

# THE GRINDING OF HARDWOODS

**STUDIES ON SWAMP TUPELO, PAPER BIRCH, GREEN ASH,  
SUGARBERRY, EASTERN COTTONWOOD, BLACK WILLOW,  
AND AMERICAN ELM**

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## THE GRINDING OF HARDWOODS

Studies on Swamp Tupelo, Paper Birch, Green Ash,  
Sugarberry, Eastern Cottonwood, Black Willow, and American Elm

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### Summary

Investigations of the grinding of hardwoods have been conducted at the Forest Products Laboratory over a period of years with results that should be of interest to manufacturers of papers containing groundwood, who now obtain suitable softwood species at considerable distances from their mills. Hardwoods, by their ready accessibility to many groundwood mills, offer distinct advantages from the standpoint of pulpwood transportation costs. Increased use of hardwoods would also aid in the improvement of mixed stands of hardwoods and coniferous woods, and would expand our pulpwood resources.

Swamp tupelo, if ground soon after cutting, yields a groundwood pulp that is light colored and short fibered. It lacks the strength considered essential in the pulps produced from spruce and other softwoods but, even so, can be used in appreciable quantities as filler stock in the manufacture of book, magazine, and newsprint paper. Groundwood pulp made from paper birch has similar properties. The absorbent quality of this pulp was demonstrated in the production of a highly absorbent toweling paper. The pulps made from green ash and sugarberry were stronger than those made from tupelo and birch, but not so strong as standard pulp made from spruce. Satisfactory newsprint papers were made, however, in which both species constituted a considerable part of the furnish. The groundwood pulps obtained from southern cottonwood and black willow were comparable in strength with commercial groundwood. Although the color of the latter is too dark to permit its use in newsprint or other light colored papers, it should be suitable for papers and boards in which the dark color is not objectionable. Groundwood pulp made from American elm was both short fibered and dark colored, qualities which limit its use to such products as filler stock for boards and papers of low color.

The energy consumed in the making of groundwood pulps from hardwoods need not be so high as is generally believed necessary. For many purposes a satisfactory groundwood can be made from these woods with less energy than is ordinarily consumed in the grinding of softwoods. Some hardwoods, moreover, yield more pulp per cord than can be obtained from the softwoods.

## Introduction

Although spruce still is fairly plentiful in some sections of the United States and Canada, groundwood mills in some regions of this country have been compelled to transport wood from distant points. Thus, the increased cost of the wood offsets to a great extent the cheapness of the process. The spruces are the most desirable species from which to make groundwood pulp, with the true firs, western hemlock, and southern pine following in order. The idea of employing hardwoods in this process is not new, and certain of the hardwood species have been used to a limited extent for a number of years. In fact, aspen was one of the first species used in the groundwood process. An increased use of hardwood species is important not only because they are a cheap and abundant material resource, but also because their use is in the interest of good forestry practice resulting in lasting future benefits. Increased utilization of hardwoods in the Southern and Eastern States would be conducive to improved forest stands throughout those areas.

The grinding of hardwoods has been attempted many times, but the amount of published technical information on the subject is relatively small. Thickens and McNaughton (8) studied the grinding of aspen, paper birch, and black tupelo and noted that relatively dull stone surfaces and higher energy consumption were required to produce pulp comparable with spruce groundwood. Running (6) reported that strength approximating only one-half to two-thirds that of spruce is obtained from aspen ground under the same conditions. Cottonwood and poplar require more power and the pulps have lower freeness for given bursting strengths than some of the coniferous species, according to experiments conducted by Wynn-Roberts (9). Munro (5) suggests that the use of a 9- or 10-cut, high-lead burr, or even a thread burr, is better for the grinding of aspen than a 12 or 14 straight or diamond burr. A moderate pressure and low temperature are also desirable. Benninger (1) found that beech was more easily ground than spruce. The foaming of the beech groundwood was, however, quite troublesome. He also reported that a 50-50 mixture of beech and spruce groundwood pulps was satisfactorily used. Other foreign investigators (2, 3) have published results similar to those of the American observers. Boiling or steaming the hardwood before grinding aids in improving strength, increasing fiber length, and lowering energy consumption per ton, but produces a brown pulp (4, 8).

Since the early work of Thickens and McNaughton, the Forest Products Laboratory has conducted various experiments in the grinding of several hardwoods. This report summarizes the results of these researches.

## Swamp Tupelo

Table 1 contains data for the grinding of swamp tupelo (Nyssa sylvatica var. biflora) (formerly swamp black gum, N. biflora), an abundant species in the southern United States. It ranges from Maryland to Florida and westward to eastern Texas. The samples tested were obtained from North Carolina. The wood was ground as received and again after treatment with sodium sulfite

solutions. In all experiments on untreated wood, the pulps obtained were low in strength and average fiber length as compared to standard spruce groundwood. The pulps obtained by grinding on a dull-surfaced stone and with high pressure were more completely fibrillated and slightly stronger than those obtained with the use of sharper stone surfaces.

These swamp tupelo groundwood pulps had an excellent color. The color of groundwood pulps obtained in other experiments was found, however, to be influenced greatly by the conditions of storage prevailing prior to pulping of the wood. It has been pointed out in a previous publication (7) that the light-colored sapwood in the freshly cut wood became discolored in less than 2 months if stored in a warm, moist condition, such as might prevail in southern climates during the summer. The fresh wood did not discolor if dried rapidly, indicating that moisture was an essential factor in the discoloration. Pulping the wood soon after cutting, before discoloration can occur, would appear to be a desirable practice.

The wood was chemically treated before grinding to improve the strength and increase the average fiber length of the pulp. Most pretreating processes, however, discolor the wood, and this discoloration, of course, prevents the use of the groundwood pulp in light-colored papers. Since the neutral sulfite solutions used in the semichemical process of treating chips do not discolor the wood if properly applied, the liquor used in these experiments was of that type, i.e., a mixture of sodium sulfite and sodium bicarbonate. Log sections about 28 inches long were weighted down in a treating cylinder and covered with the chemical solution. The conditions of the various treatments are summarized in table 2.

When the temperature of treatment was in the range of 150° to 170° C., the wood was discolored and the brownish groundwood pulps were obtained. When alternating vacuum and pressure were used, with the temperature during the pressure period not exceeding 130° C., the pulps obtained from the treated wood were not discolored. When wood treated by the latter method was ground on a dull stone with moderate pressure, the pulps had fair strength and were longer fibered than the untreated wood pulps.

Papermaking experiments indicated that the tupelo groundwood pulps made from untreated wood were more useful as filler stock than to provide strength. Data for newsprint and book papers are given in table 3. In most of the newsprint experiments in which 70 to 75 percent of groundwood and 30 to 25 percent of sulfite pulp were used, the strengths were below standard for this grade of paper. One, however, (machine run 447) in which 70 percent of tupelo groundwood was combined with 30 percent of commercial spruce sulfite pulp, was of slightly higher weight, but otherwise equal to standard newsprint. Another experiment in which 50 percent of the furnish consisted of tupelo groundwood, 20 percent of slash pine groundwood, and the remainder spruce sulfite pulp, (machine run 350) had normal strength. A run in which the tupelo groundwood content was reduced to 50 percent and the slash pine sulfite component was increased to 50 percent (machine run 443) had higher than standard newsprint strength. Although no trials were made in which hardwood and coniferous groundwood pulps were combined with either hardwood

neutral sulfite semichemical or pine semibleached sulfate pulps, the applicability of swamp tupelo groundwood in such furnishes is suggested by the results of experiments, to be discussed later, in which a paper birch groundwood of similar type was so used.

Acceptable sheets of book paper were made, in which the normal component of soda pulp was substituted in whole or in part with tupelo groundwood (machine runs 339, 441, and 442). These papers possessed good color, finish, and strength. One of the papers in this group (run 340) was, except for its low bursting strength, typical of rotogravure paper in its properties.

The papers having treated tupelo groundwood as part of their furnish were rough of surface and weak. Further study of pulps of this type is necessary to learn more about their papermaking characteristics.

### Paper Birch

Paper birch (Betula papyrifera) is an important northern hardwood. It ranges from Labrador to Hudson Bay, southward to Long Island and northern Pennsylvania, and westward through Ontario, Michigan, and northern Wisconsin to western Minnesota and eastern Manitoba. The wood used in the experiments reported here was obtained from northern Wisconsin and Michigan. The grinding data are given in table 4.

The pulps produced were, in general, like those from the swamp tupelo; short fibered and low in strength, but, in spite of their short-fibered characteristics, quite free. Increasing the pressure of the wood on the stone surface from 20 pounds per square inch to 30 pounds and then to 40 pounds, successively, reduced both the strength and the unit energy consumption. Freeness was increased, but there was little change in fiber length. Contrary to experience with softwoods, raising the pit temperature (without change in consistency) produced a negligible effect.

Although the birch wood, especially when green, is quite white, the pulps were inclined to have a more or less pronounced orange tint. The coloring matter appeared to be water-soluble, but showed a tendency to become adsorbed on the pulp to some extent when standing in suspension. A sample of the pulp washed immediately after discharge from the grinder was decidedly improved in color.

The properties of the birch groundwood described above did not bar its use in several types of paper. Table 5 shows data for newsprint paper. When combined with birch neutral sulfite semichemical pulp and a coniferous groundwood pulp, birch groundwood may be used in proportions up to 30 percent of the total furnish with satisfactory results. The 50 percent of birch semichemical pulp used with this amount of birch groundwood brought the total hardwood content of the sheet to 80 percent. Comparing the properties of the experimental papers with the averages for commercial newsprint papers, it is noted that nearly all of the experimental papers are equal to or better than the commercial standard in most properties.

Certain grades of toweling paper contain from 40 to 50 percent of groundwood pulp, usually made from spruce and balsam, the remainder of the furnish being spruce sulfite pulp. The short fiber, softness, and apparent absorbent qualities of birch groundwood suggested its possible use in this grade of paper. The principal data obtained in several experiments in the making of toweling paper are given in table 6. The birch groundwood was substituted for part or all of the spruce groundwood in amounts varying from 15 to 45 percent of the total furnish. The birch groundwood lowered the strength slightly, but this was overcome to some extent by a little beating or jordaning. The drainage from the wire was slower and the wet strength of the web before passing the creping doctor was lowered. Considerable picking occurred on the dryers. In commercial operation, these machine-operating characteristics will need to be controlled by appropriate countermeasures. The water-absorption rate of the toweling paper was greatly increased by the addition of the birch pulp. One of the best papers, meeting most of the strength requirements of the standard toweling paper, contained 25 percent of birch groundwood (machine run 1707). This paper had more than 3 times the absorbency of the standard.

#### Green Ash, Sugarberry, and Eastern Cottonwood

Green ash, sugarberry, and cottonwood were received and tested at the same time. For this reason, it is convenient to compare them here with each other. Green ash (Fraxinus, pennsylvania lanceolata) is widely spread throughout southern Canada and the United States as far west as the eastern ranges of the Rocky Mountains. Sugarberry (Celtis laevigata), also commonly known as hackberry, is a bottomland hardwood growing in the southern United States, being quite plentiful in the Mississippi valley. Eastern cottonwood (Populus deltoides Bartr.) (formerly P. deltoides virginiana) occurs in river valleys throughout the eastern, southern, and central United States. The woods used in this study were received from the delta region of Arkansas.

The grinding data are given in table 7, which includes for comparison purposes data on paper birch and southern pine and average values for commercial newsprint groundwood pulps.

By lowering the grinding pressure on the sugarberry from 30 to 20 pounds per square inch of wood on the stone surface the pulp strength was raised a little but a large increase in energy consumption per ton was attained. When the pressure was raised to 40 pounds, on the other hand, very little lowering of strength was produced and both a marked increase in production and a lowering of energy consumption were achieved. The response with ash was similar to that with sugarberry, except that the increase in pressure reduced the unit energy consumption only slightly.

Comparing the groundwood pulps produced at 30 pounds per square inch, it is apparent that the unit energy consumptions for these three hardwoods are in the range of commercial practice for newsprint groundwood, with that from sugarberry being somewhat high. The fibers of the sugarberry and ash were much shorter (as indicated by the screen analysis) than average fibers of

the commercial groundwoods and slightly shorter than those of birch pulp. The cottonwood was low in the coarsest mesh fraction (24-mesh), but otherwise approached commercial pulps in screen analysis. The sugarberry and ash had only fair bursting and tensile strengths and poor tearing strength. The cottonwood equaled the commercial average in bursting and tensile strength, but was somewhat lower in tearing strength. The sugarberry, ash, and cottonwood were all superior in strength to the birch groundwood although none was as strong as the southern pine groundwood. All of them were comparable with spruce groundwood in color.

These hardwood groundwood pulps were used in newsprint papermaking experiments with southern pine groundwood pulp and semibleached southern pine sulfate pulp. The data are given in table 8. On the basis of machine runs 1770, and 1771, it was found that a furnish containing 20 percent of cottonwood groundwood, 60 percent of pine groundwood, and 20 percent of pine sulfate, lightly jordaned, gave a paper about equal to the average commercial newsprint. The whiteness, at 65 percent, was very good. When the cottonwood groundwood content was increased to 40 percent (machine run 1772) and the same total groundwood content was maintained, the tensile strength was lowered about one-fifth, but there was practically no change in bursting strength. The tearing strength was higher than the standard average.

The relative effect of the three hardwood species may be noted by comparing machine runs 1772, 1773, and 1775. The paper of run 1772, containing cottonwood groundwood, was about equal in quality to that of run 1773, which contained an equal amount of ash groundwood, while the paper from run 1775, containing sugarberry groundwood, was poorer. Machine run 1777 was made with a furnish consisting of equal amounts of the three hardwood groundwoods, 39 percent in all. The rest of the furnish was pine groundwood and semibleached sulfate in about the proportions used in the three runs just discussed. With the exception of tearing resistance, the test values for all strength properties are less than the average for commercial newsprint. In these newsprint experiments it appeared that at least 20 percent of semibleached sulfate pulp was required to bring the bursting and tensile strengths up to values comparable with commercial newsprint. This amount of sulfate pulp produced a tearing strength higher than the standard. Although none of the hardwood-containing papers were quite as strong as the average for pine groundwood and sulfate alone, they are considered satisfactory for use as newsprint paper.

Summarizing these experiments, it is indicated that groundwood pulp of acceptable quality can be made from cottonwood, green ash, and sugarberry. In the making of newsprint paper, these pulps can be combined, in quantities as high as 40 percent, with southern pine groundwood and semibleached sulfate pulps to produce a satisfactory furnish.

#### Black Willow and American Elm

Black willow (Salix nigra) occurs in bottomlands throughout the northeastern, eastern, central, and southern United States except in Florida and the southeastern parts of South Carolina, Georgia, and Alabama. American elm (Ulmus americana) ranges from southern Canada south to central Florida and west



through the Central States to the foothills of the Rocky Mountains. The samples tested at the Laboratory were received from the Arkansas delta region, as were the three hardwoods discussed in the foregoing section. The data are given in table 7.

The black willow groundwood, like the cottonwood, was low in the 24-mesh screen fraction, but was about equal to the commercial groundwoods in strength. The elm groundwood was more like the sugarberry in fiber length and strength. Under comparable grinding conditions, the energy consumption for the elm was higher than that for the willow, which was normal for groundwood of newsprint grade. The dark color of these pulps was their principal defect, and it was for this reason that papermaking tests were not made with them. It is entirely possible that willow and elm groundwood pulps can be used in papers and boards in which color is not so important, as, for instance, in insulating board or container board filler, but no experiments were made to ascertain this.

### General Considerations

It is generally believed that the production of groundwood pulp from hardwoods requires a high expenditure of energy. This is often true when it is sought to produce pulp comparable to spruce groundwood in strength and fiber length. In fact, it is doubtful whether these properties can be obtained with such dense, short-fibered hardwoods as tupelo, birch, beech, maple, sugarberry, and ash. There are uses for groundwood pulp, however, in which the strength and fiber length normally obtained from spruce are not necessarily required. The data in tables 1, 4, and 7, give evidence that pulps satisfactorily for certain purposes can be made from this class of hardwoods with average or below average energy consumption. Hardwoods of lower density such as cottonwood, aspen, willow, etc., yield relatively free groundwoods with average strength and normal energy consumption. The fiber length of these groundwoods is, as a rule, somewhat less than that of spruce, and the color of some of them limits their field of usefulness.

Because of the short fiber of some hardwood groundwood pulps, considerable difficulty is experienced in attempting to form laps on the wet machine in the customary manner. It might be better, in such instances, to take the pulp off the machine in loose, crumbled form and store it in bales instead of laps. Better still, perhaps, would be the use of a slush system entirely when grinding hardwoods. Close attention must also be paid to the prevention of white water fiber losses when operating with hardwood groundwood pulps, by providing a properly closed system and adequate save-alls. In some mills the grinding of hardwoods has been abandoned because low yields were obtained. A modification of the wet machine operation and white water system might have been a solution to these difficulties.

Some of the hardwoods have fairly high densities in contrast to the softwoods usually used for groundwood manufacture. The resulting higher weight of wood per cord, and the consequent higher weight yield of pulp are factors to be considered in their favor. For instance, the hardwoods studied, with the



exception of cottonwood and willow, ranged from about 2,400 to 2,700 pounds of moisture-free wood per standard cord. The cottonwood and willow were comparable with spruce in weight per cord, namely around 2,000 pounds.

#### Literature Cited

- (1) Benninger, Fritz  
Groundwood from beech. Wochbl. Papier fabr. 72:118-120 (1941).
- (2) Brecht, W.; Schrotter, H.; Suttinger, R.  
A comparison of various woods in mechanical pulp manufacture. Papier fabr. (Tech. Wiss Teil) 36 413-420 (1938)
- (3) Briefkasten.  
Groundwood from aspen. Wochbl. Papier fabr. 68 (33):622; (35):655; (36):681; (Aug. 14, 28, Sept. 4, 1937).
- (4) Kin, Myron; Libby, C. E.  
The manufacture of brown mechanical pulps from hardwoods. I yellow birch. Paper Ind. and Paper World 22 (7):675 (Octo. 1940); (9):918-923 (Dec. 1940); (10):1043-1048 (Jan. 1941).
- (5) Munro, W. A.  
Poplar wood as a substitute in the manufacture of groundwood. Paper Trade Jour. 77 (20):60 (Nov. 15, 1923).
- (6) Running, K. D.  
Hardwood utilization by the paper industry. Pulp and Paper Mag. Can. 42 (2) 104-106 (Convention issue 1941).
- (7) Schafer, E. R.; Pew, J. C.; Pillow, M. Y.  
Discoloration of swamp black gum pulpwood in storage. Tech. Assoc. Papers 22:405-8 (1939).
- (8) Thickens, J. H. and McNaughton, G. C.  
Groundwood pulp. U. S. Dept. Agric. Bull. 343 (April 26, 1916).
- (9) Wynn-Roberts, R. I.  
Grinding characteristics of various woods. Paper Trade Jour. 104 (6) 46-48 (Feb. 11, 1937).



Table 2.—Chemical treatment of aspen tunnels before gridding

Dishes	Wood used in grinders No.	Wood		Treating liquor		Chemical absorbed	Impregnation		Cooking	Duration of cycles	Alternate pressure-vacuum treatment	
		Amount of wood In Inches dia. bolts etc.	Amount of wood In Inches dia. bolts etc.	Fresh Concentration of Na <sub>2</sub> SO <sub>3</sub> (%)	Spent Concentration of Na <sub>2</sub> SO <sub>3</sub> (%)		Maxi- mum time hours	Average time hours			Maxi- mum time hours	Range of temperature
2122	18	1.1	1.1	35.0	35.0	0.61	2	106	145	1.5	170	185
2123	19	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2124	20	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2125	21	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2126	22	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2127	23	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2128	24	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2129	25	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2130	26	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2131	27	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2132	28	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2133	29	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2134	30	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2135	31	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2136	32	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2137	33	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2138	34	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2139	35	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2140	36	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2141	37	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2142	38	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2143	39	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2144	40	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2145	41	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2146	42	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2147	43	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2148	44	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2149	45	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2150	46	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2151	47	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2152	48	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2153	49	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2154	50	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2155	51	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2156	52	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2157	53	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2158	54	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2159	55	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2160	56	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2161	57	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2162	58	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2163	59	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2164	60	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2165	61	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2166	62	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2167	63	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2168	64	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2169	65	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2170	66	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2171	67	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2172	68	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2173	69	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2174	70	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2175	71	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2176	72	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2177	73	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2178	74	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2179	75	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2180	76	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2181	77	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2182	78	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2183	79	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2184	80	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2185	81	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2186	82	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2187	83	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2188	84	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2189	85	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2190	86	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2191	87	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2192	88	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2193	89	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2194	90	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2195	91	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2196	92	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2197	93	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2198	94	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2199	95	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2200	96	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2201	97	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2202	98	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2203	99	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185
2204	100	1.2	1.2	35.0	35.0	0.61	2	106	145	1.5	170	185

Present as Na<sub>2</sub>SO<sub>3</sub> but calculated as Na<sub>2</sub>CO<sub>3</sub>.  
 % cycles consisted of one vacuum and one pressure phase.

Table 3.--Book and newsprint papers containing swamp tupelo ground-wood pulp

Machine run		Furnish		Properties of the paper													
No.	Ground wood	Sulfite pulp	Site	Alum <sup>1</sup>	Weight per ream - 25 x 40 - 500	Thick- ness	Bursting <sup>2</sup> per ream - 25 x 40 - 500	Tearing <sup>3</sup> per pound - 25 x 40 - 500	Stretch	White- ness	Castor oil pene- tration	Opacity	Gloss				
	Amount	Species	No. & Amount	Percent	Founds	Mile	Point	Gram	Percent	Percent	Seconds	Percent	Percent				
Newsprint papers																	
350	9 { 50 }	Spruce	3443	30	1.0	1.5	39	3.2	0.23	0.57	3080	0.95	63	49	93	34	
346	10 { 70 }	Slash pine	3449	30	1.3	1.3	38	3.3	.15	.42	2090	1.15	62	70	93	34	
422	14 { 70 }	do.	3457	27	5	2.0	33	3.0	.14	.50	1798	1.12	86	26	85	29	
362	15 { 73 }	Spruce	3474	35	3.0	4.5	26	4.0	.17	.61	1615	1.25	64	26	84	21	
404	22 { 70 }	Slash pine	P-946	30	3.0	3.0	43	3.1	.26	.53	3123	1.50	73	147	93	38	
443	26 { 50 }	Spruce	3452	50	3	3.0	35	3.0	.33	.57	1835	1.15	67	27	86	26	
476	26 { 35 }	do.	3485	30	5	3.0	33	4.0	.20	.63	1205	1.15	68	11	83	29	
465	27 { 50 }	do.	3485	30	5	3.0	41	4.0	.13	.39	1378	1.10	70	8	84	24	
463	28 { 50 }	do.	3485	15	5	3.0	36	4.3	.16	.48	1369	1.40	61	26	97	35	
536	45 { 70 }	Swamp tupelo	3506	30	5	7.0	38	3.6	.18	.64	510	1.75	73	5	87	35	
481	531 { 70 }	Slash pine	P-946	30	3	3.0	40	4.0	.10	.24	1308	1.30	69	15	87	44	
459	532 { 70 }	do.	P-946	30	3	3.0	39	4.0	.15	.41	611	.50	70	10	81	30	
464	533 { 20 }	Slash pine	3485	30	5	3.0	41	3.9	.13	.36	2944	1.41	63	36	90	35	
530	42 { 70 }	do.	3506	30	5	7.0	38	3.5	.19	.69	1890	1.19	62	22	90	31	
529	43 { 80 }	do.	3506	20	5	7.0	35	3.3	.15	.60	2795	1.00	59	50	92	41	
Average of 56 commercial newsprint papers.																	
					38	3.3	.25	.54									
Book papers																	
7340	8	60	Slash pine	3446	40	1.5	2.5	56	5.4	.12	.42	1480	1.25	70	42	90	26
339	8	50	do.	3446	50	1.5	3.0	56	4.5	.23	.72	2422	1.25	76	80	87	29
441	26	20	Spruce	P-927	60	1.5	3.0	57	3.3	.22	.78	2271	1.85	79	152	91	35
442	26	40	Hardwood	P-925	20	1.5	3.0	54	4.5	.28	.65	2350	2.55	81	120	86	36
		40	Spruce	P-927	60	1.5	3.0	54	4.5	.28	.65	2350	2.55	81	120	86	36

<sup>1</sup>Alum preceding the number of the pulp indicates a commercial product.

<sup>2</sup>To improve color, dye was added to the stock in the beater before adding alum.

<sup>3</sup>To convert the bursting and tearing strengths of the newsprint papers to the trade ream basis 24 x 36 - 500, multiply by 1.157.

<sup>4</sup>Slash pine ground-wood pulp.

<sup>5</sup>Wood treated before grinding.

<sup>6</sup>Furnish for machine runs 339 and 340 contained 15 percent of clay based on total fiber; runs 441 and 442, 25 percent of clay.

<sup>7</sup>A rotogravure type of paper.

<sup>8</sup>Commercial soda pulp.

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Table 4. - Analysis of wood chips

Grinder run No.	Average wood properties							Drying data					Properties of pulp suspension										Properties of pulp test sheets																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																												
	Diam. (in.)	Age (years)	Rate of growth (in. per year)	Density (lb. per cu. ft.)	Moisture (percent)	Weight of green volume (lb.)	Pressure of wood (lb. per sq. in.)	Stone (lb. per 100 lb. wood)	Time (min.)	Temp. (°F.)	Per- cent	Yield (lb. per 100 lb. wood)	Loss (lb. per 100 lb. wood)	Moisture (percent)	Temp. (°F.)	Con- cent	Yield (lb. per 100 lb. wood)	Loss (lb. per 100 lb. wood)	Moisture (percent)	Temp. (°F.)	Con- cent	Yield (lb. per 100 lb. wood)	Loss (lb. per 100 lb. wood)	Moisture (percent)	Temp. (°F.)	Con- cent	Yield (lb. per 100 lb. wood)	Loss (lb. per 100 lb. wood)	Moisture (percent)	Temp. (°F.)	Con- cent	Yield (lb. per 100 lb. wood)	Loss (lb. per 100 lb. wood)	Moisture (percent)	Temp. (°F.)	Con- cent	Yield (lb. per 100 lb. wood)	Loss (lb. per 100 lb. wood)																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																													
363	9.5	120.0	25.2	29.6	78.8	28.8	17.1	160	17.1	160	4.4	91.3	0.26	1.25	122	73	470	0.6	3.7	15.1	14.3	62.1	0.072	0.11	0.33	644	0.26	63	6.4-0	0																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																					</

Table 5.--Newsprint papers containing birch ground wood and neutral sulfite semichemical pulps

Machine run No.	Birch pulp		Coniferous ground wood		Properties of the paper									
	Ground wood	Neutral sulfite semichemical	Species	Amount	Weight: Thick-Bursting: Tearing:		Ten-White:		Castor:		Porosity		Per-cent	Per-cent
	Grinder: Amount: run No.	Cook No.		Percent	per ream: 25 x 40: - 500	per ream: 25 x 40: - 500	per ream: 25 x 40: - 500	per ream: 25 x 40: - 500	oil penetration	oil penetration	Seconds	Seconds		
1659	377	18	3917-N	31	40	0.24	0.61	2940	63	73	57	90		
1720	378	20	3920-N	20	38	.75	.61	4450	53	74	49	88		
1660	377	20	3917-N	35	39	.25	.57	2835	61	95	55	91		
1647	363	21	3912-N	34	37	.25	.44	3120	58	95	144	91		
1727	378	20	3921-N	30	40	.28	.59	2980	60	52	62	91		
1728	378	20	3921-N	20	38	.26	.49	2550	63	54	60	92		
1721	378	30	3920-N	50	39	.33	.54	3730	55	42	49	91		
1724	378	30	3921-N	20	39	.28	.58	3640	60	43	60	88		
1725	378	30	3921-N	20	38	.33	.60	3360	60	56	65	88		
1723	378	30	3921-N	30	38	.25	.49	2770	63	38	62	90		
1722	378	40	3920-N	40	41	.21	.47	1720	61	23	19	93		
Average of 56 commercial newsprint papers.....					38	.25	.54	2537	59	50	52	92		

The jack pine was from grinder run 361; the spruce was commercial ground wood.

To convert to the newsprint trade ream basis 24 x 36 - 500, multiply by 1.157.

Table 6.--Effect of birch ground-wood pulp in toweling paper

Mach- ine run No.	Birch ground wood :Amount: :Amount: :Amount:	Unbleached : of : spruce : sulfite	Jor- : daning: : dering: : dering:	Calen- : dering: : dering: : dering:	Weight: : per : ream : 25x40- : 500	Thick- : ness : frac- : tion	Solid: : : : : : :	Burst: : : : : : :	Tear : : : : : :	Ten- : sile : : : :	Stretch: : : : :	Absorp- : tion of : : : water	
	Per- cent	Per- cent	Per- cent	Per- cent	Pounds: : : : : : :	Mils : : : : : :			Point: : per : pound: : per : ream	Grams : per : pound: : per : ream	Pounds: : per : square : inch	Per- cent	Sec- onds
1702	None	45.0	55.0	None	None	39.5	10.52	0.14	0.21	1.09	525	4.65	263
1703	376	22.5	55.0	None	Jor- : daned:	39.8	10.34	.14	.18	.85	502	4.80	58
1704	376	45.0	None	None	None	38.5	10.01	.14	.18	.85	416	5.50	37
1706	375	15.0	30.0	Beaten:	None	37.4	10.76	.13	.19	.98	312	7.10	179
1707	375	25.0	20.0	Beaten:	Jor- : daned:	42.6	10.53	.15	.20	1.06	500	6.15	80
1708	375	25.0	20.0	None	Jor- : daned:	41.3	8.87	.17	.21	.87	659	5.75	125
1705	376	25.0	25.0	Beaten:	None	41.7	10.56	.15	.14	.69	450	4.60	87

Commercial pulp.



7.--The winding of southern cottonwood, sugarberry, green ash, black willow and American elm

[illegible]

... of the ... divided by the area represented by the product of the pocket width and the wood length.

The actual thrust of the pressure foot (determined by calibration of the pressure indicator) was 1.5 lb. The pressure foot was sharpened by use of a 14-point diamond burr. The hours given in Table I are the sum of the time spent in sharpening the pressure foot and the time spent in sharpening the grinding wheel. The time spent in sharpening the grinding wheel was estimated on the basis of three-pocket operation at this peripheral speed. The peripheral speed of the stone was 3150 feet per minute. Although only two pockets of the grinder were in use at any one time, the time equivalent of the three-pocket operation was used in estimating the grinding time. The grinding time was estimated on the basis of three-pocket operation at this peripheral speed. The grinding time was estimated on the basis of three-pocket operation at this peripheral speed.

ATTENTION: INFORMATION WILL BE FURNISHED TO

the temperature of grinding was 100° F.

per square foot of wood-stone contact area per 24 hours.

Color measured by eyes  
The chart is designed as follows: 0, 0.01, 0.02, 0.03, 0.04, 0.05, 0.06, 0.07, 0.08, 0.09, 0.10, 0.11, 0.12, 0.13, 0.14, 0.15, 0.16, 0.17, 0.18, 0.19, 0.20, 0.21, 0.22, 0.23, 0.24, 0.25, 0.26, 0.27, 0.28, 0.29, 0.30, 0.31, 0.32, 0.33, 0.34, 0.35, 0.36, 0.37, 0.38, 0.39, 0.40, 0.41, 0.42, 0.43, 0.44, 0.45, 0.46, 0.47, 0.48, 0.49, 0.50, 0.51, 0.52, 0.53, 0.54, 0.55, 0.56, 0.57, 0.58, 0.59, 0.60, 0.61, 0.62, 0.63, 0.64, 0.65, 0.66, 0.67, 0.68, 0.69, 0.70, 0.71, 0.72, 0.73, 0.74, 0.75, 0.76, 0.77, 0.78, 0.79, 0.80, 0.81, 0.82, 0.83, 0.84, 0.85, 0.86, 0.87, 0.88, 0.89, 0.90, 0.91, 0.92, 0.93, 0.94, 0.95, 0.96, 0.97, 0.98, 0.99, 1.00, 1.01, 1.02, 1.03, 1.04, 1.05, 1.06, 1.07, 1.08, 1.09, 1.10, 1.11, 1.12, 1.13, 1.14, 1.15, 1.16, 1.17, 1.18, 1.19, 1.20, 1.21, 1.22, 1.23, 1.24, 1.25, 1.26, 1.27, 1.28, 1.29, 1.30, 1.31, 1.32, 1.33, 1.34, 1.35, 1.36, 1.37, 1.38, 1.39, 1.40, 1.41, 1.42, 1.43, 1.44, 1.45, 1.46, 1.47, 1.48, 1.49, 1.50, 1.51, 1.52, 1.53, 1.54, 1.55, 1.56, 1.57, 1.58, 1.59, 1.60, 1.61, 1.62, 1.63, 1.64, 1.65, 1.66, 1.67, 1.68, 1.69, 1.70, 1.71, 1.72, 1.73, 1.74, 1.75, 1.76, 1.77, 1.78, 1.79, 1.80, 1.81, 1.82, 1.83, 1.84, 1.85, 1.86, 1.87, 1.88, 1.89, 1.90, 1.91, 1.92, 1.93, 1.94, 1.95, 1.96, 1.97, 1.98, 1.99, 2.00, 2.01, 2.02, 2.03, 2.04, 2.05, 2.06, 2.07, 2.08, 2.09, 2.10, 2.11, 2.12, 2.13, 2.14, 2.15, 2.16, 2.17, 2.18, 2.19, 2.20, 2.21, 2.22, 2.23, 2.24, 2.25, 2.26, 2.27, 2.28, 2.29, 2.30, 2.31, 2.32, 2.33, 2.34, 2.35, 2.36, 2.37, 2.38, 2.39, 2.40, 2.41, 2.42, 2.43, 2.44, 2.45, 2.46, 2.47, 2.48, 2.49, 2.50, 2.51, 2.52, 2.53, 2.54, 2.55, 2.56, 2.57, 2.58, 2.59, 2.60, 2.61, 2.62, 2.63, 2.64, 2.65, 2.66, 2.67, 2.68, 2.69, 2.70, 2.71, 2.72, 2.73, 2.74, 2.75, 2.76, 2.77, 2.78, 2.79, 2.80, 2.81, 2.82, 2.83, 2.84, 2.85, 2.86, 2.87, 2.88, 2.89, 2.90, 2.91, 2.92, 2.93, 2.94, 2.95, 2.96, 2.97, 2.98, 2.99, 3.00, 3.01, 3.02, 3.03, 3.04, 3.05, 3.06, 3.07, 3.08, 3.09, 3.10, 3.11, 3.12, 3.13, 3.14, 3.15, 3.16, 3.17, 3.18, 3.19, 3.20, 3.21, 3.22, 3.23, 3.24, 3.25, 3.26, 3.27, 3.28, 3.29, 3.30, 3.31, 3.32, 3.33, 3.34, 3.35, 3.36, 3.37, 3.38, 3.39, 3.40, 3.41, 3.42, 3.43, 3.44, 3.45, 3.46, 3.47, 3.48, 3.49, 3.50, 3.51, 3.52, 3.53, 3.54, 3.55, 3.56, 3.57, 3.58, 3.59, 3.60, 3.61, 3.62, 3.63, 3.64, 3.65, 3.66, 3.67, 3.68, 3.69, 3.70, 3.71, 3.72, 3.73, 3.74, 3.75, 3.76, 3.77, 3.78, 3.79, 3.80, 3.81, 3.82, 3.83, 3.84, 3.85, 3.86, 3.87, 3.88, 3.89, 3.90, 3.91, 3.92, 3.93, 3.94, 3.95, 3.96, 3.97, 3.98, 3.99, 4.00, 4.01, 4.02, 4.03, 4.04, 4.05, 4.06, 4.07, 4.08, 4.09, 4.10, 4.11, 4.12, 4.13, 4.14, 4.15, 4.16, 4.17, 4.18, 4.19, 4.20, 4.21, 4.22, 4.23, 4.24, 4.25, 4.26, 4.27, 4.28, 4.29, 4.30, 4.31, 4.32, 4.33, 4.34, 4.35, 4.36, 4.37, 4.38, 4.39, 4.40, 4.41, 4.42, 4.43, 4.44, 4.45, 4.46, 4.47, 4.48, 4.49, 4.50, 4.51, 4.52, 4.53, 4.54, 4.55, 4.56, 4.57, 4.58, 4.59, 4.60, 4.61, 4.62, 4.63, 4.64, 4.65, 4.66, 4.67, 4.68, 4.69, 4.70, 4.71, 4.72, 4.73, 4.74, 4.75, 4.76, 4.77, 4.78, 4.79, 4.80, 4.81, 4.82, 4.83, 4.84, 4.85, 4.86, 4.87, 4.88, 4.89, 4.90, 4.91, 4.92, 4.93, 4.94, 4.95, 4.96, 4.97, 4.98, 4.99, 5.00, 5.01, 5.02, 5.03, 5.04, 5.05, 5.06, 5.07, 5.08, 5.09, 5.10, 5.11, 5.12, 5.13, 5.14, 5.15, 5.16, 5.17, 5.18, 5.19, 5.20, 5.21, 5.22, 5.23, 5.24, 5.25, 5.26, 5.27, 5.28, 5.29, 5.30, 5.31, 5.32, 5.33, 5.34, 5.35, 5.36, 5.37, 5.38, 5.39, 5.40, 5.41, 5.42, 5.43, 5.44, 5.45, 5.46, 5.47, 5.48, 5.49, 5.50, 5.51, 5.52, 5.53, 5.54, 5.55, 5.56, 5.57, 5.58, 5.59, 5.60, 5.61, 5.62, 5.63, 5.64, 5.65, 5.66, 5.67, 5.68, 5.69, 5.70, 5.71, 5.72, 5.73, 5.74, 5.75, 5.76, 5.77, 5.78, 5.79, 5.80, 5.81, 5.82, 5.83, 5.84, 5.85, 5.86, 5.87, 5.88, 5.89, 5.90, 5.91, 5.92, 5.93, 5.94, 5.95, 5.96, 5.97, 5.98, 5.99, 6.00, 6.01, 6.02, 6.03, 6.04, 6.05, 6.06, 6.07, 6.08, 6.09, 6.10, 6.11, 6.12, 6.13, 6.14, 6.15, 6.16, 6.17, 6.18, 6.19, 6.20, 6.21, 6.22, 6.23, 6.24, 6.25, 6.26, 6.27, 6.28, 6.29, 6.30, 6.31, 6.32, 6.33, 6.34, 6.35, 6.36, 6.37, 6.38, 6.39, 6.40, 6.41, 6.42, 6.43, 6.44, 6.45, 6.46, 6.47, 6.48, 6.49, 6.50, 6.51, 6.52, 6.53, 6.54, 6.55, 6.56, 6.57, 6.58, 6.59, 6.60, 6.61, 6.62, 6.63, 6.64, 6.65, 6.66, 6.67, 6.68, 6.69, 6.70, 6.71, 6.72, 6.73, 6.74, 6.75, 6.76, 6.77, 6.78, 6.79, 6.8

Table 8.--Newsprint papers from southern cottonwood, green ash, sugarberry and pine

Machine run	Ground-wood pulp		Semi-bleached		Properties of the paper									
	Hardwood	Southern pine	Amount	Percent	Weight per ream	Thick-ness	Bursting strength	Tearing strength	Tensile strength	White-ness	Castor oil penetration	Porosity	Opacity	Gloss
No.	Species	Amount	Percent	Percent	per 25 x 40 - 500	per 25 x 40 - 500	per pound	per ream	per square inch	per ream	per square inch	per ream	per square inch	per ream
					Pounds	Mile	Point	Gram	Pounds	Percent	Seconds	Seconds	Percent	Percent
1770	Cottonwood	20	60	20	42	4.18	0.22	0.69	2,186	65	46	25	92	34
1771	Do.	20	60	20	38	3.60	.24	.57	2,549	65	56	55	91	36
1772	Do.	40	40	20	37	4.45	.23	.66	2,020	65	43	29	91	33
1773	Green ash	40	40	20	40	3.85	.22	.64	2,151	67	35	27	94	35
1774	Do.	40	45	15	43	4.21	.18	.57	1,852	66	30	20	95	35
1775	Sugarberry	40	40	20	41	4.06	.19	.61	1,801	67	33	19	93	34
1776	Do.	40	45	15	40	4.26	.17	.70	1,685	66	36	21	93	34
1777	Cottonwood	13	41	20	39	4.07	.18	.70	1,805	65	32	21	93	34
	Green ash	13												
	Sugarberry	13												
Southern pine newsprint <sup>4</sup>			80	20	32	3.34	.29	.75	2,420	65	79	75	91	36
Average of 56 commercial newsprint papers					38	3.30	.25	.54	2,537	59	50	49	92	41

Species grinder  
Run No.

Cottonwood : 389  
Green ash : 388  
Sugarberry : 395  
Southern pine : 392

<sup>1</sup> In addition to the fiber furnish 0.25 percent of rosin size, dye, and alum to a pH of 4.5 to 5.0 was added. The semibleached pulp used was prepared from commercial southern pine kraft bleached to a whiteness of 56 as measured by the Ives photometer.

<sup>2</sup> To convert to the newsprint trade ream basis 24 x 36 - 500, multiply by 1.157.

<sup>3</sup> Average of machine runs 1088-1092 inclusive, 1148, 1149, 1152-1154 inclusive.