PULPS AND CORRUGATING PAPERBOARDS FROM FARM WOODLAND HICKORY

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PULPS AND CORRUGATING PAPERBOARDS FROM FARM WOODLAND HICKORY[1]

By

J. N. McGOVERN, Chemical Engineer
E. L. KELLER, Chemist
and
J. S. MARTIN, Chemical Engineer

Forest Products Laboratory,[2] Forest Service
U.S. Department of Agriculture

Summary

Mockernut hickory (Carya tomentosa) and pignut hickory (Carya glabra), two species growing extensively in farm woodlands of the Eastern States, were pulped individually and in mixture by the sulfate, sulfate semichemical, and neutral sulfite semichemical processes. Semichemical pulps made in yields of 70 to 75 percent by weight of the moisture-free wood were adequate in strength for conversion to corrugating paperboard. The strength properties of the paperboards made from these pulps were equal to or greater than those of a number of commercial hardwood semichemical corrugating boards. The strength properties of semichemical pulps made in yields of 55 to 65 percent indicated that these pulps might be suitable if mixed with stronger, longer fibered pulps in the production of other paperboard products. The sulfate pulp was made with a relatively small amount of chemical and had properties that indicated its possible use as a filler pulp in printing, writing, and tissue papers. With respect to the amount of chemical required for pulping, pulp yield and pulp strength, the hickory woods ranked medium in the range of hardwoods used for pulping.

Introduction

Hickory grows in every State east of the Mississippi River and in several States west of the river. Two of the important species, mockernut and pignut, were used in this study. These species have overlapping, but not

[1]This investigation was conducted with funds provided under the Research and Marketing Act. Report originally dated December 1949.

[2]Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

coinciding, commercial ranges of growth. Pignut hickory is found chiefly in the Appalachian range, Indiana, Ohio, Kentucky, Tennessee, eastern Pennsylvania, and southeastern New York. Mockernut hickory also grows in the Appalachian range, as well as the Gulf States and in the Atlantic States south of Pennsylvania.

High-quality hickory is strong, tough, and stiff, and is much in demand for the manufacture of tool handles and vehicle parts. A large part of the total supply of hickory, however, is not suitable for these uses because of low density, cross grain, or other defects. In many cases, only one high-quality log can be cut from a tree, and the rest of the wood must be used for fuel or discarded. Substantial quantities of this low-quality hickory are found in woodlots in the eastern and southern parts of the country. If this material could be used for the production of corrugating board or other pulp and paper products, its value and marketability might be greatly increased. Factors that might affect the use of hickory in the pulp and paper industry are: (1) the relative difficulty of removing the bark and (2) the hardness of the wood as it affects chipping operation.

Experimental Work

Material

The hickory used in these experiments was obtained from the Southeastern Forest Experiment Station, Asheville, N. C., and grew in that area. The wood as received had been split from bolts of mockernut 14 inches in diameter and of pignut hickory 24 inches in diameter. After the bark was removed, disks were cut for the determination of the density of the wood. The split sections were chipped to standard 5/8-inch size, and the chips were screened to obtain material that passed a 1-1/4-inch opening but was retained on a three-mesh screen. The acceptable chips were analyzed for their lignin, holocellulose, alpha-cellulose, and total pentosan content.

Sulfate Pulping[3]

A mixture consisting of approximately two-thirds pignut and one-third mockernut hickory chips was used in these experiments. Duplicate lots of the mixture were digested for 1.5 hours at 170° C. in steam-jacketed, rotary, spherical iron autoclaves having a capacity of 0.5 cubic foot. Three

[3]Acknowledgment is made to M. Heinig, former chemist at the Forest Products Laboratory, for assistance in the sulfate and sulfate semichemical pulping.

ratios of active chemical (sodium hydroxide plus sodium sulfide) to wood were selected in order to study their effect on pulp yield. The ratios were varied by changing the volume of digesting liquor used. The pulp was passed through a slotted diaphragm screen having 0.012-inch openings, and the yields of acceptable pulp and screening rejects were determined. The pulps were tested to determine the permanganate number and the strength, as measured by the standard TAPPI[4] beater test.

Sulfate Semichemical Pulping

The same hickory mixture was used in the sulfate semichemical pulping experiments. Preliminary digestions were made in the autoclaves to establish conditions for producing pulp in a wide range of yields. These conditions were then used in digestions in a steam-jacketed, tumbling-type, steel digester having a capacity of 14 cubic feet. As in the sulfate pulping, the ratio of chemical to wood was varied in order to study its effect on pulp yield. In this study, however, the ratio was varied by changing the initial chemical concentration in the cooking liquor, so as to obtain a wide difference in the degree of pulping. The pulp yields from autoclave digestions were determined after fiberizing the entire lot of partially pulped chips in a small attrition mill. The yield of pulp from the digesters was obtained after milling an aliquot sample and washing out the soluble residues. The remainder of the partially digested chips from the larger scale digestions was fiberized in an attrition mill of commercial size. The strength of the pulp was determined by means of the standard beater test.[4]

Neutral Sulfite Semichemical Pulping

The pignut and mockernut hickory were digested separately in the neutral sulfite semichemical pulping experiments. A nearly identical series of digestions was made on each species in a steam-jacketed, tumbling-type, stainless steel-lined digester having a capacity of 13 cubic feet. The ratio of chemical (sodium sulfite and sodium bicarbonate) to wood again was varied to produce semichemical pulps in a wide range of yields. The digestions were conducted as follows: (1) The chips were steamed at atmospheric pressure for 0.5 hour and then impregnated with digesting liquor at 120° C. for 1 hour; (2) the unabsorbed liquor was run out of the digester, and the impregnated chips were heated at 170° C. for a period that depended on the chemical-wood ratio. Then the partially digested chips were fiberized and pulp yield and strength determined as above.

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[4] Technical Association of the Pulp and Paper Industry.

Preparation of Corrugating Board

The semichemical pulps were made into corrugating board on an experimental Fourdrinier paper machine having a 12-inch web width. The neutral sulfite semichemical boards were made from a pulp mixture prepared by combining equal portions of each pulp which had been made in nearly the same yield. Specimens about 24 inches in length were cut from the boards and corrugated on a small commercial corrugator operating at a speed of approximately 25 feet per minute.

Discussion of Results

Density of the Wood

The density of the wood, expressed in pounds per cubic foot, was as follows: pignut hickory, 32.6; mockernut hickory, 37.2; and the two-to-one mixture of these species, 35.4. Hickory of good quality, however, varies in density from 40 to 48 pounds per cubic foot. Thus, the low-grade material used in these experiments was characteristically low in density.

Chemical Composition of the Wood

The chemical composition of the two species of hickory used was nearly the same (table 1), except that the pignut contained roughly 10 percent more lignin. In comparison with typical hardwoods, these species were (1) high in alpha-cellulose and pentosan contents, (2) medium to high in lignin content, (3) low in holocellulose content, and (4) low in solubility in organic solvents, hot water, and 1 percent sodium hydroxide solution. The amounts of lignin and holocellulose present gave indications that low pulp yields would be obtained from these hickories--indications that were substantiated by the tests.

Sulfate Pulping

When the amount of chemical was increased from 17.5 to 22.5 pounds per 100 pounds of wood (the normal range for sulfate pulping of hardwoods), the yield of acceptable screened pulp decreased from 48.4 to 45.5 percent (table 2). At the same time, the amount of screening rejects decreased from 0.8 to 0.3 percent, and the permanganate number, which measures the degree of pulping or delignification, decreased from 16.8 to 14.0. The highest yield of screened pulp was thus obtained with the least amount of digesting chemical. Moreover, the amount of screening rejects was not excessive and the permanganate number was sufficiently low. Thus, there appears to be little or no advantage in using more than 17.5 pounds of chemical per 100 pounds of wood. The total active chemical required to obtain the highest yield of pulp from hickory was somewhat lower than the 20 percent normally required for satisfactory pulping of many softwoods and hardwoods. The pulp yield of 48.4 percent obtained under these conditions was medium in the range for hardwoods. Because of the high density of the wood, this percentage corresponds to a very attractive yield of approximately 17 pounds of pulp per cubic foot of wood. A high yield of pulp per unit digester volume can also be expected from this high-density wood.

The strength of the sulfate pulps did not vary greatly with yield (table 3). In general, the pulps made in the lowest yields (highest chemical-wood ratios) were slightly weaker than the others.

Except for the high tearing strength, these pulps ranked medium in the strength range for hardwood sulfate pulps. Thus, it would be expected that unbleached hickory pulp would find little use alone but might be useful for blending with long-fibered pulps in the production of paper of moderate strength. Although bleaching tests were not made, the relatively low lignin content (table 1) and low permanganate numbers (table 2) of the sulfate pulp indicated that hickory might be suitable for bleachable pulp. Possible outlets for the bleached pulp would be in the manufacture of book and other printing papers, bond and writing papers, and tissue and toweling papers, where highest strength would not be essential.

Sulfate Semichemical Pulping

The yield of sulfate semichemical pulp varied from 51.6 to 74.5 percent (table 2). The decrease in yield with an increase in the quantity of chemical consumed was nearly linear within the range of the experiments. The semichemical pulps of any specified yield were produced with lower chemical requirements than necessary for corresponding yields from most hardwoods. In other words, the percentage yields obtained with a given amount of chemical were lower for the hickory than for most hardwoods. This difference was more pronounced at lower than at higher yields in the semichemical pulping and was in agreement with the results from the full sulfate pulping experiments. This relative ease of pulping, as compared to other hardwoods, cannot be accounted for by the presence of large quantities of material soluble in water and weak caustic soda solution, but it may be due to certain hemicelluloses which can be easily solubilized under the conditions of pulping.

The strength of the sulfate semichemical pulps decreased with increasing pulp yield (table 3). The pulp made in the highest yield, 73.9 percent, was appreciably weaker than the pulp made in the lowest yield, 56.5 percent, when the comparison was made on the basis of pulps beaten to equal freeness values. The pulp obtained in highest yield was, however, more bulky than the others, and the variance in strength within the yield range would probably not be so great if the comparisons were made on the basis of pulps beaten so as to produce test sheets of equal density. The bursting strength of the pulp obtained in highest yield (73.9 percent) was probably at the lower limit for commercial corrugating boards. The pulp obtained in medium yield would be expected to be more than adequate for the same purpose. The strength of the pulp made in a yield of about 70 percent was in the range specified for high-quality corrugating board. The pulp obtained in lowest yield was strong enough for blending in small percentages with stronger, longer fibered pulps for container board liners of moderate strength.

Neutral Sulfite Semichemical Pulping

The yields of the neutral sulfite semichemical pulps varied about 20 percent (table 4), the range being roughly 10 percent higher than that of the sulfate semichemical pulps. The chemical absorption data, pulp yields, and chemical analysis of the pulps (tables 1 and 4) indicated that the pignut and mockernut hickories had quite similar pulping characteristics. This would be expected from the similarity in chemical composition of the two species. The mockernut chips tended to give slightly lower pulp yields than the pignut material, but the differences were too small and the data too limited to establish this point. In general, the samples of the two hickory species appeared to pulp equally well.

The pulp yield decreased normally as the chemical requirements and pulping time increased. The sodium sulfite required to produce pulps of a specified yield from these hickory species was intermediate in the normal range for hardwoods.[5] For example, the sodium sulfite required for pulping the hickories was higher than that for oak, but lower than that for cottonwood. The sodium bicarbonate consumption for the hickories, on the other hand, was higher than for most hardwoods. This may indicate that a large quantity of wood acid was formed and neutralized in the impregnation stage. In a commercial operation employing a conventional, single-stage pulping procedure, the amount of sodium bicarbonate required to maintain a slight alkalinity in the digesting liquor would probably be considerably less than that required in these experiments. It is calculated that the production of 1 ton

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[5] Chidester, G. H. "Semichemical Pulping," Proc. For. Prod. Res. Soc., 1949.

of air-dry pulp made in a yield of 75 percent would require the following approximate amounts of basic chemicals: 65 pounds of sulfur and 300 pounds of sodium carbonate. Pulp made in this yield is considered satisfactory for use in preparing corrugating boards.

The two hickory species yielded pulps generally of quite similar chemical composition but occasionally differing somewhat more than would be expected from the analysis of the wood samples (table 1). The lignin content of the mockernut hickory pulps tended to be slightly lower and the pentosan content slightly higher than in the pignut hickory pulps, in agreement with the analysis of the wood samples. The holocellulose content of the pignut hickory pulps was lower than that of the mockernut pulps, which might be expected from the lignin analysis of the pulps, but the difference was not apparent in the analysis of the wood samples. The lignin content of the pulps obtained in lowest yield was relatively high. Although bleaching tests were not made, it is believed that, for satisfactory bleaching, it would be necessary to digest the chips to a slightly lower lignin content and pulp yield than was achieved in these experiments, especially with the pignut hickory. This would indicate that there is only limited promise for production of bleached semichemical pulps in economical yields and chemical consumptions from hickory. The pentosans content of these hickory pulps was normal for hardwood semichemical pulps, and the values, as usual, were approximately the same in the pulp as in the wood. As would be expected, the lignin content decreased and the alpha-cellulose content increased with decreasing yield. Contrary to expectations, the holocellulose content was lowest in the pulps obtained in medium yield and about the same in those obtained in high and low yield.

The neutral sulfite semichemical pulps from the two species of hickory were medium in strength (table 3). Since, for equal yields, the strength of the two pulps was nearly the same, only the average values are reported in table 3. Compared with semichemical pulps made in approximately the same yield from other hardwoods, the hickory pulps were slightly below average strength.[4] The pulp strength and the density of the test sheets increased with decreasing yield, as expected. The pulp obtained in lowest yield was approximately 100 percent higher in bursting and tensile strength and 50 percent higher in tearing strength than the one obtained in highest yield. The strength of pulps made in yields of approximately 75 percent was in the range specified for products such as corrugating board. Pulps made in lower yields were stronger and appeared suitable for use in combination with stronger, longer fibered pulps for the manufacture of paperboard products such as liners for container board. The dark color of the neutral sulfite pulps is due to the color of the wood (the brightness values shown in table 5 were obtained from tests on corrugating boards made from the pulps).

The energy consumed in fiberizing the softened, semichemically pulped hickory chips was high and increased with increasing yield. The energy consumed in producing pulps whose freenesses ranged from 550 to 600 cubic centimeters (Canadian Standard) increased from 20 to 36 horsepower-days per ton of air-dry pulp as the pulp yield varied from 67 to 87 percent. These values were higher than would be expected in a continuous commercial multistage operation.

Properties of Corrugating Boards

The strength of the corrugating boards made from sulfate semichemical pulps increased, as did the strength of the pulp itself, as the pulp yield decreased (table 5). The experimental board from the highest yield pulp (73.9 percent) had somewhat lower bursting and tensile strength, but higher tearing strength and compressive resistance than the average commercial semichemical board (table 5). The boards made from the lower yield sulfate semichemical pulps were stronger than the average commercial board and probably were considerably stronger than necessary for this type of product. All of the hickory boards could be corrugated satisfactorily in the short test runs carried out. A consideration of the strength of both the pulp and the corrugating board indicated that a board made from pulp produced in a yield of about 70 percent would be suitable for use as the corrugated member in a fiber container board.

The strength of boards made from neutral sulfite semichemical pulp also increased as the pulp yield decreased (table 5). Board made from the highest yield pulp was too weak and too soft to meet commercial requirements. That made from medium-yield pulp (78.7 percent) was at least as strong as the average commercial boards and also corrugated satisfactorily. Board made from the lowest yield pulp was considerably stronger than is generally required for products such as corrugating board.

The freeness values of both the sulfate and the neutral sulfite semichemical pulps were probably near the lower limit of the range considered satisfactory for commercial production of corrugating boards. For high-speed machines, in particular, a higher freeness would be desirable.

Comparison of Sulfate Semichemical and Neutral Sulfite Semichemical Pulping

Compared at a semichemical pulp yield of 65 percent, the sulfate semichemical and neutral sulfite semichemical processes produced pulps and corrugating boards having strength properties approximately the same, except that the tearing strength of the sulfate pulps was higher. When the two processes were compared at a pulp yield of 75 percent, the neutral sulfite products were appreciably stronger in all respects except tearing strength. As expected, the neutral sulfite process gave products much lighter in color than did the sulfate process (table 5). In order to produce corrugating boards of approximately the same quality, the sulfate pulps might be made in a yield of 70 percent and the neutral sulfite pulp in a yield of 75 percent. The sodium oxide requirements would then be roughly 8 percent of the moisture-free wood for sulfate pulping and 7 percent for neutral sulfite pulping. In producing lower yield pulps for products whose strength requirements are greater than those of corrugating board, more chemical would be required for neutral sulfite than for sulfate pulping. At a yield of 65 percent, where the pulps were practically as strong regardless of process (except for the higher tearing strength of the sulfate semichemical pulp), the sodium oxide requirement would be about 13 percent for sodium sulfite, and 9 percent for sulfate pulping.

Table 1.--Chemical analyses of wood, sulfate pulp, and neutral sulfite semichemical pulp made from mockernut and pignut hickory

Material	Shipment or digestion No.	Pulp yield	Lignin	Holo-cellulose	Alpha-cellulose	Total pentosans	Solubility in-- Alcohol-benzene	Solubility in-- Ether	Solubility in-- 1% NaOH	Solubility in-- Hot water
		Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent	Percent
Mockernut hickory										
Chips	2740	......	22.8	72.7	51.1	18.7	2.3	0.3	14.8	3.1
Neutral sulfite semichemical pulp	5435	67.2	10.3	82.0	64.5	17.5	....	.....	......	....
	5433	78.7	15.6	80.6	62.6	18.7	....	.....	......	....
	5434	87.5	20.1	83.0	53.2	18.1	....	.....	......	....
Pignut hickory										
Chips	2740	......	25.5	73.2	50.8	17.5	1.7	.2	13.5	2.0
Neutral sulfite semichemical pulp	5431	66.8	11.9	81.0	64.5	16.9	....	.....	......	....
	5429	77.2	16.7	75.6	57.7	16.9	....	.....	......	....
	5430	86.4	20.8	80.0	57.2	16.9	....	.....	......	....
Mixture[1]										
Sulfate pulp	2072 and 2075	[2]47.4	2.5	95.2	79.8	20.2	....	.....	......	....

[1] Approximately two-thirds pignut and one-third mockernut.

[2] Yield of screened pulp.

Table 2.--Digestion conditions for pulping, yields, and properties of sulfate and sulfate semichemical pulps from hickory[1]

Digestion number[2]	Digestion condition[3]: Chemical: Initial concentration: Calculated as Na_2O	Chemical: Per 100 pounds of moisture-free wood: NaOH plus Na_2S	Chemical: Per 100 pounds of moisture-free wood: Calculated as Na_2O	Liquor-wood ratio	Chemical: Consumed during digestion	Black liquor: density at 15° C.	Digestion time at 170° C.	Yield of moisture-free pulp per 100 pounds of moisture-free wood: Screened	Yield: Screenings	Yield: Total	Brightness: Unbleached pulp	Brightness: Pulp bleached with 8.75 percent chlorine	Permanganate number
	Gm. per liter	Lb.	Lb.		Percent	°B.	Hours	Lb.	Lb.	Lb.			
Sulfate semichemical:													
2061X	18.3	9.38	7.3	4.0	96.2	5.4	0	...	...	75.2	...	...	
2988	18.3	9.38	7.3	4.0	93.5	5.7	0	...	...	73.9	12.2	16.2	...
2052X	19.5	10.00	7.8	4.0	96.2	5.7	0	...	...	73.3	...	...	...
2062X	22.0	11.25	8.8	4.0	96.6	6.8	1.5	...	...	65.1	...	...	...
2989	22.0	11.25	8.8	4.0	96.2	7.4	1.5	...	...	64.4	...	...	...
2053X	24.0	12.50	9.8	4.0	96.2	7.6	1.5	...	...	61.2	...	15.1	...
2063X	26.9	13.75	10.7	4.0	94.5	8.4	1.5	...	...	55.7	...	...	...
2990	26.9	13.75	10.7	4.0	92.5	8.5	1.5	...	...	56.5	16.6	37.0	...
2054X	29.3	15.00	11.7	4.0	92.2	8.9	1.5	...	...	51.6	...	...	...
Sulfate:													
2071X, 2074X	39.1	17.5	13.7	3.5	90.0	11.1	1.5	48.4	0.8	49.2	18.9	64.3	16.8
2072X, 2075X	39.1	20.0	15.6	4.0	87.2	10.6	1.5	47.4	.6	48.0	19.1	64.2	15.8
2073X, 2076X	39.1	22.5	17.6	4.5	81.9	10.5	1.5	45.5	.3	45.8	21.4	69.2	14.0

[1] A mixture consisting of approximately two-thirds pignut and one-third mockernut hickory was used.

[2] Digestions marked with "X" were made in the autoclaves.

[3] All digestions were made at 30 percent sulfidity and 170° C. maximum temperature, with a 1.5-hour temperature-rise period between room temperature and 170° C.

Z M 83742 F

Table 3.--Properties of sulfate and semichemical pulps made from hickory

Digestion number	Pulping process	Yield	Freeness (Canadian Standard)	Strength properties of pulp test sheets: Bursting[1] strength	Tearing[1] strength	Tensile[1] strength: Breaking length	Folding endurance	Density
		Percent	Cc.	Pts. per lb. per ream[2]	Gm. per lb. per ream[2]	Meters	Number of double folds	Gm. per cc.
2073-76X	Sulfate[3]	[4]45.5	600	0.41	1.08	4,050	8	0.53
			450	.64	1.16	5,200	43	.67
2072-5X	....do............	[4]47.4	600	.40	1.22	4,100	10	.55
			450	.63	1.47	5,700	56	.65
2071-74X	....do............	[4]48.4	600	.42	1.13	3,740	10	.54
			450	.67	1.29	5,440	90	.66
2990	Sulfate semichemical[3]	56.5	600	.34	1.56	3,400	17	.50
			450	.62	1.46	4,750	250	.63
2989	....do............	64.4	600	.34	1.42	3,050	15	.51
			450	.55	1.30	4,250	75	.60
2988	....do............	73.9	600	.23	1.12	2,600	4	.43
			450	.36	1.24	3,700	20	.50
5431-5	Neutral sulfite semichemical[5]	67.0	600	.31	.90	2,900	6	.48
			450	.48	1.00	4,100	20	.55
5429-33	....do............	78.0	600	.26	.69	2,600	2	.46
			450	.39	.81	3,600	9	.53
5430-4	....do............	87.0	600	.12	.54	1,500	1	.37
			450	.19	.64	2,200	2	.42

[1]Data interpolated from freeness vs. strength curves.

[2]Five hundred 25- by 40-inch sheets, the standard ream.

[3]A mixture consisting of approximately two-thirds pignut and one-third mockernut hickory was used.

[4]Yield of screened pulp.

[5]Average of results from separate digestions of each of the two hickory species.

Z M 83743 F

Table 4.--Digestion conditions and yields of neutral sulfite semichemical pulps made from pignut and mockernut hickory

Species and digestion No.	Concentration of impregnating liquor: Na_2SO_3	Concentration of impregnating liquor: $NaHCO_3$	Chemicals absorbed: Na_2SO_3	Chemicals absorbed: $NaHCO_3$	Digestion time at 170° C.	Na_2SO_3 in spent liquor	Pulp yield
	G. per l.	G. per l.	Percent of moisture-free wood	Percent of moisture-free wood	Hr.	G. per l.	Percent
Pignut hickory							
5431	149.5	49.7	20.0	8.4	4.5	8.9	66.8
5429	104.0	45.3	10.8	7.9	[1]1.0	9.7	77.2
5430	45.7	25.0	6.1	5.0	[1].1	11.5	86.4
Mockernut hickory							
5435	154.5	47.4	20.8	8.4	4.5	11.0	67.2
5433	107.3	48.0	10.4	7.9	[1]1.1	8.3	78.7
5434	46.4	21.7	5.4	4.7	[1].2	13.8	87.5

[1] 160° C.

Rept. No. 1753

Table 5.--Properties of experimental hickory and commercial hardwood semichemical corrugating boards

Properties of pulp and boards	Experimental hickory boards						Commercial hardwood boards
	Sulfate pulp yield			Neutral sulfite pulp yield			
	56.5 percent	64.4 percent	73.9 percent	67.2 percent	78.7 percent	87.5 percent	
Machine run number	3100	3099	3098	3086	3085	3084	(1)
Headbox freeness of pulp[2] ... cc.	485	410	510	410	510	455	...
Properties of corrugating board:							
Weight ... lb. per 1,000 sq. ft.	27.0	25.9	26.5	27.2	27.3	27.5	27.4
Caliper ... 0.001 in.	8.7	8.8	8.9	8.9	9.4	10.7	10.0
Density ... g. per cc.	.60	.57	.57	.59	.56	.49	.53
Bursting strength:							
Mullen ... pts.	60.7	58.0	30.4	62.5	44.8	25.3	36.3
Unit ... pts. per lb.[3]	.65	.63	.33	.66	.47	.26	.38
Tearing strength ... g. per lb.[3]	1.81	1.59	1.18	1.60	1.24	.75	1.00
Tensile strength ... lb. per in. width	42.9	37.3	28.5	43.1	36.7	24.2	30.1
Stretch ... percent	4.6	5.4	2.0	3.2	2.0	1.5	2.0
Folding endurance ... double folds	178	151	36	151	...	3	31
Compression resistance ... lb.	...	55.9	56.3	59.8	50.0	...	[4]49.4
Brightness ... percent	13.8	12.6	13.8	32.8	34.4	34.0	...

[1] Shipments Nos. 2560, 2785, 2786, 2878, 2883, and 2894 used.

[2] Canadian Standard.

[3] Standard ream size--500 sheets, 25 by 40 inches.

[4] Average of tests on two samples of commercial semichemical corrugating board not included in footnote 1 above.