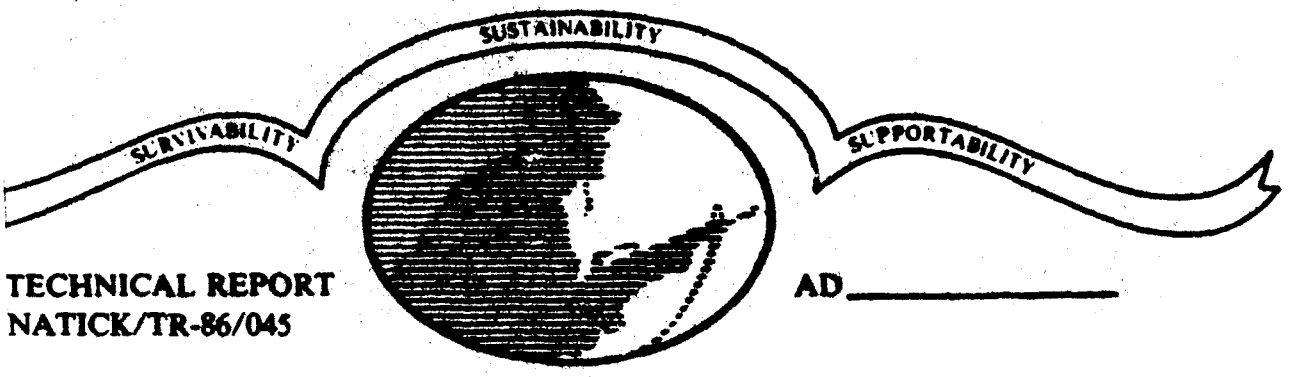

TECHNICAL REPORT
NATICK/TR-86/045

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SUMMARY OF LABORATORY AND FIELD COMFORT STUDIES ON CANDIDATE FABRICS FOR A YEAR-ROUND UNIFORM

BY

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The program objective was to choose a year-round uniform from three candidate fabrics to replace the two uniforms (lightweight 50/50 polyester/cotton and 55/45 polyester/wool tropical) currently in use. The candidate fabrics were 55/45 polyester/wool, 75/25 polyester wool, and 100 polyester. Laboratory techniques employed for psychological assessment of trouser comfort by 27 men, and later 25 women, were the same.

A large-scale field study involving 1100 to 1400 Army personnel was conducted to evaluate both durability and comfort of the 3 candidate fabrics for a proposed year-round uniform. Personnel from 28 installations wore a uniform constructed from one of these fabrics for the entire year.

The trouser test showed the 50/50 polyester/cotton control was most comfortable for both men and women, and the 100% polyester experimental least comfortable. The full uniform field
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19. ABSTRACT (Cont'd)

test showed that the level of comfort improved with increasing levels of fabric polyester. 100% polyester uniform was judged most comfortable by 78% of the respondents.

SUMMARY

Experimental twill fabrics of 55/45 polyester/wool, 75/25 polyester/wool, and 100% polyester were examined as candidates for a year-round service uniform in laboratory fabric tests, in garment field trials, and as trousers in controlled comfort trials on men and women.

In the NRDEC fabric tests of weight, air permeability, thickness, stiffness, moisture vapor transmission, and insulation, the candidate fabrics were quite comparable to the lightweight 50/50 polyester/cotton and 55/45 polyester/wool tropical uniforms of current use. Moisture regain values measured were, as expected, determined entirely by the fiber content of each fabric. Wettability and wicking values, although somewhat different from the controls, were not useful in predicting wear acceptance because water contents did not correspond to those experienced in normal wear.

Information from the field trials on full uniforms, which was determined by questionnaires on winter and summer performance, revealed that wearers generally preferred the experimental fabrics over regular issue. Unfortunately, there were no side by side comparisons of the experimental with regular controls and it is felt that providing the wearers with the knowledge that the uniforms were "new" may have dominated the responses received.

The laboratory evaluations on trouser wearing comfort performed on 27 men, and later on 25 women, involved a standard Harris Research Laboratories procedure for assessing wearing acceptance. Significant differences in comfort were noted for the wearing sensations of snug, loose, heavy, lightweight, stiff, sticky, nonabsorbent, clammy, damp, clingy, picky, rough, and scratchy in a wearing protocol of warm-dry, warm-humid, and cool-humid conditions, with and without exercise. For both men and women the 50/50 polyester/cotton control was most comfortable, using most of the wearing sensations. Neither men nor women preferred the 55/45 polyester/wool experimental over the control in the same blend. None of the men and few of the women found the 75/25 polyester/wool control acceptable in relation to the 50/50 polyester/cotton control.

The relations between the laboratory findings on fabrics, the field trial results, and the laboratory comfort tests are discussed in this report, and recommendations for an improved approach to laboratory tests and field trials are given.

PREFACE

This report was prepared by the Gillette Research Institute, Rockville, MD under U. S. Army Contract No. DAAK60-79-C-0083. The project was administered by the U. S. Army Natick Research and Development Command, now the U. S. Army Natick Research, Development and Engineering Center (NRDEC), under Project Number 1L162723AH98 Clothing and Equipment. Ms. Barbara Kirkwood served as the Project Officer and Ms. Joan Callahan as the Contracting Officer for NRDEC.

This report summarizes the work completed by the Gillette Research Institute from January 1979 to January 1980.

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SUMMARY OF LABORATORY AND FIELD COMFORT STUDIES ON CANDIDATE FABRICS FOR A YEAR-ROUND UNIFORM

I. INTRODUCTION

A year-round service uniform has been proposed for Army personnel, and three candidate fabrics were evaluated in a large-scale field test from January 1979 to January 1980. Among the evaluation questions were those concerning comfort. However, weather conditions in these tests varied widely and were not documented. Drawing relationships of comfort responses to specific conditions of temperature/humidity/physical activity were impossible. Thus, there was a need for more specific data in order to improve U. S. Army Natick Research and Development (NARADCOM)* understanding of psychological responses and subjective attitudes toward comfort and to assess the effectiveness of the NARADCOM laboratories in predicting comfort from laboratory tests of fabrics. Accordingly, the Harris Research Laboratories (HRL) undertook the task of evaluating the comfort attributes of the three candidate fabrics under carefully controlled warm-dry, warm-humid, and cool-humid microclimate conditions encountered by active personnel in the real life use of garments prepared from these fabrics in summer and winter environments. This was a laboratory study in which personnel activity was also controlled by various exercise cycles. Evaluations were made using established procedures for psychophysical testing developed by HRL for next-to-skin clothing comfort.[1]

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The three candidate year-round fabrics included a 55/45 polyester/wool, 75/25 polyester/wool, and a 100% polyester fabric each in a 2 x 2 twill construction. These were compared with the 50/50 polyester/cotton summer weight and the 55/45 polyester/wool summer green fabrics currently in use by the U. S. Army. Trousers were constructed from these various fabrics to be worn by test subjects during the laboratory comfort testing. A 65/35 polyester/cotton short sleeved shirt was worn by the test subjects in conjunction with the trousers described above.

The laboratory comfort tests involved the use of male subjects in the first test and female subjects in the second. It was necessary to determine what differences, if any, the two subject types would find among the various fabrics. This summary report describes the results and comparisons of these two laboratory tests as well as comparisons of these tests and fabric physical data supplied by NARADCOM. Finally, the data from all of the above are compared with the large-scale wear test conducted by the U. S. Army.

II. BACKGROUND

The procedures for using human response to wearing conditions of clothing in a specific environment using psychological scaling were applied by HRL in work on Army cold weather clothing for outdoor environments.[2] Comfort evaluations were sufficiently influenced by changes in weather that later studies on shirts for the U. S. Department of Agriculture were carried out both indoors and outdoors to permit a closer

control of the microclimate surrounding the wearers. These shirt studies revealed that indoor studies in a controlled environmental room were better suited to detect differences noted by individual wearers, provided that the climate ranges used corresponded to real-life conditions.[3]

After several years of such testing, a more or less standard procedure evolved for making such next-to-skin garment comparisons. Comfort information from wearers was obtained in the form of comfort sensation descriptors, such as "sticky" or "scratchy", combined with intensity ratings of these sensations during microclimate and exercise changes. Garment differences were judged by the differences in intensity ratings of these descriptors under a closely controlled and repeated climate and exercise protocol.[4] Fabric type, fiber type, and chemical finishing level were all found to influence the comfort levels experienced by wearers in next-to-skin garments and these differences were particularly sharp under wearing conditions involving mild to heavy sweating at the skin-garment interface.[5]

The evaluation of comfort using these psychological scaling procedures is beginning to be both understood and relatable to the fabric properties used for garments[6] and there seems to be a logical relationship between the subjective evaluations of comfort and the other attributes of clothing influencing wear acceptance.[7] This portion of the report deals with the results of direct subjective testing in the laboratory of candidate uniforms in relation to standard Army constructions of known

acceptability in summer and winter wear. Furthermore, this report contains comparisons between these laboratory comfort studies and a large-scale field study where the climatic conditions were uncontrolled and unrecorded. Correlations between the human wear test studies and fabric physical properties are discussed.

III. FABRIC PROPERTIES

A. Fabric Descriptions

1. Trousers (laboratory tests) and uniforms (large-scale filed test)

(a) Military Specification MIL-C-43791B dated 13 February 1979 entitled "Cloth, Twill, Polyester/Cotton (Durable Press)" Type I, a 50/50 polyester/cotton 2/1 right-hand twill weighing 7.3 oz. $yd.^2$ (nominal), has an approved durable press and soil release treatment. This fabric is referred to throughout this report as the current summer uniform.

(b) Military Specification MIL-C-21115H dated 26 November 1975 entitled "Cloth, Tropical, Polyester/Wool, Type I, Class 3." This fabric, 55/45 polyester/wool plain weave with 2 ply yarns, weighing 6.4 oz/yd^2 (nominal), referred to throughout this report as Summer Green (SG) or Tropical.

(c) Raeford Uniform Fabric Co. Style 10312: 55/45 polyester/wool, 2 x 2 right-nand twill, 6.8 oz/yd^2 (nominal).

(d) Raeford Uniform Fabric Co. Style 14221: 75/25 polyester/wool made up of end and end, pick and pick construction

with 100% texturized polyester yarns alternating with 55/45 spun polyester/wool yarns, 2 x 2 right-hand twill, 6.8 oz/yd^2 (nominal).

(e) Klopman Mills style 6506: 100% texturized polyester, 2 x 2 right-hand twill, 8.9 oz/yd^2 (nominal).

2. Shirt (laboratory tests)

The trousers for both male and female subjects in the laboratory comfort tests were worn with a 65/35 polyester/cotton (3.2 - 3.6 oz/yd^2 broadcloth) short sleeved shirt. HRL furnished these. Subjects wore their own articles of clothing normally worn for indoor use.

B. Fabric Physical Properties

The physical properties of the fabrics used for trousers in the laboratory tests and for uniforms in the large-scale field study were measured at NARADCOM and are shown in Tables 1 - 6 and Figures 1 - 3. Appendix A indicates the specific testing procedures that were used in determining the data shown in these tables and figures.

TABLE 1. Control Fabric - Off Bolt.

Properties	50/50 P/C Tan 445	55/45 P/W Tropical	55/45 P/W Exp.	75/25 P/W Exp.	100 P Exp.
Yarns/in W	106	51	66	62	52
F	54	44	68	56	42
Weight, oz/yd^2	7.1	6.3	7.4	6.9	8.0
Air Perm, $ft^3/min/ft^2$	11.94	43.70	15.06	30.79	28.94
Thickness, mils	17	17	20	21	26
Stiffness ($x10^{-4}$) W	7.9	1.8	1.7	2.1	3.4
F	2.2	1.6	1.2	1.6	2.1
Moisture Regain, %	15.6	25.7	28.9	17.5	2.2
MVT, $g/m^2/24$ hr	1130	1300	1200	1280	1220
Wettability - Spec 1	>1 hr	7' 17"	7' 52"	1' 34"	0' 9"
Spec 2	>1 hr	6' 56"	9' 46"	1' 32"	0' 7"
Wicking W	1"/24 hr	11' 44"	14' 38"	10' 57"	0' 58"
(1 inch) F	1"/24 hr	16' 7"	15' 21"	14' 0"	1' 46"
Clo - ARIEM	0.57	0.55	0.55	0.57	0.52
NAVY	0.51	0.52	0.51	0.53	0.49
i_m - ARIEM	0.61	0.58	0.54	0.60	0.50
NAVY	0.47	0.48	0.48	0.50	0.50
i_m/Clo - ARIEM	1.07	1.06	0.99	1.05	0.97
NAVY	0.92	0.92	0.94	0.94	1.02

All tests were conducted at 95°F, 70% R.H. except for the following:

ARIEM Clo - plate 92°F, air 80°F

i_m - plate 92°F, air 90°F, 80% R.H.

NAVY Clo - plate 89°F, air 65.5°F, 40% R.H.

i_m - plate 89°F, air 94°F, 19% R.H.

TABLE 2. Trousers and Fabric - Laundered 5X.

Properties	50/50 P/C Tan 445	55/45 P/W Tropical	55/45 P/W Exp.	75/25 P/W Exp.	100 P Exp.
Yarns/in W	104	50	68	64	52
F	52	44	64	56	44
Weight, oz/yd^2	7.3	6.7	7.4	6.9	8.0
Air Perm, $ft^3/min/ft^2$	15.21	30.55	16.82	34.00	29.32
Thickness, mils	18	21	23	23	27
Stiffness ($x10^{-4}$)W	2.3	1.6	1.2	1.8	3.6
F	1.5	1.6	1.1	1.6	2.2
Moisture Regain, %	16.3	28.4	31.0	18.0	2.4
MVT, $g/m^2/24$ hr	1250	1275	1270	1375	1280
Wettability - Spec 1	>1 hr	0' 31"	0' 51"	0' 31"	<1"
Spec 2	>1 hr	0' 36"	4' 5"	0' 5"	<1"
Wicking W	½in/24 hr	1' 26"	2' 20"	0' 39"	0' 47"
(1 inch)F	½in/24 hr	1' 39"	2' 17"	0' 47"	0' 57"
Clo - ARIEM	0.60	0.61	0.63	0.62	0.55
NAVY	0.54	0.57	0.58	0.58	0.51
i_m - ARIEM	0.58	0.62	0.58	0.59	0.61
NAVY	0.47	0.52	0.48	0.48	0.48
i_m/Clo - ARIEM	0.97	1.02	0.92	0.95	1.11
NAVY	0.87	0.91	0.83	0.83	0.94

All tests were conducted at 95°F, 70% R.H. except for the following:

ARIEM Clo - plate 92°F, air 80°F

i_m - plate 92°F, air 90°F, 80% R.H.

NAVY Clo - plate 89°F, air 65.5°F, 40% R.H.

i_m - plate 89°F, air 94°F, 19% R.H.

TABLE 3. Fabric - Dry-Cleaned 5X.

Properties	50/50 P/C Tan 445	55/45 P/W Tropical	55/45 P/W Exp.	75/25 P/W Exp.	100 P Exp.
Yarns/in W	104	50	68	60	50
F	52	44	64	56	40
Weight, oz/yd^2	7.1	6.1	7.5	6.8	7.9
Air Perm, $ft^3/min/ft^2$	18.65	49.21	16.70	32.87	29.91
Thickness, mils	16	17	21	22	26
Stiffness ($x10^{-4}$) W	4.8	1.5	1.6	2.1	2.9
F	1.2	1.3	1.1	1.6	1.8
Moisture Regain, %	15.0	24.0	29.7	17.3	5.2
MVT, $g/m^2/24$ hr	1340	1560	1365	1430	1430
Wettability - Spec 1	1 hr	1' 56"	6' 3"	12' 45"	1' 14"
Spec 2	1 hr	2' 3"	6' 33"	12' 30"	2' 38"
Wicking W	½in/24 hr	2' 26"	6' 18"	5" 47"	5' 25"
(1 inch) F	½in/24 hr	3' 10"	7' 8"	5' 55"	5' 49"
Clo - NAVY	0.51	0.56	0.57	0.57	0.50
i_m - NAVY	0.48	0.49	0.49	0.53	0.48
i_m/Clo - NAVY	0.94	0.88	0.86	0.93	0.96

All tests were conducted at 95°F, 70% R.H. except for the following:

NAVY Clo - plate 89°F, air 65.5°F, 40% R.H.

i_m - plate 89°F, air 94°F, 19% R.H.

TABLE 4. Evaporative Characteristics of Candidate Year-Round and Army Standard Fabrics (Off Bolt).

Material: Off the Bolt (CONTROL) Specimen Size: 5" x 5"

	(1) Poly/Cotton (50/50) D.P. Finish Tan 445 $\frac{2}{1}$ R.H.T.	(2) Poly/Wool (55/45) Tropical AG-344-Pl. Weave	(3) Poly/Wool (55/45) $\frac{2}{2}$ R.H.T. Army Green	(4) Poly/Wool (75/25) $\frac{2}{2}$ R.H.T. Army Green	(5) 100% Poly Texturized $\frac{2}{2}$ R.H.T. Army Green
Dry Weight (gms)	3.4537	3.1316	3.6401	3.4816	3.8570
Wet out & drained 5 minutes / Wgt of water	5.8988 (2.4451)	5.9788 (2.8472)	7.4886 (3.8485)	7.3571 (3.8755)	8.9701 (5.1131)
Gms. Water Lost at 15 min intervals:					
15	0.7566	0.8906	0.8338	0.8553	0.8906
30	1.5152	1.6556	1.6638	1.6931	1.6357
45	2.2551	2.3931	2.4270	2.4700	2.4631
60 (1 hr)	2.4045	2.8150	3.1957	3.2842	3.2446
75	2.4029	2.8315	3.7813	3.8495	4.0165
90	2.4002	2.8326	3.7897	3.8624	4.7517
105	2.4	2.8326	3.8321	3.8653	5.1105
120	2.4	2.8	3.8335	3.8676	5.1108
135					5.1111
150					5.1115

TABLE 5. Evaporative Characteristics of Candidate Year-Round and Army Standard Fabrics (Laundered 5X).

Material: Trousers or Fabric (Laundered 5x) Specimen Size: 5" x 5"

	(1) Poly/Cotton (50/50) D.P. Finish Tan 445 $\frac{2}{1}$ R.H.T.	(2) Poly/Wool (55/45) Tropical AG-344-Pl. Weave	(3) Poly/Wool (55/45) $\frac{2}{2}$ R.H.T. Army Green	(4) Poly/Wool (75/25) $\frac{2}{2}$ R.H.T. Army Green	(5) 100% Poly Texturized $\frac{2}{2}$ R.H.T. Army Green
Dry Weight (gms)	4.0563	3.6796	4.2156	3.9001	4.5189
Wet out & drained 5 minutes Wgt. of Water	7.2981 (3.2418)	7.0048 (3.3252)	8.6693 (4.4537)	8.2687 (4.3686)	10.6090 (6.0901)
Gms. Water Lost at 15 min intervals:					
15	0.8915	0.8449	0.8796	0.7977	0.8715
30	1.5768	1.6432	1.6724	1.5905	1.7399
45	2.3029	2.2903	2.4491	2.3912	2.5950
60 (1 hr)	2.9689	3.0505	3.1921	3.1167	3.3100
75	3.2320	3.2750	3.9039	3.8283	4.1681
90	3.2378	3.2920	4.3735	4.3167	4.8804
105	3.2382	3.2951	4.4190	4.3516	5.5574
120 (2 hr)	3.2383	3.2955	4.4233	4.3584	6.0648
135	3.2402	3.2983	4.4245	4.3668	6.0939
150	3.2401	3.3008	4.4289		
165	3.2419	3.3001	4.4310		
180 (3 hr)	3.2402	3.3042	4.4324		
240	3.2409		4.4330		
300	3.2379				

TABLE 6. Evaporative Characteristics of Candidate Year-Round and Army Standard Fabrics (Dry-Cleaned 5X).

Material: (Dry-Cleaned 5x) Speciment Size: 5" x 5"

	(1) Poly/Cotton (50/50) D.P. Finish Tan 445 $\frac{2}{1}$ R.H.T.	(2) Poly/Wool (55/45) Tropical AG-344-Pl. Weave	(3) Poly/Wool (55/45) $\frac{2}{2}$ R.H.T. Army Green	(4) Poly/Wool (75/25) $\frac{2}{2}$ R.H.T. Army Green	(5) 100% Poly Texturized $\frac{2}{2}$ R.H.T. Army Green
Dry Weight (gms)	3.9848	3.5305	4.1864	3.8738	4.4932
Wet out & drained 5 minutes	6.9942	6.7541	8.5811	8.6194	10.4733
Wgt. of Water	(3.0094)	(3.2236)	(4.3947)	(4.7456)	(5.9801)
Gms. Water Lost at 15 min. intervals:					
15	0.8116	0.7472	0.7782	0.8475	1.3156
30	1.5269	1.4426	1.5637	1.6508	1.5452
45	2.3033	2.3001	2.2735	2.3721	2.3073
60 (1 hr)	2.9408	2.8246	2.9676	3.0933	3.0893
75	3.0537	3.1758	3.8080	3.8366	3.8604
90	3.0535	3.1890	4.2729	4.4768	4.5413
105	3.0553	3.1951	4.3545	4.7217	5.2435
120 (2 hr)	3.0566	3.1929	4.3547	4.7279	5.8281
135		3.1959	4.3591	4.7319	5.9794
150		3.1987	4.3608	4.7294	5.9794
165		3.1992	4.3643	4.7301	5.9793
180 (3 hr)		3.1959	4.3619	4.7303	
210		3.1979	4.3667	4.7337	

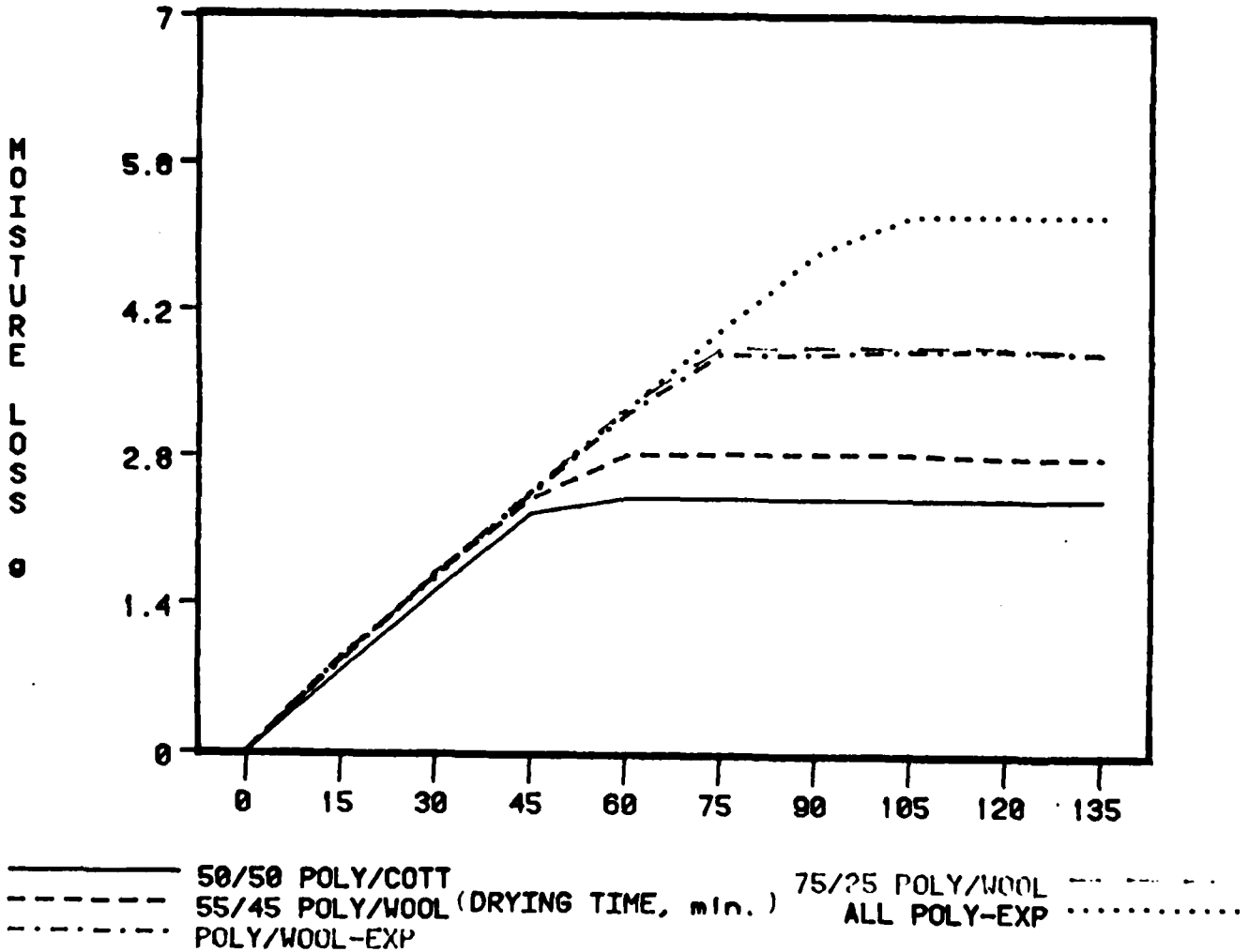

Figure 1. Evaporative characteristics - control.

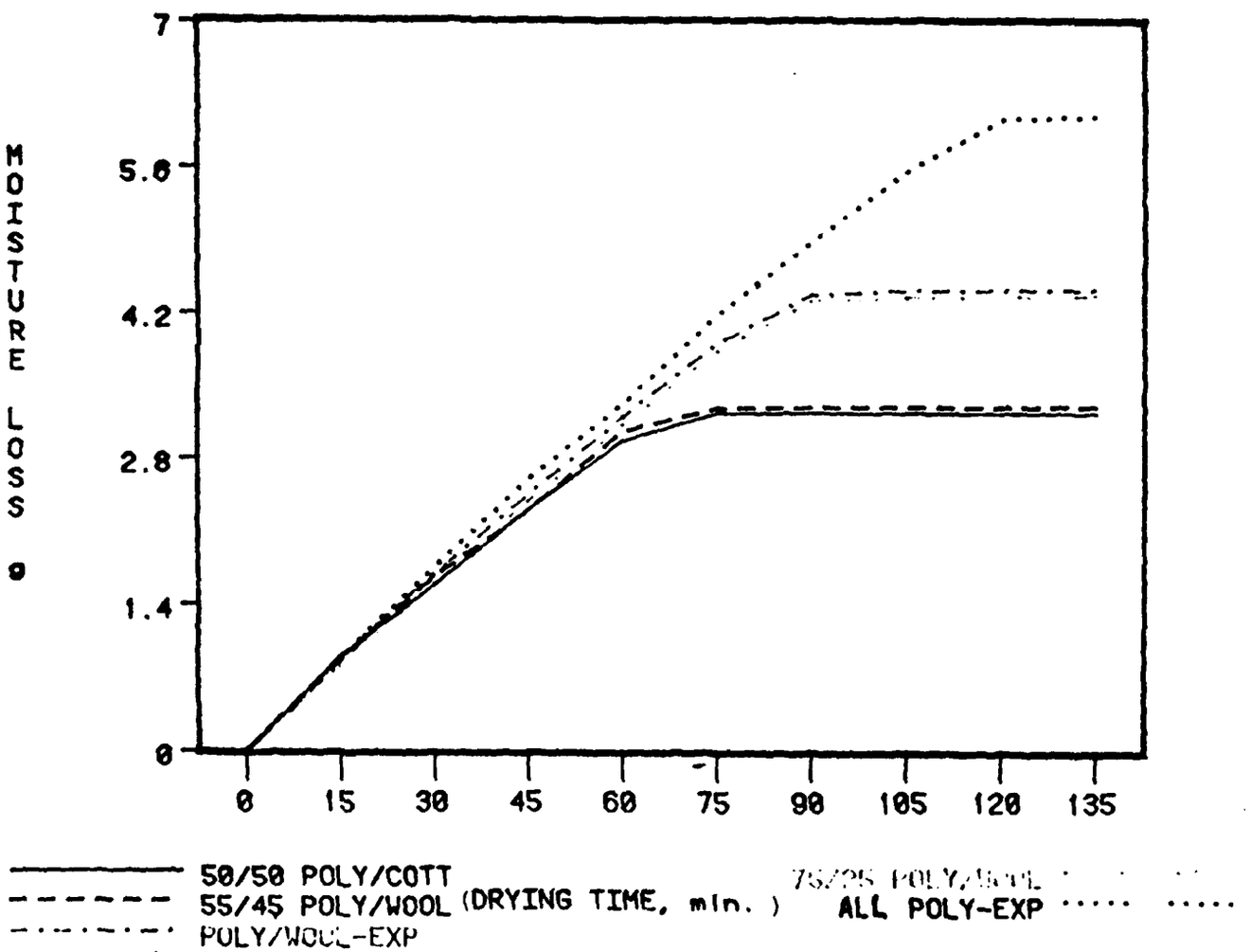

Figure 2. Evaporative characteristics - after 5 launderings.

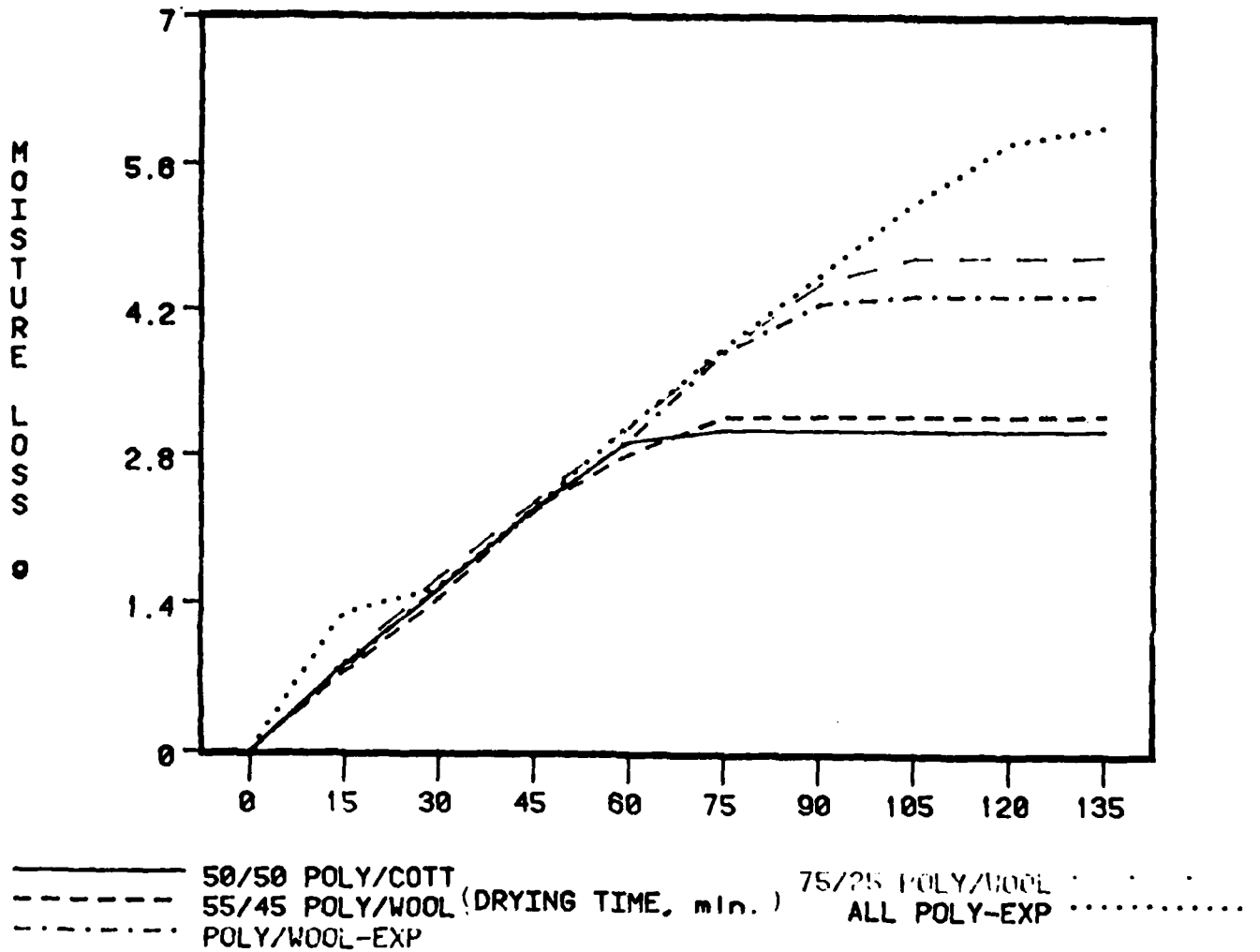

Figure 3. Evaporative characteristics - after 5 drycleanings.

C. Analysis of the Fabric Property Results

Considering the properties summarized in Table 1, it is possible to compare the fabric properties influenced mainly by construction differences. These include weight, air permeability, thickness, and stiffness. Although there were minor differences in the properties between the fabric types (for example, stiffness in the warp direction of the 50/50 P/C control), most of these differences were lost in laundering and drycleaning as shown in Tables 2 and 3, respectively. Indeed if the data in Table 2 after five laundering cycles, corresponding to the use condition of trouser wear and care, are examined closely, it is possible to conclude that structure choices in fabric construction resulted in remarkably similar fabrics. The variations in weight, air permeability, and thickness are not likely to have been noted by individuals wearing trousers of these fabrics.[8] These similarities are further confirmed by noting the Clo insulation values at the bottom of these tables obtained from the Army Research Institute of Environmental Medicine and the Naval Medical Research Laboratories.[9]

Listed also in these tables are the results from four tests related to the water handling ability of the fabrics. Included are the measurements of regain, moisture vapor transmission (MVT), wettability, and wicking. A comparison of the values for these properties in Tables 1, 2, and 3 reveals

again there was little effect due to laundering or dry cleaning. Focussing on the values for laundered fabrics in Table 2 it can be seen that differences due to fabric type were obtained for regain, wettability and wicking while water vapor transmission values were remarkably similar. The large regain values were due primarily to the fact that the measurements were made at 95°F and 70% relative humidity. The variations in regain were due primarily to the fiber content variations of wool, cotton, and polyester.[10] Differences in the wicking rate of the fabrics were not entirely unexpected although the very slow rate for the 50/50 P/C was atypical of DP finished and properly scoured blends. The probable effects of laundering detergent remaining in the fabric are seen in comparing the wicking values for the 100 P fabric after dry cleaning (Table 3) with after laundering (Table 2).

The permeability index (i_m) values reflecting ease of water vapor transmission were quite similar for all the fabrics as might be expected from the similar moisture vapor transmission values.[9,10] Indeed, except for moisture regain the property values in these tables were probably not affected by carrying out the measurements at 95°F and 70% relative humidity.

Tables 4 through 6 and Figures 1 through 3 summarize the results from drying experiments on the five trouser fabrics. Again, laundering and dry cleaning produced only minor

differences in the drying time to equilibrium moisture loss. Focussing on the results for laundered fabrics in Figure 2, it appears that equilibrium drying time was reached most quickly with the 50/50 P/C and 55/45 P/W controls and most slowly with the 100 P experimental fabric. These differences appear to be due primarily to the fact that a 5 minute drainage period was used, allowing drainage and partial drying to occur for some fabrics before the weight recordings were begun.[11] Drying time measurements can be used to discern fabric differences possibly related to clothing comfort.[12]

D. Fabric Properties Related to Clothing Comfort

In a recent review of fabric properties most useful to measure for clothing comfort,[8] it was pointed out that there are accepted ranges for clothing performance as appreciated by the wearer for weight, stiffness, thickness, water and air permeability. The Army trouser fabrics of this study fell well into these acceptable ranges.

The review[8] also pointed out that liquid water properties of fabrics have been singularly unsuccessful in predicting clothing contact satisfaction on the skin, and this lack of success has been attributed to the fact that the water content of fabrics is next-to-skin clothing seldom exceeds 20% as is generally less than 10%. Thus, insufficient water is available to fill the interfiber capillaries and cause a wicking or wetting action. Rather, water sensation differences in

clothing are dominated by thin condensed layers whose effect on water mobility is caused by some combination of the effects of small internal pores in the fibers and the ability of the fibers to hold water.[6] Methods are being developed to detect these differences in clothing fabrics which should eventually permit the screening of clothing fabrics for acceptable water transmission properties.[12]

Fabric contact with the skin also influences the type and intensity of sensation experienced by wearers, depending on the type of exercise and microclimate of wear.[3] A variety of methods are available for assessing surface contact on dry and moist fabrics that depend on counting the surface fibers as a function of the pressure of contact.[10]

IV. GARMENT PREPARATION

For the laboratory comfort studies, all candidate fabrics were woven in a 2 x 2 right-hand twill construction using intimate blend staple yarns for the 55/45 polyester/wool blend, alternating 100% texturized polyester and 55/45 spun polyester/wool yarns for the 75/25 polyester/wool and 100% textured polyester for the third candidate. Tne laundering stability of each candidate fabric was measured before garment manufacture and these results are given in Table 7. None of the fabrics had excessive shrinkage using the mild laundering and drying procedures proposed for the comfort comparison work.

For the male comfort study, 20 trousers were constructed from each candidate fabric by the Saco Uniform Company, of Philadelphia, using Military Specification MIL-T-41828F dated 28 June 1974 with Amemdment 2, dated 1 April 1976. In addition, 20 durable press 50/50 polyester/cotton trousers per Military Specification MIL-T-43853A dated 7 March 1975, Amendment 2, dated 1 April 1976, and 20 55/45 polyester/wool tropical trousers Military Specification MIL-T-41828F were supplied by the U. S. Army Natick Research, Development and Engineering Center. Uniforms were culled to match the sizes of available male subjects for subjective comfort testing. The cotton and wool blend control trousers were chosen because of their known satisfactory acceptance by wearers in summer and winter environments, respectively.

TABLE 7. Shrinkage of Candidate Trouser Fabrics Following Laundering and Tumble Drying.*

Blend Fiber Ratio		Shrinkage in Percent After			
Polyester	Wool	1 Cycle(L+TD)		5 Cycles(L+TD)	
		w	f	w	f
55	45	0.0	0.0	-0.5	-0.5
		-0.5	0.0	-0.5	0.0
		-0.5	0.0	-0.5	-0.5
75	25	-0.5	-0.5	-0.5	-0.5
		-0.5	-0.5	-0.5	-0.5
		-0.5	0.0	-0.5	0.0
100	0	-0.5	-0.5	-0.5	-0.5
		0.0	0.0	0.0	0.0
		0.0	+0.5	-0.5	+0.5

*Three swatches were washed for 10 minutes on permanent press cycle in cold water followed by a cold rinse and spin dry. Ninety grams of AATCC standard detergent was used in each wash, cotton duds were added to achieve a load of 1.8 kg (4 lb). Swatches were dried in a standard AATCC dryer on permanent press cycle. Shrinkage measurements were made after conditioning at 21°C (70°F), 65% relative humidity for 2 hours.

In comfort tests with female subjects, both the candidate year-round control fabrics (although not currently worn by female Army personnel) evaluated by male subjects were also evaluated by female subjects. Trousers were furnished by NARADCOM for this study.

Again, 20 pairs of trousers, in the size range suitable for the contractor's test subject pool were manufactured from each of the 5 fabric types according to requirements in Military Specification MIL-S-43985, dated 8 June 1978, entitled "Slacks, Woman's, Gabardine, Army Green 344." The sources of these trousers were as follows:

(a) Military Specification MIL-C-43791B dated 13 February 1979 entitled "Cloth, Twill, Polyester/Cotton (Durable Press)" Type I, a 50/50 polyester/cotton 2/1 right-hand twill weighing 7.3 oz/yd^2 has an approved durable press and soil release treatment (U. S. Army issue).

(b) Military Specification MIL-C-21115H dated 26 November 1975 entitled "Cloth, Tropical, Polyester/Wool, Type I, Class 3" is 55/45 polyester/wool plain weave with 2 ply yarns weighing 6.4 oz/yd^2 (U. S. Army issue).

(c) Raeford Uniform Fabric Co. style 10313: 55/45 polyester/wool, 2 x 2 right-hand twill, 6.8 oz/yd^2.

(d) Raeford Uniform Fabric Co. style 14221: 75/25 polyester/wool made up of end and end, pick and pick construction with 100% texturized polyester yarns alternating with 55/45 spun polyester/wool yarns, 2 x 2 right-hand twill, 8.0 oz/yd^2.

Shrinkage of these fabrics following laundering and tumble drying was established as minimal during the previous study. The laundering procedure for all fabrics, used in both male and female studies, was a 10-minute permanent press wash cycle with 90 grams of AATCC standard detergent with brighteners, followed by a cold rinse. Garments were tumble dried in a standard AATCC dryer on permanent press cycle for 40 minutes. All trousers were labeled and laundered once prior to wearing.

In the large-scale field study, complete uniforms from each of the three experimental fabrics were issed by the Army to the individual soldiers.

V. FIELD COMFORT STUDIES

During the period January 1979 to January 1980 NARADCOM conducted a large-scale field study with some 1100 to 1400 Army personnel to evaluate the 3 candidate fabrics for a proposed year-round uniform. Uniforms were constructed from the fabrics and these were issued to Army personnel (males and females) having the appropriate garment sizes. Each soldier wore a uniform constructed from one of the three fabrics for the entire year. In some instances, however, there were delays in getting uniforms to the participants, and, therefore, some personnel wore the uniform less than a year. The personnel were stationed at the 28 installations shown in Table 8.

During the Cold Weather Phase evaluation, which was conducted first, 70% of the personnel indicated that the coldest temperature which they experienced during the evaluation ranged between 14°F and 49°F. During the Hot Weather Phase evaluation, roughly 75% of the participants indicated the warmest temperature experienced during the evaluation was greater than 80°F. At the end of each phase, each participant was required to fill out the appropriate questionnaire to aid in the evaluation of the uniforms. The questionnaires for the cold and hot weather phases are shown in Appendixes B and C, respectively. In addition, when the year long evaluation was completed, each participant was required to respond to both a Termination Phase questionnaire and a Supplemental questionnaire. These are shown as Appendixes D and E, respectively.

TABLE 8. Participants - Army Green Uniforms for Year-Round Wear.

Installation Code		Clothing Zone
01	Ft. Ben Harrison	V
02	Ft. Monroe	III
*03	Ft. Sheridan (Recruiters)	
04	West Point	V
05	USAREUR	VI
06	Ft. McPherson	III
07	CID Command	III
08	Ft. Sam Houston	III
09	Presidio of San Francisco	III
10	Ft. Huachuca	V
11	Ft. Meade	III
12	Ft. Jackson	III
13	Pentagon/AUS	III
14	CAFCOM	III
15	Ft. McClellan	III
16	Ft. Eustis	III
17	Ft. Bliss	III
18	National Guard Bureau	III
19	Hawaii	I
20	Panama	I
21	Ft. Lee	III
22	Ft. Leavenworth	V
23	NARADCOM	V
24	Ft. Ord	III
25	Fitzsimmons A.M.C.	V
26	Ft. Rucker	III
27	Rock Island	V
28	Ft. Myer/MDW	III

*No Clothing Zone assigned for wear test purposes because the recruiters tested the uniform all over the U.S.

All of the data was transcribed and computer summarized. Table 9 summarizes the field evaluation data, particularly that encompassing uniform comfort. The table shows that 71% of the evaluating personnel felt that the test, or candidate, uniform was overall more comfortable than the summer green uniform. This combined both the cold and hot weather phases. Furthermore, the level of comfort apparently improved with increasing levels of fabric polyester content (100% P was judged by 78% of the respondents as being more comfortable, 75/25 P/W = 72%, and 55/45 P/W = 63%). Regarding the specific comfort descriptors of "Coolness", "Feel" or "Hand", "Scratchiness", "Heaviness", "Clamminess" ("Coldness", "Dampness"), and "Stickiness or "Dampness" during the hot weather phase, again the 100% polyester fabric was most preferred to the current summer and summer green uniforms with the 75/25 P/W and 55/45 P/W candidate fabrics being also preferred and at a parity with each other.

TABLE 9. Summary of Field Comfort Evaluations.

I. Overall Reaction (Termination Phase)

Comfort of test (55/45 P/W exp., 75/25 P/W exp., and 100% P exp.) uniform compared to summer green uniform (question 15)

71% test more comfortable

55/45 P/W exp. 63%

75/25 P/W exp. 72%

100% P exp. 78%

13% test same

16% test less comfortable

II. Cold Weather (Cold Weather Phase)

73% considered test warmer than summer green in cold weather (question 14)

85% considered test satisfactory for cold wather (question 20)

83% felt test uniform should replace the summer green uniforms for cold weather (question 26)

72% preferred the test uniform to both summer green and winter green uniforms for cold weather (question 28)

(There was little difference in the four responses above due to fabric type)

TABLE 9. (cont'd).

III. Hot Weather (Hot Weather Phase)

Coolness of test uniform compared to summer green in hot weather (question 14)

52% test cooler

55/45 P/W exp. 46%

75/25 P/W exp. 50%

100% P exp. 59%

19% test same

29% test warmer

Coolness of test uniform compared to current summer (khakis for males, cords or new mint greens for females) in hot weather (question 15)

58% test cooler

55/45 P/W exp. 53%

75/25 P/W exp. 57%

100 P exp. 63%

14% test same

27% test warmer

(Note - At the Pentagon 45% said test uniform was somewhat warmer than the current summer uniform)

TABLE 9. (cont'd).

Is the test uniform satisfactory for hot weather? (question 24)

71% yes	
55/45 P.W. exp.	67% yes
75/25 P/W exp.	67% yes
100 P exp.	78% yes

(Note - There were installation exceptions:)

Pentagon	52% yes
CID	50% yes
Ft. McPherson	58% yes

Uniform preference for hot weather (question 25)

Test Uniform	65%
55/45 P/W exp.	62%
75/25 P/W exp.	61%
100 P exp.	72%
Summer Green Uniform	14%
Current Summer Uniform	20%
Winter Green Uniform	Less than 1%

TABLE 9. (cont'd).

IV. Feel ("Hand") of Test Uniform vs. Summer Green Uniform (question 16, Termination Phase)

80% test uniform better

55/45 P/W exp. 73%

75/25 P/W exp. 79%

100 P exp. 88%

11% test same

9% test worse

V. Allergies (questions 31 & 32, Termination Phase)

96% to 98% said there were no allergies to the test or summer green uniforms

VI. Scratchiness (question 10, Supplemental Phase)

61% test uniform less scratchy than summer green uniform

55/45 P/W exp. 57% less

75/25 P/W exp. 54% less

100 P exp 72% less

23% same

16% more scratchy

TABLE 9. (cont'd).

VII. Heaviness (question 11, Supplemental Phase)

49% test uniform less heavy than summer green uniform

55/45 P/W exp. 49% less

75/25 P/W exp. 43% less

100 P exp. 56% less

13% same

38% more heavy

VIII. Clamminess (Coldness, Dampness) (question 12, Supplemental Phase)

63% said test uniform was less clammy than summer green uniform (little differences between fabric types)

28% same

9% more clammy

IX. Stickiness & Dampness (questions 13 & 14, Supplemental Phase)

56% said test uniform was less sticky and damp than summer green

55/45 P/W exp. 54% less

75/25 P/W exp. 51% less

100 P exp. 62% less

20% same

25% more sticky & damp

TABLE 9. (cont'd).

52% said test uniform was less sticky and damp than the current summer uniform

55/45 P/W exp. 52% less

75/25 P/W exp. 47% less

100 P exp. 57% less

15% same

33% more sticky and damp

The method used for carrying out the experimental uniform evaluations in the field left considerable doubt as to the value of the results as a means for choosing a new uniform type. Some of the questions raised included the influence of having the wearers know they were testing a "new" uniform, and the absence of side-by-side comparison of uniforms (experimental versus control). An even more serious problem was that the answering of critical questions of performance was carried out well after the fact and response testing has shown that this procedure can negate even the most closely controlled subjective study.[6] Experience has shown that in even controlled subjective wear studies, with a double blind submission of garments in a random order, the use of specific questionnaires can generate answers about garment behavior, which are merely a matter of mental choice and are not based on real experience.[1] It was for these reasons the uniforms were compared on men and women using open-ended questionnaires in the repeated controlled environmental wearing studies, as described in the sections that follow.

VI. LABORATORY COMFORT STUDIES

A. Male Subjects

1. Techniques for Garment Comparisons

The medical histories of the potential panelists were reviewed. Only men 18-35 years of age in good health were selected. The 27 approved subjects were informed of the temperature and relative humidity extremes, the exercise protocol and potential risks involved, and each signed a release prior to the commencement of comfort tests.

The climate and exercise protocol followed in the tests are outlined in Table 10. The 10-minute period of exercise, in a warm room on a stationary bicycle, was included to induce mild sweating and to bring all subjects to a definable metabolic state prior to entering the environmental chamber. Details of this protocol are discussed in a separate publication.[1]

Test subjects were fitted with prelaundered trousers and assigned a size that was worn throughout the study. Trousers were presented in an unidentified manner and every subject evaluated each fabric type at least twice before completing the study. With the trousers, the men wore a 65/35 polyester/cotton short sleeve shirt similar to VEE 4068A worn by military personnel. Other articles of clothing were those normally worn for indoor use.

Ratings of comfort perception were requested and recorded by the subject on a chart of the type in Table 11. A rating

TABLE 10. Microclimate and Exercise Protocol.

Subjects exercise in Antechamber for 10 Minutes at 150-180 kg cal/m^2 hour at 30°C (86°F) - 33°C (92°F).

Rating Period	Time In Chamber min	Exercise After Rating*	Air Temperature °C (°F)	Relative Humidity
1	0	yes	35 (95)	20
2	1	no	35 (95)	20
3	15	yes	35 (95)	70
4	16	no	35 (95)	70
5	30	yes	35 (95)	70
6	31	no	35 (95)	70
7	45	no	35 (95)	45
8	60	no	21 (70)	75
9	75	no	17 (60)	75

*Exercise time 20 seconds using knee bends, hands at hips

TABLE 11. Subjective Comfort Rating Chart used for Trouser Comparisons.

During the run you will be asked to fill in this chart under an appropriate time period. Please rate the intensity of the comfort sensations for the trousers you are wearing. If any of the comfort descriptors listed below are sensed, put a rating in the appropriate box according to the intensity of the sensation, when requested by the panel operator. If you perceive additional sensations due to wearing the trousers, please note these comments at the bottom of the page and the time period in which they were noticed.

Use this intensity scale:
4 (partially)
3 (mildly)
2 (definitely)
1 (totally)

	Rating Periods								
	1	2	3	4	5	6	7	8	9
Snug									
Loose									
Heavy									
Lightweight									
Stiff									
Staticy									
Sticky									
Non absorbent									
Cold									
Clammy									
Damp									
Clingy									
Picky									
Rough									
Scratchy									

Comments on the locations that feel uncomfortable _____

_____

Additional Sensations Noted _____

_____

of 3 assigned to the descriptor "scratchy" would be interpreted as meaning that the garment was "mildly scratchy". If no comment was made by the wearer, a rating of 5, "totally comfortable", was assigned.

The environment was varied from hot-dry through hot-humid to cool-humid as described in Table 10. The subject exercised briefly at each new microclimate level and recorded comfort sensations, both before and after exercise. A record of subjective thermal response to the environment was recorded at each rating period using the McGinnis Scale, which is given in Table 12.

The responses of individuals to the different garments changed in intensity with each change in microclimate, dependent mainly on the amount of sweating that occurred in each microclimate period. For the descriptors "sticky", "clammy", "damp", "clingy", "picky", "rough", and "scratchy", this occurred mainly in periods 1 through 7, independent of the amount of exercise carried out at periods 4 and 6. On the other hand, differences in intensity of descriptors "snug", "loose", "heavy", "lightweight", and "stiff" were noted over all nine time periods. With none of the descriptors was there a consistent effect of exercise on rating level. The data chosen for computer analysis of trouser differences was therefore based on seven or nine time periods in each analysis for individual comfort sensations, which permitted a distinction in the trouser types.

TABLE 12. McGinnis Scale.

1. SO COLD I AM HELPLESS
2. NUMB WITH COLD
3. VERY COLD
4. COLD
5. UNCOMFORTABLY COOL
6. COOL BUT FAIRLY COMFORTABLE
7. COMFORTABLE
8. WARM BUT FAIRLY COMFORTABLE
9. UNCOMFORTABLY WARM
10. HOT
11. VERY HOT
12. ALMOST AS HOT AS I CAN STAND
13. SO HOT I AM SICK AND NAUSEATED

2. Trouser Ranking From Descriptor Intensities

After all subjects had worn each trouser type at least twice, individual comfort ratings (see Table 11) were transferred to computer storage for further analysis.

Table 13 lists the descriptors used by the male panelists to describe the wearing sensations of the five trouser types. The descriptors are grouped according to sensations that most closely and similarly distinguish between the trouser types. The rank placement values given are mean rank values for all descriptors in each group in which a high ranking in each case reflects the lowest intensity as described in Table 11. The five descriptors "sticky", "non-absorbent", "clammy", "damp", and "clingy", which connote moisture involvement when used by the men wearing these trousers, did indeed show a common mode of garment separation. Thus, trousers prepared from 100% polyester were deemed most unsuitable while fabrics 75/25 P/W (exp.) and 55/45 P/W (exp.) were equal and only slightly less desirable than the two control fabrics, 55/45 P/W (trop.) and 50/50 P/C. With the descriptors "picky", "rough", and "scratchy", all of the wool containing fabrics were equal and least desired, with the 100% polyester fabric being only slightly more desirable; the 50/50 P/C fabric was by far the most preferred.

The descriptors "loose" and "heavy" were found to produce similar garment separations with the controls in first place

TABLE 13. Rank Placement of Trousers From Mean Comfort Ratings by Descriptor Groups.*

Descriptors In Each Group	Mean Rank Placement for Each Garment				
	50/50 P/C	55/45 P/W (Trop.)	55/45 P/W (exp.)	75/25 P/W (exp.)	100 P (exp.)
Sticky, Nonabsorbent Clammy, Damp, Clingy	2.2	2.2	2.8	2.8	5.0
Picky, Rough, Scratchy	1.0	3.7	3.7	3.7	3.0
Loose, Heavy	1.5	1.5	3.5	4.5	4.0
Snug, Lightweight	4.5	4.0	2.0	2.0	2.5

*Based on mean rating values shown in Table 16.

and well ahead of any of the candidate garments. Indeed, the responses of the wearers using these two descriptors were qualitatively similar to all of the other descriptors that have been discussed thus far. The common underlying feature is that all of these descriptors have a negative connotation so high ratings and low rankings can be interpreted as greater comfort. According to this scheme, responses using descriptors "snug" and "lightweight" were the exact opposite with controls ranked lower than the candidate trousers. This strongly suggests that the descriptors "snug" and "lightweight" were viewed as positive comfort attributes, so that in this case, favored garments (controls) are rated lowest (highest intensity) and ranked last according to the foregoing scheme. This type of finding in using descriptors has occurred quite frequently in other studies using human perception analysis and is one of the benefits that comes from using an open-ended rating chart (Table 11), i.e., one having no prejudices regarding a descriptor's positiveness or negativeness.

3. Trouser Differences Sensed by Individual Wearers

One of the most powerful procedures for translating the comfort intensity data into meaningful garment differences involves nonparametric comparisons of the comfort ratings for individual wearers and descriptors by garment pairs. By this means the significance of differences between garments can be computed without any assumptions concerning the type of

distribution represented by the data. In addition, each garment performance is assessed using each wearer as his own control.

The subjective comfort ratings for individual wearers were compared for each descriptor using the Wilcoxon Signed-Rank statistical procedure.[1] In this manner it was possible to compare the performance of each candidate trouser type with each of the trouser controls.

Table 14 summarizes the results of these comparisons for trousers containing fabrics 100 P, 75/25 P/W (exp.), and 55/45 P/W (exp.) against the 50/50 P/C control fabric, both for individual descriptors and for descriptor groups. The data are presented as the number of individual subjects discerning one garment over the other at the 90% confidence level.

For the descriptors "sticky", "nonabsorbent", "clammy", "damp", and "clingy" there were no preferences for the 50/50 P/C control fabric over the candidate fabrics 55/45 P/W (exp.) or 75/25 P/W (exp.); however, the control fabric was definitely preferred over the 100 P (exp.) fabric with this group of descriptors. For the descriptor group "picky", "rough", and "scratchy" there was an overwhelming preference for the polyester/cotton control over all the candidate fabrics.

Use of the descriptors "snug", "loose", "heavy", and "lightweight" in these comfort trials was unusual in that they

TABLE 14. Summary of the Number of Subjects Indicating Differences Between Trouser Types For Individual Descriptors (50/50 P/C Control).

Descriptor		Based on Wilcoxon Sign-Rank Analysis at the 90% Confidence Level								
		50/50 P/C > 55/45 P/W (exp.)	No Diff.	55/45 P/W (exp.) > 50/50 P/C	50/50 P/C > 75/25 P/W (exp.)	No Diff.	75/25 P/W (exp.) > 50/50 P/C	50/50 P/C > 100 P (exp.)	No Diff.	100 P (exp.) > 50/50 P/C
Sticky	(Rating Periods 1-7)	7	8	7	3	14	5	9	9	4
Nonabsorbent		5	1	7	5	3	5	7	4	2
Clammy		2	1	1	1	2	1	2	2	0
Damp		4	5	6	6	6	4	6	8	1
Clingy		4	5	2	3	4	4	7	2	2
		22	20	23	18	29	19	31	25	8
Picky	(Rating Periods 1-7)	4	1	1	5	0	1	4	1	1
Rough		14	2	0	13	2	1	13	2	1
Scratchy		19	0	0	18	1	0	13	4	5
		37	3	1	36	3	2	30	7	7
Loose	(Rating Periods 1-9)	8	6	10	10	10	4	13	9	2
Heavy		8	4	1	7	5	1	7	4	2
		16	10	11	17	15	5	20	13	4
Snug	(Rating Periods 1-9)	4	4	6	4	3	7	1	5	8
Lightweight		4	2	11	2	4	11	4	3	10
		8	6	17	6	7	18	5	8	18

were used by most of the subjects indicating consistently strong sensations for a trouser garment. The general design and fit of the garments on the wearers was indeed trim and neat as probably desired for Army use, and this degree of trouser to skin contact probably contributes to the frequent use of these terms. Garment measurements themselves, however, did not show differences due to fit and so the results obtained must represent true sensations of contact comfort. For the negative terms "heavy" and "loose" and the positive terms "snug" and "lightweight" the control garment 50/50 P/C was distinctly preferred over any of the candidate fabrics, although this difference was least for candidate 55/45 P/W (exp.). This is a particularly interesting result when one notes that none of the subjects had worn these trousers before, or were told what were the variations in the garments.

A similar set of data for the polyester/wool control, 55/45 P/W (trop.), is given in Table 15. The control fabric was consistently preferred over the candidate fabrics for the descriptor group "sticky", "nonabsorbent", "clammy", "damp", and "clingy" and the preference was greater the greater the candidate fabric polyester content. Regarding the descriptor group "picky", "rough", and "scratchy", the control fabric was comparable to the candidate fabrics save the 100 P (exp.), which was slightly more preferred. For the negative

TABLE 15. Summary of the Number of Subjects Indicating Differences Between Trouser Types for Individual Descriptors (55/45 P/W Tropical Control).

Descriptor		Based on Wilcoxon Sign-Rank Analysis at the 90% Confidence Level								
		55/45 P/W (trop.) > 55/45 P/W (exp.)	No Diff.	55/45 P/W (exp.) > 55/45 P/W (trop.)	55/45 P/W (trop.) > 75/25 P/W (exp.)	No Diff.	75/25 P/W (exp.) > 55/45 P/W (trop.)	55/45 P/W (trop.) > 100 P (exp.)	No Diff.	100 P exp. > 55/45 P/W (trop.)
Sticky		9	10	3	10	7	5	14	3	5
Nonabsorbent		5	3	5	8	3	2	10	3	0
Clammy	(Rating Periods 1-7)	0	3	1	0	3	1	0	4	0
Damp		4	6	5	5	6	4	9	4	2
Clingy		4	4	3	2	3	6	5	3	3
		22	26	17	25	22	18	38	17	10
Picky		2	2	2	4	1	1	1	2	3
Rough	(Rating Periods 1-7)	8	3	5	6	6	4	7	4	5
Scratchy		5	6	8	4	5	10	5	3	11
		15	11	15	14	12	15	13	9	19
Loose	(Rating Periods 1-9)	12	9	3	15	8	1	19	5	0
Heavy		8	4	1	8	3	2	4	7	2
		20	13	4	23	11	3	23	12	2
Snug	(Rating Periods 1-9)	1	4	9	3	2	9	0	1	13
Lightweight		9	1	7	7	2	8	8	5	4
		10	5	16	10	4	17	8	6	17

descriptors "loose" and "heavy" and for the positive descriptors "snug" and "lightweight", the control fabric, 55/45 P/W (trop.), was preferred over all the candidate fabrics just as the polyester/cotton control had been.

Based on past experience with such comfort trials, it is expected that the comfort wear data in this study is likely to reflect the response of any healthy man even beyond the age range 18-35 of the study. Furthermore, the warm sweating conditions achieved in these trials and the microclimates associated with them are likely to reflect garment wear behavior summer or winter as long as sweating occurs. Mild sweating of overdressed and active men in the cold is quite common. The work further suggests that the sensations "snug", "loose", "heavy", and "lightweight" may be experienced in the wearing of such garments over a much wider range of conditions of use.

To point this out, Figure 4 shows an example of how the various garments maintained the same discriminations for the descriptor "loose" regardless of the warm-dry, warm-humid, or cool-humid microclimate conditions under which they were evaluated. In contrast to this behavior, Figures 5 and 6 show the average rating levels for individual subjects for the complete series of rating periods (Tables 10 and 11) for the descriptors "damp" and "scratchy", respectively. These two figures clearly show individual changes in rating intensities and trouser type preferences as the microclimate conditions change.

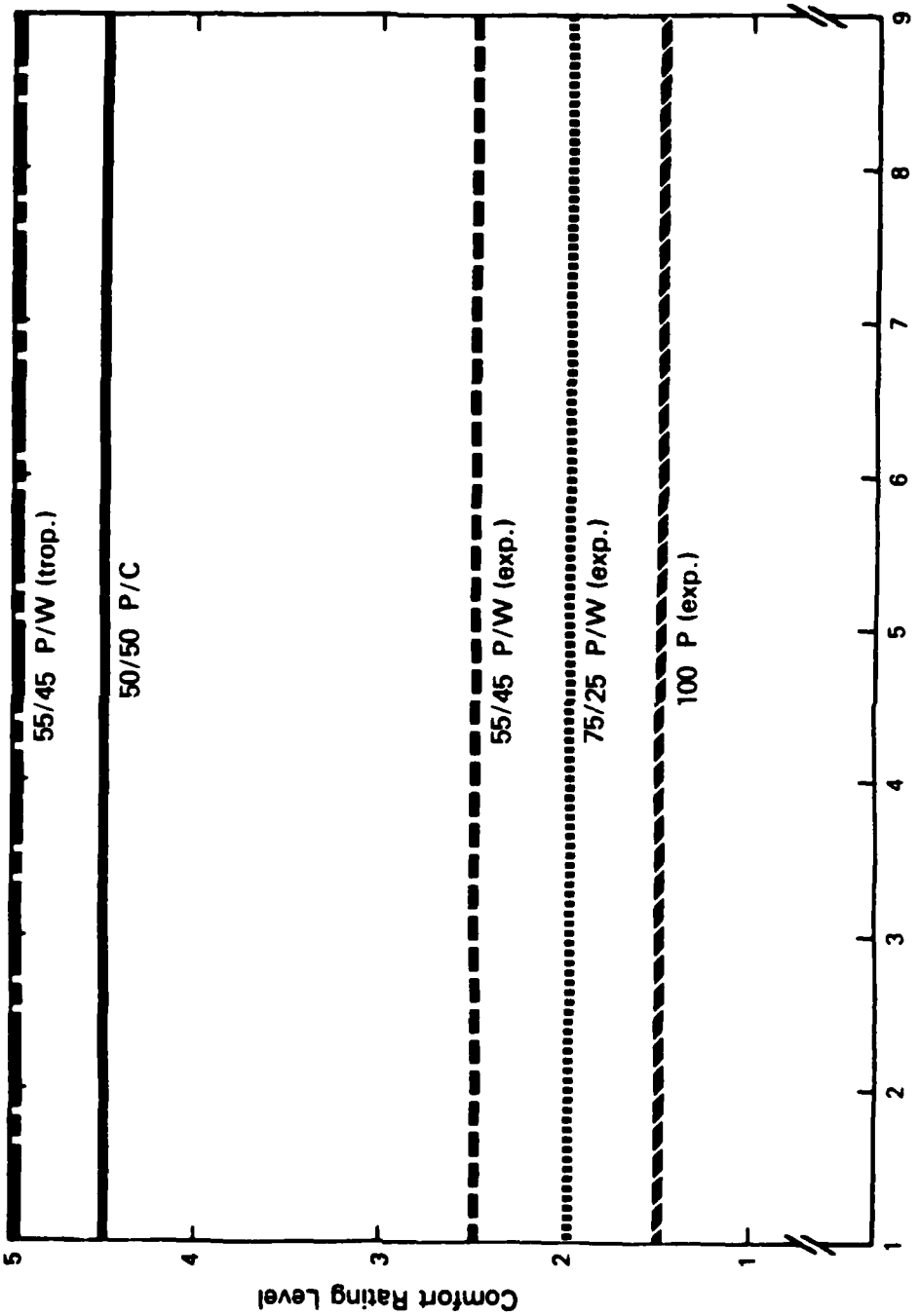

Figure 4. Time progression of comfort ratings for one subject using descriptor "loose".

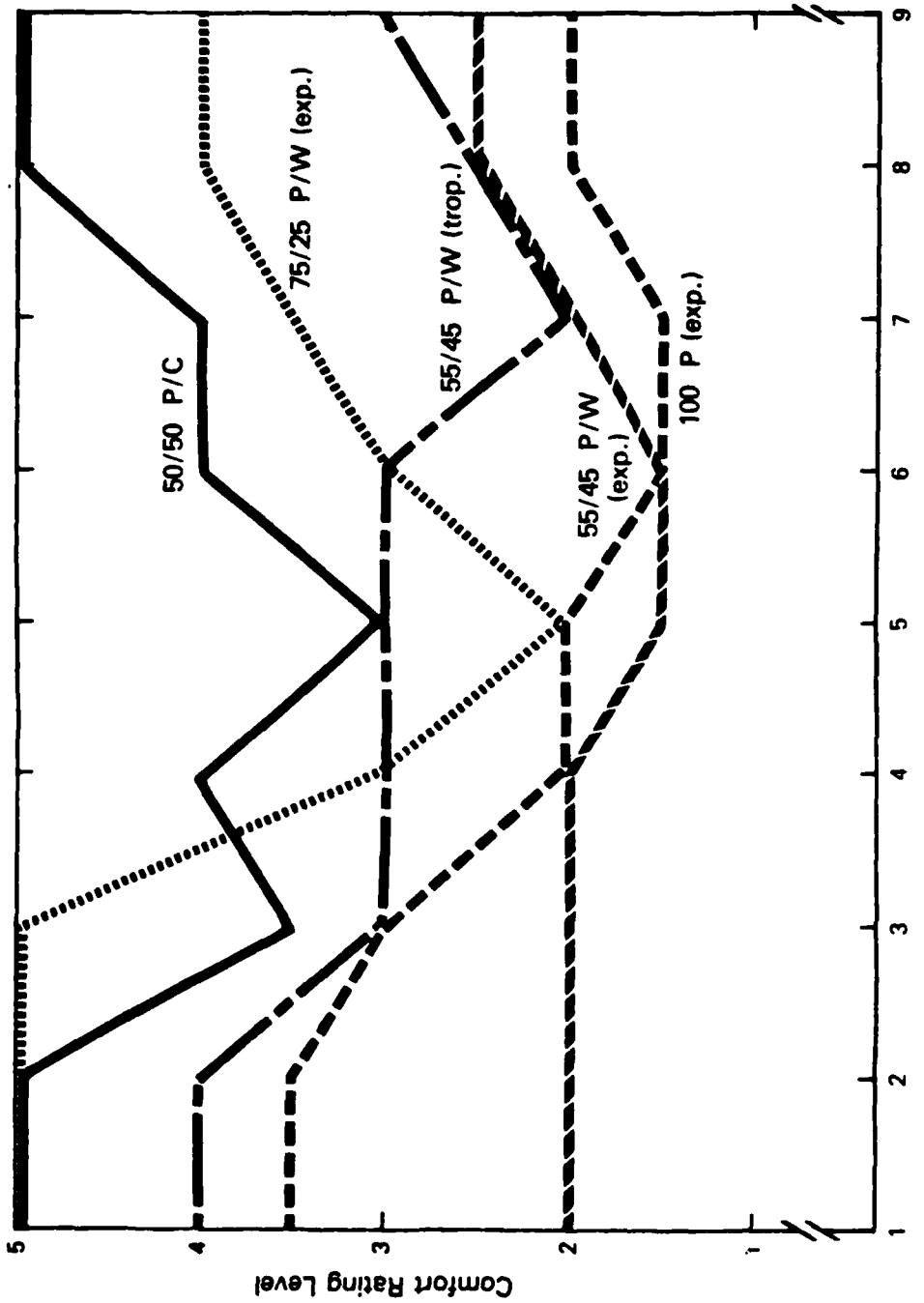

Figure 5. Time progression of comfort ratings for one subject using descriptor "damp".

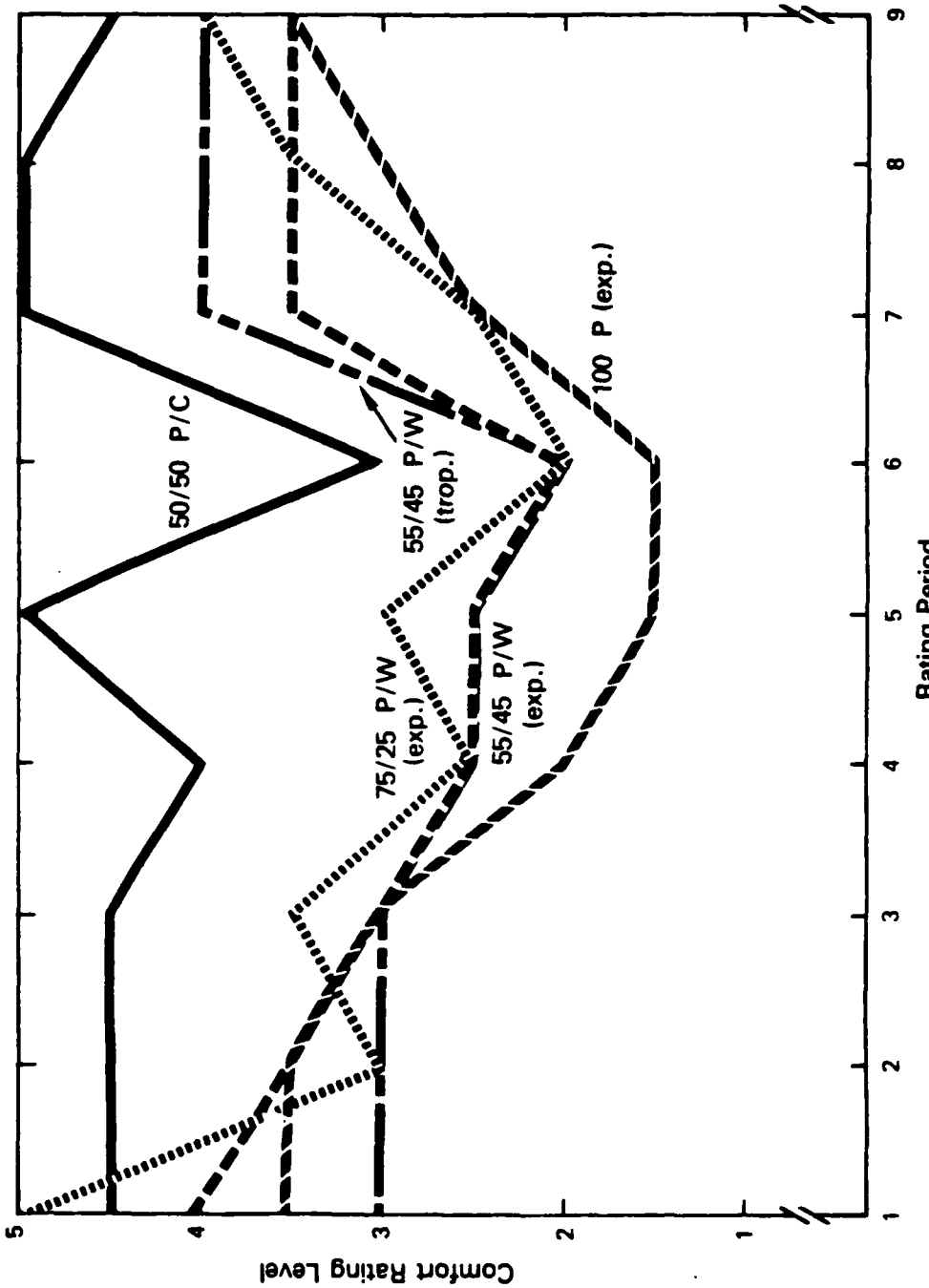

Figure 6. Time progression of comfort ratings for one subject using descriptor "scratchy".

4. Trouser Comparisons From Analysis of Variance

Further differentiation between the wearing performance of these garments was achieved by an analysis of variance of all the data by individual descriptors. These comparisons are presented in Table 16, which gives the mean comfort ratings for each garment and the differences significant at 90, 95 and 99% for individual and groups of descriptors. Inspection of the individual rating values, in which high values indicate greater comfort, reveals that garments were positioned by intensity in much the same manner as that presented in Tables 13 and 14 and 15.

From Table 16 it is also possible to calculate which descriptors were most important in the evaluation and which fabric types were associated with these descriptors. Such a calculation at the 90% confidence level is shown in Table 17. This table shows that fabric surface sensations and garment fit properties were most heavily judged. By viewing the descriptors in this table, it is seen that by far the least comfortable fabric overall is the 100 P (exp.); the 75/25 P/W (exp.) fabric is perhaps the next least desirable.

5. Conclusions on the Performance of Candidate Fabrics in Wearing Studies as Trousers on Men

The Analysis of Variance and Wilcoxon Signed-Rank statistical procedure for analyzing the comfort data gave supporting judgements about the differences in comfort level between year-around candidate garments and currently used

TABLE 16. Summary of Mean Comfort Ratings for All Trousers and Significant Differences by Descriptor From Analysis of Variance.

Comfort Descriptor Used	Mean Comfort Ratings for Trousers					Differences Significant At		
	50/50 P/C	55/45 P/W (trop.)	55/45 P/W (exp.)	75/25 P/W (exp.)	100 P (exp.)	90%	95%	99%
Sticky	3.81	3.97	3.72	3.89	3.52	0.24	0.27	0.33
Nonabsorbent	4.04	4.41	4.48	3.93	3.53	0.27	0.31	0.37
Clammy	4.16	3.79	3.96	4.13	3.79	0.51	0.57	0.69
Damp	3.95	4.04	3.97	3.89	3.39	0.28	0.32	0.39
Clingy	3.84	3.61	3.51	3.82	3.30	0.33	0.38	0.46
Picky	4.56	3.83	3.90	3.39	3.99	0.45	0.51	0.61
Rough	4.71	3.85	3.67	3.70	3.50	0.24	0.27	0.33
Scratchy	4.47	2.79	2.92	3.16	3.62	0.23	0.26	0.32
Loose	3.57	3.96	3.44	3.20	2.76	0.26	0.29	0.35
Heavy	4.06	3.86	3.51	3.49	3.71	0.35	0.39	0.47
Snug	3.58	3.19	3.77	3.72	4.06	0.33	0.37	0.45
Lightweight	2.88	3.25	3.34	3.60	3.06	0.32	0.36	0.44

TABLE 17. Descriptor Importances for Male Wearers.

Descriptor	Lowest Mean Comfort Rating	Difference Significant at 90%	Ratio *	Fabric Type
Scratchy	2.79	0.23	9.6	55/45 P/W (trop.)
Snug (least)	4.06 (highest)	0.33	9.3	100 P
Loose	2.76	0.26	8.6	100 P
Lightweight (least)	3.60 (highest)	0.32	8.1	75/25 P/W
Rough	3.50	0.24	6.3	100 P
Sticky	3.52	0.24	6.2	100 P
Damp	3.39	0.28	5.8	100 P
Nonabsorbent	3.53	0.27	5.4	100 P
Clingy	3.30	0.33	5.2	100 P
Heavy	3.49	0.35	4.3	75/25 P/W
Picky	3.39	0.45	3.6	75/25 P/W
Clammy	3.79	0.51	2.4	100 P & 55/45 P/W (trop.)

* Ratio = $\frac{\text{5-lowest mean}}{\text{diff. sign. at 90\%}}$ for negative descriptors;

for descriptors snug and lightweight (positive descriptors)

Ratio = $\frac{\text{highest mean-1}}{\text{diff. sign. at 90\%}}$

polyester/cotton summer weight and polyester/wool tropical controls. The particular microclimate variations to which the wearers were exposed from hot-dry to hot and cold-humid produced a relatively consistent response in wearers whether one examines mean comfort value or garment to garment preference in individual wearers.

The candidate garments were generally less comfortable than the controls and, in general, gave a progressive loss in comfort level in the order 55/45 P/W (exp.), 75/25 P/W (exp.) and 100 P (exp.),corresponding to increasing polyester fiber content. This behavior was noted for comfort descriptors sticky, nonabsorbent, clammy, damp, clingy, picky and rough and confirms other findings in these laboratories on the contact comfort effects of polyester. Furthermore, the loss in comfort due to polyester may have been reinforced because increased polyester content was achieved in these fabrics by adding texturized polyester filament yarn rather than staple.

B. Female Subjects

1. Techniques for Garment Comparisons

The techniques employed for the trouser comfort comparisons in the laboratory with females were the same as those employed for the males. In the study, 25 females were employed. Trousers were presented in an unidentified manner and every subject evaluated each fabric type at least twice before completing the study. With the trousers the women wore short-sleeved 65/35 polyester/cotton overblouses.

Other articles of clothing were those normally worn for indoor use.

2. Trouser Ranking From Descriptor Intensities

After all subjects had worn each trouser type at least twice, individual comfort ratings (see Table 11) were transferred to computer storage for further analysis.

Table 18 lists the descriptors used by the female panelists to describe the wearing sensations of the five trouser types. The descriptors are grouped according to sensations that most closely and similarly distinguish between the trouser types. The rank placement values given are mean rank values for all descriptors in each group in which a high ranking in each case reflects the lowest intensity as described in Table 11.

For the descriptor group "sticky", "clammy", "damp" and "clingy" the candidate fabrics 55/45 P/W (exp.) and 100 P (exp.) are ranked well behind the remaining fabrics and particularly the currently used fabric 50/50 P/C. The order of ranking for the descriptors "picky", "rough", "scratchy" and "stiff" is quite different although still lead by 50/50 P/C. In the case of the descriptors "snug" and "heavy", associated somewhat with the sensations of fit, the best fabric is the candidate 100 P (exp.), the remaining fabrics being somewhat similar in rank. The reverse is true for descriptors "loose" and "lightweight" for which the same candidate, 100 P (exp.) is ranked last. With those

TABLE 18. Rank Placement of Trousers From Mean Comfort Ratings by Descriptor Groups.

Descriptors in Each Group	Mean Rank Placement for Each Garment*				
	50/50 P/C	55/45 P/W (trop.)	55/45 P/W (exp.)	75/25 P/W (exp.)	100 P (exp.)
Sticky, Clammy, Damp, Clingy	1.8	2.3	4.3	2.0	4.8
Picky, Rough Scratchy, Stiff	1.3	4.0	5.0	3.0	1.6
Snug, Heavy	3.5	3.5	4.5	2.5	1.0
Loose, Lightweight	2.5	3.0	1.5	3.0	4.5

*Based on mean rating values shown in Table 22.

descriptors having a meaning that suggest sensations of fit, there needs to be an independent check on whether the wearers of these garments were using the terms to describe positive or negative sensations of comfort.

For the descriptors "snug" and "heavy", there is no problem in answering this question; these are negatively sensed. The primary loss in comfort for every wearer occurs as the relative humidity increases while the room remains at a high temperature in periods 3 to 7, as shown in Table 10. A quite different response occurs for the descriptors "loose" and "lightweight" as illustrated for one subject in Figure 7. Low ratings (high intensities) for the descriptor "lightweight" are noted for all five garments when the environment was either dry (period 1) or cool (periods 8 and 9). Indeed, the loss in comfort level at the lower temperatures suggests that the wearers were using the terms "loose" and "lightweight" as negative descriptors and therefore the sense of the ranking in Table 18 is correct.

Actually, for the descriptor "loose", 67% of the women indicated a loss in comfort due to chilling, and for the descriptor "lightweight", 65% of the women indicated a similar effect. For these two descriptors it is also possible to calculate how often individuals noted the chilling effect for individual garments and these values are summarized at the top of Table 19. The differences between garments from this observation by individual wearers were quite large. If one

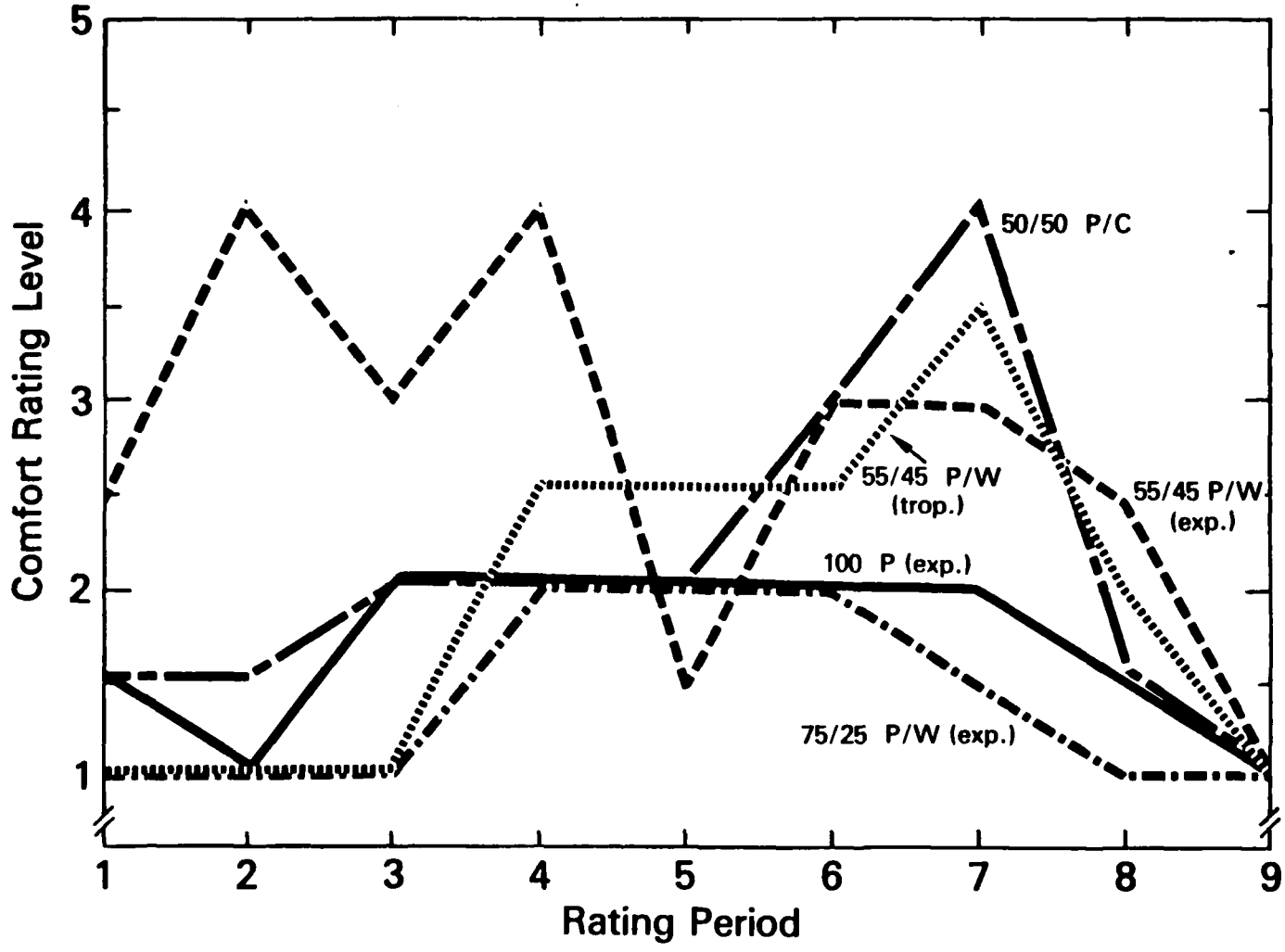

Figure 7. Time progression of comfort ratings for one subject using descriptor "lightweight".

TABLE 19. Loss in Comfort Due to Chilling Using Descriptors "Loose" and "Lightweight" for Individual Trousers.

Trouser Type	Individuals Chilled %	Rank Placement
	Women	
50/50 P/C	16	1
55/45 P/W (trop.)	53	3
55/45 P/W (exp.)	42	2
75/25 P/W (exp.)	68	4
100 P (exp.)	89	5
	Men	
50/50 P/C	30	1
55/45 P/W (trop.)	40	2
55/45 P/W (exp.)	40	2
75/25 P/W (exp.)	50	4
100 P (exp.)	70	5

ranks the values from least chilled (1^{st}) to most chilled (5^{th}), we see there is considerable agreement with ranks from ratings at all time periods given in Table 18, suggesting again that the terms "loose" and "lightweight" were indeed used as negative descriptors. This same procedure, regarding the effect of chilling on comfort ratings, was applied to the earlier data obtained from male subjects with the results given at the bottom of Table 19. Again chilling of individuals was least with the 50/50 P/C control and most with the 100 P experimental fabric. The distinctions, however, were not as sharp as those provided by the studies on women.

3. Trouser Differences Sensed by Individual Wearers

The subjective comfort ratings for individuals were compared for each descriptor using the Wilcoxon Signed-Rank analysis as previously reported for the male evaluations. Table 20 summarizes the results of this comparison for trousers 55/45 P/W (exp.), 75/25 P/W (exp.) and 100 P (exp.) against the 50/50 P/C control fabric, both for individual descriptors and for descriptor groups. The data is presented as the number of indivudal subjects discerning one garment over the other at the 90% confidence level.

For the descriptors "sticky", "clammy", "damp" and "clingy", there was a small but significant preference of the 50/50 P/C garment, over the candidate fabrics 55/45 polyester/wool, and 100% polyester. The reverse was true for the candidate with 75/25 polyester/wool. For the descriptor group

TABLE 20. Summary of the Number of Subjects Indicating Differences Between Trouser Types for Individual Descriptors (50/50 P/C Control).

Descriptor		Based on Wilcoxon Sign-Rank Analysis at the 90% Confidence Level								
		50/50 P/C > 55/45 P/W (exp.)	No Diff.	55/45 P/W (exp.) > 50/50 P/C	50/50 P/C > 75/25 P/W (exp.)	No Diff.	75/25 P/W (exp.) > 50/50 P/C	50/50 P/C > 100 P (exp.)	No Diff.	100 P (exp.) > 50/50 P/C
Sticky		4	6	4	3	6	5	4	5	5
Clammy	(Rating Periods 1-7)	2	2	0	2	1	1	2	2	0
Damp		3	1	1	1	2	2	4	0	1
Clingy		8	5	6	4	7	8	7	5	7
		17	14	11	10	16	16	17	12	13
Picky		9	4	3	15	0	1	8	7	1
Rough	(Rating Periods 1-7)	21	0	1	21	1	0	14	8	0
Scratchy		19	3	3	23	0	2	14	11	0
Stiff		3	1	1	2	3	0	1	4	0
		52	8	8	61	4	3	37	30	1
Snug	(Rating Periods 1-9)	7	4	6	8	4	7	6	4	9
Heavy		6	2	3	7	0	4	2	5	4
		13	6	9	15	4	11	8	9	13
Loose	(Rating Periods 1-9)	3	4	2	4	3	2	7	1	1
Lightweight		2	2	16	3	1	16	4	4	12
		5	6	18	7	4	18	11	5	13

"picky", "rough", "scratchy" and "stiff", there was an overwhelming preference for the 50/50 P/C control, over all the candidate fabrics. This control was again slightly preferred over candidates 55/45 P/W (exp.) and 75/25 P/W (exp.) for descriptors "snug" and "heavy", the reverse being true for candidate 100 P (exp.). For these garment pairs, there was a slight preference for the 50/50 P/C control in terms of the descriptor "loose" and the reverse was true for descriptor, "lightweight". Summing the results for all descriptors, none of the candidate fabrics were consistently equal to or preferred over the polyester/cotton control.

A similar set of data for the polyester/wool control, 55/45 P/W (trop.) in comparison with the candidate fabrics is given in Table 21. None of the candidate fabrics were consistently preferred over the polyester/wool control for the descriptor groups "sticky", "clammy", "damp", and "clingy", and descriptor groups "picky", "rough", "scratchy", and "stiff". As with the 50/50 P/C control of Table 20, these differences were most striking for the second of these descriptor groups. For descriptors "snug" and "heavy", candidate fabrics with 55/45 and 75/25 polyester/wool were judged to be very similar to the 55/45 polyester/wool control whereas the 100% polyester fabric was distinctly preferred over the control. Essentially, a reverse in this behavior was seen for the candidate fabrics for descriptors "loose" and "lightweight". Again, considering

TABLE 21. Summary of the Number of Subjects Indicating Differences Between Trouser Types for Individual Descriptors (55/45 P/W Tropical Control).

Descriptor		Based on Wilcoxon Sign-Rank Analysis at the 90% Confidence Level								
		55/45 P/W (trop.) > 55/45 P/W (exp.)	No Diff.	55/45 P/W (exp.) > 55/45 P/W (trop.)	55/45 P/W (trop.) > 75/25 P/W (exp.)	No Diff.	75/25 P/W (exp.) > 55/45 P/W (trop.)	55/45 P/W (trop.) > 100 P (exp.)	No Diff.	100 P (exp.) > 55/45 P/W (trop.)
Sticky		6	4	4	6	4	4	7	3	4
Clammy	(Rating Periods 1-7)	3	0	1	2	1	1	2	2	0
Damp		1	3	1	2	0	2	1	3	1
Clingy		7	7	5	6	7	6	8	7	4
		17	14	11	16	12	13	18	15	9
Picky		8	5	3	10	3	3	5	5	6
Rough	(Rating Periods 1-7)	15	6	1	12	6	4	9	3	10
Scratchy		14	9	2	14	7	4	15	2	8
Stiff		3	1	1	1	3	1	1	2	2
		40	21	7	37	19	12	30	12	26
Snug	(Rating Periods 1-9)	5	5	9	5	3	11	0	5	14
Heavy		6	4	1	5	2	4	3	1	7
		11	9	10	10	5	15	3	6	21
Loose	(Rating Periods 1-9)	1	5	3	2	3	4	6	3	0
Lightweight		4	5	11	4	6	10	10	3	7
		5	10	14	6	9	14	16	6	7

all descriptors, no candidate fabric was consistently equal to or better in performance than the polyester/wool control.

4. Trouser Comparisons From Analysis of Variance

Further discrimination between the comfort of the various trouser types was achieved by an analysis of variance of all the data by individual descriptors. These comparisons are shown in Table 22, which gives the mean comfort rating for each trouser type and the differences significant at the 90, 95, and 99% confidence levels for individual rating values, in which high values indicate greater comfort, reveals that garments were positioned by this analysis in much the same manner as they had been in Tables 18, 20, and 21.

From Table 22 it was possible to calculate which descriptors were most important in the evaluation and which fabric types were associated with these descriptors. Such a calculation at the 90% confidence level is shown in Table 23. Table 23 shows that fabric sensations and trouser fit properties were most heavily sensed, as indeed they were also with the male panel. Inspection of all the descriptors in the table shows that the least comfortable fabric overall is the 55/45 P/W (exp.) candidate fabric; the 100 P (exp.) fabric is perhaps the next least desirable.

TABLE 22. Summary of Mean Comfort Ratings and Significant Differences.

Comfort Descriptor	Mean Comfort Ratings for Garment					Differences Significant At		
	50/50 P/C	55/45 P/W (trop.)	55/45 P/W (exp.)	75/25 P/W (exp.)	100 P (exp.)	90%	95%	99%
Sticky	4.12	4.36	4.10	4.22	4.09	0.27	0.31	0.37
Clammy	4.73	4.59	4.18	4.50	4.32	0.38	0.43	0.52
Damp	4.44	4.29	4.27	4.60	4.14	0.42	0.48	0.58
Clingy	4.36	4.24	4.22	4.35	3.99	0.23	0.26	0.31
Picky	4.80	3.83	3.73	3.88	4.62	0.23	0.26	0.32
Rough	4.84	3.39	3.16	3.75	4.80	0.21	0.23	0.28
Scratchy	4.75	3.36	2.97	3.54	4.79	0.20	0.23	0.28
Stiff	4.81	4.81	4.13	4.49	4.81	0.31	0.35	0.42
Snug	3.23	3.23	3.83	4.11	4.76	0.21	0.24	0.29
Heavy	4.33	4.33	3.94	4.28	4.80	0.21	0.24	0.29
Loose	4.51	4.51	4.49	4.46	3.76	0.29	0.33	0.40
Lightweight	3.18	3.81	4.44	4.23	3.35	0.22	0.24	0.30

TABLE 23. Descriptor Importances for Female Wearers.

Descriptor	Lowest Mean Comfort Rating	Difference Significant at 90%	Ratio*	Fabric Type
Scratchy	2.97	0.20	10.2	55/45 P/W (exp.)
Rough	3.16	0.21	8.8	55/45 P/W (exp.)
Snug	3.23	0.21	8.4	50/50 P/C & 55/45 P/W (trop.)
Lightweight	3.18	0.22	8.3	50/50 P/C
Picky	3.73	0.23	5.5	55/45 P/W (exp.)
Heavy	3.94	0.21	5.0	55/45 P/W (exp.)
Clingy	3.99	0.23	4.4	100 P
Loose	3.76	0.29	4.3	100 P
Sticky	4.09	0.27	3.4	100 P
Stiff	4.13	0.31	2.8	55/45 P/W (exp.)
Clammy	4.18	0.38	2.2	55/45 P/W (exp.)
Damp	4.14	0.42	2.0	100 P

*Ratio = $\frac{\text{5-lowest mean}}{\text{diff. sign. at 90\%}}$ for negative descriptors.

5. Conclusions on the Performance of Candidate Fabric in Wearing Studies as Trousers on Women

From the vantage point of each statistical approach to garment performance in these comfort wearing studies, several conclusions can be drawn:

(1) Ranking, signed-rank, and analysis of variance procedures all combine to show that the women wearing these garments found no candidate trouser fabric completely acceptable in all aspects of wearing performance.

(2) None of the candidate fabrics consistently outperformed the polyester/cotton control and only one candidate fabric, the 75/25 polyester wool, came close to matching the performance of the polyester/wool control.

(3) Both of the candidate fabrics containing wool were found to be most deficient in terms of the surface and structure descriptors of "picky", "rough", "scratchy" and "stiff" although, at the same time, these trousers were favorably described in terms of the descriptors "loose" and "lightweight".

(4) In contrast to this behavior, the all polyester candidate was found to be acceptable in terms of the descriptors "picky", "rough", "scratchy" and "stiff", but much less acceptable in terms of the descriptors "sticky", "clammy", "damp", "clingy", "loose" and "lightweight".

(5) The 25 women used in this study had no difficulty in detecting these differences even though the garments were presented randomly without identifying markings.

(6) Moderate exercise by the women wearing the clothing had no significant influence on the ranking of the performance of the trousers.

(7) A significant number of the women were able to detect differences in garment performances under both hot-humid and cool-humid conditions, and the cool-humid responses were reflected in the comfort intensity ratings of the descriptors "loose" and "lightweight".

General agreement between the female comfort results and the corresponding wear studies on men was achieved. Both groups sensed the control fabrics to be more comfortable than the three experimental fabrics.

VII. COMPARISON OF LABORATORY COMFORT STUDIES WITH FABRIC PHYSICAL PROPERTIES

As summarized in Tables 1, 2, and 3 for unlaundered, laundered, and drycleaned fabric samples the observed fabric properties of weight, air permeability, thickness, stiffness and moisture vapor transmission revealed that the trouser fabrics were quite comparable to the experimental and control fabrics. This information provides a firm base on which to judge the meaning of the lab comfort studies in which garments were clearly distinguished by both men and women, based on their contact comfort attributes under mild to heavy sweating conditions. It is possible, for example, that the fabrics were indeed different in contact with the skin, particularly in the laundered state under which the lab comfort studies were made. Trial surface photos of the fabrics made in the NARADCOM study were not sufficiently detailed to reveal these differences, but surface fiber counting from the combination of photomicrographs, compression studies, and surface thermal behavior could be used to sort out the magnitude of these differences.[10]

The fabric properties of wettability and wicking in Tables 1, 2, and 3, which did reveal differences between the trouser fabrics, were not useful because they sensed differences in behavior at water content two orders of magnitude above that experienced in garment wear.[2,3] Methods do exist that permit the distinction between fabric water properties at the water levels of wearing experience. Included are a cobaltous

chloride detector method and a surface adsorption method for pore volume distribution.[8] The measurement of moisture regain as carried out by NARADCOM is of assistance in assessing the effects of moisture redistribution in worn clothing and, of course, is sensitive to fiber content differences as shown in Tables 1, 2, and 3.

The insulation values (Clo) and permeability index values (i_m) in Tables 1, 2, and 3 also reveal that, in terms of total heat and moisture transfer through the fabrics, the trousers were very comparable to one another. The drying experiment data given in Tables 4, 5, and 6, along with Figures 1, 2, and 3, again give information on the constancy and similarity of rate of water loss from all fabrics as indicated by the initial slope of the drying rate curves. Equilibrium drying times, as already discussed, were probably influenced mainly by the technique used for drying rate measurements.[11,12]

VIII. COMPARISON OF FIELD AND LABORATORY COMFORT STUDIES

It is not possible to make a direct comparison of the field data on trouser acceptance (Table 9) with the specific conclusions from laboratory comfort studies (Section VI) because of differences in the methods of gathering information and the lack of controlled procedures in the field evaluation. Wearing studies for comfort comparisons outdoors[2,3] and indoors[1,7] carried out by HRL have shown that solid information on garment differences require a series of procedures aimed at maximizing the ability of wearers to detect the true contact sensations and minimizing the effects of opinions on garment evaluation.[1] Key among these procedures are:

1. presentation of unidentified garments;
2. random presentation of garments for wear;
3. presentation of all garments being compared;
4. replicate control of environment for each wearing;
5. replicate control of wearers activity for each wearing;
6. open-ended questionnaires on wearing behavior;
7. rating of questionnaires at the time of wear evaluation;
8. repetitive controlled wearing for statistical analysis.

None of these considerations were employed in the field wear trials, so it is difficult to assess the significance of the results given in Table 9.

Perhaps the weakest procedures involved presenting the wearers with a single identified "experimental" garment in the

absence of a specific control. Procedures are available for establishing a controlled protocol for field wearing evaluation of clothing.[7]

IX. CONCLUSIONS AND RECOMMENDATIONS

The two laboratory comfort evaluations of candidate year-round uniform fabrics have shown that men and women distinguish between trousers made from these fabrics by means of different wearing sensations over a range of microclimate and exercise conditions. Differences in the fabrics were noted under warm-dry (90°F-20% R.H.) warm-humid (90°F-70% R.H.) and cool-humid (60°F-75% R.H.) wearing conditions if there was sufficient wearer activity to induce mild to heavy sweating. Individual garment types were found to have the highest or lowest comfort ratings in terms of specific descriptors, e.g., 100 P (exp.) scratchy - highest, 55/45 P/W (exp.) rough - lowest. In addition, the women found the 75/25 P/W (exp.) fabric quite acceptable for several descriptors but never the 100 P (exp.) fabric. Considering all the results, the order of preferences of fabrics for both men and women wearers was:

1. 50/50 P/C control
2. 55/45 P/W tropical
3. 55/45 P/W experimental
4. 75/25 P/W experimental
5. 100 P experimental

These differences between garments for the descriptors sticky, nonabsorbent, damp, clingy, rough, scratchy, loose and lightweight were significant at the 90% confidence level using nonparametric and parametric statistical procedures.

Although these evaluations do not answer the question of wearing acceptance of different garments in extremes of hot or cold, they suggest that the 100% polyester (and in some cases the 75/25 blends) would become intolerable to wear sooner than the current fabrics or the 55/45 P/W (exp.) fabric. It should be possible to check these ideas by field trials on a limited number of wearers using well-balanced comfort testing procedures.[7] Expanded lab evaluations of the fibers for determining fabric contact with the skin[1] and water mobility at low water contents[8] should aid in understanding why differences have been noted, and provide a base for laboratory screening for comfort aesthetics in the future.

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APPENDIX A.

Test Procedures Used for Testing of Physical Properties of Candidate Year-Round and Army Standard Fabrics

APPENDIX A.

Test Procedures Used for Testing of Physical Properties of Candidate Year-Round and Army Standard Fabrics

Physical Test	Test Method
1. Weight	5041 of FED-STD-191 1/
2. Yarns per Inch	5050 of FED-STD-191
3. Air Permeability	5450 of FED-STD-191
4. Thickness	5030 of FED-STD-191
5. Stiffness	5206 of FED-STD-191
6. Moisture Vapor Transmission	7032B of FED-STD-406 2/
7. Wettability	AATCC Method 39-1974
8. Moisture Regain	ASTMD 2654-76-Procedure 1
9. Wicking	Apparatus built here at NARADCOM (See attached for details.)
10. Drying Rate	Article from Text. Rsch. Journal January 1951 - "The Rate of Drying Fabrics" by Fourt, Sookne, Frishman & Harris. (See attached for details.)

1/ FED-STD-191 - Textile Test Methods

2/ FED-STD-406 - Plastics: Methods of Testing

Wicking Test:

Apparatus: Consist of (1) Bath - 10 inches long by 1-1/8 inches wide and 6-1/8 inches deep (made of Plexiglass)

(2) Specimen Holder Bar - This bar is held firmly on top center of bath. The bar is equipped with 6 specimen holders (spring loaded metal clips 1-1/4 inches wide) that are connected electrically to the power supply.

(3) Electrical Power Supply - The power supply is connected to a buzzer system; has a wire which is placed in the bath during test, and when sample being tested wicks up and distilled water of bath comes in contact with metal clip on holder bar, the electrical circuit is closed and buzzer goes off.

(4) Toggle Switch Board - There is a set of 6 toggle switches in a plexiglass base, (all have "ON-OFF" positions) these switches give one the ability to shut "OFF" buzzer to any one specimen after water has wicked up.

Procedure: The bath was filled with approximately 4-7/8 inches of distilled water (colorant can or can not be added to the water). No colorant was added in these tests. When the specimen holder bar was placed in position, the bottom of clip was approximately 1 inch above water level.

Specimen sizes were 1 inch wide by 6 inches long, with the long direction parallel to either the warp or filling. 6 warp specimens and 6 filling specimens were tested on each of the 5 materials.

3 specimens were tested at one time. The specimens were placed in the metal clamps on the holder bar. The bar was then placed in position over the bath with the speciment submersed in the water. At this point a stopwatch was started, and then stopped when the water had wicked up 1 inch, and set off the buzzer.

Report: The time it took for each specimen to wick up 1 inch was recorded (to the nearest whole second).

Wicking time was computed as the arithmetic average of the results obtained from the 6 specimens tested in each of the warp and filling directions.

Drying Rate:

Specimen size for this test is 5 inches by 5 inches. 2 specimens of each material were tested. All specimens were conditioned at least 24 hours in an atmosphere of 95°F and 70% R.H., and then weighed. (Conditioned dry weight)

All specimens were then wet out overnight in distilled water. At test time, 2 specimens were removed from the water, hung on a line with

paper clips, and left to drain for 5 minutes and then weighed. This weight was considered to be the total weight in grams of the specimen plus water. After these weighings the specimens were re-hung on the line, and then re-weighed after 15 minute intervals till they reached or approximated their conditioned dry weight.

Both specimens are averaged, and the results are reported as "Grams of water lost at 15 minute intervals".

APPENDIX B.

Questionnaire Year-Round Wear Test of New
Army Green Year-Round Fabric Cold Weather Phase

APPENDIX B .

January 1979

Questionnaire Year-Round

Wear Test of New Army Green Year-Round Fabric

Cold Weather Phase

1. For keypunch use.

2-7. What is your Test Subject Number?
(Write the complete number on the answer sheet in blanks 2 thru 7.)

8-9. What is the Model Number of your Test uniform?
(Place your number on the answer sheet in the blanks 8 and 9)

M_1	S_1	P_1
M_2	S_2	P_2
M_3	S_3	P_3

10. What was your rank when you were issued the Test uniform?

1. E1 - E5
2. E6 - E9
3. W1 - 03
4. 04 - 010

11. Does your Test uniform fit properly?

1. Yes
2. No

(Please make specific comments on the written portion of the answer sheet.)

12. How many days did you wear your summer green uniform during this cold weather phase of the wear test?

1. Less than 30 days.
2. 30 to 60 days.
3. More than 60 days.

13. How many days did you wear your Test uniform during this phase of the wear test?

1. Less than 30 days.
2. 30 to 60 days.
3. More than 60 days.

19 January 1979

14. How did the warmth of the Test uniform compare to the warmth of the summer green uniform during your coldest weather?

    1. Much warmer than the summer green uniform.
    2. Somewhat warmer than the summer green uniform.
    3. The same as the summer green uniform.
    4. Somewhat cooler than the summer green uniform.
    5. Much cooler than the summer green uniform.

15. How did the combined warmth of the Test uniform and the new black raincoat with liner compare with the summer green uniform and standard overcoat during cold weather?

    1. Much warmer than the summer green uniform and standard overcoat.
    2. Somewhat warmer than the summer green uniform and standard overcoat.
    3. The same as the summer green uniform and standard overcoat.
    4. Somewhat cooler than the summer green uniform and standard overcoat.
    5. Much cooler than the summer green uniform and standard overcoat.
    6. Not able to make comparison.

16. How often did you have to clean the trousers, skirt, or slacks of your summer green uniform during this phase of the test (one week equals five days wear) (Check your wear record)?

    1. Once or more per week.
    2. Once every two weeks.
    3. Once every three weeks.
    4. Once every four or more weeks.

17. How often did you have to clean the coat of your summer green uniform during this phase of the test (one week equals five days wear) (check your wear record)?

    1. Once or more per week.
    2. Once every two weeks.
    3. Once every three weeks.
    4. Once every four or more weeks.

19 January 1979

18. How often did you have to clean the trousers, skirt, or slacks of your Test uniform during this phase of the test? (One week equals five days wear) (Check your wear record.)

1. Once or more per week.
2. Once every two weeks.
3. Once every three weeks.
4. Once every four or more weeks.

19. How often did you have to clean the coat of your Test uniform during this phase of the test (one week equals five days wear) (check your wear record)?

1. Once or more per week.
2. Once every two weeks.
3. Once every three weeks.
4. Once every four or more weeks.

20. Do you consider the Test uniform to be satisfactory for wear during the coldest weather?

1. Yes 2. No

(Please make any comments on the written portion of the answer sheet.)

21. For the females who wore the pantsuit and for all males, did you ever wear thermal underwear with your test uniform?

1. Yes 2. No 3. Not applicable.

22. If your answer to Question 21 is "yes", please indicate which thermal underwear you wore.

1. Top only. 2. Bottom only. 3. Both top & bottom.

23. Which one of the following temperature ranges represents the coldest outside temperatures that you had while you were wearing the Test uniform during the Cold Weather Phase?

1. Above 80 Degrees F.
2. 68 to 80 Degrees F.
3. 50 to 67 Degrees F.
4. 32 to 49 Degrees F.
5. 14 to 31 Degrees F.
6. Below 13 Degrees F.

24. How do the static properties (cling or spark generation) of the Test uniform compare to that of the summer green uniform.

    1. The Test uniform was much less static than the summer green uniform.

    2. The Test uniform has somewhat less static than the summer green uniform.

    3. The Test uniform has the same static as the summer green uniform.

    4. The Test uniform has somewhat more static than the summer green uniform.

    5. The Test uniform has much more static than the summer green uniform.

25. In the three years prior to the start of this wear test or for the time you have been in the Army if less than 3 years, what percent of your work days have you been required to wear the summer green uniform.

    1. Less than 10%
    2. 10 to 30%
    3. 31 to 60%
    4. 61 to 90%
    5. More than 90%

26. Do you feel the Test uniform should replace the summer green uniform for wear during cold weather months?

    1. Yes
    2. No

27. Do you consider these uniform fabrics to be suitable for wear during cold weather months?

    1. Both the Test uniform fabric and the summer green uniform fabric are suitable.

    2. Only the summer green uniform fabric is suitable.

    3. Only the Test uniform fabric is suitable.

    4. Neither the Test uniform fabric nor the summer green uniform fabric are suitable.

19 January 1979

28. Your Test uniform may replace both the present winter green uniform and the summer green uniform. Which one of the following uniforms do you prefer for wear during cold weather months?

    1. Test uniform.

    2. Winter green uniform.

    3. Summer green uniform.

    4. Current summer issue uniform (Khakis for males, cords or new mint greens for females).

29. Did you develop any allergies or skin reactions as a direct result of wearing the Test uniform?

    1. Yes 2. No

    (Please make any specific comments on the written portion of the answer sheet.)

30. Did you develop any allergies or skin reactions as a direct result of wearing the summer green uniform?

    1. Yes 2. No

    (Please make any specific comments on the written portion of the answer sheet.)

31. If you have noted any problems with your test uniform during this phase, please explain in specific detail on the written portion of the answer sheet.

APPENDIX C.

Questionnaire Year-Round Wear Test of New Army Green
Year-Round Fabric Hot Weather Phase

APPENDIX C.

19 January 1979

Questionnaire Year-Round

Wear Test of New Army Green Year-Round Fabric

Hot Weather Phase

1. For keypunch use.

2-7. What is your Test Subject Number (write the complete number on the answer sheet in blanks 2 thru 7)?

8-9. What is the model number of your Test uniform?
(Place your number on the answer sheet in blanks 8 and 9).

M_1	S_1	P_1
M_2	S_2	P_2
M_3	S_3	P_3

10. What was your rank when you were issued the Test uniform?

1. E1 - E5 3. W1 - 03

2. E6 - E9 4. 04 - 010

11. Does your Test uniform fit properly?

1. Yes 2. No

(Please make specific comments on the written portion answer sheet.)

12. How many days did you wear your Summer Green uniform during this hot weather phase of the wear test?

1. Less than 30 days. 3. More than 60 days.

2. 30 to 60 days.

13. How many days did you wear your Test uniform during this phase of the wear test?

1. Less than 30 days. 3. More than 60 days.

2. 30 to 60 days.

19 January 1979

NOTE: COMPARE ALL CONFORT FACTORS IN OTHER THAN AIR CONDITIONED ENVIRONMENT.

14. How did the coolness of the Test uniform compare to the coolness of the Summer Green uniform during your hottest weather?

    1. Much cooler than the Summer Green uniform.
    2. Somewhat cooler than the Summer Green uniform.
    3. The same as the Summer Green uniform.
    4. Somewhat warmer than the Summer Green uniform.
    5. Much warmer than the Summer Green uniform.

15. How do you rate the coolness of your Test uniform (including green shirt) in comparison to your current summer issue uniform (khakis for males, cords or new mint greens for females)?

    1. Much cooler than the current summer issue uniform.
    2. Somewhat cooler than the current summer issue uniform.
    3. The same as the current summer issue uniform.
    4. Somewhat warmer than the current summer issue uniform.
    5. Much warmer than the current summer issue uniform.

16. How does the coolness of the Test uniform and the Army raincoat compare with the Summer Green uniform and Army raincoat during hot, rainy weather?

    1. Much cooler than the Summer Green uniform and Army raincoat.
    2. Somewhat cooler than the Summer Green uniform and Army raincoat.
    3. The same as the Summer Green uniform and Army raincoat.
    4. Somewhat warmer than the Summer Green uniform and Army raincoat.
    5. Much warmer than the Summer Green uniform and Army raincoat.

19 January 1979

17. Do you feel the Test uniform (trousers, slacks, or skirts plus green shirts) should replace the current summer uniform (khakis for males or cords or new mint greens for females) for wear during hot weather months?

    1. Yes 2. No

    (Be specific with written comments on the written portion of the answer sheet).

18. How often did you have to clean the trousers, skirt, or slacks of your Summer Green uniform during this phase of the wear test (one week equals 5 days wear)?

    1. Once or more per week.

    2. Once every two weeks.

    3. Once every three weeks.

    4. Once every four or more weeks.

19. How often did you have to clean the coat of your Summer Green uniform during this phase of the wear test (one week equals 5 days wear)?

    1. Once or more per week.

    2. Once every two weeks.

    3. Once every three weeks.

    4. Once every four or more weeks.

20. How often did you have to clean the trousers, skirt, or slacks of your Test uniform during this phase of the test?

    1. Once or more per week.

    2. Once every two weeks.

    3. Once every three weeks.

    4. Once every four or more weeks.

19 January 1979

21. How often did you have to clean the coat of your Test uniform during this phase of the test?

    1. Once or more per week.
    2. Once every two weeks.
    3. Once every three weeks.
    4. Once every four or more weeks.

22. Which one of the following temperature ranges represents the warmest outside temperatures that you had while you were wearing the Test uniform during the warm weather phase?

    1. Above 95 Degrees F.
    2. 80 to 95 Degrees F.
    3. 65 to 80 Degrees F.
    4. 50 to 65 Degrees F.
    5. 40 to 50 Degrees F.
    6. Below 40 Degrees F.

23. Do you consider these uniform fabrics to be suitable for wear during hot weather months?

    1. Both the Test uniform fabric and Summer Green uniform fabric are suitable.
    2. Only Summer Green uniform fabric is suitable.
    3. Only the Test uniform fabric is suitable.
    4. Neither the Summer Green uniform fabric nor the Test uniform fabric are suitable.

24. Do you consider the Test uniform to be satisfactory for wear during the hottest weather?

    1. Yes 2. No

25. Your test uniform may replace both the present winter green uniform and the present summer green uniform. Which one of the following uniforms do you prefer for wear during hot weather months?

    1. Test uniform.
    2. Summer Green uniform
    3. Current summer issue uniform (khakis for males, cords or new mint green for females)
    4. Winter green uniform

19 January 1979

26. Did you develop any allergies or skin reactions as a direct result of wearing the Test uniform?

1. Yes 2. No

(Please make any specific comments on the written portion of the answer sheet.)

27. Did you develop any allergies or skin reactions as a direct result of wearing the Summer Green uniform?

1. Yes 2. No

(Please make any specific comments on the written portion of the answer sheet.)

28. If you have noted any problems with your Test uniform during this phase please explain in specific detail on the written portion of the answer sheet.

APPENDIX D.

Questionnaire Year-Round Wear Test of New Army Green
Year-Round Fabric Test Termination Phase

APPENDIX D.

Questionnaire Year-Round

19 January 1979

Wear Test of New Army Green Year-Round Fabric

Test Termination Phase

1. For keypunch use.

2-7. What is your Test Subject Number?
(Write the complete number on the answer sheet in blanks 2-7.)

8-9. What is the model number of your Test uniform?
(Place your number on the answer sheet in blanks 8 and 9.)

M_1	S_1	P_1
M_2	S_2	P_2
M_3	S_3	P_3

10. What was your rank when you were issued the Test uniform?

1. E1 - E5
2. E6 - E9
3. W1 - 03
4. 04 - 010

11. Did your Test uniform fit properly?

1. Yes
2. No

(Please make specific comments on the written portion of the answer sheet.)

12. During the entire wear test how many days did you wear the summer green uniform? (Use your wear record.)

1. Less than 30 days.
2. 30 to 90 days.
3. 91 to 150 days.
4. More than 150 days.

13. During the entire wear test how many days did you wear your Test uniform?

1. Less than 30 days.
2. 30 to 90 days.
3. 91 to 150 days.
4. More than 150 days.

14. After pressing, which uniform retained the sharpest creases for the longest time? ("S" models have no creases.)

1. Summer Green
2. Test
3. Not applicable

19 January 1979

15. How does the total "Year-Round" comfort of the Test uniform compare to the summer green uniform?

    1. Much more comfortable than the summer green uniform.
    2. Somewhat more comfortable than the summer green uniform.
    3. The same as the summer green uniform.
    4. Somewhat less comfortable than the summer green uniform.
    5. Much less comfortable than the summer green uniform.

16. Rate the "hand" or feel of the Test uniform fabric in comparison to the summer green uniform fabric.

    1. Much better than the summer green uniform.
    2. Somewhat better than the summer green uniform.
    3. The same as the summer green uniform.
    4. Somewhat worse than the summer green uniform.
    5. Much worse than the summer green uniform.

17. Rate the ease of removing perspiration stains from the Test uniform in comparison to the summer green uniform?

    1. Much easier than the summer green uniform.
    2. Somewhat easier than the summer green uniform.
    3. The same as the summer green uniform.
    4. Somewhat harder than the summer green uniform.
    5. Much harder than the summer green uniform.

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18. Rate the ease of removing other stains or spots on the Test uniform in comparison to the summer green uniform. (Please make specific comments concerning any problem stains on the written answer sheet.)

    1. Much easier than the summer green uniform.

    2. Somewhat easier than the summer green uniform.

    3. The same as the summer green uniform.

    4. Somewhat harder than the summer green uniform.

    5. Much harder than the summer green uniform.

19. How does the dry wrinkle resistance of the Test uniform compare to the summer green uniform? (Dry wrinkles are wrinkles or creases that you get in the fabric as you wear the uniform. Consider the appearance at the end of a day's wear, how well the wrinkles hung out overnight, and how many days could the uniform be worn before the wrinkles had to be pressed out.)

    1. Much better than the summer green uniform.

    2. Somewhat better than the summer green uniform.

    3. The same as the summer green uniform.

    4. Somewhat worse than the summer green uniform.

    5. Much worse than the summer green uniform.

20. How well did the Test uniform resist pilling (the formation of small balls of fiber on the surface in high wear areas) in comparison to the summer green uniform?

    1. Much better than the summer green uniform.

    2. Somewhat better than the summer green uniform.

    3. The same as the summer green uniform.

    4. Somewhat worse than the summer green uniform.

    5. Much worse than the summer green uniform.

19 January 1979

21. How well did the fabric of the Test uniform resist snagging (pulled yarns that protrude from the surface of the fabric) in comparison to the summer green uniform?

    1. Much better than the summer green uniform.
    2. Somewhat better than the summer green uniform.
    3. The same as the summer green uniform.
    4. Somewhat worse than the summer green uniform.
    5. Much worse than the summer green uniform.

22. How do you rate the ease of attaching insignia to the Test uniform in comparison to the summer green uniform (including unsightly pulls or runs on the fabric)?

    1. Much easier than the summer green uniform.
    2. Somewhat easier than the summer green uniform.
    3. The same as the summer green uniform.
    4. Somewhat harder than the summer green uniform.
    5. Much harder than the summer green uniform.

23. How well did the Test uniform resist frosting (change in color at points of extreme wear due to worn out fibers in the yarn) in comparison to the summer green uniform?

    1. Much better than the summer green uniform.
    2. Somewhat better than the summer green uniform.
    3. The same as the summer green uniform.
    4. Somewhat worse than the summer green uniform.
    5. Much worse than the summer green uniform.

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24. Rate the Test uniform in comparison to the summer green uniform in minor construction defects (buttons lost, split seams, collar appearance).

    1. Much better than the summer green uniform.
    2. Somewhat better than the summer green uniform.
    3. The same as the summer green uniform.
    4. Somewhat worse than the summer green uniform.
    5. Much worse than the summer green uniform.

25. How well do you like the overall appearance of the Test uniform in comparison to the summer green uniform?

    1. Much better than the summer green uniform.
    2. Somewhat better than the summer green uniform.
    3. The same as the summer green uniform.
    4. Somewhat worse than the summer green uniform.
    5. Much worse than the summer green uniform.

26. After wearing and cleaning your Test uniform did it shrink or stretch enough to require alteration(s)?

    1. Yes 2. No

    (Please make specific comments on the written answer sheet.)

27. Do you feel that your Test uniform should replace the summer green uniform for Year-Round wear?

    1. Yes 2. No

28. Do you consider the Test uniform to be satisfactory for year-round wear?

    1. Yes 2. No

29. Do you consider these uniform fabrics to be suitable for year-round wear?

    1. Both the test uniform fabric and the summer green uniform fabric are suitable.

    2. Only the summer green uniform fabric is suitable.

    3. Only the test uniform fabric is suitable.

    4. Neither the summer green uniform fabric nor the test uniform fabric are suitable.

30. Your test uniform may replace both the winter green uniform and the summer green uniform. Which one of the following uniforms do you prefer for year-round wear?

    1. Test uniform

    2. Winter Green uniform

    3. Summer Green uniform

    4. Current summer issue uniform (Khakis for males, cords or new mint greens for females).

31. Did you develop any allergies or skin reactions as a direct result of wearing the test uniform?

    1. Yes 2. No

    (Please make any specific comments on the written portion of the answer sheet.)

32. Did you develop any allergies or skin reactions as a direct result of wearing the Summer Green uniform?

    1. Yes 2. No

    (Please make any specific comments on the written portion of the answer sheet.)

33. In your opinion, is the fabric in your Test uniform durable?

    1. Yes 2. No

34. Do you like the appearance of the fabric in your test uniform?

    1. Yes 2. No

19 January 1979

35. Did your Test uniform get worn thin in one or more spots?

1. Yes 2. No

36. Do you think that you could wear your Test uniform for six more months and still find it acceptable in appearance.

1. Yes 2. No

37. If you have noted any other problems with your Test uniform please explain in specific detail on the written portion of the answer sheet.

APPENDIX E.

Supplemental Questionnaire on Comfort of New Army Green Year-Round Fabric

APPENDIX E.

Supplemental Questionnaire on Comfort

Of New Army Green Year-Round Fabric

To Accompany Test Termination Phase Questionnaire

Answer Sheet

INSTRUCTIONS: Write your 6 digit Test Subject Number in blanks 2 through 7, and your Uniform Model Number (check the labels) in blanks 8 and 9. Circle only one response for each multiple choice question.

1.	4	10.	1	2	3	4	5
2.	___	11.	1	2	3	4	5
3.	___	12.	1	2	3	4	5
4.	___	13.	1	2	3	4	5
5.	___	14.	1	2	3	4	5
6.	___						
7.	___						
8.	___						
9.	___						

15. **Please add any written comments below and on the back of this sheet.**

11. How did the heaviness of your Test uniform compare to the Summer Green uniform?

    1. Much less heavy than the Summer Green uniform.
    2. Somewhat less heavy than the Summer Green uniform.
    3. Same as the Summer Green uniform.
    4. Somewhat more heavy than the Summer Green uniform.
    5. Much more heavy than the Summer Green uniform.

12. During your coldest weather, how did any clammy (cold, damp) feeling of your Test uniform compare to your Summer Green uniform?

    1. Much less clammy than the Summer Green uniform.
    2. Somewhat less clammy than the Summer Green uniform.
    3. Same as the Summer Green uniform.
    4. Somewhat more clammy than the Summer Green uniform.
    5. Much more clammy than the Summer Green uniform.

13. Recall your hottest weather and rate the dampness and stickiness of your Test uniform in comparison to your Summer Green uniform in hot weather.

    1. Much less damp or sticky than the Summer Green uniform.
    2. Somewhat less damp or sticky than the Summer Green uniform.
    3. Same as the Summer Green uniform.
    4. Somewhat more damp or sticky than the Summer Green uniform.
    5. Much more damp or sticky than the Summer Green uniform.

Supplemental Questionnaire on Comfort

Of New Army Green Year-Round Fabric

To Accompany Test Termination Phase Questionnaire

TO THE TEST SUBJECT:

These additional questions about comfort of your test uniform are being asked to relate comfort to laboratory studies of the fabric. Your responses can have considerable impact on the future development of various uniform fabrics. Please feel free to add any additional comments in the space provided on your answer sheet. Thank you.

1. For keypunch use.

2-7. What is your Test Subject Number?
(Write the six digit number in blanks 2 through 7.)

8-9. What is the Model Number of your Test Uniform?
(Place your number on the answer sheet in blanks 8 and 9.)

M_1	S_1	P_1
M_2	S_2	P_2
M_3	S_3	P_3

10. How did the scratchiness of your Test uniform compare to the Summer Green uniform?

1. Much less scratchy than the Summer Green uniform.
2. Somewhat less scratchy than the Summer Green uniform.
3. Same as the Summer Green uniform.
4. Somewhat more scratchy than the Summer Green uniform.
5. Much more scratchy than the Summer Green uniform.

14. During your hottest weather, how did the dampness and stickiness of your Test uniform compare to your current summer issue uniform (khakis for males, cords or new mint green for females)?

1. Much less damp or sticky than the summer issue uniform.
2. Somewhat less damp or sticky than the summer issue uniform.
3. Same as the summer issue uniform.
4. Somewhat more damp or sticky than the summer issue uniform.
5. Much more damp or sticky than the summer issue uniform.