NATIONAL BUREAU OF STANDARDS REPORT

4438

SPECTROPHOTOMETRIC AND COLORIMETRIC STUDY OF THE FADING OF DYED PAPERS AND CARDBOARDS UNDER NATURAL DAYLIGHT

By

Harry J. Keegan,

John C. Schleter,

Wiley A. Hall, Jr.,

and

Gladys M. Haas.

To

U. S. Department of the Air Force
Aerial Reconnaissance Laboratory
Wright Air Development Center
Wright-Patterson Air Force Base, Ohio.

U. S. DEPARTMENT OF COMMERCE
NATIONAL BUREAU OF STANDARDS

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U. S. DEPARTMENT OF COMMERCE
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PREFACE

This is one of a series of NBS reports of spectrophotometric and colorimetric work done under NBS Project No. 0201 - 20 - 2325 entitled Color Reconnaissance Studies, financed by the Aerial Reconnaissance Laboratory, Wright Air Development Center, Wright - Patterson Air Force Base, Ohio; Air Force Contract No. 33(616) 52-21. It is coordinated with Air Force Contract No. 33(616) - 262 under Dr. Hugh T. O'Neill, O'Neill Associates, Annapolis, Maryland, who requested the NBS to perform this fading test of dyed papers and cardboards for a ten-month period of exposure to natural daylight.

Harry J. Keegan
Project Leader

SPECTROPHOTOMETRIC AND COLORIMETRIC STUDY OF THE FADING OF DYED PAPERS AND CARDBOARDS UNDER NATURAL DAYLIGHT

Harry J. Keegan, John C. Schleter, Wiley A. Hall, Jr., and Gladys M. Haas *

Abstract

In the study of color photographs, either taken on the ground or in the air, some indication of the control of the color reproduction must be maintained. Accordingly, in the beginning of these color reconnaissance studies, and possibly before this time, Dr. Hugh T. O'Neill, O'Neill Associates, Annapolis, Maryland, purchased a quantity of each of the 22 dyed papers and cardboards of this test for use as working standards of color to supplement other more accurate standards as a guide of "color registers" on aerial color film.

A spectrophotometric and colorimetric study was made of the permanence of these color standards kept in dark storage and of the fading of these standards when exposed behind glass to natural North skylight and South sunlight for periods of two and of ten months. Measurements of spectral directional reflectance were made for the visible spectrum 400 to 750 millimicrons for each of these seven conditions of storage or of time of exposures. From these measurements were derived C. I. E. chromaticity coordinates, daylight reflectances, Munsell renotations, ISCC-NBS color designations, and color differences in NBS units (ΔE). From this information, predictions may be made of the time change of these paper colors from the day that they are removed from dark storage to the day that they are discarded in the field as being unfit to remain as reference standards.

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* Miss Haas is at present employed at the Mare Island Naval Shipyard, San Francisco, California.

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I. Introduction

The overall objective of this Air Force investigation is stated as follows: "To develop by visible, near infrared, and near ultraviolet spectrophotometry, methods for the detection of objects from color reconnaissance; to study the colors, tonal contrast, and color separation necessary in aerial photography to yield maximum information; to determine the wavelength region at which the film manufacturer should strive to obtain maximum sensitivity to yield clear separation of an object from its adjacent area rather than to yield true color fidelity; to determine the characteristics required in a sensitized material for the rapid and accurate extraction of this information".

The present report pertains to the materials to be used in the methods for the detection of objects from color reconnaissance. It especially pertains to the behavior of working standard colored materials under conditions of sun and skylight illumination during field use in the color photography of the terrain, or of other objects, and of a reference of these colors to their color transparencies or to color opaque reproductions of a given scene.

To fulfill the request of this study, seven separate spectral directional reflectance measurements have been made for the visible spectrum, 400 to 750 millimicrons, for each of the twenty-two colored papers. Three samples of each were selected. One was measured three times: (1) at the start of the study, (2) after two months of dark storage, and (3) after eight more months of dark storage. The other two samples were exposed

to natural daylight transmitted by window glass, one to sky-light transmitted by a window facing north, the other to daylight (sun plus sky) transmitted by a window facing south, and measured at the end of two months, and finally at the end of eight more months, making ten months in all. Colorimetric computations have been made for each of these seven conditions of dark storage or of exposure to natural daylight to obtain chromaticity coordinates and daylight reflectances for the International Commission on Illumination (C. I. E.) standard observer and coordinate system of colorimetry for C.I.E. Source C, representative of average daylight. In addition, these C.I.E. chromaticity coordinates and daylight reflectances have been converted into terms of the Munsell renotation system and into the ISCC-NBS (Inter-Society Color Council - National Bureau of Standards) system of color name designations. Further, color differences have been computed for each of these seven conditions of color changes in terms of the NBS unit of color difference, obtained in this case by means of the method developed by the late Dr. I. H. Godlove, Central Research Laboratory, General Aniline and Film Corporation, Easton, Penna.

Illustrations show these changes in the form of graphs of spectral directional reflectances, of chromaticity coordinates, of Munsell renotations, and of NBS units of color differences.

The method of measurement and computation is that requested in the original project proposal and used in the two previous reports of this project [1, 2].*

It is believed that this type of information will assist in selecting a suitable working standard for the control of the color reproductions of this project and that this information is a necessary step towards attaining the overall objective of this investigation.

II. Material

The papers and cardboards of this study, purchased in quantity by Dr. Hugh T. O'Neill, O'Neill Associates, Annapolis, Maryland, were described as follows:- "four differently colored bond (13 lb.) paper (Blue, Pink, Green, and Yellow); seven differently colored mimeo-bond paper (Blue, Tuscan, Green, Orange, Pink, Dull Yellow, and Bright Yellow); six differently colored onion-skin paper, all of the same weight (Blue, Green, Orange, Pink, Canary Yellow, and Yellow); and five differently colored Railroad Tag Board 6 ply (Blue, Green, Buff, Yellow, and Red)". The size of these twenty-two colored papers when delivered for study was 8-1/2 by 11 inches. From these papers, three sets of 2 by 4 inch samples were cut, and one set was marked for initial spectrophotometric measurements. Three thicknesses of each paper were used for backing and the composite four thicknesses of paper were backed with a wooden block covered with black paper for all of the spectrophotometric measurements. In the case of the Railroad Tag

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*Figures in brackets indicate the index reference, pages 104 and 105 of this report.

Board, a single thickness was almost completely opaque so that only one thickness was used with the same wooden block covered with black paper as backing for all of its measurements. Positioning marks were made on the rear side of each measured sample so that the same area of the sample could be measured in any future re-run of the samples.

This selected set of samples of each of the twenty-two colors was measured on January 7 and 8, 1953, and then was filed in dark storage in Room 208 East Building, National Bureau of Standards. At about this same time Munsell notations were obtained visually by comparison with the color chips of the Munsell Book of Color [3] and from these visual observations ISCC-NBS Color Names [4] were derived. * These visual estimates of Munsell notations and corresponding ISCC-NBS color name designations are listed in Table I [5], and were reported by Dr. O'Neill [6]. On February 4, 1953,

Table I

Visual Estimates of the Munsell Notations and the Corresponding ISCC-NBS (Inter-Society Color Council-National Bureau of Standards) Color Names of the Twenty-Two Dyed Papers and Cardboards.

Designated Type of Paper and Designated Name	Munsell Notation	ISCC-NBS Name
BOND		
Blue	0.5PB 8.5/3.5	Very Pale Blue
Pink	5.5R 8.5/5	Light Pink
Green	4.5G 8.8/4.0	Very Light Green
Yellow	8.5YR 7.6/12	Strong Orange Yellow
MIMEO BOND		
Blue	1 PB 8.6/3.7	Very Pale Blue
Tuscan	7.5YR 8.3/6.3	Light Orange Yellow
Green	5 G 8.7/4.3	Very Light Green
Orange	9 YR 7.8/12	Strong Orange Yellow
Pink	6 R 8.5/5	Light Pink
Dull Yellow	3 Y 9.2/6.5	Light Yellow
Bright Yellow	7.5Y 9.2/6.5	Light Greenish Yellow
ONION SKIN		
Blue	10 B 7.6/4	Very Pale Blue
Green	5 BG 6.7/3.7	Light Bluish Green
Orange	1 YR 7.2/8.7	Strong Yellowish Pink
Pink	8.5RP 7.4/8.5	Moderate Purplish Pink
Canary Yellow	8 Y 9.1/6	Light Greenish Yellow
Yellow	2 Y 8.5/7.5	Light Yellow
RAILROAD BOARD		
Blue	3 PB 6.4/6.7	Light Blue
Green	2.5G 7.4/6.5	Light Yellowish Green
Buff	7.5YR 7.6/6.5	Moderate Orange Yellow
Yellow	5.5Y 9.2/12.5	Vivid Yellow
Red	7.5R 5.5/14	Vivid Reddish Orange

*These visual estimates of Munsell notations and resulting ISCC-NBS color names were derived by Mr. K. L. Kelly.

the second and third sets of similar samples were selected and assembled in frames for exposure to natural daylight; one set was installed inside a north-facing window in Room No. 306, and the other set was installed inside a south-facing window in Room No. 315; both rooms are located on the third floor of the East Building of the National Bureau of Standards. Each set was left exposed day and night until March 27, 1953 or for a period of approximately two months when both sets were removed and spectrophotometered. Assembled again, the samples were left exposed in the same windows until November 23, 1953, or for a total of approximately ten months, when all of the samples were again disassembled and spectrophotometered on November 23 and 24, 1953 for the second time. At each period of measurement, measurements were also made on the samples kept in dark storage at each time period reported. At the end of this experiment all of the samples were dismantled and were filed in dark storage in Room 208 East Building, National Bureau of Standards, for possible further study.

III. Spectrophotometric Measurements.

Seven sets of measurements of spectral directional reflectance for the visible spectrum 400 to 750 millimicrons were made on three sets of twenty-two dyed papers and cardboards on the NBS General Electric recording spectrophotometer [7,8] for the condition of included specular component of reflected radiant energy. Slits of approximately 10 millimicrons were used for these measurements.

The initial set of measurements of the non-exposed ("dark storage") set of samples were made on January 7 and 8, 1953. As the papers of this test are to be used as working standards for the color register on aerial film, these measurements were considered to be "standard" for all subsequent measurements on samples of the same type and color and consequently were obtained with all calibration curves [9,10] ; i.e. (1) zero curve, (2) Vitrolite curve for the photometric scale and for the aging of the standard of reflectance, magnesium oxide, and (3) didymium curve for the wavelength calibration.

The second and third sets of measurements were made on March 27, 1953 and on November 23 and 24, 1953. These measurements of the three sets of samples (one non-exposed, the second exposed to north skylight, and the third to south daylight) were made on the NBS General Electric recording spectrophotometer. However, in these cases, no calibration curves were made or recorded as each graph sheet contained a curve of a "dark storage" sample, a similar sample exposed to north skylight, and a sample exposed to south daylight. Besides in these cases, precise differences between exposed and non-exposed samples rather than precise measurements of either set of samples were desired. Ozalid prints of each of these 48 recordings of the 154 determinations of these 22 colored papers are shown in Appendix A of this report.

Each of the curves of the initial set of twenty-two measurements was read and corrected at each ten millimicron interval between 400 and 750

millimicrons. The other two sets of sixty-six measurements were similarly read but uncorrected, at each ten millimicron interval for the spectral region 400 to 750 millimicrons.

These 154 spectrophotometric reductions of the data are shown on the twenty-two tables of spectral directional reflectance data in the Tables of Appendix B.

IV. Colorimetric Computations.

The spectral-directional-reflectance data of each of the seven conditions for each of the twenty-two samples of the dyed papers and cardboards (listed in Appendix B for the visible spectrum, 400 to 750 millimicrons) were converted to luminous reflectance, Y, and chromaticity coordinates, x,y, of the CIE colorimetric coordinate system by integration according to the CIE standard observer [11] for CIE source C, representative of average daylight.

V. Munsell Renotation and ISCC-NBS Color Designations.

From the above determined C.I.E. chromaticities and daylight reflectances of the seven sets of twenty-two dyed papers and cardboards determinations, the Munsell renotations were obtained from graphs of conversion from the C.I.E. system to the Munsell Renotation System [12]. These Munsell renotations were then converted into terms of the ISCC-NBS color name designations [13].

VI. Color Difference Computations.

From the Munsell renotations of the one-hundred and fifty-four determinations of the twenty-two dyed colored papers and cardboards, color differences in terms of the NBS unit of color difference (ΔE) were computed by means of the Godlove formula [14] between the initial measurement and the "dark storage" sample measurements of each type and color of sample; and between each of the "dark storage" sample measurements and both of its corresponding exposed sample measurement.

VII. Bond-Paper Colors (Pages 8 to 24)

The following 14 pages contain fourteen illustrations (Figures 1 to 14) showing a record of the initial state and the amounts of the spectrophotometric and colorimetric changes upon natural exposure of the four dyed colored specimens of (13 lb.) bond paper.

The initial state of the four bond-paper colors are shown spectrophotometrically in Figure 1, and the rate of spectrophotometric change of each of these four bond-paper colors due to exposure to natural daylight are shown in Figures 2 to 5. The data used to make these five figures

Table II

Bond Papers

Chromaticity Coordinates and Daylight Reflectances of Four Bond-Paper Colors for Seven Conditions of Storage and Exposure.

Paper Color and Exposure	Chromaticity Coordinates x	y	Daylight Reflectance Y(%)
BLUE			
Initial	0.282	0.304	61.4
Two Months, Dark	.281	.302	61.9
Two Months, North	.292	.309	62.4
Two Months, South	.296	.312	64.5
Ten Months, Dark	.283	.304	61.3
Ten Months, North	.306	.319	68.1
Ten Months, South	.313	.322	73.3
PINK			
Initial	.360	.328	63.1
Two Months, Dark	.358	.326	63.2
Two Months, North	.354	.328	64.2
Two Months, South	.347	.328	67.8
Ten Months, Dark	.358	.326	62.8
Ten Months, North	.340	.330	69.6
Ten Months, South	.327	.327	76.6
GREEN			
Initial	.291	.343	63.4
Two Months, Dark	.292	.343	63.6
Two Months, North	.294	.330	64.4
Two Months, South	.293	.322	65.5
Ten Months, Dark	.292	.342	63.2
Ten Months, North	.306	.324	69.9
Ten Months, South	.311	.325	73.1
YELLOW			
Initial	.484	.435	48.7
Two Months, Dark	.483	.434	48.9
Two Months, North	.479	.436	49.8
Two Months, South	.467	.436	50.8
Ten Months, Dark	.483	.434	48.6
Ten Months, North	.460	.431	50.7
Ten Months, South	.401	.396	55.3

Table III

Bond Papers

Munsell Renotations and ISCC-NBS Color Designations of Four Bond-Paper Colors for Seven Conditions of Storage and Exposure.

Paper Color and Exposure	Munsell Renotations	ISCC-NBS Color Designations
BLUE		
Initial	6.6B 8.1/2.8	Very pale blue
Two Months, Dark	7.7B 8.2/3.0	Very pale blue
Two Months, North	6.2B 8.1/2.0	Very pale blue
Two Months, South	4.6B 8.3/1.5	Light bluish gray
Ten Months, Dark	7.0B 8.1/2.8	Very pale blue
Ten Months, North	2.7BG 8.5/0.5	Light greenish gray
Ten Months, South	5.8GY 8.7/0.4	White
PINK		
Initial	6.6R 8.2/4.4	Light yellowish pink
Two Months, Dark	6.5R 8.2/4.4	Light yellowish pink
Two Months, North	7.7R 8.3/3.8	Light yellowish pink
Two Months, South	9.8R 8.5/3.2	Light yellowish pink
Ten Months, Dark	6.3R 8.2/4.4	Light yellowish pink
Ten Months, North	1.8YR 8.6/2.5	Pale yellowish pink
Ten Months, South	4.6YR 8.9/1.3	Pinkish white
GREEN		
Initial	7.2G 8.2/3.4	Very light green
Two Months, Dark	6.5G 8.2/3.4	Very light green
Two Months, North	0.5BG 8.3/2.2	Very pale green
Two Months, South	5.4BG 8.4/1.9	Very pale green
Ten Months, Dark	7.2G 8.2/3.3	Very light green
Ten Months, North	5.9G 8.6/0.8	Greenish white
Ten Months, South	9.6GY 8.7/0.6	Greenish white
YELLOW		
Initial	8.9YR 7.4/11.7	Strong orange yellow
Two Months, Dark	8.8YR 7.4/11.6	Strong orange yellow
Two Months, North	9.4YR 7.4/11.4	Strong orange yellow
Two Months, South	0.1Y 7.5/10.6	Strong orange yellow
Ten Months, Dark	8.8YR 7.4/11.6	Strong orange yellow
Ten Months, North	10.0YR 7.5/10.2	Strong orange yellow
Ten Months, South	1.1Y 7.8/6.1	Moderate yellow

Table IV

Bond Papers

Color Differences between Exposed and Dark Storage Samples of Four Bond-Paper Colors for Seven Conditions of Storage and Exposure.

Paper Color and Determinations Between Exposures			Color Differences ΔE
BLUE			
Initial	and	Initial	0.0
Initial	and	Two Months, Dark	2.5
Two Months, Dark	and	Two Months, North	5.5
Two Months, Dark	and	Two Months, South	8.0
Initial	and	Ten Months, Dark	0.0
Ten Months, Dark	and	Ten Months, North	15.0
Ten Months, Dark	and	Ten Months, South	19.0
PINK			
Initial	and	Initial	0.0
Initial	and	Two Months, Dark	0.0
Two Months, Dark	and	Two Months, North	4.0
Two Months, Dark	and	Two Months, South	9.5
Initial	and	Ten Months, Dark	0.5
Ten Months, Dark	and	Ten Months, North	16.5
Ten Months, Dark	and	Ten Months, South	22.0
GREEN			
Initial	and	Initial	0.0
Initial	and	Two Months, Dark	0.5
Two Months, Dark	and	Two Months, North	7.0
Two Months, Dark	and	Two Months, South	11.0
Initial	and	Ten Months, Dark	0.5
Ten Months, Dark	and	Ten Months, North	15.0
Ten Months, Dark	and	Ten Months, South	18.5
YELLOW			
Initial	and	Initial	0.0
Initial	and	Two Months, Dark	0.5
Two Months, Dark	and	Two Months, North	2.5
Two Months, Dark	and	Two Months, South	7.0
Initial	and	Ten Months, Dark	0.5
Ten Months, Dark	and	Ten Months, North	7.5
Ten Months, Dark	and	Ten Months, South	29.5

VIII. Mimeo-Bond-Paper Colors (Pages 26 to 54)

The following 23 pages contain twenty-three illustrations (Figures 15 to 37) showing a record of the initial state and the amounts of the spectrophotometric and colorimetric changes upon exposure to natural daylight of the seven dyed colored specimens of mimeo-bond papers.

The initial state of the seven mimeo-bond-paper colors are shown spectrophotometrically in Figure 15, and the rate of spectrophotometric change of each of these seven mimeo-bond-paper colors due to exposure to natural daylight are shown in Figures 16 to 22. The data used to make these eight figures was obtained from the original recordings of the Ozalid prints of the spectrophotometric curves of Appendix A, and from the reduced tables of data of Appendix B, of this report.

The chromaticity coordinates listed in Table V, pages 49-50 (together with the daylight reflectances) for these color changes are shown on the segment of the CIE chromaticity diagram in Figure 23. The derived Munsell renotations from these chromaticity coordinates and daylight reflectances are listed in Table VI, pages 51-52, and illustrated in Figures 24 to 30. In turn, color differences derived from these Munsell renotations are listed in Table VII, pages 53-54, and illustrated in Figures 31 to 37. It has been assumed in this study that the permanence of the mimeo-bond-paper samples in "dark storage" did not change appreciably relative to the changes caused by exposure to natural daylight.

Table V

Mimeo-Bond Papers

Chromaticity Coordinates and Daylight Reflectances of Seven Mimeo-Bond Paper Colors for Seven Conditions of Storage and Exposure.

Paper Color and Exposure	Chromaticity Coordinates x	y	Daylight Reflectance Y(%)
BLUE			
Initial	0.283	0.303	63.4
Two Months, Dark	.281	.300	63.2
Two Months, North	.290	.308	65.6
Two Months, South	.296	.313	68.0
Ten Months, Dark	.283	.302	62.6
Ten Months, North	.307	.319	72.9
Ten Months, South	.314	.325	74.8
TUSCAN			
Initial	.384	.367	65.2
Two Months, Dark	.382	.365	65.4
Two Months, North	.376	.364	66.5
Two Months, South	.366	.361	69.5
Ten Months, Dark	.383	.366	65.2
Ten Months, North	.355	.355	72.1
Ten Months, South	.334	.338	76.2
GREEN			
Initial	.292	.345	59.4
Two Months, Dark	.290	.342	59.5
Two Months, North	.293	.328	59.4
Two Months, South	.295	.319	63.9
Ten Months, Dark	.290	.345	59.8
Ten Months, North	.307	.320	65.9
Ten Months, South	.312	.324	71.0
ORANGE			
Initial	.480	.435	51.6
Two Months, Dark	.482	.435	51.6
Two Months, North	.477	.433	51.8
Two Months, South	.474	.436	52.3
Ten Months, Dark	.480	.436	51.9
Ten Months, North	.452	.426	54.4
Ten Months, South	.401	.394	57.5

(continued on page 50.)

Table V (cont'd)

Mimeo-Bond Papers (cont'd)

Paper Color and Exposure	Chromaticity Coordinates x	y	Daylight Reflectance Y(%)
PINK			
Initial	0.360	0.324	64.4
Two Months, Dark	.358	.322	64.7
Two Months, North	.351	.323	66.4
Two Months, South	.344	.321	69.5
Ten Months, Dark	.359	.323	64.4
Ten Months, North	.337	.326	73.1
Ten Months, South	.327	.325	78.1
DULL YELLOW			
Initial	.385	.394	74.0
Two Months, Dark	.383	.392	74.4
Two Months, North	.376	.386	74.1
Two Months, South	.364	.374	75.0
Ten Months, Dark	.384	.393	74.0
Ten Months, North	.357	.366	75.5
Ten Months, South	.336	.343	77.4
BRIGHT YELLOW			
Initial	.389	.423	79.8
Two Months, Dark	.387	.421	80.2
Two Months, North	.379	.407	79.5
Two Months, South	.363	.384	79.7
Ten Months, Dark	.387	.420	79.7
Ten Months, North	.357	.374	78.4
Ten Months, South	.335	.345	79.9

Table VI

Mimeo-Bond Papers

Munsell Renotations and ISCC-NBS Color Designations of Seven Mimeo-Bond Paper Colors for Seven Conditions of Storage and Exposure.

Paper Color and Exposure	Munsell Renotations	ISCC-NBS Color Designations
BLUE		
Initial	7.3B 8.2/2.8	Very pale blue
Two Months, Dark	9.0B 8.2/3.1	Very light greenish blue
Two Months, North	6.4B 8.4/2.1	Very pale blue
Two Months, South	3.4B 8.5/1.4	Light bluish gray
Ten Months, Dark	8.4B 8.2/2.9	Very pale blue
Ten Months, North	0.9BG 8.7/0.4	White
Ten Months, South	5.6GY 8.8/0.5	White
TUSCAN		
Initial	7.3YR 8.3/5.1	Pale orange yellow
Two Months, Dark	7.2YR 8.4/4.9	Pale orange yellow
Two Months, North	7.8YR 8.4/4.4	Pale orange yellow
Two Months, South	8.9YR 8.6/3.8	Pale orange yellow
Ten Months, Dark	6.9YR 8.3/5.1	Light yellowish pink
Ten Months, North	9.3YR 8.7/3.1	Pale orange yellow
Ten Months, South	9.7YR 8.9/1.6	Yellowish white
GREEN		
Initial	6.4G 8.0/3.5	Very light green
Two Months, Dark	7.7G 8.0/3.4	Very light green
Two Months, North	2.0BG 8.0/2.2	Very pale green
Two Months, South	6.9BG 8.3/1.6	Very pale green
Ten Months, Dark	7.1G 8.0/3.7	Very light green
Ten Months, North	8.3G 8.4/0.5	Light gray
Ten Months, South	8.0GY 8.6/0.5	White
ORANGE		
Initial	9.1YR 7.6/11.7	Strong orange yellow
Two Months, Dark	9.0YR 7.6/11.8	Strong orange yellow
Two Months, North	9.0YR 7.6/11.4	Strong orange yellow
Two Months, South	9.6YR 7.6/11.3	Strong orange yellow
Ten Months, Dark	8.5YR 7.6/12.4	Strong orange yellow
Ten Months, North	0.1Y 7.7/9.7	Moderate orange yellow
Ten Months, South	0.6Y 8.0/6.1	Moderate orange yellow

(continued on page 52.)

Table VI (cont'd)

Mimeo-Bond Papers (cont'd)

Paper Color and Exposure	Munsell Renotations		ISCC-NBS Color Designations
PINK			
Initial	5.2R	8.3/4.8	Light pink
Two Months, Dark	4.4R	8.3/4.8	Light pink
Two Months, North	5.2R	8.4/4.0	Light pink
Two Months, South	4.6R	8.6/3.6	Light pink
Ten Months, Dark	4.6R	8.3/4.8	Light pink
Ten Months, North	9.6R	8.7/2.6	Pale yellowish pink
Ten Months, South	2.5YR	9.0/1.5	Pinkish white
DULL YELLOW			
Initial	3.0Y	8.8/5.6	Light yellow
Two Months, Dark	2.9Y	8.8/5.4	Light yellow
Two Months, North	3.1Y	8.8/4.8	Pale yellow
Two Months, South	3.2Y	8.8/3.9	Pale yellow
Ten Months, Dark	2.9Y	8.8/5.4	Light yellowish pink
Ten Months, North	2.9Y	8.8/3.3	Pale yellow
Ten Months, South	1.9Y	9.0/1.8	Yellowish white
BRIGHT YELLOW			
Initial	7.5Y	9.0/6.8	Light greenish yellow
Two Months, Dark	8.0Y	9.1/6.7	Light greenish yellow
Two Months, North	7.5Y	9.0/5.8	Light greenish yellow
Two Months, South	6.5Y	9.0/4.2	Pale yellow
Ten Months, Dark	7.5Y	9.0/6.7	Light greenish yellow
Ten Months, North	5.1Y	9.0/3.6	Pale yellow
Ten Months, South	3.8Y	9.1/1.8	Yellowish white

Table VII

Mimeo-Bond Papers

Color Differences between Exposed and Dark Storage Samples of Seven Mimeo-Bond Paper Colors for Seven Conditions of Storage and Exposure.

Paper Color and Determinations Between Exposures	Color Differences ΔE
BLUE	
Initial and Initial	0.0
Initial and Two Months, Dark	2.5
Two Months, Dark and Two Months, North	6.5
Two Months, Dark and Two Months, South	11.0
Initial and Ten Months, Dark	0.5
Ten Months, Dark and Ten Months, North	17.0
Ten Months, Dark and Ten Months, South	20.0
TUSCAN	
Initial and Initial	0.0
Initial and Two Months, Dark	2.0
Two Months, Dark and Two Months, North	2.5
Two Months, Dark and Two Months, South	7.5
Initial and Ten Months, Dark	0.0
Ten Months, Dark and Ten Months, North	13.0
Ten Months, Dark and Ten Months, South	21.5
GREEN	
Initial and Initial	0.0
Initial and Two Months, Dark	0.0
Two Months, Dark and Two Months, North	7.0
Two Months, Dark and Two Months, South	12.5
Initial and Ten Months, Dark	1.0
Ten Months, Dark and Ten Months, North	18.0
Ten Months, Dark and Ten Months, South	20.5
ORANGE	
Initial and Initial	0.0
Initial and Two Months, Dark	2.0
Two Months, Dark and Two Months, North	2.0
Two Months, Dark and Two Months, South	2.5
Initial and Ten Months, Dark	4.5
Ten Months, Dark and Ten Months, North	13.5
Ten Months, Dark and Ten Months, South	23.0

(continued on page 54.)

Table VII (cont'd)

Mimeo-Bond Papers (cont'd)

Paper Color and Determinations Between Exposures			Color Differences ΔE
PINK			
Initial	and	Initial	0.0
Initial	and	Two Months, Dark	1.0
Two Months, Dark	and	Two Months, North	4.5
Two Months, Dark	and	Two Months, South	8.5
Initial	and	Ten Months, Dark	1.0
Ten Months, Dark	and	Ten Months, North	14.5
Ten Months, Dark	and	Ten Months, South	22.5
DULL YELLOW			
Initial	and	Initial	0.0
Initial	and	Two Months, Dark	1.0
Two Months, Dark	and	Two Months, North	3.0
Two Months, Dark	and	Two Months, South	7.5
Initial	and	Ten Months, Dark	1.0
Ten Months, Dark	and	Ten Months, North	10.5
Ten Months, Dark	and	Ten Months, South	18.5
BRIGHT YELLOW			
Initial	and	Initial	0.0
Initial	and	Two Months, Dark	2.0
Two Months, Dark	and	Two Months, North	5.0
Two Months, Dark	and	Two Months, South	12.5
Initial	and	Ten Months, Dark	0.5
Ten Months, Dark	and	Ten Months, North	16.0
Ten Months, Dark	and	Ten Months, South	25.0

IX. Onion-Skin-Paper Colors (Pages 56 to 81)

The following twenty pages contain twenty illustrations (Figures 38 to 57) showing a record of the initial state and the amounts of the spectrophotometric and colorimetric changes upon exposure to natural daylight of the six dyed onion-skin papers.

The initial state of the six onion-skin-paper colors are shown spectrophotometrically in Figure 38, page 56, and the rate of spectrophotometric change of each of these six onion-skin-paper colors to exposure to natural daylight are shown in Figures 39 to 44. The data used to make these seven figures were obtained from the original recordings of the Ozalid prints of the spectrophotometric curves of Appendix A, and from the reduced tables of data of Appendix B, of this report.

The chromaticity coordinates listed in Table VIII, pages 76-77 (together with the daylight reflectances) for these color changes are shown on the segment of the CIE chromaticity diagram in Figure 45. The derived Munsell renotations from these chromaticity coordinates and daylight reflectances are listed in Table IX, pages 78-79, and illustrated in Figures 46 to 51. In turn, color differences derived from these Munsell renotations are listed in Table X, pages 80-81, and illustrated in Figures 52 to 57. It has been assumed in this study that the permanence of the onion-skin-paper samples in "dark storage" did not change appreciably relative to the changes caused by exposure to natural daylight.

Table VIII

Onion Skin Papers

Chromaticity Coordinates and Daylight Reflectances of Six Onion-Skin-Paper Colors for Seven Conditions of Storage and Exposure.

Paper Color and Exposure	Chromaticity Coordinates x	y	Daylight Reflectance Y(%)
BLUE			
Initial	0.266	0.290	47.2
Two Months, Dark	.264	.287	47.7
Two Months, North	.263	.286	46.4
Two Months, South	.266	.288	47.4
Ten Months, Dark	.265	.287	47.3
Ten Months, North	.269	.291	48.5
Ten Months, South	.279	.298	50.1
GREEN			
Initial	.276	.327	44.1
Two Months, Dark	.273	.322	44.3
Two Months, North	.266	.307	42.5
Two Months, South	.267	.301	43.7
Ten Months, Dark	.273	.322	43.5
Ten Months, North	.264	.294	44.2
Ten Months, South	.275	.303	46.7
ORANGE			
Initial	.448	.377	45.2
Two Months, Dark	.450	.372	45.6
Two Months, North	.392	.356	52.4
Two Months, South	.367	.351	58.5
Ten Months, Dark	.449	.370	45.1
Ten Months, North	.336	.338	64.5
Ten Months, South	.327	.335	68.1
PINK			
Initial	.360	.295	46.6
Two Months, Dark	.358	.292	46.9
Two Months, North	.353	.301	49.4
Two Months, South	.346	.308	54.5
Ten Months, Dark	.356	.292	46.6
Ten Months, North	.339	.316	58.1
Ten Months, South	.328	.324	65.3

(continued on page 77.)

Table VIII (cont'd)

Onion-Skin Papers (cont'd)

Paper Color and Exposure	Chromaticity Coordinates x	y	Daylight Reflectance Y(%)
CANARY YELLOW			
Initial	0.374	0.409	69.3
Two Months, Dark	.371	.406	70.1
Two Months, North	.359	.382	68.7
Two Months, South	.351	.368	68.6
Ten Months, Dark	.372	.406	69.4
Ten Months, North	.336	.349	69.1
Ten Months, South	.323	.333	70.3
YELLOW			
Initial	.427	.423	60.6
Two Months, Dark	.426	.421	60.6
Two Months, North	.407	.414	61.7
Two Months, South	.394	.407	63.0
Ten Months, Dark	.425	.422	60.4
Ten Months, North	.379	.394	63.8
Ten Months, South	.344	.359	67.0

Table IX

Onion-Skin Papers

Munsell Renotations and ISCC-NBS Color Designations of Six Onion-Skin-Paper Colors for Seven Conditions of Storage and Exposure.

Paper Color and Exposure	Munsell Renotations		ISCC-NBS Color Designations
BLUE			
Initial	8.3B	7.3/4.2	Light greenish blue
Two Months, Dark	9.2B	7.3/4.4	Pale blue
Two Months, North	9.5B	7.2/4.5	Pale blue
Two Months, South	9.3B	7.3/4.3	Pale blue
Ten Months, Dark	9.6B	7.3/4.4	Pale blue
Ten Months, North	9.2B	7.4/3.0	Pale blue
Ten Months, South	9.1PB	7.5/3.1	Pale violet
GREEN			
Initial	4.7BG	7.1/3.5	Light bluish green
Two Months, Dark	6.5BG	7.1/3.6	Light bluish green
Two Months, North	1.5B	7.0/3.8	Light greenish blue
Two Months, South	4.2B	7.0/3.7	Light greenish blue
Ten Months, Dark	6.5BG	7.0/3.6	Light bluish green
Ten Months, North	6.5B	7.1/4.0	Light greenish blue
Ten Months, South	4.9B	7.2/3.1	Light greenish blue
ORANGE			
Initial	3.4YR	7.2/8.7	Moderate orange
Two Months, Dark	2.5YR	7.2/9.0	Moderate orange
Two Months, North	3.5YR	7.6/5.4	Moderate yellowish pink
Two Months, South	5.5YR	8.0/3.8	Moderate yellowish pink
Ten Months, Dark	2.3YR	7.1/9.0	Moderate orange
Ten Months, North	9.0YR	8.3/1.7	Yellowish gray
Ten Months, South	3.2Y	8.5/1.2	Yellowish gray
PINK			
Initial	6.3RP	7.2/7.2	Moderate purplish pink
Two Months, Dark	5.5RP	7.3/7.4	Moderate purplish pink
Two Months, North	7.0RP	7.4/6.1	Moderate purplish pink
Two Months, South	8.1RP	7.7/4.9	Pale purplish pink
Ten Months, Dark	5.4RP	7.2/7.3	Moderate purplish pink
Ten Months, North	1.4R	7.9/3.0	Moderate pink
Ten Months, South	1.2Y	8.3/1.7	Yellowish gray

(continued on page 79.)

Table IX (cont'd)

Onion-Skin Papers (cont'd)

Paper Color and Exposure	Munsell Renotations		ISCC-NBS Color Designations
CANARY YELLOW			
Initial	9.1Y	8.6/5.5	Light greenish yellow
Two Months, Dark	9.5Y	8.6/5.3	Light greenish yellow
Two Months, North	7.3Y	8.5/3.9	Pale greenish yellow
Two Months, South	5.7Y	8.5/3.1	Pale yellow
Ten Months, Dark	9.0Y	8.6/5.3	Light greenish yellow
Ten Months, North	5.7Y	8.5/1.9	Yellowish white
Ten Months, South	6.1Y	8.6/0.9	Yellowish white
YELLOW			
Initial	2.0Y	8.1/8.3	Brilliant yellow
Two Months, Dark	1.9Y	8.1/8.2	Brilliant yellow
Two Months, North	3.2Y	8.2/6.9	Light yellow
Two Months, South	3.4Y	8.2/6.1	Light yellow
Ten Months, Dark	2.1Y	8.1/8.2	Brilliant yellow
Ten Months, North	4.2Y	8.3/5.1	Light yellow
Ten Months, South	5.8Y	8.4/2.5	Pale yellow

Table X

Onion-Skin Papers

Color Differences between Exposed and Dark Storage Samples of Six Onion-Skin-Paper Colors for Seven Conditions of Storage and Exposure.

Paper Color and Determination Between Exposures			Color Differences ΔE
BLUE			
Initial	and	Initial	0.0
Initial	and	Two Months, Dark	1.5
Two Months, Dark	and	Two Months, North	2.0
Two Months, Dark	and	Two Months, South	0.5
Initial	and	Ten Months, Dark	2.0
Ten Months, Dark	and	Ten Months, North	7.5
Ten Months, Dark	and	Ten Months, South	13.5
GREEN			
Initial	and	Initial	0.0
Initial	and	Two Months, Dark	2.0
Two Months, Dark	and	Two Months, North	6.0
Two Months, Dark	and	Two Months, South	9.0
Initial	and	Ten Months, Dark	3.0
Ten Months, Dark	and	Ten Months, North	12.0
Ten Months, Dark	and	Ten Months, South	10.0
ORANGE			
Initial	and	Initial	0.0
Initial	and	Two Months, Dark	3.0
Two Months, Dark	and	Two Months, North	20.0
Two Months, Dark	and	Two Months, South	31.0
Initial	and	Ten Months, Dark	4.0
Ten Months, Dark	and	Ten Months, North	44.5
Ten Months, Dark	and	Ten Months, South	49.5
PINK			
Initial	and	Initial	0.0
Initial	and	Two Months, Dark	3.0
Two Months, Dark	and	Two Months, North	7.5
Two Months, Dark	and	Two Months, South	15.5
Initial	and	Ten Months, Dark	2.0
Ten Months, Dark	and	Ten Months, North	27.0
Ten Months, Dark	and	Ten Months, South	44.0

(continued on page 81.)

Table X (cont'd)

Onion-Skin Papers (cont'd)

Paper Color and Determination Between Exposures			Color Differences △E
CANARY YELLOW			
Initial	and	Initial	0.0
Initial	and	Two Months, Dark	1.0
Two Months, Dark	and	Two Months, North	8.0
Two Months, Dark	and	Two Months, South	12.0
Initial	and	Ten Months, Dark	1.0
Ten Months, Dark	and	Ten Months, North	17.5
Ten Months, Dark	and	Ten Months, South	22.0
YELLOW			
Initial	and	Initial	0.0
Initial	and	Two Months, Dark	0.5
Two Months, Dark	and	Two Months, North	7.5
Two Months, Dark	and	Two Months, South	11.0
Initial	and	Ten Months, Dark	0.5
Ten Months, Dark	and	Ten Months, North	16.5
Ten Months, Dark	and	Ten Months, South	29.5

X. Railroad Tag-Board Colors (Pages 83 to 102)

The following seventeen pages contain seventeen illustrations (Figures 58 to 74) showing a record of the initial state and the amounts of the spectrophotometric and colorimetric changes upon exposure to natural daylight of the five dyed railroad (6 ply) tag boards.

The initial state of the five railroad-board colors are shown spectrophotometrically in Figure 58, page 83, and the rate of spectrophotometric change of each of these five railroad board colors to exposure to natural daylight are shown in Figures 59 to 63. The data used to make these six figures were obtained from the original recordings of the Ozalid prints of the spectrophotometric curves of Appendix A, and from the reduced tables of data of Appendix B, of this report.

The chromaticity coordinates listed in Table XI, page 100 (together with the daylight reflectances) for these color changes are shown on the segment of the CIE chromaticity diagram in Figure 64. The derived Munsell renotations from these chromaticity coordinates and daylight reflectances are listed in Table XII, page 101, and illustrated in Figures 65 to 69. In turn, color differences derived from these Munsell renotations are listed in Table XIII, page 102, and illustrated in Figures 70 to 74. It has been assumed in this study that the permanence of the railroad board samples in "dark storage" did not change appreciably relative to the changes caused by exposure to natural daylight.

Table XI

Railroad Boards

Chromaticity Coordinates and Daylight Reflectances of Five Railroad-Board Colors for Seven Conditions of Storage and Exposure.

Paper Color and Exposure	Chromaticity Coordinates x	y	Daylight Reflectance Y(%)
BLUE			
Initial	0.240	0.249	37.7
Two Months, Dark	.238	.248	38.6
Two Months, North	.312	.322	72.1
Two Months, South	.319	.325	80.2
Ten Months, Dark	.241	.250	38.4
Ten Months, North	.322	.327	78.8
Ten Months, South	.320	.326	78.5
GREEN			
Initial	.281	.406	48.5
Two Months, Dark	.281	.404	49.7
Two Months, North	.293	.337	54.5
Two Months, South	.313	.326	71.5
Ten Months, Dark	.282	.400	49.1
Ten Months, North	.323	.329	76.8
Ten Months, South	.323	.328	76.0
BUFF			
Initial	.429	.395	57.2
Two Months, Dark	.428	.393	57.6
Two Months, North	.386	.376	62.5
Two Months, South	.351	.357	69.5
Ten Months, Dark	.428	.393	57.4
Ten Months, North	.329	.336	73.7
Ten Months, South	.322	.329	75.8
YELLOW			
Initial	.441	.468	70.0
Two Months, Dark	.440	.468	71.0
Two Months, North	.430	.449	67.2
Two Months, South	.404	.421	68.0
Ten Months, Dark	.438	.467	70.7
Ten Months, North	.366	.376	69.7
Ten Months, South	.338	.343	72.4
RED			
Initial	.553	.341	22.1
Two Months, Dark	.552	.339	21.8
Two Months, North	.510	.335	23.1
Two Months, South	.458	.334	27.2
Ten Months, Dark	.551	.341	22.5
Ten Months, North	.385	.337	43.5
Ten Months, South	.355	.344	55.7

Table XII

Railroad Boards

Munsell Renotations and ISCC-NBS Color Designations of Five Railroad-Board Colors for Seven Conditions of Storage and Exposure.

Paper Color and Exposure	Munsell Renotations	ISCC-NBS Color Designations
BLUE		
Initial	3.6PB 6.6/7.0	Light blue
Two Months, Dark	3.4PB 6.7/7.7	Light blue
Two Months, North	7.2GY 8.7/0.3	White
Two Months, South	9.2YR 9.1/0.7	White
Ten Months, Dark	3.6PB 6.7/7.5	Light blue
Ten Months, North	9.4YR 9.0/0.8	Yellowish white
Ten Months, South	0.8Y 9.0/0.7	Yellowish white
GREEN		
Initial	3.4G 7.4/8.4	Brilliant green
Two Months, Dark	3.4G 7.4/8.5	Brilliant green
Two Months, North	8.1G 7.7/2.8	Very light green
Two Months, South	7.5GY 8.7/0.6	Greenish white
Ten Months, Dark	3.4G 7.4/7.6	Brilliant green
Ten Months, North	1.0Y 8.9/0.7	White
Ten Months, South	9.6YR 8.9/0.9	Yellowish white
BUFF		
Initial	7.6YR 7.9/7.8	Moderate orange yellow
Two Months, Dark	7.3YR 7.9/7.8	Moderate orange yellow
Two Months, North	9.1YR 8.2/5.1	Pale orange yellow
Two Months, South	1.6Y 8.6/2.8	Pale yellow
Ten Months, Dark	7.0YR 7.9/7.8	Light orange
Ten Months, North	2.0Y 8.8/1.3	Yellowish white
Ten Months, South	3.6Y 8.9/0.8	Yellowish white
YELLOW		
Initial	5.3Y 8.6/11.1	Vivid yellow
Two Months, Dark	5.4Y 8.6/11.1	Vivid yellow
Two Months, North	4.6Y 8.4/9.6	Brilliant yellow
Two Months, South	4.4Y 8.5/7.1	Light yellow
Ten Months, Dark	5.6Y 8.6/11.0	Brilliant yellow
Ten Months, North	3.1Y 8.6/4.0	Pale yellow
Ten Months, South	0.7Y 8.7/1.9	Yellowish white
RED		
Initial	7.7R 5.2/14.0	Vivid reddish orange
Two Months, Dark	7.6R 5.2/14.0	Vivid reddish orange
Two Months, North	6.8R 5.4/12.1	Strong red
Two Months, South	6.6R 5.8/10.6	Deep yellowish pink
Ten Months, Dark	7.7R 5.3/14.1	Vivid reddish orange
Ten Months, North	8.6R 7.0/5.6	Moderate yellowish pink
Ten Months, South	5.5YR 7.8/3.0	Moderate yellowish pink

Table XIII

Railroad Boards

Color Differences between Exposed and Dark Storage Samples of Five Railroad-Board Colors for Seven Conditions of Storage and Exposure.

Paper Color and Determination Between Exposures			Color Differences △E
BLUE			
Initial	and	Initial	0.0
Initial	and	Two Months, Dark	4.0
Two Months, Dark	and	Two Months, North	56.0
Two Months, Dark	and	Two Months, South	64.0
Initial	and	Ten Months, Dark	3.0
Ten Months, Dark	and	Ten Months, North	61.5
Ten Months, Dark	and	Ten Months, South	61.5
GREEN			
Initial	and	Initial	0.0
Initial	and	Two Months, Dark	0.5
Two Months, Dark	and	Two Months, North	35.0
Two Months, Dark	and	Two Months, South	47.5
Initial	and	Ten Months, Dark	4.0
Ten Months, Dark	and	Ten Months, North	47.5
Ten Months, Dark	and	Ten Months, South	48.5
BUFF			
Initial	and	Initial	0.0
Initial	and	Two Months, Dark	0.5
Two Months, Dark	and	Two Months, North	15.0
Two Months, Dark	and	Two Months, South	35.0
Initial	and	Ten Months, Dark	1.5
Ten Months, Dark	and	Ten Months, North	40.0
Ten Months, Dark	and	Ten Months, South	42.0
YELLOW			
Initial	and	Initial	0.0
Initial	and	Two Months, Dark	0.0
Two Months, Dark	and	Two Months, North	9.0
Two Months, Dark	and	Two Months, South	20.0
Initial	and	Ten Months, Dark	1.0
Ten Months, Dark	and	Ten Months, North	35.5
Ten Months, Dark	and	Ten Months, South	46.5
RED			
Initial	and	Initial	0.0
Initial	and	Two Months, Dark	0.0
Two Months, Dark	and	Two Months, North	11.0
Two Months, Dark	and	Two Months, South	21.0
Initial	and	Ten Months, Dark	2.0
Ten Months, Dark	and	Ten Months, North	54.5
Ten Months, Dark	and	Ten Months, South	76.5

XI. Summary.

A series of three measurements of spectral directional reflectance on twenty-two samples of dyed papers and cardboards have been made for the visible spectrum, 400 to 750 millimicrons, on a General Electric recording spectrophotometer for the condition of included specular component of the reflected radiant energy.

These three sets of samples have been kept in three different conditions of storage or exposure to natural daylight for periods of two and of ten months; i.e. one set was kept in dark storage, another set was mounted and exposed to the radiant energy penetrating a north-facing window, the third set was similarly mounted and exposed to the radiant energy penetrating a south-facing window. These latter two sets of specimens were removed for spectrophotometric measurements at periods of approximately two and of approximately ten months of exposure.

Spectral-directional-reflectance data are shown for each of the twenty-two specimens initially and after two and ten months of exposure to natural daylight. The data are presented both in the form of reproductions of the original recording graph sheets (Appendix A) and as tables of reduced spectral-directional-reflectance data (Appendix B).

Also shown are graphical illustrations of the spectrophotometric curves of all of the twenty-two dyed papers and cardboards studied for the initial (unfaded) state as well as after exposure to natural daylight for each of the colors studied separately.

All of the papers and cardboards that had been spectrophotometered were transformed by integration into terms of the CIE chromaticity coordinates and daylight reflectances, and illustrations of these and of the corresponding Munsell renotations, and color-difference computations are included. In addition, all of these data and also initial Munsell visual notations and ISCC-NBS color names are tabulated together with all colorimetric data as well as ISCC-NBS color names derived from the Munsell renotations.

XII. Conclusions.

In this study of the fading of some typical color papers and cardboards, it has been found that all of the samples studied showed some changes in color when the samples were exposed either to north skylight or direct sunlight and skylight. In most cases the amounts of change were consistent, the least change being for the two months' north exposure, the two months' south exposure being next, the ten months' north exposure third, and the ten months' south exposure the greatest.

Spectrophotometrically, as was to be expected, most of the color changes occurred in the absorption band of the dye used to cause the

color of the paper or cardboard. For the samples exhibiting two absorption bands such as the Bond green paper, one of the bands would disappear more rapidly than the other causing a change in one direction on the CIE diagram, such as green towards blue, and then an abrupt change in another direction, such as blue towards the red part of the spectrum. It is likely that such specimens have been colored by a mixture of two dyes, one of which fades more rapidly than the other.

Roughly the samples fell into three classes, good, good for a time then fair, and bad. Those of the good class were: yellow bond, orange mimeo bond, blue onion skin, and green onion skin. Those in the bad class were all of the railroad boards, especially the blue, green and buff, and the orange onion skin. All of the rest of the samples studied fell into the middle class, and could safely be used for short periods of time in direct sunlight and for maximum total use of two months.

The permanence of all of the samples studied that were kept in dark storage was remarkably good, showing relatively no change for the ten-month period of study.

While it was realized in the beginning of these experiments that there would be some changes in the colors of the papers and cardboards upon exposure to natural sources of radiant energy, it was not possible to guess how resistant to fading some of these dyed papers would be, nor how badly some of the dyed cardboards would behave in this respect.

This study suggests that most dyed papers available commercially are sufficiently resistant to fading to serve as reference standards to obtain a register of color on a color photograph. It is recommended that railroad tag board should not be used for this purpose.

XIII. Bibliography.

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Appendix A

Ozalid prints of the 48 original records of spectral-directional-reflectance measurements made on the dyed papers and cardboards for conditions of dark storage, of exposure to natural north skylight, and of exposure to south daylight for two periods. (See Appendix B for tables of spectral reflectances read from these original recorded spectrophotometric curves.)

Index to Appendix A

Color	Exposure	Date Measured	GE Graph Sheet Serial Number	Curve Number
		BOND PAPERS		
Blue	Initial	1- 7-53	GE II-1110	4,11
	Two Months, Dark	3-27-53	-1165	1
	Two Months, North	3-27-53	-1165	2
	Two Months, South	3-27-53	-1165	3
	Ten Months, Dark	11-23-53	-1349	1
	Ten Months, North	11-23-53	-1349	2
	Ten Months, South	11-23-53	-1349	3
Pink	Initial	1- 7-53	-1110	5,10
	Two Months, Dark	3-27-53	-1166	1
	Two Months, North	3-27-53	-1166	2
	Two Months, South	3-27-53	-1166	3
	Ten Months, Dark	11-23-53	-1350	1
	Ten Months, North	11-23-53	-1350	2
	Ten Months, South	11-23-53	-1350	3
Green	Initial	1- 7-53	-1110	6,9
	Two Months, Dark	3-27-53	-1167	1
	Two Months, North	3-27-53	-1167	2
	Two Months, South	3-27-53	-1167	3
	Ten Months, Dark	11-23-53	-1351	1
	Ten Months, North	11-23-53	-1351	2
	Ten Months, South	11-23-53	-1351	3
Yellow	Initial	1- 7-53	-1110	7,8
	Two Months, Dark	3-27-53	-1168	1
	Two Months, North	3-27-53	-1168	2
	Two Months, South	3-27-53	-1168	3
	Ten Months, Dark	11-23-53	-1352	1
	Ten Months, North	11-23-53	-1352	2
	Ten Months, South	11-23-53	-1352	3
		MIMEO BOND PAPERS		
Blue	Initial	1- 8-53	-1113	4,17
	Two Months, Dark	3-27-53	-1169	1
	Two Months, North	3-27-53	-1169	2
	Two Months, South	3-27-53	-1169	3
	Ten Months, Dark	11-23-53	-1353	1
	Ten Months, North	11-23-53	-1353	2
	Ten Months, South	11-23-53	-1353	3
Tuscan	Initial	1- 8-53	-1113	5,16
	Two Months, Dark	3-27-53	-1170	1
	Two Months, North	3-27-53	-1170	2
	Two Months, South	3-27-53	-1170	3
	Ten Months, Dark	11-23-53	-1354	1
	Ten Months, North	11-23-53	-1354	2
	Ten Months, South	11-23-53	-1354	3

(continued on page 108.)

Index to Appendix A (cont'd)

Color	Exposure	Date Measured	GE Graph Sheet Serial Number	Curve Number
	MIMEO BOND PAPERS (cont'd)			
Green	Initial	1- 8-53	GE II-1113	6,15
	Two Months, Dark	3-27-53	-1171	1
	Two Months, North	3-27-53	-1171	2
	Two Months, South	3-27-53	-1171	3
	Ten Months, Dark	11-24-53	-1355	1
	Ten Months, North	11-24-53	-1355	2
	Ten Months, South	11-24-53	-1355	3
Orange	Initial	1- 8-53	-1113	7,14
	Two Months, Dark	3-27-53	-1172	1
	Two Months, North	3-27-53	-1172	2
	Two Months, South	3-27-53	-1172	3
	Ten Months, Dark	11-24-53	-1356	1
	Ten Months, North	11-24-53	-1356	2
	Ten Months, South	11-24-53	-1356	3
Pink	Initial	1- 8-53	-1113	8,13
	Two Months, Dark	3-27-53	-1173	1
	Two Months, North	3-27-53	-1173	2
	Two Months, South	3-27-53	-1173	3
	Ten Months, Dark	11-24-53	-1357	1
	Ten Months, North	11-24-53	-1357	2
	Ten Months, South	11-24-53	-1357	3
Dull Yellow	Initial	1- 8-53	-1113	9,12
	Two Months, Dark	3-27-53	-1174	1
	Two Months, North	3-27-53	-1174	2
	Two Months, South	3-27-53	-1174	3
	Ten Months, Dark	11-24-53	-1358	1
	Ten Months, North	11-24-53	-1358	2
	Ten Months, South	11-24-53	-1358	3
Bright Yellow	Initial	1- 8-53	-1113	10,11
	Two Months, Dark	3-27-53	-1175	1
	Two Months, North	3-27-53	-1175	2
	Two Months, South	3-27-53	-1175	3
	Ten Months, Dark	11-24-53	-1359	1
	Ten Months, North	11-24-53	-1359	2
	Ten Months, South	11-24-53	-1359	3
	ONION SKIN PAPERS			
Blue	Initial	1- 8-53	-1112	4,15
	Two Months, Dark	3-27-53	-1159	1
	Two Months, North	3-27-53	-1159	2
	Two Months, South	3-27-53	-1159	3
	Ten Months, Dark	11-23-53	-1343	1
	Ten Months, North	11-23-53	-1343	2
	Ten Months, South	11-23-53	-1343	3

(continued on page 109)

Index to Appendix A (cont'd)

Color	Exposure	Date Measured	GE Graph Sheet Serial Number	Curve Number
	ONION SKIN PAPERS (cont'd)			
Green	Initial	1- 8-53	GE II-1112	5,14
	Two Months, Dark	3-27-53	-1160	1
	Two Months, North	3-27-53	-1160	2
	Two Months, South	3-27-53	-1160	3
	Ten Months, Dark	11-23-53	-1344	1
	Ten Months, North	11-23-53	-1344	2
	Ten Months, South	11-23-53	-1344	3
Orange	Initial	1- 8-53	-1112	6,13
	Two Months, Dark	3-27-53	-1161	1
	Two Months, North	3-27-53	-1161	2
	Two Months, South	3-27-53	-1161	3
	Ten Months, Dark	11-23-53	-1345	1
	Ten Months, North	11-23-53	-1345	2
	Ten Months, South	11-23-53	-1345	3
Pink	Initial	1- 8-53	-1112	7,12
	Two Months, Dark	3-27-53	-1162	1
	Two Months, North	3-27-53	-1162	2
	Two Months, South	3-27-53	-1162	3
	Ten Months, Dark	11-23-53	-1346	1
	Ten Months, North	11-23-53	-1346	2
	Ten Months, South	11-23-53	-1346	3
Canary Yellow	Initial	1- 8-53	-1112	8,11
	Two Months, Dark	3-27-53	-1163	1
	Two Months, North	3-27-53	-1163	2
	Two Months, South	3-27-53	-1163	3
	Ten Months, Dark	11-23-53	-1347	1
	Ten Months, North	11-23-53	-1347	2
	Ten Months, South	11-23-53	-1347	3
Yellow	Initial	1- 8-53	-1112	9,10
	Two Months, Dark	3-27-53	-1164	1
	Two Months, North	3-27-53	-1164	2
	Two Months, South	3-27-53	-1164	3
	Ten Months, Dark	11-23-53	-1348	1
	Ten Months, North	11-23-53	-1348	2
	Ten Months, South	11-23-53	-1348	3
	RAILROAD BOARDS			
Blue	Initial	1- 8-53	-1111	4,13
	Two Months, Dark	3-27-53	-1154	1
	Two Months, North	3-27-53	-1154	2
	Two Months, South	3-27-53	-1154	3
	Ten Months, Dark	11-23-53	-1338	1
	Ten Months, North	11-23-53	-1338	2
	Ten Months, South	11-23-53	-1338	3

(continued on page 110.)

Index to Appendix A (cont'd)

Color	Exposure	Date Measured	GE Graph Sheet Serial Number	Curve Number
	RAILROAD BOARDS (cont'd)			
Green	Initial	1- 8-53	GE II-1111	5,12
	Two Months, Dark	3-27-53	-1155	1
	Two Months, North	3-27-53	-1155	2
	Two Months, South	3-27-53	-1155	3
	Ten Months, Dark	11-23-53	-1339	1
	Ten Months, North	11-23-53	-1339	2
	Ten Months, South	11-23-53	-1339	3
Buff	Initial	1- 8-53	-1111	6,11
	Two Months, Dark	3-27-53	-1156	1
	Two Months, North	3-27-53	-1156	2
	Two Months, South	3-27-53	-1156	3
	Ten Months, Dark	11-23-53	-1340	1
	Ten Months, North	11-23-53	-1340	2
	Ten Months, South	11-23-53	-1340	3
Yellow	Initial	1- 8-53	-1111	7,10
	Two Months, Dark	3-27-53	-1157	1
	Two Months, North	3-27-53	-1157	2
	Two Months, South	3-27-53	-1157	3
	Ten Months, Dark	11-23-53	-1341	1
	Ten Months, North	11-23-53	-1341	2
	Ten Months, South	11-23-53	-1341	3
Red	Initial	1- 8-53	-1111	8,9
	Two Months, Dark	3-27-53	-1158	1
	Two Months, North	3-27-53	-1158	2
	Two Months, South	3-27-53	-1158	3
	Ten Months, Dark	11-23-53	-1342	1
	Ten Months, North	11-23-53	-1342	2
	Ten Months, South	11-23-53	-1342	3

Appendix B

Spectral-directional-reflectance data for the dyed papers and cardboards for conditions of dark storage, of exposure to natural north skylight, and of exposure to south daylight for two- and ten-month periods.

(See Appendix A for the original copies of the recorded spectrophotometric curves of these determinations.)

Bond Paper
Blue

Spectral Directional Reflectance of Dyed Papers and Cardboards for the Indicated Periods of Time and Exposure. (See Appendix A for copies of the Original Recording Sheets.)

Wave length mμ	Initial	Two Months			Ten Months		
		Dark Storage	North Exposure	South Exposure	Dark Storage	North Exposure	South Exposure
400	0.636	0.660	0.610	0.610	0.626	0.595	0.615
10	.657	.679	.632	.632	.648	.616	.636
20	.672	.695	.650	.650	.667	.634	.655
30	.689	.710	.666	.666	.682	.650	.674
40	.701	.721	.677	.680	.697	.664	.688
450	.711	.731	.687	.691	.709	.676	.700
60	.721	.738	.694	.698	.716	.686	.711
70	.726	.740	.698	.702	.722	.694	.721
80	.727	.740	.699	.705	.722	.700	.728
90	.723	.734	.697	.705	.719	.704	.734
500	.714	.724	.691	.702	.711	.704	.738
10	.704	.711	.684	.696	.700	.704	.740
20	.690	.696	.675	.689	.686	.702	.741
30	.671	.676	.662	.679	.669	.699	.740
40	.649	.654	.650	.669	.646	.694	.739
550	.628	.631	.636	.658	.625	.689	.736
60	.612	.614	.625	.646	.608	.683	.735
70	.595	.598	.610	.634	.592	.676	.732
80	.573	.576	.594	.621	.572	.669	.729
90	.551	.554	.578	.606	.550	.662	.726
600	.536	.540	.567	.596	.536	.658	.725
10	.522	.526	.558	.588	.524	.655	.724
20	.506	.510	.549	.579	.509	.651	.724
30	.486	.489	.538	.570	.490	.650	.724
40	.468	.474	.530	.564	.475	.649	.724
650	.465	.470	.530	.562	.474	.650	.726
60	.468	.474	.534	.564	.477	.654	.730
70	.471	.478	.540	.567	.484	.659	.734
80	.477	.484	.548	.574	.489	.666	.740
90	.484	.490	.550	.580	.494	.674	.744
700	.484	.492	.563	.587	.496	.680	.750
10	.486	.494	.574	.595	.500	.689	.756
20	.490	.498	.588	.607	.506	.700	.764
30	.496	.504	.604	.620	.514	.710	.771
40	.514	.523	.622	.635	.536	.724	.779
750	.555	.561	.650	.664	.584	.744	.792

Bond Paper
Pink

Spectral Directional Reflectance of Dyed Papers and Cardboards for the Indicated Periods of Time and Exposure. (See Appendix A for copies of the Original Recording Sheets.)

Wave length mμ	Initial	Two Months			Ten Months		
		Dark Storage	North Exposure	South Exposure	Dark Storage	North Exposure	South Exposure
400	0.476	0.491	0.486	0.526	0.482	0.536	0.616
10	.480	.494	.492	.534	.486	.546	.634
20	.485	.502	.502	.543	.492	.555	.648
30	.497	.512	.512	.554	.504	.568	.661
40	.508	.524	.524	.566	.514	.579	.675
450	.516	.530	.532	.575	.521	.590	.686
60	.517	.529	.537	.580	.524	.600	.696
70	.514	.524	.535	.581	.520	.606	.704
80	.509	.517	.533	.580	.515	.610	.709
90	.504	.511	.530	.579	.510	.614	.715
500	.498	.504	.527	.576	.504	.616	.719
10	.494	.500	.524	.575	.499	.619	.724
20	.498	.502	.526	.578	.500	.623	.726
30	.504	.506	.532	.584	.505	.628	.732
40	.513	.514	.540	.590	.511	.633	.736
550	.536	.536	.558	.608	.530	.645	.744
60	.586	.586	.600	.644	.576	.672	.759
70	.662	.660	.665	.702	.652	.714	.779
80	.745	.739	.739	.760	.736	.758	.799
90	.805	.800	.790	.802	.796	.790	.814
600	.835	.830	.818	.827	.829	.809	.822
10	.848	.845	.832	.840	.844	.820	.829
20	.853	.852	.840	.845	.850	.826	.834
30	.856	.857	.844	.850	.854	.832	.838
40	.858	.860	.848	.854	.858	.836	.841
650	.861	.863	.851	.856	.860	.840	.845
60	.861	.864	.854	.860	.862	.844	.848
70	.861	.865	.855	.861	.864	.848	.850
80	.862	.866	.856	.863	.864	.850	.854
90	.867	.870	.860	.866	.868	.854	.855
700	.869	.872	.862	.869	.872	.856	.856
10	.870	.875	.865	.871	.874	.859	.859
20	.873	.876	.867	.873	.876	.861	.861
30	.874	.877	.868	.874	.876	.864	.864
40	.875	.878	.870	.875	.878	.865	.865
750	.874	.878	.870	.876	.880	.866	.866

Bond Paper
Green

Spectral Directional Reflectance of Dyed Papers and Cardboards for the Indicated Periods of Time and Exposure. (See Appendix A for copies of the Original Recording Sheets.)

Wave length mμ	Initial	Two Months			Ten Months		
		Dark Storage	North Exposure	South Exposure	Dark Storage	North Exposure	South Exposure
400	0.449	0.463	0.526	0.575	0.458	0.600	0.606
10	.426	.439	.524	.584	.434	.614	.626
20	.418	.432	.525	.594	.430	.629	.644
30	.433	.445	.538	.609	.444	.641	.661
40	.437	.450	.549	.621	.449	.654	.676
450	.501	.517	.592	.644	.520	.671	.690
60	.619	.637	.660	.687	.636	.692	.705
70	.695	.710	.702	.710	.704	.708	.716
80	.724	.735	.717	.721	.726	.716	.724
90	.736	.744	.725	.726	.736	.724	.732
500	.738	.746	.727	.729	.738	.729	.738
10	.736	.742	.726	.728	.736	.731	.742
20	.732	.736	.720	.723	.730	.731	.744
30	.717	.725	.710	.714	.718	.729	.745
40	.705	.706	.695	.701	.700	.724	.744
550	.681	.682	.676	.684	.676	.716	.742
60	.653	.652	.654	.666	.648	.706	.738
70	.620	.620	.630	.643	.616	.696	.732
80	.586	.586	.605	.619	.581	.682	.725
90	.552	.553	.579	.596	.550	.670	.718
600	.519	.520	.555	.574	.517	.660	.711
10	.494	.494	.536	.555	.494	.651	.709
20	.478	.476	.525	.544	.479	.648	.707
30	.466	.466	.519	.539	.469	.646	.708
40	.460	.460	.516	.536	.464	.650	.710
650	.456	.456	.518	.536	.460	.654	.714
60	.446	.446	.514	.534	.448	.654	.716
70	.428	.426	.500	.523	.430	.651	.716
80	.421	.419	.496	.519	.428	.654	.720
90	.444	.441	.519	.536	.455	.669	.728
700	.469	.470	.554	.566	.481	.687	.740
10	.485	.488	.580	.588	.500	.705	.750
20	.510	.510	.612	.614	.524	.722	.764
30	.531	.533	.636	.636	.545	.740	.775
40	.561	.560	.658	.658	.576	.755	.786
750	.603	.596	.689	.689	.621	.774	.798

Bond Paper
Yellow

Spectral Directional Reflectance of Dyed Papers and Cardboards for the Indicated Periods of Time and Exposure. (See Appendix A for copies of the Original Recording Sheets.)

Wave length mμ	Initial	Two Months			Ten Months		
		Dark Storage	North Exposure	South Exposure	Dark Storage	North Exposure	South Exposure
400	0.059	0.060	0.065	0.074	0.062	0.088	0.192
10	.057	.058	.063	.071	.060	.084	.194
20	.057	.059	.061	.071	.060	.084	.198
30	.058	.060	.063	.074	.060	.084	.204
40	.060	.062	.065	.076	.062	.087	.212
450	.064	.066	.069	.080	.066	.092	.224
60	.069	.071	.075	.088	.070	.100	.238
70	.076	.079	.083	.098	.078	.112	.255
80	.089	.092	.098	.115	.090	.129	.278
90	.113	.117	.125	.145	.114	.159	.309
500	.152	.156	.168	.190	.154	.205	.349
10	.211	.216	.231	.254	.214	.268	.392
20	.281	.283	.300	.324	.282	.334	.439
30	.344	.346	.361	.385	.345	.394	.479
40	.392	.394	.410	.435	.392	.440	.514
550	.436	.440	.454	.480	.438	.480	.545
60	.496	.493	.506	.528	.490	.524	.576
70	.561	.564	.574	.588	.559	.578	.608
80	.643	.646	.643	.650	.636	.636	.638
90	.708	.711	.711	.703	.704	.681	.666
600	.750	.755	.755	.736	.750	.720	.686
10	.777	.782	.782	.758	.776	.746	.704
20	.795	.800	.800	.774	.795	.765	.718
30	.808	.814	.812	.784	.809	.780	.730
40	.818	.824	.821	.792	.818	.792	.740
650	.826	.832	.828	.800	.826	.801	.750
60	.831	.836	.834	.806	.832	.809	.759
70	.836	.842	.838	.811	.836	.816	.766
80	.839	.845	.842	.815	.841	.821	.774
90	.844	.847	.847	.819	.844	.826	.780
700	.846	.850	.850	.824	.847	.831	.786
10	.848	.852	.852	.826	.850	.836	.791
20	.851	.853	.853	.830	.851	.839	.796
30	.852	.855	.855	.834	.854	.842	.801
40	.853	.856	.856	.836	.854	.844	.806
750	.852	.857	.857	.839	.855	.846	.810

Mimeo Bond Paper
Blue

Spectral Directional Reflectance of Dyed Papers and Cardboards for the Indicated Periods of Time and Exposure. (See Appendix A for copies of the Original Recording Sheets.)

Wave length mμ	Initial	Two Months			Ten Months		
		Dark Storage	North Exposure	South Exposure	Dark Storage	North Exposure	South Exposure
400	0.649	0.668	0.666	0.642	0.645	0.659	0.616
10	.672	.692	.685	.664	.669	.673	.637
20	.692	.711	.700	.684	.689	.689	.658
30	.710	.728	.713	.700	.706	.702	.676
40	.726	.743	.724	.714	.721	.714	.690
450	.739	.754	.732	.724	.734	.724	.705
60	.749	.761	.736	.730	.743	.733	.716
70	.754	.764	.738	.735	.746	.740	.726
80	.754	.762	.738	.738	.746	.745	.735
90	.750	.756	.735	.737	.742	.749	.742
500	.738	.744	.728	.735	.732	.750	.746
10	.725	.728	.720	.730	.718	.750	.750
20	.710	.710	.711	.723	.701	.749	.752
30	.690	.688	.698	.714	.680	.745	.754
40	.661	.658	.684	.704	.651	.741	.754
550	.634	.632	.670	.694	.626	.736	.754
60	.620	.616	.658	.684	.614	.732	.751
70	.614	.608	.642	.670	.606	.725	.750
80	.599	.592	.626	.655	.590	.718	.748
90	.581	.575	.608	.642	.574	.712	.745
600	.567	.562	.596	.632	.560	.709	.744
10	.552	.547	.585	.624	.547	.706	.742
20	.532	.528	.572	.614	.526	.702	.741
30	.505	.504	.558	.603	.504	.700	.740
40	.482	.485	.546	.596	.486	.698	.740
650	.474	.478	.544	.593	.480	.700	.742
60	.472	.481	.550	.596	.484	.701	.745
70	.471	.481	.554	.599	.485	.706	.750
80	.475	.485	.560	.604	.490	.713	.754
90	.478	.489	.567	.611	.494	.720	.759
700	.473	.488	.574	.618	.490	.726	.764
10	.469	.488	.582	.626	.490	.734	.770
20	.466	.491	.598	.637	.494	.746	.779
30	.467	.496	.612	.650	.500	.754	.784
40	.486	.512	.630	.670	.526	.766	.794
750	.532	.555	.664	.696	.580	.784	.804

Mimeo Bond Paper
Tuscan

Spectral Directional Reflectance of Dyed Papers and Cardboards for the Indicated Periods of Time and Exposure. (See Appendix A for copies of the Original Recording Sheets.)

Wave length mμ	Initial	Two Months			Ten Months		
		Dark Storage	North Exposure	South Exposure	Dark Storage	North Exposure	South Exposure
400	0.327	0.339	0.360	0.394	0.339	0.450	0.556
10	.318	.330	.350	.389	.328	.446	.566
20	.318	.330	.346	.390	.326	.446	.578
30	.326	.336	.353	.396	.330	.451	.589
40	.338	.349	.364	.409	.342	.464	.603
450	.356	.366	.382	.428	.359	.480	.616
60	.376	.386	.401	.449	.379	.500	.630
70	.400	.407	.424	.470	.400	.522	.644
80	.432	.436	.454	.500	.430	.549	.659
90	.468	.470	.489	.534	.468	.582	.676
500	.499	.504	.523	.568	.500	.614	.694
10	.523	.527	.550	.594	.526	.640	.710
20	.540	.544	.567	.613	.544	.656	.724
30	.552	.557	.580	.626	.554	.669	.732
40	.561	.565	.588	.635	.563	.678	.740
550	.578	.580	.602	.646	.578	.689	.750
60	.616	.616	.633	.673	.615	.710	.761
70	.676	.674	.684	.716	.675	.741	.778
80	.756	.750	.750	.769	.750	.780	.796
90	.816	.814	.807	.814	.812	.812	.812
600	.854	.856	.844	.844	.850	.834	.824
10	.871	.874	.860	.858	.866	.848	.830
20	.880	.882	.870	.866	.876	.856	.836
30	.882	.886	.875	.872	.881	.861	.842
40	.885	.890	.879	.876	.885	.866	.846
650	.888	.892	.883	.880	.888	.870	.850
60	.891	.894	.884	.883	.890	.874	.854
70	.893	.894	.885	.885	.891	.878	.856
80	.894	.895	.887	.887	.892	.880	.860
90	.897	.898	.890	.890	.896	.884	.864
700	.898	.902	.893	.893	.900	.887	.866
10	.901	.904	.896	.896	.904	.890	.869
20	.900	.905	.899	.899	.905	.894	.871
30	.900	.907	.900	.900	.908	.895	.874
40	.903	.909	.902	.902	.908	.896	.875
750	.902	.910	.903	.903	.910	.899	.876

Mimeo Bond Paper
Green

Spectral Directional Reflectance of Dyed Papers and Cardboards for the Indicated Periods of Time and Exposure. (See Appendix A for copies of the Original Recording Sheets.)

Wave length mμ	Initial	Two Months			Ten Months		
		Dark Storage	North Exposure	South Exposure	Dark Storage	North Exposure	South Exposure
400	0.426	0.440	0.493	0.580	0.432	0.574	0.596
10	.407	.419	.494	.591	.414	.590	.615
20	.403	.416	.500	.602	.412	.605	.630
30	.416	.430	.512	.615	.425	.617	.646
40	.424	.436	.521	.626	.432	.629	.660
450	.479	.499	.562	.645	.492	.645	.674
60	.582	.596	.605	.669	.588	.662	.686
70	.646	.660	.645	.684	.645	.676	.696
80	.676	.686	.661	.694	.670	.686	.704
90	.689	.696	.670	.699	.684	.694	.711
500	.694	.700	.673	.700	.689	.698	.716
10	.694	.700	.672	.700	.689	.700	.720
20	.689	.692	.666	.695	.684	.700	.721
30	.677	.680	.655	.686	.671	.696	.721
40	.660	.661	.641	.675	.654	.691	.720
550	.640	.638	.625	.661	.632	.684	.717
60	.610	.612	.604	.645	.608	.675	.715
70	.583	.580	.580	.628	.578	.665	.710
80	.549	.547	.556	.610	.544	.652	.706
90	.516	.514	.532	.590	.514	.641	.700
600	.483	.481	.509	.574	.482	.631	.696
10	.458	.457	.491	.560	.459	.625	.694
20	.442	.442	.480	.550	.444	.621	.694
30	.428	.431	.474	.544	.434	.620	.694
40	.419	.423	.470	.541	.426	.620	.695
650	.414	.418	.471	.541	.422	.624	.699
60	.404	.408	.467	.539	.411	.624	.700
70	.390	.392	.458	.532	.396	.624	.702
80	.387	.388	.457	.532	.396	.626	.705
90	.405	.406	.476	.546	.416	.637	.712
700	.421	.430	.502	.564	.436	.651	.720
10	.429	.440	.521	.579	.446	.666	.730
20	.445	.455	.546	.599	.461	.681	.742
30	.457	.467	.568	.616	.475	.696	.751
40	.482	.486	.589	.634	.500	.710	.760
750	.523	.522	.619	.659	.546	.729	.772

Mimeo Bond Paper
Orange

Spectral Directional Reflectance of Dyed Papers and Cardboards for the Indicated Periods of Time and Exposure. (See Appendix A for copies of the Original Recording Sheets.)

Wave length mμ	Initial	Two Months			Ten Months		
		Dark Storage	North Exposure	South Exposure	Dark Storage	North Exposure	South Exposure
400	0.066	0.065	0.070	0.070	0.068	0.106	0.201
10	.062	.062	.068	.068	.064	.103	.204
20	.061	.062	.067	.067	.064	.102	.209
30	.062	.064	.069	.069	.064	.104	.215
40	.066	.065	.071	.071	.066	.108	.224
450	.070	.070	.076	.076	.070	.114	.236
60	.077	.076	.084	.084	.076	.124	.256
70	.086	.085	.093	.093	.084	.136	.269
80	.102	.100	.109	.109	.100	.156	.292
90	.131	.127	.138	.138	.128	.196	.324
500	.177	.172	.183	.183	.175	.242	.364
10	.243	.236	.250	.250	.244	.305	.410
20	.313	.309	.316	.332	.315	.374	.455
30	.375	.373	.382	.390	.379	.432	.498
40	.422	.420	.430	.440	.425	.476	.532
550	.465	.463	.473	.484	.466	.515	.564
60	.516	.516	.522	.534	.520	.558	.594
70	.587	.588	.589	.589	.594	.611	.626
80	.666	.670	.670	.670	.673	.671	.661
90	.738	.745	.736	.736	.744	.721	.692
600	.789	.794	.784	.779	.791	.760	.716
10	.820	.825	.816	.809	.820	.788	.737
20	.840	.845	.836	.828	.840	.810	.754
30	.851	.856	.850	.842	.852	.826	.770
40	.859	.865	.858	.851	.860	.837	.781
650	.866	.871	.865	.860	.868	.849	.794
60	.871	.875	.871	.866	.872	.855	.802
70	.874	.878	.875	.870	.875	.862	.812
80	.877	.880	.879	.875	.879	.867	.821
90	.881	.885	.883	.879	.883	.872	.829
700	.884	.889	.885	.882	.886	.876	.836
10	.890	.892	.889	.886	.890	.880	.844
20	.890	.894	.892	.889	.894	.884	.849
30	.891	.896	.893	.891	.895	.888	.854
40	.894	.898	.896	.894	.898	.890	.859
750	.893	.900	.897	.895	.900	.894	.862

Mimeo Bond Paper
Pink

Spectral Directional Reflectance of Dyed Papers and Cardboards for the Indicated Periods of Time and Exposure. (See Appendix A for copies of the Original Recording Sheets.)

Wave length mμ	Initial	Two Months			Ten Months		
		Dark Storage	North Exposure	South Exposure	Dark Storage	North Exposure	South Exposure
400	0.509	0.523	0.530	0.577	0.516	0.589	0.636
10	.511	.528	.537	.585	.518	.600	.654
20	.517	.534	.547	.595	.525	.610	.670
30	.528	.546	.559	.607	.534	.622	.684
40	.537	.555	.570	.616	.544	.632	.696
450	.541	.555	.575	.622	.549	.641	.707
60	.538	.554	.575	.621	.545	.649	.716
70	.529	.544	.569	.615	.536	.650	.722
80	.521	.533	.562	.607	.529	.654	.726
90	.512	.522	.555	.600	.520	.654	.729
500	.503	.512	.547	.591	.510	.654	.731
10	.498	.506	.542	.587	.504	.654	.733
20	.501	.506	.544	.589	.506	.656	.736
30	.507	.512	.550	.592	.511	.661	.741
40	.516	.519	.556	.600	.516	.666	.746
550	.541	.542	.575	.617	.538	.679	.754
60	.592	.593	.617	.655	.590	.706	.770
70	.676	.669	.684	.715	.670	.745	.792
80	.756	.759	.759	.778	.761	.789	.816
90	.830	.830	.816	.830	.825	.825	.836
600	.866	.866	.850	.858	.862	.844	.846
10	.880	.883	.865	.873	.876	.854	.854
20	.887	.890	.872	.880	.884	.862	.860
30	.888	.894	.877	.884	.888	.868	.864
40	.888	.895	.880	.887	.890	.872	.868
650	.889	.896	.882	.891	.892	.876	.872
60	.891	.898	.885	.894	.894	.880	.874
70	.893	.900	.887	.896	.896	.883	.876
80	.893	.900	.890	.898	.898	.886	.880
90	.897	.903	.891	.900	.900	.889	.883
700	.898	.904	.894	.902	.901	.891	.886
10	.901	.904	.896	.904	.904	.894	.886
20	.899	.905	.898	.905	.904	.896	.890
30	.900	.906	.900	.906	.906	.899	.891
40	.902	.908	.900	.908	.908	.900	.893
750	.902	.909	.901	.909	.911	.902	.894

Mimeo Bond Paper
Dull Yellow

Spectral Directional Reflectance of Dyed Papers and Cardboards for the Indicated Periods of Time and Exposure. (See Appendix A for copies of the Original Recording Sheets.)

Wave length mμ	Initial	Two Months			Ten Months		
		Dark Storage	North Exposure	South Exposure	Dark Storage	North Exposure	South Exposure
400	0.300	0.310	0.332	0.380	0.312	0.429	0.538
10	.288	.298	.325	.378	.298	.426	.550
20	.285	.296	.325	.381	.294	.429	.564
30	.291	.302	.331	.390	.298	.436	.575
40	.303	.314	.344	.404	.308	.448	.589
450	.322	.333	.362	.422	.326	.464	.602
60	.345	.356	.385	.445	.350	.484	.618
70	.376	.384	.413	.471	.372	.509	.633
80	.419	.425	.450	.505	.419	.540	.650
90	.476	.480	.504	.550	.476	.580	.672
500	.539	.544	.562	.600	.540	.624	.691
10	.599	.608	.616	.646	.603	.665	.716
20	.646	.652	.659	.682	.650	.695	.733
30	.680	.686	.689	.708	.684	.718	.749
40	.704	.710	.710	.726	.704	.734	.760
550	.730	.733	.733	.745	.728	.750	.772
60	.765	.768	.764	.769	.764	.771	.784
70	.807	.810	.797	.797	.805	.795	.796
80	.842	.846	.830	.820	.840	.816	.810
90	.863	.864	.850	.837	.860	.830	.819
600	.872	.875	.860	.847	.870	.840	.826
10	.880	.882	.866	.854	.876	.849	.832
20	.888	.886	.872	.860	.882	.855	.838
30	.888	.890	.876	.866	.886	.861	.844
40	.888	.893	.880	.870	.890	.866	.848
650	.890	.896	.884	.874	.894	.871	.852
60	.892	.900	.886	.879	.896	.874	.858
70	.893	.901	.890	.882	.899	.878	.861
80	.896	.903	.892	.885	.900	.882	.866
90	.898	.905	.895	.888	.903	.884	.869
700	.898	.906	.897	.891	.905	.887	.871
10	.904	.907	.898	.894	.906	.890	.874
20	.903	.908	.900	.896	.908	.893	.876
30	.902	.909	.902	.898	.909	.895	.879
40	.904	.910	.902	.900	.910	.896	.880
750	.903	.911	.904	.900	.910	.899	.882

Mimeo Bond Paper
Bright Yellow

Spectral Directional Reflectance of Dyed Papers and Cardboards for the Indicated Periods of Time and Exposure. (See Appendix A for copies of the Original Recording Sheets.)

Wave length mμ	Initial	Two Months			Ten Months		
		Dark Storage	North Exposure	South Exposure	Dark Storage	North Exposure	South Exposure
400	0.206	0.210	0.280	0.372	0.215	0.414	0.560
10	.186	.190	.262	.362	.194	.407	.570
20	.181	.187	.260	.362	.189	.408	.578
30	.190	.196	.266	.370	.198	.414	.589
40	.196	.202	.274	.382	.204	.425	.600
450	.234	.245	.316	.410	.250	.450	.617
60	.311	.325	.376	.450	.326	.481	.634
70	.384	.396	.429	.484	.394	.513	.650
80	.447	.457	.478	.525	.454	.546	.670
90	.515	.525	.540	.580	.521	.591	.694
500	.588	.598	.609	.637	.598	.641	.718
10	.662	.674	.678	.698	.672	.692	.742
20	.728	.736	.736	.744	.732	.732	.762
30	.779	.785	.788	.788	.779	.764	.780
40	.816	.820	.806	.804	.811	.784	.794
550	.840	.842	.826	.821	.834	.802	.804
60	.856	.856	.841	.834	.850	.815	.815
70	.865	.866	.852	.845	.860	.826	.824
80	.874	.875	.861	.854	.870	.837	.830
90	.880	.881	.868	.860	.875	.845	.836
600	.881	.884	.872	.865	.879	.850	.844
10	.884	.886	.876	.869	.882	.858	.849
20	.888	.890	.880	.872	.885	.864	.852
30	.888	.892	.883	.876	.888	.868	.857
40	.889	.894	.885	.879	.890	.872	.861
650	.890	.896	.888	.882	.892	.876	.865
60	.892	.898	.890	.884	.894	.880	.870
70	.893	.898	.891	.886	.896	.882	.872
80	.896	.899	.892	.889	.896	.885	.875
90	.898	.900	.895	.891	.899	.888	.879
700	.898	.904	.897	.894	.900	.890	.880
10	.901	.904	.899	.896	.902	.894	.884
20	.899	.905	.900	.897	.904	.895	.886
30	.900	.906	.900	.899	.906	.897	.888
40	.902	.907	.901	.900	.906	.899	.889
750	.901	.908	.903	.901	.909	.900	.891

Onion Skin Paper
Blue

Spectral Directional Reflectance of Dyed Papers and Cardboards for the Indicated Periods of Time and Exposure. (See Appendix A for copies of the Original Recording Sheets.)

Wave length mμ	Initial	Two Months			Ten Months		
		Dark Storage	North Exposure	South Exposure	Dark Storage	North Exposure	South Exposure
400	0.530	0.556	0.548	0.558	0.548	0.555	0.532
10	.553	.580	.571	.576	.571	.577	.554
20	.572	.599	.590	.594	.591	.595	.571
30	.590	.616	.608	.610	.610	.612	.586
40	.605	.630	.621	.625	.624	.624	.600
450	.618	.642	.630	.633	.636	.631	.610
60	.628	.649	.635	.637	.642	.635	.614
70	.632	.650	.634	.636	.643	.634	.616
80	.630	.644	.630	.630	.638	.629	.614
90	.620	.633	.617	.617	.626	.619	.606
500	.605	.615	.599	.599	.609	.602	.595
10	.580	.589	.575	.575	.582	.582	.582
20	.557	.563	.550	.554	.558	.564	.568
30	.530	.535	.524	.530	.531	.541	.552
40	.507	.510	.500	.508	.506	.520	.536
550	.483	.486	.476	.486	.482	.500	.520
60	.461	.465	.454	.465	.461	.479	.503
70	.441	.444	.432	.444	.440	.458	.486
80	.419	.423	.410	.423	.419	.438	.470
90	.400	.402	.390	.402	.400	.416	.450
600	.380	.384	.369	.384	.380	.398	.434
10	.364	.367	.352	.367	.364	.380	.420
20	.349	.352	.336	.352	.350	.366	.406
30	.337	.341	.325	.341	.339	.354	.395
40	.329	.332	.315	.332	.330	.344	.386
650	.324	.326	.309	.326	.325	.336	.379
60	.319	.322	.304	.322	.322	.332	.374
70	.317	.320	.301	.320	.320	.329	.370
80	.316	.319	.300	.319	.320	.326	.369
90	.316	.320	.302	.320	.321	.326	.368
700	.318	.322	.304	.322	.324	.328	.369
10	.320	.325	.307	.325	.328	.330	.371
20	.324	.330	.312	.330	.332	.334	.374
30	.329	.335	.317	.335	.339	.339	.379
40	.334	.340	.323	.340	.345	.345	.384
750	.338	.346	.329	.346	.351	.351	.389

Onion Skin Paper
Green

Spectral Directional Reflectance of Dyed Papers and Cardboards for the Indicated Periods of Time and Exposure. (See Appendix A for copies of the Original Recording Sheets.)

Wave length mμ	Initial	Two Months			Ten Months		
		Dark Storage	North Exposure	South Exposure	Dark Storage	North Exposure	South Exposure
400	0.397	0.416	0.444	0.470	0.410	0.495	0.471
10	.394	.412	.450	.484	.408	.511	.492
20	.390	.409	.456	.495	.405	.529	.510
30	.395	.414	.465	.506	.410	.544	.528
40	.409	.426	.477	.520	.422	.556	.542
450	.423	.441	.489	.529	.436	.566	.555
60	.456	.475	.510	.542	.470	.574	.564
70	.506	.525	.538	.558	.518	.580	.569
80	.545	.560	.554	.564	.550	.580	.570
90	.562	.574	.556	.562	.564	.574	.568
500	.565	.574	.551	.554	.562	.565	.562
10	.556	.562	.539	.542	.550	.550	.551
20	.539	.545	.522	.525	.534	.534	.540
30	.519	.522	.500	.506	.511	.512	.524
40	.496	.497	.476	.484	.489	.489	.508
550	.469	.469	.450	.460	.462	.462	.488
60	.442	.442	.422	.435	.434	.438	.468
70	.409	.414	.394	.409	.406	.412	.448
80	.388	.386	.369	.385	.380	.388	.425
90	.363	.362	.344	.362	.356	.364	.404
600	.342	.341	.322	.341	.335	.341	.385
10	.323	.323	.303	.323	.317	.324	.368
20	.307	.306	.286	.306	.300	.308	.353
30	.292	.294	.274	.294	.289	.294	.340
40	.282	.284	.264	.284	.279	.284	.330
650	.274	.276	.256	.276	.271	.276	.324
60	.267	.270	.250	.271	.266	.270	.316
70	.263	.266	.246	.267	.263	.266	.314
80	.261	.264	.244	.266	.261	.264	.310
90	.260	.263	.244	.266	.262	.264	.310
700	.260	.264	.246	.268	.265	.266	.311
10	.262	.266	.250	.270	.264	.269	.313
20	.264	.268	.252	.274	.270	.274	.316
30	.269	.272	.257	.277	.275	.278	.320
40	.273	.276	.262	.282	.281	.284	.325
750	.276	.280	.266	.288	.287	.290	.330

Onion Skin Paper
Orange

Spectral Directional Reflectance of Dyed Papers and Cardboards for the Indicated Periods of Time and Exposure. (See Appendix A for copies of the Original Recording Sheets.)

Wave length mμ	Initial	Two Months			Ten Months		
		Dark Storage	North Exposure	South Exposure	Dark Storage	North Exposure	South Exposure
400	0.214	0.222	0.314	0.360	0.225	0.452	0.486
10	.204	.212	.314	.375	.216	.470	.509
20	.196	.205	.315	.382	.208	.486	.528
30	.192	.200	.316	.388	.202	.500	.545
40	.188	.196	.319	.395	.200	.514	.563
450	.181	.189	.316	.398	.191	.524	.576
60	.172	.179	.312	.400	.180	.535	.590
70	.163	.170	.308	.402	.171	.545	.604
80	.156	.161	.303	.404	.164	.554	.616
90	.154	.159	.302	.406	.160	.561	.626
500	.157	.163	.306	.414	.162	.570	.636
10	.164	.169	.314	.423	.168	.579	.646
20	.175	.179	.327	.439	.178	.588	.654
30	.202	.205	.359	.468	.202	.604	.664
40	.257	.262	.416	.518	.255	.624	.673
550	.357	.363	.494	.576	.354	.644	.680
60	.483	.493	.569	.626	.480	.661	.688
70	.601	.611	.625	.659	.600	.672	.694
80	.678	.686	.662	.682	.679	.681	.700
90	.736	.724	.686	.697	.720	.690	.705
600	.749	.742	.702	.710	.738	.696	.711
10	.750	.752	.714	.719	.747	.702	.715
20	.753	.756	.721	.725	.752	.708	.719
30	.754	.760	.727	.732	.756	.712	.724
40	.756	.764	.732	.737	.754	.716	.726
650	.759	.765	.737	.742	.760	.720	.729
60	.759	.767	.740	.746	.762	.724	.732
70	.759	.769	.745	.750	.764	.728	.735
80	.759	.770	.747	.754	.766	.731	.738
90	.761	.771	.750	.756	.767	.734	.740
700	.762	.772	.752	.759	.768	.736	.742
10	.763	.774	.755	.760	.770	.740	.744
20	.763	.774	.756	.762	.770	.742	.746
30	.765	.775	.757	.764	.771	.744	.748
40	.764	.775	.759	.765	.772	.746	.750
750	.763	.776	.760	.767	.772	.748	.750

Onion Skin Paper
Pink

Spectral Directional Reflectance of Dyed Papers and Cardboards for the Indicated Periods of Time and Exposure. (See Appendix A for copies of the Original Recording Sheets.)

Wave length mμ	Initial	Two Months			Ten Months		
		Dark Storage	North Exposure	South Exposure	Dark Storage	North Exposure	South Exposure
400	0.458	0.478	0.462	0.483	0.470	0.483	0.509
10	.474	.493	.480	.505	.486	.504	.534
20	.488	.508	.496	.521	.501	.521	.554
30	.505	.524	.514	.540	.519	.540	.571
40	.511	.530	.520	.550	.527	.550	.589
450	.492	.509	.509	.542	.510	.554	.600
60	.461	.474	.482	.524	.478	.548	.604
70	.426	.438	.454	.500	.441	.536	.605
80	.393	.402	.427	.479	.408	.524	.605
90	.365	.374	.402	.458	.378	.511	.604
500	.344	.350	.383	.441	.354	.500	.600
10	.330	.336	.371	.431	.339	.494	.600
20	.325	.330	.367	.430	.332	.494	.604
30	.328	.331	.370	.434	.332	.498	.609
40	.335	.338	.376	.440	.336	.502	.614
550	.354	.355	.394	.459	.351	.516	.625
60	.392	.392	.434	.500	.386	.550	.644
70	.453	.450	.494	.559	.445	.600	.670
80	.538	.540	.571	.627	.531	.650	.694
90	.636	.636	.642	.682	.631	.686	.708
600	.702	.707	.695	.716	.701	.706	.715
10	.735	.740	.720	.733	.736	.718	.720
20	.750	.756	.734	.742	.750	.724	.724
30	.755	.764	.742	.746	.760	.729	.728
40	.759	.767	.746	.750	.764	.732	.730
650	.761	.770	.748	.754	.766	.736	.732
60	.762	.771	.751	.756	.767	.738	.734
70	.763	.774	.752	.758	.769	.740	.736
80	.763	.774	.754	.759	.770	.742	.738
90	.764	.776	.755	.760	.770	.744	.740
700	.764	.778	.756	.762	.770	.746	.740
10	.766	.779	.756	.762	.770	.748	.742
20	.766	.780	.758	.764	.771	.750	.744
30	.767	.780	.759	.764	.772	.750	.745
40	.767	.781	.760	.765	.772	.751	.745
750	.765	.781	.760	.766	.773	.752	.746

Onion Skin Paper
Canary Yellow

Spectral Directional Reflectance of Dyed Papers and Cardboards for the Indicated Periods of Time and Exposure. (See Appendix A for copies of the Original Recording Sheets.)

Wave length mμ	Initial	Two Months			Ten Months		
		Dark Storage	North Exposure	South Exposure	Dark Storage	North Exposure	South Exposure
400	0.248	0.256	0.339	0.386	0.258	0.470	0.546
10	.235	.242	.330	.383	.244	.475	.560
20	.225	.234	.324	.381	.235	.480	.572
30	.227	.238	.327	.388	.236	.486	.584
40	.240	.251	.334	.400	.250	.498	.596
450	.255	.268	.352	.414	.265	.509	.608
60	.292	.312	.388	.442	.308	.531	.621
70	.363	.387	.442	.483	.379	.559	.636
80	.442	.464	.491	.518	.455	.584	.650
90	.511	.530	.532	.550	.519	.605	.661
500	.567	.583	.575	.583	.574	.626	.672
10	.617	.631	.612	.612	.620	.646	.681
20	.652	.666	.644	.642	.655	.664	.689
30	.685	.696	.672	.666	.686	.679	.696
40	.710	.717	.694	.686	.709	.691	.702
550	.725	.732	.709	.702	.725	.700	.707
60	.734	.740	.719	.714	.733	.707	.710
70	.738	.744	.725	.720	.737	.712	.712
80	.741	.746	.730	.726	.740	.716	.716
90	.744	.749	.734	.731	.744	.720	.720
600	.744	.750	.736	.734	.744	.724	.722
10	.743	.750	.738	.738	.745	.726	.724
20	.744	.751	.740	.740	.746	.728	.725
30	.744	.752	.742	.742	.748	.731	.726
40	.746	.755	.744	.744	.750	.734	.730
650	.750	.758	.748	.748	.754	.738	.732
60	.752	.760	.750	.750	.756	.740	.734
70	.754	.762	.753	.753	.758	.744	.736
80	.754	.764	.754	.754	.760	.744	.736
90	.755	.764	.755	.755	.760	.746	.738
700	.757	.765	.756	.756	.761	.746	.738
10	.758	.766	.756	.756	.762	.749	.740
20	.757	.766	.757	.757	.762	.750	.740
30	.758	.766	.757	.757	.763	.750	.740
40	.757	.766	.758	.758	.764	.750	.741
750	.756	.766	.758	.758	.764	.750	.742

Onion Skin Paper
Yellow

Spectral Directional Reflectance of Dyed Papers and Cardboards for the Indicated Periods of Time and Exposure. (See Appendix A for copies of the Original Recording Sheets.)

Wave length mμ	Initial	Two Months			Ten Months		
		Dark Storage	North Exposure	South Exposure	Dark Storage	North Exposure	South Exposure
400	0.153	0.159	0.188	0.210	0.162	0.266	0.392
10	.146	.152	.182	.206	.154	.262	.406
20	.144	.150	.181	.208	.150	.261	.416
30	.148	.153	.185	.213	.152	.265	.428
40	.153	.159	.192	.223	.158	.274	.440
450	.163	.169	.204	.236	.166	.288	.456
60	.177	.181	.221	.254	.179	.307	.474
70	.194	.198	.242	.279	.196	.330	.492
80	.220	.222	.272	.311	.220	.364	.514
90	.256	.256	.316	.356	.256	.407	.542
500	.300	.300	.369	.414	.300	.462	.572
10	.349	.350	.426	.474	.350	.516	.604
20	.399	.400	.479	.525	.400	.562	.630
30	.469	.465	.532	.574	.469	.600	.650
40	.555	.550	.589	.616	.550	.632	.666
550	.641	.639	.644	.654	.639	.659	.679
60	.699	.700	.682	.682	.694	.678	.690
70	.733	.733	.708	.702	.729	.694	.700
80	.752	.754	.725	.716	.750	.706	.706
90	.764	.765	.737	.727	.761	.714	.714
600	.770	.772	.746	.736	.768	.724	.720
10	.774	.777	.752	.743	.773	.729	.726
20	.777	.781	.756	.749	.776	.734	.731
30	.778	.784	.761	.754	.779	.740	.736
40	.780	.786	.765	.759	.781	.744	.740
650	.784	.789	.768	.764	.784	.749	.744
60	.784	.790	.771	.766	.786	.751	.747
70	.785	.792	.774	.770	.788	.756	.750
80	.786	.794	.775	.772	.789	.758	.754
90	.788	.794	.776	.774	.790	.761	.757
700	.788	.795	.777	.777	.790	.764	.760
10	.789	.795	.779	.779	.791	.766	.762
20	.788	.796	.780	.780	.792	.768	.764
30	.790	.796	.781	.781	.792	.770	.766
40	.789	.796	.782	.782	.793	.770	.767
750	.787	.796	.783	.783	.793	.773	.769

Railroad Board
Blue

Spectral Directional Reflectance of Dyed Papers and Cardboards for the Indicated Periods of Time and Exposure. (See Appendix A for copies of the Original Recording Sheets.)

Wave length mμ	Initial	Two Months			Ten Months		
		Dark Storage	North Exposure	South Exposure	Dark Storage	North Exposure	South Exposure
400	0.564	0.590	0.632	0.674	0.576	0.641	0.652
10	.600	.626	.648	.691	.610	.660	.670
20	.627	.650	.662	.708	.634	.676	.684
30	.641	.667	.674	.722	.650	.691	.697
40	.656	.680	.683	.734	.664	.704	.709
450	.666	.691	.691	.744	.674	.715	.719
60	.674	.696	.699	.753	.681	.725	.728
70	.678	.695	.704	.760	.681	.734	.734
80	.666	.684	.710	.766	.672	.742	.742
90	.645	.661	.716	.773	.650	.749	.749
500	.611	.628	.720	.778	.620	.755	.755
10	.566	.578	.724	.782	.571	.761	.761
20	.509	.523	.726	.786	.516	.766	.766
30	.450	.460	.729	.790	.455	.773	.771
40	.392	.403	.729	.794	.399	.778	.775
550	.343	.354	.728	.800	.350	.784	.780
60	.306	.313	.725	.804	.316	.790	.786
70	.286	.295	.722	.808	.294	.796	.791
80	.273	.280	.716	.812	.281	.802	.797
90	.266	.272	.710	.816	.274	.808	.802
600	.259	.266	.706	.820	.266	.814	.808
10	.253	.259	.704	.824	.261	.820	.814
20	.253	.258	.706	.826	.261	.826	.819
30	.267	.269	.713	.831	.275	.830	.824
40	.301	.299	.725	.834	.309	.836	.829
650	.358	.355	.742	.840	.370	.840	.834
60	.446	.435	.765	.845	.456	.845	.838
70	.540	.532	.786	.850	.559	.850	.841
80	.634	.630	.810	.853	.658	.854	.845
90	.714	.708	.826	.856	.734	.858	.849
700	.774	.770	.840	.860	.790	.861	.851
10	.813	.812	.851	.861	.826	.864	.854
20	.838	.840	.856	.864	.850	.868	.856
30	.854	.858	.863	.866	.866	.870	.859
40	.864	.869	.867	.867	.876	.872	.861
750	.870	.877	.870	.870	.882	.874	.864

Railroad Board
Green

Spectral Directional Reflectance of Dyed Papers and Cardboards for the Indicated Periods of Time and Exposure. (See Appendix A for copies of the Original Recording Sheets.)

Wave length mμ	Initial	Two Months			Ten Months		
		Dark Storage	North Exposure	South Exposure	Dark Storage	North Exposure	South Exposure
400	0.254	0.268	0.468	0.602	0.270	0.611	0.611
10	.256	.268	.472	.619	.270	.630	.630
20	.246	.256	.470	.632	.260	.647	.647
30	.237	.248	.470	.644	.250	.664	.660
40	.238	.249	.472	.654	.252	.676	.674
450	.252	.265	.483	.665	.268	.690	.684
60	.287	.301	.502	.676	.306	.700	.694
70	.355	.366	.532	.686	.372	.709	.701
80	.454	.465	.566	.698	.470	.718	.710
90	.559	.569	.592	.707	.572	.725	.717
500	.638	.650	.617	.715	.646	.732	.724
10	.679	.689	.629	.720	.684	.739	.730
20	.685	.694	.630	.724	.686	.746	.736
30	.662	.670	.623	.728	.664	.751	.743
40	.624	.680	.610	.729	.625	.759	.750
550	.570	.576	.588	.729	.572	.764	.756
60	.512	.519	.563	.725	.518	.770	.762
70	.452	.460	.534	.720	.460	.776	.768
80	.387	.396	.502	.714	.397	.782	.774
90	.332	.339	.474	.704	.340	.788	.780
600	.291	.300	.450	.698	.301	.794	.786
10	.270	.279	.433	.692	.280	.799	.792
20	.253	.262	.417	.689	.265	.804	.798
30	.232	.240	.402	.689	.244	.808	.802
40	.208	.216	.390	.694	.220	.813	.808
650	.198	.204	.392	.706	.210	.819	.813
60	.207	.210	.415	.729	.219	.826	.818
70	.235	.238	.462	.759	.250	.831	.822
80	.287	.289	.525	.785	.310	.836	.826
90	.368	.370	.599	.808	.396	.840	.830
700	.489	.484	.677	.825	.519	.844	.834
10	.609	.608	.740	.836	.645	.848	.836
20	.718	.720	.786	.843	.748	.850	.839
30	.784	.786	.815	.847	.806	.852	.840
40	.822	.826	.830	.850	.840	.854	.844
750	.840	.846	.838	.852	.855	.856	.845

Railroad Board
Buff

Spectral Directional Reflectance of Dyed Papers and Cardboards for the Indicated Periods of Time and Exposure. (See Appendix A for copies of the Original Recording Sheets.)

Wave length mμ	Initial	Two Months			Ten Months		
		Dark Storage	North Exposure	South Exposure	Dark Storage	North Exposure	South Exposure
400	0.245	0.257	0.343	0.442	0.256	0.536	0.585
10	.225	.234	.332	.446	.236	.556	.608
20	.214	.222	.325	.450	.224	.574	.629
30	.208	.216	.321	.455	.216	.590	.646
40	.208	.214	.322	.462	.214	.604	.663
450	.208	.214	.325	.470	.213	.618	.676
60	.210	.216	.329	.479	.212	.629	.688
70	.214	.219	.336	.492	.216	.640	.698
80	.222	.226	.350	.510	.224	.651	.708
90	.237	.240	.370	.533	.236	.664	.716
500	.260	.261	.398	.561	.258	.676	.724
10	.287	.290	.432	.591	.289	.689	.731
20	.316	.318	.466	.621	.318	.700	.738
30	.355	.357	.505	.650	.356	.714	.744
40	.428	.428	.562	.678	.430	.726	.750
550	.554	.558	.634	.705	.555	.738	.756
60	.670	.675	.690	.724	.671	.748	.762
70	.739	.743	.720	.739	.740	.756	.768
80	.772	.775	.740	.750	.774	.764	.773
90	.785	.789	.753	.760	.788	.769	.777
600	.794	.796	.764	.768	.795	.775	.781
10	.797	.801	.772	.775	.800	.780	.785
20	.800	.806	.779	.781	.804	.785	.788
30	.802	.809	.786	.786	.806	.789	.791
40	.804	.811	.790	.790	.810	.794	.794
650	.807	.814	.795	.795	.812	.798	.798
60	.808	.816	.799	.799	.814	.800	.800
70	.809	.817	.803	.803	.816	.803	.802
80	.810	.820	.806	.806	.818	.806	.806
90	.814	.821	.809	.809	.820	.808	.808
700	.815	.823	.812	.812	.822	.812	.810
10	.817	.824	.814	.814	.824	.814	.810
20	.817	.825	.816	.816	.825	.816	.812
30	.817	.826	.819	.819	.826	.819	.814
40	.818	.826	.821	.821	.826	.820	.816
750	.818	.826	.822	.822	.826	.822	.816

Railroad Board
Yellow

Spectral Directional Reflectance of Dyed Papers and Cardboards for the Indicated Periods of Time and Exposure. (See Appendix A for copies of the Original Recording Sheets.)

Wave length mμ	Initial	Two Months			Ten Months		
		Dark Storage	North Exposure	South Exposure	Dark Storage	North Exposure	South Exposure
400	0.089	0.091	0.130	0.210	0.094	0.368	0.507
10	.088	.089	.126	.206	.091	.368	.521
20	.085	.085	.122	.204	.088	.371	.534
30	.084	.084	.120	.204	.086	.375	.545
40	.084	.084	.123	.206	.086	.380	.555
450	.087	.088	.126	.212	.090	.388	.564
60	.097	.098	.138	.224	.100	.400	.572
70	.116	.116	.156	.245	.120	.418	.584
80	.147	.146	.185	.274	.150	.440	.594
90	.196	.199	.233	.321	.206	.474	.610
500	.283	.291	.314	.394	.300	.521	.631
10	.423	.431	.431	.494	.448	.578	.655
20	.568	.580	.543	.579	.590	.626	.678
30	.685	.700	.635	.646	.692	.665	.696
40	.746	.760	.691	.690	.751	.691	.712
550	.778	.790	.727	.718	.783	.713	.725
60	.798	.806	.750	.740	.800	.729	.736
70	.809	.817	.769	.757	.810	.744	.749
80	.818	.825	.784	.771	.820	.758	.758
90	.825	.832	.795	.784	.828	.769	.769
600	.831	.839	.806	.794	.834	.780	.776
10	.836	.844	.814	.802	.840	.790	.785
20	.840	.848	.820	.810	.844	.800	.792
30	.842	.851	.826	.817	.850	.808	.800
40	.845	.855	.832	.824	.854	.816	.806
650	.849	.860	.837	.828	.857	.824	.814
60	.852	.864	.842	.834	.862	.831	.819
70	.857	.867	.847	.838	.866	.838	.825
80	.860	.871	.851	.842	.870	.844	.830
90	.863	.874	.855	.846	.874	.850	.835
700	.867	.876	.859	.850	.878	.854	.839
10	.869	.879	.862	.854	.880	.858	.844
20	.871	.881	.865	.858	.884	.864	.846
30	.872	.882	.867	.860	.884	.866	.850
40	.872	.884	.870	.864	.886	.870	.853
750	.872	.886	.872	.866	.889	.872	.856

Railroad Board
Red

Spectral Directional Reflectance of Dyed Papers and Cardboards for the Indicated Periods of Time and Exposure. (See Appendix A for copies of the Original Recording Sheets.)

Wave length mμ	Initial	Two Months			Ten Months		
		Dark Storage	North Exposure	South Exposure	Dark Storage	North Exposure	South Exposure
400	0.072	0.074	0.105	0.142	0.076	0.254	0.324
10	.070	.071	.104	.145	.074	.266	.343
20	.067	.069	.102	.149	.071	.278	.362
30	.065	.067	.101	.151	.069	.289	.380
40	.063	.064	.100	.152	.066	.299	.396
450	.059	.060	.094	.150	.061	.306	.410
60	.055	.056	.089	.144	.057	.310	.424
70	.051	.052	.082	.138	.054	.312	.435
80	.049	.050	.076	.131	.050	.313	.446
90	.049	.049	.074	.126	.050	.312	.454
500	.050	.050	.072	.124	.050	.314	.464
10	.050	.050	.072	.124	.051	.314	.472
20	.052	.052	.074	.126	.054	.320	.481
30	.055	.056	.079	.132	.056	.329	.494
40	.063	.062	.088	.146	.064	.342	.507
550	.075	.074	.104	.166	.076	.364	.526
60	.099	.098	.134	.200	.102	.396	.550
70	.153	.145	.186	.254	.156	.444	.576
80	.250	.238	.270	.326	.256	.496	.604
90	.383	.375	.377	.412	.392	.546	.630
600	.538	.521	.496	.496	.545	.595	.651
10	.656	.652	.594	.571	.664	.636	.672
20	.733	.736	.669	.629	.742	.669	.690
30	.776	.783	.715	.670	.786	.696	.707
40	.799	.806	.745	.699	.809	.720	.722
650	.815	.821	.766	.721	.824	.740	.736
60	.826	.832	.782	.742	.834	.758	.750
70	.833	.841	.796	.758	.842	.774	.761
80	.840	.848	.807	.772	.850	.786	.772
90	.847	.854	.818	.784	.856	.799	.781
700	.852	.859	.826	.795	.860	.811	.790
10	.857	.864	.835	.806	.865	.821	.799
20	.859	.868	.842	.816	.869	.831	.806
30	.862	.870	.849	.824	.872	.839	.814
40	.864	.872	.855	.833	.875	.845	.821
750	.865	.874	.858	.838	.877	.850	.826