THE PERFORMANCE OF MACHINE WASHABLE AND DURABLE PRESS FABRICS OF WOOL AND WOOL BLENDS

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We hereby recommend that the thesis prepared under our supervision by Doris Frochling Greenhaw entitled "The Performance of Machine Washable and Durable Press Fabrics of Wool and Wool Blends"

be accepted as fulfilling this part of the requirements for the Degree of Master of Science.

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I N T R O D U C T I O N

The findings in this thesis are the result of an analysis of the laundering performance of fourteen fabrics composed of all-wool and blends of wool representative of machine washable and durable press finishes. Nine of the fabrics were finished for machine washability; whereas the remaining five had a durable press finish.

Before the advent of man-made fibers, wool reigned with a virtual monopoly, but with the improvement of synthetic fibers and the development of finishes for other natural and man-made fibers wool has been placed in a precarious position. Heading the agenda of developments which have been made necessary by the competitive position of wool with other fibers are machine washability with dimensional stability, actual wash-and-wear qualities, and crease retention.

Although "easy care" wool development at this point is in its infancy, a variety of processes are being tested. They include changes in the surface structure of the wool fiber by oxidation; resin additive finishes which encase each fiber; and interfacial polymerization consisting of

masking the scale structure. Wool promoters and researchers believe that these processes eventually will give wool the boost on the market which it needs to hold its own.

With the machine washable and "easy care" developments pushing wool into competition with other fibers, there seems to be a need for determining the performance of these finishes under home laundering procedures similar to those used by the average consumer. It was for this purpose the following study was designed.

OBJECTIVES OF THE STUDY

The specific objectives of the study are as follows:

1. To obtain from textile manufacturers yard goods composed of all-wool and wool blends treated with wash-and-wear and durable press finishes.

2. To subject the experimental fabrics to 25 laundering periods at temperatures of $105^{\circ} \pm 2^{\circ}$F. and $140^{\circ} \pm 2^{\circ}$F., respectively.

3. To evaluate both the machine washable and durable press fabrics, with reference to the following properties at specified intervals of laundering throughout the study:

a. Wash-and-wear appearance

b. Dimensional stability

c. Air permeability

d. Colorfastness

4. To analyze the machine washable fabrics periodically through 25 laundering periods by means of the following tests:

a. Pilling resistance

b. Breaking strength

c. Resistance to flat abrasion

d. Resistance to flexing and abrasion

5. To measure the crease retention of the durable press fabrics at specified intervals of evaluation.

HISTORICAL BACKGROUND

Extensive research has been undertaken in an effort to eliminate the felting shrinkage which has plagued the wool manufacturer for over 500 years. Evidence that this research has resulted in desirable easy care properties for wool, the lack of which threatened the survival of the fiber a few years ago, may be noted in the following information.

Since the principle underlying felting shrinkage involves the surface structure of the wool fiber and the movement and entanglement of these fibers under unfavorable conditions of heat, moisture, and pressure, shrinkproofing treatments have been founded upon this factor, according to Sweetman and Maclaren (14) and Whewell (19).

Change in the sharp scale-like projections on the surface of the wool fibers has been the objective of research in felting shrinkage of wool for many years. Some of the earliest shrink resistant treatments used to alter the scales of the wool fiber were discussed by Murray (12), such as the milling of fabrics with abrasives which had a sandpapering effect. The resulting weight loss produced by this process made it economically unfeasible. Another

process described by this author was the use of an enzyme to digest the rough surface of the fiber which was patented in England in 1934 as "papain," from the name of the enzyme used. Cost was the prohibitive factor of this procedure. One more recent effort in the development of shrink resistance for wool, which Murray discussed, was the Tootal-Broadhurst-Lee method which employed caustic soda in a solvent mixture of alcohol and naphtha. This procedure was developed in the early 1950's, but the wool was easily damaged, and the solvent method was considered dangerous by insurance companies.

Chlorination was the most popular of the early oxidative shrink resistance processes. Trotman (17) recognized in 1923 that a chemical change occurred which caused an alteration in the structure of the wool fiber when it was placed in a solution of bleaching powder. However, if the treatment was continued long enough to make the wool shrink resistant, the epithelial scales were likely to be damaged, resulting in a reduction in strength and elasticity and in increased solubility and dyeability of the fibers.

Two other such methods were described by Murray (12) in his "Round-Up on Washable Woolens" in 1954. The first of these known as the Stevenson-Woolsey process was developed in England and consisted of a batch method usually applied to the fabric during the dyeing process. The other was a

continuous process developed by the Harris Research Laboratories and known as Harriset. According to Murray, the chlorination processes were detrimental to wool in that they caused a loss of strength, weight, and natural water repellency to the fibers and had adverse effects upon the hand and color of wool fabrics.

Experimentation with the chlorination process continued into the early 1960's when McPhee (9) reported on a common industrial shrink-resist treatment which included acid, neutral, and dry chlorination. Acid chlorination was basically a controlled reaction in an acid pH which could be done continuously or in batches. The neutral chlorination was similar except that the pH ranged from 6 to 9 and sometimes a resin pretreatment was used. Chlorine gas was used for dry chlorination. Another oxidation type process reported by McPhee was the Dylanize method developed and promoted by Stevenson (U.S.A.) Incorporated using permonosulfuric acid at a pH of 7 to 12 to oxidize the wool.

In 1960 Moncrieff (11) of the CSIRO laboratories in Australia discovered that a concentrated solution of salt would protect wool from oxidative degradation and, therefore, it was a suitable treatment for imparting shrink resistance to wool when applied with potassium permanganate.

Murray's (12) report on a study by Bradbury, Rodgers, and Filshie in 1963 confirmed that the treatment

of wool with potassium permanganate in a saturated solution of salt modified the cuticle, which is necessary for effective shrink resistance. They found that a fabric which would shrink 30 per cent when treated only with the potassium permanganate solution would shrink only five per cent when "shrinkproofed" with the potassium permanganate solution containing 18 per cent salt. The treatment hardly affected the hand and sometimes improved the whiteness.

A two-stage shrink-resist oxidation process using a sulfite, studied by Sweetman and Maclaren (14) in 1965, appeared to have the advantage of producing more disulfide fission and, hence, better shrink resistance with a minimal risk of prohibitive fiber damage. This study proved that the chemical reaction could be controlled more specifically and that a milder chemical could be used.

Ozone gas has been used to impart shrink-resist properties to wool fabrics for a number of years. In 1965 Thorsen (15) reported high reaction rates and low consumption of ozone when the gas was passed through moistened fabric at room temperature. However, a more recent study by Thorsen and Kodiana (16) showed more effective and economical results by passing ozone over the surface of hot (95^{0}C.), wet fabric. Short treatments of 30 seconds did not produce any significant fabric degradation of strength or abrasion resistance or any alteration in the

hand or color of the fabric so treated; however, the natural water repellency of the fabrics was slightly reduced. The approximate cost per square yard of fabric for this treatment was found to be 0.0015 of a cent in high volume use.

All of the processes which have been discussed depend upon a change in the surface structure of the wool fiber and each is chemically degradative to the fiber. They are based on the modification of the cuticle and/or the cortex and are unpredictable in overcoming the variety of inherent felting shrinkages of the wool fibers which do not depend on the quality of the wool. This observation was noted by Anderson and McPhee (4) who found that the frequency and thickness of the scales of the wool fiber varied and could be a factor in producing inconsistent results.

The Zeset finish, developed by Dupont during the early 1960's for the purpose of imparting machine washable properties to wool fabrics, provides wool with more desirable properties than those mentioned above, according to a report published by the American Dyestuff Reporter (2). The Zeset finish is a surface modifier and therefore, instead of reducing the strength of the fabrics, forms a chemical casing on each fiber. Modified drycleaning equipment is used for the application of this treatment.

The third and currently the most promising type of finish for rendering wool actually machine washable is

interfacial polymerication (IFP), which is basically a resin-additive treatment in contrast to many commercial shrink-resist processes which are degradative, as described by Fong, Whitfield, Miller, and Brown (7). This process differs from the common resin-type finishes in that an ultra-thin film approximately 200-300 Å. thick is formed on the wool fiber surface.

Whitfield, Miller, and Wasley (24) date the beginning use of polymers for finishing wool at 1934, when cellulose acetate was first used for that purpose. Other polymer types which have been studied, according to these authors, are vinyl polymers--acrylate esters, acrylonitrile, and acrylic acids; network polymers--epoxides, phenol-formaldehyde, and melamine-formaldehyde; condensation polymers--amides, esters, and peptides; and miscellaneous polymers like cellulose acetate, proteins, and natural rubber.

The IFP process was reported in literature for the first time about 1950. One such process was developed by the Western Utilization research laboratories in Albany, California (6). Wurlan, the name of the process, came from "Western Utilization Research and Development Division" and "lana" the Latin word for wool. The process is relatively simple and readily adaptable to continuous plant operation. It involves the immersion of the wool fabrics in an aqueous solution of a diamine containing a wetting agent and sodium carbonate to neutralize the hydrochloric acid formed in the

reaction. However, the use of a strong inorganic base was found by Wasley, Whitfield, and Miller (18) to produce superior results to those obtained from the use of sodium carbonate. After excess liquor is removed the fabric is immersed in a solution of acid chloride in a water immiscible solvent. After the excess liquor is again removed by padding, leaving a two per cent pick up, the polyamide polymer forms rapidly, and no further heat treatment or curing is necessary. The IFP-treated fabric is then scoured to remove unreacted chemicals. Two successful plant trials on this method of application, one by Fong, Ash, and Miller (6) and later, another by Miller and Fong (10), were conducted using the plant facilities of the J. P. Stevens Company in Dublin, Georgia.

Feldtman, McPhee, and Pratt (5) found in a study on worsteds and commercial woolen fabrics that when stabilization was achieved with polyolefins, crosslinking was an important factor in shrinkage control. In their study application of a preformed polymer gave no dimensional stability when the fabrics were subjected to laundering.

On the basis of studies conducted by Whitfield, Miller, and Wasley (20, 23, 24) the polyamides, polyurethanes, and copolymers have given wool the most satisfactory shrink-resistance. With these finishing agents no pre-treatment of the fabric is required.

In further studies conducted by Whitfield et al. (21, 22, 24), in which a variety of stabilization treatments were evaluated, polyurethanes were found to give good results with reference to shrink-resistance, unaltered hand, and improved abrasion, breaking, and pilling resistance. Polyesters and polycarbonates proved to be ineffective with reference to shrinkage control; whereas intermediate stabilization resulted from the use of polyureas.

A study of Wurlanized fabrics by Fong, Ash, and Miller (6) revealed that breaking strength of these fabrics was the same or greater than untreated wool, but from 20 to 40 per cent higher than wool treated by standard mill oxidative procedures. Flex abrasion and washfastness of the Wurlanized fabrics were superior to those treated by oxidative processes.

In April, 1968, O'Connell, Pardo, and Fong (13) released their preliminary observations on durable press wool blend fabrics. Wool-cellulose blends of 50/50 wool-cotton and 55/45 wool-rayon were treated with the durable press resin after the Wurlan process had been applied. They achieved good durable press and easy-care characteristics in addition to a good hand, appearance, and comfort in wear, but some wear life was sacrificed. It seemed that the cellulose was degraded in the acid chloride of

the Wurlan process as well as in the crosslinking of the durable press finish.

Other studies on the durable press finishes as applied to fabrics composed of blends of wool and cellulose are underway at the present time, but few findings have been published concerning the performance of these fabrics.

PLAN OF PROCEDURE

DESCRIPTION OF FABRICS

Fourteen fabrics composed of 100 per cent wool and of blends of wool with cotton, rayon, and nylon were used as experimental fabrics in this study. Nine of the fabrics were treated with finishes which rendered them machine washable; whereas five were given the Koratron durable-press treatment.

The experimental fabrics were constructed by means of the plain and twill weaves and were representative of weights ranging from 3.9 to 8.9 ounces per square yard. The yarn counts varied from 29.6 to 74.4 yarns per inch in the warp direction, and from 25.6 to 78.0 yarns per inch fillingwise. See Summary A and Figures 1 and 2 for an outline of the construction characteristics and samples of each of the experimental fabrics.

The nine fabrics in the washable wool category were provided by the following: the United States Department of Agriculture; J. P. Stevens and Company, Incorporated; and the Arrow Shirt Company. The five durable press fabrics were provided by Koret of California.

SUMMARY A

FABRIC CONSTRUCTION DETAILS

PART I. MACHINE WASHABLE FABRICS

Fabric	Fiber Content	Initial Yarn Count		Weight per Square Yard (Ounces)	Weave
		Warp	Filling		
A	100% Wool	37.6	34.0	6.3	Plain
B	100% Wool	37.0	32.2	6.0	Plain
C	100% Wool	37.8	32.6	6.4	Plain
D	100% Wool	29.6	29.0	6.3	Plain
E	100% Wool	30.4	28.0	6.8	Plain
F	100% Wool	34.0	30.0	6.8	Twill
G	85/15 Wool-Nylon	30.0	26.8	5.8	Plain
H	85/15 Wool-Nylon	30.6	25.6	5.9	Plain
I	55/45 Wool-Cotton	74.4	78.0	3.9	Twill

PART II. DURABLE PRESS FABRICS

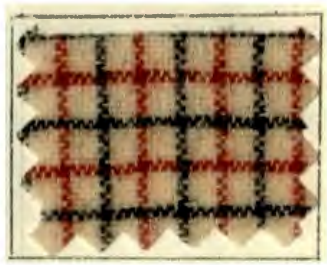
J	65/25/10 Wool-Rayon-Nylon	48.0	42.2	8.3	Twill
K	50/40/10 Wool-Cotton-Nylon	45.0	36.6	7.4	Twill
L	50/40/10 Wool-Cotton-Nylon	47.4	40.6	7.3	Twill
M	50/20/20/10 Wool-Cotton-Rayon-Nylon	45.8	36.6	7.4	Twill
N	50/40/10 Wool-Rayon-Nylon	43.8	50.4	8.9	Twill

A

100% Wool

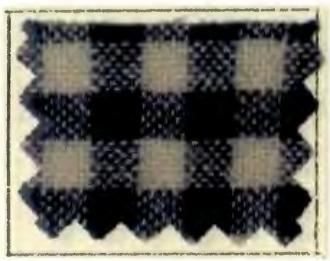
B

100% Wool



C

100% Wool



D

100% Wool

E

100% Wool

F

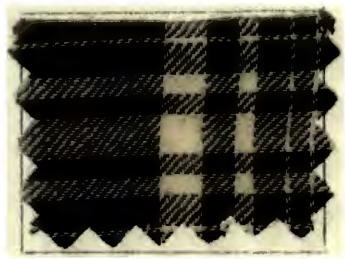
100% Wool

G

85/15 Wool-Nylon

H

85/15 Wool-Nylon

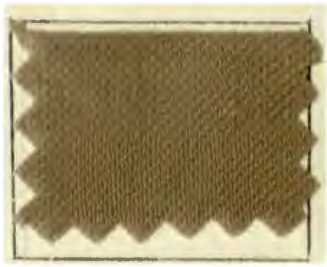


I

55/45 Wool-Cotton

FIGURE 1

MACHINE WASHABLE FABRICS



J

65/25/10 Wool-
Rayon-Nylon

K

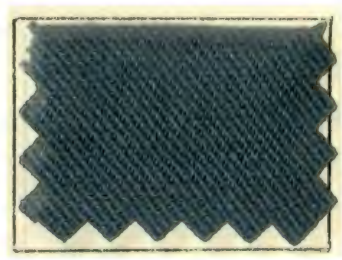
50/40/10 Wool-
Cotton-Nylon

L

50/40/10 Wool-
Cotton-Nylon

M

50/20/20/10 Wool-
Cotton-Rayon-Nylon



N

50/40/10 Wool-
Rayon-Nylon

FIGURE 2

DURABLE PRESS FABRICS

LAUNDERING PROCEDURE

In preparation for laundering each of the fourteen experimental fabrics was divided into two parts. All raw edges of the fabrics were overcast to prevent raveling, and fabrics were labeled according to the following system of identification. The machine washable fabrics were identified by letters "A" through "I", and letters "J" through "N" were used to designate the durable press fabrics. (See Summary A.) Roman numerals I and II were utilized to distinguish between the two laundering temperatures.

One of the two sets of fabrics mentioned above was subjected to 25 launderings at $105^{\circ} \pm 2^{\circ}$F., and the other set of fabrics was laundered the same number of times at a temperature of $140^{\circ} \pm 2^{\circ}$F. All laundering was done in four-pound loads in an RCA Whirlpool Imperial Mark XII automatic washer. The gentle four-minute laundering cycle with a high water level, low agitation, low spinning action followed by two warm rinses was employed. Three-fourths cup of Ivory Flakes was used for each load of laundering.

DRYING PROCEDURE

Upon completion of the full wash cycle the experimental fabrics were removed immediately from the washer and tumble dried in an RCA Whirlpool Imperial Mark XII automatic

dryer set at a gentle speed on the warm, delicate, wash-and-wear cycle. Care was taken to prevent the experimental fabrics from remaining in the dryer any longer than was necessary for drying. The drying procedure was the same for fabrics laundered at both temperatures.

FABRIC WEIGHT

The initial weight of each fabric was determined in accordance with ASTM Designation: D 1910-64, Section 38 (3g).

Two 3.5 inch squares from each experimental fabric were conditioned overnight to establish moisture equilibrium. The samples were weighed together on a Mettler analytical balance to the nearest 0.01 per cent of their weight. The following formula was used to determine the weight of each fabric in ounces per square yard:

$$\text{Weight, ounces per square yard} = \frac{\text{Weight of specimens in grams}}{\text{Total area of specimens in square inches}} \times 45.72$$

FABRIC COUNT

Each experimental fabric in the machine washable category was analyzed for fabric count initially, and after five, 10, 15, 20, and 25 periods of laundering followed by tumble drying. Only initial fabric counts were ascertained

for the durable press fabrics. The Alfred Suter Pick Counter was used in accordance with the method outlined in Sections 27 through 33 of ASTM Designation: D 1910-64 (3f).

One inch counts were taken at five different places on each fabric both in the warp and filling directions. No count was taken less than one-tenth of the width of the fabric from the selvage.

WASH-AND-WEAR APPEARANCE

The experimental fabrics were rated for smoothness after home laundering according to the overhead lighting procedure of AATCC 88A-1964T (1a). For comparative purposes in the evaluation procedure the Monsanto Three-Dimensional Wash-and-Wear Standards were used. An evaluation of each experimental fabric was made by three trained observers after one, five, 10, 15, 20, and 25 periods of laundering.

A single thickness of each fabric was attached to the center of the viewing board; and next to the fabric were hung the three-dimensional plastic replicas. The observers independently rated each fabric, standing four feet from the viewing board. The three ratings for each fabric were averaged to represent the wash-and-wear appearance of that particular fabric.

CREASE RETENTION

The durable press fabrics were evaluated with reference to their pressed-in creases according to the overhead lighting procedure outlined in AATCC 88C-1964T (1b).

After one, five, 10, 15, 20, and 25 laundering periods the fabrics were hung at eye level on the viewing board with the creases perpendicular to the floor. The AATCC photographic standards recommended in the procedure were placed beside the fabrics for comparative purposes. A 500-watt reflector flood lamp positioned in such a way that it would cast a light upon the creased specimen from a 45^{o} angle was used for supplementary lighting. Three trained observers rated each crease from a distance of four feet by assigning each specimen a rating comparable to the number of the photographic standard that most nearly matched the appearance of the crease. The three ratings for each fabric were averaged at each respective evaluation period and reported as the crease rating for that particular period.

DIMENSIONAL STABILITY

The experimental fabrics were evaluated for dimensional stability after one, five, 10, 15, 20, and 25 launderings at each temperature. The procedure used in these evaluations was generally that recommended by ASTM

Designation: D 1905-61T (3e) with some exceptions made necessary by a shortage of experimental fabrics.

Instead of the 18-inch square recommended in Paragraph 4, Section C of the procedure, five-inch squares were used for these evaluations. Each square was at least one-tenth of the fabric width from the edge. These squares were machine stitched at each corner and at midpoints between the corners after being marked parallel to the warp and filling directions by a graduated steel ruler. These stitched markings provided three warp and three filling measurements for each fabric.

At each of the six evaluation periods three measurements were made in each direction to the nearest one-tenth inch. The per cent dimensional change for the warp and filling directions was calculated as follows on the basis of an average of the three measurements in each yarn direction.

$$\text{Per Cent Dimensional Change} = \frac{\text{Original measurement} - \text{Measurement after laundering}}{\text{Original measurement}} \times 100$$

AIR PERMEABILITY

The air permeability of the experimental fabrics was determined by the Gurley Densometer according to the procedure recommended by the manufacturer of the test instrument

and by Federal Specification CCC-T-191b, Method 5452 (8). The fabrics were tested initially and after 25 laundering periods.

Three four-inch squares of each fabric type, taken from different warp and filling yarns, were tested. With a stop watch, the time required for 300 cubic centimeters of air to pass through the fabric was determined. The results were reported as the average time required for the measured amount of air to pass through three specimens from each fabric.

PILLING RESISTANCE

The Random Tumble Pilling Tester was used to ascertain the pilling resistance of the machine washable fabrics according to the procedure given in ASTM Designation: D 1375-67, Sections 24-30 (3c). Standards used in the rating procedure were prepared from a fabric representative of those which were to be tested.

Three four-inch squares which served as specimens were cut from each of the machine washable fabrics initially and after 15 and 25 laundering periods. The sides of the squares were cut parallel to the warp and filling yarns in such a way that no two specimens contained identical yarns in either direction. The edges of the specimens were sealed to prevent raveling with a 2:1 ratio of Unabond Cement and

methyl ethyl ketone, and the specimens were allowed to dry for at least two hours before pilling.

In preparation for testing, each pilling chamber of the tester was lined with cork liners which were used for an hour on each side. The three squares of a particular fabric type were placed in a chamber with approximately 0.2 inch of a 75 grain grey cotton sliver. After 30 minutes of pilling, the specimens and pilling chambers were vacuumed. If at this point, the specimens appeared to rate more than 1.5, which is representative of heavy to very severe pilling, another 0.2 inch of cotton sliver was added to each chamber and pilling was continued for another 30 minutes. After the specimens, chambers, and liners were again vacuumed, the specimens were evaluated with reference to their resistance to pilling. This procedure was performed by a panel of three trained observers who independently compared the pilled specimens with the standards which were prepared for this purpose. An average of the nine observations per fabric type was reported as the rating for a particular fabric.

BREAKING STRENGTH

The machine washable fabrics were tested for dry breaking strength following ASTM Designation: D 1682-64, Section 4.4 on Ravelled Strip Method (3d).

Five warp and five filling specimens were cut 6.0 inches by 1.25 inches and raveled to one inch after they were checked for precision with the Alfred Suter Yarn Counter. Each specimen was composed of different yarns. The fabrics were tested initially and after each fifth laundering period throughout the study. The specimens were conditioned overnight or for a minimum of eight hours at a standard temperature of $70^{o} \pm 2^{o}$F. and a relative humidity of 65% ± 2%.

The breaking strength was reported in pounds per 100 yarns and calculated as follows:

$$\text{Breaking strength per 100 yarns} = \frac{\text{Average breaking strength}}{\text{Yarn count}} \times 100$$

FLAT ABRASION

The machine washable fabrics were evaluated for their resistance to flat abrasion initially and after five, 10, 15, 20, and 25 laundering periods following ASTM Designation: D 1175-64T, Sections 32 through 41 (3a). The Taber Rotary Platform Double Head Abraser with two matched pairs of CS-10 rubber-base abrading wheels was used for these tests.

Two six-inch squares taken from different warp and filling yarns were subjected to two hundred abrasion cycles under a head weight of 500 grams. The abrasive wheels were

resurfaced after each 600 cycles of use by running them for 50 revolutions on carborundum-coated paper disks.

After abrasion two 0.75 inch strips were cut in the filling direction and two in the warp direction from each of the six-inch squares. These strips were raveled to one-half inch and checked for precision with the Alfred Suter Yarn Counter. After conditioning the specimens to standard temperature and relative humidity, they were broken on the Scott Tester. The change in breaking strength due to abrasion was calculated according to the following formula:

$$\text{Change in breaking strength, per cent} = \frac{A-B}{A} \times 100$$

Where:

A = breaking strength per 100 yarns before abrasion, and

B = breaking strength per 100 yarns after abrasion.

FLEXING AND ABRASION

The machine washable fabrics were subjected to flexing and abrasion on the Stoll Universal Wear Tester in accordance with ASTM Designation: D 1175-64T, Section 14-21 (3b). The fabrics were abraded to rupture initially and after each fifth laundering period from five through 25.

Four pounds of tension and two pounds of weight were used on the specimens during testing.

Five specimens were cut 1.25 inches by 8.0 inches in the warp and filling directions, respectively. The specimens were cut so that different yarns were represented in each specimen. The strips were raveled to one inch and allowed to reach moisture equilibrium in a standard atmosphere before testing.

The average number of cycles required to rupture the five specimens was calculated and reported as the number of cycles necessary to rupture 100 yarns:

$$\text{Cycles to rupture per 100 yarns} = \frac{\text{Average cycles to rupture per inch}}{\text{Yarn count}} \times 100$$

SPECTROPHOTOMETRIC DETERMINATION

The Beckman DU Spectrophotometer was used to determine the loss of color of the experimental fabrics due to laundering. Ten wavelengths selected at intervals of 50 millimicrons throughout the visual spectrum of 400 millicrons to 850 millimicrons were used in evaluating each type of fabric initially and after 25 laundering periods. The reflectance was compared to a standard white fabric with a 91.2 per cent reflectance value.

For the solid color fabrics a 1.5 by 4.0 inch specimen was cut. The specimens were folded in half to allow a double thickness of fabric for evaluation. For the plaid and check fabrics one 0.75 inch square was cut from each fabric and ground in a Wiley Mill using a 20 mesh screen. Care was taken to obtain specimens from identical areas of the design of a particular fabric for both evaluation periods. The ground fibers were distributed as evenly as possible to simulate a double thickness of fabric the correct size for evaluation and wrapped in Saran for ease in handling.

The color loss experienced by each fabric as a result of laundering was calculated and reported according to the following formula:

$$\text{Reflectance, per cent loss} = \frac{\text{Average initial reflectance} - \text{Average reflectance after 25 launderings}}{\text{Average initial reflectance}}$$

PRESENTATION OF DATA WITH DISCUSSION OF FINDINGS

The data accumulated through a study of fourteen wool and wool-blend fabrics are summarized in Tables I through XXVII in the Appendix of this thesis. Part A of each table concerns the machine washable fabrics; whereas Part B refers to the durable press fabrics, except in those tables pertaining to strength data when the scarcity of the durable press fabrics made these tests prohibitive.

The tabulated data were analyzed by means of the "t" test with the analysis being made on the basis of fiber content, type of finish, and laundering temperature. In some instances all of these comparisons were not feasible due to the nature of the data.

For comparative purposes the washable wool fabrics were divided into the following categories with reference to their fiber content: 100% wool; 85/15 wool-nylon; and 55/45 wool-cotton. The durable press fabrics were treated both on an individual basis and as one group in all comparisons which involved them.

WASH-AND-WEAR PERFORMANCE

The experimental fabrics were evaluated for their wash-and-wear performance after one, five, 10, 15, 20, and 25 laundering periods at temperatures of 105°F. and 140°F., respectively. Data resulting from these evaluations are recorded in Tables I and II located in the Appendix of this thesis.

Table I is devoted to a tabulation of the mean wash-and-wear ratings which were assigned to the washable wool and durable press fabrics after they were subjected to a laundering temperature of 105°F. followed by tumble drying, while Table II records the data which resulted from the higher laundering temperature of 140°F. and tumble drying.

Statistical comparisons of these data made on the basis of fiber content, fabric finish, and laundering temperature are discussed in the following section.

WASH-AND-WEAR PERFORMANCE OF FABRICS LAUNDERED AT 105°F.

Machine Washable Fabrics. A study of the wash-and-wear ratings tabulated in Table I and the statistical comparisons of these data reveals that the three categories of washable wool fabrics reacted in a comparable manner to a laundering temperature of 105°F. followed by tumble drying.

Although there were no significant differences between the cumulative mean value of 4.30 attributed to the 55/45 wool-cotton fabric and the 4.29 and 4.16 values claimed by the 100 per cent wool and the 85/15 wool-nylon fabrics, respectively, there was some indication of differences between the wash-and-wear performance of the fabrics at intervals throughout the series of 25 laundering periods. After one laundering the 55/45 wool-cotton fabrics were definitely the poorest performers, whereas after 15 and 25 periods of laundering their smoothness surpassed that of the 100 per cent wool and the wool-nylon blends. At other periods of evaluation the performance of the three types of machine washable fabrics was similar. See Figure 3 for this observation.

Durable Press Fabrics. In reviewing the data in Part B of Table I pertaining to the durable press fabrics laundered at 105°F. and tumble dried, it may be noted that the presence of cotton in the blends contributed to slightly higher wash-and-wear scores. Fabric K, a twill weave composed of 50/40/10 wool-cotton-nylon, received a mean wash-and-wear rating of 5.0 at each evaluation period. Fabric L of the same weave and fiber content as K was rated 5.0 at each evaluation period except at the final period. The wool-cotton-rayon-nylon blend (Fabric M) ranked third with reference to appearance, and the remaining two fabrics, J and N,

which were wool-rayon-nylon blends ranked last. When statistical methods were employed in comparing these individual fabrics, differences were not significant ($P<0.100$ to $P<0.200$).

When the mean wash-and-wear values for the entire group of durable press fabrics were pooled and analyzed at the various intervals of testing, little change was noted in the smoothness of the fabrics as the number of launderings increased. As can be noted from Figure 3 mean values ranged from a high of 5.0 after one and 10 laundering periods to a low of 4.5 after 20 periods of laundering at a temperature of 105°F.

COMPARISON OF THE WASH-AND-WEAR PERFORMANCE OF FABRICS LAUNDERED AT 105° F.

A comparison of the mean wash-and-wear ratings of the durable press fabrics laundered at 105°F. and tumble dried with those of their machine washable counterparts laundered under the same conditions revealed that the durable press fabrics were highly superior in smoothness to the machine washable group ($P<0.001$).

Differences were not as pronounced when the three respective categories of machine washable fabrics were

compared statistically to the durable press fabrics in relation to their wash-and-wear values. When compared to the 100 per cent wool and the 85/15 wool-nylon fabrics the superiority of the durable press fabrics amounted to a probability of $P<0.010$. In comparison with the 55/45 wool-cotton fabrics the difference in smoothness favorable to the durable press fabrics was not as great ($P< 0.020$). These comparisons are shown in Summary B, Part I.

WASH-AND-WEAR PERFORMANCE OF FABRICS LAUNDERED AT 140° F.

Machine Washable Fabrics. When intercomparisons were made between the three groups of machine washable fabrics on the basis of the cumulative wash-and-wear ratings assigned to each respective group throughout the 25 laundering periods, significant differences were not observed between any two groups of fabrics. The mean values ranged from a high of 4.12 which was accredited to the 55/45 wool-cotton to a low of 3.86 claimed by the 85/15 wool-nylon fabrics.

A gradual downward trend in wash-and-wear performance from one through 25 launderings was experienced by the three categories of washable wool fabrics laundered at the higher temperature of 140°F. and followed by tumble drying. From the data as recorded in Table II and plotted in Figure 3 there is evidence that the reaction of the 55/45

wool-cotton fabric to laundering was more erratic than that of the other two groups of washable wool fabrics. This erratic reaction to laundering in some instances proved to be favorable to the wool-cotton blend; whereas at other intervals of evaluation the 100 per cent wool and the 85/15 wool-nylon fabrics exhibited preferable ratings.

Throughout the 25 laundering periods the wash-and-wear values of the 100 per cent wool and the 85/15 wool-nylon fabrics followed the same general pattern with only negligible differences noted between the two.

Durable Press Fabrics. From an examination of the data recorded in Table II, Part B, concerning the five durable press fabrics laundered at 140°F., it is apparent that the cotton blends merited higher wash-and-wear ratings than did the remaining fabrics. Fabric K, a twill weave constructed of 50/40/10 wool-cotton-nylon, was assigned a rating of 5.0 at each evaluation interval except after the 25th laundering period when it received a 4.0 ratings. Fabric M, a 50/20/20/10 wool-cotton-rayon-nylon twill weave was second highest, having a 5.0 rating through laundering period 15. After launderings 20 and 25 Fabric M was assigned ratings of 4.3 and 3.7, respectively. Fabric L of the same weave and blend as Fabric K was rated slightly lower than Fabric M with Fabrics N and J ranking last in the order mentioned. When the fabrics were compared independently to

each other by statistical methods no difference was great enough to be of significance.

COMPARISON OF THE WASH-AND-WEAR PERFORMANCE OF FABRICS LAUNDERED AT 140°F.

When the mean wash-and-wear ratings of the entire group of machine washable fabrics laundered at 140°F. were compared to the durable press fabrics subjected to the same laundering treatment, the latter exhibited the smoother appearance ($P<0.010$) as can be observed in Summary B, Part I. A comparison of the appearance of the durable press fabrics with that of the three respective types of machine washable fabrics revealed a non-significant difference between the mean rating of 4.12 given the 55/45 wool-cotton blend and the 4.53 rating of the durable press fabrics. The durable press surpassed the 100 per cent wool and the 85/15 wool-nylon in wash-and-wear performance by differences significant at the one and five per cent levels, respectively.

COMPARISON OF THE EFFECTS OF LAUNDERING TEMPERATURES OF 105°F. AND 140°F. UPON THE WASH-AND-WEAR PERFORMANCE OF FABRICS

When the experimental fabrics laundered at 105°F. and tumble dried were compared to those laundered at 140°F.

and dried by the same method, the data indicated that the laundering temperature had no apparent effect upon the wash-and-wear scores of the machine washable fabrics. However, the lower temperature of 105°F. produced a more desirable appearance of the durable press fabrics ($P<0.050$) than did the temperature of 140°F. See Summary B, Part II for these observations.

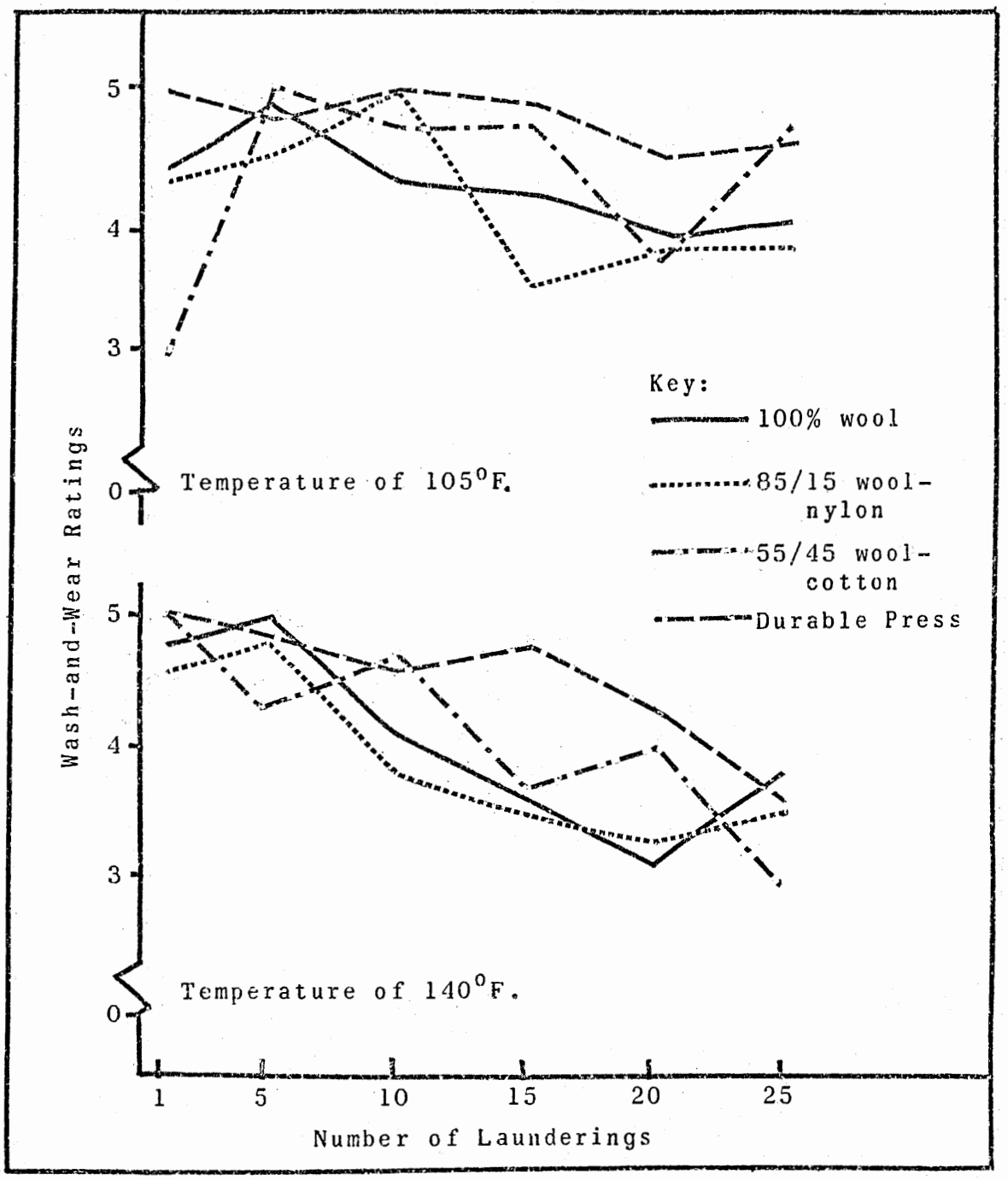


FIGURE 3

A COMPARISON OF THE WASH-AND-WEAR PERFORMANCE OF MACHINE WASHABLE AND DURABLE PRESS FABRICS LAUNDERED AT TEMPERATURES OF 105°F. AND 140°F.

SUMMARY B

STATISTICAL COMPARISONS OF THE MEAN WASH-AND-WEAR RATINGS OF THE EXPERIMENTAL FABRICS AFTER A SERIES OF 25 LAUNDERING PERIODS

PART I. FABRIC FINISHES

Fabric Types	Laundered at 105°F.		Laundered at 140°F.	
	Mean Values	Probability of Significance	Mean Values	Probability of Significance
Machine Washable Durable Press	4.26 4.80	P<0.001	4.02 4.53	P<0.010
100% Wool Durable Press	4.29 4.80	P<0.010	4.06 4.53	P<0.050
85/15 Wool-Nylon Durable Press	4.16 4.80	P<0.010	3.86 4.53	P<0.010
55/45 Wool-Cotton Durable Press	4.30 4.80	P<0.020	4.12 4.53	P<0.200

PART II. LAUNDERING TEMPERATURE

Fabric	Laundering Temperature	Mean Values	Probability of Significance
100% Wool	105°F. 140°F.	4.29 4.06	N.S.
85/15 Wool-Nylon	105°F. 140°F.	4.16 3.86	N.S.
55/45 Wool-Cotton	105°F. 140°F.	4.30 4.12	N.S.
Durable Press	105°F. 140°F.	4.80 4.53	P<0.050

CREASE RETENTION

The durable press fabrics were evaluated with reference to their ability to retain pressed-in creases after one, five, 10, 15, 20, and 25 laundering periods at 105°F. and 140°F., respectively, followed by tumble drying. The average scores assigned to the fabrics laundered at 105°F. are tabulated in Table III, Part A, while Part B of that table contains the crease ratings for the fabrics laundered at 140°F. Each rating in the table represents an average of the ratings assigned a particular fabric by the three panel members.

RETENTION OF CREASES BY DURABLE PRESS FABRICS LAUNDERED AT 105°F.

A careful examination of the mean crease ratings of the durable press fabrics laundered at 105°F gave some indication of the superior performance of the four fabrics (K, L, M. and N) composed of 40 per cent cellulosic fibers. When the data were compared by statistical means there were only two instances when significant differences occurred. The creases in Fabrics K and L, composed of 50/40/10 wool-cotton-nylon, were sharper at the two and five per cent levels, respectively, than those retained by Fabric J, a 65/25/10 wool-rayon-nylon blend. No significant differences were

noted between the ability of Fabrics K, L, M, and N to retain creases during 25 laundering periods at 105°F.

In studying the reaction of the creases in the durable press fabrics as a whole it should be mentioned that the first laundering exerted more damaging effects upon the appearance of the creases than did the remaining 24 laundering periods. After one laundering the sharpness of the creases had decreased from the initial value of 5.0 to a 3.9 rating. From that period throughout 25 laundering periods only negligible changes were noted in the creases as indicated by the mean value of 3.7.

RETENTION OF CREASES BY DURABLE PRESS FABRICS LAUNDERED AT 140°F.

An analysis of the crease retention performance of the durable press fabrics laundered at 140°F. indicated that on the basis of mean values Fabric M, a 50/20/20/10 combination of wool-cotton-rayon-nylon, retained a slightly sharper crease throughout the specified laundering periods as shown by the mean value of 3.77. Fabrics K and L, blends of 50/40/10 wool-cotton-nylon, followed with mean values of 3.72 and 3.55, respectively. While no significant differences in crease retention occurred between the five fabrics the mean values give some indication that a relationship might exist between the cellulosic fiber content and the ability of the fabrics to maintain a crease.

A study of the crease performance data recorded for the group of durable press fabrics as a whole attests to the deteriorating effects of the first laundering at 140°F. when the sharpness of the creases diminished from the initial rating of 5.0 to a low of 3.9. From that period through 20 launderings the appearance of the creases showed only negligible changes; whereas, after the final period of laundering, crease ratings had diminished to a low level of 2.8. When the crease values were pooled for the five fabrics throughout the series of 25 laundering periods the mean crease value was computed as being 3.7.

COMPARISON OF THE EFFECTS OF LAUNDERING TEMPERATURES OF 105°F. AND 140°F. UPON THE CREASE RETENTION OF DURABLE PRESS FABRICS

Figure 4 graphically illustrates a comparison of the effects of laundering temperatures of 105°F. and 140°F. upon the crease performance of the durable press fabrics. From laundering periods 10 through 25 the fabrics laundered at 105°F. had superior crease ratings to those laundered at 140°F. However, differences were not significant. It is interesting to note that after laundering period 20 the crease retention of fabrics laundered at 140°F. sharply decreased; whereas those laundered at 105°F. improved slightly.

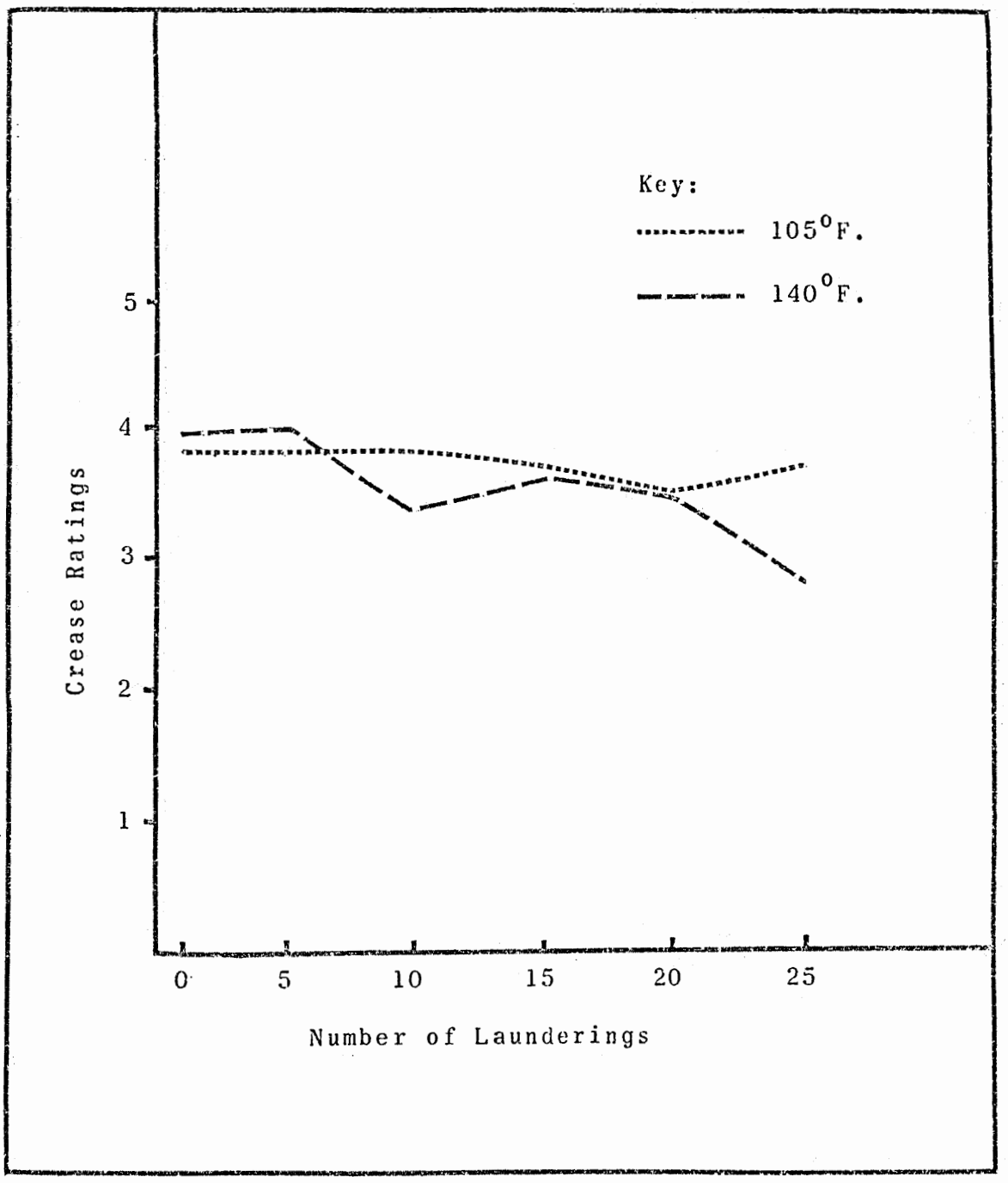


FIGURE 4

A COMPARISON OF THE MEAN CREASE RATINGS OF THE DURABLE PRESS FABRICS WITH RESPECT TO TEMPERATURE

DIMENSIONAL STABILITY

Changes in the dimensional stability of the experimental fabrics laundered at 105°F. and 140°F. were determined initially and after five, 10, 15, 20, and 25 laundering periods. The composite findings are contained in Tables IV through VII. Tables IV and V are composed of the per cent shrinkage in the warp and filling directions, respectively, of each of the fabrics laundered at 105°F., while Tables VI and VII consist of data obtained from the fabrics laundered at 140°F.

DIMENSIONAL STABILITY OF FABRICS LAUNDERED AT 105°F.

Machine Washable Fabrics. A statistical comparison of the data in Table IV revealed the superiority of the warp dimensional stability of the 55/45 wool-cotton blend over the remaining two general categories of machine washable fabrics laundered at 105°F.

When the 2.27 per cent mean dimensional loss exhibited by this fabric in the warp direction throughout the series of 25 laundering periods was compared with the mean loss sustained by the 85/15 wool-nylon (3.72 per cent) and that of the 100 per cent wool fabrics (5.23), significant differences amounting to $P<0.010$ and $P<0.001$, respectively, were noted

which were favorable to the wool-cotton blend. A comparison of the performance of the 100 per cent wool with the 85/15 wool-nylon fabrics showed no significant difference with respect to dimensional stability.

The pattern in which the warp dimensional changes occurred throughout the series of 25 laundering periods at 105°F. may be observed in Figure 5. These data depict a trend of progressive shrinkage from five through 25 laundering periods for the two categories of fabrics with the greatest percentages of wool; whereas, the 55/45 wool-cotton fabric showed a gradual loss in dimensions from the first laundering period. By the end of the twenty-fifth laundering period the 55/45 wool-cotton fabric had shrunk 3.6 per cent while the 85/15 wool-nylon showed a dimensional loss of 4.4 per cent and the 100 per cent wool a 6.6 per cent loss.

The findings in the filling direction again pointed to the excellence of the 55/45 wool-cotton fabric with reference to dimensional stability and, as was the case in the warp direction, shrinkage increased with an increase in the wool content of the experimental fabrics.

A study of Part A of Table V showed that the 100 per cent wool fabrics experienced the greatest amount of shrinkage (5.3 per cent) after laundering period one;

whereas the other two types of machine washable fabrics experienced their greatest losses after the final period of laundering. After 25 launderings the machine washable fabrics demonstrated the following losses in dimensional stability: 100 per cent wool, 5.2 per cent; 85/15 wool-nylon, 3.9 per cent; and the 55/45 wool-cotton, 4.0 per cent. It is interesting to note that the 85/15 wool-nylon fabric had a slightly lower percentage of shrinkage after 25 laundering periods than the 55/45 wool-cotton, however, the lowest mean value was merited by the latter.

Durable Press Fabrics. When the warp dimensions of the five durable press fabrics were compared there were no statistical differences between their accumulated mean values which ranged from a low of 1.27 for Fabric N to a high of 1.77 for Fabric J.

Figure 5 shows a slightly erratic pattern in the warp stability of the fabrics through 10 launderings. However, from that period few changes occurred until after the final laundering period, when a maximum shrinkage of 2.2 per cent was recorded.

The per cent shrinkage in the filling direction of the durable press fabrics was less than that for the warp direction. Fabrics K and L, both composed of 50/40/10 wool-cotton-nylon blends, demonstrated a range of mean values from 0.90 to 1.37, respectively. When the fabrics

were compared independently to each other, Fabric K was found to be superior to Fabrics L and M at the five per cent level of probability. No other statistical differences were apparent.

All of the durable press fabrics laundered at 105°F. could be classified as preshrunk fabrics for their mean shrinkage values fell within the limits allowed by the National Bureau of Standards (2.0 per cent).

COMPARISON OF THE DIMENSIONAL STABILITY OF FABRICS LAUNDERED AT 105°F.

A comparison of the warp dimensional stability of the two general categories of experimental fabrics indicated that the durable press fabrics laundered at 105°F. were highly superior to the machine washable fabrics subjected to the same laundering temperature ($P<0.001$). Statistical data showed that the same highly significant difference existed when the durable press fabrics as a whole were compared with the 100 per cent wool and the 85/15 wool-nylon machine washable groups, respectively. When the 55/45 wool-cotton and the durable press were compared the difference was not as great, though still significant ($P<0.010$).

In the filling direction the comparisons of the durable press fabrics with the machine washable fabrics

either as a group, or as three distinct categories, disclosed a highly significant superiority in favor of the durable press fabrics.

DIMENSIONAL STABILITY OF FABRICS LAUNDERED AT 140°F.

Machine Washable Fabrics. The results of the dimensional stability measurements in the warp direction of the machine washable fabrics throughout the series of 25 laundering periods at 140°F. were indicative of the following mean per cent values: 100 per cent wool, 5.93; 85/15 wool-nylon, 4.18; and 55/45 wool-cotton, 2.55. A comparison of the data recorded for the three distinct categories of machine washable fabrics showed the warp dimensional stability of the 55/45 wool-cotton to be superior both to the 100 per cent wool and to the 85/15 wool-nylon with differences significant at the respective levels of one and five per cent.

The pattern of change in the warp dimensions of the fabrics may be observed in Figure 6. From these data it is evident that the shrinkage of the 55/45 wool-cotton increased to 4.2 per cent as the launderings progressed from one through 25. The 100 per cent wool and the 85/15 wool-nylon exhibited a decrease in shrinkage after laundering period five, but throughout the remainder of the study

shrinkage increased progressively until at the final evaluation period these fabrics had suffered respective losses of 8.2 and 5.8 per cent in their measurements.

The shrinkage was less in the filling direction than in the warp for the fabrics laundered at 140°F., the mean values being 5.55 per cent for the 100 per cent wool fabrics, 3.43 per cent for the 85/15 wool-nylon, and 2.53 per cent for the 55/45 wool-cotton fabrics. The 55/45 wool-cotton and the 85/15 wool-nylon were significantly more dimensionally stable ($P<0.001$) than the 100 per cent wool. There was no difference in this respect between the 85/15 wool-nylon and the 55/45 wool-cotton fabrics. The maximum shrinkage occurred after laundering period 25 for each fabric type.

Durable Press Fabrics. A study of the statistical data concerning the dimensional stability of the durable press fabrics revealed warp losses ranging from the 1.17 per cent for Fabric L, a 50/40/10 wool-cotton-nylon blend, to a 2.0 per cent loss for fabric J, a 65/25/10 wool-rayon-nylon combination. When comparisons were made between the durable press fabrics, only one significant difference was noted. Fabric L was superior to Fabric J with a probability of significance amounting to $P<0.050$.

The dimensional stability in the filling direction of the durable press fabrics was better than in the warp.

The highest mean value of 1.50 was accredited to Fabric L. The mean values of Fabrics K and L, 0.77 and 1.50, respectively, were the only ones which produced a difference of statistical significance ($P<0.050$).

COMPARISON OF THE DIMENSIONAL STABILITY OF FABRICS LAUNDERED AT 140°F.

Upon reviewing the statistical data there was evidence that the durable press fabrics demonstrated superior dimensional stability in both the warp and filling directions to that of the entire group of machine washable fabrics or each of the three separate categories of these fabrics. The probability of significance was $P<0.001$ in each comparison in both yarn directions except when the 55/45 wool-cotton blend was compared with the durable press in the warp direction. In this case the probability of significance was less ($P<0.020$).

COMPARISON OF THE EFFECTS OF LAUNDERING TEMPERATURES OF 105°F. AND 140°F. UPON THE DIMENSIONAL STABILITY OF FABRICS

To determine the effects of the laundering temperature on the dimensional stability of the experimental fabrics, the mean warp dimensional stability values of the fabrics

laundered at 105°F. were compared to those taken from the corresponding fabrics subjected to a laundering temperature of 140°F. The same comparisons were made in the filling direction.

Statistical analyses show that the laundering temperatures had no effect upon the warp dimensional stability of any of the experimental fabrics, but in the filling direction the 100 per cent wool fabrics were distinctly more stable when laundered at the lower temperature ($P<0.020$).

It should be noted that the mean shrinkage values were lower for all of the fabrics laundered at 105°F. except the durable press fabrics which experienced only negligible shrinkage at both temperatures.

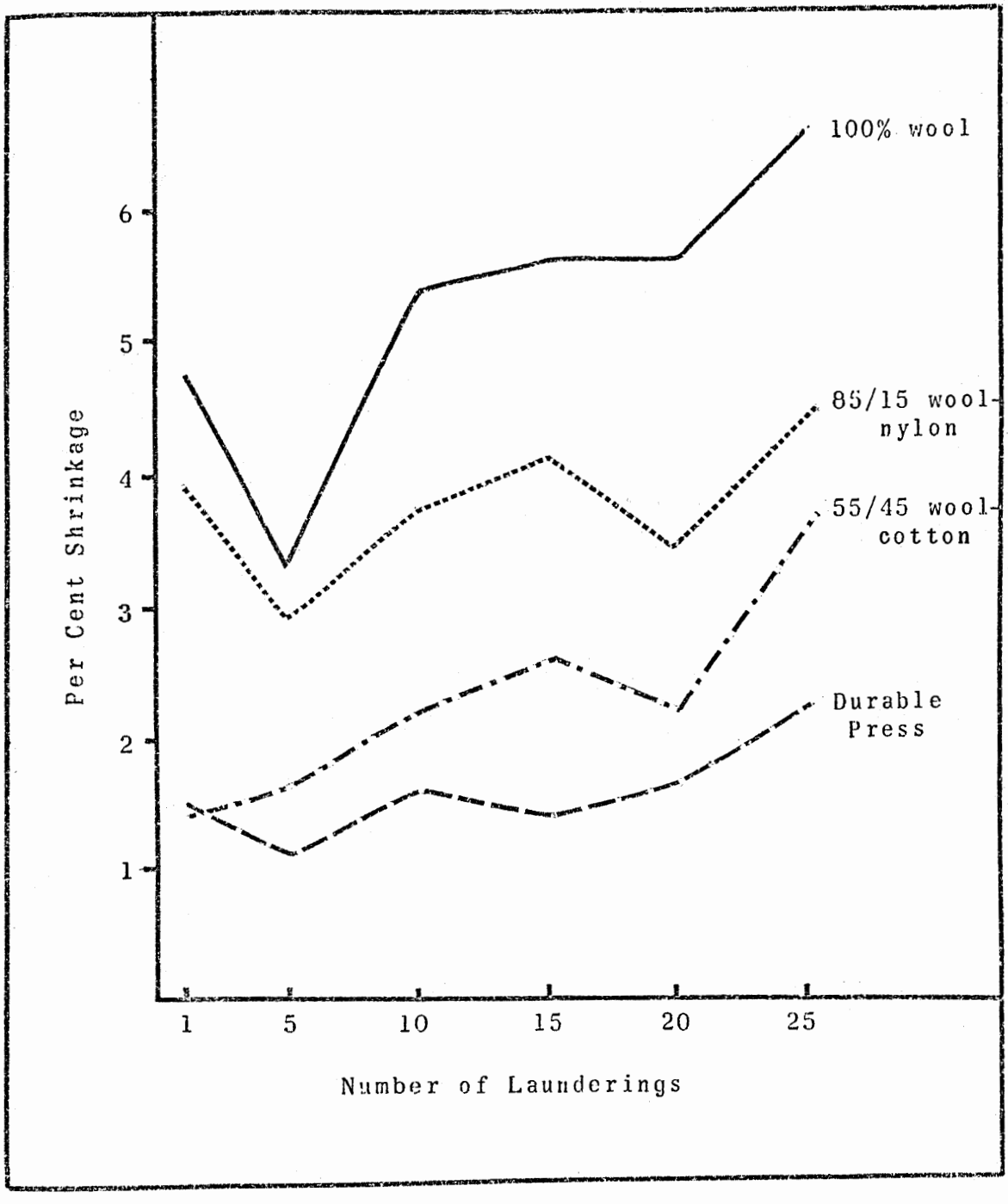


FIGURE 5

A COMPARISON OF THE DIMENSIONAL STABILITY IN THE WARP DIRECTION OF MACHINE WASHABLE AND DURABLE PRESS FABRICS LAUNDERED AT 105°F.

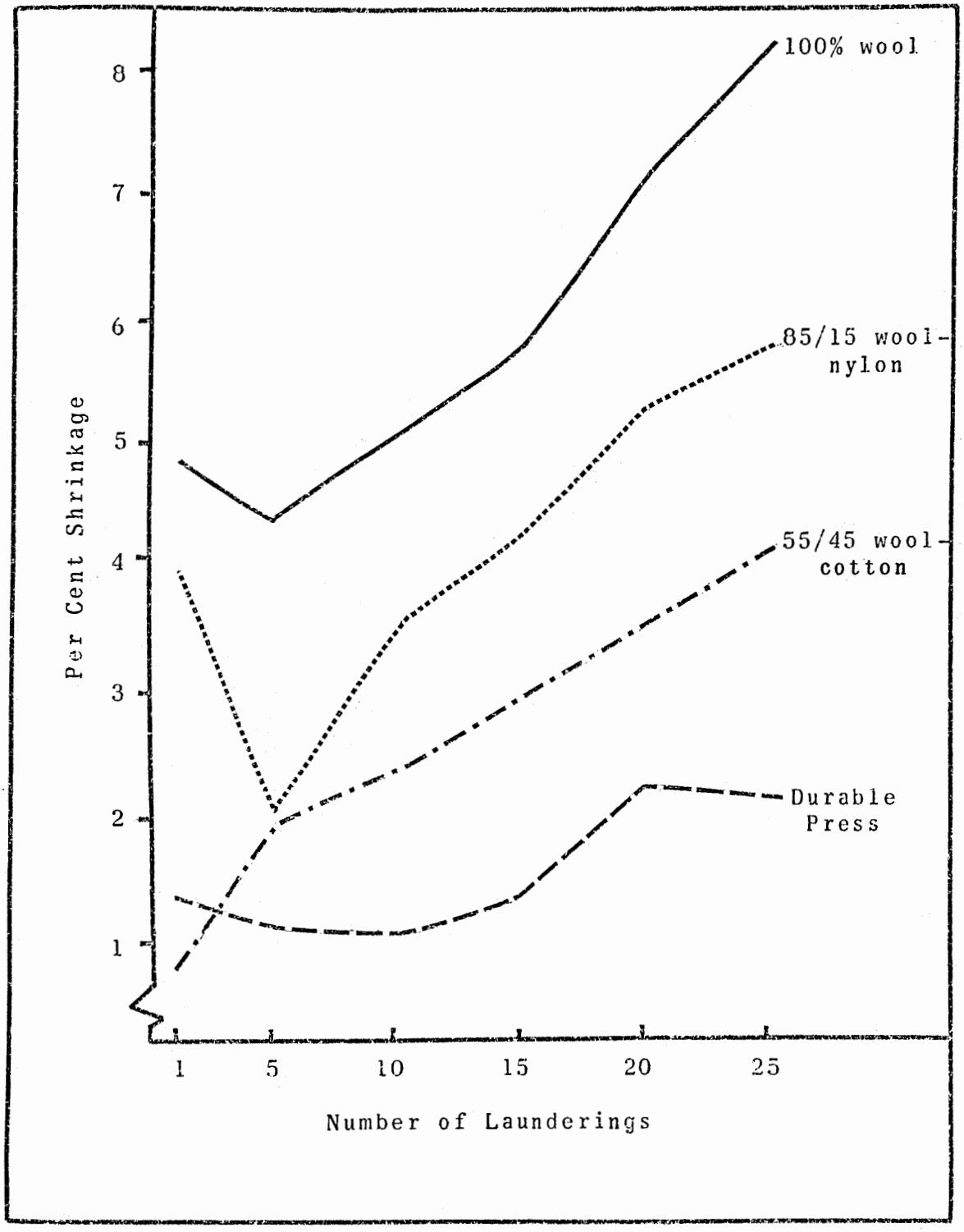


FIGURE 6

A COMPARISON OF THE DIMENSIONAL STABILITY IN THE WARP DIRECTION OF MACHINE WASHABLE AND DURABLE PRESS FABRICS LAUNDERED AT 140°F.

AIR PERMEABILITY

Tables VIII and IX in the Appendix contain the results of the tests which were administered for the purpose of determining the air permeability of the experimental fabrics. These tests were conducted on the fabrics in the initial stage and after they had been subjected to 15 and 25 laundering periods. The data pertaining to the fabrics laundered at 105°F. are recorded in Table VIII while Table IX contains the results of the fabrics laundered at 140°F. The statistical comparisons of the time required for 300 cubic centimeters of air to pass through the experimental fabrics are organized in Summary C with reference to fiber content and fabric finish.

AIR PERMEABILITY OF FABRICS LAUNDERED AT 105°F.

Machine Washable Fabrics. Statistical comparisons of the mean values of the three categories of machine washable fabrics with reference to their resistance to air penetration after 25 laundering periods at 105°F. showed the 100 per cent wool fabrics to be superior. As indicated by the comparisons shown in Summary C, the 4.98 seconds of time required for 300 cubic centimeters of air to penetrate the 100 per cent wool fabrics was less than that required by the 85/15 wool-nylon and the 55/45 wool-cotton with differences amounting to $P<0.010$ and $P<0.001$, respectively. No

difference was noted between the 85/15 wool-nylon and the 55/45 wool-cotton fabrics in this respect.

Figure 7 illustrates a slight increase in the resistance of the machine washable fabrics to the penetration of air as the number of laundering periods progressed from five through 25 periods. This seems to compare favorably with the shrinkage experienced by the fabrics throughout the study as shown in Figure 5 and discussed previously.

Durable Press Fabrics. When the compactness of each of the durable press fabrics was mathematically analyzed, Fabric M, a 50/20/20/10 wool-cotton-rayon-nylon blend, was found to have the least resistance to air permeability with a mean value of 10.73 seconds, followed by Fabric J, a 65/25/10 wool-rayon-nylon twill weave, which had a mean value of 11.47 seconds. The remaining three fabrics ranked in the following order with reference to air permeability: Fabric N, 50/40/10 wool-rayon-nylon; Fabric L, 50/40/10 wool-cotton-nylon; and Fabric K, 50/40/10 wool-cotton-nylon.

Statistical analyses of these data point to the superior performance in some instances of the fabrics composed of 50/40/10 wool-cotton-nylon (Fabrics K and L) with differences ranging from $P<0.010$ to $P<0.050$, as can be noted in Summary C.

Figure 7 shows that the resistance to air of the five durable press fabrics treated as a group was consistent

from the initial through 25 laundering periods at 105°F., thereby indicating that neither the number of laundering periods nor the temperature had any effect upon the fabrics with respect to air permeability.

COMPARISON OF THE AIR PERMEABILITY OF FABRICS LAUNDERED AT 105°F.

At the lower laundering temperature each machine washable fabric tested was distinctly more permeable to air than the durable press fabrics as shown by the statistical comparisons in Part II of Summary C. When both groups of fabrics as a whole were compared the analysis was highly favorable to the machine washable fabrics with reference to air permeability ($P<0.001$). The rate of air passage through the group of durable press fabrics remained constant throughout the specified laundering periods; whereas the air permeability decreased as laundering periods increased on the machine washable fabrics. These comparisons are shown in diagram form in Figure 7.

AIR PERMEABILITY OF FABRICS LAUNDERED AT 140°F.

Machine Washable Fabrics. The time required for a given volume of air (300 cubic centimeters) to pass through the machine washable fabrics laundered at 140°F. ranged from a low of 4.01 seconds required by the 55/45 wool-cotton

fabric to a higher value of 5.06 seconds required by the fabrics constructed of 100 per cent wool. When these two fabrics were compared by statistical means with reference to their resistance to air flow a significant difference of $P<0.001$, favorable to the 100 per cent wool, existed. The all-wool fabrics also proved to be more resistant than the 85/15 wool-nylon fabrics ($P<0.010$) as shown in Summary C, but when comparisons were made between the two blend levels a significant difference was not evident.

The pattern of resistance of air permeability of the experimental fabrics laundered at 140°F. was very similar to that shown in Figure 7. It may be noted that the resistance of the 100 per cent wool fabrics to air permeability increased progressively as laundering periods increased; whereas the patterns formed by the performance of the 85/15 wool-nylon and the 55/45 wool-cotton fabrics were erratic.

Durable Press Fabrics. The least resistance to air permeability of the durable press fabrics laundered at 140°F. was demonstrated by Fabric M, a blend of 50/20/20/10 wool-cotton-rayon-nylon, with a mean value of 11.03 seconds. Fabric J, 65/25/10 wool-rayon-nylon, ranked second with Fabrics L, K, and N showing greatest resistance to air permeability. After 25 laundering periods the air permeability of each fabric was at least slightly reduced from the initial findings.

An analysis of the performance of these fabrics from the statistical point of view showed that Fabrics K and L, composed of a 40 per cent blend of cotton, and Fabric N with a comparable amount of rayon were superior with respect to air permeability in most of the comparisons as indicated in Summary C.

An increased resistance to air permeability of the durable press fabrics as a group was observed as the laundering periods progressed to 20 and 25 periods.

COMPARISON OF THE AIR PERMEABILITY OF FABRICS LAUNDERED AT 140°F.

The durable press fabrics showed a higher resistance to air permeability than the machine washable fabrics laundered at 140°F. as indicated by a difference which was highly significant ($P<0.001$). After 25 launderings the rate of air permeability for the five durable press fabrics was 13.5 seconds, while that of the machine washable fabrics amounted to 4.63 seconds.

COMPARISON OF THE EFFECTS OF LAUNDERING TEMPERATURES OF 105°F. AND 140°F. UPON THE AIR PERMEABILITY OF FABRICS

No significant differences in air permeability could be attributed to the laundering temperatures used in the

study. However, according to mean values, each fabric laundered at 140°F. had a greater resistance to air permeability than those laundered at 105°F.

In comparing the machine washable fabrics to the durable press it was evident that both at 105°F. and 140°F. the machine washable fabrics were more permeable by air than the durable press fabrics, the probability of significance being $P<0.001$ at each temperature.

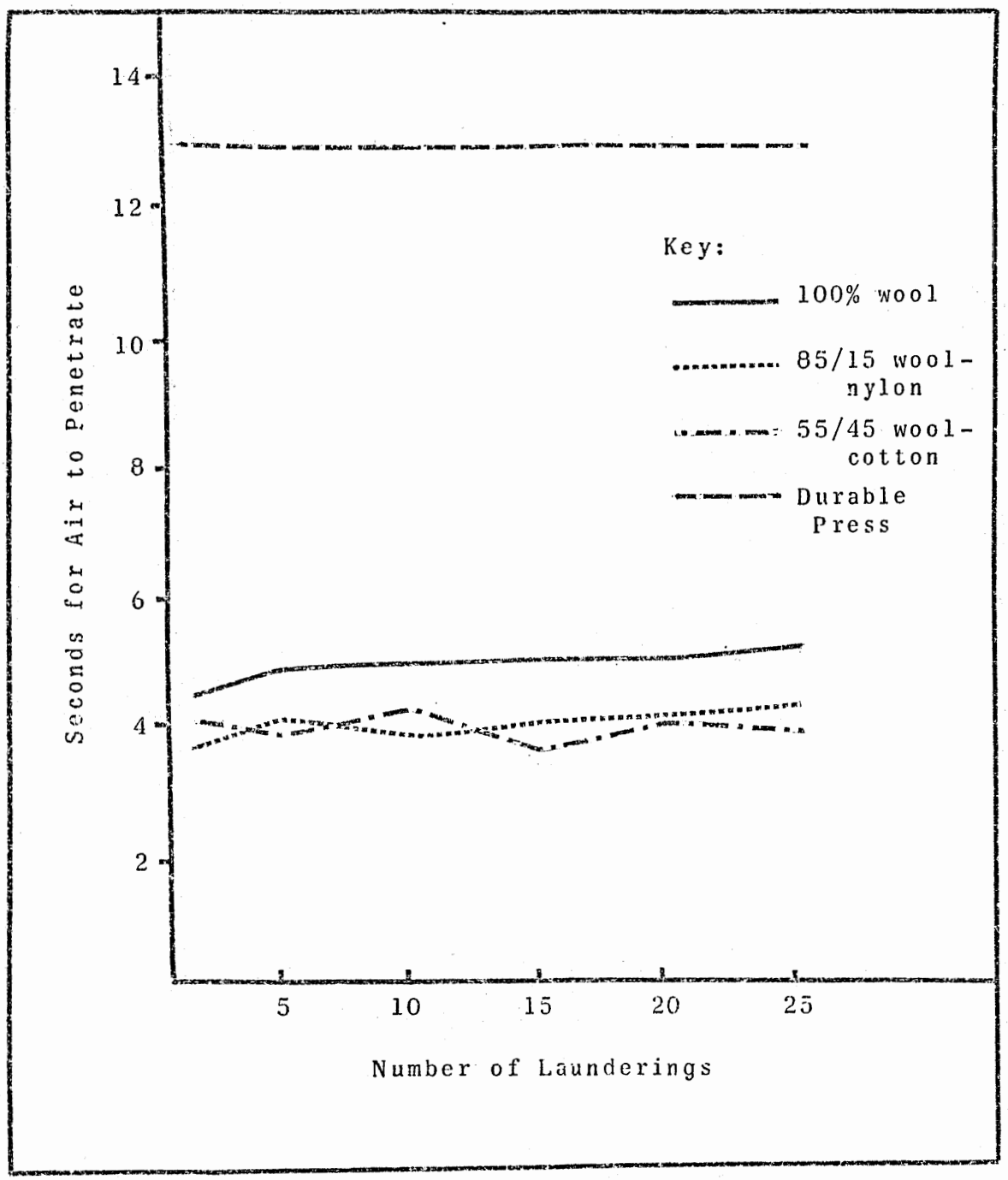


FIGURE 7

A COMPARISON OF THE AIR PERMEABILITY OF MACHINE WASHABLE AND DURABLE PRESS FABRICS LAUNDERED AT 105°F.

SUMMARY C

STATISTICAL COMPARISONS OF THE MEAN RATE OF AIR PERMEABILITY OF THE EXPERIMENTAL FABRICS AFTER A SERIES OF 25 LAUNDERING PERIODS

PART I. FIBER CONTENT

Fabric Comparisons	Laundered at 105°F.		Laundered at 140°F.	
	Mean Value	Probabil. of Signif.	Mean Value	Probabil. of Signif.
Machine Washable Fabrics				
100% Wool	4.98	P<0.010	5.06	P<0.010
85/15 Wool-Nylon	4.00		4.22	
100% Wool	4.98	P<0.001	5.06	P<0.001
55/45 Wool-Cotton	3.97		4.01	
85/15 Wool-Nylon	4.00	N.S.	4.22	P<0.200
55/45 Wool-Cotton	3.97		4.01	
Durable Press Fabrics				
J 65/25/10 Wool-Rayon-Nylon	11.47	P<0.050	11.40	P<0.050
K 50/40/10 Wool-Cotton-Nylon	14.43		14.27	
J 65/25/10 Wool-Rayon-Nylon	11.47	P<0.200	11.40	N.S.
L 50/40/10 Wool-Cotton-Nylon	13.80		12.67	
J 65/25/10 Wool-Rayon-Nylon	11.47	N.S.	11.40	N.S.
M 50/20/20/10 Wool-Cotton-Rayon-Nylon	10.73		11.03	
J 65/25/10 Wool-Rayon-Nylon	11.47	P<0.200	11.40	P<0.020
N 50/40/10 Wool-Rayon-Nylon	13.57		15.60	
K 50/40/10 Wool-Cotton-Nylon	14.43	N.S.	14.27	P<0.200
L 50/40/10 Wool-Cotton-Nylon	13.80		12.67	
K 50/40/10 Wool-Cotton-Nylon	14.43	P<0.010	14.27	P<0.020
M 50/20/20/10 Wool-Cotton-Rayon-Nylon	10.73		11.03	
K 50/40/10 Wool-Cotton-Nylon	14.43	N.S.	14.27	N.S.
N 50/40/10 Wool-Rayon-Nylon	13.57		15.60	

SUMMARY C (CONTINUED)

STATISTICAL COMPARISONS OF THE MEAN RATE OF AIR PERMEABILITY OF THE EXPERIMENTAL FABRICS AFTER A SERIES OF 25 LAUNDERING PERIODS

PART I. FIBER CONTENT (CONTINUED)

Fabric Comparisons	Laundered at 105°F.		Laundered at 140°F.	
	Mean Value	Probabil. of Signif.	Mean Value	Probabil. of Signif.
L 50/40/10 Wool-Cotton-Nylon	13.80	P<0.050	12.67	P<0.200
M 50/20/20/10 Wool-Cotton-Rayon-Nylon	10.73		11.03	
L 50/40/10 Wool-Cotton-Nylon	13.80	N.S.	12.67	P<0.050
N 50/40/10 Wool-Rayon-Nylon	13.57		15.60	
M 50/20/20/10 Wool-Cotton-Rayon-Nylon	10.73	P<0.100	11.03	P<0.010
N 50/40/10 Wool-Rayon-Nylon	13.57		15.60	

PART II. FABRIC FINISHES

Machine Washable	4.52	P<0.001	4.62	P<0.001
Durable Press	12.80		12.99	
100% Wool	4.98	P<0.001	5.06	P<0.001
Durable Press	12.80		12.99	
85/15 Wool-Nylon	4.00	P<0.001	4.22	P<0.001
Durable Press	12.80		12.99	
55/45 Wool-Cotton	3.97	P<0.001	4.01	P<0.001
Durable Press	12.80		12.99	

PILLING RESISTANCE

The nine machine washable fabrics were subjected to the random tumble pilling test before laundering and after 15 and 25 periods of laundering. The resulting data may be found in Tables X and XI in the Appendix. The performance of the fabrics laundered at 105°F. is shown in Table X, while Table XI contains the data for the fabrics laundered at 140°F. Due to a lack of fabric the durable press fabrics were not tested for pilling resistance.

PILLING RESISTANCE OF MACHINE WASHABLE FABRICS LAUNDERED AT 105°F.

The statistical comparisons of the machine washable fabrics showed no significant differences between the three categories of fabrics relative to their resistance to pilling. The mean values were as follows:

Fabrics	Mean Values
100% Wool	4.31
85/15 Wool-Nylon	4.07
55/45 Wool-Cotton	4.29

The degree to which each of the respective types of machine washable fabrics pilled as a result of laundering at 105°F. is illustrated in the linear graph of Figure 8. It may be observed that through the first five laundering periods the 55/45 wool-cotton fabrics showed a greater

resistance to pilling than did the other fabrics, but after 15 laundering periods a slightly greater resistance was noted in the 100 per cent wool fabrics. The supporting data are contained in Table X.

PILLING RESISTANCE OF MACHINE WASHABLE FABRICS LAUNDERED AT 140°F.

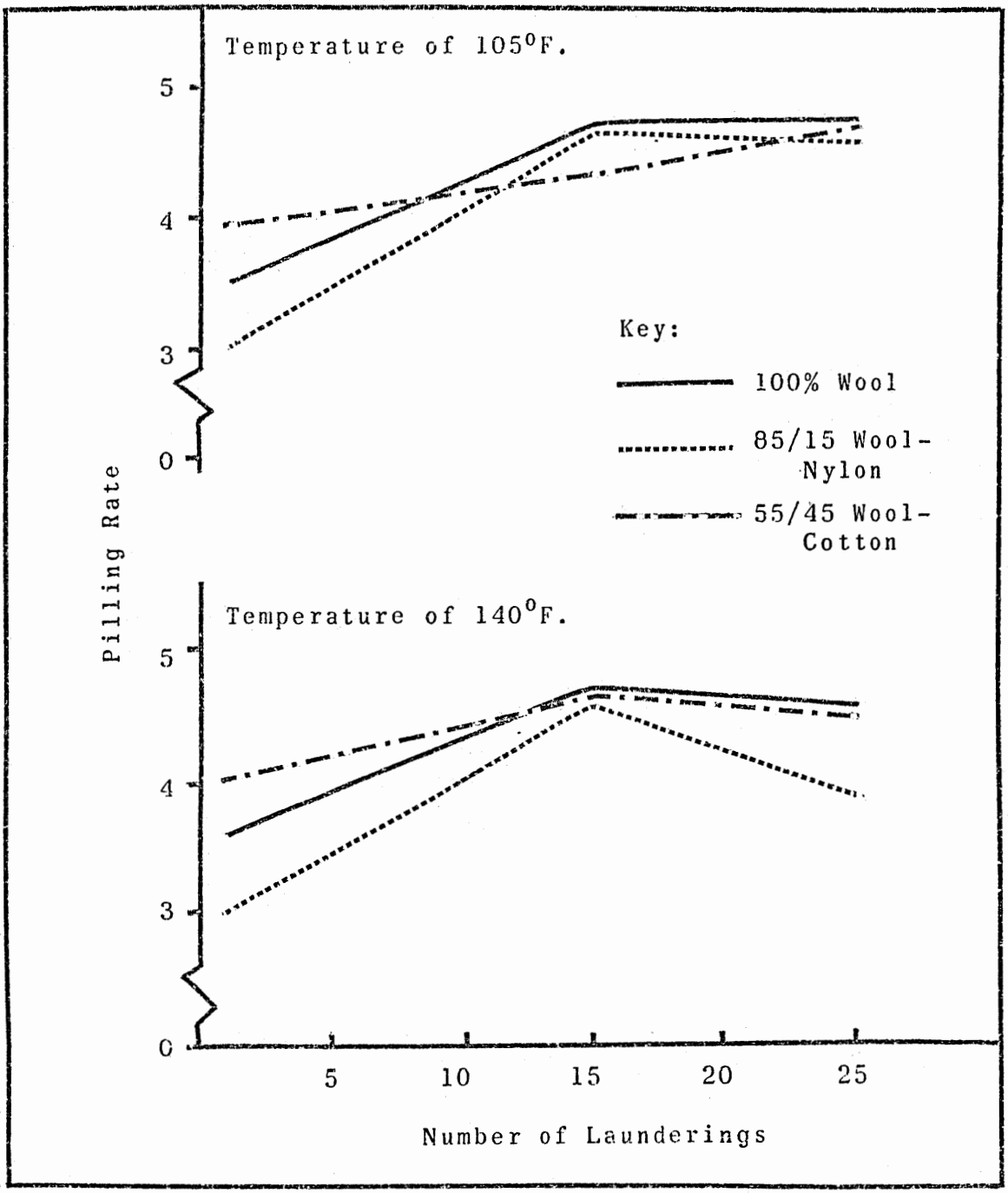
When the machine washable fabrics laundered at 140°F. were evaluated for their pilling resistance, the data did not reveal significant differences between the fabrics. The mean values representative of the pilling resistance of these fabrics were as follows:

Fabrics	Mean Values
100% Wool	4.25
85/15 Wool-Nylon	3.86
55/45 Wool-Cotton	4.33

From laundering periods 15 through 25 the 100 per cent wool and the 55/45 wool-cotton showed good pilling resistance as indicated by ratings ranging from 4.50 to 4.65 shown in Figure 8. The 85/15 wool-nylon varied from the other two machine washable fabrics in its pattern of pilling resistance in that it showed increased resistance to pilling through 15 laundering periods, but this resistance decreased considerably from that period through the remainder of the study.

COMPARISON OF THE EFFECTS OF LAUNDERING TEMPERATURES OF 105°F. AND 140°F. UPON THE PILLING RESISTANCE OF THE FABRICS

The effect of the laundering temperatures on the experimental fabrics was determined by a statistical comparison of the fabrics laundered at 105°F. with the corresponding fabrics laundered at 140°F. The results indicated that temperature was not an important factor in the pilling resistance of the machine washable fabrics.


Temperature of 105°F.
5
4
3
0
Key:
100% Wool
85/15 Wool-Nylon
55/45 Wool-Cotton
Temperature of 140°F.
5
4
3
0
Pilling Rate
5
10
15
20
25
Number of Launderings

BREAKING STRENGTH

The breaking strength test was performed on the machine washable fabrics before laundering and after five, 10, 15, 20, and 25 laundering periods, respectively. Tables XII through XV in the Appendix contain the data which resulted from these tests. Mean breaking strength values for the warp and filling directions of the fabrics laundered at 105°F. are tabulated in Tables XII and XIII; whereas the values for the fabrics laundered at 140°F. are located in Tables XIV and XV. All strength values were calculated on the basis of pounds of breaking strength per 100 yarns.

Due to a shortage of durable press fabrics the breaking strength was not determined on these fabrics.

BREAKING STRENGTH OF MACHINE WASHABLE FABRICS LAUNDERED AT 105°F.

Warp Direction. The 85/15 wool-nylon fabrics proved to be consistently stronger in the warp direction at each testing interval when laundered at 105°F. than either the 100 per cent wool or the 55/45 wool-cotton fabric. The pattern of performance for the three types of fabrics is shown in Figure 9.

Despite the fact that the 85/15 wool-nylon fabrics were stronger warpwise throughout the study than the other

fabrics they suffered the greatest percentage of strength loss (19.2 per cent) due to the series of 25 launderings. The strength values of these fabrics declined from an initial strength of 66.2 pounds per 100 yarns to 42.6 pounds while the loss experienced by the 100 per cent wool fabrics ranged from 51.2 to 42.6 pounds. The least amount of strength loss (six pounds) was observed in the warp direction of the 55/45 wool-cotton fabric.

A statistical comparison of the mean breaking strength data for the three machine washable fabrics revealed the actual strength of the 85/15 wool-nylon fabrics to be highly superior ($P<0.001$) at each comparison as is evident in Summary D. The superior strength of the 85/15 wool-nylon fabric may be attributed to the nylon content. With reference to the 55/45 wool-cotton fabric it should be noted that this fabric was lighter in weight than the other experimental fabrics which may account in part for its lower breaking strength. The breaking strength difference between the 100 per cent wool and the 55/45 wool-cotton was not significant.

Filling Direction. In the filling direction the 85/15 wool-nylon again excelled in breaking strength having a mean value of 57.3 pounds per 100 yarns; whereas the 100 per cent wool and the 55/45 wool-cotton exhibited mean values of 44.4 and 31.2 pounds, respectively. The

superiority in tensile strength of the 85/15 wool-nylon was significant ($P<0.001$) when compared with both the 100 per cent wool and the 55/45 wool-cotton. The difference in filling breaking strength between the 100 per cent wool and the 55/45 wool-cotton was in favor of the 100 per cent wool fabrics at the one per cent level of significance. See Summary D.

Figure 9 shows that the 85/15 wool-nylon fabrics demonstrated the greatest breaking strength of the machine washable fabrics at each interval of testing. As was the case in the warp direction the fabrics decreased in filling strength to a greater extent than did the other two types of machine washable fabrics. The 100 per cent wool fabrics had an average initial strength of 51.2 pounds, and after 25 launderings their strength decreased to 41.8. The 55/45 wool-cotton fabric showed the most consistent filling breaking of the machine washable fabrics with an initial strength of 32.8 pounds and a final strength of 29.8 pounds per 100 yarns after 25 laundering periods. There was little fluctuation in strength at the various testing intervals for the 55/45 wool-cotton fabric which can be observed in Figure 9.

BREAKING STRENGTH OF MACHINE WASHABLE FABRICS LAUNDERED AT 140°F.

Warp Direction. On studying the data in Part II of Summary D it can be observed that the 85/15 wool-nylon was

superior in warp breaking strength to both the 100 per cent wool and the 55/45 wool-cotton with a probability of significance of $P<0.001$. There was no statistical difference when the 100 per cent wool and 55/45 wool-cotton were compared with reference to the warp breaking strength values.

After 25 laundering periods the 85/15 wool-nylon maintained the highest warp breaking strength, but the strength lost by this fabric was greater than that lost by the other fabrics. The 85/15 wool-nylon had an initial warp breaking strength of 66.2 which decreased to 54.5 after 25 launderings. The 100 per cent wool changed from 51.2 pounds per 100 yarns before laundering to 41.0 pounds after 25 laundering periods. The 55/45 wool-cotton maintained a fairly constant breaking strength throughout the specified laundering periods varying only from 42.5 initially to 37.7 pounds after the last laundering. Figure 10 shows the change in warp breaking strength as the number of laundering periods at 140°F. progressed. Further supporting data may be found in Table XIV of the Appendix.

Filling Direction. When statistical comparisons were made of the breaking strength values in the filling direction, it was found that the 85/15 wool-nylon was superior to the 100 per cent wool ($P<0.010$) and to the 55/45 wool-cotton ($P<0.001$). A comparison of the 100 per cent wool and the 55/45 wool-cotton exhibited breaking

strength differences significant at the one per cent level in favor of the 100 per cent wool.

After 25 laundering periods the 85/15 wool-nylon fabrics retained the highest filling tensile strength (49.8 pounds per 100 yarns). The final breaking strengths for the 100 per cent wool and the 55/45 wool-cotton were 41.0 and 28.9 pounds, respectively. The 55/45 wool-cotton varied little in strength throughout the specified launderings.

COMPARISON OF THE EFFECTS OF THE LAUNDERING TEMPERATURES OF 105°F. AND 140°F. ON THE BREAKING STRENGTH OF FABRICS

When the warp breaking strength values were compared with reference to laundering temperature, it was noted that the breaking strength values were generally lower, but not to a significant degree, for the fabrics laundered at 140°F. than for the same fabrics laundered at 105°F.

A comparison of the filling breaking strengths of the machine washable fabrics laundered at the two temperatures revealed results similar to those obtained in the treatment of the warp data.

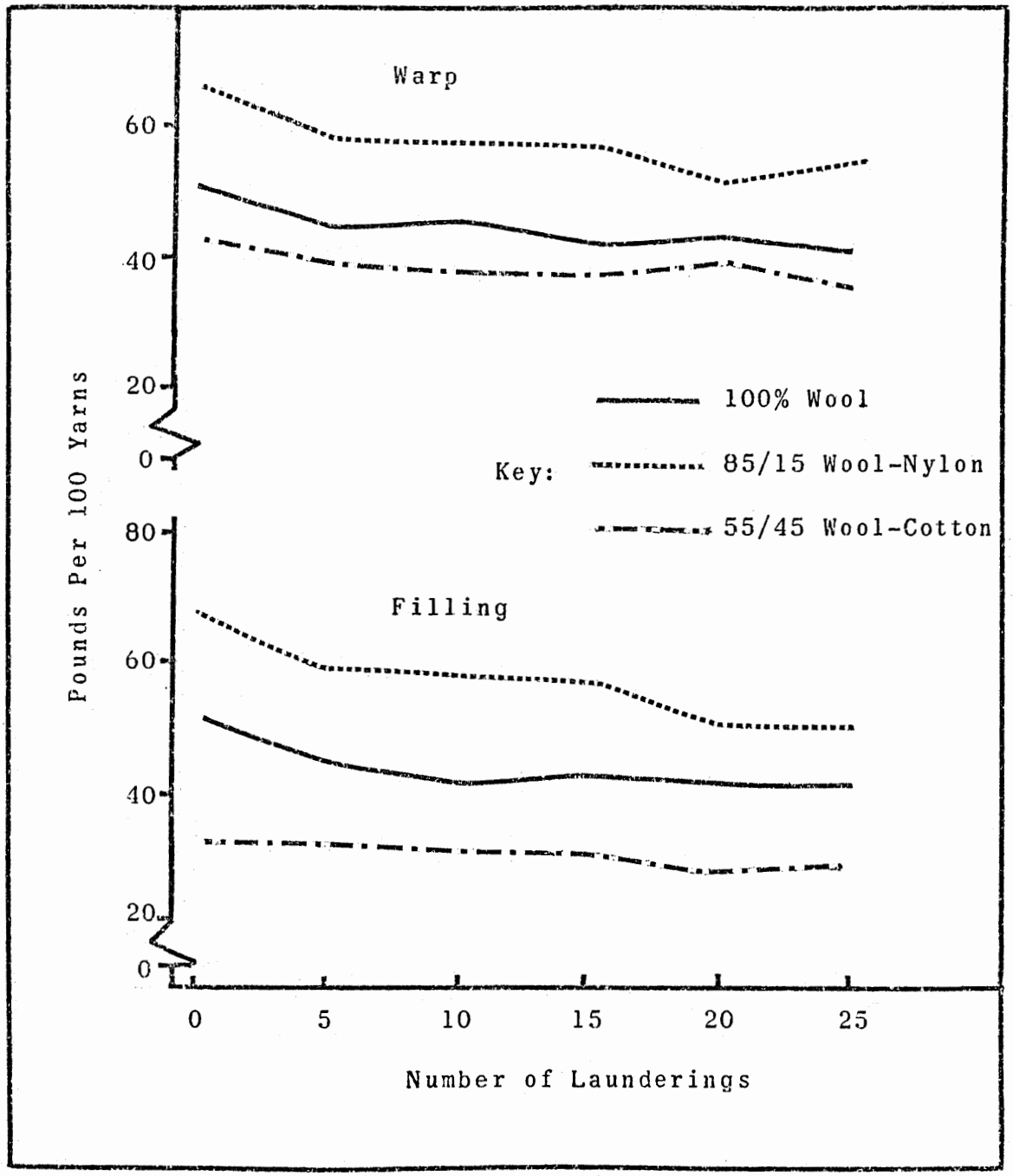


FIGURE 9

A COMPARISON OF THE BREAKING STRENGTH VALUES OF THE MACHINE WASHABLE FABRICS LAUNDERED AT 105°F.

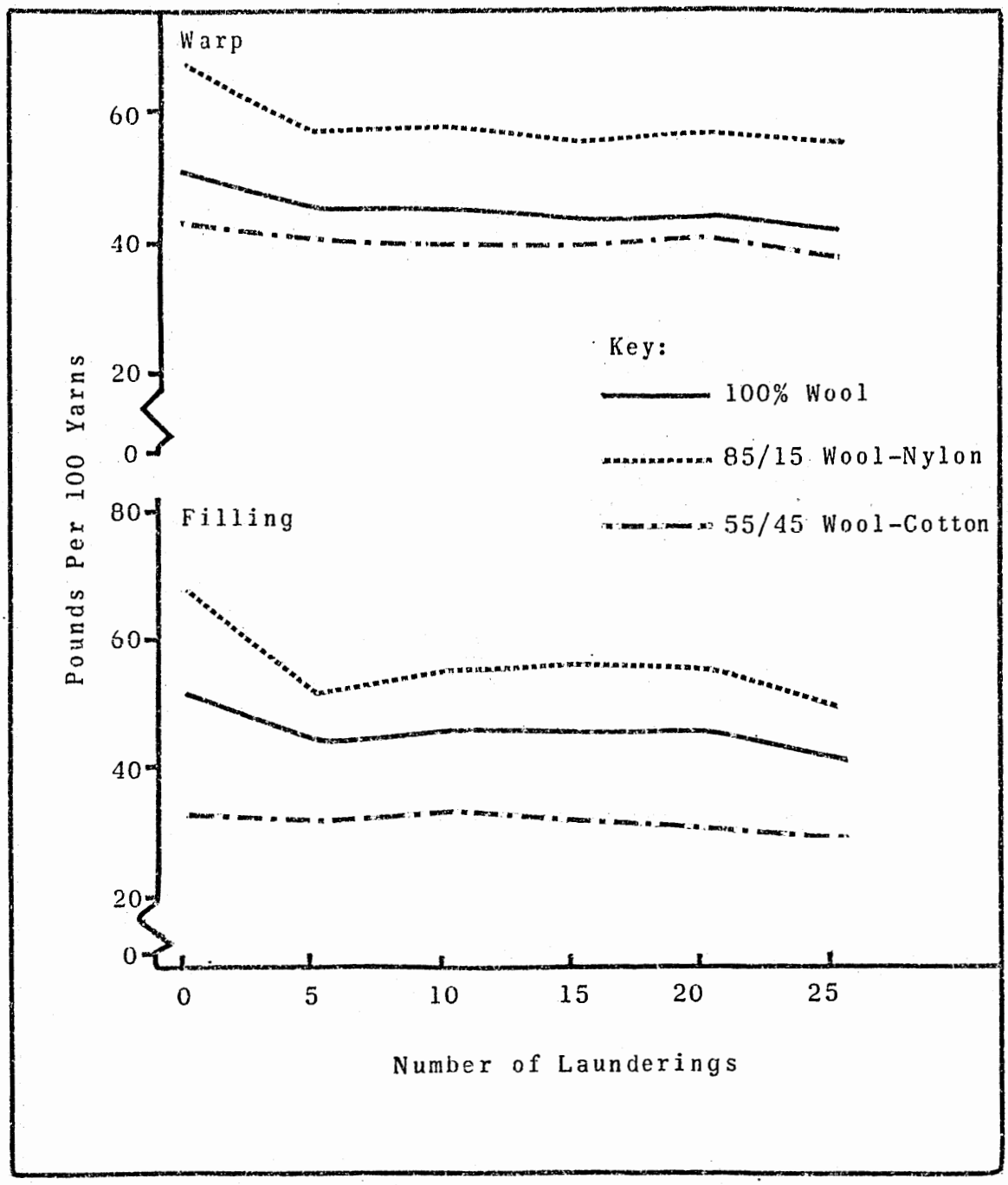


FIGURE 10

A COMPARISON OF THE BREAKING STRENGTH VALUES OF THE MACHINE WASHABLE FABRICS LAUNDERED AT 140°F.

SUMMARY D

STATISTICAL COMPARISONS OF THE MEAN BREAKING STRENGTH VALUES OF THE MACHINE WASHABLE FABRICS AFTER A SERIES OF 25 LAUNDERINGS AT 105°F. AND 140°F.

PART I. LAUNDERING TEMPERATURE 105°F.

Fabric Comparisons	Warp Direction		Filling Direction	
	Mean Values	Probability of Significance	Mean Values	Probability of Significance
100% Wool 85/15 Wool-Nylon	45.6 58.8	P<0.001	44.4 57.3	P<0.001
100% Wool 55/45 Wool-Cotton	45.6 39.8	N.S.	44.4 31.2	P<0.010
85/15 Wool-Nylon 55/45 Wool-Cotton	58.8 39.8	P<0.001	57.3 31.2	P<0.001

PART II. LAUNDERING TEMPERATURE 140°F.

100% Wool 85/15 Wool-Nylon	44.9 57.7	P<0.001	45.1 55.7	P<0.010
100% Wool 55/45 Wool-Cotton	44.9 39.9	N.S.	45.1 31.0	P<0.010
85/15 Wool-Nylon 55/45 Wool-Cotton	57.7 39.9	P<0.001	55.7 31.0	P<0.001

PART III. COMPARISON OF LAUNDERING TEMPERATURES

100% Wool 105°F. 140°F.	45.6 44.9	N.S.	44.4 45.1	N.S.
85/15 Wool-Nylon 105°F. 140°F.	58.8 57.7	N.S.	57.3 55.7	N.S.
55/45 Wool-Cotton 105°F. 140°F.	39.8 39.9	N.S.	31.2 31.0	N.S.

RESISTANCE TO FLAT ABRASION

The resistance of the machine washable fabrics to flat abrasion was derived from calculations of the per cent loss in breaking strength which these fabrics suffered after 200 cycles of abrasion. The determinations which were made before laundering and after five, 10, 15, 20, and 25 laundering periods are in Tables XVI through XIX in the Appendix of this thesis. Tables XVI and XVII contain the findings from the fabrics laundered at 105°F. while the changes in breaking strength recorded for the fabrics laundered at 140°F. are contained in Tables XVIII and XIX. The durable press fabrics were not subjected to flat abrasion because there was an insufficient amount of these fabrics for the tests.

RESISTANCE TO FLAT ABRASION OF MACHINE WASHABLE FABRICS LAUNDERED AT 105°F.

Warp Direction. When statistical comparisons were made between the three categories of machine washable fabrics laundered at 105°F., it was found that the 100 per cent wool had superior abrasion resistance in the warp direction to that of the 85/15 wool-nylon and the 55/45 wool-cotton with differences of $P<0.001$ and $P<0.050$, respectively. The 100 per cent wool experienced only a negligible mean warp loss in strength of 0.15 per cent while the 55/45 wool-cotton

showed a mean loss of 7.68 per cent and the 85/15 wool-nylon a loss of 11.66 per cent. The difference in breaking strength loss due to flat abrasion was not significant when the 85/15 wool-nylon and the 55/45 wool-cotton were compared. The basis for these facts may be observed in Part I of Summary E.

Figure 11 graphically depicts the effects of flat abrasion upon the breaking strength of the warp yarns of these machine washable fabrics. The 85/15 wool-nylon and the 55/45 wool-cotton showed varying degrees of loss in breaking strength at each evaluation period except after five laundering periods when the 85/15 wool-nylon experienced a fractional per cent gain in strength. The 100 per cent wool fabrics exhibited gains in strength from laundering periods 10 through 20.

Filling Direction. In comparing the statistical results for the filling direction it may be noted that only one difference of significance occurred among the three fabric types. The resistance of the 100 per cent wool was superior to that of the 55/45 wool-cotton fabric at the one per cent level. According to mean values representative of the resistance to flat abrasion the experimental fabrics were automatically arranged in the following sequence: 100 per cent wool; 85/15 wool-nylon; and 55/45 wool-cotton.

The filling pattern of resistance to flat abrasion may be observed in Figure 11. The 100 per cent wool and the 85/15 wool-nylon each experienced some gains in strength as a result of abrasion.

RESISTANCE TO FLAT ABRASION OF
MACHINE WASHABLE FABRICS
LAUNDERED AT 140°F.

Warp Direction. An investigation of the data in Part II of Summary E indicates that the 100 per cent wool fabrics excelled warpwise in their resistance to flat abrasion when compared to the 85/15 wool-nylon ($P<0.020$). No other noteworthy differences occurred in the warp direction.

The 100 per cent wool fabric experienced a gain in strength following flat abrasion after laundering periods 10, 15, and 20 while the 55/45 wool-cotton demonstrated a gain in strength of 3.0 per cent after 20 laundering periods and the 85/15 wool-nylon sustained varying degrees of loss in strength at each interval of testing. See Figure 12.

Filling Direction. In the filling direction the 100 per cent wool exhibited a superior resistance ($P<0.010$) to flat abrasion when compared to the 55/45 wool-cotton while no difference was observed in a comparison between the 100 per cent wool and the 85/15 wool-nylon. In a comparison between the 85/15 wool-nylon and the 55/45 wool-

cotton fabrics no difference of significance was apparent. Supporting data may be observed in Part II of Summary E.

The graph in Figure 11 concerned with the filling direction of the fabrics shows that each fabric suffered a loss in breaking strength due to flat abrasion at each evaluation period except the 85/15 wool-nylon which experienced a fractional gain in strength after 20 laundering periods.

COMPARISON OF THE EFFECTS OF LAUNDERING TEMPERATURES OF 105°F. AND 140°F. UPON THE BREAKING STRENGTH OF MACHINE WASHABLE FABRICS AFTER FLAT ABRASION

To determine the effects of the two laundering temperatures on the breaking strength of the experimental fabrics after flat abrasion, the fabrics laundered at 105°F. were compared to the corresponding fabrics laundered at 140°F. The findings indicated that the laundering temperature was not a significant factor in the breaking strength after flat abrasion in either the warp or filling directions of the three categories of machine washable fabrics. Results of a statistical analysis of these data are shown in Part III of Summary E.

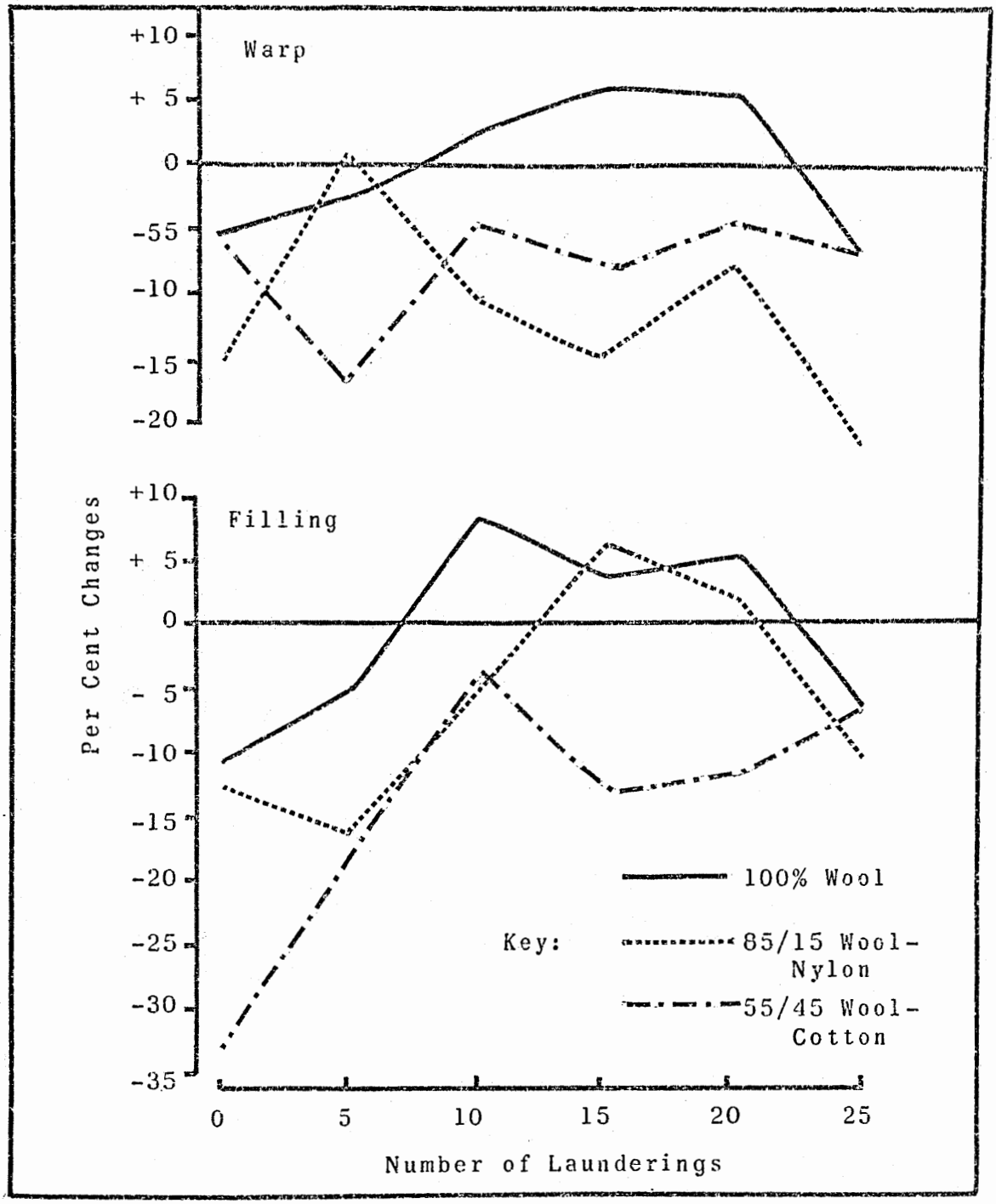
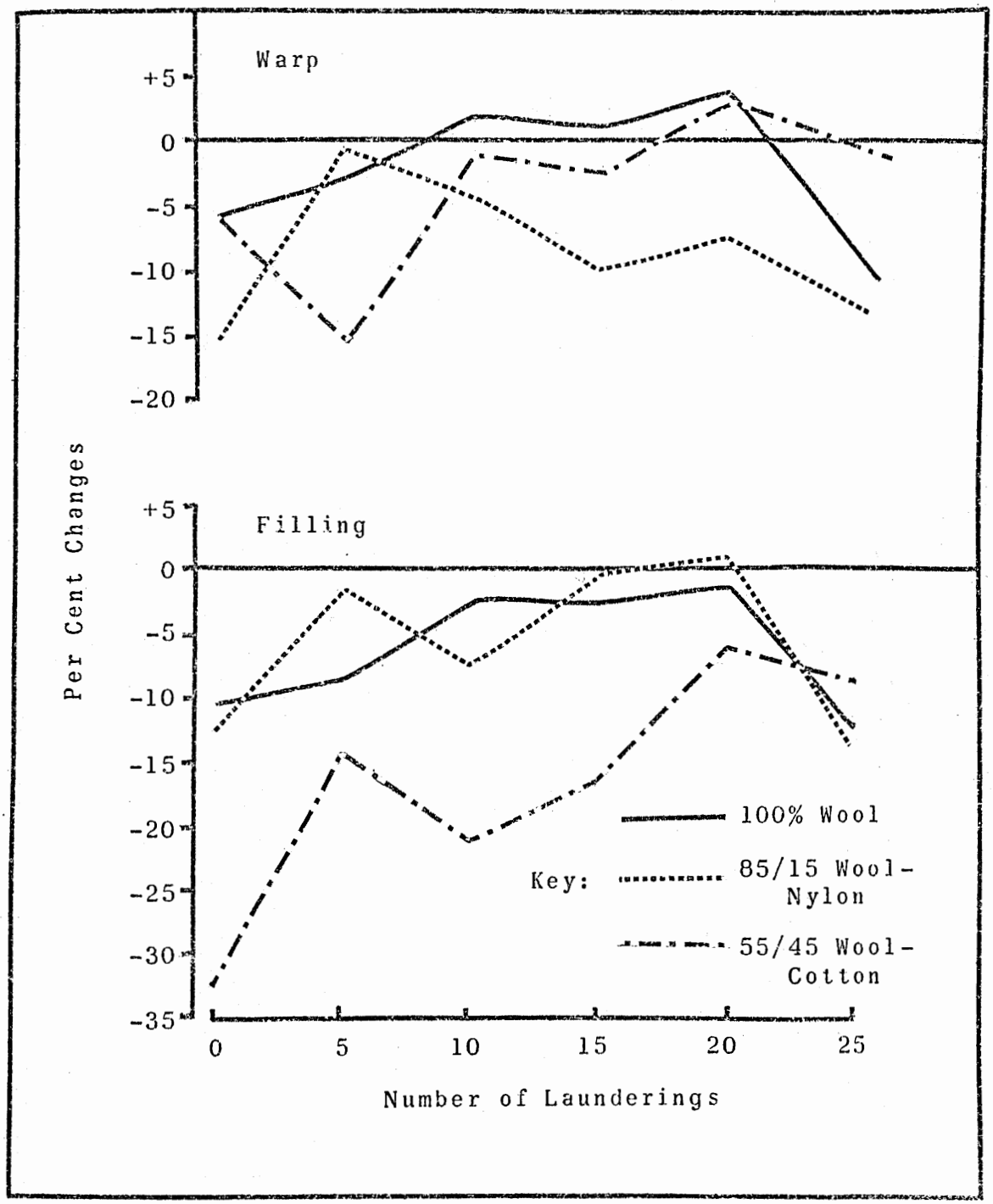


FIGURE 11

A COMPARISON OF THE MEAN PER CENT CHANGES IN BREAKING STRENGTH DUE TO FLAT ABRASION OF MACHINE WASHABLE FABRICS LAUNDERED AT 105°F.


Warp
+5
0
-5
-10
-15
-20
Filling
+5
0
-5
-10
-15
-20
-25
-30
-35
Per Cent Changes
0
5
10
15
20
25
Number of Launderings
Key:
100% Wool
85/15 Wool-Nylon
55/45 Wool-Cotton

SUMMARY E

STATISTICAL COMPARISONS OF THE PER CENT CHANGES IN BREAKING STRENGTH OF THE MACHINE WASHABLE FABRICS AFTER A SERIES OF 25 LAUNDERING PERIODS AT 105°F. AND 140°F.

PART I. LAUNDERING TEMPERATURE 105°F.

Fabric Comparisons	Warp Direction		Filling Direction	
	Mean Values	Probability of Significance	Mean Values	Probability of Significance
100% Wool 85/15 Wool-Nylon	- 0.15 -11.66	P<0.001	- 0.90 - 6.36	P<0.200
100% Wool 55/45 Wool-Cotton	- 0.15 - 7.68	P<0.050	- 0.90 -14.47	P<0.010
85/15 Wool-Nylon 55/45 Wool-Cotton	-11.66 - 7.68	N.S.	- 6.36 -14.47	P<0.200

PART II. LAUNDERING TEMPERATURE 140°F.

100% Wool 85/15 Wool-Nylon	- 1.64 - 8.48	P<0.020	- 6.30 - 6.74	N.S.
100% Wool 55/45 Wool-Cotton	- 1.64 - 3.63	N.S.	- 6.30 -16.58	P<0.010
85/15 Wool-Nylon 55/45 Wool-Cotton	- 8.48 - 3.63	N.S.	- 6.74 -16.58	P<0.100

PART III. COMPARISON OF LAUNDERING TEMPERATURES

100% Wool 105°F. 140°F.	- 0.15 - 1.64	N.S.	- 0.90 - 6.30	N.S.
85/15 Wool-Nylon 105°F. 140°F.	-11.66 - 8.48	N.S.	- 6.36 - 6.74	N.S.
55/45 Wool-Cotton 105°F. 140°F.	- 7.68 - 3.63	N.S.	-14.47 -16.58	N.S.

RESISTANCE TO FLEXING AND ABRASION

The nine machine washable fabrics were subjected to flexing and abrasion tests before laundering and after five, 10, 15, 20, and 25 laundering periods. The results of the tests which are contained in Tables XX through XXIII of the Appendix were calculated on the basis of the average number of cycles necessary to rupture 100 yarns. Tables XX and XXI are concerned with the data on the fabrics laundered at 105°F., while Tables XXII and XXIII are composed of the findings from the fabrics laundered at 140°F. The flexing and abrasion resistance was not determined on the durable press fabrics due to a shortage of fabric.

Statistical comparisons were made with reference to fiber content and laundering temperature and used as the basis for the following discussion.

FLEXING AND ABRASION RESISTANCE OF MACHINE WASHABLE FABRICS LAUNDERED AT 105°F.

Warp Direction. When the fabrics were analyzed statistically for their resistance to flexing and abrasion in the warp direction, no significant differences occurred from any of the comparisons. A consideration of the mean values revealed that the 55/45 wool-cotton fabric ranked first with a mean of 568 cycles required to affect a rupture.

The 85/15 wool-nylon and the 100 per cent wool followed in the order mentioned with mean values of 522 and 516, respectively, required for rupture.

Filling Direction. Although the differences were not statistically significant in the filling direction the flexing and abrasion resistance of the 85/15 wool-nylon, on the basis of mean values, surpassed that of both the 55/45 wool-cotton and the 100 per cent wool. Cycles of flexing and abrasion necessary for rupturing the fabrics were as follows: 505 cycles for the wool-nylon fabrics; 421 cycles for the 55/45 wool-cotton; and 393 cycles for the 100 per cent wool fabrics.

The changes in the flexing and abrasion resistance as the laundering periods progressed had no detectable pattern in either the warp or the filling direction as may be noted in Tables XX and XXI.

FLEXING AND ABRASION RESISTANCE OF MACHINE WASHABLE FABRICS LAUNDERED AT 140°F.

Warp Direction. A review of the statistical comparisons revealed no significant differences in the warp flexing and abrasion resistance of the fabrics laundered at 140°F. On the basis of mean values the fabrics ranked in

the following order with reference to their resistance: 55/45 wool-cotton; 85/15 wool-nylon; and 100 per cent wool.

Filling Direction. In the filling direction no differences were found between the fabric categories when a statistical analysis of the data was conducted. The mean values ranged from a high of 472 cycles required to rupture the 85/15 wool-nylon fabrics to a low of 361 cycles required by the 100 per cent wool. An intermediate value of 409 cycles was recorded for the 55/45 wool-cotton fabric.

COMPARISON OF THE EFFECTS OF LAUNDERING TEMPERATURES OF 105°F. AND 140°F. UPON THE FLEXING AND ABRASION RESISTANCE OF FABRICS

Notable differences in resistance to flexing and abrasion could not be attributed to the laundering temperatures either in the warp or filling directions of the experimental fabrics. However, it should be pointed out that in both directions each fabric category showed higher mean values when laundered at 105°F. than its counterpart did laundered at 140°F. The diagrammatical comparison in Figure 13 substantiates this statement. A similarity of pattern in the flexing and abrasion resistance can be seen when the fabrics laundered at two temperatures were compared in the graph. It is interesting to note that the three categories of machine washable fabrics ranked in the following order irrespective of laundering temperature.

Rank	Warp	Filling
I	55/45 Wool-Cotton	85/15 Wool-Nylon
II	85/15 Wool-Nylon	55/45 Wool-Cotton
III	100% Wool	100% Wool

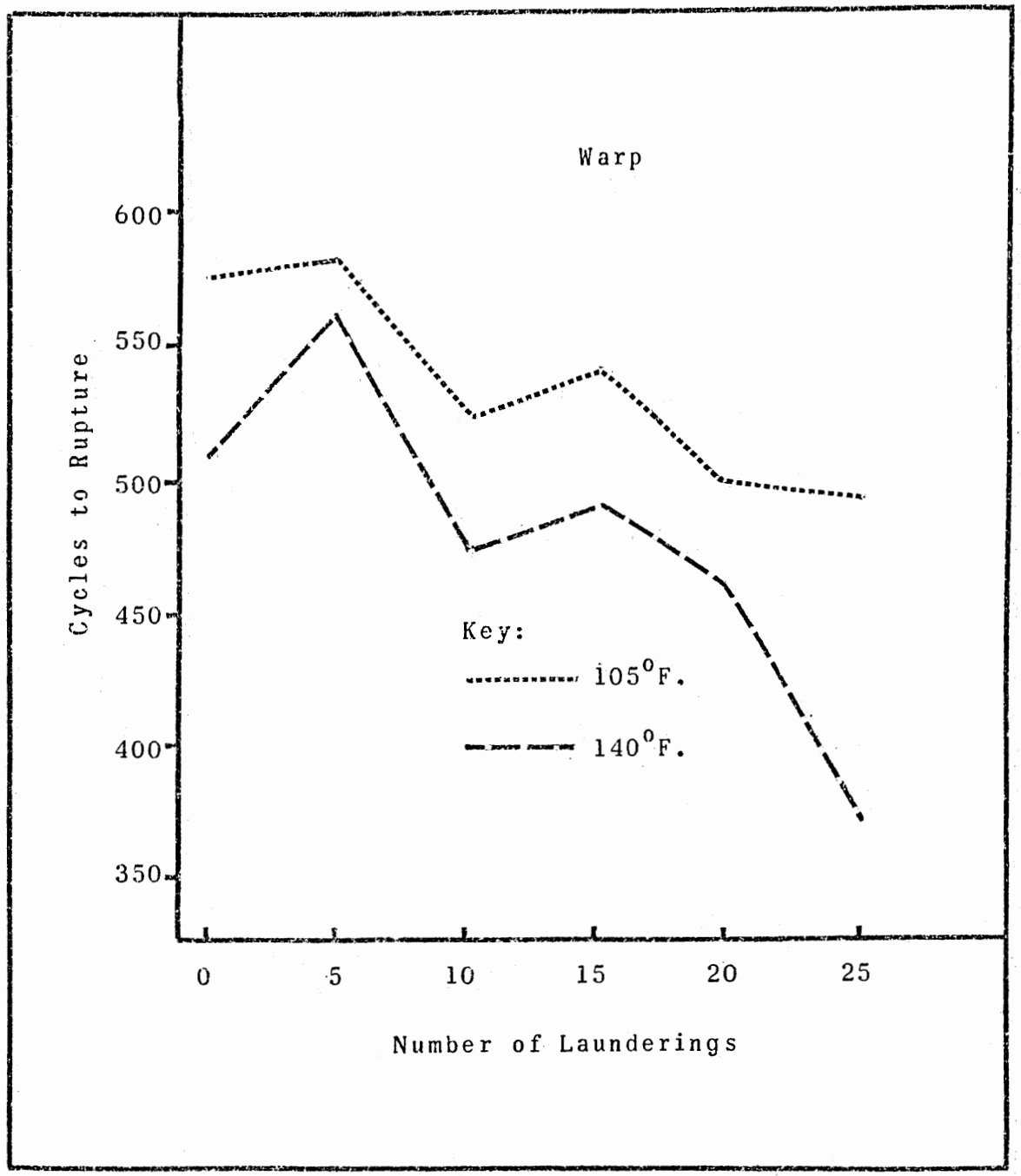


FIGURE 13

A COMPARISON OF THE RESISTANCE TO FLEXING AND ABRASION OF THE MACHINE WASHABLE FABRICS LAUNDERED AT 105°F. AND 140°F.

COLORFASTNESS TO LAUNDERING

The Beckman DU Spectrophotometer was used in determining the colorfastness of the experimental fabrics to laundering. The per cent change in reflectance was calculated from reflectance readings taken at ten different wavelengths, 50 millimicrons apart and ranging from 400 to 850 millimicrons, before laundering and after 25 periods of laundering. Table XXIV in the Appendix is composed of the findings on the experimental fabrics laundered at 105°F. while Table XXV is a compilation of the results of laundering at 140°F.

COLORFASTNESS OF FABRICS LAUNDERED AT 105°F.

Machine Washable Fabrics. The three types of machine washable fabrics laundered at 105°F. were compared to each other, but differences of statistical significance could not be attributed to any particular type of fabric. Color losses of the three categories of fabrics ranged from 13.3 to 29.1 per cent.

Durable Press Fabrics. When statistical analyses were made regarding the colorfastness of the durable press fabrics laundered at 105°F., some differences of significance occurred. When Fabric J, a blend of 65/25/10 wool-rayon-nylon, was compared to Fabric L (50/40/10 wool-cotton-nylon)

and Fabric M (50/20/20/10 wool-cotton-rayon-nylon) a difference favorable to Fabric J was evident in both comparisons ($P<0.010$). No other significant differences were observed among the durable press fabrics. Fabric M, a combination of 50/20/20/10 wool-cotton-rayon-nylon, experienced the greatest amount of color loss as indicated by a mean value of 5.9 per cent. The least change in color after the 25 laundering periods was exhibited by Fabric K, a 50/40/10 wool-cotton-nylon blend, with a mean color change of 0.8 per cent.

COMPARISON OF THE COLORFASTNESS OF FABRICS LAUNDERED AT 105°F.

The machine washable and durable press fabrics laundered at 105°F. were statistically compared to determine differences in colorfastness due to fabric finish. As may be noted in Summary F, the durable press fabrics demonstrated colorfastness highly superior to that shown by the entire group of machine washable fabrics ($P<0.001$). When the machine washable fabrics were compared by category to the durable press fabrics the latter were superior in each comparison ($P<0.001$).

COLORFASTNESS OF FABRICS LAUNDERED AT 140°F.

Machine Washable Fabrics. In comparing the machine washable fabrics laundered at 140°F. no statistically

significant difference was found between the colorfastness of the three groups. In ranking the fabrics on the basis of mean per cent values beginning with the best retention of original color, the following order was obtained: 55/45 wool-cotton; 100 per cent wool; and 85/15 wool-nylon.

Durable Press Fabrics. Upon examination of the colorfastness data of the durable press fabrics it was observed that the only differences of significance occurred when Fabrics K and L, blends of 50/40/10 wool-cotton-nylon, and Fabric M, 50/20/20/10 wool-cotton-rayon-nylon, were found to be superior to Fabric J, a combination of 65/25/10 wool-rayon-nylon. However, it should be pointed out that both Fabrics K and L exhibited color gain which could have been taken on as the other fabrics faded. All of the other durable press fabrics showed varying degrees of fading. Fabric M experienced the lowest per cent of color change having a mean color change of 0.2 per cent; whereas the greatest amount of fading occurred in Fabric J with a 6.9 mean per cent of color loss after the specified number of launderings.

COMPARISON OF THE COLORFASTNESS OF FABRICS LAUNDERED AT 140°F.

Statistical calculations show that the colorfastness of the durable press fabrics was highly superior to the

machine washable fabrics when treated either as a group or in their three respective categories. See Summary F.

COMPARISON OF THE EFFECTS OF LAUNDERING TEMPERATURES OF 105°F. AND 140°F. ON THE COLORFASTNESS OF FABRICS

The experimental fabrics laundered at 105°F. were each compared to their counterpart laundered at 140°F. to determine the effects of the laundering temperature on the colorfastness of the fabrics. On the basis of the statistical findings there was no apparent change in colorfastness due to either the 105°F. or 140°F. laundering temperature as can be noted in Part II of Summary F.

SUMMARY F

STATISTICAL COMPARISONS OF THE PER CENT CHANGE IN REFLECTANCE OF THE EXPERIMENTAL FABRICS AFTER 25 LAUNDERING PERIODS AT 105°F. AND 140°F.

PART I. FABRIC FINISH

Fabric Type	Laundered at 105°F.		Laundered at 140°F.	
	Mean Values	Probability of Significance	Mean Values	Probability of Significance
Machine Washable Durable Press	25.1 1.9	P<0.001	29.3 0.9	P<0.001
100% Wool Durable Press	25.8 1.9	P<0.001	30.8 0.0	P<0.001
85/15 Wool-Nylon Durable Press	29.1 1.9	P<0.001	35.4 0.9	P<0.001
55/45 Wool-Cotton Durable Press	13.3 1.9	P<0.001	8.7 0.9	P<0.010

PART II. LAUNDERING TEMPERATURE

Fabric Type	Laundering Temperature	Mean Values	Probability of Significance
100% Wool	105°F. 140°F.	25.8 30.8	N.S.
85/15 Wool-Nylon	105°F. 140°F.	29.1 35.4	N.S.
55/45 Wool-Cotton	105°F. 140°F.	13.3 8.7	N.S.
Durable Press	105°F. 140°F.	1.9 0.9	N.S.

S U M M A R Y

Fourteen wool and wool blend fabrics were used as specimens for this study. Nine of the fabrics were treated with finishes to make them machine washable while the remaining five fabrics were finished with the Koratron durable-press treatment.

Each of the experimental fabrics was divided into two parts, thus providing two sets of fabrics, one to be subjected to a series of 25 laundering periods at 105°F. and the other to be laundered an equal number of periods at 140°F. All fabrics were tumble dried.

For comparative purposes the washable wool fabrics were grouped into the following categories with reference to fiber content: 100 per cent wool, 85/15 wool-nylon, and 55/45 wool-cotton; whereas durable press fabrics were treated both on an individual basis and as a group in all comparisons which involved them. Fabric comparisons were made with reference to fiber content, fabric finish, and laundering temperature at each interval of testing.

Each of the experimental fabrics was subjected to the following tests, when the supply of fabric permitted,

at specified intervals throughout the study: wash-and-wear appearance, crease retention, dimensional stability, air permeability, pilling, breaking strength, flat abrasion, flexing and abrasion, and colorfastness.

The composite data collected from these observations at each testing period were statistically analyzed by means of the "t" test to determine the significance, if any, of the fiber content, fabric finish, or laundering temperature.

Wash-and-Wear Performance. A review of the data revealed that neither fiber content nor temperature had any significant effect upon the wash-and-wear appearance of the machine washable fabrics. At the lower temperature of 105°F. there was some indication of differences between the performance of the three categories of fabrics which was sometimes favorable to one category and at other times favorable to another. A gradual downward trend of wash-and-wear scores was observed as the launderings progressed at the higher temperature (140°F.).

The durable press fabrics which contained cotton had higher wash-and-wear scores than the other fabrics when laundered at both experimental temperatures. In comparing the individual fabrics at both temperatures no statistical differences were observed. When the durable press fabrics were analyzed as a group there was little change in their

smoothness as the number of laundering periods increased. However, the lower temperature was conducive to an improved appearance in these fabrics.

A comparison of the wash-and-wear ratings with reference to fabric finish revealed the smoothness of the durable press fabrics to be superior in each comparison to that of the machine washable fabrics treated either as a group or in their three respective categories. These findings were evident in all instances except at the higher temperature when the smoothness of the 55/45 wool-cotton fabric was comparable to that of the durable press fabrics.

Crease Retention. At the laundering temperature of 105°F. the four durable press fabrics composed of 40 per cent cellulosic fibers merited higher crease scores, two of which were significant, than did the remaining fabric. The two blends of 50/40/10 wool-cotton-nylon retained sharper creases than those observed in 65/25/10 wool-rayon-nylon fabric. No significant differences were noted at the 140°F. temperature, but the mean values favored the fabrics with the cellulosic fiber content. The first laundering period exerted more deteriorating effects than any of the following 24 laundering periods at both temperatures.

When the results of the crease retention test were compared with reference to temperature the crease ratings

were found to be higher for the durable press fabrics laundered at 105°F. than for those laundered at 140°F. although the differences were not significant.

Dimensional Stability. According to the statistical comparisons of the three categories of machine washable fabrics the 55/45 wool-cotton fabric excelled in most cases, warpwise and fillingwise, at both laundering temperatures. An exception to this pattern of performance was evident in a comparison of this fabric with the 85/15 wool-nylon fabrics when differences were not observed between the two types of fabrics in the filling direction after 25 laundering periods at 140°F.

The durable press fabrics laundered at the lower temperature were not significantly different when they were compared independently, in the warp direction. In the filling direction Fabric K, a blend of 50/40/10 wool-cotton-nylon was found to be superior to Fabrics L and M, respectively. At the laundering temperature of 140°F. one difference of significance occurred when individual fabric comparisons were made in the warp direction. Fabric L, a blend of 50/40/10 wool-cotton-nylon, was superior to Fabric J, composed of 65/25/10 wool-rayon-nylon. In the filling direction differences worthy of mention and favorable to Fabric K occurred when Fabrics K and L, both blends of 50/40/10 wool-cotton-nylon, were compared.

When comparisons were made to determine the effect of fabric finish it was found that the durable press fabrics demonstrated highly superior dimensional stability, warpwise and fillingwise, at both temperatures of 105°F. and 140°F.

The laundering temperatures exerted no effect upon the warp dimensional stability of any of the experimental fabrics, but in the filling direction the 100 per cent wool fabrics were distinctly more stable when laundered at the lower temperature.

Air Permeability. After 25 periods of laundering the statistical data on the machine washable fabrics revealed that the 100 per cent wool fabrics were more air permeable regardless of the temperature used in laundering; whereas differences were not observed between the 85/15 wool-nylon and the 55/45 wool-cotton fabrics.

When independent comparisons were made between the durable press fabrics after being subjected to the specified laundering periods the superiority of the two 50/40/10 wool-cotton-nylon fabrics was revealed at both temperatures.

To determine the effect of fabric finish upon the air permeability comparisons were made between the machine washable fabrics and the durable press fabrics at each temperature which indicated a significance in favor of the machine washable fabrics at each comparison. No significant

differences in air permeability could be attributed to the two laundering temperatures used in the study.

Pilling Resistance. Significant differences did not appear between the pilling resistance of any of the three categories of machine washable fabrics laundered at the two respective temperatures used in the study.

Breaking Strength. The 85/15 wool-nylon fabrics demonstrated superiority in breaking strength, warpwise and fillingwise, at both laundering temperatures. The other two fabric categories showed no differences worthy of note in the warp direction at either temperature. In the filling direction the 100 per cent wool fabrics were stronger than the 55/45 wool-cotton fabrics when laundered at each temperature.

When comparisons were made with reference to laundering temperature, it was noted that both in the warp and filling directions the breaking strengths were lower for the fabrics laundered at 140°F. than for the same fabrics laundered at 105°F. with one exception. Temperature did not alter the strength of the 55/45 wool-cotton fabric.

Flat Abrasion. In the warp direction the 100 per cent wool fabrics demonstrated superior flat abrasion resistance both to the 85/15 wool-nylon and the 55/45 wool-cotton when laundered at 105°F. At the laundering temperature of 140°F. in the same direction a superiority in favor

of the 100 per cent wool was found only when comparisons were made with the 85/15 wool-nylon fabric. Other warp comparisons with reference to fiber content at either laundering temperature did not reveal any significant differences.

In the filling direction the 100 per cent wool fabrics had better flat abrasion resistance than did the 55/45 wool-cotton when laundered either at 105°F. or 140°F., but significant differences did not exist between the remaining categories of machine washable fabrics.

Comparisons of fabrics at the two laundering temperatures indicated that temperature was not a significant factor in the breaking strength after flat abrasion in either the warp or filling directions of the three categories of machine washable fabrics.

Flex Abrasion. According to comparisons the fiber content of the machine washable fabrics had no significant effect upon the flexing and abrasion resistance of the fabrics warpwise or fillingwise, at either the 105°F. or 140°F. laundering temperature.

On the basis of the statistical analysis the resistance to flexing and abrasion was not affected by the laundering temperature either in the warp or the filling direction.

Colorfastness. Significant differences in colorfastness could not be attributed to fiber content with either laundering temperature in the machine washable fabrics.

The durable press fabric laundered at the lower temperature and composed of a blend of 65/25/10 wool-rayon-nylon exhibited a superior performance with respect to colorfastness than did Fabric L (50/40/10 wool-cotton-nylon) and Fabric M (50/20/20/10 wool-cotton-rayon-nylon). However, both of the 50/40/10 wool-cotton-nylon blends and the 50/20/20/10 wool-cotton-rayon-nylon fabric showed superior retention of color when compared with the 65/25/10 wool-rayon-nylon fabric at the 140°F. laundering temperature. No other noteworthy differences occurred between the durable press fabrics either at the 105°F. or the 140°F. temperature.

The durable press fabrics demonstrated highly superior colorfastness in comparison with the machine washable fabrics either as a group or by categories at both laundering temperatures.

According to statistical findings the laundering temperature did not have any effect upon the color of the experimental fabrics.

A more concise analysis of the data with reference to the effects of fiber content, fabric finish, and laundering temperature upon the performance of the experimental fabrics showed the following significant results:

Fiber Content.

1. Crease ratings were higher for the two durable press fabrics composed of a 50/40/10 combination of wool-cotton-nylon than for the 65/25/10 wool-rayon-nylon fabric following a laundering temperature of 105°F.

2. Of the machine washable fabrics the 55/45 wool-cotton fabric, with one exception, exhibited superior dimensional stability in each yarn direction when laundered at both temperatures. The 85/15 wool-nylon fabrics were found to be comparable to the 55/45 wool-cotton fabrics in the filling direction after being laundered at 140°F.

3. The air permeability of the 100 per cent wool machine washable fabrics and the 50/40/10 wool-cotton-nylon durable press fabrics was superior when comparisons were made within the two general categories of fabrics.

4. The 85/15 wool-nylon was superior in breaking strength, warpwise and fillingwise, irrespective of temperature. In the filling direction the 100 per cent wool fabrics exhibited superior breaking strength in comparison with the 55/45 wool-cotton fabric at each temperature.

5. Warpwise the 100 per cent wool fabrics demonstrated a flat abrasion resistance superior to that of the other machine washable fabrics laundered at 105°F.; to the

85/15 wool-nylon fabrics in the filling direction when laundered at 140°F.; and to the 55/45 wool-cotton when laundered at both temperatures.

6. The colorfastness of the durable press blend of 65/25/10 wool-rayon-nylon was better when laundered at 105°F. than that of Fabric L, a 50/40/10 wool-cotton-nylon blend, and the 50/20/20/10 wool-cotton-rayon-nylon fabric. On the other hand, the reverse was true at a temperature of 140°F. with the 50/40/10 wool-cotton-nylon fabrics and the 50/20/20/10 wool-cotton-rayon-nylon fabric showing more excellent colorfastness properties than the 65/25/10 wool-rayon-nylon fabric.

Fabric Finish.

1. The durable press fabrics demonstrated superior performance in wash-and-wear appearance to that of the washable wool fabrics with each comparison and temperature except at 140°F. when the appearance of the 55/45 wool-cotton fabrics was comparable. The superiority of the durable press fabrics was observed also in comparison with the machine washable fabrics in dimensional stability and colorfastness at both temperatures.

2. The machine washable fabrics were more air penetrable than the durable press fabrics.

Laundering Temperatures.

The laundering temperature was not significant in any of the tests to which the fabrics were subjected, except in wash-and-wear appearance when the durable press fabrics showed better performance at 105°F. than at 140°F.

B I B L I O G R A P H Y

1. American Association of Textile Chemists and Colorists, Technical Manual and Year Book, 43 (1967)

   a. AATCC Tentative Test Method: 88A-1964 Appearance of Fabrics in Wash-and-Wear Items After Home Laundering.

   b. AATCC Tentative Test Method: 88C-1964 Appearance of Creases in Wash-and-Wear Items After Home Laundering

2. American Dyestuff Reporter, New Process for Washable Wool Garments, American Dyestuff Reporter, 55: Number 9, 354 (1966)

3. American Society for Testing and Materials, ASTM Standards--Textile Materials--General Methods and Definitions, prepared by Committee D-13 on Textile Materials (1967)

   a. ASTM Designation: D 1175-64T, Flat Abrasion of Textile Fabrics

   b. ASTM Designation: D 1175-64T, Flexing and Abrasion of Textile Fabrics

   c. ASTM Designation: D 1375-67, Pilling Resistance and Other Surface Effects of Textile Fabrics

   d. ASTM Designation: D 1682-64, Breaking Strength of Woven Fabrics

   e. ASTM Designation: D 1905-61T, Dimensional Changes in Woven Textiles

   f. ASTM Designation: D 1910-64, Sections 30-33 on Warp and Filling Yarn Counts

   g. ASTM Designation: D 1910-64, Section 38 on Fabric Weight

4. Anderson, C. A., and J. R. McPhee, The Variability of Wool Tops in Treatments with Oxidative Shrink Resist Reagents, Textile Research Journal 37: Number 7, 582 (1967)

5. Feldtman, H. D.; J. R. McPhee; and A. J. Pratt, Treatment of Wool with Polyolefins, Textile Research Journal 37: Number 7, 46 (1967)

6. Fong, W.; J. F. Ash; and L. A. Miller, Plant Trials of the Wurlan Shrink-Resist Process on Woolen Fabrics, American Dyestuff Reporter 52: Number 5, 160 (1963)

7. Fong, W.; R. E. Whitfield; L. A. Miller; and A. H. Brown, Wool Fabric Stabilization by Intefacial Polymerization. II. Developmental Studies of Process Variables, American Dyestuff Reporter 51: Number 9, 325 (1962)

8. General Services Administration, Federal Specifications CCC-T-191b, Textile Methods, Method 5452, Permeability to Air; Cloth; Falling Cylinder Method, Government Printing Office (1951)

9. McPhee, J. R., Shrink-Resistant Treatment of Wool Fabrics, Textile Research Journal 31: Number 12, 1045 (1961)

10. Miller, L. A. and W. Fong, Production Range for Wurlan Shrink-resist Treatment of Woolen Fabrics, American Dyestuff Reporter 54: Number 18, 662 (1965)

11. Moncrieff, R. W., Salt-permanganate Method for Shrink Resistance, Wool Record (June 11, 1965)

12. Murray, E. A., Here's a Round-Up on Washable Woolens, Textile World 54: Number 9, 87 (1954)

13. O'Connell, R. A.; C. E. Pardo; and W. Fong, Preliminary Observations on Durable Press Wool Blend Fabrics, American Dyestuff Reporter 57: Number 8, 245 (1968)

14. Sweetman, B. J., and J. A. Maclaren, Chemical Reactions Involved in the Shrinkproofing of Wool by Oxidation--Sulfite Processes, Textile Research Journal 35: Number 4, 315 (1965)

15. Thorsen, W. J., New Aspects on Ozonization of Wool, Textile Research Journal 35: Number 7, 638 (1965)

16. Thorsen, W. J., and R. Y. Kodani, Continuous Shrink-Resist Treatment of Wool Fabric with Ozone, Textile Research Journal 37: Number 11, 975 (1967)

17. Trotman, S. R., The Unshrinkable Finish on Wool, Journal of Society of Dyers and Colorists 39: Number 12, 359 (1923)

18. Wasley, W. L.; R. E. Whitfield; and L. A. Miller, Wool Fabric Stabilization by Interfacial Polymerization. Part VII. Improvement Through the Use of Strong Bases, Textile Research Journal 34: Number 8, 736 (1964)

19. Whewell, C. S. Progress in the Finishing of Wool Fabrics, Wool Record (April 1, 1966)

20. Whitfield, R. E.; L. A. Miller; and W. L. Wasley, Wool Fabric Stabilization by Interfacial Polymerization. Part I. Polyamides, Textile Research Journal 31: Number 8, 704 (1961)

21. Whitfield, R. E.; L. A. Miller; and W. L. Wasley, Wool Fabric Stabilization by Interfacial Polymerization. Part III. Polyurethanes, Textile Research Journal 32: Number 9, 743 (1962)

22. Whitfield, R. E.; L. A. Miller; and W. L. Wasley, Wool Stabilization by Interfacial Polymerization. Part IV. Polyureas, Polyesters, Polycarbonates, and Further Studies on Polyamides, Textile Research Journal 33: Number 6, 440 (1963)

23. Whitfield, R. E.; L. A. Miller; and W. L. Wasley, Wool Fabric Stabilization by Interfacial Polymerization. Part V: Copolymers, Textile Research Journal 33: Number 9, 752 (1963)

24. Whitfield, R. E.; L. A. Miller; and W. L. Wasley, Wool Fabric Stabilization by Interfacial Polymerization. Part VIII. Location and Nature of the Polymer, Textile Research Journal 35: Number 6, 237 (1965)

A P P E N D I X

TABLE I

WASH-AND-WEAR RATINGS OF EXPERIMENTAL FABRICS LAUNDERED AT 105°F.

PART A. WASHABLE FABRICS

Fabric Types	Number of Launderings					
	1	5	10	15	20	25
100% Wool						
A	4.0	5.0	2.7	3.3	2.7	3.0
B	4.7	5.0	4.7	3.0	3.3	5.0
C	4.0	5.0	5.0	5.0	4.7	5.0
D	5.0	5.0	5.0	5.0	5.0	5.0
E	4.0	5.0	4.0	4.0	3.7	3.0
F	5.0	4.3	4.3	4.7	4.0	3.3
Average	4.4	4.9	4.3	4.2	3.9	4.0
85/15 Wool-Nylon						
G	4.3	4.0	5.0	2.0	3.0	3.3
H	4.3	5.0	5.0	5.0	4.7	4.3
Average	4.3	4.5	5.0	3.5	3.8	3.8
55/45 Wool-Cotton						
I	3.0	5.0	4.7	4.7	3.7	4.7

PART B. DURABLE PRESS FABRICS

65/25/10 Wool-Rayon-Nylon						
J	5.0	4.3	5.0	5.0	4.0	4.7
50/40/10 Wool-Cotton-Nylon						
K	5.0	5.0	5.0	5.0	5.0	5.0
L	5.0	5.0	5.0	5.0	5.0	4.7
50/20/20/10 Wool-Cotton-Rayon-Nylon						
M	5.0	5.0	5.0	4.7	4.3	4.3
50/40/10 Wool-Rayon-Nylon						
N	5.0	4.7	5.0	5.0	4.0	4.3
Average	5.0	4.8	5.0	4.9	4.5	4.6

TABLE II

WASH-AND-WEAR RATINGS OF EXPERIMENTAL FABRICS LAUNDERED AT 140°F.

PART A. WASHABLE FABRICS

Fabric Types	Number of Launderings					
	1	5	10	15	20	25
100% Wool						
A	4.0	4.7	3.0	2.7	2.0	3.0
B	5.0	5.0	5.0	3.7	3.0	4.0
C	5.0	5.0	5.0	5.0	4.0	4.3
D	5.0	5.0	5.0	5.0	4.7	5.0
E	5.0	5.0	3.3	2.0	2.0	3.0
F	5.0	5.0	3.3	3.0	3.0	3.3
Average	4.8	5.0	4.1	3.6	3.1	3.8
85/15 Wool-Nylon						
G	4.3	4.7	2.7	3.0	3.3	3.0
H	5.0	5.0	4.0	4.0	3.3	4.0
Average	4.6	4.8	3.3	3.5	3.3	3.5
55/45 Wool-Cotton						
I	5.0	4.3	4.7	3.7	4.0	3.0

PART B. DURABLE PRESS FABRICS

65/25/10 Wool-Rayon-Nylon						
J	5.0	4.3	4.0	4.5	4.0	3.3
50/40/10 Wool-Cotton-Nylon						
K	5.0	5.0	5.0	5.0	5.0	4.0
L	5.0	5.0	4.7	5.0	4.3	3.7
50/20/20/10 Wool-Cotton-Rayon-Nylon						
M	5.0	5.0	5.0	5.0	4.3	3.7
50/40/10 Wool-Rayon-Nylon						
N	5.0	5.0	4.0	4.7	4.0	3.3
Average	5.0	4.9	4.5	4.8	4.3	3.6

TABLE III

CREASE RATINGS OF DURABLE PRESS FABRICS LAUNDERED AT 105°F. AND 140°F.

PART A. LAUNDERED AT 105°F.

Fabric Types	Number of Launderings					
	1	5	10	15	20	25
65/25/10 Wool-Rayon-Nylon J	3.7	4.0	3.0	3.0	2.7	3.3
50/40/10 Wool-Cotton-Nylon K	4.0	4.0	4.0	4.0	4.0	3.3
L	4.0	4.0	4.0	4.0	3.7	4.0
50/20/20/10 Wool-Cotton-Rayon-Nylon M	3.7	3.3	4.0	4.0	4.0	3.7
50/40/10 Wool-Rayon-Nylon N	4.0	3.7	4.0	3.3	3.3	4.0
Average	3.9	3.8	3.8	3.7	3.5	3.7

PART B. LAUNDERED AT 140°F.

65/25/10 Wool-Rayon-Nylon J	4.0	4.0	3.0	3.0	3.0	2.3
50/40/10 Wool-Cotton-Nylon K	4.0	4.0	4.0	3.3	3.7	3.3
L	4.0	4.0	3.0	4.0	4.0	2.3
50/20/20/10 Wool-Cotton-Rayon-Nylon M	4.0	4.0	4.0	4.0	3.3	3.3
50/40/10 Wool-Rayon-Nylon N	3.7	4.0	3.0	3.7	3.3	3.0
Average	3.9	4.0	3.4	3.6	3.5	2.8

TABLE IV

DIMENSIONAL LOSSES IN THE WARP DIRECTION OF EXPERIMENTAL FABRICS LAUNDERED AT 105°F. (PER CENT)

PART A. WASHABLE FABRICS

Fabric Types	Number of Launderings					
	1	5	10	15	20	25
100% Wool						
A	7.4	5.2	7.8	8.2	7.6	8.8
B	3.8	2.0	4.6	5.0	5.0	5.8
C	3.2	2.8	3.8	2.6	3.8	5.2
D	5.4	3.8	6.0	6.0	6.2	7.4
E	6.8	4.2	8.8	10.4	10.0	10.6
F	2.2	1.6	1.6	1.6	1.2	1.8
Average	4.8	3.3	5.4	5.6	5.6	6.6
85/15 Wool-Nylon						
G	4.0	3.4	4.0	4.4	3.6	4.8
H	3.6	2.4	3.4	3.8	3.2	4.0
Average	3.8	2.9	3.7	4.1	3.4	4.4
55/45 Wool-Cotton						
I	1.4	1.6	2.2	2.6	2.2	3.6

PART B. DURABLE PRESS FABRICS

65/25/10 Wool-Rayon-Nylon						
J	1.6	1.2	1.8	1.6	1.8	2.6
50/40/10 Wool-Cotton-Nylon						
K	1.4	1.2	1.6	1.6	1.8	2.2
L	1.6	1.0	1.4	1.4	1.6	2.2
50/20/20/10 Wool-Cotton-Rayon-Nylon						
M	1.8	1.4	1.6	1.4	1.6	2.4
50/40/10 Wool-Rayon-Nylon						
N	1.2	0.8	1.4	1.0	1.4	1.8
Average	1.5	1.1	1.6	1.4	1.6	2.2

TABLE V

DIMENSIONAL LOSSES IN THE FILLING DIRECTION OF EXPERIMENTAL FABRICS LAUNDERED AT 105°F. (PER CENT)

PART A. WASHABLE FABRICS

Fabric Types	Number of Launderings					
	1	5	10	15	20	25
100% Wool						
A	5.4	3.8	5.0	5.2	4.2	4.8
B	4.4	1.8	3.2	3.6	3.2	4.2
C	5.0	5.0	5.8	5.0	4.8	6.6
D	6.2	4.0	6.4	5.8	5.6	6.4
E	5.0	2.4	2.4	4.0	3.2	3.8
F	5.6	4.8	5.8	5.8	4.6	5.6
Average	5.3	3.6	4.8	4.9	4.3	5.2
85/15 Wool-Nylon						
G	4.0	4.0	3.8	4.2	3.6	4.0
H	2.8	2.4	2.8	2.6	2.6	3.8
Average	3.4	3.2	3.3	3.4	3.1	3.9
55/45 Wool-Cotton						
I	2.4	1.4	2.6	2.4	2.0	4.0

PART B. DURABLE PRESS FABRICS

65/25/10 Wool-Rayon-Nylon						
J	1.4	1.2	0.8	0.6	1.0	1.6
50/40/10 Wool-Cotton-Nylon						
K	1.0	0.6	1.0	0.6	0.8	1.4
L	1.4	1.2	1.2	1.2	1.4	1.8
50/20/20/10 Wool-Cotton-Rayon-Nylon						
M	1.4	1.2	1.2	1.2	1.2	1.6
50/40/10 Wool-Rayon-Nylon						
N	1.4	1.0	1.0	0.4	0.8	1.6
Average	1.3	1.0	1.0	0.8	1.0	1.6

TABLE VI

DIMENSIONAL LOSSES IN THE WARP DIRECTION OF EXPERIMENTAL FABRICS LAUNDERED AT 140°F. (PER CENT)

PART A. WASHABLE FABRICS

Fabric Types	Number of Launderings					
	1	5	10	15	20	25
100% Wool						
A	6.6	6.6	6.2	7.6	9.4	10.0
B	4.2	4.4	4.6	5.0	7.2	8.0
C	3.4	1.4	3.6	4.6	6.4	7.0
D	5.4	5.4	6.0	6.4	8.4	9.4
E	7.6	6.6	8.8	9.4	10.1	11.4
F	2.4	1.8	1.6	1.6	1.6	3.4
Average	4.9	4.4	5.1	5.8	7.2	8.2
85/15 Wool-Nylon						
G	4.4	2.0	3.8	4.6	5.8	6.2
H	3.6	2.2	3.4	4.0	4.8	5.4
Average	4.0	2.1	3.6	4.3	5.3	5.8
55/45 Wool-Cotton						
I	0.8	2.0	2.4	3.0	3.6	4.2

PART B. DURABLE PRESS FABRICS

65/25/10 Wool-Rayon-Nylon						
J	1.6	1.6	1.6	1.6	2.8	2.8
50/40/10 Wool-Cotton-Nylon						
K	1.4	1.0	1.4	1.8	2.4	2.4
L	1.2	1.0	0.6	0.8	1.8	1.6
50/20/20/10 Wool-Cotton-Rayon-Nylon						
M	1.6	1.2	1.4	1.8	2.4	2.6
50/40/10 Wool-Rayon-Nylon						
N	1.2	1.0	0.6	1.2	2.0	1.8
Average	1.4	1.2	1.1	1.4	2.3	2.2

TABLE VII

DIMENSIONAL LOSSES IN THE FILLING DIRECTION OF EXPERIMENTAL FABRICS LAUNDERED AT 140°F. (PER CENT)

PART A. WASHABLE FABRICS

Fabric Types	Number of Launderings					
	1	5	10	15	20	25
100% Wool						
A	6.4	5.8	4.6	5.0	6.8	7.6
B	5.2	4.4	3.4	3.4	4.8	3.8
C	6.2	3.2	5.4	6.6	7.0	8.2
D	3.8	7.4	6.4	7.0	8.6	9.4
E	4.8	1.8	3.6	4.2	5.4	5.4
F	3.3	6.6	5.0	5.8	6.6	6.8
Average	5.0	4.9	4.7	5.3	6.5	6.9
85/15 Wool-Nylon						
G	4.0	2.4	4.2	3.6	4.6	4.6
H	3.2	1.4	2.6	3.0	3.4	4.2
Average	3.6	1.9	3.4	3.3	4.0	4.4
55/45 Wool-Cotton						
I	1.0	1.8	2.8	2.2	3.2	4.2

PART B. DURABLE PRESS FABRICS

65/25/10 Wool-Rayon-Nylon						
J	1.0	0.6	0.4	0.4	1.4	1.8
50/40/10 Wool-Cotton-Nylon						
K	0.8	0.4	0.4	0.4	1.2	1.4
L	1.4	1.2	1.0	1.4	1.8	2.2
50/20/20/10 Wool-Cotton-Rayon-Nylon						
M	0.8	0.6	0.6	0.6	1.4	1.6
50/40/10 Wool-Rayon-Nylon						
N	1.4	1.0	0.6	0.6	1.8	2.2
Average	1.1	0.8	0.6	0.7	1.5	1.8

TABLE VIII

AIR PERMEABILITY OF EXPERIMENTAL FABRICS LAUNDERED AT 105°F. (SECONDS)

PART A. WASHABLE FABRICS

Fabric Types	Number of Launderings					
	1	5	10	15	20	25
100% Wool						
A	5.0	5.3	5.6	5.3	5.7	6.0
B	4.7	4.8	4.8	4.6	5.0	5.1
C	5.0	5.1	5.3	6.0	5.2	5.7
D	4.3	5.1	4.9	4.9	4.8	5.0
E	4.2	4.9	5.2	5.2	5.1	5.3
F	4.0	4.4	4.2	4.6	5.0	4.7
Average	4.5	4.9	5.0	5.1	5.1	5.3
85/15 Wool-Nylon						
G	4.0	4.2	4.1	4.2	4.3	4.6
H	3.1	4.0	3.8	4.0	4.0	4.1
Average	3.6	4.1	3.9	4.1	4.2	4.4
55/45 Wool-Cotton						
I	4.2	3.9	4.3	3.7	4.1	4.0

PART B. DURABLE PRESS FABRICS

65/25/10 Wool-Rayon-Nylon						
J	12.4	*	*	10.7	11.4	11.3
50/40/10 Wool-Cotton-Nylon						
K	15.2	*	*	13.6	15.2	14.5
L	12.2	*	*	14.5	13.7	14.7
50/20/20/10 Wool-Cotton-Rayon-Nylon						
M	10.1	*	*	11.3	10.6	10.8
50/40/10 Wool-Rayon-Nylon						
N	15.1	*	*	14.8	14.6	13.9
Average	13.0	*	*	13.0	13.1	13.0

*Shortage of fabric prevented testing at these periods.

TABLE IX

AIR PERMEABILITY OF EXPERIMENTAL FABRICS LAUNDERED AT 140°F. (SECONDS)

PART A. WASHABLE FABRICS

Fabric Types	Number of Launderings					
	1	5	10	15	20	25
100% Wool						
A	5.0	5.7	5.8	6.0	6.2	6.3
B	4.7	4.8	4.9	5.2	5.1	5.1
C	5.0	5.0	5.6	5.8	5.4	5.9
D	4.3	5.1	5.1	5.2	5.4	4.6
E	4.2	4.8	5.3	5.2	5.9	6.0
F	4.0	4.1	4.7	4.2	4.3	5.1
Average	4.5	4.9	5.2	5.3	5.4	5.5
85/15 Wool-Nylon						
G	4.0	4.2	4.5	4.2	4.5	4.4
H	3.1	3.4	4.0	4.0	3.7	4.2
Average	3.6	3.8	4.2	4.1	4.1	4.3
55/45 Wool-Cotton						
I	4.2	3.8	4.0	3.7	4.1	4.1

PART B. DURABLE PRESS FABRICS

65/25/10 Wool-Rayon-Nylon						
J	12.4	*	*	10.4	10.5	11.4
50/40/10 Wool-Cotton-Nylon						
K	15.2	*	*	13.5	15.0	14.1
L	12.2	*	*	12.1	12.7	13.7
50/20/20/10 Wool-Cotton-Rayon-Nylon						
M	10.1	*	*	11.3	13.1	11.7
50/40/10 Wool-Rayon-Nylon						
N	15.1	*	*	15.0	15.6	16.7
Average	13.0	*	*	12.5	13.4	13.5

*Shortage of fabric prevented testing at these periods.

TABLE X

PILLING RESISTANCE OF MACHINE WASHABLE FABRICS LAUNDERED AT 105°F.

Fabric Types	Number of Launderings		
	0	15	25
100% Wool			
A	3.72	4.89	4.50
B	3.28	4.61	4.50
C	3.83	5.00	4.89
D	4.33	4.50	5.00
E	2.89	4.33	4.50
F	3.33	4.67	4.78
Average	3.56	4.67	4.70
85/15 Wool-Nylon			
G	2.45	4.67	4.45
H	3.56	4.61	4.67
Average	3.00	4.64	4.56
55/45 Wool-Cotton			
I	3.94	4.33	4.61

TABLE XI

PILLING RESISTANCE OF MACHINE WASHABLE FABRICS LAUNDERED AT 140°F.

Fabric Types	Number of Launderings		
	0	15	25
100% Wool			
A	3.72	4.61	4.67
B	3.28	4.26	4.72
C	3.83	5.00	4.78
D	4.33	5.00	4.89
E	2.89	4.56	3.94
F	3.33	4.45	4.28
Average	3.56	4.65	4.55
85/15 Wool-Nylon			
G	2.45	4.33	3.50
H	3.56	4.89	4.43
Average	3.00	4.61	3.96
55/45 Wool-Cotton			
I	3.94	4.56	4.50

TABLE XII

WARP BREAKING STRENGTH OF THE MACHINE WASHABLE FABRICS LAUNDERED AT 105°F.

(POUNDS PER 100 YARNS)

Fabric Types	Number of Launderings					
	1	5	10	15	20	25
100% Wool						
A	29.8	27.4	27.2	26.3	20.8	25.0
B	45.4	39.8	38.4	37.6	37.3	35.0
C	57.4	47.2	50.0	42.8	48.2	46.9
D	62.8	51.0	51.6	48.4	50.3	45.1
E	58.6	53.4	53.1	50.6	52.6	50.3
F	53.5	55.9	56.0	55.1	55.9	53.4
Average	51.2	45.8	46.0	43.5	44.2	42.6
85/15 Wool-Nylon						
G	71.3	60.2	58.1	55.8	52.8	53.8
H	61.1	59.1	59.6	60.7	54.8	58.8
Average	66.2	59.6	58.8	58.2	53.8	56.3
55/45 Wool-Cotton						
I	42.5	40.3	39.8	39.8	40.2	36.4

TABLE XIII

FILLING BREAKING STRENGTH OF THE MACHINE WASHABLE FABRICS LAUNDERED AT 105°F.

(POUNDS PER 100 YARNS)

Fabric Types	Number of Launderings					
	1	5	10	15	20	25
100% Wool						
A	32.9	28.5	27.4	26.1	19.7	25.5
B	51.9	36.9	36.0	35.8	37.5	35.5
C	54.3	47.3	46.8	47.4	47.4	45.0
D	63.1	52.6	45.8	49.7	50.3	46.8
E	57.5	51.7	49.3	52.6	52.3	50.6
F	47.7	53.9	47.3	48.7	48.0	47.6
Average	51.2	45.2	42.1	43.4	42.5	41.8
85/15 Wool-Nylon						
G	72.0	59.3	56.2	59.1	51.8	47.5
H	61.7	58.6	59.8	56.7	51.4	53.3
Average	66.8	59.0	58.0	57.9	51.6	50.4
55/45 Wool-Cotton						
I	32.8	32.2	31.8	30.8	29.7	29.8

TABLE XIV

WARP BREAKING STRENGTH OF THE MACHINE WASHABLE FABRICS LAUNDERED AT 140°F.

(POUNDS PER 100 YARNS)

Fabric Types	Number of Launderings					
	1	5	10	15	20	25
100% Wool						
A	29.8	27.1	25.9	23.9	20.0	22.5
B	45.4	39.1	37.0	37.0	35.8	35.6
C	57.4	48.5	51.3	44.3	46.2	44.9
D	62.8	50.0	48.4	46.8	47.1	43.3
E	58.6	54.1	53.9	53.8	52.8	44.8
F	53.5	53.9	55.0	55.2	55.6	54.7
Average	51.2	45.4	45.2	43.5	42.9	41.0
85/15 Wool-Nylon						
G	71.3	55.1	56.4	52.9	53.2	52.9
H	61.1	60.4	57.9	57.9	58.5	55.2
Average	66.2	57.8	57.1	55.4	55.8	54.0
55/45 Wool-Cotton						
I	42.5	40.4	39.3	39.5	40.0	37.7

TABLE XV

FILLING BREAKING STRENGTH OF THE MACHINE WASHABLE FABRICS LAUNDERED AT 140°F.

(POUNDS PER 100 YARNS)

Fabric Types	Number of Launderings					
	1	5	10	15	20	25
100% Wool						
A	32.9	28.6	26.5	27.4	22.5	25.5
B	51.9	38.4	40.0	37.9	37.5	34.0
C	54.3	47.9	46.2	44.8	47.1	43.3
D	63.1	51.6	46.1	49.4	52.3	44.3
E	57.5	52.0	52.6	48.7	50.0	50.6
F	47.7	48.0	63.2	62.6	47.3	48.3
Average	51.2	44.4	45.8	45.1	42.8	41.0
85/15 Wool-Nylon						
G	72.0	51.1	52.8	57.4	56.9	50.0
H	61.7	51.9	56.3	54.1	54.1	49.6
Average	66.8	51.5	54.6	55.8	55.5	49.8
55/45 Wool-Cotton						
I	32.8	30.2	32.4	31.8	30.2	28.9

TABLE XVI

PER CENT CHANGE IN WARP BREAKING STRENGTH DUE TO FLAT ABRASION OF MACHINE WASHABLE FABRICS LAUNDERED AT 105°F.

Fabric Types	Number of Launderings					
	1	5	10	15	20	25
100% Wool						
A	+ 2.7	-11.2	+ 3.4	+11.4	+14.2	+ 2.6
B	- 4.8	+ 2.0	- 3.8	+ 5.4	+17.8	-14.8
C	-15.9	+ 2.4	+10.2	+11.6	- 4.0	-13.9
D	- 8.6	- 3.5	- 0.0	- 0.6	- 3.8	-13.6
E	+ 1.1	- 0.3	- 1.7	+ 0.6	+ 3.7	- 3.5
F	- 6.6	- 7.0	+ 5.3	+ 8.2	+ 6.1	+ 3.4
Average	- 5.4	- 2.9	+ 2.2	+ 6.1	+ 5.7	- 6.6
85/15 Wool-Nylon						
G	- 8.9	-10.6	-16.2	-12.8	- 3.5	-16.7
H	-22.9	+10.8	- 4.2	-17.1	-11.6	-26.2
Average	-15.9	+ 0.1	-10.2	-15.0	- 7.6	-21.4
55/45 Wool-Cotton						
I	- 5.8	-16.9	- 4.2	- 7.9	- 4.8	- 6.5

TABLE XVII

PER CENT CHANGE IN FILLING BREAKING STRENGTH DUE TO FLAT ABRASION OF MACHINE WASHABLE FABRICS LAUNDERED AT 105°F.

Fabric Types	Number of Launderings					
	1	5	10	15	20	25
100% Wool						
A	- 1.8	- 6.8	+ 2.0	+ 6.4	+25.0	+ 2.6
B	-16.2	+22.9	+ 3.8	+ 8.1	+ 1.6	+ 0.4
C	- 8.2	- 2.5	+10.1	+ 0.6	+ 1.0	- 8.5
D	-11.2	-14.0	+10.9	+ 5.7	- 0.2	-15.5
E	-11.5	- 1.6	+14.8	+ 4.0	- 0.6	- 8.6
F	-14.3	-30.0	+ 6.4	- 2.4	+ 3.9	- 8.7
Average	-10.5	- 5.3	+ 8.0	+ 3.7	+ 5.1	- 6.4
85/15 Wool-Nylon						
G	-15.8	-24.6	- 2.6	+ 0.3	+ 0.7	-15.4
H	- 9.8	- 8.7	- 7.2	+10.2	+ 2.8	- 6.2
Average	-12.8	-16.7	- 4.9	+ 5.3	+ 1.8	-10.8
55/45 Wool-Cotton						
I	-32.6	-17.0	- 4.2	-13.6	-12.1	- 7.3

TABLE XVIII

PER CENT CHANGE IN WARP BREAKING STRENGTH DUE TO FLAT ABRASION OF MACHINE WASHABLE FABRICS LAUNDERED AT 140°F.

Fabric Types	Number of Launderings					
	1	5	10	15	20	25
100% Wool						
A	+ 2.7	+10.3	- 5.0	+11.1	+17.2	- 2.3
B	- 4.8	-11.6	+17.7	+ 6.1	+ 8.5	- 6.0
C	-15.9	- 4.8	- 6.2	- 1.4	- 2.3	-13.8
D	- 8.6	- 2.9	+ 1.0	+ 1.0	+ 2.0	-17.2
E	+ 1.1	- 3.2	- 1.9	- 4.1	-14.2	- 6.4
F	- 6.6	- 1.6	+ 2.8	- 6.7	+10.4	- 3.6
Average	- 5.4	- 2.3	+ 1.4	+ 1.0	+ 3.6	- 8.2
85/15 Wool-Nylon						
G	- 8.9	+ 1.7	+ 2.9	-10.1	- 7.6	-22.2
H	-22.9	- 2.7	-11.0	- 9.7	- 7.6	- 3.6
Average	-15.9	- 0.5	- 4.1	- 9.9	- 7.6	-12.9
55/45 Wool-Cotton						
I	- 5.8	-15.5	- 1.0	- 2.2	+ 3.0	- 0.3

TABLE XIX

PER CENT CHANGE IN FILLING BREAKING STRENGTH DUE TO FLAT ABRASION OF MACHINE WASHABLE FABRICS LAUNDERED AT 140°F.

Fabric Types	Number of Launderings					
	1	5	10	15	20	25
100% Wool						
A	- 1.8	-14.6	+ 7.9	- 8.1	+ 7.1	- 2.7
B	-16.2	-10.7	+ 4.2	+ 3.5	+11.8	-16.9
C	- 8.2	- 2.8	- 9.3	+ 4.9	- 0.3	-12.4
D	-11.2	- 8.2	+ 4.9	- 1.0	-14.6	-17.3
E	-11.5	- 7.6	- 3.1	+ 1.4	- 4.6	-19.9
F	-14.3	- 6.9	-21.1	-15.8	- 5.8	- 5.6
Average	-10.5	- 8.5	- 2.8	- 2.5	- 1.1	-12.5
85/15 Wool-Nylon						
G	-15.8	- 9.1	- 2.0	- 2.2	-15.6	-13.6
H	- 9.8	+ 5.8	-12.2	+ 1.3	+16.4	-24.1
Average	-12.8	- 1.6	- 7.1	- 0.4	+ 0.4	-18.8
55/45 Wool-Cotton						
I	-32.6	-14.6	-21.0	-16.6	- 6.3	- 8.4

TABLE XX

WARP FLEXING AND ABRASION RESISTANCE OF MACHINE WASHABLE FABRICS LAUNDERED AT 105°F.

(CYCLES PER 100 YARNS)

Fabric Types	Number of Launderings					
	1	5	10	15	20	25
100% Wool						
A	215.4	157.4	159.7	147.9	123.6	107.9
B	325.9	258.0	216.7	228.5	203.8	191.7
C	886.7	769.0	726.7	706.2	737.5	628.7
D	513.5	415.4	334.8	382.6	332.3	286.4
E	730.9	861.1	804.9	875.3	612.2	649.0
F	863.2	594.3	967.0	781.8	900.6	888.3
Average	589.3	509.2	535.0	520.4	485.0	458.7
85/15 Wool-Nylon						
G	819.3	436.5	333.8	359.1	293.6	311.5
H	101.3	809.1	731.3	690.2	819.0	564.6
Average	460.3	622.8	532.6	524.6	556.3	438.0
55/45 Wool-Cotton						
I	669.0	624.5	498.6	581.7	450.6	585.4

TABLE XXI

FILLING FLEXING AND ABRASION RESISTANCE OF MACHINE WASHABLE FABRICS LAUNDERED AT 105°F.

(CYCLES PER 100 YARNS)

Fabric Types	Number of Launderings					
	1	5	10	15	20	25
100% Wool						
A	220.0	146.9	172.6	155.0	108.0	109.7
B	278.9	255.0	209.8	169.1	232.6	204.6
C	794.4	545.8	695.2	755.0	581.1	527.0
D	516.6	323.0	303.2	401.3	300.0	272.2
E	606.4	730.6	610.6	832.7	516.9	640.9
F	278.0	209.5	296.6	486.0	350.0	309.7
Average	449.0	368.5	381.3	466.5	348.1	344.0
85/15 Wool-Nylon						
G	805.9	340.4	305.8	435.8	228.8	262.8
H	640.6	486.5	854.1	809.7	327.7	564.4
Average	723.2	413.4	579.9	622.7	278.2	413.6
55/45 Wool-Cotton						
I	534.1	488.0	379.7	381.0	366.9	378.8

TABLE XXII

WARP FLEXING AND ABRASION RESISTANCE OF MACHINE WASHABLE FABRICS LAUNDERED AT 140°F.

(CYCLES PER 100 YARNS)

Fabric Types	Number of Launderings					
	1	5	10	15	20	25
100% Wool						
A	215.4	173.4	156.0	140.4	126.8	107.8
B	325.9	256.4	237.5	184.6	179.5	175.4
C	886.7	761.1	708.7	560.0	570.8	491.4
D	513.5	388.5	307.0	253.2	245.5	233.5
E	730.9	911.9	789.7	500.0	493.8	329.3
F	836.2	710.6	584.9	732.4	863.8	675.5
Average	584.8	533.7	464.0	395.1	413.4	335.5
85/15 Wool-Nylon						
G	819.3	415.4	280.0	322.6	294.8	283.9
H	101.3	870.8	669.7	681.2	693.3	421.0
Average	460.3	643.1	474.8	501.9	494.0	352.4
55/45 Wool-Cotton						
I	669.0	514.8	485.5	575.5	646.8	432.2

TABLE XXIII

FILLING FLEXING AND ABRASION RESISTANCE OF MACHINE WASHABLE FABRICS LAUNDERED AT 140°F.

(CYCLES PER 100 YARNS)

Fabric Types	Number of Launderings					
	1	5	10	15	20	25
100% Wool						
A	220.0	167.0	141.3	109.5	119.8	107.5
B	278.9	262.2	181.8	252.1	207.3	140.8
C	794.4	766.0	518.0	473.4	470.5	376.8
D	516.6	377.8	242.6	284.6	276.0	200.6
E	606.4	758.3	637.5	541.4	482.2	374.7
F	278.0	107.0	560.2	599.3	291.1	273.6
Average	449.0	406.4	380.2	376.7	307.8	245.7
85/15 Wool-Nylon						
G	805.9	345.7	276.4	368.3	249.3	306.6
H	640.6	619.7	617.2	790.4	351.1	286.8
Average	723.2	482.7	446.8	579.3	300.2	296.7
55/45 Wool-Cotton						
I	534.1	370.1	380.3	377.8	436.8	354.9

TABLE XXIV

PER CENT CHANGE IN REFLECTANCE OF EXPERIMENTAL FABRICS DUE TO 25 LAUNDERING PERIODS AT 105°F.

Fabric Types	Wavelengths in Millimicrons									
	400	450	500	550	600	650	700	750	800	850
100% Wool										
A	+25.0	0.0	-20.0	+12.5	+10.0	+17.1	+11.3	+ 7.4	+ 6.1	+ 5.6
B	+107.1	+50.0	+45.4	+39.1	+40.9	+47.6	+25.0	+17.1	+18.0	+14.3
C	+76.7	+60.0	+61.8	+60.0	+52.3	+28.6	+41.9	+32.1	+28.0	+27.2
D	+90.6	+88.6	+93.3	+81.8	+94.4	+51.8	+29.7	+34.6	+37.5	+44.7
E	-11.1	-14.3	-33.3	+11.1	+10.0	+ 1.1	+10.0	+10.6	+ 9.8	+ 9.1
F	0.0	-14.3	-20.0	-20.0	- 7.1	0.0	+ 3.0	+ 2.3	+ 1.7	+ 2.2
85/15 Wool-Nylon										
G	-20.0	-28.6	-20.0	-20.0	0.0	- 6.7	- 4.4	- 2.2	- 0.5	- 1.6
H	+175.0	+135.7	+100.0	+72.7	+66.7	+16.9	+27.9	+27.2	+35.8	+28.9
55/45 Wool-Cotton										
I	+15.0	+ 4.8	0.0	+14.5	- 4.5	+17.6	+13.3	+23.6	+28.4	+30.6
Durable Press 65/25/10 Wool-Rayon-Nylon										
J	-11.4	- 2.4	- 6.9	- 4.3	0.0	+ 1.1	0.0	- 2.2	- 2.1	- 1.0
50/40/10 Wool-Cotton-Nylon										
K	0.0	0.0	0.0	0.0	+ 7.1	+10.0	- 3.8	0.0	- 6.0	+ 0.8
L	+ 8.8	+ 8.0	+ 2.6	+ 4.5	+ 6.5	+ 9.1	+ 2.6	+ 1.4	- 2.6	- 2.0
50/20/20/10 Wool-Cotton-Rayon-Nylon										
M	+20.0	+ 7.7	+ 4.5	+ 4.0	+ 6.2	+11.8	+ 2.8	+ 1.5	- 1.8	+ 2.1
50/40/10 Wool-Rayon-Nylon										
N	+ 4.1	+17.2	0.0	0.0	+ 2.6	+10.0	- 1.3	-10.1	+ 0.6	- 2.6

TABLE XXV

PER CENT CHANGE IN REFLECTANCE OF EXPERIMENTAL FABRICS DUE TO 25 LAUNDERING PERIODS AT 140°F.

Fabric Types	Wavelengths in Millimicrons									
	400	450	500	550	600	650	700	750	800	850
100% Wool										
A	+25.0	0.0	-20.0	+12.5	+ 6.7	+19.5	+ 4.1	+ 8.3	+ 6.1	+ 4.9
B	+285.7	+135.0	+113.6	+69.6	+77.3	+76.2	+35.0	+23.7	+20.0	+19.6
C	+36.7	+25.7	+35.3	+40.0	+45.4	+21.4	+30.6	+28.6	+21.5	+22.8
D	+59.4	+62.8	+66.7	+81.8	+100.0	+74.1	+46.9	+44.2	+48.2	+52.6
E	0.0	-14.3	-16.7	+11.1	+16.7	+ 5.3	+11.8	+11.5	+ 9.7	+10.5
F	+20.0	-14.3	-20.0	-20.0	-11.9	-11.0	- 3.6	- 2.3	- 2.8	- 2.2
85/15 Wool-Nylon										
G	+20.0	-14.3	-20.0	-40.0	- 6.5	- 6.1	- 1.1	+ 1.1	+ 2.7	+ 1.1
H	+216.7	+157.1	+123.5	+81.8	+69.7	+15.4	+25.6	+26.3	+31.7	+24.4
55/45 Wool-Cotton										
I	+20.0	+19.0	- 4.5	0.0	-13.6	+ 5.9	+ 3.3	+16.4	+20.9	+19.4
Durable Press 65/25/10 Wool-Rayon-Nylon										
J	+ 2.8	+14.3	+10.3	+ 8.6	+14.5	+ 9.7	+ 5.5	+ 2.7	0.0	+ 1.0
50/40/10 Wool-Cotton-Nylon										
K	-10.0	-10.0	- 6.7	0.0	+ 7.1	+20.0	- 3.8	- 3.7	- 7.0	+ 1.5
L	- 8.8	- 4.0	- 5.1	- 4.5	- 4.3	+ 4.5	+ 3.9	- 2.7	- 2.1	- 4.0
50/20/20/10 Wool-Cotton-Rayon-Nylon										
M	+10.0	0.0	0.0	+ 8.0	+12.5	- 5.9	- 2.9	-11.8	- 7.1	- 0.7
50/40/10 Wool-Rayon-Nylon										
N	+ 2.0	+17.2	- 1.5	0.0	- 2.6	+ 5.0	+ 2.6	- 8.0	+ 3.0	- 2.6

TABLE XXVI

YARN COUNTS OF MACHINE WASHABLE FABRICS LAUNDERED AT 105°F.

PART A. WARP DIRECTION

Fabric Types	Number of Launderings					
	0	5	10	15	20	25
100% Wool						
A	37.6	39.0	38.2	38.4	39.0	38.0
B	37.0	31.4	37.2	37.2	37.0	38.6
C	37.8	38.8	39.6	39.2	38.4	39.0
D	29.6	31.0	31.0	31.2	31.0	30.8
E	30.4	32.4	32.6	32.4	31.2	31.4
F	34.0	35.6	35.2	35.2	35.4	35.8
85/15 Wool-Nylon						
G	30.0	31.2	30.8	30.8	31.4	31.2
H	30.6	32.8	33.2	32.8	33.6	32.8
55/45 Wool-Cotton						
I	74.4	73.2	74.2	74.4	73.2	74.2

PART B. FILLING DIRECTION

100% Wool						
A	34.0	35.8	35.8	36.0	37.6	37.2
B	32.2	32.0	32.8	33.0	32.8	34.4
C	32.6	33.6	34.0	34.6	34.0	34.0
D	29.0	30.4	31.0	30.0	30.4	31.0
E	28.0	30.0	30.0	30.6	30.8	30.8
F	30.0	35.8	29.8	30.0	29.6	28.8
85/15 Wool-Nylon						
G	26.8	31.2	27.4	27.4	27.8	28.0
H	25.6	26.8	26.6	26.8	27.4	27.0
55/45 Wool-Cotton						
I	78.0	80.4	79.2	80.0	80.4	80.4

TABLE XXVII

YARN COUNTS OF MACHINE WASHABLE FABRICS LAUNDERED AT 140°F.

PART A. WARP DIRECTION

Fabric Types	Number of Launderings					
	0	5	10	15	20	25
100% Wool						
A	37.6	37.6	38.6	37.6	39.6	38.6
B	37.0	37.6	36.8	37.6	38.0	37.4
C	37.8	39.0	39.0	40.0	39.8	39.4
D	29.6	31.4	31.2	31.2	31.2	32.8
E	30.4	31.8	33.0	32.0	32.0	32.8
F	34.0	35.8	35.8	36.4	35.4	36.0
85/15 Wool-Nylon						
G	30.0	27.2	31.0	31.0	31.0	31.0
H	30.6	33.6	33.0	33.0	32.8	32.4
55/45 Wool-Cotton						
I	74.4	73.2	74.6	74.4	74.0	74.6

PART B. FILLING DIRECTION

100% Wool						
A	34.0	36.4	35.8	35.8	37.4	37.2
B	32.2	32.8	33.0	33.8	32.8	33.8
C	32.6	33.6	34.4	34.6	34.6	35.4
D	29.0	30.6	31.0	31.2	30.8	31.4
E	28.0	30.2	30.4	30.4	30.4	30.8
F	30.0	30.2	29.6	29.4	29.2	29.6
85/15 Wool-Nylon						
G	26.8	28.0	28.0	27.2	27.6	27.2
H	25.6	26.4	26.8	29.2	27.0	27.2
55/45 Wool-Cotton						
I	78.0	80.4	81.2	80.2	79.4	80.2