamarack pulps.

Wood Type	No. of Revs.	CSF, mL	Sheet Density, kg/m^3	Burst Index, $kPa\cdot m^2/g$	Tear Index, $mN\cdot m^2/g$	Breaking Length, km	Tensile[a] Index, N·m/g	TEA, J/m^2
				Kappa 50 Pulps				
Young	0	705	559	4.1	15.1	5.7	56	55.4
	2500	660	701	6.7	11.5	8.3	82	104.3
	4000	600	725	7.2	10.7	9.0	89	115.2
	5400	515	738	7.6	10.0	9.1	90	105.9
	6300	460	757	7.9	10.6	9.2	91	110.5
	8000	355	780	7.9	9.6	9.3	92	127.7
Mature	0	730	530	3.3	20.8	4.9	49	50.7
	2400	665	632	5.9	15.0	7.8	77	81.2
	3500	600	657	6.2	13.3	8.1	80	86.5
	4500	520	684	6.9	12.9	8.2	81	105.1
	5750	430	706	7.2	12.0	9.4	93	108.6
	7000	340	718	7.4	10.9	8.9	88	122.6
				Kappa 30 Pulps				
Young	0	680	633	4.5	15.6	6.3	63	74.3
	600	640	700	5.9	13.0	7.8	78	93.6
	1400	605	718	6.6	11.9	9.0	89	96.6
	2800	520	764	7.3	10.2	8.4	82	98.6
	3900	450	771	7.7	10.8	8.9	88	108.4
	5200	370	777	7.8	10.3	9.5	94	120.2
Mature	0	725	559	3.3	20.4	5.5	50	47.6
	1500	650	653	5.9	15.0	7.8	78	79.7
	2500	585	693	6.9	13.8	8.6	85	93.6
	3400	520	699	6.8	13.6	9.4	93	110.2
	4000	455	708	7.3	12.5	9.3	92	110.6
	5000	365	726	7.4	12.3	8.6	85	104.1

[a]Tensile index = breaking length in km x 9.8.

(breaking length). Such refining increases sheet density, breaking length, and bursting strength and decreases tearing strength.

One extremely useful way of comparing two pulps is at a constant sheet density. When this is done, the same level of bonding is involved in making the evaluation. When such a comparison was made using the tear factor data generated, the kappa 30 tear values were higher but were not significantly better than the kappa 50 pulps.*

As a result, the kappa 30 and 50 data were combined for comparisons between mature and young wood pulp sources. Differences between the two pulp sources in the sheet density range of 600 to 800 were not statistically significant (Fig. 10). "Mature/young" differences were greater at the low sheet densities (unbeaten pulps). The tear index values for both the young and mature wood pulps were typical of good quality conifer pulps, were greater than the pulps from the earlier evaluated red pine thinnings, and were very similar to pulps from red pine mature wood (Progress Report Seven, p. 62). Pulps from both the tamarack young wood and mature wood can be expected to perform satisfactorily where high tear strength is required.

Tensile strength (breaking length) normally increases as the level of refining and sheet density increases. The tamarack pulps behaved as expected with refining. When the kappa 30 and 50 tensile strength (breaking length) data were evaluated at comparable sheet densities, there were no significant differences for either the young wood or the mature wood. This again allowed

*The standard error of estimates of the regression lines were used to determine when significant differences existed between pulps. Differences were considered significant when the t_{05} s_y values for the regression lines did not overlap.

combining the kappa 30 and 50 data prior to comparing the tensile strength of the mature and young wood pulps.

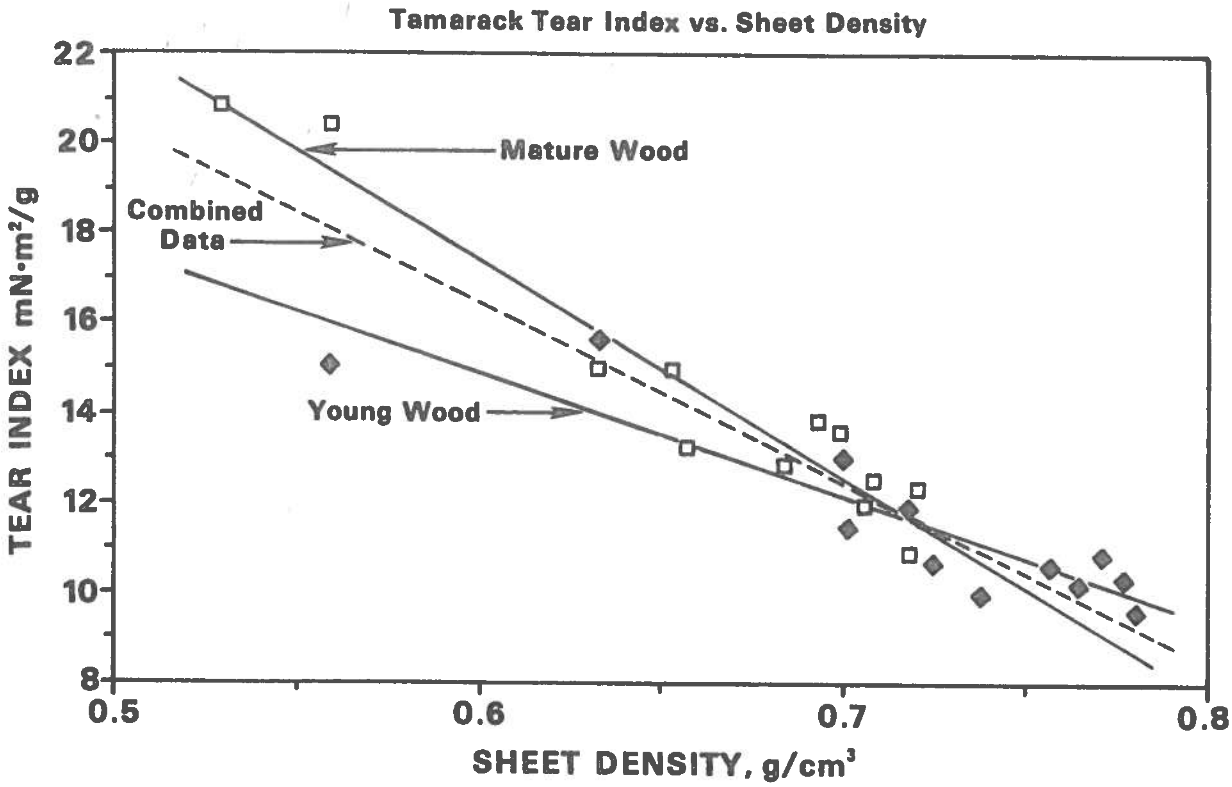

Figure 10. Tear index for young and mature tamarack wood did not differ significantly. The combined data regression equation is tear index = 40.4 - 39.63x, R = 0.93.

When the kappa 30 and kappa 50 tensile strength data were combined, and an appropriate regression analysis applied (Fig. 11), the mature wood pulps had 7 to 12% higher breaking length at sheet densities of 650 to 750 kg/m^3. When, however, the differences were compared using the standard error of estimate for the pulp sources, the differences were not statistically significant (95% probability level). It should also be noted, as will be illustrated later, the tensile strength (breaking length) values of the tamarack pulps were lower than normal when compared to the earlier evaluated conifer pulps. This was not entirely unexpected because when tear values are higher than normal, tensile and burst values are usually lower than normal.

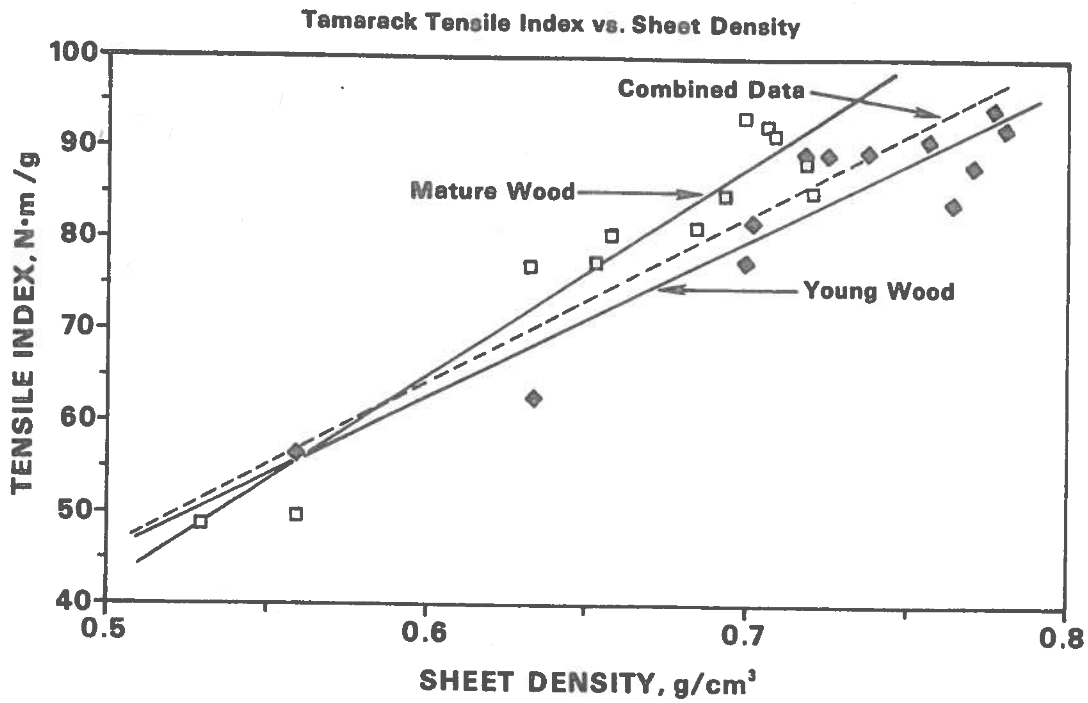

Figure 11. Tensile index (breaking length) for the two sources of tamarack wood did not differ significantly. The regression equation for the combined data is tensile index = 42.01 + 178.26 x, R = 0.91.

Bursting strength usually reacts to refining in a manner similar to tensile strength, i.e., increases as refining and sheet density increase. When, as with tear and tensile strength, the kappa 30 and 50 data were evaluated, the differences were not significant (Fig. 12). As expected, the tamarack young wood pulps produced handsheets of higher sheet density. When, however, burst is evaluated at comparable sheet densities, the mature wood pulps have burst values that are 10 to 12% greater at sheet densities of 700 to 750. These differences, however, are confined to a very narrow sheet density range and the overall differences between sources of wood are not statistically significant.

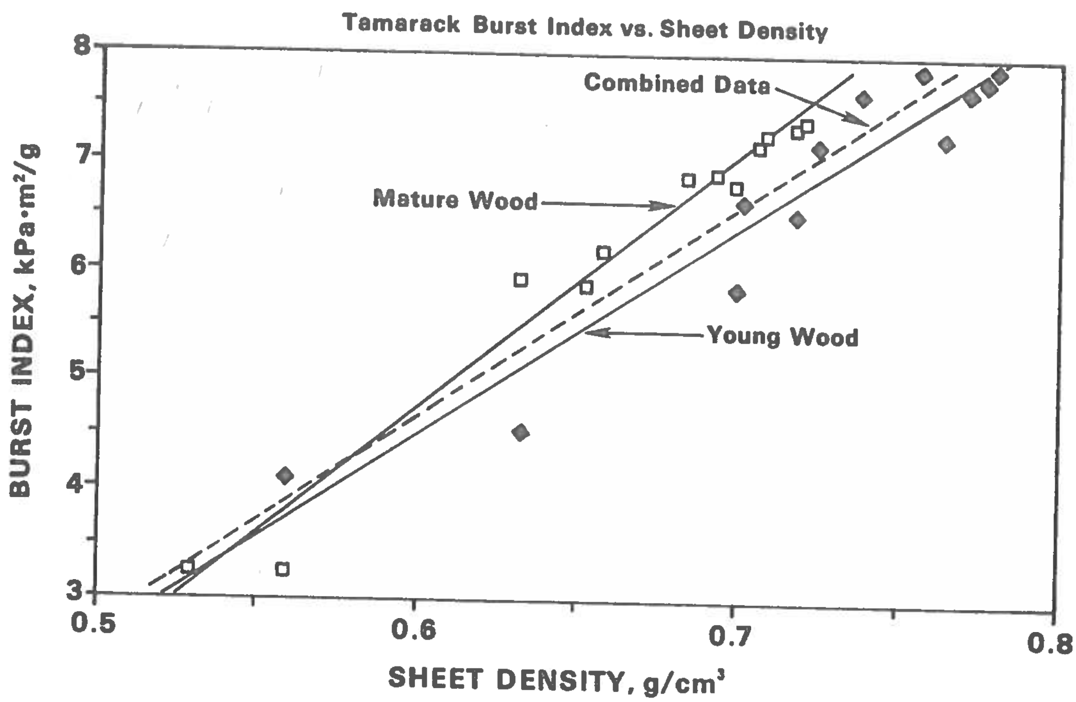

Figure 12. Burst index differences between young wood and mature wood were not statistically significant. The regression equation for the combined data is burst index = 6.72 + 19.102 x, R = 0.95.

Tensile energy absorption (TEA), which is a measure of the ability of paper to absorb energy prior to tensile failure, is an important property of multiwall sacks, packaging, and wrapping papers. Comparisons made regarding the influence of kappa number on TEA demonstrated there were no differences between kappa 30 and 50 pulps for either wood sources. When the TEA for the two types of pulps were compared at the same sheet density, the source of wood (mature vs. young wood) had only a minor influence on TEA values. Mature wood pulps were about 6 to 10% greater in TEA at a sheet density of 700 to 750 and were the same at a sheet density of 600 (Fig. 13). When evaluated using the standard error of estimate for regressions, the differences were not significantly different.

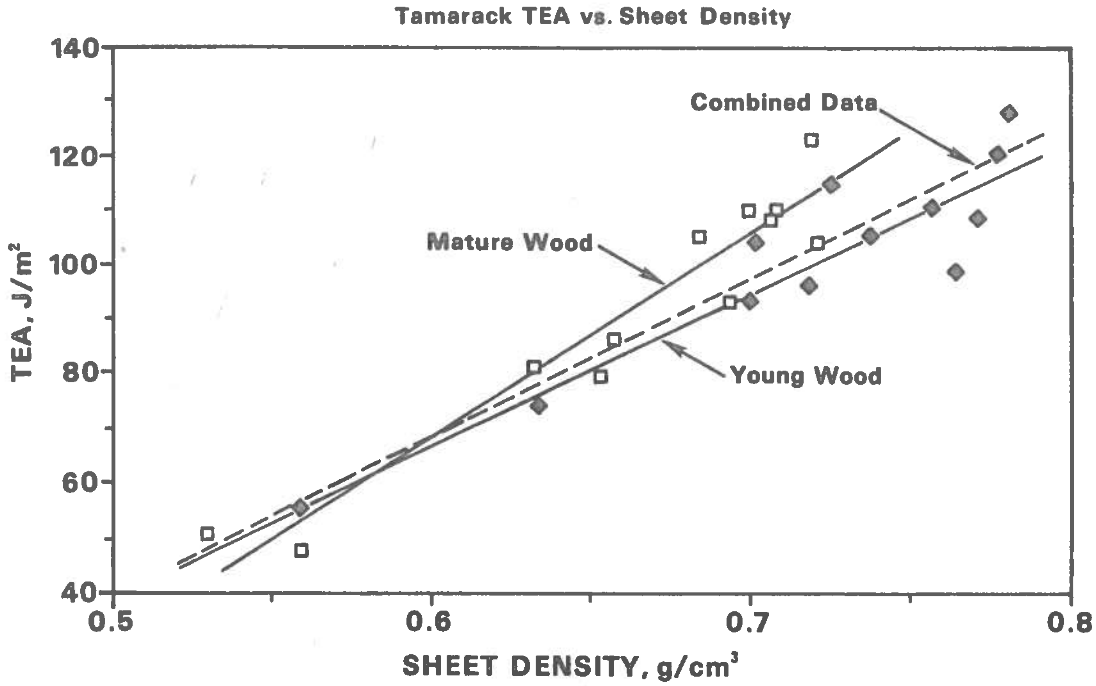

Figure 13. Tensile energy absorption (TEA) differences between the wood sources were not statistically significant. The regression equation for the combined data is TEA = 106.89 + 294.09 x, R = 0.92.

Another method of comparing the usefulness of a pulp is to plot a strength property of interest over breaking length. The reasoning in this approach is that the paper furnish being produced requires a certain minimum breaking length, and the pulp is refined to obtain the needed breaking length. By plotting various strength properties over breaking length, it is possible to determine what happens to these properties when you refine to obtain the needed tensile strength. Figure 14 is a plot of tear index over breaking length using the combined data for the two sources of pulp. Most of the mature wood tear index data fell above the regression line for the combined data. This suggests that mature wood pulps can be refined to a greater degree to obtain the needed breaking length and, at a particular level of refining and breaking length, will have a higher tear index than similarly treated tamarack young wood. Figures 15 and 16 make similar comparisons by plotting burst index and TEA data over breaking length. In these comparisons there appears to be little influence from wood source (young wood vs. mature wood) on the relationship between burst and breaking length and TEA and breaking length.

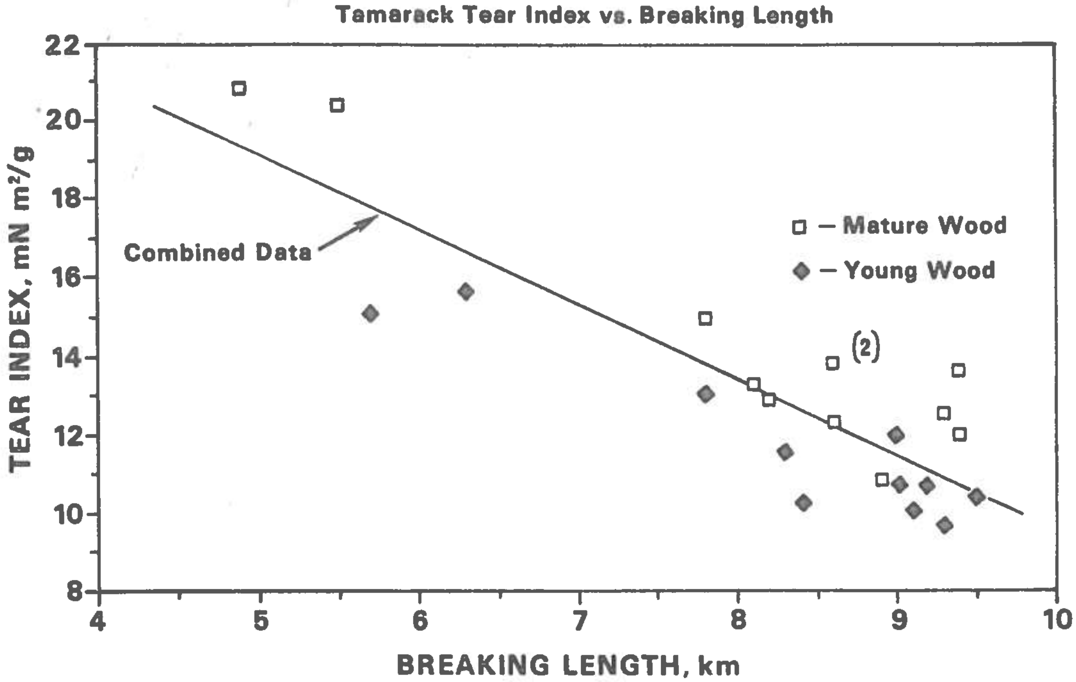

Figure 14. Refining pulps to improve breaking length (tensile strength) reduces tearing strength. Young wood pulps had lower tear than mature wood pulps when compared at equivalent breaking lengths.

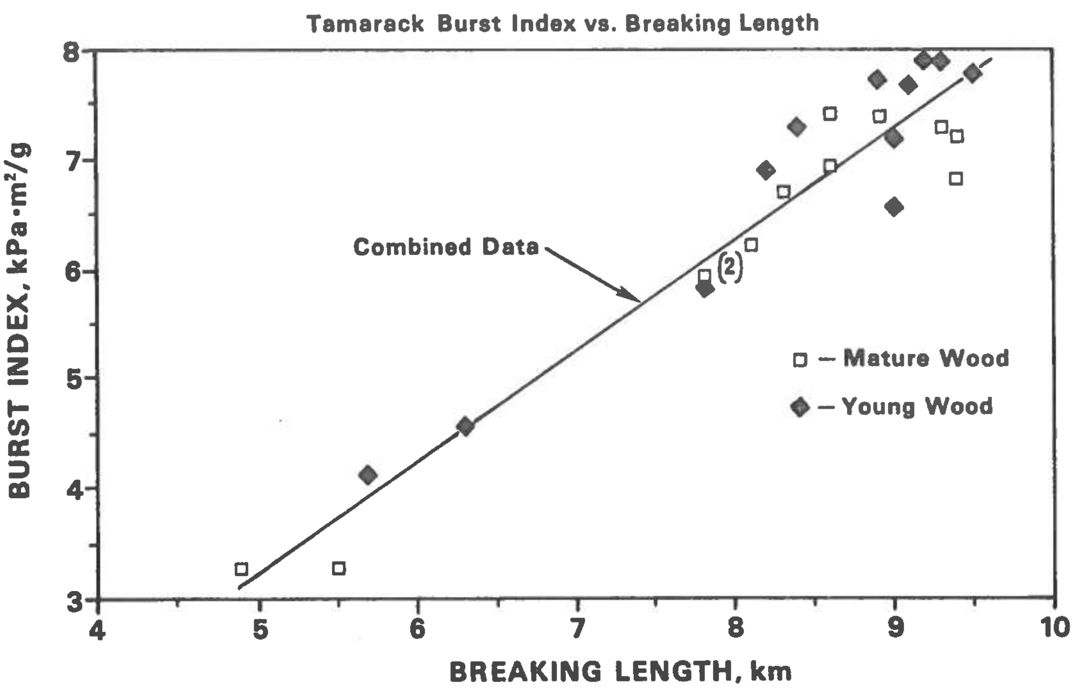

Figure 15. Burst index increased as breaking length increased with no burst différences between tamarack wood sources.

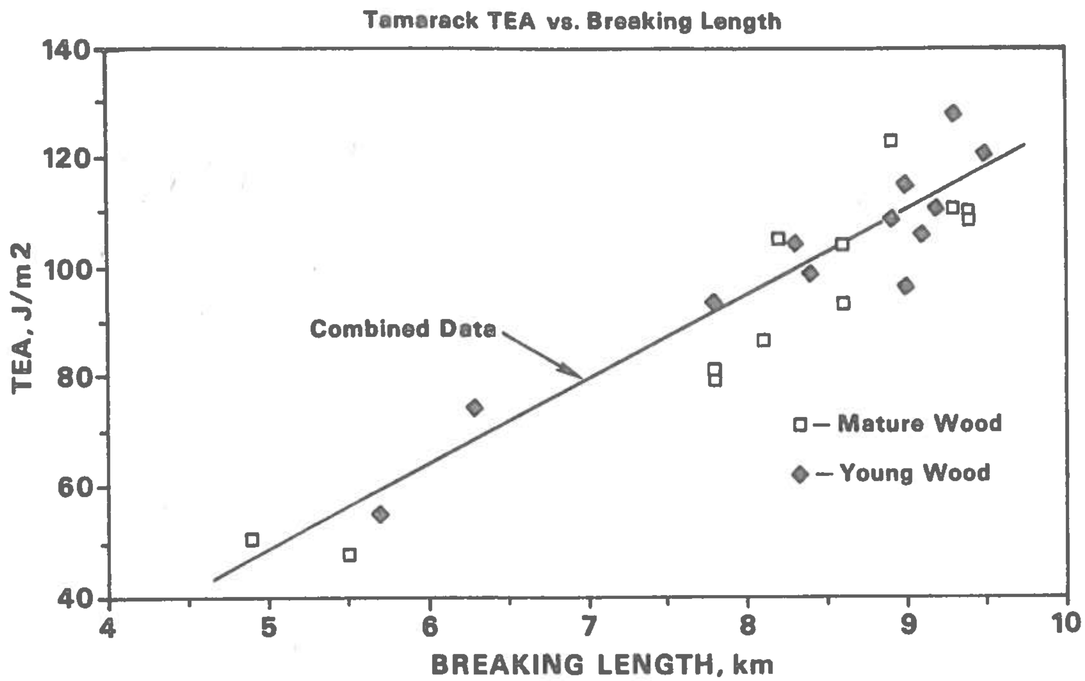

Figure 16. TEA increased as breaking length (tensile strength) increased with no TEA differences between tamarack wood sources.

REFINING CHARACTERISTICS

Breaking length (tensile strength) is an important sheet property, and as indicated in previous comments, pulps are normally refined (beaten) to improve breaking length. Pulps are usually evaluated on the degree of beating required to reach acceptable breaking length, and on the maximum attainable breaking length. Figure 17 illustrates the influence of refining on breaking length for the tamarack pulps. Regression lines of the form y = a + b log x gave the best fit of the data. The curves for the mature wood and young wood were very similar to the combined data curve given in Fig. 17. The young wood curve was displaced slightly to the right of the mature wood curve, indicating the young wood pulps required less beating and reached higher maximum breaking lengths. The differences between curves were small and not statistically significant due to large standard errors of estimate. The overall degree of beating results suggest the tamarack pulps evaluated required considerable refining and reached lower maximum breaking length values than jack pine control pulps and the 18-year-old European larch pulps (see comments in the comparison section that follows).

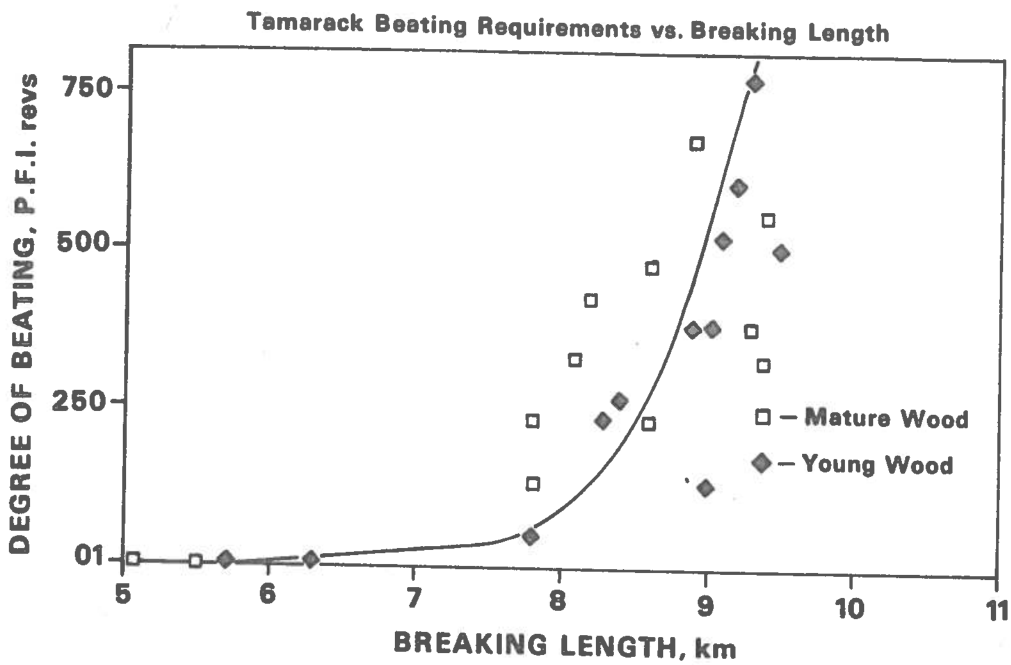

Figure 17. Tamarack beating requirements vs. breaking length. Breaking length = 5.58 + 0.54 logx, x = degree of beating; standard error of estimate = 0.46.

CONCLUSIONS

The wood from the 26-year-old tamarack had a relatively high specific gravity (0.41), high levels of juvenile wood, 35% heartwood, and produced pulp yields that were equal to the yields from mature tamarack chips. Additionally, the kappa 50 young wood pulps had Cuene viscosities 4 to 5 units higher than the mature wood pulps, while the viscosity of the kappa 30 young wood pulps were about equal to the kappa 30 mature wood pulps. Pulping rates, based upon H-factor/kappa number comparisons, were the same for the two tamarack wood sources and they pulped faster than the larch and jack pine control chips but not as rapidly as red pine.

The two sources of tamarack pulp (mature and young wood) bleached without difficulty to a G.E. brightness of 88 and had very similar bleaching chemical requirements. The two sources of pulp also had comparable refining requirements but developed lower than anticipated maximum breaking length.

The pulps from the plantation grown tamarack, when evaluated at higher sheet densities, had comparable tear index, slightly lower burst (10 to 12%), modestly lower breaking length (7 to 12%), and slightly lower TEA values (6 to 10%), when compared with pulps produced from tamarack mature wood. The cited strength differences between young and mature wood pulps were confined to a narrow range of sheet densities, and in no instance were the overall differences between wood sources statistically significant.

COMPARISONS WITH EARLIER EVALUATED RED PINE, JACK PINE, AND *LARIX* SPECIES

The usefulness of pulps from tamarack were evaluated further by comparing the data generated in the above described study with the yield, pulping rate, refining requirements, and paper strength information for red pine from Project 3409, Progress Report Seven and the earlier published data for mature jack pine and plantation larch.[12]

When the newly acquired tamarack pulping rate data are compared with the earlier Project 3409 pulping rate information for jack pine, red pine, and larch species (Fig. 18), it becomes evident that tamarack young wood and mature wood pulped with greater ease than jack pine and larch and less rapidly than red pine. At kappa 30, for example, H-factor values for tamarack were 7% less (1707 vs. 1832) than for age 18 European larch plantation trees. Differences are even greater when the comparison is made with jack pine and hybrid larch.

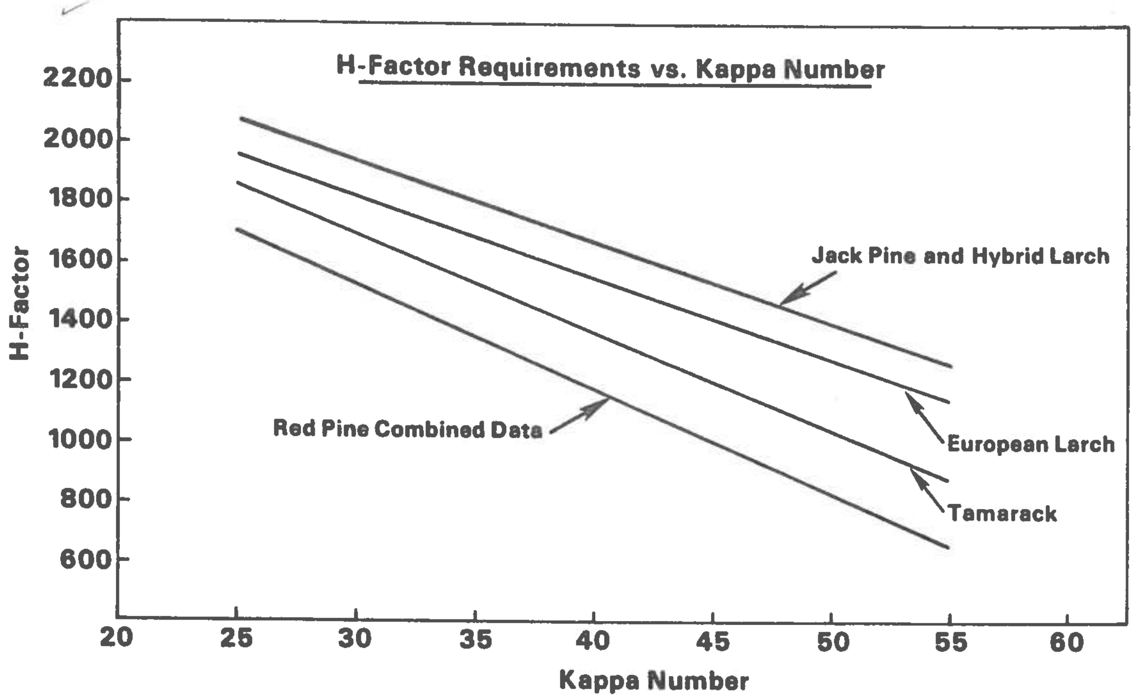

Figure 18. Comparison of H-factor requirement vs. kappa number for tamarack with similar data for red pine, European larch, jack pine, and hybrid larch.

Kraft pulp yield data available from this and earlier studies have been adjusted to kappa 35 to facilitate comparisons (Table 14). Pulp yields evaluated in this latest study were comparable to yield data from mature jack pine pulpwood bolts (44.0 vs. 44.6). This comparison suggests younger plantation grown tamarack (age 26 years) have unscreened pulp yields (44.0% at kappa 35) that are only 1% less than jack pine plantation thinnings but are less than red pine "mature wood," European larch plantation trees, and hybrid larch plantation trees by 4.0 to 5.2%.

Table 14. Summary of kraft pulp yields.

Material	Tree Age, year	Kappa 35 Unscreened Pulp Yield, %[a]	Data Source
Red pine plantation trees[b]	22	46.0	3409 Progress Report Three
Jack pine plantation trees[b]	25	45.0	3409 Progress Report Three
European larch plantation trees	18	48.0	3409 Progress Report Three
Japanese larch plantation trees	22	45.6	3409 Progress Report Three
Hybrid larch plantation trees	23	49.2	3409 Progress Report Three
Jack pine pulpwood bolts	55	44.6	3409 Progress Report Three
Red pine plantation "thinnings"	24	45.7	3409 Progress Report Seven
Red pine plantation "mature wood"	49	48.5	3409 Progress Report Seven
Tamarack plantation "thinnings"	26	44.0	3409 Progress Report Eight
Tamarack native "mature wood"	69	44.0	3409 Progress Report Eight

[a]All pulp yields were adjusted to kappa 35.
[b]Data provided by a cooperating firm.

The energy requirements for refining the tamarack pulps were compared with the requirements of earlier pulped species. The comparisons were made by determining the level of refining required to reach specific breaking length levels (plotting breaking length vs. degree of beating). The mature wood tamarack pulps refined with a little more difficulty than the young wood pulps but differences were not statistically significant. Figure 19 compares the tamarack young wood pulps (kappa 30 + kappa 50) with the kappa 50 pulps of hybrid larch, mature jack pine bolts, and 18-year-old European larch. The comparison demonstrates that pulps from plantation grown tamarack (young wood) require greater refining to reach a specific breaking length and develop a lower maximum breaking length than the jack pine and European larch pulps. Tamarack pulps do not differ greatly from hybrid larch in overall refining requirements.

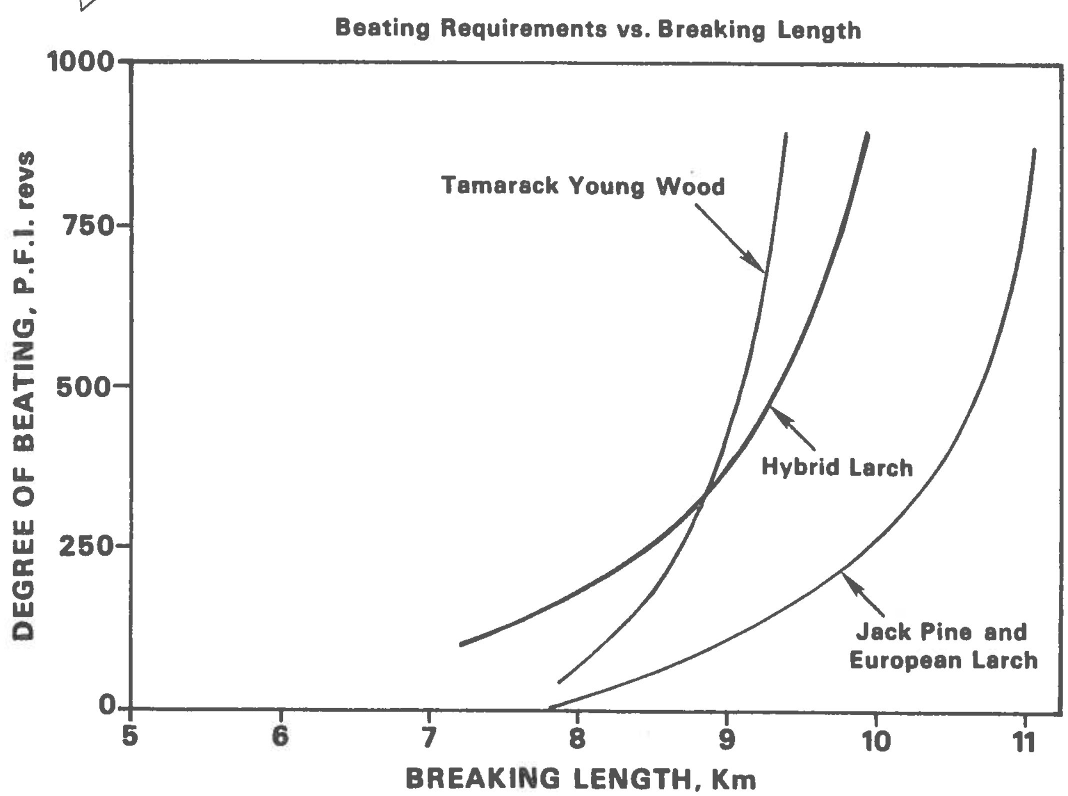

Figure 19. Beating requirements vs. breaking length comparison of tamarack young wood pulps with kappa 50 pulps of hybrid larch, jack pine, and European larch. Breaking length of tamarack young wood pulps = 5.98 + 0.497 logx, standard error of estimate = 0.32.

The tamarack young wood pulps and mature wood pulps developed adequate but significantly lower (18%) breaking length than the jack pine control and European and hybrid larch pulps when evaluated at equal sheet densities (Fig. 20). When, however, the tamarack pulps are compared with jack pine and 18-year-old European larch at equivalent breaking length, the pulp strengths are very promising. Figures 21, 22, and 23 illustrate what happens to tear, burst, and TEA when tamarack pulps are refined to obtain a satisfactory breaking length. The newly generated data were plotted with the results from the larch, red pine, and jack pine. This approach allows the comparison of the strength properties of pulps from tamarack with information from the above species at a constant breaking length. Briefly, these pulp strength comparisons demonstrate that pulps from tamarack, at breaking length 9, for example, had

1) 15% lower tear index (13.5 vs. 11.5),
2) 5% greater burst index (7.3 vs. 6.9), and
3) equal TEA (111.0 vs. 112.0)

when compared to pulps from 18-year-old European larch and mature jack pine pulpwood bolts. Comparisons at other breaking length levels are possible using the data in these figures.

The use of tamarack as a source of conifer pulp represents an alternative to using slow growing black spruce for poorly drained, frost-prone sites, and has produced excellent growth on upland sites. Tamarack chips cook readily and the pulps refine with only modestly greater beating requirements than jack pine and other *Larix* species. The tamarack pulps do not develop as high a maximum breaking length as most other larch pulps evaluated but when compared at equivalent breaking length have only modestly lower tear and comparable burst and TEA.

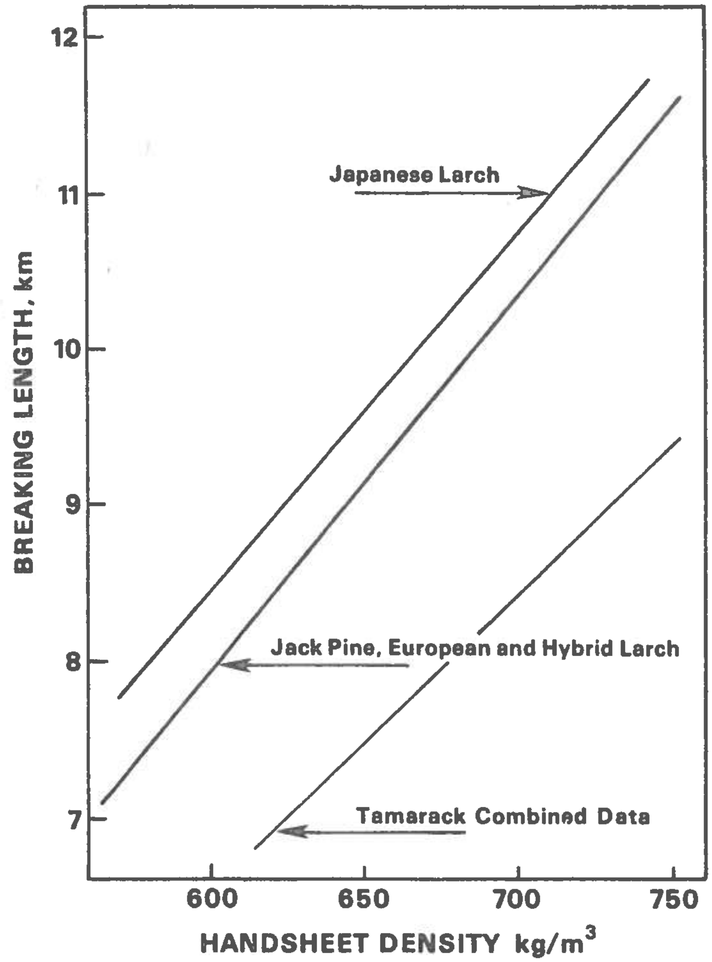

Figure 20. Breaking length vs. handsheet density. Tamarack pulps have lower breaking length values when evaluated at comparable handsheet densities.

The tamarack pulps evaluated in this study bleached readily to a G.E. 88 brightness and appeared to have only slightly higher bleaching chemical requirements than pine and larch pulps. The principal drawback to the use of tamarack appears to be the 4 to 5% lower pulp yield when compared to red pine and exotic Larix species. The wood property and pulp strength differences between mature wood and young wood were not as great as anticipated. This appears to have resulted because the growth rate and age differences between the two sources were not as great as required to produce the expected pulp strength differences.

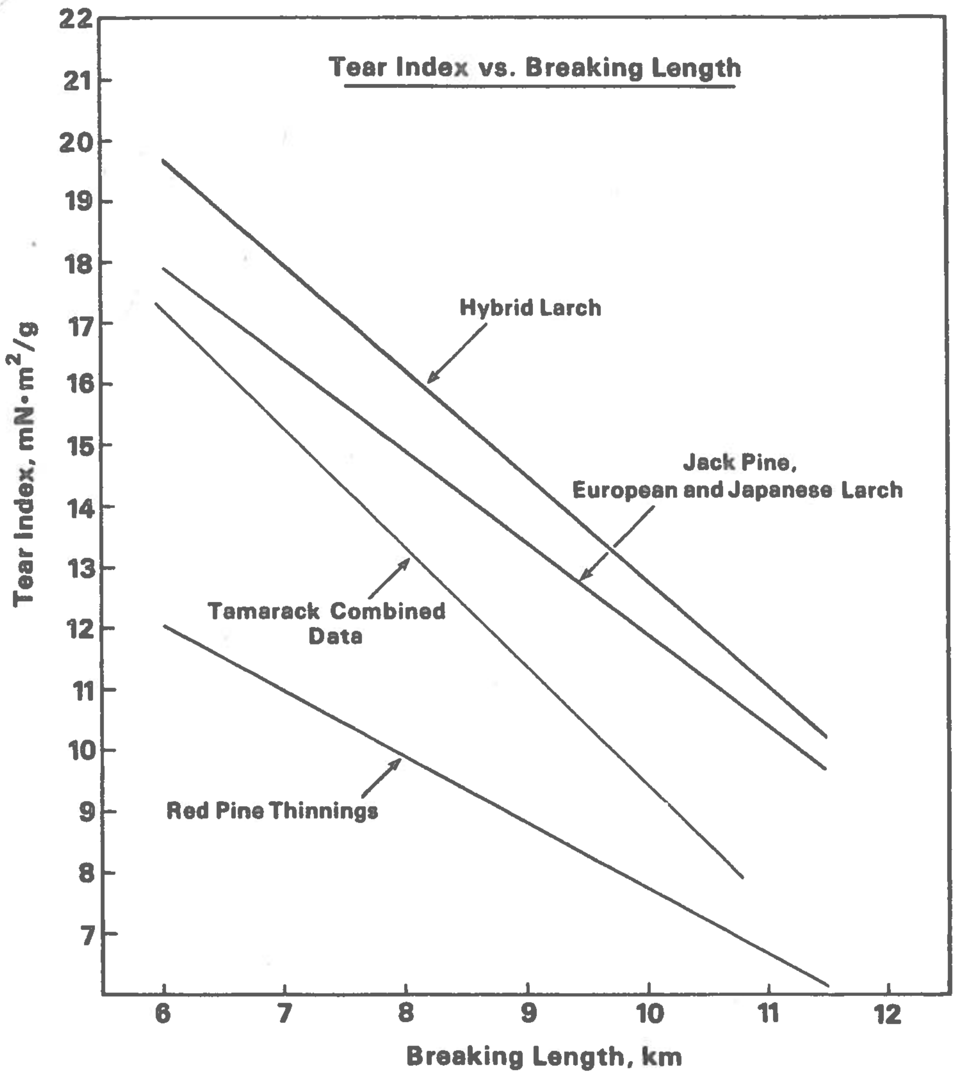

Figure 21. Tamarack pulps were 6-20% lower than jack pine and European and Japanese larch when evaluated at comparable breaking lengths.

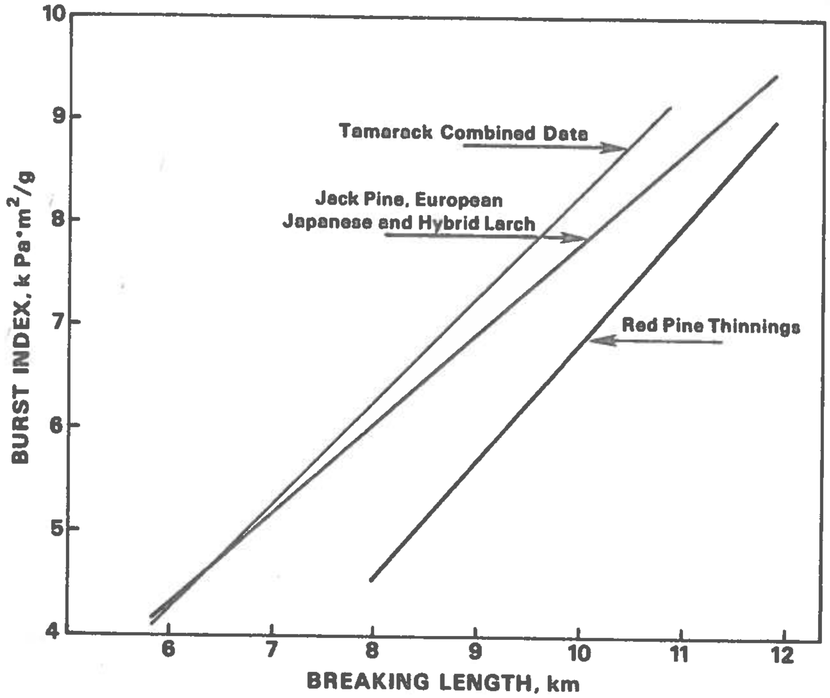

Figure 22. Burst index vs. breaking length. Burst index for tamarack is about the same as jack pine, European, Japanese and hybrid larch. At breaking length 9 km the difference is approximately 5%.

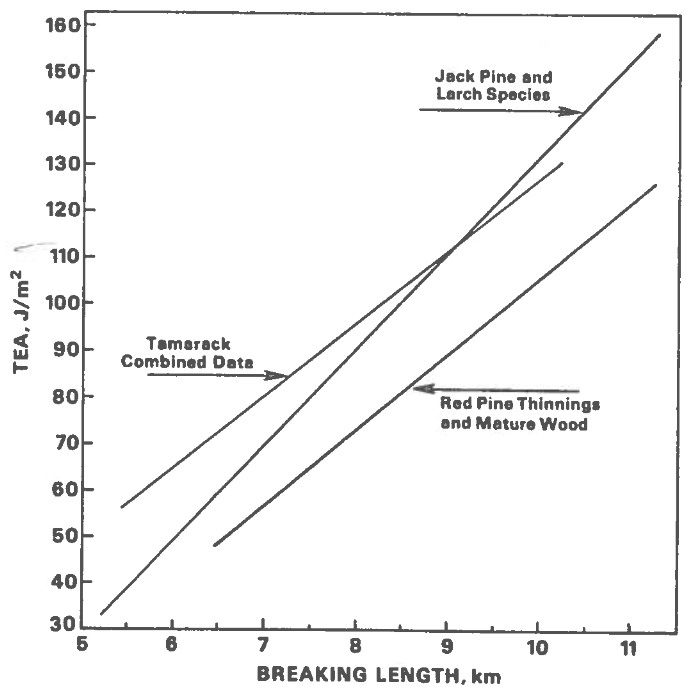

Figure 23. TEA vs. breaking length. Comparison of pulps at equivalent breaking lengths demonstrated that tamarack pulps have TEA levels similar to jack pine and larch species and greater than red pine.