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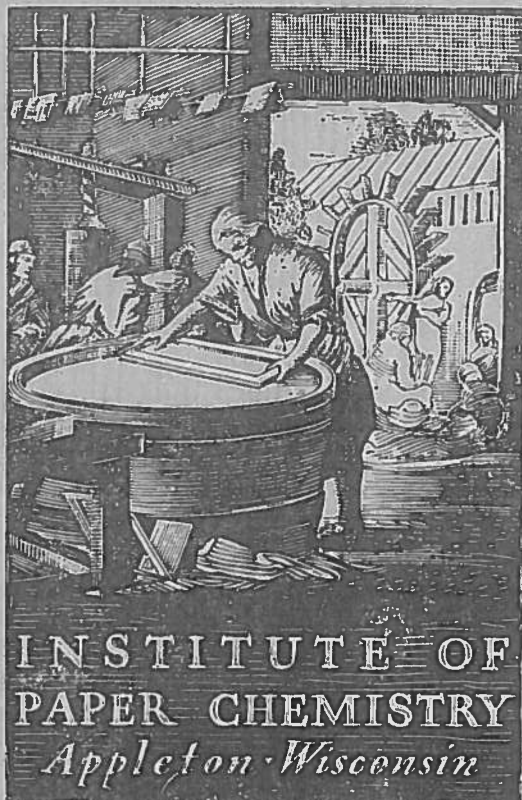

GENETIC IMPROVEMENT OF LARCH

Project 3409

Report One
A Progress Report
to
MEMBERS OF GROUP PROJECT 3409

March 4, 1981

WOOD QUALITY AND PULPING

WOOD QUALITY OF SELECTED TREES

When the larch project was first developed, we compared the wood quality of Japanese and European larch with several other commonly pulped native species. Table IX gives some of those comparisons. Larch compared favorably with these species in terms of wood density, fiber length and alcohol-benzene extractives. Hot-water extractives of mature trees, as reported in the literature and given in Table IX, are high. However, in pulping work done at the Institute on younger trees (18-24 years old), hot-water extractives of chip samples averaged approximately 5%. Consequently, it appears hot-water extractives would not be a problem if younger-aged material was utilized.

Wood quality evaluation is an important part of any tree improvement program. To provide a base line for evaluating younger prospective parent trees, we are evaluating selected trees in terms of specific gravity, fiber length, alcohol-benzene extractives and hot-water extractives. Samples for these determinations are obtained by taking four 10-mm increment cores from each tree. In some cases, it hasn't been possible to take cores because we either couldn't receive permission to remove cores from the trees or else we received scions and didn't have access to the original tree. To date, 60 selections have been made, 33 European larch and 27 Japanese larch. Wood quality determinations have been made on 27 of these.

Specific gravity is obtained on a green volume basis on the complete core of all four cores. Rings 14-16 are then cut from two cores and specific gravity measured again, to give an age 15 specific gravity. Total core specific gravity of the Japanese larch ranged from 0.338 to 0.388 with an average of 0.374. These measurements were made on trees approximately 20 years old. When rings 14-16 were sectioned

TABLE IX

WOOD QUALITY COMPARISONS OF MATURE TREES
LITERATURE VALUES

Characteristic	European Larch	Japanese Larch	Balsam Fir	White Spruce	Black Spruce	White Pine	Red Pine	Jack Pine
Wood density[a]								
g/cc	0.49	0.44	0.34	0.35	0.40	0.34	0.44	0.39
lb/cu ft	30.6	27.4	21.2	21.8	25.0	21.2	27.4	24.3
Fiber length, mm	3.6	3.6	3.5	3.3	3.5	3.0	3.4	3.5
Fiber width, µm	46	--	30-40	25-30	25-30	25-35	30-40	28-40
Alcohol-benzene extractives, %	2.0	1.9	1.2	2.0	2.2	6.4	3.5	3.7
Hot-water extractives, %	7-9	7-9	3.6	2.5	2.1	5.0	4.4	3.0

[a]Expressed in terms of green volume.

from the cores, specific gravity averaged 0.378. Included in this average was one tree with a whole core specific gravity of 0.338 and a specific gravity of rings 14-16 of 0.294. This particular tree may be discarded because of its exceptionally low specific gravity and again points up the value of wood quality determinations as part of a tree's evaluation.

Total core specific gravity of the European larch averaged 0.404 with a range of 0.390 to 0.421. When rings 14-16 were sectioned from the cores, specific gravity averaged 0.432. The lower specific gravity of the young Japanese larch selections compared with the European larch is consistent with the relationships given in Table IX for older trees.

The cores that were used for specific gravity measurements were then sectioned for fiber length determinations. Rings 11-15 were removed from two cores and rings 14-16 were used from the remaining two cores. The sectioned cores were macerated and 600+ intact fibers measured for each determination. Intact fibers are measured on wood samples to give a better indication of the tree's true fiber length. This is contrasted with pulp samples where all fibers 0.3 mm and longer are measured to give an indication of actual fiber length going into the papermaking process.

Arithmetic average fiber lengths of rings 11-15 of the Japanese larch averaged 2.77 mm while rings 14-16 averaged 2.90 mm. Fiber lengths of rings 11-15 of the European larch averaged 2.82 mm, while rings 14-16 averaged 2.94 mm. Again, similar to the case for specific gravity, European larch has a slight advantage over Japanese larch in fiber length. However, fiber lengths for both species are comparable to those reported for any young, fast-growing, short-rotation conifer.

Fiber length/age curves were also completed for European, Japanese and hybrid larch. These curves showed that fiber length increases steadily from the pith outward and, in the outer rings, is comparable to fiber length obtained for mature European and Japanese larch. Table X gives the fiber length/age curve information for all three types of larch.

TABLE X

LARCH FIBER LENGTH/AGE CURVE[a]
ARITHMETIC AVERAGE

mm

Rings	Japanese Larch	European Larch	Hybrid Larch
0-5	1.50	1.59	--
6-8	1.76	2.00	1.67
9-10	2.03	2.33	2.08
11-13	2.58	2.72	2.28
14-15	2.79	2.95	2.51
16-18	2.97	3.10	2.95
19-20	3.23		3.25
21-23	3.27[b]		3.36

[a]Average based upon three trees for each type of larch.
[b]Rings 21-22 rather than 21-23.

Because of budget limitations, extractives information was not obtained on trees selected early in the project. However, since hot-water extractives, in particular, are so important in evaluating larch as a pulpwood species, we have decided to obtain both alcohol-benzene and hot-water extractives information on all future selected trees.

The procedure involves removing the first ten rings from all four cores collected for specific gravity and fiber length information and obtaining alcohol-benzene and hot-water extractives separately (not consecutively) on a composited sample of all four cores using TAPPI Standards T 204 os-76 (alcohol-benzene) and T 207 os-75 (hot-water). Given in Table XI are the first extractives values obtained. Although the values for hot-water extractives are high, they essentially represent extractives found in the heartwood, since only the first ten rings were used. If extractives had been run on the entire core, these percentages would, of course, have been reduced, since the sapwood has lesser amounts of extractives. Also, by using increment cores, the center of the tree is weighted heavier than it would be if disk or chip samples were used.

TABLE XI

EXTRACTIVES INFORMATION[a]
SELECTED TREES

Tree[b]	Alcohol-Benzene Extractives, %	Hot-Water Extractives, %
LD-23-80	3.6	16.7
LD-24-80	7.0	17.6
LD-30-80	2.5	16.9
LL-23-80	5.6	18.9
LL-24-80	3.3	19.0

[a]Sample used included 1st 10 rings of the composited sample of four cores for each tree.
[b]LD = *Larix decidua*, LL = *Larix leptolepis*.

Extractives have been measured routinely on chip samples of trees cut for pulping studies and those data show much lower levels of extractives. The chip samples represent the entire bole without bark to a 4-inch top of three composited trees. Given in Table XII for comparison purposes are the values obtained on these chip samples.

TABLE XII

EXTRACTIVES INFORMATION[a]
PULPING TREES

Species	Alcohol-Benzene Extractives, %	Hot-Water Extractives, %
23-Year-old Japanese larch	3.0	7.4
18-Year-old European larch	1.8	3.9
23-Year-old hybrid larch	2.5	4.2

[a]Samples used were chip samples representing the entire bole without bark to a 4-inch top of three composited trees for each species.

Based on the wood quality information given in this section, and coupled with growth rate, pulping properties, etc., larch appears to be a viable, alternative conifer fiber source. Table XIII summarizes wood quality information obtained on young Japanese, European and hybrid larch as part of this project. This information can be compared with the literature values given in Table IX for mature trees. Figure 13 illustrates a cross section of Japanese larch wood. As shown in the photo-micrograph, the latewood zone is sharply delineated and conspicuous, growth rings are distinct, and transition from earlywood to latewood is abrupt. Resin canals can also be seen.

As a further service to project cooperators, a literature search was done on the use of larch in solid wood products. A copy of the results of this search is available upon request.

TABLE XIII

WOOD QUALITY COMPARISONS
SELECTED TREES

Property	Japanese Larch	European Larch
Age 15 Specific gravity[a]	~~0.38~~ .39	0.43
Age 15 Fiber length, mm ~~[b]~~ [B]	~~2.90~~ 3.2	~~2.94~~ 3.0
Alcohol-benzene extractives, % ~~[b]~~ [c]	~~4.4~~ 3.6	~~4.4~~ 2.9
Hot-water extractives, % ~~[b]~~ [c]	~~19.0~~ 7.0	~~17.1~~ 6.1

[a]Green volume basis.
[b]Arithmetic average of intact fibers only.
[c]Based on first ten rings of increment cores.

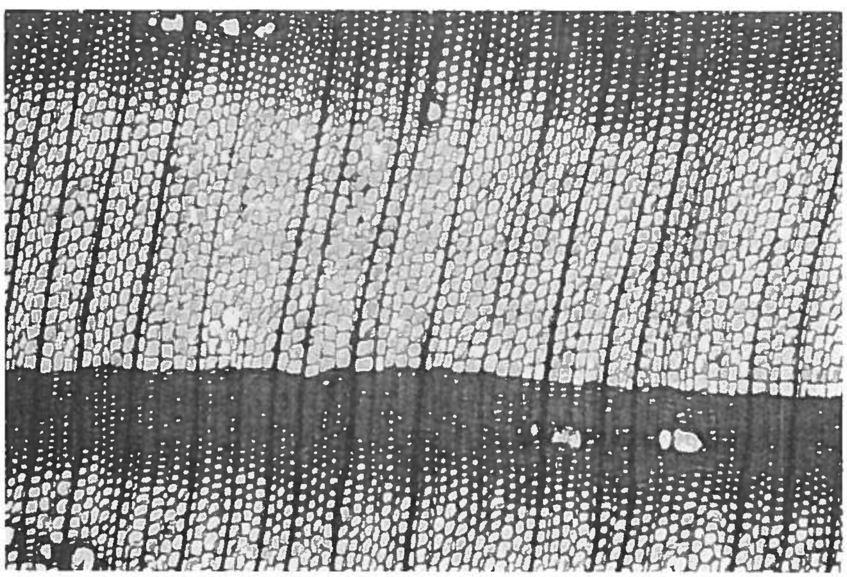

Figure 13. Cross Section of Japanese Larch Wood. As Shown in the Photomicrograph, the Latewood Zone is Sharply Delineated and Conspicuous, Growth Rings are Distinct, and Transition from Earlywood to Latewood is Abrupt. Resin Canals can Also be Seen. Magnification - 40X

PULP PROPERTIES OF LARCH KRAFT PULPS

Introduction

Most previous investigations have examined the wood and pulping characteristics of larch of ages in excess of 50 years. Little is known about wood and pulp properties of European, Japanese and/or hybrid larch grown primarily for fiber at rotation ages of 18 to 25 years. Objectives of the larch pulping studies are to determine the usefulness of young (18-25 years) larch in the production of bag and bleachable grade papers. Four sources of larch, including 18-year-old European larch, 23-year-old hybrid larch, 8-year-old hybrid larch and 55-year-old jack pine (control), were pulped separately and in several mixtures of 75% jack pine/25% larch*.

The larch wood chips were investigated for their usefulness as bag paper by cooking to a kappa number of approximately 50 and for use as part of the furnish of bleachable grade pulps by cooking to a kappa number 30. Jack pine was used as a basis of comparison because of its common use in the Lake States and the Northeast. The mixtures selected were used because it appeared that, with the relatively limited supply of larch, the species would not be cooked alone but in mixtures with other conifers and that very likely these mixtures would contain 25% or less of larch. We presently are not advocating the use of material as small or as young as the 8-year-old hybrid larch (U.S. Forest Service), but the material does provide an extreme in wood, fiber and pulp properties that will be useful for comparison purposes.

*Age 22 Japanese larch is in the process of being pulped in a comparable manner so the results can be integrated into the study described above.

Experimental Materials

The wood chips used in the studies came from three sources of larch and a mill-run source of jack pine. Table XIV summarizes the age, tree size, percent heartwood, and percent compression wood for the four types of material used in the study. The 18-year-old European larch was from a U.S. Forest Service/Wisconsin DNR planting near LaCrosse, Wisconsin. The 23-year-old hybrid larch* was from an Institute planting near Rhinelander, Wisconsin. The 8-year-old trees were part of a U.S. Forest Service intensive management planting near Rhinelander and the jack pine was harvested in northern Wisconsin and came from the Thilmany Pulp & Paper Company woodpile at Kaukauna, Wisconsin.

TABLE XIV

TREE SIZE AND WOOD QUALITY DATA[a]

Type of Material	Age, yr	Height, feet	Diam., inches	Bark, %	Breast Height, (4.5 feet) Specific Gravity	Breast Height, (4.5 feet) Fiber Length, Age 15, mm	Compression-wood, %	Heart-wood, %
Ripco hybrid larch	24	55.6	7.0	10.1	0.413	2.75	0.4	47.6
European larch	18	54.4	7.6	10.8	0.395	3.02	5.3	46.2
U.S.F.S. hybrid larch	8	21.0	2.0	18.0	0.370	--	12.1	14.9
Jack pine control	55	--	--	--	0.436	--	7.5	28.7

[a]Values based on an average of three trees for the European and Ripco hybrid larch, eight trees for the U.S. Forest Service larch and eight pulpwood bolts for the jack pine.

All materials except the 8-year-old U.S. Forest Service hybrid larch were debarked, chipped and screened prior to pulping. Chips passing the 3/4-inch screen

*22-year-old Japanese larch from this same planting is presently being pulped and evaluated and will be reported on later.

and retained on the 1/2 and the 1/4-inch screens were the fractions that were pulped. The 8-year-old hybrid larch was designated as "whole-tree" chips because the material contained branches and twigs as well as the wood and bark of the main stem. Bark levels were determined to be 23%, on an oven dry basis.

Cooking and Bleaching Conditions

Pulping runs were carried out in a stainless steel vessel of about 72 liters capacity, fitted with external circulation and indirect heating. The chips were charged into a stainless steel basket, which closely matched the interior contours of the digester and which could be removed with the contents following cooking. The cooking liquors were prepared from a solution of sodium hydroxide and sodium sulfide of known concentration and density, together with the appropriate amount of dilution water. The pulping conditions employed are given in Table XV. The pulp was screened through a 0.006-inch 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 standard methods after beating in a PFI mill at 10% consistency.

TABLE XV

PULPING CONDITIONS

Constant Conditions	
Wood charge, kg o.d.	4.0
Water-to-wood ratio, cc/g	4.0
Effective alkali, % o.d. wood	16.0
Sulfidity, %	25.0
Time to 172°C, min	90
Cooking temperature, °C	172

The kappa 30 pulps were bleached using a CEDED sequence prior to physical property evaluation. Bleaching runs were done using heat sealable polyester bags. Pulp in a crumb form was charged into the bags, diluted with deionized water and the required bleach solution added to give the appropriate bleach consistency. The bleaching conditions and chemical charges employed are shown in Table XVI. Upon completion of the bleaching time, the bag was removed, opened and the sample of pulp removed from the bleaching chemical. The pulp was thoroughly washed and returned to the bag and the remaining steps in the 5-stage bleaching sequence completed in a similar manner. Pulp from the final chlorine dioxide stage was diluted to a 1% consistency and acidified to pH 3 by bubbling SO_2 gas through the pulp suspension to quench any remaining chlorine dioxide activity. Brightness and handsheet strength properties were determined according to TAPPI standard methods.

TABLE XVI

BLEACHING CONDITIONS

Bleach Stage	Bleach Chemical	Chemical Charge, % on o.d. pulp[a]	Consistency, %	Temp., °C	Time, min
1	Chlorine (C)	8.3	3.0	Ambient	45
2	NaOH (E)	4.7	10	70	70
3	Chlorine dioxide (D_1)	1.5	10	60	180
4	NaOH (E_2)	1.0	10	60	60
5	Chlorine dioxide (D_2)	0.5	10	60	180
6	Sulfur dioxide	0.5 to pH 3	1	Ambient	1

[a]Pulp o.d. weight 500 g.

Results and Discussion

Introduction

Space limitations make it desirable to reduce and summarize the many observations and extensive data generated in this study. With such an abbreviated approach, some valuable data must be eliminated. As a partial solution to this problem, the decision has been made to prepare an interim Project 3409 report that would go into greater detail than is appropriate at this time. The interim report would also include results of the Japanese larch pulping work presently under way.

Wood and Fiber Properties

In addition to the wood and fiber properties summarized in Table XIV, which were values based upon disk samples taken at 4.5 feet (breast height), fiber properties of the pulps were measured and this information is summarized in Table XVII.

The specific gravity values for the 18-year-old European larch and the 23-year-old hybrid larch were similar. The jack pine wood samples were higher in specific gravity than any of the larch samples investigated and the 8-year-old hybrid larch had the lowest specific gravity (0.37). The 8-year-old larch also had the highest level of compression wood, suggesting that, if the compression wood had not been present, the specific gravity would have been even lower.

The pulp fiber dimensions summarized in Table XVII were surprisingly similar for the several sources of larch and larch/jack pine mixtures. Fiber length of the European larch and 8-year-old hybrid larch appeared to be slightly less than the other pulps. Also, the fiber width and coarseness of this relatively young material appeared to be lower than the other pulps evaluated. Most of the values given in Table XVII are consistent with the exception of the coarseness of the hybrid larch/jack pine mixture involving the 23-year-old larch. These values were lower than anticipated and the results will be rechecked. In the samples evaluated, lower wood density was associated with the lower fiber coarseness. Also of interest was the similarity in coarseness between the jack pine control pulps and the two older sources of larch.

TABLE XVII

PULP FIBER DIMENSIONS

Type of Material	Fiber Length, mm Arith.	Fiber Length, mm Weighted	Fiber Width, µm	Cell Wall Thickness, µm	Coarseness, mg/100 m	Kappa No.
Ripco hybrid	1.7	2.2	46.7	5.5	24.6	53.4
larch	1.7	2.2	47.7	5.1	21.2	34.6
European larch	1.6	2.1	44.3	5.1	24.6	52.7
	1.6	2.0	45.8	4.7	17.5	31.4
U.S.F.S. hybrid larch	1.6	2.1	40.6	4.6	18.0	54.8
Jack pine	1.9	2.2	42.1	4.5	22.0	51.1
control	1.9	2.3	44.3	5.7	20.5	34.4
25% Hybrid larch/	1.9	2.3	40.3	5.3	15.7	52.2
75% jack pine	2.1	2.5	44.2	5.1	17.6	31.1
25% European larch/	1.9	2.4	42.2	4.6	19.3	49.5
75% jack pine	1.9	2.3	42.7	4.4	20.8	29.4
25% U.S.F.S. hybrid	1.7	2.2	39.9	5.5	21.3	51.6
larch/75% jack pine	1.7	2.2	42.3	4.6	19.1	34.2

Wood Chemical Comparisons

Pulp yields are related to cooking conditions and lignin and extractive levels in the original wood samples. Table XVIII summarizes this information for the four sources of experimental chips. All sources had similar levels of lignin and the three sources of larch were similar in levels of alcohol-benzene extractives and lower than jack pine in this property. Hot-water extractives, in contrast, were higher for larch than jack pine and the 8-year-old hybrid larch had the highest level (7.4%), presumably because of the high levels of bark (23%). The lower pulp yields of the 8-year-old larch described in the section that follows reflects the lack of fibers in the bark and the high extractive levels. It should, however, be pointed out that hot-water extractive levels reported for the 18- and 23-year-old larch were about 1/2 the levels found in the literature for older larch.

TABLE XVIII

CHEMICAL PROPERTIES OF WOOD

Type of Material	Lignin, %	Extractives, % Alcohol-Benzene	Extractives, % Hot Water
Ripco hybrid larch	27.94	2.47 --	4.18 --
European larch	27.60	1.80 --	3.90 --
U.S.F.S. hybrid larch	--	2.40	7.39
Jack pine control	27.45	3.54 --	2.31 --

Pulp Yields

The pulping procedure followed was to establish the goals of kappa number* 50 (bag papers) and 30 (bleachable pulps) and then vary cooking conditions (H-factor) to obtain pulps that could be used in pulp strength comparisons. Table XIX summarizes these results. It should be noted that the 100% 8-year-old hybrid larch was not cooked to kappa 30 because it didn't seem appropriate in view of the high levels of bark (23%).

The pulp yield information provided several interesting results. Comparing unscreened pulp yields**, for example, consistently demonstrated a 3-4% yield advantage for the 18- and 23-year-old larch over the 55-year-old jack pine. The lowest

*Kappa number reflects the lignin remaining in the pulp.
**Even though rejects are high for the 100% European and the 100% 23-year-old hybrid larch, in practice, these fibers would be returned to the digester and pulped further and the fiber not lost.

yield resulted from the pulping of the 8-year-old hybrid larch (36.3%) and presumably reflects the effect of the high levels of bark, compression wood and juvenile wood.

TABLE XIX

PULPING DATA

Composition	Factor	Kappa No.	Unscreened Yield, % o.d. wood	Screened Yield, % o.d. wood	Screened Rejects, % o.d. wood
100% Jack pine	1850	34.4	43.8	43.2	0.6
	1450	49.2	47.1	46.2	0.9
25% European larch	1850	29.4	47.1	46.5	0.6
	1350	54.4	47.9	47.0	0.9
100% European larch	1850	31.4	47.1	46.8	0.3
	1200	52.7	51.1	40.1	11.0
25% Hybrid (23 yr) larch	1850	31.1	46.6	46.1	0.5
	1350	52.2	49.7	46.8	2.9
100% Hybrid (23 yr) larch	1850	34.6	48.5	47.1	1.4
	1200	53.4	51.8	41.5	10.3
25% Hybrid (8 yr) larch	1900	34.2	46.3	44.8	1.5
	1600	51.6	48.4	46.3	2.1
100% Hybrid (8 yr) larch	1800	54.8	36.3	35.3	1.0

Equally important is compatibility of the jack pine and the 18- and 23-year-old larch to cooking conditions when cooked either alone or in mixture. Figure 14 illustrates this relationship and suggests all sorts of larch/jack pine mixtures could be cooked together without complications. In contrast, the 8-year-old hybrid larch chips with high levels of bark and compression wood were more difficult to cook alone and also required more severe cooking conditions when cooked as a 25% larch/ 75% jack pine mixture.

Kappa 50 Pulp Strength

Table XXIII of the Appendix summarizes the physical properties of unbleached kappa 50 pulp. Figures 15 through 18 illustrate a number of important strength property interrelationships. Figure 15 illustrates the amount of beating required to reach a given breaking length and demonstrates the differences which exist between the pulps in terms of maximum attainable breaking length. It is apparent that European larch, both alone and in the mixture with jack pine, beats at a rate similar to pure jack pine. The hybrid larch, both 8-year-old and 23-year-old, were consistently more difficult to beat and attained significantly lower maximum tensile strength. The beating characteristics and maximum breaking length values of the 25% larch/75% jack pine were similar to that of the pure jack pine, particularly for the European larch/jack pine mixture.

The 8-year-old hybrid larch was the most difficult to beat and attained the lowest maximum breaking length. The juvenile nature of the fibers and the percent compression wood are believed to be factors involved. Photomicrographs (U.S.F.S.) taken at various beating levels demonstrated that, at low beating levels, a fairly dense, well-bonded handsheet of collapsed fibers was formed and additional beating did not improve the situation. The lower zero-span tensile values (Appendix Table XXIII) suggest lower fiber strength (juvenile and compression wood) may also be involved.

Another useful way to compare pulps is to plot tear factor versus breaking length. This approach assumes the pulps are beaten to improve breaking length and, with increased beating, there will be a tearing strength loss. The better pulps are those that attain good breaking length (9-11 km) and retain tear factor values of 120 or more. Figure 16 illustrates such a comparison for the pulps involved in this study. The 8-year-old hybrid larch and the mixture of this hybrid and jack pine had lower strength values, while the 23-year-old hybrid larch, the 18-year-old European larch and the 25% larch/75% jack pine mixtures appeared to be comparable and had better tear/breaking length strength properties than pulps containing the 8-year-old "whole tree" pulps.

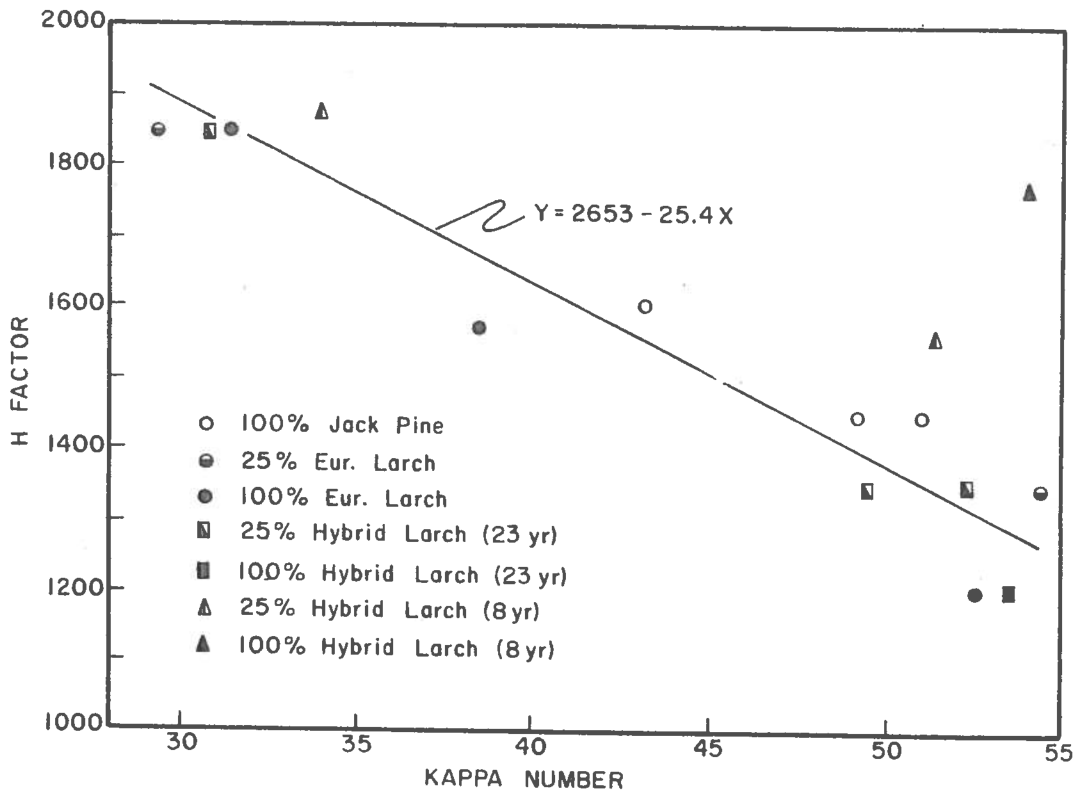

Figure 14. H-Factor Requirements vs. Kappa Number

Plotting burst factor vs. breaking length (Fig. 17) and apparent density vs. breaking length (Fig. 18) indicated that the pulps behaved in a manner typical of most conifers and that there were no important differences between the pulps evaluated.

Kappa 30 Bleaching Results

Literature describing pulping of older-aged larch often described bleaching problems. The bleaching characteristics of the kappa 30 pulp were investigated using the previously described bleaching procedure. Table XX describes the use of a CEDED bleaching sequence. The bleached pulps produced were then evaluated for strength

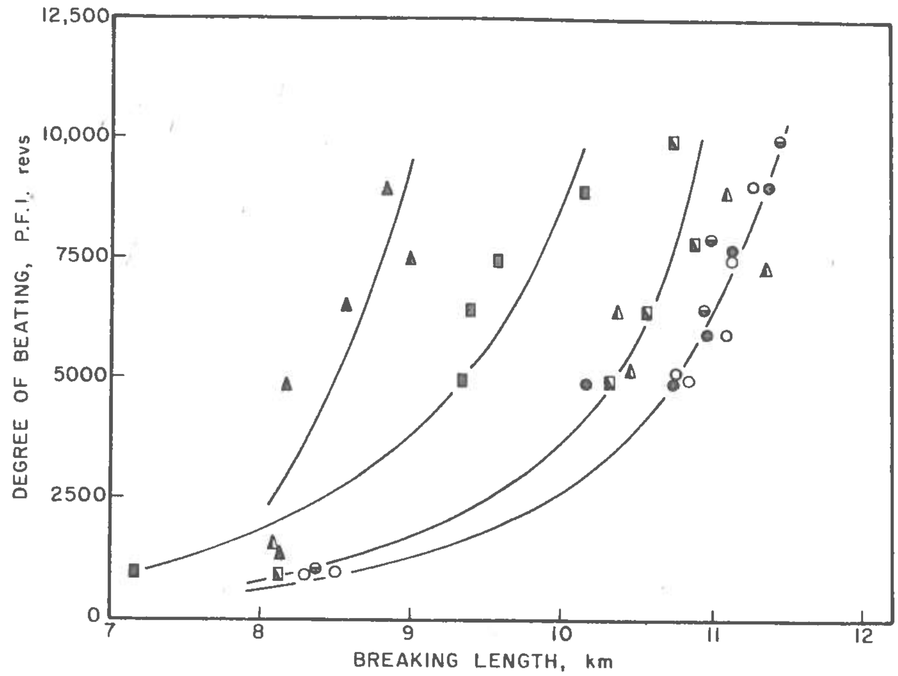

Figure 15. Degree of Beating Required vs. Breaking Length, Kappa 50 Pulps

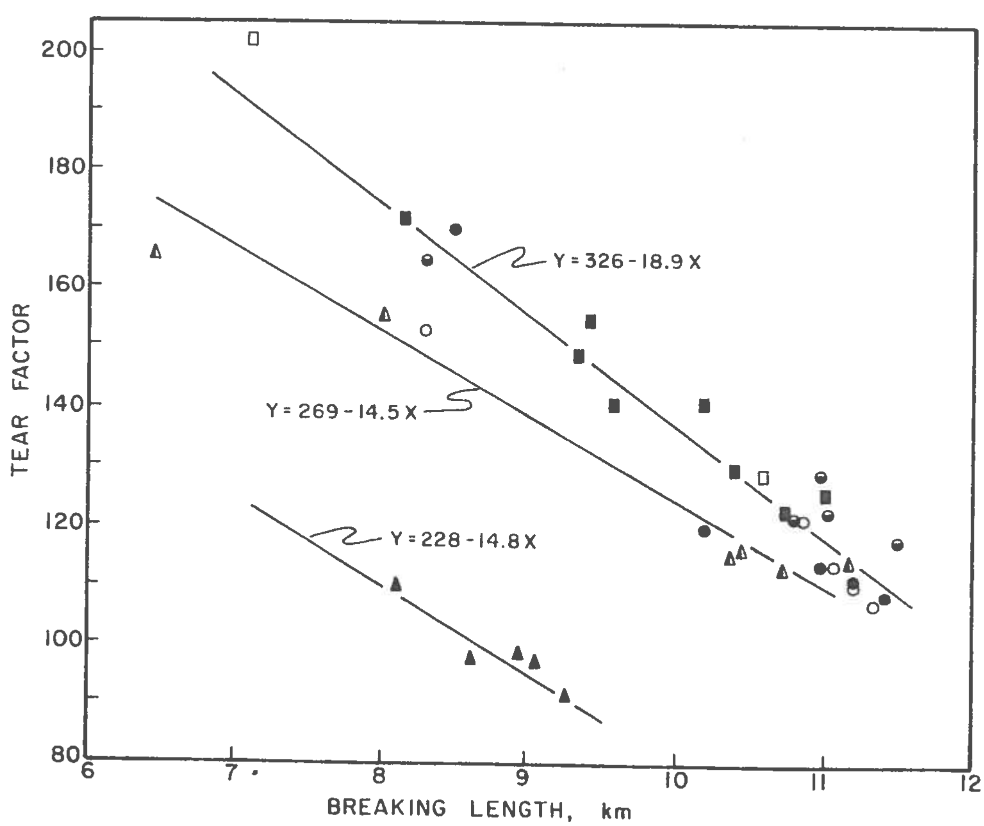

Figure 16. Tear Factor vs. Breaking Length, Kappa 50 Pulps

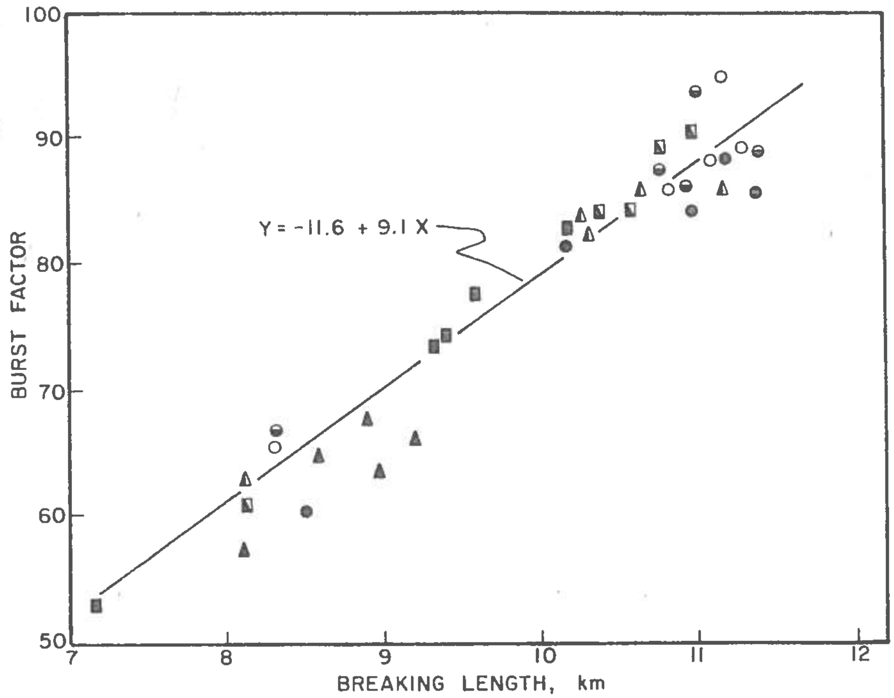

Figure 17. Burst Factor vs. Breaking Length, Kappa 50 Pulps

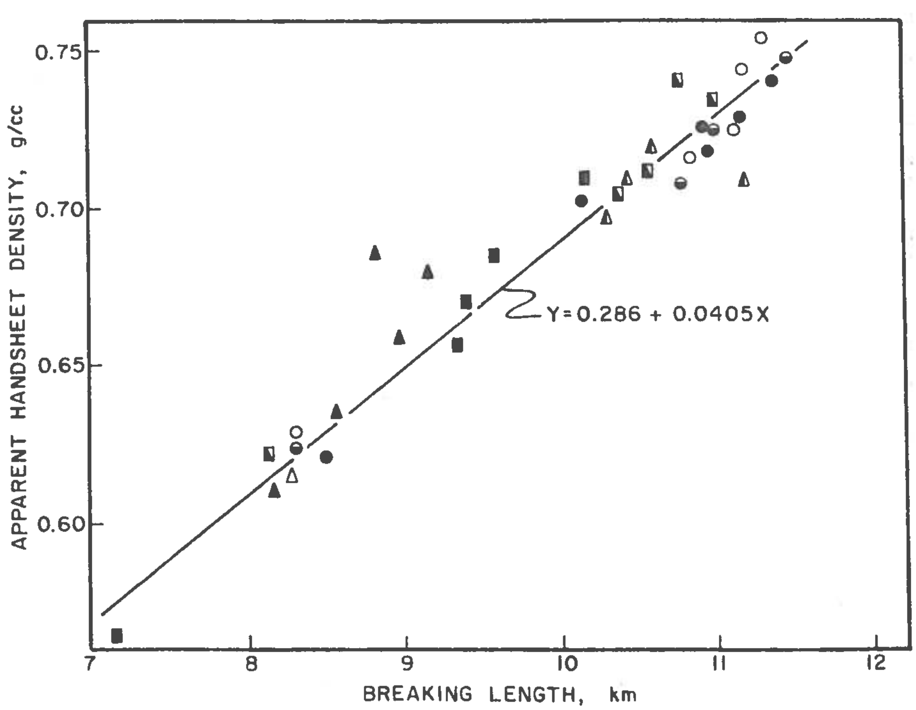

Figure 18. Apparent Handsheet Density vs. Breaking Length, Kappa 50 Pulps

TABLE XX

BLEACHING RESULTS OF 30 KAPPA PULPS

Wood Type	Chlorination Stage (C_1) % Cl_2 Consumed on o.d. pulp	Extraction Stage (E_1) Permanganage No. (25 mL)		Chlorine Dioxide Stage (D_1) % ClO_2 Consumed on o.d. Pulp	Extraction Stage (E_2) End pH	Chlorine Dioxide Stage (O_2) % ClO_2 Consumed on o.d. Pulp	G.E. Brightness, %
		Permanganage No. (25 mL)	End pH				
100% Jack pine	7.0	5.2	12.0	1.20	10.5	0.4	90.3
100% European larch	7.3	5.3	12.2	1.44	10.9	0.4	88.2
100% Hybrid (23) larch	7.0	5.7	12.2	1.32	11.3	0.21	88.3
75% Jack pine + 25% European larch	7.2	4.9	12.3	1.28	10.8	0.25	89.5
75% Jack pine + 25% hybrid (23) larch	7.0	4.6	12.7	1.27	10.4	0.23	90.2
75% Jack pine + 25% hybrid (8) larch	8.3	5.9	12.4	1.38	12.3	0.20	84.6

properties. The pulps from the two older sources of larch and the pulp from mixtures of the older larch with jack pine attained appropriate brightness levels and had similar chemical consumption as the jack pine control pulp. The pulp mixture of the 25% 8-year-old larch/75% jack pine had higher first-stage chlorine consumption and a lower final brightness.

Kappa 30 Pulp Strength Properties

The kappa 30 bleached pulps were evaluated using procedures similar to those used for the kappa 50 pulps. Appendix Table XXIV summarizes these evaluations. The kappa 30 pulp reacted to beating in a similar manner and developed similar strength as the kappa 50 pulps. Figure 19 illustrates the breaking length beating requirements. The European larch and jack pine behaved, as with the kappa 50 pulps, in a very similar manner. The 23-year-old hybrid and the two 25% hybrid larch/75% jack pine mixtures also reacted to beating in a manner similar to the jack pine bleached pulp. This appears to have occurred because, as the result of cooking to kappa 30 and bleaching, additional lignin was removed.

Removing greater amounts of lignin reduced inherent differences between fiber sources and, as a result, they reacted to refining in much the same way. Figures 20 through 22 confirm that the bleached kappa 30 pulps tended to respond to refining in a similar manner. Scattering coefficient measurements are related to bonding (lower values equal greater bonding). Figure 23 compares the response of the several pulps in terms of scattering coefficients *versus* beating and further substantiates the similar nature of the kappa 30 bleached pulps.

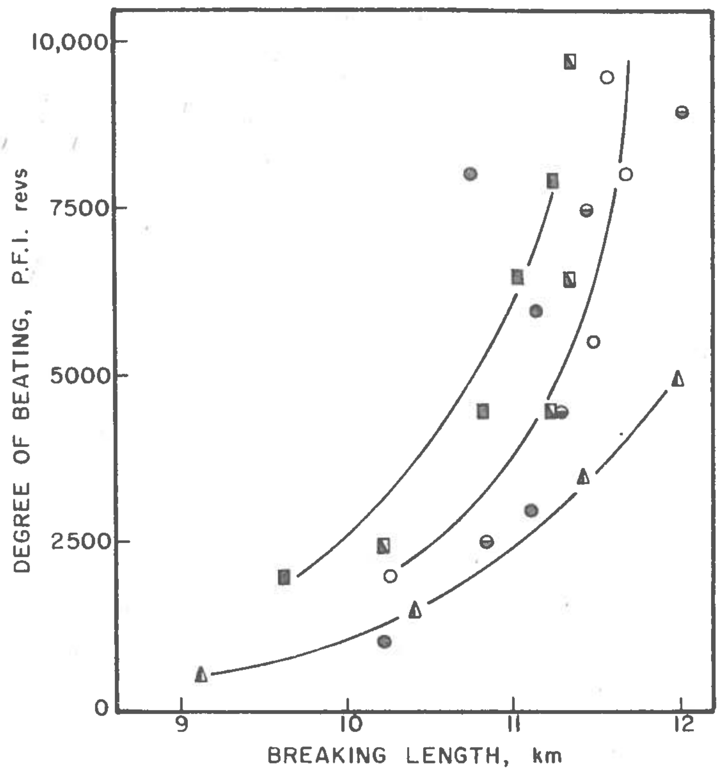

Figure 19. Degree of Beating Required vs. Breaking Length, Kappa 30 Bleached Pulps

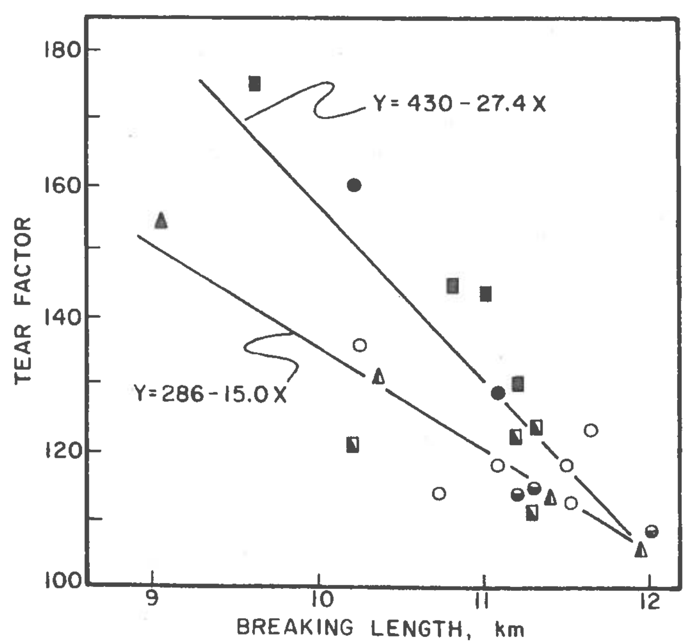

Figure 20. Tear Factor vs. Breaking Length, Kappa 30 Bleached Pulps

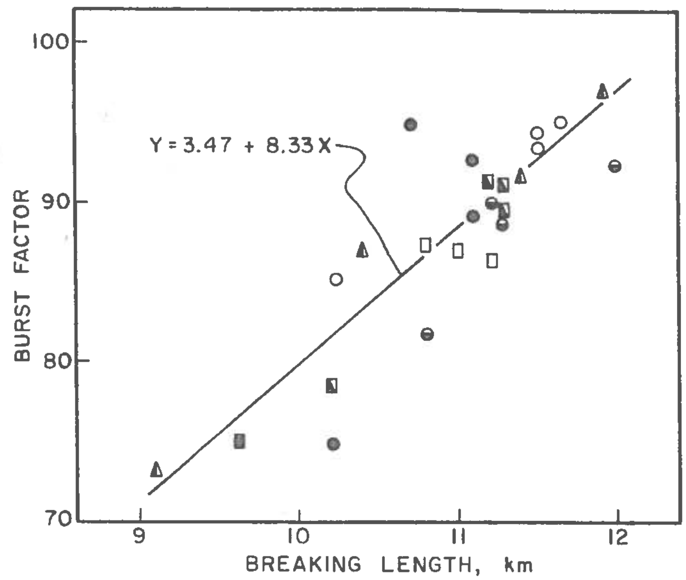

Figure 21. Burst Factor vs. Breaking Length, Kappa 30 Bleached Pulps

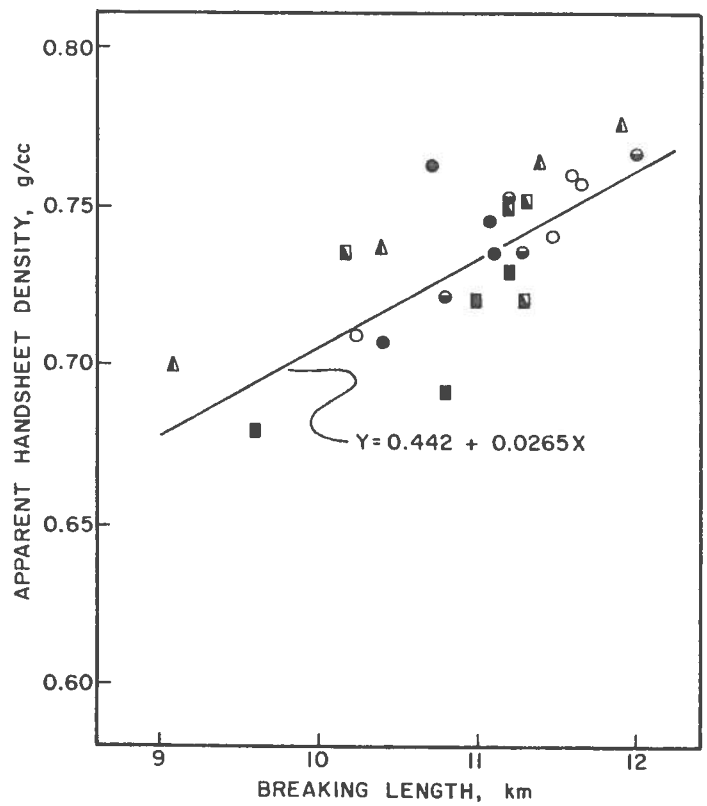

Figure 22. Apparent Handsheet Density vs. Breaking Length, Kappa 30 Bleached Pulps

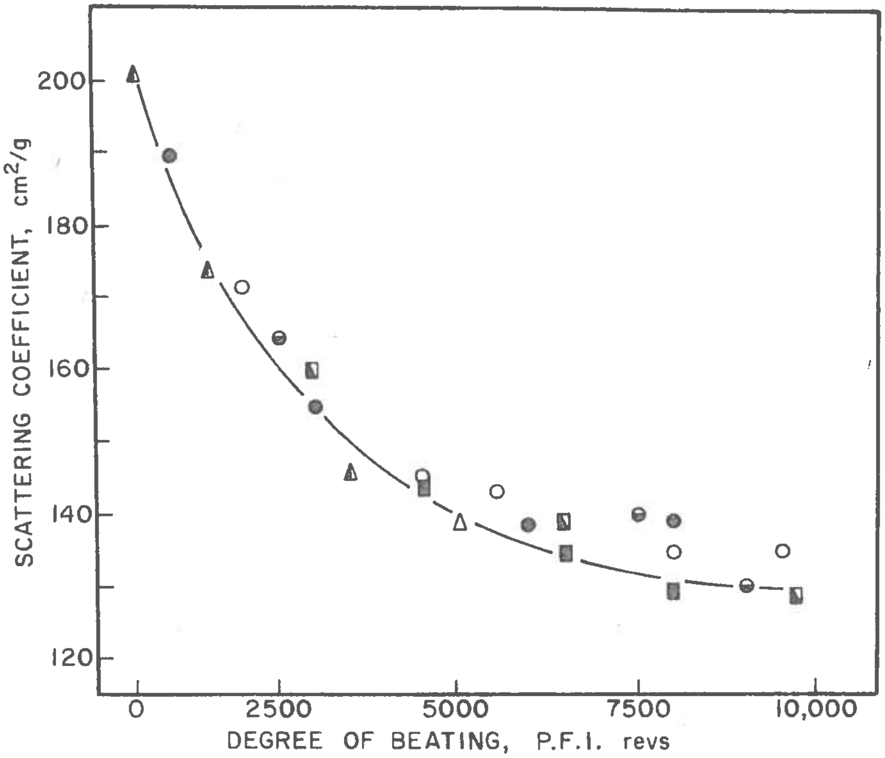

Figure 23. Scattering Coefficient vs. Degree of Beating

Strength Properties of Kappa 30 Bleached Pulp/Hardwood Pulp Mixtures

To evaluate the relative usefulness of the bleached kappa 30 pulps in improving the properties of bleached hardwood pulps, the following mixtures were prepared and evaluated:

Symbols	
O	50% bleached jack pine + 50% bleached hardwood pulp
□	50% bleached European larch + 50% bleached hardwood pulp
△	50% bleached hybrid larch (23 yr) + 50% bleached hardwood pulp
■	50% bleached jack pine/European larch mixture + 50% bleached hardwood pulp
▲	50% bleached jack pine/hybrid larch (23 yr) mixture + 50% bleached hardwood pulp
X	50% bleached jack pine/hybrid larch (8 yr) mixture + 50% bleached hardwood pulp

Appendix Table XXV summarizes the results of these comparisons and Fig. 24 through 27 illustrate the reaction of these pulp mixtures in terms of strength properties and bonding (scattering coefficients) to refining. All of the bleached conifer/bleached hardwood mixtures responded in a similar manner with the exception of the mixture containing the 8-year-old hybrid larch pulp. This pulp was better bonded than the other pulps (when compared at comparable levels of beating and/or handsheet density) but had lower tearing strength at comparable breaking length levels.

<u>Summary</u>

Kappa 50 pulps for use as bag papers and kappa 30 pulps for bleached grade pulps were produced by pulping European larch, two sources of hybrid larch and jack pine control chips along with several 25% larch/75% jack pine mixtures. Standard TAPPI methods were used in evaluating the pulps. The results are summarized as follows:

1. The larch chip sources and the mixtures with jack pine cooked at similar or slightly faster rates than jack pine.
2. Unscreened yields, except for the 8-year-old, whole-tree chips, were 3-4% higher for larch than jack pine. Pulp yields of the larch/jack pine mixtures reflected the presence of larch in the mixtures.
3. Unscreened yields of kappa 50 pulps from the 8-year-old hybrid larch whole-tree chips were about 11% lower than the bark-free jack pine chips.
4. Cooking larch chips to kappa number 50 resulted in large quantities of screen rejects that were eliminated by cooking to kappa number 30.

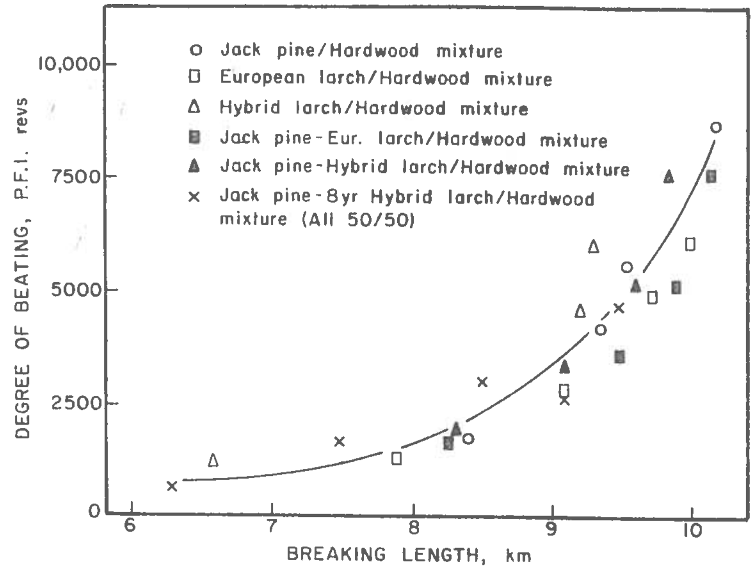

Figure 24. Degree of Beating vs. Breaking Length, Bleached Conifer/Bleached Hardwood Pulp Mixtures

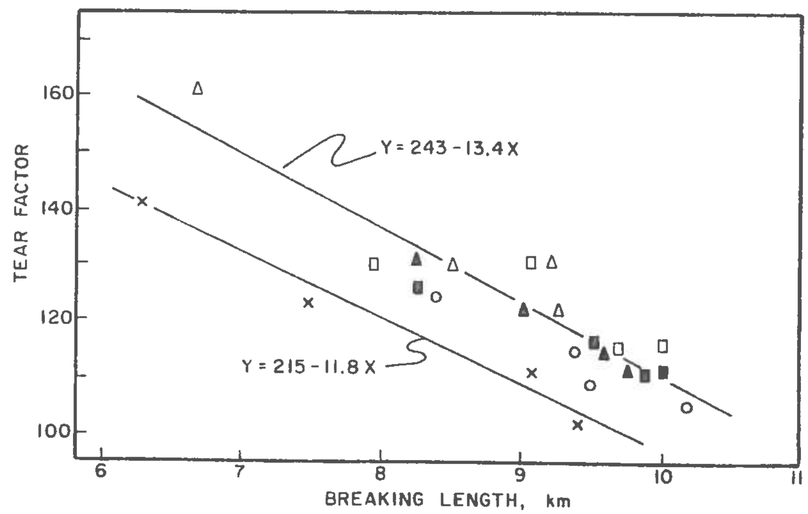

Figure 25. Tear Factor vs. Breaking Length, Bleached Conifer/Bleached Hardwood Pulp Mixtures

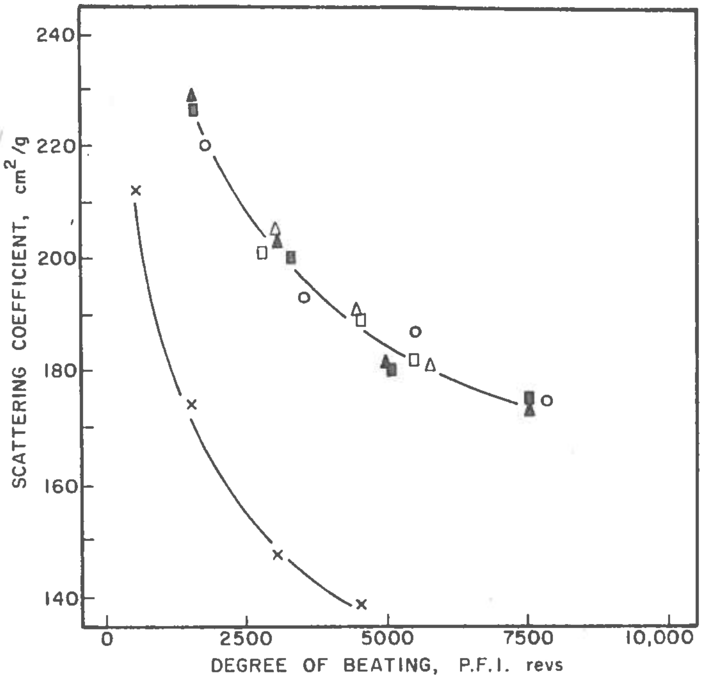

Figure 26. Scattering Coefficient vs. Degree of Beating, Bleached Conifer/Bleached Hardwood Pulp Mixtures

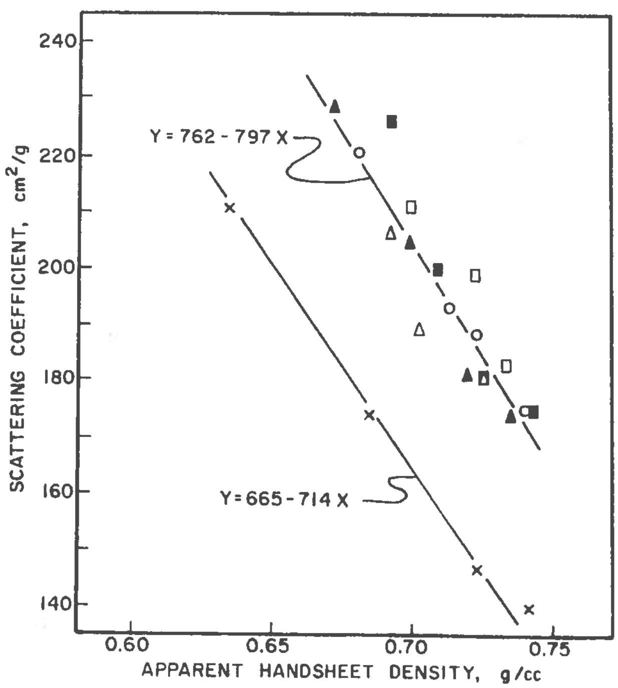

Figure 27. Scattering Coefficient vs. Apparent Handsheet Density, Bleached Conifer/Bleached Hardwood Pulp Mixtures

5. The kappa 50 pulps of the 23-year-old hybrid larch and the 8-year-old hybrid larch were more difficult to beat and developed lower ultimate breaking length than the European larch, jack pine and the 25% larch/ 75% jack pine mixtures.
6. The kappa 50 pulps from the 8-year-old hybrid larch and the mixtures with jack pine had lower tear and the lowest ultimate tensile strength. Tearing strength of the European larch and the 23-year-old hybrid larch was slightly higher than jack pine at the same breaking length.
7. The bleachability of the larch pulps was similar to the jack pine control pulps, with the exception of the pulp mixtures involving the 8-year-old hybrid larch and jack pine, which was more difficult to bleach.
8. Pulping larch and larch/jack pine mixtures to a kappa 30 followed by bleaching resulted in pulps that had strength properties that were very similar to the jack pine control. Only the 8-year-old hybrid larch/ jack pine mixture had lower tear as the result of refining to develop breaking length.
9. When bleached larch and bleached larch/jack pine pulps were mixed with bleached hardwood pulps, the strength properties were comparable to the strength of pulps prepared from bleached jack pine/bleached hardwood pulp mixtures. The only exception was the bleached 8-year-old hybrid larch-jack pine/bleached hardwood pulp mixture. This mixture had lower scattering coefficient and lower tear than the other pulp mixture.