ENERGY REQUIREMENTS FOR THE MAINTENANCE OF MEN'S SHIRTS COMPOSED OF 100 PERCENT COTTON, COTTON-POLYESTER BLENDS AND 100 PERCENT POLYESTER

A DISSERTATION

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We hereby recommend that the dissertation prepared under our supervision by Mary R. Jeffers entitled ENERGY REQUIREMENTS FOR THE MAINTENANCE OF MEN'S SHIRTS COMPOSED OF 100 PERCENT COTTON, COTTON-POLYESTER BLENDS AND 100 PERCENT POLYESTER

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CHAPTER I

INTRODUCTION

Facing the very real possibility of future energy shortages, the consumer is now in a state that requires energy to be put to its most efficient use. Awareness of energy requirements for maintenance of apparel can assist the consumer in wise utilization of available energy.

Many studies have been undertaken on durability, comfort and laundering of cotton, cotton-polyester blends and polyester. Comparisons of the required energy for production, manufacturing and maintenance of these fabrics only recently have been a concern of the textile industry.

At present there are two opinions in relation to the energy requirement for the maintenance of wearing apparel. One opinion states that although less energy is required to produce cotton and to manufacture a cotton shirt than is required to make a shirt from polyester, the advantage is lost in the wearing and maintenance cycle. Polyester was claimed to have a wear life equal to one and one-half times that of cotton (25).

The other opinion claims that total energy consumption should include energy requirements for maintenance and durability of the garment. However, the wear life of a garment is determined not only by its durability, but by other appearance features as rated by the consumer (7).

Consumer concerns for appearance have been noted many times in wear studies involving men's dress shirts. Recently, concerns of the consumer as well as the manufacturers of home laundering equipment have brought about changes in the design of washing machines which will assist in the conservation of energy.

This information leaves the following questions unanswered: Is there a difference in the minds of many with regard to the wear life of a garment? Is durability the concern of the consumer in evaluating the wear life of the garment? Also, can cotton perform under the same maintenance procedures as polyester? This study was undertaken to answer these questions.

Objectives

The overall objective of this study was to compare the amount of energy required for maintenance of four different types of men's white dress shirts during their normal wear life. The following specific objectives were chosen to provide this information:

1. To determine the availability of shirts of the four fabric types (100 percent cotton, 60/40 cotton-polyester,

65/35 polyester-cotton and 100 percent polyester) with equivalent fabrics and shirt style.

2. To develop procedures for measuring the energy needed to wash, dry and press each of the four shirt types.

3. To determine the differences between the energy required for maintenance of the four shirt types laundered at temperatures of 105°F and 120°F.

4. To evaluate the comparative performance of the four shirt types during normal wear on the basis of parameters associated with durability, appearance and comfort at two wash temperatures.

CHAPTER II

REVIEW OF RELATED LITERATURE

For many decades energy has been priced at a level which encouraged consumption with even lower prices offered to consumers with greater usages. The consumer was not concerned with the price or availability of energy sources until the shortage following the 1973 Arab oil embargo and the critical gas shortage of 1977.

Until man-made fibers became available for apparel, home laundering was a relatively simple procedure. The wash load was cotton, there was little or no choice of detergents, and the wash water was usually hot (120°-150°F). (11)

Morey and Shuck (16) stated in 1978, that approximately 95 percent of the direct energy consumed in laundering a load of white or colorfast garments is consumed in raising water temperature to desired temperatures. Conditions once considered necessary were 140°F hot wash temperature and 100°F warm rinse temperature. The authors pointed out that obviously the conservation of energy requires immediate scrutiny of wash temperature and its functional effect on cleaning.

Polyzou (19) reported in Family Economics Review that clothing and shoes comprised only 6.6 percent of personal consumption expenditures during the first three quarters of 1978. However, clothing and shoes are purchased frequently and do require a great amount of care.

Maintenance of apparel requires energy. As this is a repetitive procedure in the household, the total energy consumption in clothing maintenance is worthy of examination as related to household energy conservation.

According to Rudd (22), much information is available on attitudes toward or perceptions of the energy situation. More research needs to be directed toward areas such as clothing selection. Comparative energy cost of different choices and performing tasks in different ways were suggestions for research. Information should be made available to the consumer by reducing findings to guidelines that people can understand and use.

Two studies, which are reported below, illustrate that the direction of research has changed over the last few years. Two decades ago Barlow (4) presented a paper related to the comparative cost of several methods of laundering resin-treated and untreated men's, cotton, dress shirts. No allowance, however, was made for depreciation of the washing machine or for the cost of water, electricity, detergent, starch, bleach and labor for the home laundering method.

With a change in priorities, Mork (17), in 1970, presented information on the cost of home laundering. The findings were dependent on several things: the initial investment in laundering equipment, the frequency of the use of the equipment, the required fuel and water, the rates paid for these utilities and the cost of supplies.

At present there are two opinions in relation to the energy requirements for the maintenance of wearing apparel. The Man-Made Fiber Producers Association (9) has published information stating that cotton garments use substantially more energy for maintenance than do comparable garments from synthetic fabrics. This statement was based on research which compared moisture retention after a wash-spin cycle, drying time and touch-up ironing of different fabric types.

Van Winkle (25) examined men's white dress shirts in comparing the energy used to maintain cotton, cotton-polyester blends and polyester. The cotton shirts were washed at hot wash/hot rinse cycle; whereas, the polyester blends were washed at a hot wash/cold rinse cycle. The results of the energy measurement part of this study revealed that, although less energy is required to produce cotton and to manufacture a cotton shirt than is required to make the fiber and construct a shirt from polyester, the advantage is lost in the wearing and maintenance cycles. Based on durability, the polyester blend shirt was reported to have a lifetime of one and one-half times that of the all-cotton shirt.

Wallenberger (26) reported results of a research study which indicated that in home laundering and drying, the combined energy demand for 100 percent cotton fabrics is several times higher than for 100 percent polyester or blends having a high polyester content. The fabrics used in his study were single knit, T-shirt fabrics consisting of 100 percent Dacron polyester, 100 percent cotton (with and without resin finish) and 100 percent Orlon acrylic. Also, fabric blends of various percentages of Dacron, cotton, Orlon and rayon were included. As home washing and drying is repeated 20 to 50 times during the wear life of the fabric, the difference in the energy required to launder polyester versus cotton in 50 million households was reported to be equal to 330 trillion BTU's annually. However, the two hydrophilic cotton fabrics were laundered at 140°F and rinsed at 104°F. The man-made fiber fabrics were laundered at 104°F and rinsed at 54°F.

The other opinion concerning the energy maintenance requirements of polyester versus cotton is supported by information released by the National Cotton Council (7) to the effect that any comparison of energy consumption should include the maintenance and durability of the garment. However, many factors limit the wear life of a garment other than durability, such as whiteness retention, pilling and smoothness. Consumer habits influence both the amount of energy used in maintenance and length of wear life.

The concern of the consumer for the appearance of apparel has been reflected in results of a shirt study reported by the editors of Consumers' Research Magazine (15). Seven brands of woven, "Natural Blend" shirts, which had been exposed to 52 laundering periods, were rated according to seam strength, soil release properties, appearance, quality of construction and workmanship, shrinkage and tensile and tearing strength. Ratings for the tested shirts were reported by ranking the brand names represented.

The concern of consumers as well as manufacturers of home laundering equipment has resulted in changes in designs of washing machines which will assist in conservation of energy. The editors of Consumers' Research Magazine (27) reported that some of the changes which have been made are larger drum sizes, numerous water level selections and recycling of hot water.

Hirst (14) pointed out that there is nothing consumers can do to reduce fuel costs, but they can control these costs by improving the efficiency of fuel usage. Two suggestions were made which could bring about these changes. First, the consumer can change the way in which existing systems are operated, such as changes in thermostat settings.

Secondly, changes must be made in improving the technical efficiency of the equipment used and of the home in which the consumer lives.

The Federal Energy Administration Act in 1974, and the Energy Policy and Conservation Act in 1975, began to change the lifestyle of consumers. As a result of these Acts, research has been directed toward collecting accurate and usable information to aid the consumer in energy conservation.

The Energy Policy and Conservation Act of 1975 directed the Federal Trade Commission to issue labeling rules for the energy efficiency of home appliances. Final approval of the labels came in September 1979, and black and yellow labels appeared on appliances in the Spring of 1980. These labels provided information for comparison shopping by disclosing standard operating cost or energy efficiency. Claims made by manufacturers must be supported by test data resulting from tests conducted in the energy department laboratories (8). This program is aimed at roughly 90 percent of the energy used in homes. At first the regulations will include the manner in which the appliance is to be advertised and marketed, but will eventually set mandatory energy-efficiency standards (16).

The washing machine industry has made significant contributions to energy conservation by recommending that all rinses be performed in cold water. No losses in cleaning performance have been observed through this procedure (16), (6).

Hassoun (13) investigated characteristics of families and ownership of home electric equipment as predictors of electric usage. The information revealed a positive significant relationship between total, direct energy used and: household size, employment of home manager, water heater types and number of major appliances owned. Torres (23) stated that only 19 percent of the participants in an energy related study could classify more than seven of 12 common home appliances by broad wattage ratings. Awareness of wattage ratings is necessary in order to determine the additional electrical demand that is made by each appliance used.

The consumer is faced with a wide variety of fabrics, soils and cleaning products. Morey and Shuck (16) noted that improved detergency, fabric developments and machine improvements will enable acceptable laundering at lower energy consumption for many families. The authors reported that the ultimate decision must be based on natural or real soil removal measured in an actual wear and wash sequence. However, they reported that there are heavily soiled clothes in some families which will continue to require hot water and thus high energy consumption for acceptable cleaning.

Woodfin (28) investigated the interaction of detergent type, detergent concentration and laundering temperature in the removal of soil from standard soiled polyester, cotton and cotton-polyester fabrics. The most efficient combination for cleaning both cotton and polyester fabrics was the use of the recommended concentration of non-ionic detergents at a wash temperature of 160°F. The addition of more detergent was found to be feasible only when hot water was used; higher temperatures were beneficial only when detergent concentration was "ample".

The energy reduction potential in apparel maintenance in the area of household energy consumption is a challenge which must be met with improved detergency, machine efficiency, soil-release fabrics and adequate consumer guidelines. If the results of the research directed toward apparel maintenance are made available to the consumer, the consumer will be able to contribute to the conservation and preservation of the energy resources.

CHAPTER III

PLAN OF PROCEDURE

The procedure has been divided into the following sections: 1) description of the experimental shirts, 2) selection of the wearers, 3) wearing procedure, 4) laundering procedure, 5) energy measurement, 6) equipment, 7) visual and physical evaluations and 8) data analyses.

Description of the Experimental Shirts

One hundred men's long sleeve white dress shirts of four fabric types (100 percent cotton, 60/40 cotton-polyester, 65/35 polyester-cotton and 100 percent polyester) were used as experimental garments in the study. The fabric descriptions are given in table 1. There were 25 shirts of each of the four types; 12 shirts of each type were laundered at each of the respective temperatures, and one was reserved for initial evaluations. The shirts were made of woven fabrics in similar weights. Particular details such as interfacings, thread, buttons and style were as comparable as possible for all fabric types.

Selection of the Wearers

Participants in this study included 48 male, white

TABLE 1

CONSTRUCTION DETAILS OF THE SHIRT FABRICS

Fabric Code	Fiber Content	Weave	Yarn Count	
			Warp	Filling
1, 5	100% cotton	Plain	124/in.	110/in.
2, 6	60/40 cotton-polyester	Plain	133/in.	69.8/in.
3, 7	65/35 polyester-cotton	Plain	134.6/in.	103.8/in.
4, 8	100% polyester	Twill	118.4/in.	95.2/in.

collar university personnel. All men selected were of medium build and average sleeve length as all shirts were purchased in the same size to facilitate laundering of like loads. A partially balanced incomplete block design was utilized in assigning two shirts to each participant.

Wearing Procedure

The shirts were coded as to fabric type, wash temperature and shirt number. This code was permanently marked on the right front tail of each shirt.

The participants were instructed to wear each shirt for a minimum of eight hours before returning it to be laundered. The shirts were examined and treated for stains, washed and evaluated before they were returned to the wearer for additional wear. This plan continued until all shirts had been exposed to 25 wear/laundering periods.

Laundering Procedure

Laundering was accomplished as recommended in washing conditions I and II of AATCC Test Method 143-1975 (1). Twelve shirts of each type were laundered together for each of the two temperatures being employed.

In preparation for laundering, each shirt was checked for heavy soiling stains. Stains were pretreated with a paste of equal parts of laundry detergent and water. After pretreatment, the detergent paste was washed out of the shirt. All of the shirts were sprayed with Spray-and-Wash on the collar, inside of neck band, cuff edges and any other heavily soiled areas.

The wash cycle was set for twelve minutes, and 127.8 grams of AATCC #124 detergent with brightners was used in each wash load. The water level was set on high, and the permanent press cycle was selected for the laundering cycle.

The shirts were removed immediately after the wash cycle was completed and transferred to the dryer. The dryer was set for the permanent press cycle with a cool down ending cycle. The "normal dry" setting was selected in order to utilize the moisture sensor in the dryer to measure drying time for each fabric type.

After the drying cycle was completed, the shirts were removed, marked and placed on a wire hanger for evaluation or for pressing and redistribution. Any pressing that was required to provide at least a 4.0 durable press value was done by means of a hand iron.

Energy Measurement

Electric meters provided by the City of Denton were used to measure the amount of energy used to wash, dry and press the shirts and to heat the wash water for this wear/laundering study. The meter revolutions were counted and the following formula, supplied by the City of Denton official, Mr. John Goldman (12), was used to calculate the kilowatt hours used. The energy cost of operation was obtained by using $.04 as the average cost per kilowatt hour in the City of Denton at the time this study was conducted.

Formula:

$$\frac{3.6}{1000} \times \text{No. of revolutions} = \frac{\text{watt hrs.}}{1000} = \text{kilowatt hrs.}$$

Kilowatt Hours x $.04 = Operation cost

The hot water heater thermostats were adjusted to yield water at a temperature of 105°F. Then the water was drained from the hot water heater and refilled with tap water. The amount of energy necessary to heat the 40 gallon tank of water to 105°F was recorded as the number of meter revolutions. Since the wash cycle used 23 gallons, 58 percent of the total kilowatt hours used by the water heater was considered to be the amount of energy required for the heating of the water. This procedure was repeated for the other temperature of 120°F.

The dryer lint trap was cleaned, and the dryer was preheated five minutes before the shirts were put into the dryer. The revolutions of the meter required to dry 12 shirts of each fabric type were counted and recorded. The moisture sensor was used to determine when each fabric type was dried.

The washing machine energy requirements were measured by recording the number of meter revolutions required to wash a load of 12 shirts. The energy requirements for the iron were measured after the iron had been preheated for two minutes. As the meter revolutions reading was so small for the pressing of one shirt, six shirts of the same fabric type were pressed on a continual basis in order to calculate the time and energy requirements per shirt.

Equipment

A domestic washing machine as specified in AATCC Test Method #124 was used for all launderings. The design of this machine included an extra large 2.71 cubic foot washing drum, two washing agitator speeds and two spin speeds. The rinse consisted of a power spray rinse and an agitated deep rinse.

Two tumble speeds and a permanent press cycle with an automatic cool down were two of the features of the selected dryer, which was a domestic, Whirlpool LDE with a 6.9 cubic foot drum. This model was equipped with a moisture sensor with three dryness selections.

Individual electric meters were used for the hot water heater, washing machine, dryer and iron as a means of measuring the amount of energy required during the refurbishing of the shirts. Meter revolutions were counted and converted to kilowatt hours.

A Sears hand, steam iron was used for necessary pressing, with a setting of #3 Permanent Press. Water heating for the two wash temperatures was accomplished with a 40 gallon Rheem electric hot water heater.

Visual and Physical Evaluations

During the course of the study, the shirts were evaluated with regard to parameters that were important to the consumer at intervals of 0, 5, 10, 15, 20 and 25 wearings. The visual evaluations made after each wear interval included soiling, durable press, broken yarns, pilling and whiteness retention.

After the visual evaluations were completed, physical testing was performed which included breaking strength, air permeability, absorbency and electrostatic build-up. Specimens for the tests performed after the terminal wearing and washing were cut from the shirts as indicated in fig. 4. All specimens were tested under standard conditions specific to the test conducted.

Soiling

Prior to each five laundering periods, the shirts which had been worn were rated by visual examination according to their degree of soiling. Each shirt was checked by a technician who was elevated above the shirts by the use of a high stool. A fluorescent light, which was 18 inches above the shirt, was the light source. The degree of soil on the collar and the overall appearance of the shirt were ascertained in determining the assigned rating.

The amount of soil was rated according to the following scale as used by Roch (20), Turner (24), Ball (3), Roemhildt (21) and Calvert (5):

Rating	Description of Soiling and Staining
5	Clean all over; no visible spots of stains
4	Light soil; small oil stains; pencil and ink marks or other discoloration
3	Medium soil; medium-sized or many oil, food or earth stains; shoe polish; small permanent stains
2	Dirty overall; localized ground-in soil; large oil stains; splattered paint; persistent discoloration
1	Heavy soil; dirty oil stain; large or many paint stains; other permanent, unsightly discolorations.

Durable Press Appearance

The durable press appearance of the shirts was determined by the AATCC Test Method 124-1973 (1) after each five wear/laundering periods. After removing the shirts from the dryer, each shirt was placed on a wire hanger. The top button was buttoned, and the shirt was allowed to hang for two hours before being evaluated. The durable press appearance was rated individually by three panel members in a semi-darkened room with walls draped with black-out curtains to eliminate any possible light reflections. A fluorescent overhead lighting system provided the lighting for the shirt evaluations. The shirt on a wire hanger was hung on a hook on a viewing board below the light. The back of the shirt faced the evaluator with AATCC Photographic Standards for smoothness placed on either side of the shirt. Each of the three evaluators stood four feet from the viewing board and compared the smoothness of the shirt with the standards.

Broken Yarns

A preliminary examination was made on each shirt before they were assigned to the wearers. Fabric flaws, ruptured yarns and slub yarns were recorded. After every five laundering periods, this examination was repeated and the findings recorded. At each evaluation period, a different color of ink was used to mark the diagram representative of the front and back views, sleeves and collar of the shirts (figure 1). When holes and tears were observed in the shirt between the evaluation periods, these yarns were counted and recorded. Any damaged areas were mended, and the shirt was returned to circulation.

The examinations were performed over a light box with the aid of a Suter yarn counter. Additional light was provided by an overhead fluorescent light placed 15 inches

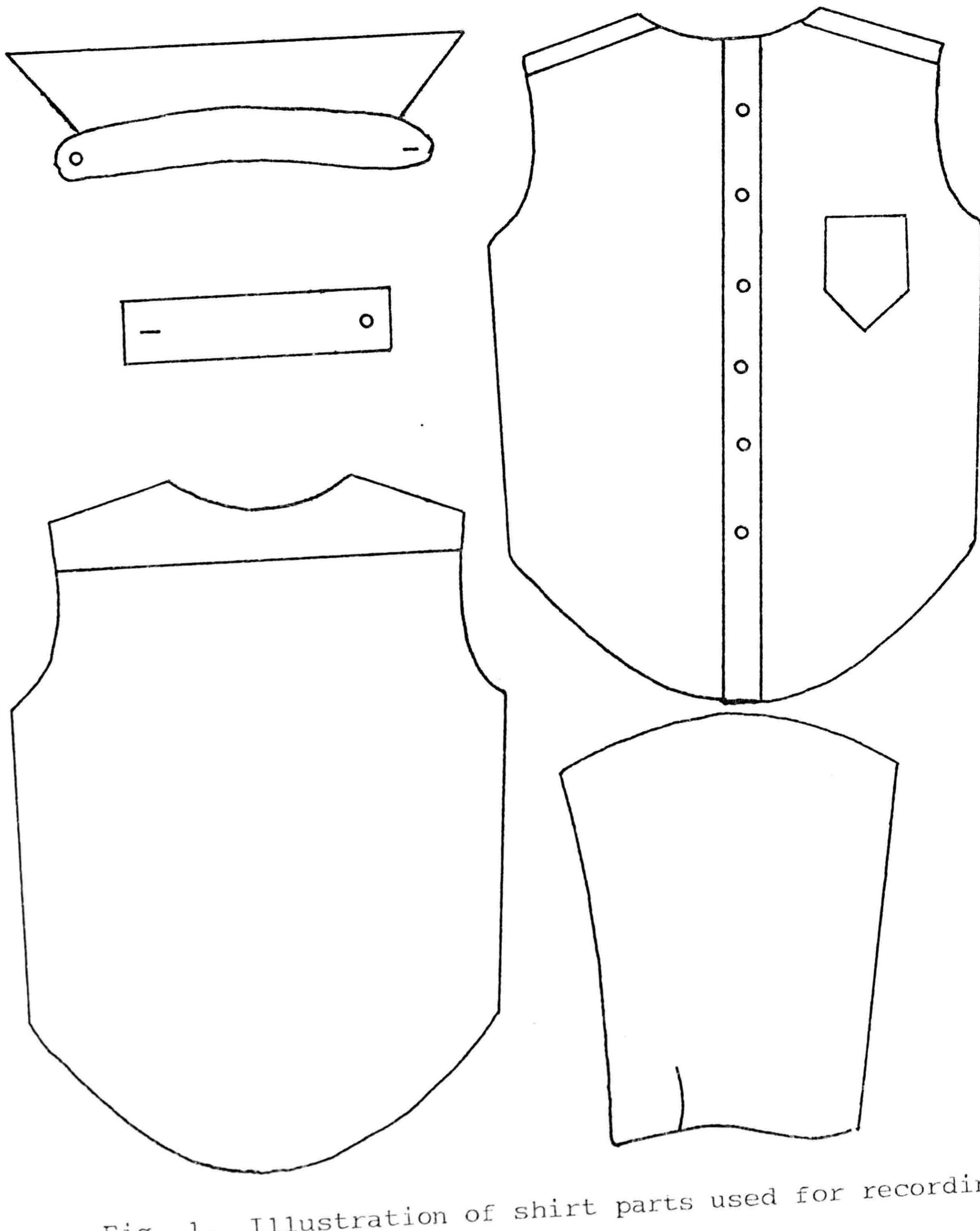


Fig. 1. Illustration of shirt parts used for recording broken yarns.

from the light box.

Pilling

A pill was defined to be an accumulation of fibers which was attached to the fabric by another fiber. A black plastic plate with four one-inch holes was centered over the right side of the collar and neck band seam at the center back of the shirt (figure 2). After the shirt was placed over the light box, a technician counted and recorded the number of pills within each opening. A pick and a magnifying glass aided in the observation.

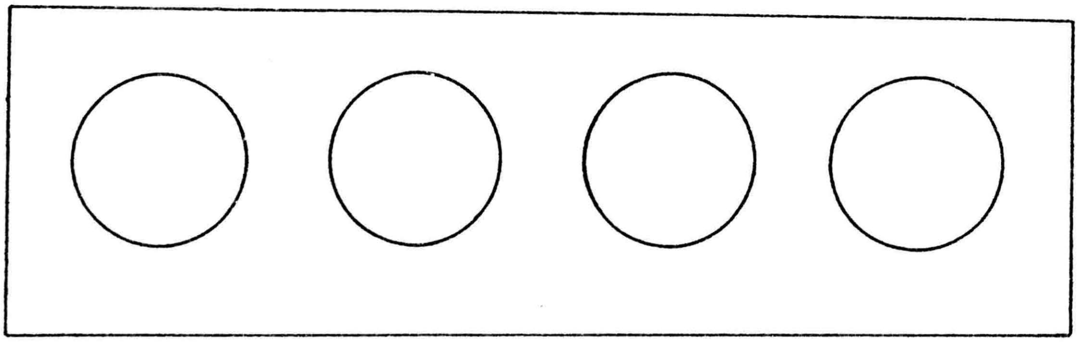
Whiteness Retention

Each shirt was evaluated for whiteness retention initially and after each five wear/laundering periods. A Hunterlab Model D-40 Reflectometer was used to determine the whiteness retention of the shirts according to AATCC Test Method 110-1972 (1).

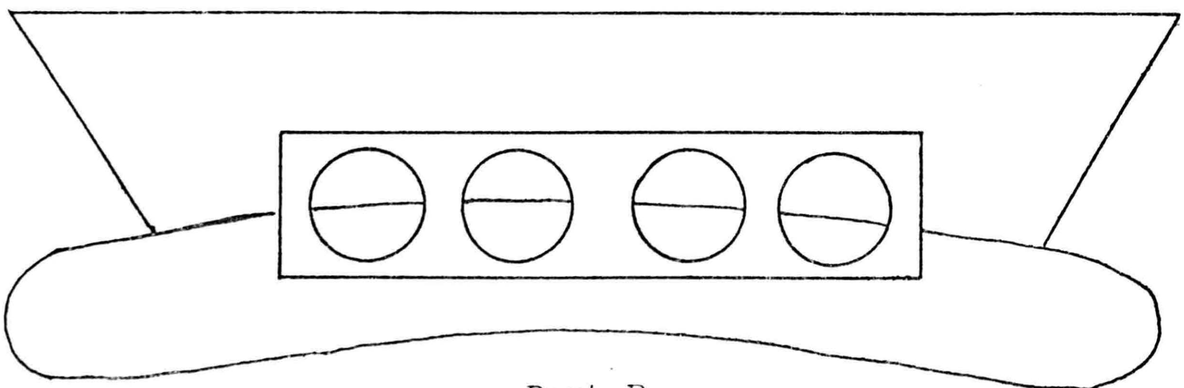
Reflectance readings were made in the following five areas of each shirt: center back (below yoke), center back (waistline), center front (waistline) and sleeves (right and left upper front).

Air Permeability

The four areas of the shirt selected for air permeability tests were: center back (waistline), right front



Part A



Part B

Fig. 2. Part A. Pattern used for pilling evaluations.

Part B. Diagram of shirt collar indicating areas where pills were counted.

(waistline), left front (underarm) and left sleeve back (underarm (figure 3).

The falling cylinder method, Federal Test Method 5452 (10), was employed to measure the rate at which air passed through the specimen. This was determined by the use of a stop watch to measure the time necessary for the division marks on the inner cylinder to pass the upper edge of the outer cylinder. Air permeability values were the average of the specimen readings, and were reported to the nearest second.

Breaking Strength

The grab method, specified by ASTM Designation: 1682-70 (2), was used to determine the breaking strength of the shirt fabrics. Five warp and five filling specimens which measured four inches wide and six inches long were cut on the straight of grain (figure 4). An Instron Tensile Tester was used to measure the number of pounds of force required to break the specimens for each shirt. The results were reported to the nearest 0.1 pound.

Absorbency

The absorbency data of the four fabric types were collected by the use of AATCC Test Method 79-1975 (1). The shirts were exposed to standard conditions prior to conducting the test. The tail of the shirt, approximately two inches

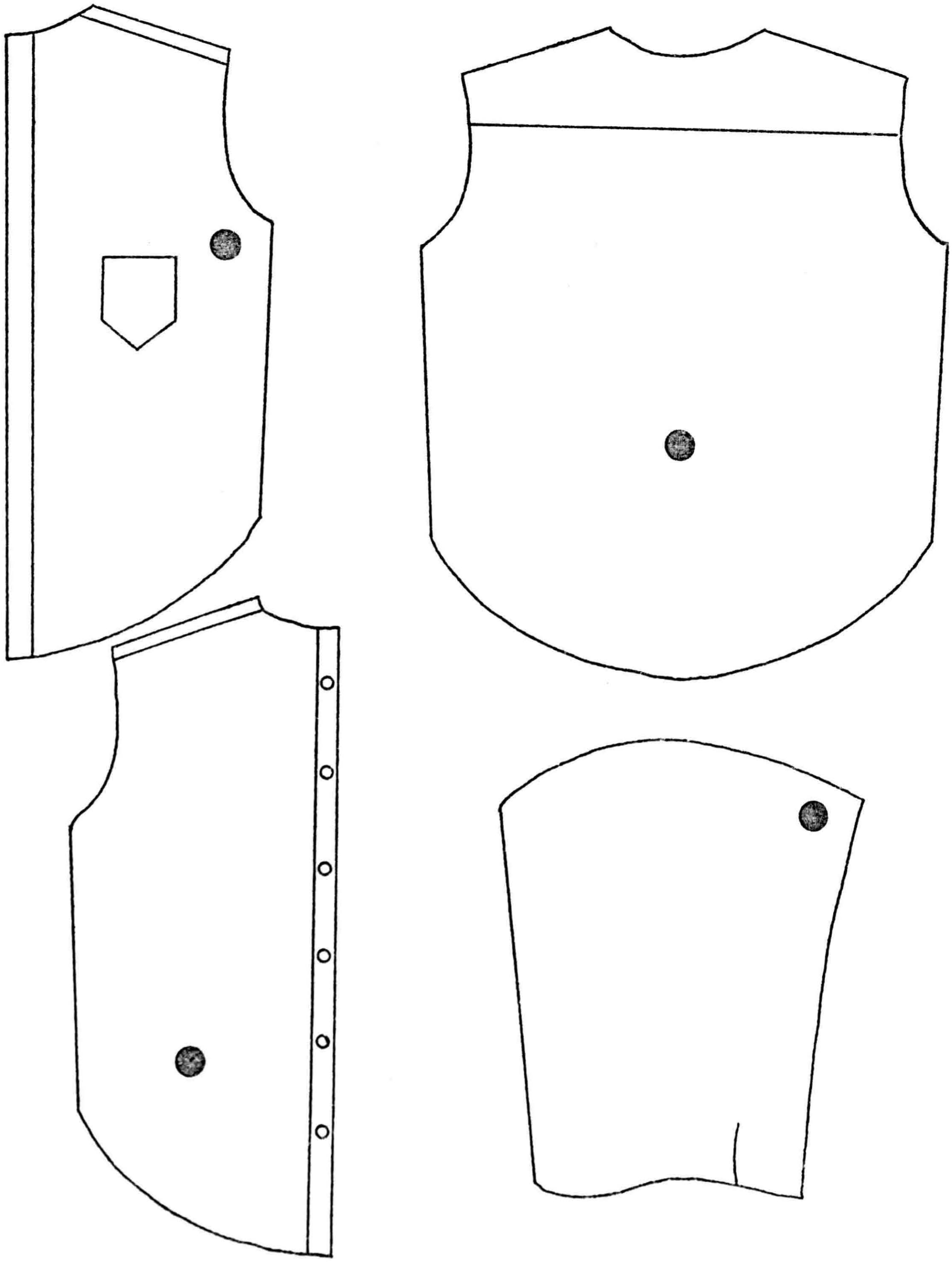


Fig. 3. Locations on the shirts for air permeability tests.

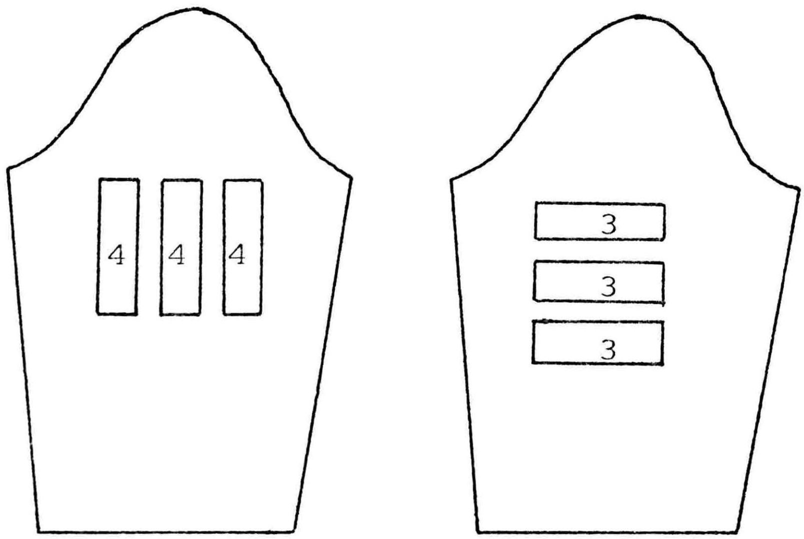
from the hem, was stretched taut in an embroidery hoop and placed on a stand 3/8 inch below the tip of a burette which had been filled with distilled water. The burette was adjusted to deliver one drop of water every five seconds. Each drop was observed until it was completely absorbed and registered no light reflectance. Five readings were taken on each shirt and recorded to the nearest one-tenth of a second.

Electrostatic Build-up

AATCC Test Method 115-1977 (1) was used to evaluate the electrostatic build-up of the experimental shirts. Six specimens, three warp and three filling, were cut from the upper sleeves of each garment (figure 4). A metal plate was used to simulate the charged surface of the human body. The fabric specimen, after being de-charged with a 500 microcuries Staticmaster Ionizing Unit, was attached to the standing metal plate with a clamp. A piece of nylon test fabric, stretched over a block of wood, was used to develop an electrostatic charge. The time required for the charge of the fabric specimen to deteriorate enough for the gravitational forces to intervene and pull the specimen away from the metal plate was measured and recorded to the nearest one-hundredth of a minute.

Data Analyses

The experimental design selected was a partially



Key: 1. Grab breaking (filling)
2. Grab breaking (warp)
3. Electrostatic build-up (filling)
4. Electrostatic build-up (warp)

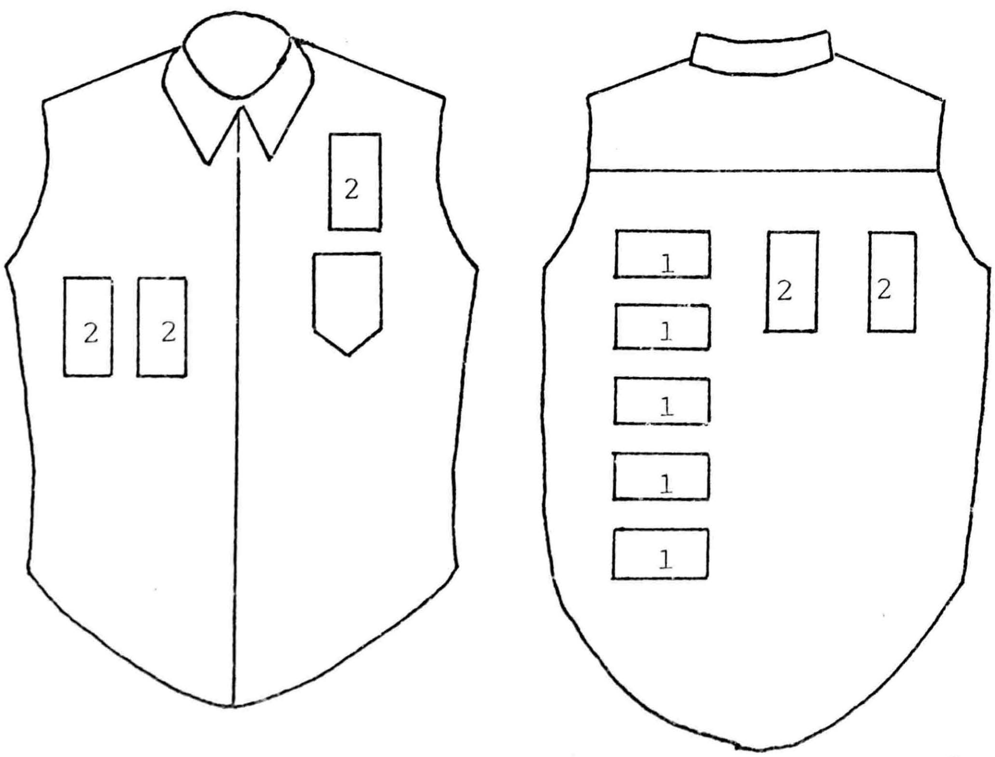


Fig. 4. Illustration of front, back and sleeve of shirt showing location of test specimens.

balanced incomplete block design. This design was selected because of the preset number of wearers and shirts; each individual wearer constituted a block; each block contained the two "treatments". Certain of the fabrics occurred together in some blocks; others did not. Nevertheless, analysis permitted comparison of fabric types washed at the same temperature and at different temperatures. Bonferroni's Test was utilized to determine significant differences at the 0.05 level of probability that existed when the treatments were compared.

The broken yarn data were analyzed separately by presenting totals and comparing simple means, as the broken yarns were a combined total of broken yarns resulting from tears and abrasion. With few exceptions the soil ratings were all rated as fours (five is maximum); therefore, these data were also totaled and averaged for presentation.

The final two evaluation tests, breaking strength and electrostatic build-up, which were destructive to the fabrics were not suitable for the block design, as four shirts from each fabric type were retained for further wearing. These results were analyzed with a one-way analysis of variance, and significant differences were calculated using Newman-Keuls Multiple Comparison Test. Comparisons were made between the four fabric types washed at the two wash temperatures.

CHAPTER IV

PRESENTATION OF DATA AND DISCUSSION OF FINDINGS

One hundred men's white dress shirts were purchased for experimental testing in order to evaluate the energy cost requirements for the four fabric types represented: 100 percent cotton, 60/40 cotton-polyester, 65/35 polyester-cotton and 100 percent polyester. Each shirt was worn and laundered 25 times. Visual and physical tests were performed to determine the durability and appearance of the shirts after 5, 10, 15, 20 and 25 wear/laundering periods. Data collected from tests for absorbency, electrostatic build-up and air permeability were included to provide information concerning the comfort features of the four fabric types.

Energy Measurement

The energy cost figures (table 2) are based on averages taken when outside temperatures varied during the course of this study. Twenty-three gallons of water were used per wash cycle. A cold rinse was used for all fabrics; therefore, this was not a factor in the energy cost as in other studies (25), (26). Table 2 shows that the average cost to heat 23 gallons of water from the average initial temperature of 77°F (standard deviation of 5) to 105°F was \$.0838 and to heat 23 gallons of water to 120°F was \$.122. The energy efficiency of the electric hot water heater was calculated using the initial average tap water temperature (77°F) during the duration of this study. In raising the water temperature to 105°F, the hot water heater had an efficiency rating of 85 percent; whereas, for a 120°F reading the efficiency rating was 89 percent. Regardless of the fabric fiber content, the washing machine operation cost for washing 12 shirts was \$.077. The average costs to operate the clothes dryer for 12 shirts were:

100% cotton shirts	\$.09
60/40 cotton-polyester shirts	\$.07
65/35 polyester-cotton shirts	\$.055
100% polyester shirts	\$.06

The drying cost per shirt was less than one cent, regardless of fiber content. The 100 percent polyester shirt felt wet when removed from the washer which might account for the cost being more than for the 65/35 blend.

The costs of pressing 12 shirts of each fabric type were:

100% cotton shirts	\$.012
60/40 cotton-polyester shirts	\$.006
65/35 polyester-cotton shirts	\$.007
100% polyester shirts	\$.007

The cost of pressing twelve all-cotton shirts was twice the cost for pressing the 100 percent polyester

TABLE 2

UNIT COSTS FOR REFURBISHING THE SHIRTS WHEN LAUNDERED AT TWO WASH TEMPERATURES

	Heating of Water	Washing Machine	Clothes Dryer	Hand Ironing	Tot. Cost 12 shirts	Tot. Cost 1 shirt
105°F:						
100% cotton	$.0838	$.077	$.09	$.012	$.2628	$.0219
60/40 cotton-polyester	.0838	.077	.07	.006	.2368	.0197
65/35 polyester-cotton	.0838	.077	.055	.006	.2218	.0185
100% polyester	.0838	.077	.060	.007	.2278	.0190
120°F:						
100% cotton	$.122	$.077	$.09	$.012	$.301	$.025
60/40 cotton-polyester	.122	.077	.07	.006	.275	.023
65/35 polyester--cotton	.122	.077	.055	.006	.260	.022
100% polyester	.122	.077	.060	.007	.266	.022

shirts; however, the small cost of energy for pressing is obvious when the cost of the 12 shirts is divided to reveal the individual cost of pressing one shirt. As noted in table 2,the unit costs for refurbishing the shirts in this study did not agree with results of previous researchers who reported that cotton garments require "substantially" more energy for maintenance than do comparable garments of synthetic fabrics.

Soiling

The mean soiling values of the shirts observed before the 5, 10, 15, 20 and 25 laundering periods are shown in table 3. As most shirts, with few exceptions, received a rating of four or better out of a possible five, the degree of soiling was not found to be important in this study. Results revealed no observable soil accumulation at either temperature on any of the four shirt types examined; however, the 100 percent polyester shirt registered the lowest value of the four shirts at the final evaluation period at both temperatures.

Durable Press Appearance

The appearance of 96 men's white shirts laundered at 105°F or 120°F wash temperature were evaluated by a panel of three textile specialists according to AATCC procedure at

TABLE 3

MEAN SOILING VALUES OF THE SHIRTS OBSERVED BEFORE THE 5, 10, 15, 20 AND 25 LAUNDERING PERIODS

	Wear/Laundering Periods				
Fabric Code[a]	5	10	15	20	25
1	4.1	4.0	4.0	4.2	4.2
2	4.3	4.0	4.0	4.2	4.2
3	4.5	4.1	4.1	4.1	4.2
4	4.2	4.1	4.0	4.0	4.0
5	4.1	3.9	4.0	4.0	4.1
6	4.2	4.1	4.2	4.2	4.1
7	4.2	4.1	4.0	4.0	4.1
8	4.0	4.1	3.9	4.2	3.9

a

105°F	Fabric	120°F
1	100% cotton	5
2	60/40 cotton-polyester	6
3	65/35 polyester-cotton	7
4	100% polyester	8

5, 10, 15 20 and 25 wear/laundering periods. The mean durable press values of the eight shirt codes are presented in table 4 and figure 5. The all-cotton shirt received the lowest value of the four shirts at both wash temperatures; however, their smoothness improved after the 20 wear/laundering interval. The durable press value of the two blended shirts and the 100 percent polyester shirt registered similar high values at both temperatures. Although the value for the all-polyester shirt was second at both wash temperatures at the five wear/laundering evaluation period, the value continued to decline and was third highest by the final wear/laundering evaluation period. The 65/35 polyester-cotton shirt had the highest durable press value at the first evaluation period of all of the four shirt types. This shirt maintained this throughout all testing intervals at both wash temperatures.

Results of Bonferroni's Test are presented in table 5. There were significant differences between the durable press values of the all-cotton shirt and the other three fabric types at both 105°F and 120°F wash temperatures at each of the five evaluation periods.

Smaller significant differences were noted after five and 15 wear/laundering evaluation periods at the 105°F wash temperature. At the five laundering period, the 65/35 polyester-cotton shirt showed a slightly better smoothness appearance than did the 60/40 cotton-polyester shirt. The 65/35 polyester-cotton values again showed positive significant differences when compared with the durable press values of the 100 percent polyester shirt following the 15 wear/laundering period. Only one significant difference was found among the four fabric types when laundered at the 120°F. This difference occurred at the terminal test interval when the 65/35 polyester-cotton was found to have a smoother appearance than the 100 percent polyester shirt.

At three evaluation periods, 5, 10 and 25 launderings, the significant differences between shirts supported the fact that the 100 percent cotton had a superior durable press value when washed at the 120°F temperature. At the higher temperature, after the 10 wear/laundering period, the 65/35 polyester-cotton shirt and the 100 percent polyester shirt received a significantly better smoothness score than did the identical fabric refurbished at the lower temperature.

Although significant differences were found at various testing periods, the graphic illustration in figure 5 shows that durable press appearance did not change noticeably after the first evaluation period regardless of the wash temperature. The two cotton-polyester blends claimed

TABLE 4

MEAN DURABLE PRESS VALUES OF THE SHIRTS AFTER 5, 10, 15, 20 AND 25 WEAR/LAUNDERING PERIODS AT TWO WASH TEMPERATURES

Fabric Code[a]	Wear/Laundering Periods				
	5	10	15	20	25
1	2.56	2.64	2.33	2.13	2.32
2	3.53	3.44	3.42	3.35	3.43
3	3.83	3.50	3.36	3.42	3.44
4	3.71	3.46	3.33	3.32	3.31
5	2.82	2.50	2.25	2.22	2.49
6	3.49	3.31	3.40	3.36	3.40
7	3.64	3.50	3.49	3.40	3.49
8	3.62	3.42	3.35	3.18	3.06

[a]

105°F	Fabric	120°F
1	100% cotton	5
2	60/40 cotton-polyester	6
3	65/35 polyester-cotton	7
4	100% polyester	8

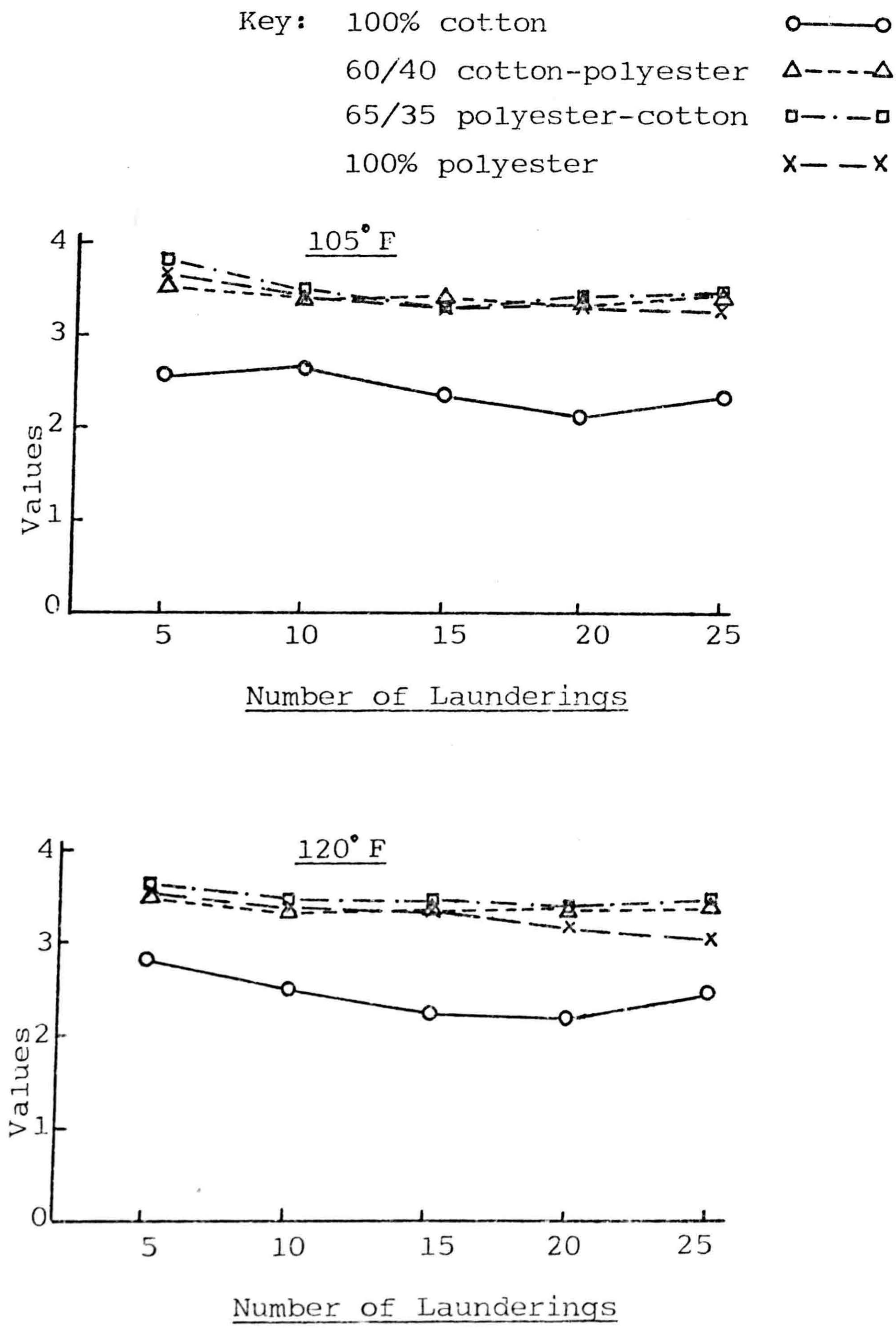


Fig. 5. Mean durable press values of the shirts after 5, 10, 15, 20 and 25 wear/laundering periods at two wash temperatures.

TABLE 5

BONFERRONI'S TEST FOR SIGNIFICANT DIFFERENCES BETWEEN DURABLE PRESS VALUES OF THE SHIRTS AFTER 5, 10, 15, 20 AND 25 WEAR/LAUNDERING PERIODS AT TWO WASH TEMPERATURES

105°F:

Wear/Laundering	Fabric Comparisons					
Period	1 vs 2	1 vs 3	1 vs 4	2 vs 3	2 vs 4	3 vs 4
5						
Adjusted Mean Difference	-1.08	-1.38	-1.21	-0.29	-0.12	0.17
T-Value	-10.99*	-13.94*	-12.26*	-2.96*	-1.27	1.69
10						
Adjusted Mean Difference	-0.79	-0.79	-0.74	0.00	0.06	0.06
T-Value	-8.36*	-8.36*	-7.77*	0.00	0.59	0.59
15						
Adjusted Mean Difference	-0.94	-0.96	-0.10	-0.01	-0.06	-0.04
T-Value	-9.29*	-9.42*	-9.84*	-0.14	-0.55	-0.41
20						
Adjusted Mean Difference	-1.39	-1.54	-1.22	-0.15	0.17	0.32
T-Value	-13.21*	-14.66*	-11.62*	-1.45	1.58	3.30*
25						
Adjusted Mean Difference	-1.10	-1.32	-1.04	-0.22	0.06	0.28
T-Value	-11.28*	-13.56*	-10.71*	-2.28	0.57	2.86

TABLE 5--Continued

120°F:

Wear/Laundering Period	Fabric Comparisons					
	5 vs 6	5 vs 7	5 vs 8	6 vs 7	6 vs 8	7 vs 8
5						
Adjusted Mean Difference	-0.69	-0.81	-0.94	-0.11	-0.25	-0.14
T-Value	-7.04*	-8.17*	-9.58*	-1.13	-2.54	-1.41
10						
Adjusted Mean Difference	-0.72	-0.99	-0.92	-0.26	-0.19	0.07
T-Value	-7.62*	-10.41*	-9.68*	-2.78	-2.05	0.73
15						
Adjusted Mean Difference	-1.12	-1.15	-0.93	-0.03	0.20	0.22
T-Value	-11.10*	-11.37*	-9.15*	-0.27	1.94	2.22
20						
Adjusted Mean Difference	-1.12	-1.19	-0.92	-0.07	0.21	0.28
T-Value	-10.70*	-11.36*	-8.72*	-0.67	1.98	2.64
25						
Adjusted Mean Difference	-0.89	-1.10	-0.61	-0.21	0.28	0.49
T-Value	-9.14*	-11.28*	-6.28*	-2.14	2.86	5.00*

TABLE 5--Continued

105°F and 120°F:

Wear/Laundering Period	Fabric Comparisons 1 vs 5	2 vs 6	3 vs 7	4 vs 8
5				
Adjusted Mean Difference	-0.38	0.01	0.19	-0.11
T-Value	-4.07*	0.15	2.11	-1.21
10				
Adjusted Mean Difference	-0.32	-0.25	-0.52	-0.50
T-Value	-3.64*	-2.86	-5.84*	-5.68*
15				
Adjusted Mean Difference	0.13	-0.06	-0.07	0.20
T-Value	1.33	-0.60	-0.75	2.06
20				
Adjusted Mean Difference	-0.28	-0.02	0.07	0.02
T-Value	-2.86	-0.18	0.67	0.25
25				
Adjusted Mean Difference	-0.30	-0.09	-0.08	0.13
T-Value	-3.32*	-1.03	-0.88	1.41

*Significant at 0.05 level of probability

first and second values; whereas, polyester was third, with cotton fourth.

Broken Yarns

Table 6 shows the total number of broken yarns observed in the warp and filling directions of the shirts at each wear/laundering evaluation period. The grand total appears in the last column. A statistical analysis was not applied to these data as they are a combination of broken yarns caused from abrasion and tears. A few tears that were noted appeared at the waistline where the shirt buttoned over the stomach and may have been caused by stress (figure 6). The tears occurred on the all-cotton shirt and the 60/40 cotton-polyester shirt. The all-cotton shirt had the largest number of broken yarns; the blends received the two middle places; the all-polyester shirt had the fewest number of broken yarns. Although snags and pulls were not considered as broken yarns, they did affect the appearance, as shown pictorially in figure 7.

Pilling

The mean pilling evaluations made on shirt collars and neck bands are recorded in table 7 as the average number of pills counted for each fabric type. Figure 8 depicts a 0.0 to 0.3 range for number of pills counted for the

TABLE 6

NUMBER OF BROKEN YARNS OBSERVED INITIALLY AND AT 5, 10, 15, 20 AND 25 WEAR/LAUNDERING PERIODS AT TWO WASH TEMPERATURES

Shirt Type	Wear/Laundering Periods						Totals	Grand Totals
	0	5	10	15	20	25		
All-cotton								
105°F	10	17	73	80	40	21	241	
120°F	4	131	23	231	35	30	454	695
60/40 cotton-polyester								
105°F	17	85	21	30	33	44	230	
120°F	4	33	47	30	19	17	150	380
65/35 polyester-cotton								
105°F	14	21	23	25	29	33	136	
120°F	26	63	36	17	19	36	197	333
All-polyester								
105°F	15	38	2	5	10	123	193	
120°F	4	6	33	7	7	11	68	261

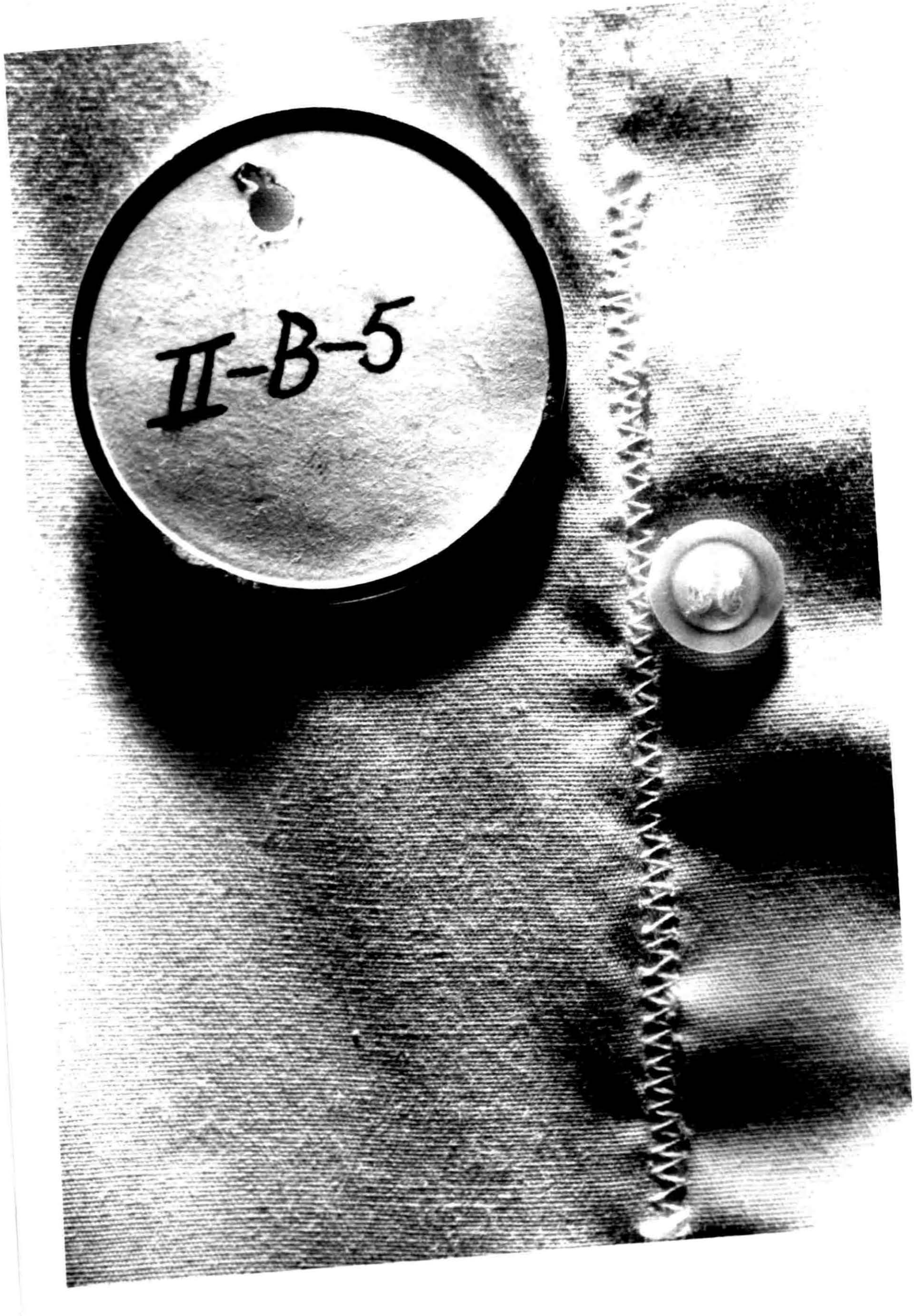


Fig. 6. A pictorial example of a tear observed on a 60/40 cotton-polyester shirt.

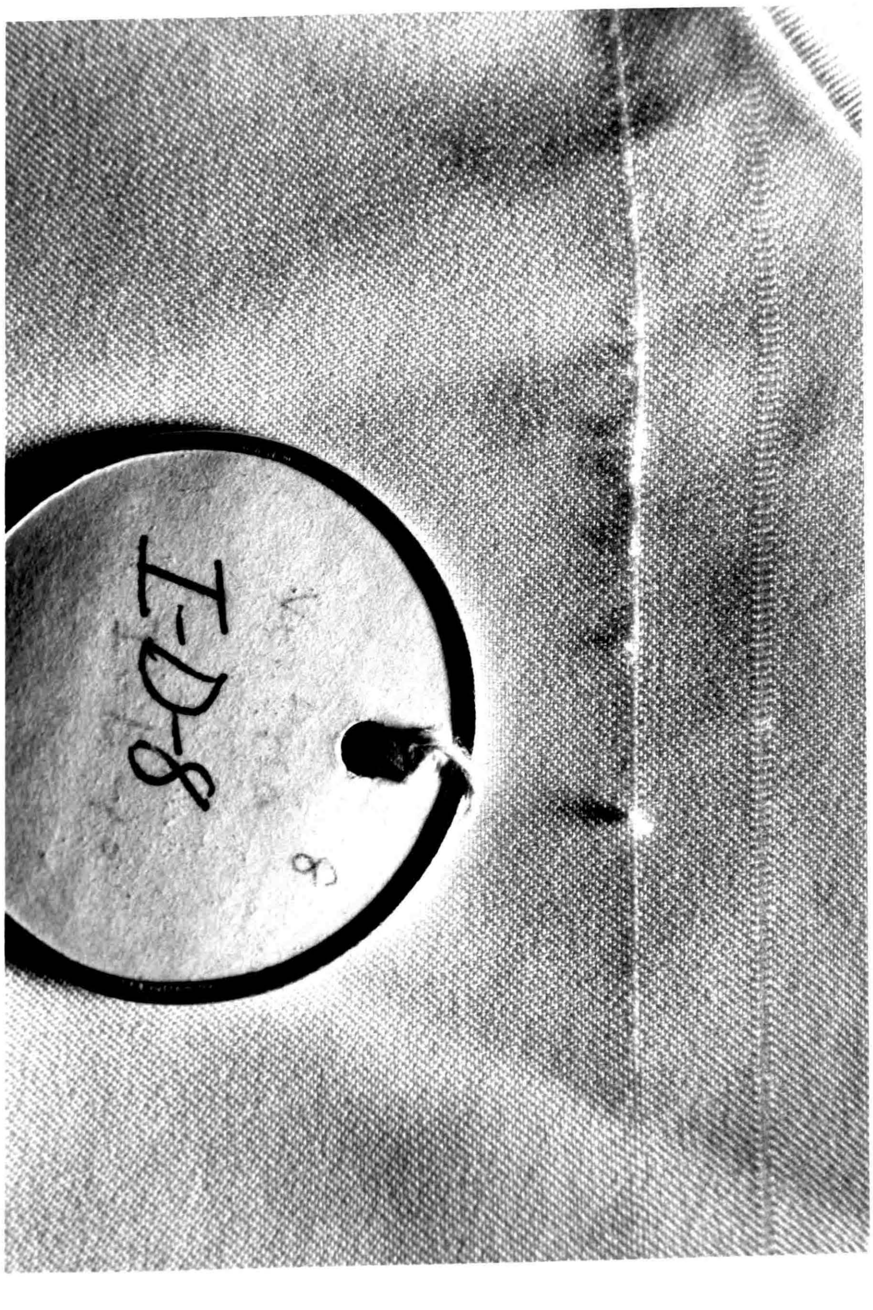


Fig. 7. A pictorial example of snags observed on a 100 percent polyester shirt.

TABLE 7

MEAN PILLING VALUES OF THE SHIRTS AFTER 5, 10, 15, 20 AND 25 WEAR/LAUNDERING PERIODS AT TWO WASH TEMPERATURES

	Wear/Laundering Periods				
Fabric Code[a]	5	10	15	20	25
1	0.0	0.0	0.0	0.0	0.0
2	0.2	0.3	0.0	0.0	0.0
3	1.2	3.4	2.0	1.8	1.2
4	0.4	3.3	6.2	9.3	9.0
5	0.0	0.1	0.2	0.0	0.4
6	0.0	0.1	0.2	0.0	0.0
7	3.2	6.2	5.1	4.0	1.6
8	0.0	0.4	1.8	1.8	3.5

[a]

105°F	Fabric	120°F
1	100% cotton	5
2	60/40 cotton-polyester	6
3	65/35 polyester-cotton	7
4	100% polyester	8

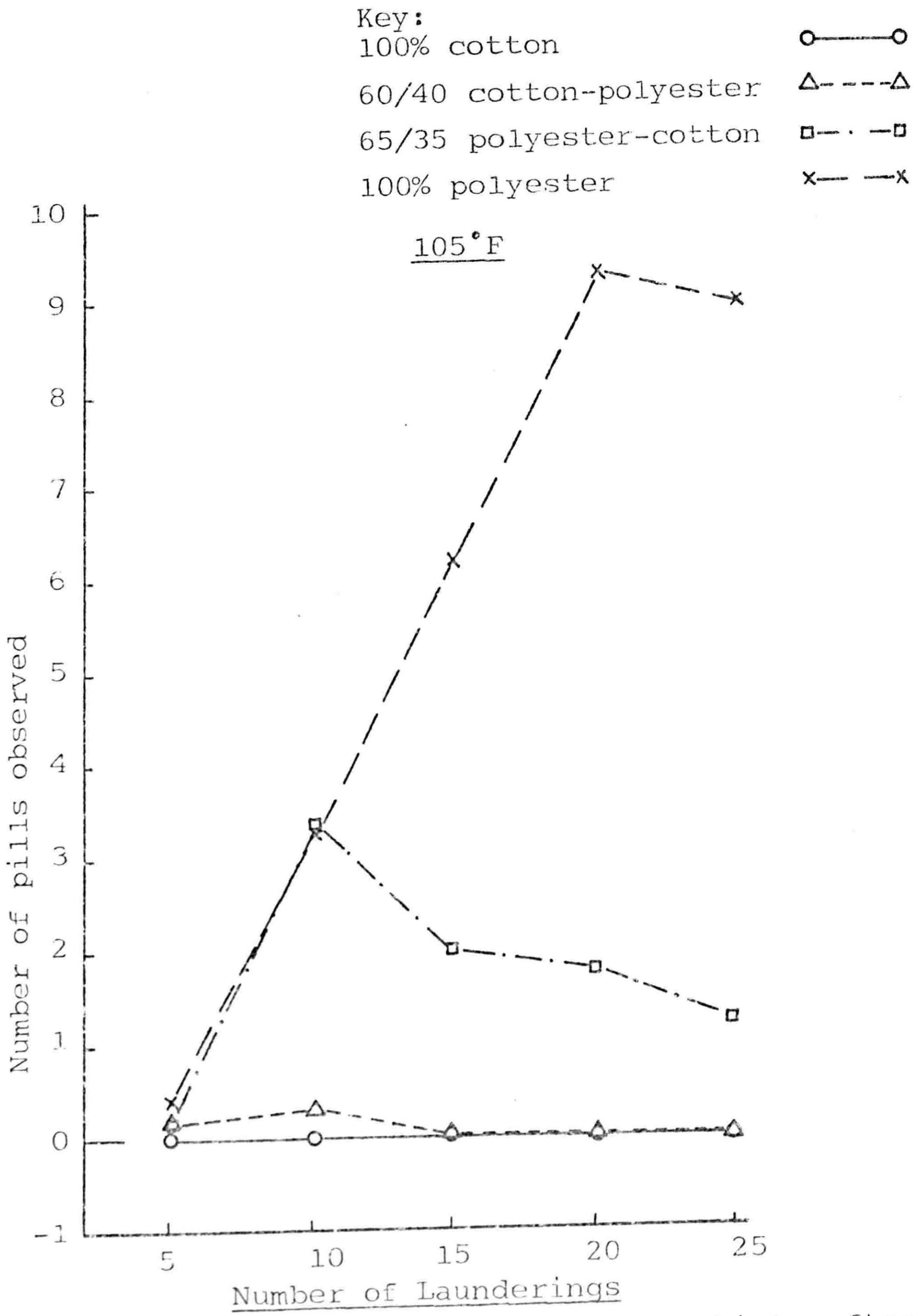


Fig. 8. Mean pilling values of the shirts after 5, 10, 15, 20 and 25 wear/laundering periods at 105°F wash temperature.

all-cotton and 60/40 cotton-polyester shirts at the lower temperature, as these two shirt types produced fewer pills. The largest number of pills counted for an evaluation period were observed on the 65/35 polyester-cotton blend at the second evaluation period. The number of pills counted on this shirt type declined in the final two evaluation periods. At the lower temperature evaluation periods, the number of pills counted on the 100 percent polyester shirts continued to increase as use-launderings increased with the 20 wear/laundering period being the peak. This shirt was highest in number of pills counted at the 25 wear/laundering period when compared to the other three shirt types.

Table 7 and figure 9 report information obtained at the five evaluation periods for the shirts washed at 120°F. The two lowest number of pills were recorded for 60/40 cotton-polyester and 100 percent cotton shirts. The 65/35 blend had the most pills at 5, 10, 15 and 20 wear/laundering periods, but the highest number of pills were counted on the 100 percent polyester shirts in the final evaluation period. A continued increase in pilling at each wear/laundering period was observed on the 100 percent polyester shirt.

Significant differences between pilling values of the 100 percent cotton and the 60/40 cotton-polyester shirts (1 vs 4, 2 vs 4) and the 100 percent polyester shirts

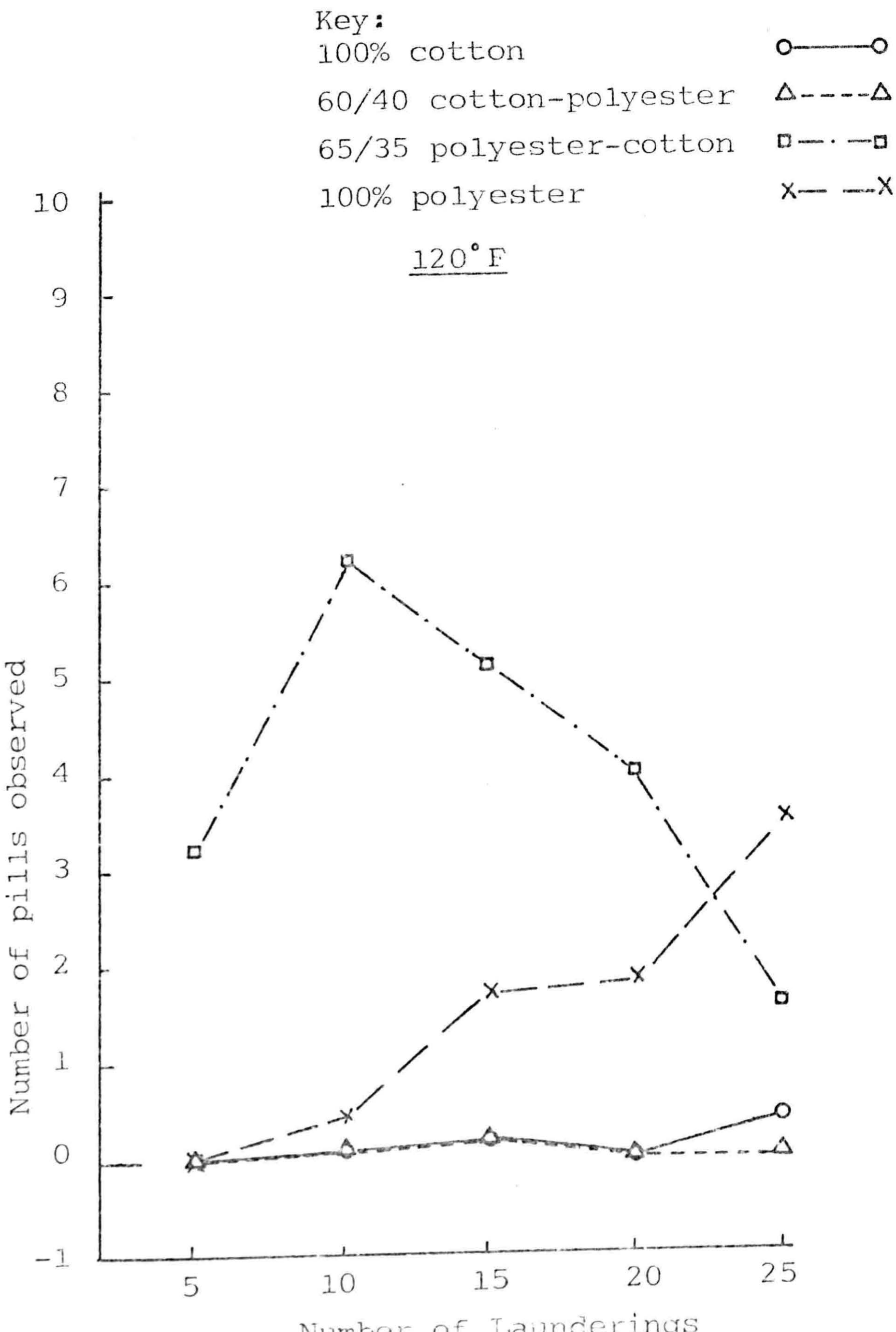


Fig. 9. Mean pilling values of the shirts after 5, 10, 15, 20 and 25 wear/laundering periods at 120°F wash temperature.

occurred at the last three testing intervals when laundered at 105°F. This denotes that the 100 percent cotton shirts were better relative to pilling than were the 100 percent polyester shirts. The 60/40 cotton-polyester shirts were also better relative to pilling than were the 100 percent polyester shirts. At the 20 and 25 wear/laundering periods, the 65/35 polyester-cotton shirts (3 vs 4) had significantly fewer pills than did the 100 percent polyester shirts when washed at the lower (105°F) temperature (table 8).

Comparisons made between the pilling values of the shirts when washed at 120°F revealed significant differences between the 100 percent cotton and the 65/35 polyester-cotton (5 vs 7) after the tenth laundering and between the 100 percent cotton and 100 percent polyester (5 vs 8) shirts after the final wear/laundering period. These findings demonstrate cotton's superiority over the other fabrics investigated in resistance to pilling.

Comparisons of the pilling values of the blended fabrics disclosed significant differences between the 60/40 cotton-polyester and the 65/35 polyester-cotton (6 vs 7) after the 15, 20 and 25 wear/laundering periods and between the 60/40 cotton-polyester blend and 100 percent polyester (6 vs 8) after the final washing. The results again illustrate the remarkable ability of cotton to resist pilling.

TABLE 8

BONFERRONI'S TEST FOR SIGNIFICANT DIFFERENCES BETWEEN PILLING VALUES OF THE SHIRTS AFTER 5, 10, 15, 20 AND 25 WEAR/LAUNDERING PERIODS AT TWO WASH TEMPERATURES

105°F:

Wear/Laundering	Fabric Comparisons					
Period	1 vs 2	1 vs 3	1 vs 4	2 vs 3	2 vs 4	3 vs 4
5						
Adjusted Mean Difference	0.01	-0.02	-0.01	-0.03	-0.02	0.01
T-Value	0.00	-0.02	-0.01	-0.02	-0.01	0.01
10						
Adjusted Mean Difference	-0.33	-4.50	-2.83	-4.17	-2.50	1.67
T-Value	-0.18	-2.42	-1.52	-2.24	-1.34	0.89
15						
Adjusted Mean Difference	-0.17	-2.92	-7.00	-2.75	-6.83	-4.08
T-Value	-0.09	-1.58	-3.78*	-1.48	-3.69*	-2.20
20						
Adjusted Mean Difference	-0.25	-2.17	-8.92	-1.92	-8.67	-6.75
T-Value	-0.12	-1.04	-4.29*	-0.92	-4.17*	-3.25*
25						
Adjusted Mean Difference	-0.33	-1.92	-9.42	-1.58	-9.08	-7.50
T-Value	-0.19	-1.09	-5.37*	-0.90	-5.18*	-4.28*

TABLE 8--Continued

120°F:

Wear/Laundering Period	Fabric Comparisons 5 vs 6	5 vs 7	5 vs 8	6 vs 7	6 vs 8	7 vs 8
5						
Adjusted Mean Difference	0.01	-0.03	-0.00	-0.04	-0.01	0.03
T-Value	0.01	-0.02	-0.00	-0.02	-0.01	0.02
10						
Adjusted Mean Difference	0.50	-6.67	-2.17	-7.17	-2.67	4.50
T-Value	0.27	-3.58*	-1.16	-3.85*	-1.43	2.42
15						
Adjusted Mean Difference	2.83	-4.67	-2.75	-7.50	-5.58	1.92
T-Value	1.53	-2.52	-1.48	-4.05*	-3.01	1.04
20						
Adjusted Mean Difference	2.08	-5.50	-4.25	-7.58	-6.33	1.25
T-Value	1.00	-2.65	-2.05	-3.65*	-3.05	0.60
25						
Adjusted Mean Difference	1.50	-2.25	-5.92	-3.75	-7.42	-3.67
T-Value	0.86	-1.28	-3.37*	-2.13	-4.22*	-2.09

TABLE 8--Continued

105°F and 120°F:

Wear/Laundering	Fabric Comparisons			
Period	1 vs 5	2 vs 6	3 vs 7	4 vs 8
5				
Adjusted Mean Difference	0.01	0.02	0.01	0.03
T-Value	0.01	0.01	0.01	0.02
10				
Adjusted Mean Difference	-0.25	0.58	-2.42	0.42
T-Value	-0.14	0.34	-1.39	0.24
15				
Adjusted Mean Difference	-2.73	0.27	-4.48	1.52
T-Value	-1.58	0.16	-2.558	0.88
20				
Adjusted Mean Difference	-7.58	-5.25	-10.92	-2.92
T-Value	-3.90*	-2.70	-5.62*	-1.50
25				
Adjusted Mean Difference	-7.08	-5.25	-7.42	-3.58
T-Value	-4.32*	-3.20*	-4.52*	-2.18

*Significant at 0.05 level of probability

Comparisons of identical shirt fabrics washed at the two selected temperatures also were made with respect to pilling values. Results revealed no significant differences between any of the experimental fabric types washed under the two different temperatures until after the 20 wear/laundering period. At both the 20 and 25 washing periods the pilling values of the identical 100 percent cotton shirts differed significantly as did the difference between the identical 65/35 polyester-cotton shirts. Only one significant difference between the identical shirts of 60/40 cotton-polyester occurred and this was after the final washing.

Results of pilling value analyses showed that the all-cotton and 60/40 cotton-polyester blend shirts developed very few pills throughout the study. In some comparisons the 65/35 polyester-cotton shirts and the 100 percent polyester shirts were not significantly higher in number of pills than were the other experimental fabrics, but these fabrics consistenly registered the greatest number of pills at each evaluation period. Pictorial examples of observed pills on these two fabric types appear in figures 10, 11, 12 and 13.

Whiteness Retention

Table 9 shows the mean whiteness retention values of the shirts initially and at specified use-laundering

Fig. 10. A pictorial example of pills observed after 25 wear/laundering periods on the collar of a 65/35 polyester-cotton shirt washed at 105°F.

Fig. 11. A pictorial example of pills observed after 25 wear/laundering periods on the shirt front of a 100 percent polyester shirt washed at 105°F.

Fig. 12. A pictorial example of pills observed after 25 wear/laundering periods on the shirt front of a 100 percent polyester shirt washed at 105°F.

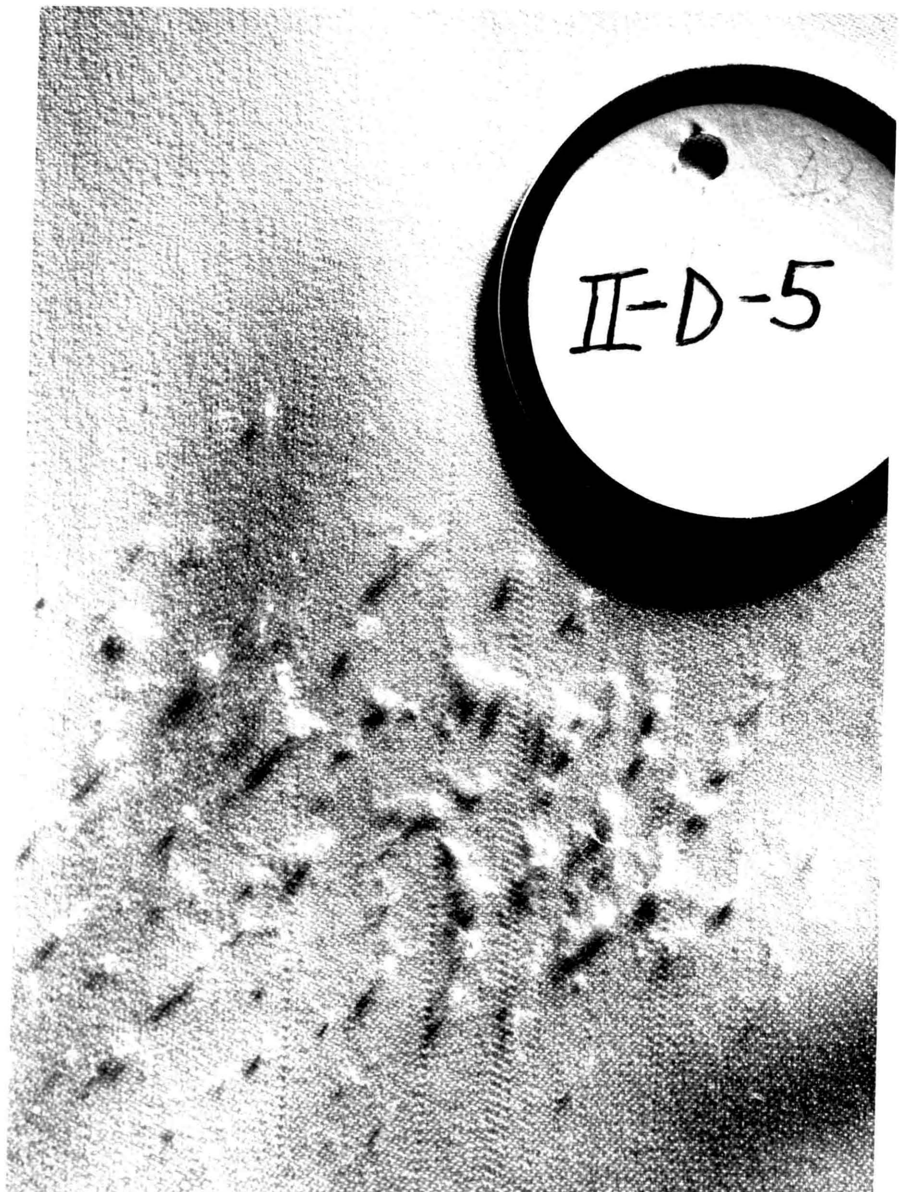


Fig. 13. A pictorial example of pills observed after 25 wear/laundering periods on the shirt front of a 100 percent polyester shirt washed at 120°F.

periods and graphically illustrated in figure 14. As was expected the whiteness retention values of the four fabric types usually decreased as the wearings and launderings increased with three exceptions. The 60/40 cotton-polyester showed a veryslight increase in whiteness retention after the fifth and the final laundering at the 105°F temperature and after the twentieth laundering at the 120°F temperature.

Table 10 shows results of Bonferroni's Test for significant differences between the whiteness retention values of the shirt fabric types initially and at each specified testing period when washed at two temperatures. When the all-cotton shirts were compared with the 60/40 cotton-polyester shirts (1 vs 2), the 65/35 polyester-cotton shirts (1 vs 3) and the 100 percent polyester shirts (1 vs 4) at the 105°F temperature, significant differences occurred between the whiteness retention values at all testing intervals except at the 20 laundering period when all-cotton shirts were compared with the 60/40 cotton polyester shirts. The whiteness retention values of the 60/40 cotton-polyester shirts were significantly different from those of the 65/35 polyester-cotton and the 100 percent polyester shirts at all evaluation periods when washed at the lower temperature. The 65/35 polyester-cotton shirts differed significantly in whiteness retention from the 100 percent polyester shirts after 10, 15 and 25 wear/launderings at 105°F.

When the four fabric types were washed at the higher temperature (120°F), significant differences between whiteness retention values of the 100 percent cotton shirts and the other three fabric types were noted at all testing intervals except between all-cotton and 100 percent polyester fabrics at the 20 laundering period. Comparisons between the 60/40 cotton-polyester shirt fabric and both the 65/35 polyester-cotton and the 100 percent polyester fabrics Revealed significant differences in whiteness retention at all six evaluation periods. Significant differences between the whiteness values of the 65/35 polyester-cotton shirts and the 100 percent polyester shirts also were noted after 10 and 15 washings at 120°F.

Results of comparisons made between identical shirts of the four fabric types laundered at the two temperatures disclosed significant differences between the whiteness retention values of 100 percent cotton at the initial, third, fifth and final testing intervals. Shirts of 60/40 cotton-polyester differed significantly at the initial, third and final evaluation periods, while shirts of 65/35 polyester-cotton were significantly different at the initial, third, fourth, fifth and final testing periods. The 100 percent polyester shirts differed significantly in whiteness

TABLE 9

MEAN WHITENESS RETENTION VALUES OF THE SHIRTS TESTED INITIALLY AND AFTER 5, 10, 15, 20 AND 25 WEAR/LAUNDERING PERIODS AT TWO WASH TEMPERATURES

Fabric Code[a]	Wear/Laundering Periods					
	0	5	10	15	20	25
1	84.4	76.2	75.1	73.1	71.8	69.2
2	82.9	84.3	81.2	79.7	75.4	75.8
3	74.7	70.2	67.7	65.5	63.6	58.3
4	73.8	71.7	69.6	66.6	61.6	60.9
5	82.5	76.5	74.0	71.5	70.7	66.8
6	85.4	83.9	82.5	80.7	81.0	73.7
7	74.2	70.0	66.0	65.3	61.7	53.9
8	73.5	71.9	68.7	66.3	64.3	61.6

[a]

105°F	Fabric	120°F
1	100% cotton	5
2	60/40 cotton-polyester	6
3	65/35 polyester-cotton	7
4	100% polyester	8

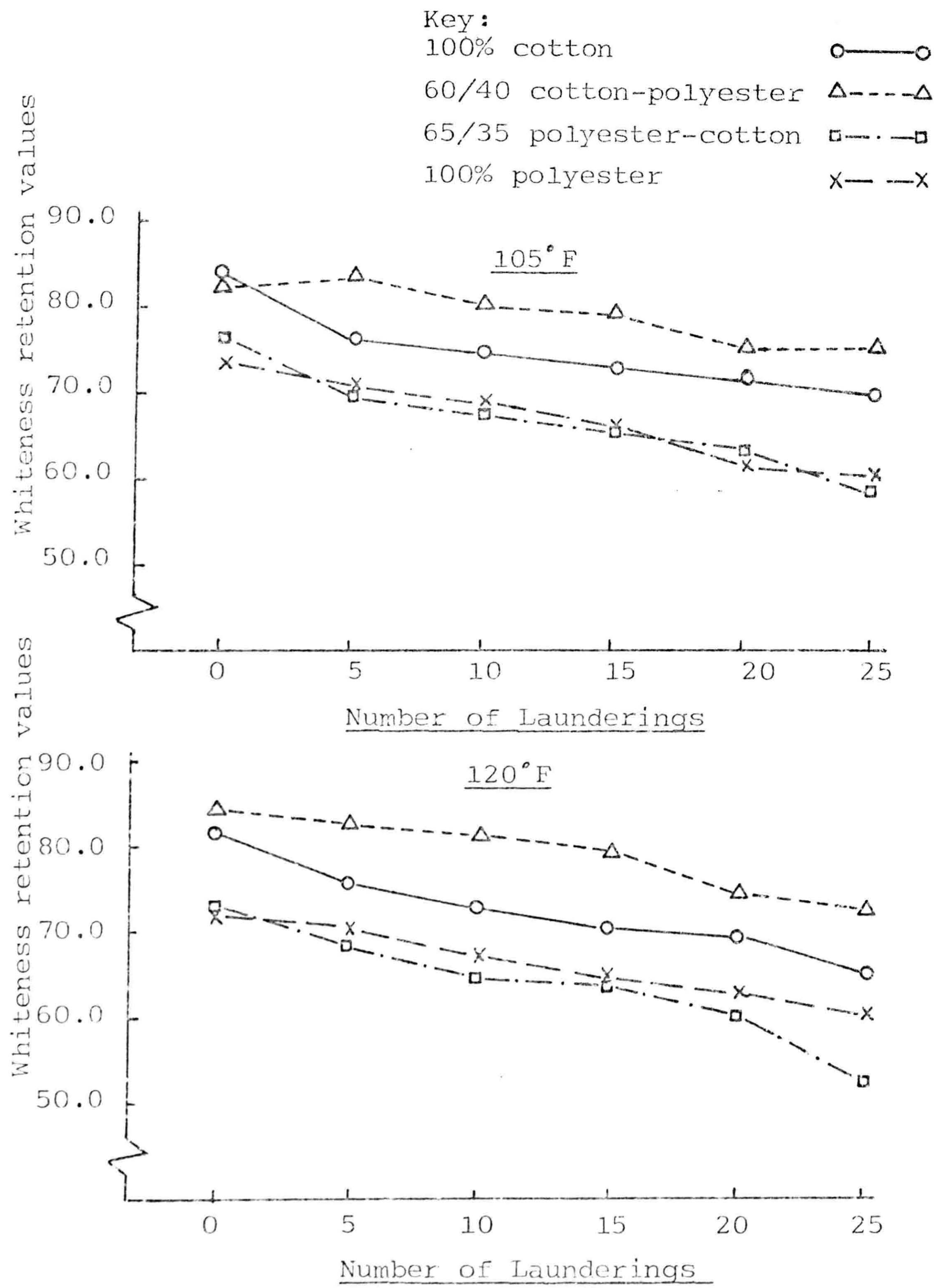


Fig. 14. Mean whiteness retention values of the shirts tested initially and after 5, 10, 15, 20 and 25 wear/laundering periods at two wash temperatures.

TABLE 10

BONFERRONI'S TEST FOR SIGNIFICANT DIFFERENCES BETWEEN WHITENESS RETENTION VALUES OF THE SHIRTS TESTED INITIALLY AND AFTER 5, 10, 15, 20 AND 25 WEAR/LAUNDERING PERIODS AT TWO WASH TEMPERATURES

105°F:

Wear/Laundering	Fabric Comparisons					
Period	1 vs 2	1 vs 3	1 vs 4	2 vs 3	2 vs 4	3 vs 4
0						
Adjusted Mean Difference	2.05	9.57	10.17	7.52	8.12	0.60
T-Value	4.15*	19.36*	20.57*	15.21*	16.42*	1.21
5						
Adjusted Mean Difference	-7.73	5.54	4.31	13.27	12.04	-1.23
T-Value	-13.24*	9.50*	7.40*	22.74*	20.63*	-2.11
10						
Adjusted Mean Difference	-6.36	7.83	4.32	14.18	10.68	-3.50
T-Value	-9.19*	11.32*	6.25*	20.51*	15.44*	-5.06*
15						
Adjusted Mean Difference	-7.87	8.61	4.71	16.48	12.58	-3.91
T-Value	-9.03*	9.88*	5.40*	18.91*	14.43*	-4.48*
20						
Adjusted Mean Difference	-4.55	9.03	8.14	13.58	12.69	-0.89
T-Value	-2.07	4.12*	3.71*	6.19*	5.79*	-0.40
25						
Adjusted Mean Difference	-6.13	12.83	7.34	18.96	13.46	-5.49
T-Value	-3.52*	7.37*	4.25*	10.89*	7.74*	-3.16*

TABLE 10--Continued

120°F:

Wear/Laundering Period	Fabric Comparisons					
	5 vs 6	5 vs 7	5 vs 8	6 vs 7	6 vs 8	7 vs 8
0						
Adjusted Mean Difference	-3.30	8.51	9.59	11.81	12.89	1.08
T-Value	-6.66*	17.22*	19.40*	23.88*	26.07*	2.18
5						
Adjusted Mean Difference	-6.82	5.86	4.44	12.68	11.25	-1.43
T-Value	-11.68*	10.05*	7.60*	21.73*	19.28*	-2.44
10						
Adjusted Mean Difference	-8.16	6.97	4.93	15.13	13.09	-2.04
T-Value	-11.80*	10.08*	7.13*	21.88*	18.93*	-2.95*
15						
Adjusted Mean Difference	-7.09	5.77	3.15	12.86	10.24	-2.62
T-Value	-8.14*	6.62*	3.62*	14.76*	11.75*	-3.00*
20						
Adjusted Mean Difference	-11.74	9.07	4.94	20.80	16.68	-4.12
T-Value	-5.35*	4.13*	2.25	9.49*	7.61*	-1.88
25						
Adjusted Mean Difference	-6.61	10.40	7.13	17.00	13.74	-3.26
T-Value	-3.80*	5.97*	4.10*	9.77*	7.89*	-1.87

TABLE 10--Continued

105°F and 120°F:

Wear/Laundering Period	Fabric Comparisons 1 vs 5	2 vs 6	3 vs 7	4 vs 8
0				
Adjusted Mean Difference	1.66	-3.69	0.60	1.08
T-Value	3.59*	-7.97*	1.30	2.34
5				
Adjusted Mean Difference	-0.54	0.37	-0.22	-0.41
T-Value	-0.98	0.68	-0.40	-0.76
10				
Adjusted Mean Difference	-2.56	-4.37	-3.42	-1.96
T-Value	-3.96*	-6.75*	-5.29*	-3.03*
15				
Adjusted Mean Difference	-0.52	0.26	-3.36	-2.08
T-Value	-0.64	0.32	-4.13	-2.55
20				
Adjusted Mean Difference	9.24	2.05	9.28	6.04
T-Value	4.50*	0.10	4.52*	2.94*
25				
Adjusted Mean Difference	-9.45	-9.93	-11.88	-9.65
T-Value	-5.80*	-6.10*	-7.30*	-5.93*

*Significant at 0.05 level of probability

retention after 10, 20 and 25 washings.

An overall examination of the data did not show any one fabric type as being consistently dependent on a higher temperature in order to retain whiteness. With the lower washing temperature, the 60/40 cotton-polyester and the 100 percent cotton shirts maintained the two top values throughout the study. Even though all four fabric types decreased in whiteness values when laundered at the higher temperature, the 60/40 cotton-polyester and 100 percent cotton shirts retained the two top highest whiteness retention values at all five evaluation periods (figure 14).

Air Permeability

The ability of air to pass through a fabric is related to many factors, such as yarn count and structure, fiber content, fabric construction and/or textile finishes. The measurements of air permeability were conducted both from the outside to the inside of the garment and from the inside to the outside. As the measurements showed no difference in regard to the direction in which the tests were conducted, the readings were grouped together as air permeability values. The findings related to air permeability of the shirts are shown in tables 11 and 12 and figure 15.

The mean values in seconds of the four fabric types measured initially and after 25 wear/laundering periods at two temperatures are presented in table 11 and graphically in figure 15. The 100 percent polyester control shirt required the least amount of time for air to permeate. The 65/35 polyester-cotton shirt required the second least amount of time; while the cotton was third, and the blend with the higher percentage of cotton was fourth.

After the shirts had been exposed to 25 wear/laundering periods, a pattern among the four fabric types was established that was evident at both the temperatures. The blend with the higher percentage of polyester was first, as it required the least amount of time for air to permeate the fabric. The 100 percent polyester was second in air permeability time; whereas, the 60/40 cotton-polyester shirt was third in the fewest number of seconds required for this value. The 100 percent cotton shirt required the longest time in air permeability values.

All 16 fabric type comparisons resulted in significant differences between air permeability values as noted in table 12. At the 105°F wash temperature, the air permeability values of the 60/40 cotton-polyester, the 65/35 polyester cotton and the 100 percent polyester shirts (1 vs 2, 1 vs 3, 1 vs 4) were significantly lower than that of the 100 percent cotton shirt. Both the 65/35 polyester-cotton and the 100 percent polyester (2 vs 3, 2 vs 4) required

TABLE 11

MEAN AIR PERMEABILITY VALUES IN SECONDS OF THE SHIRTS TESTED INITIALLY AND AFTER 25 WEAR/LAUNDERING PERIODS AT TWO WASH TEMPERATURES

Initial:

Fabric Type	Mean Value[a]
100% cotton	7.30
60/40 cotton-polyester	11.55
65/35 polyester-cotton	6.00
100% polyester	5.40

After 25 Wear/Laundering Periods:

Fabric Code	Fabric Type	Temp.	Mean Value[a]
1	100% cotton	105°F	7.81
2	60/40 cotton-polyester	105°F	6.82
3	65/35 polyester-cotton	105°F	4.90
4	100% polyester	105°F	6.04
5	100% cotton	120°F	8.17
6	60/40 cotton-polyester	120°F	7.38
7	65/35 polyester-cotton	120°F	5.02
8	100% polyester	120°F	5.89

[a]In seconds

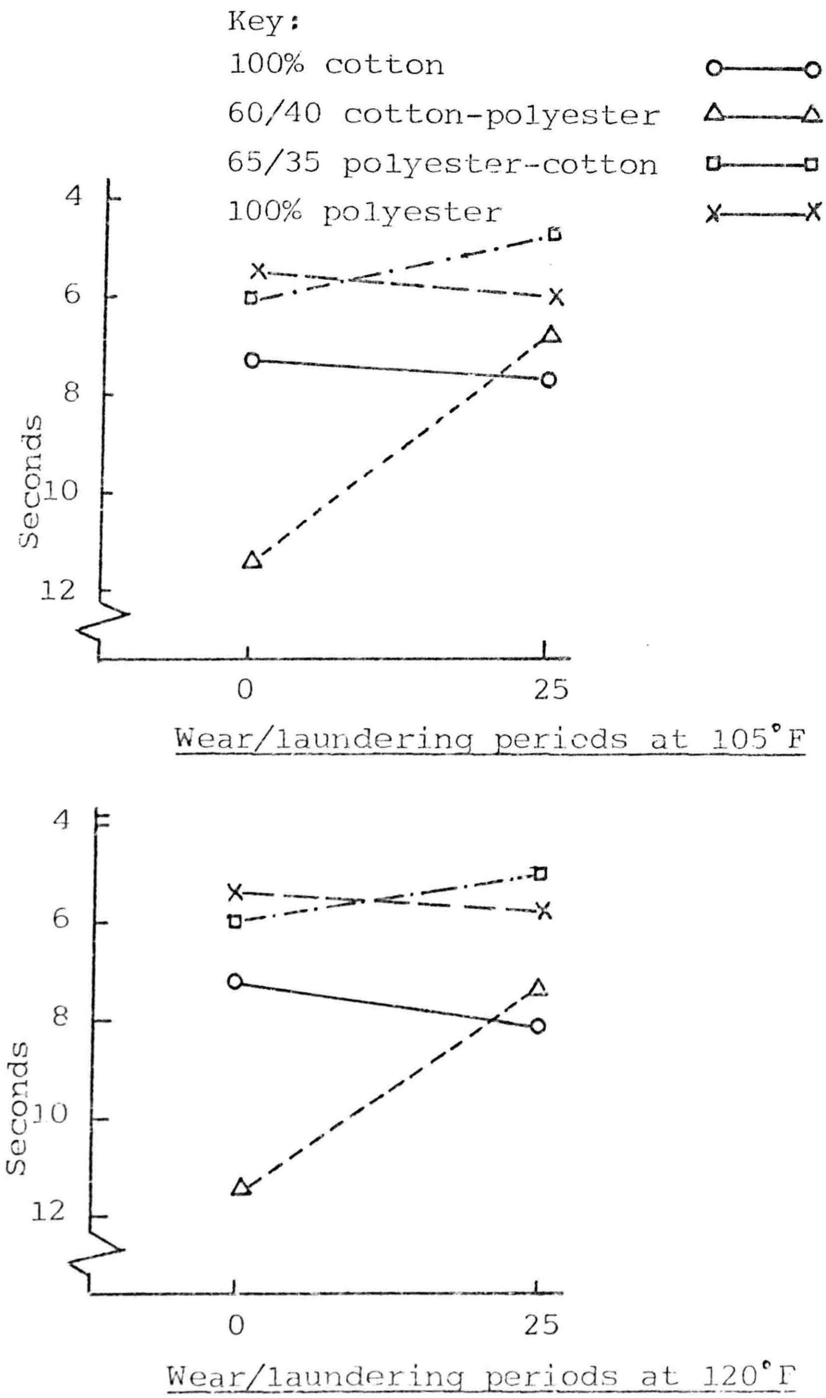


Fig. 15. Mean air permeability values in seconds of the shirts tested initially and after 25 wear/laundering periods at two wash temperatures.

TABLE 12

BONFERRONI'S TEST FOR SIGNIFICANT DIFFERENCES BETWEEN AIR PERMEABILITY VALUES OF THE SHIRTS AFTER 25 WEAR/LAUNDERING PERIODS AT TWO WASH TEMPERATURES

Fabric Code Comparisons [a]	Adjusted Mean Difference	T-Value
1 vs 2	1.13	5.46*
1 vs 3	2.93	14.14*
1 vs 4	1.86	8.98*
2 vs 3	1.80	8.68*
2 vs 4	0.73	3.52*
3 vs 4	-1.07	-5.16*
5 vs 6	0.86	4.15*
5 vs 7	3.48	16.84*
5 vs 8	1.93	9.35*
6 vs 7	2.62	12.68*
6 vs 8	1.08	5.20*
7 vs 8	-1.55	-7.49*
1 vs 5	1.02	5.28*
2 vs 6	0.75	3.88*
3 vs 7	1.58	8.16*
4 vs 8	1.10	5.67*

*Significant at 0.05 level of probability

[a]

105°F	Fabric	120°F
1	100% cotton	5
2	60/40 cotton-polyester	6
3	65/35 polyester-cotton	7
4	100% polyester	8

significantly less time for air to permeate than did the 60/40 cotton-polyester shirt. At the lower temperature the 65/35 polyester-cotton was significantly higher than the 100 percent polyester shirt (3 vs 4) in air permeability values.

An identical pattern of air permeability values was observed at the higher temperature. The significant differences are indicated in table 12.

Comparisons of all of the four fabric types showed significant differences when identical fabric types were subjected to two wash temperatures. Without exception, the fabric type comparisons (1 vs 5, 2 vs 6, 3 vs 7, 4 vs 8) required fewer seconds for air to permeate the fabric after being washed 25 times at the higher temperature.

The yarn count of each fabric type (table 1) may have exerted an influence on the air permeability values. Although the fabrics were selected to be as similar as possible, the selection was limited to the shirts which were available in the market place. These differences in fabric weave and yarn count could have had some influence on air permeability.

Breaking Strength

The breaking strength values of the four fabric types initially and those washed at two temperatures are shown in table 13 and graphically illustrated in figures 16 and 17. Initially, cotton in the warp direction was significantly stronger than the other three fabric types, also the blend high in cotton in the warp direction was significantly stronger than the two shirts higher in polyester. The 100 percent polyester rated third in warp strength; whereas, the 65/35 polyester-cotton was last in warp strength (table 14).

When the filling strength was tested in the control shirts, the 100 percent polyester was significantly better than the other three fabric types. The 100 percent cotton and 65/35 polyester-cotton shirts were ranked second and third but did not differ significantly in strength. The 60/40 cotton-polyester was significantly weaker than the other three fabrics.

After the 25 wear/laundering periods at 105°F, the warp direction results showed the 60/40 cotton-polyester and the 100 percent cotton to be the two strongest fabrics; however, there was no significant differences noted between these two fabrics. Polyester and the 65/35 polyester-cotton blend were third and fourth with no significant differences between the two fabric strengths. The filling direction results placed the 65/35 polyester-cotton significantly stronger than the two shirts higher in cotton. The 100 percent cotton shirt was third and was significantly stronger than

TABLE 13

MEAN BREAKING STRENGTH IN POUNDS OF THE SHIRTS TESTED INITIALLY AND AFTER 25 WEAR/LAUNDERING PERIODS AT TWO WASH TEMPERATURES

Initial:

Fabric Type	Mean Breaking Strength [a]	
	Warp	Filling
100% cotton	63.5	39.8
60/40 cotton-polyester	60.1	31.5
65/35 polyester-cotton	44.4	38.9
100% polyester	52.0	87.3

After 25 Wear/Laundering Periods:

Fabric Code	Fabric Type	Temp.	Mean Breaking Strength [a]	
			Warp	Filling
1	100% cotton	105°F	60.0	39.2
2	60/40 cotton-polyester	105°F	62.0	28.5
3	65/35 polyester-cotton	105°F	49.3	42.6
4	100% polyester	105°F	49.3	40.6
5	100% cotton	120°F	57.6	40.0
6	60/40 cotton-polyester	120°F	58.7	28.4
7	65/35 polyester-cotton	120°F	43.7	42.9
8	100% polyester	120°F	51.4	42.4

[a] In pounds

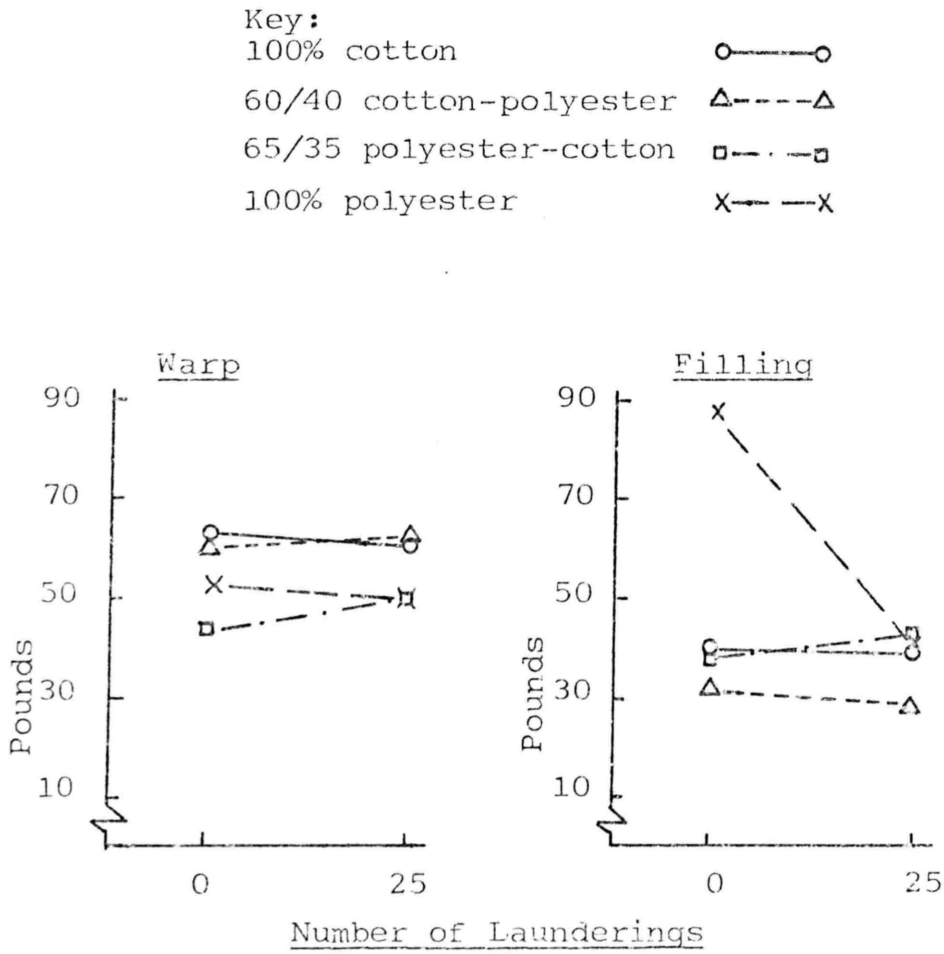


Fig. 16. Mean breaking strength values in pounds of the shirts tested initially and after 25 wear/laundering periods at 105°F wash temperature in the warp and filling directions.

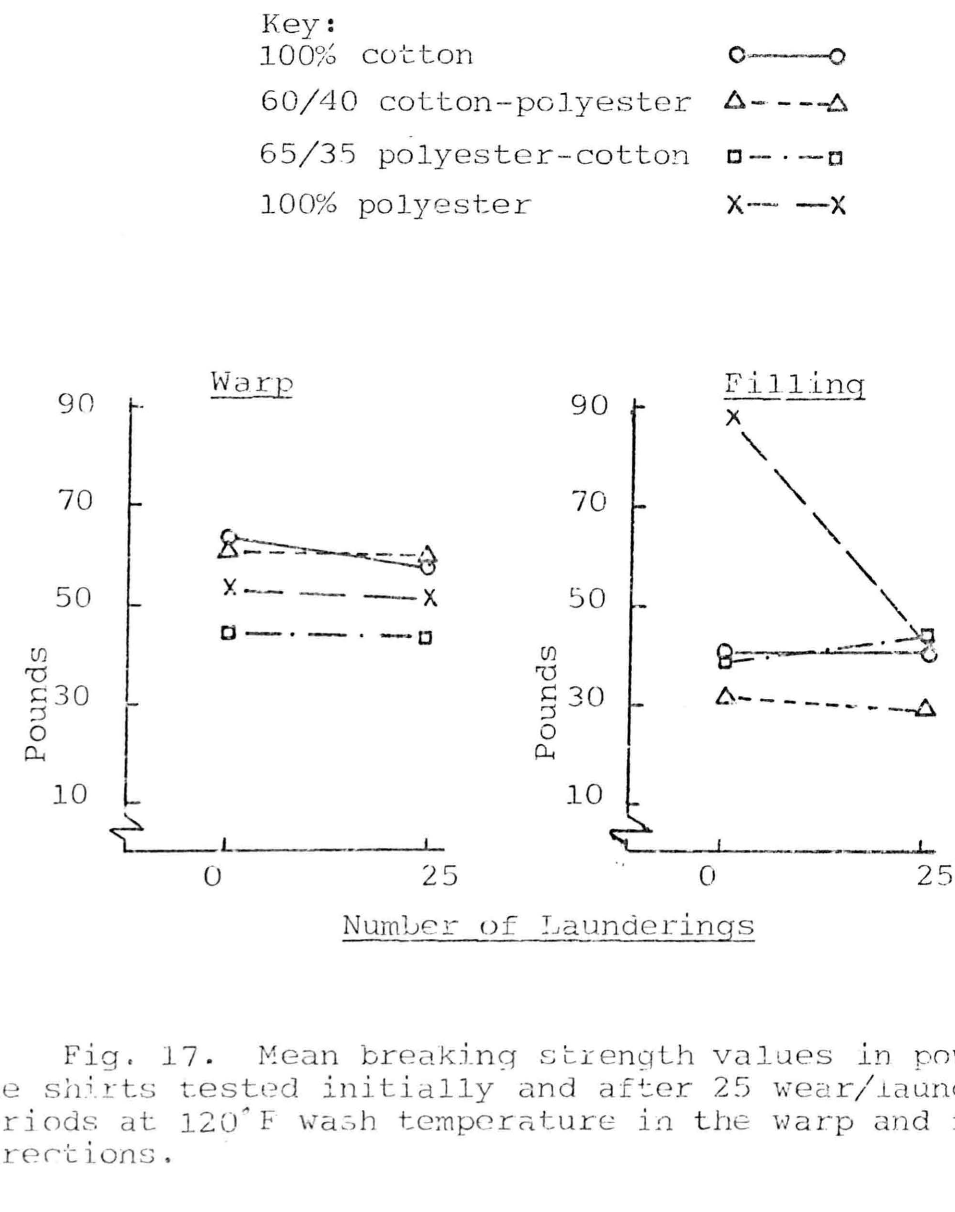


Fig. 17. Mean breaking strength values in pounds of the shirts tested initially and after 25 wear/laundering periods at 120°F wash temperature in the warp and filling directions.

TABLE 14

NEWMAN-KEULS MULTIPLE COMPARISONS OF BREAKING STRENGTH IN POUNDS OF THE SHIRTS TESTED INITIALLY AND AFTER 25 WEAR/LAUNDERING PERIODS AT TWO WASH TEMPERATURES

Initial:	Warp				Filling			
Fabric Code[a]	1/5	2/6	3/7	4/8	1/5	2/6	3/7	4/8
Mean Strength	63.5	60.1	52.5	44.4	87.3	39.8	38.9	31.5
After 25 Wear/Launderings: (105°F)								
Fabric Code[a]	2	1	4	3	3	4	1	2
Mean Strength	62.0	60.0	49.3	49.3	42.6	40.6	39.2	28.5
After 25 Wear/Launderings: (120°F)								
Fabric Code[a]	6	5	8	7	7	8	5	6
Mean Strength	58.7	57.6	51.4	43.7	42.9	42.4	40.0	28.4

After 25 Wear/Launderings: (105°F and 120°F, warp and filling combined)								
Fabric Code[a]	1	5	8	3	2	4	6	7
Mean Strength	49.6	48.8	46.9	46.0	45.2	45.0	43.6	43.3

Note: There is a difference at the 0.05 level of probability in the means not underlined by the same line.

[a] 1, 5 = 100% cotton
2, 6 = 60/40 cotton-polyester
3, 7 = 65/35 polyester-cotton
4, 8 = 100% polyester

the 60/40 cotton-polyester shirt which was fourth.

The pattern discussed above was repeated at the 120°F wash temperature as far as the mean values observed. The two shirts higher in cotton (types 5 and 6) were stronger in the warp direction than the two shirts higher in polyester (types 7 and 8). A significant difference, not found at the lower temperature, was noted when the 100 percent polyester was significantly stronger in the warp direction than was the 65/35 polyester-cotton. There was no difference in the strength of the filling direction at 120°F when the 65/35 polyester-cotton shirt was compared with the 100 percent polyester.

To compare the four fabrics at the two wash temperatures, the warp and filling data were grouped together and results are shown in table 14. There were no significant differences in the breaking strengths of the fabrics when laundered at two different temperatures. The two cotton types (1 and 5) were first and second in overall breaking strength. The all-polyester (types 4 and 8) were third and sixth; while the blends (types 3 and 7, 2 and 6) claimed the other ranks.

Absorbency

The absorbent properties of fabrics used for apparel are related to comfort in that body perspiration can be absorbed and passed through the fabric creating a cooling effect. The findings listed in table 15 and illustrated graphically in figure 18 show that 100 percent cotton was superior in absorbency of all the shirts which were worn and laundered 25 times at 105°F. The results after 25 wear/laundering periods at 120°F, revealed that the 60/40 cotton-polyester blend, with a smaller mean, was more absorbent than the other two shirts and only slightly less absorbent than the all cotton shirt washed at 105°F.

Bonferroni's test was used to determine significant differences between two different fabric types when laundered at 105°F or 120°F and between identical fabric types which had been washed at the two temperatures. Table 16 shows these results.

Two comparisons of the shirts washed at 105°F resulted in significant differences. There was a significant difference at 0.05 level of probability between the absorbency values of 100 percent cotton and the 65/35 polyester-cotton (1 vs 3), with cotton being more absorbent. Of note is the no significant difference in absorbency between 100 percent polyester and 100 percent cotton, which usually would be expected. Although 100 percent polyester versus 100 percent cotton (1 vs 4) at this temperature did not result in a significant difference, the adjusted mean difference was almost twice as large as the adjusted mean difference recorded for the comparison of 100 percent cotton versus 60/40 cotton-polyester (1 vs 2).

The other significant difference observed between the shirts laundered at 105°F was in the comparison of 60/40 cotton-polyester versus 65/35 polyester-cotton (2 vs 3) with the shirt higher in cotton content being more absorbent.

The largest significant difference was discovered between fabrics five and eight when washed at 120°F. The absorbency of the 60/40 cotton-polyester shirt was found to be significantly greater than that of the 100 percent polyester shirt (6 vs 8). Other large significant differences were observed when comparing 100 percent cotton versus 100 percent polyester (5 vs 8) and 65/35 polyester-cotton versus 100 percent polyester (7 vs 8) with the cotton shirt and the polyester-cotton blend shirt being significantly more absorbent than the 100 percent polyester shirt. When the 65/35 polyester-cotton was compared to the 100 percent cotton shirt (7 vs 5), the result was the lowest adjusted mean difference of all the comparisons at both temperatures, and no significant difference resulted.

No significant differences in absorbency values were found when the identical fabrics of 100 percent cotton and 60/40 cotton-polyester were compared at the two temperatures (1 vs 5, 2 vs 6); however, the 65/35 polyester-cotton

TABLE 15

MEAN ABSORBENCY VALUES IN SECONDS OF THE SHIRTS TESTED INITIALLY AND AFTER 25 WEAR/LAUNDERING PERIODS AT TWO WASH TEMPERATURES

Initial:

Fabric Type	Mean Value[a]
100% cotton	10.55
60/40 cotton-polyester	104.55
65/35 polyester-cotton	300.00
100% polyester	1.15

After 25 Wear/Laundering Periods:

Fabric Code	Fabric Type	Temp.	Mean Value[a]
1	100% cotton	105°F	18.0
2	60/40 cotton-polyester	105°F	42.8
3	65/35 polyester-cotton	105°F	48.6
4	100% polyester	105°F	41.7
5	100% cotton	120°F	12.6
6	60/40 cotton-polyester	120°F	7.5
7	65/35 polyester-cotton	120°F	65.5
8	100% polyester	120°F	61.5

[a] In seconds

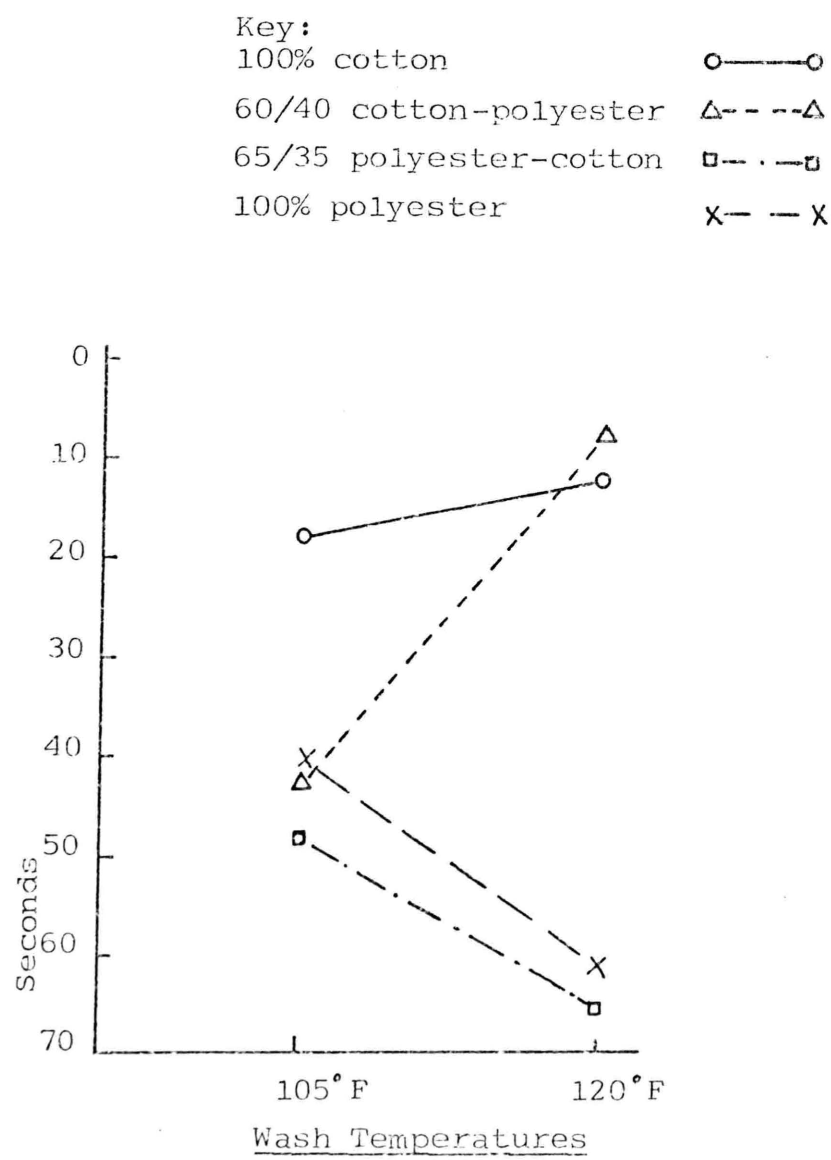


Fig. 18. Mean absorbency values in seconds of the shirts after 25 wear/laundering periods at two wash temperatures.

TABLE 16

BONFERRONI'S TEST FOR SIGNIFICANT DIFFERENCES BETWEEN ABSORBENCY VALUES OF THE SHIRTS AFTER 25 WEAR/LAUNDERING PERIODS AT TWO WASH TEMPERATURES

Fabric Code[a] Comparisons	Adjusted Mean Difference	T-Value
1 vs 2	-10.95	-1.08
1 vs 3	-40.91	-4.02*
1 vs 4	-20.56	-2.02
2 vs 3	-29.96	-2.94*
2 vs 4	-9.62	0.94
3 vs 4	20.35	2.00
5 vs 6	19.62	1.93
5 vs 7	8.99	0.88
5 vs 8	-42.52	-4.18*
6 vs 7	-10.63	-1.04
6 vs 8	-62.14	-6.10*
7 vs 8	-51.51	-5.06*
1 vs 5	-19.48	-2.04
2 vs 6	11.09	1.16
3 vs 7	30.42	3.19*
4 vs 8	-41.44	-4.35*

*Significant at 0.05 level of probability

a

105°F	Fabric	120°F
1	100% cotton	5
2	60/40 cotton-polyester	6
3	65/35 polyester-cotton	7
4	100% polyester	8

shirts (3 vs 7) became more absorbent at the higher temperature as revealed by the significant difference result. The significant difference between identical polyester shirts (4 vs 8) indicates an effect of the higher wash temperature on the absorbency of the 100 percent polyester.

Absorbency data are predictable if one knows the hydrophobic and hydrophilic properties of the fabrics being tested; however, some of the results of this study do not follow the usual pattern of predictability. The mean values of the control shirts (table 15) point out the unusual and erratic behavior of the 100 percent polyester experimental fabric. The yarn construction and the fabric weave apparently had some effect on these results. Of note is the result that at 105°F there was no significant difference between the 100 percent cotton and the 100 percent polyester; however, this was not true of these two fabrics at 120°F wash temperature when cotton was more absorbent. Of further note is the finding that only the 65/35 polyester blend became more significantly absorbent after the 25 wear/laundering periods at 120°F when compared to the similar shirts laundered at 105°F.

Electrostatic Build-up

The electrostatic build-up of a fabric is related to the comfort factor from the consumer's point of view.

When the static build-up factor is high, the clinging of the fabric increases, resulting in discomfort. Table 17 shows the mean values of the electrostatic build-up which are graphically depicted in figures 19 and 20. Results of the Newman-Keuls Multiple Comparisons Test are shown in table 18.

Initially, the 100 percent cotton, the 60/40 cotton-polyester and the 65/35 polyester-cotton shirts registered no static cling in the warp or filling directions. The 100 percent polyester shirt had significantly higher electrostatic build-up readings in the warp and filling directions.

The above pattern found in the control shirts was evident without exception throughout the wash/wear duration at both 105°F and 120°F temperatures. The 100 percent cotton and the two blends were ranked the top three in the least amount of static build-up with no significant differences between the three fabrics. As was expected, the 100 percent polyester continued to have higher readings in electrostatic build-up and was ranked the least in both warp and filling directions at both temperatures.

There was no significant difference noted between the identical fabrics washed at the two temperatures when the filling and warp data were combined for an overall value. The two cotton shirts (1 and 5) were rated one and two; whereas, the 100 percent polyester shirts (4 and 8) had the greatest static cling. The 60/40 cotton-polyester (2 and 6) ranked better than the 65/35 polyester cotton shirts (3 and 7) as less static build-up was measured.

TABLE 17

MEAN ELECTROSTATIC BUILD-UP VALUES IN SECONDS OF THE SHIRTS TESTED INITIALLY AND AFTER 25 WEAR/LAUNDERING PERIODS AT TWO WASH TEMPERATURES

Initial:

Fabric Type	Mean Value[a] Warp	Mean Value[a] Filling
100% cotton	0.0	0.0
60/40 cotton-polyester	0.0	0.0
65/35 polyester-cotton	0.0	0.0
100% polyester	180.0	180.0

After 25 wear/Laundering Periods:

Fabric Code	Fabric Type	Temp.	Mean Value[a] Warp	Mean Value[a] Filling
1	100% cotton	105°F	4.6	1.2
2	60/40 cotton-polyester	105°F	26.3	9.2
3	65/35 polyester-cotton	105°F	38.0	54.9
4	100% polyester	105°F	475.4	353.0
5	100% cotton	120°F	0.0	0.0
6	60/40 cotton-polyester	120°F	21.4	29.0
7	65/35 polyester-cotton	120°F	29.0	38.7
8	100% polyester	120°F	408.0	371.0

[a]In seconds

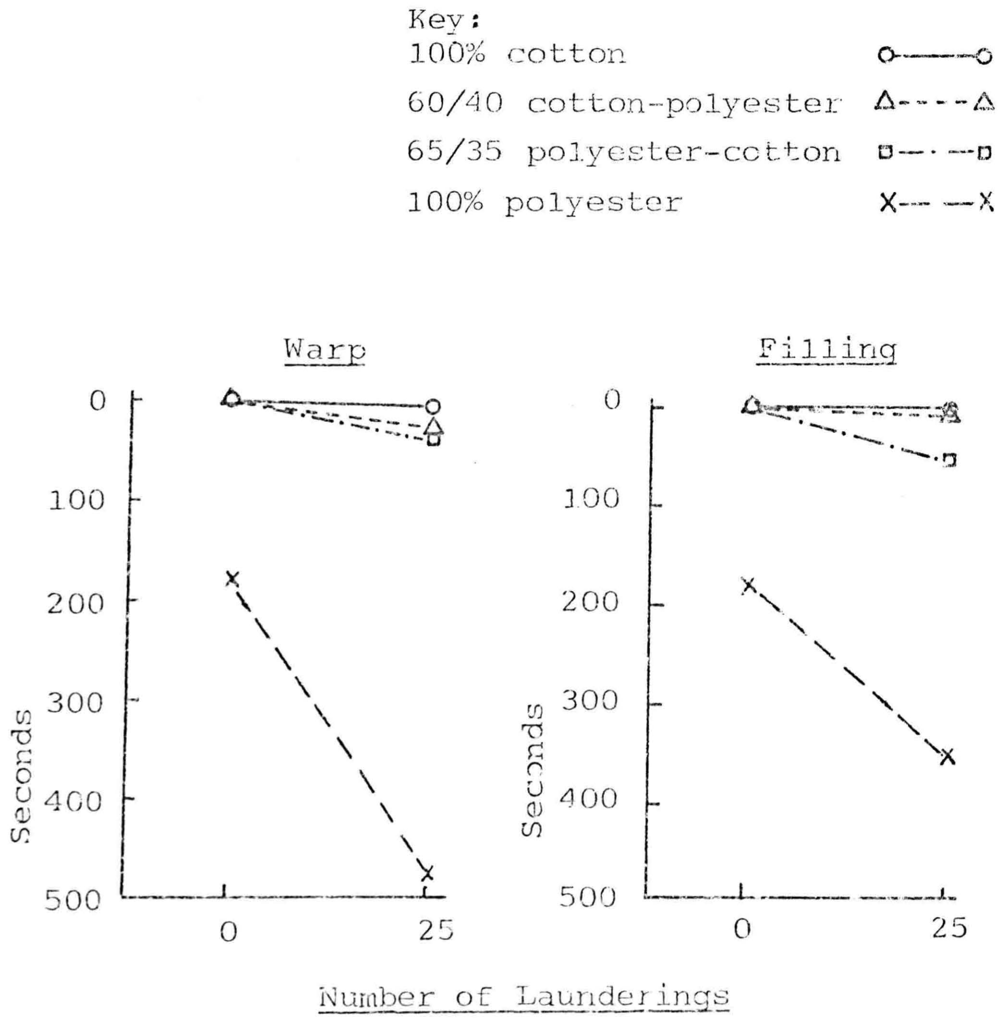


Fig. 19. Mean electrostatic build-up values in seconds of the shirts tested initially and after 25 wear/laundering periods at 105°F wash temperature in the warp and filling directions.

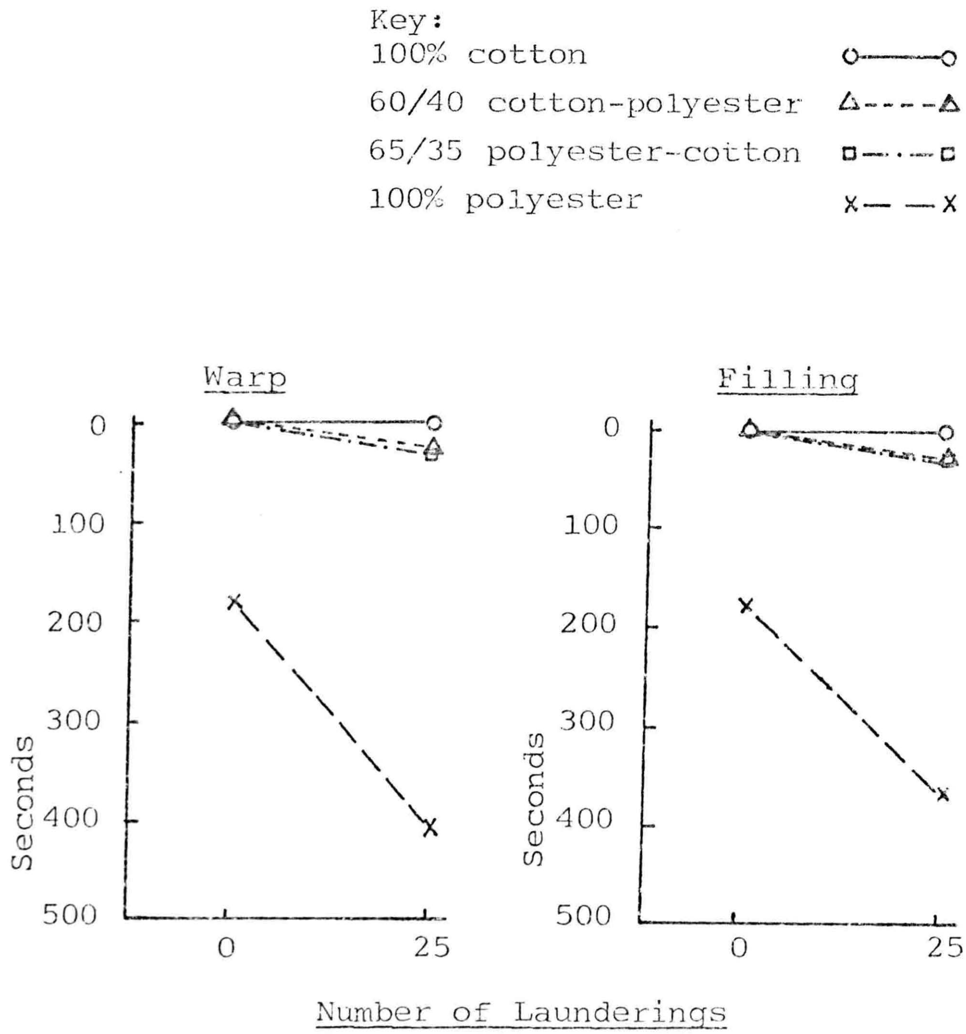


Fig. 20. Mean electrostatic build-up values in seconds of the shirts tested initially and after 25 wear/laundering periods at 120°F wash temperature in the warp and filling directions.

TABLE 18

NEWMAN-KEULS MULTIPLE COMPARISONS OF ELECTROSTATIC BUILD-UP VALUES IN SECONDS OF THE SHIRTS TESTED INITIALLY AND AFTER 25 WEAR/LAUNDERING PERIODS AT TWO WASH TEMPERATURES

Initial:	Warp				Filling			
Fabric Code[a]	1/5	2/6	3/7	4/8	1/5	2/6	3/7	4/8
Mean Values	0.0	0.0	0.0	180.0	0.0	0.0	0.0	180.0
After 25 Wear/Launderings: (105°F)								
Fabric Code[a]	1	2	3	4	1	2	3	4
Mean Values	4.6	26.3	38.0	475.4	1.2	9.2	54.9	353.0
After 25 Wear/Launderings: (120°F)								
Fabric Code[a]	5	6	7	8	5	6	7	8
Mean Values	0.0	21.4	29.0	408.0	0.0	29.0	38.7	371.0

After 25 Wear/Launderings: (105°F and 120°F, warp and filling combined)

Fabric Code[a]	5	1	2	6	7	3	8	4
Mean Values	0.0	2.9	17.8	25.2	33.9	46.4	389.5	414.2

Note: There is a difference at the 0.05 level of probability in the means not underlined by the same line.

[a]1, 5 = 100% cotton
2, 6 = 60/40 cotton-polyester
3, 7 = 65/35 polyester-cotton
4, 8 = 100% polyester

CHAPTER V

SUMMARY AND RECOMMENDATIONS

This wear-study involved 100 men's white dress shirts of four fabric types (100 percent cotton, 60/40 cotton-polyester, 65/35 polyester-cotton and 100 percent polyester). All of the shirts were purchased in size 15½ x 33 so as to facilitate like laundering loads for energy measurements. The shirts were worn for 25 eight-hour wearing periods by male, white collar, university personnel. During the duration of the study, the energy required for maintenance was measured for each fabric type with individual meters provided by the City of Denton. At each five wear/laundering period, the shirts were evaluated for features important for the appearance, durability and comfort of the shirts.

The cost for the energy used in maintaining each shirt, regardless of fiber content, was less than two and one-half cents when washed at a 105°F wash temperature. The cost for the all-cotton shirt was $.0219. Costs for the other three shirt types were: 60/40 cotton-polyester $.0197, 65/35 polyester-cotton $.0185 and 100 percent polyester $.0190. The difference between the highest cost and the lowest cost was slightly more than one-third of one cent. At the 120°F wash temperature, the all-cotton shirt required $.025 in energy cost maintenance; whereas, the 60/40 cotton-polyester cost $.023 to refurbish. At the higher temperature the blend higher in polyester required $.022 in energy maintenance cost with the 100 percent polyester maintenance costing $.0222. The difference in the cost for refurbishing the four types of fabric included in this study was one third of one cent. The minute difference observed does not make cotton a large energy consumer when compared to the other fabric types.

The soiling evaluations did not reveal a soil build-up; therefore, the fabrics were being cleaned at both temperatures. Although most shirts did receive high ratings, the 100 percent polyester shirt received the lowest rating of the four shirt types at the final evaluation period at both temperatures.

The durable press appearance did not change noticeably after the first evaluation period regardless of wash temperature. The two fabric blends, 65/35 polyester-cotton and 60/40 cotton-polyester, were rated first and second; whereas, the 100 percent polyester shirt was a close third with cotton receiving the lowest durable press rating.

Initially and after each five wear/laundering periods, the broken yarns were recorded and totaled. The two fabrics higher in cotton had the largest totals. The fabrics higher in polyester exhibited the smaller totals. Although snags were not included in the study, they were a problem in the wearing appearance of the 100 percent polyester shirt.

The all-cotton and the 60/40 cotton-polyester shirts developed fewer pills throughout the study. At every evaluation period, the 65/35 polyester-cotton shirt and the 100 percent polyester shirt had the greatest number of pills.

The whiteness retention results did not single out any shirt type dependent on high temperature for whiteness. The 60/40 cotton-polyester and 100 percent cotton maintained the two top values at both temperatures throughout the study. At the 25 wear/laundering period, all of the shirts, with the exception of polyester, were whiter at the lower temperature.

After the shirts had been exposed to 25 wear/laundering periods, the air permeability values were the same at both temperatures. The blend higher in polyester was the most permeable, as it required the least amount of time for air to permeate the fabric. The 100 percent polyester was second; whereas, the 60/40 cotton-polyester shirt was third in the fewest number of seconds required to permeate the fabric. The 100 percent cotton required the longest time for the air to permeate it. The difference in fabric weave and yarn count could have had some influence on air permeability.

In order to determine overall breaking strengths, the warp and filling readings were grouped together. The temperature at which the fabrics were washed did not significantly affect the strength of any of the four fabric types. In overall breaking strength at the lower temperature, the 100 percent cotton was strongest; the 60/40 blend rated second; the 65/35 blend was third; and the 100 percent polyester placed last. At the higher wash temperature, cotton was again stronger than the other three fabric types. Polyester was next in overall strength with the two blends following.

The two fabrics higher in cotton were found to be the most absorbent fabrics in the study with only slight exceptions. The unpredictable absorbency data for the control shirts point to the fact that this is a difficult property to accurately measure as fabric weave, finish and yarn construction apparently had some effect on this property.

The 100 percent cotton shirts were found to have less electrostatic build-up than the other three fabrics tested. The blend higher in cotton percentage exhibited less static cling than did the blend with the higher percentage of polyester. The 100 percent polyester had the greatest electrostatic build-up and was significantly different from the other three fabric types.

The overall results of this study showed that there is, as expected, a difference in energy costs when refurbishing four fabric types. However, this difference was found to be much smaller than that reported by previous researchers. The polyester and the blend with the higher percentage in polyester were superior in fewer broken yarns and air permeability time. The 100 percent polyester shirt was superior in durable press values; however, the blend with the higher percentage of cotton was rated above the blend with a higher percentage of polyester. The cotton and cotton-polyester blend had fewer pills, less static cling and were more absorbent than the 65/35 polyester-cotton and 100 percent polyester shirts. The 100 percent cotton shirt was the strongest overall of the four fabric types. Not only the energy requirements, but the comfort, appearance and durability features are all factors needed to be considered in the selection of a garment.

Recommendations

The data generated from this study have suggested possibilities for future research and study. As appliances, fabrics and test methods change, additional information will be needed. Recommendations are as follows:

1. Development of methods for measuring the absorption of body moisture by the fabric.

2. Investigate the effect of yarn construction, finishes and fabric weave on air permeability.

3. A follow-up study of energy maintenance requirements as new blends and finishes appear on the market.

4. Conduct a comparison of energy maintenance requirements and labor using different laundering procedures.

5. A study to compare the cost of doing laundering at home versus commercial laundering.

6. Conduct an assessment of consumer opinion as to the wear life of a garment, man-made versus natural fabrics.

7. Follow-up study using different temperatures to determine if higher temperature result in significantly improved whiteness.

8. A study to determine the part detergents and bleach might play in energy conservation by compensating for lower washing temperatures.

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