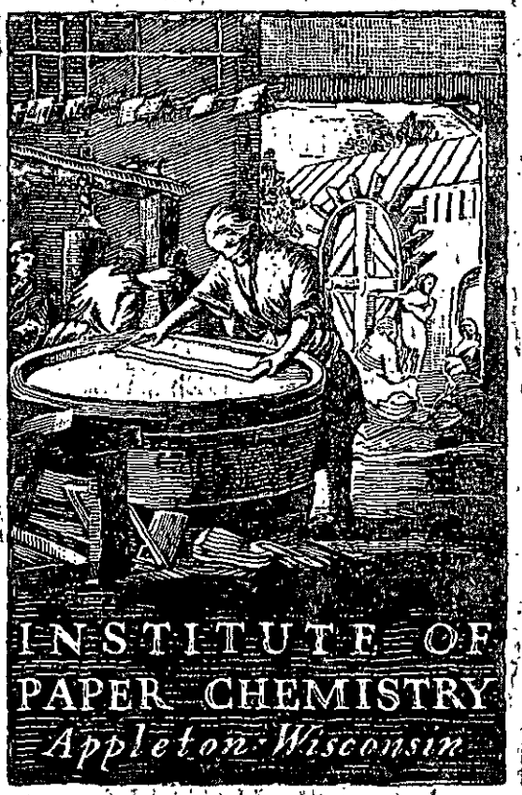

THE DEVELOPMENT OF A SINGLE FILTER METHOD FOR DETERMINING LUMINOUS REFLECTANCE AND COMPARISON OF VISUAL RANKING OF COLOR DIFFERENCES IN 42-LB. UNBLEACHED KRAFT LINERBOARD WITH ITS OPTICAL CHARACTERISTICS

Project 1108-15

Report Four

A Progress Report

to

FOURDRINIER KRAFT BOARD INSTITUTE, INC.

January 30, 1961

THE INSTITUTE OF PAPER CHEMISTRY

Appleton, Wisconsin

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TABLE OF CONTENTS

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SUMMARY

At the request of the Fourdrinier Kraft Board Institute, Inc., the Institute has pursued an investigation of (1) means of measuring the color characteristics of 42-lb. unbleached kraft linerboard and (2) methods for specifying the color of unbleached kraft liner. The objectives of the work reported herein were as follows:

1. To develop a special filter for the brightness tester to permit direct measurement of luminous reflectance.

2. To compare luminous reflectance values determined with the simple filter against values obtained by the two-reflectance method developed in previous work.

3. To test the hypothesis that visual rankings of color differences in kraft linerboard are primarily influenced by luminous reflectance rather than luminous reflectance and purity.

For these purposes the optical characteristics of 72 samples of 42-lb. unbleached kraft liner were determined and specimens from the samples were distributed among the Fourdrinier Kraft Board Institute member mills for visual ranking.

Among the conclusions which may be drawn from the study are the following:

1. Luminous reflectance values determined using the single-filter method were in reasonably good agreement with values determined by the two-reflectance method.

2. Luminous reflectance was more highly correlated with visual ranking of color differences than purity.

3. The inclusion of purity with luminous reflectance in a two-factor relationship gave only slightly better estimates of visual ranking than luminous reflectance by itself.

4. On the basis of the results obtained in this study, it appears that luminous reflectance, by itself, will predict the visual ranking of unbleached kraft linerboard as well as luminous reflectance plus purity. In addition, the relationship between luminous reflectance and visual ranking appears to be of sufficient precision as to warrant the use of luminous reflectance as a means of evaluating the visual ranking of unbleached kraft linerboard in a quality control program associated with a manufacturing process wherein the dominant wavelength is unchanged from that exhibited by the samples used in this study.

INTRODUCTION

During the past several years, the Institute has pursued, on behalf of the Fourdrinier Kraft Board Institute, an investigation of (1) means of measuring the color characteristics of 42-lb. unbleached kraft liner and (2) methods for adequately specifying the color of unbleached kraft liner. These studies were apparently prompted by the reaction of the "consumer" of linerboard to the wide range of colors exhibited in current linerboard production. The results obtained were summarized in three reports (1-3).

Among the conclusions reached in the early work were the following:

1. Of the three optical characteristics--dominant wavelength, purity (p), and luminous reflectance (Y)--the dominant wavelength is nearly constant for 42-lb. unbleached kraft samples. This indicated that the problem of measuring and controlling the color of unbleached kraft linerboard is essentially one of measuring and controlling the purity and luminous reflectance.

2. The G. E. reflection meter with four special filters for measuring reflectances at 457, 512, 582, and 596 mμ can be utilized for obtaining the optical data. A later simplification making use of the fact that dominant wavelength is essentially constant indicated that purity and luminous reflectance could be obtained using reflectance measurements at only two of the above wavelengths (457 and 596 mμ)--designated as two-reflectance method.

3. In 1956, over a period of 6 months, about 600 samples of linerboard from the 18 mills in the group were evaluated for p and Y. Extreme samples differed in purity by about 12 units and in luminous reflectance by about 13 units. The major number of samples fell in a purity range from 27 to 33% and a luminous reflectance range from 22 to 29%.

4. For the group as a whole, a correlation between p and Y appeared to exist although the relationship was not a strong one as evidenced by the correlation coefficient of -0.57. Correlation coefficients for individual months ranged from -0.44 to +0.71 and for individual mills ranged from +0.07 to -0.90.

Based on the above and their own independent work, various members of the FKBI suggested that

1. Mill specifications and control in terms of both p and Y would be impractical.

2. Visual ranking of linerboard samples appeared to be primarily influenced by differences in Y. Therefore, it should be practical to establish color standards in terms of Y alone.

The Institute was requested, therefore, to

1. Prepare a special filter for the brightness meter to enable direct measurement of Y alone.

2. Compare Y values obtained with the single filter and two-reflectance measurement method.

3. Test the hypothesis that visual ranking of color differences of kraft linerboard is primarily affected by differences in luminous reflectance Y rather than by both p and Y.

With regard to the above, the Institute prepared the special filter required to determine luminous reflectance directly using the brightness meter. It is now prepared to furnish such filters to interested mills and includes a special "check" sample in its calibration service for users of the Brightness tester having the special filter. However, because of variations in phototube response and in the spectral transmission of the lenses, it is essential that the brightness tester be returned to the Institute to permit proper initial adjustment of filter and instrument.

PROCEDURE

PHASE I. COMPARISON OF LUMINOUS REFLECTANCE (Y) VALUES OBTAINED WITH THE SINGLE-FILTER AND TWO-REFLECTANCE METHODS

For this phase 72 samples of 42-lb. unbleached kraft liner were selected from the liner baseline study--one sample per mill per month for December through March, 1960. The following values were obtained for each sample.

1. Luminous reflectance--single-filter method
2. Luminous reflectance--two-reflectance method
3. Purity --two-reflectance method

The procedure employed is outlined below in stepwise fashion. [See also Reference (3)].

1. Measure the reflectance of each specimen (5 specimens were employed using

   a. The single filter for luminous reflectance

   b. The 457 and 596 mμ filters

2. Average the readings separately for the 457 and 596 mμ filters and substitute in the equations below to compute the tristimulus values X and Z.

$$X = \frac{0.9804\,[10.60\,R_{456} + 44.77\,R_{596}]}{55.37}$$

$$Z = 1.1812\,R_{455}$$

where R = reflectance at indicated wavelength (reflectance at 457 mμ used for R_{456} and R_{455}).

3. Calculate $\underline{S}$ (equals $\underline{X} + \underline{Y} + \underline{Z}$) using the following equation:

$$\underline{S} = \frac{1.733,380\ \underline{X} + \underline{Z}}{1 - 0.088,753}$$

4. Divide the tristimulus value $\underline{X}$ by $\underline{S}$ to obtain the trichromatic coefficient $\underline{x}$.

5. Substitute $\underline{x}$ in the equation $\underline{y} = 0.088,753 + 0.733,380\ \underline{x}$ to compute the trichromatic coefficient $\underline{y}$.

6. Multiply $\underline{y}$ by $\underline{S}$ to obtain the tristimulus value $\underline{Y}$ which is equal to luminous reflectance. (Note: $\underline{Y}$ can also be obtained by difference after Step 3 since $\underline{Y} = \underline{S} - \underline{X} - \underline{Z}$.

7. Enter a chromaticity chart such as is shown in Fig. 1 at the value of $\underline{X}$ and $\underline{Y}$ and read the purity ($\underline{p}$).

PHASE 2. COMPARISON OF VISUAL RANKING OF COLOR DIFFERENCES OF KRAFT LINERBOARD WITH PURITY AND LUMINOUS REFLECTANCE VALUES

A. Selection of Samples

The 72 samples evaluated in Phase 1 were split into four sets of 18 samples as follows:

1. The 72 samples were arranged in order of increasing luminous reflectance and divided into 18 groups of four samples each.

2. One sample was randomly selected from each of the 18 groups and the resulting 18 samples were identified as Set I.

3. Step 2 was repeated three times to obtain Sets II, III, and IV.

B. Selection of Standard Sample

One sample (Sample 185318) was selected as a standard to have approximately average luminous reflectance and purity values. Its luminous reflectance was 27.0% (single-filter method) and its purity was 29.8%.

Chart No. 13

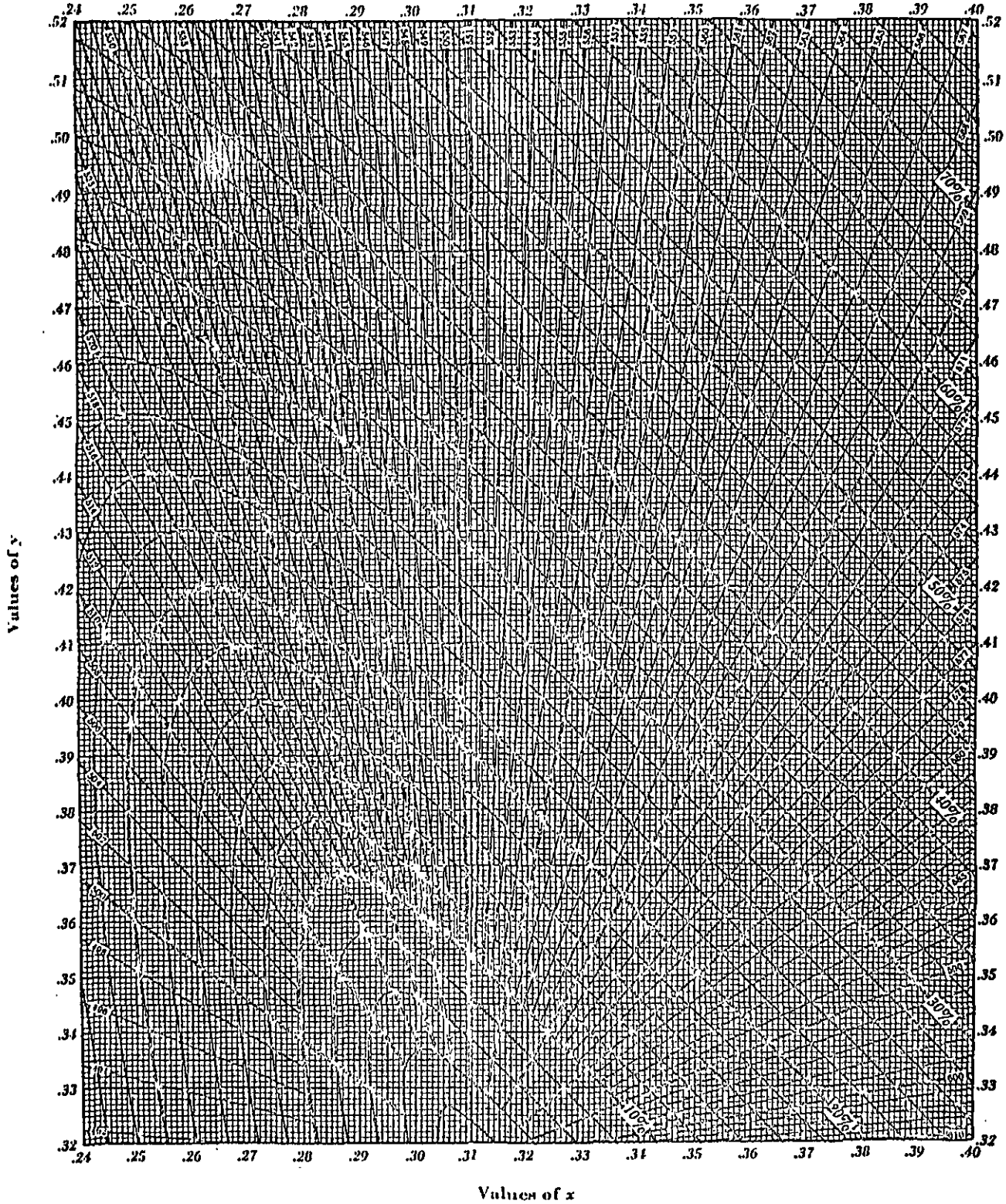

Figure 1. Chromaticity Diagram

C. Distribution of Samples

Two by three-inch specimens (2-inch dimension in machine direction) were cut from each sample and marked on the wire side with an identifying number bearing no relation to the optical characteristics of the sample. These specimens were arranged in sets as specified in A. above and distributed to the mills as follows:

	Mill Code		
Set I	Set II	Set III	Set IV
A	B	G	J
C	D	O	M
F	E	Q	N
H	L	R	S
I	P		

Thus, Mills A, C, F, etc., received packets of Set I samples; B, D, etc. received Set II samples, etc.

D. Color Ranking

The color ranking instructions which accompanied the samples sent to each mill may be found in Appendix A of this report. As may be noted in the instructions, each mill was requested to have one or more of their personnel rank the samples with respect to the standard--with the provision that each observer's rankings should be forwarded to the Institute. Replies were received from all mills except Mill E and the number of observers per mill ranged from 1 to 7. After receipt at the Institute, each observer's rankings were examined to determine if any obvious misinterpretation of the

instructions had occurred. Where this appeared to be the case, that observer's results were not used in the subsequent analysis. A summary of the replies received by mill may be found in Table I and the individual observer's rankings may be found in Appendix B.

TABLE I

SUMMARY OF COLOR RANKING REPLIES

Mill Code	No. of Replies	No. of Replies Used in Analysis
A	3	2
B	4	1
C	2	2
D	3	3
E	no replies received	
F	6	3
G	4	2
H	2	2
I	2	2
J	7	3
L	4	4
M	3	3
N	4	4
O	4	4
P	5	4
Q	1	1
R	3	3
S	3	3

DISCUSSION OF RESULTS

PHASE I. COMPARISON OF LUMINOUS REFLECTANCE (Y) VALUES AS DETERMINED BY THE SINGLE-FILTER AND TWO-REFLECTANCE METHODS

As mentioned previously, luminous reflectance values determined using the single filter were compared with corresponding values based on reflectance measurements at 457 and 596 mμ. Both procedures employed the standard brightness tester. The results for the 72 samples of unbleached kraft liner evaluated are summarized in Table II. In addition, to assist in interpreting the color ranking results to be discussed in Phase 2, the purity value for each sample is also tabulated.

Referring to the table, it may be noted that the two methods of determining luminous reflectance (Y) were in reasonably good agreement. Differences ranged from +0.1 to -0.5 units and, on an over-all basis, the average difference was 0.28 units with the single-filter method giving slightly higher results. It may be concluded, therefore, that the single-filter method is suitable for determining luminous reflectance of unbleached kraft liner and should be preferred because of its greater simplicity.

Previous work has indicated that some relationship between luminous reflectance and purity exists for 42-lb. unbleached kraft liner (1,2). With this in mind, the data in Table II were statistically correlated to determine the degree of relationship between luminous reflectance (Y) (single-filter method), and purity (p). The results obtained are summarized in Table III and graphically illustrated in Fig. 2.

TABLE II

OPTICAL CHARACTERISTICS OF 42-LB. LINER SAMPLES

Mill	File No.	Luminous Reflectance, % Single-Filter Method	Luminous Reflectance, % Two-Reflectance Method	Diff.[a]	Purity, % Two-Reflectance Method
A	185280	26.6	26.3	-0.3	31.3
	185281	28.0	27.8	-0.2	29.8
	185282	22.6	22.4	-0.2	32.5
	185283	22.4	22.4	0.0	31.4
B	185284	25.9	25.6	-0.3	33.4
	185285	28.9	28.5	-0.4	28.1
	185286	29.4	28.9	-0.5	30.2
	185287	28.2	27.7	-0.5	30.1
C	185288	26.2	25.8	-0.4	32.8
	185289	25.8	25.4	-0.4	32.1
	185290	26.9	26.6	-0.3	30.0
	185291	26.3	26.1	-0.2	29.7
D	185292	28.5	28.3	-0.2	29.7
	185293	28.8	28.4	-0.4	29.5
	185294	29.8	29.4	-0.4	27.6
	185295	29.3	29.0	-0.3	28.0
E	185296	22.3	22.4	+0.1	33.8
	185297	24.4	24.4	0.0	34.2
	185298	26.9	26.5	-0.4	31.1
	185299	28.3	27.9	-0.4	30.0
F	185300	27.0	26.6	-0.4	28.7
	185301	26.8	26.4	-0.4	29.0
	185302	30.3	29.8	-0.5	27.3
	185303	27.9	27.5	-0.4	28.2
G	185304	30.2	29.8	-0.4	29.5
	185305	26.0	25.6	-0.4	30.6
	185306	26.7	26.3	-0.4	29.9
	185307	27.2	27.0	-0.2	30.2
H	185308	28.4	28.1	-0.3	27.8
	185309	28.8	28.4	-0.4	29.1
	185310	28.4	28.1	-0.3	26.4
	185311	29.8	29.4	-0.4	26.9

[a] Arbitrarily based on single-filter method.

TABLE II--CONTINUED

OPTICAL CHARACTERISTICS OF 42-LB. LINER SAMPLES

Mill	File No.	Luminous Reflectance, % Single-Filter Method	Luminous Reflectance, % Two-Reflectance Method	Diff.[a]	Purity, % Two-Reflectance Method
I	185312	28.3	27.9	-0.4	31.6
	185313	27.1	26.9	-0.2	32.1
	185314	26.4	26.1	-0.3	31.5
	185315	26.3	26.0	-0.3	32.6
J	185316	25.1	24.9	-0.2	31.0
	185317	24.0	23.6	-0.4	28.0
	185318	27.0	26.8	-0.2	29.8
	185319	24.6	24.5	-0.1	30.7
L	185320	28.0	27.7	-0.3	31.9
	185321	28.2	27.9	-0.3	31.0
	185322	27.8	27.5	-0.3	30.1
	185323	28.1	27.9	-0.2	30.1
M	185324	29.1	28.9	-0.2	28.2
	185325	29.8	29.5	-0.3	28.3
	185326	29.4	29.2	-0.2	27.0
	185327	29.6	29.2	-0.4	27.8
N	185328	31.6	31.1	-0.5	29.0
	185329	31.8	31.4	-0.4	27.7
	185330	32.3	31.8	-0.5	27.9
	185331	28.4	28.2	-0.2	29.6
O	185332	28.5	28.1	-0.4	27.8
	185333	29.9	29.4	-0.5	27.3
	185334	29.5	29.0	-0.5	27.0
	185335	28.6	28.4	-0.2	27.5
P	185336	26.5	26.4	-0.1	29.2
	185337	24.3	24.3	0.0	30.2
	185338	23.3	23.4	+0.1	30.0
	185339	24.1	23.9	-0.2	30.0
Q	185340	25.8	25.4	-0.4	30.3
	185341	26.9	26.7	-0.2	29.2
	185342	24.3	24.2	-0.1	28.6
	185343	25.7	25.5	-0.2	27.4

[a] Arbitrarily based on single-filter method.

TABLE II--CONTINUED

OPTICAL CHARACTERISTICS OF 42-LB. LINER SAMPLES

Mill	File No.	Luminous Reflectance, % Single-Filter Method	Luminous Reflectance, % Two-Reflectance Method	Diff.[a]	Purity, % Two-Reflectance Method
R	185344	22.9	22.7	-0.2	34.5
	185345	23.8	23.6	-0.2	33.8
	185346	23.6	23.5	-0.1	33.9
	185347	21.9	21.7	-0.2	33.9
S	185348	24.3	24.0	-0.3	32.0
	185349	22.4	22.4	0.0	31.9
	185350	25.4	25.1	-0.3	30.2
	185351	24.7	24.4	-0.3	29.8

[a] Arbitrarily based on single-filter method.

PURITY. %

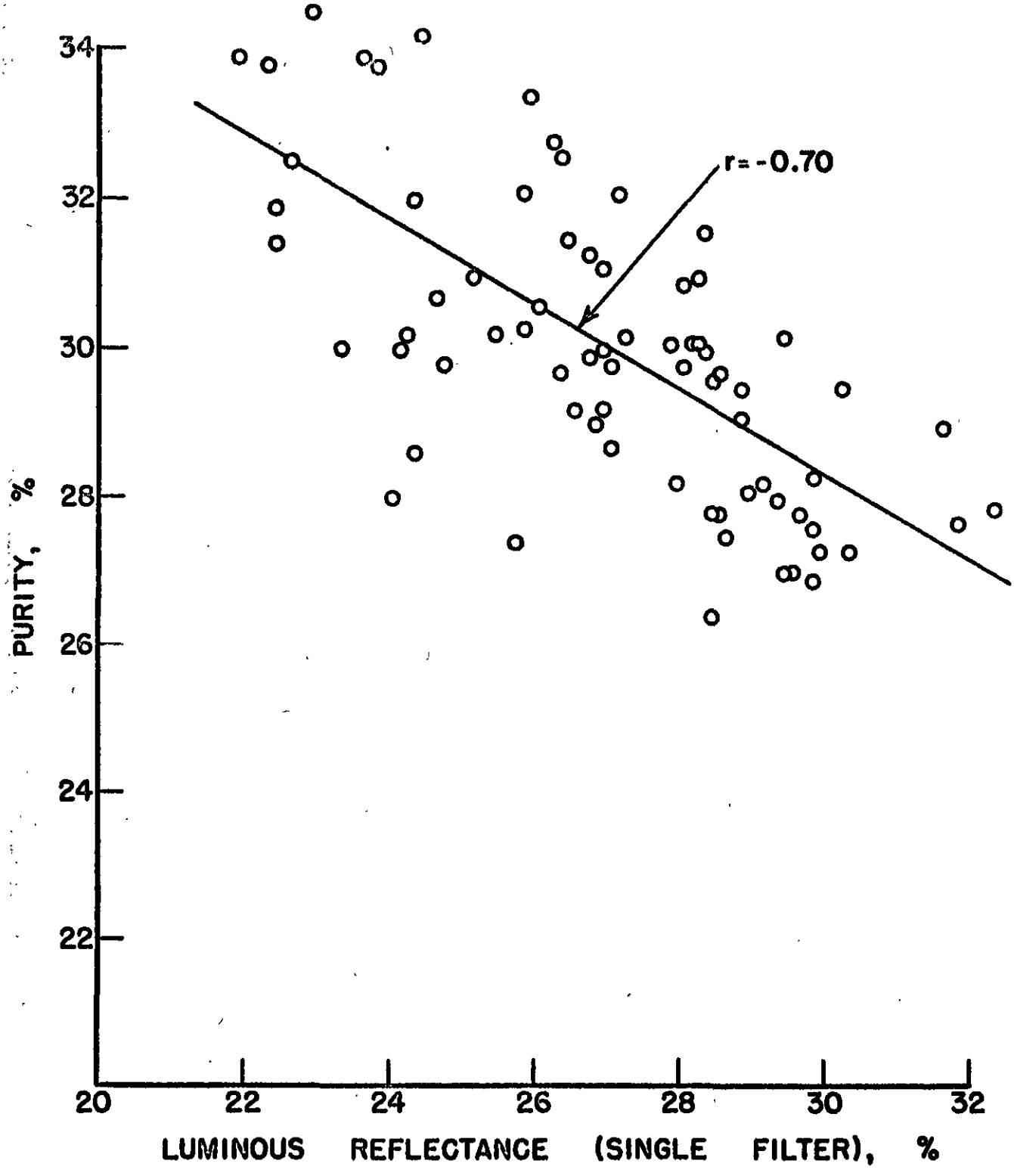

Figure 2. Relationship Between Purity and Luminous Reflectance

TABLE III

CORRELATION BETWEEN OPTICAL PROPERTIES

Relationship	Correlation Coefficient	Regression Equation
Purity *vs.* luminous reflectance	-0.70	$p = 45.32 - 0.567\ Y$

PHASE II. COMPARISON OF VISUAL RANKING OF COLOR DIFFERENCES OF KRAFT LINERBOARD WITH THE OPTICAL CHARACTERISTICS OF THE BOARD

As mentioned previously, a major objective of this study was to test the hypothesis that visual ranking of color differences of kraft linerboard is primarily affected by differences in luminous reflectance (Y) rather than by both purity (p) and Y. If such were the case, practical color standards might be established in terms of Y alone.

The experimental design selected involved

(a) Color ranking of a series of samples by observers in each mill and

(b) Correlation of the color rankings with the optical characteristics of the board.

In this way, it was felt that an objective evaluation of the relative importance of the various optical characteristics to visual ranking could be established.

For this purpose, four sets of 18 samples were selected from the original 72 samples in such a manner that each set covered the entire luminous

reflectance range of the original samples. Set 1 samples were distributed to Mills A, C, F, H, and I; Set II to Mills B, D, L, and P; Set III to G, O, Q, and R; and Set IV to Mills J, M, N, and S. After ranking by one or more observers at each mill (see Appendix A for color ranking instructions and Appendix B for individual rankings), the individual rankings from each mill were averaged together and then composited for the four or five mills in each set.

The final results obtained are tabulated in Tables IV through VII together with the optical characteristics of the samples. Inspection of the tables indicates that

1. Appreciable differences in color ranking occurred between mills and hence between observers--in part because of small differences in optical properties between adjacent samples.

2. The observers generally gave the lowest luminous reflectance samples the most negative rankings and conversely as would be expected.

With the above in mind the composite average rankings were correlated with the optical characteristics with the results shown in Table VIII and graphically illustrated in Fig. 3 and 4. The correlation coefficients are statistically significant. However, luminous reflectance was better related to the visual ranking as indicated by the higher coefficient--and smaller scatter in the figures.

TABLE IV

COLOR RANKINGS AND OPTICAL CHARACTERISTICS FOR SET I SAMPLES

Mill	File No.	Luminous Reflectance,[a] %	Purity, %	Average Color Ranking by Mill A n=2	C n=2	F n=3	H n=2	I n=2	Composite Av. Ranking
S	185349	22.4	31.9	-13.0	-15.0	-17.0	-14.0	-14.5	-14.7
R	185344	22.9	34.5	-15.5	-16.5	-15.3	-16.5	-16.5	-16.1
R	185345	23.8	33.8	-15.5	-16.5	-15.0	-16.5	-16.5	-16.0
Q	185342	24.3	28.6	-14.5	-12.0	-10.0	- 5.5	-11.5	-10.7
S	185350	25.4	30.2	- 8.5	-10.0	- 6.3	- 7.0	-12.5	- 8.9
G	185305	26.0	30.6	- 4.5	- 2.0	- 0.7	- 1.0	- 9.5	- 3.5
I	185315	26.3	32.6	- 8.0	- 8.0	- 1.0	+ 0.5	-12.5	- 5.8
F	185301	26.8	29.0	+ 3.5	- 6.0	- 6.3	- 5.5	- 1.0	- 3.1
E	185298	26.9	31.1	-10.5	-13.0	- 6.0	- 0.5	- 6.5	- 7.3
J	185318	27.0	29.8	0.0	+ 0.5	0.0	0.0	- 0.5	0.0
L	185320	28.0	31.9	- 5.0	-14.0	+ 5.7	+ 2.0	- 3.0	- 2.9
E	185299	28.3	30.0	+ 2.0	- 8.5	+ 8.3	+ 1.0	- 7.5	- 0.9
O	185332	28.5	27.8	+ 7.0	+ 1.5	+ 8.3	+12.0	+ 7.5	+ 7.3
D	185293	28.8	29.5	+ 3.0	- 1.5	+ 2.7	+ 7.0	+ 3.5	+ 2.9
M	185324	29.1	28.2	+ 8.5	+ 5.5	+ 9.3	+11.0	+ 5.0	+ 7.9
M	185327	29.6	27.8	+10.0	+ 5.5	+ 9.7	+12.5	+ 6.5	+ 8.8
O	185333	29.9	27.3	+12.0	+ 9.5	+12.3	+14.5	+ 8.5	+11.4
F	185302	30.3	27.3	+ 6.0	+ 4.5	+ 9.3	+ 7.0	+ 5.0	+ 6.4

[a] Simple-filter method.

TABLE V

COLOR RANKING AND OPTICAL CHARACTERISTICS FOR SET II SAMPLES

Mill	File No.	Luminous Reflectance,[a] %	Purity, %	Average Color Ranking by Mills B n=1	D n=3	L n=4	P n=4	Composite Av. Ranking
E	185296	22.3	33.8	-17.0	-16.7	-16.2	-16.8	-16.7
P	185338	23.3	30.0	-16.0	-15.7	-12.0	-16.0	-14.9
P	185339	24.1	30.0	-15.0	-12.3	- 9.2	-10.8	-11.8
E	185297	24.4	34.2	-14.0	-15.3	-11.5	-15.0	-14.0
S	185350	25.4	30.2	-13.0	-12.0	-11.8	- 8.2	-11.2
B	185284	25.9	33.4	- 4.0	-14.3	- 4.0	- 7.8	- 7.5
C	185288	26.2	32.8	0.0	-11.0	- 3.5	- 3.8	- 4.6
G	185306	26.7	29.9	+ 6.0	- 4.7	+ 2.5	- 0.2	+ 0.9
Q	185341	26.9	29.2	+ 8.0	- 3.3	+ 3.8	+ 5.2	+ 3.4
L	185322	27.8	30.1	+ 5.0	- 5.0	+ 2.2	+ 4.2	+ 1.6
L	185323	28.1	30.1	+ 3.0	- 2.3	+10.2	+ 4.5	+ 3.8
S	185287	28.2	30.1	+ 1.0	- 5.7	- 2.5	- 7.2	- 3.6
H	185308	28.4	27.8	+ 9.0	+ 2.7	+ 8.8	+ 8.5	+ 7.2
O	185335	28.6	27.5	+ 7.0	+ 1.3	+ 8.2	+ 4.0	+ 5.1
B	185286	29.4	30.2	+ 2.0	- 4.3	+ 4.0	+ 3.2	+ 1.2
M	185326	29.4	27.0	+10.0	+ 5.0	+10.5	+10.2	+ 8.9
H	185311	29.8	26.9	+11.0	+ 6.3	+13.5	+12.2	+10.8
N	185330	32.3	27.9	+12.0	+ 8.3	+14.5	+13.5	+12.1

[a] Single-filter method.

TABLE VI

COLOR RANKING AND OPTICAL CHARACTERISTICS FOR SET III SAMPLES

Mill	File No.	Luminous Reflectance,[a] %	Purity, %	Average Color Ranking by Mills G n=2	O n=4	Q n=1	R n=3	Composite Av. Ranking
A	185283	22.4	31.4	-15.0	-16.2	-16.0	-16.7	-16.0
R	185346	23.6	33.9	-15.0	-16.0	-17.0	-16.3	-16.1
J	185317	24.0	28.0	-10.0	-11.5	-15.0	-12.3	-12.2
P	185337	24.3	30.2	- 6.0	-10.2	-14.0	-10.0	-10.0
J	185316	25.1	31.0	- 5.0	- 1.5	- 9.0	- 7.3	- 5.7
Q	185340	25.8	30.3	+ 1.5	+ 1.2	-11.0	+ 1.0	- 1.8
I	185314	26.4	31.5	+ 4.5	+ 1.0	- 8.0	- 6.7	- 2.3
P	185336	26.5	29.2	+ 1.0	+ 2.2	- 6.0	+ 2.0	- 0.2
C	185290	26.9	30.0	+ 6.0	+ 4.0	- 7.0	- 0.7	+ 0.6
G	185307	27.2	30.2	+ 7.5	+ 7.2	+ 1.0	+ 5.3	+ 5.2
F	185303	27.9	28.2	0.0	+ 3.2	- 3.0	+ 3.0	+ 0.8
I	185312	28.3	31.6	+ 8.5	+ 9.2	- 5.0	+ 7.7	+ 5.1
N	185331	28.4	29.6	+12.0	+10.8	0.0	+ 9.7	+ 8.1
H	185309	28.8	29.1	+11.0	+10.8	+10.0	+11.7	+10.9
B	185285	28.9	28.1	+ 6.5	+ 5.5	- 4.0	+ 5.3	+ 3.3
O	185334	29.5	27.0	+10.5	+11.5	+ 2.0	+ 8.3	+ 8.1
C	185304	30.2	29.5	+15.0	+13.5	+12.0	+13.0	+13.4
N	185329	31.8	27.7	+16.0	+15.0	+13.0	+14.0	+14.5

[a] Single-filter method.

TABLE VII

COLOR RANKING AND OPTICAL CHARACTERISTICS FOR SET IV SAMPLES

Mill	File No.	Luminous Reflectance,[a] %	Purity, %	Average Color Rankings by Mills J n=3	M n=3	N n=4	S n=3	Composite Av. Ranking
R	185347	21.9	33.9	-16.7	-17.0	-15.0	-16.7	-16.4
A	185282	22.6	32.5	-15.7	-16.0	-14.5	-12.3	-14.6
S	185348	24.3	32.0	-14.0	-14.7	-12.0	- 8.3	-12.2
J	185319	24.6	30.7	-11.3	- 8.7	- 6.8	- 6.0	- 8.2
S	185351	24.7	29.8	-13.7	-14.0	-11.2	- 5.3	-11.0
C	185289	25.8	32.1	- 5.7	-11.0	- 6.0	- 2.0	- 6.2
C	185291	26.3	29.7	- 1.3	-10.3	- 1.5	0.0	- 3.3
A	185280	26.6	31.3	- 5.3	- 8.0	- 1.8	+ 1.7	- 3.4
F	185300	27.0	28.7	-11.0	- 7.7	- 2.5	- 0.7	- 5.5
I	185313	27.1	32.1	- 6.3	-11.0	- 1.8	+ 1.7	- 4.4
A	185281	28.0	29.8	+ 1.3	+ 0.3	- 5.8	+ 4.7	+ 3.0
L	185321	28.2	31.0	+ 5.3	- 1.0	+ 4.8	+ 9.0	+ 4.5
H	185310	28.4	26.4	+ 4.3	- 2.7	+ 4.0	+ 9.7	+ 3.8
D	185292	28.5	29.7	+ 0.3	+ 1.3	+ 3.5	+11.0	+ 4.0
D	185295	29.3	28.0	+ 6.7	+ 4.3	+10.5	+13.7	+ 8.8
M	185325	29.8	28.3	+10.0	+ 6.7	+12.5	+14.7	+11.0
D	185294	29.8	27.6	+ 5.3	+ 5.3	+ 8.8	+11.3	+ 7.7
N	185328	31.6	29.0	+12.7	+ 7.7	+ 9.8	+16.3	+11.6

[a] Single-filter method.

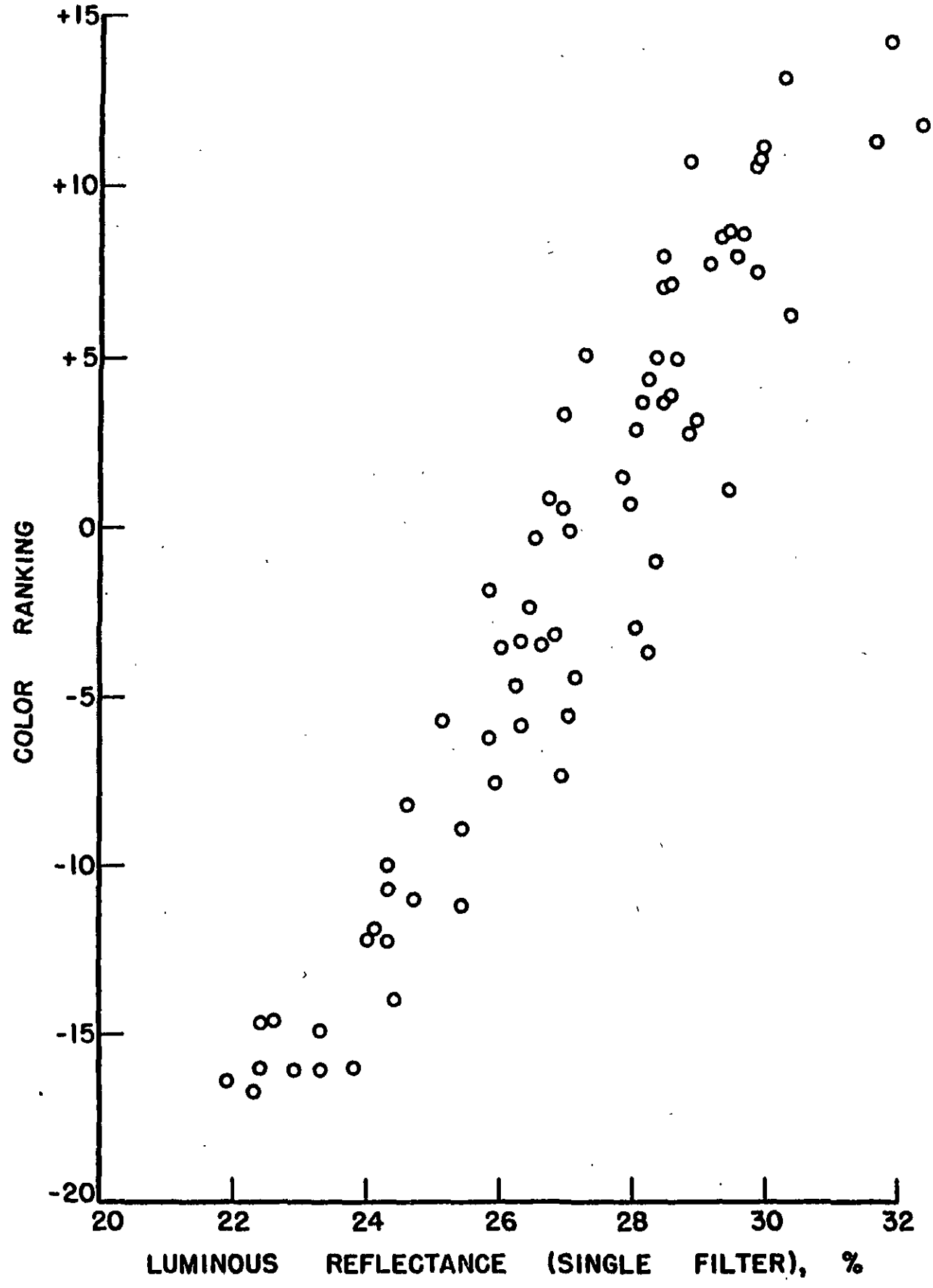

Figure 3. Relationship Between Visual Ranking and Luminous Reflectance

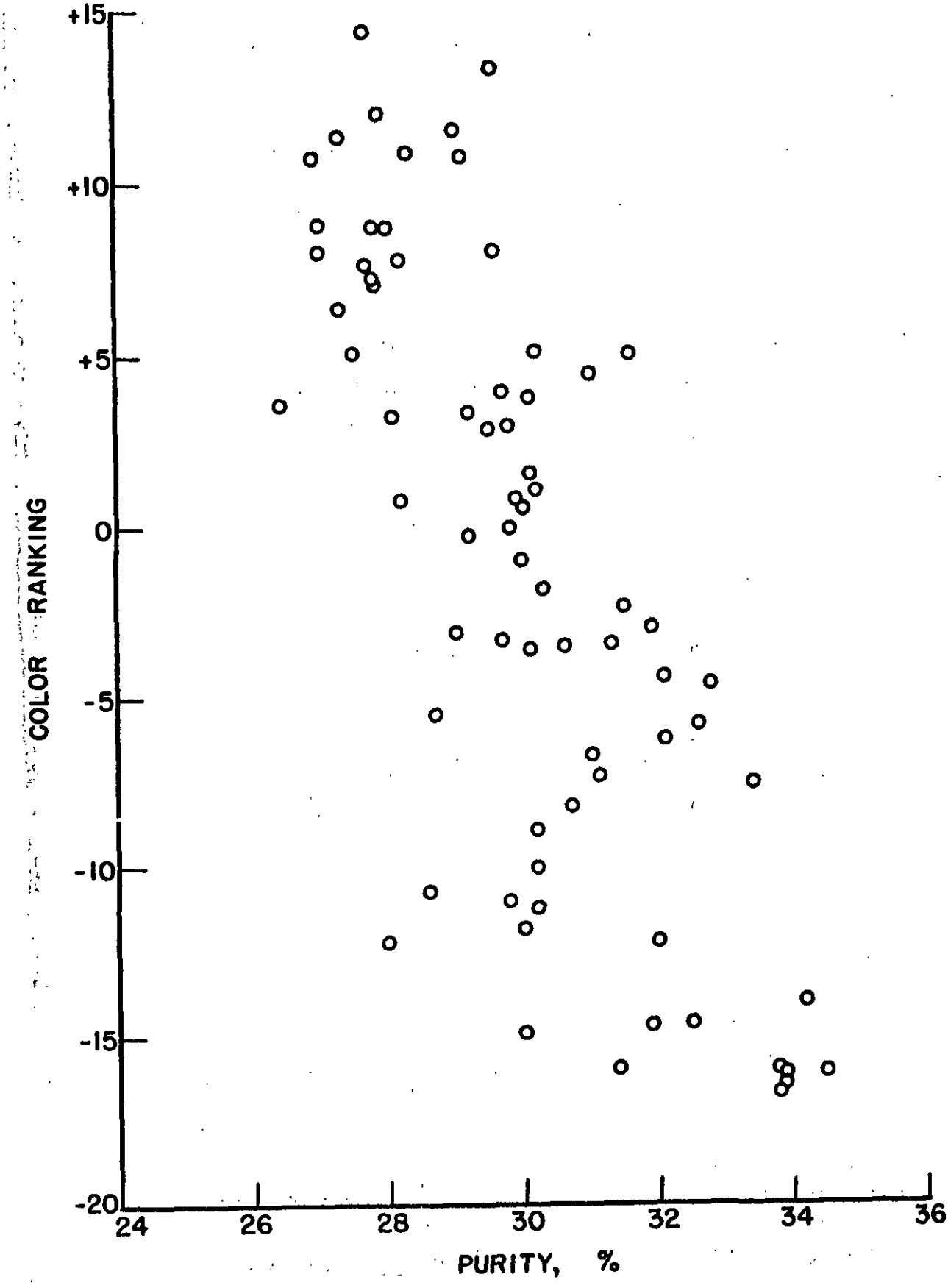

Figure 4. Relationship Between Visual Ranking and Purity

TABLE VIII

CORRELATION OF VISUAL RANKING WITH OPTICAL CHARACTERISTICS

Relationship	Correlation Coefficient
Ranking vs. luminous reflectance	0.95
Ranking vs. purity	-0.73

In addition to the above analysis, a two-factor multiple correlation involving luminous reflectance and purity was performed using the forward Doolittle techniques (4). The following equation was obtained:

$$R = 3.107\,Y - 0.600\,p - 67.174$$

where Y = luminous reflectance

R = visual ranking

and p = purity

The analysis of variance table took the following form:

Source of Variance	d.f.	Mean Square	F
Due to luminous reflectance	1	5086.81	658.91**
Due to purity	1	52.49	6.80*
Residual	69	7.72	

* Significant at the 5% level.

** Very highly significant (beyond 1% level).

The above indicates that both factors significantly affected the observers' rankings; however, the major portion of the total variance was explained by luminous reflectance.

Finally, to assist the reader in comparing the two optical characteristics, the regression equations were used to calculate rank values. These are compared to the actual visual rank values in Tables IX through XII. As expected from the foregoing, luminous reflectance was more effective in predicting color ranking. Very slightly better estimates were obtained using the multiple regression equation involving both luminous reflectance and purity.

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In general, therefore, the results from this phase indicate that, for unbleached kraft linerboard,

1. Luminous reflectance is more highly correlated than purity with visual rankings of color differences.

2. The addition of purity in a two-factor relationship gave only slightly better estimates of visual ranking.

3. On the basis of the above results, it appears that for the unbleached kraft samples used in this study, luminous reflectance by itself will predict visual ranking by the method used about as well as luminous reflectance and purity.

F

91**

80*

4. It is believed that the good predictive ability of luminous reflectance is due to the fact that the reflectance curve for most unbleached krafts is linear or approximately so. A small percentage of unbleached krafts exhibit reflection curves in the visual region which consist of two intersecting straight lines. Therefore, it is anticipated that the relationship found above will hold as long as the present processes and materials, which give linear reflectance curves, are used. There is some question if

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TABLE IX

COMPARISON OF VISUAL RANKING WITH ESTIMATED RANKINGS BASED ON THE OPTICAL CHARACTERISTICS (SET I)

File No.	Visual Ranking	Computed Ranking: Based on Luminous Reflectance	Diff.[a]	Based on Purity	Diff.[a]	Based on Luminous Reflectance and Purity	Diff.[a]
185349	-14.7	-17.1	-2.4	-7.5	+7.2	-16.7	-2.0
185344	-16.1	-15.4	+0.7	-16.0	+0.1	-16.7	-0.6
185345	-16.0	-12.3	+3.7	-13.7	+2.3	-13.5	+2.5
185342	-10.7	-10.6	+0.1	+3.3	+14.0	- 8.8	+1.9
185350	- 8.9	- 5.8	+3.1	-2.0	+6.9	- 5.4	+3.5
185305	- 3.5	- 4.7	-1.2	-3.3	+0.2	- 4.8	-1.3
185315	- 5.8	- 3.7	+2.1	-9.8	-4.0	- 5.0	+0.8
185301	- 3.1	-2.0	+1.1	+2.0	+5.1	- 1.3	+1.8
185298	- 7.3	- 1.6	+5.7	-4.9	+2.4	- 2.3	+5.0
185318	0.0	- 1.3	-1.3	-0.6	-0.6	- 1.2	-1.2
185320	- 2.9	+ 2.2	+5.1	-7.5	-4.6	+ 0.7	+3.6
185299	- 0.9	+ 3.2	+4.1	-1.3	-0.4	+ 2.8	+3.7
185332	+ 7.3	+ 3.9	-3.4	+5.9	-1.4	+ 4.7	-2.6
185293	+ 2.9	+ 4.9	+2.0	+0.3	-2.6	+4.6	+1.7
185324	+ 7.9	+ 5.9	-2.0	+4.6	-3.3	+ 6.3	-1.6
185327	+ 8.8	+ 7.7	-1.1	+5.9	-2.9	+ 8.1	-0.7
185333	+11.4	+ 8.7	-2.7	+7.5	-3.9	+ 9.3	-2.1
185302	+ 6.4	+10.1	+3.7	+7.5	-1.1	+10.6	+4.2
Average difference			2.5		3.5		2.3

[a] Difference equals estimated minus observed rank.

[a] Difference equals estimated minus observed rank.

TABLE X

COMPARISON OF VISUAL RANKING WITH ESTIMATED RANKINGS BASED ON OPTICAL CHARACTERISTICS (SET II)

File No.	Visual Ranking	Computed Ranking: Based on Luminous Reflectance	Diff.[a]	Based on Purity	Diff.[a]	Based on Luminous Reflectance and Purity	Diff.[a]
185296	-16.7	-17.5	-0.8	-13.7	+3.0	-18.2	-1.5
185338	-14.9	-14.0	+0.9	- 1.3	+13.6	-12.8	+2.1
185339	-11.8	-11.3	+0.5	-1.3	+10.5	-10.3	+1.5
185297	-14.0	-10.3	+3.7	-15.0	-1.0	-11.9	+2.1
185350	-11.2	- 6.8	+4.4	- 2.0	+9.2	- 6.4	+4.8
185284	- 7.5	- 5.1	+2.4	-12.4	-4.9	- 6.7	+0.8
185288	- 4.6	- 4.0	+0.6	-10.4	-5.8	- 5.4	-0.8
185306	+0.9	- 2.3	-3.2	- 1.0	-1.9	- 2.2	-3.1
185341	+ 3.4	- 1.6	-5.0	+ 1.3	-2.1	- 1.1	-4.5
185322	+ 1.6	+ 1.5	-0.1	-1.6	-3.2	+ 1.1	-0.5
185323	+ 3.8	+ 2.5	-1.3	- 1.6	-5.4	+ 2.1	-1.7
185287	- 3.6	+ 2.8	+6.4	- 1.6	+2.0	+ 2.4	+6.0
185308	+ 7.2	+ 3.5	-3.7	+ 5.9	-1.3	+ 4.4	-2.8
185335	+ 5.1	+ 4.2	-0.9	+ 6.8	+1.7	+ 5.2	+0.1
185286	+ 1.2	+ 7.0	+5.8	- 2.0	-3.2	+ 6.1	+4.9
185326	+ 8.9	+ 7.0	-1.9	+ 8.5	-0.4	+8.0	-0.9
185311	+10.8	+ 8.4	-2.4	+ 8.8	-2.0	+ 9.3	-1.5
185330	+12.1	+17.0	+4.9	+ 5.5	-6.6	+16.4	+4.3
Average difference			2.7		4.3		2.4

[a] Difference equals estimated minus observed ranking.

TABLE XI

COMPARISON OF VISUAL RANKING WITH ESTIMATED RANKINGS BASED ON THE OPTICAL CHARACTERISTICS (SET III)

File No.	Visual Ranking	Computed Ranking: Based on Luminous Reflectance	Diff.[a]	Based on Purity	Diff.[a]	Based on Luminous Reflectance and Purity	Diff.[a]
185283	-16.0	-17.1	-1.1	-11.4	+4.6	-16.4	-0.4
185346	-16.0	-13.0	+3.1	-14.0	+2.1	-14.2	+1.9
185317	-12.2	-11.6	+0.6	+5.2	+17.4	-9.4	+2.8
185337	-10.0	-10.6	-0.6	- 2.0	+8.0	- 9.8	+0.2
185316	- 5.7	- 7.8	+2.1	- 4.6	+1.1	- 7.8	-2.1
185340	- 1.8	- 5.4	-3.6	- 2.3	-0.5	- 5.2	-3.4
185314	- 2.3	- 3.4	-1.1	- 6.2	-3.9	- 4.0	-1.7
185336	- 0.2	- 3.0	-2.8	+ 1.3	+1.5	- 2.4	-2.2
185290	+ 0.6	- 1.6	-2.2	- 1.3	-1.9	- 1.6	-2.2
185307	+ 5.2	- 0.6	-5.8	- 2.0	-7.2	- 0.8	-6.0
185303	+ 0.8	+ 1.8	+1.0	+ 4.6	+3.8	+ 2.6	+1.8
185312	+ 5.1	+ 3.2	-1.9	- 6.5	-11.6	+ 1.8	-3.3
185331	+ 8.1	+ 3.5	-4.6	0.0	-8.1	+ 3.3	-4.8
185309	+10.9	+ 4.9	-6.0	+ 1.6	-9.3	+ 4.8	-6.1
185285	+ 3.3	+ 5.3	+2.0	+ 4.9	+1.6	+ 5.8	+2.5
185334	+ 8.1	+ 7.3	-0.8	+ 8.5	+0.4	+ 8.3	+0.2
185304	+13.4	+ 9.7	-3.7	+ 0.3	-13.1	+ 9.0	-4.4
185329	+14.5	+15.3	+0.8	+ 6.2	-8.3	+15.0	+0.5
Average difference			2.4		5.8		2.6

[a] Difference equals computed minus observed ranking.

TABLE XII

TABLE XII

COMPARISON OF VISUAL RANKING WITH ESTIMATED RANKINGS BASED ON OPTICAL CHARACTERISTICS (SET IV)

File No.	Visual Ranking	Computed Ranking: Based on Luminous Reflectance	Diff.[a]	Based on Purity	Diff.[a]	Based on Luminous Reflectance and Purity	Diff.[a]
185347	-16.4	-18.9	-2.5	-14.0	+2.4	-19.5	-3.1
185282	-14.6	-16.5	-1.9	- 9.4	+5.2	-16.5	-1.9
185348	-12.2	-10.6	+1.6	- 7.8	+4.4	-10.9	+1.3
185319	- 8.2	- 9.6	-1.4	-3.6	+4.6	- 9.2	-1.0
185351	-11.0	- 9.2	+1.8	-0.6	+10.4	- 8.3	+2.7
185289	- 6.2	- 5.4	+0.8	- 8.1	-1.9	- 6.3	-0.1
185291	- 3.3	- 3.7	+0.4	- 0.3	+3.0	- 3.3	0.0
185280	- 3.4	- 2.7	-0.7	- 5.5	-2.1	- 3.3	+0.1
185300	- 5.5	- 1.3	+4.2	+ 2.9	+8.4	- 5.0	+0.5
185313	- 4.4	- 0.9	+3.5	- 8.1	-3.7	- 2.2	+2.2
185281	+ 3.0	+ 2.2	-0.8	-0.6	-3.6	+ 1.9	-1.1
185321	+ 4.5	+ 2.8	-1.7	- 4.6	-9.1	+ 1.8	-2.7
185310	+ 3.8	+ 3.5	-0.3	+10.4	+6.6	+ 5.2	-1.4
185292	+ 4.0	+ 3.9	-0.1	- 0.3	-4.3	+ 3.6	-0.4
185295	+ 8.8	+ 6.6	-2.2	+ 5.2	-3.6	+ 7.1	-1.7
185325	+11.0	+ 8.4	-2.6	+ 4.2	-6.8	+ 8.4	-2.6
185294	+ 7.7	+ 8.4	+0.7	+ 6.5	-1.2	+ 8.9	+1.2
185328	+11.6	+14.6	+3.0	+ 2.0	-9.6	+13.6	+2.0
Average difference			1.7		5.0		1.4

[a] Difference equals computed minus observed ranking.

they will hold, if for example dyes are used, to try to bring the color of kraft board produced by different mills closer together since it would be an unusual dye which would act on the reflectance in a linear fashion.

To some extent, at least, the correlations between the optical characteristics and visual ranking must depend upon the experimental design. In this connection, it may be recalled that the observers were first required to rank the samples in order of luminous reflectance as ranking in terms of purity was considered impractical. It is possible, therefore, that this operation introduced a natural bias tending to favor higher correlation of visual ranking with luminous reflectance than purity. With this reservation it is believed that the results bear out the original hypothesis, namely, that visual rankings of color differences in unbleached kraft linerboard are better related to luminous reflectance than to purity. "Color" specifications for unbleached kraft linerboard based on luminous reflectance alone would, therefore, appear practical--at least in the present state of the art.

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LITERATURE CITED

1. An investigation of a method of specifying and measuring the color of 42-lb. unbleached kraft linerboard. Project 1108-15, Progress Report One to the Technical Committee, Fourdrinier Kraft Board Institute, Inc., June 15, 1956.

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3. A simplified method for determining the purity and luminous reflectance of 42-lb. unbleached kraft linerboard. Project 1108-15, Progress Report Three to Fourdrinier Kraft Board Institute, Inc., May 1, 1958.

4. Hunter, J. Stuart. Determination of optimum operating conditions by experimental methods. Part II-1, Models and Methods. Ind. Quality Control 15, no. 6:16-24 (Dec., 1958); no. 7:7-15; no. 8:6-14(Jan., Feb., 1959).

THE INSTITUTE OF PAPER CHEMISTRY

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Container Section

NO PAGE #32 IN THE ORIGINAL TEXT

APPENDIX A

INSTRUCTIONS FOR COLOR RANKING OF UNBLEACHED LINERBOARD SAMPLES

During recent months the Institute has carried out, on behalf of the Fourdrinier Kraft Board Institute, a comparison of two methods of measuring the luminous reflectance of unbleached kraft linerboard. As a second phase of the study, the Institute was requested to compare visual ranking of color differences of kraft linerboard with the instrumental rankings. For that purpose we are requesting that one or more observers from each mill visually grade or rank a set of samples with respect to a standard using the procedure described below:

I. Samples: Included with this letter are

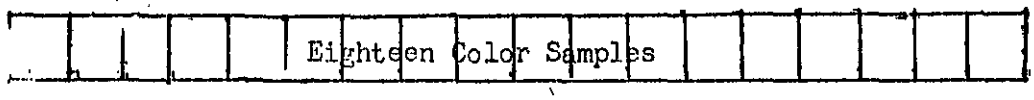
(a) Eighteen, two by three-inch samples of liner. The samples are marked on the wire side with Institute file numbers which bear no relation to the optical characteristics of the samples.

(b) One, 2 by 3-inch sample marked "standard" on the wire side.

II. Conditions of viewing: All viewing should be from the smooth-finish side of sample. The rating should be carried out using "natural north sky light" illumination against a neutral background. The samples should be protected against unnecessary exposure to light in the event that the rating session is interrupted or the samples are rated by several observers. The samples should be held by the edges to avoid fingerprints on the main body of the samples.

III. Rating system: Three steps are required in the rating process as follows:

A. Arrange the samples in order of increasing luminous reflectance (over-all brightness) as schematically shown in Fig. 1 below:



increasing brightness

Dullest ——————————→ Brightest

Figure 1

As examples of differences in luminous reflectance, two sets of samples have been arranged in Fig. 2 in the order of decreasing luminous reflectance. Set a involves samples which are essentially alike in purity (depth of color) but vary in luminous reflectance. Set b vary in both luminous reflectance and purity. In both cases the "brightest" sample is at the top and the "dullest" at the bottom.

B. Insert standard sample in array as follows:

(1) Compare the luminous reflectance of the standard sample with the array and insert the standard sample in its proper "brightness" position. When the samples are arranged as shown in Fig. 3, all the samples to the right of the standard sample will be "brighter" than the standard sample and those to the left "duller." The position of the standard sample in the array is not necessarily at the mid-point of the array.

(2) Arrange the samples as shown in Fig. 3. The samples "brighter" than the standard are to be lettered +a, +b, +c, etc., until all the samples have been assigned a letter. The lettering should start with the sample nearest in "brightness" to the standard sample.

(3) The same general procedure is used for the samples which are "duller" than the standard sample. Letter the sample nearest in "brightness" to the standard -a, the next "duller" samples, -b, -c, etc., until all the "duller"samples have been lettered.

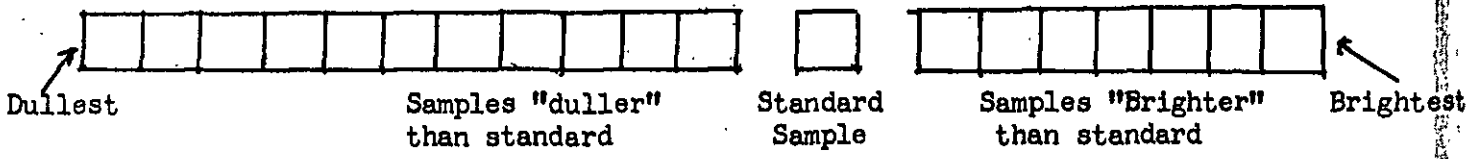


Figure 3

C. Intercompare (+) and (-) samples on basis of color match as follows:

(1) Compare the +a and --a samples with the standard. Assign the numeral "0" to the sample giving the better color match with the standard For example, if -a were the better color match, it would be given the ranking "0" as shown in Fig. 4.

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"Dullest"

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Figure 2. Illustration of Brightness and Dullness

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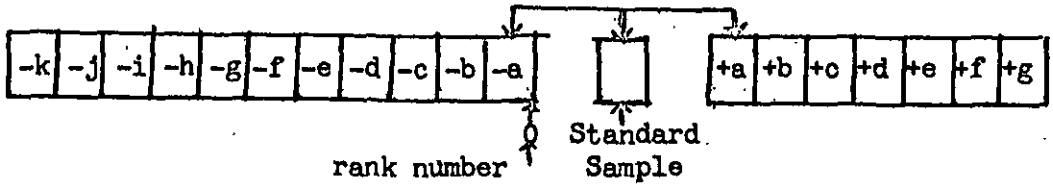

Figure 4

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(2) Compare the color match of the next lowest lettered samples remaining in the (+) and (-) groups with the standard sample. Assign the rank number 1 to the sample exhibiting better match and prefix the proper sign. For example, if -a were eliminated in (1) above, then samples -b and +a would be compared in this step. If sample -b were the better color match, it would be given the rank number -1 as shown in Fig. 5.

match as

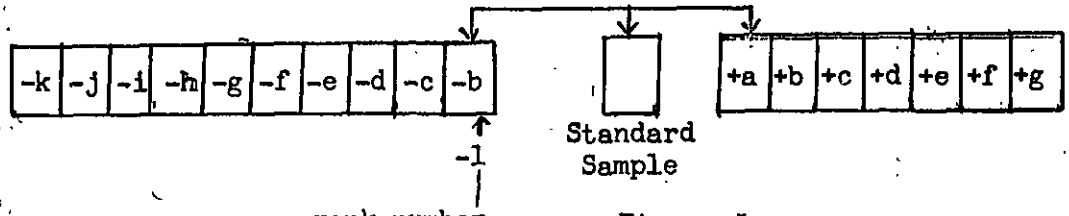

Figure 5

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. 4.

(3) Compare the lowest lettered samples remaining in the (+) and (-) groups with the standard sample. Assign the rank number 2 to the sample giving the better match and prefix the proper sign. For example, if samples -a and -b were eliminated above, samples -c and +a would be compared in this step. For example, if -c appeared to be the better color match, it would be given the rank number -2, as shown in Fig. 6.

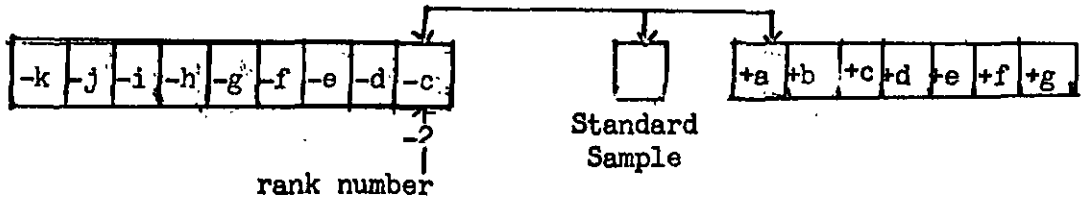

Figure 6

(4) Compare the lowest letter sample remaining in the (+) and (-) groups with the standard. Assign the rank number 3 to the sample giving the better match and prefix the proper sign. For example, if -d and +a were being compared in this step and +a were the better match, it would be given the rank number +3.

(5) Continue the above until the samples in either the + or - group are exhausted. The samples in the remaining group are to be compared as follows: Compare the two lowest letter samples with the standard sample and assign proper rank numbers. Continue until all samples in the group have been compared with standard samples and assigned rank numbers.

(6) Record the rank numbers for each sample on the attached data sheets and mail one copy to The Institute of Paper Chemistry, Appleton, Wisconsin, in care of R. C. McKee.

APPENDIX B

INDIVIDUAL OBSERVER RANKINGS

TABLE B-1

INDIVIDUAL OBSERVER RANKINGS FROM MILL A
(Set I samples)

File No.	Luminous Reflectance Ranking Machine Result	Luminous Reflectance Ranking Observers A-1	A-2	A-3	Color Ranking Observers A-1	A-2[a]	A-3	Average
185349	22.4	-h	-a	-e	-14	-9	-12	-13.0
185344	22.9	-j	-b	-f	-17	-10	-14	-15.5
185345	23.8	-i	-c	-g	-16	-11	-15	-15.5
185342	24.3	-f	-e	-h	-12	-13	-17	-14.5
185350	25.4	-g	-d	-b	-13	-12	- 4	- 8.5
185305	26.0	-d	+a	+a	-10	0	+ 1	- 4.5
185315	26.3	-c	-g	-c	- 9	-15	- 7	- 8.0
185301	26.8	+a	-h	+c	+ 1	-16	+ 6	+ 3.5
185298	26.9	-e	-f	-d	-11	-14	-10	-10.5
185318	27.0	-a	-i	-a	0	-17	0	0.0
185318[b]	27.0							
185320	28.0	-b	+b	+d	-15	+ 2	+5	- 5.0
185299	28.3	+b	+c	+b	+ 2	+ 3	+ 2	+ 2.0
185332	28.5	+e	+f	+g	+ 5	+ 5	+ 9	+ 7.0
185293	28.8	+c	+d	+e	+ 3	+ 1	+ 3	+ 3.0
185324	29.1	+f	+g	+h	+ 6	+ 6	+11	+ 8.5
185327	29.6	+g	+h	+i	+ 7	+ 7	+13	+10.0
185333	29.9	+h	+i	+j	+ 8	+ 8	+16	+12.0
185302	30.3	+d	+e	+f	+ 4	+ 4	+ 8	+ 6.0

[a] Observer A-2's results were discarded after examination indicated a possible misinterpretation of the procedure.

[b] Standard sample.

TABLE B-2

INDIVIDUAL OBSERVER RANKINGS FROM MILL B

(Set II samples)

File No.	Luminous Reflectance Ranking Machine Result	Luminous Reflectance Ranking Observers B-1	B-2	B-3	B-4	Color Ranking Observers B-1	B-2	B-3	B-4
185296	22.3	-f	-b	-g	-h	-17	-17	-15	-16
185338	23.3	-e	-g	-h	-e	-16	-12	-16	-17
185339	24.1	-d	-e	-f	-f	-15	-13	-14	-14
185297	24.4	-b	-d	-e	-g	-14	-16	-13	-15
185350	25.4	-c	-h	-d	-c	-13	-14	-12	-11
185284	25.9	-a	-c	-c	-d	- 4	-15	-17	-13
185288	26.2	+a	+a	-b	-b	0	+10	-10	-10
185306	26.7	+f	+g	+a	+d	+ 6	+ 5	0	+ 3
185341	26.9	+h	+j	+b	+c	+ 8	+ 8	+ 1	+ 2
185318[a]	27.0								
185322	27.8	+e	+f	+d	+b	+ 5	+ 7	+ 3	0
185323	28.1	+d	+e	+f	+f	+ 3	+ 6	+ 5	+ 5
185287	28.2	+b	-a	-a	-a	+ 1	-11	-11	-12
185308	28.4	+i	+b	+h	+g	+ 9	+ 4	+ 7	+ 6
185335	28.6	+g	+i	+c	+e	+ 7	0	+ 2	+ 4
185286	29.4	+c	-b	+e	+a	+ 2	- 9	+ 4	+ 1
185326	29.4	+j	-h	+g	+h	+ 10	+ 1	+ 6	+ 7
185311	29.8	+k	+d	+i	+i	+11	+ 2	+ 8	+ 8
185330	32.3	+l	+c	+j	+j	+12	+ 3	+ 9	+ 9

[a] Standard sample.

Note: Observers B-2, B-3, and B-4 results were discarded after examination indicated a possible misinterpretation of the procedure.

TABLE B-3

INDIVIDUAL OBSERVER RANKINGS FROM MILL C

(Set I samples)

		Luminous Reflectance Ranking			Color Ranking		
		Machine	Observers		Observers		
B-4	File No.	Result	C-1	C-2	C-1	C-2	Average
-16							
-17	185349	22.4	-i	-m	-15	-15	-15.0
-14	185344	22.9	-k	-l	-17	-16	-16.5
-15	185345	23.8	-j	-k	-16	-17	-16.5
-11	185342	24.3	-e	-i	-12	-12	-12.0
	185350	25.4	-d	-h	- 9	-11	-10.0
-13							
-10	185305	26.0	-a	-c	- 2	- 2	- 2.0
+ 3	185315	26.3	-c	-e	- 8	- 8	- 8.0
+ 2	185301	26.8	-f	-b	-11	- 1	- 6.0
	185298	26.9	-h	-j	-13	-13	-13.0
	185318	27.0	+b	-a	+ 1	0	+ 0.5
0							
+ 5	185318[a]	27.0					
-12	185320	28.0	-g	-f	-14	-14	-14.0
+ 6	185299	28.3	-b	-g	- 7	-10	- 8.5
+ 4	185332	28.5	+a	+a	0	+ 3	+ 1.5
	185293	28.8	+c	-d	+ 3	- 6	- 1.5
+ 1							
+ 7	185324	29.1	+f	+c	+ 6	+ 5	+ 5.5
+ 8	185327	29.6	+d	+d	+ 4	+ 7	+ 5.5
+ 9	185333	29.9	+g	+e	+10	+ 9	+ 9.5
	185302	30.3	+e	+b	+ 5	+ 4	+ 4.5

ina-

[a] Standard sample.

TABLE B-4

INDIVIDUAL OBSERVER RANKINGS FROM MILL D

(Set II samples)

File No.	Luminous Reflectance Ranking: Machine Result	Luminous Reflectance Ranking: Observers D-1	D-2	D-3	Color Ranking: Observers D-1	D-2	D-3	Average
185296	22.3	-l	-o	-k	-17	-16	-17	-16.7
185338	23.3	-k	-m	-h	-16	-17	-14	-15.7
185339	24.1	-h	-k	-g	-13	-12	-12	-12.3
185297	24.4	-j	-n	-j	-15	-15	-16	-15.3
185350	25.4	-g	-l	-f	-12	-13	-11	-12.0
185284	25.9	-i	-h	-i	-14	-14	-15	-14.3
185288	26.2	-f	-g	-d	-11	- 9	-13	-11.0
185306	26.7	-e	-j	+d	- 9	-11	+ 6	- 4.7
185341	26.9	-d	-c	+a	- 8	- 2	0	- 3.3
185316[a]	27.0							
185322	27.8	-c	-e	-a	- 7	- 7	- 1	- 5.0
185323	28.1	-b	-d	-b	- 2	- 3	- 2	- 2.3
185287	28.2	+b	-i	-e	+ 3	-10	-10	- 5.7
185308	28.4	+d	-a	+b	+ 5	0	+ 3	+ 2.7
185335	28.6	+a	-b	+c	0	- 1	+ 5	+ 1.3
185286	29.4	-a	-f	-c	- 1	- 8	- 4	- 4.3
185326	29.4	+c	+a	+e	+ 4	+ 4	+ 7	+ 5.0
185311	29.8	+e	+b	+f	+ 6	+ 5	+ 8	+ 6.3
185330	32.3	+f	+c	+g	+10	+ 6	+ 9	+ 8.3

[a] Standard sample.

TABLE B-5

INDIVIDUAL OBSERVER RANKINGS FROM MILL F
(Set I samples)

File No.	Machine Result	Luminous Reflectance Ranking Observers F-1	F-2	F-3	F-4	F-5	F-6	Color Ranking Observers F-1	F-2	F-3	F-4	F-5	F-6	Average
185349	22.4	-h	-j	-i	-k	-g	-k	-17	-16	-17	-16	-17	-16	-17.0
185344	22.9	-g	-h	-h	-i	-f	-j	-16	-14	-16	-15	-16	-15	-15.3
185345	23.8	-f	-i	-g	-j	-e	-i	-15	-15	-15	-17	-15	-17	-15.0
185342	24.3	-a	-k	-f	-h	-c	-h	-10	-17	- 9	-13	- 4	-14	-10.0
185350	25.4	-d	-f	-d	-f	-b	-f	-13	-12	- 4	-11	- 3	-11	- 6.3
185305	26.0	+c	-b	-b	-a	+a	-e	+ 2	- 1	- 2	- 7	+ 1	-10	- 0.7
185315	26.3	-e	-d	-a	-b	+c	-b	-14	- 8	- 1	- 9	+ 6	- 9	- 1.0
185301	26.8	-b	-g	-e	-g	+b	-g	-11	-13	- 8	-12	+ 2	-13	- 6.3
185298	26.9	-c	-e	-c	-d	-d	-d	-12	-10	- 3	-14	- 5	-12	- 6.0
185318	27.0	+b	-a	+a	-e	-a	+a	- 1	0	0	-10	0	0	0.0
185318[a]	27.0													
185320	28.0	+e	+b	+b	-c	+f	-a	+ 4	+ 3	+ 5	- 8	+9	- 7	+ 5.7
185299	28.3	+f	+g	+c	+c	+e	-c	+ 5	+11	+ 6	+ 2	+ 8	- 8	+ 8.3
185332	28.5	+a	+d	+e	+a	+g	+b	0	+ 5	+10	0	+10	+ 1	+ 8.3
185293	28.8	+g	-c	+d	+b	+d	+d	+ 6	- 6	+ 7	+ 3	+ 7	+ 3	+ 2.7
185324	29.1	+i	+a	+h	+b	+j	+f	+ 8	+ 2	+13	+ 1	+13	+ 5	+ 9.3
185327	29.6	+h	+e	+f	+e	+h	+e	+ 7	+ 7	+11	+ 4	+11	+ 4	+ 9.7
185333	29.9	+j	+f	+i	+g	+k	+g	+ 9	+ 9	+14	+ 6	+14	+ 6	+12.3
185302	30.3	+d	+c	+g	+f	+i	+c	+ 3	+ 4	+12	+ 5	+12	+ 2	+ 9.3

[a] Standard sample.

Note: Observe F-1, F-4 and F-6 results were discarded after examination indicated a possible misinterpretation of the procedure.

TABLE B-6

INDIVIDUAL OBSERVER RANKINGS FROM MILL G

(Set III samples)

File No.	Luminous Reflectance Ranking			Color Ranking		
	Machine Result	Observers G-1	G-2	Observers G-1	G-2	Average
185283	22.4	-f	-b	-14	-16	-15.0
185346	23.6	-e	-c	-13	-17	-15.0
185317	24.0	-g	-d	-15	- 5	-10.0
185337	24.3	-c	-a	- 8	- 4	- 6.0
185316	25.1	-d	+a	-10	0	- 5.0
185340	25.8	-a	+d	0	+3	+ 1.5
185314	26.4	+b	+e	+ 3	+6	+ 4.5
185336	26.5	+a	+b	+ 1	+1	+ 1.0
185290	26.9	+d	+f	+ 5	+7	+ 6.0
185318[a]	27.0					
185307	27.2	+f	+g	+ 7	+ 8	+ 7.5
185303	27.9	-b	+c	- 2	+ 2	0.0
185312	28.3	+e	+i	+ 6	+11	+ 8.5
185331	28.4	+i	+k	+12	+12	+12.0
185309	28.8	+g	+l	+ 9	+13	+11.0
185285	28.9	+c	+h	+ 4	+ 9	+ 6.5
185334	29.5	+h	+j	+11	+10	+10.5
185304	30.2	+j	+m	+16	+14	+15.0
185329	31.8	+k	+n	+17	+15	+16.0

[a] Standard sample.

Note: Four replies were received, two of which were incomplete and are not entered in the table.

TABLE B-7

INDIVIDUAL OBSERVER RANKINGS FROM MILL H

(Set I samples)

File No.	Luminous Reflectance Ranking Machine Result	Luminous Reflectance Ranking Observers H-1	Luminous Reflectance Ranking Observers H-2	Color Ranking Observers H-1	Color Ranking Observers H-2	Average
185349	22.4	-f	-i	-13	-15	-14.0
185344	22.9	-h	-j	-17	-16	-16.5
185345	23.8	-g	-k	-16	-17	-16.5
185342	24.3	-d	-b	- 3	- 8	- 5.5
185350	25.4	-e	-h	- 4	-10	- 7.0
185305	26.0	-b	-a	- 1	- 1	- 1.0
185315	26.3	+a	-c	+ 5	- 4	+ 0.5
185301	26.8	-c	-g	- 2	- 9	- 5.5
185298	26.9	+b	-e	+ 6	- 7	- 0.5
185318	27.0	-a	+a	0	0	0.0
185318[a]	27.0					
185320	28.0	+c	-b	+ 7	- 3	+ 2.0
185299	28.3	+d	-d	+ 8	- 6	+ 1.0
185332	28.5	+g	+f	-11	+13	+12.0
185293	28.8	+e	+c	+ 9	+ 5	+ 7.0
185324	29.1	+f	+e	+10	+12	+11.0
185327	29.6	+i	+d	+14	+11	+12.5
185333	29.9	+j	+g	+15	+14	+14.5
185302	30.3	+h	+b	+12	+ 2	+ 7.0

[a] Standard sample.

TABLE B-8

INDIVIDUAL OBSERVER RANKINGS FROM MILL I

(Set I samples)

File No.	Luminous Reflectance Ranking			Color Ranking		
	Machine Result	Observers I-1	I-2	Observers I-1	I-2	Average
185349	22.4	-i	-i	-15	-14	-14.5
185344	22.9	-k	-k	-17	-16	-16.5
185345	23.8	-j	-j	-16	-17	-16.5
185342	24.3	-g	-d	-14	- 9	-11.5
185350	25.4	-h	-g	-13	-12	-12.5
185305	26.0	-b	-c	-11	- 8	- 9.5
185315	26.3	-e	-h	-12	-13	-12.5
185301	26.8	-d	+a	- 3	+ 1	- 1.0
185298	26.9	-c	-f	- 2	-11	- 6.5
185318	27.0	-b	-a	- 1	0	- 0.5
185318[a]	27.0					
185320	28.0	+a	-e	+ 4	-10	- 3.0
185299	28.3	-a	-b	0	-15	- 7.5
185332	28.5	+f	+f	+ 9	+ 6	+ 7.5
185293	28.8	+b	+b	+ 5	+ 2	+ 3.5
185324	29.1	+d	+c	+ 7	+ 3	+ 5.0
185327	29.6	+e	+e	+ 8	+ 5	+ 6.5
185333	29.9	+g	+g	+10	+ 7	+ 8.5
185302	30.3	+c	+d	+ 6	+ 4	+ 5.0

[a] Standard sample.

TABLE B-9

INDIVIDUAL OBSERVER RANKINGS FROM MILL J

(Set IV samples)

	Luminous Reflectance Ranking								Color Ranking							
	Machine	Observers							Observers							
File No.	Result	J-1	J-2	J-3	J-4	J-5	J-6	J-7	J-1	J-2	J-3	J-4	J-5	J-6	J-7	Average
185347	21.9	-k	-j	-h	-k	-k	-j	-j	-17	-16	-17	-17	-17	-17	-17	-16.7
185282	22.6	-j	-k	-g	-j	-j	-g	-i	-16	-17	-16	-16	-16	-14	-10	-15.7
185348	24.3	-i	-i	-e	-i	-h	-i	-g	-15	-12	-14	-15	-15	-15	- 8	-14.0
185319	24.6	-h	-f	-d	-h	-g	-f	-h	-14	- 9	-13	-13	-13	-12	- 9	-11.3
185351	24.7	-g	-h	-f	-g	-i	-h	-f	-13	-11	-15	-14	-14	-16	- 7	-13.7
185289	25.8	-d	-e	+h	-e	-c	-a	-b	-10	- 8	- 9	-11	- 8	-1	- 4	- 5.7
185291	26.3	-a	-d	+c	-c	-b	+b	-a	- 1	- 7	- 8	- 4	- 2	+ 5	0	- 1.3
185280	26.6	-e	-b	+a	-a	-d	-c	-e	-11	- 4	-10	- 5	- 9	- 3	- 6	- 5.3
185300[a]	27.0	-f	-g	-b	-f	-f	-e	-d	-12	-10	-12	-12	-12	-11	- 3	-11.0
185318[a]	27.0															
185313	27.1	-c	-c	-c	-d	-e	-d	+c	- 6	- 5	-11	-10	-10	- 4	+11	- 6.3
185281	28.0	+b	-a	+d	+b	-a	+c	+a	0	- 2	0	0	0	+ 6	+ 1	+ 1.3
185321	28.2	+a	+f	+i	+d	+b	-b	-c	+ 2	+15	+ 2	+ 1	+ 3	- 2	- 2	+ 5.3
185310	28.4	+c	+b	-a	+c	+d	+d	+e	+ 4	+ 1	+ 4	+ 3	+ 5	+ 7	+13	+ 4.3
185292	28.5	-b	+a	+e	-b	+a	+a	+b	- 3	0	+ 1	- 9	+ 1	0	+ 5	+ 0.3
185295	29.3	+d	+d	+g	+a	+e	+e	+d	+ 5	+ 6	+ 5	+ 2	+ 6	+ 8	+12	+ 6.7
185325	29.8	+f	+e	+h	+f	+f	+g	+g	+ 8	+13	+ 6	+ 7	+ 7	+10	+15	+10.0
185294	29.8	+e	+c	+f	+e	+c	+f	+f	+ 7	+ 3	+ 3	+ 6	+ 4	+ 9	+14	+ 5.3
185328	31.6	+g	+g	+j	+g	+g	+h	+h	+ 9	+14	+ 7	+ 8	+11	+13	+16	+12.7

[a] Standard sample.

Note: Observers J-1, J-3, J-4, and J-7 results were discarded after examination indicating a possible misinterpretation of the procedure.

TABLE B-10

INDIVIDUAL OBSERVER RANKINGS FROM MILL L

(Set II samples)

File No.	Luminous Reflectance Ranking					Color Ranking				
	Machine Result	Observers L-1	L-2	L-3	L-4	Observers L-1	L-2	L-3	L-4	Average
185296	22.3	-g	-g	-j	-e	-16	-17	-16	-16	-16.2
185338	23.3	-h	-d	-d	-f	-17	- 7	- 7	-17	-12.0
185339	24.1	-f	-c	-c	-d	-15	- 6	- 2	-14	- 9.2
185297	24.4	-d	-f	-i	-b	-11	-16	-13	- 6	-11.5
185350	25.4	-e	-e	-h	-c	-12	-15	-11	- 9	-11.8
185284	25.9	-c	-b	-e	+c	- 8	- 3	- 8	+ 3	- 4.0
185288	26.2	-b	-a	-f	+b	- 7	0	- 9	+ 2	- 3.5
185306	26.7	+c	+b	+c	-a	+ 3	+ 2	+ 5	0	+ 2.5
185341	26.9	+a	+d	+a	+f	0	+ 5	+ 3	+ 7	+ 3.8
185318[a]	27.0									
185322	27.8	+b	+c	-a	+d	+ 1	+ 4	0	+ 4	+ 2.2
185323	28.1	+e	+f	+f	+k	+ 5	+ 9	+14	+13	+10.2
185287	28.2	-a	+a	-g	+a	- 2	+ 1	-10	+ 1	- 2.5
185308	28.4	+h	+h	+d	+g	+10	+11	+ 6	+ 8	+ 8.8
185335	28.6	+g	+g	+b	+h	+ 9	+10	+ 4	+10	+ 8.2
185286	29.4	+d	+e	-b	+e	+ 4	+ 8	- 1	+ 5	+ 4.0
185326	29.4	+f	+i	+e	+j	+ 6	+12	+12	+12	+10.5
185311	29.8	+i	+j	+h	+i	+13	+13	+17	+11	+13.5
185330	32.3	+j	+k	+g	+l	+14	+14	+15	+15	+14.5

[a]Standard sample

TABLE B-11

INDIVIDUAL OBSERVER RANKINGS FROM MILL M

(Set IV samples)

	Luminous Reflectance Ranking				Color Ranking			
	Machine	Observers			Observers			
File No.	Result	M-1	M-2	M-3	M-1	M-2	M-3	Average
185347	21.9	-k	-k	-l	-17	-17	-17	-17.0
185282	22.6	-j	-j	-k	-16	-16	-16	-16.0
185348	24.3	-i	-i	-j	-15	-14	-15	-14.7
185319	24.6	-a	-g	-i	0	-12	-14	- 8.7
185351	24.7	-h	-h	-h	-14	-15	-13	-14.0
185289	25.8	-g	-f	-d	-13	-13	- 7	-11.0
185291	26.3	-d	-e	-g	- 9	-10	-12	-10.3
185280	26.6	-c	-c	-c	-10	- 8	- 6	- 8.0
185300	27.0	-b	-d	-f	- 3	- 9	-11	- 7.7
185318[a]	27.0							
185313	27.1	-f	-b	-e	-12	-11	-10	-11.0
185281	28.0	+a	+a	+a	+ 1	0	0	+ 0.3
185321	28.2	+c	-a	-b	+ 4	- 2	- 5	- 1.0
185310	28.4	-e	+b	+b	-11	+ 1	+ 2	- 2.7
185292	28.5	+b	+c	-a	+ 2	+ 3	- 1	+ 1.3
185295	29.3	+d	+d	+d	+ 5	+ 4	+ 4	+ 4.3
185325	29.8	+e	+f	+e	+ 6	+ 6	+ 8	+ 6.7
185294	29.8	+g	+e	+c	+ 8	+ 5	+ 3	+ 5.3
185328	31.6	+f	+g	+f	+ 7	+ 7	+ 9	+ 7.7

[a] Standard sample.

TABLE B-12

INDIVIDUAL OBSERVER RANKINGS FROM MILL N

(Set IV samples)

File No.	Luminous Reflectance Ranking: Machine Result	Luminous Reflectance Ranking: Observers N-1	N-2	N-3	N-4	Color Ranking: Observers N-1	N-2	N-3	N-4	Color Ranking: Average
185347	21.9	-k	-f	-k	-e	-17	-17	-17	- 9	-15.0
185282	22.6	-j	-e	-j	-h	-16	-12	-15	-15	-14.5
185348	24.3	-g	-c	-i	-g	-13	- 5	-16	-14	-12.0
185319	24.6	-i	-b	-b	-a	-15	- 1	-11	0	- 6.8
185351	24.7	-h	-d	-e	-f	-14	- 7	-12	-12	-11.2
185289	25.8	-f	+a	-g	-b	-12	+ 2	-13	- 1	- 6.0
185291	26.3	-a	+c	-d	-c	- 2	+ 4	- 6	- 2	- 1.5
185280	26.6	-e	+b	-c	+c	-11	+ 3	- 5	+ 6	- 1.8
185300	27.0	-c	-a	+b	-d	- 7	0	+ 2	- 5	- 2.5
185318[a]	27.0									
185313	27.1	-d	+e	-h	+d	- 8	+ 8	-14	+ 7	- 1.8
185281	28.0	+b	+j	-a	+e	+ 1	+14	0	+ 8	+ 5.8
185321	28.2	+a	+i	-b	+f	0	+13	- 4	+10	+ 4.8
185310	28.4	-b	+k	+c	+a	- 5	+15	+ 3	+ 3	+ 4.0
185292	28.5	+c	+d	+a	+b	+ 3	+ 6	+ 1	+ 4	+ 3.5
185295	29.3	+e	+f	+g	+i	+ 6	+ 9	+10	+17	+10.5
185325	29.8	+f	+l	+f	+j	+ 9	+16	+ 9	+16	+12.5
185294	29.8	+d	+h	+d	+h	+ 4	+11	+ 7	+13	+ 8.8
185328	31.6	+g	+g	+e	+g	+10	+10	+ 8	+11	+ 9.8

[a] Standard sample.

TABLE B-13

INDIVIDUAL OBSERVER RANKINGS FROM MILL O

(Set III samples)

File No.	Luminous Reflectance Ranking: Machine Result	Luminous Reflectance Ranking: Observers 0-1	0-2	0-3	0-4	Color Ranking: Observers 0-1	0-2	0-3	0-4	Color Ranking: Average
185283	22.4	-e	-e	-f	-h	-16	-16	-16	-17	-16.2
185346	23.6	-d	-d	-e	-e	-17	-17	-15	-15	-16.0
185317	24.0	-c	-c	-d	-f	-10	-13	- 9	-14	-11.5
185337	24.3	-b	-b	-c	-g	- 9	- 8	- 8	-16	-10.2
185316	25.1	-a	-a	-b	-d	0	0	- 1	- 5	- 1.5
185340	25.8	+d	+a	+c	-c	+ 4	+ 1	+ 4	- 4	+ 1.2
185314	26.4	+a	+c	-a	-b	+ 1	+ 3	0	- 1	+ 1.0
185336	26.5	+b	+b	+b	+a	+ 2	+ 2	+ 3	+ 2	+ 2.2
185290	26.9	+e	+f	+d	-a	+ 5	+ 6	+ 5	0	+ 4.0
185318[a]	27.0									
185307	27.2	+g	+g	+f	+e	+ 7	+ 7	+ 7	+ 8	+ 7.2
185303	27.9	+c	+e	+a	+b	+ 3	+ 5	+ 2	+ 3	+ 3.2
185312	28.3	+h	+h	+j	+d	+ 8	+ 9	+13	+ 7	+ 9.2
185331	28.4	+i	+j	+g	+h	+11	+11	+10	+11	+10.8
185309	28.8	+j	+i	+i	+f	+12	+10	+12	+ 9	+10.8
185285	28.9	+f	+d	+e	+c	+ 6	+ 4	+ 6	+ 6	+ 5.5
185334	29.5	+k	+k	+h	+g	+13	+12	+11	+10	+11.5
185304	30.2	+l	+l	+k	+i	+14	+14	+14	+12	+13.5
185329	31.8	+m	+m	+l	+j	+15	+15	+17	+13	+15.0

[a] Standard sample.

TABLE B-14

INDIVIDUAL OBSERVER RANKINGS FROM MILL P

(Set II samples)

File No.	Luminous Reflectance Ranking: Machine Result	Luminous Reflectance Ranking: Observers P-1	P-2	P-3	P-4	P-5	Color Ranking: Observers P_1	P_2	P_3	P_4	P_5	Color Ranking: Average
185296	22.3	-h	-i	-i	-f	-h	-17	-17	-17	-16	-16	-16.8
185338	23.3	-f	-f	-h	-h	-f	-15	-16	-16	-17	-17	-16.0
185339	24.1	-b	-d	-g	-g	-e	- 7	-10	-11	-15	-13	-10.8
185297	24.4	-g	-h	-f	-e	-g	-16	-15	-15	-14	-14	-15.0
185350	25.4	-c	-e	-d	-d	-a	- 8	-11	- 3	-11	- 1	- 8.2
185284	25.9	-d	-g	-c	-b	-c	-11	-14	- 2	- 4	-15	- 7.8
185288	26.2	-a	-b	-b	-c	-b	- 6	- 3	- 1	- 5	- 2	- 3.8
185306	26.7	+a	-a	-a	-a	-d	0	- 1	0	0	-12	- 0.2
185341	26.9	+e	+e	+f	+b	+a	+ 4	+ 6	+ 9	+ 2	0	+ 5.2
185318[a]	27.0											
185322	27.8	+d	+a	+c	+f	+c	+ 3	0	+ 6	+ 8	+ 4	+ 4.2
185323	28.1	+c	+c	+b	+e	+e	+ 2	+ 4	+ 5	+ 7	+ 6	+ 4.5
185287	28.2	-e	-c	-e	+a	+b	-12	- 8	-10	+ 1	+ 3	- 7.2
185308	28.4	+h	+f	+e	+g	+g	+10	+ 7	+ 8	+ 9	+ 8	+ 8.5
185335	28.6	+f	+d	+d	+c	+f	+ 5	+ 5	+ 7	+ 3	+ 7	+ 4.0
185286	29.4	+b	+b	+a	+d	+d	+ 1	+ 2	+ 4	+ 6	+ 5	+ 3.2
185326	29.4	+g	+g	+h	+h	+h	+ 9	+ 9	+13	+10	+ 9	+10.2
185311	29.8	+i	+h	+g	+i	+i	+13	+12	+12	+12	+10	+12.2
185330	32.3	+j	+i	+i	+j	+j	+14	+13	+14	+13	+11	+13.5

[a] Standard sample.

Note: Observer J-5's results were discarded after examination indicated a possible misinterpretation of the procedure.

TABLE B-15

INDIVIDUAL OBSERVER RANKINGS FROM MILL Q

(Set III samples)

File No.	Luminous Reflectance Ranking: Machine Result	Luminous Reflectance Ranking: Observer Q-1	Color Ranking: Observer Q-1
185283	22.4	-k	-16
185346	23.6	-j	-17
185317	24.0	-l	-15
185337	24.3	-i	-14
185316	25.1	-g	- 9
185340	25.8	-h	-11
185314	26.4	-f	- 8
185336	26.5	-d	- 6
185290	26.9	-e	- 7
185318[a]	27.0		
185307	27.2	+b	+ 1
185303	27.9	-a	- 3
185312	28.3	-c	- 5
185331	28.4	+a	0
185309	28.8	+d	+10
185285	28.9	-b	- 4
185334	29.5	+c	+ 2
185304	30.2	+e	+12
185329	31.8	+f	+13

[a] Standard sample

TABLE B-16

INDIVIDUAL OBSERVER RANKINGS FROM MILL R

(Set III samples)

File No.	Luminous Reflectance Ranking: Machine Result	Luminous Reflectance Ranking: Observer R-1	Luminous Reflectance Ranking: Observer R-2	Luminous Reflectance Ranking: Observer R-3	Color Ranking: Observer R-1	Color Ranking: Observer R-2	Color Ranking: Observer R-3	Color Ranking: Average
185283	22.4	-f	-h	-h	-16	-17	-17	-16.7
185346	23.6	-g	-g	-g	-17	-16	-16	-16.3
185317	24.0	-e	-f	-e	-13	-11	-13	-12.3
185337	24.3	-c	-e	-f	- 8	- 7	-15	-10.0
185316	25.1	-d	-d	-c	- 9	- 6	- 7	- 7.3
185340	25.8	-a	+a	+b	0	0	+ 3	+ 1.0
185314	26.4	-b	-c	-d	- 1	- 5	-14	- 6.7
185336	26.5	+e	-a	+a	+ 6	- 1	+ 1	+ 2.0
185290	26.9	+a	-b	-b	+ 2	- 2	- 2	- 0.7
185318[a]	27.0							
185307	27.2	+f	+b	+e	+ 7	+ 3	+ 6	+ 5.3
185303	27.9	+d	+c	-a	+ 5	+ 4	0	+ 3.0
185312	28.3	+b	+g	+f	+ 3	+12	+ 8	+ 7.7
185331	28.4	+g	+f	+g	+10	+10	+ 9	+ 9.7
185309	28.8	+i	+h	+h	+12	+13	+10	+11.7
185285	28.9	+c	+d	+c	+ 4	+ 8	+ 4	+ 5.3
185334	29.5	+h	+e	+d	+11	+ 9	+ 5	+ 8.3
185304	30.2	+j	+i	+i	+14	+14	+11	+13.0
185329	31.8	+k	+j	+j	+15	+15	+12	+14.0

[a] Standard sample

TABLE B-17

INDIVIDUAL OBSERVER RANKINGS FROM MILL S

(Set IV samples)

	Luminous Reflectance Ranking				Color Ranking			
	Machine	Observer			Observer			
File No.	Result	S-1	S-2	S-3	S-1	S-2	S-3	Average
185347	21.9	-h	-g	-j	-17	-16	-17	-16.7
185282	22.6	-g	-f	-i	- 9	-13	-15	-12.3
185348	24.3	-f	-d	-h	- 6	- 7	-12	- 8.3
185319	24.6	-d	-e	-g	- 3	- 8	- 7	- 6.0
185351	24.7	-e	-c	-f	- 5	- 5	- 6	- 5.3
185289	25.8	-b	-b	-b	- 1	- 3	- 2	- 2.0
185291	26.3	-a	+c	-d	0	+ 4	- 4	0.0
185280	26.6	+a	+d	-e	+ 4	+ 6	- 5	+ 1.7
185300	27.0	-c	-a	-a	- 2	0	0	- 0.7
185318[a]	27.0							
185313	27.1	+b	+a	-c	+ 7	+ 1	- 3	+ 1.7
185281	28.0	+e	+b	+a	+11	+ 2	+ 1	+ 4.7
185321	28.2	+d	+e	+b	+10	+ 9	+ 8	+ 9.0
185310	28.4	+c	+g	+d	+ 8	+11	+10	+ 9.7
185292	28.5	+f	+h	+c	+12	+12	+ 9	+11.0
185295	29.3	+h	+i	+f	+14	+14	+13	+13.7
185325	29.8	+i	+j	+g	+15	+15	+14	+14.7
185294	29.8	+g	+f	+e	+13	+10	+11	+11.3
185328	31.6	+j	+k	+h	+16	+17	+16	+16.3

[a] Standard sample