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SUITABILITY OF VARIOUS PLASTICS FOR USE IN AIRPLANE DOPES

By Gordon M. Kline and Cyrus G. Malmberg

ABSTRACT

A number of different cellulose derivatives of potential interest as film-forming constituents for airplane dopes have recently become available commercially. An investigation has been undertaken at the National Bureau of Standards to determine the fundamental factors involved in the formulation of dopes containing these new derivatives to obtain optimum tautness and durability. Data are presented in this paper relative to the effect of varying the acyl or ethoxyl content and the viscosity of cellulose esters and ethers on the tautness of fabrics doped with them. It is concluded that the solvents and diluents govern to a large extent the tautening properties of the dope and the durability of the film deposited on the fabric.

CONTENTS

I. INTRODUCTION

The problem of producing a fire-resistant doped fabric to replace the hazardous cellulose nitrate product was investigated in 1933 at the National Bureau of Standards for the National Advisory Committee for Aeronautics, and the results were reported in this journal.[1] It was established that none of the synthetic resins then available would produce films of satisfactory tautness when used alone on the fabric, and that their addition to either cellulose nitrate or cellulose acetate dope resulted in a corresponding lowering of the fabric tension. Data were also obtained on the comparative rates of burning of fabrics doped with various cellulose nitrate and cellulose acetate compositions, both with and without the addition of fire-retarding salts to the fabric. It was shown that cellulose acetate dope yields a relatively nonhazardous product when applied to untreated fabric,

[1] G. M. Kline, *Fire-resistant doped fabric for aircraft*, J. Research NBS **14**, 575-587 (1935) RP788.

and that when it is applied to fabric treated with boric-acid-borax mixture, a product which is nonflammable under ordinary conditions is obtained. However, the investigation was not continued at that time to include a study of the effect of varying the ingredients of a cellulose acetate dope on the tautening characteristics and particularly on the moisture sensitivity of the doped fabric.

Cellulose acetate has now become available commercially in several grades, representing materials of different degrees of acetylation and viscosity. Likewise, other cellulose derivatives, possessing characteristics which indicate that they might make satisfactory dope bases, are being manufactured. Among these more recently developed products are ethylcellulose, cellulose acetobutyrate, cellulose acetopropionate, and cellulose nitroacetate. These products are also available in various grades denoting differences in chemical composition and in viscosity. The proper formulation of dopes based on these new materials to obtain the requisite balance of solvents, diluents, and plasticizers, both as to types and amounts, can be accomplished only by a thorough laboratory study of the various factors involved. The Bureau of Aeronautics of the U. S. Navy Department has, therefore, requested the National Bureau of Standards to undertake such an experimental study in order to develop a dope, based on these comparatively nonflammable cellulose derivatives, which will compare favorably with or surpass cellulose nitrate dope with respect to the effect of high relative humidity on the tautness of the doped fabric.

In the first phase of this work a variety of cellulose derivatives and synthetic resins were applied to airplane fabric to study the relation of tautness to the type of plastic base used in the dope, the percentage of acyl or alkyl substitution in the various cellulose derivatives, and the viscosity [2] of these derivatives. These panels are also providing data on the relative resistance to weathering of the various doped fabrics, while tests are in progress to determine the effect of solvents, diluents, and plasticizers on the tautening property and to establish the moisture relations of the various doped fabrics.

II. DETAILS OF TEST MATERIALS AND MEASUREMENTS

1. PROPERTIES OF THE PLASTICS

The materials tested were furnished by various manufacturers whose interest and cooperation in this investigation have been very helpful. They also supplied data regarding the viscosity and chemical composition of the compounds, shown in table 1. In the manufacturers' reports the chemical composition was expressed as percentages. The number of equivalents of each substitution group present in the compounds and also of free hydroxyl groups were calculated from these percentage figures. These latter values are listed in table 1 and indicate immediately the degree of hydrolysis, which is closely related to the solubility [3] and moisture-absorbing [4] properties of the cellulose derivative.

[2] The term "viscosity" is used in this paper to denote certain flow characteristics of solutions of the various plastics as measured in the manner described in the footnote to table 1.

[3] W. Coltof, *Solubility properties of certain highly polymeric substances.* J. Soc. Chem. Ind. **56**, 363T-375T (1937).

[4] S. E. Sheppard and P. T. Newsome, *The sorption of water vapor by cellulose and its derivatives.* J. Phys. Chem. **33**, 1817-35 (1929).

TABLE 1.—*Viscosity and composition of test materials*

Material	Sample designation	Viscosity [a]	Composition: Percentage basis	Composition: Equivalents basis
Cellulose acetate	CA-a1	9.4 sec	39.1 acetyl	2.38 acetyl; 0.62 hydroxyl.
Do	CA-a2	6.2 sec	40.0 acetyl	2.48 acetyl; 0.52 hydroxyl.
Do	CA-a3	10.5 sec	40.9 acetyl	2.57 acetyl; 0.43 hydroxyl.
Do	CA-a4	28 sec	40.4 acetyl	2.51 acetyl; 0.49 hydroxyl.
Do	CA-a5	44 sec	40.0 acetyl	2.48 acetyl; 0.52 hydroxyl.
Do	CA-a6	56 sec	38.4 acetyl	2.32 acetyl; 0.68 hydroxyl.
Do	CA-a7	81 sec	38.7 acetyl	2.35 acetyl; 0.65 hydroxyl.
Do	CA-a8	83 sec	38.4 acetyl	2.32 acetyl; 0.68 hydroxyl.
Do	CA-a9	94 sec	39.1 acetyl	2.38 acetyl; 0.62 hydroxyl.
Do	CA-a10			ca.3 acetyl.
Do	CA-b1	2 sec	39.0 acetyl	2.37 acetyl; 0.63 hydroxyl.
Do	CA-b2	33 sec	40.3 acetyl	2.51 acetyl; 0.49 hydroxyl.
Do	CA-b3	64 sec	39.2 acetyl	2.39 acetyl; 0.61 hydroxyl.
Do	CA-b4	77 sec	38.1 acetyl	2.29 acetyl; 0.71 hydroxyl.
Cellulose acetopropionate	CAP-a1	31 sec	17.1 acetyl; 26.9 propionyl	1.13 acetyl; 1.34 propionyl; 0.53 hydroxyl.
Do	CAP-b1	34.5 cp [b]	15.5 acetyl; 31.3 propionyl	1.08 acetyl; 1.64 propionyl; 0.28 hydroxyl.
Do	CAP-b2	470 cp	15.5 acetyl; 31.3 propionyl	1.08 acetyl; 1.64 propionyl; 0.28 hydroxyl.
Do	CAP-b3	650 cp	15.5 acetyl; 31.3 propionyl	1.08 acetyl; 1.64 propionyl; 0.28 hydroxyl.
Do	CAP-c1	35 cp	14.0 acetyl; 34.0 propionyl	1.00 acetyl; 1.83 propionyl; 0.17 hydroxyl.
Do	CAP-c2	42 cp	11.0 acetyl; 34.0 propionyl	0.74 acetyl; 1.72 propionyl; 0.54 hydroxyl.
Do	CAP-c3	90 cp	9.0 acetyl; 33.0 propionyl	0.58 acetyl; 1.60 propionyl; 0.82 hydroxyl.
Cellulose acetobutyrate	CAB-b1	36 cp	32.5 acetyl; 15.4 butyryl	2.31 acetyl; 0.66 butyryl; 0.03 hydroxyl.
Do	CAB-b2	315 cp	32.2 acetyl; 15.2 butyryl	2.27 acetyl; 0.65 butyryl; 0.08 hydroxyl.
Do	CAB-b3	665 cp	32.0 acetyl; 16.1 butyryl	2.28 acetyl; 0.69 butyryl; 0.03 hydroxyl.
Cellulose nitroacetate	CNA-b1	Medium		
Cellulose nitrate	CN-c1	0.5 sec		
Do	CN-c2	10.5 sec		
Do	CN-c3	84 sec		
Methylcellulose	MC-b1	Low		
Ethylcellulose	EC-b1	6.2 sec	47.5 ethoxyl	2.43 ethoxyl; 0.57 hydroxyl.
Do	EC-b2	22 sec	47.7 ethoxyl	2.44 ethoxyl; 0.56 hydroxyl.
Do	EC-b3	66 sec	48.2 ethoxyl	2.48 ethoxyl; 0.52 hydroxyl.
Do	EC-d1	20 cp	48.3 ethoxyl	2.49 ethoxyl; 0.51 hydroxyl.
Do	EC-d2	30 cp	52.0 ethoxyl	2.77 ethoxyl; 0.23 hydroxyl.
Do	EC-d3	35 cp	48.7 ethoxyl	2.52 ethoxyl; 0.48 hydroxyl.
Do	EC-d4	75 cp	48.0 ethoxyl	2.47 ethoxyl; 0.53 hydroxyl.
Do	EC-d5	150 cp	48.3 ethoxyl	2.49 ethoxyl; 0.51 hydroxyl.
Do	EC-d6	210 cp	49.5 ethoxyl	2.58 ethoxyl; 0.42 hydroxyl.
Benzylcellulose	BC-b1	Medium		
Chlorinated rubber	CR-b1	125 cp		
Methyl methacrylate	MM-c1			

[a] The viscosity values were obtained in the manufacturers' laboratories by the following variety of methods (all parts by weight unless otherwise noted):

Cellulose acetate series CA-a: ASTM falling-ball method, using 20-percent solutions in acetone. (See ASTM Standards, 1936, part II, Nonmetallic Materials, published by the American Society for Testing Materials, Philadelphia, Pa.)

Cellulose acetate series CA-b: ASTM falling-ball method, using 20-percent solutions in a mixture of 90 parts of acetone and 10 parts of ethyl alcohol.

Cellulose acetopropionate series CAP-a: ASTM falling-ball method, using 20-percent solutions in acetone.

Cellulose acetopropionate series CAP-b: capillary viscometer, using 10-percent solution in acetone at 25° C.

Cellulose acetopropionate series CAP-c: Same as above.

Cellulose acetobutyrate series CAB-b: Same as above.

Cellulose nitrate series CN-c: ASTM falling-ball method.

Ethylcellulose series EC-b: ASTM falling-ball method, using a 20-percent solution in a mixture of 80 parts of toluene and 20 parts of ethyl alcohol.

Ethylcellulose series EC-d: Capillary viscometer method, using a 5-percent solution in a mixture of 80 parts of toluene and 20 parts of absolute ethyl alcohol by volume at 25° C.

Chlorinated rubber CR-b: Capillary viscometer, using a 20-percent solution in toluene at 25° C.

[b] cp=centipoise.

2. COMPOSITION OF THE DOPES

Inasmuch as it was desired to compare the behavior of various cellulose derivatives with one another, the same solvent mixture and plasticizer, triphenyl phosphate, were employed in a majority of the dopes. In most cases the proportions of the latter were one part of plasticizer to nine parts of cellulose derivative. Preliminary tests indicated that varying the concentration of the cellulose base in the solvent mixture between the limits of 5 and 10 percent had comparatively little effect on the tautness produced. A concentration of about 6.4 percent was, therefore, used for most samples, although it was necessary to dilute some of the aluminum-pigmented dopes to obtain a solution of suitable viscosity for brushing. Complete data concerning the formulas of the dopes are shown in table 2. Formula I was used in general for the cellulose esters and formula VI for the ethylcelluloses. The other formulas were introduced because of the special solubility characteristics of certain derivatives, such as cellulose triacetate, or to compare with those above solvent compositions recommended in the literature or by the manufacturer.

TABLE 2.—*Formulas of experimental dopes*

Formula	Plastic base	Plasticizer	Aluminum powder	Solvent	Composition of solvent (parts by weight)
	Percent	*Percent*	*Percent*	*Percent*	
I, clear	6.4	0.6 triphenyl phosphate	None	93.0	Acetone 48, ethyl acetate 20, methyl ethyl ketone 20, diacetone alcohol 5.
I, pigmented	6.0	1.2 triphenyl phosphate	4.8	88.0	Acetone 50, ethyl acetate 15, methyl ethyl ketone 15, diacetone alcohol 8.
IA, clear	6.4	None	None	93.6	Acetone 48, ethyl acetate 20, methyl ethyl ketone 20, diacetone alcohol 5.
IA, pigmented	6.0	do	4.8	89.2	Acetone 50, ethyl acetate 15, methyl ethyl ketone 15, diacetone alcohol 8.
II, clear	6.4	0.6 triphenyl phosphate	None	93.0	Acetone 50, ethyl alcohol 10, toluene 40.
II, pigmented	6.0	1.2 triphenyl phosphate	4.8	88.0	Do.
IIA, clear	6.4	0.3 triphenyl phosphate	None	93.3	Do.
IIA, pigmented	6.0	do	4.8	88.9	Do.
IIB, clear	6.4	None	None	93.6	Do.
IIB, pigmented	6.0	do	4.8	89.2	Do.
III, clear	10.4	1.0 benzyl alcohol	None	88.6	Acetone 16.5, ethyl alcohol 8.5, benzene 36.6, toluene 18.0, xylene 9.0.
III, pigmented	6.0	0.6 benzyl alcohol	4.8	88.6	Do.
IV, clear	6.4	do	None	93.0	Do.
IV, pigmented	6.0	do	4.8	88.6	Do.
VI, clear	6.4	None	None	93.6	Acetone 25, ethyl acetate 20, toluene 45, diacetone alcohol 10.
VI, pigmented	6.0	do	4.8	89.2	Do.
VIA, clear	6.4	0.6 Dow No. 6	None	93.0	Do.
VIA, pigmented	6.0	1.2 Dow No. 6	4.8	88.0	Do.
VII, clear	6.4	0.6 triphenyl phosphate	None	93.0	Ethyl acetate 25, methyl ethyl ketone 25, butyl acetate 25, Methyl Cellosolve 25.
VII, pigmented	6.0	1.2 triphenyl phosphate	4.8	88.0	Do.
VIIA, clear	6.4	None	None	93.6	Do.
VIIA, pigmented	6.0	do	4.8	89.2	Do.
VIII, clear	6.4	0.6 triphenyl phosphate	None	93.0	Methyl Cellosolve.
VIII, pigmented	6.0	1.2 triphenyl phosphate	4.8	88.0	Do.
IX, clear	3.8	0.4 triphenyl phosphate	None	95.8	Chloroform 70, tetrachloroethane 30.
IX, pigmented	2.4	do	1.9	95.2	Do.

TABLE 2.—*Formulas of experimental dopes*—Continued

Formula	Plastic base	Plasticizer	Aluminum powder	Solvent	Composition of solvent (parts by weight)
	Percent	*Percent*	*Percent*	*Percent*	
X, clear	7.7	None	None	92.3	Toluene.
X, pigmented	6.0	do	4.8	89.2	Do.
XI, clear	7.6	do	None	92.4	Toluene 33.1, xylene 22.3, Cellosolve 22.3, methyl amyl ketone 22.3.
XI, pigmented	6.0	do	4.8	89.2	Toluene 26.8, xylene 24.4, Cellosolve 24.4, methyl amyl ketone 24.4.
XII, clear	4.5	do	None	95.5	Water.
XII, pigmented	4.5	do	3.6	91.9	Do.

3. METHOD OF PREPARING THE DOPED PANELS

Wooden frames (fig. 1), constructed in accordance with specification SP-16 of the U. S. Naval Aircraft Factory, were used in these tests. Cotton airplane fabric, weighing approximately 4 oz/yd^2, was placed over the frame and a 50-pound weight was attached to each side. In this way uniform tension in both directions of the weave of the cloth was produced. The fabric was tacked to the frame with

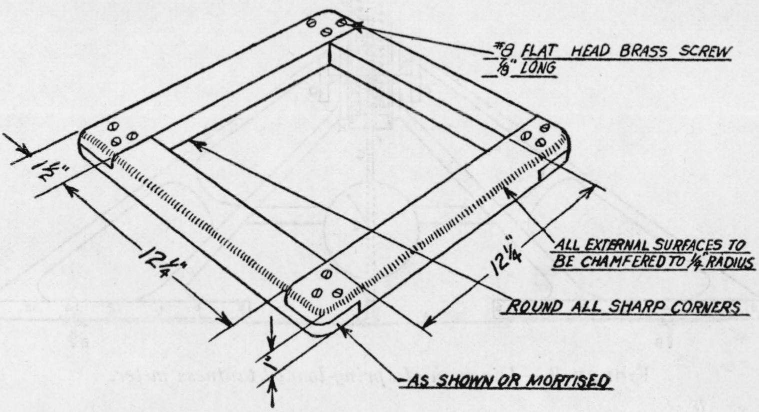

FIGURE 1.—*Construction of exposure panel.*

No. 4 upholsterer's tacks, spacing them approximately 1 inch apart. Four coats of clear dope and, in the case of the pigmented panels, two coats of aluminum-pigmented dope were brushed on the panels. The average weight of the clear doped fabrics after drying was 7.2 oz/yd^2 and of the pigmented doped fabrics was 8.7 oz/yd^2.

4. METHODS OF TESTING THE FABRICS

The measurements of tautness of the fabric were made with a spring-loaded tautness meter, the construction of which is shown in figure 2. The instrument is essentially a Schiefer Compressometer,[5] modified to adapt it to measuring the deflection of a doped fabric instead of the thickness and compressibility of textile fabrics and similar materials.

[5] H. F. Schiefer, BSJ. Research **10**, 705-13, (1933) RP561. The assistance of Dr. Schiefer in designing the tautness meter and in preparing figure 2 is gratefully acknowledged.

For measuring tautness, the instrument is placed upon the fabric, *A*, of a panel or wing section with the foot, *C*, midway between the two ribs, *B*. The foot, *C*, is of spherical shape with a 0.5-inch radius of curvature. It is fastened to the bottom of the spindle, *D*, of the lower dial micrometer, *E*. The rod, *F*, is fastened to the top of the spindle, *D*, at *G* and to the top of a helical spring, *H*, at *I*. The bottom of the spring is fastened to the tube, *J*, at *K*. The upper dial micrometer, *L*, is fastened to the top of the tube at *M*. The spindle, *N*, of the upper dial micrometer is attached to the rod, *F*, at *O* by a ball and socket union. The tube may be moved up or down relative to the frame, *P*, by turning the knob, *Q*, of the rack and pinion, *R*. The frame, *P*, consists of an aluminum beam having a three-point support which rests on the framework of the panel or on any two

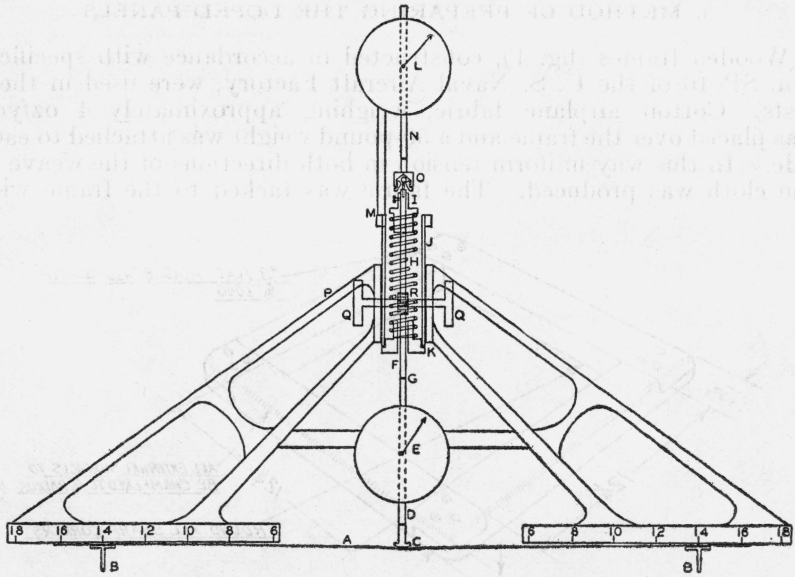

FIGURE 2.—*Diagram of spring-loaded tautness meter.*

adjacent ribs of a wing. Graduations on the beam indicate the width of the rib spacing so that the instrument may be centered quickly and conveniently. By turning the knob the foot may be lowered upon the doped fabric. The load which is applied to the specimen by the foot may be ascertained from the upper dial reading, which indicates the elongation of the spring, and a calibration curve of the spring. The amount of deflection of the doped fabric when loaded is indicated on the lower dial, which is graduated to read directly to 0.001 inch.

For the estimation of tautness of doped fabrics, the foot is lowered upon the specimen by means of the rack and pinion until the load on the fabric is 3 ounces, as indicated by the upper dial. A reading of the lower dial is taken at this load. Then the load on the fabric is increased to 19 ounces and a second reading of the lower dial is taken. The difference between these two readings of the lower dial is the deflection in thousandths of an inch of the fabric under one pound load, as tested. The less the deflection under a given load, the greater is the tautness.

Tautness measurements were made on the fabrics conditioned at approximately 70° F. and 65-percent relative humidity. For the cloth alone a 2-ounce loading is employed instead of 1 pound in order to avoid excessive stretching. The average deflection observed for the undoped fabrics with the 2-ounce load was 45 mils with an average variation of ± 2.5 and a maximum difference of ± 6 mils. A 1-pound load deflects such fabrics approximately 260 mils.

After drying for at least 1 week in the laboratory, the doped panels were placed in a room kept at 70° F and 65-percent relative humidity. Three measurements of tautness were made in this room at intervals during a period of 1 week. The panels were placed upon the roof of the Industrial Building of the National Bureau of Standards on August 14, 1937, on racks inclined at an angle of 45° and facing south. Measurements of tautness and brittleness were made at intervals under prevailing conditions of temperature and humidity. Brittleness of the film, i. e., tendency to "ringworm", was determined by pressing the thumb firmly into the fabric covering at each corner of the panel.

5. RESULTS OF TESTS ON THE DOPED PANELS

Data obtained on the doped panels in the conditioning room and on the roof are presented in table 3.

TABLE 3.—*Tautness and flexibility data obtained in aging tests of doped fabrics*

[Tautness values are reported as the number of mils deflection of the fabric under a 1-pound load; brittleness, i. e., "ringworming," of the film is indicated by the letter *R*; deterioration of the film leading to surface cracking is indicated by the letter *c*; *S* indicates slackness of the fabric, in which condition deflection values are meaningless; *W* indicates removal of the film by rain. Panels were placed on the roof on August 14, 1937]

Panel number				1	2	3	4	5	6	7	8	9	10	11	12
Material				CA-a1	CA-a1	CA-a2	CA-a2	CA-a3	CA-a3	CA-a4	CA-a4	CA-a4	CA-a5	CA-a5	CA-a5
Formula				I	I	I	I	I	I	I	I	VII	I	I	IA
Pigmentation				Clear	Al	Clear	Al	Clear	Al	Clear	Al	Al	Clear	Al	Al
Exposure conditions															
Temperature	Relative humidity	Number of days on roofs	Prevailing weather												
°F	Percent														
74	64	(a)	(a)	100	83	107	88	100	85	104	84	73	109	85	79
73	64	(a)	(a)	101	83	110	88	101	84	104	84	72	108	84	79
73	63	(a)	(a)	100	83	109	88	101	84	105	84	72	108	84	79
90	40	2	Sunshine	94	83	106	96	105	93	92	90	79	107	87	88
94	52	5	do	93	84	103	85	95	98	93	88	78	101	92	80
63	97	9	Rain	120	106	115	92	127	106	106	92	112	130	110	107
65	99	11	do	127	116	128	102	135	106	108	102	115	130	115	108
92	52	17	Sunshine	93	87	110	84	95	88	95	86	78	100	90	68
74	35	31	do	94	84	109	92	101	95	105	94	84	100	88	74
52	63	56	Cloudy	113	94	130	99	110	97	120	94	90	113	92	90
50	90	67	Rain	136	125	145	112	140	115	114	110	117	140	120	120
54	41	78	Sunshine	92	79	113	100	94	89	115	90	78	104	84	75
52	43	93	Cloudy	*R*	82	116	87	*R*	86	101	83	84	108	88	80
54	96	105	Rain	------	*S*	*S*	*S*	------	*S*	*S*	*S*	*S*	*S*	*S*	*S*
30	56	121	Cloudy	------	103	138	116	------	102	142	115	86	125	100	88
43	43	128	Sunshine	------	67	92	74	------	70	86	74	69	87	70	62

Panel number				13	14	15	16	17	18	19	20	21	22	23	24
Material				CA-a5	CA-a5	CA-a6	CA-a6	CA-a7	CA-a7	CA-a8	CA-a8	CA-a9	CA-a9	CA-a10	CA-a10
Formula				VII	VIII	I	I	I	I	I	I	I	I	IX	IX
Pigmentation				Al	Al	Clear	Al	Clear	Al	Clear	Al	Clear	Al	Clear	Al
74	64	(a)	(a)	71	67	104	86	98	86	112	85	101	87	78	61
73	64	(a)	(a)	73	68	105	86	96	87	110	85	100	87	78	60
73	63	(a)	(a)	72	67	105	87	97	87	110	85	100	87	78	60
90	40	2	Sunshine	68	63	102	87	101	87	116	90	98	89	100	73
94	52	5	do	77	67	94	84	99	87	105	87	90	83	98	75
63	97	9	Rain	113	110	95	91	117	104	140	107	100	92	101	80
65	99	11	do	111	110	97	101	118	112	120	106	107	98	108	80
92	52	17	Sunshine	72	68	104	78	100	90	105	82	104	87	*R*	80
74	35	31	do	73	*R*	117	100	104	85	105	85	111	95	---	75
52	63	56	Cloudy	80	---	140	98	121	90	122	88	130	98	---	75
50	90	67	Rain	110	---	120	100	135	116	137	116	114	110	---	93
54	41	78	Sunshine	70	---	128	107	105	82	110	84	125	100	---	75
52	43	93	Cloudy	71	---	125	83	107	89	123	87	115	88	---	73
54	96	105	Rain	*S*	---	*S*	*S*	*S*	*S*	*S*	*S*	*S*	*S*	---	120
30	56	121	Cloudy	83	---	152	118	124	98	130	99	170	117	---	69
43	43	128	Sunshine	58	---	95	82	84	69	93	69	94	78	---	63

(a) Exposed in laboratory conditioning room.

TABLE 3.—*Tautness and flexibility data obtained in aging tests of doped fabrics*—Continued

			Panel number	25	26	27	28	29	30	31	32	33	34	35	36
			Material	CA-b1	CA-b1	CA-b2	CA-b2	CA-b3	CA-b3	CA-b4	CA-b4	CAP-a1	CAP-a1	CAP-a1	CAP-b1
			Formula	I	I	I	I	I	I	I	I	I	I	VII	I
			Pigmentation	Clear	Al	Clear	Al	Clear	Al	Clear	Al	Clear	Al	Al	Clear
Exposure conditions															
Temperature	Relative humidity	Number of days on roof	Prevailing weather												
°*F*	*Percent*														
74	64	(a)	(a)	107	90	98	82	99	90	104	84	112	92	79	116
73	64	(a)	(a)	107	90	96	83	103	89	104	86	112	93	80	116
73	63	(a)	(a)	107	90	96	82	102	89	105	85	112	92	79	117
90	40	2	Sunshine	114	99	97	89	102	91	104	84	123	109	89	12
94	52	5	do	106	95	97	88	90	87	96	82	122	107	100	130
63	97	9	Rain	118	110	118	116	120	120	125	103	114	110	107	120
65	99	11	do	124	118	109	104	108	117	130	110	125	100	108	125
92	52	17	Sunshine	120	104	105	97	92	90	96	83	131	109	106	135
74	35	31	do	118	97	107	99	106	90	100	81	130	115	100	140
52	63	56	Cloudy	143	104	140	105	115	96	116	92	135	101	108	*R*
50	90	67	Rain	125	116	130	100	120	120	135	117	130	107	105	----------
54	41	78	Sunshine	*R*	90	111	99	112	98	99	80	132	108	98	----------
52	43	93	Cloudy	----------	94	116	95	108	95	104	80	127	98	92	----------
54	96	105	Rain	----------	*S*	*S*	*S*	*S*	*S*	*S*	*S*	*S*	*S*	*S*	----------
30	56	121	Cloudy	----------	112	143	120	142	120	125	96	146	111	98	----------
43	43	128	Sunshine	----------	80	85	80	80	76	83	68	107	80	85	----------

Panel number				37	38	39	40	41	42	43	44	45	46	47	48
Material				CAP-b1	CAP-b2	CAP-b2	CAP-b3	CAP-b3	CAP-c1	CAP-c1	CAP-c2	CAP-c2	CAP-c3	CAP-c3	CAB-b1
Formula				I	I	I	I	I	I	I	I	I	I	I	I
Pigmentation				Al	Clear	Al	Clear	Al	Clear	Al	Clear	Al	Clear	Al	Clear
74	64	(a)	(a)	90	103	89	109	90	110	76	116	90	122	92	95
73	64	(a)	(a)	93	104	89	107	90	110	76	118	94	128	93	94
73	63	(a)	(a)	93	104	89	107	90	110	76	118	93	129	93	95
90	40	2	Sunshine	110	125	112	120	103	126	89	132	107	140	102	110
94	52	5	do	108	123	110	123	108	130	100	131	108	132	97	107
63	97	9	Rain	110	105	102	112	105	106	90	126	113	133	122	84
65	99	11	do	103	108	95	104	102	115	90	125	111	135	115	99
92	52	17	Sunshine	118	125	104	126	107	140	*R*	135	125	143	106	*R*
74	35	31	do	114	140	115	131	113	*R*	-	140	115	135	104	-
52	63	56	Cloudy	107	140	102	130	103	-	-	*R*	117	150	107	-
50	90	67	Rain	110	117	109	115	102	-	-	-	112	140	121	-
54	41	78	Sunshine	113	*R*	115	145	103	-	-	-	112	140	105	-
52	43	93	Cloudy	101	-	100	125	100	-	-	-	108	*R*	103	-
54	96	105	Rain	*S*	-	120	*S*	*S*	-	-	-	*S*	-	*S*	-
30	56	121	Cloudy	108	-	110	142	108	-	-	-	112	-	112	-
43	43	128	Sunshine	88	-	99	103	87	-	-	-	91	-	84	-

(a) Exposed in laboratory conditioning room.

TABLE 3.—*Tautness and flexibility data obtained in aging tests of doped fabrics*—Continued

Panel number				49	50	51	52	53	54	55	56	57	58	59	60
Material				CAB-b1	CAB-b2	CAB-b2	CAB-b2	CAB-b3	CAB-b3	CNA-b1	CNA-b1	CN-c1	CN-c1	CN-c2	CN-c2
Formula				I	I	I	VII	I	I	I	I	I	I	I	I
Pigmentation				Al	Clear	Al	Al	Clear	Al	Clear	Al	Clear	Al	Clear	Al
Exposure conditions															
Temperature	Relative humidity	Number of days on roof	Prevailing weather												
°*F*	*Percent*														
74	64	(a)	(a)	79	91	76	65	96	75	98	82	122	94	107	85
73	64	(a)	(a)	79	90	76	65	97	77	97	83	124	95	108	87
73	63	(a)	(a)	79	90	76	65	96	76	97	83	123	95	108	86
90	40	2	Sunshine	92	101	90	74	105	90	107	90	150	120	134	109
94	52	5	do	94	100	90	75	106	91	96	87	150	114	135	115
63	97	9	Rain	78	82	72	84	80	71	108	110	120	112	110	107
65	99	11	do	83	101	83	85	102	87	108	107	118	109	115	94
92	52	17	Sunshine	*R*	106	90	83	107	91	110	97	*R*	133	140	120
74	35	31	do	----------	114	98	80	116	105	105	97	----------	123	*R*	105
52	63	56	Cloudy	----------	110	90	*R*	122	92	*R*	94	----------	115	----------	94
50	90	67	Rain	----------	111	96	----------	127	96	----------	117	----------	105	----------	102
54	41	78	Sunshine	----------	117	108	----------	114	105	----------	90	----------	114	----------	98
52	43	93	Cloudy	----------	103	84	----------	109	88	----------	85	----------	112	----------	96
54	96	105	Rain	----------	135	110	----------	140	120	----------	*S*	----------	130	----------	114
30	56	121	Cloudy	----------	133	104	----------	130	108	----------	120	----------	118	----------	102
43	43	128	Sunshine	----------	94	80	----------	100	85	----------	75	----------	110	----------	84

Panel number				61	62	63	64	65	66	67	68	69	70	71	72
Material				CN–c2	CN–c3	CN–c3	MC–b1	MC–b1	EC–b1	EC–b1	EC–b2	EC–b2	EC–b3	EC–b3	EC–d1
Formula				VII	I	I	XII	XII	VI	VI	VI	VI	VI	VI	VI
Pigmentation				Al	Clear	Al	Clear	Al	Clear	Al	Clear	Al	Clear	Al	Clear
74	64	(a)	(a)	60	105	90	138	100	109	90	106	86	104	84	110
73	64	(a)	(a)	61	104	90	138	96	112	90	108	86	105	83	111
73	63	(a)	(a)	61	105	90	138	96	111	90	108	86	105	83	111
90	40	2	Sunshine	75	133	113	83	55	130	104	128	101	130	99	122
94	52	5	do	80	128	116	71	45	127	100	128	107	122	104	120
63	97	9	Rain	78	116	116	*W*	*W*	120	100	112	105	115	99	138
65	99	11	do	80	115	106	----------	----------	126	110	111	110	110	101	150
92	52	17	Sunshine	86	125	125	----------	----------	135	111	136	104	135	105	*R*
74	35	31	do	83	*R*	122	----------	----------	*R*	112	*R*	110	*R*	112	----------
52	63	56	Cloudy	76	----------	110	----------	----------	----------	113	----------	110	----------	107	----------
50	90	67	Rain	88	----------	116	----------	----------	----------	118	----------	118	----------	116	----------
54	41	78	Sunshine	75	----------	112	----------	----------	----------	109	----------	108	----------	107	----------
52	43	93	Cloudy	76	----------	108	----------	----------	----------	107	----------	104	----------	106	----------
54	96	105	Rain	97	----------	120	----------	----------	----------	*S*	----------	*S*	----------	*S*	----------
30	56	121	Cloudy	69	----------	115	----------	----------	----------	114	----------	112	----------	116	----------
43	43	128	Sunshine	70	----------	96	----------	----------	----------	98	----------	95	----------	97	----------

([a]) Exposed in laboratory conditioning room.

TABLE 3.—*Tautness and flexibility data obtained in aging tests of doped fabrics*—Continued

Panel number				73	74	75	76	77	78	79	80	81	82	83	84
Material				EC-d1	EC-d2	EC-d2	EC-d3	EC-d3	EC-d4	EC-d4	EC-d5	EC-d5	EC-d5	EC-d5	EC-d5
Formula				VI	VIA	VIA	VI	VI	VI	VI	IIB	IIB	IIA	IIA	II
Pigmentation				Al	Clear	Al	Clear	Al	Clear	Al	Clear	Al	Clear	Al	Clear
Exposure conditions															
Temperature	Relative humidity	Number of days on roof	Prevailing weather												
°*F*	*Percent*														
74	64	(a)	(a)	95	114	91	110	85	115	88	107	92	111	96	118
73	64	(a)	(a)	95	115	88	108	86	114	88	109	95	110	97	116
73	63	(a)	(a)	95	115	87	110	85	114	88	109	95	111	97	117
90	40	2	Sunshine	112	135	102	125	92	129	110	120	103	130	108	130
94	52	5	do	110	137	106	120	101	126	109	114	101	121	110	135
63	97	9	Rain	122	114	100	141	107	145	120	128	106	137	115	115
65	99	11	do	130	115	101	145	122	140	125	115	107	135	109	122
92	52	17	Sunshine	120	*R*	125	125	108	137	110	*R*	*R*	*R*	*R*	*R*
74	35	31	do	125	--------	112	125	106	135	107	--------	--------	--------	--------	--------
52	63	56	Cloudy	*R*	--------	*R*	*R*	105	*R*	107	--------	--------	--------	--------	--------
50	90	67	Rain	--------	--------	--------	--------	104	--------	102	--------	--------	--------	--------	--------
54	41	78	Sunshine	--------	--------	--------	--------	100	--------	106	--------	--------	--------	--------	--------
52	43	93	Cloudy	--------	--------	--------	--------	96	--------	111	--------	--------	--------	--------	--------
54	96	105	Rain	--------	--------	--------	--------	*S*	--------	*S*	--------	--------	--------	--------	--------
30	56	121	Cloudy	--------	--------	--------	--------	102	--------	109	--------	--------	--------	--------	--------
43	43	128	Sunshine	--------	--------	--------	--------	87	--------	98	--------	--------	--------	--------	--------

Panel number				85	86	87	88	89	90	91	92	93	94	95	96	97
Material				EC–d5	EC–d5	EC–d5	EC–d5	EC–d6	EC–d6	BC–b1	BC–b1	BC–b1	BC–b1	CR–b1	CR–b1	MM–c1
Formula				II	VI	VI	VII	VI	VI	III	IV	VII	III	X	X	IX
Pigmentation				Al	Clear	Al	Al	Clear	Al	Clear	Al	Al	Al	Clear	Al	Al
74	64	(a)	(a)	111	106	83	85	112	88	121	104	101	101	130	98	98
73	64	(a)	(a)	108	105	88	86	113	91	125	102	103	105	133	99	96
73	63	(a)	(a)	109	105	87	85	113	90	124	102	103	103	131	99	97
90	40	2	Sunshine	122	124	110	100	124	106	135	125	119	120	155	130	125
94	52	5	do	125	120	103	103	120	101	130	122	120	120	143	125	120
63	97	9	Rain	117	135	114	115	132	115	120	114	103	107	114	92	103
65	99	11	do	113	135	114	120	135	118	127	109	104	115	120	85	107
92	52	17	Sunshine	*R*	125	110	107	124	105	*R*	135	132	125	*S*	127	135
74	35	31	do	----	*R*	118	109	*R*	113	----	120	122	128	----	130	118
52	63	56	Cloudy	----	----	113	113	----	109	----	113	115c	113c	----	115c	103
50	90	67	Rain	----	----	120	115	----	124	----	109	110c	114c	----	93c	107
54	41	78	Sunshine	----	----	113	104	----	105	----	113	123c	120c	----	150c	107
52	43	93	Cloudy	----	----	109	108	----	98	----	113	120c	114c	----	130c	100
54	96	105	Rain	----	----	*S*	*S*	----	*S*	----	120	121c	117c	----	101c	110
30	56	121	Cloudy	----	----	114	107	----	104	----	112	112c	106c	----	136c	90
43	43	128	Sunshine	----	----	100	100	----	93	----	105	118c	107c	----	134c	95

(a) Exposed in laboratory conditioning room.

III. EFFECT OF VARIOUS FACTORS ON INITIAL TAUTNESS OF DOPED FABRICS

1. TYPE OF PLASTIC

The tautness values of the fabrics doped with the different plastic materials, measured in the conditioning room at 70° F and 65-percent relative humidity, are summarized in table 4. It will be noted that most of the cellulose plastics produced tautnesses ranging between 82

TABLE 4.—*Summary of tautening properties of various types of plastics used in dopes containing aluminum pigment*

Material	Number of samples tested	Formula used	Average deflection under 1-lb. load	Variation
			Mils	*Mils*
Cellulose acetate (hydrolyzed)	13	I	86	82 to 90.
Cellulose triacetate	1	IX	60	
Cellulose acetopropionate	7	I	91	[a]89 to 92.
Cellulose acetobutyrate	3	I	77	76 to 79.
Cellulose nitroacetate	1	I	83	
Cellulose nitrate	3	I	90	86 to 95.
Methylcellulose	1	XII	97	
Ethylcellulose	8	II	88	83 to 95.
Benzylcellulose	1	III	103	Most panels slack.
Chlorinated rubber	1	X	99	
Methyl methacrylate resin	1	XI	97	

[a] One panel read 76.

and 97. Cellulose triacetate and the cellulose acetobutyrate, which was also practically a triester, had average tautness values of 60 and 77, respectively. Great difficulty was experienced in obtaining a taut fabric with benzylcellulose. Plasticizer was omitted from most of the ethylcellulose dopes because of the comparatively poor tautening qualities of this type of cellulose derivative and its reported characteristic of forming flexible films without it. However, it was necessary to add plasticizer to the high ethoxyl compound (panels 74 and 75) because the unplasticized films of this material ringwormed spontaneously 1 day after doping. The resinous materials, such as chlorinated rubber and methyl methacrylate polymer, did not tighten the fabric as well as did most of the cellulosic materials. Solutions of butyl methacrylate and Methyl Cellosolve methacrylate polymers failed to tighten the fabric when applied in the same solvent mixture used for the methyl derivative.

2. ACYL OR ALKYL SUBSTITUTION

The data in table 3 indicate that varying the acetyl content of cellulose acetate between the limits of 2.29 and 2.57 equivalents did not have an apparent effect on the ability of the compound to tighten the fabric. Likewise, the results obtained with ethylcellulose containing from 2.43 to 2.77 ethoxyl equivalents did not show a correlation between ethoxyl content and tautening property. There was not sufficient variation in the acyl composition of the cellulose acetopropionates and cellulose acetobutyrates to indicate its effect on tautness. Tests to determine this relationship are now under way on materials of this type having a greater variation in acyl content.

3. VISCOSITY

The absence of any effect of the size of the cellulose molecules, as indicated by the viscosity of solutions of these materials, on the tautening property is shown by the data in table 3. Cellulose acetates varying in viscosity from 2 to 94 seconds, as measured by the falling-ball test, did not differ markedly in their tautening ability. The same was true for ethylcelluloses whose 5-percent solutions in a mixture of 80 parts of toluene and 20 parts of ethyl alcohol gave viscosity values of 20 to 210 centipoises.

4. SOLVENT COMPOSITION

The results obtained with the different solvent formulas which were tested in this investigation lead to the rather startling conclusion that the most important single factor involved in the tautening property of a dope is the solvent composition employed. In the term "solvent composition" are included those organic liquids which form colloidal solutions of the cellulose derivatives, those which have only cosolvent and swelling action, and those which are merely diluents in the blend. It has been the usual practice to formulate the solvent composition on the basis of such requirements as drying time, anti-blushing characteristics, solvent property, and economy, without an adequate appreciation that the choice of the solvent composition governs not only the tautening property of the dope but also the flexibility (conversely the brittleness) of the film deposited on the fabric.

TABLE 5.—*Effect of various solvent compositions on the production of tautness by cellulose dopes containing aluminum pigment*

Formulas	Cellulose acetate	Cellulose acetopropionate	Cellulose acetobutyrate	Cellulose nitrate	Ethylcellulose
	Mils	*Mils*	*Mils*	*Mils*	*Mils*
No. I	84	92	76	86	----
No. VII	72	79	65	61	85
Methyl Cellosolve	67	----	----	----	----
No. II	----	----	----	----	94
No. VI	----	----	----	----	86

Table 5 presents the data obtained on the effect of various solvent compositions on the tautness of the doped fabric. It will be noted that the difference in the tautness values of the two cellulose nitrate panels listed in this table is much greater than the tautness differences shown in table 4 for the various types of cellulose derivatives or for compounds varying only in viscosity and percentage substitution. Since these panels were prepared, the effect of various solvents and mixtures of solvents and nonsolvents on the shrinkage and flexibility of films of cellulose derivatives has been studied in detail. The solutions are poured into glass Petri dishes with and without a Cellophane lining. The film in contact with the glass provides information on the adhesive property of the composition and is also used to follow the rate of drying. The film in contact with Cellophane is used to obtain an estimate of the amount of shrinking characteristic of the dope; in only a few instances has tenacious adherence of the film to Cellophane been noted. These tests are still in progress, but it may be noted here that they indicate that in order to obtain a maximum tautening effect it is necessary to formulate a dope so that a minimum of active solvent will be present during the final drying stage. Some solvent action is necessary in this stage to prevent precipitation (blushing) of the cellulose derivative. The selection of this solvent is an important factor in avoiding the formation of a brittle film, which Sheppard and Newsome [6] found to be associated with the presence of large crystallites. Thus, cellulose acetate dissolved in Methyl Cellosolve gave the maximum tautness for this cellulose derivative (table 5), but reference to table 3 shows that the film is brittle and ringworms after a few days' exposure on the roof. Likewise, cellulose acetobutyrate in formula VII (panel 52), which contains 25 percent of Methyl Cellosolve, tautens well but yields a brittle film. However, although our tests have not yet been completed, present indications are that it will be possible to formulate dopes with these cellulose derivatives which will tauten the fabric satisfactorily without yielding brittle films.

IV. EFFECT OF WEATHERING ON TAUTNESS OF DOPED FABRICS

In order to obtain comparative information on the effect of variations in temperature and humidity on the tautness of fabrics doped with various cellulose derivatives, it would be desirable to have all the panels at about the same initial tautness. This was not achieved with the panel tests reported in table 3. However, the tautnesses obtained with the cellulose compounds, using the solvent blend listed as formula VII, were more nearly alike than with any other composition. The variation in the tautness values obtained for these panels under different weather conditions is shown in figure 3.

The cellulose acetate panels were not markedly affected by the heat of the sun, but did slacken during periods of rain to a greater extent than any of the other cellulose derivatives. The cellulose acetopropionate panels also showed marked slackening in rainy weather after 3 months of exposure on the roof. The cellulose acetobutyrate and cellulose nitrate panels behaved about alike, becoming less taut when removed from the conditioning room into the sunlight and, in general, showing a slight additional decrease in tautness in rainy weather. The ethylcellulose and benzylcellulose panels were considerably poorer in initial tautness than those covered with the cellulose esters. Both of the cellulose ethers underwent a decrease in tautness in sunlight. During periods of rain the ethylcellulose panels showed additional slackening, whereas the benzylcellulose panels had a tendency to tighten.

It should be emphasized that the behavior of these cellulose films under various weather conditions with respect to both tautness and moisture absorption is dependent to a large extent upon the type and amount of plasticizer employed. For the above tests triphenyl

[6] S. E. Sheppard and P. T. Newsome. *Film formation with cellulose derivatives*, J. Soc. Chem. Ind. **56**, 256T–261T (1937).

phosphate, present to the extent of 10 percent of the total nonvolatiles, was used throughout. In the course of the phase of our investigation dealing with the effect of plasticizers on tautness, both initially and upon exposure, compositions should become available which will have greater uniformity of tension under varying weather conditions.

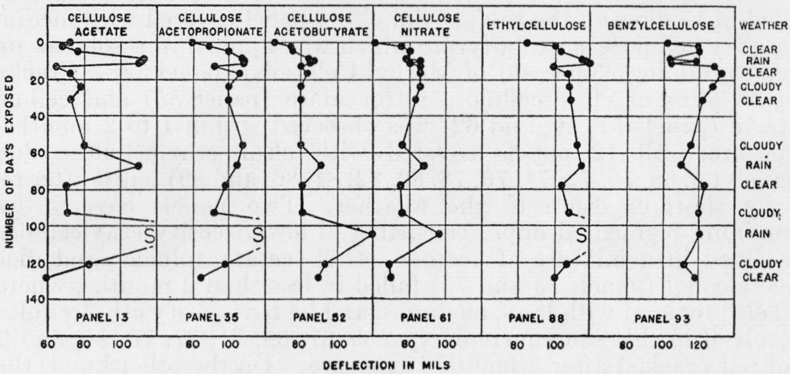

FIGURE 3.—*Variation in tautness of doped fabrics exposed on the roof.*

Formula VII was used for all of the dopes. "S" indicates slackness of the fabric. Weather conditions on the days when measurements were made were as follows:

Time on roof	Tempera-ture	Relative humidity	Time on roof	Tempera-ture	Relative humidity
Days	° *F.*	*Percent*	*Days*	° *F.*	*Percent*
2	90	40	31	74	35
5	94	52	56	52	63
9	63	97	67	50	90
10	64	98	78	54	41
11	65	99	93	51	43
13	86	62	105	54	96
17	92	52	121	30	56
24	72	74	128	43	43

V. EFFECT OF WEATHERING ON FLEXIBILITY OF THE DOPED FILM

The results of exposure tests on panels doped with the different cellulose derivatives, shown in table 3, must be considered as only tentative evidence of their relative stability. A formulation which yields a flexible and durable film with one derivative may produce a brittle and unstable film with another cellulose compound because of differences in their solubility. However, certain trends can be observed in the data in table 3. The cellulose acetate films are, in general, very stable to sunlight. The only panels which gave evidence of embrittlement were three covered with clear dope made from low-viscosity cellulose acetate (panels 1, 5, and 25), one panel covered with clear cellulose triacetate dope (panel 23), and one panel covered with aluminum-pigmented dope made by dissolving cellulose acetate of medium viscosity in Methyl Cellosolve (panel 14), in which case the embrittlement is directly attributable to the solvent employed. The clear dope films made with cellulose acetopropionates of various viscosities failed on five (panels 36, 38, 42, 44, and 46) of the seven panels exposed. One panel covered with cellulose acetopropionate of low viscosity and containing aluminum pigment (panel 43) failed in 17 days on the roof. However, a sample of medium-viscosity cellulose acetopropionate of more recent manufacture than the rest showed good stability (panels 33, 34, and 35). The low-viscosity cellulose acetobutyrate dopes, both clear and pigmented (panels 48 and 49), failed in 17 days on the roof, as did also a panel covered with medium-viscosity cellulose acetobutyrate which was applied in a solvent mixture containing 25 percent of Methyl Cellosolve (panel 52). Cracking of the films of clear cellulose nitroacetate (panel 55) and cellulose nitrate (panels 57, 59, and 62) was observed within 1 to 2 months of exposure. All 12 panels covered with clear ethylcellulose dopes (panels 66, 68, 70, 72, 74, 76, 78, 80, 82, 84, 86, and 89) failed after relatively short exposure to the weather. Two panels covered with aluminum-pigmented dopes consisting of low-viscosity ethylcelluloses dissolved in a mixture of acetone, ethyl acetate, toluene, and diacetone alcohol (panels 73 and 75) failed in less than 2 months, whereas panels prepared with low-, medium-, and high-viscosity ethylcelluloses dissolved in this same formula (panels 67, 69, 71, 77, 79, 87, and 90) had not cracked after 3 months' exposure. On the other hand, three panels of pigmented medium-viscosity ethylcellulose applied in a mixture of toluene, ethyl alcohol, and acetone (panels 81, 83, and 85) failed in 17 days, which indicated that this particular formula apparently tends to lay down a film which is inherently brittle. The clear benzylcellulose film (panel 91) cracked and yellowed very soon after exposure. The pigmented benzylcellulose films (panels 92, 93, and 94) showed evidences of cracking after about 2 months of exposure, although the fabric was not tautened sufficiently for the typical "ringworm" type of failure to occur. The panels covered with methylcellulose (panels 64 and 65) showed remarkable tautness during the first week of exposure, but the methylcellulose was completely removed by the first rain. This action was, of course, anticipated, but the rapidity with which the aluminum-pigmented methylcellulose film was dissolved by the rain was rather surprising in view of the comparatively slow rate of solution of methylcellulose in the laboratory at ordinary temperature. The film of clear chlorinated rubber of low viscosity (panel 95) yellowed and disintegrated very rapidly upon exposure to sunlight. The pigmented film (panel 96) cracked in a manner similar to the benzylcellulose films after about 2 months' exposure. The pigmented methyl methacrylate film (panel 97) did not show any evidence of cracking after 3 months on the roof.

VI. SUMMARY AND CONCLUSIONS

1. The tautnesses of airplane fabric doped with various plastics dissolved in a variety of solvent mixtures were determined. It was observed that the most important single factor involved in the initial tautening property of a dope is the solvent composition. In order to obtain a maximum tautening effect, it is necessary to formulate a dope so that a minimum of active solvent will be present during the final drying stage. The selection of this solvent is also an important factor in avoiding the formation of a film which is initially brittle or which rapidly becomes brittle upon exposure out of doors.

2. The highest initial-tautness values were obtained with cellulose triesters, such as cellulose triacetate and a practically completely acylated cellulose acetobutyrate. Varying the acyl or ethoxyl content of partially hydrolyzed cellulose derivatives did not have a pronounced effect on the ability of the compounds to tighten the fabric. The initial tautening property is also apparently independent of the size of the cellulose molecule, as indicated by certain flow characteristics of solutions of these materials. The tests for the majority of the cellulose esters were made with films containing 10 percent of triphenyl phosphate.

3. In exposure tests the cellulose acetobutyrate and cellulose nitrate panels behaved quite similarly, slackening somewhat when removed from the conditioning room into the sunlight, and, in general, showing a slight additional decrease in tautness in rainy weather. The cellulose acetate panels slackened during periods of rain to a greater extent than any of the other derivatives. The cellulose acetopropionate panels also showed marked slackening in rainy weather after 3 months of exposure on the roof. The ethylcellulose and benzylcellulose panels were considerably poorer in initial tautness and slackened still further upon exposure. However, the results of these exposure tests must be considered as only exploratory and preliminary to the testing of dopes formulated to develop optimum tautness, flexibility, and moisture resistance. Before dopes having these characteristics can be formulated, it will be necessary to obtain detailed information on the effect of various solvents, diluents and plasticizers on the properties of the film-forming plastics.

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