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Evaluation of Archival Stability of Copies From Representative Office Copying Machines

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Paper Evaluation Section
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Interim Report

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U. S. DEPARTMENT OF COMMERCE, Frederick B. Dent, Secretary

NATIONAL BUREAU OF STANDARDS, Richard W. Roberts, Director

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SECTION I

DEVELOPMENT OF METHODS AND EVALUATION OF STABILITY OF COPIES

1. INTRODUCTION

Technology has been very kind to the office worker, the scientist, the librarian, the archivist, and the businessman by providing, over the past 20 years, a plethora of machines for making copies of originals by pressing a button. This kindness represents a mixed blessing to those who wish to retain copies for some time. As indicated by the deterioration of some copies that have been in file several years, it is obvious that a problem does exist. This problem is especially acute for archivists, librarians, and for county, city, and state offices that require permanent and/or durable paper.

Three factors must be considered with respect to paper for permanent records. These are: (1) physical properties that can be measured in the laboratory, (2) relationship between durability and these measured physical properties, and (3) retention of properties with time. Unfortunately, efforts to start with first principles and build paper structures that satisfy the boundary conditions of permanence (chemical stability), durability (resistance to wear), and cost in relation to known variables have not been particularly fruitful. Even alkaline-filled papers may be unstable if improperly made [1]*. Therefore, the point must be made that we are working with an incomplete matrix of data, although recent information obtained on naturally aged papers [1] may help to fill in some of the voids. Enough empirical information is available to write useful specifications.

An added complication in the use of paper in office copying machines is that the paper must be capable of being transported through the copying machine for which it is intended. Although paper for use in electrostatic copiers, either plain or coated, may be purchased from sources other than the suppliers of the copying machines, this is not frequently done. Properties of the paper in relation to transport and to imaging may be difficult to specify for specific machines. It can be done, but the purchaser must be aware of these potential problems.

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*Figures in brackets indicate literature references at end of report.

Standards for permanent record papers require the availability of an accelerated aging method for estimating relative stability of paper. An accelerated aging method for paper was developed by Hall [2] in which paper was heated in an oven at 100°C for various times and then checked for changes in physical and chemical properties. Rasch [3] selected 72 hours at 100°C in a circulating oven as a standard accelerated aging test. This test was adopted by TAPPI [4] and ASTM [5], but somewhere in the process of standardizing committee activity, the aging temperature was changed from 100°C to 105°C.

The validity of this test for predicting the relative stability of papers has never been widely accepted by the paper industry or by independent research laboratories. Browning and Wink [6] reasoned that the moisture content of paper should remain constant during aging and that, under the conditions used, in which the moisture content was maintained constant, accelerated aging was valid for estimating the relative permanence of paper. They used the Arrhenius approach, i.e., aging at various temperatures and extrapolating some function of change due to accelerated aging to room temperature. Stamm [7], van Royen [8], and Barrow [9] also have used this approach.

Although it is strictly empirical, one may compare the data from accelerated aging with that from natural aging. This approach has been used by the National Bureau of Standards [3, 10, 11, 12] and by van Royen [8]. Others [13, 14] have tested papers after several years of natural aging.

Work at the Institute of Paper Chemistry (IPC) [6] and previous work at NBS on the present project on preservation of records [15, 16] leaned toward a moist aging atmosphere. It was assumed that paper should contain approximately the same moisture content during an accelerated aging procedure as during natural aging. The absolute amount of water vapor in the aging atmosphere to maintain the same moisture content in the paper increased with temperature, and so the partial pressure of oxygen in the aging atmosphere, at constant moisture content of the paper, decreases. Recent work indicated that oxygen and moisture both play significant roles in the degradation of paper [17, 18, 19].

This work also indicated that (1) moist accelerated aging may not be superior to dry aging, and (2) that tools such as wet strength, fiber strength (zero span), and development of acidity may be valuable in the evaluation of naturally aged papers in order to make a selection between moist accelerated aging and dry aging. Folding endurance decreases in both types of accelerated aging, but it decreases more rapidly during moist aging.

The permanence of the "usual" types of printing, such as letterpress and offset, normally is not considered to be a problem, but the stability of images formed by quick copy processes is not known. Therefore, some method, or methods, of evaluation must be devised. This is not as easily said as done, for each type of copy may present a different problem in mechanism of degradation. New processes are continuously appearing on the market, so a complete evaluation represents an impossible job.

A very elementary example is provided by the zinc oxide coated paper that is widely used in direct electrostatic copying. The zinc oxide coating causes the paper to exhibit an alkaline reaction with respect to extract pH [20, 21]. The base paper itself may be quite acid, as it must be well sized to provide the proper hold-out properties in order to prevent the paper from absorbing some of the coating solvent. This would give a spotty coating.

Standards for manifold papers [22], bond and ledger papers [23], and file folders [24] have been written based on pH requirements. These papers are not coated, so a pH value can be used as a rough indicator of stability. The pH value of a coated paper, in which the extract pH of the coating may be radically different from that of the paper, cannot be used as an indicator of stability.

The only answer is to use an accelerated aging method, and test the copy before and after aging for retention of properties. Standard methods are available for the heat aging of paper [4, 5], for the irradiation of materials by carbon arc [25] or xenon arc [26], for the erasability of inked ribbons [27], and for the image evaluation of electrostatic business copies [28]. Until the question of the proper conditions for the heat aging of paper has been clarified, it will be necessary to use the present heat aging method [4, 5] in conjunction with the other tests mentioned above and to supplement these as necessary in order to provide interim standards for quick copies of archival quality. As indicated above, this approach is feasible only because data (unreported) indicate that dry accelerated aging may be useful.

2. SAMPLES

Several manufacturers of office copy machines were contacted and invited to submit samples of paper, both unimaged and imaged, for evaluation. Suppliers were requested to submit only paper and copies that would be expected to last a minimum of 50 years. The samples received were for use either in the "plain paper" copiers, or the direct electrostatic copiers that require coated papers.

Data on the unimaged papers are given in Table 1. Nos. 2100 through 2108 are uncoated, and Nos. 2111, 2112, 2113, and 2127 are coated papers. No. 2100 is an experimental alkaline-filled paper. The nominal basis weights of most of the papers are in the 20 lb. class.

Five bond papers that were used in the development of specifications for bond and ledger papers for permanent records [29] were included in this study. Data on these papers are given in Table 2. One alkaline-filled paper and one paper that apparently is neutral-sized (pH 7.3) are included.

Suppliers were asked to submit good copy for evaluation of the effect of light on the printing. These samples are described in Table 3.

In order to work out a method for evaluating the durability of images produced by office copying machines, both perfect and imperfect copies were needed. Some of the manufacturers made copies in two or three categories of perfection for this study, and these copies are described in Table 4.

3. METHODS OF TESTING

3.1 Aging at Elevated Temperature

ASTM Method D776 [5] was followed using a forced draft oven with a calibrated thermometer. Only one sample of paper was placed in the oven during an aging period, as two samples may interact and give spurious results [30].

3.2 Light Exposure, Xenon Arc

ASTM Standard Recommended Practice G27-70 [26] was followed for light exposure to the 2500-watt water-cooled type xenon arc at 25°C and 50 percent relative humidity for 24, 48, 72, and 96 hours. The light dosage was monitored with NBS Light-Sensitive Papers [31], and the output of the lamp was adjusted to correspond to the required dosage.

3.3 Image Evaluation

An ASTM recommended practice for image evaluation of electrostatic copies is available [28], but the procedures essentially are subjective in nature. The density of the image and the reflectance of the background may be measured, and this was done by using a special print contrast measuring instrument described in 3.5.

3.4 Erasability

The erasability of imaged copy was evaluated using an ASTM method of testing for erasability of inked ribbons [27]. This method specified a specific apparatus for abrasing the imaged specimen, a specific abrasion wheel, and the measurement of reflectance of a relatively large area (0.5 in. in diameter) before and after abrasion. The coefficient of image removal, C, for a pattern area = (F-I) x 100, where F = final reflectance and I = initial reflectance. Print contrast, as described in 3.5, was measured instead of the reflectance of an area 0.5 in. in diameter (3.6).

3.5 Print Contrast and Reflectance of Image and Paper

The reflectance of the image and the paper was measured with a print contrast meter using a tungsten light source and a specimen area 0.008 in. in diameter. Measurements were made with the unfiltered light source and with a filter with a maximum wavelength of 460 nm. By setting the reflectance of the paper at 1.0, the print contrast, which is a function of the reflectance of the image, can be measured directly. As an infinite number of combinations of image and paper reflectances can give the same print contrast ratio value, the reflectances of the ink and paper also were measured, and print contrast ratio was calculated from

$$PC = \left(1 - \frac{R_{ink}}{R_{paper}}\right), \text{ where}$$

PC = print contrast ratio, R_{ink} = reflectance of ink, and R_{paper} = reflectance of paper.

The meter was calibrated with a barium sulfate standard with an absolute reflectance of 99 percent. A secondary opal glass standard with a reflectance of 98 percent was used as a working standard.

3.6 Reflectance

Many approaches are possible to the measurement of reflectance, and the approach depends on the requirements of the job at hand. Print contrast, described in 3.5, is one approach to the measurement of reflectance, but (1) the procedure is not standard and (2) a very small specimen area reduces the precision. ASTM D985 [32] describes the measurement of 45°, 0° directional reflectance of blue light at 457 nm of a specimen area 0.5 in. in diameter. This method is standard in the paper industry, and was used to obtain the reflectance of the unimaged paper.

3.7 Conventional Tests

Folding endurance, bursting strength, tearing resistance, thickness, basis weight, opacity, and pH were obtained by the appropriate ASTM methods [33].

3.8 Statistical Treatment of Data

The standard deviation, s, is a measure of dispersion of the data obtained from n measurements (x_1, x_2 . . . x_n) of the sample, and is estimated by means of the expression

$$s = \sqrt{\frac{\Sigma (x-\bar{x})^2}{n-1}} \qquad [34\text{-}36]$$

$\bar{x}$ is the arithmetic mean of n measurements.

The confidence interval is the range which is expected to include, with a certain degree of probability, the value of interest. It is a measure of the component of uncertainty of the reported average that is due to measurement error and sampling variabilities.

After the degree of probability is selected, the confidence interval may be calculated from the formula

$$\bar{x} \pm \frac{ts}{\sqrt{n}} \qquad [35, \text{page } 2\text{-}3]$$

The value of t is obtained from a statistical table of t distribution, and depends on the number of observations and the specified degree of probability.

In order to compare the performance of two materials (in this report, unaged and aged paper), we will assume that the variability in performance of each (A, unaged, and B, aged) is unknown, but can be assumed to be about the same. Some information already is available indicating that the

difference in variability between test results of unaged and aged papers is not particularly significant [15]. After $\bar{x}_A$, $\bar{x}_B$, S_A, and S_B are calculated, a pooled value, Sp, for the standard deviation is calculated

$$Sp = \sqrt{\frac{(n_A-1)S_A^2 + (n_B-1)S_B^2}{n_A + n_B - 2}} \quad [35, \text{ page } 3\text{-}24]$$

Then a value for u, the test criterion for detecting a difference at 95 percent (in this report) confidence, may be calculated:

$$u = t\ Sp \sqrt{\frac{n_A + n_B}{n_A n_B}} \quad [35, \text{ page } 3\text{-}24]$$

If $\bar{x}_A - \bar{x}_B$ is larger than u, one can conclude that there is a true difference, with 95 percent confidence of being right, between the performances of A and B. This procedure may be used if $n_A = n_B$.

3.9 Sampling

Sheets were selected at random from the supply of paper at hand to create the sample. One half of each sheet was tested (controls), and the other half was aged and tested.

Of the blank sheets that were run through copying machines, half of each sheet was tested, and the other half was aged and tested. Thus, the controls above come from a slightly different statistical population than the sheets that were processed through copying machines.

For evaluating the effect of heat aging and light on imaged copy, an attempt was made to retest the same area each time, but several measurements were made in order to obtain a reasonably small standard deviation.

The imaged copies for measuring the durability of the image were from a different statistical population than the sheets for physical testing. This should not cause any difficulty.

4. RESULTS AND DISCUSSION

The relation between physical properties of paper that can be measured in the laboratory and performance often is elusive. Specifications must be built around products that are available unless the demand is great enough to justify a special production run. Most office copies are not destined for archival use, so it is not to the advantage of either supplier or purchaser to strive for unneeded quality or permanence.

Data on office copy papers and bond papers included in this study are given in Tables 1 and 2. Further data on bond papers are given in NBS Report 10 844, Development of Specifications for Bond and Ledger Papers for Permanent Records, in Tables 1-3 [29].

Some broad generalizations may be made about the properties of the papers in Tables 1 and 2. The papers for "plain paper" copiers, 2100-2108, do not exhibit high fold or tear values. In comparison, the coated papers have somewhat lower tear values and much higher fold values. The bond papers appear to be higher in tear. Although the papers are not particularly directional with respect to tear, they are very directional with respect to fold.

Setting minimum values for tear and fold for specification purposes must be somewhat arbitrary. One is not likely to be able to achieve favorable values in all properties. For example, No. 2100 is an alkaline-filled paper, but its tear and fold values are not high. No. 2104 exhibits relatively good tear and fold values, but the pH is only 4.8, hot extraction. Therefore, a specification document should not be used too rigidly by the purchaser, as suitable paper may be obtained by relaxing one of the requirements.

A brightness minimum should be specified. Opacity may be important for imaging purposes. This, along with other properties such as curl, moisture content, smoothness, stiffness, etc., may be significant to imaging and transport through specific machines, but this is beyond the scope of this report. If a purchaser wishes to buy paper for a particular machine from an independent source, the required characteristics of the paper must be determined or obtained from the manufacturer.

An alkaline filler can be specified for paper for "plain paper" copiers, but alkaline-filled coated papers are not likely to be available except on special order. Although filler and pH requirements can be given for the various levels of permanence, they are not significant for coated papers. One must rely on aging requirements.

Test data for office copy papers after aging for 72 hours at 105°C are given in Table 5, and data on percent retention after aging are given in Table 6. Data on selected bond papers after aging and percent retention are given in Table 7. Retention of fold and tear against hot extraction pH are plotted in Figures 1 and 2, respectively.

The plot in Figure 1 shows that some correlation exists between hot extraction pH and retention of fold after aging. The five ledger papers fall on a straight line, but the office copy papers are very erratic. Three of the four coated papers show good stability toward accelerated aging. The other coated paper probably is an acid paper with poor stability. The "plain paper" copier papers show considerable variation in pH values (4.1-5.2), and retention of fold after accelerated aging varies from 16 percent to 109 percent.

Resistance to tear with aging, shown in Figure 2, does not indicate a wide range in values with aging, as the lowest retention value is 60 percent. Retention of burst after aging is not particularly useful, as the lowest retention value is 78 percent. Retention of brightness was good and was never less than 90 percent.

As the effect of the processing machine on subsequent stability of paper cannot be ignored, several papers were passed through selected copying machines. Some of each sample were then tested and some were aged for 72 hours at 105°C. The test data are given in Table 8, and data on retention of properties are given in Tables 9-11. Averages, standard deviations, and numbers of specimens are given in Tables 12-14, and data for estimating statistical significance of the test data are given in Table 15.

Although fold appears to be the most sensitive criterion of change due to aging, tear next, and burst the least sensitive, the u values are much larger for fold than for tear or burst. Therefore, one must look at the $\bar{x}_A - \bar{x}_B$ values in relation to the u values. The latter usually represents about 20 percent of the fold value, which means that differences of less than about 20 percent in fold may not be significant. This figure can be reduced by making a larger number of observations. The u values for tear and burst usually lie within 5-10 percent of the average values.

The significance of the data for each test, sample, and aging condition is indicated in Table 16. If $\bar{x}_A - \bar{x}_B$ is not appreciably greater than u for a specific test, aging did not produce a measurable difference in the paper with respect to this particular test. If $\bar{x}_A - \bar{x}_B$ is appreciably greater than u, significant change has occurred during the aging procedure.

It is obvious that Nos. 2100, 2111, 2112, 2127, 233, and 238 are stable toward accelerated aging. There is little indication that copying processes degrade the paper or that copy processing enhances the aging process.

Data on the effect of irradiation with a xenon arc, aging for 72 hours at 105°C, and irradiation followed by heat aging are given in Tables 17-19. Reflectance data were obtained using (1) a light source with a dominant wavelength of 460 nm, and (2) an unfiltered incandescent lamp. It is obvious that none of these aging conditions appreciably changed the print contrast ratios.

The "light" specimens described in the tables are readable, although any volume of copy with such a low print contrast ratio would not be comfortable to read.

Print contrast data obtained at a dominant wavelength of 460 nm or with an unfiltered incandescent lamp are satisfactory for evaluation of changes due to aging. Reflectance at 460 nm is more sensitive and, therefore, is preferable, but not every instrument is fitted with this filter. Print contrast data obtained by direct reading of the instrument and by calculation from reflectance data gave essentially the same results.

Changes in print contrast after various cycles of abrasion for copied material having images that are properly fused to paper, marginally fused, or poorly fused, are given in Table 20. An end point of 20 cycles was selected for comparing resistance to abrasion. The print contrast ratios for several samples after abrasion for 20 cycles are given in Table 21.

The effects of aging and of abrasion on print contrast data on several papers, with various image quality levels, are given in Table 22. With one exception, print contrast data placed the image quality in the correct order. Aging for 72 hours at 105°C did little to the unabraded specimens. Aging appeared to do little to the properly imaged specimens, but aging apparently fused the improperly imaged specimens so that they were changed little by abrasion.

Data on differential thermal analysis of the paper evaluated in this project are given in Table 23. Although there is some correlation between T_2 and T_3 and pH, it is very poor. Previous data have indicated that a good correlation between pH and T_3 exists for a homogeneous group of paper [16]. For a heterogeneous group, the correlation is not as good [37].

5. CONCLUSIONS

1. A plot of retention of folding endurance with accelerated aging against hot extraction pH indicates that, with the exception of some coated papers, a relationship exists between these properties.

2. A similar plot of retention of tearing strength with accelerated aging against hot extraction pH is not as convincing as the plot for folding endurance, but apparently the less stable papers can be identified.

3. Assuming that accelerated aging for 72 hours at 105°C is a valid test, it is possible to set arbitrary limits for retention of fold and tear after aging.

4. As data in the literature have shown that there is a correlation between pH and stability of paper, it is reasonable to set pH limits for paper for "plain paper" copiers.

5. Print contrast appears to be an adequate test for measuring the reflectance of office copy images.

6. Print contrast of the samples studied did not change appreciably with accelerated aging, either after 72 hours at 105°C or by irradiation with a xenon lamp.

7. The abrasion test used in this study appears to be adequate to distinguish between properly fused and improperly fused images.

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Table 1. Test data for office copy papers[1] included in aging study.

Sample No.	Type of Paper	Weight per Unit Area		Thickness		Tearing Resistance		MIT Folding Endurance		Bursting Strength	Brightness	Opacity	pH		Source of Paper
		g/m^2	17"x22",500	in.	micrometer	g		1 kg double folds		points	%	%	cold	hot	
						MD	CD	MD	CD						
2100	U[2]	61.7	16.3	0.0043	110	37	38	79	26	23.6	83.9	86.2	8.4	8.8	A
2101	U	76.3	20.2	.0037	94	45	58	70	14	27.4	86.8	91.0	5.2	4.9	A
2102	U	78.2	20.7	.0036	92	38	45	27	15	21.6	86.6	88.3	5.4	4.6	A
2103	U	77.6	20.6	.0043	110	50	66	55	12	22.8	79.8	85.9	4.4	4.1	A
2104	U	76.2	20.2	.0043	110	58	55	120	39	35.2	78.7	88.1	5.4	4.8	A
2105	U	77.2	20.4	.0039	99	52	58	42	17	22.4	85.0	87.2	5.4	4.8	A
2106	U	77.9	20.6	.0040	100	61	59	65	31	27.5	83.1	87.4	5.7	5.1	A
2107	U	75.1	19.9	.0041	100	51	59	96	38	30.6	84.1	85.7	5.8	5.2	B
2108	U	74.7	19.8	.0046	120	47	57	61	18	25.0	87.4	93.6	5.9	5.2	B
2111	C	85.5	22.6	.0029	74	30	33	360	180	26.2	81.4[3] 76.3[4]	93.7	7.1	7.7	C
2112	C	92.7	24.5	.0035	89	41	42	460	290	33.6	83.8 81.3	95.2	7.5	7.2	C
2113	C	82.9	21.9	.0031	79	53	45	620	230	26.0	80.7 77.8	95.7	7.8	8.3	C
2127	C	91.1	24.1	.0028	71	28	32	730	320	32.8	79.7 75.2	93.2	7.1	6.7	D

[1]All were wood pulp papers.
[2]U = uncoated, C = coated on one side only.
[3]Coated side, which takes images
[4]Uncoated side.

Table 2. Test data for selected bond papers[1] included in aging study.

Sample No.	Weight per Unit Area		Thickness		Tearing Resistance		MIT Folding Endurance		Burst	Brightness	Opacity	pH	
	g/m^2	17"x22",500	in.	micrometer	g		1 kg double folds		points	%	%	cold	hot
					MD	CD	MD	CD					
231	75.9	20.1	0.0047	119	45	50	42	16	24.0	88.2	88	5.3	4.7
233	79.0	21.0	.0041	104	74	71	170	140	31.5	80.2	91	8.6	9.5
235	74.4	19.7	.0042	107	49	49	22	20	21.3	82.2	88	5.7	5.1
238	77.4	20.5	.0047	119	70	86	350	120	37.4	87.1	86	7.3	7.2
258	84.9	22.6	.0052	132	62	70	100	37	32.7	87.2	90	4.9	4.4

[1]All are wood pulp papers.

Table 3. Imaged samples for evaluation of resistance to xenon arc.

Sample No.	Imaging Process	Nature of Image	Base Paper	Source
2100 - a	radiant	dark, uniform	2100	
- b	radiant	dark and light	2100	A
- c	heat and pressure	dark, uniform	2100	
- d	heat, pressure	dark and light	2100	
2101 - a, b, c, d			2101	A
2102 - a, b, c, d			2102	A
2103 - a, b, c, d			2103	A
2104 - a, b, c, d			2104	A
2105 - a, b, c, d			2105	A
2106 - a, b, c, d			2106	A
2109	radiant	dark and light	2107	B
2110	radiant	dark and light	2108	B
2114	radiant	dark	2111	C
2117	radiant	dark	2112	C
2120	radiant	dark	2113	C
2128	hot air	dark	2127	D

Table 4. Imaged samples for evaluation of mechanical durability of image.

Sample No.	Imaging Process	Nature of Image	Nature of Fixing	Base Paper	Source
2100 a	radiant	dark	proper	2100	A
c	heat and pressure	dark	proper	2100	A
2101 a	radiant	dark	proper	2101	A
c	heat and pressure	dark	proper	2101	A
2102 a	radiant	dark	proper	2102	A
c	heat and pressure	dark	proper	2102	A
2103 a	radiant	dark	proper	2103	A
c	heat and pressure	dark	proper	2103	A
2104 a	radiant	dark	proper	2104	A
c	heat and pressure	dark	proper	2104	A
2105 a	radiant	dark	proper	2105	A
c	heat and pressure	dark	proper	2105	A
2106 a	radiant	dark	proper	2106	A
c	heat and pressure	dark	proper	2106	A
2109	radiant	dark and light	proper	2107	B
2110	radiant	dark and light	proper	2108	B
2114	radiant	dark	proper	2111	C
2115	radiant	dark and light	poor	2111	C
2116	radiant	dark and light	marginal	2111	C
2117	radiant	dark	proper	2112	C
2118	radiant	dark and light	poor	2112	C
2119	radiant	dark and light	poor	2112	C
2120	radiant	dark	proper	2113	C
2121	radiant	dark	proper	--	A
2122	radiant	dark and light	marginal	--	A
2123	radiant	dark and light	poor	--	A
2124	heat and pressure	dark	proper	--	A
2125	heat and pressure	dark and light	marginal	--	A
2126	heat and pressure	dark and light	poor	--	A
2128	hot air	dark	proper	2127	D

Table 5. Test data for office copy papers after aging for 72 hours at 105°C.

Sample No.	Tearing Resistance g		MIT Folding Endurance 1 kg double folds		Bursting Strength points	Brightness %	pH cold	pH hot
	MD	CD	MD	CD				
2100	34	37	63	26	22.6	80.8	8.3	8.8
2101	34	42	17	6	21.8	80.7	5.2	5.0
2102	29	36	10	9	19.9	80.2	5.3	4.6
2103	32	38	7	4	18.2	75.1	4.4	4.0
2104	55	45	68	28	31.0	74.5	5.3	4.7
2105	44	54	24	11	20.0	78.9	5.2	4.6
2106	59	58	50	27	27.4	79.8	5.4	4.8
2107	45	50	100	37	28.7	79.2	5.7	4.9
2108	36	49	39	13	23.2	81.7	5.5	4.9
2111	28	30	320	150	23.1	81.0[1] 68.9[2]	7.1	7.1
2112	40	37	450	260	30.4	82.6 72.6	7.3	7.0
2113	34	33	160	71	27.8	84.0 69.5	7.8	8.0
2127	26	29	840	280	31.5	78.4 66.7	6.9	6.6

[1]Coated side, which takes images.
[2]Uncoated side.

Table 6. Retention of properties of office copy papers after aging for 72 hours at 105°C.

Sample No.	Initial pH, hot	Percent Retention After Aging[1]				
		Tear[2]	Fold[2]	Burst	Brightness	
2100	8.8	95	85	96	96	
2101	4.9	75	27	79	93	
2102	4.6	78	45	92	93	
2103	4.1	60	16	80	94	
2104	4.8	88	62	88	95	
2105	4.8	89	59	90	93	
2106	5.1	98	80	99	96	
2107	5.2	86	102	94	94	
2108	5.2	82	66	93	93	
2111	7.7	92	87	88	100[3]	90[4]
2112	7.2	93	95	91	98	89
2113	8.3	69	28	107	104	89
2127	6.7	92	107	96	98	89

[1]Percent of value for unaged paper
[2]Average of machine and cross directions.
[3]Coated side.
[4]Uncoated side.

Table 7. Test data for selected bond papers after aging, and percent retention of properties after aging.

Sample No.	Tearing Resistance		MIT Folding Endurance		Burst	Brightness	pH		Percent Retention After Aging			
									Tear[1]	Fold[1]	Burst	Brightness
	g		1 kg double folds		points	%	cold	hot				
	MD	CD	MD	CD								
231	40	43	18	10	22.9	83.3	5.1	4.4	87	48	96	94
233	69	61	170	150	31.6	78.5	8.1	9.3	90	103	100	98
235	38	37	11	10	19.7	77.8	5.7	4.7	77	50	92	95
238	64	78	290	94	37.2	84.7	7.0	6.4	91	82	99	97
258	52	56	27	17	28.7	81.3	5.0	4.2	82	32	87	93

[1]Average of machine and cross direction.

Table 8. Test data for office copy papers and bond papers (1) after exposure to radiant, or heat plus pressure, processing in quick copy machines (unaged); and (2) after processing followed by aging for 72 hours at 105°C (aged).

Sample No.	Imaging Process	MIT Folding Endurance double folds, 1 kg				Internal Tearing Resistance, g				Bursting Strength points		Brightness %	
		Unaged		Aged		Unaged		Aged		Unaged	Aged	Unaged	Aged
		MD	CD	MD	CD	MD	CD	MD	CD				
2100	heat and pressure	69	27	63	26	37	42	35	39	22.7	23.0	83.8	80.5
	radiant	84	30	70	25	37	40	38	39	23.9	23.0	83.8	80.4
2101	heat and pressure	82	20	21	9	49	57	36	41	29.9	24.0	86.8	80.3
	radiant	53	15	17	7	45	56	34	42	27.1	22.2	86.8	81.1
2102	heat and pressure	26	14	8	8	41	46	33	34	20.8	19.7	88.2	79.8
	radiant	32	15	9	8	37	46	31	34	22.1	19.2	88.0	81.5
2103	heat and pressure	48	11	4	4	51	62	27	35	23.1	17.2	81.3	76.3
	radiant	60	13	4	4	50	64	28	36	23.2	17.7	81.6	76.6
2104	heat and pressure	110	39	75	27	53	53	44	48	34.4	32.3	78.0	74.8
	radiant	150	43	73	30	44	51	41	49	37.6	33.8	79.3	74.6
2105	heat and pressure	39	18	22	11	49	57	44	50	22.6	19.8	85.9	79.1
	radiant	50	20	23	13	49	58	45	52	21.8	20.4	85.7	79.6
2106	heat and pressure	60	33	48	27	57	61	51	61	28.0	26.9	83.9	80.7
	radiant	72	38	48	26	55	62	52	54	28.5	27.1	84.1	80.5
2127	hot air	620	370	510	230	34	31	27	26	29.4	29.7	--	--
231	heat and pressure	39	17	23	12	51	53	44	44	24.1	21.2	88.2	82.6
	radiant	39	20	23	12	48	51	43	44	23.4	22.8	87.9	82.2
233	heat and pressure	150	110	140	80	76	63	74	72	30.4	30.4	80.4	78.3
	radiant	180	140	160	150	70	66	72	74	31.4	30.8	80.4	78.6
235	heat and pressure	20	17	10	10	49	47	40	42	20.7	18.6	82.8	78.0
	radiant	22	18	11	10	54	45	42	39	22.0	18.5	82.5	78.3
238	heat and pressure	300	88	270	76	64	74	68	74	36.2	35.3	88.0	85.2
	radiant	370	120	370	93	61	75	65	75	36.6	36.0	87.8	85.2
258	heat and pressure	84	30	25	15	61	70	49	55	30.4	27.0	87.0	80.5
	radiant	110	40	22	13	59	71	50	55	29.2	26.5	86.4	80.3

Table 9. Retention of the internal tearing resistance of quick copy papers and bond papers (1) after accelerated aging for 72 hours at 105°C; (2) after exposure to quick copy process; and (3) after the latter exposure, followed by aging for 72 hours at 105°C.

Sample No.	Percent Retention[1] After:						
	Aging	Quick Copy Processing			Quick Copy Processing Plus Aging		
		Radiation	Heat and Pressure	Hot Air	Radiation	Heat and Pressure	Hot Air
2100	95	103	105		103	99	
2101	75	97	103		74	75	
2102	78	100	105		78	81	
2103	60	98	97		55	53	
2104	88	84	94		79	81	
2105	89	97	97		88	86	
2106	98	98	98		88	93	
2127	92			108			88
231	87	104	109		92	93	
233	90	94	96		101	101	
235	77	101	98		83	84	
238	91	87	88		90	91	
258	82	99	99		80	75	

[1]Percent of value for unaged paper, average of machine and cross directions.

Table 10. Retention of folding endurance of quick copy papers and bond papers (1) after accelerated aging for 72 hours at 105°C, (2) after exposure to quick copy processes, and (3) after the latter exposure followed by aging for 72 hours at 105°C.

Sample No.	Percent Retention[1] After:						
	Aging	Quick Copy Processing			Quick Copy Processing Plus Aging		
		Radiation	Heat and Pressure	Hot Air	Radiation	Heat and Pressure	Hot Air
2100	85	109	91		90	84	
2101	27	81	121		29	36	
2102	45	112	95		40	38	
2103	16	109	88		12	12	
2104	62	126	94		66	66	
2105	59	114	94		59	54	
2106	80	115	97		77	78	
2127	107			95			71
231	48	102	97		60	60	
233	104	103	84		98	70	
235	50	96	91		50	48	
238	82	104	83		98	74	
258	32	101	82		25	29	

[1]Percent of value for unaged paper, average of machine and cross directions.

Table 11. Retention of bursting strength of quick copy papers and bond papers (1) after accelerated aging for 72 hours at 105°C, (2) after exposure to quick copy processes, and (3) after the latter exposure followed by aging for 72 hours at 105°C.

Sample No.	Percent Retention[1] After:						
	Aging	Quick Copy Processing			Quick Copy Processing Plus Aging		
		Radiation	Heat and Pressure	Hot Air	Radiation	Heat and Pressure	Hot Air
2100	96	101	96		97	97	
2101	79	99	109		81	88	
2102	92	102	96		89	91	
2103	80	102	101		78	75	
2104	88	107	98		96	92	
2105	90	97	101		91	88	
2106	99	104	102		99	98	
2127	96			90			91
231	96	98	100		95	88	
233	100	100	97		98	97	
235	92	103	97		87	87	
238	99	98	97		96	94	
258	87	89	93		81	83	

[1]Percent of value for unaged paper

Table 12. Mean internal tearing resistance and standard deviation for quick copy papers and bond papers before and after various treatments, including accelerated aging.

Sample No.	Nature of Sample Treatment Prior to Testing														
	No Treatment					Heat Aging					Processing by Radiation				
	MD g	CD g	MD s^2 g	CD s g	n^1	MD g	CD g	MD s g	CD s g	n	MD g	CD g	MD s g	CD s g	n
						Quick Copy Papers									
2100	37	38	1.7	3.6	10	34	37	2.1	1.7	10	37	40	2.7	2.4	12
2101	45	58	3.1	7.6	10	34	42	2.1	3.8	10	45	56	3.8	5.5	12
2102	38	45	4.9	3.2	10	29	36	1.8	3.8	10	37	46	3.1	3.5	12
2103	50	66	3.4	6.5	10	32	38	2.9	4.5	10	50	64	4.0	4.6	12
2104	58	55	8.4	6.3	10	55	45	17.3	4.6	10	44	51	6.2	2.8	12
2105	52	58	7.3	5.6	10	44	54	2.5	5.9	10	49	58	5.7	5.8	12
2106	61	59	3.7	4.1	10	59	58	8.4	4.0	10	55	62	4.3	4.5	12
2107	51	59	6.1	5.8	10	45	50	4.2	2.4	10					
2108	47	57	4.1	4.5	10	36	49	7.1	3.9	10					
2111	30	33	2.5	1.6	10	28	30	2.0	1.1	10					
2112	41	42	2.7	1.1	10	40	36	3.9	1.4	10					
2113	53	45	7.6	4.1	10	34	33	4.2	4.4	10					
2127	28	32	2.1	2.2	12	26	29	1.3	1.6	12	34[3]	31[3]	2.9[3]	4.5[3]	12
						Bond Papers									
231	45	50	4.5	3.6	12	40	43	4.6	3.1	12	48	51	5.2	1.7	10
233	74	71	9.0	12.2	12	69	61	9.7	4.0	12	70	66	9.5	8.9	12
235	49	49	8.2	7.3	12	38	37	4.1	2.9	12	54	45	9.9	2.0	12
238	70	86	9.5	19.7	12	64	78	4.4	8.8	12	61	75	4.5	8.8	12
258	62	70	4.6	6.3	12	52	56	4.7	7.8	12	59	71	3.5	4.2	12

Table 12 continued

Sample No.	Nature of Sample Treatment Prior to Testing														
	Processing by Radiation and Heat Aging					Processing by Heat and Pressure					Processing by Heat & Pressure & Heat Aging				
	MD g	CD g	MD s[2] g	CD s g	n[1]	MD g	CD g	MD s g	CD s g	n	MD g	CD g	MD s g	CD s g	n
						Quick Copy Papers									
2100	38	39	2.3	5.1	12	37	42	3.1	3.7	12	35	39	2.3	2.6	12
2101	34	42	1.9	2.3	12	49	57	3.8	4.1	12	36	41	4.3	2.1	12
2102	31	34	3.1	2.0	12	41	46	7.0	5.3	12	33	34	4.0	2.2	12
2103	28	36	2.7	4.7	12	51	62	5.0	5.8	12	27	35	2.0	4.1	12
2104	41	49	9.1	7.2	12	53	53	12.6	8.8	12	44	48	10.1	5.1	12
2105	45	52	3.2	4.1	12	49	57	3.0	3.3	12	44	50	7.4	5.0	12
2106	52	54	5.2	3.5	12	57	61	2.1	5.7	12	51	61	2.5	10.1	12
2107															
2108															
2111															
2112															
2113															
2127	27[3]	26[3]	1.8[3]	1.7[3]	12										
						Bond Papers									
231	43	44	6.3	3.1	10	51	53	7.0	2.3	12	44	44	8.8	3.1	12
233	72	74	9.4	10.4	12	76	63	8.4	5.4	12	74	72	12.1	16.4	12
235	42	39	6.9	5.0	12	49	47	4.8	4.4	12	40	42	4.3	7.2	12
238	65	75	11.6	9.1	12	64	74	6.0	7.9	12	68	74	8.9	10.2	12
258	50	55	7.0	7.0	12	61	70	5.2	9.3	12	49	55	3.9	6.7	12

[1]n = number of replicate tests.
[2]s = standard deviation of the mean.
[3]Processing by hot air.

Table 13. Mean MIT folding endurance and standard deviation for quick copy papers and bond papers before and after various treatments, including accelerated aging.

Sample No.	Nature of Sample Treatment Prior to Testing														
	No Treatment					Heat Aging					Processing by Radiation				
	MD	CD	MD s[2]	CD s	n[1]	MD	CD	MD s	CD s	n	MD	CD	MD s	CD s	n
	double folds		double folds			double folds		double folds			double folds		double folds		
						Quick Copy Papers									
2100	79	26	15	6	10	63	26	12	4	10	84	30	19	5	12
2101	70	14	28	4	10	17	6	4	2	10	53	15	11	5	12
2102	27	15	6	3	10	10	9	2	2	10	32	15	4	5	12
2103	55	12	12	2	10	7	4	3	1	10	60	13	14	4	12
2104	116	39	59	12	10	68	28	31	8	10	152	43	64	15	12
2105	42	17	7	5	10	24	11	7	2	10	50	20	9	7	12
2106	65	31	7	6	10	50	27	12	8	10	72	37	14	8	12
2107	96	38	21	11	10	100	37	36	14	10					
2108	61	18	14	6	10	39	13	12	7	10					
2111	360	180	107	75	10	320	150	107	45	10					
2112	460	290	144	124	10	450	260	129	45	10					
2113	622	230	211	50	10	160	71	74	19	10					
2127	729	320	202	119	12	836	280	260	93	12	622[3]	369[3]	145[3]	38[3]	12
						Bond Papers									
231	42	16	9	6	12	18	10	4	3	12	39	20	10	8	10
233	167	140	42	43	12	170	150	43	46	12	181	143	58	57	12
235	22	19	6	4	12	11	10	4	3	12	22	18	6	3	12
238	352	120	96	31	12	290	94	59	30	12	366	119	64	30	12
258	103	37	23	11	12	27	17	8	6	12	110	40	22	10	12

Table 13 continued

Sample No.	Nature of Sample Treatment Prior to Testing														
	Processing by Radiation & Heat Aging					Processing by Heat and Pressure					Processing by Heat & Pressure & Heat Aging				
	MD	CD	MD s[2]	CD s	n[1]	MD	CD	MD s	CD s	n	MD	CD	MD s	CD s	n
	double folds		double folds			double folds		double folds			double folds		double folds		
						Quick Copy Papers									
2100	70	25	17	3	12	69	27	13	3	12	63	26	16	5	12
2101	17	7	3	2	12	82	20	24	6	12	21	9	5	3	12
2102	9	8	3	2	12	26	14	5	4	12	9	8	2	2	12
2103	4	4	2	1	12	48	11	11	2	12	4	4	2	1	12
2104	73	30	32	6	12	108	39	55	12	12	75	27	40	7	12
2105	23	13	3	3	12	38	18	5	3	12	22	11	4	2	12
2106	48	26	11	6	12	59	33	14	7	12	48	27	14	4	12
2107															
2108															
2111															
2112															
2113															
2127	512[3]	230[3]	153[3]	54[3]	12										
						Bond Papers									
231	23	12	4	3	12	39	17	10	4	12	23	12	7	3	12
233	157	148	42	40	12	153	112	41	50	12	138	80	34	34	12
235	11	10	3	2	12	20	17	5	5	12	10	10	3	2	12
238	369	93	70	28	12	302	88	49	18	12	271	76	61	20	12
258	22	13	6	3	12	84	30	20	7	12	25	15	5	6	12

[1]n = number of replicate tests.
[2]s = standard deviation from the mean.
[3]Processing by hot air.

Table 14. Mean bursting strength and standard deviation for quick copy papers and bond papers before and after various treatments including accelerated aging.

Sample No.	Nature of Sample Treatment Prior to Testing																	
	No Treatment			Heat Aging			Processing by Radiation			Processing by Radiation & Heat Aging			Processing by Heat & Pressure			Processing by Heat & Pressure & Heat Aging		
	Burst points	s[1] points	n[2]	Burst points	s points	n	Burst points	s points	n	Burst points	s points	n	Burst points	s points	n	Burst points	s points	n
								Quick Copy Papers										
2100	23.6	1.7	10	22.6	1.2	10	23.9	2.0	12	23.0	1.8	12	22.7	1.6	12	23.0	1.3	12
2101	27.4	1.9	10	21.8	2.4	10	27.1	2.3	12	22.2	1.8	12	29.9	3.5	12	24.0	1.4	12
2102	21.6	1.4	10	19.9	1.3	10	22.1	1.5	12	19.3	1.4	12	20.8	1.4	12	19.7	1.3	12
2103	22.8	2.1	10	18.2	0.8	10	23.2	1.9	12	17.7	1.3	12	23.1	1.0	12	17.2	0.9	12
2104	35.2	4.5	10	31.0	4.4	10	37.6	4.3	12	33.8	3.3	12	34.4	4.6	12	32.3	5.2	12
2105	22.4	1.6	10	20.0	1.7	10	21.8	2.2	12	20.5	1.6	12	22.6	2.0	12	19.8	1.4	12
2106	27.5	2.1	10	27.4	1.0	10	28.5	2.3	12	27.1	1.0	12	28.0	1.5	12	26.9	1.8	12
2107	30.6	1.0	10	28.7	1.5	10												
2108	25.0	0.9	10	23.2	1.4	10												
2111	26.2	3.1	10	27.8	1.7	10												
2112	33.6	1.9	10	30.4	3.1	10												
2113	26.1	1.2	10	23.1	1.4	10												
2127	32.8	2.2	12	31.5	1.6	12	29.4[3]	2.1	12	29.7[3]	1.9	12						
								Bond Papers										
231	24.0	2.3	12	22.9	1.3	12	24.1	1.3	12	22.8	1.9	12	23.4	1.8	12	21.2	1.8	12
233	31.5	1.8	12	31.6	2.3	12	31.4	2.2	12	30.8	3.2	12	30.4	1.5	12	30.4	2.7	12
235	21.3	1.9	12	19.7	1.6	12	22.0	2.3	12	18.5	1.2	12	20.7	1.7	12	18.6	1.7	12
238	37.4	2.4	12	37.3	2.5	12	36.6	2.1	12	36.0	3.4	12	36.2	1.8	12	35.3	2.6	12
258	32.7	1.6	12	28.7	1.2	12	29.3	3.0	12	26.5	1.7	12	30.4	1.9	12	27.0	1.6	12

[1]s = standard deviation from the mean.
[2]n = number of replicate tests.
[3]Processing by hot air.

Table 15. Data for estimating significance of changes at the 95% confidence level in tearing strength, folding endurance, and bursting strength of office copy and bond papers after various treatments. $\bar{X}_a$ = average for untreated paper, $\bar{X}_b$ = average for treated paper, and u is the test criterion at the 95% confidence level. R = radiant energy processing; HP = heat and pressure processing, aging = 105°C for 72 hours.

Sample No.	Treatment	Tearing Resistance, g			Folding Endurance			Burst, points		
		$\bar{X}_a$ or $\bar{X}_b$	$\bar{X}_a - \bar{X}_b$	u	$\bar{X}_a$ or $\bar{X}_b$	$\bar{X}_a - \bar{X}_b$	u	$\bar{X}_a$ or $\bar{X}_b$	$\bar{X}_a - \bar{X}_b$	u
2100	none	37	-	-	79	-	-	23.6	-	-
	aging	34	3	1.8	63	16	13	22.6	1.0	1.4
	R	37	0	2.1	84	+5	15	23.9	+0.3	1.7
	R + aging	38	+1	1.8	70	9	14	23.0	0.6	1.6
	HP	37	0	2.3	69	10	12	22.7	0.9	1.5
	HP + aging	35	2	1.8	63	16	13	23.0	0.6	1.3
2101	none	45	-	-	70	-	-	27.4	-	-
	aging	34	11	2.5	17	53	19	21.8	5.6	2.0
	R	45	0	3.2	53	17	18	27.1	0.3	1.9
	R + aging	34	11	2.2	17	53	17	22.2	5.2	1.7
	HP	49	+4	3.2	82	+8	23	29.9	+1.5	2.6
	HP + aging	36	9	3.4	21	49	17	24.0	3.4	1.5
2102	none	38	-	-	27	-	-	21.6	-	-
	aging	29	9	3.5	10	17	4	19.9	1.7	1.3
	R	37	1	3.6	32	+5	5	22.1	+0.5	1.3
	R + aging	31	7	3.6	9	18	4	19.3	2.3	1.3
	HP	41	+3	5.5	26	1	5	20.8	0.8	1.3
	HP + aging	33	5	4.0	9	18	4	19.7	1.9	1.2
2103	none	50	-	-	55	-	-	22.8	-	-
	aging	32	18	3.1	7	48	9	18.2	4.6	1.5
	R	50	0	3.3	60	+5	11	23.2	+0.4	1.8
	R + aging	28	22	2.7	4	51	7	17.7	5.1	1.5
	HP	51	+1	3.9	48	7	8	23.1	+0.3	1.4
	HP + aging	27	23	2.4	4	51	7	17.2	5.6	1.4

Table 15 continued

Sample No.	Treatment	Tearing Resistance, g			Folding Endurance			Burst, points		
		$\bar{X}_a$ or $\bar{X}_b$	$\bar{X}_a - \bar{X}_b$	u	$\bar{X}_a$ or $\bar{X}_b$	$\bar{X}_a - \bar{X}_b$	u	$\bar{X}_a$ or $\bar{X}_b$	$\bar{X}_a - \bar{X}_b$	u
2104	none	58	-	-	116	-	-	35.2	-	-
	aging	55	3	12.8	68	48	44	31.0	4.2	4.2
	R	44	14	6.5	152	+36	55	37.6	+2.4	3.9
	R + aging	41	17	7.8	73	43	41	33.8	1.4	3.5
	HP	53	5	9.7	108	8	51	34.4	0.8	4.1
	HP + aging	44	14	8.4	75	41	44	32.3	2.9	3.9
2105	none	52	-	-	42	-	-	22.4	-	-
	aging	44	8	5.1	24	18	7	20.0	2.4	1.6
	R	49	3	5.8	50	+8	7	21.8	0.6	1.7
	R + aging	45	7	4.8	23	19	5	20.5	1.9	1.4
	HP	49	3	4.8	38	4	5	22.6	+0.2	1.6
	HP + aging	44	8	6.6	22	20	5	19.8	2.6	1.3
2106	none	61	-	-	65	-	-	27.5	-	-
	aging	59	2	6.0	50	15	9	27.4	0.1	1.6
	R	55	6	3.6	72	+7	10	28.5	+1.0	2.0
	R + aging	52	9	4.1	48	17	8	27.1	0.4	1.4
	HP	57	4	2.6	59	6	10	28.0	+0.5	1.6
	HP + aging	51	10	2.8	48	17	10	26.9	0.6	1.7
2107	none	51	-	-	96	-	-	30.6	-	-
	aging	45	6	4.9	100	+4	28	28.7	1.9	1.2
2108	none	47	-	-	61	-	-	25.0	-	-
	aging	36	11	5.4	39	22	12	23.2	1.8	1.1
2111	none	30	-	-	360	-	-	26.2	-	-
	aging	28	2	2.1	320	40	100	27.8	+1.6	2.4
2112	none	41	-	-	460	-	-	33.6	-	-
	aging	40	1	3.1	450	10	100	30.4	3.2	1.7
2113	none	53	-	-	622	-	-	26.1	-	-
	aging	34	19	5.8	160	462	148	23.1	3.0	1.2

Table 15 continued

Sample No.	Treatment	Tearing Resistance, g			Folding Endurance			Burst, points		
		$\bar{X}_a$ or $\bar{X}_b$	$\bar{X}_a-\bar{X}_b$	u	$\bar{X}_a$ or $\bar{X}_b$	$\bar{X}_a-\bar{X}_b$	u	$\bar{X}_a$ or $\bar{X}_b$	$\bar{X}_a-\bar{X}_b$	u
2127	none	28	-	-	729	-	-	32.8	-	-
	aging	26	2	1.5	836	+107	238	31.5	1.3	1.6
	R	34	+6	2.2	622	107	149	29.4	3.4	1.8
	R + aging	27	1	1.7	512	227	151	29.7	3.1	1.8
231	none	45	-	-	42	-	-	24.0	-	-
	aging	40	5	3.9	18	24	6	22.9	1.1	2.0
	R	48	+3	4.1	39	3	8	24.1	+0.1	1.6
	R + aging	43	2	4.7	23	19	6	22.8	1.2	1.8
	HP	51	+6	5.0	39	3	8	23.4	0.6	1.8
	HP + aging	44	1	5.9	23	19	7	21.2	2.8	1.8
233	none	74	-	-	167	-	-	31.5	-	-
	aging	69	5	7.9	170	+3	36	31.6	+0.1	1.8
	R	70	4	7.8	181	+14	43	31.4	0.1	1.7
	R + aging	72	2	7.8	157	10	36	30.8	0.7	2.2
	HP	76	+2	7.4	153	14	35	30.4	1.1	1.4
	HP + aging	74	0	9.0	138	29	32	30.4	1.1	1.9
235	none	49	-	-	22	-	-	21.3	-	-
	aging	38	11	5.5	11	11	4	19.7	1.6	1.5
	R	54	+5	7.7	22	0	5	22.0	+0.7	1.8
	R + aging	42	7	6.4	11	11	4	18.5	2.8	1.4
	HP	49	0	5.7	20	2	4	20.7	0.6	1.5
	HP + aging	40	9	5.5	10	12	4	18.6	2.7	1.5
238	none	70	-	-	352	-	-	37.4	-	-
	aging	64	6	6.3	290	62	53	37.3	0.1	2.1
	R	61	9	6.3	366	+14	69	36.6	0.8	1.9
	R + aging	65	5	9.0	369	+17	70	36.0	1.4	2.5
	HP	64	6	6.7	302	50	65	36.2	1.2	1.8
	HP + aging	68	2	7.8	371	+19	68	35.3	2.1	2.1
258	none	62	-	-	103	-	-	32.7	-	-
	aging	52	10	3.9	27	76	15	28.7	4.0	1.2
	R	59	3	3.5	110	+7	19	29.3	3.4	2.0
	R + aging	50	12	5.0	22	81	14	26.5	6.2	1.4
	HP	61	1	4.2	84	19	18	30.4	2.3	1.5
	HP + aging	49	13	3.6	25	78	14	27.0	5.7	1.4

Table 16. Significance of the various tests with respect to individual samples and aging processes.

Sample No.	Tearing Strength			Folding Endurance			Bursting Strength		
	Aging	Process.	Process. + Aging[1]	Aging	Process.	Process. + Aging[1]	Aging	Process.	Process. + Aging[1]
2100	X[2]	X	X	MS	X	X	X	X	X
2101	S	X	X	S	X	X	S	X	X
2102	S	X	X	S	X	X	MS	X	X
2103	VS	X	X	VS	X	X	VS	X	X
2104	X	X	X	X	X	X	X	X	X
2105	MS	X	X	S	X	X	MS	X	X
2106	Data not consistent.			MS	X	X	X	X	X
2107	X	-	-	X	-	-	X	-	-
2108	MS	-	-	MS	-	-	MS	-	-
2111	X	-	-	X	-	-	X	--	-
2112	X	-	-	X	-	-	MS	-	-
2113	VS	-	-	VS	-	-	MS	-	-
2127	X	X	X	X	X	X	X	MS	X
231	X	X	X	S	X	X	X	X	X
233	X	X	X	X	X	X	X	X	X
235	S	X	X	S	X	X	MS	X	X
238	X	X	X	X	X	X	X	X	X
258	S	X	X	VS	X	X	S	S	X

[1]This is a comparison of aging with processing plus aging, i.e., does processing enhance aging?

[2]Code: S = significant; VS = very significant; MS = marginally significant; X = not significant.

Table 17. Print contrast ratios for unaged samples and samples irradiated 96 hours with a xenon arc from reflectance measurements using unfiltered incandescent lamp.

Sample No.	Unfiltered Incandescent Lamp					
	Print Contrast Ratios				Paper Reflectance (%)	
	Unaged		Aged		Unaged	Aged
	Dark Image	Light Image	Dark Image	Light Image		
2100 a	0.91	--	0.91	--	78	75
b	0.88	0.25	0.88	0.22	80	79
c	0.86	--	0.86	--	78	77
d	0.85	0.34	0.82	0.33	81	78
2101 a	0.94	--	0.94	--	82	72
b	0.86	0.44	0.89	0.41	82	81
c	0.91	--	0.91	--	82	83
d	0.86	0.47	0.86	0.49	83	83
2102 a	0.92	--	0.92	--	83	80
b	0.88	0.48	0.87	0.47	89	87
c	0.90	--	0.90	--	80	80
d	0.89	0.63	0.89	0.63	89	89
2103 a	0.96	--	0.94	--	79	78
b	0.84	0.37	0.83	0.32	77	77
c	0.89	--	0.88	--	76	75
d	0.78	0.40	0.78	0.38	78	77
2104 a	0.91	--	0.90	--	75	76
b	0.86	0.27	0.87	0.21	75	76
c	0.91	--	0.91	--	77	76
d	0.85	0.45	0.86	0.45	77	78
2105 a	0.95	--	0.94	--	80	81
b	0.85	0.28	0.86	0.29	79	79
c	0.90	--	0.90	--	79	78
d	0.83	0.45	0.83	0.45	77	78
2106 a	0.91	--	0.91	--	78	78
b	0.86	0.33	0.85	0.30	78	78
c	0.92	--	0.91	--	80	80
d	0.86	0.41	0.85	0.41	78	78
2109	0.79	0.56	0.77	0.52	72	70
2110	0.86	0.67	0.84	0.62	81	80
2114	0.75	--	0.72	--	79	84
2115	0.52	--	0.51	--	81	81
2116	0.75	--	0.73	--	78	82
2117	0.76	--	0.76	--	81	83
2118	0.58	--	0.52	--	82	84
2119	0.76	--	0.76	--	78	78
2120	0.81	--	0.80	--	75	83
2128	0.85	0.21	0.83	0.19	78	83

Table 18. Print contrast ratios for unaged samples and samples aged for 72 hours at 105°C from reflectance measurements using a light source with a dominant wavelength of 460 nm and an unfiltered incandescent lamp.

Sample No.	460 nm						Unfiltered Incandescent Lamp					
	Print Contrast Ratios				Paper Reflectance (%)		Print Contrast Ratios				Paper Reflectance (%)	
	Unaged Samples		Oven Aged Samples		Unaged Samples	Oven Aged Samples	Unaged Samples		Oven Aged Samples		Unaged Samples	Oven Aged Samples
2100 a	0.92	--	0.91	--	75	76	0.93	--	0.91	--	76	77
b	0.84	0.33	0.83	0.30	79	75	0.86	0.36	0.86	0.32	77	79
c	0.88	--	0.88	--	78	77	0.90	--	0.88	--	78	76
d	0.78	0.33	0.79	0.32	75	75	0.81	0.34	0.80	0.35	78	76
2101 a	0.94	--	0.93	--	84	80	0.94	--	0.94	--	80	82
b	0.87	0.57	0.85	0.45	82	78	0.88	0.47	0.88	0.45	80	82
c	0.90	--	0.93	--	82	77	0.94	--	0.92	--	77	78
d	0.86	0.56	0.88	0.58	83	79	0.90	0.59	0.87	0.60	80	83
2102 a	0.92	--	0.93	--	83	82	0.93	--	0.94	--	80	81
b	0.86	0.48	0.89	0.47	84	82	0.89	0.47	0.87	0.46	82	83
c	0.90	--	0.94	--	84	78	0.94	--	0.92	--	81	80
d	0.86	0.64	0.89	0.62	82	80	0.90	0.64	0.89	0.64	81	81
2103 a	0.92	--	0.90	--	78	75	0.93	--	0.93	--	75	76
b	0.87	0.43	0.86	0.45	81	74	0.87	0.45	0.87	0.44	78	78
c	0.90	--	0.92	--	78	71	0.92	--	0.91	--	75	79
d	0.80	0.45	0.78	0.41	78	72	0.82	0.47	0.81	0.43	76	77
2104 a	0.92	--	0.91	--	76	72	0.91	--	0.92	--	75	76
b	0.88	0.46	0.88	0.50	77	72	0.90	0.47	0.91	0.42	74	75
c	0.91	--	0.93	--	79	74	0.94	--	0.92	--	77	76
d	0.85	0.53	0.86	0.52	78	72	0.89	0.56	0.89	0.55	76	76
2105 a	0.93	--	0.93	--	82	77	0.95	--	0.94	--	77	77
b	0.88	0.48	0.88	0.57	81	79	0.90	0.53	0.89	0.46	79	80
c	0.90	--	0.93	--	79	74	0.94	--	0.91	--	75	78
d	0.86	0.56	0.90	0.59	79	77	0.91	0.65	0.88	0.66	78	80

Table 18 continued

Sample No.	460 nm						Unfiltered Incandescent Lamp					
	Print Contrast Ratios				Paper Reflectance (%)		Print Contrast Ratios				Paper Reflectance (%)	
	Unaged Samples		Oven Aged Samples		Unaged Samples	Oven Aged Samples	Unaged Samples		Oven Aged Samples		Unaged Samples	Oven Aged Samples
2106 a	0.94	--	0.94	--	80	77	0.95	--	0.95	---	77	80
b	0.88	0.48	0.88	0.48	80	78	0.90	0.51	0.89	0.46	78	80
c	0.91	--	0.94	--	80	75	0.95	--	0.92	--	77	78
d	0.86	0.66	0.90	0.69	79	77	0.91	0.68	0 88	0.64	78	78
2109	0.80	--	0.80	--	76	72	0.81	--	0.82	--	74	74
2110	0.77	--	0.78	--	84	78	0.77	--	0.81	--	78	78
2114	0.73	--	0.72	--	77	80	0.74	--	0.73	--	79	82
2115	0.34	--	0.32	--	76	78	0.38	--	0.32	--	78	79
2116	0.67	--	0.74	--	76	77	0.71	--	0.74	--	77	76
2117	0.72	--	0.73	--	81	79	0.74	--	0.68	--	81	77
2118	0.36	--	0.43	--	78	84	0.34	--	0.45	--	81	84
2119	0.70	--	0.71	--	79	78	0.74	--	0.77	--	78	81
2120	0.80	--	0.77	--	78	83	0.78	--	0.78	--	84	82
2128	0.82	0.13	0.82	0.14	79	79	0.80	0.14	0.83	0.13	78	81

Table 19. Print contrast ratios for unaged samples and samples irradiated 96 hours with a xenon arc followed by aging for 72 hours at 105°C using a light source with a dominant wavelength of 460 nm and an unfiltered incandescent lamp.

Sample No.	λ = 460 nm						Unfiltered Incandescent Lamp					
	Print Contrast Ratios				Paper Reflectance (%)		Print Contrast Ratios				Paper Reflectance (%)	
	Unaged		Aged		Unaged	Aged	Unaged		Aged		Unaged	Aged
	Dark Image	Light Image	Dark Image	Light Image			Dark Image	Light Image	Dark Image	Light Image		
2100 a	0.90	--	0.92	--	80	75	0.90	--	0.93	--	71	67
b	0.83	0.09	0.81	0.18	78	74	0.85	0.08	0.85	0.26	68	69
c	0.86	--	0.85	---	78	76	0.88	--	0.90	--	67	71
d	0.79	0.34	0.80	0.36	78	74	0.83	0.34	0.83	0.36	70	71
2101 a	0.91	--	0.91	--	82	74	0.93	--	0.84	--	72	70
b	0.84	0.44	0.82	0.43	84	74	0.89	0.48	0.84	0.43	73	70
c	0.88	--	0.91	--	83	71	0.90	--	0.94	--	72	71
d	0.83	0.49	0.83	0.46	84	72	0.87	0.61	0.89	0.44	69	69
2102 a	0.92	--	0.91	--	85	73	0.95	--	0.95	--	74	71
b	0.86	0.33	0.85	0.41	83	72	0.87	0.47	0.90	0.44	75	72
c	0.92	--	0.89	--	83	71	0.91	--	0.94	--	73	70
d	--	--	0.85	0.55	--	72	0.87	0.59	0.88	0.60	74	69
2103 a	0.91	--	0.91	--	78	66	0.91	--	0.92	--	70	68
b	0.81	0.35	0.84	0.41	78	66	0.87	0.39	0.89	0.45	69	67
c	0.89	--	0.89	--	78	65	0.91	--	0.90	--	70	68
d	0.81	0.38	0.80	0.39	75	67	0.84	0.35	0.84	0.33	69	66
2104 a	0.91	--	0.91	--	76	69	0.93	--	0.93	--	70	66
b	0.83	0.26	0.83	0.26	75	68	0.87	0.26	0.87	0.23	70	65
c	0.89	--	0.89	--	78	68	0.89	--	0.92	--	70	68
d	0.83	0.44	0.82	0.47	76	69	0.86	0.50	0.85	0.56	70	68

Table 19 continued

Sample No.	λ = 460 nm						Unfiltered Incandescent Lamp					
	Print Contrast Ratios				Paper Reflectance (%)		Print Contrast Ratios				Paper Reflectance (%)	
	Unaged		Aged		Unaged	Aged	Unaged		Aged		Unaged	Aged
	Dark Image	Light Image	Dark Image	Light Image			Dark Image	Light Image	Dark Image	Light Image		
2105 a	0.93	--	0.92	--	79	67	0.93	--	0.93	--	71	70
b	0.84	0.18	0.83	0.36	78	68	0.88	0.15	0.88	0.28	70	69
c	0.89	--	0.90	--	79	69	0.90	--	0.93	--	70	66
d	0.83	0.58	0.84	0.41	81	68	0.87	0.56	0.85	0.50	72	67
2106 a	0.92	--	0.92	--	80	73	0.95	--	0.93	--	71	69
b	0.86	0.35	0.85	0.40	78	72	0.88	0.40	0.89	0.36	72	68
c	0.89	--	0.90	--	78	72	0.90	--	0.93	--	72	68
d	0.84	0.56	0.82	0.45	81	74	0.86	0.57	0.85	0.49	72	70
2109	0.81	0.45	0.80	0.55	78	66	0.79	0.56	0.76	0.52	76	70
2110	0.76	0.60	0.78	0.56	84	72	0.86	0.67	0.82	0.60	80	79
2114	0 70	--	0.71	--	79	77	0.72	--	0.73	--	84	82
2115	0.49	--	0.42	--	80	79	0.51	--	0.41	--	81	81
2116	0.72	--	0.74	--	78	74	0.73	--	0.74	--	81	78
2117	0.76	--	0.75	--	80	79	0.76	--	0.77	--	83	82
2118	0.49	--	0.46	--	80	79	0.52	--	0.47	--	84	83
2119	0.74	--	0.77	--	79	74	0.76	--	0.78	--	78	80
2120	0.80	--	0.80	--	78	80	0.80	--	0.80	--	83	81
2128	0.85	.15	0.79	0.12	82	82	0.85	.21	0.81	.19	78	83

Table 20. Effect of abrasion on print contrast ratios,using an unfiltered incandescent lamp, of (a) poorly fused, (b) marginally fused, and (c) properly fused images on office copies.

No. of Abrasion Cycles	Imaging Process	Quality of Image Fusion		
		Poor	Marginal	Proper
		Print Contrast Ratio		
0	radiant	0.75	0.85	0.84
20	radiant	0.28	0.48	0.77
30	radiant	0.28	0.27	0.73
40	radiant	0.16	0.44	0.73
50	radiant	0.16	0.40	0.74
60	radiant	0.29	0.40	0.62
0	heat, pressure	0.83	0.84	0.89
20	heat, pressure	0.24	0.46	0.73
30	heat, pressure	0.41	0.24	0.71
40	heat, pressure	0.39	0.39	0.60
50	heat, pressure	0.24	0.28	0.59
60	heat, pressure	0.29	0.21	0.56

Table 21. Print contrast ratios, using unfiltered incandescent light, of properly fused office copies before and after abrasion for 20 cycles with wheel No. CS-10F at a total load of 500 g.

Sample No.	Processing Method	Print Contrast Ratio	
		Before Abrasion	After Abrasion
2100	radiation	92	92
	heat, pressure	84	57
2101	radiation	93	93
	heat, pressure	90	80
2102	radiation	93	92
	heat, pressure	90	71
2103	radiation	93	93
	heat, pressure	87	55
2104	radiation	94	93
	heat, pressure	88	85
2105	radiation	92	92
	heat, pressure	90	78
2106	radiation	94	93
	heat, pressure	90	78
2109	radiation	80	69
2110	radiation	79	73
2128	hot air	86	49

Table 22. Effect of oven aging at 105°C for 72 hours on the abrasion resistance of quick copy papers bearing images that had been properly, marginally, and poorly fixed on the paper.

Sample No.	Type of Finish	Quality of Image Fix	Imaging Process	Print Contrast Ratios			
				Unaged Samples		Oven Aged Samples	
				Unabraded	Abraded[1]	Unabraded	Abraded[1]
2114	coated	proper	radiant	.74	.71	.72	.72
2115	coated	marginal	radiant	0.74	0.60	0.74	0.69
2116	coated	poor	radiant	0.38	0.11	0.35	0.35
2117	coated	proper	radiant	0.72	0.69	0.75	0.77
2118	coated	marginal	radiant	0.75	0.56	0.79	0.65
2119	coated	poor	radiant	0.32	0.06	0.46	0.37
2120	coated	proper	radiant	0.78	0.64	0.78	0.69
2121	uncoated	proper	radiant	0.86	0.83	0.86	0.81
2122	uncoated	marginal	radiant	0.85	0.70	0.85	0.82
2123	uncoated	poor	radiant	0.77	0.21	0.77	0.70
2124	uncoated	proper	heat, pressure	0.90	0.61	0.90	0.83
2125	uncoated	marginal	heat, pressure	0.82	0.23	0.88	0.80
2126	uncoated	poor	heat, pressure	0.88	0.48	0.85	0.76

[1]20 cycles; abrader load totalled 500 g.

Table 23. Differential thermal analysis data[1] on office copy papers and bond papers.

Sample No.	pH Hot	T_2 (°C)	T_3 (°C)	T_4 (°C)
2100	8.8	258	333	352
2101	4.9	214	333	355
2102	4.6	215	325	360
2103	4.1	210	331	354
2104	4.8	237	338	362
2105	4.8	230	338	358
2106	5.1	220	349	368
2107	5.2	254	347	364
2108	5.2	240	334	362
2111	7.7	-	-	348
2112	7.2	-	-	350
2113	8.3	305	343	363
2127	6.7	252	333	353
231	4.7	238	322	360
233	9.5	270	357	375
235	5.1	230	338	358
238	7.2	267	353	374
258	4.4	220	319	355

[1] T_2 is the temperature at the beginning of a massive decomposition endotherm, T_3 is the temperature at the peak of decomposition, and T_4 is the temperature of a small exotherm after the major decomposition.

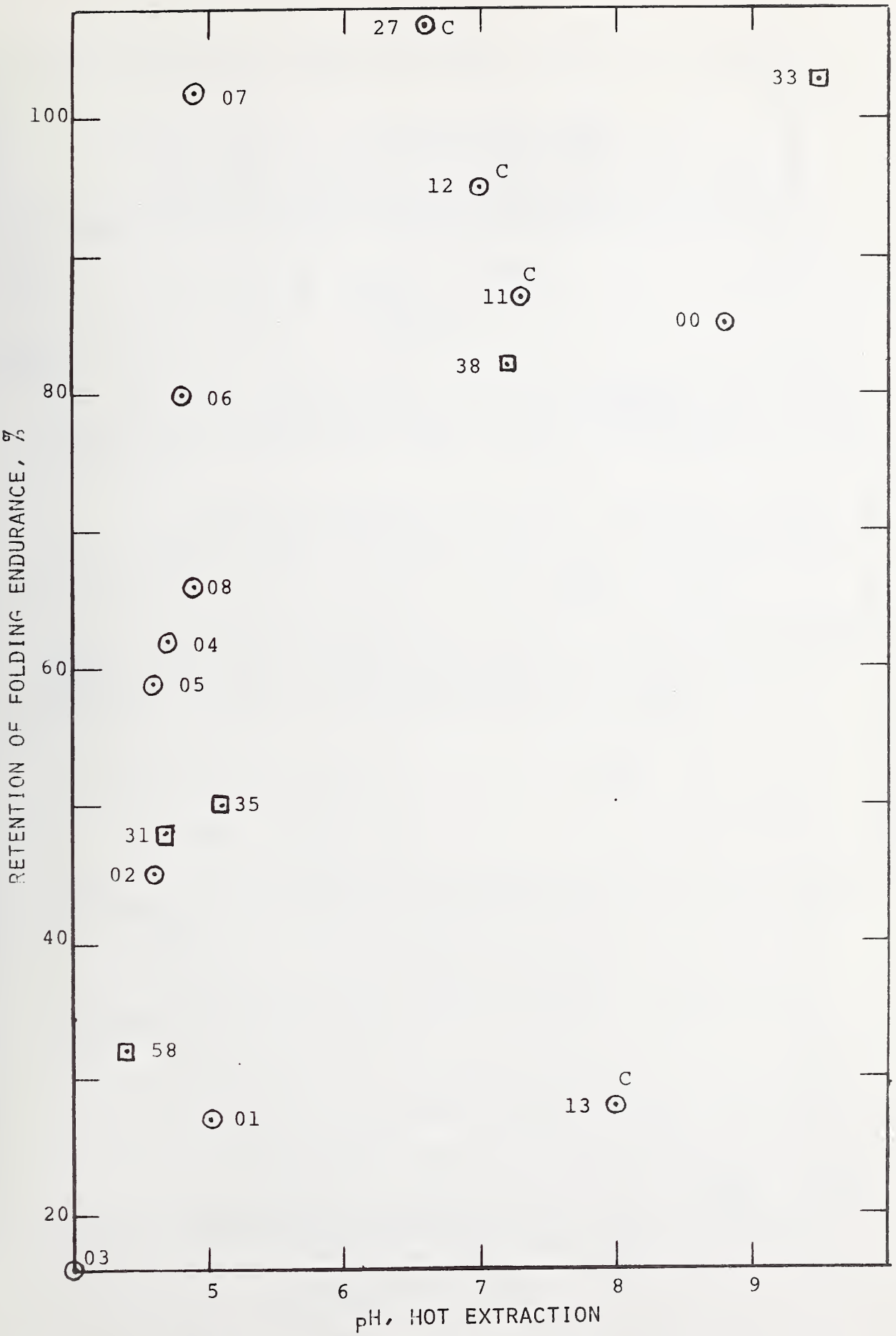

Figure 1. Retention of folding endurance after aging for 72 hours at 105°C as a function of pH, hot extraction.

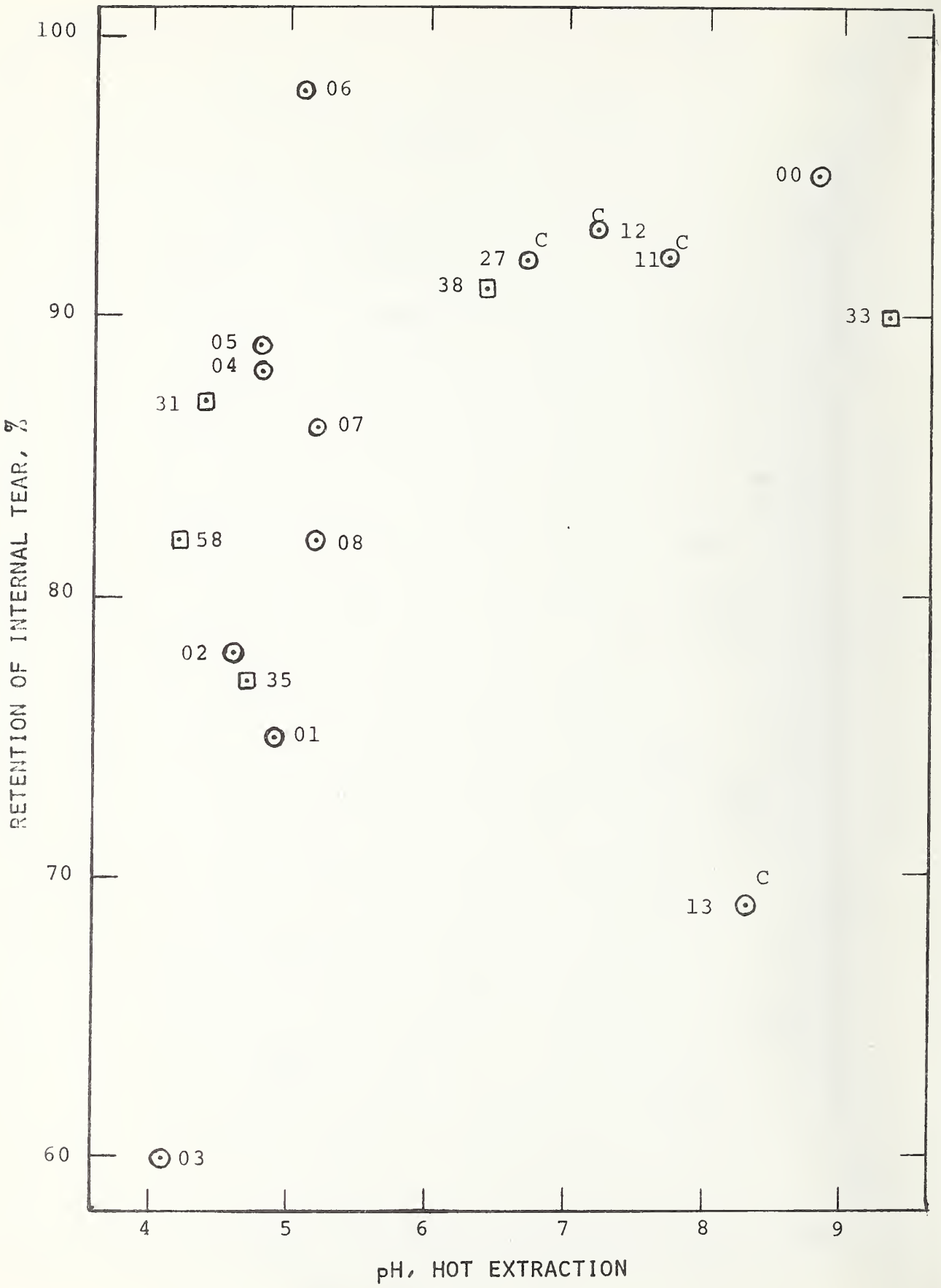

Figure 2. Retention of internal tear after aging for 72 hours at 105°C as a function of pH, hot extraction.

SECTION II

SUGGESTED SPECIFICATIONS [1] FOR COPIES FROM OFFICE COPYING MACHINES FOR PERMANENT RECORDS

PART 1 - PAPER

1. SCOPE

1.1 This specification covers coated or uncoated papers, for permanent records, for use in direct or indirect electrostatic copy processes and other types of office or quick copy processes.

1.2 It has been shown [2, 3] that permanence is at least an approximate function of the pH of an aqueous extract of the paper. Three pH levels, reflecting three levels of permanence (for plain paper) are specified.

1.3 It has been shown [3, 4] that a relationship exists between accelerated aging for 72 hours at 105°C and natural aging. Retention of properties after accelerated aging is, therefore, a part of this specification.

2. APPLICABLE DOCUMENTS

2.1 ASTM Documents [5]

D 585, Sampling and Accepting a Single Lot of Paper, Paperboard, Fiberboard, or Related Product.

D 589, Test for Opacity of Paper

D 644, Test for Moisture Content of Paper and Paperboard by Oven Drying

D 645, Test for Thickness of Paper and Paperboard.

D 646, Test for Basis Weight of Paper and Paperboard.

D 689, Test for Internal Tearing Resistance of Paper.

D 776, Test for Relative Stability of Paper (Effect of Heat on Folding Endurance).

D 778, Test for Hydrogen Ion Concentration (pH) of Buffered Paper Extracts.

D 985, Test for 45-deg, 0-deg. Directional Reflectance for Blue Light (Brightness) of Paper.

D 1030, Test for Fiber Analysis of Paper and Paperboard.

D 2176, Test for Folding Endurance of Paper by the MIT Tester.

2.2 Other Documents

U.S. Government Paper Specification Standards [6].

Determination of Fluorescence [7].

3. CLASSIFICATION

3.1 Types. Three types of paper for office copying machines, according to permanence level, are specified. These permanence levels are differentiated by (1) pH, (2) type of filler or sizing, or both, and (3) an accelerated aging requirement. For situations where the copies will be handled frequently, the grade is described as "high referral." A higher tearing resistance is specified for this category, a folding endurance requirement is optional, and the purchaser may wish to specify all or part new cotton or linen.

The coating of coated papers for use in some copying machines by present technology contains zinc oxide, and the pH of this type of paper is on the alkaline side.

3.2 Type I, maximum permanence

3.2.1 Grade 1 - Ordinary use.

3.2.2 Grade 2 - High referral.

3.3 Type II, high permanence

3.3.1 Grade 1 - Ordinary use.

3.3.2 Grade 2 - High referral.

3.4 Type III, medium permanence

3.4.1 Grade 1 - Ordinary use.

3.4.2 Grade 2 - High referral.

4. DEFINITIONS AND DESCRIPTION OF TERMS

4.1 Alkaline-filled paper - A paper containing calcium or magnesium carbonate or both. Such a paper is alkaline (pH usually in the range from 7.5 to 9.5) and contains a reserve buffering capacity that can neutralize acidic gases sorbed from the atmosphere.

4.2 Bond paper - A grade of writing or printing paper which, historically, was used where permanence, strength, and durability were required. Now, it is also used for letterheads and forms, and for many other situations where permanence and durability are unimportant. Therefore, bond papers cover a wide spectrum of quality. Most bond papers receive some printing (for example, letterheads or forms) before use, so printing properties as well as writing, erasing, cleanliness, etc., are important.

4.3 Durability - The ability of a paper to resist the effects of wear and tear in performance situations. For example, paper currency should be durable, but permanence is not a problem.

4.4 High referral - The grade that describes situations where copies are frequently handled (see 3.1).

4.5 Ledger paper - Originally, ledger paper was used especially for pen and ink records. Most ledger papers today are surface sized. They frequently are subjected to appreciable wear and must have a high degree of permanence and durability. They are characterized by high strength, high tearing resistance, erasability, water and ink resistance, uniformity of surface, and smoothness.

4.6 Paper, neutral-sized - A paper that has been sized with a rosin-alum system in which sodium aluminate has been substituted for part of the alum that normally is used, or with one of the synthetic sizes such as ketene dimer or acrylic emulsion.

4.7 Paper with a minimum pH value - Paper usually is sized in a slightly acidic medium. The specification of a minimum pH, as practiced by the U.S. Government (2.2) provides some assurance that the paper will have medium permanence, as defined in 4.8 of this specification. It has been shown that the stability of paper is an approximate function of pH, so a minimum pH is one approach to specifying a stable paper.

4.8 Permanence - This basically is a function of the chemical stability of the paper and its ability to maintain initial properties over a long period of time. Permanence must be defined with respect to the end use, as one paper might be expected to last 50 years and another to last indefinitely. The three levels of permanence covered in section 3 may be described as follows:

4.8.1 Maximum permanence - The document is expected to last several hundred years.

4.8.2 High permanence - The document is expected to last in excess of 100 years.

4.8.3 Medium permanence - The document is expected to last at least 50 years, and up to 100 years.

4.9 Coated paper - Has been surface treated with clay or some other pigment and adhesive mixture, or other suitable material, to improve the finish with respect to printing performance, color, smoothness, opacity, conductivity, or other surface properties.

4.10 "Office copies" or "quick copies" - Reproductions made by direct or indirect electrostatic printing, thermographic processing, etc., as contrasted to conventional printing such as letterpress, offset, etc.

5. BASIS OF PURCHASE

5.1 Orders shall specify type and grade, dimensions, color, and, if necessary, fiber analysis, and printing requirements. The paper shall perform suitably in the specific copying machine for which it is intended.

6. COMPOSITION AND CHEMICAL REQUIREMENTS

6.1 Fiber Analysis. The paper shall be made from cotton or linen pulp, fully bleached wood pulp, or a mixture as specified at the time of purchase. The paper shall be free of unbleached wood pulp or groundwood.

6.2 Hydrogen Ion Concentration (pH). The pH shall be as follows:

6.2.1 Type I - 7.5 to 9.5

6.2.2 Type II - minimum 6.5

6.2.3 Type III - minimum of 5.5.

6.3 Filler. Type I paper, if for use in a "plain paper" copier, shall contain an alkaline filler of calcium or magnesium carbonate, or both. The minimum shall be 2 percent, calculated to calcium carbonate, based on the oven-dry weight of the finished paper. The determination of carbonate filler shall conform to the method described in 12.4

Coated papers normally are not made with alkaline fillers, so for this kind of paper one must rely on the accelerated aging requirement in section 8.

7. PHYSICAL REQUIREMENTS

7.1 Weight per Unit Area is not a requirement of this specification, unless agreed to between buyer and seller, but the nominal weight per unit area may be used to describe the paper.

Most copy papers are in the 75 g/m^2 class (20 lb, 17 x 22, 500), but some 60 g (16 lb) and 90 g (24 lb) papers are supplied. If the buyer specifies a weight per unit area, the variation of test unit averages within a shipment (or lot) shall be not more than 5 percent above or below the lot sample average value.

7.2 Thickness. Thickness is not a requirement of this specification unless agreed to between the buyer and the seller. If specified, thickness shall be expressed as micrometers (1×10^{-6} m) or as mils (1×10^{-3} in.), and the variation of test unit averages within a shipment (or lot) shall be not more than 5 percent above or below the average value.

7.3 Internal Tearing Resistance. The average internal tearing resistance in each direction shall be not less than that given in Table 1.

7.4 Directional Reflectance (Brightness). For white papers, the average brightness shall be not less than 75 percent with the fluorescence component excluded. The brightness requirement does not apply to colored papers. Optical brighteners are not excluded, unless specifically stated at time of purchase.

7.5 Fluorescence. The fluorescent component of brightness for white papers, if fluorescence is objectionable to the end use, shall not exceed 2 percent. Fluorescence shall be determined in accordance with 12.2.

7.6 Opacity. If the paper is to be printed on both sides, the minimum opacity shall be not less than 85 percent. For printing on one side only, the opacity requirement may be reduced to 80.

7.7 Folding Endurance. The average folding endurance for the machine and cross directions shall be not less than that given in Table 1.

7.8 Color. The paper shall be white, or colored, as specified at time of purchase.

8. RETENTION OF PHYSICAL PROPERTIES AFTER ACCELERATED AGING

After accelerated aging, the retention of tearing strength and folding endurance shall conform to the requirements listed in Table 1.

9. DIMENSIONS, GRAIN, AND TRIM

9.1 The paper shall be furnished in the size, or sizes, specified at time of purchase, to a tolerance of ± 1/32 inch (0.8 mm), and shall be trimmed square.

9.2 Grain. The paper shall be supplied grain long or grain short at the option of the seller, unless otherwise specified by the purchaser.

10. ADDITIONAL REQUIREMENTS

10.1 Sizing. The paper shall be internally sized and surface sized so that it shall be suitable for the intended purpose, as indicated by the purchaser.

10.2 Printing Properties. The paper shall be suitable for the duplication process for which it is purchased.

10.3 Erasing Quality. This property shall be evaluated as follows:

Visible feathering shall not be apparent after the paper has been written on with aqueous ink, erased, and written on again in the erased area with aqueous ink.

11. SAMPLING

11.1 The paper shall be sampled in accordance with Method D 585, using Plan II for all properties.

12. METHODS OF TEST

12.1 ASTM Standards - Conduct the tests in accordance with the following ASTM Standards:

12.1.1 Opacity - Method D 589

12.1.2 Moisture Content - Method D 644

12.1.3 Thickness - Method D 645

12.1.4 Basis Weight - Method D 646

12.1.5 Hydrogen Ion Concentration (pH) - Method D 778

12.1.6 Directional Reflectance - Method D 985

12.1.7 Internal Tearing Resistance - Method D 689

12.1.8 Fiber Analysis - Method D 1030

12.1.9 Folding Endurance - Method D 2176

12.2 Fluorescence (ΔB)

12.2.1 Apparatus

12.2.1.1 Filter Reflectometer, with 0 to 45° geometry.

12.2.1.2 Light Source, with a color temperature of 3100°K.

12.2.1.3 Blue Filter, approximating the CIE Z function.

12.2.1.4 Ultraviolet-absorbing Filter, movable, permitting inclusion or exclusion of the ultraviolet component from the light falling on the test area.

12.2.1.5 Ceramic Tile Calibration Standard, with a known value for the function Z.

12.2.2 Test Specimens - Test two sheets from each test unit. The test area shall be a circle 57 mm in diameter. Make measurements at the top and bottom of both sides of each test sheet.

12.2.3 Procedure

12.2.3.1 With the calibration standard positioned at the specimen window, adjust the instrument to give the reflectance value assigned to the standard.

12.2.3.2 With the unknown test specimen at the window and the ultraviolet filter positioned to include the ultraviolet component of the incident light, obtain the reflectance of the specimen.

12.2.3.3 Without moving the test specimen and with the filter positioned to exclude the ultraviolet component, obtain the reflectance of the specimen.

12.2.3.4 Calculate the difference between readings, 12.2.3.2 and 12.2.3.3; this is ΔB.

12.2.4 Report - Report ΔB for the wire and felt sides separately, and the average for both sides.

12.3 Carbonate Content of Paper - Qualitative

12.3.1 Procedure - Place approximately 0.5 g of paper in a test tube of any convenient size. Cover it to a depth of about 10 mm with 6 N hydrochloric acid (HCl). A gentle continuous effervescence (not to be confused with initial desorption of gases from the surface of the paper) indicates the presence of carbonate.

12.4 Carbonate Content of Paper - Quantitative

12.4.1 Procedure

12.4.1.1 Weigh out approximately 1 g of paper to the nearest 1 mg, making a correction for the moisture content (Note 1) and place it in approximately 25 cm^3 of water in a 125-cm^3 Erlenmeyer flask. Pape 20 cm^3 (Note 2) of standardized 0.1 N hydrochloric acid (HCl) into the flask, heat to boiling, and boil for approximately 1 min. Add 3 drops of aqueous methyl red. Cool to room temperature and titrate to the first lemon yellow with standardized 0.1 N sodium hydroxide solution (NaOH).

Note 1 - The specimen for analysis may be dried and weighed, or a separate portion may be used for moisture determination.

Note 2 - For a 1-g specimen, 20 cm^3 of 0.1 N HCl is sufficient to neutralize the carbonate in a paper containing approximately 10 percent carbonate.

12.4.1.2 If a trace of pink indicator remains adsorbed on the surface of the paper, boil the paper briefly to desorb the pink color. Usually a further drop of NaOH solution will restore the lemon yellow to the solution.

12.4.2 Calculations - Calculate the carbonate content of the paper as percent calcium carbonate ($CaCO_3$) as follows:

$$CaCO_3, \% = \frac{(cm^3 \times N)_{HCl} - (cm^3 \times N)_{NaOH} \times 0.050 \times 100}{\text{weight of specimen, g}}$$

where 0.050 is the milliequivalent weight of $CaCO_3$. Duplicate determinations should agree within 0.3 percent $CaCO_3$.

12.4.3 Report - Report the carbonate content as percent $CaCO_3$ of the oven-dry paper to the nearest 0.1 percent.

13. INSPECTION

13.1 Inspection of the paper shall be agreed upon by the purchaser and the seller as part of the purchase contract.

14. CERTIFICATION

14.1 Upon request of the purchaser, a manufacturer's certification that the paper was manufactured and tested in accordance with this specification, together with a report of the test results, shall be furnished at the time of shipment.

14.2 Test results obtained by both the seller and the purchaser shall be made available, upon request, to either party.

15. PACKAGING AND MARKING

15.1 The paper shall be packaged in 500 or 1000 sheet quantities. These shall be wrapped and securely sealed, or packaged in boxes or cartons, in order to provide adequate protection during shipment and storage. Each package shall be marked to show the type of paper, quantity, color, size, basis weight (weight per unit area), and the name of the manufacturer.

15.2 Packaging in exterior containers for shipment shall be adequate to avoid damage during shipment and storage.

APPENDIX

X1. ADDITIONAL INFORMATION

X1.1 As there are many variables in the manufacture of paper and in the use and storage of records, it is impossible to place definitive values on the number of years that various categories of records will endure. It has been established that the rates of both natural and accelerated aging are approximate functions of the pH of the paper. The following information may be used as a guide:

X1.1.1 Type I Papers - Machine-made papers with an alkaline filler have existed, apparently with little change, for at least 70 years. Handmade papers containing an alkaline filler have survived for almost 400 years. Acid papers have survived this long, but their condition is, comparatively speaking, not as good and is an approximate function of acidity.

X1.1.2 Type II Papers - The probable longevity of these papers should lie somewhere between Type I and Type III papers.

X1.1.3 Type III Papers - The relative condition of paper in old books and documents has been correlated approximately with pH. Barrow has shown that the condition of naturally aged paper definitely is a function of pH. Manifold papers in U.S. Government files with pH values as low as 4.2 have survived almost 50 years, and the physical properties of these papers are an approximate function of pH. A minimum pH of 5.5 should indicate longevity greater than 50 years.

X1.2 Papers containing cotton or linen, or both, are considered by many people to be more durable than wood pulp papers. As both rag and wood pulp papers may cover a wide spectrum of permanence and durability, generalizations are not possible.

X1.3 Paper may be procured on the basis of a standard sample, on the basis of requirements other than those listed in this specification, or one or more of the requirements may be waived. In order to obtain the degree of permanence required, it is very important that the pH requirements of this specification should be met for the type and grade of paper purchased, and the retention of properties after accelerated aging should meet or exceed the specification

NOTES

1. This specification is under the jurisdiction of ASTM Committee D-6, Paper and Paper Products.

2. Barrow, W. J., Deterioration of Book Stock; Causes and Remedies, The Virginia State Library, Richmond, Va. (1959).

3. Wilson, W. K., Harvey, J. L., Mandel, J., and Worksman, T., Accelerated Aging of Record Papers Compared with Normal Aging, Tappi 38, No. 9, 543 (1955).

4. van Royen, A. H., Comparison of the Accelerated Aging of Cellulose with Normal Aging at Room Temperature, Assoc. Tech. Ind. Papetiere, Bull. 6, 223 (1957); Papierwereld 12, 219 (1958); Abstr. Bull. Inst. Paper Chem. 29, 92 (1958).

5. 1974 Annual Book of ASTM Standards, Part 20.

6. Available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402.

7. Based on Part 2 of the U.S. Government Paper Specification Standards of the Congressional Joint Committee on Printing.

Table 1. Requirements for papers for use in office copying machines for permanent records.

Type	pH[1]	Tearing[2] Resistance		Folding[2] Endurance		Brightness minimum	Opacity[3] minimum	Retention after Aging, %	
		Grade 1	Grade 2	Grade 1	Grade 2	%	%	Tear	Fold
I	Alkaline filler, 7.5-9.5	35	50	--	200	75	85	80	80
II	Minimum, 6.5	35	50	--	200	75	85	80	80
III	Minimum, 5.5	35	50	--	200	75	85	80	60

[1]The extract pH of the coating of a coated paper may be radically different from that of the base paper, and cannot be used as an indicator of stability. One must rely on the accelerated aging test as an indicator of stability for coated papers.

[2]These values are representative of stronger papers that are supplied specifically for office copying machines. Characteristics of these papers also depend on copy machine requirements. If more durable papers are required, ASTM D 3290, Specifications for Bond and Ledger Papers for Permanent Records, may be used, but a statement, "The paper shall perform properly in the copy machine for which it is intended," should be included.

[3]May be reduced to 80% if paper is to be printed on one side only.

PART 2 - IMAGED COPY

1. SCOPE

1.1 This specification covers the permanence and durability of images made on coated or uncoated paper used in the direct or indirect electrostatic copy processes and other types of office or quick copy systems.

1.2 It is limited to those cases where the material that forms the image is deposited on a paper substrate.

2. APPLICABLE DOCUMENTS

2.1 ASTM Standards

D 776, Test for Relative Stability of Paper (Effect of Heat on Folding Endurance)

F 360, Image Evaluation of Electrostatic Business Copies

F 362, Erasability of Inked Ribbons

G 27 , Standard Recommended Practice for Operating Xenon-Arc Type Apparatus for Light Exposure of Nonmetallic Materials.

3. CLASSIFICATION

Although many office copy processes are available for transferring images to plain paper or to coated paper, no distinctions are made among these processes.

4. DESCRIPTION OF TERMS

4.1 Imaged Copy - An imaged copy is a reproduction on paper of an original by some process, such as electrostatic, other than some form of conventional printing, such as letterpress or offset.

4.2 Permanence - Permanence is a function of the chemical stability of the image and its ability to maintain initial properties over a long period of time.

4.3 Durability - The durability of an image is its resistance to handling in use situations, and its ability to stick to the paper.

4.4 Print Contrast Ratio - Print contrast ratio is defined as $(1 - R_{ink}/R_{paper})$, where R_{ink} = reflectance of the image, and R_{paper} = reflectance of the paper. An instrument is available that gives print contrast directly when the reflectance of the paper is set at 1.0.

5. TEST ORIGINAL

This is covered in general under ASTM F 360. The test original should have an average print contrast ratio of 0.90 or greater. It may be made using a typewriter, or it may be a Test Chart for Copying Machines, both of which are described in ASTM F 360. Other test originals may be used as long as the print contrast ratio of part of the test original is 0.90, or greater.

6. COPY EVALUATION

6.1 Print Contrast - For a series of 50 random measurements, the average print contrast shall be no less than 70.

6.2 Other copy evaluation techniques, as applicable, may be used as described in ASTM F 360-72, section 7.

7. RETENTION OF PRINT CONTRAST AFTER ACCELERATED AGING

After exposure to the xenon lamp for 96 hours at 25°C and 50 percent relative humidity (2.1) or to oven aging for 72 hours at 105°C (2.1), the average print contrast ratio shall not decrease by more than 20 percent of the original value.

8. RETENTION OF PRINT CONTRAST AFTER ABRASION

After abrasion for 20 cycles with wheel No. CS-10F, the average print contrast ratio shall not decrease by more than 20 percent of the original value.

9. SAMPLING

At least 100 sheets of imaged copy shall be obtained for evaluation either from the supplier or from preparation of copy on a selected machine. The copy machine should be in good working order and properly adjusted to produce good copy. Sheets for evaluation shall be selected at random from the sample.

10. METHODS OF TEST

10.1 ASTM Standards - Conduct the tests in accordance with the following ASTM Standards:

10.1.1 Exposure to xenon arc - Method G 27, 25°C at 50 percent relative humidity.

10.1.2 Image evaluation - Method F 360, using a print contrast reflectometer capable of measuring the reflectance of an area 0.008 in. in diameter. Reflectance should preferably be in the blue end of the spectrum around 460 nm, but unfiltered incandescent light may be used.

10.1.3 Abrasion resistance - Method F 362, 20 cycles with wheel No. CS-10F with a weight of 500 g.

10.1.4 Reflectance to accelerated aging - Method D 776.

Table 1. Summary of print contrast ratio requirements.

Imaged copy, minimum	70
Maximum percentage loss after	
Exposure to xenon arc	20
Oven aging	20
Abrasion	20

11. ADDITIONAL INFORMATION

Several processes are in use for producing images on paper in office copying machines. In some cases, the machines and materials are available only from one manufacturer. In other cases, one can buy the machine from one supplier, the paper from another, and the imaging materials from yet another. In addition, a manufacturer may change composition at any time, without notice. It is desirable for a purchaser to establish a reliable source of supply, test the product, and obtain assurance that significant changes will not be made without notice.

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15. SUPPLEMENTARY NOTES

16. ABSTRACT *(A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)*

Information has been developed on the stability of papers used in preparing copy on office copying machines as well as stability of images formed by representative quick copy processes. Retention of physical properties after accelerated aging according to ASTM Method D776 was used as one criterion of probable stability. Acidity as measured by ASTM Method D778 also was used as a criterion of potential stability. Abrasion resistance of the image after exposure to a xenon arc and after accelerated aging according to ASTM D776 was used as a criterion of stability of image. Representative papers made especially for specific copying machines, and representative copies from these machines, were used in the testing program. Suggested specifications for copies for permanent records, based on the data developed in this report, are presented.

17. KEY WORDS *(six to twelve entries; alphabetical order; capitalize only the first letter of the first key word unless a proper name; separated by semicolons)*

Aging of paper; office copies; office copies, permanence; paper permanence; permanence of paper; specifications for office copies; stability of office copies; stability of paper.

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