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A STUDY OF THE PROPERTIES OF HOUSEHOLD BLANKETS[1]

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ABSTRACT

The fiber composition, weight, thickness, compressibility, compressional resilience, thermal transmission, air permeability, breaking strength, and shrinkage of 156 different blankets are recorded. The effects of laundering; of laundering and renapping; of laundering, renapping, and abrasion; of dry cleaning and renappng; and of dry cleaning, renapping, and abrasion on these properties of a large number of blankets are shown. A linear relationship was found between the compressional resilience and the wool content of cotton-wool blankets. The thermal transmission of the blankets was found to be independent of the kind of fiber. The reciprocal of thermal transmission was found to be related linearly to the thickness. The thermal transmission computed by means of the equation $1/T=3.0\,t_{0.1}+0.63$, where T is the thermal transmission in Btu/(°F hr ft^2), and $t_{0.1}$ is the thickness in inches at a pressure of 0.10 lb/in.^{2}, was found to agree with the measured values within ± 10 percent, 95 times out of 100. Empirical relationships were also found among thermal transmission, thickness at 1.0 lb/in.^{2}, and compressibility; and among thickness at 0.10 lb/in.^{2}, compressibility, and weight. The relation between breaking strength and weight, and that between breaking strength and compressibility, are discussed. Minimum requirements are suggested for the properties of blankets for use in a performance specification.

CONTENTS

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I. INTRODUCTION

Blankets are an essential article in every home, hospital, and hotel, and in other places of abode. In time of war they form a vital part of the protective clothing of the soldier, sailor, and marine on battle fronts and in training camps. They furnish shelter to the wounded and to those forced to take to lifeboats and life rafts at sea. In time of peace blankets are an essential article for camping and other outdoor recreation and sport. In a major emergency they provide temporary shelter to the unfortunate victims.

Although blankets form such an essential part of life in war and in peace, adequate methods for testing them and essential information regarding their performance characteristics have not been available. New blankets are usually soft, lofty, fluffy, flexible, and warm. It is desirable to have them retain these characteristics during use. Changes in the characteristics of blankets during use are probably attributable mainly to the effect of laundering or dry cleaning. This is particularly true if the temperature and alkalinity of the water used in laundering wool or acetate blankets are too high or not controlled, or if the blankets receive excessive mechanical action during washing or dry cleaning.

New blankets differ considerably in their characteristics, and some will change more than others when washed or dry cleaned. A blanket which is considerably felted when new, for example, would not be expected to change greatly, whereas one which is soft, fluffy, and flexible is more likely to become felted and less flexible during cleaning. The cleaning procedure for blankets of the latter type would have to be controlled more closely to minimize changes in their desirable characteristics.

The results of tests on a large number of blankets of different fiber composition are given in this paper. The effects of laundering; of laundering and napping; of laundering, napping, and abrasion; of dry cleaning and napping; and of dry cleaning, napping, and abrasion on the properties of blankets are discussed. Information is given concerning the correlation between various properties of the blankets, and requirements for a performance specification of blankets are suggested.

II. MATERIALS TESTED

The blankets which were tested, 156 in number, are listed in table 1 according to their fiber composition and weight. Most of the blankets were obtained directly from manufacturers by the National Bureau of Standards, the Medical Corps of the United States Army, and the Ellen H. Richards Institute, Pennsylvania State College. Some were purchased from retail stores. A few were submitted for test by Government departments. It is believed that these blankets are a good representation of the qualities of blankets available at the time this investigation was made.

TABLE 1.—*Results of tests on 156 blankets*

Blanket No.	Fiber composition				Weight	Thickness at—		Compressibility	Compressional resilience	Thermal transmission	Air permeability at ½ in. H_2O pressure	Breaking strength (grab method)		Shrinkage in 10 washings [a]		Relative thermal insulation per unit weight [b]	Thermal insulating value [c]
	Wool	Cotton	Viscose rayon	Acetate rayon		0.10 lb/in.²	1.0 lb/in.²					Warp	Filling	Warp	Filling		
	%	%	%	%	*oz/yd²*	*in.*	*in.*	*in./in. / lb/in.²*	%	*Btu/(°F hr ft²)*	*ft³/(min ft²)*	*lb*	*lb*	%	%	*°F hr ft² yd² / Btu oz*	%
1	100	—	—	—	5.6	0.080	0.044	0.34	49	1.15	257	32	19	10	3	150×10⁻³	28
2	100	—	—	—	8.4	.141	.083	.33	46	—	—	29	11	—	—	—	—
3	100	—	—	—	8.5	.140	.089	.28	48	—	—	32	29	—	—	—	—
4	100	—	—	—	8.6	.147	.091	.32	48	—	—	40	18	—	—	—	—
5	100	—	—	—	9.5	.172	.099	.34	49	0.94	261	54	43	3	0	112	41
6	100	—	—	—	9.5	.182	.093	.42	52	.84	263	34	14	11	9	125	47
7	100	—	—	—	9.7	.167	.097	.31	43	.88	223	—	—	—	—	117	45
8	100	—	—	—	9.7	.161	.093	.32	44	.89	241	—	—	—	—	116	44
9	100	—	—	—	9.7	.198	.105	.43	47	.82	223	36	18	—	—	126	49
10	100	—	—	—	9.8	.164	.102	.30	45	.93	208	46	33	3	1	110	42
11	100	—	—	—	9.8	.193	.102	.40	50	.82	326	34	13	7	5	125	49
12	100	—	—	—	9.9	.178	.093	.40	47	.82	246	—	—	—	—	123	49
13	100	—	—	—	10.0	.164	.098	.33	45	.88	144	—	—	—	—	114	45
14	100	—	—	—	10.2	.137	.087	.28	36	.99	221	41	32	2	1	99	38
15	100	—	—	—	10.4	.192	.113	.35	45	—	—	24	12	—	—	—	—
16	100	—	—	—	11.0	.184	.106	.39	48	.78	290	33	31	4	2	117	51
17	100	—	—	—	11.1	.185	.114	.31	55	.89	164	35	21	6	2	101	44
18	100	—	—	—	11.2	.188	.109	.36	45	.82	161	38	18	—	—	109	49
19	100	—	—	—	11.9	.191	.111	.36	48	.77	232	34	30	3	4	109	52
20	100	—	—	—	12.0	—	.108	.36	51	.69	—	45	21	*3	*5	121	57
21	100	—	—	—	12.0	.193	.103	.49	54	.75	111	50	21	3	10	111	53
22	100	—	—	—	12.1	.204	.119	.37	48	.78	264	30	22	3	3	106	51
23	100	—	—	—	12.1	.221	.137	.28	46	—	—	31	26	—	—	—	—
24	100	—	—	—	12.5	.172	.105	.27	42	.86	152	—	—	—	—	93	46
25	100	—	—	—	12.5	.236	.139	.35	46	—	—	32	22	—	—	—	—
26	100	—	—	—	12.6	.231	.122	.34	47	.74	498	37	39	12	0	107	54
27	100	—	—	—	12.6	—	.126	.34	44	.75	—	37	12	*7	*1	106	53
28	100	—	—	—	13.0	.249	.147	.33	42	—	—	40	52	—	—	—	—
29	100	—	—	—	13.0	.214	.134	.30	44	.80	103	—	—	—	—	96	50
30	100	—	—	—	13.0	.228	.115	.43	39	.75	187	51	31	4	6	103	53

See footnotes at end of table.

TABLE 1.—*Results of tests on 156 blankets*—Continued

Blanket No.	Fiber composition: Wool	Fiber composition: Cotton	Fiber composition: Viscose rayon	Fiber composition: Acetate rayon	Weight	Thickness at—: 0.10 lb/in.[2]	Thickness at—: 1.0 lb/in.[2]	Com-press-ibility	Com-pres-sional resili-ence	Thermal trans-mission	Air perme-ability at ½ in. H_2O pressure	Breaking strength (grab method): Warp	Breaking strength (grab method): Filling	Skrinkage in 10 washings [a]: Warp	Skrinkage in 10 washings [a]: Filling	Relative thermal insulation per unit weight [b]	Thermal insulat-ing value [c]
	%	%	%	%	*oz/yd*^{2}	*in.*	*in.*	$\frac{in./in.}{lb/in.^2}$	%	*Btu/(°F hr ft*^{2}*)*	*ft*^{3}*/(min ft*^{2}*)*	*lb*	*lb*	%	%	$\frac{°F\ hr\ ft^2\ yd^2}{Btu\ oz}$	%
1	100	-----	-----	-----	13.1	.128	.083	.23	50	1.01	77	68	56	8	4	75×10^{-3}	37
2	100	-----	-----	-----	13.1	.215	.127	.32	44	-----	-----	48	14	-----	-----	-----	-----
3	100	-----	-----	-----	13.7	-----	.138	.30	50	.74	-----	45	41	*8	*6	99	54
34	100	-----	-----	-----	13.8	.292	.164	.41	46	.69	263	43	33	7	3	105	57
35	100	-----	-----	-----	13.8	.204	.120	.36	54	.73	190	40	25	6	3	99	54
36	100	-----	-----	-----	14.3	.265	.167	.33	47	.73	153	46	35	-----	-----	96	54
37	100	-----	-----	-----	14.3	.152	.098	.23	48	.96	101	63	59	8	6	73	40
38	100	-----	-----	-----	14.5	.305	.161	.45	46	.72	280	30	24	11	12	96	55
39	100	-----	-----	-----	14.6	.147	.098	.30	48	1.00	70	77	59	8	4	69	38
40	100	-----	-----	-----	14.6	.253	.153	.31	44	.75	148	-----	-----	-----	-----	91	53
41	100	-----	-----	-----	14.6	.136	.095	.21	53	.96	91	-----	-----	-----	-----	71	40
42	100	-----	-----	-----	14.6	.200	.121	.28	45	.85	187	-----	-----	-----	-----	81	47
43	100	-----	-----	-----	14.7	.233	.157	.28	50	.82	127	56	48	10	9	83	49
44	100	-----	-----	-----	14.8	.165	.114	.23	44	.93	125	29	26	3	0	73	42
45	100	-----	-----	-----	14.9	.270	.143	.46	51	.65	216	33	32	7	5	103	59
46	100	-----	-----	-----	14.9	.230	.128	.37	50	.78	212	56	36	8	3	86	51
47	100	-----	-----	-----	14.9	.137	.095	.21	49	.91	95	-----	-----	-----	-----	74	43
48	100	-----	-----	-----	14.9	.242	.136	.34	46	-----	-----	81	50	-----	-----	-----	-----
49	100	-----	-----	-----	15.0	.231	.143	.31	41	.78	173	-----	-----	-----	-----	86	51
50	100	-----	-----	-----	15.2	.250	.165	.27	44	.75	105	-----	-----	-----	-----	88	53
51	100	-----	-----	-----	15.3	.212	.143	.24	48	.85	103	54	63	7	4	77	47
52	100	-----	-----	-----	15.3	.178	.118	.29	35	.85	-----	53	54	-----	-----	77	47
53	100	-----	-----	-----	15.9	.178	.121	.23	50	.93	53	74	70	8	3	68	42
54	100	-----	-----	-----	16.4	.141	.103	.18	49	.93	94	-----	-----	-----	-----	66	42
55	100	-----	-----	-----	16.5	.151	.100	.22	48	.95	45	68	71	8	3	64	41
56	100	-----	-----	-----	16.7	.193	.125	.31	40	.83	-----	58	51	-----	-----	72	48
57	100	-----	-----	-----	16.7	.156	.114	.19	51	.91	99	-----	-----	-----	-----	66	43
58	100	-----	-----	-----	17.5	.256	.159	.32	52	.77	142	31	27	6	0	74	52
59	100	-----	-----	-----	17.7	.277	.182	.28	48	.72	99	57	75	-----	-----	78	55
60	100	-----	-----	-----	17.8	.207	.137	.24	42	.87	101	75	48	2	1	65	46

61	100				18.3	.170	.120	.23	41	.90		79	67			61	44
62	100				19.3	.175	.120	.24	39	.93		73	72			56	42
63	100				19.4	.404	.221	.40	50	.57	122					90	64
64	100				22.4	.382	.228	.35	49	.60	86					74	63
65	80	20			8.8	.160	.089	.38	47			33	17				
66	71	29			9.3	.156	.085	.38	42	.91	116					118	43
67	80	20			9.6	.136	.087	.26	50	.97	124	46	46	8	12	107	39
68	75	25			10.0	.198	.097	.42	51		232	48	31				
69	73	27			10.1	.159	.087	.34	41	.94	187					105	41
70	75	25			10.5	.164	.095	.33	42	.93	105					102	42
71	79	21			11.4	.185	.106	.36	43	.82	160	46	42	2	**1	107	49
72	84	16			12.2	.243	.148	.38	44			37	22				
73	81	19			12.2	.122	.083	.20	38			22	11				
74	98	2			14.2	.138	.096	.22	42	.97	93	45	38	3	2	78	39
75	80	20			14.7	.269	.173	.29	39			49	60				
76	81	19			15.3	.205	.122	.30	42	.88	134					74	45
77	82	18			15.4	.292	.169	.41	41	.72	151					90	55
78	86	14			15.6	.145	.104	.19	42	.95	123	45	21	3	1	67	41
79	91	9			15.8	.139	.096	.20	41	1.00	126	59	39	3	1	63	38
80	87	13			19.7	.240	.159	.26	49	0.84	74	56	88	12	4	60	47
81	51	49			9.8	.194	.114	.37	36	.81	266	35	20	5	7	126	49
82	62	38			12.4	.145	.100	.21	36			24	19				
83	50	50			14.4	.170	.109	.27	37	.86	88	53	59	12	10	81	46
84	53	'7			14.7	.155	.111	.22	36	.95	63	22	41	4	4	68	41
85	50	[illegible]			14.7	.179	.114	.27	35	.89	90	52	65	13	11	77	44
86	59	41			14.8	.167	.114	.21	40			38	24				
87	50	50			15.2	.175	.114	25	.35	.90	85	53	90	12	13	73	44
88	50	50			15.6	.168	.110	.25	36	.90	82	52	84	11	13	71	44
89	49	51			19.1	.203	.147	.18	32			36	34				
90	28	72			7.0	.143	.076	.37	34			28	15				
91	41	59			7.2	.123	.073	.30	42			32	9				
92	26	74			7.5	.143	.082	.35	31			45	5				
93	27	73			7.8	.149	.085	.38	33	.85		31	11			151	47
94	33	67			9.7	.122	.070	.29	31	1.06	115					97	34
95	26	74			9.9	.142	.089	.28	35			54	18				
96	37	63			9.9	.120	.071	.30	38	1.04	124	56	38	14	0	97	35
97	34	66			10.0	.135	.072	.32	36	0.97	107					103	39
98	25	75			10.9		.152	.44	33	.67		41	17	*7	*7	137	58
99	40	60			11.1	.147	.087	.29	39	.97	105	63	33	12	0	93	39
100	25	75			11.8	.239	.139	.36	29			39	35				

See footnotes at end of table.

Table 1.—*Results of tests on 156 blankets*—Continued

Blanket No.	Fiber composition				Weight	Thickness at—		Compressibility	Compressional resilience	Thermal transmission	Air permeability at ½ in. H_2O pressure	Breaking strength (grab method)		Shrinkage in 10 washings [a]		Relative thermal insulation per unit weight [b]	Thermal insulating value [c]
	Wool	Cotton	Viscose rayon	Acetate rayon		0.10 lb/in.²	1.0 lb/in.²					Warp	Filling	Warp	Filling		
	%	%	%	%	oz/yd²	in.	in.	in./in. / lb/in.²	%	Btu/(°F hr ft²)	ft³/(min ft²)	lb	lb	%	%	°F hr ft² yd² / Btu oz	%
101	29	71	----	----	12.4	.266	.156	.37	31	----	----	42	34	----	----	----	----
102	29	71	----	----	12.6	.123	.088	.17	38	----	----	28	26	----	----	----	----
103	25	75	----	----	13.5	.215	.137	.30	27	.84	135	47	45	15	13	88×10⁻³	47
104	25	75	----	----	13.6	.206	.128	.31	29	.80	137	58	47	16	12	92	50
105	25	75	----	----	14.2	.213	.135	.30	29	.85	116	58	62	12	10	83	47
106	25	75	----	----	14.2	.211	.131	.30	26	.80	135	62	53	16	14	88	50
107	38	62	----	----	15.1	.204	.117	.29	35	.86	102	----	----	----	----	77	46
108	38	62	----	----	15.1	.174	.113	.24	38	.96	86	----	----	----	----	69	40
109	3	97	----	----	6.8	.200	.097	.39	18	.92	----	31	10	----	----	160	42
110	4	96	----	----	6.9	.140	.080	.39	26	.93	----	35	13	----	----	156	42
111	6	94	----	----	6.9	.142	.084	.32	28	----	----	36	21	----	----	----	----
112	1	99	----	----	7.6	.133	.084	.29	34	----	----	33	10	----	----	----	----
113	17	83	----	----	8.2	.142	.084	.32	34	----	----	43	8	----	----	----	----
114	1	99	----	----	8.7	.215	.118	.35	20	.87	----	----	----	----	----	132	46
115	3	97	----	----	8.9	.195	.118	.37	24	.86	----	34	14	----	----	131	46
116	8	92	----	----	9.4	.200	.113	.36	33	----	----	36	19	----	----	----	----
117	5	95	----	----	10.6	.235	.128	.32	16	.90	----	28	37	----	----	105	44
118	2	98	----	----	11.1	.195	.132	.27	35	----	----	54	21	----	----	----	----
119	----	100	----	----	4.1	.059	.031	.35	31	1.07	----	30	8	----	----	228	33
120	----	100	----	----	4.3	.065	.033	.39	28	1.05	----	29	12	----	----	221	34
121	----	100	----	----	4.6	.079	.039	.36	29	----	----	29	11	----	----	----	----
122	----	100	----	----	4.8	.070	.039	.33	33	1.06	----	----	----	----	----	196	34
123	----	100	----	----	5.4	.097	.052	.50	24	0.98	----	31	19	----	----	189	39
124	----	100	----	----	6.0	.081	.046	.37	29	1.05	----	37	28	----	----	159	34
125	----	100	----	----	6.4	.103	.060	.37	28	1.03	----	27	31	----	----	152	36
126	----	100	----	----	6.5	.100	.058	.34	26	1.00	----	21	37	----	----	154	38
127	----	100	----	----	9.5	.182	.114	.38	29	0.84	178	41	13	7	**1	125	47
128	----	100	----	----	11.0	.192	.126	.32	29	.86	155	38	24	6	4	106	46
129	78	----	22	----	15.6	.208	.133	.31	33	.77	----	42	37	----	----	83	52
130	33	62	5	----	10.0	.179	.109	.34	33	.82	----	33	19	----	----	122	49

131	29	53	18	--------	13.9	.231	.160	.33	32	.76	178	43	45	4	9	95	52
132	27	55	18	--------	8.7	.141	.081	.36	33	--------	208	47	23	--------	--------	--------	--------
133	26	43	31	--------	11.8	.204	.128	.37	33	.80	248	41	30	5	**2	106	50
134	25	38	37	--------	12.4	.313	.175	.44	19	.70	--------	42	35	--------	--------	115	56
135	24	37	39	--------	12.3	.317	.172	.49	20	.68	--------	40	32	--------	--------	120	57
136	23	38	39	--------	11.1	.237	.126	.38	24	.81	--------	42	30	--------	--------	111	49
137	23	24	53	--------	11.7	.307	.149	.50	18	.71	--------	36	35	--------	--------	120	56
138	23	31	46	--------	13.0	.275	.172	.39	29	.73	224	41	32	4	1	105	54
139	21	47	22	--------	10.7	.303	.129	.56	18	.68	--------	34	23	--------	--------	138	57
140	17	55	28	--------	6.6	.212	.074	.57	17	.84	--------	30	14	--------	--------	180	47
141	12	1	87	--------	12.8	.281	.175	.36	24	.74	216	33	40	5	7	106	54
142	7	55	38	--------	8.6	.232	.095	.46	16	.83	--------	36	22	--------	--------	140	48
143	6	62	32	--------	12.2	.212	.145	.31	26	.82	168	45	32	4	4	100	49
144	--------	25	75	--------	10.0	.279	.126	.57	21	.73	--------	38	19	--------	--------	137	54
145	--------	18	82	--------	13.9	.154	.112	.22	22	.91	74	57	57	9	**5	81	43
146	--------	13	87	--------	15.1	.239	.148	.35	25	.83	343	49	50	7	10	80	48
147	75	--------	--------	25	15.9	.144	.089	.29	40	.87	--------	56	61	--------	--------	72	46
148	70	--------	--------	30	16.3	.143	.099	.23	53	.93	30	--------	--------	--------	--------	66	42
149	50	--------	--------	50	14.7	.110	.070	.27	30	.99	--------	55	52	--------	--------	69	38
150	27	22	--------	51	14.5	.245	.152	.31	30	.76	141	50	56	10	7	91	52
151	25	25	--------	50	5.3	.076	.040	.33	33	1.04	269	31	16	6	1	182	35
152	25	26	--------	49	10.6	.286	.153	.49	30	0.68	331	36	22	11	10	139	57
153	25	25	--------	50	15.9	.229	.155	.30	29	.75	--------	54	58	--------	--------	84	53
154	22	27	--------	51	15.5	.253	.157	.33	29	.72	160	49	71	8	12	90	55
155	--------	--------	--------	100	14.2	--------	.124	.25	41	.78	--------	55	8	*3	*2	90	51
156	--------	--------	--------	100	19.6	--------	.130	.23	43	.77	--------	65	45	*5	*0	66	52

[a] The values marked with a single asterisk are shrinkage after 5 washings. The values marked with 2 asterisks indicate a stretch instead of a shrinkage.

[b] $\frac{1}{TW}$

[c] $\frac{100(1.60-T)}{1.60}$

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III. TESTING PROCEDURE

The weight, thickness, compressibility, compressional resilience, breaking strength, shrinkage, air permeability, and thermal transmission of the blankets before and after washing or dry cleaning were measured with equipment[4] and methods of testing[5] previously described.

Weight is expressed in ounces per square yard hereafter referred to as areal weight. Thickness is given for stated pressures. Breaking strength is expressed as the load at failure in the "grab" procedure, wherein a specimen considerably wider than the clamps is tested. Shrinkage is expressed as the percentage change in the dimensions of the specimen in each of its two principal directions.

Compressibility, $(\Delta t/t_{1.0})/\Delta P$, is the decrease in thickness, Δt, in unit thickness at a pressure of 1.0 lb/in.^{2}, $t_{1.0}$, per unit change of pressure, ΔP. For convenience in the numerical calculation of compressibility, Δt is taken to be $t_{0.5}-t_{1.5}$, where $t_{0.5}$ and $t_{1.5}$ are the thickness values at pressures of 0.5 and 1.5 lb/in.^{2}, respectively, and ΔP, the difference between these two pressures, is therefore 1.0 lb/in^2. The unabridged unit, (in./in.)/(lb/in.^{2}), rather than the contracted form, in.^{2}/lb, previously used, is used in this paper because its physical meaning is more readily understood.

Compressional resilience is the work recovered when the pressure is decreased from 2.0 to 0.10 lb/in.^{2} expressed as a percentage of the work done when the pressure is increased from 0.10 to 2.0 lb/in^2.

Thermal transmission is measured by the rate of loss of heat energy through a unit area of the material per unit temperature difference, when there is a temperature difference of 20°C (68°F) between the hot plate and the hood (cold plate).

Air permeability is measured by the volume of air flowing in unit time through a unit area of the material when the pressure difference across one thickness of the blanket is ½ in. of water.

The blankets were conditioned by exposure to air having a relative humidity of 65 percent and a temperature of 70°F, with a tolerance of ±2 percent in relative humidity and ±2°F in temperature. All the tests, except thermal transmission, were made under these conditions.

Some of the blankets were washed 10 times in a commercial laundry without brushing or renapping after washing. Some were washed 10 times in the United States Army laundry at Fort Myer, Va., without renapping after washing. Others were washed 10 times at the National Bureau of Standards in a reversing wash wheel, in an 0.5-percent soap solution at 100° F for 15 min, followed by three 5-min rinses also at 100° F. The samples were then centrifuged for 1 min and dried in a horizontal position without tension. Some of these blankets were not renapped after each washing, whereas others were renapped after each washing. Duplicate samples of the latter were renapped and then abraded before the next washing to simulate the mechanical wear during use. Some of the blankets were dry

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[4] Herbert F. Schiefer, *The Compressometer, an instrument for evaluating the thickness, compressibility, and compressional resilience of textiles and similar materials*, BS J. Research **10**, 705 (1933) RP561.
R. S. Cleveland, *An improved apparatus for measuring the thermal transmission of textiles*, J. Research NBS **19**, 675 (1937) RP1055.
Herbert F. Schiefer and Paul M. Boyland, *Improved instrument for measuring the air permeability of fabrics*, J. Research NBS **28**, 637 (1942) RP1471.

[5] Herbert F. Schiefer, *Advantages of a blanket-and-sheet combination for outdoor use*, J. Research NBS **30**, 209 (1943) RP1529.

cleaned in a commercial plant with a washer 36 in. in diameter and 54 in. in length and normal load of 60 to 70 lb. Stoddard solvent, conforming to Commercial Standard Specification CS3–40, and a commercial paste type of soap, which contained about 10 percent of water, were used. One pound of soap was used for every 25 lb of load. The dry cleaning procedure consisted of a 10-min run in solvent without soap; a 20-min run in solvent and soap; and a 20-min rinse in solvent. The blankets were centrifuged and then dried in a tumbler for 30 min. The temperature of the air leaving the tumbler was approximately 160° F. The dry-cleaned samples of blankets were renapped after each dry cleaning. Duplicate samples were renapped and then abraded before the next dry cleaning.

The properties of the blankets were measured when new and most of them were measured again after 1, 5, and 10 washings or dry cleanings.

Some of the laundered and dry-cleaned blanket samples were abraded with a machine similar to the one developed by Haven.[6] The Haven machine was modified to permit testing a blanket sample 14 in. wide and 18 in. long. The length of the stroke was reduced to 14 in. The area abraded was 14 by 14 in. The blanket sample was fastened to two clamps specially constructed for these tests. One clamp was fastened to the reciprocating mechanism of the machine. The blanket sample was placed over a horizontal, smooth shaft, which was 1 in. in diameter and mounted in ball bearings, and to the other clamp was attached a 5-lb weight. A horizontal bar weighing 5 lb [7] and covered with No. 8 duck was placed on the blanket directly above the shaft. This bar was rectangular in cross section and was held in place by vertical guides at each end. The blanket sample was drawn back and forth over the shaft, which rotated freely, and underneath the duck-covered bar, which remained stationary. The back-and-forth movement of the blanket sample relative to the duck fabric abraded the nap of the blanket. After 200 back-and-forth movements, the blanket sample was turned over and the reverse side was abraded the same number of strokes. This abrasion procedure was repeated before each subsequent laundering or dry cleaning.

The fiber composition of the blankets was determined microscopically. If more than one kind of fiber was found in a blanket, a chemical analysis was made.

IV. RESULTS AND DISCUSSION

The results of the tests of the original blankets are given in table 1. The results of the tests of the blankets after laundering and dry cleaning are omitted to conserve space; however, the over-all changes in the properties of the blankets are brought out in the following discussion.

1. EFFECT OF LAUNDERING

The effect of laundering without renapping on the properties of 43 blankets is shown in figure 1, where the amount of change in a property after 1, 5, and 10 washings, expressed as a percentage of the value of the property of the blanket when new, is plotted as abscissa. For

[6] Textile World **76**, p. 2654–2656, 2662 (1929).
[7] In some of the early tests a weight of 1 lb was used but was found to be insufficient.

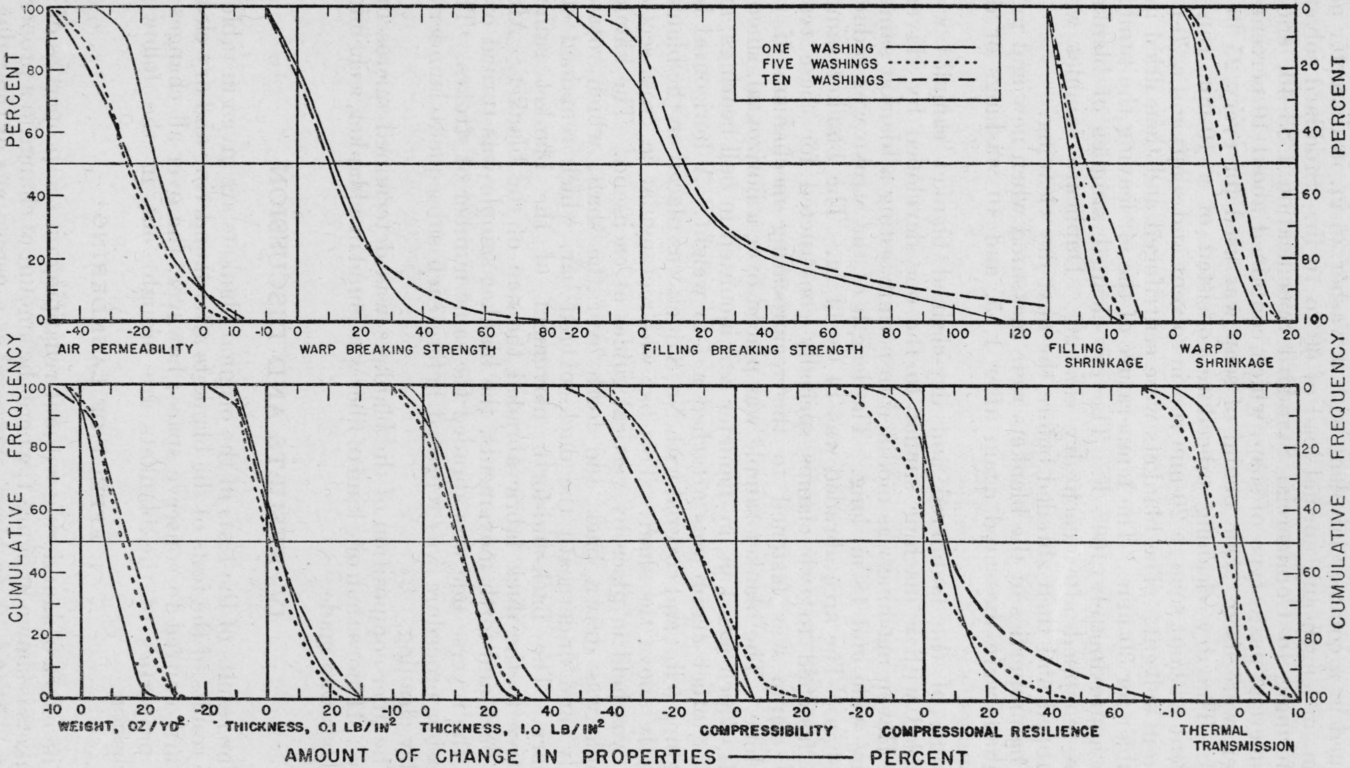

FIGURE 1.—*Frequency with which the blankets changed a given amount in properties after 1, 5, and 10 washings.*

each property the cumulative frequency, expressed as the percentage of blankets that changed more or less than a given amount is plotted as ordinate, the left-hand frequency scale being used for positive changes and the right-hand scale for negative changes. As an example, in 10 washings the areal weight decreased slightly for less than 10 percent of the blankets, whereas half of them increased 15 percent or more in areal weight, and a sixth of them increased in areal weight as much as 25 percent.

All of the blankets shrank in the warp and filling directions when washed. Most of the shrinkage occurred in the first washing, although the shrinkage increased consistently with the number of washings. The shrinkage in the warp direction was approximately twice as great as the shrinkage in the filling direction. The shrinkage of the blankets accounts for their increase in areal weight. It also accounts in part for the increase in breaking strength and thickness and for the decrease in air permeability. In addition to shrinkage, the blankets became felted or matted during washing. This condition is measured by the change in compressibility. A high value for compressibility indicates a greater amount of napping, whereas a low value indicates a greater amount of felting or matting. The considerable decrease in compressibility with the number of washings indicates that the blankets became felted or matted. This change affects the feel to the hands and also the appearance of the blanket. Brushing or renapping of the blanket after washing decreased these changes and restored the blanket more nearly to its condition when new. A blanket which became felted during washing increased in breaking strength and decreased in air permeability.

The compressional resilience of blankets after the fifth washing is appreciably lower than after the first or tenth washing. A high value for compressional resilience indicates greater ability of the blanket to come back to its initial state upon release of a compressive load. The compressional resilience of a blanket will be decreased if the fibers become damaged during use or laundering. This decrease results because damaged fibers have less ability to recover from flexure than undamaged fibers. On the other hand, the compressional resilience of a blanket will increase if it becomes felted during use or laundering. This increase results because there is less motion of the fibers relative to each other when a compressive load is applied owing to the greatly reduced compressibility of a felted blanket. The energy which is lost, frictional forces between fibers times relative movement of fibers, is therefore considerably reduced and the compressional resilience, which is the ratio of the energy recovered when the compressive load is removed to the total energy expended when the compressive load is applied, is increased. The consistent increase in compressional resilience between the fifth and tenth washings resulted from felting of the blankets. The discussion of the change in resilience of a blanket during laundering is general and independent of the kind of fiber. The compressional resilience of a new blanket depends, however, upon the kind of fiber from which it is made. This dependence of resilience upon the fiber composition will be discussed later in this paper.

When a blanket shrinks the thickness at a pressure of 0.10 lb/in.^{2} is increased, and when it becomes felted the density is increased and the thickness at 0.10 lb/in.^{2} is decreased. However, if further shrinkage occurs during felting the thickness may be increased. As all of these changes occurred when the blankets were washed, the thickness at 0.10 lb/in.^{2} showed no consistent increase or decrease. This is not true for the thickness at a pressure of 1.0 lb/in.^{2}, because the thickness at this pressure is not greatly affected by felting. Laundering increased the thickness at 1.0 lb/in.^{2}, most of the increase being obtained in the first washing owing to the shrinkage.

The thermal transmission of the blankets was affected little by the number of launderings. None of the blankets increased over 10 percent in thermal transmission, and less than 10 percent of the blankets decreased over 10 percent during the 10 washings. A low value for thermal transmission indicates a high insulating value. In general the thermal transmission of a blanket changes inversely with both thickness and compressibility. Hence if thickness increases while compressibility decreases, the changes tend to annul each other in their effect on thermal transmission. This probably accounts for the fact that the thermal transmission of the blankets is in general affected little by laundering.

The large increase in the filling breaking strength for some 10 percent of the blankets was obtained because they had a low strength when new. These blankets were highly napped and had a high compressibility. It is noteworthy that these initially weak blankets did not become weaker when laundered but became stronger. This increase resulted from the felting and shrinkage produced by laundering.

It is apparent that a number of properties of the blankets changed materially during laundering. Some of the changes, such as the increase in breaking strength, are not objectionable. The smallness of the change in thermal transmission is particularly desirable. However, the rather large decrease in compressibility is objectionable. It denotes a change in the feel and appearance of the blankets. Fortunately, most of this change can be overcome by brushing or renapping of the blanket after washing. This fact is brought out in subsection 2.

2. EFFECT OF LAUNDERING AND RENAPPING, AND OF LAUNDERING, RENAPPING, AND ABRASION

The effects of laundering and renapping; and of laundering, renapping, and abrasion on the properties of 27 blankets are shown in figure 2, where the amount of change in a property after 10 launderings, expressed as a percentage of the value of the property of the blanket when new, is plotted as abscissa, and the cumulative frequency is plotted as ordinate as in figure 1. The changes in a real weight, thickness, thermal transmission, air permeability, breaking strength, and shrinkage are similar in general to the changes shown in figure 1 for laundering without renapping. Compressibility is materially improved by renapping after laundering, whereas compressional resilience is decreased by renapping. The effect of renapping after washing on the appearance of several typical blankets is shown in figures 3 and 4.

The curves showing the changes in the properties of the laundered, renapped, and abraded blankets differ only slightly from the curves for the unabraded blankets. The difference in appearance between the abraded and unabraded blankets was also slight. The weight and thickness of the abraded blanket samples are consistently lower, and

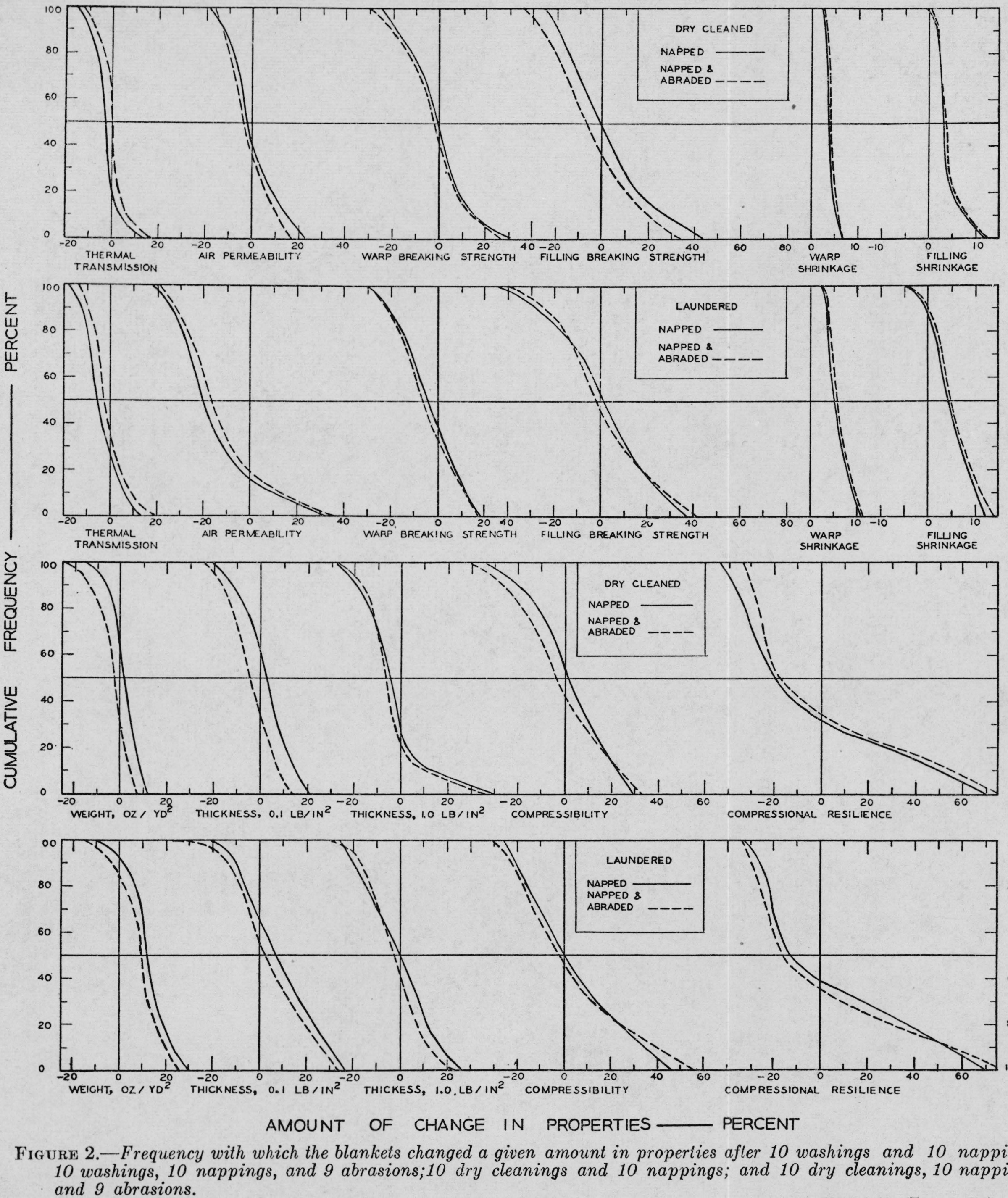

FIGURE 2.—*Frequency with which the blankets changed a given amount in properties after 10 washings and 10 nappings; 10 washings, 10 nappings, and 9 abrasions; 10 dry cleanings and 10 nappings; and 10 dry cleanings, 10 nappings, and 9 abrasions.*

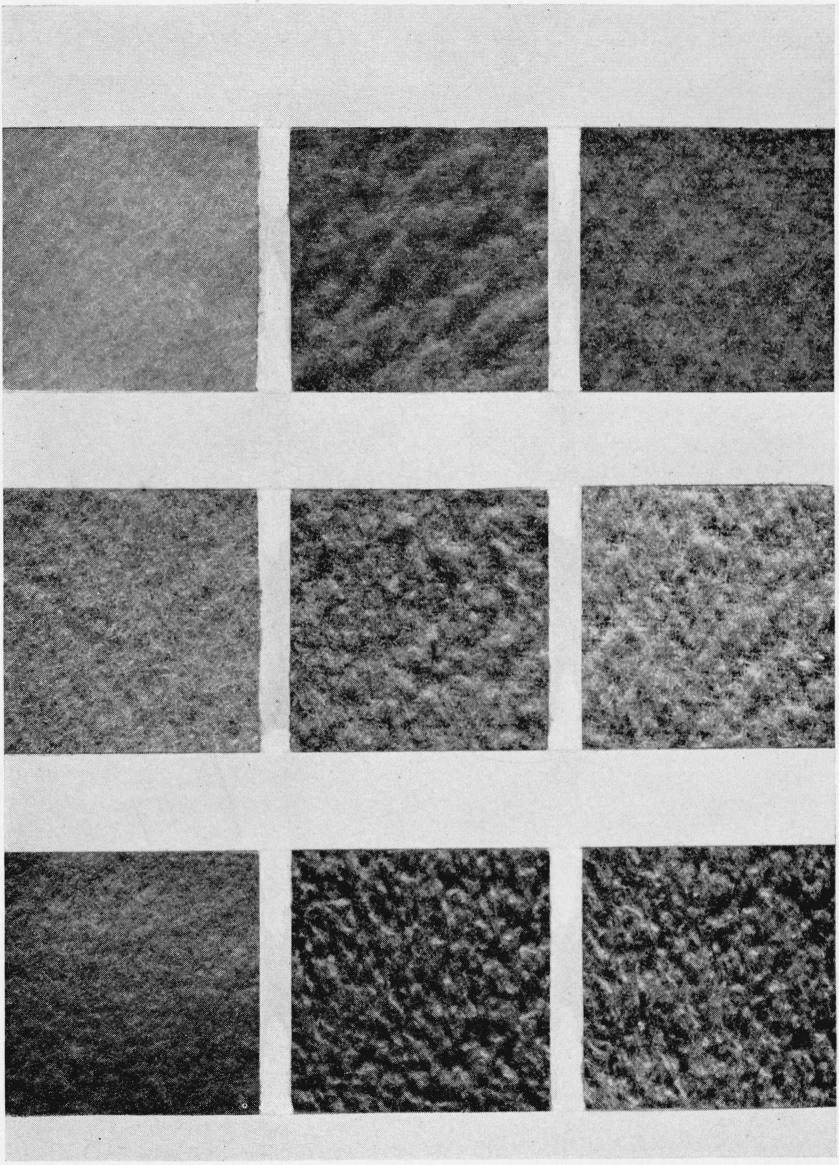

FIGURE 3.—*Appearance of blankets when new and after the tenth washing before and after the tenth napping.*

Left column, original.
Middle colum, 10 washings and 9 nappings.
Right column, 10 washings and 10 nappings.

Top row, 100 percent of wool.
Middle row, 51 percent of wool, 49 percent of cotton.
Bottom row, 100 percent of cotton.

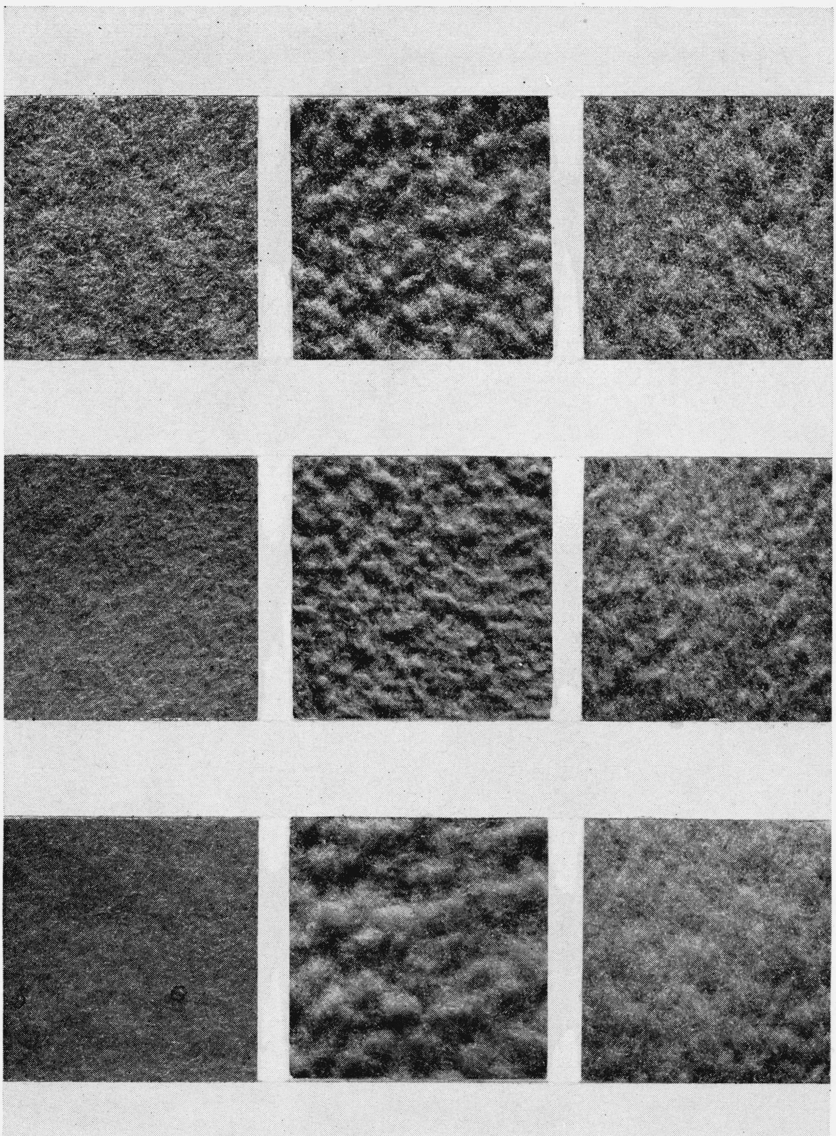

FIGURE 4.—*Appearance of blankets when new and after the tenth washing before and after the tenth napping.*

Left column, original.

Middle column, 10 washings and 9 nappings.

Right column, 10 washings and 10 nappings.

Top row, 23 percent of wool, 31 percent of cotton, 49 percent of viscose rayon.

Middle row, 6 percent of wool, 62 percent of cotton, 32 percent of viscose rayon.

Bottom row, 12 percent of wool, 1 percent of cotton, 87 percent of viscose rayon.

the thermal transmission and air permeability are consistently higher than for the unabraded samples.

3. EFFECT OF DRY CLEANING AND RENAPPING, AND OF DRY CLEANING, RENAPPING, AND ABRASION

The effects of dry cleaning and renapping, and of dry cleaning, renapping, and abrasion on the properties of 27 blankets are also shown by curves in figure 2. These curves show practically the same changes as those for the laundered blankets.

4. EFFECT OF FIBER COMPOSITION ON THE PROPERTIES OF BLANKETS

The blankets in table 1 are listed according to fiber composition. It can be readily seen that there is no correlation between the properties of the blankets and the fiber composition, except for compressional resilience. The average compressional resilience, computed for those blankets having similar fiber composition, is plotted in figure 5 against the wool content. A linear relationship is obtained for blankets containing a mixture of wool and cotton. The difference in compressional resilience between the groups of blankets is statistically highly significant, except between the 5-percent-wool and the all-cotton groups. The addition of 5 percent of wool does not increase the compressional resilience significantly. If a portion of the cotton is replaced with viscose rayon, the compressional resilience is significantly decreased, and if a portion of the cotton is replaced with acetate rayon, the compressional resilience is increased slightly. Several of the 100-percent-wool blankets were known to be made from all-virgin wool. The average compressional resilience of this group was 50 percent, which is higher than the general average of the all-wool blankets. Likewise, a number of blankets were known to be made from a high percentage of reprocessed and reused wool. The average compressional resilience of this group was only 41 percent, which is considerably below the general average of the all-wool blankets. There seems to be a relationship between the compressional resilience of blankets and the quality of wool used. If mechanically damaged wool is used in blankets, the compressional resilience of the blanket is lowered.

5. RELATIONSHIP BETWEEN THERMAL TRANSMISSION AND THICKNESS

The reciprocal of the thermal transmission of blankets and some underwear fabrics recently measured in this laboratory is plotted in figure 6 against the thickness at a pressure of 0.10 lb/in^2. A linear relationship is obtained. Lines indicating 5 and 10 percent deviation are shown in figure 6. The relationship between thermal transmission and thickness is given by equation 1

$$T=\frac{1}{3.0t_{0.1}+0.63}Btu/(°F\ hr\ ft^2), \qquad (1)$$

where T is the thermal transmission, and $t_{0.1}$ is the thickness at a pressure of 0.10 lb/in^2. It will be noted that T is 1.6 when $t_{0.1}$ is zero. This is the value which is obtained when a measurement is made with the bare apparatus. This value of T was used in computing the thermal insulating values given in table 1. The thermal

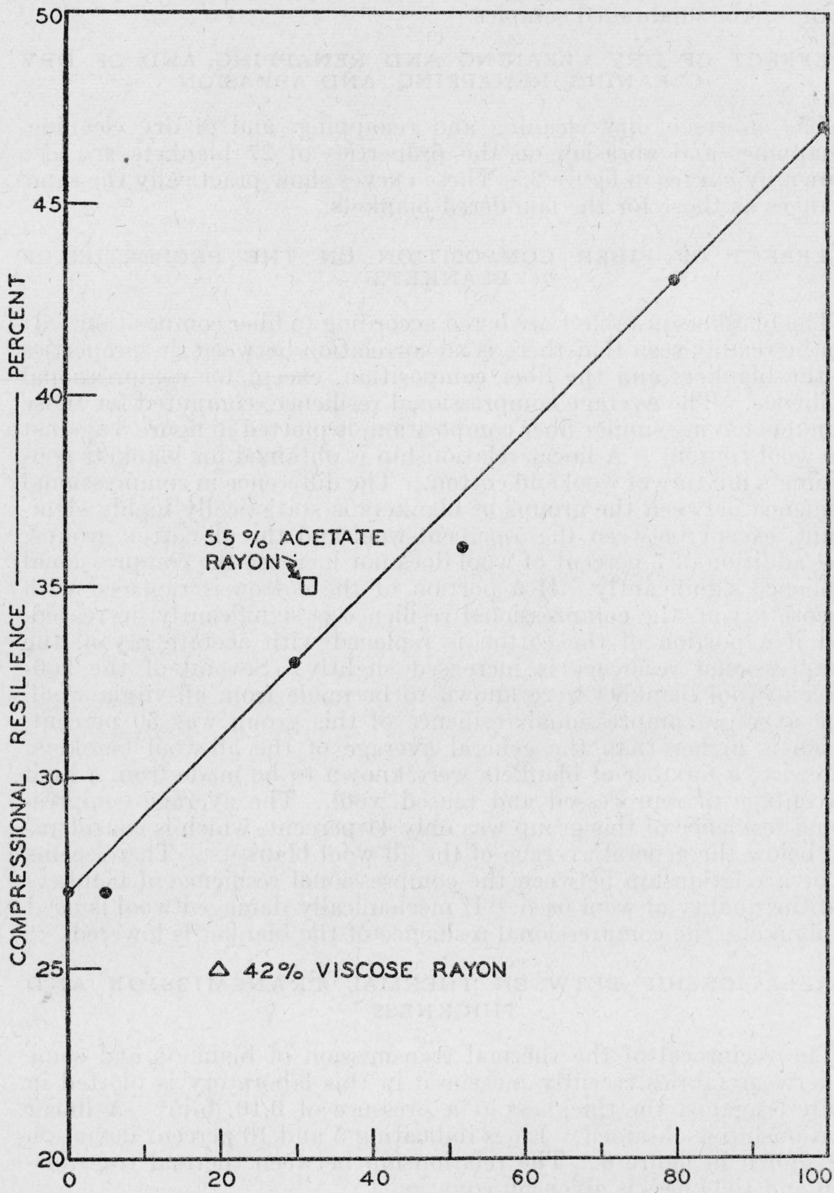

FIGURE 5.—*Linear relationship between compressional resilience and wool content of blankets made from mixtures of wool and cotton.*

Each point represents the average compressional resilience of blankets having approximately the same fiber mixture.

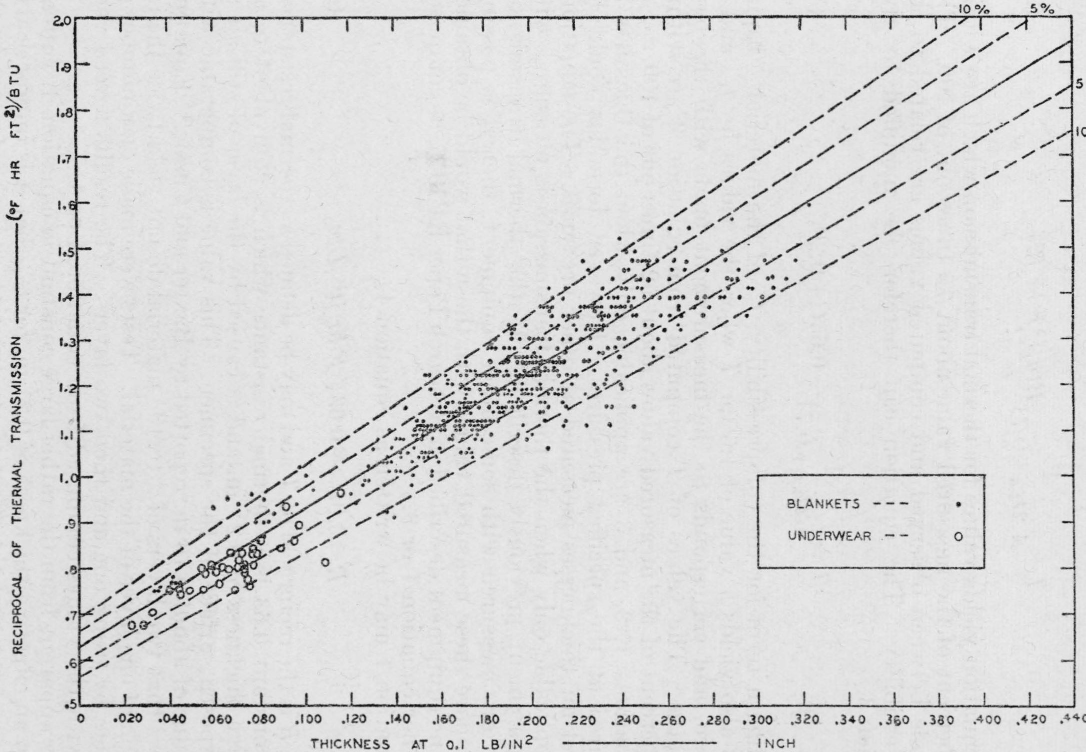

FIGURE 6.—*Linear relationship between the reciprocal of thermal transmission and thickness at 0.10-lb/in.² pressure.*

The dashed lines indicate 5- and 10-percent departures.

transmission computed by means of equation 1 is within ±10 percent of the measured value about 95 times out of 100. This difference is frequently less than the difference which is obtained when two different portions of one blanket are measured.

The relationship between the thermal transmission and the thickness at a pressure of 1.0 lb/in.^{2} is given in equation 2.

$$T=\frac{1}{4.2t_{1.0}+0.71} Btu/(°F\ hr\ ft^2). \tag{2}$$

This equation yields values for thermal transmission which are within ±10 percent of the measured value about 75 times out of 100. The residuals between observed and computed values are related to the compressibility. The equation can therefore be modified to give equation 3,

$$T=\frac{1}{4.2t_{1.0}+0.71}-0.65C+0.20, \tag{3}$$

including a term for the compressibility, C, of the material. Equation 3 also yields a value of 1.6 for T when the values for $t_{1.0}$ and C are zero, and corresponds to the measurement made with the bare apparatus. The values of T computed from equation 3 are within ±10 percent of the measured values about 92 times out of 100.

Equations 1, 2, and 3 are applicable only when the thickness is measured at the specified pressures. However, formulas could be derived for thicknesses measured at other pressures. The equations are applicable only when the thermal transmission is measured with the equipment previously described.[8] If the thermal transmission values are measured with some other equipment, then it is possible to compare these measured values with those that would be obtained with the equipment described in Research Paper RP1055, as computed by either equation 1 or 3.

Equation 1 may be written as equation 4,

$$R=3.0t_{0.1}+0.63 (°F\ hr\ ft^2)/Btu, \tag{4}$$

where R is the reciprocal of T and may be defined as thermal resistance. The constant 0.63 is a thermal resistance which is equivalent to an effective thickness of 0.21 in. and is caused by the layer of still air at the exposed surface of the specimen. This value is comparable with the value of about 0.16 in. reported by Baxter and Cassie.[9] Equation 4 shows that two layers of a textile material do not yield twice the insulation of one layer of the material. Tests were made on a number of blankets by using one and then two layers. The results agreed very well with the values computed from equation 4 or 1.

It is apparent from the rather large constant in equation 4, equivalent to an effective thickness of 0.21 in. for $t_{0.1}$, that it is impractical to attempt to measure the effect of construction and other factors on the thermal resistance of thin materials, such as light underwear and dress fabrics, since the thermal resistance contributed by thin fabrics may amount to only some 10 to 20 percent of that of the layer of still air.

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[8] R. S. Cleveland, J. Research NBS **19**, 675 (1937) RP1055.
[9] *Thermal insulating properties of clothing,* J. Textile Inst. **34**, No. 7, T41–T54 (July 1943).

6. RELATIONSHIP BETWEEN WEIGHT AND THICKNESS

A linear relationship between thickness and areal weight is often assumed or taken for granted. It is shown in figure 7, however, that

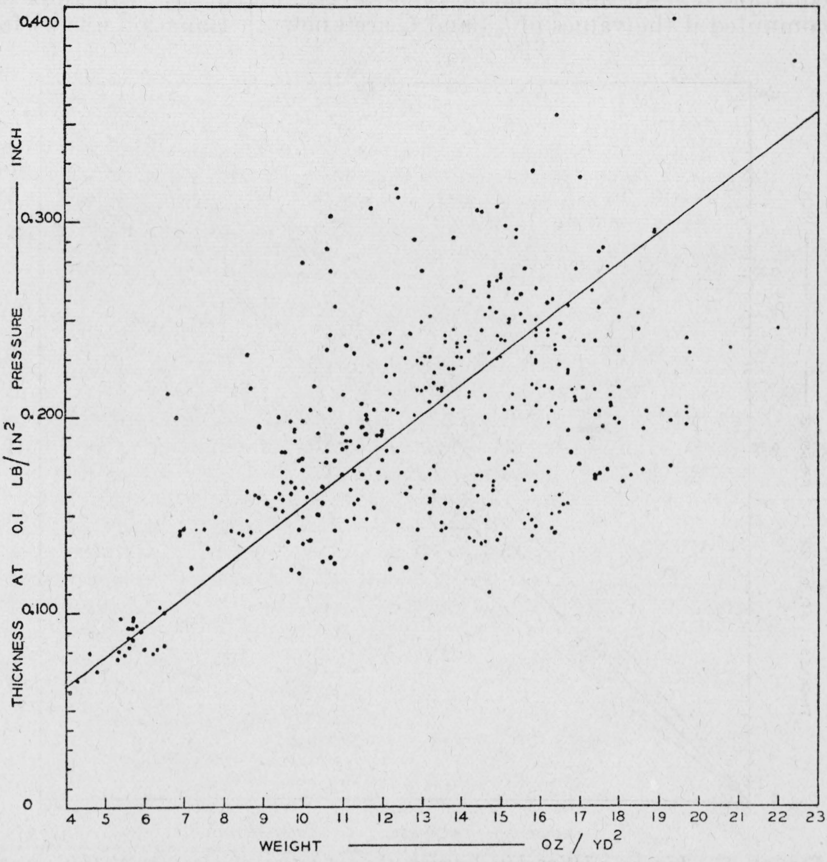

FIGURE 7.—*Relationship between the thickness of blankets at 0.10-lb/in.² pressure and the weight.*

such a correlation is very poor. The best straight line through the plotted points corresponds to equation 5

$$t_{0.1}=0.0155W, \tag{5}$$

in which $t_{0.1}$ is the thickness at 0.10 lb/in.², and W is the areal weight A further study indicates that the points are scattered about this line in a manner closely associated with the compressibility. If the ratio of the observed values of $t_{0.1}$ to the values computed by means of equation 5 are plotted against compressibility, an approximate linear relationship is obtained. Equation 5 can thus be modified to yield equation 6,

$$t_{0.1}=0.05CW, \tag{6}$$

where C is the compressibility.

If the thicknesses of the blankets computed by means of equation 6 are plotted against the measured values, figure 8, a straight line with unit slope is obtained. The points, although still scattered considerably, lie for the most part within ± 20 percent of the line given by equation 6. An approximate value of the weight, W, can thus be computed if the values of $t_{0.1}$ and C are known. Equation 6 is useful

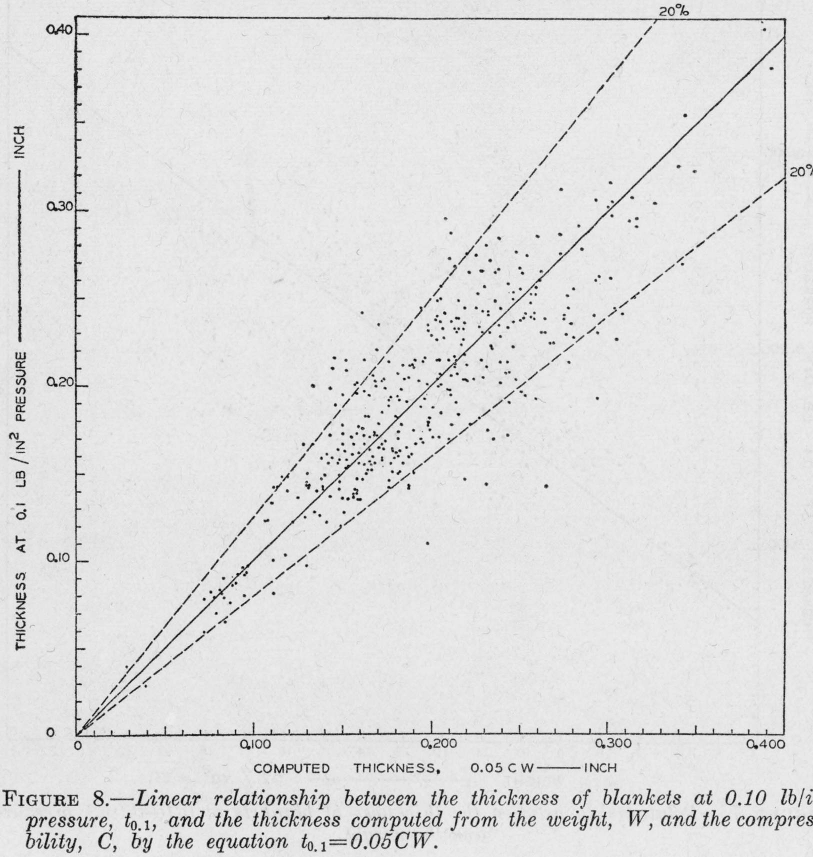

FIGURE 8.—*Linear relationship between the thickness of blankets at 0.10 lb/in.² pressure, $t_{0.1}$, and the thickness computed from the weight, W, and the compressibility, C, by the equation $t_{0.1}=0.05CW$.*

The dashed lines indicate a 20-percent departure.

as a guide in specifying minimum compatible requirements for a performance specification for blankets.

7. RELATION OF STRENGTH TO WEIGHT AND TO COMPRESSIBILITY

The breaking strength of blankets was found to increase in general with the areal weight and to decrease with the compressibility. Although the functional relationships between strength and areal weight and between strength and compressibility are not well defined, they suffice for use as a guide in specifying minimum requirements for a performance specification of blankets that will be compatible with the other requirements and also provide reasonable assurance of satisfactory performance.

8. RELATIVE THERMAL INSULATION PER UNIT WEIGHT

The reciprocal of thermal transmission has been used as a measure of the relative thermal insulation of textiles. This value divided by the areal weight of the material has been used to indicate the efficacy as an insulating material and is given in table 1. It can be readily seen that it varies with the thickness but not with fiber composition. In general, the greater the thickness of the blanket the lower is the value of the thermal resistance per unit weight. The correlation, however,

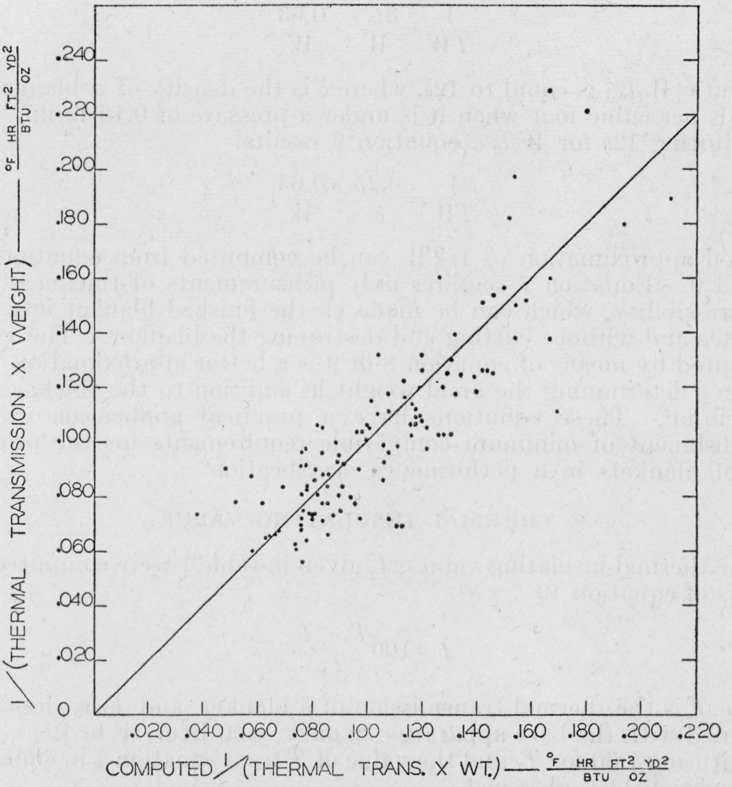

FIGURE 9.—*Linear relationship between the reciprocal of thermal transmission times weight and the value computed by means of equation 7.*

is far from good for the blankets as a group. The correlation is greatly improved if the blankets are grouped according to their compressibility. The general relation can be expressed by equation 7, where T is thermal transmission, W is weight, C is compressibility,

$$\frac{1}{TW}=0.4C-0.4t_{0.1}+0.05, \qquad (7)$$

and $t_{0.1}$ is thickness at 0.10 lb/in². The values of $1/TW$ computed by means of equation 7 are plotted in figure 9 against the values computed from the measured values of T and W. The points lie fairly close to a straight line having a slope of unity. This indicates that equation 7 represents the data fairly well.

The physical significance represented by equation 7 is not immediately apparent, except that the relative thermal insulation of blankets per unit weight depends upon the thickness and compressibility and therefore upon the structure of the blanket. However, the compressibility and thickness of a blanket of a given weight are inversely related to the density. The relative thermal insulation per unit weight given by equation 7 is therefore inversely related to the density. This relationship can be derived directly from equation 1 or 4 and is given by equation 8.

$$\frac{1}{TW}=\frac{3t_{0.1}}{W}+\frac{0.63}{W}, \tag{8}$$

The ratio $W/t_{0.1}$ is equal to 12δ, where δ is the density of a blanket in pounds per cubic foot when it is under a pressure of 0.10 lb/in^2. By substituting 12δ for $W/t_{0.1}$, equation 9 results.

$$\frac{1}{TW}=\frac{0.25}{\delta}+\frac{0.63}{W}, \tag{9}$$

A good approximation of $1/TW$ can be computed from equations 7, 8, and 9. Equation 7 requires only measurements of thickness and compressibility, which can be made on the finished blanket in a few minutes and without cutting and destroying the blanket. The value computed by means of equation 8 or 9 is a better approximation, but requires determining the areal weight in addition to the thickness at 0.10 lb/in^2. These equations have a practical application in the establishment of minimum compatible requirements for the properties of blankets in a performance specification.

9. THERMAL INSULATING VALUE

The thermal insulating values, I, given in table 1 were computed by means of equation 10

$$I=100\frac{T_b-T}{T_b}, \tag{10}$$

where T is the thermal transmission of a blanket, and T_b is the value obtained with the bare apparatus, namely, 1.60 Btu/(°F hr ft^2). By substituting 1.60 for T_b and the value of T from equation 1 in equation 10, equation 11 is obtained,

$$I=\frac{100}{1+0.21/t_{0.1}}, \tag{11}$$

where $t_{0.1}$ is the thickness at a pressure of 0.10 lb/in^2. In figure 10 the values of I from table 1 are plotted against $t_{0.1}$ and the curve shown is the locus of equation 11. The thermal insulating value obtained for underwear fabrics, blankets, and several lined jackets agree very well with the curve representing equation 11. It can be readily seen that the thermal insulating value of textiles having the same thickness, $t_{0.1}$, as measured in this investigation, does not depend upon the fiber composition and type of fabric construction. A very good value of I can be computed with equation 11 if the value of

$t_{0.1}$ is known. This value of a fabric or garment is readily measurable and does not require cutting or destroying the material for the test.

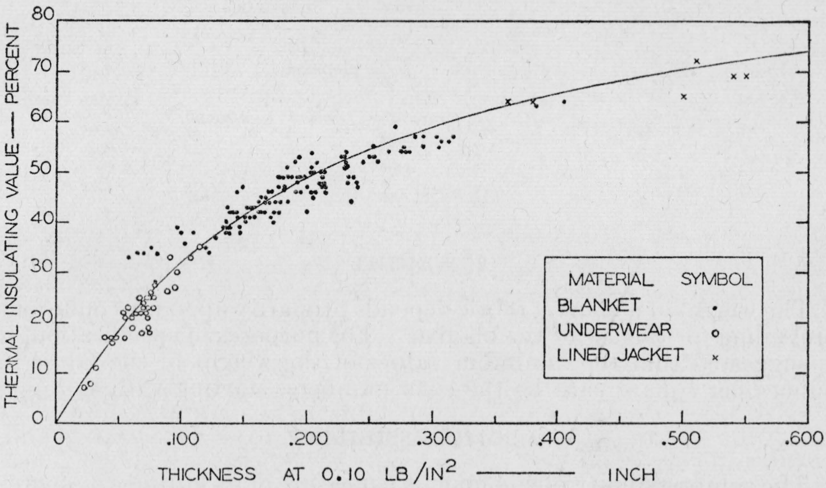

FIGURE 10.—*Relationship between the thermal insulating value, I, of blankets and the thickness, $t_{0.1}$ at 0.10-lb/in² pressure.*

The curve represents equation 11.

V. SUGGESTED REQUIREMENTS FOR A PERFORMANCE SPECIFICATION FOR BLANKETS

The results obtained in this investigation can be used as the basis for the preparation of performance specifications for blankets. Limits for compressional resilience, weight, compressibility, thickness at 0.10 lb/in.² pressure, breaking strength, and shrinkage are suggested in the following paragraphs.

1. COMPRESSIONAL RESILIENCE

A soft, fluffy, flexible, and warm blanket having a high compressional resilience is expected to retain these characteristics more nearly during use than one having a low compressional resilience. The compressional resilience was found to be linearly related to the fiber composition of blankets containing cotton and wool. It could therefore serve as a requirement in a performance specification in place of fiber composition, since it is readily measured without cutting or destroying a blanket. The minimum values suggested for a performance specification are given in table 2. The approximate fiber composition corresponding to the suggested values for compressional resilience is indicated. The suggested values for compressional resilience are applicable to blankets regardless of their weight.

TABLE 2.—*Suggested values of compressional resilience for use in a performance specification*

Type of blanket	Minimum compressional resilience	Approximate fiber composition	
		Wool, minimum	Cotton
	Percent	*Percent*	*Percent*
A	45	90	10
B	40	65	35
C	35	40	60
D	30	15	85
E	25	----------	100

2. WEIGHT

The weight of a blanket fabric depends primarily upon the conditions prevailing for the use of the blanket. For purposes of specification, it is suggested that the minimum values of the weight of the fabric in ounces per square yard be the even numbers, starting with 4.

3. COMPRESSIBILITY

The compressibility of a blanket is a measure of its loftiness or degree of napping. The values to be specified depend again upon the conditions of intended use and also upon individual preferences for the feel and appearance of blankets. For purposes of specification, it is suggested that the minimum values specified be in increments of 0.05 beginning with 0.20 (in./in.)/(lb/in^2). A blanket having a low compressibility is one which is greatly felted, little napped, and stiff, or boardy, and one having a high compressibility is lofty, soft, highly napped, and flexible.

4. THICKNESS

The thickness of a blanket is probably the most important characteristic to be specified in a performance specification. It has been shown that the thermal transmission and the thermal insulationg value correlate exceedingly well with the thickness at 0.10 lb/in^2. Simple formulas, equations 1 and 11, have been derived for calculating these values from this thickness. Minimum values for thickness are suggested in table 3 for various weights and compressibilities in preference to either thermal transmission or thermal insulating values, because of the ease of measurement of thickness which is obtained when the measurements for compressional resilience and compressibility are made, and because the thickness can be measured without the need of cutting or destroying the blanket. However, computed thermal transmission and thermal insulating values are given in table 4 for different thicknesses as a guide for converting the thickness values of table 3 to these quantities. The densities in pounds per cubic foot at a pressure of 0.10 lb/in.^{2} are given in table 3 for information and correspond to blankets having different compressibility.

TABLE 3.—*Minimum thickness at 0.10 lb/in.*^{2} *suggested for blankets of various weights and compressibilities*

Weight	Compressibility, $\frac{in./in.}{lb/in.^2}$								
	0.20	0.25	0.30	0.35	0.40	0.45	0.50	0.55	0.60
oz/yd ^{2}	*in.*	*in.*	*in.*	*in.*	*in.*	*in.*	*in.*	*in.*	*in.*
4	0.040	0.050	0.060	0.070	0.080	0.090	0.100	0.110	0.120
6	.060	.075	.090	.105	.120	.135	.150	.165	.180
8	.080	.100	.120	.140	.160	.180	.200	.220	.240
10	.100	.125	.150	.175	.200	.225	.250	.275	.300
12	.120	.150	.180	.210	.240	.270	.300	.330	.360
14	.140	.175	.210	.245	.280	.315	.350	.385	.420
16	.160	.200	.240	.280	.320	.360	.400	.440	.480
18	.180	.225	.270	.315	.360	.405	.450	.495	.540
Density, lb/ft^3, at 0.10 lb/in.^{2}	8.3	6.7	5.5	4.8	4.2	3.7	3.3	3.0	2.8

TABLE 4.—*Thermal transmission and thermal insulating values corresponding to various thicknesses at 0.10 lb/in.*^{2}

Thickness at 0.10 lb/in.^{2}	Thermal transmission	Thermal insulating value
in.	*Btu/(°F hr ft* ^{2}*)*	*Percent*
0.010	1.52	4.5
.020	1.45	8.7
.040	1.33	16
.060	1.23	22
.080	1.15	28
.100	1.08	32
.125	1.00	37
.150	0.93	42
.175	.87	45
.200	.81	49
.250	.72	54
.300	.65	59
.350	.60	62
.400	.55.	66
.450	.50	68
.500	.47	70
.550	.44	72
.600	.41	74

5. BREAKING STRENGTH

The breaking strength was found to be related to the weight and to the compressibility of a blanket. Minimum values for breaking strength (grab method) of the warp and filling for blankets of various weights and compressibilities are suggested in table 5. Manufacturers should have no difficulty in meeting the strength requirements suggested. Most blankets meeting the other requirements will exceed the suggested values for breaking strength. Furthermore, since blankets generally increased in breaking strength during laundering, it is believed that the values suggested in table 5 will assure satisfactory performance of the blankets for ordinary use.

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TABLE 5.—*Minimum breaking strength (grab method) suggested for blankets of various weights and compressibilities*

Weight	Warp strength			Filling strength		
	Compressibility, $\frac{in./in.}{lb/in.^2}$			Compressibility, $\frac{in./in.}{lb/in.^2}$		
	Below 0.25	0.25 to 0.35	Above 0.35	Below 0.25	0.25 to 0.35	Above 0.35
oz/yd [2]	*lb*	*lb*	*lb*	*lb*	*lb*	*lb*
4	25	20	15	15	10	5
6	30	25	20	20	15	10
8	35	30	25	25	20	15
10	40	35	30	30	25	20
12	45	40	35	35	30	25
14	50	45	40	40	35	30
16	55	50	45	45	40	35
18	60	55	50	50	45	40

6. AIR PERMEABILITY

No requirements are suggested for air permeability, since in general blankets will be used in nominally still air. For outdoor uses a combination of blanket-and-wind resistant cloth has decided advantages.[10]

7. SHRINKAGE

The maximum allowable shrinkage suggested is 5 percent in the warp and in the filling. This amount of shrinkage is to be expected in normally manufactured blankets. Proper precautions in laundering blankets to preserve their characteristics should automatically safeguard against excessive and objectionable shrinkage. It seems advisable to specify nominal dimensions of the blankets 5 percent greater than necessary so that the blankets will not be too small after a shrinkage of 5 percent.

WASHINGTON, December 28, 1943.

[10] Herbert F. Schiefer, *Advantages of a blanket-and-sheet combination for outdoor use*, J. Research NBS 30, 209 (1934) RP1529.