RP100

LIGHT FASTNESS OF LITHOGRAPHIC INK PIGMENTS

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ABSTRACT

One hundred and thirty-six specially prepared lithographic prints, representing 31 pigments, were exposed to daylight in several different ways and to the light from a glass-inclosed carbon arc. The fading observed is reported in this paper, and a classification of the fastness of the pigments as used in lithographic inks is given.

CONTENTS

I. INTRODUCTION

A study of the light fastness of lithographic ink pigments was made through the cooperation of the Lithographic Technical Foundation (Inc.) and the Bureau of Standards. The foundation selected the pigments, prepared the inks, and from them the printed samples which were exposed at the Bureau of Standards to daylight under various conditions and to the light from a glass-inclosed carbon arc. The results of these experiments are recorded in this paper.[1]

One of the objects of the exposures was to determine whether the prints in a series show the same relative fading when they are exposed under different daylight conditions. Another object was to investigate the suitability of the carbon arc lamp for laboratory tests. A third object was to find suitable standards of fastness to light. Since all of the inks were exposed simultaneously in each type of test, a classification of their relative fastness is possible.

[1] This work was carried out simultaneously with an elaborate series of tests of dyed fabrics conducted by the American Association of Textile Chemists and Colorists and the Bureau of Standards during the summers of 1926 and 1927. A report on the dyed fabrics will be found in the American Dyestuff Reporter for June 24, 1929. Although the tests were planned from the standpoint of dyed fabrics, they were found applicable to lithographic prints, and the results obtained with the prints are of sufficient interest to be placed on record.

II. PROCEDURE

1. PREPARATION OF SAMPLES

To provide material for the tests, 31 of the pigments and lake colors more commonly used in lithographic and "offset" inks were selected. These were ground in "burnt" lithographic varnish with the necessary additions of bases and driers to produce inks having good working qualities. The bases consisted of aluminum hydrate, mixtures of aluminum hydrate with blanc fixe, commonly known as "gloss white," and magnesium carbonate. The driers consisted of lead and manganese resinates and linoleates. A total of 34 inks were prepared which in every respect were comparable with commercial "offset" inks. Detailed information regarding the compositions of the inks is given in Table 1.

Solid impressions of these inks were made by means of an offset proving press on a good grade of white, machine-finished paper, care being taken to secure medium prints, not undercharged or overcharged with ink. Each ink was printed in four strengths, as follows:

1. 1 part ink, 25 parts laketine.
2. 1 part ink, 10 parts laketine.
3. 1 part ink, 5 parts laketine.
4. Full-strength ink.

Laketine is a white ink used for diluting colored inks to produce tints. The laketine used in this work consisted of 4 parts of magnesium carbonate, 2 parts of aluminum hydrate, and 1 part of lead carbonate in a vehicle composed of lithovarnish, with some rosin and water. In all, 136 prints were used in the tests.

TABLE 1.—*Samples used and results obtained in the light exposures*

Serial No.[1]	Colour Index No.	Name of pigment	Approximate concentration in percentage of coloring matter in pigment	Additional base parts added per 100 parts of pigment	Ratio coloring matter to total base	Approximate total solids in ink	Approximate coloring matter in ink	Dilution of ink with laketine	Other constituents	Fastness class	Special characteristics
						Per cent	*Per cent*				
1101	1270	Chrome yellow, C. P. lemon	100	15 (gloss white)	67–10	70	61	1–25	Drier	5	Becomes progressively duller but does not fade appreciably.
2								1–10	do	5	
3								1– 5	do	5	
4								1– 0	None	5	
1105	1270	Chrome yellow, C. P. medium	100	do	67–10	70	61	1–25	Drier	5	Do.
6								1–10	do	5	
7								1– 5	do	5	
8								1– 0	None	5	
1109	640	Tartrazine, barium lake	[2] 40	0	2– 3	55	22	1–25	Drier	2	Fades less in north skylight than in sun exposure,[3] slight dulling precedes fading.
10								1–10		2	
11								1– 5		2	
12								1– 0		3	
1113	10 and 655.	Naphthol yellow S and auramine, barium lake.	[2] 20	0	1– 4	55	11	1–25	do	1	Fades slightly less in north skylight and slightly more in arc light than in sun exposure; [3] dulling precedes regular fading.
4								1–10		1	
5								1– 5		1	
6								1– 0		2	
1117	1270	Chrome orange, C. P. dark	100	66.7 (gloss white)	3– 2	72	43	1–25	do	5	Becomes slightly duller on exposure but does not fade appreciably.
8								1–10	do	5	
9								1– 5	do	5	
20								1– 0	None	5	
1121	151	Acid orange II, tin lake	[2] 30	0	10–23	50	15	1–25	Drier	1	Fades slightly less in north skylight than in sun exposure; [3] very fugitive.
2								1–10		1	
3								1– 5		1	
4								1– 0		1	

[1] Samples whose serial numbers are followed by "x," like 1133x, were exposed simultaneously with set K samples and not with set A.
[2] On aluminum hydrate.
[3] When the exposures are timed to produce the same average fading in the group of samples in the 2 types of exposure.

TABLE 1.—*Samples used and results obtained in the light exposures*—Continued

Serial No.	Colour Index No.	Name of pigment	Approximate concentration in percentage of coloring matter in pigment	Additional base parts added per 100 parts of pigment	Ratio coloring matter to total base	Approximate total solids in ink	Approximate coloring matter in ink	Dilution of ink with laketine	Other constituents	Fastness class	Special characteristics
						Per cent	Per cent				
1125	151	Acid orange II, barium lake	[4] 40	0	2-3	50	20	1-25	Drier	1	Fades slightly less in north skylight than in sun exposure; [3] very fugitive.
6								1-10		1	
7								1-5		1	
8								1-0		1	
1129	165	Lake red C, sodium toner	100	100 (gloss white)	1-1	50	25	1-25	do	1	Fades less in north skylight and in the arc light than in sun exposure; [3] slight dulling precedes fading.
30								1-10		1	
1								1-5		2	
2								1-0		3	
1133x		Permanent red R [5]	100	do	1-1	50	25	1-25	do	1	Fades slightly more in the arc light than in sun exposure; [3] slight dulling precedes fading.
4x								1-10		3	
5x								1-5		4	
6x								1-0		5	
1137	1280	English vermilion (mercury sulphide).	100	5 (gloss white)	20-1	80	76	1-25	do	4	Becomes progressively duller but does not fade appreciably.
8								1-10	do	4	
9								1-5	do	4	
40								1-0	None	5	
1141x	165	Lake red C, barium toner	100	100 (gloss white)	1-1	60	32	1-25	Drier	1	Fades slightly less in the arc light than in sun exposure.[3]
2x								1-10		1	
3x								1-5		2	
4x								1-0		4	
1145x	69	Toluidine red toner	100	do	1-1	50	25	1-25	do	2	Fades slightly less in north skylight and slightly more in the arc light than in sun exposure; [3] slight dulling precedes fading.
6x								1-10		3	
7x								1-5		4	
8x								1-0		5	
1149x	189	Lithol red R, sodium toner	100	do	1-1	50	25	1-25	do	1	Fades slightly more in the arc light than in sun exposure; [3] becomes dull and loses bronze before fading.
50x								1-10		1	
51x								1-5		2	
52x								1-0		4	

1153x 4x 5x 6x	189	Lithol red R, barium toner	100	do	1- 1	50	25	1-25 1-10 1- 5 1- 0	do	1 1 2 4	Becomes distinctly bluer and duller before fading appreciably; loses its bronze quickly.
1157x 8x 9x 60x	189	Lithol red R, calcium toner	100	do	1- 1	50	25	1-25 1-10 1- 5 1- 0	do	1 1 2 4	Loses its bronze and becomes duller before fading.
1161 2 3 4	189	Lithol red R, sodium toner	100	100 (magnesium carbonate).	1- 1	50	25	1-25 1-10 1- 5 1- 0	do	1 1 2 4	Fades slightly more in the arc light than in sun exposure;[3] becomes dull and loses bronze before fading.
1165 6 7 8	189	Lithol red R, barium toner	100	do	1- 1	50	25	1-25 1-10 1- 5 1- 0	do	1 1 2 4	Becomes bluer and duller before fading appreciably.
169 70 71 72	189	Lithol red R, calcium toner	100	do	1- 1	50	25	1-25 1-10 1- 5 1- 0	do	1 1 2 4	Do.
1173 4 5 6	216	Pigment scarlet 3B, barium lake.	[4] 34	0	10-19	60	20	1-25 1-10 1- 5 1- 0	do do do None	1 2 5 5	Fades less in arc light than in sun exposure;[3] becomes much bluer and duller before fading appreciably.
1177 8 9 80	163	Lithol rubine B, calcium lake	50	50 (gloss white)	1- 2	60	20	1-25 1-10 1- 5 1- 0	Drier	2 3 4 5	Becomes slightly bluer and dull before fading appreciably.
1181 2 3 4	1027	Madder lake	[6] 25	0	1- 3	36	9	1-25 1-10 1- 5 1- 0	do do do None	4 4 5 5	Fades slightly less in the arc light than in sun exposure;[3] becomes dull before fading appreciably.
1185 6 7 8	44	Para toner, light	100	100 (gloss white)	1- 1	50	25	1-25 1-10 1- 5 1- 0	Drier	1 2 3 5	Fades slightly more in the arc light than in sun exposure;[3] becomes slightly dull before fading.
1189 90 91 92	44	Para toner, dark	100	do	1- 1	50	25	1-25 1-10 1- 5 1- 0	do	1 1 2 5	Fades slightly less in north skylight and slightly more in the arc light than in sun exposure;[3] becomes slightly dull before fading.

[3] When the exposures are timed to produce the same average fading in the group of samples in the 2 types of exposure.
[4] On gloss white.
[5] 2-chloro-4-nitrobenzene-azo-2-naphthol.
[6] Base not known.

TABLE 1.—*Samples used and results obtained in the light exposures*—Continued

Serial No.	Colour Index No.	Name of pigment	Approximate concentration in percentage of coloring matter in pigment	Additional base parts added per 100 parts of pigment	Ratio coloring matter to total base	Approximate total solids in ink	Approximate coloring matter in ink	Dilution of ink with laketine	Other constituents	Fastness class	Special characteristics
						Per cent	*Per cent*				
1193 4 5 6	680	Methyl violet, tannin toner	100	100 (gloss white)	1- 1	50	25	1-25 1-10 1- 5 1- 0	Drier	1 1 1 2	Blackens and loses its bronze before fading; very fugitive.
1197 8 9 1200	680	Methyl violet, tungstic toner	100	do	1- 1	50	25	1-25 1-10 1- 5 1- 0	do	1 1 1 3	Becomes dull before fading; fades considerably slower than tannin lake.
1201 2 3 4	1288	Milori blue, C. P. light (soda)	100	0	No base.	50	50	1-25 1-10 1- 5 1- 0	do do do None	5 5 5 5	Becomes dull but does not fade; exposure increases bronze of full strength print.
1205 6 7 8	1288	Milori blue, C. P. medium (soda).	100	0	No base.	50	50	1-25 1-10 1- 5 1- 0	Drier do do None	5 5 5 5	Do.
1209 10 11 12	1288	Bronze blue, C. P. (potash)	100	0	No base.	55	55	1-25 1-10 1- 5 1- 0	Drier do do None	5 5 5 5	Do.
1213 4 5 6	704	Alkali blue, green shade	100	0	1- 0	50	50	1-25 1-10 1- 5 1- 0	Drier	2 2 3 4	Fades slightly less in the arc light than in sun exposure;[3] becomes dull and loses bronze gradually.
1217 8 9 20	704	Alkali blue, red shade	100	0	No base.	50	50	1-25 1-10 1- 5 1- 0	do	2 2 3 4	Fades slightly less in the arc light than in sun exposure;[3] becomes dull and loses bronze.

1221	1290	Ultramarine blue	100	16.7 (gloss white)	6–1	65	56	1–25	do	2	Becomes duller and redder before fading appreciably.
2								1–10	do	3	
3								1–5	do	5	
4								1–0	None	5	
1225	671	Peacock blue (erioglaucine, barium lake).	[2] 35	0	10–19	50	17.5	1–25	Drier	1	Very fugitive; blackens first and then fades.
6								1–10		1	
7								1–5		1	
8								1–0		1	
1229	1308	Carbon black	100	0	No base.	33	33	1–25	do	5	Practically no change on exposure.
30								1–10		5	
1								1–5		5	
2								1–0		5	
1233	1298	Chrome green [7]	100	25 (gloss white)	4–1	75	60	1–25	do	5	Becomes progressively duller but does not fade.
4								1–10	do	5	
5								1–5	do	5	
6								1–0	None	5	
1237		Sample of white M. F. paper on which prints were made.									Becomes distinctly brown in sun exposures up to 96 hours, after which it bleaches perceptibly but does not completely return to its original whiteness.

[2] On aluminum hydrate.
[3] When the exposures are timed to produce the same average fading in the group of samples in the 2 types of exposure.
[7] 3 parts primrose yellow, 1 part milori blue C. P. light.

2. METHOD OF EXPOSURE

(a) SUN AND DAYLIGHT EXPOSURES

The prints were cut into pieces which were mounted on heavy opaque black paper and labeled as shown in Figure 1. Six complete sets of samples were thus prepared. Each set was designated by a letter and each sample in the set by the serial number of the print from which it was cut.

The individual samples of each set were assembled in numerical order, 25 in a row, beginning on the right, and attached to one another with wire staples along the bottom, so that each sample overlapped the left-hand half of the preceding sample. In this manner the opaque backing of sample A 1102 masked the left-hand half of sample A 1101, etc. The cardboard chips on the upper and lower right-hand corners of each sample (fig. 1) served as guides for the covering sample, so that it could be removed at any time in order to examine the sample under it and replaced exactly in its original position. The samples thus mounted were fastened on boards as shown in Figure 2.

The exposure racks are located on the roof of the Industrial Building, Bureau of Standards, Washington, D. C. They are shown in Figures 3 and 4. The racks run east and west and are open to the full light of the sky. The samples, mounted on boards, were exposed to light by placing them in the racks as shown.

The glass covers were set at a distance of ½ inch from the samples, and provision was made for free access of air to the latter. The covers were 5 inches larger in each direction than the boards supporting the samples, so that there was no significant shading by the framework of the cover. Ordinary window glass was used. It was purchased under a specification which required selection for uniformity in color, thickness, and composition. By actual measurement the minimum and maximum thicknesses of the pieces used were 0.112 and 0.139 inch, respectively, and the average thickness was 0.125 inch. The spectral transmission of two samples of the glass taken at random is shown in Figure 5. The glass covers were cleaned frequently.

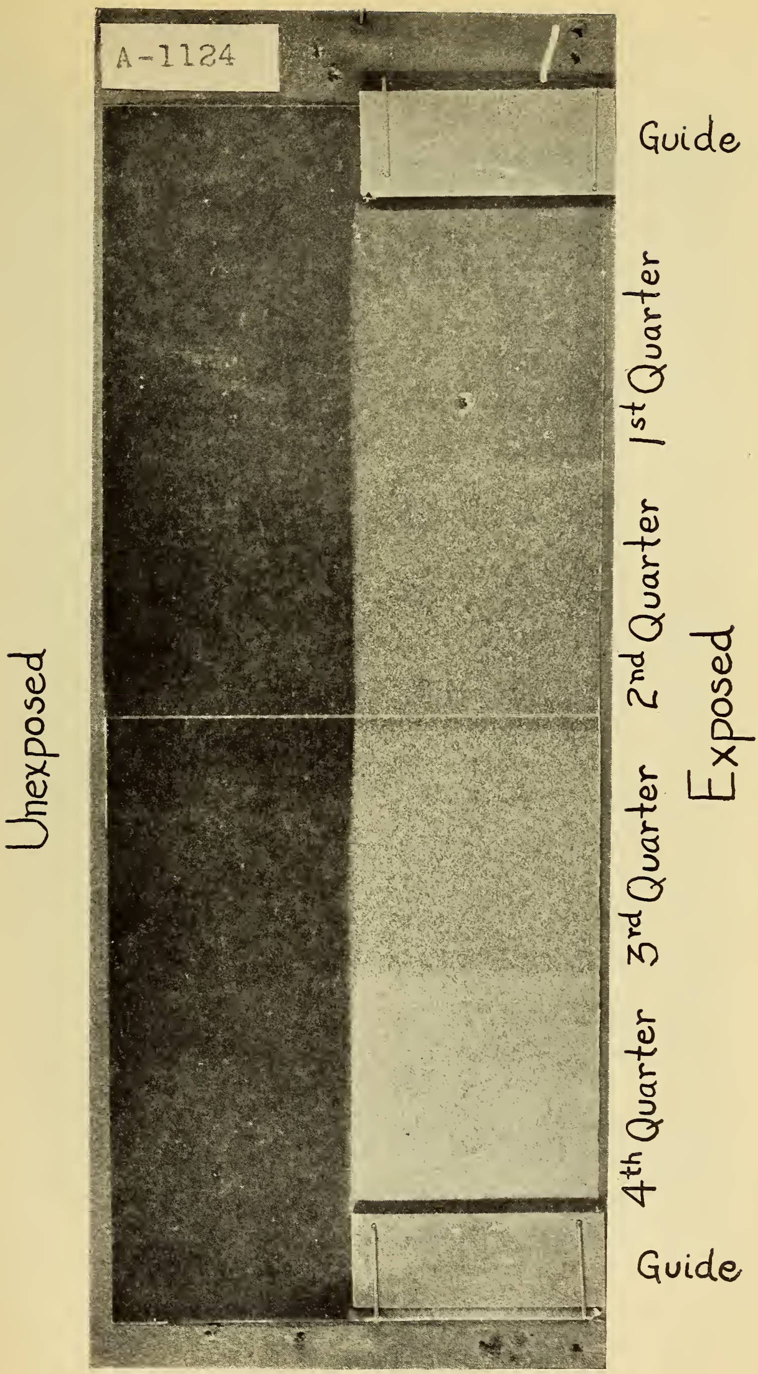

Figure 1.—*Sample (after exposure) showing method of mounting, and the four exposed areas*

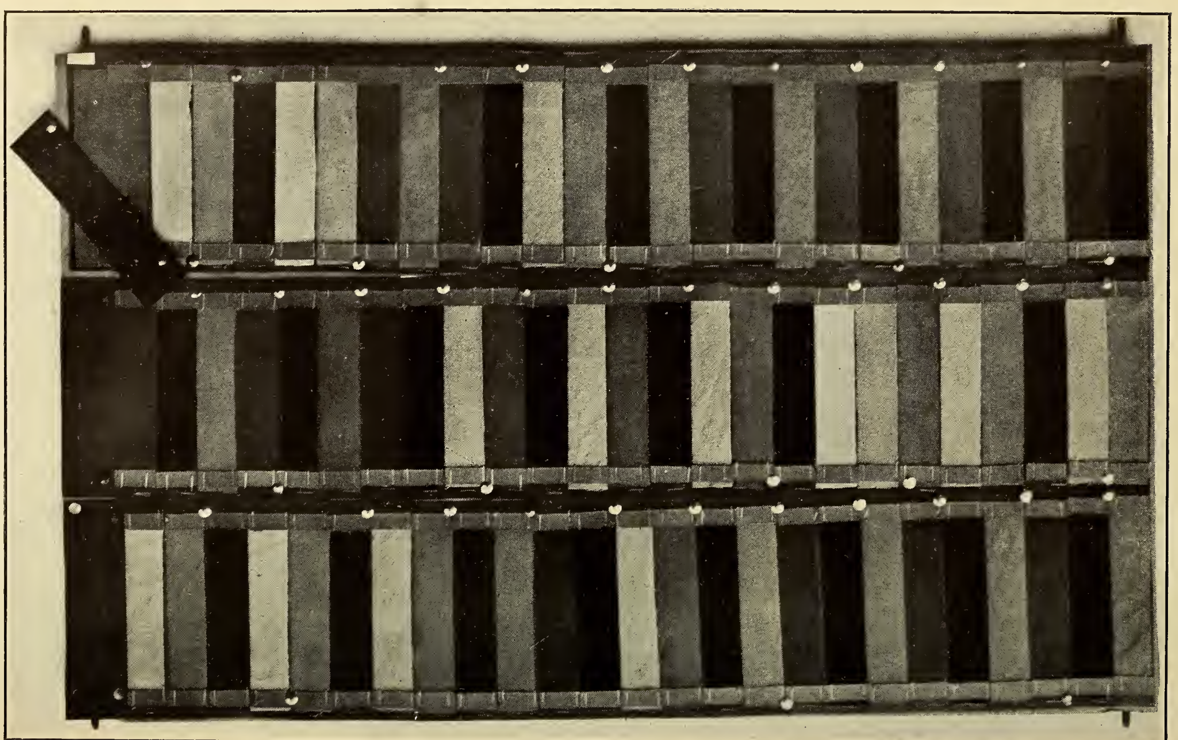

FIGURE 2.—*Samples mounted on board ready for exposure*

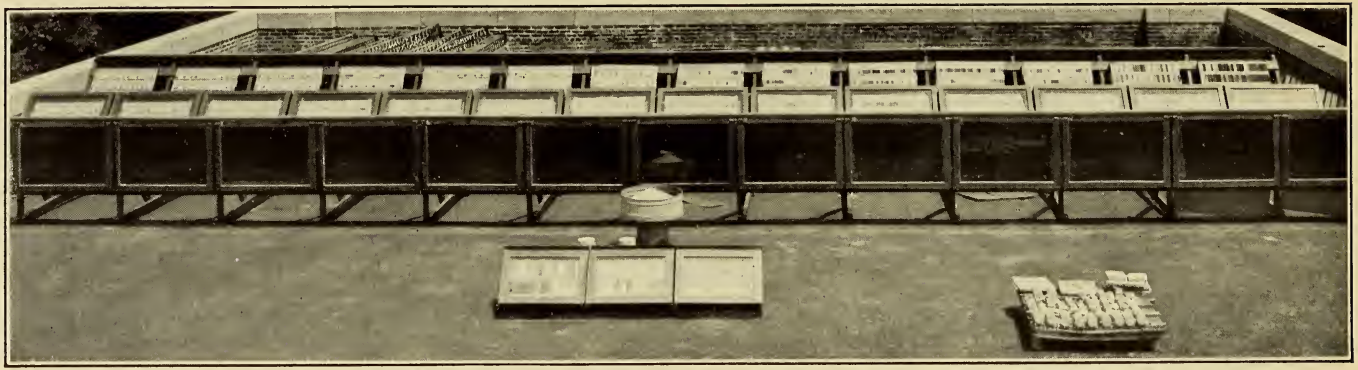

FIGURE 3.—*Exposure rack (from the south)*

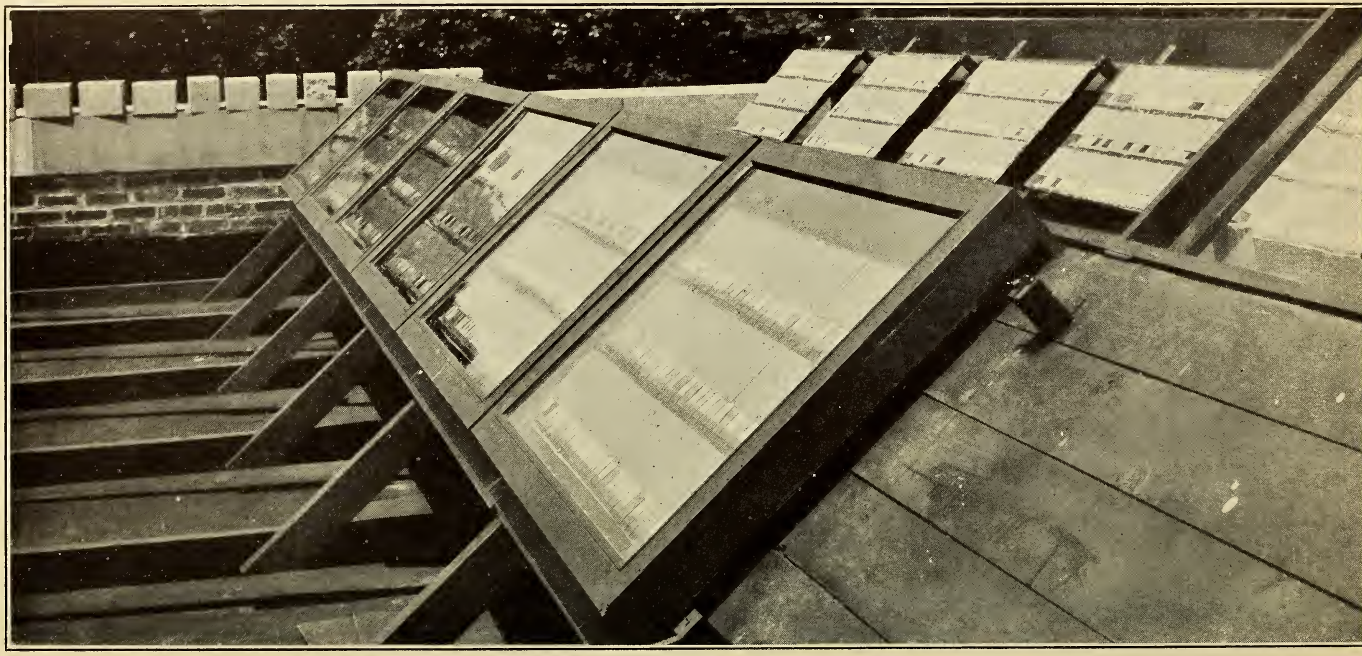

FIGURE 4.—*One of the exposure racks (near view)*

The six duplicate sets of samples were exposed during the summer and autumn months under the following conditions:

Set A. Exposed only on clear days between 9 a. m. and 3 p. m. under glass, at an angle of 45° from the horizontal facing south. If clouds came up, the samples were promptly covered.

Set B. Simultaneously with set A and under the same conditions except that no glass cover was used over the samples.

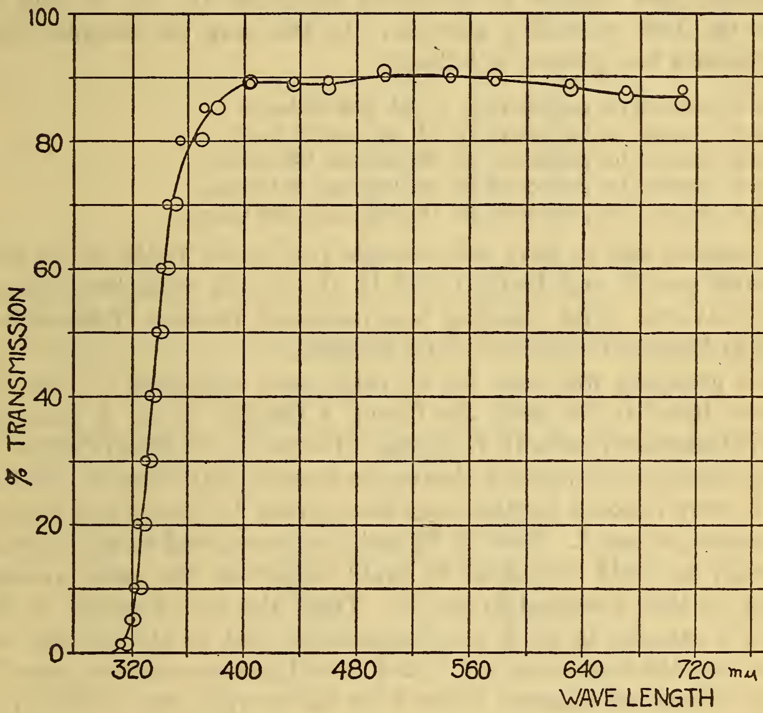

FIGURE 5.—*Spectral transmission of cover glass*

Set D. Exposed continuously day and night, regardless of the weather, under glass, vertical, facing south.

Set E. Exposed continuously, under glass, at an angle of 45° facing south.

Set F. Exposed continuously, under glass, vertical, facing north.

Set K. Exactly like set A but during the summer of 1927, the set A exposures having been made principally in 1926.

Set A was taken as the standard in timing the exposures. When placed in the rack and exposed for 6 hours, such set A samples as showed an alteration in color were remounted separately and labeled Group 1. Then the upper fourth of the exposed portions of these prints was covered with black opaque cardboard, and the remaining

three-fourths was exposed for 6 hours longer. The cardboard was then moved so as to cover the second quarter in addition to the first. This was continued until the four quarters of the Group 1 prints had received 6, 12, 24, and 48 hours exposure, respectively.

The prints of set A which did not show an alteration in color in the first 6 hours were exposed for 6 hours longer on the first quarter, after which those samples showing an alteration were remounted separately and exposed as described above for 12, 24, 48, and 96 hours on their respective quarters. In this way the samples were divided into five groups, as follows:

Group 1, exposed for periods of 6, 12, 24, and 48 hours.
Group 2, exposed for periods of 12, 24, 48, and 96 hours.
Group 3, exposed for periods of 24, 48, 96, and 192 hours.
Group 4, exposed for periods of 48, 96, 192, and 384 hours.
Group 5, exposed for periods of 96, 192, 288, and 480 hours.

The purpose was to have each sample just barely faded in the first exposure period and badly faded in the fourth with two distinct steps between. The grouping was necessary because of the differences in fastness of the individual samples.

This grouping was used for all other sets, regardless of how the samples faded in the sets; the Group 1 samples in set A were the Group 1 samples in sets B, K, F, etc. However, the time of exposure of the different sets was not always the same as that of set A. Sets B and K were exposed for the same time, group by group and quarter by quarter, as set A. Sets D, E, and F were exposed so as to obtain as nearly as could be judged by rapid inspection the same average fading as that obtained in set A. Thus, the first quarters of the Group 1 samples in set F were exposed so that on the average the fading was the same as in set A, the second quarters were exposed to match the second quarters of set A on the average, etc. The object of this procedure was to determine the time required to produce the same amount of fading in the different exposures and the effect of the different conditions of exposure on the relative fading of individual colors.

A summary of the time of exposure of the different sets is given in Table 2. The average temperature and relative humidity of the air during the exposures are given in Table 3.

TABLE 2.—*Time of exposure of the samples*

Group	Quarter	Sets A, B, and K	Set D	Set E	Set F	Sets G-H
		Hours	*Days*	*Days*	*Days*	*Hours*
1	1	6	2.3	0.7	3	2.3
	2	12	4	2.2	4.7	4.7
	3	24	6.3	4	11	9.3
	4	48	14	6.6	17	18.7
2	1	12	4	2.2	4.7	4.7
	2	24	6.3	4	11	9.3
	3	48	14	6.6	22	18.7
	4	96	32	12.7	61	37.3
3	1	24	9	[1] 9	34	9.3
	2	48	17.3	[1] 17	70	18.7
	3	96	31	17	149	37.3
	4	192	49	31	260	74.7
4	1	48	19	10.5	6	18.7
	2	96	31.3	20	9.5	37.3
	3	179.3	49	41.3	27.1	74.7
	4	275.7	84	65.3	83.8	149.3
5	1	96	35	26	[2] 30	37.3
	2	192	64	53	[2] 70	74.7
	3	288	101	106	[2] 146	149.3
	4	480	144	167	[2] 260	298.7

[1] Overexposed.
[2] These exposures were not carried to completion because of the time required and because most of these samples did not fade even in the set A exposure.

TABLE 3.—*Temperature and relative humidity of the air*

[The average of observations made at 9 a. m., 12 noon, and 3 p. m. on days when samples were exposed are given]

Set	Temperature	Relative humidity
A	44	25
K	39	26
B	32	46
D	33	43
E	42	35
F	25	45

TABLE 4.—*Spectral distribution of the radiation* [1] *from the glass-inclosed arc lamp compared with sunlight at Washington, D. C., on May 25, 1926, 11 a. m. to 12 noon*

Spectral range (in mμ)	Percentage of the total radiation	
	Arc	Sun
170 to 320	0.0	2.0
320 to 360	2.0	2.8
360 to 480	18.5	12.6
480 to 600	9.3	21.9
600 to 1,400	16.5	38.9
1,400 to 4,200	22.1	21.4
4,200 to 12,000	31.6	0.4

[1] Measurements by W. W. Coblentz, Bureau of Standards.

After the exposures made during 1926 were completed it was found that the prints of a number of the colors were too lightly inked. Fresh prints of these were made and were exposed during 1927. These samples were designated with an x after the sample number (see 1133x in Table 1).

(b) CARBON ARC LIGHT EXPOSURES

The commercially available inclosed carbon arc lamp known as the "fade-ometer" was used for these tests because it runs without attention for over 24 hours, and because it is in rather general use in, industrial laboratories for this purpose. It is a glass-inclosed arc, giving little or no radiation below a wave length of 320 mμ, but much from 350 to 480 mμ. Its spectral distribution in comparison with sunlight is given in Table 4. The solid carbons furnished with the lamp were used. The "fade-ometer" was operated on a 230 to 240 volt d. c. circuit at 12 to 13 amperes. The samples were placed in the holders provided with the apparatus and were thus exposed at a distance of 10 inches from the axis of the arc. Two of the lamps were used in making the tests.

The arc exposures were made on set G-H, which was identical with those previously described, except that the samples were cut to measure 2¼ by 3 inches, so that they would go in the "fade-ometer" holders. For this reason only two different exposures could be made on each sample and two samples were required. G samples were given exposures corresponding to the first and second quarters of set A sun exposures, and H samples were given exposures corresponding to the third and fourth quarters of set A. A piece of thin sheet aluminum was used to shield one half while exposure of the other half was being completed.

According to the manufacturer, one "fade-ometer" hour is equivalent to 1.3 hours of summer sunlight for textiles and 5 hours of summer sunlight for printing inks. The lithographic prints, however, did not fade as much in 1.2 "fade-ometer" hours as in 6 hours exposure to sunlight at Washington, and it was determined by close observation of the prints that 2.33 "fade-ometer" hours was approximately equivalent to 6 hours' sun exposure for the inks. Longer exposures gave the same time ratio for equivalent fading.

In making the arc exposures, interruptions were avoided as far as possible. Each sample was exposed for approximately half the time in the upper row of openings and the other half in the lower row, since it is claimed that somewhat more fading is produced in the upper row than in the lower in a given length of time.[2] The receptacles below the lamps were supplied with water at all times, and the globes

[2] Gordon, Am. Dyestuff Reporter, **14**, p. 488; 1925.

were cleaned daily. No difficulties were experienced in the operation of the machines.

The maximum temperature indicated by a mercury thermometer, the bulb of which was covered with black paper and placed near the samples during exposure to the arc, was 80° C. Without the covering of black paper the maximum observed temperature was 70° C.

3. METHOD OF STUDYING RESULTS

As stated above, set A was exposed so as to produce as far as practicable a barely noticeable fading of the first quarter of each sample. By this means set A was subdivided into five groups according to the time necessary to produce this result. After the group exposures were completed the fading of all four quarters of each sample was carefully studied, checked against set K exposures, and the samples finally classified in the following way which, in many instances, led to results differing from the tentative grouping used in making the exposures.

Class 1. All samples showing marked alteration or fading at the end of 6 hours' exposure.

Class 2. Samples showing but slight alteration in 6 hours, distinct alteration in 12 hours, and more and more alteration in 24 and 48 hours' exposure.

Class 3. Samples showing but slight alteration in 12 hours, distinct alteration in 24 hours.

Class 4. Samples showing but slight alteration in 24 hours and distinct alteration 48 hours.

Class 5. Samples showing but slight alteration in 48 hours' exposure.

Very much longer exposures would be needed to split off a still faster class from class 5.

The difference in fastness between these classes is sufficient to make possible a clear-cut classification of most of the samples. Naturally there are some which exhibit intermediate degrees of fastness. Others do not fade in regular steps, so that their satisfactory classification is difficult. The behavior of all four quarters was considered in judging the fastness of such samples.

Certain effects other than simple fading of the pigment were observed and were also carefully considered in determining the classification. These effects were:

1. The paper darkened during the shorter exposures sufficiently to cause pale colors to appear dull. This darkening of the paper became less marked after longer exposure because of the bleaching action of light.
2. Samples originally having a bronzy appearance usually lost it more or less completely in six hours' exposure to sunlight.
3. The yellowing of the varnish vehicle in the absence of light and its bleaching in strong light caused the unexposed portions of certain blue samples to appear greener than the exposed portions.

4. Certain samples developed a somewhat different color at the increased temperature of the exposure and could properly be judged only after allowing them to cool. Several days elapsed before some of the samples returned to their original color in the unexposed portion.

The other exposures (sets B, D, E, F, and G-H) were compared individually with the corresponding samples in sets A and K to determine which prints faded more or less than the average under the various conditions. The more important deviations are pointed out in Table 1 under "special characteristics." Table 5 gives the number of samples in each set which faded "more" than, "slightly more" than, "equal" to, "slightly less" than, and "less" than the corresponding samples in set A in this comparison.

TABLE 5.—*Summary of comparisons with set A*

[The columns give the number of samples that are "less," "slightly less," "equal," "slightly more," or "more," faded than the corresponding samples in set A]

Group	Set B					Set D					Set E					Set F					Set G–H					Set K				
	Less	Slightly less	Equal	Slightly more	More	Less	Slightly less	Equal	Slightly more	More	Less	Slightly less	Equal	Slightly more	More	Less	Slightly less	Equal	Slightly more	More	Less	Slightly less	Equal	Slightly more	More	Less	Slightly less	Equal	Slightly more	More
1	0	20	63	5	0	9	15	57	5	2	0	0	64	19	5	14	14	47	7	6	7	6	61	2	12	0	0	56	5	13
2	0	2	28	2	0	3	2	24	3	0	0	0	27	5	0	4	0	23	3	2	5	3	21	0	3	0	0	18	7	1
3	0	0	13	8	3	0	1	21	2	0	0	2	20	1	1	1	1	14	7	1	2	3	17	2	0	0	0	22	0	0
4	0	0	2	0	0	0	0	2	0	0	0	0	0	2	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0
5	0	0	12	2	0	0	0	14	0	0	0	0	12	2	0	0	0	14	0	0	0	0	8	1	5	0	0	14	0	0
Total	0	22	118	17	3	12	18	118	10	2	0	2	123	29	6	19	15	100	17	9	14	12	109	5	20	0	0	110	12	14

III. RESULTS

The classification of the prints according to fastness is shown in Table 1. In using these results it must be remembered that the resistance of a film of ink to the action of light is affected by its thickness and transparency, factors which are difficult to control. This, together with the variability of pigments made from nominally the same materials by different manufacturers, would make it difficult to reproduce exactly the results which were obtained from this particular set of prints. However, the results given here should be a useful guide in the classification of similar pigments from other sources.

The comparison of the samples in set K with those in set A, given in Table 5, shows that exposure under the conditions represented by these two sets can be duplicated reasonably well, though some samples in set K are more faded than their duplicates in set A. This type of exposure has been adopted by the American Association of Textile Chemists and Colorists as a standard sunlight exposure. It

can be recommended for lithographic prints where a drastic sunlight exposure test is desired.

The fading of set B is very similar to that of sets A and K. The presence or absence of the glass cover evidently affects the fading of relatively few samples.

Sets D, E, and F, which were exposed continuously, can not be duplicated because of varying weather conditions. It was observed (see Table 5 and also Table 1, "special characteristics") that certain samples faded more and others less in set F than in set A. This behavior was noticed to a less extent in sets D and E. It was not as pronounced in the printing ink tests as in similar tests of dyed textiles. (See footnote 1, p. 359.) These differences in relative fading among samples in one set compared with those in another are to be attributed in part, at least, to the different light intensities and environmental conditions during the exposures. Sets A and K were exposed to light of high intensity and set F in particular to light of low intensity. The temperature of the set F exposures was, on the average, nearly 20° C. lower than that of set A exposures. (See Table 3.) The relative humidity of the atmosphere at the samples was 20 per cent higher for set F than for set A.

From the data given in Tables 2 and 5 it is obvious that the time required to produce the same amount of fading in the several types of daylight exposures is different with different samples and on different days. In a very general way 6 hours' exposure under the conditions of set A is equivalent to 1 day under the conditions of set E, 2 days of set D, and 3 days of set F. (See reference in footnote 1 for the wide variability in this respect of individual samples of dyed textiles.)

Set G–H, the arc lamp exposure, should be duplicable. The majority of the arc exposures match the sunlight exposures, set A, rather closely. Two and one-third hours' exposure in the "fade-ometer" is practically equivalent to six hours' exposure to sunlight between 9 a. m. and 3 p. m. at Washington, D. C. during summer and autumn. Samples showing markedly exceptional behavior in the arc exposure are indicated in Table 2 under "special characteristics." (See also Table 5.)

With due regard to the exceptional samples, the results of these tests indicate that certain prints may be selected for use as standards of fastness to light. Some additional work will be necessary, however, to develop a simple, practical means of preparing the standards and making the tests.

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IV. ACKNOWLEDGMENTS

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V. SUMMARY

1. Although the relative fading of a majority of the lithographic prints is the same in the different exposures, a few fade decidedly faster and others slower than the average in certain exposures.

2. The yellowing of the varnish in the absence of light and its bleaching in strong light must be taken into consideration in judging the fastness of pale colors.

3. The heat during exposure affects certain prints and causes a reversible change in color.

4. The carbon arc lamp appears to be a reasonably satisfactory source of light for fading tests of lithographic inks. It is possible that better agreement with sun exposures would be obtained if the samples were placed far enough from the arc to fade at about the same rate as in sunlight, and if the temperature were controlled so that the samples would not be heated above the temperature reached in the exposures to sunlight (approximately 44° C.).

5. A classification of the fastness of 136 samples representing 31 pigments is given. Since the fastness of a given pigment depends on its concentration in the ink film of the print, each pigment may be given more than one fastness classification, according to its concentration.

WASHINGTON, April 12, 1929.