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EFFECT OF PROTECTIVE COATINGS ON THE ABSORPTION OF MOISTURE BY GELATIN-LATEX GAS-CELL FABRICS

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Abstract

The effects of six variations in protective coating on the percentage of moisture held at 21° C (70° F) and various relative humidities, and the rates at which this moisture is absorbed, have been determined by a static method for two lightweight gelatin-latex gas-cell fabrics. The two fabrics differed only in their content of gelatin (which was plasticized with polyglycerol). At relative humidities below 94 percent the amount and distribution of paraffin do not affect the final amounts of moisture held by the fabrics. Slightly higher values are found for varnish coatings, as compared with paraffin coatings, because of the hygroscopicity of the varnishes. At relative humidities above 94 percent, mold growth and leaching of gelatin and polyglycerol by moisture cause the fabrics to lose weight before the maximum possible absorption of moisture can occur. Increasing the thickness of the paraffin lowers the rate of absorption of moisture. Application to both surfaces of the fabric reduces the rate much more than a comparable increase in weight of paraffin on one side only. When varnish containing aluminum powder is used, an increased rate is found. Reduction of the amount of the gelatin layer gives a reduction in the total amount of moisture held, and gives smaller differences for variations in protective coatings. A consideration of the absorptive properties of the fabric constituents, based on available data, and of the permeabilities of the materials surrounding the very hygroscopic gelatin layer, indicates that the combination of these factors readily explains the moisture absorption relations of the completed fabrics.

CONTENTS

I. INTRODUCTION

In the manufacture of gas-cells from gelatin-latex fabric, it is customary to coat one or both surfaces of the cell with paraffin as a protection against the absorption of moisture or the loss of some constituent of the fabric. It was shown in a previous article on this subject [1] that the rate of absorption of moisture by this type of fabric is retarded by the application of paraffin, though the total absorption remains practically unchanged. The Goodyear Zeppelin Corporation kindly submitted for our study samples of the standard lightweight

[1] G. M. Kline, J. Research NBS 14, 67 (1935) RP758. This article contains references to the previous investigations of these materials.

fabric, and of an experimental fabric containing less gelatin, which were coated by them with different amounts of paraffin or other type of protective coating. This investigation was made to determine the effects of variations in amount, distribution, and type of protective coating on the rate and amount of absorption of moisture by these fabrics. The results obtained are considered on the basis of the present study coupled with pertinent information obtained from other sources.

II. MATERIALS

The fabrics studied are listed and described in table 1; the fabric designated as Q39–A–10 contains less gelatin than the standard light-weight fabric Q39–A–2, and is hereafter referred to as "improved fabric." The amount of paraffin on the samples was determined at the beginning of the investigation. Samples 1 to 6 are referred to as set 1, and samples 7 to 12 as set 2.

TABLE 1.—*Description of materials*

Sample	Fabric	Type of coating	Weight of coated fabric	Amount of coating indicated by manufacturer		Total paraffin found
				Inside	Outside	
			oz/yd²	oz/yd²	oz/yd²	oz/yd²
1	Goodyear Code Q39–A–2.	Paraffin	5.41		0.2	0.3
2	do	do	5.66		.4	.6
3	do	do	5.83	0.2	.2	.7
4	do	do	5.96	.2	.4	.8
5	do	Paraffin and Goodyear Code 755C aluminum paint. [1]	5.94	.2	{.2 paraffin .2 Al paint}	[3] .6
6	do	Aluminum powder in flexible spar varnish. [2]	7.30			
7	Goodyear Code Q39–A–10.	Paraffin	5.58		.2	.35
8	do	do	5.82		.4	.6
9	do	do	6.00	.2	.2	.8
10	do	do	5.96	.2	.4	.8
11	do	Paraffin and Goodyear Code 755C aluminum paint. [1]	6.07	.2	{.2 paraffin .2 Al paint}	[3] .7
12	do	Aluminum powder in flexible spar varnish. [2]	6.95			

[1] The aluminum paint and the flexible spar varnish are apparently of different composition.
[2] Flexible spar varnish containing aluminum dust is applied to both surfaces. Total weight of coating for sample 6 is 2.2 oz/sq yd; for sample 12 is 1.8 oz/sq yd.
[3] Value may be slightly high as a result of breakdown of the paint coating.

III. APPARATUS AND PROCEDURE

The determination of the amounts of moisture held by the fabrics was made by the static method described by Evans and Critchfield,[2] and used in the previous paper [3] on this subject. In this method a sample, measuring 2 by 8 inches, was suspended on a wire passing through a glass tube of small bore in the stopper of a 6-ounce bottle. The glass tube was closed between weighings by a paraffined cork through which the wire passed. The sample was weighed without removal from the bottle by placing the latter on a bridge over the balance pan and suspending the wire from the balance hook. The

[2] W. D. Evans and C. L. Critchfield, BS J. Research **11**, 151 (1933) RP583.
[3] See page 68 of reference 1.

following reagents, used to maintain the various humidities,[4] were placed in the bottom of the bottles.

Relative humidity (percent)	Reagent
0	Phosphorus pentoxide.
86	Saturated solution of potassium chloride.
94	Saturated solution of potassium nitrate.
97	Saturated solution of potassium sulphate.
100	Water.

All the samples were conditioned at 65 percent relative humidity and 21° C (70° F), the standard atmosphere, until constant weight was obtained. The edges were then sealed with paraffin by dipping them into a solution of Parowax in petroleum ether. The samples were again conditioned to the standard atmosphere, and the added weight of paraffin was determined, before exposure to the various humidities was begun. Weighings were made at suitable intervals until no sample, after a week's time, showed an increase greater than 0.3 percent by weight, calculated on the uncoated fabric. The tests were all made in a room held at a temperature of 21±1° C. The controls of temperature and humidity were shut off several times during the latter part of the investigation for periods approximating 1½ days each; these periods are reflected in the results by slight but unimportant irregularities.

IV. EXPERIMENTAL RESULTS

The data obtained for the absorption of moisture by the fabrics described above are presented in tables 2 to 6. For intercomparison, the results are all calculated as percentage change in weight based on the weight of the uncoated fabric.

TABLE 2.—*Percentage change in weight of light-weight gelatin-latex gas-cell fabrics, which had been conditioned in air at 21° C and 65 percent relative humidity, when exposed at 0 percent relative humidity*

Time in days	Percentage change in weight of samples—											
	1	2	3	4	5	6	7	8	9	10	11	12
1/24	−1.2	−0.9	−0.4	−0.2	−0.4	−0.9	−1.7	−1.1	−0.2	−0.3	−0.2	−0.5
1/8	−2.8	−2.4	−1.0	−0.7	−1.7	−2.1	−2.8	−2.6	−0.7	−0.6	−0.7	−1.4
1/4	−4.3	−3.7	−1.7	−1.2	−2.0	−3.5	−4.0	−3.8	−1.2	−1.2	−1.3	−2.4
1	−6.7	−6.2	−4.4	−3.3	−4.9	−7.0	−5.7	−5.8	−3.3	−3.3	−3.5	−5.2
2	−7.2	−7.0	−5.9	−4.9	−6.6	−8.1	−6.2	−6.5	−4.8	−4.8	−5.0	−6.3
3	−7.4	−7.3	−6.5	−5.3	−7.3	−8.5	−6.5	−6.8	−5.6	−5.6	−5.7	−6.7
4	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	−6.1	−6.9
5	−7.6	−7.5	−7.0	−6.7	−8.0	−8.9	−6.7	−7.1	−6.3	−5.9	-----	-----
7	−7.7	−7.6	−7.2	−7.1	−8.3	−9.0	−6.8	−7.3	−6.6	−6.7	−6.7	−7.2
14	−7.8	−7.7	−7.6	−7.5	−8.6	−9.2	−7.0	−7.5	−7.0	−7.2	−6.9	−7.3
21	−7.7	−7.7	−7.7	−7.6	−8.8	−9.3	−7.0	−7.6	−7.1	−7.3	-----	-----
25	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	−7.1	−7.4
28	−7.8	−7.7	−7.7	−7.6	−8.8	−9.3	−7.0	-----	-----	-----	-----	-----
32	-----	-----	-----	-----	-----	-----	-----	−7.7	−7.2	−7.4	-----	-----
35	−7.8	−7.7	−7.7	−7.6	-----	-----	-----	-----	-----	-----	−7.1	−7.4
36	-----	-----	-----	-----	-----	-----	-----	−7.7	−7.3	−7.4	-----	-----
39	-----	-----	-----	-----	−8.8	−9.4	−7.1	-----	-----	-----	-----	-----

[4] Int. Crit. Tables **1**, 67; (McGraw-Hill Book Co., New York, 1926).

Table 3.—*Percentage change in weight of light-weight gelatin-latex gas-cell fabrics, which had been conditioned in air at 21° C and 65 percent relative humidity, when exposed at 86 percent relative humidity*

Time in days	Percentage change in weight of samples—											
	1	2	3	4	5	6	7	8	9	10	11	12
1/24	0.5	0.4	0.2	0.1	0.5	0.3	0.4	0.4	0.1	0.1	0.1	0.2
1/8	1.3	1.0	0.5	0.3	0.9	0.7	1.2	0.9	0.3	0.3	0.3	0.5
1/4	2.1	1.8	0.9	0.6	1.4	1.3	2.0	1.7	0.5	0.5	0.5	0.8
1	5.8	5.1	2.7	1.8	3.6	3.8	4.6	4.2	1.7	1.7	1.7	2.8
2	7.9	7.3	4.4	3.0	5.7	5.9	6.2	5.8	2.9	2.9	2.9	4.4
3	9.4	8.7	5.7	4.0	7.1	7.3	7.0	6.7	3.8	3.7	3.8	5.4
4	------	------	------	------	------	------	------	------	------	------	4.5	6.1
5	10.6	10.3	7.5	5.5	9.2	9.3	7.8	7.7	5.2	5.1	------	------
7	11.0	10.7	8.6	6.5	10.4	10.5	8.2	8.1	6.0	5.9	5.8	7.2
14	11.6	11.8	10.4	8.8	12.3	12.3	8.5	8.6	7.5	7.5	7.3	8.0
21	11.8	12.0	11.2	10.0	12.8	12.7	8.4	8.7	8.1	8.1	------	------
25	------	------	------	------	------	------	------	------	------	------	7.7	7.7
28	11.7	12.0	11.3	10.6	13.0	12.9	8.4	------	------	------	------	------
29	------	------	------	------	------	------	------	------	------	------	7.9	7.9
35	11.9	12.1	11.5	11.0	------	------	------	------	------	------	7.9	7.9
42	------	------	11.6	11.2	------	------	------	8.4	8.5	8.5	8.0	7.9
43	------	------	------	------	13.0	12.9	8.3	------	------	------	------	------
56	------	------	------	11.4	13.3	------	8.1	8.5	8.5	8.5	8.1	------
63	------	------	------	------	------	------	8.1	8.6	8.7	8.6	8.1	------

Table 4.—*Percentage change in weight of light-weight gelatin-latex gas-cell fabrics, which had been conditioned in air at 21° C and 65 percent relative humidity, when exposed at 94 percent relative humidity*

Time in days	Percentage change in weight of samples—											
	1	2	3	4	5	6	7	8	9	10	11	12
1/24	0.6	0.5	0.2	0.2	0.7	0.4	0.6	0.5	0.2	0.2	0.2	0.3
1/8	1.7	1.6	0.6	0.5	1.3	1.1	1.7	1.4	0.5	0.4	0.5	0.7
1/4	3.0	2.7	1.2	0.9	2.2	1.9	2.9	2.4	0.9	0.8	0.9	1.4
1	8.2	7.7	3.9	3.2	6.2	5.8	7.1	6.6	2.8	2.8	2.9	4.4
2	12.3	11.6	6.4	5.4	10.0	9.4	10.3	10.0	4.8	4.8	5.0	7.1
3	15.3	14.5	8.5	7.3	12.9	12.0	12.6	12.3	6.4	6.4	6.6	9.2
4	------	------	------	------	------	------	------	------	------	------	8.0	10.9
5	19.3	18.6	11.6	10.1	17.3	16.2	15.6	15.5	9.0	9.1	------	------
7	22.0	21.4	14.2	12.3	20.4	19.2	17.6	17.4	10.8	11.5	10.9	14.1
14	27.1	26.8	19.7	17.5	26.8	25.3	21.0	20.6	15.2	15.6	15.1	18.3
21	29.6	29.5	23.3	21.1	29.6	28.5	22.1	22.3	17.9	18.4	------	------
25	------	------	------	------	------	------	------	------	------	------	18.2	20.3
28	29.5	30.5	25.5	23.7	31.5	30.7	22.9	------	------	------	------	------
29	------	------	------	------	------	------	------	------	------	------	19.0	21.1
32	------	------	------	------	------	------	------	22.3	19.9	20.6	------	------
35	28.1	30.9	26.9	25.4	------	------	------	------	------	------	19.9	21.6
39	------	------	------	------	32.0	30.9	22.5	------	------	------	------	------
42	------	------	27.6	26.8	------	------	------	23.0	21.5	22.7	20.6	21.8
43	------	------	------	------	32.4	30.4	22.9	------	------	------	------	------
49	------	------	27.2	27.6	32.4	------	23.0	23.3	22.2	22.0	21.1	21.5
56	------	------	------	27.6	32.2	------	22.8	23.3	22.5	23.3	21.8	------
63	------	------	------	------	------	------	22.3	23.6	22.9	23.9	22.1	------
74	------	------	------	------	------	------	------	22.5	------	------	22.7	------

TABLE 5.—*Percentage change in weight of light-weight gelatin-latex gas-cell fabrics, which had been conditioned in air at 21° C and 65 percent relative humidity, when exposed at 97 percent relative humidity*

Time in days	Percentage change in weight of samples—											
	1	2	3	4	5	6	7	8	9	10	11	12
1/24	1.0	0.7	0.3	0.2	0.5	0.5	0.7	0.7	0.3	0.3	0.2	0.3
1/8	2.4	1.9	0.8	0.6	1.2	1.3	2.0	1.7	0.7	0.6	0.5	0.9
1/4	4.2	3.3	1.5	1.1	2.3	2.3	3.5	3.0	1.2	1.1	1.1	1.7
1	11.1	9.1	4.8	3.4	7.3	6.9	8.8	8.1	3.9	3.6	3.3	5.3
2	16.9	14.1	8.2	5.9	12.3	11.5	13.5	12.3	6.8	6.3	5.8	8.9
3	21.5	18.2	11.1	8.2	16.2	15.1	17.0	15.5	9.1	8.5	7.8	11.7
4											9.8	14.2
5	28.3	24.5	15.8	11.9	23.5	21.4	22.5	20.7	13.0	12.4		
7	34.2	30.2	20.0	15.2	29.2	26.5	26.6	24.4	16.0	15.4	14.2	19.7
14	48.0	43.1	29.9	25.6	43.2	39.4	36.9	33.8	24.5	23.7	24.5	29.5
21	55.9	51.0	37.5	34.7	52.7	49.1	43.4	40.6	31.4	30.1		
25											31.4	38.3
28	50.1	57.0	45.4	42.6	60.6	56.7	48.7					
29											34.4	41.4
32								48.3	39.7	38.9		
35	40.5	51.6	51.8	45.5							38.0	42.5
39					66.3	53.4	53.6					
42			56.8	48.2				52.2	45.4	46.1	41.6	44.2
49			52.1	52.1	69.9		55.7	53.0	47.5	48.9	44.4	42.9
56				49.7	67.2		54.8	52.9	46.8	50.1	46.4	
63							53.0	54.0	47.7	50.8	48.0	
70								54.6	47.3	48.0		
74								54.5			48.8	

TABLE 6.—*Percentage change in weight of light-weight gelatin-latex gas-cell fabrics, which had been conditioned in air at 21° C and 65 percent relative humidity, when exposed at 100 percent relative humidity*

Time in days	Percentage change in weight of samples—											
	1	2	3	4	5	6	7	8	9	10	11	12
1/24	1.2	0.9	0.4	0.3	0.9	0.7	0.9	0.8	0.4	0.4	0.3	0.4
1/8	3.0	2.3	1.3	0.7	2.3	1.8	2.4	2.0	1.0	1.0	0.8	1.0
1/4	5.1	4.0	1.9	1.3	4.1	3.1	4.0	3.5	1.8	1.8	1.4	1.8
1	13.2	10.6	6.0	4.3	12.5	9.3	10.1	9.2	5.7	5.5	4.5	5.7
2	19.5	16.7	10.3	7.5	21.9	15.6	15.8	14.6	10.2	9.4	7.9	9.6
3	24.8	22.0	14.0	10.5	29.3	20.5	19.8	18.6	13.8	12.1	10.7	12.6
4											13.3	15.3
5	33.1	30.4	20.8	15.4	41.6	28.5	26.6	25.1	20.2	17.1		
7	40.9	38.4	27.1	19.8	49.6	35.0	32.5	30.4	25.3	21.4	19.9	21.8
14	63.3	59.3	43.5	33.5	72.2	52.4	48.2	45.6	41.0	34.9	33.1	35.4
21	79.0	77.5	59.6	46.6	90.6	67.8	61.5	58.2	54.2	46.4		
25											56.1	52.6
28	65.0	77.3	73.9	58.4	107.1	82.8	69.7					
29											58.1	52.6
32								73.8	73.0	60.2		
35	48.1	62.3	82.7	67.7							68.0	53.9
39					120.2	63.7	82.5					
42			75.3	72.5				87.4	75.1	67.2	70.3	54.8
49			67.6	69.6	135.9		95.1	90.2	80.6	66.1	74.0	52.4
56				60.4	130.7		100.6	94.7	78.8	66.3	74.4	
63							100.2	90.6	77.4	66.9	74.5	
67											78.5	

The maximum values for gain in weight of the materials, calculated to percentage gain based on the weight of the uncoated fabric at 0 percent relative humidity, are collected in table 7. This table also indicates the time required for the attainment of these values, and the approximate periods of time after which mold growth became apparent on visual inspection. This mold growth appeared after various periods of time upon practically all the samples exposed at 21° C to relative humidities of 94 percent or over.

TABLE 7.—*Maximum moisture contents of light-weight gelatin-latex gas-cell fabrics observed at various relative humidities (based on weight of dry, uncoated fabric), and times elapsed before mold growth became visible*

Sample	Values at various relative humidities of—												
	65%	86%			94%			97%			100%		
			Period of exposure preceding—			Period of exposure preceding—			Period of exposure preceding—			Period of exposure preceding—	
	Moisture content	Moisture content	Maximum gain	Visible mold growth	Moisture content	Maximum gain	Visible mold growth	Moisture content	Maximum gain	Visible mold growth	Moisture content	Maximum gain	Visible mold growth
	%	%	*Days*	*Days*	%	*Days*	*Days*	%	*Days*	*Days*	%	*Days*	*Days*
0 [a]	8.5	21.3	21	------	41.2	21	ca10	85.4	42	ca10	115.3	35	ca10
1	8.5	21.4	35	------	40.6	21	24	69.1	21	14	94.2	21	14
2	8.3	21.5	35	------	41.8	35	------	70.1	28	21	92.3	21	21
3	8.3	20.9	42	------	38.2	42	------	69.9	42	28	97.9	35	28
4	8.2	20.6	56	------	38.1	49	------	64.6	49	28	86.7	42	28
5	9.7	24.2	56	------	45.2	43	35	86.3	49	28	158.7	49	21
6	10.4	24.7	43	------	44.5	39	28	73.0	28	21	101.8	28	21
7	7.6	16.8	14	------	32.4	49	39	68.7	49	39	115.9	56	39
8	8.3	17.8	21	------	33.9	63	32	67.5	70	32	111.0	56	32
9	7.9	17.3	63	------	32.6	63	32	59.3	63	32	94.8	49	21
10	8.0	17.3	63	------	33.8	63	42	62.9	63	32	80.6	42	21
11	7.6	16.4	56	------	32.1	74	------	60.2	74	25	92.1	67	25
12	8.0	16.5	29	------	31.2	42	29	54.4	42	25	64.6	42	25

[a] Values for sample 0 are calculated from an experiment by G. M. Kline on uncoated edge-sealed Q39–A–2 fabric (J. Research NBS **14**, 80 (1935) table 13) RP758. Other numbers refer to samples described in table 1.

Differences in the rates of attainment of the maximum values are apparent in the results for various samples in a set. These differences become increasingly characteristic with increasing relative humidity up to 97 percent. At a relative humidity of 100 percent, irregularities become great enough to interfere with comparisons. Accordingly, the rates of approach to maximum values at 97 percent relative humidity are plotted in figure 1 for comparison. These rates are based on percentages of total gains in weight of fabrics conditioned at 65 percent relative humidity and 21° C.

In connection with the results shown in figure 1, it should be remembered that the weights of the protective coatings on samples 6 and 12 are 2.2 and 1.8 oz/sq yd, respectively, whereas those on the other samples are less than 0.9 oz/sq yd. On an airship of the GZ–1 type, such as the *Macon*, 54,000 sq yd of fabric are required for the gas cells. If the heavier protective coatings were to be used on the cells in place of the lighter ones, there would be a minimum difference in weight of approximately 1.5, tons aside from any considerations of absorption of moisture.

V. DISCUSSION

In order to discuss adequately the effects of variations in protective coatings on gelatin-latex fabrics, it is appropriate to determine what the operative factors are in the problem. These resolve themselves essentially into factors causing gains in weight on exposure to humid atmospheres and those causing losses under the same conditions. The factors causing gains in weight may further be viewed with respect to amount and rate—the properties of absorptivity and permeability.

The nature and relative location of the materials in the gelatin-latex gas-cell fabrics investigated are indicated in figure 2. The protective coating may or may not be present on the inner surface of the fabric. In all cases here considered, the edges are sealed with paraffin as described in section III, and indicated in figure 2.

Information on the absorptive properties of most of the materials used is available in the literature. Pertinent values have been collected and are presented in table 8. For an uncoated fabric it may be seen that the chief absorbing materials are cloth and gelatin. The absorptivity of the gelatin layer is actually much greater than indicated because in the gas-cell fabric it is plasticized with polyglycerol, which is very hygroscopic. The paraffin coatings have very low

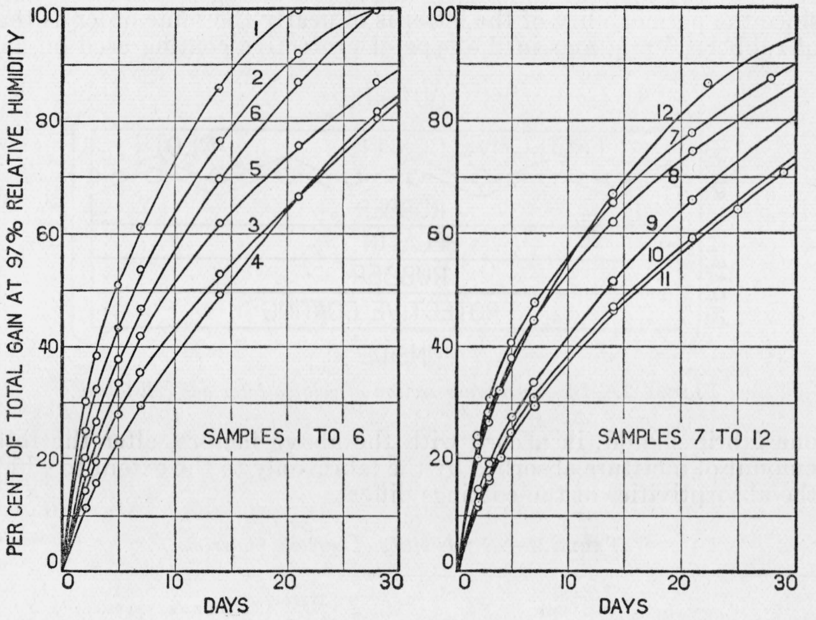

FIGURE 1.—*Rates of attainment of maximum absorption of moisture by gelatin-latex gas-cell fabrics.*

absorptive powers; varnishes have somewhat greater absorptivity, as may be seen from a comparison of the values given for samples 5 and 6 of set 1 in table 7 with the values for the remainder of the set.

TABLE 8.—*Moisture contents of materials at various relative humidities*

Material	Percentage of moisture held at relative humidity of—					
	13%	30%	50%	70%	90%	100%
Rubber [1]	0.17	0.28	0.60	0.74	0.99	
Gelatin (dry) [1]	1.01	2.80	4.92	7.6	11.4	
Cotton cloth [1]	2.99	4.56	6.7	9.6	13.5	
Balloon cloth, unmercerized [2]	2.6	4.3	5.6	7.6	12.5	27.1
Raw cotton [3]	2.7	4.1	6.0	8.2	13.9	

[1] R. E. Wilson and Tyler Fuwa, Ind. Eng. Chem. **14**, 916 (1922).
[2] G. M. Kline, J. Research NBS **14**, 72 (1935) RP758. Values are interpolated except at 100 percent relative humidity.
[3] A. R. Urquhart and A. M. Williams, J. Textile Inst. **15**, T138 (1924). Interpolated values.

Since the gelatin layer (the most hygroscopic) is in the center of the fabric, the permeabilities of the other layers to water vapor are also of importance. The layer of cloth offers no resistance to the entrance of moisture. Data on the permeability to moisture of rubber, paraffin, and varnishes, taken from information in the literature, are given in table 9 as "diffusivities"; this term is defined by Hermann [5] as "the number of grams of water which pass through a 1-cm cube in 1 hour under a vapor-pressure difference of 1 mm of mercury at a definite temperature." From the data shown, it would be expected that the rate of penetration of moisture into a paraffin-coated fabric would be governed more by the thickness of the coating than by the nature of the other materials. It would not appear to be so definitely controlled by a similar coating of varnish containing aluminum powder, since the permeability of the latter is of nearly the same order as that of rubber. Variations in the type of protective coating used on any

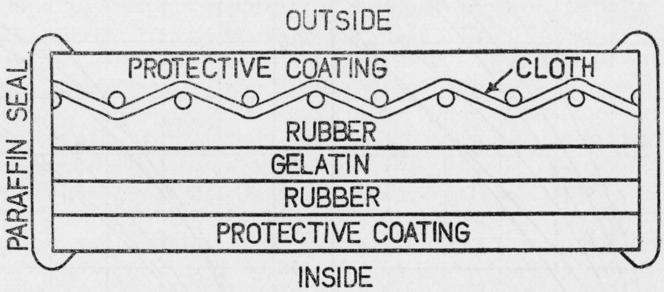

FIGURE 2.—*Idealized cross section of gelatin-latex gas-cell fabric.*

one fabric should, in accord with the above factors, alter the total amount of moisture absorbed by the fabric only to the extent to which the absorptivities of the coatings differ.

TABLE 9.—*Diffusivities of various materials*

Substance	Temp. °C	Diffusivity constants × 10 [8]
Hydrocarbon wax [1]	25	0.1.
Soft vulcanized rubber [2]	{ 25	2.3–2.8 (against vapor).
	25	4.6–5.1 (against liquid).
Do.[1]	25	7.0.
Clear varnishes [3]	27	15–60.
Varnishes containing aluminum powder [3]	27	6–10.

[1] D. B. Hermann, Bell Lab. Record **13**, 47 (1934).
[2] Caculated from measurements of permeability to water by J. D. Edward and S. F. Pickering, BS Sci. Pap. 387.
[3] Calculated from values for moisture impedance by R. I. Wray and A. R. Van Vorst, Ind. Eng. Chem. **25**, 842 (1933).

Two factors do, however, lower the total amount of moisture absorbed at high relative humidities—mold growth and leaching. Apparently, their effects are negligible at 21° C for relative humidities of less than 94 percent. Mold growth appears after periods of 2 weeks or longer on practically all samples which are exposed to relative humidities of 94 percent or more. Since the rate of loss in

[5] D. B. Hermann, Bell Lab. Record **13**, 47 (1934).

weight caused by this mold growth is increasing with time, and the rate of gain in weight of absorbed moisture is simultaneously decreasing, the sample soon begins to lose weight. The leaching effect is of a lesser magnitude, but at high humidities is probably a cause of irregularities. The moisture taken up by the fabric at these high humidities forms, after several weeks, droplets on the surface of the material. These droplets contain glycerol and gelatin leached from the fabric and, if accidentally lost during handling, cause slight apparent irregularities in the rate of change. Since some hygroscopic material is removed by such a loss, there is a tendency to lower the maximum absorption values.

A review of the results obtained with set 1 shows rather close correlation with the various gain and loss factors considered above. The maximum absorption values of the paraffined samples are all approximately the same until humidities are reached at which mold growth affects the final values. Apparently, increasing amounts of paraffin do not inhibit mold growth to the same extent that they retard the absorption of moisture, and the result is that lower maximum absorption values are obtained with increasing weights of protective coating. Since mold growth is favored by humidity, these maximum values decrease with increasing humidity. There is a definite increase in total moisture absorbed, however, at all humidities when the protective coating contains varnish. It has been found by Kline [6] that the same maximum values are reached by paraffined and uncoated fabrics at humidities at which mold growth is not an important factor.

The rates of attainment of maximum absorption decrease with increase of paraffin coating. This is illustrated at 97 percent relative humidity in figure 1, as shown by comparison of the rates for samples 1 and 2, or 3 and 4. The change in rate is not so great, however, as that between samples coated on one surface only and those coated on both surfaces. This may be seen by comparing rates for samples 2 and 3. The change is an expected one, since coating on only one surface leaves the other protected by the more permeable rubber film alone. The application of aluminum paint to the outer surface before putting on the paraffin coat, as shown by sample 5, does not decrease the rate. If aluminum varnish alone is used, the rate is greater than for a sample paraffined on both sides and approaches that of fabric paraffined on only one side; this is true despite the heavier coatings used when varnish is applied.

Similar effects are found in set 2 (samples 7 to 12). Here, because of the smaller amount of the hygroscopic gelatin-polyglycerol layer in the fabric, all the rates are lower, and the differences between them are less. For humidities at which attack by mold is not an important factor, the maximum absorption values are definitely less than for set 1, but at high humidities the lowered values obtained are of the same order. The approximate equality of the total moisture absorbed by the samples having various coatings is again shown, though here the increased value in the presence of varnish is not noticeable. The lowering of maximum absorption with increasing weight of coating, caused by the lack of inhibition of mold growth, is once more found at the higher humidities. The decrease in rate

[6] See p. 79 of reference 1.

of attainment of the maximum absorption with increased weight of paraffin is also evident in this set, as is the lowering of the rate by the application of the coating to both sides of the fabric. The application of aluminum paint before the paraffin in this set appears to have a slight beneficial effect (sample 11 of fig. 1), but when only aluminum varnish is used as a coating (sample 12) the rate becomes the highest of the set.

VI. CONCLUSIONS

(1) Increasing the thickness of the paraffin coating decreases the rate of absorption of moisture by gelatin-latex gas-cell fabric.

(2) Application of the paraffin coating to both surfaces of the fabric is much more effective than the application of an equal weight on one side only.

(3) Substitution of aluminum varnish for paraffin as a protective coating results in an increased rate of absorption of moisture by the fabric, though the coatings of varnish are much heavier.

(4) Except for the absorptivities of the coatings themselves, variation in type of coating does not appear to alter the total amount of moisture absorbed by the fabric at a given humidity.

(5) Reduction of the amount of gelatin plasticized with polyglycerol lowers the total amount of moisture absorbed by the fabric.

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