PERMANENCE STUDIES OF CURRENT COMMERCIAL BOOK PAPERS

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ABSTRACT

This is one of a series of articles dealing with permanence studies of current commercial writing and printing papers. A wide variety of current book papers was tested for purity and strength and the effects of an artificial aging treatment on these papers were studied. In general, these book papers do not have as high purity as has been found in writing papers made of the same kind and quality of fibrous materials, nor do they resist to as great an extent the effects of the heat test used as an artificial aging treatment. The lower permanence qualities of the book papers are probably caused by the emphasis placed on printing quality instead of permanence qualities during their manufacture. The content of acid materials of many of the papers is quite high. Data previously procured indicate that the acidity of a permanent paper should not exceed the equivalent of 0.1 per cent sulphuric anhydride. This is further substantiated by the data obtained in the present study. There is a good correlation between the acidity of the paper and the change in strength and purity caused by the accelerated aging treatment.

Using the test results obtained as a basis, the papers were classified as to their relative permanence qualities. According to this classification system only one of the 28 papers studied could qualify as a permanent paper, but several were only slightly deficient. There was no constant relation between the quality of the raw materials used and the permanence qualities of the papers as judged from the tests applied.

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I. INTRODUCTION

The National Bureau of Standards, in cooperation with various interested governmental and private agencies, is studying problems connected with the permanence of papers used for records. A comprehensive program¹ was formulated, part of which involved the testing of commercial writing and book papers and the fibrous raw

¹ Scribner, B. W., Bureau of Standards Studies on the Deterioration of Paper, Pacific Pulp and Paper Industry, 4, No. 11, pp. 30-34; October, 1930.

materials used in their manufacture to determine as far as possible their probable permanence. A report of the results obtained in the study of the paper-making fibers and of a wide range of current commercial writing papers has been published.² A study of the permanence of representative commercial bond and ledger papers furnished by the United States Government Printing Office has been completed, and the results will be reported later. The present article contains the results of a study of current commercial book papers. The American Library Association and the National Association of Book Publishers both expressed their desire for this particular information. Thus, this article completes a rather thorough survey from a permanence standpoint of papers used for written and printed records that are obtainable on the market at the present time.

II. DESCRIPTION OF PAPERS STUDIED

An outline of the work planned was sent to several manufacturers of book papers with the request that they submit any papers which they considered suitable for the purpose. Some papers were also obtained from deliveries to the United States Government Printing Office. The papers received from these two sources are believed to be representative of current commercial book papers. Following is a list of the papers studied with the descriptions of the materials used in their preparation as furnished by the manufacturers. The numbers of the papers are those used throughout the article:

1. New cotton rags, 85 per cent, and new linen rags, 15 per cent; rosin sized.
2. Chemical wood fiber containing some highly purified wood fiber; rosin sized; clay filled.
3. Bleached cotton fiber, 75 per cent, and bleached sulphite pulp, 25 per cent; sized with 2 per cent rosin and alum.
4. Bleached sulphite pulp, 50 per cent, and unbleached sulphite pulp, 50 per cent; rosin sized; clay filled.
5. The same as paper No. 2, except that the highly purified wood fiber was replaced with an equal amount of cotton linters.
6. Rag fiber, 50 per cent, and sulphite pulp, 50 per cent; rosin sized; clay filled.
7. Rag fiber, 85 per cent, and sulphite pulp, 15 per cent; rosin sized; clay filled.
8. White, uncooked rags, 100 per cent; rosin sized.
9. Rag fiber, "twos and blues" grade, 55 per cent, and chemical wood fiber, 45 per cent; rosin sized; clay filled.
10. Rag fiber, "twos and blues" grade, 50 per cent, and chemical wood fiber, 50 per cent; rosin sized; clay filled.
11. Bleached chemical wood fiber, 100 per cent; rosin sized, clay filled.
12. Rag fiber, "twos and blues" grade, 100 per cent; rosin sized; clay filled.
13. Rag fiber, "No. 1 white" grade, 100 per cent; rosin sized; clay filled.
14. Rag fiber, "No. 2 white" grade, 100 per cent; rosin sized.
15. Rag fiber, "No. 2 white" grade, 100 per cent; rosin sized.

² Rasch, R. H., A Study of Purified Wood Fibers as a Paper-Making Material, *B. S. Jour. Research*, **3**, pp. 469-506; September, 1929.

17. White linen and cotton rags, 100 per cent; rosin sized.
22. Rag fiber, 50 per cent, and bleached chemical wood fiber, 50 per cent; rosin sized; clay filled.
24. Bleached chemical wood fiber, 100 per cent; rosin sized; clay filled.
25. Rag fiber, 100 per cent; rosin sized; used for permanent editions of newspapers and periodicals.
28. Rag fiber, 50 per cent, and bleached chemical wood fiber, 50 per cent; rosin sized; clay filled.
31. Bleached chemical wood fiber, 100 per cent; double coated book paper.
32. Rag fiber, 50 per cent, and bleached chemical wood fiber, 50 per cent; double coated book paper.
37. New rags, 100 per cent; rosin sized.
38. "No. 1 white" grade of rags, 37.5 per cent, "thirds and blues" grade of rags, 37.5 per cent, and sulphite wood fiber, 25 per cent; rosin sized; clay filled.
40. Rag fiber, 50 per cent, bleached chemical wood fiber, 50 per cent; rosin sized; clay filled.
41. Rag fiber, 50 per cent, and bleached chemical wood fiber, 50 per cent; double coated book paper.
45. New white and cream rags, 100 per cent; rosin sized. This paper was manufactured especially with a view to permanence.
46. Same as paper No. 45 but from a different delivery.

III. DESCRIPTION OF TEST METHODS EMPLOYED

1. PREPARATION OF PAPERS FOR TESTING

The samples for physical testing were conditioned and tested in a room maintained at a relative humidity of 65 per cent, ± 2 per cent, and at a temperature of 21°C. , $\pm 2^{\circ}\text{C.}$ (70°F. , $\pm 5^{\circ}\text{F.}$). These conditions are those specified by the paper testing committee of the technical Association of the Pulp and Paper Industry. The samples for the chemical purity tests were reduced to a uniform fibrous condition by means of mechanical disintegration. This method of preparation has been found necessary in order to insure complete reaction of the reagents with the fibers. A description of the grinder used and the reasons for this method of preparation have been given in full in previous publications.³

2. PHYSICAL TESTS

The determinations of thickness, weight, fiber composition, opacity, bursting strength, tearing strength, and tensile strength were made by the official testing methods of the Technical Association of the Pulp and Paper Industry.⁴ The folding endurance was determined with a M. I. T. (Massachusetts Institute of Technology) type of tester, which is also described in Paper Testing Methods. This type of tester was used instead of the Schopper tester because it was necessary to use different tensions when testing different papers. Most of the book papers had insufficient strength to give a significant folding

³ Burton, J. O., and Rasch, R. H., The Determination of the Alpha Cellulose Content and Copper Number of Paper, *B. S. Jour. Research*, **6**, pp. 603-619; April, 1931. See also footnote 2, p. 430.

⁴ Paper Testing Methods, prepared by the Committee on Paper Testing of the Technical Association of the Pulp and Paper Industry, Lockwood Trade J. Co., New York; 1929.

endurance value when the Schopper machine available was used with the specified tension of 1 kg. A folding endurance of at least 100 double folds was desired on all of the papers. To obtain this value the tension on the folding strip would have to be less than 1 kg for most of the papers. On the other hand, for accuracy and to save time in testing, the maximum tension consistent with obtaining a significant folding endurance value should be used. Therefore, different tensions were required for testing different papers. The tension on the paper strip in the Schopper tester may be varied only to a slight extent without changing the spring, and each change of tension requires a painstaking recalibration, whereas the tension on the strip in the M. I. T. tester may be varied over a much wider range and recalibrated with ease. Therefore, the latter type of tester was used. However, even with this machine it was not always possible to obtain a folding endurance value of 100.

3. CHEMICAL PURITY TESTS

All of the chemical tests used have been described in the literature. The determinations of the amounts of rosin, ash, and casein were made by the official methods of the Technical Association of the Pulp and Paper Industry.⁵ The alphacellulose method⁶ was a modification of that of Jentgen, the copper-number method⁶ was essentially that of Braidy, and the acidity method⁷ was the one designed by Kohler and Hall.

4. ACCELERATED AGING TEST

A heat treatment at 100° C. (212° F.), for 72 hours was used to produce accelerated aging. The oven used for this purpose was equipped with a fan and duct for rapidly circulating the air. The temperature was controlled by means of a thermostat and relays to within $\pm 1^\circ$ C. ($\pm 2^\circ$ F.). No attempt was made to purify the air nor to control its humidity. A detailed description and photograph of this oven were included in a previous publication.⁸ The effects of this treatment were measured by the change in the strength of the papers and changes in their chemical purity.

IV. DISCUSSION OF TEST DATA

The test data are given in Table 1. Following is a discussion of them.

1. STRENGTH TESTS

It is difficult to compare the papers with one another as they vary widely in weight and finish. However, the strength of book papers is not such an important indication of quality as it is in the case of writing papers, since the latter are subjected to greater stresses. The folding endurance values obtained mean little in so far as the strengths of the papers are concerned, although they are significant in interpreting the effect of the aging treatment. This is because there is no common basis upon which the papers may be compared, since the

⁵ See footnote 4.

⁶ See footnote 3.

⁷ S. Kohler, and G. Hall, *Acidity in Paper*, *The Paper Ind.*, 7, No. 7; October, 1925.

⁸ See footnote 2, p. 430.

tests were made at various tensions, and as far as is known there is no constant relation between the amount of tension and the folding value. The tearing strength and tensile strength are probably more indicative of the relative strengths of the papers. Some of the book papers compare very favorably with bond papers of the same weight in these two respects.

2. PERMANENCE TESTS

(a) CHEMICAL PURITY TESTS

The basic component of paper is cellulose, but several additional ingredients are added in the manufacturing process. For a permanent paper the cellulose composing the paper should have a high

FIGURE 1.—*Relation between the copper number and the alpha-cellulose content of the book papers studied*

purity, and the amount of added ingredients, especially of those known to be harmful, should be a minimum. The copper number and the alpha-cellulose content are usually regarded as a measure of the purity of the cellulose. Papers of good quality are characterized by low copper numbers and high alpha-cellulose contents. Although there is no infallible rule relating these two purity tests, materials having a low copper number usually have a correspondingly high alpha-cellulose content. That this relation holds in general may be seen from Figure 1, where the copper numbers and alpha-cellulose contents of all the book papers studied are plotted with copper numbers as ordinates and alpha-cellulose contents as abscissas. There are nearly always two, and sometimes three, materials added

to book papers during the manufacturing process. These are rosin and alum for sizing and mineral filler for increasing the opacity and improving the printing quality. An excess of either of the first two is considered harmful. Excessive use of alum results in high acidity, which has a pronounced deteriorative effect upon paper. Nearly all mineral fillers used are chemically inert and are usually regarded as having no harmful effect upon the permanence of the paper.

The values obtained for the alpha-cellulose contents and the copper numbers (see Table 1) indicate a wide variation of purity among the different papers. In general, these book papers have a lower degree of purity than is found in writing papers made of the same quality of fibrous materials. This is probably due to the more severe cooking treatment given the fibers during book paper manufacture in order that the finished paper shall have the desired softness for printing; for the fibers of some of the papers appear to have been very severely treated. These papers, including many having fibers said to be derived from originally high-grade materials, had a very low alpha-cellulose content and high copper number. On the other hand, many of the papers containing fibers derived from materials usually regarded as being of inferior quality had a high degree of cellulosic purity. This shows the importance of careful treatment during the manufacture of permanent record papers. Fibers of high quality may have their purity seriously lowered by improper processing, and fibers of much lower original purity may be purified to a high degree by proper treatment.

The amount of titratable acidity in many of the samples is large. There are considerable data to show that high acidity is associated with rapid deterioration of paper and that an acidity equivalent to 0.1 per cent sulphuric anhydride should not be exceeded. The rosin content of most of the samples is within the limit considered desirable for permanent papers, indicating the tendency of paper manufacturers to use the least rosin possible to obtain the correct printing qualities. This is a commendable practice as there is good reason to believe that rosin has a harmful effect upon cellulose. But with the lowering of the rosin content it should be possible to avoid the use of much of the alum, which, if done, would result in a lower acidity. It is questionable if the use of rosin in book papers is necessary.

TABLE 1.—Test data on current commercial book papers

Sample No.	Fiber composition			Sizing		Ash	Weight, 500 sheets 24 by 40 inches	Thick- ness	Opacity	Bursting strength	
	Rag	Chemical wood, coniferous	Chemical wood, deciduous	Rosin	Casein					Before heat- ing	After heat- ing
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Pounds	Inch	Per cent	Points	Points
1-----	100			1.2		0.60	53.9	0.0037	83.0	34.6	30.0
2-----		50	50	0.5		14.67	54.1	.0040	92.9	14.9	14.5
3-----	75	15	10	1.6		1.61	38.5	.0030	79.4	15.2	14.0
4-----		100		1.4		16.43	35.9	.0021	86.1	8.8	7.8
5-----				0.7		15.53	54.0	.0041	93.0	11.7	11.2
6-----	50	50		1.1		14.26	62.3	.0052	93.4	19.3	19.0
7-----	90	10		1.0		12.35	62.2	.0066	94.0	11.8	12.1
8-----	100			1.3		.18	63.4	.0073	93.0	13.8	14.5
9-----	30	10	60	1.7		7.55	40.5	.0030	85.0	11.9	10.7
10-----	50	10	40	0.7		14.43	52.1	.0030	88.6	11.7	10.8

TABLE 1.—Test data on current commercial book papers—Continued

Sample No.	Fiber composition			Sizing		Ash	Weight, 500 sheets 24 by 40 inches	Thick- ness	Opacity	Bursting strength	
	Rag	Chemical wood, coniferous	Chemical wood, deciduous	Rosin	Casein					Before heat- ing	After heat- ing
	Per cent	Per cent	Per cent	Per cent	Per cent	Per cent	Pounds	Inch	Per cent	Points	Points
11.....		40	60	1.1		8.52	41.1	0.0031	84.4	14.6	10.4
12.....	100			1.3		7.97	53.1	.0038	85.2	17.8	16.3
13.....	100			1.7		11.12	66.0	.0066	93.4	11.0	9.5
14.....	100			2.4		3.91	41.8	.0041	84.8	10.0	9.5
15.....	95	5		1.7		6.06	57.3	.0032	90.0	15.3	13.8
17.....	100			1.4		1.33	88.8	.0118	94.9	33.6	33.3
22.....	50	30	20	2.5		5.50	43.5	.0035	87.1	13.1	9.5
24.....		40	60	0.9		9.68	46.5	.0026	83.1	13.0	10.8
25.....	100			1.0		.77	40.7	.0030	81.5	14.6	14.8
28.....	50	50		0.8		11.00	46.7	.0030	85.6	14.4	13.9
31.....		70	30	1.0	4.90	24.00	70.2	.0034	95.0	20.4	18.7
32.....	60	40		1.4	5.96	23.30	87.0	.0042	97.7	31.8	30.8
37.....	100			1.2		.64	45.1	.0071	96.2	25.7	26.2
38.....	75	25		1.4		12.68	41.9	.0027	86.7	13.6	12.5
40.....	50	50		2.0		9.87	40.0	.0031	86.6	10.8	12.3
41.....	60	35	5	1.5	5.78	24.86	89.3	.0042	97.0	28.4	27.9
45.....	100			1.7		.29	77.7	.0063		44.9	44.1
46.....	100			1.2		.20	76.7	.0060		52.3	51.5

Sample No.	Folding endurance								Tearing strength							
	Machine direction				Across machine direction				Machine direction				Across machine direction			
	Tension	Before heating	After heating	Retention	Before heating	After heating	Retention	Average retention	Before heating	After heating	Retention	Average retention	Before heating	After heating	Retention	Average retention
	kg	Double folds	Double folds	Per cent	Double folds	Double folds	Per cent	Per cent	g	g	Per cent	Per cent	g	g	Per cent	Per cent
1.....	1.0	159	75	47	98	62	63	55	100.4	66.4	66	66	104.0	68.4	66	66
2.....	.5	36	29	81	27	19	70	76	57.0	55.0	96	115	42.6	49.2	115	106
3.....	.5	142	81	57	39	32	82	70	42.8	43.6	102	95	37.8	33.4	88	95
4.....	.4	18	11	61	18	3	17	39	25.3	16.8	66	63	24.3	14.7	60	63
5.....	.4	23	16	70	18	14	78	74	37.6	36.4	97	93	36.8	32.6	89	93
6.....	.5	299	174	58	68	52	76	67	78.4	70.0	90	89	76.4	67.6	88	89
7.....	.3	57	41	72	27	21	78	75	46.4	46.4	100	95	42.0	39.8	95	98
8.....	.3	119	88	74	50	37	74	74	58.6	53.4	91	96	50.4	50.6	100	96
9.....	.5	16	10	63	16	10	63	63	33.2	26.0	78	84	30.4	27.2	89	84
10.....	.5	12	5	42	11	5	45	44	35.2	28.4	81	84	31.2	27.2	87	84
11.....	.5	53	3	6	32	4	13	10	36.6	18.4	50	50	29.2	14.8	50	50
12.....	.5	40	13	33	48	17	35	34	43.2	38.4	89	83	44.0	34.0	77	83
13.....	.3	21	7	33	18	7	39	36	54.4	45.0	83	89	47.4	45.0	95	89
14.....	.5	17	7	41	9	6	67	54	38.2	32.6	85	90	32.6	31.0	95	90
15.....	.5	41	17	41	23	15	65	53	49.0	37.6	77	80	38.9	31.8	82	80
17.....	.5	168	56	33	135	69	51	42	81.2	82.0	101	100	80.4	79.6	99	100
22.....	.5	118	9	8	35	8	23	16	38.8	35.2	91	102	31.0	34.8	112	102
24.....	.5	27	10	37	25	10	40	39	36.8	26.4	72	73	31.4	23.0	73	73
25.....	.5	299	316	106	138	100	72	89	58.4	62.4	107	102	60.0	57.8	96	102
28.....	.5	171	77	45	66	43	65	55	45.0	45.4	101	96	41.6	38.0	91	96
31.....	.5	21	18	86	34	28	82	84	36.0	32.2	89	87	36.4	30.6	84	87
32.....	.8	248	162	65	82	67	82	74	76.4	71.4	93	92	69.6	63.4	91	92
37.....	.5	177	158	89	74	87	118	104	98.0	97.2	99	100	99.2	99.2	100	100
38.....	.5	288	187	65	54	53	98	82	61.8	55.6	90	89	56.8	49.8	88	89
40.....	.5	54	30	56	12	12	100	78	38.0	37.2	98	105	33.6	37.6	112	105
41.....	.7	213	105	49	93	68	73	61	66.0	60.8	92	74	57.2	31.6	55	74
45.....	(1)	740	702	95	289	203	70	83	136.8	124.8	91	93	140.8	133.2	95	93
46.....	(1)	1,699	1,331	78	639	500	78	78	121.6	115.6	95	97	124.4	122.0	98	97

1 The folding endurance of papers 45 and 46 was determined with the Schopper folding endurance machine .

TABLE 1.—Test data on current commercial book papers—Continued

Sample No.	Tensile strength							Alpha-cellulose content			Copper No.			Acidity	
	Machine direction			Across machine direction			Average retention	Before heating	After heating	Loss	Before heating	After heating	Increase	Sulphuric anhydride	Acid number
	Before heating	After heating	Retention	Before heating	After heating	Retention									
	kg	kg	Per cent	kg	kg	Per cent	Per cent	Per cent	Per cent	Per cent				Per cent	
1-----	6.90	6.71	97	4.18	3.95	95	96	86.56	82.36	4.20	2.56	3.09	0.53	0.096	24
2-----	3.92	3.89	99	2.17	2.11	97	98	76.53	76.26	.27	3.25	3.64	.39	.024	6
3-----	3.35	3.46	103	1.91	1.77	93	98	86.98	82.80	4.18	2.14	2.73	.59	.120	30
4-----	2.26	2.16	96	1.29	1.38	107	102	81.04	78.38	2.66	4.53	4.98	.45	.148	37
5-----	3.07	2.85	93	1.76	1.70	97	95	78.91	77.55	1.36	2.98	3.22	.24	.032	8
6-----	5.60	5.51	98	2.31	2.30	100	99	89.60	84.70	4.90	2.34	2.86	.52	.048	12
7-----	3.48	3.50	101	1.65	1.73	105	103	91.98	83.68	8.30	1.82	2.39	.57	.020	5
8-----	3.93	4.10	104	2.04	2.18	107	106	93.54	85.99	7.55	1.41	1.90	.49	.040	10
9-----	3.08	2.90	94	1.86	1.79	96	95	74.09	68.75	5.34	3.69	4.29	.60	.232	58
10-----	3.16	2.93	93	1.78	1.72	97	95	70.95	63.93	7.02	5.33	5.70	.37	.188	47
11-----	3.78	3.62	96	1.83	1.61	88	92	71.08	58.61	12.47	4.75	5.56	.80	.240	60
12-----	4.20	3.86	92	2.56	2.37	93	93	73.90	69.53	4.37	4.40	4.88	.48	.180	45
13-----	3.19	2.84	89	1.96	1.83	93	91	72.23	66.87	5.36	5.75	6.15	.40	.152	38
14-----	2.64	2.51	95	1.26	1.28	102	99	83.49	77.63	5.86	2.61	3.17	.56	.184	46
15-----	4.02	3.82	95	2.19	2.08	95	95	77.37	71.16	6.21	4.03	4.32	.29	.208	52
17-----	6.93	6.82	98	4.92	5.05	103	101	88.45	84.02	4.43	1.72	2.19	.47	.152	38
22-----	3.31	2.69	81	1.56	1.39	89	85	83.31	67.68	15.63	3.07	4.17	1.10	.196	49
24-----	3.70	3.50	95	1.90	1.90	100	98	74.43	68.42	6.01	4.35	4.84	.49	.196	49
25-----	3.10	3.20	103	1.80	1.90	106	105	91.92	91.06	.86	1.32	1.46	.14	.080	20
28-----	4.00	3.80	95	2.00	2.00	100	98	83.40	81.37	2.03	2.95	3.28	.33	.092	23
31-----	5.15	4.82	94	3.14	2.85	91	93	79.23	76.56	2.67	3.10	3.18	.08	-----	-----
32-----	7.20	6.93	96	3.77	3.66	97	97	86.09	85.82	.27	1.13	1.77	.64	-----	-----
37-----	6.10	6.30	103	3.70	3.70	100	102	93.36	92.16	1.20	.77	1.02	.25	.060	15
38-----	3.30	3.20	97	1.60	1.50	94	96	91.51	90.21	1.30	1.85	2.37	.51	.048	12
40-----	3.50	3.70	106	1.60	1.70	106	106	86.92	85.23	1.69	2.87	3.34	.47	.068	17
41-----	7.30	7.20	99	3.80	3.80	100	100	84.20	82.10	2.10	2.48	2.95	.47	-----	-----
45-----	9.27	9.22	99	5.30	5.47	103	101	95.00	92.49	2.51	.40	.93	.53	.028	7
46-----	10.02	9.93	99	6.22	6.33	102	101	94.40	92.38	2.02	.35	.64	.29	.015	4

* The acid number is the number of ml of 0.01 *N* NaOH required to neutralize the three successive hot water extracts of 10 g of ground paper.

(b) ACCELERATED AGING TEST

The effect of the accelerated aging treatment, heating for 72 hours at 100° C. (212° F.), is shown by the change in strength of the papers and changes in their chemical purity. In an investigation such as this where a number of kinds of papers from a variety of sources is being studied there are too many variables to obtain very definite relationships among the properties determined. However, several general relationships may be observed.

A high content of acid materials is accompanied by a correspondingly large decrease in alpha-cellulose content. It is noticeable that all of the papers appear to fall into two groups. One of these groups contains papers which lose less than 2 per cent alpha cellulose during the heat treatment, and the other group contains papers which lose more than 4 per cent. The papers in the first group have an acidity less than 0.1 per cent sulphuric anhydride, and those in the second group have an acidity greater than 0.1 per cent sulphuric anhydride. Papers 6, 7, and 8 are exceptions to this classification. These three papers were made by the same manufacturer and according to his

description were made from good materials. They had low acidities, but the decrease of alpha-cellulose content of all three was high. This large decrease in alpha-cellulose content during the heat treatment may have been caused by a too severe treatment of the stock during manufacture.

The increase of the copper number by the heat treatment was not particularly significant. There is a very general relationship in that the best papers, judged from the other tests, increased very little in copper number. Other than this there appeared to be no constant relation between increase in copper number and the other tests.

The loss of strength caused by the heat treatment is best measured by the change in folding endurance. The other strength factors are but slightly changed by this treatment and the more sensitive folding endurance test is the best criterion of loss in strength. There was a general relationship between the chemical purity tests and the retention of folding strength after the accelerated aging treatment. Papers which retained the most strength decreased the least in alpha-cellulose content. There was again the occurrence of two distinct groups of papers. Those which decreased less than 2 per cent in alpha-cellulose content retained more than 70 per cent of their folding strength. Those which decreased more than 4 per cent in alpha-cellulose content retained less than 70 per cent of their folding strength. Samples 6, 7, and 8 are again exceptions to this grouping.

V. CLASSIFICATION OF THE PAPERS RELATIVE TO THEIR PERMANENCE QUALITIES

A system of classification of printing and writing papers relative to their permanence qualities has been suggested by the National Bureau of Standards.⁹ This classification is based upon the purity and strength of the finished paper. The values given are derived from the results of the extensive investigations of this bureau during the past four years on the permanence of paper. In these investigations tests similar to the ones described here have been made on a large number and variety of papers, and it is believed that papers fulfilling the requirements of the various groups will have the relative degree of permanence indicated.

In this system of classification all papers are divided into four classes. The first class contains those papers which may be expected to have maximum longevity. A book paper fulfilling the requirements of this class would be particularly suitable for bound volumes of records having permanent value. The second class contains papers of high purity. Papers used for semipermanent records and in fine editions of rare and costly books should fulfill the requirements of this class. The third class is composed of papers which, while not having as high a degree of purity as those in the first two classes, have a fair degree of purity. Such papers could be used where moderate longevity is desired, such as in reference periodicals. Papers in the fourth class are those suitable for current use only. Table 2 illustrates in detail how such a system of classification might be applied to book papers. Of the book papers studied in the present investiga-

⁹ B. W. Scribner, *Permanence Standards for Printing and Writing Papers*, Trans. A. S. M. E., 52, No. 19, P. I. 52-55; May-August, 1930. Also, *Paper Mill*, 53, p. 13; June 21, 1930.

tion No. 37 is the only one that fulfills completely the requirements of Class I. Some of the other papers fulfill the requirements of this class except in one or two respects. Nos. 25, 32, 38, 45, and 46 fall in Class II; Nos. 1, 2, 3, 5, 6, 7, 8, 17, 28, 31, 40, and 41, in Class III; and the remainder in Class IV.

TABLE 2.—*Classification of book papers*

Class I. PAPERS OF MAXIMUM PURITY FOR PERMANENT RECORDS

Stock: Free from unbleached or ground wood fibers. Alpha cellulose content not less than 90 per cent.

Copper number not more than 1.0.

Acidity: pH value not less than 4.5 and acid number less than 25.

Rosin: Not more than 1.0 per cent.

Stability: When heated for 72 hours at 100° C. the alpha-cellulose content shall decrease not more than 1.5 per cent, the folding endurance shall decrease not more than 25 per cent, and the copper number shall increase not more than 0.5.

Weight, strength, and opacity:

Weight: (25 by 40, 500).....	pounds..	35	40	50	60	70
Weight: (25 by 38, 500).....	pounds..	33.3	38.0	47.5	57.0	66.5
Folding endurance: Average each direction, not less than double folds.....		75	100	125	160	200
Bursting strength: Average not less than.....	points..	20	25	30	35	40
Thickness: Average.....	inch..	0.0035	0.0040	0.0050	0.0060	0.0060
Tensile breaking strength: Average not less than kg per 15 mm width—						
Machine direction.....		4.0	5.0	6.0	7.0	8.0
Across machine direction.....		2.0	2.5	3.0	3.5	4.0
Opacity: Contrast ratio not less than.....	per cent..	84	86	89	90	90

Color, finish, formation, cleanliness, and printing quality: Shall be in accordance with sample.

Testing methods: The testing methods shall be those approved by the Technical Association of the Pulp and Paper Industry. The physical specifications are for a relative humidity of 65 per cent and a temperature of 70° F., which are the testing conditions approved by this association.

Class II. PAPERS OF HIGH PURITY FOR SEMIPERMANENT RECORDS

Stock: Free from unbleached or ground wood fibers. Alpha-cellulose content not less than 80 per cent.

Copper number not more than 2.0.

Acidity: pH value not less than 4.5 and acid number less than 25.

Rosin: Not more than 1.5 per cent.

Weight, strength, and opacity:

Weight: (25 by 40, 500).....	pounds..	35	40	50	60	70
Weight: (25 by 38, 500).....	pounds..	33.3	38.0	47.5	57.0	66.5
Folding endurance: Average each direction, not less than double folds.....		30	40	60	80	100
Bursting strength: Average not less than.....	points..	12	14	18	22	26
Thickness: Average.....	inch..	0.0030	0.0035	0.0045	0.0050	0.0050
Tensile breaking strength: Average not less than kg per 15 mm width—						
Machine direction.....		3.0	3.0	4.0	5.0	6.0
Across machine direction.....		1.5	1.5	2.0	2.5	3.0
Opacity: Contrast ratio not less than.....	per cent..	84	86	89	90	90

Color, finish, formation, cleanliness, and printing quality: Shall be in accordance with sample.

Testing methods: The testing methods shall be those approved by the Technical Association of the Pulp and Paper Industry. The physical specifications are for a relative humidity of 65 per cent and a temperature of 70° F., which are the testing conditions approved by this association.

Class III. PAPERS OF FAIR PURITY FOR RECORDS REQUIRING MODERATE LONGEVITY

Stock: Free from unbleached or ground wood fibers. Alpha-cellulose content not less than 70 per cent.

Copper number not more than 3.5.

Acidity: pH value not less than 4.5 and acid number less than 25.

Rosin: Not more than 2.0 per cent.

Weight, strength, and opacity:

Weight: (25 by 40, 500).....	pounds..	35	40	50	60	70
Weight: (25 by 38, 500).....	pounds..	33.3	38.0	47.5	57.0	66.5
Folding endurance: Average each direction not less than.....	double folds..	15	20	30	40	50
Bursting strength: Average not less than.....	points..	11	12	15	19	22
Thickness: Average.....	inch..	0.0025	0.0030	0.0033	0.0040	0.0050
Tensile breaking strength: Average not less than kg. per 15 mm. width—						
Machine direction.....		3.0	3.0	3.5	3.5	4.0
Across machine direction.....		1.5	1.5	2.0	2.0	2.5
Opacity: Contrast ratio not less than.....	per cent..	84	86	89	90	90

Color, finish, formation, cleanliness, and printing quality: Shall be in accordance with sample.

Testing methods: The testing methods shall be those approved by the Technical Association of the Pulp and Paper Industry. The physical specifications are for a relative humidity of 65 per cent and a temperature of 70° F., which are the testing conditions approved by this association.

TABLE 2.—*Classification of book papers*—Continued

Class IV. PAPERS FOR TEMPORARY USE

Stock, acidity, and rosin: No requirements.

Weight, strength, and opacity:

Weight: (25 by 40,500).....	pounds..	35	40	50	60	70
Weight: (25 by 38,500).....	pounds..	33.3	38.0	47.5	57.0	66.5
Bursting strength: Average not less than.....	points..	9	10	12	14	15
Thickness: Average.....	inch..	0.0025	0.0030	0.0033	0.0040	0.0050
Tensile breaking strength: Average not less than						
kg. per 15 mm. width—						
Machine direction.....		3.0	3.0	3.5	3.5	4.0
Across machine direction.....		1.5	1.5	2.0	2.0	2.0
Opacity: Contrast ratio not less than.....	per cent..	84	86	89	90	90

Color, finish, formation, cleanliness, and printing quality: Shall be in accordance with sample.

Testing methods: The testing methods shall be those approved by the Technical Association of the Pulp and Paper Industry. The physical specifications are for a relative humidity of 65 per cent and a temperature of 70° F., which are the testing conditions approved by this association.

VI. SUMMARY

1. In general, the book papers studied have a lower degree of purity and are affected to a greater extent by the heat test than writing papers made of the same kind and quality of fibrous materials.

2. The rosin content of most of the papers does not appear to be excessive, but the high acidity of many of them indicates an excessive use of alum, a practice which is very detrimental to the permanence of the papers.

3. The accelerated aging test shows that the change in purity, as measured by the change in alpha-cellulose content, is closely related to the loss of strength, as measured by the change in folding endurance, and that both of these factors are closely related to the acidity of the paper.

4. In general, the stability of these papers, as determined by the heat test, was dependent primarily on their chemical purity and had little relation to the source of the paper fiber or to its initial quality.

5. The system of classification suggested distributes the papers among the various classes in about the ratio to be expected of commercial papers selected in the manner herein described.

VII. CONCLUSION

The data produced in this study indicate that book papers, as they are commercially available at the present time, do not have, in general, as high permanence qualities as have been found in writing papers. This is probably largely true because in book papers printing quality appears, in general, to have been given more consideration than permanence, possibly because the purchaser of book papers is usually not so directly concerned with the preservation of printed records as is the purchaser of paper for written records. However, the fact that one of the papers may be classed as a paper of maximum permanence shows that it is possible to obtain permanence qualities in book papers comparable to those which can be obtained in writing papers, and at the same time preserve the printing qualities. A decided trend toward realization of this and of the need for more consideration of permanence qualities by book-paper makers and users is evident. The increasing cooperation in this respect between manufacturer, printer, and librarian will, no doubt, assist materially in making more certain that the paper in publications containing valuable records will have the desired longevity.

WASHINGTON, June 16, 1931.