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THE EFFECT OF BACKGROUNDS UPON SPECIMENS EXPOSED TO ULTRA-VIOLET RADIATION

by

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INTRODUCTION

Numerous studies which have been conducted prove that ultra-violet radiation causes a definite weakening of fabrics. None of these studies has given special attention to the effect of the backgrounds used. Since reflection factors of materials vary considerably, the use of different backgrounds may result in variations in the changes which take place within the fiber. The purpose of this experiment was to determine, if possible, the effect of ultra-violet radiation on bleached and unbleached sheeting when exposed against different backgrounds.

REVIEW OF LITERATURE

The ultra-violet spectrum is composed of many invisible "colors," each having its own properties and characteristics, which are very different from one another (Stockbarger, 1930). Any ray of light whose wave length is, approximately speaking, less than 4000 or greater than 8000 angstroms is invisible. Consequently the field of ultra-violet radiation is invisible as the wave lengths are from about 4000 down to 136 angstroms (McEwen, 1932).

When light falls upon a body it may be partly reflected, partly transmitted, or partly absorbed. This absorbed energy may appear as heat or, in some cases, is re-emitted as light of a different character from that of the incident beam. This secondary radiation is usually of a longer wave length than that of the exciting light. Objects possessing the property of re-emitting light of a different character are called fluorescent (McEwen, 1932).

The reflection characteristics of invisible ultra-violet rays are decidedly different from those of visible light rays. Recent measurements have shown that many materials such as white lead paint, for example, are efficient reflectors of visible light and have the property of absorbing a large part of the invisible ultra-violet radiation striking them (Management Methods, 1932). Two white objects having the same reflectivities for visible rays appear alike when viewed by ordinary light, but one may reflect one kind of ultra-violet much more readily than does the other (Stockbarger, 1930).

A number of investigations have been conducted to determine the effect of ultra-violet radiation upon fabrics. Dorée (1917) states that ultra-violet converts cellulose, with complete loss of tensile strength, into oxycellulose. The ultra-violet rays may act in two ways: there may be a physical action of the rays themselves on the fabric, or the change may result from the formation of ozone. Heermann (1929) has reached the conclusion that the rays themselves exert the destructive action.

Rays of less than 4000 angströms seem to cause the greatest weakening of cotton and linen fibers. Therefore ultra-violet radiation has a much greater effect on fibers than visible radiations (Barr, 1924).

The general result of the work conducted by Cunliffe (1928) shows that bleached cotton is more rapidly tendered than raw when exposed to ultra-violet radiation. The difference between raw and bleached material is obscured when long exposures involving great loss of strength are considered. Tendering slows down for all materials after about 50 per cent of the strength is lost. When long exposures are made the percentage loss of strength of equally exposed fine and coarse yarns may appear to be the same.

According to Barr (1924) coarse yarns are less affected by ultra-violet radiation than fine yarns, for in the former, the outer layers protect the inner layers.

Brugmann (1931) concludes that light is the primary factor in the deterioration of cellulose when it is exposed to sunlight and air. Oxygen acting in the presence of light greatly increases the rapidity of deterioration.

Ultra-violet transmission through a fabric is greatly decreased when it is dyed or slightly yellowed with age. Bleached cotton material has great transparency to ultra-violet radiation (Hirst, 1928).

APPARATUS USED

A standard Luxor Model Alpine Sun Lamp, with a quartz mercury arc was chosen as the source of light. A Lowinson's Micrometer was used to determine the number of threads per inch.

The thickness of the materials was measured with a Randall Stickney thickness gauge. The average of ten measurements was considered to be the thickness of materials.

The breaking strength determinations were made with a combination Scott Tester, the jaws of which were set three inches apart. Automatic stretch-strain charts made as the fabrics were broken, were used to measure the stretch. The Scott Tester was installed in a room equipped with a Carrier Unit Air Conditioner. A relative humidity of 64 to 66 per cent at a temperature of 69° to

71°F. was maintained.

THE SELECTION AND TREATMENT OF SPECIMENS

Bleached and unbleached sheetings constructed from yarns of approximately the same coarseness were chosen for this experiment. Physical analyses such as thread count, thickness, breaking strength and percentage desizing were made according to methods recommended by Committee D-13 (1930). The stretch was obtained from the automatically made stress-strain curves secured as the fabric was broken.

The fabrics were desized then cut warpwise into strips for testing the tensile strength and stretch of materials. Each specimen was cut six inches long by one and one-fourth inches wide and raveled to a width of one inch. In order that all specimens would be fairly representative of the fabric they were not cut nearer to the selvage than one-tenth the width of the material (Bureau of Standards, 1929).

The prepared specimens were divided into sets consisting of several groups of five strips each. Except during the time of exposure the specimens were kept between folds of filter paper in a darkened room having a

Table 1. Physical Analyses of Fabrics

	Breaking Strength in lbs.		Stretch in inches		Thread Count		Thickness in inches	Width in inches
	Ends	Picks	Ends	Picks	Ends	Picks		
Bleached								
(a)	42.0	37.0	.20	.35	72	60	.011	81.5
(b)	50.4	45.5	.22	.39	77	70	.012	81.0
(c)	53.0	45.0	.26	.42	78	68	.012	82.5
Unbleached								
(a)	39.8	34.2	.40	.32	69	64	.015	82.0
(b)	46.2	45.2	.50	.36	70	74	.016	81.5
(c)	55.7	52.0	.50	.35	78	69	.015	80.5

relative humidity of 64 to 66 per cent at a temperature of 69° to 71°F.

The backgrounds chosen were slate, the floor and dull and highly lustrous materials of white, gray and black. When materials other than the floor were used the specimens were placed directly above the background, otherwise they were suspended 31 inches from the floor. Specimens were exposed against the following backgrounds.

Set I. Controls - specimens unexposed

Set II. White background
1. Dull surface
2. Lustrous surface

Set III. Gray background
1. Dull surface
2. Lustrous surface

Set IV. Black background
1. Dull surface
2. Lustrous surface

Set V. Slate background

Set VI. Without a definite background; sample being suspended 31 inches above the floor.

The dull and lustrous surfaces were of unglazed and highly glazed paper.

Since ultra-violet radiation has a much greater effect on fibers than invisible radiation, each set of specimens was exposed to ultra-violet radiation for definite periods. The first period was for 4 hours, the second for 8 hours and each succeeding one 8 hours longer than the preceding. Thus the actual periods were 4, 8, 16, 24, 32 and 40 hours, with a 16-hour interval between each 8-hour exposure. The 16-hour exposure, therefore, required two days, the 40-hour, five days. During all exposures the lamp was 25 inches above the specimens.

At the completion of each exposure the specimens were returned to the conditioning room for periods of 18 to 20 hours before the tensile strength and stretch were measured.

The pH was determined immediately after the final exposure. A piece of fabric, one and one-half by three inches, was suspended in twenty-five cubic centimeters of distilled water for one hour. The pH of the supernatant liquid was assumed to be that of the fabric.

DISCUSSION OF RESULTS

The extent to which fabrics are weakened by light depends upon a number of factors. The pH of the materials is believed to be one of importance. The pH of the specimens exposed ranged between 4.15 and 6.3, the average for the unbleached being 5.12, the bleached 5.23. The pH of the fabrics exposed against lustrous backgrounds was less than with dull backgrounds. pH values are recorded in Tables 11 and 12.

The weakening of the fibers was measured by the percentage loss in breaking strength, the tensile strength of unexposed specimens being used as the basis for comparison. These data are recorded in Tables 3 to 6. Unbleached specimens lost in tensile strength and stretch more rapidly than did the bleached when exposed over the different backgrounds, as is shown in Figures 1 to 16. This is contrary to the results of investigations made by Cunliffe (1928).

Specimens exposed for a longer period of time showed greater loss in tensile strength with dull backgrounds. When exposed against white backgrounds, specimens were tendered more rapidly than when exposed against other backgrounds. Bleached and unbleached fabrics show the least variation in loss and gain in tensile strength when exposed to ultra-violet radiation without a definite background. Also, the tensile strength of bleached and unbleached specimens showed similar variations when exposed with no definite background; exposures against definite backgrounds showed wide variations. This is graphically illustrated in Figures 1 to 8. The small variations, with no backgrounds, may be due to greater circulation of air and to the elimination of the reflection factor which must be considered when specimens are being exposed close to the background.

Slate, which is the most generally accepted background, causes a marked variation in the stretch and strength of bleached and unbleached specimens. The unbleached showed a definite gain in strength during the 4, 8 and 16 hour periods of exposure (Fig. 7).

The significance of the difference between the mean of controls and of specimens exposed for 32 and 40 hours against different backgrounds was tested by using the formula

$$t = \bar{x} - \bar{x}' \cdot \sqrt{\frac{(n_1 + 1)(n_2 + 1)(n_1 + n_2)}{n_1 + n_2 + 2}} \cdot \frac{1}{\sqrt{s(x - \bar{x})^2 + s(x' - \bar{x}')^2}}$$

$\bar{x}$ and $\bar{x}'$ represent the mean breaking strength of the groups being compared, x and x' the breaking strength of each specimen in the group, n the number of specimens. P, the probability of falling outside the range of $\pm t$, was obtained from the table of t for each value of n. The values of P are recorded in the following table. Those exceeding .02 were not considered significant (Fisher, 1925).

Table 2. Value of P

Background	Bleached		Unbleached	
	Exposed 32 hours	Exposed 40 hours	Exposed 32 hours	Exposed 40 hours
White				
Dull	.078	.010	.010	.010
Lustrous	.775	.900	.368	.084
Gray				
Dull	.023	.049	.010	.010
Lustrous	.290	.011	.042	.163
Black				
Dull	.052	.010	.464	.842
Lustrous	.640	.648	.010	.010
Slate	.282	.328	.192	.174
No Background	.443	.366	.010	.282

At 40-hour periods the specimens showed a more uniform change in stretch than at any other period of exposure. Unbleached specimens exposed over dull and lustrous white background, and all specimens exposed against dull gray background showed a definite gain in stretch during the 40-hour exposure (Tables 7 to 10 and Figs. 9 to 16). The stretch of the bleached specimens exposed against lustrous black backgrounds was the same as that of the controls; all other specimens showed a definite loss in stretch during the 40-hour period of exposure.

Table 3. Tensile Strength, in Pounds, of Bleached Fabrics

Tensile Strength of Unexposed Specimens (a) 37.4 (b) 39.2 (c) 31.7

Hours Exposed	White Background: Dull	White Background: Lustrous	Gray Background: Dull	Gray Background: Lustrous	Black Background: Dull	Black Background: Lustrous	Slate Background	No Definite Background
4	35.0 (a)	38.1 (a)	41.7 (a)	38.1 (b)	37.2 (b)	38.0 (b)	29.2 (c)	31.1 (c)
8	38.8 "	35.0 "	40.7 "	40.0 "	33.2 (a)	40.5 (a)	27.5 "	29.0 "
16	39.0 "	35.9 "	37.3 "	42.0 "	35.0 "	40.2 "	28.2 "	31.2 "
24	37.4 "	34.0 "	36.9 "	38.3 "	31.6 "	35.1 "	29.8 "	31.8 "
32	33.5 "	39.7 (b)	32.3 "	36.9 "	33.7 "	36.5 "	30.9 "	30.1 "
40	27.5 "	39.0 "	33.3 "	36.2 "	30.6 "	36.5 "	30.3 "	30.6 "

Table 4. Tensile Strength, in Pounds, of Unbleached Fabrics

Tensile Strength of Unexposed Specimens (a) 35.4 (b) 44.6 (c) 44.3

Hours Exposed	White Background: Dull	White Background: Lustrous	Gray Background: Dull	Gray Background: Lustrous	Black Background: Dull	Black Background: Lustrous	Slate Background	No Definite Background
4	34.5 (a)	44.5 (b)	39.0 (a)	37.2 (b)	43.0 (b)	43.9 (b)	45.3 (c)	41.8 (c)
8	32.8 "	39.7 "	33.9 "	43.4 "	44.9 "	34.3 (a)	49.2 "	43.7 "
16	32.4 "	42.2 "	32.8 "	42.8 "	42.7 "	33.7 "	51.0 "	43.1 "
24	27.9 "	44.0 "	32.7 "	43.8 "	43.6 "	28.2 "	43.2 "	44.6 "
32	29.6 "	43.0 "	26.8 "	40.6 "	43.6 "	27.1 "	40.9 "	43.0 "
40	29.1 "	47.1 "	27.8 "	42.3 "	44.3 "	28.9 "	40.5 "	41.3 "

(a) Control for specimens
(b) Control for specimens
(c) Control for specimens

Table 5. Percentage Loss in Tensile Strength of Bleached Fabrics

Hours Exposed	White Background		Gray Background		Black Background		Slate Background	No Definite Background
	Dull	Lustrous	Dull	Lustrous	Dull	Lustrous		
4	6.41	-1.87	-11.49	2.80	0.53	3.06	4.90	1.75
8	-3.74	6.41	-8.82	-2.04	11.23	-8.28	1.33	6.48
16	-4.27	4.01	0.26	-7.14	6.41	-7.49	10.99	1.42
24	0.0	9.09	1.06	2.29	15.50	6.50	5.96	-0.31
32	10.42	-1.27	13.63	5.86	9.89	2.40	3.10	5.05
40	26.47	0.51	10.96	7.65	18.18	2.40	4.53	3.34

Table 6. Percentage Loss in Tensile Strength of Unbleached Fabrics

Hours Exposed	White Background		Gray Background		Black Background		Slate Background	No Definite Background
	Dull	Lustrous	Dull	Lustrous	Dull	Lustrous		
4	2.54	0.24	-10.16	16.58	3.52	1.56	-2.92	5.59
8	7.34	10.98	4.23	2.69	-0.67	3.10	-11.11	3.63
16	8.47	5.38	7.34	4.03	4.26	4.80	-14.69	2.81
24	21.18	1.34	7.62	1.79	2.24	20.33	2.51	-0.66
32	16.38	3.58	24.29	8.97	2.24	23.44	7.57	2.91
40	14.97	-5.58	21.47	5.15	0.67	18.36	8.65	6.92

Table 7. Stretch in Inches of Bleached Fabrics

Hours Exposed	White Background: Dull	White Background: Lustrous	Gray Background: Dull	Gray Background: Lustrous	Black Background: Dull	Black Background: Lustrous	Slate Background	No Definite Background
	Stretch of Unexposed Specimens (a) 0.15 (b) 0.21 (c) 0.15							
4	0.12(a)	0.15 (a)	0.13 (a)	0.19 (b)	0.19 (b)	0.17 (b)	0.15 (c)	0.15 (c)
8	0.18 "	0.15 "	0.14 "	0.16 "	0.12 (a)	0.16 (a)	0.12 "	0.13 "
16	0.16 "	0.18 "	0.14 "	0.16 "	0.15 "	0.16 "	0.13 "	0.11 "
24	0.14 "	0.18 "	0.14 "	0.15 "	0.13 "	0.17 "	0.13 "	0.17 "
32	0.12 "	0.18 (b)	0.13 "	0.17 "	0.15 "	0.15 "	0.14 "	0.19 "
40	0.13 "	0.16 "	0.19 "	0.13 "	0.13 "	0.15 "	0.11 "	0.12 "

Table 8. Stretch in Inches of Unbleached Fabrics

Hours Exposed	White Background: Dull	White Background: Lustrous	Gray Background: Dull	Gray Background: Lustrous	Black Background: Dull	Black Background: Lustrous	Slate Background	No Definite Background
	Stretch of Unexposed Specimens (a) 0.31 (b) 0.35 (c) 0.35							
4	0.26(a)	0.35 (b)	0.34 (a)	0.25 (b)	0.41 (b)	0.42 (b)	0.44 (c)	0.31 (c)
8	0.27 "	0.37 "	0.25 "	0.28 "	0.40 "	0.24 (a)	0.37 "	0.35 "
16	0.25 "	0.39 "	0.25 "	0.28 "	0.28 "	0.26 "	0.34 "	0.25 "
24	0.26 "	0.36 "	0.29 "	0.27 "	0.33 "	0.28 "	0.33 "	0.37 "
32	0.25 "	0.35 "	0.28 "	0.27 "	0.36 "	0.24 "	0.31 "	0.39 "
40	0.26 "	0.39 "	0.34 "	0.23 "	0.32 "	0.25 "	0.27 "	0.28 "

(a) Control for specimens
(b) Control for specimens
(c) Control for specimens

Table 9. Percentage Stretch in Bleached Fabrics

Hours Exposed	White Background		Gray Background		Black Background		Slate Background	No Definite Background
	Dull	Lustrous	Dull	Lustrous	Dull	Lustrous		
4	2	0	13	9	-26	19	0	0
8	-2	0	6	23	20	-6	22	13
16	-6	-20	6	23	0	-6	16	25
24	6	-20	6	28	13	-13	16	-13
32	2	14	13	19	0	0	5	-30
40	13	23	-26	38	13	0	25	20

Table 10. Percentage Stretch in Unbleached Fabrics

Hours Exposed	White Background		Gray Background		Black Background		Slate Background	No Definite Background
	Dull	Lustrous	Dull	Lustrous	Dull	Lustrous		
4	16	0	-25	29	-17	-20	-25	14
8	13	-5	19	20	-14	22	-5	0
16	19	-11	19	20	20	16	2	29
24	16	-2	6	24	5	9	5	-57
32	19	22	16	22	-2	22	11	-11
40	16	13	-9	33	8	19	23	20

Table 11. pH of Bleached Fabrics

Hours Exposed	White Background: Dull	White Background: Lustrous	Gray Background: Dull	Gray Background: Lustrous	Black Background: Dull	Black Background: Lustrous	Slate Background	No Definite Background
	pH of Unexposed (a) 5.88 (b) 5.55 (c) 4.90							
4	5.70(a)	6.04 (a)	5.85 (a)	5.40 (b)	5.79 (b)	6.26 (b)	4.40 (c)	4.25 (c)
8	5.80 "	5.65 "	5.40 "	5.65 "	5.80 (a)	5.00 (a)	4.56 "	4.40 "
16	5.60 "	5.51 "	5.09 "	5.90 "	5.86 "	5.41 "	5.00 "	4.45 "
24	5.60 "	5.65 "	5.43 "	6.07 "	5.58 "	5.30 "	4.74 "	5.05 "
32	5.60 "	4.95 (b)	5.14 "	6.30 "	5.60 "	4.55 "	5.40 "	5.03 "
40	5.80 "	4.63 "	5.26 "	6.20 "	6.00 "	5.65 "	5.55 "	5.20 "

Table 12. pH of Unbleached Fabrics

Hours Exposed	White Background: Dull	White Background: Lustrous	Gray Background: Dull	Gray Background: Lustrous	Black Background: Dull	Black Background: Lustrous	Slate Background	No Definite Background
	pH of Unexposed (a) 5.68 (b) 5.90 (c) 5.25							
4	5.60(a)	5.95 (b)	5.65 (a)	5.30 (b)	5.63 (b)	5.51 (b)	4.15 (c)	4.25 (c)
8	5.76 "	5.30 "	5.00 "	5.40 "	6.02 "	5.00 (a)	4.56 "	4.32 "
16	5.91 "	5.29 "	5.04 "	6.07 "	5.40 "	5.30 "	4.50 "	5.35 "
24	5.60 "	5.65 "	5.31 "	6.02 "	5.60 "	4.85 "	4.78 "	5.12 "
32	5.60 "	5.10 "	5.06 "	6.20 "	5.65 "	4.55 "	5.19 "	4.54 "
40	6.00 "	4.95 "	5.15 "	6.20 "	5.16 "	5.76 "	5.42 "	5.10 "

(a) Control for specimens
(b) Control for specimens
(c) Control for specimens

FIGURE 1. (Bleached)

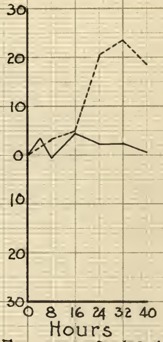


FIGURE 2. (Unbleached)

Black Background

FIGURE 3. (Bleached)

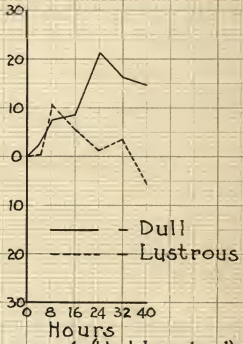


FIGURE 4. (Unbleached)

White Background

PERCENTAGE LOSS IN TENSILE STRENGTH

FIGURE 5. (Bleached)

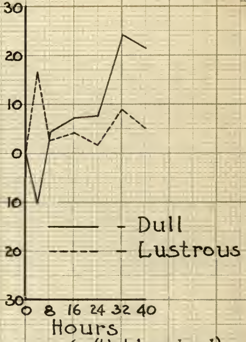


FIGURE 6. (Unbleached)

Gray Background

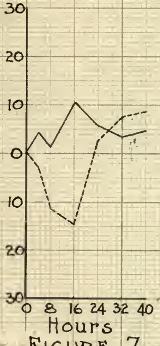


FIGURE 7.
Slate Background

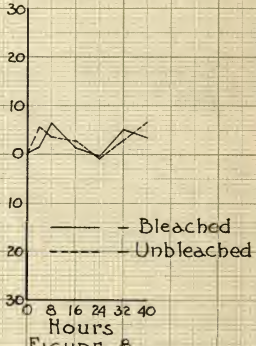


FIGURE 8.
No Definite Background

PERCENTAGE LOSS IN TENSILE STRENGTH

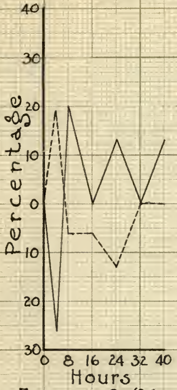


FIGURE 9. (Bleached)

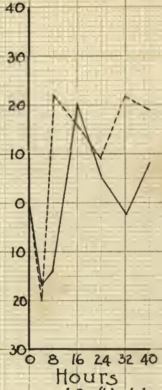


FIGURE 10. (Unbleached)

Black Background.

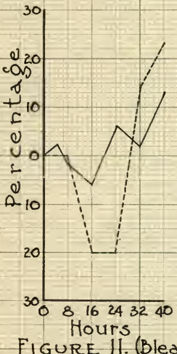


FIGURE 11. (Bleached)

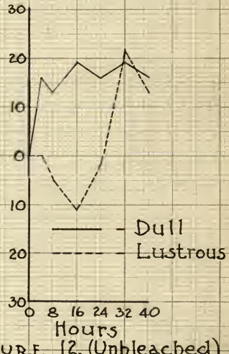


FIGURE 12. (Unbleached)

White Background

PERCENTAGE LOSS IN STRETCH

FIGURE 13. (Bleached)

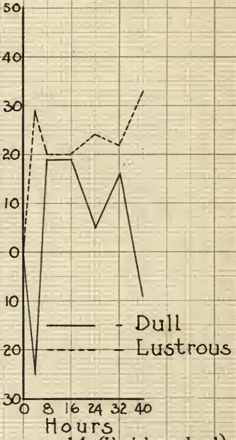
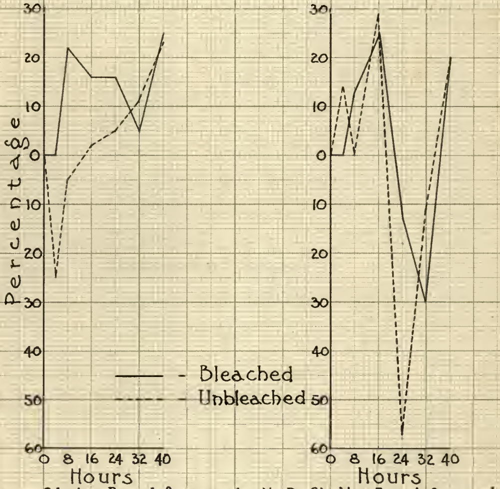


FIGURE 14. (Unbleached)

Gray Background

PERCENTAGE LOSS IN STRETCH



Slate Background — Figure 15.

No Definite Background — Figure 16.

PERCENTAGE LOSS IN STRETCH

SUMMARY

1. Specimens exposed against white backgrounds were tendered more rapidly than those exposed against other backgrounds.

2. Long periods of exposure against dull backgrounds caused the greatest loss in tensile strength.

3. Specimens exposed to ultra-violet radiation without a definite background showed the least variation in loss and gain in tensile strength.

4. When exposed without a definite background the changes in tensile strength of bleached and unbleached materials were more nearly parallel.

5. No agreement was apparent between the pH, tensile strength and stretch of the exposed specimens.

ACKNOWLEDGMENT

The writer wishes to express her appreciation to Professor Esther Bruner for directing this study.

LITERATURE CITED

Barr, Guy.
Action of light on textiles. Chem. Abs., 18: 2607. 1924.

Brugmann, E. W., Turner, L. B., and Philips, J. B.
Action of sunlight on cotton. Text. World, 79: 1553. 1931.

Bureau of Standards.
General specifications for textile materials. Dept. of Commerce, Washington, D. C., 3 p. 1929.

Committee D-13 on Textile Materials.
Specifications and methods of testing for textile materials. Philadelphia. A. S. T. M., 122 p. 1930.

Cunliffe, P. W., and Farrow, F. D.
The loss of strength of cotton exposed to light. Jour. Text. Inst., 19, Pt. 2: 169-181. 1928.

Doree, Charles, and Dyer, Joseph W.
Some effects of the action of ultra-violet light on cotton fabrics. Chem. Abs., 11: 1753. 1917.

Fisher, R. A.
Statistical methods for research workers. London. Oliver and Boyd, 109 p. 1925.

Heerman, P., and Sommer, H.
The influence of ultra-violet rays on strength properties of fibre materials. Jour. Text. Inst., 20: A54. 1929.

Hirst, H. R., King, P. E., and Lambert, P. H.
Ultra-violet fabric penetration. Text. World, 74: 2299. 1928.

McEwen, Joseph L.
Some effects of ultra-violet light upon certain articles and colors. Amer. Dyestuff Rept., 21: 337-338. 1932.

Stockbarger, D. C.
Some characteristics and uses of ultra-violet.
Amer. Dyestuff Rept., 19: 586-587. 1930.

Ultra-violet Reflection Factors.
Management Methods, 61: 628. 1932.