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COMPARISON OF AMERICAN AND FOREIGN CLAYS AS PAPER FILLERS

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Bureau of Standards

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By Merle B. Shaw and George W. Bicking

ABSTRACT

The purpose of this investigation was to ascertain the relative merits of American and foreign clays for use as paper fillers.

Most of the tests were made in the experimental paper mill of the Bureau of Standards, although duplicate tests of part of the work were made in a commercial paper mill. Eight representative clays were used. Preliminary runs were made to establish best method of handling clay and to determine constant factors. Comparative tests were made varying kind and percentage of clay, and using both fresh water and machine water for the paper runs.

The comparative study included the amount of clay retained in the paper, the quality of the paper produced, and those physical properties of the clay (grit, etc.) that might affect the paper-manufacturing processes. Measurements for clay retention include analyses of samples taken at 13 different positions on the paper machine. The results show that the amount of clay retained in the finished paper and the quality of the paper, in general, are the same for both American and foreign clays. The color and grit tests favor very slightly the foreign clays,[1] but not sufficiently to justify the consideration of only these properties in selecting clays.

The results of the commercial-mill test agree with those of the duplicate work in the experimental mill. They also include additional data on white-water losses and the value of a save-all for recovery of materials.

Tests for physical properties of the clays failed to show any correlation between such properties and amount of clay retention in the paper, but data on these tests are given for their general interest.

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[1] Since the completion of this investigation two samples of domestic clays as white or whiter than the foreign clays included herein have been received for examination.

I. PURPOSE OF INVESTIGATION

There are approximately from 200,000 to 300,000 tons of clay used annually in the paper industry of the United States. Considering that the larger portion of this amount is of foreign source and that the clay resources of the United States are to a great extent undeveloped, the investigation herein reported was made to ascertain the relative merits of American and foreign clays for use as paper fillers. Since it is believed that more general use of domestic clays is in many cases restricted by prejudice, it was purposed to study American and foreign clays comparatively with regard to physical properties and also actual behavior under paper-manufacturing conditions. This latter study necessarily includes degree of retention in paper, reuse of backwaters, and influence upon quality of finished paper.

II. MATERIALS USED

1. PULPS

The pulps used for this investigation were 50 per cent sulphite and 50 per cent soda. Grellet Collins, president of Dill & Collins Co., Philadelphia, Pa., kindly made 4,500 pounds of bleached soda pulp available for this work.

2. CLAYS

(*a*) General Characteristics of Paper-Making Clays.—The term "clay" is applied to a variety of earthy substances, differing widely in their origin and composition and in many of their physical properties. The essential requirements of paper-making clays are: Good white color; low content of grit, mica, and other impurities; and uniformity. The first requirement must be possessed by the clay in its original state, but the percentage of impurities, such as grit and mica, can be lowered by washing and separation.[2]

To judge the quality of a good clay by feel or touch requires long experience, and a written description of such a method is, at best, inadequate. In general, however, it can be said that it has a greasy feel, adheres to the tongue when placed upon it, and disintegrates readily when mixed with water.

Preliminary examination was made of 38 samples of clays, 18 of which were foreign and 20 domestic. The clays were compared as to grit content, color, and plasticity and, considering these properties as well as the sources of the clays, eight representative samples were selected for paper-making tests. Clays numbered 1 to 5 are of domestic origin; numbered 6 to 8 are foreign.

(*b*) Sources of Clays Used in Tests.—The sources of the clays and the treatment given before shipment were as follows:

No. 1. Mined in South Carolina. The company which handles it says: "* * * is very carefully selected, likewise very carefully dried, and again selected, and then refined by the Raymond pulverizing process, which reduces the clay to a very fine powder."

No. 2. Mined in Georgia, "* * * and air dried in open sheds before shipment. It is not given any treatment, but shipped in its natural state."

No. 3. Mined in Georgia, and washed before shipment.

No. 4. Mined in South Carolina. No information was given as to its preparation.

No. 5. Mined in Virginia. No information was given as to its preparation.

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[2] All clays can be classed as either primary or secondary. Primary (sometimes called "residual") clays are those which are found overlying, or in close association with, the rocks from which they have been derived and are thus distinguished from secondary (or "transported") clays which have been carried some distance away from their place of origin. The majority of the American clays are secondary clays, which fact may account for the nonuniformity of which manufacturers complain and which would exist if the clays were not washed or specially prepared before shipment or use.

No. 6. "* * * mined in Cornwall, England; is an excellent filler clay with pronounced carrying properties resulting from its exceptional fatness."

No. 7. Filler clay.

No. 8. Filler clay. This is not only a high-grade filler clay, but is also one of the best coating clays. The reason for selecting it was its good color. (See figs. 5, 6, and 7.)

III. PAPER-MAKING EQUIPMENT USED

The paper section of the Bureau of Standards is equipped for making paper in a semicommercial way and under practical mill conditions. The experimental paper-making equipment available for the work on clay consisted of a 50-pound wood tub beater with manganese-bronze bars and plate (see fig. 1), a small Jordan with iron bars (see fig. 2), a 4-plate screen, and a 29-inch Fourdrinier machine with wire 33 feet long and having two presses, nine 15-inch dryers, a small machine stack of seven rolls, and a reel (see figs. 3a and 3b).[3]

IV. TEST PROCEDURE

1. DEVELOPMENT OF METHOD FOR HANDLING CLAYS

In order to compare the paper to be made in the numerous experimental runs it was necessary to determine some uniform procedure for handling the materials and the machine, as well as to select definite places and methods for taking samples for test. It was desired that the methods used should duplicate mill conditions, but inasmuch as the various authorities differed widely as to the

[3] For those not familiar with the paper-making process the following brief description is given:

Paper making consists of two stages, namely, the preparation of the pulp and the conversion of the prepared pulp into a dry, continuous sheet of paper. The paper making of this investigation begins with the final stage in the preparation of the pulp—the beating.

The paper stock consists of the admixture of the pulp with the other paper-making materials, such as clay, rosin size, etc. The stock is mixed and the fibers cut and brushed in the beater, a tub fitted with a revolving roll, containing metallic blades which engage a metallic plate on the bottom. After beating has been carried on sufficiently long to prepare most of the stock for use, the stock is dropped to the beater chest (storage tank). From the beater chest the stock is pumped to the stuff box where the amount going through the Jordan is regulated. The Jordan, a refining engine used to give the fibers the final brushing out, consists of a conical-shaped plug equipped with metallic bars, revolving inside a similarly shaped shell, likewise equipped with metallic bars. The stock after passing through the Jordan is diluted with a suitable amount of water (which may be white water from the machine) and passed through a screen to the Fourdrinier machine where it is converted into paper.

In the Fourdrinier machine the paper stock flows onto a traveling, endless wire cloth. Water drains away as the sheet formed is carried forward and the paper is further freed from water by passing over suction boxes, under a felt-covered roll (couch roll) where the sheet is transferred to an endless felt, between rolls which press out water (press rolls), over steam-heated drying cylinders, through calenders which give the dry sheet a final pressing and smoothing, and to the reel on which the finished paper is wound.

The waters removed at the various parts of the paper machine are referred to as machine waters. These waters contain a certain amount of pulp and other paper constituents, the amount depending on the machine position of the water.

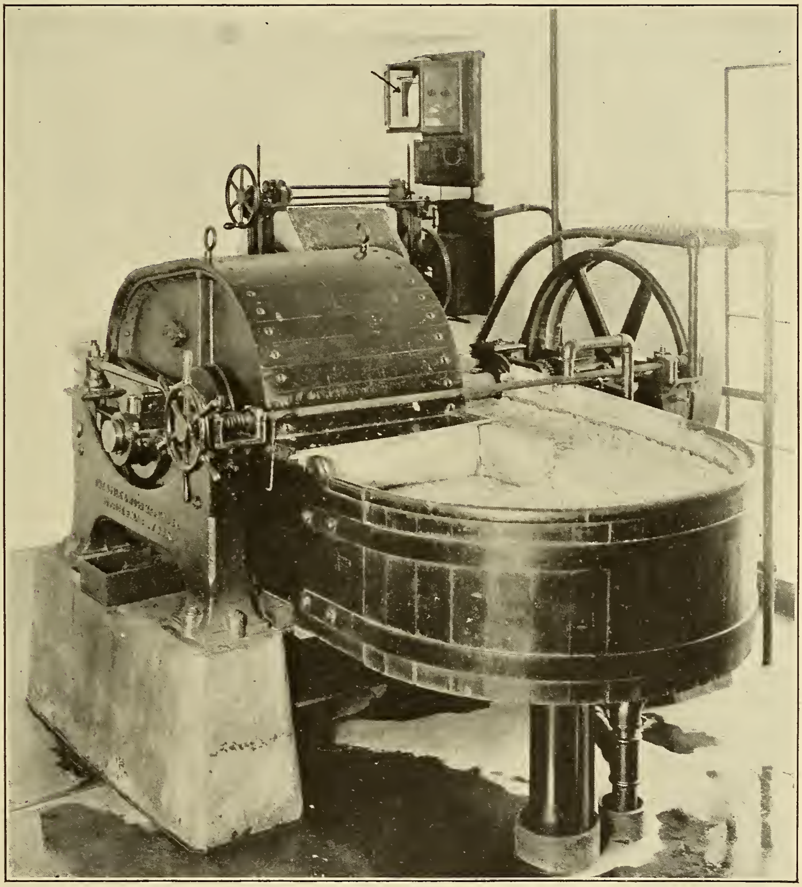

FIG. 1.—*Beater*

Ammeter chart for motor indicated by arrow (see fig. 17)

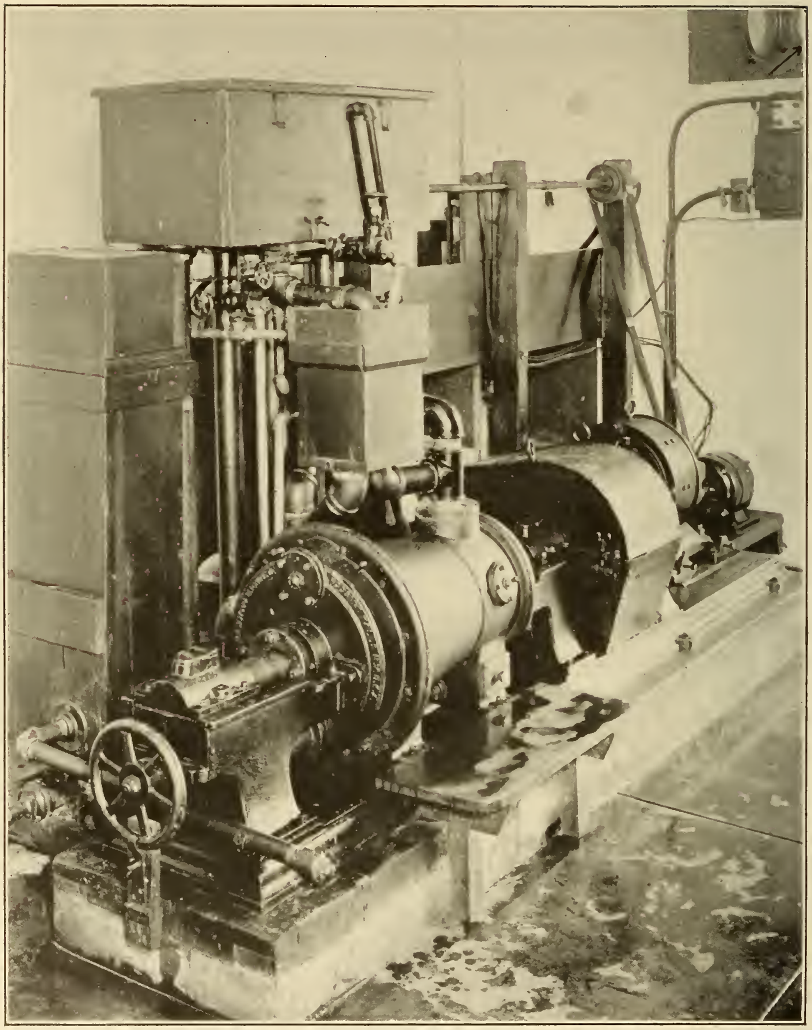

FIG. 2.—*Jordan*

Ammeter chart for motor indicated by arrow (see fig. 18)

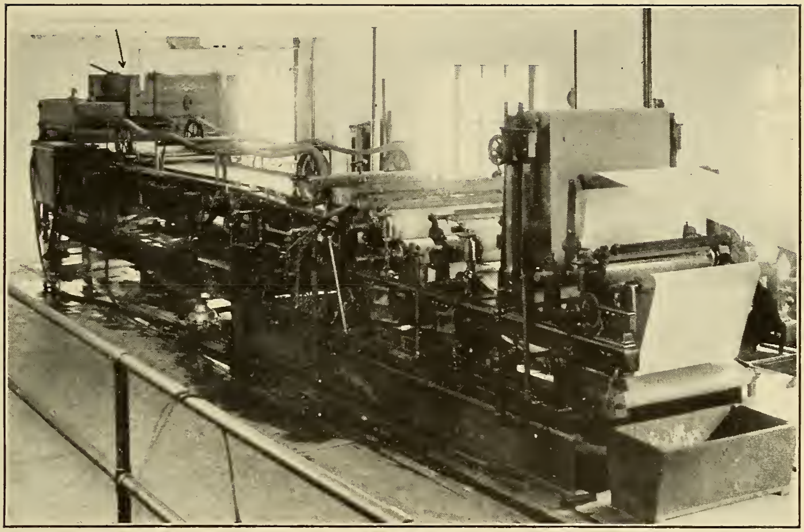

FIG. 3a.—*Fourdrinier machine*

Four-plate screen indicated by arrow

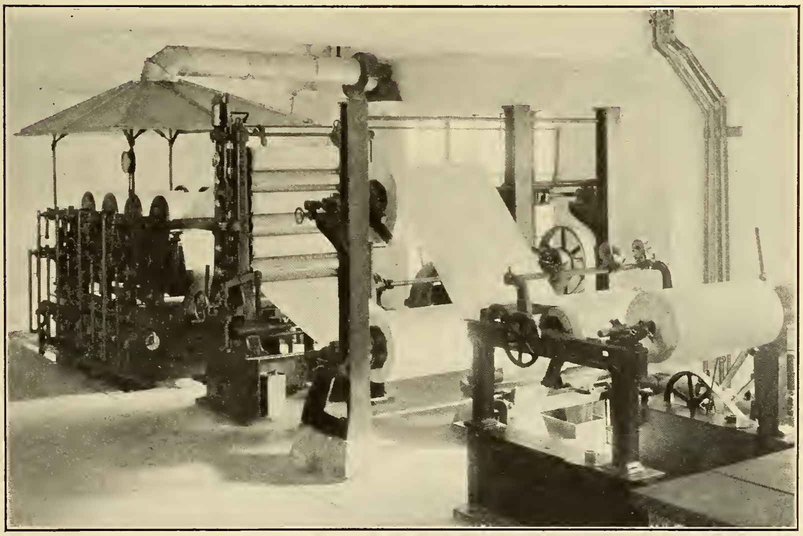

FIG. 3b.—*Fourdrinier machine*

time of adding the clay in order to obtain greatest retention, several preliminary runs were made to determine which method would give the highest retention with ease in handling materials. The clay slip was made up in the ratio of 1 part clay to 5 of water, and each batch was agitated a fixed length of time. It was screened through an 80-mesh wire before being added to the beater, much dirt being eliminated by this process.

A brief description of the methods used in the preliminary runs is as follows:

(1) The clay slip was added at the time of furnishing the beater, the size was added later, and the alum was added after the beating was finished, just before the stock was dropped to the machine chest.

(2) The size solution was added at the time of furnishing the beater and the clay slip was added later, the alum being added just before the stock was dropped to the chest.

(3) The size and clay slip were mixed together and the resulting mixture added when furnishing the beater. As in both previous methods the alum was added just before the stock was dropped to the chest.

(4) The size solution was added when furnishing and the alum some time later, but the clay slip was not added until shortly before dropping the stock, sufficient time being permitted, however, for good mixing.

(5) Soda ash was used to deflocculate the clay and the slip was then added at time of furnishing.

Two or more runs were made for each method outlined above. The results obtained varied little in percentage of clay retention and the small variations could easily have been due to experimental differences of machine runs. The first method was adopted for the comparative work which follows. This method (adding the clay slip to the beater when furnishing, following later with the size, and adding the alum after the beating was finished) is also the one most used in practice, since it facilitates the handling of the stock in the beater.

2. TAKING AND RECORDING OF DATA

(*a*) General Data.—The method of handling the paper machinery and of taking and recording data is indicated in the "form sheets" of Appendix B. (See pp. 369 to 378.) These "form sheets" are used regularly in the paper laboratory of the bureau for recording the data taken during runs. The records thus obtained also

make it possible to duplicate the conditions of any run when desired. The appended forms are the complete records for one machine run, and show in detail the conditions existing during the run.

(*b*) RETENTION DATA.—Samples for clay retention determinations were taken as follows:

Stuff box.—The stock coming from the beater chest was sampled at the stuff box. A tared cylinder was filled with the stock and weighed, after which the sample was poured onto a filter paper in a Buechner funnel, sucked down, and placed in the oven to dry.

Head box.—The sample taken here was of the stock at the head of the machine, just before it went onto the wire. It consisted of the stock coming from the stuff box (through the Jordan) after dilution with white water No. 1. A tared cylinder was filled and weighed, the sample then being poured onto a filter paper in a Buechner funnel, sucked down, and placed in the oven to dry.

Before suction boxes.—A sample of the stock was scooped from the center of the wire, about 7 feet from the slicers, placed in a tared can provided with a tight cover, weighed, and dried.

After suction boxes.—Same as "Before suction boxes," except that sample was taken after the stock had left the suction boxes.

Couch.—After the paper had passed the couch roll a strip was torn from the center of the sheet, placed in a tared moisture-tight container, weighed, and dried.

After first press.—After passing first press a strip was torn from the center of the sheet and treated as above.

After second press.—Sample taken after second press.

Reel.—Sample taken just before paper went onto the reel.

White water No. 1.—White water No. 1 was a composite of wire water and suction water[4] and was the water used for diluting the stock going from the Jordan to the machine. The excess portion was collected in a chest and measured, and from it a sample of 1 gallon was taken. The sample was filtered through a filter paper in a Buechner funnel, the solid material retained by the filter paper being dried and weighed. This weight was used in determining pounds of stock per thousand gallons. The material was analyzed in the same manner as that of the other samples.

Wire water.—Samples of the wire water before mixing with the suction water were taken at frequent intervals and from the composite sample thus obtained 1 gallon was taken.

[4] The wire water was the water caught by a tray under the table rolls and extending from the breast roll to the first suction box. The suction water was from the suction boxes. The two waters mixed in a box back of the machine and this mixture was called white water No. 1.

Suction water.—Samples were taken of the suction water before mixing with the wire water.

White water No. 2.—This was the water collected by a tray under the wire and extending from the first tray (white water No. 1) nearly to the couch roll. The water was collected and weighed and from it a composite sample of 1 gallon was taken.

Press water No. 1.—The water removed by the first press was collected and weighed. The procedure followed was that for the white waters.

3. METHOD FOR DETERMINING PERCENTAGE OF ASH DUE TO CLAY

It was necessary to establish first the percentage of ash content of paper without clay at the several places of sampling. For this purpose three machine runs were made on straight stock, size, and alum. Samples were taken at the places previously specified and ash determinations made on the bone-dry samples. The averages of the three runs were considered as the factors representing the ash content of the paper at the different places.

When filler is added to the paper there is not then the 100 per cent stock that there was in the three runs made when no clay was used, therefore, subtracting the ash for these three runs from that for paper containing filler does not correctly give the ash due to clay. However, the variation at a given place on a paper machine at different times during the run will exceed the difference obtained by these two methods of computation. Therefore, for practical purposes it is believed that the former method is satisfactory for comparative work and the per cent ash for stock from the blank runs, subtracted from the per cent ash on samples taken from runs using clay filler is considered to give the per cent of ash due to the clay. But since clay loses a certain amount of water on ignition, it is necessary to divide the percentage due to clay by such a factor as will give the true percentage of clay in the paper. This factor was determined by igniting a weighed amount of bone-dry clay under the same conditions as those under which ash was run on the paper samples. The loss in weight represents combined moisture. The weight remaining (expressed as its part of total weight) is the factor by which to divide.

For example, if in the three runs an ash factor of 0.62 was obtained for the stuff-box sample without clay, and if in later runs 17.63 was the ash determination for sample with clay, and 0.136 the loss on ignition of the clay used, then the per cent clay of this sample was $\frac{17.63-0.62}{1-0.136}=\frac{17.01}{0.864}=19.7$. (See fig. 23, p. 378.)

4. METHOD OF DETERMINING RETENTION

The percentage of retention is considered as that proportion of the filler added to the engine which appears in the finished paper. The different methods used in different laboratories for computing retention account in some degree for the varying results obtained and reported. The authors are indebted to Edwin Sutermeister of the S. D. Warren Co., Cumberland Mills, Me., for the formula used in this work. The formula is:

$$\text{Retention} = \frac{0.94B(100-C-A)}{A(100-C-B)}$$

in which

A = per cent of ash in bone-dry stock going to machine,
B = per cent of ash in bone-dry paper at reel,
C = per cent of bone-dry filler lost on ignition.

Determinations by measurements on 20 machine runs, each using 20 per cent clay (these runs included the eight clays under test), accounted for an average of 0.94 of the material furnished to the beater. This is also the figure given in the formula. Mr. Sutermeister's formula, being found to check the determinations by weight, was used to compute the retentions hereinafter reported.[5]

Any formula should be tested by a mill before making use of it as the conditions in the mill might be such as to make one formula better than another for those particular conditions. Many factors other than filler influence retention, but it is impossible to estimate their effects except in a general way. Some of the conditions which affect the retention of fillers are:

(1) The kind of stock used.
(2) The extent of its beating (hydration).
(3) Consistency of pulp and the amount of clay added.
(4) Weight of paper made and speed of machine.
(5) The pull on the suction boxes, or any mechanical attachment to the machine which quickly removes water from the pulp.
(6) Chemicals used, such as starch, sodium silicate, or viscose materials.
(7) Use of save-alls.

In the work of this investigation the beating, jordaning, and machine runs were controlled very carefully, the only changes made being the kind and percentage of clay added. (See figs. 16 to 21, pp. 371 to 376.)

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[5] The Technical Association of the Pulp and Paper Industry also gives in its publication on Paper Testing Methods (1922) a method for figuring retention.

V. COMPARATIVE WORK

1. VARYING KIND OF CLAY

Tests were run on each of the eight clays using 20 per cent clay, by weight, of the furnish (clays Nos. 1 to 5, domestic; Nos. 6 to 8, foreign). The results are given in the upper half of Tables 1 to 3, and are in each case the average of two, and in some cases three, runs.

Table 1 gives the per cent of solids at the different places of sampling on the machine and the pounds of solid material per thousand gallons for the different machine waters. Table 2 gives the per cent of clay in the solid material, or stock, of the different samples and also the retention figures. Table 3 gives the test data on the finished paper.

In comparing the clays for retention (Table 2) it will be seen that the difference between the highest and lowest retention is not sufficient to warrant the selection of one clay over another, assuming that there is no difference between them in other respects.

2. VALUE OF WHITE WATER FOR "FURNISHING"

A special run was made for one clay (No. 8), white water No. 1 from a previous run being used instead of fresh water in furnishing the beater. In figuring the retention for this run the amount of clay and pulp added in the white water in furnishing was taken into consideration and the value 0.648 obtained. This checks very closely with that of the previous run which was 0.655. If the retention for the clay in the finished paper was figured only on the clay slip added to the beater, not including the clay contained in the white water, the retention figure would have been higher. This difference in retention, or the recovery of stock, shows plainly the desirability of using white water for furnishing.

3. VARYING PERCENTAGE OF CLAY

On one domestic clay and one foreign clay comparative runs were made using 30 per cent, 10 per cent, and 5 per cent of clay, respectively. The results are shown in the lower half of Tables 1 to 3, and here again it will be seen that one clay practically checks the other in retention. The increased retention when using smaller amounts of clay is very evident, as would be expected.

TABLE 1.—Solid Material in Samples

Clay number	Per cent clay	Position on machine								Water samples				
		Stuff box	Head box	Before suction boxes	After suction boxes	After couch roll	After first press	After second press	Reel	White water No. 1	White water No. 2	Press water No. 1	Wire water	Suction water
		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Lbs./1,000 gal.	Lbs./1,000 gal.	Lbs./1,000 gal.	Lbs./1,000 gal.	Lbs./1,000 gal.
1	20	3.52	0.752	4.03	18.60	25.16	38.67	38.70	94.93	13.80	6.53	36.83	8.32	24.33
2	20	3.45	.689	4.30	18.20	24.35	39.40	39.40	95.53	15.20	7.20	29.60	9.50	26.65
3	20	3.46	.685	3.73	18.90	24.60	39.00	39.40	95.45	14.70	6.13	28.30	9.62	24.00
4	20	3.50	.650	4.25	19.15	24.35	39.98	40.03	95.50	13.25	6.21	24.60	9.69	21.30
5	20	3.52	.655	3.75	19.05	24.25	39.55	39.75	95.13	13.45	5.58	25.05	9.14	22.10
6	20	3.49	.697	3.73	19.02	22.33	38.44	38.72	95.38	13.83	5.74	21.33	9.45	21.07
7	20	3.50	.681	3.63	19.63	22.10	39.11	39.21	95.18	13.40	5.29	18.00	10.40	18.50
8	20	3.49	.678	3.90	19.78	22.11	39.63	39.63	95.43	12.50	5.03	22.35	9.33	17.60
8	[1] 20+	3.60	.674	3.50	20.33	22.56	39.30	40.00	96.00	12.80	5.27	21.90	10.40	16.50
3	30	3.74	.800	3.39	21.09	24.45	40.59	40.71	96.43	18.63	5.99	39.30	13.28	25.13
6	30	3.80	.818	3.21	21.38	24.55	41.08	41.53	96.04	17.15	6.72	31.15	15.15	20.10
3	10	3.27	.549	3.75	18.61	22.13	38.06	38.78	95.08	5.20	2.31	10.05	3.36	7.70
6	10	3.42	.571	3.63	18.71	21.85	38.36	38.63	95.23	6.07	2.49	10.10	4.48	8.44
3	5	3.32	.561	4.22	17.25	21.18	37.80	37.80	95.34	3.45	2.04	6.17	2.68	5.58
6	5	3.21	.572	3.94	17.60	21.46	37.23	37.58	94.57	3.43	2.14	5.49	2.53	5.24
Bentonite	5	3.09	.621	3.28	18.47	23.14	37.80	38.08	95.71	5.12	2.33	13.63	3.58	7.21

[1] Special, using white water No. 1 from previous run for furnishing beater.

TABLE 2.—Clay in Solid Material of Samples

Clay number	Clay in furnish	Reten-tion	Position on machine								Water samples				
			Stuff box	Head box	Before suction boxes	After suction boxes	After couch roll	After first press	After second press	Reel	White water No. 1	White water No. 2	Press water No. 1	Wire water	Suction water
	Per cent		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
1	20	0.620	20.48	25.43	22.13	15.58	14.84	14.22	14.30	14.41	71.83	61.60	68.20	66.90	75.20
2	20	.611	19.95	26.80	21.20	14.90	14.16	13.57	13.72	13.80	74.65	65.75	67.45	73.55	76.70
3	20	.636	20.03	27.23	21.88	15.30	14.70	14.18	14.32	14.48	74.10	67.73	64.00	72.30	76.30
4	20	.630	19.70	27.20	20.65	14.85	14.21	13.77	13.86	14.05	75.10	67.90	67.50	74.60	77.00
5	20	.633	19.95	26.95	21.00	15.15	14.72	14.25	14.18	14.26	74.50	69.35	66.60	72.20	76.25
6	20	.655	20.33	26.33	21.43	15.68	15.51	15.05	15.07	15.00	72.40	70.03	64.56	71.70	74.30
7	20	.642	20.15	27.00	21.20	15.05	14.87	14.60	14.66	14.57	73.45	70.85	64.05	72.90	75.30
8	20	.655	19.45	25.75	20.75	14.87	14.67	14.16	14.20	14.30	73.00	71.25	64.40	72.25	74.90
8	[1] 20+	.648	21.2	27.4	22.8	15.90	15.75	15.50	15.45	15.47	72.7	71.6	65.1	72.3	75.0
3	30	.600	29.65	35.56	30.52	22.05	21.40	20.83	20.93	21.00	82.00	88.20	72.20	83.10	83.00
6	30	.632	29.55	36.00	31.20	22.37	22.30	22.00	21.90	21.95	77.25	74.85	67.85	77.00	78.25
3	10	.720	9.92	11.07	10.44	8.01	7.81	7.70	7.70	7.66	65.00	70.20	58.20	64.20	64.50
6	10	.748	9.46	12.40	10.50	7.86	7.72	7.53	7.56	7.57	56.60	49.65	54.66	55.66	62.50
3	5	.744	5.20	6.22	5.53	4.23	4.09	4.00	4.02	4.02	52.00	51.15	48.65	43.85	52.25
6	5	.740	5.28	6.49	5.35	4.28	4.20	4.08	4.07	4.11	46.25	42.10	45.55	43.30	50.00
Bentonite	5	.742	5.09	6.10	5.65	4.38	4.11	3.95	3.88	3.96	39.93	29.60	43.96	27.73	44.30

[1] Special, using white water No. 1 from previous run for furnishing beater.

TABLE 3.—Test Data on Finished Paper

Clay number	Clay in furnish	Physical tests								Color tests			Finish (gloss)		Fiber composition		Chemical tests		Sizing quality	
		Weight, 25 by 40–500	Bursting strength	Thickness	Ratio bursting strength to weight, 25 by 40–500	Tensile strength (1 inch width)		Tearing strength machine direction	Brittleness cross direction	Coefficient of reflection (average of wire and felt side)			Felt side	Wire side	Sulphite pulp	Soda pulp	Ash	Resin	Curl	Stöckigt
						Machine direction	Cross direction			Blue	Green	Red								
	Per cent	Pounds	Points	Inch	Per cent	kg	kg	g	Per cent				Per cent	Per cent	Per cent	Per cent	Per cent	Per cent		
	......	51.00	16.20	0.0032	31.80	6.53	3.60	27.50	41.20	0.709	0.777	0.805	28.25	29.80	50	50	0.60	1.30	33	60
1	20	56.00	8.21	.0033	14.70	4.56	2.16	28.86	41.66	.743	.800	.825	31.03	30.66	50	50	12.76	1.34	22	28
2	20	54.95	9.40	.0032	17.10	5.20	2.65	33.00	48.75	.736	.800	.826	33.80	33.00	50	50	12.35	1.35	24	55
3	20	56.00	9.13	.0032	16.25	5.00	2.56	32.46	49.03	.742	.800	.826	35.33	35.53	50	50	12.90	1.50	24	56
4	20	54.70	9.54	.0033	17.50	4.20	2.90	32.00	41.75	.756	.806	.833	34.25	34.50	50	50	12.20	1.35	21	63
5	20	55.40	10.04	.0032	18.15	4.40	2.65	34.35	33.40	.749	.802	.828	33.25	34.25	50	50	12.80	1.50	27	25
6	20	54.06	10.80	.0032	19.93	4.50	2.53	36.63	37.90	.757	.803	.829	31.03	32.63	50	50	13.40	1.23	33	55
7	20	55.35	11.50	.0032	20.75	4.70	2.75	31.30	39.50	.742	.797	.823	30.35	30 50	50	50	13.10	1.11	35	82
8	20	54.40	9.95	.0031	18.30	4.85	2.40	34.00	31.75	.752	.802	.824	30.90	31.55	50	50	13.05	1.30	32	57
8	[1]20+	54.3	12.3	.0032	22.6	4.8	2.5	36.4	41.4	.743	.791	.815	32.7	31.8	50	50	13.7	1.4	22	20
3	30	57.50	8.56	.0034	14.86	2.63	1.61	40.80	26.60	....	....	....	34.63	34.43	50	50	18.24	1.57	15	9
6	30	57.10	8.55	.0031	14.95	3.25	2.10	31.40	28.65	....	....	....	34.35	33.25	50	50	19.55	1.15	22	25
3	10	55.67	15.80	.0035	28.35	4.68	3.18	49.00	42.90	....	....	....	32.80	33.00	50	50	7.00	1.83	30	69
6	10	55.40	13.63	.0034	24.60	5.53	3.30	40.46	35.10	....	....	....	31.23	31.30	50	50	7.03	1.25	29	62
3	5	55.53	15.85	.0033	28.56	6.26	3.68	39.40	38.06	....	....	....	29.26	30.16	50	50	3.97	1.36	26	59
6	5	56.25	18.10	.0033	32.20	6.60	3.60	37.93	40.87	....	....	....	30.93	32.00	50	50	3.87	1.34	27	66
Bentonite	5	57.10	14.74	.0033	25.80	6.21	3.24	50.26	36.43	....	....	....	30.26	30.56	50	50	4.23	1.43	26	80

[1] Special, using white water No. 1 from previous run for furnishing beater.

4. BENTONITE

Bentonite is a peculiar variety of clay used for certain special purposes. It is fine-grained, soft, and absorbs over three times its weight of water accompanied by swelling, and when fresh has a yellowish-green color.

Runs were made on bentonite, using only 5 per cent, since in a preliminary run it was found that 20 per cent was very difficult to handle on the machine. The retention for 5 per cent checks very well with that for clays Nos. 3 and 6. (See Table 2.)

Bentonite might be expected to show marked differences from other clays due to its "highly colloidal nature," but no such differences were observed for retention. It is claimed that when bentonite is used with another clay it increases the retention of that clay,[6] but no tests were made for this quality.

VI. DUPLICATION OF COMMERCIAL-MILL TEST IN BUREAU OF STANDARDS EXPERIMENTAL PAPER MILL

1. TESTS MADE

In connection with the study of foreign and domestic clays in paper making it was thought advisable to make a commercial-mill test for clay retention in paper and losses in white water. With the hearty cooperation of the Miami Paper Co., West Carrollton, Ohio, these tests were made in the mill of that company, under the personal supervision of the authors, February 27, 1923. A complete report of the test results was prepared and submitted to the Miami Paper Co. A copy of that report (with the addition of graphic charts and a few minor changes in form) is given in Appendix A, pages 360 to 369.[7]

At the time of making the commercial-mill tests plans were made for making several runs in the experimental paper mill of the Bureau of Standards, duplicating as nearly as possible the mill conditions of the Miami test. For this work sufficient clay and pulps for several runs were furnished the bureau by the Miami Paper Co. One of the clays received (designated as $Miami_1$ in this publication) was that used in the test reported in Appendix A; the other ($Miami_2$) was a mill clay and was submitted for comparative tests; the bureau added another (clay No. 1) for the comparative tests.

[6] Wilkinite, A new loading material, by Sidney D. Wells, Paper Trade Jour., Nov. 18, 1920.

[7] The report also includes additional data on the value of a save-all and on the amount and analysis of stock at different parts of the paper machine.

Three runs were made on each of these clays using the same percentages of stock as were used in the Miami test. The values given for each clay in Tables 4 and 5 are the averages of the three results for that clay. The mill of the bureau is, however, not equipped with a save-all, as was the mill of the Miami Paper Co., and in comparing the data this should be considered.

TABLE 4.—Solids in Machine Samples

SOLID MATERIAL

Clay	Position on machine								Waters		
	Stuff box	Head box	Before suction	After suction	After couch	After first press	After second press	Reel	White water No. 1	White water No. 2	Press water No. 1
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Lbs./1,000 gal.	Lbs./1,000 gal.	Lbs./1,000 gal.
Miami 1	3.54	0.722	3.92	16.59	24.72	36.12	36.28	96.49	14.07	8.43	17.37
Miami 2	3.55	.685	3.12	17.30	24.44	36.31	36.46	96.26	11.04	5.56	13.43
No. 1	3.49	.674	2.44	16.70	25.20	35.50	35.80	96.00	12.17	5.60	35.67
CLAY (ON SOLIDS)											
Miami 1	19.48	26.13	20.20	15.23	14.95	14.78	14.77	14.91	77.37	78.73	75.00
Miami 2	20.00	26.30	21.53	16.73	16.50	16.43	16.46	16.48	78.60	78.23	70.10
No. 1	20.00	26.40	22.50	16.65	15.95	15.60	15.65	15.65	79.80	77.50	81.00

TABLE 5.—Physical and Chemical Tests on Finished Paper

Clay	Weight, 25 by 40–500	Weight, 44 by 62–500	Bursting strength	Thickness	Ratio [1]	Resins	Ash
	Pounds	Pounds	Points	Inch	Per cent	Per cent	Per cent
Miami 1	56.1	153.1	13.80	0.0031	24.60	1.68	13.82
Miami 2	55.4	151.0	14.67	.0030	26.47	1.68	14.92
No. 1	54.0	147.2	10.90	.0029	20.20	1.61	14.01

[1] Ratio is obtained by dividing the bursting strength by the weight of the standard size ream (25 by 40–500) and multiplying the result by 100.

2. COMPARISON OF CLAY RETENTION

Since the bureau mill was not equipped with a save-all, comparison of clay retention in the two mills was based on the ratios of clay at reel to clay at head box. Comparative data for the three clays are as follows:

Miami 1 clay

Miami mill: Per cent

Clay at head box .... [8] 31.6

Clay at reel 17.9

$$\frac{17.9}{31.6}=0.567$$

Bureau of Standards mill:

Clay at head box .... [9] 26.13

Clay at reel 14.91

$$\frac{14.91}{26.13}=0.571$$

[8] See p. 362. [9] See p. 350.

The high percentage of clay at the head box in the test made at the Miami mill was due to the fact that the stock from the machine chest was diluted not only with machine white water, but also with water from the save-all. Table 13 (p. 364) states that "water from bottom of save-all used to dilute stock" had in it 31.15 pounds of material per thousand gallons, and that 56.24 per cent of this was clay.

The value of the save-all is again shown very clearly. The stock at the stuff box in the Miami test was 19.9 per cent clay (see Table 12, p. 362) while the stock at the head box was 31.6 per cent clay, an increase of 58.8 per cent over that at the stuff box. The work in the bureau mill on the same stock and clay showed the stock at the stuff box to have 19.48 per cent clay (see Table 4, p. 350) and that at the head box 26.13 per cent, an increase of only 34.1 per cent. This comparison shows that the use of white water for dilution purposes is an important factor in the retention or recovery of clay.

There has been considerable objection to the use of a save-all, as it is thought by some that it causes slime. It is believed, however, that if the trays catching the different machine waters were permitted to collect only the water containing no dirt and oil from the bearings, and if care is taken to keep the various parts of the recovery system as clean as the other paper-making equipment, there would be very little trouble from slime. The saving in water and material would well pay for the extra work imposed. (See data of p. 369.)

The results of tests in the two mills were considered as checking each other, so with them as a basis the other two clays were compared with Miami$_1$, the runs being made with the same stock and percentages and under the same conditions.

Miami $_2$ clay

	Per cent
Bureau of Standards mill:	
Clay at head box	[10] 26.30
Clay at reel	16.48

$$\frac{16.48}{26.30}=0.627$$

As previously stated the value thus obtained (0.627) is not the per cent retention, but is a comparative value. The retention for this clay was approximately 70 per cent.

[10] See p. 350.

Clay No. 1

Bureau of Standards mill:	Per cent
Clay at head box	[11] 26.40
Clay at reel	15.65

$\frac{15.65}{26.40}=0.594$

In comparing clays Miami$_1$, Miami$_2$ (both foreign), and No. 1 (domestic) for retention it will be noted that their relative order is Miami$_2$, No. 1, and Miami$_1$.

3. COMPARISON OF COLOR OF PAPERS MADE

Color tests were run on the papers containing Miami$_1$, Miami$_2$, and No. 1 clays. Figure 4 shows the comparative color values.[12] It will be noted that the curves for Miami$_1$ (Miami test) and Miami$_2$ have the same slope, but that Miami$_1$ made a brighter sheet. The sheet for clay No. 1 had a yellowish or brownish cast, which was also noticeable to the eye when comparing the three sheets.

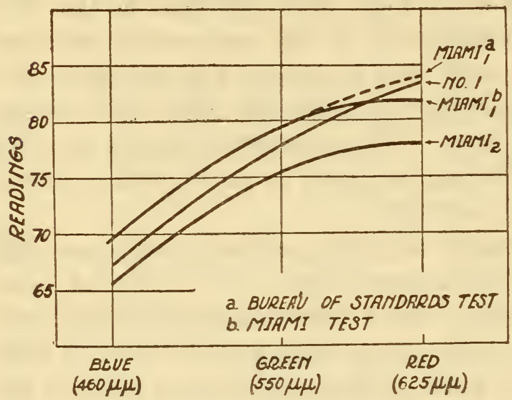

FIG. 4.—*Color characteristics*

VII. PHYSICAL PROPERTIES OF CLAYS USED IN THE PAPER TESTS

The purpose of the tests on the physical properties of the clays was to determine whether there was a relation between any physical property and the amount of retention in paper. A number of these tests are reported not for their direct value, but for the general information they give. There were no chemical analyses made. The tests on physical properties, with the exception of color, were made by F. P. Hall, ceramics division, Bureau of Standards.

1. COLOR

The color or degree of whiteness of clays is important in their selection, especially for use in high-grade papers. The usual method of comparing clays for color is to place them side by side and to grade by the eye, but by this method it is impossible to give numerical values. Therefore, for the tests reported in Table 6, a

[11] See p. 350.

[12] For description of color test see VII, 1, p. 352.

Pfund colorimeter [13] was used to determine the color characteristics of the clays. This instrument shows very slight variations in color and gives numerical values as a basis for comparison.

The tests were made on dry clay, since the color of clay under water is usually different from the color when dry. The dry clay was pressed on the lower plate of the colorimeter, and a white paint was used for the upper plate. Magnesium oxide was included with the samples in order to give a value of white for comparative purposes.

TABLE 6.—Color Characteristics

Sample	Blue (wave length 460 μμ)	Green (wave length 550 μμ)	Red (wave length 625 μμ)	Brightness values
MgO	86.5	89.1	90.1	89.33
1	65.9	73.2	77.6	74.66
2	65.0	75.2	80.5	76.96
3	65.5	73.2	77.6	74.65
4	70.9	77.4	81.2	78.65
5	61.9	69.6	73.4	70.84
6	69.2	74.1	77.7	75.30
7	64.1	70.7	74.1	71.80
8	72.5	76.3	78.2	76.87

The curves of Figure 6 show more readily the color comparison of the clays. For these curves the reading for blue was taken as the zero in each case. Values for a true gray, or rather a clay which is nonselective in color, will give a horizontal line, the reflection coefficients for blue, green, and red being equal Pfund's article [14] states:

> * * * if it reflects nonselectively it is to be called "white." According to this nomenclature, true grays are whites of different brightness.

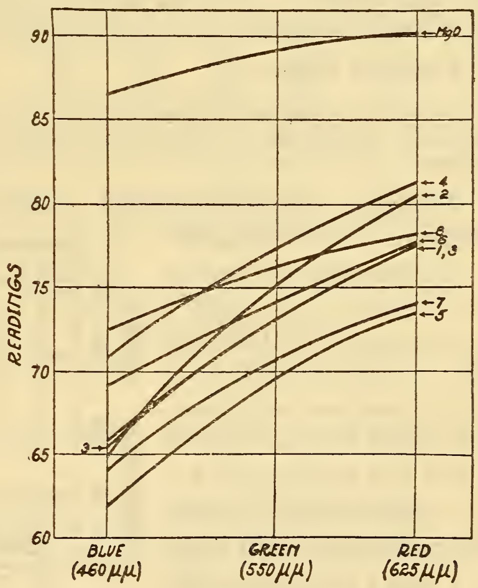

FIG. 5.—*Color characteristics*

As the color becomes more selective; that is, shows a tint or dominant hue, the values for the reflection coefficients diverge. This is especially true for clay No. 2. (See fig. 6.)

[13] Pfund, A. H., "A new colorimeter for white pigments and some results obtained by its use." Amer. Soc. for Test. Matrls., June, 1920.

[14] See footnote 13.

To give the clays a true rating, brightness as well as color must be considered. It is a well-known fact that the excitation value for blue is extremely small compared with that for red and green. The "brightness values" given in Table 6 were figured by using factor values with the readings for red, green, and blue given in that table. The factor values were taken from the "Report of Committee on Colorimetry for 1920–21," by L. T. Troland, chairman, Journal Optical Society of America, 1922. That article states, pages 550–551:

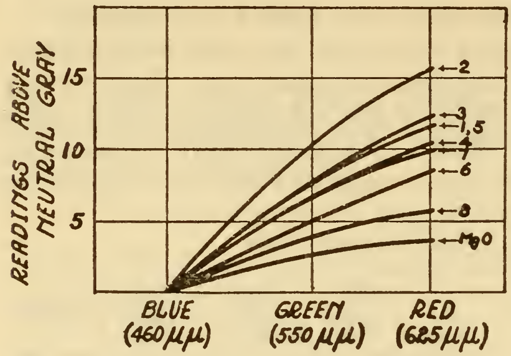

FIG. 6.—*Color curves*

* * * Mr. Weaver and the writer (Mr. Troland) have made new experimental determinations of the chromatic visibility coefficients for their own eyes and those of one other subject. * * * The average values for the factors obtained from our three subjects were: Red, 0.370; green, 0.617; and blue, 0.012.

Page 582 states:

To simplify computation, these valences have been expressed so as to represent the fractional contributions of the three excitations to the luminosity of a white, taken as unity, * * *.

Applying these determined factors the brightness values of Figure 7 were obtained.

Considering the curves of Figures 5, 6, and 7 collectively, it will be seen that domestic clays 3, 1, and 4 compare very favorably with foreign clays 6 and 8, and perhaps excel 7. If a small amount of blue dye were added with clays 3, 1, and 4 the paper made would doubtlessly be as good in color as that obtained with clays 6 and 8, but the blue would make the paper less selective, approaching more of a gray, and there would be some loss in brightness.[15]

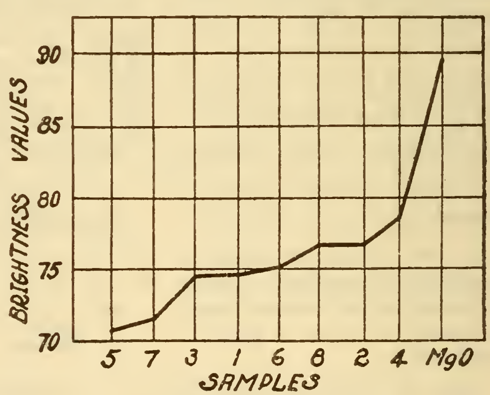

FIG. 7.—*Brightness curve*

[15] See footnote 1, p. 337.

2. GRIT

Three standard screens (100, 200, and 330 mesh) were stacked so that the 100-mesh screen was on top and the 330 on the bottom. A 100 g bone-dry sample of clay was mixed with water and made into a slip. The slip was poured onto the stack of screens and sprayed with a gentle stream of water until the water running through the screens showed no trace of clay. The residues were examined to see that the particles retained were individual particles and not conglomerates of particles, since some domestic clays tend to "ball up" on the screens, resulting in the grit being reported higher than it really is. The use of a deflocculating agent, such as sodium hydroxide or sodium carbonate, will prevent this. The amount of grit left on the screens is reported in Table 7.

TABLE 7.—Grit, in Clay, Left on Screen

Screen mesh	Clay number—							
	1	2	3	4	5	6	7	8
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
100	0.126	0.058	0.009	0.030	0.048	0.011	0.032	0.004
200	.055	.100	.336	.130	.442	.063	.045	.015
330	.605	.204	.605	.380	.910	.832	.220	.115
100+200	.181	.158	.345	.160	.490	.074	.077	.019
100+200+330	.786	.362	.950	.540	1.400	.906	.297	.134

The character of the residue from clays may vary greatly, although it consists ordinarily of quartz and mica. Microscopic examination of the residues from the eight clays reported above showed the following compositions:[16]

No. 1. Principally mica, with 5 per cent or less of quartz, a small amount of kaolin, and some hydrated iron oxide.

No. 2. About 60 per cent mica, 35 to 40 per cent kaolin, and little or no quartz.

No. 3. Less than 10 per cent kaolin, practically no quartz, and remainder mica.

No. 4. About 75 per cent mica and 20 to 25 per cent kaolin.

No. 5. Principally fine-grained mica, some kaolin, and a very little quartz.

No. 6. Less than 3 per cent quartz, less than 10 per cent kaolin, and the remainder mica.

No. 7. Practically all mica, with less than 5 per cent quartz.

No. 8. Less than 5 per cent quartz, 15 to 20 per cent kaolin, and the remainder mica.

[16] Examination of residues was made by Dr. Herbert Insley, Bureau of Standards.

3. PLASTICITY

Clay slips made from the several clays were tested to determine the relative plasticities of the clays used. The Bingham plastometer was used for the test. This plastometer is fully described in an article by E. C. Bingham and Henry Green in the "Proceedings of the American Society for Testing Materials, 1919 and 1920," and the method used for comparing the plasticities is described in Bureau of Standards Technologic Paper No. 234. The same capillary was used in all of the tests.

The curves of Figure 8 show clay No. 1 to be the most plastic and clay No. 4 to be the least plastic.

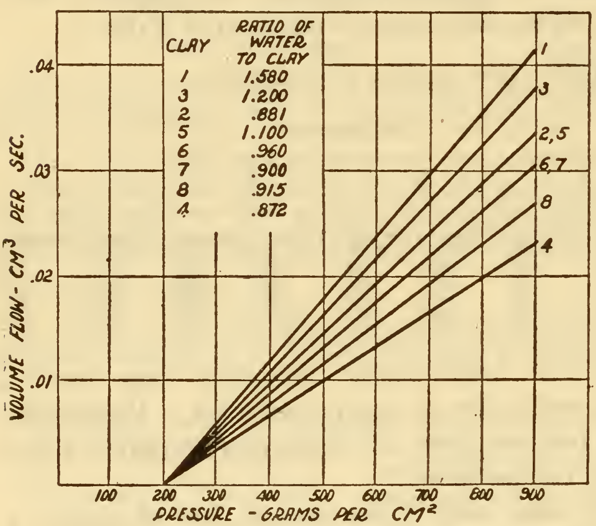

FIG. 8.—*Bingham plastometer curves*

One writer states that "Degree of plasticity of the clays seems to play an important rôle, since it is found that a given paper will often retain a greater quantity of some clays than others, those of which the greatest quantity is retained being the most plastic." If this were true clays could be graded as to retention by determining their relative plasticities, but the curves of Figure 8 do not show the plasticities to be in the same respective order as the retention values for the clays. (See Table 2, p. 347.)

4. TIME OF SLAKING IN WATER, VOLUME SHRINKAGE AND WATER OF PLASTICITY, TRANSVERSE STRENGTH OF CLAY IN DRY STATE, RATIO OF PORE TO SHRINKAGE WATER, TRUE SPECIFIC GRAVITY

These tests were all made according to the recommendations of the committee on standards, American Ceramic Society, in its report of April, 1922, Journal of the American Ceramic Society. The results of the tests are given in Table 8.

TABLE 8.—Miscellaneous Physical Tests on Paper Clays

Clay number	True specific gravity	Slaking time	Volume shrinkage	Water of plasticity	Ratio of pore to shrinkage water	Transverse strength
		Minutes	Per cent	Per cent		Lbs./in.²
1	2.609	6½	21.73	48.33	1.97	49
2	2.616	5	19.23	41.36	2.08	126
3	2.622	6	22.50	46.70	1.85	88
4	2.608	10	13.40	34.40	2.91	33
5	2.625	5	19.50	49.20	2.31	55
6	2.632	10	20.06	41.20	1.98	45
7	2.636	43	12.49	34.18	3.15	23
8	2.616	11½	15.35	40.06	2.70	47

5. ELUTRIATION

The construction and use of the elutriator used in these tests is described by Charles F. Binns in the Transactions of the American Ceramic Society, volume 17. The results of the tests are given in Table 9.

TABLE 9.—Elutriation of Paper Clays

Clay number	Upward velocity mm/sec.					
	1.50	0.70	0.18	0.08	0.04	Overflow
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
1	0.44	0.26	1.59	3.50	3.92	90.29
2	.38	.26	3.20	17.10	15.00	64.06
3	.58	.55	1.63	9.50	11.60	76.14
4	.44	.23	8.40	14.00	21.00	55.93
5	.74	.91	9.00	14.10	16.30	58.95
6	.40	.41	8.23	6.20	12.43	72.33
7	.15	.30	2.69	20.30	20.00	56.56
8	.13	.21	2.32	12.78	5.78	78.78

6. FLOWABILITY OF CLAY SLIP

The Bleininger efflux viscosimeter [17] was used in making these tests. The so-called viscosity, or, better, the flowability, of clay slips with varying water content was determined for each clay. The results are shown in Figure 9. The factor value is the ratio of the time required for 200 cm³ of clay slip to flow through an orifice to the time required for the same amount of distilled water to flow through the same orifice. This factor is plotted against the per cent of clay in the slip.

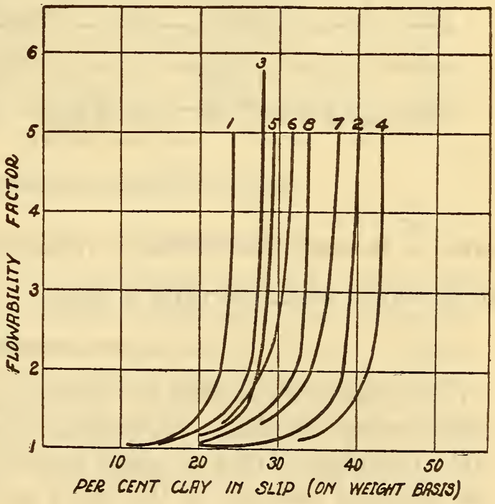

Fig. 9.—*Flowability curves*

[17] B. S. Tech. Paper No. 51.

Adding sodium hydroxide to clay slip will deflocculate the clay and lower the factor, while adding alum has the converse effect. Thus a clay slip that will not flow through the viscosimeter can be made to do so by the addition of a small amount of sodium hydroxide.

7. RATE OF SETTLING OF CLAY IN WATER

The rate of settling is given in Figures 10 and 11 for ratios of water to clay of 5 to 1 and 20 to 1, respectively. When the

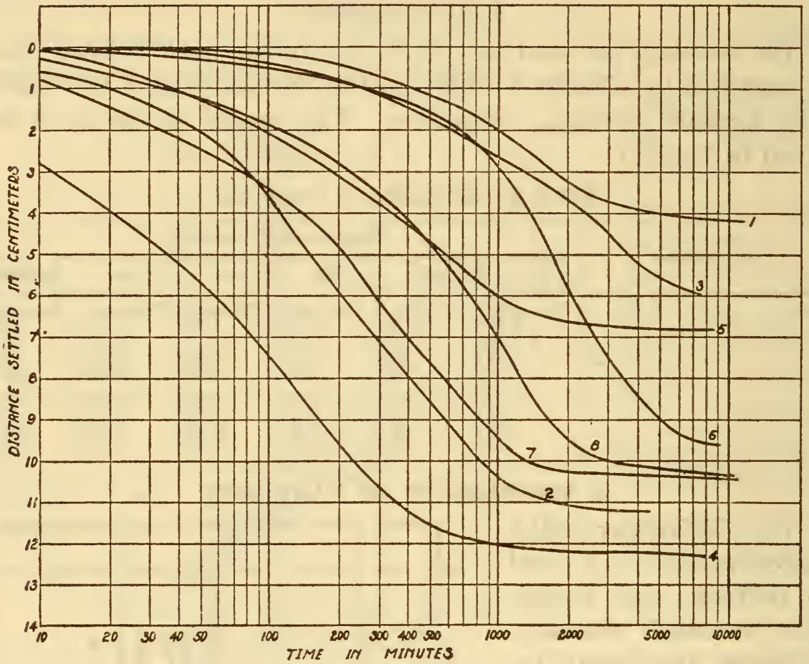

FIG. 10.—*Rate of settling in water* $\left(\frac{W}{C}=\frac{5}{1}\right)$

ratio $\frac{W}{C}$ is small the settling is retarded. Fineness is more likely to be shown when the ratio is large.

8. CONCLUSIONS

It is quite evident that to understand and interpret the results given under plasticity, elutriation, flowability of clay slip, and rate of settling of clay in water it would be necessary to measure the colloidal content of the clays and perhaps determine their alkali salts, as it is realized that these constituents have considerable effect upon the physical properties of clays. It is believed the continuation of this work, including the study of colloidal

matter and alkali salts contained in clays and their effect on physical properties, would be very desirable. The data in this paper are reported for general information only and it is hoped that they will lead to a further study of clay properties or clay constants.

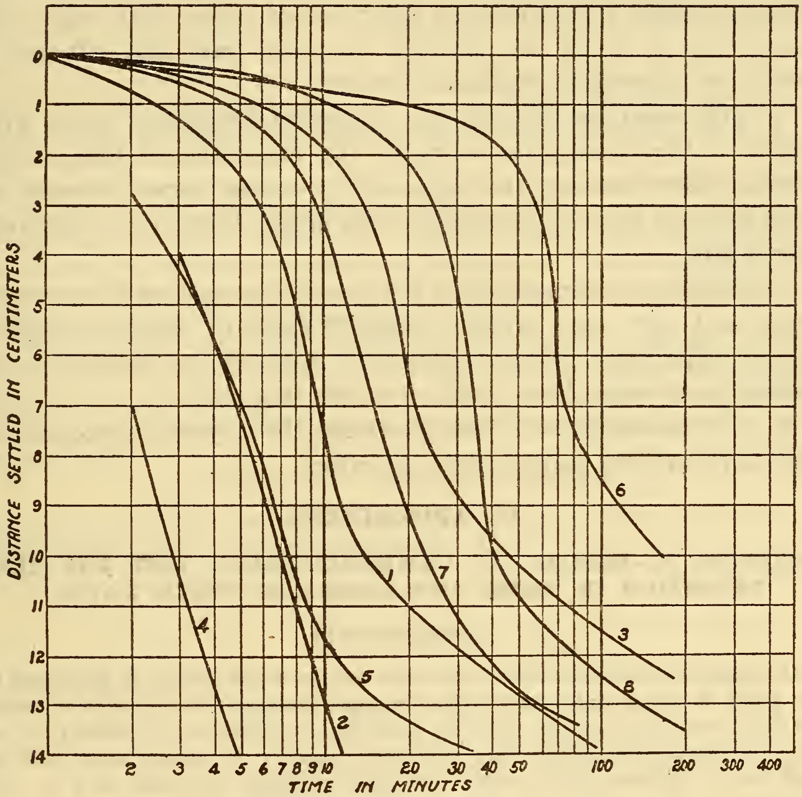

FIG. 11.—*Rate of settling in water* $\left(\frac{W}{C}=\frac{19.6}{1}\right)$

VIII. SUMMARY AND CONCLUSIONS

Comparative paper runs have been made in the experimental paper mill of the Bureau of Standards using eight (five American and three foreign) representative commercial clays as fillers. Tests have also been made on the physical properties of the clays. Additional data on clay retention in paper and losses in white water were obtained on samples taken in a commercial paper mill from a machine in operation. The results point to the following general conclusions:

1. The amount of clay retained in the paper at any of the places of sampling on the paper machine is practically independent of the kind of clay used.

2. The physical characteristics of the finished paper (bursting strength, finish, etc.) are essentially the same for all the clays.

3. The study of white-water losses in a commercial paper mill showed the per cent of clay retention in paper to be considerably increased by the use of a save-all. The save-all not only increased stock recovery by permitting the reuse of water with high concentration of stock for dilution purposes, but also effected a saving of thousands of gallons of water.

4. The retention data of the commercial-mill test agree with those of the duplicative work in the experimental mill of the bureau, thus showing the applicability to the paper industry of data derived from experimental runs in the Bureau of Standards paper mill.

5. Differences were noted in the physical properties of the clays, color and grit tests favoring slightly those of foreign source.[18] These differences are not sufficient, however, to warrant consideration of only these qualities in selecting clays.

6. No correlation was found between the physical properties of the clays and the papers made therefrom.

IX. APPENDIXES

APPENDIX A.—REPORT ON COMMERCIAL-MILL TEST FOR CLAY RETENTION IN PAPER AND LOSSES IN WHITE WATER[19]

1. INTRODUCTION

In connection with the work of the paper section of the Bureau of Standards in the study of foreign and domestic clays in paper making, it was thought advisable for that section to cooperate with the committee on waste in the industry, of the Technical Association of the Pulp and Paper Industry, in making some practical mill tests to determine white-water waste and to obtain additional data on clay retention.

In this investigation it was planned not to interrupt operations in the mills where the tests were to be made or to interfere with their production. The necessary data were to be secured from samples of stock taken at different points from a machine in operation. The sampling was to be so timed that the breaks in the paper would come at the time of changing the rolls at the reel.

To obtain other data on the comparative values of various foreign and domestic clays it was planned to follow the commercial-mill test with runs in the paper mill of the bureau, duplicating as nearly as possible the conditions found in the commercial mill. For this purpose, sufficient clay and pulps for several 50-pound beater runs have been supplied to the section, and the tests on its machine will soon be completed. The mill of the paper section is, however, not equipped with a save-all, and in comparing the data with that of mills having save-alls this will have to be considered.

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[18] See footnote 1, p. 337. [19] See Section VI, p. 349.

2. COLLECTION OF DATA IN COMMERCIAL MILL

(*a*) BEATER.—The amount of pulps and paper broke used in furnishing the beaters was determined by weighing. The clay slip and size solution were measured by volume, and from analysis of representative samples the amount of solid material added was determined. The alum was weighed and added dry.

The water going to make up the furnish, except that added with the clay and size, was drawn from the save-all. Samples of this were taken and the amount of stock per gallon determined.

Before the stock in the beater was dropped to the chest, a sample of it was taken and from this the concentration of the stock was determined. Ash was run on the bone-dry sample of the stock, and from the results thus obtained the percentage of clay was figured.

(*b*) MACHINE.—Samples were taken at the following places on the machine: Stuff box, head box, after leaving wire, after first press, after second press, and at the reel. The percentage of solids and percentage of moisture were determined for these samples, and the ash of the bone-dry content was determined. From the percentage of ash the percentage of clay was figured. The paper made, including the paper at the reel, the dry broke and the wet broke, was weighed.

(*c*) WHITE WATER.—White-water samples were taken from the water going to the save-all, at the bottom of the save-all (water used to dilute stock going to the machine) and from the save-all water going to the sewer. From these samples the percentage of stock per gallon was determined, and from the bone-dry contents the percentage of clay and fibers.

3. TABULATION AND EXPLANATION OF DATA

The following tables of data are supplemented with such explanation as it was thought might be helpful in their interpretation:

TABLE 10.—Beater Furnish

Beater number	Bone-dry material					
	Sulphite pulp	Soda pulp	Broke paper	Clay	Rosin	Alum
	Pounds	Pounds	Pounds	Pounds	Pounds	Pounds
1	1,333.8	216.0	96.5	421.8	23.5	45
2	1,333.8	216.0	96.5	421.8	23.5	45
3	1,333.8	225.0	168.8	421.8	23.5	45
4	1,538.1	200.7	111.0	464.7	23.5	45
5	1,538.1	200.7	140.9	464.7	23.5	45
6	1,333.8	225.0	159.2	464.7	23.5	45

TABLE 11.—Water from Save-All Used to Furnish Beater

Beater number	Stock per 1,000 gallons	Clay in stock	Water from save-all
	Pounds	Per cent	Gallons
1	1.19	68.6	2,690
2	1.28	67.6	2,874
3	11.1	53.8	2,630
4	16.2	53.7	2,804
5	12.2	52.0	3,008
6	12.8	57.5	2,759

Samples were taken on the machine at the places specified in Table 12. They were weighed, dried in an electric oven, and again weighed to obtain the dry weight. From these weighings the per cent of solids in the sample was obtained. Ash determinations were made on the bone-dry samples and are reported as per cent ash. The results are given in Table 12 and shown graphically in Figures 12 and 13.

Under "average" is given the average percentage of solids and of ash for each kind of sample. The per cent ash for the stock was taken from work in the paper section, and is an average of three runs on sulphite and soda stock, made into paper in the usual way but having no clay in the furnish.

The per cent ash for stock subtracted from the per cent ash on samples taken gives the per cent of ash due to the clay, but since clay loses a certain amount of water on ignition, it is necessary to divide the per cent due to clay by such a factor as will give the true percentage of clay actually in the paper. The factor for the clay was determined by igniting a weighed amount of bone-dry clay under the same conditions as those under which ash was run on the paper samples. The loss in weight represents combined moisture.

The clay used in the mill test lost 11 per cent on ignition. Since only 89 per cent of the clay remained, 0.89 is the factor by which to divide the per cent ash due to clay in order to get the true percentage of clay in solids. For example,

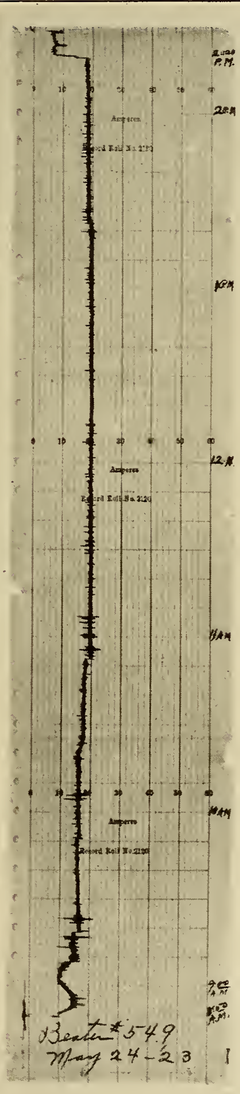
	Per cent
Ash	=18.52
Ash for stock	= .82
Ash due to clay	=17.70

$$\frac{17.70}{0.89}=19.9 \text{ (true percentage of clay in solid).}$$

TABLE 12.—Data on Machine Samples

Time of taking samples	Material	Machine position of samples: Stuff box	Head box	After couch	After first press	After second press	Reel
a. m.		Per cent	Per cent	Per cent	Per cent	Per cent	Per cent
10	Solids	5.48	0.920	20.4	29.2	34.0	96.0
	Ash [1]	18.66	27.55	17.24	16.42	16.62	16.49
11.05	Solids	4.67	.845	20.9	30.4	34.3	96.1
	Ash [1]	17.12	27.70	17.21	17.00	16.62	16.66
p. m.							
12.15	Solids	5.12	.873	21.6	28.0	33.6	95.5
	Ash [1]	19.61	30.00	17.48	17.03	17.04	16.83
1.20	Solids	5.23	.837	21.1	29.3	33.6	96.1
	Ash [1]	19.55	30.54	18.37	17.38	17.64	16.97
2.15	Solids	5.13	.873	21.8	30.0	33.6	96.5
	Ash [1]	19.20	30.76	17.88	17.80	17.55	17.49
3	Solids	4.95	.834	21.0	29.7	33.9	98.5
	Ash [1]	18.30	29.68	16.35	16.15	16.10	16.16
4.15	Solids	4.95	.875	20.6	29.0	32.9	97.7
	Ash [1]	17.90	29.26	18.17	17.37	17.65	17.44
5.15	Solids	4.95	.871	21.8	29.2	31.8	95.5
	Ash [1]	17.85	27.06	16.83	16.20	16.10	16.07
AVERAGE							
	Solids	5.06	0.866	21.15	29.35	33.46	96.5
	Ash [1]	18.52	29.07	17.44	16.92	16.91	16.71
	Ash for stock [2]	.82	.89	.88	.79	.79	.78
	Clay [2]	19.9	31.6	18.6	18.1	18.1	17.9

[1] Based on total solids. [2] See preceding explanation, p. 362.



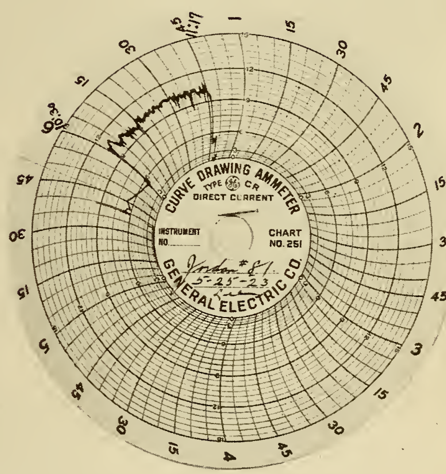


FIG. 17.—*Beater chart*

FIG 18.—*Jordan chart*

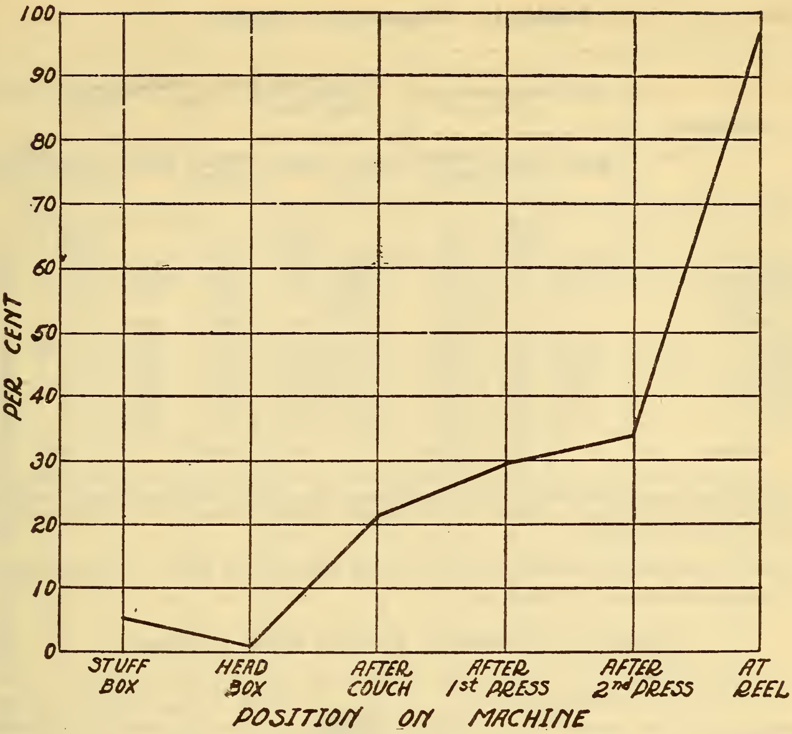


FIG. 12.—*Per cent solids on machine samples*

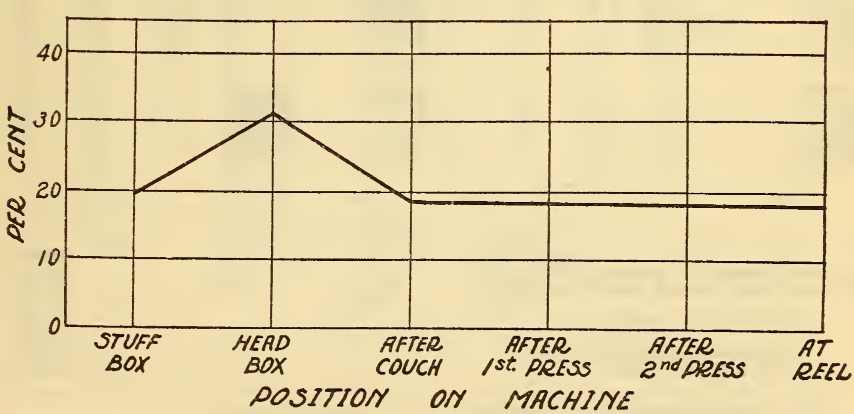


FIG. 13.—*Per cent clay in solids on machine samples*

Clay determinations were run on white-water samples also. Table 13 lists the results obtained, while Figure 14 shows these results graphically.

TABLE 13.—White-Water Samples [1]

Time interval	Water going to save-all			Water from bottom of save-all used to dilute stock			Water going from save-all to sewer		
	Solids	Solids	Clay in solids	Solids	Solids	Clay in solids	Solids	Solids	Clay in solids
a. m.	Lbs./gal.	Lbs./1,000 gals.	Per cent	Lbs./gal.	Lbs./1,000 gals.	Per cent	Lbs./gal.	Lbs./1,000 gals.	Per cent
10.35 to 11	0.0124	12.4	55.0	0.0332	33.2	52.1	0.00047	0.47	96.2
11.30 to 11.45	.0121	12.1	54.3	.0325	32.5	50.3	.00041	.41	88.2
p. m.									
12.15 to 12.30	.0137	13.7	55.4	.0274	27.4	56.3	.00075	.75	74.1
12.50 to 1.15	.0129	12.9	60.4	.0348	34.8	57.1	.00060	.60	84.4
1.30 to 2	.0116	11.6	60.4	.0282	28.2	57.0	.00068	.68	84.4
2.30 to 2.50	.0137	13.7	60.4	.0324	32.4	58.8	.00057	.57	85.1
3.10 to 3.30	.0124	12.4	61.9	.0306	30.6	59.4	.00037	.37	88.4
3.45 to 4.15	.0125	12.5	58.5	.0342	34.2	58.0	.00038	.38	83.0
4.30 to 4.45	.0120	12.0	58.3	.0271	27.1	57.2	.00070	.70	76.5
Average	....	12.59	58.29	....	31.15	56.24	....	.548	84.53

[1] Samples were taken by George D. Bearce, vice chairman committee on waste in the industry, Pulp and Paper Association. Investigation and tests of samples made by Merle B. Shaw and F. E. Frawley, paper section, Bureau of Standards.

Table 14 shows the amount of save-all water going to the sewer. The analysis of this water was shown in Table 13.

TABLE 14.—Amount of Save-All Water to Sewer [1]

Filling of tank No. 1	Time of filling			Water to sewer	Filling of tank No. 2	Time of filling			Water to sewer
	Start	Completion	Period			Start	Completion	Period	
			Min.	Inches				Min.	Inches
First	11.00	11.30	30	26	First	11.30	12.00	30	26
Second	12.00	12.15	15	26	Second	12.15	12.30	15	28
Third	12.30	12.45	15	25	Third	12.45	12.55	10	25
Fourth	12.55	1.10	15	24	Fourth	1.10	1.35	25	29
Fifth	1.35	1.50	15	25	Fifth	1.50	2.01	11	25
Sixth	2.01	2.15	14	25	Sixth	2.15	2.27	12	26
Seventh	2.27	2.41	14	25	Seventh	2.41	3.00	19	29
Eighth	3.00	3.10	10	25	Eighth	3.10	3.21	11	25
Ninth	3.21	3.34	13	24	Ninth	3.34	3.45	11	24
Tenth	3.45	3.56	11	23	Tenth	3.56	4.07	11	25
Eleventh	4.07	4.18	11	25	Eleventh	4.18	4.30	12	29
Twelfth	4.30	5.00	30	25					
Total	....	....	....	298	Total	....	....	....	291

	Gallons
To sewer through No. 1 in 6 hours, 298×155.16 [2]	46,237
To sewer through No. 2 in 6 hours, 291×153.18 [3]	44,575
Total to sewer in 6 hours	90,812
Total to sewer during test of 7¼ hours	109,729
Total to sewer per 24 hours	363,248

[1] Measurements were made during the test from 11 a. m. to 5 p. m. (six hours).
[2] Tank No. 1 was 29 feet by 103 inches.
[3] Tank No. 2 was 29 feet by 105 inches, but had two 2-foot square piers in it, thus making it necessary to deduct 5 gallons per inch of depth measurement.

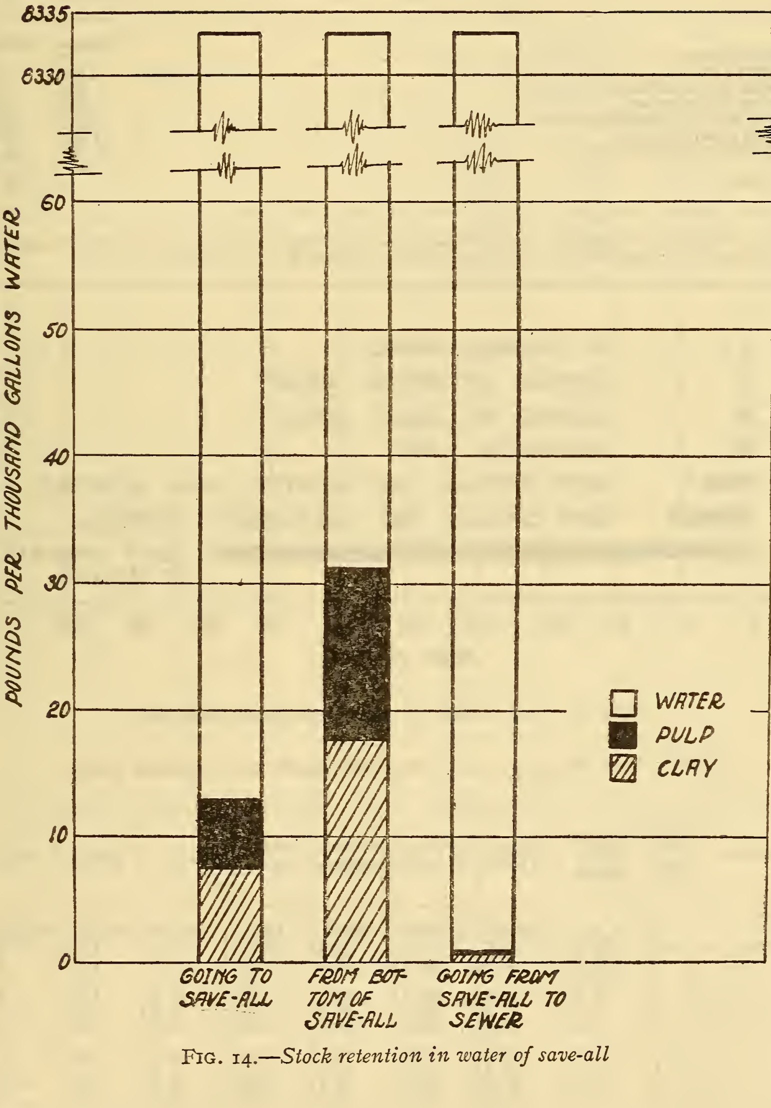


FIG. 14.—*Stock retention in water of save-all*

Table 15 and Figure 15 were derived from the data of the preceding tables. Table 15 shows the amount and distribution of water used during the run.

TABLE 15.—Approximate Distribution and Elimination of Water

Water	Amount during test (7½ hours)	Amount during 24 hours
	Gallons	Gallons
In finished paper	52	172
Evaporated off	2,786	9,212
Removed by second press	602	1,992
Removed by first press	1,925	6,372
From save-all for furnishing beaters [1]	16,765	55,492
Washing down beaters	9,693	32,084
Overflow from save-all to sewer	109,729	363,248
Total	....	468,572

[1] Three thousand nine hundred and seventy-eight extra gallons of water were added with clay slip and size solution in furnishing beaters during test, or the equivalent of 13,167 gallons per 24 hours.

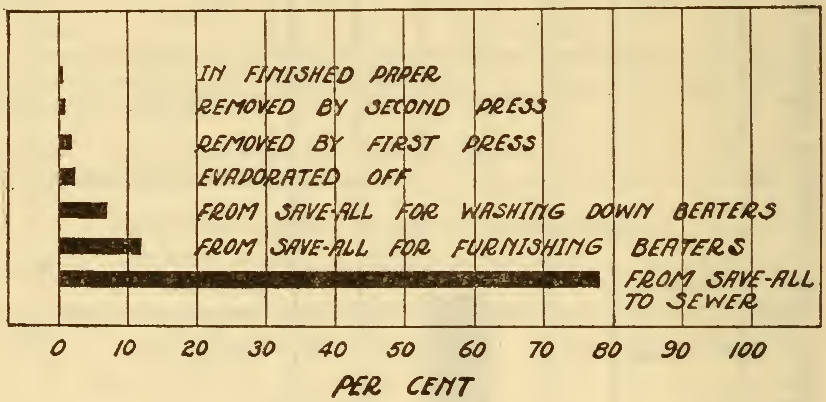


FIG. 15.—*Distribution of water throughout paper run*

TABLE 16.—Physical and Chemical Tests on Finished Paper

Test number	Sample number	Time of taking sample	Weight, 25 by 40	Weight, 44 by 62	Bursting strength	Thickness	Ratio [1]	Resins	Ash [2]
		a. m.	Pounds	Pounds	Points	Inch	Per cent	Per cent	Per cent
8817	1	10.00	55.0	150.0	11.5	0.0031	21.0	1.17	15.6
8818	2	11.00	48.6	132.6	11.1	.0030	22.8	1.08	15.9
		p. m.							
8819	3	12.10	53.4	145.3	11.5	.0032	21.5	1.29	16.5
8820	4	1.20	51.3	139.5	10.0	.0030	19.6	1.28	16.6
8821	5	2.15	52.2	142.2	10.1	.0030	19.5	1.16	17.1
8822	6	3.10	50.2	137.8	10.1	.0030	20.3	1.09	15.8
8823	7	4.10	53.9	147.0	11.1	.0030	20.6	1.16	16.9
8824	8	5.15	55.6	154.2	11.1	.0032	20.0	1.11	15.4

[1] Ratio is obtained by dividing the bursting strength by the weight of the standard size ream (25 by 40–500) and multiplying the result by 100.
[2] Ash not run on a bone-dry sample, but on sheet at time of analysis.

4. AMOUNT AND ANALYSIS OF STOCK AT DIFFERENT PARTS OF THE PAPER MACHINE

The following data are not included as having any direct value in the study of clay retention or losses in white water. It was believed, however, that little general information has been obtained as to either the amount or kind of stock at the different parts of a paper machine, therefore, the determinations for this run are included as being of general interest.

(*a*) Beater.—

Beater number	Weight of dry furnish	Weight of stock and water from concentration figures	Water in furnish	Water from save-all
	Pounds	Pounds	Gallons	Gallons
1	2,136	29,882	3,324	2,690
2	2,136	31,411	3,508	2,874
3	2,218	29,455	3,263	2,630
4	2,383	31,563	3,496	2,804
5	2,413	33,282	3,699	3,008
6	2,251	31,048	3,451	2,759
Total	13,537	186,641	20,741	16,765

In figuring beater furnish no account has been taken of the stock furnished with the water drawn from the save-all. The amount of stock would only have been from 150 to 250 pounds for six beaters. (See Table 11.) A small error in moisture or weight on six beaters would have been as great as that, or a slight error in measuring the stock in the beater chest or machine chest at the beginning or the end of the test would have affected the results to that extent. Therefore, the amount of stock for the test is considered as the total amount added to the six beaters, and this is also considered as the amount delivered to the head box.

Considering that 13,537 pounds (the total weight of dry furnish) represent 7.25 per cent (by analysis) of the total weight of stock and water and that this was the average concentration of the six beaters, the computed weight of stock and water is 186,717 pounds, or only about 9 gallons more than the amount obtained by adding the individual beater figures. This is considered a good check on the analysis.

(*b*) Stuff Box.—The average concentration of stock at the stuff box was 5.06 per cent. The dilution from 7.25 per cent to 5.06 per cent was due to the water which was used in washing down the beaters and which was taken from the save-all.

Assuming that 13,537 pounds represent 5.06 per cent of the total amount, this percentage representing the average concentration of the stock at the stuff box, the total weight of stock and water delivered to the stuff box was 267,530 pounds. This is 80,889 pounds more material than the beater furnishes (186,641 pounds) and is the 9,693 gallons of water coming from the save-all.

The total amount of water now with the stock is 30,436 gallons, of which 26,458 gallons have been drawn from the save-all to bring about the dilution at this point.

(*c*) Head Box.—Under head box was figured the amount of water necessary to dilute the stock coming from the stuff box to the dilution delivered at the head box. The weight of the stock delivered to the head box was considered as 13,537 pounds and the average concentration figures showed it to represent 0.866 per cent of the total. This makes 1,563,164 pounds the total weight of material furnished at the head box during the test. Up to this point the amount of material was 267,530 pounds. The difference between these two amounts gives the quantity of water necessary to bring about this further dilution. It is thought that not all this water can be considered as having come from the save-all. (The approximate amount of water necessary to make a 0.866 per cent dilution is 1,295,634 pounds, or 155,258 gallons.)

(*d*) First Press.—The amounts used for the total weight of the paper leaving the wire and passing to the first and second presses are not theoretically correct. It is known that losses occur before the paper leaves the wire and that stock is removed by the presses, but to get these data the equipment and layout required would be so elaborate that it was considered that the method actually used was correct for practical purposes. Also there was a suction box on the first press, but it was thought to return so little material to the system that the water removed by first press was considered as not going back to the save-all.

The total weight of paper made, including finished paper, dry broke, and wet broke converted to bone-dry basis, is considered as having passed through the first press. This amount is 12,133 pounds. When coming off the wire, and before going through the first press, these 12,133 pounds represent 21.15 per cent of the whole, making 57,366 pounds the weight of material going to the first press. After going through the first press the 12,133 pounds represent 29.35 per cent of the whole, making 41,339 pounds the weight of material leaving the first press. The difference between these two weights gives the amount of water removed after leaving the wire and before reaching the second press. This amount is 16,027 pounds, or 1,925 gallons in 7¼ hours (265 gallons per hour, or 6,360 gallons (850 cubic feet) per 24 hours).

(*e*) Second Press.—One-half the wet broke was considered as having gone through the second press. There were 11,909 pounds of bone-dry paper made, and this, with one-half of the wet broke converted to dry basis (112 pounds), makes the total bone-dry paper going through the second press 12,021 pounds. Before going through the second press these 12,021 pounds represent 29.35 per cent of the whole, giving 40,954 pounds as the amount of material going to the second press. After going through the second press this weight of 12,021 pounds represents 33.46 per cent of the whole, making 35,926 pounds the weight of material leaving at this point. The difference between these two weights gives the amount of water removed by the second press in 7¼ hours, 5,028 pounds, or 602 gallons (83 gallons per hour, or 1,992 gallons (266 cubic feet) per 24 hours).

(*f*) Dryers.—The weight of paper made, including the dry broke, was 12,341 pounds, with an average moisture of 3.5 per cent. This gives 11,909 pounds as the amount of bone-dry paper made and is also the amount to be considered as total solids going over the dryers in 7 hours and 15 minutes, or during the test.

The paper going onto the dryers had an average of 33.46 per cent solids. This means that 11,909 pounds is 33.46 per cent of the whole that goes onto the dryers. The total weight of material going to the dryers is, therefore, 35,592 pounds. The difference between this total weight and the total weight of bone-dry paper at the dry end gives the amount of water going to the dryers. The amount of water was, therefore, 23,683 pounds (2,833 gallons), but since there were 432 pounds left in the finished paper, 23,251 pounds, or 2,786 gallons, is the amount of water evaporated off at the dryers in 7¼ hours (384 gallons per hour, 9,216 gallons (1,233 cubic feet) per 24 hours).

5. RECOVERY AND CLAY RETENTION

The amount of paper made was:

	Pounds
Paper at reel	10,400
Dry broke	1,941
Wet broke	715

This converted to bone-dry basis gives:

	Pounds
10,400 pounds×0.965=	10,036
1,941 pounds×0.965=	1,873
715 pounds×0.314=	224
Total	12,133

12,133 pounds×0.179 (see Table 12)=2,172 pounds, dry clay in finished paper. The amount of dry clay added to the six beaters was 2,660 pounds. The amount of clay in the 773 pounds of paper broke added to the six beaters was 773 pounds×0.179, or 138 pounds. 2,660 pounds+138 pounds=2,798 pounds (total weight of dry clay added).

$$\frac{2,172}{2,798}=77.62 \text{ per cent retention (or recovery) of clay.}$$

The recovery of the total amount of material furnished to the six beaters was:

$$\frac{12,133}{13,537}=89.62 \text{ per cent recovery of total furnish.}$$

The per cent recovery of total furnish seems low, but this may be accounted for in either or both of the following ways: A small error in the moisture or the weight of the materials going to make up the furnish of the six beaters or a slight error in measuring the stock in the beater chest or the machine chest at the beginning or the end of the test.

6. VALUE OF A SAVE-ALL

Some of the advantages in the use of a save-all are shown in the following: The approximate saving in water can be considered at least as the amount drawn from the save-all in furnishing and washing down the beaters, or 18.7 per cent of the total water used in the run. If fresh water were used in furnishing the beater, and no arrangement were made for using the water from the machine over again, other than for diluting stock coming onto the machine (mill practice), the amount of water going to the sewer would be, on a 24-hour basis (see Table 15):

	Gallons
Overflow from save-all to sewer	363,248
From save-all for furnishing beaters	55,492
From save-all for washing down beaters	32,084
Total (which would have gone to sewer)	450,824

If the water going from the machine to the sewer carried away the same amount of stock per gallon as that now going to the save-all (see Table 13), or 12.6 pounds per thousand gallons, the loss would be 450.8 × 12.6 pounds = 5,680 pounds. Analysis showed that 58.29 per cent (see Table 15) of the stock in the water going to the save-all was clay. If the water going to the save-all were not used there would then be a loss of 3,311 pounds of clay and 2,369 pounds of pulp in the 24-hour run. With the use of the save-all only 363,248 gallons per 24 hours goes to the sewer, and analysis showed it to contain only 0.548 pounds of stock per thousand gallons, thus giving a loss of only 199 pounds, of which 84.53 per cent, or 168 pounds, is clay and 31 pounds is pulp. The returning of water with high concentration of stock from the save-all for dilution purposes before going onto the machine no doubt materially increases the clay retention.

APPENDIX B.—LOG SHEETS OF OBSERVED AND DERIVED DATA FOR A MACHINE RUN

The method, in general, of handling the paper machinery and of taking and recording data is indicated in Figures 16 to 23. The form sheets here shown are used regularly in the paper laboratory of the bureau for recording data taken during the runs. The following forms constitute a complete record for one machine run.

The beater record of Figure 16 (front) shows the furnish, water record, concentration, type of beater used, speed of roll, speed of circulation of stock, position of the bedplate, and the kind of bars. Figure 16 (back) gives the data relative to the handling of the beater roll, time of adding the size and alum, and the temperature of the stock at different times. The chart of Figure 17 gives the amperes drawn by the beater

motor throughout the run. This information is very helpful in duplicating beater runs. It will be noted in Figure 16 (back) that the stock received very little hard beating, was dropped to the chest below, and was diluted a definite amount (in this case 37½ inches), determined by the gauge in the chest after the beater was washed down.

To make the work more nearly duplicative of mill conditions a small Jordan was used, the stock being jordaned directly to the machine. The complete data for the run are given in Figure 19. An ampere curve (see fig. 18) proves helpful for close control work, although watt-meter recorders for the beater and the Jordan might be preferable to the ampere-meter recorders used.

Figures 20 (front) and 20 (back) are records of the paper machine and are self-explanatory, Figure 21 gives the speed of different parts of the machine during the run, Figure 22 shows the manner of reporting the results of the usual physical and chemical tests on the finished paper, and Figure 23 is the "data sheet" of determinations on the various samples described above and completes the records for the machine run.

Form 447
DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS
PAPER SECTION

BEATER RECORD 549
Cooking record —
Jordan record 81
Machine record 342
Test record —

Date May 24, 1923

Object Clays for Fillers — Retention
~~Last previous treatment~~ 20% Number 4 Clay (Domestic)
Pulps: 50% sulphite, 50% Soda — 1½% Size and 2% Alum on Pulps and Clay.
Disposition after beating Dropped to Chest #1 — 37½"

FURNISH

Material	Weight of Material: Gross	Tare	Net	Per cent dry	Dry wt. furnished	Per cent of total	Remarks
			~~lbs~~		~~lbs~~		Per Cent
Sulphite Pulp			29.90	83.7	25.00	38.34	39.7 } Pulps
Soda Pulp			26.75	93.5	25.00	38.34	39.7 and
							Clay
Number 4 Clay (13+ lbs in 1 cu. ft. water)			13.+	99.5	13.00	19.94	20.6 } furnish
14 Liters Size #24			.95	(Rosin)	.95	1.46	1.5 } on pulps
Alum			1.25		1.25	1.92	2.0 } and Clay
					65.20	100.00	

WATER RECORD

Item	Meter reading	Cu. ft.	Gallons
Initial	038762.6		
Furnished	038779.2	16.6	
Added with Clay slip (~~Washed~~)		1.4	
Bleached-washed			
In chest	038787.1	7.9	
Total		25.9	193.7

CONCENTRATION

Item	Quantity
Stock added	65.2 lbs.
Water added	1160 "
Calculated	5.32 Per cent
Wet wt. sample	376.0 grams
Dry wt. sample	19.3 "
Actual concentration	5.13 Per cent
ash	17.71 %

Beater used 50-Pound Wood Tub
at 2:10 P.M.
Speed of roll 212 r.p.m. 1325 ft./min
Speed of Circulation 6 ft/11 sec or 32.7 ft/min
Position of bedplate Centered
Type of bedplate Medium Manganese-Bronze
Kind of fly-bars " "
Remarks

Operator G.W.B.-M.B.S.-A.E.L.
Recorder M.B.S.

(OVER)

FIG. 16 (front).—*Beater record*

LOG OF 50 LB. BEATER # 549

Clock time 5-24-23	Time interval Hr. min.	Position of roll*	~~Consistency~~	~~Amperes~~	~~Volts~~	Temp. °C.	Remarks
8:50	0-0	+10	Lighter - bar up				Started up and furnishing
9:05	0-15	+10	Clay slip added				
9:10	0-20	+10	Lighter - bar down				Furnished
9:15	0-25	+2				23.0	
9:50	1-00	+1				24.5	
10:20	1-30	+1	added 14 liters size # 24			25.5	
10:50	2-00	0				27.0	
11:50	3-00	0				30.0	
12:50	4-00	0				32.5	
1:20	4-30	0	added 1¼ lbs. alum (dissolved)			33.5	
2:20	5-30	0	Lighter - bar up				Dropped to
							chest and
							shut down

* Indicate position of roll by turns of handwheel or by adjustment of weights.

FIG. 16 (back).—*Beater record*

Form 446
DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS
PAPER SECTION

JORDAN RECORD 81
Cooking record ——
Beater record 549
Machine record 342
Test record ——

Date May 25, 1923

Object Clays for Fillers—Retention
~~Last previous treatment~~ 20% Number 4 Clay (Domestic)
Pulps: 50% Sulphite, 50% Soda—1½% Size and 2% Alum on Pulps and Clay
Disposition after jordaning Jordaned direct to machines

LOG

Clock time	Time interval Hr.—min.	Position of plug*	Speed (~~Height of head~~) r.p.m.	Amperes	Volts	Kw.	Remarks
10:30	0—0						started up
10:40	0—10		330	10.0	217		
10:50	0—20		335	10.3	224		
11:00	0—30		337	10.0	224		
11:17	0—47						Stock out
11:20	0—50						shut down

Speed —— r. p. m.
Kind of knives Iron

Remarks

* Indicate position of plug by number of turns of handwheel.

Operator G.W.B.
Recorder M.B.S.—A.B.L.

FIG. 19.—*Jordan record*

DEPARTMENT OF COMMERCE
BUREAU OF STANDARDS
PAPER SECTION
FORM 445

PAPER MACHINE RECORD 342

Cocking record ——

Beater record 549

Jordan 81

Test record 9578

Date May 25, 1923

Object Clays for Fillers – Retention

~~Last previous treatment~~ 20% Number 4 Clay (Domestic)

Pulps: 50% Sulphite, 50% Soda – 1½% Size and 2% alum on Pulps and Clay

Disposition after manufacturing

Kind of paper Book Paper

Shut down					
Started up					
Net time out					

Time paper on reel 10:33 A.m.

Time shut down 11:23 A.m.

Duration of run ...... hrs.

Net running time ...... hrs. 50 min.

Fourdrinier ✓—Cylinder (indicate which) 70 Mesh Wire

Screen plates .014

Concentration of stock at apron .686 per cent. Temp. 25 C.

Concentration of white water #1 ~~per cent~~ 13.5 pounds per 1000 gallons

Speed of machine 54–56 ft. per min.

Shake 3/16 inch at 263–267 r. p. m.

Deckles 17¾ inches.

Suction boxes, 2 boxes on at 5+ in. Hg.

Dandy Small one – No Watermark

Condition of clothing (wire, jackets, weights, etc.): O.K.

Couch 27½ Pound Weights on – out 5"

First press 26 " " " – " 0

Second press 8 " " " – " 12"

Dryers: Used ½" Valve on Main Line

Pressure on regulator ...... lb.

Pressure on steam header ...... lb. Temp. ...... °F.

Pressure on exhaust header ...... lb. Temp. ...... °F.

Calendars 11 Pound Weights on – out 5 to 10"

Reel ...... Width of roll 17 3/16 inches. Total shrinkage 9/16 in. Shrinkage/ft. .380

Production 38.2 lb. paper. x .9573 = 36.6 lb.

17.6 lb. broke. x .9573 = 16.85

6.0 lb wet " x .40 = 2.4

Total Bone Dry Paper 55.85 lb

↗ This does not include the weight of samples taken.

Operator G.W.B.–M.B.S.–A.B.D.

(OVER)

Recorder M.B.S.

GOVERNMENT PRINTING OFFICE

FIG. 20 (front).—*Paper machine record*

WATER RECORD

	Meter reading	Cu. ft.	Gallons	Stuff Box meter
Initial	0161 413			93 962.0
Paper started over wire	0161 428	15		93 965.2
Stock out	0161 710	282		93 973.0
Washed up	0161 735	25		11.0
Total water used		333	2490	

CONDENSATE FROM DRYERS

Time	Gross	Tare	Net	

Remarks: Stock carried water well up on wire. Run O.K.

FIG. 20 (back).—*Paper machine record*

MACHINE RUN NO. 342

LOG SHEET

Date May 25, 1923.

Recorder Lee

A.M. Time	Speed constant drive Motor R.P.M.	Speed of shaker R. P. M.	Speed of machine ft./min.	Weight of paper 17x22-500 Pounds	Speed of Screen Shaft r.p.m.	
10:40	735	263	56.0		168	
10:50	740	267	55.0	21.0	172	
11:00	740	263	54.0	21.0	168	

Elevation of Wire:- (-¼")

Remarks:-

FIG. 21.—*Machine record (speed observations)*

DEPARTMENT OF COMMERCE

FAC:CH
VII-5

Bureau of Standards

Report

ON TESTS OF ONE SAMPLE OF

PAPER

Submitted by Paper Laboratory

Marked Book Paper Run 342

Weight (25×40, 500)	55.4	pounds
Weight ( )		pounds
Bursting strength	9.97	points
Thickness	.0034	inch
Ratio bursting strength to weight (25×40)	18.0	

Fiber composition:	Rag	100	
	Chemical pulp, bleached		%
	Chemical pulp, unbleached		%
	Chemical coniferous pulp		%
	Chemical broad-leaf pulp		%
	Ground-wood pulp		%
	Manila and jute		%
			%
			%
Chemical tests:	Ash	12.2	%
	Total resins	1.5	%
	Animal size		%

Absorption in 10 minutes (Klemm's method):	Machine		mm
	Cross		mm
Folding endurance, double folds (Schopper):	Machine		
	Cross		
Tensile strength per 25 mm (approx. 1 in.):	Machine	4.8	~~mm~~ Kg
	Cross	2.9	~~mm~~ Kg

Contrast Ratio
(Index of transparency or opacity. See B. S. circular on this subject.)

Remarks: Tearing Strength- Machine Direction 30.4 Grams
Brittleness 46.4% Sizing Quality- Curl 21 -Stockigt 68

Color	Felt Side Coe-Reflect.	Wire Side Coe-Reflect.
Blue	.759	.758
Green	.810	.805
Red	.839	.831

Gloss	
32.5%	Felt Side
33.0%	Wire Side

Test Number, Tnp: Investigation
Laboratory Number 9578
Washington, D. C.,

George K. Burgess
~~S. W. STRATTON~~
Director.

Form 62

FIG. 22.—*Report of physical and chemical tests on paper*

DATA SHEET FOR SAMPLES FROM MACHINE RUN No. 342. Date May 25, 1923

Number 4 Clay (Domestic) Merle B. Shaw

Time	*	Stuff Box	Head Box	Before Suction Boxes	After Suction Boxes	After Couch Roll	After First Press	After Second Press	Reel	White Water No. 1	White Water No. 2	Press Water No. 1
10:45	a	X	X	31	2	3	4	5	1	51" in chute #1+2	296 lbs	101 lbs
	b	1069	1083	49.650	43.300	39.720	29.070	35.545	92.550		or	or
	c	519	533	29.72	19.70	20.23	9.16	14.80	23.58	40 cu. ft.	35.4 gals.	12.1 gals.
	d			21.220	27.380	24.575	23.635	26.645	91.530	or		
	e	18.51	3.770	1.29	3.78	5.09	3.66	5.90	22.56	299 gals.		
	f	3.57	.707	4.35	19.2	25.1	40.2	39.9	95.7			
	g	17.66	23.06	19.12	13.61	12.72	12.37	12.56	12.66	1 gal. sample	1 gal. sample	1 gal. sample
10:57	a	X	X	32	7	8	9	10	2	(e) 6.12	(e) 3.14	(e) 12.17
	b	1085	1090	43.240	34.015	36.400	28.600	35.170	86.510	13.5 lbs	6.92 lbs	26.8 lbs
	c	535	540	25.07	15.43	15.29	9.38	12.94	22.95	per M gals.	per M gals.	per M gals.
	d			19.260	21.570	24.870	22.960	27.395	85.610	ash=9.246 g	ash=1.954 g	ash=8.800 g
	e	18.79	3.640	1.08	2.99	3.76	3.74	5.17	22.05	69.4%	62.2%	72.4%
	f	3.50	.675	4.31	19.3	24.6	39.9	39.9	95.8	75.2% clay	67.8% clay	67.0% clay
	g	17.70	24.40	19.05	13.45	13.03	12.59	12.71	12.71			
										Wire Water		Suction Water
11:09	a	X	X	33	12	13	14	15	3			
	b	1075	1095	53.740	49.440	40.000	31.095	37.280	92.980			
	c	525	545	33.48	24.63	19.02	10.91	15.32	25.72	1 gal. Sample		1 gal. Sample
	d			21.685	29.555	25.670	24.540	28.180	91.880	(e) 4.46		(e) 9.62
	e	18.25	3.680	1.43	4.74	4.68	4.36	6.22	24.62	9.83 lbs per M gals.		21.2 lbs. per M gals.
	f	3.48	.675	4.27	19.2	24.6	39.9	40.5	95.7	ash=3.000 g		ash=6.880 g
	g	17.53	24.25	18.79	13.57	12.71	12.27	12.40	12.70	67.2%		71.5%
Average Per Cent												
Solids	f	3.52	.686	4.31	19.2	24.8	40.0	40.1	95.73	74.5% clay		76.8% clay
Ash	g	17.63	23.90	18.99	13.54	12.82	12.41	12.56	12.68			
Clay		19.7	26.9	20.7	14.80	14.05	13.60	13.83	14.00			

*a Can number
b Weight of can and sample in grams
c Weight of sample as taken in grams
d Weight of can and sample in grams after drying
e Weight of bone-dry sample in grams
f Per cent of bone-dry material
g Per cent ash on bone-dry material

FIG. 23.—*Record of derived data*

APPENDIX C.—BIBLIOGRAPHY

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