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AN EXPERIMENTAL STUDY OF BEATER PRACTICE IN THE MANUFACTURE OF OFFSET PAPERS

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ABSTRACT

Sixty-three experimental papers were made in the Bureau's semicommercial mill in studies to determine the relationship between the mechanical beating of the fibers and the properties of paper for multicolor offset printing. A series of papers was made from each of the kinds of wood fibers commonly used in offset papers and from various mixtures of these fibers. Each series comprised papers made with widely different degrees of beating, and the effects of the variations were determined by laboratory and printing tests of the papers.

The data obtained indicate that for the best results in multicolor printing, the papers should be made with the minimum of beating necessary to obtain the required formation and finish. The formation of gel on the fibers should be carefully controlled, because the high strength associated with gel, particularly high folding endurance, is directly opposed to several of the properties most important in multicolor lithography.

The admixture of filler pulp with a strong pulp such as sulfite lessens the adverse effects of beating and assists in obtaining suitable formation and finish. The best all-around results were obtained with sulfite-soda and sulfate-soda mixtures. Deinked book stock had excellent opacity, but papers containing appreciable amounts of it curled excessively.

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I. INTRODUCTION

A program of research on lithographic papers, in which the National Bureau of Standards and the Lithographic Technical Foundation are cooperating, has been in progress at the Bureau since July 1930. Previous publications [1] have contained information on the manufacture, care, and treatment of offset papers for optimum register in multicolor printing. The importance of numerous properties, particularly low expansivity, has been shown. This article contains the re-

[1] See the references at the end of this paper.

sults of a study of the relationship between the beating of wood fibers and the important properties of offset lithographic papers made from them. Various types of commercial wood pulps commonly used in lithographic papers were studied singly and in combinations. A series of papers was made in the Bureau's semicommercial paper mill from each furnish with controlled variations in the beating and with the other factors kept constant insofar as possible.

The relationship between beating and sheet properties was determined by means of laboratory and printing tests on the finished papers. The printing tests were made at the Coast and Geodetic Survey, Department of Commerce.

The research on lithographic papers is carried on with the assistance of a fund deposited with the Lithographic Technical Foundation by a group of manufacturers of offset papers. All the studies are planned with the counsel of an advisory committee of technical representatives of the sponsors under the chairmanship of R. F. Reed, Director of Lithographic Research, University of Cincinnati.

II. PAPERMAKING EQUIPMENT

The equipment of the Bureau's paper mill is semicommercial in size, and is adapted to the experimental manufacture of paper under conditions which simulate those of industrial mills. Detailed descriptions and photographs of the equipment are contained in previous publications.[2 3 4] The equipment used in this investigation consisted essentially of the following: a 50-pound beater with copper-lined wooden tub and manganese-bronze bars and plate, and equipped with a washing cylinder; a jordan refiner with bars of bronze and steel alloy; a four-plate, flat screen; and a 29-inch fourdrinier papermaking machine with a wire 33 feet in length, two presses, nine 15-inch dryers, a calender stack of seven rolls, and a reel.

III. PAPERMAKING RAW MATERIALS

The fibrous materials were selected with the cooperation of the Advisory Committee, with the idea of covering the types of pulps commonly used in the manufacture of commercial offset papers. The pulps selected were all bleached. They included those having long fibers needed to give the papers strength, and those with short bulky fibers commonly used as fillers in mixture with the strong pulps, to improve formation and other qualities that affect printing. Two pulps were reclaimed waste-paper stocks. Specifically, the following pulps were used:

1. Eastern sulfite, a typical strong pulp made by cooking wood chips in an acidic solution, usually bisulfite of calcium, to dissolve the nonfibrous binding constituents of the wood and permit the separation of the fibers. The pulp used was considered a standard-quality bond grade made from eastern spruce.

2. Western sulfite, a strong pulp corresponding to the eastern sulfite, but made from western hemlock, which is similar to spruce in papermaking characteristics.

[2] Tech. Pap. BS 21, 338 (1927) T340.
[3] BS J. Research 3, 904 (1929) RP121.
[4] Paper Trade J. 89, 19, 60 (1929).

3. Bleached sulfate, a typical strong pulp made by cooking wood as in the sulfite process except that the cooking liquor is a strong caustic solution containing caustic soda and sodium sulfide. The sulfate-cooked fibers are usually the longest and strongest of the ordinary chemical wood fibers.

4. Northern soda pulp, a typical filler pulp produced by cooking chips in a strong solution of caustic soda. The fibers are characteristically short, soft, and bulky with little strength. The northern soda pulp was made from the deciduous wood, poplar.

5. Southern soda pulp, a filler pulp corresponding to the northern soda, but made from southern species of deciduous woods.

6. Soft alpha, a special form of sulfite wood pulp, highly purified by removing the undesirable forms of cellulose normally found in wood pulps. This pulp combined medium strength with soft bulky properties.

7. Reclaimed ledger stock, a pulp obtained by deinking old ledger papers by cooking them in dilute caustic to remove the ink. These fibers have some of the properties of sulfite, but are shorter and softer, and no longer respond to mechanical beating in the same manner as new pulps.

8. Reclaimed book stock, a short-fibered filler type of pulp obtained by deinking waste book papers. This stock contained considerable mineral filler, which is to be expected because fillers are usually present in book papers.

The chemical characteristics of these pulps are given in table 1.

TABLE 1.—*Chemical characteristics of fibrous materials used in experimental manufacture of offset papers*

Fibrous material	Alpha-cellulose [1]	Beta-cellulose [1]	Gamma-cellulose [1]	Pentosans	Copper number	Ash [2]	Resin [2]	Acidity of pulp (glass - electrode method)	
								Cold-water extraction	Hot-water extraction
	%	%	%	%		%	%	pH	pH
Eastern sulfite pulp	84.4	3.6	12.0	4.2	1.3	0.2	0.4	5.8	5.5
Western sulfite pulp	84.8	1.8	13.4	2.8	2.0	.2	.3	5.9	5.5
Northern soda pulp	67.5	28.8	3.7	15.4	3.2	.7	.2	8.6	7.4
Southern soda pulp	60.8	32.6	6.6	16.2	6.2	.3	.2	5.3	4.8
No. 1 soft alpha pulp	91.9	3.3	4.8	2.5	0.5	.1	.2	6.4	6.3
Bleached sulfate pulp	84.1	11.3	4.6	8.0	.5	.2	Trace	8.0	7.4
Deciduous-wood sulfite pulp	83.6	10.9	5.5	6.0	1.0	.2	.1	6.9	6.2
Deinked ledger stock	68.4	25.3	6.3	4.5	3.0	.9	.1	6.7	6.1
Deinked book-paper waste	80.5	11.0	8.5	5.1	2.2	17.9	.9	7.6	7.0
Do.[3]	81.1	10.7	8.2	5.3	2.0	13.5	1.1	8.1	8.4

[1] Based on total cellulose.
[2] On oven-dry basis.
[3] Two different samples (see test, p. 244).

Alpha-cellulose and copper number are measures of the purity of the cellulose, the purer forms of cellulose having a high alpha-cellulose content and a low copper number.

The eastern and western sulfite pulps were both of excellent quality. Although obtained from different kinds of woods, they were similar in chemical purity. The western sulfite did not seem to bulk as much in the beater, and it circulated faster, whether used alone or in mixture with filler pulp.

The northern soda pulp apparently had been insufficiently washed, as is shown by the high ash and the pH values in the table, and by the excessive amount of alum that was required to adjust the pH of the stock to 5.0 when making the paper-machine runs.

The southern soda pulp was acid. The acidity and high copper number, 6.2, may have been caused by the cooking, bleaching, or final washing conditions. Pulps having such high copper numbers would not be considered for use in the manufacture of permanent papers. A bundle of paper made from this pulp (run 1235) cut into 17- by 22-inch sheets and stored for only 2 years, showed very decided yellowing of the edges to a depth of 1 inch on all four sides.

Because of the low alpha-cellulose content of the deinked ledger stock, a microscopic analysis also was made. The analysis showed the stock to be 15 percent rag and 85 percent chemical wood pulp.

Except for the deinked book-paper stock, each roll or bale of fibrous material used was of uniform quality throughout, and was of the same quality as any other roll or bale of the particular type of pulp. For the deinked waste book papers, however, samples from different parts of the roll showed considerable difference in ash content. A sample from the first part of the roll had an ash content of 17.9 percent, and a sample from the first beater furnish, 15.5 percent. The ash content of the next two beater furnishes was approximately 13.0 percent, whereas a sample from the next part of the roll showed 13.4 percent. A microscopic analysis of the deinked book-paper stock showed it to be 100 percent chemical wood pulp.

IV. MANUFACTURE AND TESTING

1. BEATING PRACTICE AND MACHINE OPERATION

Pulp is prepared for formation into paper by a mechanical process known as beating, which is done by treating the pulp in water in large vats. Each vat has a cylindrical roll with horizontal metal bars protruding around its periphery, which impinge on similar parallel bars protruding from a bedplate on the floor of the vat. The pulp is circulated by turning the roll rapidly, and as it circulates, it passes between the two sets of bars. The degree of beating is controlled by the length of time the stock is circulated in the beater, and by the setting of the roll with respect to the clearance between the bars on the roll and those on the bedplate. Here the fibers are separated from clusters, brushed and frayed so that they will felt properly, and shortened to the length that will produce the desired formation. In addition to these purely mechanical changes, wood fibers undergo a structural alteration during beating. They absorb water and form a gelatinous substance by a process commonly referred to as "hydration." The amount of gel formed on the fiber during beating is referred to as the degree of hydration, and is reflected sharply in some of the characteristic properties of the paper. The mechanism involved in hydration is not clearly understood. However, its effects are particularly important because they are associated with some of the most troublesome difficulties encountered in printing, namely, curling, waving, and buckling of paper, and misregister of color prints.

After beating the pulp it is usually given further treatment in a machine called a jordan, after the name of its inventor, Joseph Jordan.

The jordan, which is often referred to as a refiner, is essentially a conical shell within which a cone-like plug is revolved at high speed. Bars protruding from the plug impinge on similar bars protruding from the inside of the shell. The pulp is forced by pump-pressure between the shell and the plug from one end of the jordan to the other, and the severity of the action is controlled by the clearance between the bars on the rotating plug and those on the shell inside which it runs.

In order to determine the effects of beating, a series of papers was made from each of the fibers, and from various mixtures of them, with controlled variations in the beating. The procedure followed in furnishing the stock to the beater, unless otherwise noted, was as follows. The beater tub was partially filled with water, the pulp was added, and more water was added until the desired concentration was obtained. The time required for furnishing was approximately 15 minutes. Data on the beating intervals, beater-roll settings, jordan settings, freeness of the stock at the completion of the beatings, freeness at the head box, the distance the water was carried beyond the second slice [5] on the paper machine wire, and the shrinkage in width while drying are shown in table 2. The position of the beater roll is expressed as the number of turns above (+) or below (−) zero setting, which is the point of contact between the roll and the bedplate. One turn moves the roll 0.008 inch.

The term "freeness" is used in the paper industry to indicate the relative rates of drainage of water from pulps while the fibers are being felted into a sheet of paper. Freeness is affected by many factors, the most important of which are rate of hydration of the pulp, length of fibers, extent of brushing or degree of fibrillation, flexibility or felting quality, presence of sizing and loading materials. The relative extent to which the various individual factors affect the readings is not known. Therefore, freeness values for one type of furnish are not strictly comparable with values for other furnishes, and readings are of value for control purposes when duplicating papers from a given furnish but are not comparable with values for different kinds of furnishes. The same property is often referred to in the paper industry as "slowness" or "wetness", according to the type of instrument used in its measurement and the method of reporting results.

The numerical expression of freeness is an arbitrary figure peculiar to the instrument used. At present, the scale of measurement is not standardized, therefore, for comparison of pulps the readings should be made on the same instrument. The freeness results reported in table 2, however, for reasons beyond control, were not all obtained with the same instrument. For runs 1225 to 1257, inclusive, the measurements were made with a Schopper-Riegler instrument, and the values were converted to units of the Williams precision freeness tester by use of published data.[6] For the remainder, a Williams precision freeness tester was used.

The Schopper-Riegler apparatus has a cone with two discharge orifices of different sizes placed at different levels. By means of this construction a sudden rush of water from free pulps is quickly discharged through the higher, and larger, orifice; whereas with very slow pulps, nearly all of the water is discharged through the lower, and smaller opening.

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[5] The slice is an adjustable opening across the width of the wire near the breast roll to control the flow of the stock onto the wire and keep the thickness even. A machine making fine papers usually has two slices.

[6] Tech. Assn. Pap. **14,** 347 (1931).

TABLE 2.—*Data on beating and condition of stock for different*

Paper machine run number	Beater furnish			Position of beater roll after beating time of—								
	Fiber (pulp	Rosin [1]	Alum [1]	0.0 hr [4]	0.25 hr [5]	0.5 hr	1.0 hr	1.5 hr	2.0 hr	2.5 hr	3.0 hr	3.5 hr
		% [2]	% [3]									
1225	100% eastern sulfite	1	0.9	+10	+10	+3	+3	+3	------	------	------	------
1226	do	1	0.9	+10	+10	+3	+3	+2½	+2½	+2	+2	+2
1227	do	1	1.0	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1229	do	1	1.0	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1230	do	1	1.0	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1231	do	1	1.3	+10	+10	−½	−½	−½	−½	−½	------	------
1232	do	1	1.0	+10	+10	+3	+3	+3	------	------	------	------
1233	100% southern soda	1	1.0	+10	+10	+3	+3	+3	------	------	------	------
1234	do	1	0.9	+10	+10	+3	+2	+1	+½	+½	0	0
1235	do	1	0.9	+10	+10	+3	+2	+1	+½	+½	0	0
1236	100% northern soda	1	2.2	+10	+10	+3	+2	+1	+½	+½	0	0
1237	25% eastern sulfite and 75% northern soda	1	1.9	+10	+10	+3	+3	+3	------	------	------	------
1241	75% eastern sulfite and 25% northern soda	1	1.4	+10	+10	+3	+3	+3	------	------	------	------
1238	25% eastern sulfite and 75% southern soda	1	1.0	+10	+10	+3	+3	+3	------	------	------	------
1242	75% eastern sulfite and 25% southern soda	1	1.0	+10	+10	+3	+3	+3	------	------	------	------
1243	100% western sulfite	1	1.0	+10	+10	+3	+3	+3	------	------	------	------
1244	so	1	1.0	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1245	do	1	1.0	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1246	do	1	1.0	+10	+10	+3	+3	+3	------	------	------	------
1249	25% western sulfite and 75% northern soda	1	2.3	+10	+10	+3	+3	+3	------	------	------	------
1247	75% western sulfite and 25% northern soda	1	1.5	+10	+10	+3	+3	+3	------	------	------	------
1248	50% western sulfite and 50% northern soda	1	1.9	+10	+10	+3	+3	+3	------	------	------	------
1250	do	1	2.0	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1251	do	1	2.0	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1252	50% western sulfite and 50% southern soda	1	1.1	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1253	100% No. 1 soft alpha	1	1.3	+10	+10	+3	+3	+3	------	------	------	------
1254	do	1	1.3	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1255	do	1	1.2	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1256	do	1	1.2	+10	+10	+3	+3	+3	------	------	------	------
1261	100% bleached sulfate	1	1.3	+10	+10	+3	+3	+3	------	------	------	------
1262	do	1	1.3	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1263	do	1	1.4	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1264	do	1	1.5	+10	+10	+3	+3	+3	------	------	------	------
1266	100% deciduous-wood sulfite	1	1.7	+10	+10	+3	+2	+1	+½	+½	0	0
1269	25% eastern sulfite and 75% deciduous-wood sulfite	1	1.3	+10	+10	+3	+3	+3	------	------	------	------
1271	75% eastern sulfite and 25% deciduous-wood sulfite	1	1.4	+10	+10	+3	+3	+3	------	------	------	------
1270	50% eastern sulfite and 50% deciduous-wood sulfite	1	1.3	+10	+10	+3	+3	+3	------	------	------	------
1272	do	1	1.3	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1274	do	1	1.2	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1239	50% eastern sulfite and 50% northern soda	1	1.8	+10	+10	+3	+3	+3	------	------	------	------
1275	do	1	1.8	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1276	do	1	1.8	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1240	50% eastern sulfite and 50% southern soda	1	1.0	+10	+10	+3	+3	+3	------	------	------	------
1277	do	1	1.0	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1278	do	1	1.0	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1279	50% No. 1 soft alpha and 50% northern soda	1	1.9	+10	+10	+3	+3	+3	------	------	------	------
1257	do	1	2.0	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1280	do	1	1.9	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1281	50% bleached sulfate and 50% northern soda	1	2.0	+10	+10	+3	+3	+3	------	------	------	------
1265	do	1	2.0	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1282	do	1	2.0	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½

See footnotes at end of table.

types of pulp furnishes in the study of experimental offset papers

Paper machine run number	Position of beater roll after beating time of—Continued: 4.0 hr	4.5 hr	5.0 hr	5.5 hr	6.0 hr	6.5 hr	7.0 hr	7.5 hr	8.0 hr	8.5 hr	9.0 hr	9.5 hr	Freeness of stock completion of beating [6]		Jordan setting	Acidity at head box quinhydrone method	Freeness of stock at head box [6]		Sheet shrinkage in width as formed [7]	Distance water was carried beyond second slice [8]
													A	B		pH	A	B	%	*in.*
1225	----	----	----	----	----	----	----	----	----	----	----	----	11	13	+8	5.0	24	28	1.9	7
1226	----	----	----	----	----	----	----	----	----	----	----	----	17	20	+8	5.0	28	33	2.5	11
1227	+1½	+1	+1	+1	----	----	----	----	----	----	----	----	18	21	+8	5.0	29	34	3.1	15
1229	+1½	+1	+1	+½	+½	0	0	0	----	----	----	----	28	33	+8	5.0	53	62	3.8	27
1230	+1½	+1	+1	+½	+½	0	0	−½	−½	−1	−1	−1	72	84	+8	5.2	109	126	5.6	39
1231	----	----	----	----	----	----	----	----	----	----	----	----	29	34	0	5.0	100	116	4.4	53
1232	----	----	----	----	----	----	----	----	----	----	----	----	13	15	−3	4.9	125	145	4.7	61
1233	----	----	----	----	----	----	----	----	----	----	----	----	15	17	+8	4.9	24	28	0.9	10
1234	----	----	----	----	----	----	----	----	----	----	----	----	24	28	+8	5.0	39	46	1.3	16
1235	0	−½	−½	−½	----	----	----	----	----	----	----	----	35	41	+8	5.0	65	76	1.9	26
1236	----	----	----	----	----	----	----	----	----	----	----	----	35	41	+8	5.1	39	46	0.9	19
1237	----	----	----	----	----	----	----	----	----	----	----	----	20	23	+8	5.2	31	36	1.3	12
1241	----	----	----	----	----	----	----	----	----	----	----	----	15	17	+8	4.9	28	33	2.2	12
1238	----	----	----	----	----	----	----	----	----	----	----	----	13	15	+8	5.1	24	28	1.3	9
1242	----	----	----	----	----	----	----	----	----	----	----	----	11	13	+8	4.9	25	30	1.9	12
1243	----	----	----	----	----	----	----	----	----	----	----	----	9	10	+8	4.9	16	19	1.9	8
1244	+1½	+1	+1	+1	----	----	----	----	----	----	----	----	15	17	+8	4.9	33	39	2.5	13
1245	+1½	+1	+1	+½	+½	0	0	−½	−½	−1	−1	−1	63	74	+8	4.9	111	129	4.7	43
1246	----	----	----	----	----	----	----	----	----	----	----	----	10	12	−3	5.0	109	127	4.4	49
1249	----	----	----	----	----	----	----	----	----	----	----	----	17	20	+8	5.3	31	36	1.3	17
1247	----	----	----	----	----	----	----	----	----	----	----	----	11	13	+8	5.2	33	39	1.9	14
1248	----	----	----	----	----	----	----	----	----	----	----	----	17	20	+8	5.2	31	36	1.6	15
1250	+1½	+1	+1	+1	----	----	----	----	----	----	----	----	22	26	+8	5.0	41	48	1.9	22
1251	+1½	+1	+1	+½	+½	0	0	−½	−½	−1	−1	−1	80	93	+8	4.9	123	143	3.4	51
1252	+1½	+1	+1	+1									18	21	+8	5.0	41	48	2.2	19
1253	----	----	----	----	----	----	----	----	----	----	----	----	10	12	+8	4.9	17	20	2.2	11
1254	+1½	+1	+1	+1	----	----	----	----	----	----	----	----	18	21	+8	4.8	29	34	2.8	18
1255	+1½	+1	+1	+½	+½	0	0	−½	−½	−1	−1	−1	60	70	+8	5.0	109	127	3.8	35
1256	----	----	----	----	----	----	----	----	----	----	----	----	10	12	−3	4.9	78	91	3.4	35
1261	----	----	----	----	----	----	----	----	----	----	----	----	13	14	+8	4.9	22	28	1.3	11
1262	+1½	+1	+1	+1	----	----	----	----	----	----	----	----	18	21	+8	4.9	34	40	1.9	15
1263	+1½	+1	+1	+½	+½	0	0	−½	−½	−1	−1	−1	61	72	+8	5.0	106	119	4.7	35
1264	----	----	----	----	----	----	----	----	----	----	----	----	11	14	−3	5.0	148	170	4.3	54
1266	----	----	----	----	----	----	----	----	----	----	----	----	38	44	+8	5.0	38	41	1.9	33
1269	----	----	----	----	----	----	----	----	----	----	----	----	23	28	+8	4.9	34	40	1.9	24
1271	----	----	----	----	----	----	----	----	----	----	----	----	13	18	+8	4.9	34	38	2.2	14
1270	----	----	----	----	----	----	----	----	----	----	----	----	18	21	+8	4.9	34	39	2.2	19
1272	+1½	+1	+1	+1	----	----	----	----	----	----	----	----	29	34	+8	4.9	42	50	2.8	21
1274	+1½	+1	+1	+½	+½	0	0	−½	−½	−1	−1	−1	75	84	+8	4.8	100	116	3.8	30
1239	----	----	----	----	----	----	----	----	----	----	----	----	17	20	+8	4.9	29	34	1.6	13
1275	+1½	+1	+1	+1	----	----	----	----	----	----	----	----	29	35	+8	4.8	46	54	2.2	18
1276	+1½	+1	+1	+½	+½	0	0	−½	−½	−1	−1	−1	82	94	+8	4.9	142	165	3.4	45
1240	----	----	----	----	----	----	----	----	----	----	----	----	13	15	+8	5.0	31	36	1.6	11
1277	+1½	+1	+1	+1	----	----	----	----	----	----	----	----	22	26	+8	4.9	41	49	2.5	17
1278	+1½	+1	+1	+½	+½	0	0	−½	−½	−1	−1	−1	94	107	+8	5.0	166	198	3.8	58
1279	----	----	----	----	----	----	----	----	----	----	----	----	14	17	+8	5.1	27	32	1.6	16
1257	+1½	+1	+1	+1	----	----	----	----	----	----	----	----	25	29	+8	5.0	37	43	2.2	19
1280	+1½	+1	+1	+½	+½	0	0	−½	−½	−1	−1	−1	79	90	+8	4.9	129	152	3.4	44
1281	----	----	----	----	----	----	----	----	----	----	----	----	16	19	+8	4.9	28	34	1.3	11
1265	+1½	+1	+1	+1	----	----	----	----	----	----	----	----	33	40	+8	5.6	48	56	2.2	20
1282	+1½	+1	+1	+½	+½	0	0	−½	−½	−1	−1	−1	77	90	+8	4.9	132	153	3.7	44

See footnotes at end of table.

TABLE 2.—*Data on beating and condition of stock for different types of*

Paper machine run number	Beater furnish: Fiber (pulp)	Rosin [1]	Alum [1]	Position of beater roll after beating time of— 0.0 hr [4]	0.25 hr [5]	0.5 hr	1.0 hr	1.5 hr	2.0 hr	2.5 hr	3.0 hr	3.5 hr
		% [2]	% [3]									
1283	100% deinked book	1	2.2	+10	+10	+3	+3	+3	----	----	----	----
1284	do	1	2.8	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1285	do	1	3.0	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1286	50% deinked book and 50% eastern sulfite	1	2.3	+10	+10	+3	+3	+3	----	----	----	----
1287	do	1	2.4	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1288	do	1	2.4	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1298	100% ledger waste	1	1.2	+10	+10	+3	+3	+3	----	----	----	----
1299	do	1	1.2	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1300	do	1	1.3	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1301	50% ledger waste and 50% northern soda	1	1.9	+10	+10	+3	+3	+3	----	----	----	----
1302	do	1	1.9	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½
1303	do	1	1.9	+10	+10	+3	+3	+2½	+2½	+2	+2	+1½

[1] Rosin size was added 1 hour, and the alum ½ hour, before the stock was dropped to the beater chest.
[2] Based on dry weight of fiber.
[3] Based on dry weight of fiber and rosin.
[4] Lighter-bar up.
[5] Lighter-bar down.

The values indicate the number of milliliters of water, generally spoken of as quick-drainage water, discharged from the upper outlet when using 1 liter of stock at 0.2-percent consistency and 20° C.

The Williams precision freeness tester consists of a graduated glass cylinder placed above a metal cone having a valve in the bottom. A number 80 wire screen forms the bottom of the cylinder. To determine the freeness of stock, the apparatus is filled with clean water to the zero mark, which is slightly above the wire. One liter of the stock to be tested is poured into the cylinder, the valve is opened, and the time required for 1,000 ml of water to drain from the instrument is noted. Two sets of values, distinguished by the letters *A* and *B*, are reported. The values for *A* are for a sample containing 3 g of dry stock in 1,000 ml when added to the instrument, whereas the values for *B* are for a sample whose actual concentration in the cylinder of the instrument was 3 g of dry stock per 1,000 ml of mixture.

Fifty pounds of pulp was furnished to the beater in each instance with the following exceptions: for runs 1225–26–27–28–29–30–32, 1261–62–63–64, the amount was 48 pounds, and for run 1231, 40 pounds. These reductions were necessary to increase the rate of flow so that the circulation in the beater would be comparable in all instances. The beaten stock was dropped to a chest and pumped in a continuous stream through the stuff box and the jordan to the paper machine without the use of a machine chest. The stuff box was of the conventional regulating-box type, having a constant head over an adjustable orifice. Since the long-fibered stock showed a tendency to collect at the adjustable gate, it was necessary to agitate the stock above the gate. Screen plates with 0.018-inch slots were used for all the runs. The stock was uniformly mixed by baffles in the head box and the temperature of the stock was maintained at 90° F±2° at that point.

pulp furnishes in the study of experimental offset papers—Continued

Paper machine run number	Position of beater roll after beating time of—Continued 4.0 hr	4.5 hr	5.0 hr	5.5 hr	6.0 hr	6.5 hr	7.0 hr	7.5 hr	8.0 hr	8.5 hr	9.0 hr	9.5 hr	Freeness of stock completion of beating [6] A	B	Jordan setting	Acidity at head box quinhydrone method	Freeness of stock at head box [6] A	B	Sheet shrinkage in width as formed [7]	Distance water was carried beyond second slice [8]
													A	B		pH	A	B	%	*in.*
1283													114	129	+8	5.0	205	265	2.5	69
1284	+1½	+1	+1	+1									163	185	+8	5.1	285	400	2.2	([9])
1285	+1½	+1	+1	+½	+½	0	0	−½	−½	−1	−1	−1	625	730	+8	5.1	990	1170	3.4	([9])
1286													33	38	+8	5.0	79	94	2.5	16
1287	+1½	+1	+1	+1									53	62	+8	4.9	104	127	3.1	28
1288	+1½	+1	+1	+½	+½	0	0	−½	−½	−1	−1	−1	235	280	+8	5.0	420	520	4.0	78
1298													102	115	+8	5.0	265	305	2.8	54
1299	+1½	+1	+1	+1									184	210	+8	4.9	465	600	2.8	([9])
1300	+1½	+1	+1	+½	+½	0	0	−½	−½	−1	−1	−1	650	770	+8	4.9	1200	1360	4.0	([9])
1301													47	55	+8	4.9	80	95	2.5	19
1302	+1½	+1	+1	+1									82	98	+8	5.0	125	145	2.5	28
1303	+1½	+1	+1	+½	+½	0	0	−½	−½	−1	−1	−1	215	245	+8	5.0	400	520	3.8	72

[6] Values for runs 1225 to 1257, inclusive, were obtained on a Schooper-Riegler freeness tester (converted for comparison); for other runs, a Williams freeness tester was used.
[7] Change in width of dried sheet as wound on reel from width of sheet as formed on the machine.
[8] Measurement indicates point at which drainage of water off table rolls seemed practically to have stopped.
[9] To suction box.

Rosin size only was used, and the amount added was the same in all instances, 1 percent. Sufficient alum was used to obtain a pH of 5.0 and neither filler nor pigment was added.

There are two slices on the machine. The distance the water was carried beyond the second slice of the machine indicates the point at which drainage of water off the table rolls seemed to have practically stopped. The sheet shrinkage is the difference between the width of the dried sheet as wound on the reel and the width when formed on the machine wire. All the papers were given the same degree of calendering, 6 nips [7] of the machine calender being used.

Every effort was made to keep the entire machine operation the same for all of the runs, so that all of the differences found subsequently in the properties of the papers could be definitely ascribed to the controlled variations in beating.

2. TESTING

All the physical and chemical tests of the pulps and papers were made by the official methods [8] of the Technical Association of the Pulp and Paper Industry with the following exceptions, for which no official methods were available.

The bond test was that of Sutermeister and Osgood.[9] This test is essentially one of measuring the force required to split paper when the stress acts perpendicularly to its surface.

The degree of curl was determined by the Carson [10] method, which measures the maximum angle through which a specimen of the paper will curl when one side is placed in contact with water while the other side remains dry.

[7] A nip is the line of contact between two calender rolls.
[8] Copies of the official methods may be obtained from the Association at 122 East 42d St., New York, N. Y.
[9] Tech. Assn. Pap. **24**, 136 (1941).
[10] Paper Ind. Paper World **22**, 246 (June 1940).

The smoothness of the papers was determined with a Bekk [11] Smoothness Tester. This test consists in determining the time required to pass a given volume of air under controlled pressure between the surface of the paper in question and a polished metal plate which is held against the surface under a fixed pressure.

Permeability to air was measured with a Carson Precision Permeability Tester.[12] With this instrument the rate of air flow through the paper is measured for a given area with a pressure difference of 1 g/cm^2.

Two separate sets of the experimental papers were printed in five colors at the Coast and Geodetic Survey. A set comprised a number of sheets from each machine run. The purpose was to obtain data on the printing quality, that could be correlated with the information on fiber composition, degree of beating, and properties of the papers. One set of the papers was conditioned to equilibrium with a relative humidity 7 percent higher than that in the pressroom. Thus, this set was in the optimum hygrometric condition [13] for multicolor offset printing. The second set was conditioned to equilibrium with a humidity 20 percent below that in the pressroom in order to determine the degree of misregister when this paper was too dry for good results in multicolor work. Both sets were included in the same pile of paper, and printed without adjustment of the press other than was necessary to keep the feeders functioning. Considerable difficulty was encountered with the feed rollers owing to the wide range of papers, and as a result it was not possible to get comparable printing data on all of the papers.

V. DESCRIPTION OF EXPERIMENTAL PAPERS

Seven papers were made with the eastern sulfite pulp. For the first, machine run number 1225, table 3, the stock was given the minimum amount of beating required for forming a sheet. The beating was increased for each succeeding run, up to and including 1230, which was given the maximum beating that was practicable. From a consideration of the results of these variations, the three beating intervals, 1½, 5½, and 9½ hours, were selected as minimum, medium, and maximum beating treatments and were used with subsequent furnishes except some of the unmixed filler pulps which were too short and tender for such treatment. The jordan was used as a mixer only, except for a limited number of runs made for the express purpose of obtaining data on the effects of jordanning.

Data relative to the beater furnish, beating time, and condition for each paper-machine run, and on the properties of the resulting papers are given in table 3.

VI. INTERPRETATION AND DISCUSSION OF DATA

In order to facilitate an interpretation of the data, relationships between the most important factors and the properties of the finished papers are shown graphically in figures 1 to 6. In all of these figures, the scales are arranged so that the data for the different properties are directly comparable irrespective of their absolute values. For the

[11] Paper Trade J. **94**, 41 (June 30, 1932).
[12] BS J. Research **12**, 567 (1934) RP681.
[13] J. Research NBS **16**, 93–103 (1936) RP859.

properties for which low values are desirable, the scales are inverted so that, in all instances, a relatively high position on the scale indicates excellence from the standpoint of utility and, conversely, a low position does not. The arbitrary division into three classes according to position on the scale is to make it easier to read.

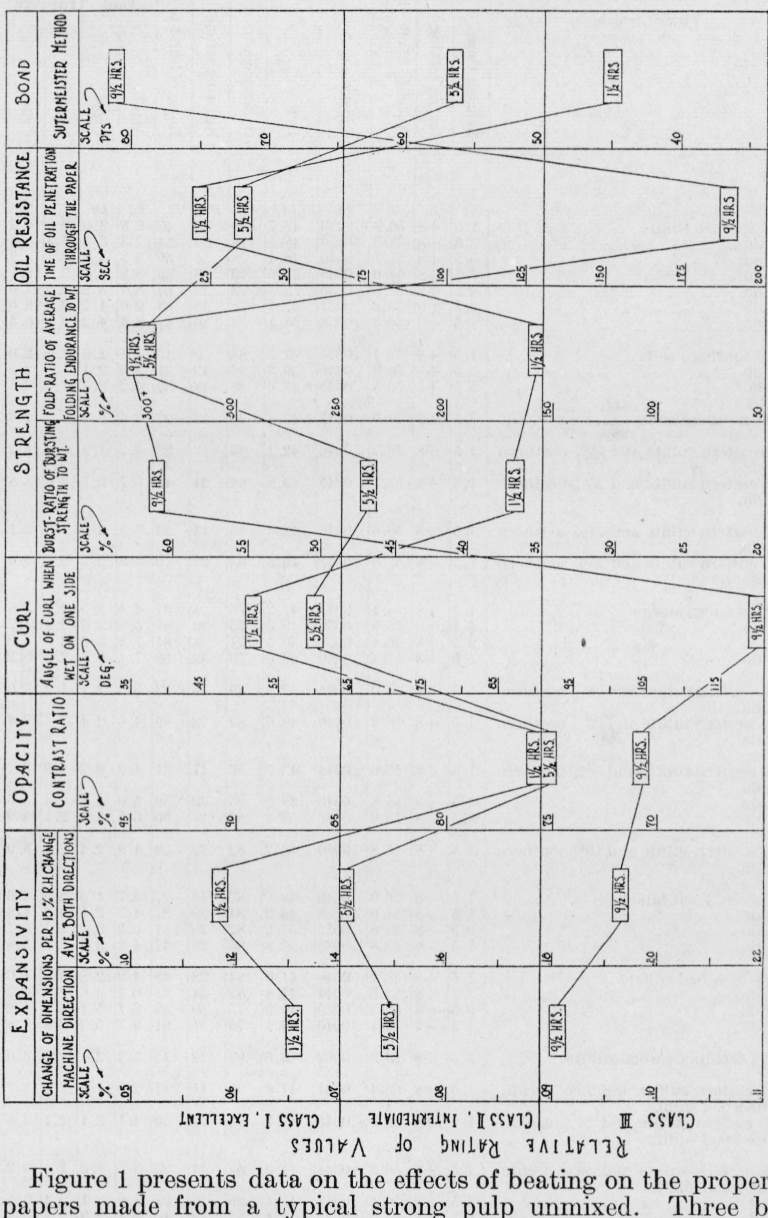

FIGURE 1.—*Effects of degree of beating on properties of papers made from a fiber furnish of 100-percent sulfite (western hemlock) pulp.*

Beating intervals, 1½ hours or minimum, 5½ hours or medium, and 9½ hours or maximum.

Figure 1 presents data on the effects of beating on the properties of papers made from a typical strong pulp unmixed. Three beating intervals, minimum, medium, and maximum, are represented. Figure 2 presents comparable data for papers made of the same strong pulp in 50–50 mixture with a typical filler pulp. It is important to note in figure 1 that as the strength properties are improved by increased

TABLE 3.—*Properties of ex*

Paper machine run number	Fiber furnish	Beating time	Jordan setting	Weight 25x40 inches, 500 sheets	Thickness	Density	Opacity contrast ratio	Bursting strength	Ratio of burst to weight	Tensile properties: Breaking load, Mach.	Tensile properties: Breaking load, Cross	Tensile properties: Elongation at rupture, Mach.	Tensile properties: Elongation at rupture, Cross
		hr		*lb*	*in*	*lb/ft³*	*%*	*Pts*	*%*	*kg*	*kg*	*%*	*%*
1225	100% eastern sulfite	1.5	+8	56.3	0.0040	48.7	79	26	47	6.8	3.0	2.0	4.2
1226	do	3.5	+8	54.3	.0039	48.1	78	29	54	7.3	3.3	2.3	4.4
1227	do	5.5	+8	57.1	.0040	49.4	78	34	59	8.3	3.6	2.4	5.3
1229	do	7.5	+8	57.0	.0039	50.6	76	39	69	8.9	4.1	2.5	5.7
1230	do	9.5	+8	55.5	.0036	53.3	73	36	64	8.9	3.9	2.5	7.0
1231	do	2.5	0	55.8	.0037	52.1	74	35	63	9.0	4.2	2.0	6.0
1232	do	1.5	−3	56.3	.0036	54.1	74	36	64	8.4	4.2	2.5	6.5
1233	100% southern soda	1.5	+8	57.4	.0053	37.3	88	9	15	2.3	1.6	1.0	2.0
1234	do	3.5	+8	56.9	.0050	39.3	86	12	21	3.3	2.1	1.5	2.5
1235	do	5.5	+8	56.8	.0045	43.6	85	18	32	4.2	2.7	1.5	3.5
1236	100% northern soda	3.5	+8	54.9	.0047	40.4	90	12	22	3.6	2.3	1.3	2.3
1237	25% eastern sulfite and 75% northern soda.	1.5	+8	56.2	.0046	42.1	89	13	23	3.2	1.9	1.3	2.2
1241	75% eastern sulfite and 25% northern soda.	1.5	+8	57.1	.0045	43.8	84	24	42	5.7	2.7	2.0	3.8
1238	25% eastern sulfite and 75% southern soda.	1.5	+8	56.6	.0046	42.4	86	13	23	3.3	2.0	1.3	2.1
1242	75% eastern sulfite and 25% southern soda.	1.5	+8	57.0	.0043	45.9	83	23	40	5.3	2.7	2.1	3.6
1243	100% western sulfite	1.5	+8	56.1	.0041	47.3	76	21	37	4.4	2.5	2.5	3.8
1244	do	5.5	+8	55.9	.0039	49.6	75	26	47	5.9	3.0	2.4	4.7
1245	do	9.5	+8	55.4	.0038	50.5	71	34	61	7.8	3.6	3.0	7.0
1246	do	1.5	−3	57.4	.0040	49.6	73	32	56	7.4	3.7	2.2	6.2
1249	25% western sulfite and 75% northern soda.	1.5	+8	55.3	.0045	42.5	89	13	23	3.5	2.1	1.2	3.0
1247	75% western sulfite and 25% northern soda.	1.5	+8	56.2	.0040	48.6	82	22	39	4.6	2.4	2.6	3.8
1248	50% western sulfite and 50% northern soda	1.5	+8	55.6	.0044	43.7	86	17	31	4.2	2.2	1.8	3.2
1250	do	5.5	+8	55.8	.0040	48.2	85	20	36	5.0	2.4	2.0	3.6
1251	do	9.5	+8	53.9	.0035	53.3	82	27	50	6.6	3.4	2.3	5.9
1252	50% western sulfite and 50% southern soda.	5.5	+8	55.8	.0040	48.2	82	22	39	4.9	2.4	2.1	3.9
1253	100% No. 1 soft alpha	1.5	+8	56.3	.0040	48.7	87	15	27	2.7	1.3	3.0	3.6
1254	do	5.5	+8	54.0	.0038	49.2	84	20	37	4.3	2.1	2.7	4.8
1255	do	9.5	+8	54.8	.0035	54.2	82	28	51	6.2	3.2	3.1	6.7
1256	do	1.5	−3	55.8	.0038	50.8	85	26	47	5.8	3.1	2.6	5.8
1261	100% bleached sulfate	1.5	+8	58.1	.0049	41.0	84	28	48	4.9	2.8	3.0	4.0
1262	do	5.5	+8	55.8	.0044	43.8	82	34	61	6.2	3.6	2.8	4.7
1263	do	9.5	+8	56.3	.0039	49.9	75	50	89	9.7	5.1	3.5	8.2
1264	do	1.5	−3	56.1	.0040	49.7	76	51	91	9.7	5.2	3.8	7.8
1266	100% deciduous-wood sulfite	3.5	+8	78.3	.0062	43.6	93	12	15	3.2	2.1	1.6	3.0
1269	25% eastern sulfite and 75% deciduous-wood sulfite.	1.5	+8	65.4	.0054	41.8	90	11	17	2.9	1.7	1.8	2.7
1271	75% eastern sulfite and 25% deciduous-wood sulfite.	1.5	+8	56.9	.0045	43.7	84	17	30	4.1	2.1	2.1	3.5
1270	50% eastern sulfite and 50% deciduous-wood sulfite.	1.5	+8	56.3	.0044	44.2	87	14	25	3.3	1.6	2.1	3.2
1272	do	5.5	+8	56.1	.0043	45.1	86	16	28	3.9	2.1	2.4	3.5
1274	do	9.5	+8	55.5	.0035	54.8	85	22	40	5.4	2.9	2.5	5.3
1239	50% eastern sulfite and 50% northern soda.	1.5	+8	56.8	.0044	44.5	86	19	33	4.9	2.3	1.9	3.2
1275	do	5.5	+8	55.4	.0042	45.6	89	19	34	4.9	2.5	1.9	3.3
1276	do	9.5	+8	55.9	.0037	52.2	86	27	48	6.9	3.9	2.5	5.7

perimental offset papers [1]

Paper machine run number	Tearing strength: Mach.	Tearing strength: Cross	Folding endurance (Schopper): Mach.	Folding endurance (Schopper): Cross	Expansivity per 15% relative humidity variation, Direction: Mach.	Expansivity per 15% relative humidity variation, Direction: Cross	Curl	Smoothness (Bekk instrument)	Air permeability	Oil penetration	Sizing value (Dry indicator method)	Bond test	Printing-test data: Register rating [2]	Printing-test data: Show through rating [3]	Printing-test data: Pick [4]
	g	*g*	*Double folds*	*Double folds*	%	%	*Degrees*	*Seconds*	$(cm^3/m^2)/sec$ / g/cm^2	*Seconds*	*Seconds*	*lb*			*Color number*
1225	99	115	1088	95	0.072	0.200	69	26	447	46	29	46.5	Poor	48	------
1226	93	99	1724	173	.074	.220	87	24	288	56	30	56.0	Fair	54	------
1227	98	105	2629	276	.079	.260	96	27	232	62	31	62.0	do	55	------
1229	86	91	2660	672	.081	.300	155	17	80	163	31	82.3	do	56	------
1230	72	91	1850	726	.088	.316	180+	18	25	336	36	99.0	do	57	------
1231	73	93	1630	774	.085	.285	172	24	25	426	36	87.7	do	58	------
1232	73	90	2049	873	.093	.307	180+	20	14	480	36	88.3	do	59	------
1233	46	34	1	1	.055	.127	19	12	4,010	18	31	18.7	Good	10	2 to 5
1234	45	45	3	2	.062	.143	32	16	2,260	23	32	36.1	do	11	5
1235	41	46	6	3	.067	.173	50	22	911	35	33	56.6	Fair	12	------
1236	38	41	4	2	.059	.140	25	22	2,014	13	36	35.4	Good	13	5
1237	61	69	7	3	.066	.131	25	24	1,972	15	39	25.7	do	30	5
1241	86	100	234	34	.074	.176	50	28	668	30	52	39.2	do	35	5
1238	72	78	8	4	.072	.139	27	20	1,990	18	40	25.0	do	31	5
1242	88	91	207	26	.077	.175	54	25	670	24	51	42.4	Fair	49	------
1243	148	150	141	33	.066	.172	52	19	1,236	20	49	44.3	do	60	------
1244	126	144	390	58	.075	.207	60	20	570	32	51	55.7	do	61	------
1245	97	102	1527	342	.091	.284	180+	17	52	195	58	85.8	do	62	------
1246	94	109	1492	264	.083	.312	180+	14	39	228	60	75.0	do	63	------
1249	61	90	7	3	.066	.141	29	26	2,221	13	38	29.7	do	18	------
1247	124	141	116	18	.071	.154	49	23	1,074	16	36	45.6	Good	64	------
1248	101	98	31	8	.069	.151	35	28	1,437	13	38	37.9	do	17	5
1250	90	114	63	13	.073	.171	46	41	851	20	36	49.3	Fair	19	5
1251	70	81	344	57	.082	.209	86	45	119	104	36	80.5	Poor	20	------
1252	103	107	60	15	.076	.177	40	23	923	25	39	49.4	Fair	21	------
1253	111	142	19	8	.100	.207	53	39	1,627	16	33	32.6	------	39	------
1254	99	106	118	25	.102	.234	74	48	626	31	33	58.9	------	40	------
1255	68	71	791	63	.098	.305	180+	53	99	102	33	94.0	Poor	41	------
1256	74	83	446	60	.094	.290	140	62	134	111	33	73.8	Fair	42	------
1261	162	180	177	63	.081	.175	30	14	1,635	26	29	37.1	Good	50	5
1262	165	177	1200	319	.087	.179	51	15	843	37	38	52.6	Fair	51	------
1263	128	113	2790	2254	.099	.315	162	12	77	203	38	97.2	do	52	------
1264	127	118	3090	2384	.085	.270	148	14	39	408	35	88.8	Poor	53	------
1266	45	43	2	2	.093	.197	21	19	1,169	25	46	32.9	Fair	5	2 to 5
1269	61	71	4	2	.074	.171	29	20	1,414	18	38	25.3	Good	43	2 to 5
1271	92	107	62	15	.074	.193	43	36	699	33	33	34.8	Fair	45	------
1270	73	83	16	4	.074	.187	38	34	1,115	22	32	31.7	------	44	5
1272	72	85	30	7	.076	.234	45	35	744	32	32	40.5	Poor	46	------
1274	60	56	129	47	.081	.240	103	47	139	117	37	75.1	Fair	47	------
1239	74	83	54	11	.070	.157	38	33	935	22	37	35.8	do	33	5
1275	71	82	62	13	.068	.177	47	32	719	35	31	46.2	------	6	5
1276	59	55	348	82	.082	.223	100	35	98	149	42	85.5	Poor	26	------

TABLE 3.—*Properties of experi*

Paper machine run number	Fiber furnish	Beating time	Jordan setting	Weight 25x40 inches, 500 sheets	Thickness	Density	Opacity contrast ratio	Bursting strength	Ratio of burst to weight	Tensile properties: Breaking load, Mach.	Tensile properties: Breaking load, Cross	Tensile properties: Elongation at rupture, Mach.	Tensile properties: Elongation at rupture, Cross
		hr		*lb*	*in.*	*lb/ft*³	*%*	*Pts*	*%*	*kg*	*kg*	*%*	*%*
1240	50% eastern sulfite and 50% southern soda.	1.5	+8	56.1	.0046	42.1	84	18	32	4.8	2.5	1.8	3.2
1277	do	5.5	+8	56.2	.0042	46.2	86	19	34	4.7	2.7	2.0	3.9
1278	do	9.5	+8	56.4	.0038	51.2	83	28	49	6.8	3.6	2.8	5.5
1279	50% No. 1 soft alpha and 50% northern soda.	1.5	+8	75.9	.0062	42.3	94	14	18	3.9	2.1	1.7	2.8
1257	do	5.5	+8	53.8	.0042	44.3	88	16	30	3.9	2.2	2.2	4.4
1280	do	9.5	+8	54.3	.0038	49.3	88	23	43	5.2	2.8	2.3	4.6
1281	50% bleached sulfate and 50% northern soda.	1.5	+8	58.1	.0047	42.7	88	14	24	3.5	2.2	1.4	2.7
1265	do	5.5	+8	56.5	.0045	43.4	87	22	39	5.1	2.5	2.4	3.9
1282	do	9.5	+8	56.7	.0039	50.3	83	33	58	7.3	4.3	2.7	5.8
1283	100% deinked book	1.5	+8	54.9	.0035	54.2	95	14	25	3.3	1.8	1.6	3.3
1284	do	5.5	+8	54.8	.0035	54.1	95	16	30	4.0	2.4	2.3	4.0
1285	do	9.5	+8	54.9	.0030	63.2	93	16	29	4.3	2.3	2.0	3.5
1286	50% deinked book and 50% eastern sulfite.	1.5	+8	55.5	.0035	54.7	90	19	35	4.8	2.3	1.8	3.7
1287	do	5.5	+8	55.4	.0033	58.1	88	24	43	6.1	2.7	2.4	4.7
1288	do	9.5	+8	54.0	.0035	53.2	86	28	52	6.8	3.7	2.6	6.6
1298	100% ledger waste	1.5	+8	54.9	.0040	47.5	86	19	35	3.7	2.6	2.3	3.9
1299	do	5.5	+8	55.1	.0039	48.9	86	21	38	4.4	3.1	2.8	4.3
1300	do	9.5	+8	54.7	.0037	51.8	84	22	40	5.6	3.2	2.4	4.8
1301	50% ledger waste and 50% northern soda.	1.5	+8	56.0	.0045	43.5	89	15	27	3.8	2.2	1.9	3.3
1302	do	5 5	+8	56.2	.0045	43.2	88	17	30	4.4	2.7	2.0	3.6
1303	do	9.5	+8	54.9	.0040	47.4	87	21	38	4.8	3.5	2.5	5.1

[1] All physical tests made under conditions of 65 percent relative humidity and 70°F.
[2] Comparative register rating.

mental offset papers [1]—Continued

Paper machine run number	Tearing strength: Mach.	Tearing strength: Cross	Folding endurance (Schopper): Mach.	Folding endurance (Schopper): Cross	Expansivity per 15% relative humidity variation, Direction: Mach.	Expansivity per 15% relative humidity variation, Direction: Cross	Curl	Smoothness (Bekk instrument)	Air permeability	Oil penetration	Sizing value (Dry indicator method)	Bond test	Printing-test data: Register rating [2]	Printing-test data: Show-through rating [3]	Printing-test data: Pick [4]
	g	*g*	*Double folds*	*Double folds*	*%*	*%*	*Degrees*	*Seconds*	*(cm³/m²)/sec g/cm²*	*Seconds*	*Seconds*	*lb.*			*Color number*
1240	79	81	47	11	.073	.162	36	21	1,062	22	50	32.9	Good	34	5
1277	73	76	44	21	.069	.172	44	29	659	41	33	48.4	Fair	27	5
1278	54	54	273	81	.089	.243	110	26	67	224	42	89.0	do	28	
1279	115	111	14	4	.074	.166	20	20	1,363	29	40	27.6	do	4	5
1257	71	93	24	8	.092	.221	42	42	998	26	34	50.7	Good	23	
1280	52	61	59	26	.092	.261	75	52	152	98	32	87.7	Fair	29	
1281	96	109	17	7	.074	.145	22	19	1,740	18	29	29.4	do	8	5
1265	104	113	91	20	.090	.194	33	24	1,018	33	30	46.9	do	22	5
1282	88	86	704	231	.085	.244	72	29	160	97	36	85.4	Poor	32	
1283	48	55	9	6	.079	.179	58	75	114	108	10	51.6		1	
1284	47	53	19	11	.090	.184	68	90	76	163	12	60.1		2	
1285	36	40	26	13	.100	.246	180+	63	19	343	10	99.1	Poor	3	
1286	68	85	97	20	.070	.205	59	54	244	60	22	51.6		9	
1287	62	71	338	31	.071	.214	91	69	138	98	27	66.4	Poor	24	
1288	53	55	482	265	.094	.256	180+	38	22	415	24	97.2	do	25	
1298	49	53	20	14	.087	.168	57	36	83	186	28	69.6	Good	36	
1299	52	53	22	19	.091	.187	84	36	51	253	31	77.9	Poor	37	
1300	41	43	23	21	.095	.242	151	32	18	466	33	108.3	do	38	
1301	51	55	9	4	.071	.144	30	31	514	62	31	49.1	Good	14	
1302	51	53	14	8	.071	.154	37	35	313	82	35	62.7	Fair	15	
1303	43	48	14	12	.081	.192	78	29	72	212	35	95.2	do	16	

[3] Relative amounts, in increasing order.
[4] Color number at which pick is first noted.

beating, the important properties of expansivity, opacity, oil absorption, and tendency to curl are affected adversely. By a comparison of figures 1 and 2, it will be readily seen that the addition of filler pulp

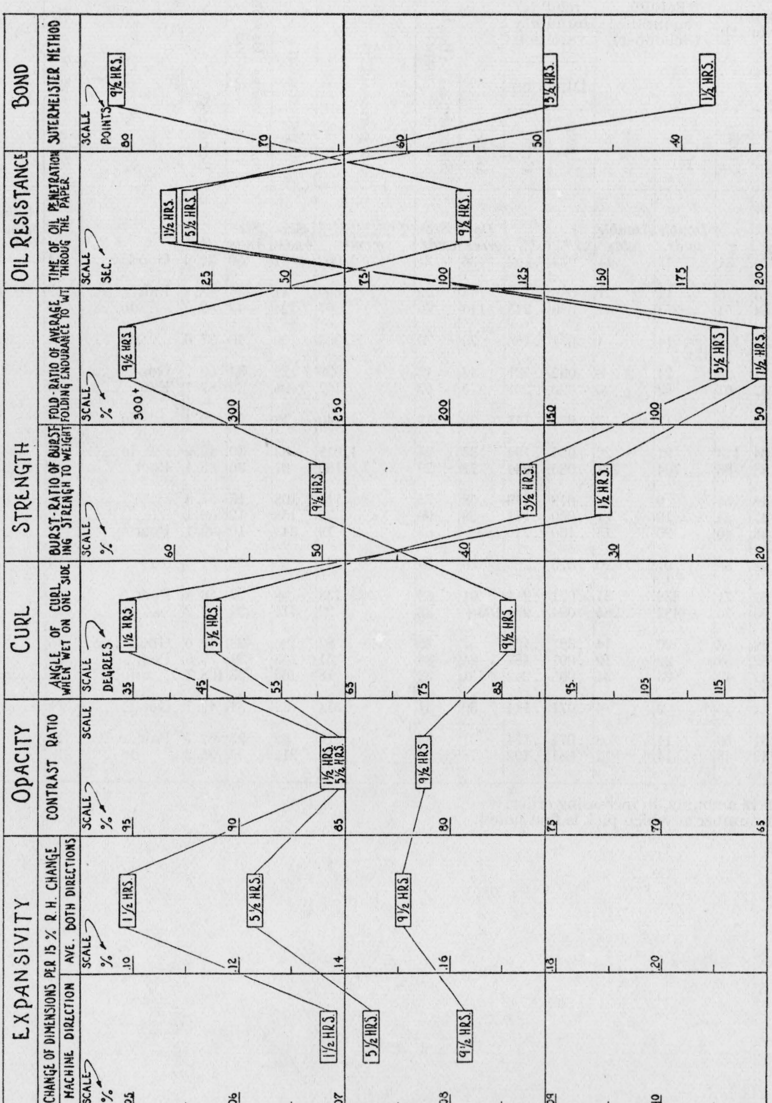

FIGURE 2.—*Effects of degree of beating on properties of papers made from a fiber furnish of 50-percent sulfite (western hemlock) and 50-percent soda pulp.*

retards the adverse effects of beating, so that the sulfite-soda paper with the maximum beating has a better average value than the all-sulfite paper with the medium beating.

Figures 3 and 4 show graphically the comparative properties of papers made of different fibers, unmixed, with like beating treatments.

The beating for all the papers shown in figure 3 was medium, or 5½ hours, and for those in figure 4, maximum, or 9½ hours. It will be noted that for the medium beating, only 23 percent fall below class II,

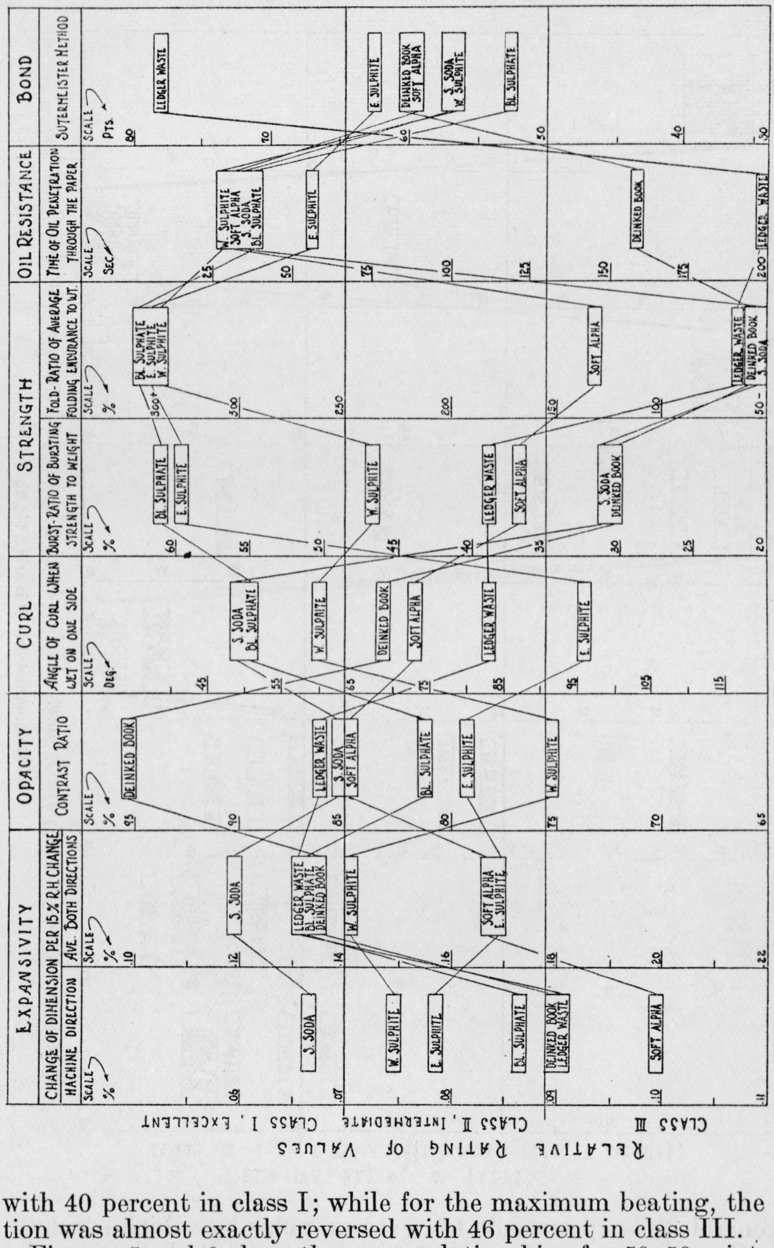

FIGURE 3.—*Properties of papers made with like beating treatment from unmixed fiber furnishes.*

Medium degree of beating, 5½ hours.

with 40 percent in class I; while for the maximum beating, the situation was almost exactly reversed with 46 percent in class III.

Figures 5 and 6 show the same relationships for 50–50 mixtures of strong pulps and filler pulp as are shown for the unmixed strong pulps in figures 3 and 4, respectively. The effects on the properties of paper of adding filler pulp to any specific strong pulp can be conveniently noted by comparing the positions of the unmixed papers in figures 3 and 4 with the relative positions of the mixtures of the selected strong pulp and a filler pulp in figures 5 and 6, respectively.

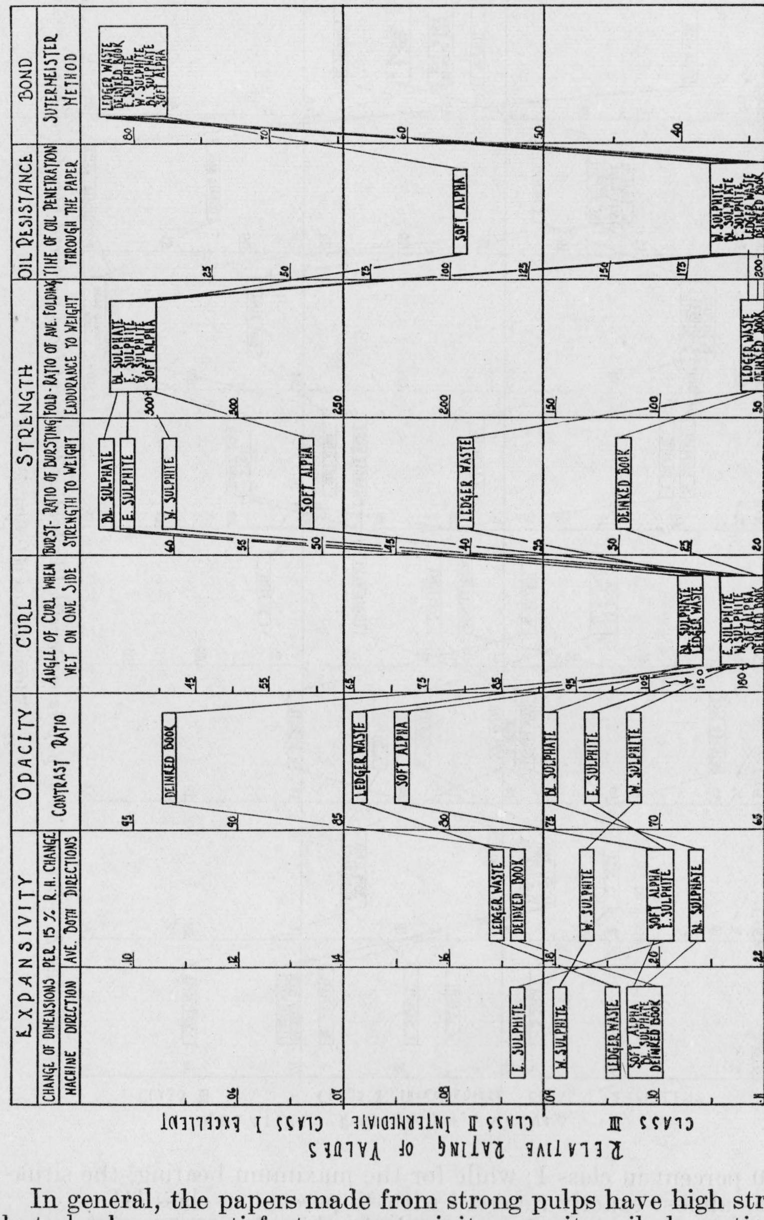

FIGURE 4.—*Properties of papers made with like beating treatment from unmixed fiber furnishes.*

Maximum degree of beating, 9½ hours.

In general, the papers made from strong pulps have high strength, but also have unsatisfactory expansivity, opacity, oil absorption, and curling properties. The filler pulps are excellent in these latter respects, but they have insufficient strength to be used unmixed. The data show that the strength of the papers made from the strong pulps is developed largely by beating, and is closely associated with gel formation or so-called hydration, and this produces the undesirable properties. Filler pulps hydrate only slightly. Hence, the best all-

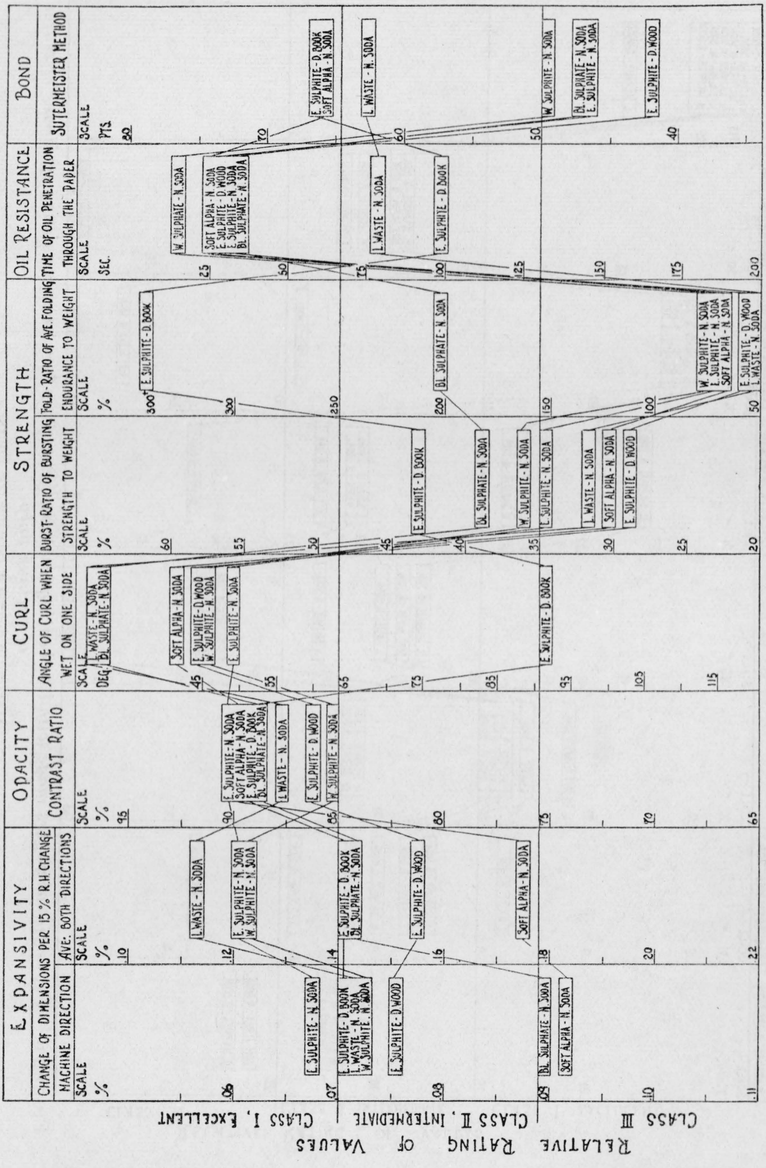

FIGURE 5.—*Properties of papers made with like beating treatment from fiber furnishes consisting of 50–50 mixtures of various pulps.*

Medium degree of beating, 5½ hours.

around properties in an offset paper are obtained by blending strong pulp with filler pulp. The admixture of the filler pulp tends to permit sufficient beating to obtain suitable formation and finish without all of the undesirable effects of hydration. The effects of blending are illustrated in figures 1 to 6. They become evident when the papers are graded, if 100 percent is assumed for a paper that is class I in all respects. This may be done arbitrarily by allowing 12½, 8, or 4 percent for each property for classes I, II, and III, respectively. A

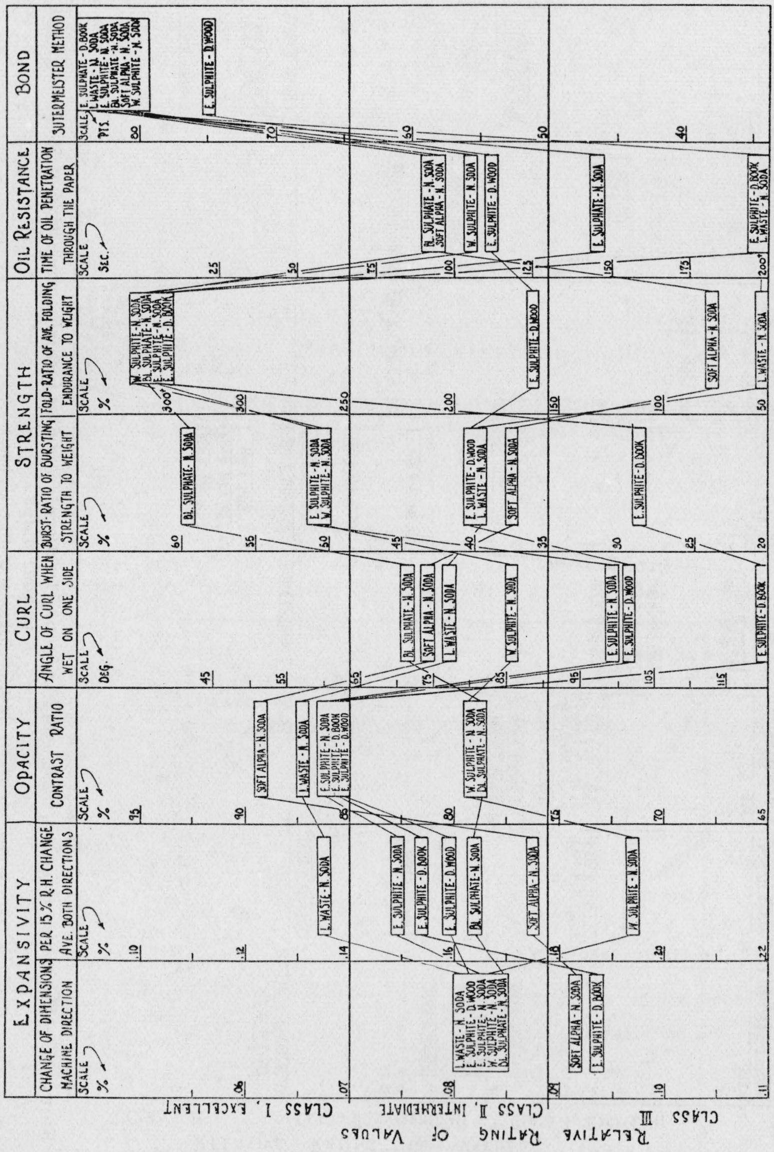

FIGURE 6.—*Properties of papers made with like beating treatment from fiber furnishes consisting of 50–50 mixtures of various pulps.*

Maximum degree of beating, 9½ hours.

summary of ratings obtained by this method is given in table 4. Figures 3 to 6, were not extended to include minimum beating, because none of those papers with less than the medium degree of beating had suitable formation to be of interest as printing papers.

TABLE 4.—*Ratings of papers in figures 1 to 6*

Fiber furnish	Rating values		
	Minimum beating	Medium beating	Maximum beating
	Percent	*Percent*	*Percent*
Western sulfite	78.0	73.5	57.5
50% western sulfite, 50% soda	74.5	74.0	73.5
Eastern sulfite		73.5	61.5
50% eastern sulfite, 50% soda		74.0	74.0
Bleached sulfate		86.5	57.5
50% bleached sulfate, 50% soda		69.5	77.5
Soft alpha		60.5	65.5
50% soft alpha, 50% soda		70.0	65.0
Ledger waste		69.5	52.5
50% ledger waste, 50% soda		69.5	69.5
Soda		78.5	
Deinked book		61.0	52.5
Average unmixed	78.0	68.4	56.5
Average 50 : 50% mixtures	74.5	70.9	71.7

The medium beating represents about the minimum required to produce the formation, finish, and bonding strength necessary for printing.

The sulfite-soda mixtures had the best average values. However, bleached sulfate had the highest average of any unmixed fiber in the medium beating class, and in mixture with filler pulp, it had the highest rating of those beaten for the maximum period. Hence this pulp appears to offer certain advantages where beating for high strength is important.

It is noteworthy that a high fold ratio is consistently opposed to some of the other desirable properties of the papers, particularly low

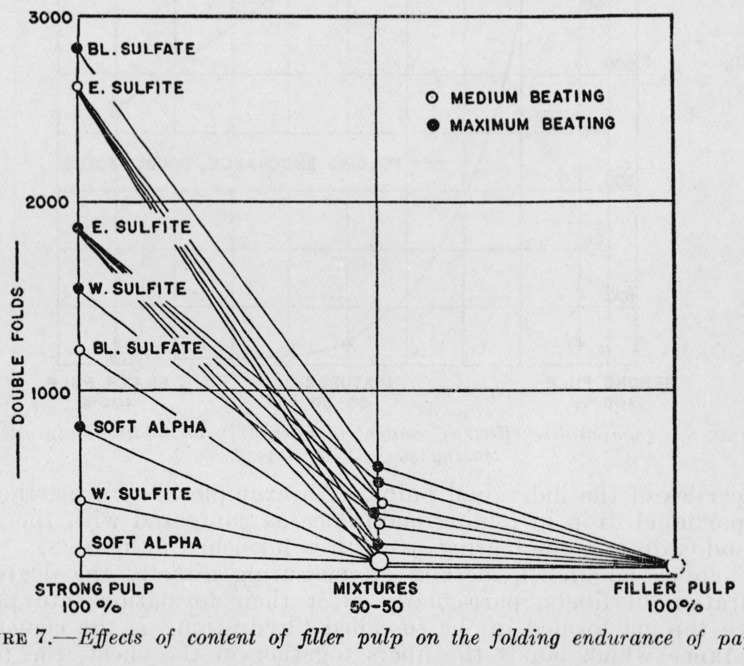

FIGURE 7.—*Effects of content of filler pulp on the folding endurance of papers.*

expansivity and curl, and high opacity. It is of interest also that a paper made of a mixture of two pulps usually has a fold value little higher than that of the weaker pulp instead of approaching the average as one might expect, and as is the case with other strength properties. This disproportional drop in folding endurance with the addition of a filler pulp to a strong pulp was noted for all the mixed furnishes. It is illustrated graphically in figure 7. Other important strength properties conform more closely to the values calculated from the

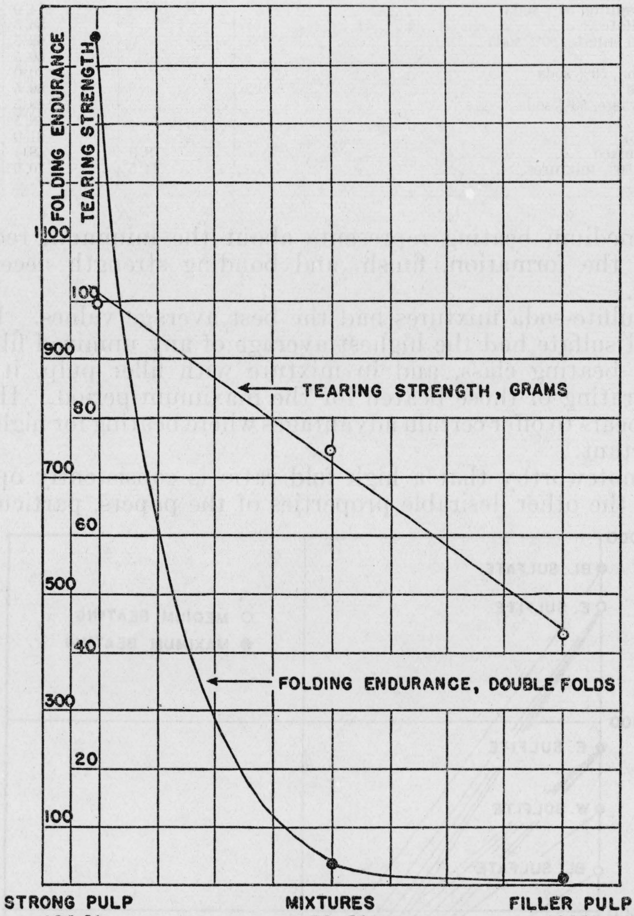

FIGURE 8.—*Comparative effects of content of filler pulp on folding endurance and tearing strength of papers.*

properties of the individual pulps. An example illustrating the disproportional drop in folding endurance as compared with the more orthodox drop in the tearing strength is furnished in figure 8.

There is no known method of measuring directly the degree of hydration of fibers, particularly after their formation into paper. Since the gel formed in the so-called "hydration" is the cementing substance which bonds the fibers together in the sheet, the bond-strength values are assumed to be roughly indicative of the degree of hydration. Figure 9, which shows the relationship between the degree of beating and bond values, indicates the correctness of that assumption, at least insofar as the degree of beating controls hydration.

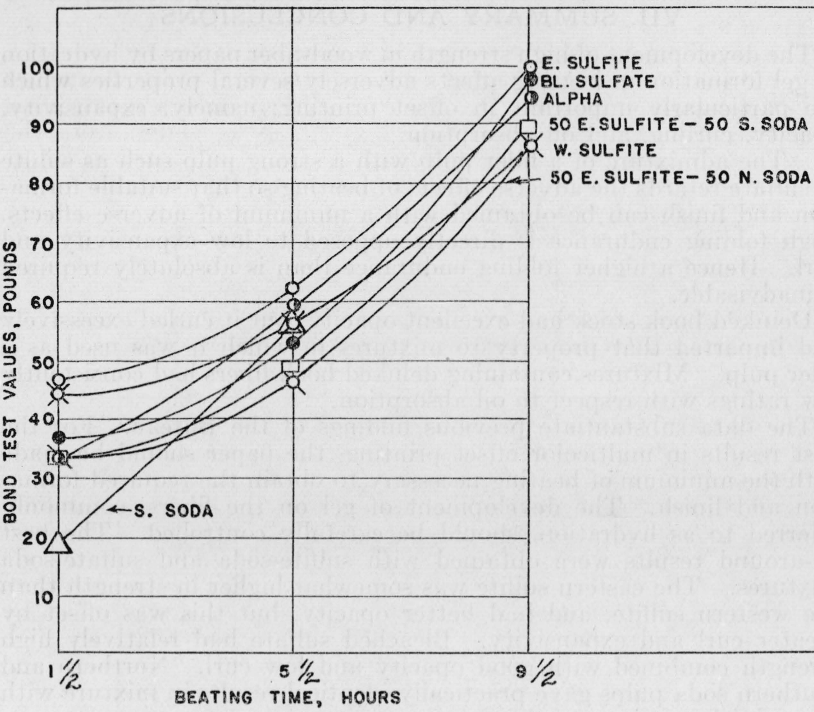

FIGURE 9.—*Effects of degree of beating on the bond strength of papers.*

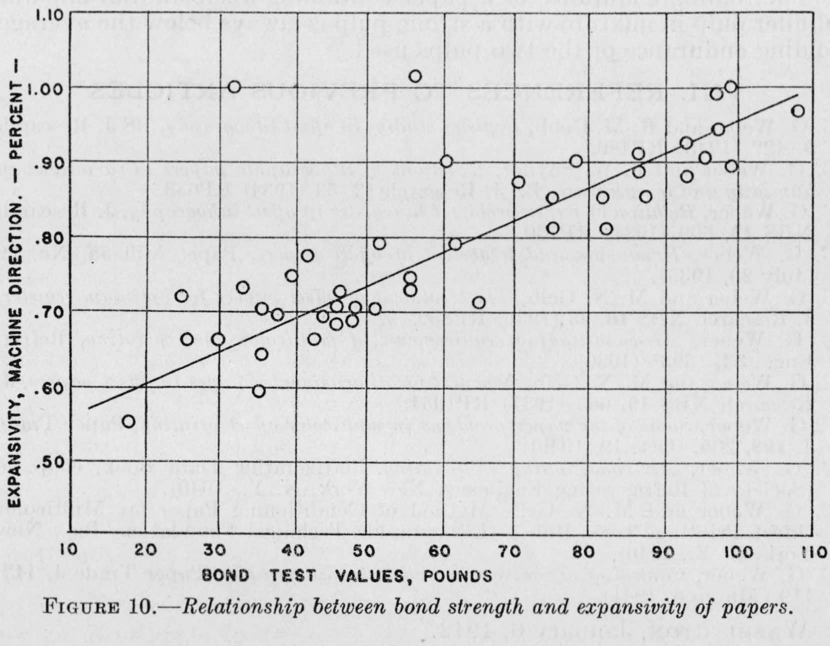

FIGURE 10.—*Relationship between bond strength and expansivity of papers.*

Figure 10 shows a surprising relationship between bond-strength values and expansivity.

VII. SUMMARY AND CONCLUSIONS

The development of high strength in wood-fiber papers by hydration or gel formation in beating affects adversely several properties which are particularly important in offset printing; namely, expansivity, opacity, curling, and oil absorption.

The admixture of a filler pulp with a strong pulp such as sulfite or sulfate retards the adverse effects of beating so that suitable formation and finish can be obtained with a minimum of adverse effects. High folding endurance is directly opposed to low expansivity and curl. Hence a higher folding endurance than is absolutely required is inadvisable.

Deinked book stock had excellent opacity, but it curled excessively and imparted that property to mixtures in which it was used as a filler pulp. Mixtures containing deinked book fibers had consistently low ratings with respect to oil absorption.

The data substantiate previous findings of the Bureau. For the best results in multicolor offset printing, the paper should be made with the minimum of beating necessary to obtain the required formation and finish. The development of gel on the fibers, commonly referred to as hydration, should be carefully controlled. The best all-around results were obtained with sulfite-soda and sulfate-soda mixtures. The eastern sulfite was somewhat higher in strength than the western sulfite, and had better opacity, but this was offset by greater curl and expansivity. Bleached sulfate had relatively high strength combined with good opacity and low curl. Northern and southern soda pulps gave practically identical results in mixture with strong pulps.

The folding endurance of a paper containing a substantial amount of filler pulp in mixture with a strong pulp is always below the average folding endurance of the two pulps used.

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