REPORT No. 39.

THE TESTING OF BALLOON FABRICS.

PART I.—Characteristic Exposure Tests of Balloon Fabrics.

PART II.—Use of Ultra-Violet Light for Testing Balloon Fabrics.

PART I.

CHARACTERISTIC EXPOSURE TESTS OF BALLOON FABRICS.

By Junius David Edwards and Irwin L. Moore.

1. INTRODUCTION.

The determination of the probable life of a balloon fabric in service by experimental means is of the greatest value in choosing the most suitable fabrics for a given purpose and in pointing the way to improvements in compounding and construction. The usefulness of exposure to the weather for this purpose has been amply demonstrated. Various attempts have been made to reproduce by artificial means the conditions promoting deterioration in service, but without marked success. Exposure to the weather remains the most satisfactory method for this purpose, and a consideration of the characteristics of such tests is therefore important. The results of a typical series of exposure tests made in 1917 and their significance were discussed by Edwards, Tuttle, and Walen in the Third Annual Report of the National Advisory Committee.[1] Since that time a large number of tests have been completed and furnish the basis for more detailed conclusions.

2. COMPARISON OF FABRIC DETERIORATION WITH WEATHER CONDITIONS.

The chief difficulty in the interpretation of the results of exposure tests lies in the fact that the conditions of test are not entirely under control and not exactly reproducible. This difficulty may be largely overcome, however, if sufficient data are obtained regarding the rate of deterioration and the weather conditions. Furthermore, by simultaneous exposure of fabrics whose characteristics are known, very satisfactory comparative results may be secured. With this in view we have made a study of exposure results obtained at Washington during the period of July, 1917, to September, 1918, and also at Pensacola, Fla., during the four months period beginning December 25, 1917.

The exposures at Pensacola were made at the United States naval air station at the suggestion and with the cooperation of the Bureau of Construction and Repair of the Navy Department. The exposures at Washington were made at the Bureau of Standards. The fabrics for exposure were mounted on frames with a southern exposure running east and west and inclined at an angle of 10° to the horizontal to allow rain to drain off quickly. The details of the methods of test are described in the Third Annual Report, National Advisory Committee for Aeronautics, 1917; a more extended description of the method of determining permeability is contained in Bureau of Standards Technologic Paper No. 113.

[1] Third Annual Report, National Advisory Committee for Aeronautics, 1917, p. 459.

The results of a number of such tests are given in figures 1 to 8. In these figures both the permeability at 25° in liters of hydrogen per square meter per 24 hours and the percentage of acetone extract are plotted as ordinates on the same scale. The solid lines indicate the permeability and the broken lines the acetone extract. The period of exposure is given in the legend. Permeabilities of 50 and over, which may be considered excessive, are indicated by arrows; these mark the period of complete deterioration.

The temperature conditions prevailing during these tests are shown in figure 9. The ordinates plotted are the averages by weeks of the daily mean temperatures. A smooth curve has been drawn to give an approximate idea of the temperature gradient. The curve for the average maximum temperature is roughly parallel to the curve as given, but is about 10° higher in summer and 5° higher in winter. This information has been furnished by the Weather Bureau from measurements made at their stations at American University, Washington, D. C., and at Pensacola, Fla.

A study of the data in these figures leads us to estimate that the rate of increase of acetone extract of fabrics exposed at Pensacola during the winter months (December to March) is about 1.5 to 2 times as rapid as in the case of exposures made at Washington during the same period. The times required to show complete deterioration as evidenced by an excessive permeability stand also in about the same ratio. The rate of deterioration in summer at Washington is about three times as rapid as during the winter at the same place. Except in the rate of deterioration no very characteristic differences between summer and winter exposure have been noted.

As would be expected, the rate of deterioration increases with increase of temperature, but the increase is not uniform. Passing from winter to summer, the rate of deterioration shows a sharp increase in May and June. At this period, which may be regarded as critical, the mean temperature is about 70° F. The last 30 days of the Pensacola exposure showed the beginning of this period of rapid increase.

A more significant factor to examine than temperature is the variation of solar radiation for different periods, since light is an important if not the chief deteriorating agent in exposure tests. However, the curve for solar radiation at Washington follows in a general way the temperature curve. The variations in the intensity of the solar radiation are considerably greater than is the case with the mean temperature, because cloudy weather has a more marked effect in reducing the solar radiation. Attention may be called to the fact that the solar radiation reached approximately its maximum as early as April and May. Unfortunately no radiation measurements were made at Pensacola. There is not much additional information to be gained from inspection of the radiation data.

The question of the strength of fabrics after exposure has been discussed by Walen in the third annual report,[1] and further treatment here is unnecessary. The effect of aging upon the strength of fabrics has been followed throughout the exposure by means of bursting strength determinations. This method was used in preference to tensile strength tests because the results of the latter are frequently misleading. So long, however, as the durability of the cloth is greater than that of the rubber, the strength tests are of secondary importance.

3. CHARACTERISTIC CHANGES IN PERMEABILITY AFTER EXPOSURE.

Examination of the results of a large number of permeability tests after exposure reveals certain facts which are characteristic of such tests. It was pointed out in the third annual report (p. 461) that the aging of the fabric is usually accompanied by a decrease in permeability. This decrease is characterized by a hardening or stiffening of the rubber, which causes the gas retaining rubber film to crack when wrinkled. In order to detect this condition, all exposed samples are wrinkled before determining their permeability.

It will be noted that in figures 5, 6, and 7 the permeability rises immediately after exposure, usually reaching a maximum after about 30 days; the permeability then decreased as the

[1] Third Annual Report, National Advisory Committee for Aeronautics, 1917, p., 466, 1917.

aging continued. The results of 95 exposure tests were examined to determine the percentage of cases in which this occurred. Of this number, the permeability decreased from the start in 43 cases; in the remaining 52 tests the permeability increased immediately after exposure. The maximum increase was noted at 30 days in 37 of these tests, at 60 days in 10 tests, and 90 days in 5 tests. In the cases where the permeability increased this increase was later followed by the customary decrease and hardening of the rubber compound in the fabric.

Speculation as to the cause of this behavior has led to no definite conclusions. The explanation may lie in the fact that for some time after vulcanization the various components of the rubber compound have not yet reached chemical and physical equilibrium. It is a common occurrence, for example, to have some of the sulphur crystallize out from solid solution and "bloom" out on the surface of new fabrics. It may be that some such change as this temporarily increases the permeability, after which the oxidation processes which cause the decrease in permeability show their effect. The increase in permeability may take place in the majority of cases, but the times of testing are not such as to detect it. The fabric shown in figure 4 always showed a decrease in permeability after exposure. The permeability of the original piece ran uniformly about 15.4 liters during the first few months after manufacture; a year later the permeability of the unexposed fabric had risen to 19.2 liters. Similar increases on storage are evident in figures 1 and 2. The fabrics were stored under ideal conditions. A great many ideas as to these changes have been considered, but the data at hand are not sufficient to confirm them. It will require further investigation designed to settle specific points before any definite conclusions can be reached. It is to be noted, however, that in the tests so far made the behavior of the fabrics in this respect is apparently a property of the fabric, that is, the same phenomenon has been noted in all exposures of the same fabric.

4. CHARACTERISTIC CHANGES IN ACETONE EXTRACT AFTER EXPOSURE.

As previously pointed out by Tuttle,[1] normal ageing of balloon fabrics is accompanied by a slow and uniform rise in the acetone solubility of the rubber compound, while serious deterioration is marked by a rapid increase in the acetone extract. This offers an excellent means of tracing the deterioration of a fabric. Depending on the weight of the fabric and the composition of the rubber compounds, the acetone extract in the original sample will usually vary from 0.7 to 3 per cent. When the permeability has become excessive, the acetone extract has usually risen above 15 per cent; no definite figures can be given, however, since the rate of increase is the significant factor. During long and severe exposures the acetone extract reaches a maximum, after which there may be a slight decrease due, presumably, to the production of acetone insoluble products formed from those previously soluble. (See figs. 4 and 6, for example.)

The acetone extract is the best test available for determining the condition of the rubber in empannage fabrics, because the fabrics are not constructed to be gas tight and no permeability tests are made on them. In certain two-ply fabrics the acetone extract has been found normal even after the permeability had become excessive. These were experimental fabrics containing an open-weave cloth which may have permitted a mechanical weakening of the gas film without deterioration of the rubber. This emphasizes the importance of considering all the tests in judging the condition of a fabric, since any one alone might be misleading.

The determinations of acetone extract were made under the direction of Mr. A. H. Smith, of the Bureau of Standards, to whom acknowledgment is made for the data furnished.

5. EXAMINATION OF THE FABRIC.

In addition to the tests made in the laboratory, a very valuable indication of the relative deterioration is secured from an examination of the cloth and rubber compounds themselves. The exposed sample should be compared with the original and any change in its characteristic properties noted. Such features as hardening of the rubber, tendering of the cloth, loss of

[1] Third Annual Report, p. 463.

"tack," etc., should be observed. The loss of "tack," or the property of the freshly exposed rubber surface adhering to itself, is a very significant point to be watched for. With some experience a very good estimate of the condition of the fabric may be formed.

6. SUMMARY.

Exposure to the weather is the best means now available for determining the relative value of balloon fabrics. The results of tests secured at different periods of the year can be correlated by a study of the weather conditions at those times. Deterioration on exposure is accompanied by characteristic behavior as regards the permeability, acetone extract, and strength. The appearance and feeling of the fabric offers an exceedingly helpful supplementary means of determining the condition of the sample after exposure.

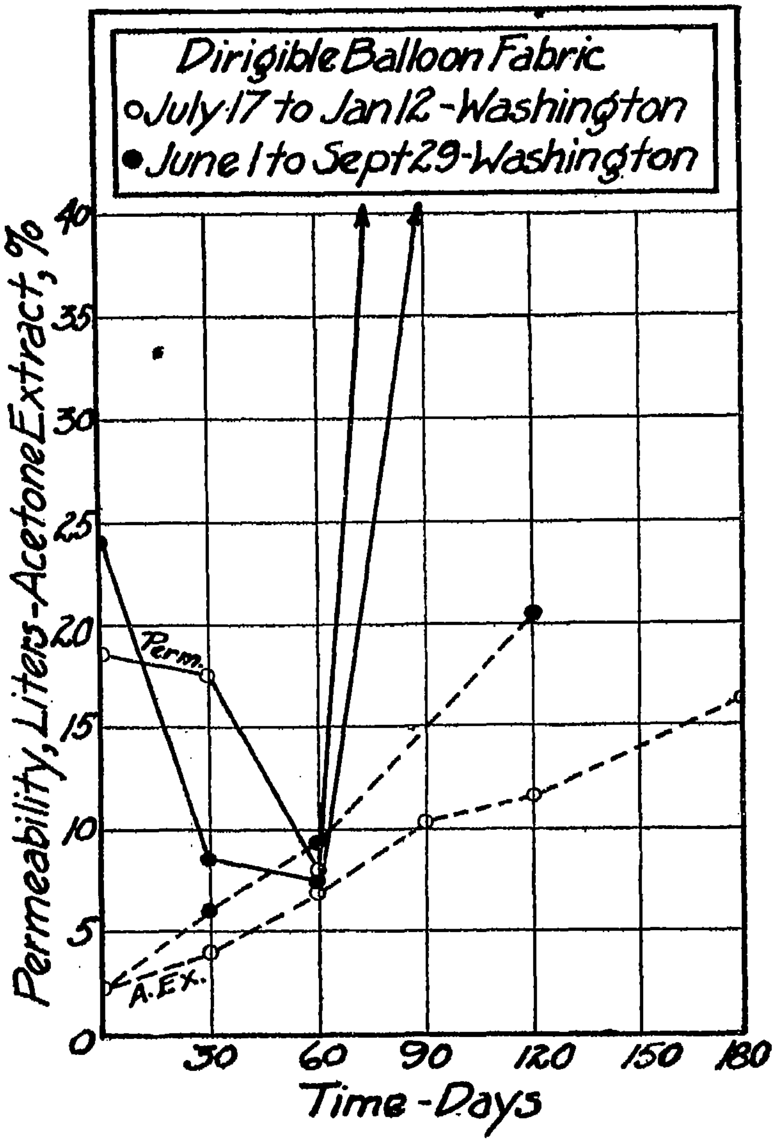

Dirigible Balloon Fabric
○ July 17 to Jan 12 - Washington
● June 1 to Sept 29 - Washington
Permeability, Liters - Acetone Extract, %
Perm.
A. EX.
0
5
10
15
20
25
30
35
40
30
60
90
120
150
180
Time - Days

FIG. 1.

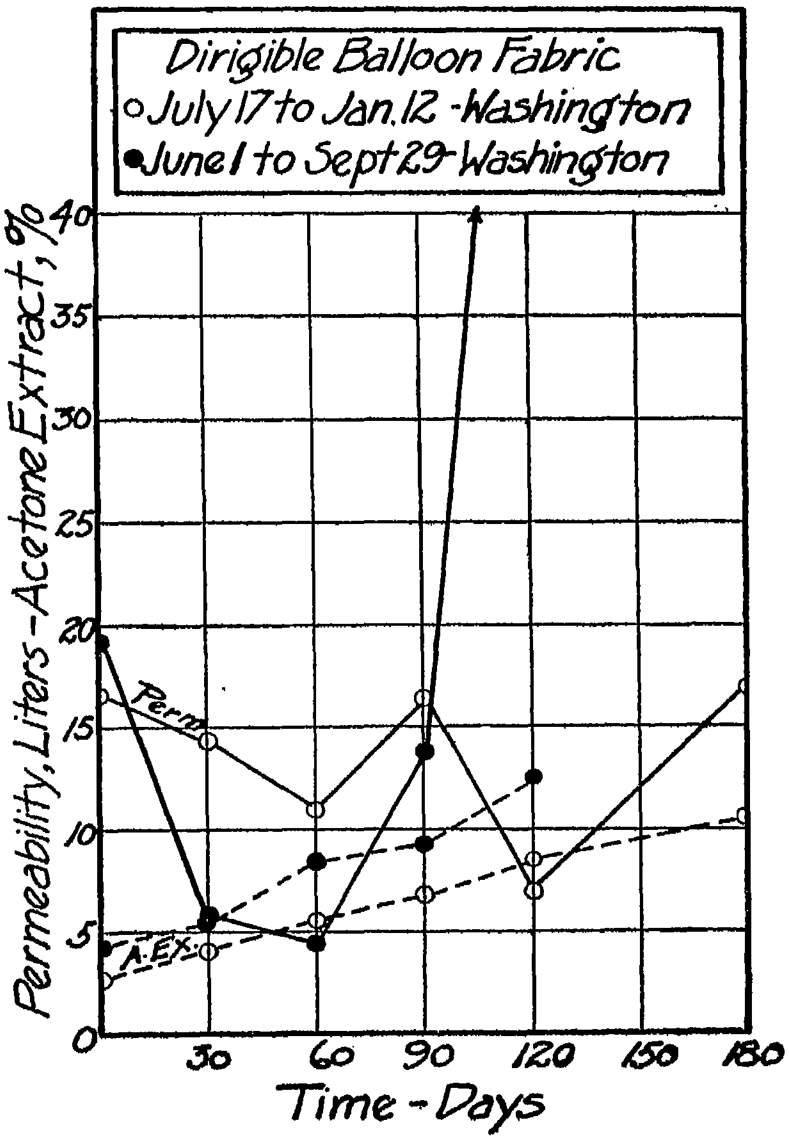

Dirigible Balloon Fabric
○ July 17 to Jan. 12 - Washington
● June 1 to Sept 29 - Washington
Permeability, Liters - Acetone Extract, %
Perm.
A. EX.
0
5
10
15
20
25
30
35
40
30
60
90
120
150
180
Time - Days

FIG. 2.

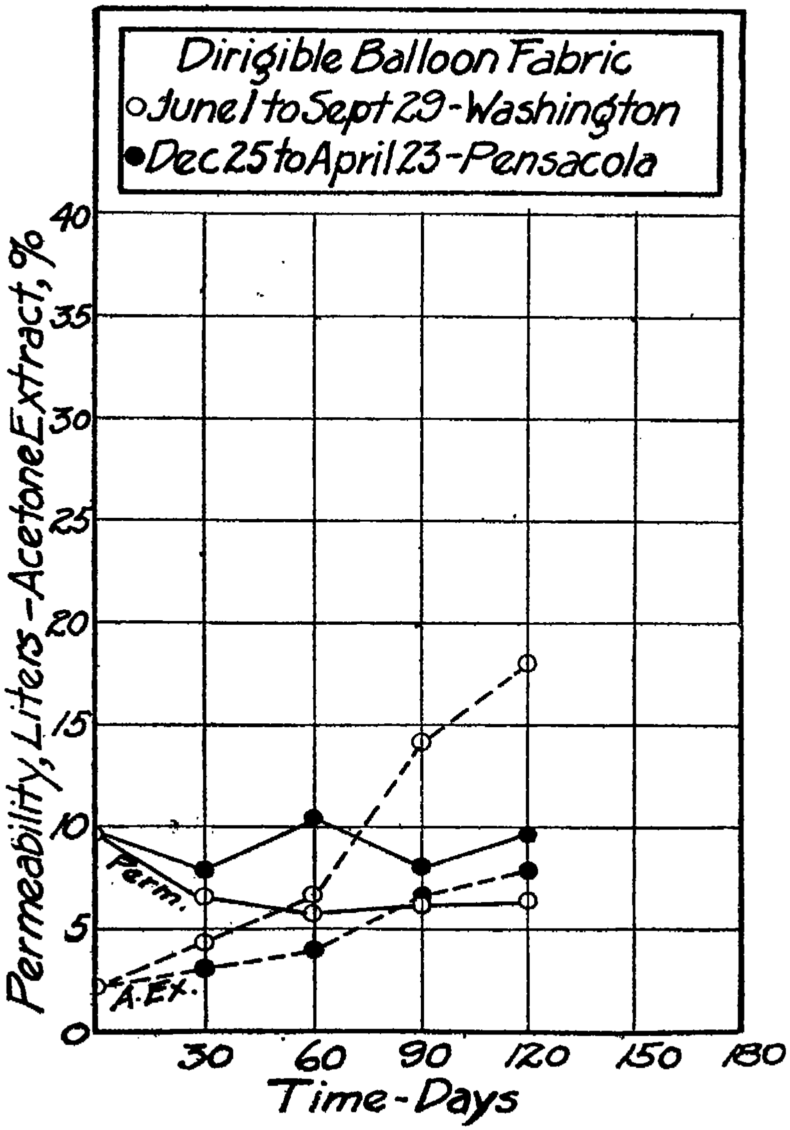

Dirigible Balloon Fabric
○ June 1 to Sept 29 - Washington
● Dec 25 to April 23 - Pensacola
Permeability, Liters - Acetone Extract, %
Perm.
A. Ex.
0
5
10
15
20
25
30
35
40
30
60
90
120
150
180
Time - Days

FIG. 3.

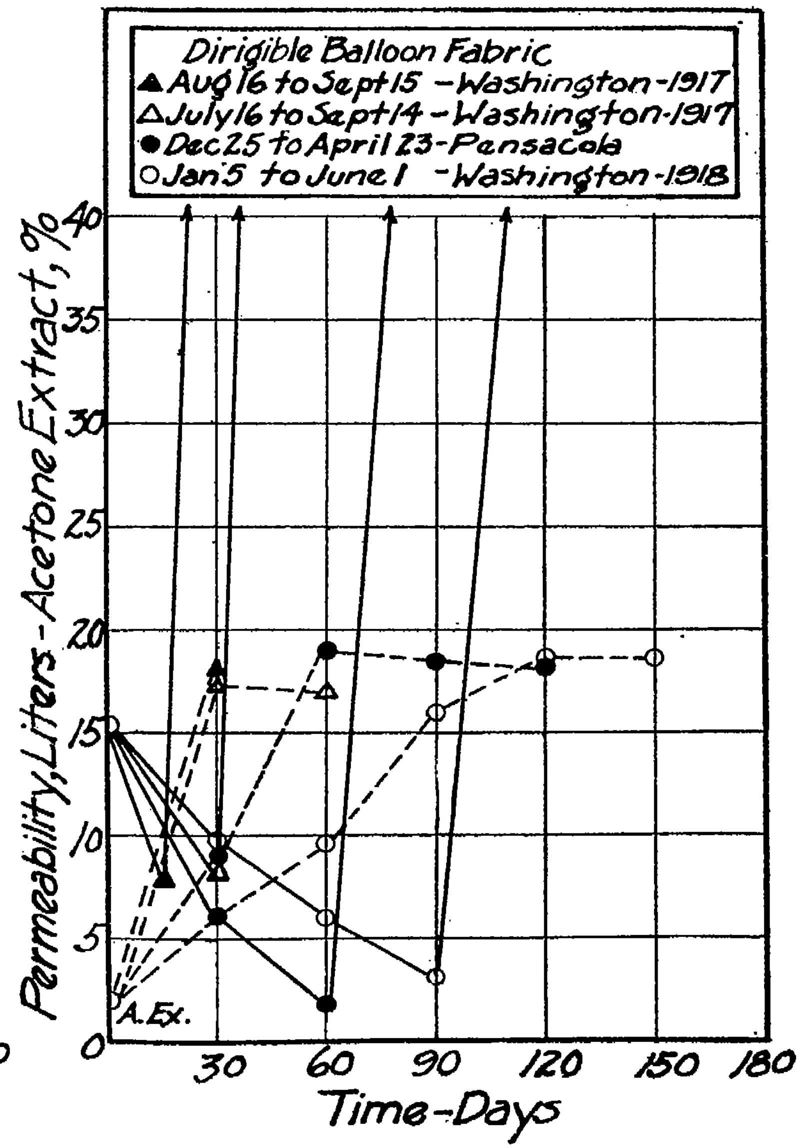
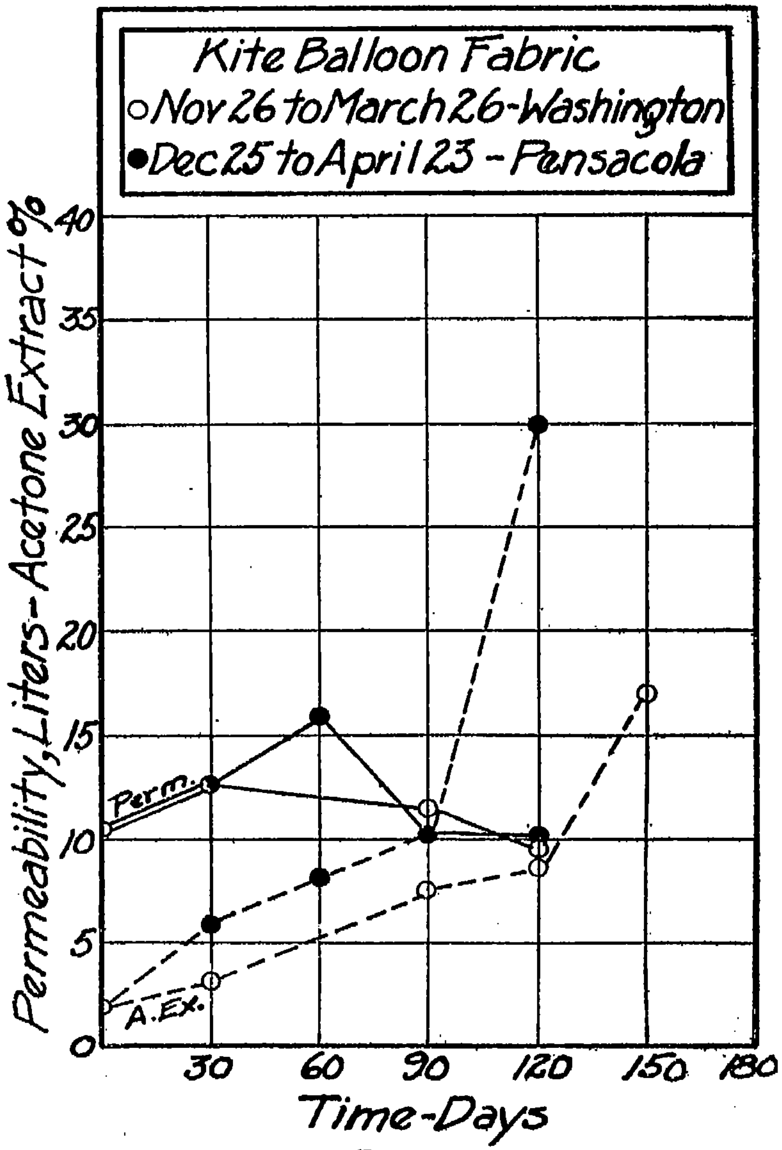
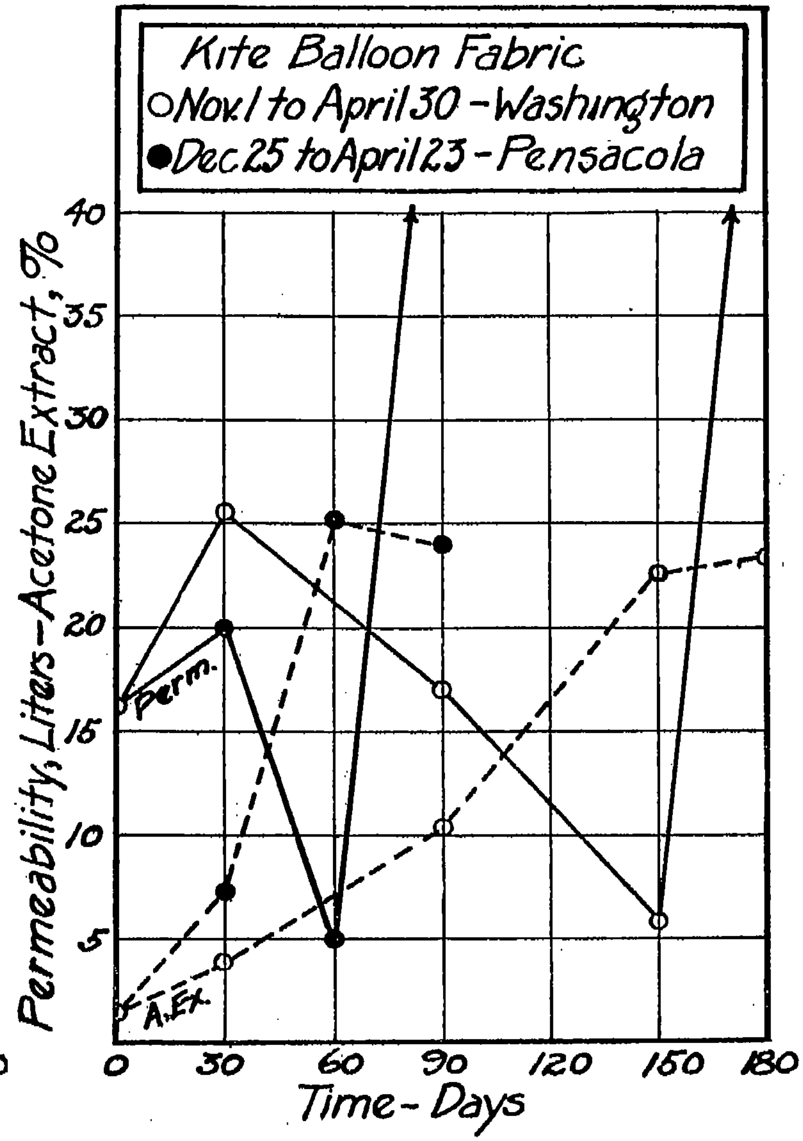

Dirigible Balloon Fabric
▲ Aug 16 to Sept 15 - Washington - 1917
△ July 16 to Sept 14 - Washington - 1917
● Dec 25 to April 23 - Pensacola
○ Jan 5 to June 1 - Washington - 1918
Permeability, Liters - Acetone Extract, %
A. Ex.
0
5
10
15
20
25
30
35
40
30
60
90
120
150
180
Time - Days

FIG. 4.



Kite Balloon Fabric
○ Nov 26 to March 26 - Washington
● Dec 25 to April 23 - Pensacola
Permeability, Liters - Acetone Extract %
Perm.
A. Ex.
0
5
10
15
20
25
30
35
40
30
60
90
120
150
180
Time-Days

Fig. 5.



Kite Balloon Fabric
○ Nov. 1 to April 30 - Washington
● Dec 25 to April 23 - Pensacola
Permeability, Liters - Acetone Extract, %
Perm.
A. Ex.
5
10
15
20
25
30
35
40
0
30
60
90
120
150
180
Time - Days

Fig. 6.

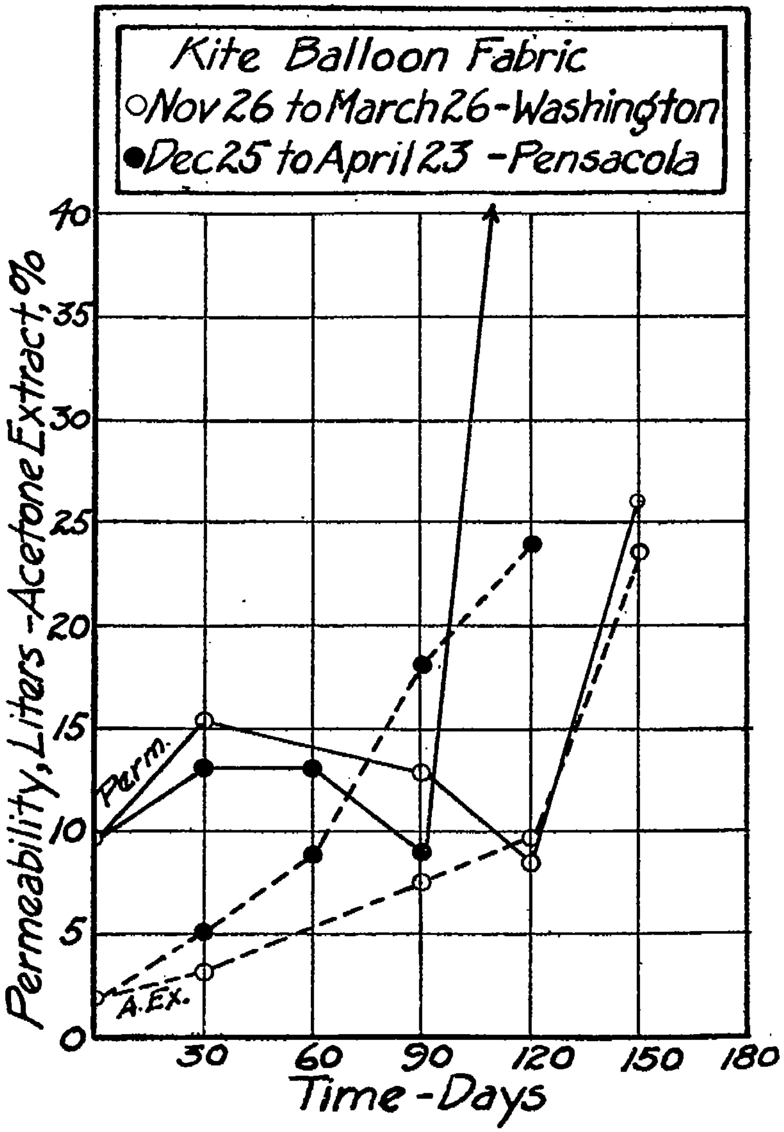

Kite Balloon Fabric
○Nov 26 to March 26 - Washington
●Dec 25 to April 23 - Pensacola
Permeability, Liters - Acetone Extract, %
0
5
10
15
20
25
30
35
40
30
60
90
120
150
180
Time - Days
Perm.
A.EX.

Fig. 7

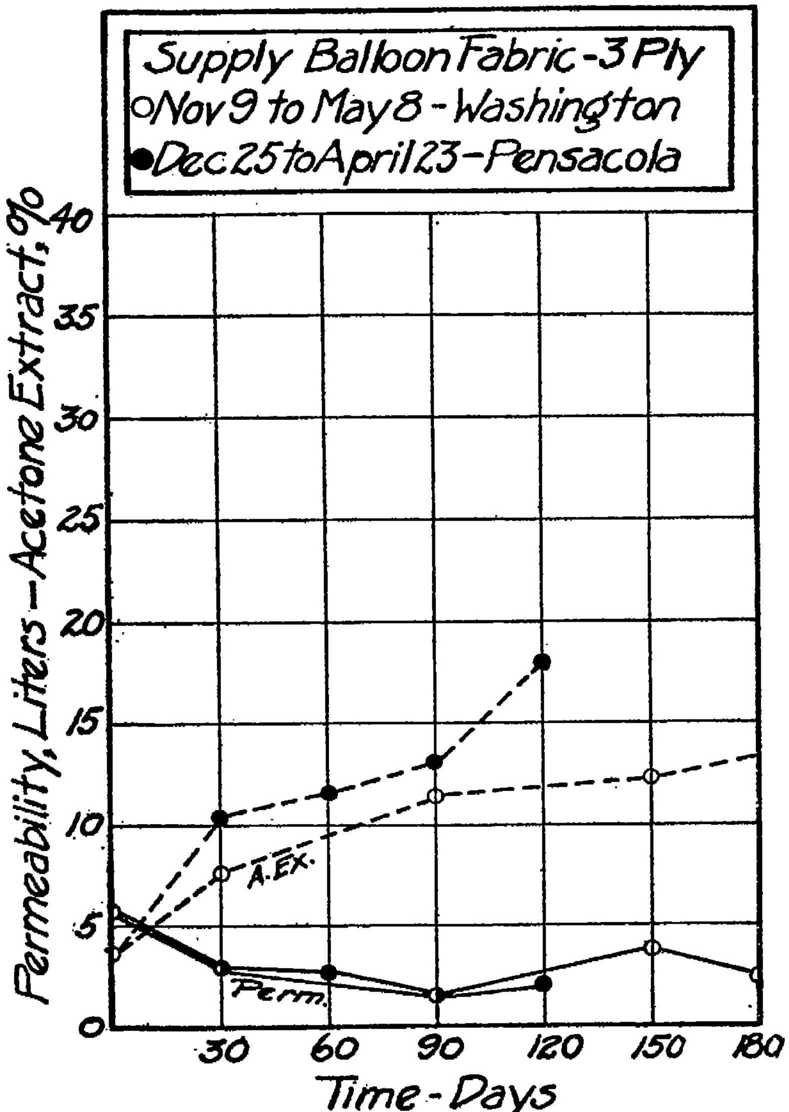
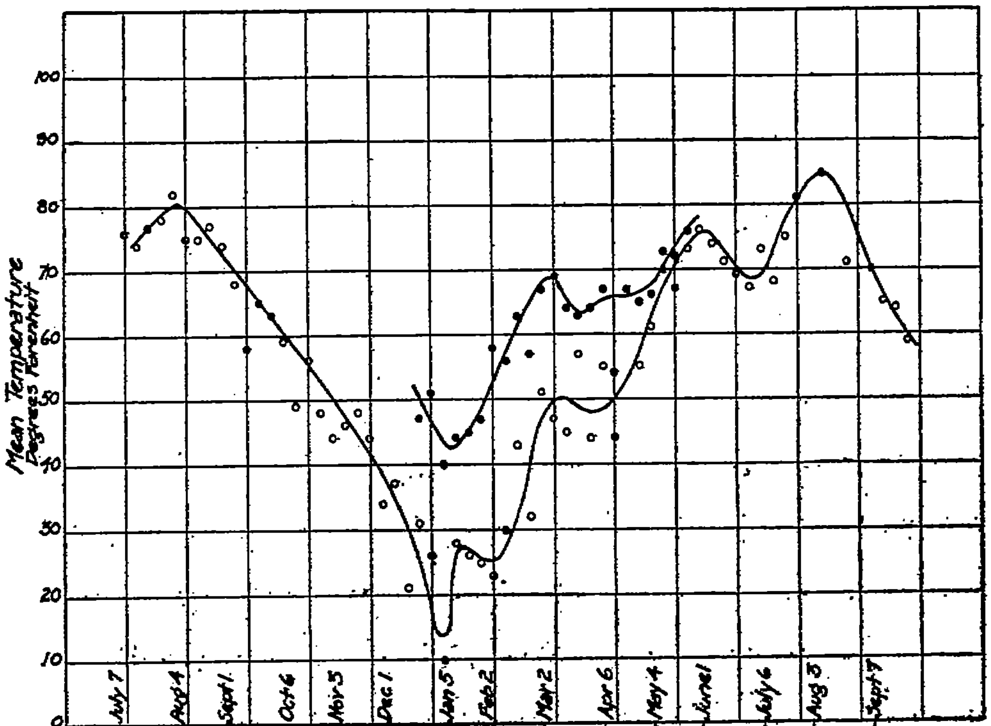

Supply Balloon Fabric - 3 Ply
○Nov 9 to May 8 - Washington
●Dec 25 to April 23 - Pensacola
Permeability, Liters - Acetone Extract, %
0
5
10
15
20
25
30
35
40
30
60
90
120
150
180
Time - Days
A.EX.
Perm.

Fig. 8



Temperature Conditions at Washington ○ and Pensacola ● —July 1917 to October 1918
Average of Daily Means by Weeks

FIG. 9.

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PART II.

USE OF ULTRA-VIOLET LIGHT FOR TESTING BALLOON FABRICS.

By JUNIUS DAVID EDWARDS and IRWIN L. MOORE.

INTRODUCTION.

It is quite necessary to be able to determine in advance of construction of a balloon the probable resistance of the fabric to the deteriorating conditions of service. Extensive tests made at the Bureau of Standards and other places have shown that reliable indications as to the relative lasting qualities of different fabrics can be obtained by testing after exposure to the weather.

Deterioration from exposure to the weather is due, among other things, to the combined action of light, heat, and moisture. These conditions are extremely variable, and as a result tests made during different periods of the year are not strictly comparable. For that reason it is highly desirable to secure a reproducible and, if possible, accelerated ageing test. The effect of exposure to heat has been investigated by Edwards,[1] Tuttle, and Walen, and it was shown that the relative deterioration of balloon fabrics produced by heating was not a reliable indication of their durability in service. Exposure to light from an ultra-violet lamp has also been suggested and used for obtaining an accelerated ageing test, on the assumption that the ultra-violet radiation in sunlight was one of the chief factors in the deterioration of balloon fabrics.

Rosenhain, Barr, and Booth[2] exposed balloon fabrics to ultra-violet light from a mercury-vapor arc in a quartz bulb. Two fabrics, both of which showed marked deterioration on exposure to the weather for 50 days, were exposed to the ultra-violet light for 64 days. The action of the light produced no significant change in permeability in the case of one fabric whereas there was marked deterioration in the case of the other.

Victor Henri[3] has studied the effect of ultra-violet light on rubber. Using a mercury-vapor arc in a quartz tube placed 20 centimeters from the exposing floor, he ran tests on samples of thin sheets of rubber 0.5 millimeter thick. He found that unvulcanized rubber showed marked deterioration in 20 hours; the rubber became dark and shiny and cracked easily when stretched. The vulcanized sheets took 48 to 72 hours before showing any marked deterioration. He concluded that the addition of compounding agents generally increased the resistance of the rubber to oxidation. Litharge was especially marked in this effect. On the other hand, antimony sulphide greatly facilitated oxidation. Applying his conclusions to balloon fabrics, he recommends that (1) in their construction there should be no unvulcanized rubber, (2) that the cloth shall be dyed with lead chromate or aniline yellow so as to form a screen to ultra-violet light, (3) that some yellow coloring matter be used in the rubber itself.

BUREAU OF STANDARDS TESTS.

The tests made at the Bureau of Standards were primarily for the purpose of determining the value of exposure to ultra-violet light for accelerated ageing tests on balloon fabrics. The light source used was a mercury-vapor arc, taking approximately 600 watts, in a quartz tube. This was mounted with a reflecting screen on a frame painted black and the whole placed in a

[1] Third Annual Report of the National Advisory Committee for Aeronautics, 1917, p. 459.

[2] W. Rosenhain, Guy Barr, and Harris Booth, Report of British Advisory Committee for Aeronautics, 1910-11, p. 60.

[3] Le Caoutchouc et Gutta-Percha 1910, 7 pp., 4371-4376.

galvanized-iron container through which air was constantly drawn by a fan at the top. Two samples of fabric, 11 inches square, were tacked on a frame so shaped that the fabrics were on a 120° arc of a cylinder (radius = 11 inches) of which the lamp formed the axis. Radiation measurements were made from time to time to determine the total radiation from the lamp and the percentage of ultra-violet radiation. The radiation measurements were made by W. W. Coblentz and M. B. Long, and a description of the performance and characteristics of the lamps are given in Bureau of Standards Scientific Paper No. 330.

Numerous tests of balloon fabrics exposed to the weather have shown that normal ageing is usually accompanied by a slow increase in acetone extract and an initial decrease in permeability which is followed by a very large increase in permeability when the gas film becomes brittle and cracks. The deterioration of the fabric can thus be judged by a comparison of the permeability and acetone extract determined before and after exposure. The permeability was determined by the Bureau of Standards' method as described in Technologic Paper No. 113. The permeability is expressed in liters per square meter per 24 hours. The percentage acetone extract was determined by the method described in the Third Annual Report of the Advisory Committee previously referred to. The results of a series of tests on balloon fabrics after exposure to ultra-violet light are given in Table 1. The results of similar tests of the same fabrics before and after exposure to the weather for 30 and 60 days are given in Table 2.

A brief description of each fabric is given in the following tabulation.

No. 22151.—Two-ply fabric, olive-green rubber coating on outside.

No. 23987.—Two-ply fabric, gray rubber coating on outside.

No. 10650.—Two-ply fabric, gray rubber coating on outside.

No. 24580.—Two-ply fabric, olive-drab dyed fabric on outside.

No. 22151X.—Same construction as 22151 but from different roll.

No. 27331.—Single-ply fabric coated with fine Para rubber and sulphur.

No. 27291.—Single-ply fabric, same coating as 27331, except that lampblack has been added to the compound.

TABLE 1.—*Effect of exposure of balloon fabrics to ultra-violet light.*

Fabric No.		Permeability (25 degrees C.) and per cent acetone extract after exposure.							
	Time of exposure, in hours	Original.	48	144	158	162		360	196
	Total radiation in gram calories per square centimeter		1,015	2,675	2,410	1,317		7,410	1,575
	Ultra-violet radiation in gram calories per square centimeter		670	1,712	1,495	738		4,650	898
	Moisture condition		Wet.	Dry.	Wet.	Wet.	Dry.	Wet.	Dry.
	TEST.								
22151	Permeability	15.4	13.4						
	Per cent acetone extract	2.2	3.4						
23987	Permeability	11.4	14.6						
	Per cent acetone extract	1.7	2.6						
10650	Permeability	17.5		12.5	11.1				
	Per cent acetone extract	1.6		3.6	4.8				
24580	Permeability	9.4		5.0	4.9			320	
	Per cent acetone extract	2.0		5.5	7.2			13.9	
22151X	Permeability	15.4				10.1	12.1	17,800	
	Per cent acetone extract	2.0				5.8	4.8	15.6	
27291	Per cent acetone extract	1.3							4.7
27331	Per cent acetone extract	1.9							16.6

NOTE.—All samples were wrinkled before testing for permeability by being drawn ten times over a metal edge (angle 90 degrees) under a constant tension of 1 pound per inch.

NOTE.—The values given in the column marked "Total radiation" are for all wave lengths from 0 to 1.2μ. The values in the column marked "Ultra-violet radiation" are for all wave lengths from 0 to 0.45μ.

TABLE 2.—*Effect of exposure of balloon fabrics to the weather.*

Fabric No.	Test.	Permeability (25° C.), per cent acetone extract after exposure and solar radiation. Time of exposure. Original.	30 days.	60 days.
22151	Permeability	15.4	600	27,000
	Per cent acetone extract	2.2	17.4	20.0
	Solar radiation	....	11,400	21,000
23987	Permeability	11.4	14.8	12.1
	Per cent acetone extract	1.7	3.1	2.7
	Solar radiation	....	8,500	15,600
10650	Permeability	17.5	19.5	3,750
	Per cent acetone extract	1.5	14.4	24.8
	Solar radiation	....	11,400	21,000
24580	Permeability	9.4	14.2	14.1
	Per cent acetone extract	2.0	2.9	5.7
	Solar radiation	....	7,400	13,400
22151X	Permeability	15.4	6.1	1.8
	Per cent acetone extract	2.0	9.1	18.9
27291	Per cent acetone extract	1.3	11.5	....
27331	Per cent acetone extract	1.9	31.	....

NOTE.—"Solar radiation" is expressed in gram calories per square centimeter of horizontal surface for wave lengths from 0 to 1.2 μ. These values were calculated from the daily observations of the Weather Bureau at Washington.

NOTE.—All samples were wrinkled before testing for permeability by being drawn ten times over a metal edge (angle 90°) under a constant tension of 1 pound per inch.

For the proper interpretation of the data obtained in these tests it is necessary to consider the character of the radiation to which the fabrics were exposed. The figures given in the table for total radiation from the mercury arc are for all wave lengths from 0 to 1.2 μ. The total radiation for all wave lengths (from 0 to infinity), is, however, about five times as great. This is due to the large amount of heat radiated from the hot quartz tube and electrode. The values for the range 0 to 1.2 μ have been used for purposes of comparison because over 80 per cent of the solar radiation is of wave lengths less than 1.2 μ. The visible portion of the spectrum lies approximately between the wave lengths 0.40 μ to 0.72 μ.

Measurements on the mercury arc show that the radiation changes in character and intensity during the life of the lamp. At first as high as 70 per cent of the total radiation was of wave lengths shorter than 0.45 μ (ultra-violet); this percentage decreased steadily with use until finally only about 50 per cent of the radiation was ultra-violet. The intensity decreased at the same time until it was only about one-third of the original value.

For purposes of comparison there is given in Table 3 the approximate composition and intensity of the radiation from the mercury arc and the sun. The values for solar radiation are for average summer conditions in Washington and the values for the lamp are an average of the conditions under which the fabrics were exposed. The intensity and distribution of radiation from the two sources is shown by this table to be quite different. The rate of radiation of ultra-violet light is about three times as great from the lamp as from the sun. Even this radiation is not of the same character as that from the mercury arc as most of the ultra-violet radiation from the sun is of wave lengths between 0.4 μ and 0.3 μ, while the ultra-violet radiation from the mercury arc extends below 0.2 μ.

TABLE 3.—*Comparison of solar radiation with radiation from quartz mercury lamps.*

A. COMPARISON FOR ALL WAVE LENGTHS 0 TO ∞.

Wave lengths of radiation in μ.	Solar radiation at Washington.		Mercury arc radiation.	
	Gram calories per square centimeter per second.	Per cent of total.	Gram calories per square centimeter per second.	Per cent of total.
0 to 0.45	0.0008	5	0.0026	12
0.45 to 1.2	0.0121	78	0.0017	8
1.2 to ∞	0.0026	17	0.0176	80
0 to ∞	0.0155	100	0.0219	100

B. COMPARISON FOR WAVE LENGTHS LESS THAN 1.2 μ.

0 to 0.45	0.0008	6	0.0026	60
0.45 to 1.2	0.0121	94	0.0017	40
0 to 1.2	0.0129	100	0.0043	100

The values for solar radiation were calculated from data given in the Smithsonian Physical Tables.
The values for the radiation from the mercury lamp are for a distance of 28 centimeters from the quartz tube and are an average along its length.

A consideration of the data in Tables 1 and 2 shows that exposure to the ultra-violet light produces deterioration comparable, qualitatively at least, with that obtained by exposure to the weather. It was found, however, that the action of the ultra-violet lamp was not nearly as rapid as had been hoped for, despite its high rate of radiation of ultra-violet light. For example, fabric No. 22151 showed rapid deterioration in summer weather in less than two weeks, whereas under the ultra-violet light there was no marked deterioration in 43 hours. For this reason it was necessary to extend the period of exposure in order to secure positive evidence of deterioration.

Further experiments showed that it required between 162 and 360 hours' exposure to secure complete deterioration of fabrics Nos. 22151 and 24580. Practically the same result was obtained after 30 days' weather exposure in the case of No. 22151, while the deterioration under the lamp in 360 hours was greater in the case of 24580 than in 60 days' exposure to the weather. Judging from service tests and weather exposure tests fabric No. 24580 is far superior to No. 22151 and yet the exposure to ultra-violet light shows only a slight difference in their durability. Even when the amounts of ultra-violet radiation were the same in both outdoor and mercury arc exposures the degrees of deterioration produced were very different. In the case of fabric No. 22151 the ultra-violet radiation from the sun during 30 days' exposure to the weather was 700 calories; during 43 hours' exposure under the lamp the ultra-violet radiation was 670 calories. Yet this fabric showed no significant deterioration in 43 hours under the lamp but was practically destroyed by 30 days' outdoor exposure. Take another example: Fabric No. 10650 during 158 hours' exposure under the lamp did not show very great deterioration but was ruined by 60 days' weather exposure. The ultra-violet radiation in the first case was 1,495 calories and in the second case 1,300 calories.

Tests were made to determine, if possible, the influence of moisture on the rate of deterioration. In the tests marked "wet" the samples were sprayed with water twice daily. The "wet tests" show a somewhat more rapid action than those made with the fabric dry. That the difference between tests made under the two conditions is not greater may be due to the fact that the normal humidity of the air in the room is sufficient to maintain an appreciable percentage of moisture in the "dry fabric."

The effect of temperature upon the deterioration is a factor the influence of which is hard to estimate. Fabrics exposed under the lamp were at a temperature of about 50° C. Fabric No. 22151 when exposed in bright sunshine in midsummer frequently reached this temperature. The average temperature of fabrics under outdoor exposure was much lower, however, than those under the lamp.

CONCLUSIONS.

It seems evident from these few tests that the relative deterioration of different fabrics under ultra-violet light is not strictly comparable with the deterioration experienced in service or in outdoor exposure. The radiation from the mercury arc lamp varies greatly in intensity and character, and exposures made at different times are not strictly comparable. Moreover, it is not practicable in most laboratories to measure the radiation from the lamps. The tests are thus far from being reproducible and are not particularly accelerated compared with summer exposure in Washington.