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THE EFFECT OF CERTAIN LIGHT RAYS UPON WEIGHTED AND UNWEIGHTED SILK FABRICS

By

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INTRODUCTION

Silk materials on the market today often fail to render the service which the consumer desires. This lack of durability may be attributed to the combined action of serveral factors. Certain of these, such as weighting and reagents used in cleaning processes are controllable. Other conditions, such as mechanical abrasion, perspiration, and exposure to atmospheric moisture and light are less easily regulated. Investigators have studied the effect upon silk of a number of these factors. They have found that the kind and amount of weighting influences the durability of the fabrics (Heerman, 1927 and Stockhausen, 1930). Drycleaning solvents alone do not cause any appreciable deterioration of the silk, but the temperature at which the material is pressed often destroys it entirely. Under certain conditions the drycleaning soaps may be precipitated on the fabric and cause a decoloration of the fabric (Hubbard, 1928). Perspiration, both human and synthetic, is known to be destructive to silk especially that which contains weighting (Trotman, 1929 and Cormany, 1932). Ultraviolet radiation, or light rays of shorter wave lengths, cause a definite weakening of fibers; in the presence of moisture this tendering increases (Heerman, 1927). It seemed desirable to investigate the effect of other light waves upon silk. The purpose of this experiment was to determine, if possible, the effect of certain light rays, other than the ultra-violet, upon weighted and unweighted silk fabrics.

REVIEW OF LITERATURE

The deterioration of fabrics by light did not attract much attention until the beginning of the World War. With the advent of the airplane and airship some means had to be devised to protect the lightweight materials used in their construction from the action of light. Since then a number of investigations have been made to determine the amount of deterioration caused by light rays. Light was found to be the most important factor causing the weakening of airplane fabrics (Turner, 1920). Dorse (1917) attributes this destructive quality of sunlight to the presence of ultra-violet rays, acting alone or in conjunction with ozone produced during radiation. Other authorities are of the opinion that ozone which is developed acts strongly upon the fibers in the presence of moisture. According to Johnson (1927), Heerman believed that the deterioration was due to the action of ultra-violet rays alone.

Visible light is made up of rays of the magnitude 4000 to 8000 Angstrom units. The colors of the ordinary spectrum, red, orange, yellow, green, blue, indigo, and violet, taken together make up the visible light, that is, light of such frequency and wave length that it registers upon the retina of the eye. The longest rays of light that the eye can detect are at the red end of the spectrum, while the shortest ones are at the violet end. Any ray of light whose wave length is approximately less than 4000 or greater than 8000 Angstroms is invisible. The ultra-violet spectrum is an invisible area having wave lengths below 4000 Angstrom units (McEwen, 1932).

Heerman found that both unweighted and weighted silks were affected by light and that loss in strength of weighted silk depended upon the amount of weighting. Results of recent work (Cormany, 1932) indicate that both pure silk and weighted silk are affected by ultra-violet radiation and by perspiration. According to Stockhausen (1930) the kind of weighting used for silks may make a difference in its resistance to light. He found that the tensile strength of silk weighted with a tin or tin-phosphate was less when exposed to light than when weighted with tin-phosphate-silicate. He is of the opinion that the crystalline structure of the stannic acid plays an important part in weakening silk fabrics.

The pH of the silk cloth is believed to be an important factor in the weakening of silk exposed to light. Harris and Jessup (1931) found that the maximum stability of silk is about pH 10; above pH 11 and below pH 3 the stability decreases rapidly. They also found that in the neutral region, pH 6 to 8, silk is less resistant to light than when it is more acid or alkaline. Mahin (1932) defines pH as the reciprocal log of the hydrogen ion concentration expressed in grams per liter. In other words the hydrogen ion concentration and measurement is a simple means of expressing the acidity or alkalinity of a solution, the scale being set out in the pH values. On this scale pH 7 represents complete neutrality, that is, the solution is neither acid nor alkaline. Values above pH 7 represent alkalinity, and those below 7, acidity.

The pH value of a solution is measured either electrically or by comparison with colored standards. The electrical method, a direct means for measuring acidity or alkalinity, consists in measuring the electromotive force, or voltage, developed at suitable electrodes immersed in the solution to be tested. One colorimetric method is based on the use of indicators. These indicators do not show whether a solution is acid or alkaline, for their range does not cover absolute neutrality, or pH 7. In another method the color of the solution is compared with a colored glass standard. The pH value of the solution under test can be read off directly, without any calculations (Mann,1933).

Harris (1932) assumes that the isoelectric point of silk, that is, the point at which the particle is electrically neutral with respect to its surrounding medium, is pH 2.5. He further states that because of this low isoelectric point, silk is one of the most acid proteins known. This is in accordance with some of the properties of silk, for Meunier and Rey (Harris,1932) found silk to contain only seven parts of amino nitrogen per ten thousand. The pronounced affinity of silk for basic dyestuffs is further confirmation of its acidic nature.

Shelton (1930) believes the changes which occur when a textile fiber is exposed to the ultra-violet rays are dependent upon the physical and chemical structure of the fiber. Silk is one of the strongest fibers, but it is easily affected by light radiation. Studies conducted by Heerman and Somner (1929) show that ultra-violet rays affect the tensile strength of silk more than other textile fibers. They attribute this to the fineness of the fiber since the fine filaments, which are from 0.004 to 0.008 inches in diameter (Johnson, 1927), are easily penetrated by light rays. Yarns made from silk filaments are usually fine and would, therefore, be affected by light rays to a greater extent than coarse ones (Barr, 1924).

EXPERIMENTAL PROCEDURE

Materials and Apparatus

Silk fabrics were obtained from the research laboratories of Cheney Brothers. One portion of a plain woven, undyed silk crepe was degummed; another piece was degummed and weighted by the tin-phosphate-silicate method to 35.98 per cent (Mease, 1932).

Physical analyses of the fabrics were made according to the specifications recommended by the American Society for Testing Materials (1930). The breaking strength determinations and the stretch of the fabrics were made with a Combination Scott Tester. Thickness was measured with a Randall and Stickney's thickness gauge. A Lowinson's Micrometer was used for counting the threads. The results of these analyses are given in Table 1.

Table 1. Analyses of Silk Fabrics

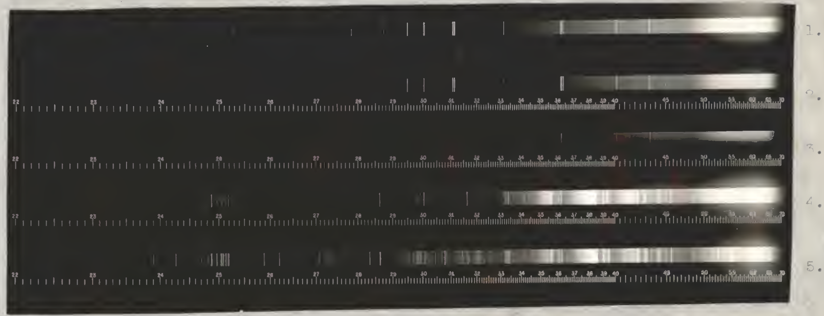
	Unweighted Silk	Weighted silk
Breaking strength in pounds		
Ends	18.10	17.30
Picks	52.92	59.17
Stretch in inches		
Ends	0.68	0.79
Picks	0.62	0.58
Thread count		
Ends	181	194
Picks	77	81
Thickness in inches	.0065	.0095
Width in inches	39.25	37.00
Percentage weighting	.00	35.98

The pH of the materials was measured on a Cenco Hydrogen Ion Concentration Apparatus by means of the quinhydrone electrode. A Bausch and Lomb Universal Spectrophotometer was used for measuring the degree of yellowing of the fabrics.

An S-2 Sun Lamp of approximately 350 candle power was chosen as the source of light. It 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.

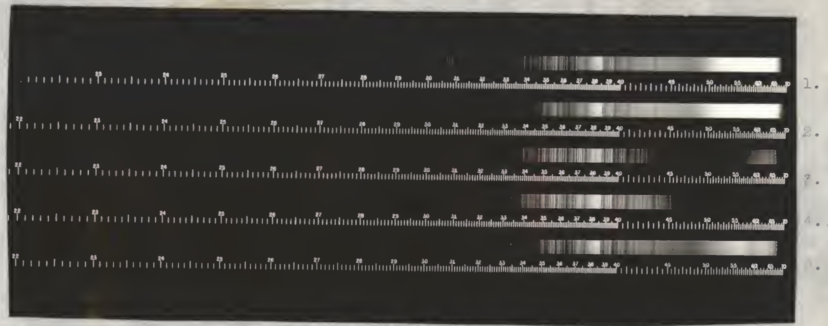
Filters were used to exclude rays of certain wave lengths. Before selecting them spectograms were made with a Bausch and Lomb Spectrometer of the S-2 Sun Lamp, a carbon arc rich in ultra-violet rays, and the carbon arc screened by colored cellophanes or glasses. These spectrograms showed that yellow, violet and blue cellophane filters, and window glass allowed practically all of the wave lengths to be transmitted. Since the blue and violet glass excluded nearly the same wave lengths, the latter was used. Red and green cellophane, orange, green, red, yellow, cobalt, and violet glass filters excluded rays of different wave lengths and were therefore selected for the experiment. The wave lengths for these filters are given in Table 2. Spectrograms of the filters are shown in Plates I to IV.

Plate I



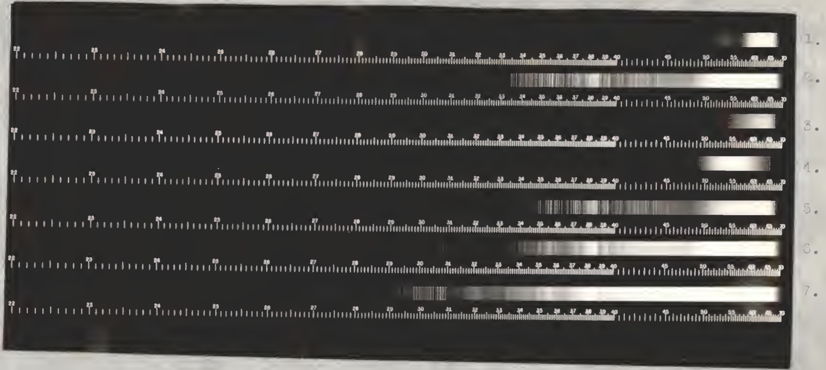
1. S-2 Sun Lamp
2. S-2 Sun Lamp
3. S-2 Sun Lamp
4. Carbon Arc
5. Carbon Arc

PLATE I



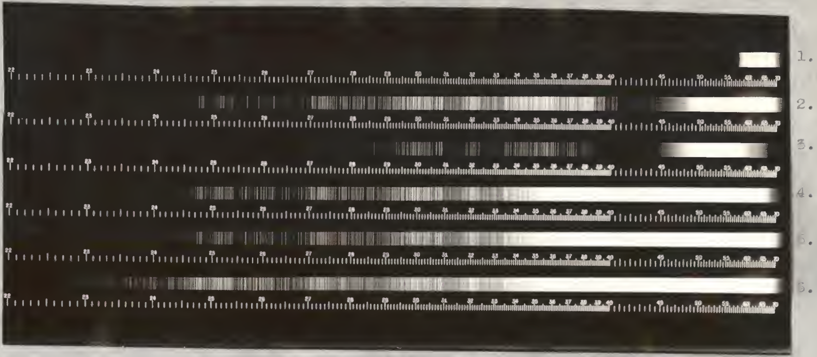
1. Carbon arc
2. Window glass
3. Violet glass
4. Cobalt glass
5. Blue glass

Plate III



1. Red Glass
2. Yellow Glass
3. Orange Glass
4. Green Glass
5. Window Glass
6. Carbon Arc
7. Carbon Arc

PLATE IV



1. Red Cellophane
2. Yellow Cellophane
3. Green Cellophane
4. Blue Cellophane
5. Violet Cellophane
6. Carbon Arc

Table 2. Wave Length of Light

	Angstrom units
Sun lamp	2530 to 5750
Yellow glass	3070 to 5750
Cobalt glass	3200 to 4700
Violet glass	3260 to 4550 and 5200 to 5750
Red glass	3400 to 5750
Red cellophane	3900 to 4150 and 5200 to 5750
Green glass	4600 to 5750
Green cellophane	4850 to 5750
Orange glass	5150 to 5750

Treatment of Specimens

The materials were cut into warpwise strips according to the specifications for testing tensile strength. These are recommended by the American Society for Testing Materials (1930) and by the Bureau of Standards(1929). The pH determinations were made on warpwise strips three inches by five-eights of an inch. The specimens were kept between folded sheets of white filter paper in a darkened conditioning room except during time of exposure.

The prepared specimens were divided into sets. Set I consisted of untreated specimens of the two materials which were used as controls. Sets II to X were exposed to light rays of different wave lengths.

Set II. Exposed to direct rays of the S-2 Sun Lamp.

Set III. Exposed to the rays of the S-2 Sun Lamp using red cellophane as a filter.

Set IV. Exposed to the rays of the S-2 Sun Lamp using green cellophane as a filter.

Set V. Exposed to the rays of the S-2 Sun Lamp using orange glass as a filter.

Set VI. Exposed to the rays of the S-2 Sun Lamp using green glass as a filter.

Set VII. Exposed to the rays of the S-2 Sun Lamp using red glass as a filter.

Set VIII. Exposed to the rays of the S-2 Sun Lamp using yellow glass as a filter.

Set IX. Exposed to the rays of the S-2 Sun Lamp using Cobalt glass as a filter.

Set X. Exposed to the rays of the S-2 Sun Lamp using violet glass as a filter.

Sets II to X were subdivided into groups of three specimens each for testing the breaking strength and one specimen each for making the pH determinations. These were exposed to light rays for definite periods, the length of time varying:

A. Exposed for 24 hours.

B. Exposed for 32 hours.

C. Exposed for 40 hours.

D. Exposed for 48 hours.

E. Exposed for 56 hours.

F. Exposed for 72 hours.

In order to keep conditions as nearly uniform as possible the experiment was performed in a conditioned room with a relative humidity of 64 to 66 per cent at a temperature of 69° to 71°F. Specimens were placed between folded sheets of filter paper and placed in the room at least two hours before exposure. During the exposure the temperature of the air immediately above the samples was five degrees higher than the air of the room. The lamp was adjusted eighteen inches above the specimens which were suspended, horizontally, by wooden clips on a string framework one inch above a background of white filter paper. Filters were placed directly over the specimens.

The pH was determined immediately after each exposure by suspending the small piece of fabric in fifteen cubic centimeters of distilled water for one hour. The pH of the supernatant liquid was considered to be that of the fabric. The average of three readings is recorded in Table 3.

Exposed specimens were placed between folded pieces of filter paper and kept in the darkened conditioning room at

Table 3. pH of Exposed Fabrics

Unweighted -- pH unexposed 5.20

Hours exposed	Sun lamp	Red cellophane	Green cellophane	Orange Glass	Green glass	Red glass	Yellow glass	Cobalt glass	Violet glass
24	6.15	4.77	5.86	5.50	5.86	5.42	5.70	5.34	5.30
32	6.26	5.45	5.55	5.97	5.55	5.97	5.81	5.99	5.90
40	6.25	4.86	6.00	5.15	5.36	5.46	5.39	5.10	5.13
48	6.19	5.34	4.81	5.30	4.60	5.51	5.55	5.40	5.35
56	5.23	5.11	5.15	5.45	5.30	5.00	5.17	5.64	5.40
72	5.37	5.13	5.00	5.95	5.75	5.80	5.25	5.60	5.85

Weighted -- pH unexposed 6.25

Hours exposed	Sun lamp	Red cellophane	Green cellophane	Orange glass	Green glass	Red glass	Yellow glass	Cobalt glass	Violet glass
24	7.05	6.28	6.65	5.85	6.10	6.07	6.24	6.25	6.40
32	7.28	5.97	6.12	6.45	6.65	6.89	6.21	7.00	5.86
40	7.26	6.18	6.14	6.55	6.77	6.16	6.17	7.20	6.84
48	7.26	6.37	6.55	6.81	6.69	5.80	6.65	6.40	6.25
56	5.87	5.96	6.30	6.55	6.97	6.74	5.85	5.87	6.31
72	6.71	6.50	6.02	6.30	6.35	6.25	6.11	6.70	6.96

least four hours before the tensile strength and stretch tests were taken. The average breaking strength of three specimens was considered to be that of the fabric. The stretch of the specimens was automatically recorded when the tensile strength was determined.

DISCUSSION OF RESULTS

The extent to which silk is weakened by light depends upon a number of factors. Indications are that the pH of the silk cloth is one important factor. In general the pH of the unweighted silks was below 6, and that of the weighted silks was slightly above 6. Harris and Jessup (1931) found that silk was less resistant to light in the neutral region, pH 6 to 8. Therefore, the unweighted fabric should be more resistant to the effect of light. The breaking strength substantiates this supposition. The pH of the specimens exposed to the direct rays of the sun lamp was slightly higher than with any of the filters in both the unweighted and weighted fabrics. In general the pH of the specimens exposed to the direct rays of the sun lamp was in the neatral region of pH 6 to 8. This may be significant, for greater yellowing of fabrics occurred with the sun lamp.

The weakening of the fibers was measured by the percentage loss in breaking strength. The untreated materials were used as a basis for comparison with the treated specimens of the same fabric. The tensile strength and the percentage loss in tensile strength are recorded in Tables 4 and 5. In general a definite loss in tensile strength was apparent for both materils after being exposed to the direct rays of the sun lamp for 24 hours. This loss was followed by a decided gain for the weighted silks at approximately the 40 hour exposure. Then a well defined loss was apparent at the 48 to 56 hour periods of exposure, followed by another slight increase and finally a gradual decrease. The unweighted fabrics gained in strength at the 32 to 40 hour periods of exposure, then gradually lost after the 40 hour period. The trend for both of the materials was downward but less for the unweighted fabrics than for the weighted.

These alternate losses and increases in tensile strength are similar to the results reported in former experiments carried out here and at the Ohio Experiment Station (1931). These fluctuations may be due to the intermolecular rearrangement of the protein molecule.

Filters appeared to retard the action of the light rays about eight hours. The longer and intermediate wave lengths caused more fluctuations in tensile strength of both fabrics; the shorter wave lengths caused a steady loss. A graphic comparison of fabrics exposed to the sun lamp with and without the various filters is shown in figures 1 to 3

Table 4. Tensile Strength in Pounds of Exposed Fabrics

Unweighted -- Tensile Strength of unexposed 52.92 lbs.

H Hours Exposed	:Sun :lamp	:Red :cellophane	:Green :cellophane	:Orange :glass	:Green :glass	:Red :glass	:Yellow :glass	:Cobalt :glass	:Violet :glass
24	49.50	51.33	45.20	52.00	51.50	52.50	49.67	51.33	52.50
32	52.06	51.50	50.37	52.33	52.50	51.83	49.70	51.83	50.50
40	50.43	50.73	52.67	48.33	50.17	49.90	52.67	54.00	53.83
48	50.83	55.50	47.33	51.33	50.67	50.00	51.07	52.00	52.37
56	47.67	50.83	49.17	50.77	52.00	50.17	53.67	50.00	50.67
72	49.83	47.93	50.50	49.93	50.00	49.67	50.20	49.00	51.40

Weighted -- Tensile Strength of unexposed 59.17 lbs.

Hours exposed	:Sun : lamp	:Red :cellophane	:Green :cellophane	:Orange :glass	:Green :glass	:Red :glass	:Yellow :glass	:Cobalt :glass	:Violet :glass
24	52.90	49.50	50.33	52.60	53.73	52.00	54.83	58.00	59.17
32	55.47	56.67	52.73	56.67	57.33	57.17	57.67	56.50	56.00
40	51.40	56.47	55.16	59.83	60.83	60.17	58.23	56.00	56.00
48	53.33	58.33	52.73	54.00	54.33	57.47	55.50	57.17	57.27
56	50.87	55.00	50.00	61.07	56.17	58.00	56.87	55.50	53.33
72	49.33	53.33	53.90	59.50	54.73	54.27	57.87	55.77	55.33

Table 5. Percentage Loss in Tensile Strength

Unweighted

Hours exposed	Sun lamp	Red cellophane	Green cellophane	Orange glass	Green glass	Red glass	Yellow glass	Cobalt glass	Violet glass
24	6.46	3.01	14.59	1.76	2.68	0.79	6.14	3.00	0.79
32	1.63	2.68	4.82	1.11	0.79	2.06	6.08	2.05	4.57
40	2.82	4.14	0.47	8.67	4.66	5.71	0.47	-2.04	-1.71
48	3.95	4.88	10.56	3.00	4.25	5.51	3.50	1.73	1.03
56	9.92	3.95	7.09	4.06	1.74	5.20	-1.42	5.51	4.25
72	5.84	9.43	4.57	5.65	5.51	6.14	5.14	7.40	2.87

Weighted

Hours exposed	Sun lamp	Red cellophane	Green cellophane	Orange glass	Green glass	Red glass	Yellow glass	Cobalt glass	Violet glass
24	6.21	12.33	10.76	6.74	4.73	7.80	2.78	1.98	0.00
32	1.65	4.22	6.51	4.23	3.11	3.38	2.54	4.51	5.35
40	4.96	-0.12	2.20	-1.12	-2.81	-1.69	1.59	5.35	5.35
48	5.44	-3.40	6.51	8.74	8.18	3.38	6.12	3.38	3.21
56	9.80	2.48	11.35	-3.21	5.07	1.98	3.89	6.20	9.70
72	12.54	5.44	4.43	-0.56	7.33	8.28	2.20	5.74	6.49

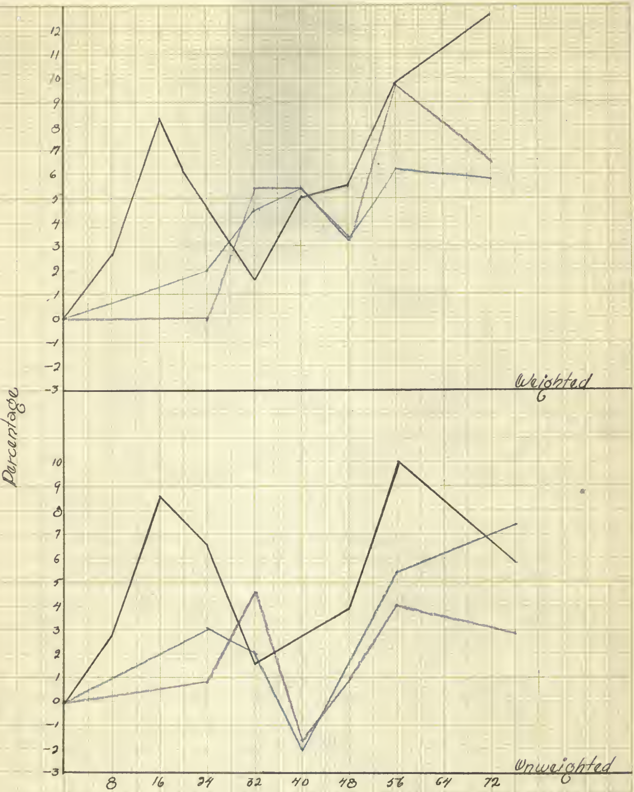


Figure I - Percentage Loss of Breaking Strength

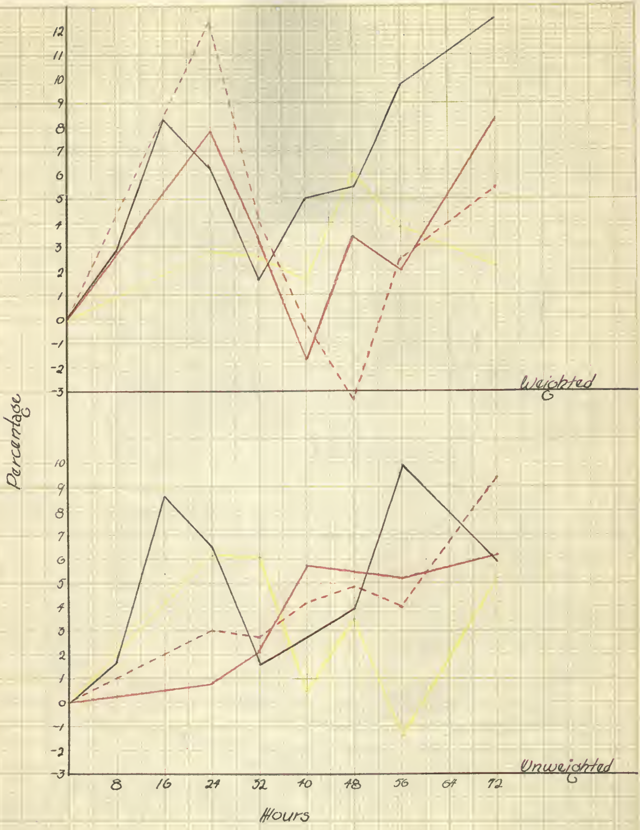


Figure 2 - Percentage Loss of Breaking Strength

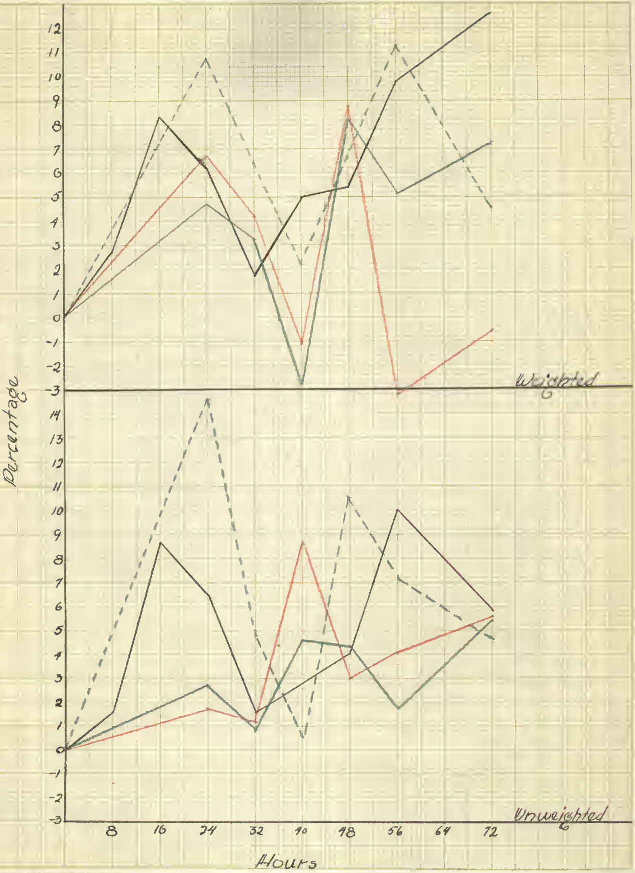


Figure 3 - Percentage Loss of Breaking Strength

inclusive. Continuous colored lines represent glass filters of that color; broken colored lines indicate the cellophane filters of the same color.

Weighted specimens exposed to the direct rays of the sun lamp showed a decided loss in stretch. This was rapid during the 24 hour period, gradual to the 32 hour period. At the 40 hour period there was a slight gain over the 32 hour period, followed by a rapid decrease through the 72 hour exposure. The trend for the unweighted specimens was similar to the weighted, but the loss was less marked. The decrease in stretch of the unweighted silks was more rapid without filters but was less rapid than that of the weighted ones. The amount of stretch is recorded in Table 6. Figures 4 and 5 show a graphic comparison of the materials exposed to the sun lamp with and without the various filters. Continuous colored lines represent the effect on materials of light passing through glass filters of that color; broken colored lines indicate the effect of light passing through cellophane filters of the same color.

As spectrophotometric analyses failed to indicate the degree of yellowing of the originally white specimens, a visual comparison of the specimens was made. Specimens exposed to the direct rays of sun lamp were more yellow than those exposed to filtered rays. Weighted silk became slightly yellow after the 24 hour exposure; yellowing gradually

Table 6. Percentage Stretch of Exposed Fabrics

Unweighted

Hours exposed	Sun lamp	Red cellophane	Green cellophane	Orange glass	Green glass	Red glass	Yellow glass	Cobalt glass	Violet glass
24	14.71	-11.76	-1.47	-5.88	0.00	-4.41	2.94	5.88	4.41
32	2.94	- 4.41	-1.47	.00	-1.47	-1.47	10.29	-5.88	-1.47
40	-2.94	- 8.82	.00	2.94	-2.94	-2.94	-1.47	-2.94	2.94
48	7.35	- 7.35	-2.94	-1.47	-7.35	.00	-2.94	.00	2.94
56	4.41	- 7.35	-1.47	-1.47	-5.88	2.94	-5.88	-1.47	-1.47
72	14.70	- 8.82	7.35	-1.47	.00	-2.94	-1.47	-1.47	.00

Weighted

Hours exposed	Sun lamp	Red cellophane	Green cellophane	Orange glass	Green glass	Red glass	Yellow glass	Cobalt glass	Violet glass
24	20.93	3.48	10.46	2.32	-2.32	3.48	0.00	7.59	2.53
32	22.09	-2.53	-2.53	1.26	-6.32	1.26	-6.32	3.79	7.59
40	17.44	3.48	10.46	3.79	12.65	5.06	8.86	-2.53	-1.26
48	18.60	3.48	3.48	2.53	1.26	-1.26	3.79	.00	-2.53
56	19.76	4.65	15.11	3.79	12.65	8.86	7.59	5.06	11.39
72	31.39	6.97	13.95	-5.06	-2.53	-1.26	-2.53	-2.53	2.53

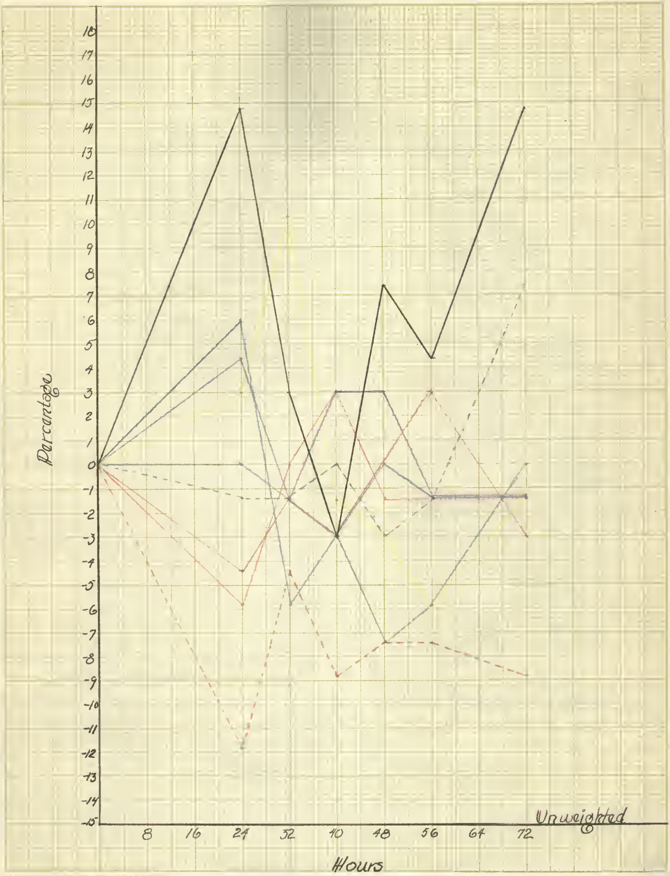


Figure 4 - Percentage Stretch of Fabrics

Figure 5 - Percentage Stretch of Fabrics

increased through the 72 hour period. The yellowing of unweighted silk was not noticeable until after 40 hours of exposure, with a gradual increase through the 72 hour period. At no time was the degree of yellowing in the unweighted silk as great as that of the weighted silk for the corresponding period.

Filters reduced the yellowing of the weighted silk somewhat. Glass filters apparently excluded more light rays for yellowing under them was less than in the materials under cellophane filters. The change in color was about the same for all colored glass filters used. Color of the unweighted fabrics was practically unchanged with filtered rays.

This yellowing of silk fabrics is probably due to the oxidation of the protein. The direct rays of the sun lamp appeared to cause more rapid yellowing, or oxidation, than the filtered rays.

CONCLUSIONS

1. Rays from the S-2 Sun Lamp which fell between 5750 and 2530 A. caused the greatest change in tensile strength, stretch, pH, and color.
2. Specific filters did not show sufficient variation to conclude which rays are most destructive.

3. Silk fabrics exposed to direct rays of the sun lamp were tendered to a greater extent than when exposed to filtered rays.
4. The weighted silk showed a greater loss in tensile strength than the unweighted silk.
5. Direct rays of the sun lamp caused the greatest percentage loss in stretch. The weighted silk lost more than the unweighted.
6. Silk fabrics were yellowed more by direct rays of sun lamp than by filtered rays.
7. The weighted silk was yellowed to a greater extent than the unweighted.

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