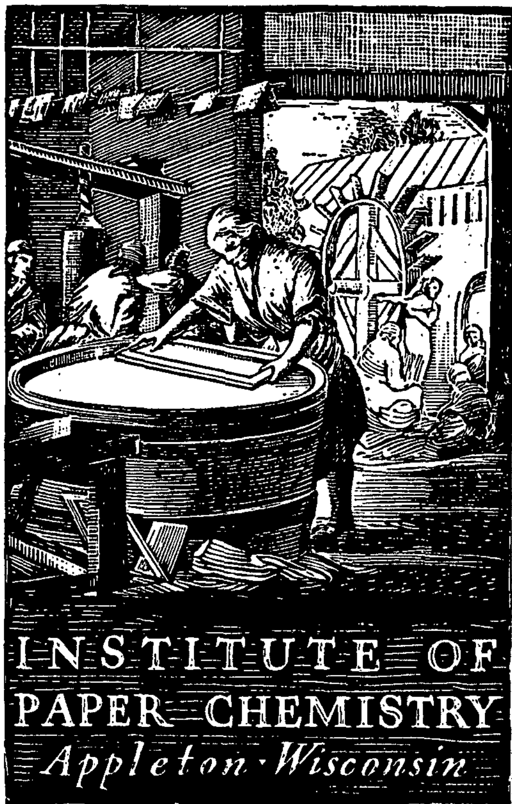

IMPROVED WEIGHT FACTORS FOR FIBER ANALYSIS

Project 3033

Report One

A Progress Report

to

MEMBERS OF GROUP PROJECT 3033

April 12, 1972

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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Crown Zellerbach Corporation

Great Northern Paper Company

Hammermill Paper Company

Kimberly-Clark Corporation

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St. Regis Paper Company

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TABLE OF CONTENTS

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

IMPROVED WEIGHT FACTORS FOR FIBER ANALYSIS

SUMMARY

The initiation of the project called for a survey of the cooperators to decide what pulp samples should be included in the weight factor determinations. All of the participating companies of Project 3033 were asked to list, in order of priority, wood species together with their pulping processes, ten pulps which were of most interest to them. Company interests were tabulated and, on the basis of this information, a list of pulps to be included in the weight factor study was determined. A later request was made for the cooperators to supply authentic samples of the pulps in which they had expressed interest.

This report includes the results of weight factor determinations made on most of the softwood and hardwood chemical pulps which have been received, one pulp from the TAPPI Fibrary and one grass (Esparto) pulp. A few of the wood pulp samples received, which supposedly contained but one species, were highly contaminated with other species. No determinations were made on these pulps.

The results of the weight factor determinations made to date, although similar to the proposed weight factors listed in TAPPI Standard T 401 m-60, confirm that species has a considerable effect on the weight factor of a pulp.

GENERAL BACKGROUND

An accurate quantitative fiber analysis of a paper, board, or pulp sample makes it desirable to have available a set of weight factors for the various pulps which may be contained in their furnishes. Spence and Krauss (1) first demonstrated that equal areas or equal lengths of different kinds of fibers do not necessarily represent equal weights. For example, when a mixture of equal weights of two pulps (e.g., one gram each of rag and soda pulps) is mixed thoroughly and standard slides prepared and examined under a microscope, it is observed that there are approximately twice as many soda fibers present as rag fibers. Therefore, if rag is given a value of 1.0, soda would have a value of 0.5. These relative values have been designated weight factors, which are correction factors, used in the quantitative analysis of mixed paper furnishes.

The weight factors of pulps show marked variation between species of wood and also between pulps of the same species but from different geographic locations. The factors are affected to a lesser extent by the type and degree of cook, beating, and bleaching. Pulps prepared from species of maple, for example, have a factor of approximately 0.4 whereas species of gum pulps are considerably coarser (coarseness is defined as the weight per unit length of fiber and is expressed as milligrams per 100 meters) and have a weight factor of approximately 1.0. Investigations made at The Institute of Paper Chemistry (2) on kraft pulps prepared from species of coastal and interior Douglas-fir revealed that they have weight factors of 1.45 and 1.0, respectively. Pulps prepared from most species of southern yellow pine have a factor of approximately 1.5 while pulps prepared from Virginia pine and species of northern softwoods (i.e., species of jack pine, hemlock, spruce, true fir, etc.) are not nearly as coarse and have a weight factor of about 0.9. Early investigations of relative weight factors by both Landes (3) and Graff (4) revealed that the weight factors for Scandinavian softwood pulps were higher than those for eastern softwood pulps; the values for west coast pulps were found to be somewhat higher than those for Scandinavian pulps.

Graff (5) showed in some of his work that beating has little or no effect upon the relative weight factor of a pulp. This fact is not surprising since, as Clark (6) has pointed out, the only connection between weight factors and freeness is the relatively minor effect (except in pulps from cotton or bast fibers) which the lengthwise splitting of the fibers has in reducing the freeness. Neither the fibrils still attached to the parent fibers or the separated fibrillar debris are included in the fiber counts when making most weight factor determinations of wood pulps. Investigations on the effect of beating on the weight factor for cotton linters were made by Isenberg and Peckham (7). They found that although the standard deviation for the different degrees of freeness is relatively small, the weight factors decrease with a decrease in the freeness.

Most of the weight factors presently used at The Institute of Paper Chemistry, in the determination of quantitative analyses, were originally determined by Graff. They have, in most instances, later been confirmed by other Institute personnel in a continuing program of weight factor studies on authentic species.

An inexperienced analyst, when in doubt, can use the width of the fibers as a guide in determining the weight factor to be used for a pulp furnish. Clark (6) has suggested that the estimated average width in micrometers of the fiber be divided by factors of 20 if rag or bast, 30 if coniferous, and 35 if deciduous or grass pulps.

Ranger (8) has proposed a method for determining weight factors based on a microscopic method for calculating the relative grex or international denier value of pulp fibers. This grex value is proportional to the relative weight factor determined in the usual manner. Weight factors are also proportional to the coarseness or decigrex of the pulp as determined by TAPPI method T 234 su-64.

Probably the most common method for determining the weight factor of a pulp is by relating it to some standard pulp with a known relative weight factor. The composition of a furnish can be checked to within ± 2-3% or less, as stated in TAPPI standard T 401 m-60 if it is possible to actually check the relative weight factors of the pulps present in a furnish. When this is not possible, an experienced analyst will recognize the wood species present in the furnish and, using a set of known relative weight factors as a guide, will choose appropriate factors to complete the analysis.

The initial work of Project 3033 concerns itself with the determination of relative weight factors of submitted chemical pulp samples prepared from individual tree species, a wood pulp from the TAPPI Fibrary, and one grass (Esparto) pulp.

EXPERIMENTAL

METHODS

A fifty-fifty mixture by weight of a standard pulp (i.e. cotton linters — J. H. Munktells Swedish Filtering Paper for Chromatography) with a known relative wt. factor of 1.1 and the pulp under investigation are thoroughly mixed in a large Erlenmeyer flask. This fiber suspension is poured into six test tubes and each is diluted to the desired consistency (i.e., approximately 0.05%). Standard slides are prepared (a one-inch square field at each end of every slide) from each of the six pulp mixtures and the fibers mounted and differentially stained with Graff "C" stain (Refer to TAPPI Standard T 401 m-60). The fibers are counted at a magnification of 100 diameters with the aid of a binocular microscope equipped with a mechanical stage and an eyepiece with a pointer. The fiber field is moved horizontally and all the fibers counted as they pass under the end of the pointer. The one square inch field is scanned five times on lines 4 mm. apart for a total count which usually totals between 200-300 fibers. Both sides of the six slides are determined in this manner for each determination. Since the weight factor for the standard pulp is known, the relative weight factor for the pulp being examined is readily calculated.

SAMPLES

The pulp samples investigated were secured from cooperating companies of Project 3033 and from the TAPPI Fibrary. They are as follows:

	Pulp	Source
1.	Southern Yellow Pine — Alpha Grade of Bl. Kraft (Mercerized)	Riegel Paper Corp.
2.	Southern Yellow Pine — Bleached Kraft	Riegel Paper Corp.
3.	Loblolly Pine — Bleached Kraft	Hammermill Paper Co.
4.	Slash Pine (Georgia) — Unbleached Kraft (Soft Cook)	Fibrary Sample No. 128
5.	Jack Pine (North Central U.S.) — Unbleached Kraft	Hammermill Paper Co.
6.	Tamarack (Michigan) — Unbleached Kraft	Hammermill Paper Co.
7.	Sweetgum (Alabama) — Bleached Kraft	Hammermill Paper Co.
8.	White Oak (Alabama) — Bleached Kraft	Hammermill Paper Co.
9.	Red Oak (Alabama) — Bleached Kraft	Hammermill Paper Co.
10.	Maple (Wisconsin) — Unbleached Kraft	Hammermill Paper Co.
11.	*Populus* sp. — Unbleached Kraft	Scott Paper Co.
12.	Beech — Unbleached Kraft	Scott Paper Co.
13.	Birch — Unbleached Kraft	Scott Paper Co.
14.	Esparto (Tunisia) — Bleached Kraft	Riegel Paper Corp.

DESCRIPTION OF WOOD SPECIES AND RESULTS OF WEIGHT FACTOR DETERMINATIONS

A brief description of the general characteristics, gross and microscopic features (9, 10) of the wood species from which the submitted pulps were prepared and the results of weight factor determinations made on these pulps are recorded in the following section.

SOUTHERN YELLOW PINE (SPECIES OF LONGLEAF, SHORTLEAF, LOBLOLLY, SLASH, PITCH, POND, VIRGINIA, etc.)

General Description and Minute Anatomy of Wood Species

The wood contained in species of southern yellow pine is moderately heavy to heavy (av. sp. gr. 0.45-0.56 green, 0.52-0.66 ovendry). The growth rings in the species are distinct, delineated by pronounced bands of thick-walled latewood fibers. The transition from earlywood to latewood is very abrupt and the widths of each vary within wide limits. The earlywood zone varies from very wide (slash pine, loblolly pine) to narrow (slow-growth shortleaf pine, etc.) while the latewood zone ranges from broad to narrow, varying greatly in width and density depending upon the age of the tree, conditions of growth and, within general limits, according to species. The rays are very fine and not visible (cross section) to the naked eye, except where they include a transverse resin canal, forming a fine, close, inconspicuous fleck on the quarter surface. Parenchyma are not visible. Both longitudinal (av. 90-150 µm. in diameter) and transverse (usually less than 70 µm. in diameter) resin canals with thin-walled epithelium are present. Canals in the heartwood are frequently occluded with tylosoids. The tracheids are up to 60 (av. 35-45) micrometers in diameter. The average length of the tracheids of longleaf, shortleaf, and slash pine is 4.5-5 mm. while that of loblolly is 3.5-4.0 mm., pond 3.0 mm. and Virginia 2.0-2.5 mm. The rays are of two types, uniseriate and fusiform. The uniseriate rays are numerous and 1 to 8^+ cells high. The fusiform rays are scattered, with a horizontal resin canal 2 to 4 — seriate in the central portion, tapering to a uniseriate margin, up to 12^+ cells high. Ray tracheids are present in both types of rays and are marginal and interspersed. The ray parenchyma are thin walled. The volume occupied by the rays averages approximately 8.4%.

The yellow or hard pines of southeastern and eastern United States cannot be separated on the basis of wood structure.

Weight Factor Determination

The weight factor determinations made on the submitted pulps prepared from species of southern yellow pine are listed in Table I. The results show that the overall agreement between analysts is very good. The determined weight factors of 1.54 and 1.46, for pulp samples no. 1 and no. 3, respectively, agree favorably with the suggested factor of 1.55 listed for species of southern pine kraft in TAPPI Standard T 401 m-60 (Table II). The sample of slash pine (Fibrary sample no. 128) is slightly coarser than the average southern pine kraft pulps (i.e., using 1.55 as a criterion) while the loblolly pine kraft is finer. The difference between the weight factors of these two pulps is undoubtedly due to the species involved and not to bleaching.

Photomicrographs of the furnishes of the four pulp samples are illustrated in Fig. 1, 2, 3, and 4. Only the earlywood and latewood tracheids are included in the counts when making a weight factor determination.

TABLE I

WEIGHT FACTORS — SOUTHERN PINE

No.	Pulp Sample	Weight Factors Analyst A	B	C	Av.
1	Southern Yellow Pine — Alpha Grade of Bleached Kraft (mercerized) — Riegel	1.50	1.59	--	1.54
2	Slash Pine — Unbleached Kraft (soda cook) Fibrary Sample No. 128	1.75	1.77	--	1.76
3	Southern Yellow Pine — Bleached Kraft — Riegel	--	1.45	1.47	1.46
4	Loblolly Pine — Bleached Kraft — Hammermill	--	1.24	1.26	1.25

TABLE II

WEIGHT FACTORS
(TAPPI Standard T 401 m-60)

Fibers	Factors
Rag	1.00
Cotton linters	1.25
Bleached flax and ramie	0.50
<u>Softwood fibers</u>	
Unbleached and bleached sulfite and kraft (except hemlock, Douglas-fir and southern kraft)	0.90
Western hemlock	1.20
Douglas-fir	1.50
Southern kraft	1.55
Alpha (northern)	0.70
<u>Hardwood fibers</u>	
Soda, sulfate or sulfite (except gum and alpha)	0.60
Gum	1.00
Alpha	0.55
Groundwood	1.30
Unbleached bagasse fibers as prepared for boards	0.90
Bleached and unbleached bagasse fibers as prepared for papers	0.80
Esparto	0.50
Manila and jute	0.55
Sisal	0.60
Straw for board	0.65
Bleached straw	0.35

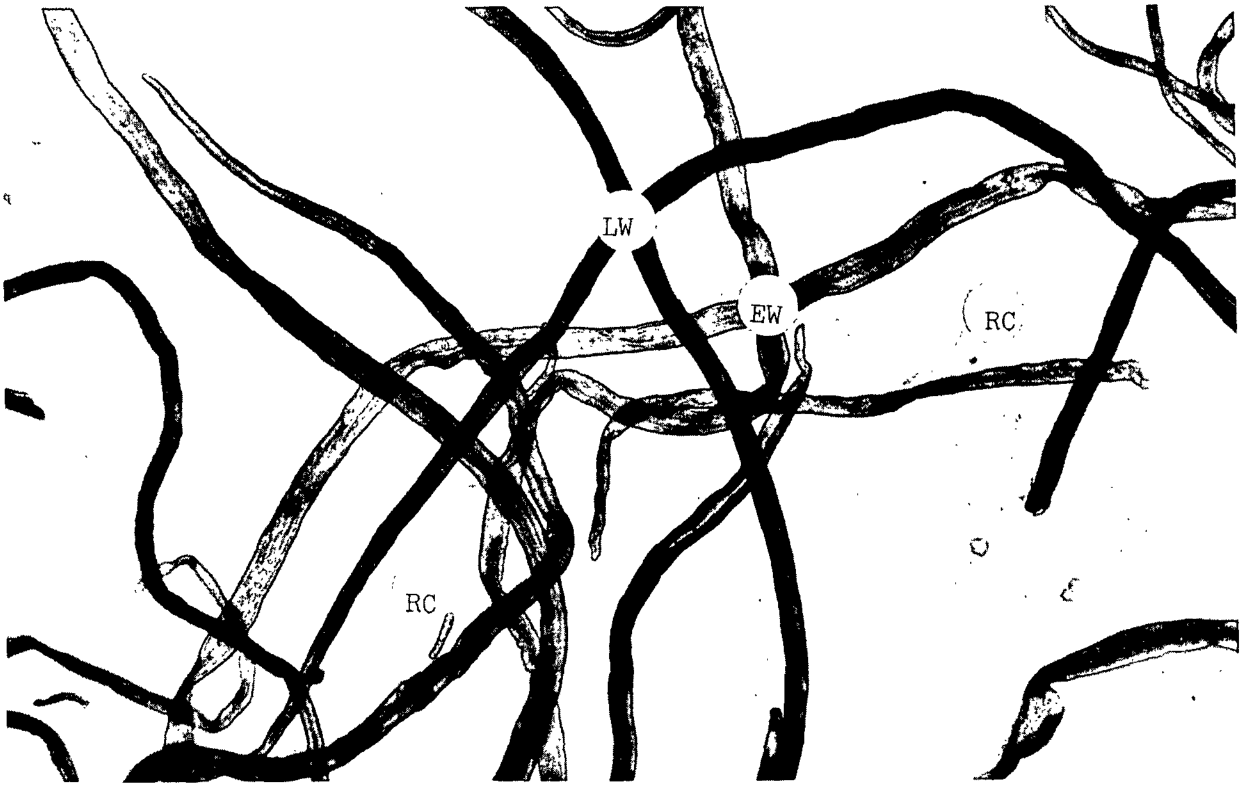

Figure 1. Pulp Sample of Southern Yellow Pine Alpha Grade of Bleached Kraft Mercerized (Submitted by Riegel Paper Corp.). Latewood Tracheids (LW), Earlywood Tracheids (EW), Ray Cells (RC). Magnification — 90 Diameters, Weight Factor — 1.54

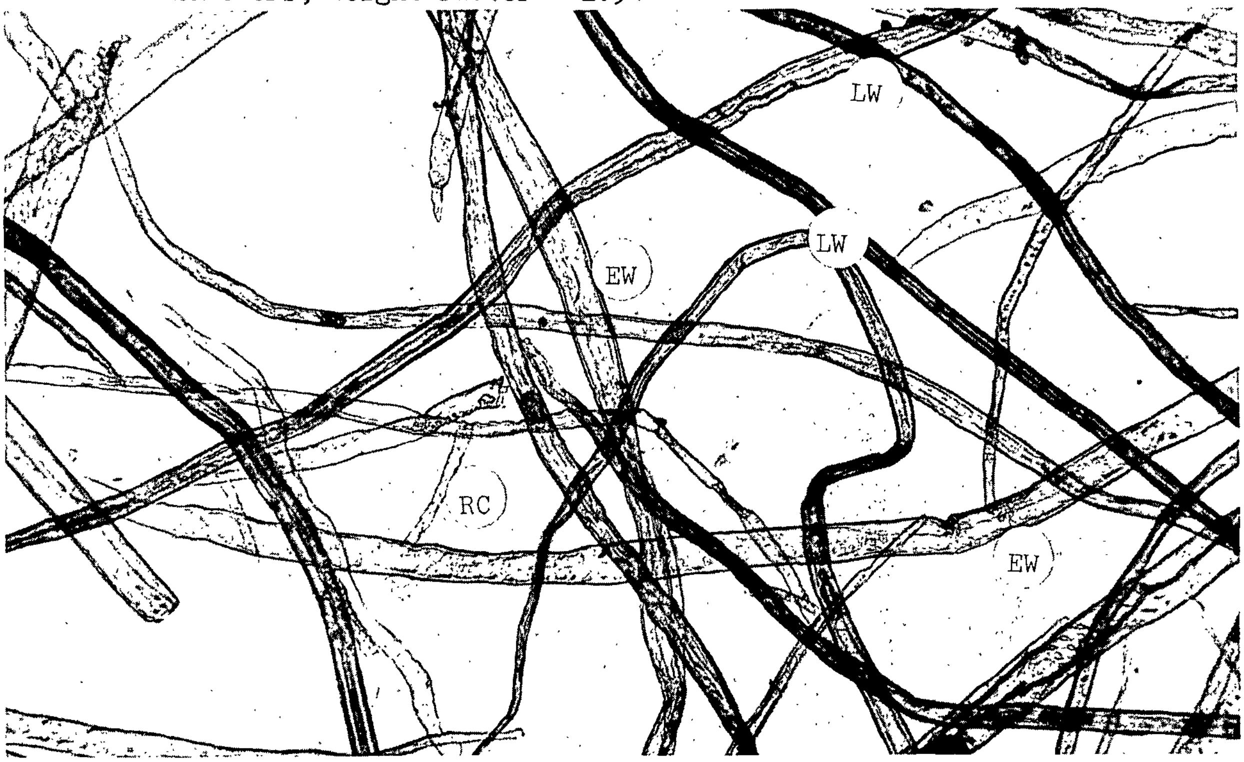

Figure 2. Pulp Sample of Slash Pine Soft Cooked Unbleached Kraft. Fibrary Sample No. 128. Latewood Tracheids (LW), Earlywood Tracheids (EW), Ray Cells (RC). Magnification — 90 Diameters, Weight Factor — 1.76

Figure 3. Sample of Southern Yellow Pine Bleached Kraft (Submitted by Riegel Paper Corp.). Latewood Tracheids (LW), Earlywood Tracheids (EW), Ray Cells (RC). Magnification — 90 Diameters, Weight Factor — 1.46

Figure 4. Pulp Sample of Loblolly Pine Bleached Kraft (Submitted by Hammermill Paper Co.). Latewood Tracheids (LW), Earlywood Tracheids (EW), Ray Cells (RC). Magnification — 90 Diameters, Weight Factor — 1.25

JACK PINE

General Description and Minute Anatomy

The wood of jack pine is moderately heavy (sp. gr. approx. 0.40 green, 0.46 ovendry). The growth rings are distinct, delineated by a band of dark-colored latewood. The transition from earlywood to latewood is fairly abrupt. The earlywood zone is variable in width and is usually much wider than the denser latewood zone. The rays are very fine and not visible to the naked eye. Parenchyma cells are absent. Longitudinal (80-95 µm. in width) and transverse (less than 45 µm. in width) resin canals with thin-walled epithelium are present. Canals in the heartwood are frequently occluded with tylosoids. The tracheids are up to 45 µm. (av. 27-37 µm.) in diameter and 3.5 mm. (1.5 to 5.7 mm.) in length. The rays are of two types, uniseriate and fusiform. The uniseriate rays are 1-8 plus cells in height and are numerous. The scattered fusiform rays with a transverse resin canal are 2-3 seriate through the central thickened portion and 10 plus cells in height in the uniseriate margins. Ray tracheids are present in both types of rays, the low rays frequently consisting entirely of ray tracheids. The ray parenchyma cells are thin-walled.

Weight Factor Determination

The weight factor determinations made on the submitted pulp sample of jack pine are as follows:

	Weight Factor Determination		
	Analyst		
Pulp Sample	A	B	Av.
Jack Pine — Unbleached Kraft — Hammermill Paper Co.	1.00	0.98	0.99

The average weight factor of 0.99 determined for the submitted pulp sample of jack pine agrees favorably with the suggested factor of 0.90 listed in the TAPPI Standard.

A photomicrograph of the fiber furnish of the submitted sample of jack pine pulp is illustrated in Fig. 5.

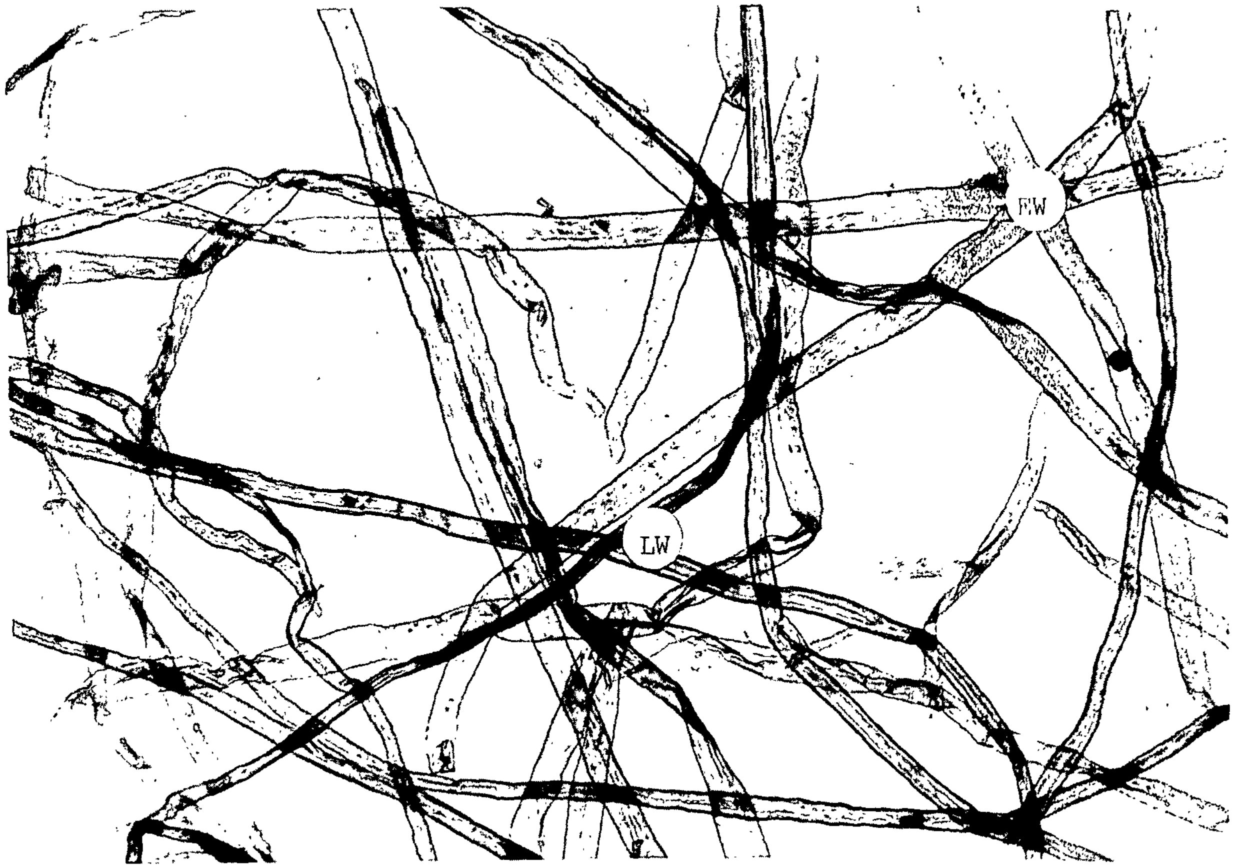

Figure 5. Pulp Sample of Jack Pine Unbleached Kraft (Submitted by Hammermill Paper Co.). Latewood Tracheids (LW), Earlywood Tracheids (EW). Magnification — 90 Diameters, Weight Factor — 0.99

TAMARACK

General Description and Minute Anatomy

The wood of tamarack is moderately heavy (sp. gr. approx. 0.49 green, 0.53 ovendry). The growth rings are distinct, delineated by a pronounced band of darker-colored latewood. The transition from earlywood to latewood is abrupt. The earlywood zone usually occupies three-fourths or more of the ring. The rays are very fine and not distinct to the naked eye. Longitudinal (60-90 μm. in diameter) and transverse (less than 25 μm. in diameter) resin canals with thick-walled epithelial cells and few tylosoids are present. The tracheids are up to 45 (av. 25-35) micrometers in diameter and 3.6 mm. (1.7 to 5.6 mm.) in length. The rays are two types, uniseriate or rarely in part biseriate and fusiform. The uniseriate cells are numerous and 1-16 plus cells in height. The biseriate cells are sparse and scattered or wanting. The fusiform rays are 2-3 seriate in the central portion, tapering to uniseriate margins up to 16^+ cells in height. Ray tracheids are present in both types of rays and are marginal or but rarely interspersed. Longitudinal parenchyma are terminal and very sparse or wanting.

Weight Factor Determination

The weight factors determined for the submitted sample of tamarack pulp are as follows:

Pulp Sample	Weight Factor Determination Analyst A	B	Av.
Tamarack — Unbleached Kraft — Hammermill Paper Co.	1.00	1.02	1.01

The average weight factor of 1.01 determined for the submitted sample of tamarack pulp is a little larger than the TAPPI suggested factor of 0.90 for unbleached and bleached, sulfite and kraft coniferous fibers (see Table II).

Figure 6 is a photomicrograph of the fiber furnish of the submitted sample of tamarack pulp.

SWEETGUM

General Description and Minute Anatomy

Sweetgum is a diffuse-porous wood containing numerous, small, uniform pores invisible to the naked eye evenly distributed throughout the growth ring. The wood is moderately heavy (sp. gr. 0.44 green, 0.53 ovendry). Parenchyma are not visible. The rays are not distinct to the naked eye, are very close, and seemingly occupy half of the area on the transverse surface. Longitudinal wound (traumatic) gum canals are sometimes present in tangential rows, and usually appear at wide intervals. The vessels average 120-180 per sq. mm. The largest vessels are between 60-95 µm. in diameter and average approximately 1.32 mm. in length. The fiber tracheids are moderately thick-walled, 20-40 µm. in diameter, and have an average length of 1.8 mm. (1.0-2.5 mm.). The volume occupied by the vessels and fibers is 54.9 and 26.8%, respectively. The rays are unstoried, 1 to 3 (mostly 2) — seriate and mostly heterogeneous. The volume occupied is 18.3%.

Weight Factor Determination

The results of weight factor determinations made on the submitted sample of sweetgum pulp are as follows:

	Weight Factor Determination		
	Analyst		
Pulp Sample	A	B	Av.
Sweetgum Bleached Kraft — Hammermill Paper Co.	0.81	0.86	0.84

The average weight factor for the submitted pulp sample is in fairly good agreement with the factor of 0.9-1.00 usually employed for pulps prepared from this species. The pulps prepared from species of gum are generally relatively coarse as compared to pulps prepared from other hardwood species.

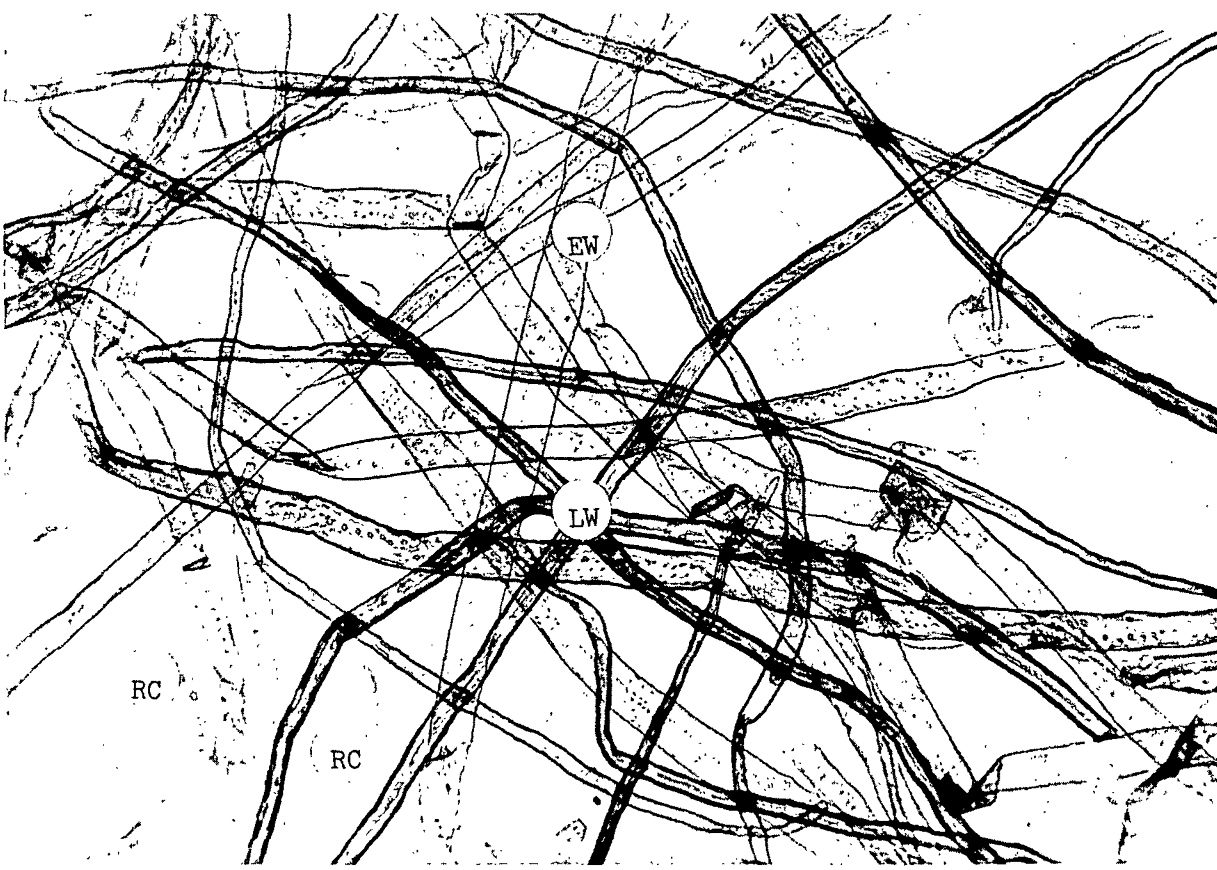

Figure 6. Pulp Sample of Tamarack Unbleached Kraft (Submitted by Hammermill Paper Co.). Latewood Tracheids (LW), Earlywood Tracheids (EW), Ray Cells (RC). Magnification — 90 Diameters, Weight Factor — 1.01

A photomicrograph showing the relatively coarse hardwood fiber tracheids and vessel elements which are characteristic of sweetgum pulps is illustrated in Fig. 7.

WHITE OAK

General Description and Minute Anatomy

The wood of species of white oak is heavy to very heavy (sp. gr. 0.55-0.64 green, 0.66-0.79 ovendry). The wood is typically ring porous, containing large earlywood pores distinctly visible to the naked eye, forming a conspicuous band 1-3 pores in width. The pores are frequently occluded with tyloses in the heartwood. The transition from early to latewood is abrupt or somewhat gradual. The latewood pores are numerous, small, and not sharply defined with a hand lens. There are two types of rays present in the species, broad (oak type) and narrow. The broad rays are very distinct to the naked eye and are separated by several to many narrow rays which are indistinct without magnification. There are between 20-120 latewood vessels per sq. mm. The largest earlywood vessels are 180-380 μm. in diameter and average approximately 0.40 mm. in length. The fibers are medium thick to thick-walled, frequently gelatinous, 14-22 micrometers in diameter and 1.4 mm. in length. Paratracheal, apotracheal-diffuse and banded parenchyma are abundant and visible with a hand lens. Vasicentric tracheids are present, intermingled with parenchyma. The rays are unstoried and homogeneous. The broad rays are 12 to 30 plus seriate, 150-400^{+} micrometers wide through the central portion and many cells (into hundreds) in height. The narrow rays are numerous, uniseriate or occasionally in part biseriate, very variable in height (1-20 plus) cells.

Species of the various oaks belonging to the white oak groups (Leucobalanus) cannot be identified from one another with certainty.

Figure 7. Pulp Sample of Sweetgum Bleached Kraft (Submitted by Hammermill Paper Co.). Fiber Tracheids (FT), Vessel Elements (V), Ray CElls (RC). Magnification — 90 Diameters, Weight Factor — 0.84

RED OAK

General Description and Minute Anatomy

The wood of red oak is similar to that described for white oak species except for the following:

(1) The transition from earlywood to latewood is generally more gradual for species of red oak.

(2) The earlywood pores in the heartwood of red oak species are usually not occluded with tyloses.

(3) The latewood pores in the red oaks are plainly visible with a hand lens and are thick-walled. There are only 10 to 30 vessels per sq. mm. as compared with 12-120 vessels per

sq. mm. for species of white oak. The largest earlywood vessels in red oak species are 200 to 430 µm. in diameter.

(4) The large rays in species of red oak average 0.25 to 0.5 inches high and rarely more than 1.5 inches.

The woods of the various red oaks belonging to the red oak group (Erythrobalanus) cannot be identified with certainty.

Weight Factor Determination

The weight factors determined for the two species of submitted oak pulps are as follows:

	Weight Factor Determination		
	Analyst		
Pulp Sample	A	B	Av.
White Oak — Bleached Kraft — Hammermill Paper Co.	0.49	0.49	0.49
Red Oak — Bleached Kraft — Hammermill Paper Co.	0.48	0.49	0.48

The overall agreement of results between analysts for the two submitted species of oak kraft is very good. The factors, although slightly lower, are in fairly good agreement with the suggested factor of 0.60 covering all species of hardwood fibers except gum prepared by the soda, sulfate, or sulfite process listed in TAPPI Standard (T 401 m-60).

Photomicrographs of the cellular elements present in the submitted pulp samples of white and red oak are illustrated in Fig. 8 and 9, respectively.

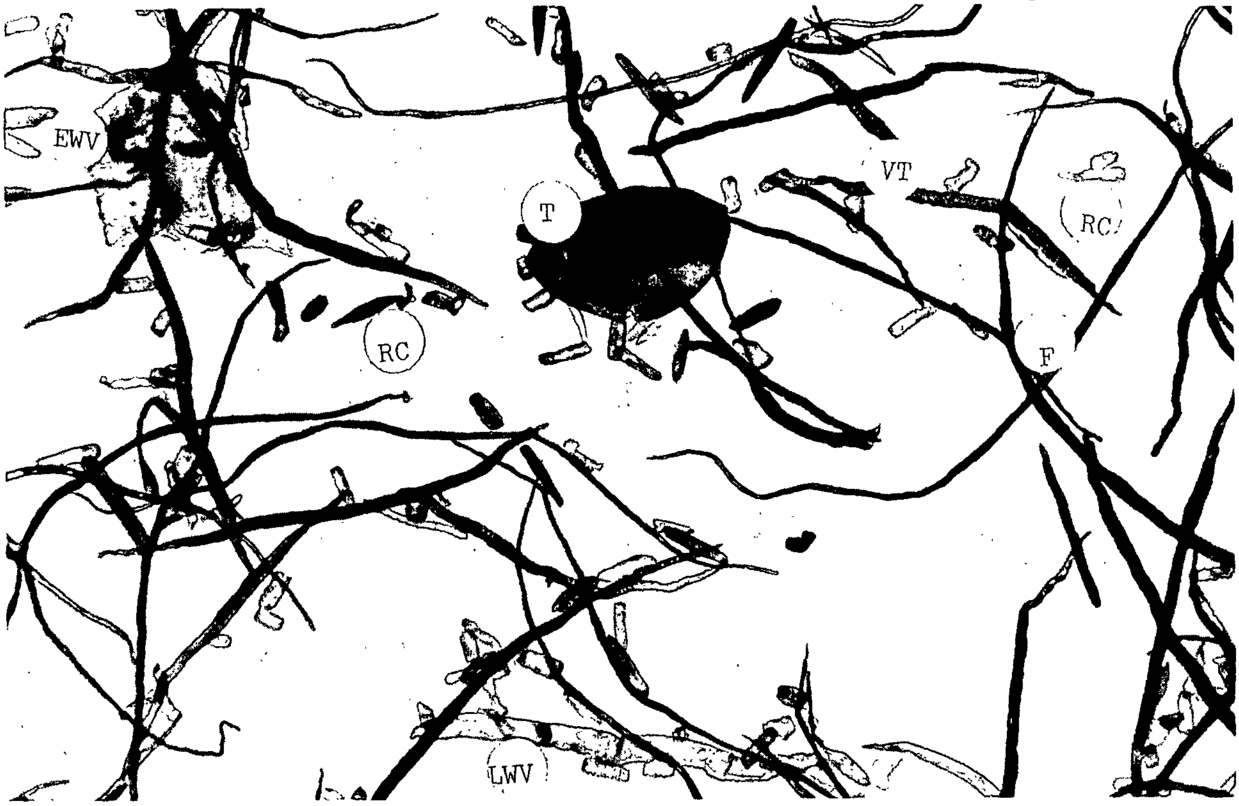

Figure 8. Pulp Sample of White Oak Bleached Kraft (Submitted by Hammermill Paper Co.). Earlywood Vessel Element (EWV), Latewood Vessel Element (LWV), Tylosis (T), Fibers (F), Vasicentric Tracheids (VT), Ray Cells (RC). Magnification — 90 Diameters, Weight Factor — 0.49

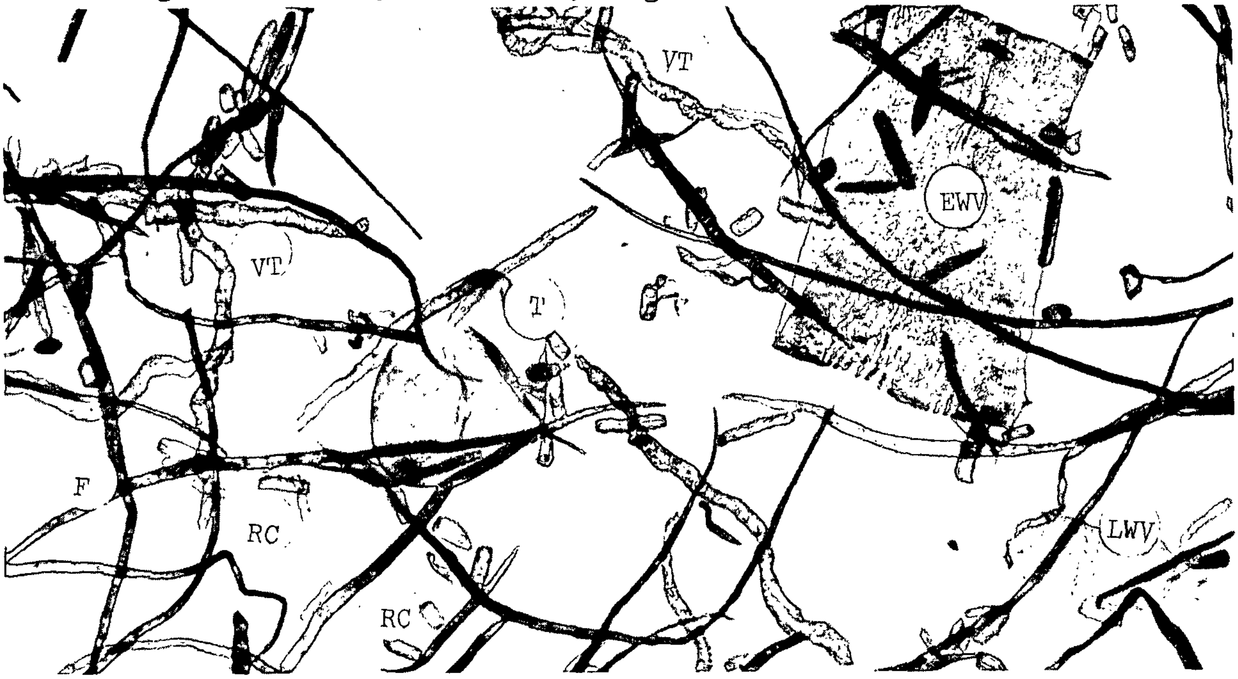

Figure 9. Pulp Sample of Red Oak Bleached Kraft (Submitted by Hammermill Paper Co.). Earlywood Vessel Element (EWV), Latewood Vessel Element (LWV), Tylosis (T), Fibers (F), Vasicentric Tracheids (VT), Ray Cells (RC). Magnification — 90 Diameters, Weight Factor — 0.48. Note: Tyloses are not Common in Species of Red Oak. The Pulp Sample is Possibly Contaminated with a Percentage of White Oak

MAPLE

General Description and Minute Anatomy

Red maple is a diffuse-porous wood containing small pores, indistinct without a hand lens, evenly distributed throughout the growth ring. The wood is moderately heavy (sp. gr. 0.44-0.49 green, 0.51-0.55 ovendry). The rays are visible to the naked eye, intergrading in width, the broadest about as wide as the largest pores, forming a pronounced close ray fleck on the radial or quarter surface. Parenchyma cells are not visible. There are between 30-80 vessels per square millimeter, the largest 60-80 micrometers in diameter and averaging 0.42 mm. in length. The fibers are thin to moderately thick-walled, 16 to 30 µm. in diameter and 0.7 mm. (0.3 to 1.1 mm.) long. The volume occupied by the vessels and fibers is 18.0 and 68.7%, respectively. The rays are unstoried, 1-5 seriate and essentially homogeneous. The volume occupied by the rays is 13.3%.

Weight Factor Determination

The average weight factor determined for the submitted pulp sample prepared from species of maple is as follows:

	Weight Factor Determination		
	Analyst		
Pulp Sample	A	B	Av.
Maple — Unbleached Kraft — Hammermill Paper Co.	0.38	0.36	0.37

Pulps prepared from species of maple are relatively fine when compared with pulps prepared from other species of North American hardwoods. The average weight factor of 0.37 is in very good agreement with the suggested factor of 0.4 for this pulp species.

A photomicrograph of the furnish of the submitted pulp sample of maple is illustrated in Fig. 10.

Figure 10. Pulp Sample of Maple Unbleached Kraft (Submitted by Hammermill Paper Co.). Vessel Elements (V), Fibers (F), Ray Cells (RC). Magnification 90 Diameters, Weight Factor — 0.37

POPULUS sp.

General Description and Minute Anatomy

The woods of quaking and bigtooth aspen are quite similar and cannot be separated from each other with certainty. The woods of the cottonwoods are quite similar to aspen but coarser in texture. The following description is for species of aspen.

The woods of quaking and bigtooth aspen are moderately light to light (sp. gr. approx. 0.34 green, 0.41 ovendry). The growth rings are inconspicuous and narrow to wide. The pores are numerous, small, the largest barely visible to the naked eye in the earlywood, decreasing gradually in size through the latewood. The wood is semiring to diffuse porous. The parenchyma are terminal and generally not visible to the naked eye. The rays are fine, scarcely visible with a hand lens. The vessels number 30-120 per sq. mm., the largest 90-160 micrometers in diameter and 0.65 mm. in length. The fibers are thin to moderately thick walled, occasionally gelatinous, 15 to 30 µm. in diameter and 1.04 mm. (0.4 to 1.9 mm.) in length. The volume occupied by the vessels is 33.8% while that for the fibers is 55.1%. The rays are unstoried, uniseriate, up to 25 cells in height and homogeneous. The volume occupied by the rays is 11.1%.

Weight Factor Determination

The results of a weight factor determination made on the submitted sample of Populus sp. pulp are as follows:

	Weight Factor Determination			
	Analyst A		Analyst B	
Pulp Sample	Trial 1	Trial 2	Trial 1	Av.
Populus sp. Unbleached Kraft — Scott Paper Co.	0.41	0.41	0.43	0.42

The original factors of 0.41 (Analyst A) and 0.43 (Analyst B) determined for the submitted Populus sp. pulp sample are considered to be fairly low for most pulps prepared from these species. New samples of the pulp and the cotton linters used as a standard were therefore weighed out and a second determination made by Analyst A (Trial 2). The results of the two determinations were the same. The submitted pulp is not as coarse as most pulps prepared from species of Populus and emphasizes the fact that in some cases a table of weight factors is at best a guide and whenever possible factors should be determined for the actual pulps used in a sample being analyzed.

Figure 11 is a photomicrograph of the furnish of the submitted pulp sample of Populus sp. The fibers are relatively short and thin walled.

Figure 11. Pulp Sample of Populus sp. Unbleached Kraft (Submitted by Scott Paper Co.). Vessel Elements (V), Fibers (F), Ray Cells (RC). Magnification — 90 Diameters, Weight Factor — 0.42

BEECH

General Description and Minute Anatomy

The wood of beech is heavy (sp. gr. approx. 0.56 green, 0.67 ovendry). The growth rings are distinct, delineated by a dark line or band of denser latewood. The wood is diffuse-porous, the pores being small and indistinct without a hand lens, usually crowded and largest in the earlywood, decreasing in number and size through the central portion of the growth ring, scattered and very small in the late latewood. The parenchyma are not visible with a hand lens or zonate in the later latewood, the lines then appearing very finely punctate. The rays are of two types, broad (oak type) and narrow. The broad rays are plainly visible to the naked eye while the narrow rays are not visible without magnification. There are 50-200 vessels per sq. mm., the largest 60-90 micrometers in diameter and 0.61

mm. in length. Tyloses are present in the heartwood. The fibers are thick-walled, 16-22 µm. in diameter and 1.3 mm. (0.6 to 1.9 mm.) in length. The broad rays are 15-25 plus seriate and one to several millimeters in height along the grain. The narrow rays are numerous, 1-5 seriate and up to 500 plus micrometers in height. The volume occupied by the rays is 20.4%.

Weight Factor Determination

The results of a weight factor determination made on the submitted pulp sample of beech are as follows:

Pulp Sample	Weight Factor, Analyst A	Weight Factor, Analyst B	Av.
Beech — Unbleached Kraft — Scott Paper Co.	0.49	0.50	0.50

The agreement of the results of the weight factor determination for the sample of beech pulp between analysts is very good. The average weight factor of 0.50 is in fairly good agreement with the factor of 0.60 currently being used for pulps prepared from this wood species.

The pulp furnish of the submitted sample of beech kraft is illustrated in Fig. 12.

BIRCH

General Description and Minute Anatomy

The woods of the different species of *Betula* cannot be separated on the basis of either gross structure or minute anatomy. Black birch and yellow birch are harder, heavier, and stronger than the other native species.

The wood of the species is heavy to very heavy (sp. gr. 0.45-0.60 green, 0.55-0.71 ovendry). The growth rings are not distinct without a hand lens. The wood is diffuse porous, the pores appearing as whitish dots to the naked eye, nearly uniform in size and evenly distributed throughout the growth ring. Parenchyma cells are not visible. The rays are fine, narrower than the largest pores and generally not distinct to the naked eye. There are 50-100 vessels per sq. mm. and the largest are 60-160 μm. in diameter and approx. 1.0 mm. in length. The fibers are thin to moderately thick walled, 20-36 micrometers in diameter and average approximately 1.4 mm. in length. The rays are unstoried, 1-5-seriate and homogeneous. The volume occupied by the vessels, fibers and rays is 21.4, 65.8 and 10.8%, respectively. The longitudinal parenchyma are apotracheal-diffuse, and in aggregates, paratracheal and marginal. The volume occupied by parenchyma cells is 2.0%.

Figure 12. Pulp Sample of Beech Unbleached Kraft (Submitted by Scott Paper Co.). Vessel Elements (V), Fibers (F), Ray Cells (RC). Magnification — 90 Diameters, Weight Factor — 0.50

Weight Factor Determination

Pulp Sample	Weight Factor Determination Analyst A	B	Av.
Birch — Unbleached Kraft — Scott Paper Co.	0.60	0.59	0.60

The results of the weight factor determinations are in good agreement between analysts and the average weight factor of 0.60 is generally employed for a hardwood pulp furnish containing principally species of birch.

Photomicrograph

A photomicrograph of the furnish of the submitted pulp sample of birch kraft is illustrated in Fig. 13. The pulp contains relatively long fibers and vessel elements.

Figure 13. Pulp Sample of Birch Unbleached Kraft (Submitted by Scott Paper Co.). Vessel Elements (V), Fibers (F), Ray Cells (RC). Magnification — 90 Diameters, Weight Factor — 0.60

ESPARTO

General Description and Minute Anatomy

There are two species (*Stipa tenacissima* and *Lygeum spartum*) of grasses which are the source of the esparto fiber in the paper industry. The grasses grow in Algeria, Morocco, Tunisia, Tripolitania (Northwest Libya) and Spain. The fiber is very fine, having an average width of 7 µm. (range 4 µm.-11 µm.). The average length of the fiber is 1.5 mm. (0.5 to 2.5 mm.). There are many serra epidermal cells present in the pulps prepared from these species and the presence tear-shaped cells derived from the stiff hooked hairs on the surface of the leaf distinguish esparto from straw and other pulp fibers (11).

Weight Factor Determination

The results of a weight factor determination made on the submitted pulp sample of Esparto bleached kraft pulps are as follows:

Pulp Sample	Weight Factor Determination, Analyst A	B	Av.
Esparto Bleached Kraft — Riegel Paper Corp.	0.43	0.43	0.43

The agreement of results between analysts, as for the other weight factor determinations made in this study, is very good. The average weight factor of 0.43 is also in fairly good agreement with the suggested (TAPPI Standards) factor of 0.50 for this pulp.

Figure 14 is a photomicrograph showing the various cellular elements and fineness of the fiber furnish of the submitted sample of esparto pulp. None of the epidermal hairs or cells the size of these minute hairs are included in the count when making a weight factor determination of this pulp.

Figure 14. Pulp Sample of Esparto Bleached Kraft-Tunisia (Submitted by Riegel Paper Corp.). Fibers (F), Epidermal Cell (EC) with Scalloped Wall, Epidermal Hairs (EH). Magnification — 90 Diameters, Weight Factor — 0.43

DISCUSSION OF RESULTS

The results of the weight factor determinations made on the pulp samples included in this report are, in most instances, in reasonable agreement with the suggested weight factors listed in TAPPI Standard T 401 m-60. The results of this study reemphasize that there is considerable variation in coarseness (and weight factors) between tree species and indicates the improvement in accuracy that will result from the use of the improved weight factors being developed.

A table of weight factors for various wood species is most helpful in fiber analysis work and, providing some degree of discretion is exercised in their application, the composition of a furnish should be checked to within the following tolerances (TAPPI Standard T 401 m-60):

Percentage of Given Fiber in Total Furnish	Tolerance
Less than 20	± 2
20-30	± 3
30-40	± 4
40-60	± 5
60-70	± 4
70-80	± 3
Over 80	± 2

The factors determined in this study for the samples of loblolly pine and Populus sp. pulps were 20-30% lower than the recommended weight factors listed in the TAPPI Standard. This emphasizes that whenever possible and practicable, weight factors should be determined for the actual pulps present in a furnish or the more accurate "species weight factor" should be employed. The composition of the furnish of a sample can then be checked to within ± 1-2%.

PLANS

The immediate plans are to complete weight factor determinations on the additional softwood and hardwood species pulps which are of interest to the participating companies. Possible differences within species due to geographic origin will be examined for several species. Weight factor determinations will also be considered for any "special" pulps which may be of interest. Special attention will be given to the development of a set of relative weight factors of hardwood species based on "vessel counts."

The relationship of the determined weight factors of the submitted pulp samples to coarseness, relative grex, or international denier values and to fiber width would be of considerable interest and the determination of these values should be considered in future work.

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GLOSSARY

Apotracheal parenchyma. Axial parenchyma typically independent of the pores or vessels. (Formerly known as metatracheal.)

Biseriate ray. Ray consisting of two rows of cells, as viewed in the tangential section.

Decigrex. Coarseness of pulp fibers. See TAPPI Suggested Method T 234 sm-60.

Epidermis. The outer single layer of cells on an organ.

Epithelium. Excreting parenchymatous tissue surrounding the cavity of resin and gum canals.

Fibril. Microscopic fibrous body of which cell walls are composed.

Fusiform ray. Spindle-shaped ray, as viewed in a tangential section of wood, containing a transverse resin canal.

Gelatinous fiber. Fiber, the inner wall of which is gelatinous, or jellylike.

Grex. International standard denier.

Paratracheal parenchyma. Parenchyma obviously associated with the vessels.

Parenchyma. Tissue consisting of short, relatively thin-walled cells, generally with simple pits; concerned primarily with storage and distribution of carbohydrates.

Ray. Ribbon-shaped strand of tissue extending in a radial direction.

Resin canal. An intercellular space, often bordered by secreting cells, containing resin.

Tracheid. Fibrous lignified cell with bordered pits and imperforate ends; in coniferous wood, the tracheids are very long (up to 7+ mm.) and are equipped with large, prominent bordered pits on their radial walls; tracheids in hardwoods are shorter fibrous cells (seldom over 1.5 mm.), are as long as the vessel elements with which they are associated, and possess small bordered pits.

Tyloses. Saclike or cystlike structures that sometimes develop in a vessel and rarely in a fiber through the proliferation of the protoplast (living contents) of a parenchyma cell through a pit pair.

Tylosoids. Balloon-like structures in resin canals resembling tyloses in hardwoods.

Storied. Arranged in tiers or in echelon, as viewed on a tangential surface or in a tangential section.

Uniseriate. Arranged in a single row, series, or layer. Also said of a wood ray which is one cell wide in cross-section.

Vasicentric. Paratracheal.

Vessel. Composite, and hence articulated, tubelike structure found in porous wood (hardwoods), arising through the fusion of the cells in a longitudinal row through the partial or complete disappearance of the common walls.