THE WEAR LIFE PERFORMANCE OF MEN'S ALL COTTON DRESS SHIRTS FINISHED BY FOUR DIFFERENT APPLICATION METHODS

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CHAPTER I

INTRODUCTION

The widespread market penetration of durable press cotton garments has spurred many textile companies to see their future as one involved in solving problems associated with processing cotton (25). One of textile industry's major concerns is the energy crisis. The maximum utilization of available energy is a priority of the industry.

The cotton industry is investigating ways in which it can best meet the problem of energy and still increase consumer demand for cotton. One area of investigation concerns finishes. The industry is evaluating the utility of low wet pick-up systems for finishing cotton fabrics (23).

In laboratory experiments, to test this new finishing application, low wet pick-up techniques performed as being strongly recommended. Not only did the experiments result in lower energy and chemical costs but also better abrasion resistance (26).

This study was designed to investigate the new minimum application finish in comparison to established finishing techniques following a designated wear/laundering procedure.

Statement of Purpose

The purpose of this study was to evaluate the wear life performance of 100 percent cotton broadcloth shirts finished by four different application methods.

Justification for Study

Market research studies in the late sixties revealed that consumers viewed cotton fabrics as having some acceptable characteristics. These characteristics were identified as a high degree of absorbency and non-irritability to the skin, good launderability, vivid prints, and versatility. Consumers, however, preferred synthetic fibers because cotton lacked easy-care characteristics, had poor luster, and was not considered fashionable (14). Consumers' opinions have since changed. Cotton is making a come back. There is an increasing demand for 100 percent cotton fabrics, mainly because of improvements in easy-care performance, fashion trends, and advertising activity (43).

With the introduction and acceptance of 100 percent cotton, no-iron shirts in late 1978, the cotton industry has shown a renewed interest in treatments for cotton. Finishes can provide the consumer simultaneously, with the comfort of cotton, the convenience of durable press, and an adequate wear life.

The cotton industry is also concerned with the rising energy cost of cotton production. Although, it takes less fossil fuel energy to produce cotton fiber than the synthetics, more energy is required to convert cotton to finished fabric (25).

The cumulative effect of this renewed interest in cotton is that many textile companies are developing technologies for solving their economic cost increases while improving the quality of cotton products offered. This study evaluated the effects of one of these new technological developments.

Objectives

This study was designed to obtain information concerning the wearlife performance of 100 percent cotton broadcloth shirts, supplied by Cotton Incorporated, that were finished with four different application methods.

Specific objectives of the study were:

1. To secure 24 men's shirts made of 100 percent cotton, finished with each of the following application methods:
    a. Sanfor-Set and minimum application finish (MA), at a 40 percent wet pick-up
    b. Minimum application finish (MA), at a 40 percent wet pick-up

c. Sanfor-Set and pad-dry-cure, at a 65 percent wet pick-up

d. Pad-dry-cure, at a 65 percent wet pick-up

2. To subject the shirts to 25 periods of wear and laundering

3. To evaluate the performance of the shirts at various intervals during the wear and laundering periods with reference to:

    a. Durable Press Appearance

    b. Shrinkage

    c. Wear Failure

4. To determine the tensile strength, the tearing strength, abrasion resistance, and color change initially and at the termination of the study

5. To conduct a panel evaluation of the shirts at the end of the study.

Assumptions

In conducting this study the following assumptions were made:

1) That the men selected for the wear panel will be dependable subjects.

2) A shirt will be worn by the participants a minimum of eight hours between wear/launderings.

3) The shirts will be worn in typical white collar situations.

Delimitations

1) The 80 light blue men's dress shirts of 100 percent cotton broadcloth.

2) The four different application methods used in applying finishes on the shirts.

3) The 25 wear-laundering periods.

Definitions of Terms

For the purposes of this study, the following terms were defined:

Sanfor-Set. A process that reduces residual or service shrinkage to a minimum under home-wash/tumble-dry conditions and provides no-iron characteristics, a registered trademark.

Minimum Application. A finishing process that uses a minimum amount of resin in the fabric, approximately 40 percent wet pick-up. Designated: MA.

Pad-Dry-Cure. A conventional finishing process consisting of padding with a laboratory pad to about 65 percent wet pick-up and drying on pin frames in a forced-air oven.

Durable Press. Setting the shape of garments so that good appearance-retention is maintained during the wear life of a garment.

CHAPTER II

REVIEW OF LITERATURE

Literature was reviewed in order to examine: 1) how durable press evolved; 2) the durable press process; 3) studies related to durable press finishes; and 4) new technological processes for durable press finishes.

Development of Durable Press

Durable press is a term used to describe the qualities of garments that retain their shape, pressed appearance, and fit after laundering. This shape retentive finish had its beginning back in the 1960's, but the beginnings of easy care started much earlier.

The initial step to easy care was the development of the wrinkle resistance finish for spun rayon. This resin finish was first developed and used in England in the 1920's but was not used in the United States until 1940. The resin finish was found to work equally well on cotton (21).

Cellulosic fibers do not have natural cross-links that are necessary for fiber recovery. Cross-links hold adjacent molecular chains together and are essential in pulling them back into position after the fiber has been bent. This prevents the formation of wrinkles. The resin finish forms a cross-link that will prevent wrinkles from forming, thus providing the fiber with good wrinkle recovery. The first resin used was urea formaldehyde, since then there have been different and improved resins (29).

The wrinkle resistant finish provided smooth, flat, wrinkle resistant fabric but also had many problems associated with the finish. Fabric had decreased tear strength, poor abrasion resistance, and usually developed a fishy odor (21).

Continued development toward easy-care fabrics next produced wash-and-wear finishes. This chemical treatment of fabrics utilized a higher percentage of applied resin. The increased use of resin improved the properties of wash-and-wear finished fabric. The fabric resists wrinkling and mussiness imposed during wear, while maintaining creases, pleats, and other ironed-in formations (29). Garments constructed of durable press finished fabric required special care. Smaller wash and drying loads are essential to prevent sealing in wrinkles.

An analysis of the laundering performance of garments sold as wash-and-wear was conducted by Muller (36). The garments that were hand-laundered showed the highest ratings on appearance of stitching and seams. Automatic home laundered garments did rate slightly below those that had been hand-laundered, but the power laundered garments were well below both.

Mousa (35) also conducted a study on the effects of three laundering procedures on the performance of all-cotton fabrics treated with wash-and-wear finishes. The results after 50 launderings showed that hand laundering produced slightly superior flat abrasion resistance, wash-and-wear performance, whiteness retention, and less dimensional change. Automatic, home machine laundering rated second, with power laundering third.

Other problems associated with a wash-and-wear finish are brittle fibers and loss of about one-third of the fabrics wear resistance. Loss of the finish through repeated washings also can occur (29).

The culmination of these early finishes resulted in durable press. Durable press wash-and-wear garments were first produced in 1956 and 1957, on dry-cleaning equipment. Cotton garments were impregnated with dimethylolethyleneurea and metal-salt catalysts. Excess liquor was removed, the garments were damp dried at low temperatures, and hot pressed to cure the resin and thereby render the pressed effect fairly permanent (33). Simultaneously the National Cotton Council of America and the Southern Regional

Laboratories of the United States Department of Agriculture were producing durable-press wash-and-wear garments. Little use was made of this new finish because the amount of resin used left the strength of cotton fabrics unserviceable, and the prohibitive expense of installing ovens for curing garments.

The first commercially produced durable press garments appeared on the market in the early 1960's with the introduction of Koratron's "Oven-Baked" men's pants (21). This process simply separated existing processes, where garment manufacturers cured the chemicals that finishers had applied (10).

An in-use study by Turner (50) evaluated men's post-cured durable press trousers constructed from five fiber-finish combinations. Three of these were all-cotton with three different durable press treatments, Fixapert PCL, Fixapert CP-40, and the Koratron process. Both the Fixapert PCL and CP-40 durability exhibited in laboratory tests were in opposition to their performance during the wear trials. Neither met the minimum standards required to be classed as a durable press fabric. The all-cotton fabric with the Koratron process did keep its neat pressed appearance, but its lack of durability placed it far short of an acceptable standard of wear.

Durable press finishes can be applied by many different processes, but the most prominent categories are the pre- and post-cured. The precured process involves saturating the fabric with a resin cross-linking solution, drying, curing, making into garments, and re-curing by pressing.

> This causes minimum interference to the routine of the finishing plant. Further, the storage-stability of the resin on the fabric is unlimited. The process does not involve the garment manufacturer in special, unfamiliar curing operations and there is little possibility of unpleasant odors developing on re-curing in the high temperature presses. The function of the re-curing stage is claimed to be the breaking of bonds between the resin (or cross-linking agent) and the cellulose molecules and their reformation in any given configuration. (10:8)

The post-cure process first saturates the cloth with a resin cross-linking solution and is dried. The fabric is then made-up into garments, pressed into shape, and cured by putting the garments into a curing oven.

> The post-curing (or delayed curing) process requires impregnation of the fabric with chemicals which do not cure on drying or on storage, but which can be made to cure easily after the garment is made up. This requires careful choice of resin and catalyst system plus careful drying. (10:8)

The most widely used application method for a durable press finish is the pad-dry-cure. In this method the fabric is impregnated with a solution containing the crosslinking agent, a catalyst, a lubricant and optionally a stiffener.

The fabric is preferably dried on a tenter, and then baked under conditions that are governed by the choice of cross-linking agent to complete the chemical reaction involved (curing) (20).

Kim (27) analyzed the performance characteristics of permanent press fabrics for use in women's or children's casual dresses. Results identified that the higher percentage of cotton contributed to superior wash-and-wear ratings after line drying, and to more dimensional stability in both the warp and filling directions. The method of curing also had effects on performance. Post-cured fabrics were more effective in crease performance after line and tumble drying, in wet and dry tensile and tearing strength values, and in resistance to flexing and abrasion in the warp direction. The pre-cured fabrics were superior in wash-and-wear evaluations after line and tumble drying, and in dimensional stability.

Later Kim (28) evaluated the in-use performance of five types of sheets. Two of the sheets were all-cotton with durable press finishes, and one all-cotton which did not have a durable press finish. The study concluded that line drying enhanced the wash-and-wear ratings, and tumble drying reduced the ratings on durable press values. The same general wash-and-wear results were obtained for both the finished and unfinished all-cotton sheets, as was wrinkle recovery and whiteness. The all-cotton with no durable press finish was higher in values of dry and wet breaking strength, and both dry and wet tearing strength.

A wear study in 1969 by York (24) compared five major types of white shirts. Three of the types were all-cotton. Two had durable press finishes, and one had a wash-and-wear finish. The study identified the wash-and-wear finished cotton shirts as ranking generally very low. The durable press finished all-cotton shirts ranked highest in whiteness, above average for breaking and tearing strength, average in flat abrasion, but below average in wash-and-wear performance.

Men's durable press trousers of five fabric-fiber-finish categories were evaluated by Ball (3). Three of the trouser types were 100 percent cotton and differed only in the type of experimental durable press finish which had been applied. The varied finishes were a wet-fixation treatment, a modified pad-dry-cure treatment, and a standard pad-dry-cure treatment. The standard pad-dry-cure treatment had the best smoothness performance, sharpest creases, smoothest seams, but, the highest soiling. The modified pad-dry-cure rated second in all the tests, with the wet-fixation treatment being third.

Haas (16) evaluated the same trousers in relation to their resistance to abrasion damage. The all-cotton trousers with a wet-fixation and modified pad-dry-cure durable press finish rated higher in resistance to general wear than the standard pad-dry-cure. All three types of finishes on the all-cotton trousers rated highest on crease abrasion performance, with the wet-fixation first, modified pad-dry-cure second, and Koratron third.

Utilizing the same trousers, Salalahi (42) determined their appearance and durability after line and tumble drying and Morgan (34) analyzed their wrinkle-recovery, durability, and color loss. The all-cotton trousers received the lowest ratings on appearance, but compared equally to the blends in durability. Also, the trousers generally showed the lowest ranks in wrinkle recovery, approximately average in durability, and well above average, or highest in the least amount of noticeable color change.

With the introduction and acceptance of 100 percent cotton, no-iron shirts in late 1978, the cotton industry has shown a renewed interest in treatments for cotton. Harper (17) further stated:

> The early durable press garments were 100 percent cotton, but their rapid failure due to lack of abrasion resistance prompted a swift change to blended fabrics. In response to this loss of

> markets, research on cotton finishing veered away from its traditional concentration on the improvement of crosslinking agents, new processes were sought which would yield cotton fabrics with high wrinkle recovery and improved breaking strength, tearing strength, and abrasion resistance. (17:1)

Calvert (6) conducted an investigation to determine the performance of four types of durable press finishes applied to all-cotton work trousers. There were two variations of the vapor phase finish, a proprietary finish, and a conventional pad-dry-cure finish. The trousers finished with the pad-dry-cure received the highest appearance ratings but the lowest overall performance rank. The two vapor phase treatments received the highest ratings for strength values.

In 1976 Caldwell (5) also conducted a study evaluating the performance of jeans treated with different durable press finishes. The Cotton Press 10.11™ treatment, pad-dry-cure method, and untreated fabric, were all 100 percent cotton fabric. The findings identified the finished cotton as being superior in durable press appearance to the untreated fabric. Finished cotton also rated higher in sharpness of creases, color fastness, and dimensional stability. However, the untreated jeans were similar in strength properties to the Cotton Press 10.11™. Both types were generally superior to the pad-dry-cure treated jeans regarding strength retention.

New Technological Processes for Durable Press Finishes

In 1978, durable press resins accounted for 180 million pounds used for textile finishing. Textile finishing agents are estimated to increase in pounds by three percent per year (38). These finishing resins are a part of the rising cost of durable press finishes.

Probably the primary concern of the finishing industry is the energy crisis. Finishers are the largest users of energy in the textile industry (9). Their major concern is with maximum utilization of available energy.

With rising energy costs, oil embargos, gas shortages, and the threat of further shortages, the textile industry has no choice but to evaluate methods of increasing energy efficiency. Most of the efforts by the textile industry to conserve energy have been focused on water. Texas Tech University's Textile Research Center is also currently investigating the possibility of decreasing energy requirements during wet processing (12). How it is applied, removed, and recovered is the point of interest (44).

> Nowdays, it seems ludicrous to apply finishing agents with, typically 60-80% water on the weight of the fabric, which water then is removed immediately with thermal energy. Although some improvements can be made by using more effective extraction methods, such as absorbent squeeze rolls or vacuum-extracting the excess liquor out,

> greater savings in energy can be achieved by reducing the amount of liquor that's applied in the first place. (25:5)

Low wet pick-up finishing was first devised to save energy costs, but other advantages were realized. Not only did low wet pick-up finishing save in energy costs but also in chemical costs. The new low wet pick-up processing has also been found to improve product quality by improving abrasion resistance (23).

There have been a variety of methods developed to achieve a reduced wet pick-up. Some of these methods are uniquely suited for certain fabrics, finishes, and situations, while other methods are more versatile. Some of the reasons for the selection of a particular method may include capital cost, finish to be applied, fabric type, variety and yardage of fabrics, labor required, uniformity of application, and ability to control the application (49).

One of the various systems involved in low wet pick-up is the kiss roll applicator. It is one of the oldest and simplest methods of limiting the wet pick-up during application of a finish (49). For many years kiss rolls have been used for back filling. Fabric and roll speeds can be independently varied, and by adjusting the ratio of the two speeds the wet pick-up is easily varied (25).

Thiatex AG of Switzerland developed a highly sophisticated kiss roll system for applying finishes uniformly. This system has been used in Europe for about ten years. The Triatex MA system was the first automatically controlled reduced wet pick-up system to be widely adopted in European countries. The Triatex system was not brought to the United States until 1978, when Cotton Incorporated and Dan River, Inc., cooperated to install the first three MA units in this country (23).

Dan River has equipped two of their finishing ranges with the Triatex MA systems, a controlled "kiss coat" low wet pick-up system. When completed, over half of their finishing ranges will be equipped for finishing with methods other than the conventional aqueous pad application system (11).

Preliminary results show that about 40 percent wet pick-up, compared to 50-70 percent for typical wet pick-up, is required with 100 percent cotton fabric to give adequate finish uniformity. This figure can be lowered to 30-35 percent wet pick-up by special preparation of the fabric. By pretreating the fabric with Sanfor-Set a better uniformity is obtained and allows for the reduction in wet pick-up percentage (26).

Engraved roll is another system. This technology has been used in the paper and film coating industries from their early beginnings (48). For low wet pick-up it is used with a top rubber squeeze roll. Fabric and roll speed cannot be independently varied, and the wet pick-up achieved on any fabric is constant, depending on the engraving volume. According to Jones (23):

> The design of the engraved roll pad is extremely simple. In some respects it is quite similar to the conventional pad. There are four major components: the engraved roll, top resilient roll, doctoring assembly, and solution pan. The engraved roll turning in the solution has its cavities filled with the application liquor. The cavities have the excess liquor removed as the engraved roll turns by the doctor blade. As the fabric goes through the nip of the engraved roll and the top resilient roll, the liquor from the cavities of the engraved roll is forced into the fabric. (49:11)

Other systems being studied utilize sprays, vapors, and foams. Many finishing plants have examined foam systems, but there are two widely discussed systems promoted by United Merchants and Manufacturers, Union Carbide, and Gaston County (25).

United Merchants and Manufacturers' method is to apply a stable foam with conventional equipment, and then collapse the foam into the fabric using squeeze rolls. The foam must be kept stable while it is metered into the fabric, otherwise uneven application results (25).

In contrast, the Union Carbide method requires a semi-stable foam which is formulated to wet the substrate rapidly. Gaston County Company makes the special applicator that is required. The foam is forced through a slot into the fabric, in the filling direction. At a given fabric speed, the total wet pick-up is determined by the liquor flow rate into the foamer. The flow ratio can then be adjusted by controlling the air flow into the foamer. Further control is provided by varying the foam shearing speed. This will cause the bubble size and foam quality to vary. Controls are adjusted so that the foam collapses during its passage through the fabric (25).

Foam finishing technology was introduced in this country in the late 1970's (24). In recent years, research and development of foam technology for finishing have made great progress. For example, United Merchants and Manufacturers' Research Division, after investigation of other application methods, has settled on the use of foam as a cost-effective, controllable and practical technique for applying a wide variety of chemicals and finishes.

A study conducted by Gregorian and Namboodri (37) compared the durable press finishing of cotton and cotton/polyester blend fabrics by conventional pad-dry-cure application method to the foam application method. Durable press ratings and selected physical properties of the finished fabrics were compared after three home launderings. The results concluded that the durable press ratings of the foam finished cotton fabrics were significantly higher than the ratings of the fabrics finished by the conventional process. The study also showed that the optimum performance for both fabrics was obtained at a wet pick-up level of about 30 percent (37).

The final system is the airless spray. Sprays have long been used to apply finishes, especially to pile fabrics where uniformity of application was not critical (49). Texspray, through their agent, Burlington Textile Machinery Corporation, supplies airless spray systems for applying a variety of finishes. Finishes can be applied very uniformly in this way (23).

Only through investigation and analysis can the full potential of the low wet pick-up systems be realized. The possibilities of savings seem endless as the technology for conserving energy in the finishing plant continues to grow rapidly.

CHAPTER III

PLAN OF PROCEDURE

The following is an overview of the procedure which was used to study the performance of 100 percent cotton shirts finished by four different application methods.

Shirt Types

There were 80 light blue men's dress shirts of 100 percent cotton broadcloth used as experimental garments for the study. Twenty shirts of each of the four finishing techniques were used. The Dan River Company manufactured the four types of shirting fabric and the shirts were assembled by the Arrow Shirt Company. Shirt sizes were selected according to the size requirements of the men chosen to participate in the study.

The shirts were coded as to chemical finish and shirt number. The four chemical finishes were coded as follows:

Type A--Sanfor-Set and minimum application

Type B--Minimum application

Type C--Sanfor-Set and pad-dry-cure

Type D--Pad-dry-cure

Wear Panel

Participants in this study included 24 male white-collar workers employed at Texas Woman's University. The men selected were those who had participated in previous shirt studies who had proven to be dependable subjects.

Each participant was issued four shirts, one of each of the four types. Each shirt was worn for a minimum of eight hours and returned to the designated drop-off point at a specified time each day. The shirts were examined and treated for stains (if necessary), laundered, evaluated, and pressed before being returned to the subjects for additional wear. This plan continued until all shirts had been subjected to 25 wear-laundering periods.

Laundering Procedure

Laundering was accomplished as recommended in washing condition II (120° F.) of AATCC Test Method 143-1974 (1).

Twelve shirts constituted each washing load, with the use of 90 grams of Tide detergent. The shirts were removed immediately after completion of the washing cycle and transferred to the dryer. Tumble drying was done according to AATCC Test Method B 143-1975 (1). The permanent press setting was used with a cool down period. The dryer was equipped with a moisture sensor. Twelve shirts constituted each drying load. After the drying cycle was completed, the shirts were removed, marked, and placed on a coat hanger. A technician then evaluated them by the AATCC Test method 143-1975 (1) and any touch-up ironing necessary to provide at least a 4.0 durable press value was applied by means of a hand iron.

Equipment

Washing was done in a domestic Whirlpool LDA 9800 washer equipped with a #600 Kenmore Agitator as specified in AATCC Test Method 143-1975 (1). The design of this machine included an extra large washing drum, two washing agitator speeds, and two spin speeds. The rinse consisted of a power spray rinse and an agitated deep rinse.

Tumble drying was done in a Whirlpool LDE Model dryer, set on permanent press with a cool down period.

A Sears hand, steam iron was used for touch-up ironing when necessary. Permanent press #3 was the setting.

Evaluation Procedure

During the course of this study, the shirts were evaluated with regard to parameters that are important to the consumer. The table below gives the parameters, the test method, and the frequency of evaluation.

TABLE 1

PERFORMANCE EVALUATION

Parameter of Evaluation	Test	Frequency Evaluation (wear-laundering intervals)
Durable Press Appearance	AATCC 124-1975	5, 25
Shrinkage	ASTM D-1905-73	5, 25
Tensile Strength	ASTM D-1682	0, 25
Tearing Strength	ASTM D-1424-63	0,25
Abrasion	AATCC 93-1978	0, 25
Color Evaluation	Hunterlab Manual Method 4.2.3	0, 25
Wear Failure (collar, cuff, placket) Broken Yarns	Counted	0, 15, 20, 25
Panel Evaluation of Appearance		0, 25

Durable press appearance values were assigned to the shirts after 5 and 25 wear-laundering periods, according to AATCC 124-1975. A panel of three technicians evaluated the shirts on the front placket, side seam, and back.

Shrinkage values were determined on three shirts of each of the four fabric types following 5 and 25 wear-launderings as designated in accordance with Cotton Incorporated instructions. Measurements were taken on the chest, sleeve, collar, and back length of the shirts.

Shrinkage values were determined also on shrinkage squares of each of the four fabric types. The shrinkage squares were laundered and dried with the shirts with three measurements taken in the warp and filling directions of each, according to ASTM D-1905-73, after 5 and 25 wear-launderings.

The shirts were evaluated with regard to their warp and filling breaking strengths by means of Instron Model 1130, initially and following 25 wear-launderings. According to ASTM Designation: D-1682-64 (Reapproved 1970), three specimens were tested each in the warp and filling directions, by means of the grab method.

The resistance to tearing of the shirts was determined initially and after 25 wear-launderings from three specimens in each yarn direction. ASTM Designation: D-1424-62

(Reapproved 1970) was followed and the Elmendorf Tear Tester was used on specimens cut on the Punch Press Model NAEF.

The experimental shirts were evaluated with regard to abrasion resistance using AATCC 93-1978, Accelerated Method. Specimens of each fabric type were weighed initially in grams and following abrasion. The difference in weight was expressed as amount of fabric loss in grams and converted to percentage of abrasion by use of the following formula:

$$\frac{D_1 - D_2}{D_1} \text{ X } 100 = \text{Percentage of fabric loss}$$

D_1 = Original weight

D_2 = Weight after abrasion

Color differences of the four shirt types were determined by comparing initial color readings with color readings following 25 wear-launderings. The Hunterlab Color Difference Meter was used to determine color values using Method 4.2.3 in the Hunterlab Manual. The following formula was used to calculate Delta E for Color Difference determinations:

$$E = \sqrt{(\Delta L)^2 + (\Delta A)^2 + (\Delta B)^2}$$

Wear failure was evaluated by counting the number of broken yarns on each of the shirts initially and following 15, 20, and 25 wear-launderings, both in the warp and filling directions. Broken yarns were observed by placing each shirt under a 4" diameter magnifying glass and a mounted magnifying lens attached to a high intensity light. The yarns were counted by means of an Alfred Suter yarn counter. The number of broken yarns was recorded on drawings of each shirt, showing locations of broken yarns on the collar, cuff and placket. Pens with different colored ink were used to identify the broken yarns at the designated laundering periods.

The overall appearance of the shirts was evaluated in the laboratory by a panel of three observers who had no relationship with the study. Each shirt was placed on a clothes hanger and covered with an opaque plastic cover which permitted panel members to rate each shirt for crispness, softness, and smoothness by feel alone. The plastic covers were removed to allow panel members to evaluate appearance of the cuffs, collars, and plackets, and of the color and wrinkle resistance. Hand and appearance were evaluated following 25 wear-launderings on six shirts of each of the four types. The following scale was used to rate the shirts:

5. Excellent
4. Good
3. Satisfactory
2. Poor
1. Not acceptable

All physical testing was done under controlled conditions according to ASTM Designation: D-1776-67 with a temperature of 70° ± 2° F. and relative humidity of 65% ± 2%. Specimens were conditioned a minimum of four hours prior to testing.

Analysis of Data

The mean and standard deviation were calculated for each shirt type for breaking and tearing strengths, shrinkage, abrasion, durable press appearance, and panel evaluation at selected intervals. One-way and two-way analysis of variance was used to determine if significant differences existed between the four shirt types of various parameters. The Newman-Keuls' Multiple Comparison Test was used at the .05 percent significance level to see if significant differences existed between the various shirts with regard to property and wear-laundering period. Broken yarns and signs of wear were recorded at designated periods in total number counted on specified areas of the shirts.

CHAPTER IV

PRESENTATION OF DATA AND DISCUSSION OF FINDINGS

This study was involved with the evaluation of the wear life performance of 80 men's 100 percent cotton broadcloth, light blue dress shirts. One shirt of each of the four finishing types was issued to 20 men who wore each shirt 25 times. Fabrics, manufactured by the Dan River Company, were coded as: Type A--Sanfor-Set, minimum application; Type B--minimum application; Type C--Sanfor-Set, pad-dry-cure; and Type D--pad-dry-cure. Shirts were manufactured by the Arrow Shirt Company and supplied for the study by Cotton Incorporated. Parameters important to the consumer were evaluated at intervals throughout the study.

Data which resulted from an evaluation of the performance of the shirts are summarized in Tables 2 through 29, and Figures 1 through 7. The data are representative of the durable press appearance, shrinkage, and broken yarns of the shirts after specified laundering intervals and of the tensile strength, tearing strength, abrasion resistance, color change, and panel evaluation initially and after 25 periods of wear and laundering.

Durable Press Appearance

The experimental shirts were evaluated for their durable press appearance after 5 and 25 wear-laundering periods. At each evaluation period three different areas of the shirt--back, placket, and side seam--were evaluated by a panel of three technicians with reference to their smoothness.

Results of the statistical analysis of the data obtained by these observations such as the mean durable press appearance values, standard deviations, two-way analysis of variances, and Newman-Keuls' Comparisons of the marginal means are presented in Tables 2 through 4. In addition, Figure 1 provides a graphical description of the mean durable press values of the back, placket, and side seam areas of the shirts at 5 and 25 wear-laundering periods.

Table 2 shows the durable press appearance values followed a similar trend throughout the study for all four application methods. The highest durable press rating the shirts could obtain was a 5.0 rating, the lowest was 1.0. Figure 1 graphically shows that the appearance of the back of the Sanfor-Set, pad-dry-cure finished shirt (Type C) was given the highest rating at the 5 wear-laundering period with a 3.10. After 25

TABLE 2

MEANS AND STANDARD DEVIATIONS OF DURABLE PRESS APPEARANCE VALUES OF BLUE SHIRTS AFTER 5 AND 25 WEAR-LAUNDERING PERIODS

Shirt Type	Mean Values		Standard Deviations	
	Number of Launderings			
	5	25	5	25
BACK				
Sanfor-Set, Minimum Application	3.06	3.12	0.17	0.22
Minimum Application	2.94	3.02	0.26	0.11
Sanfor-Set, Pad-Dry-Cure	3.10	2.96	0.14	0.33
Pad-Dry-Cure	3.04	3.02	0.16	0.15
PLACKET				
Sanfor-Set, Minimum Application	2.74	2.84	0.40	0.24
Minimum Application	2.85	2.84	0.42	0.31
Sanfor-Set, Pad-Dry-Cure	2.56	2.68	0.39	0.42
Pad-Dry-Cure	2.59	2.74	0.24	0.25
SIDE SEAM				
Sanfor-Set, Minimum Application	2.89	2.84	0.31	0.27
Minimum Application	2.78	2.86	0.40	0.37
Sanfor-Set, Pad-Dry-Cure	2.77	2.70	0.28	0.25
Pad-Dry-Cure	2.76	2.92	0.33	0.20

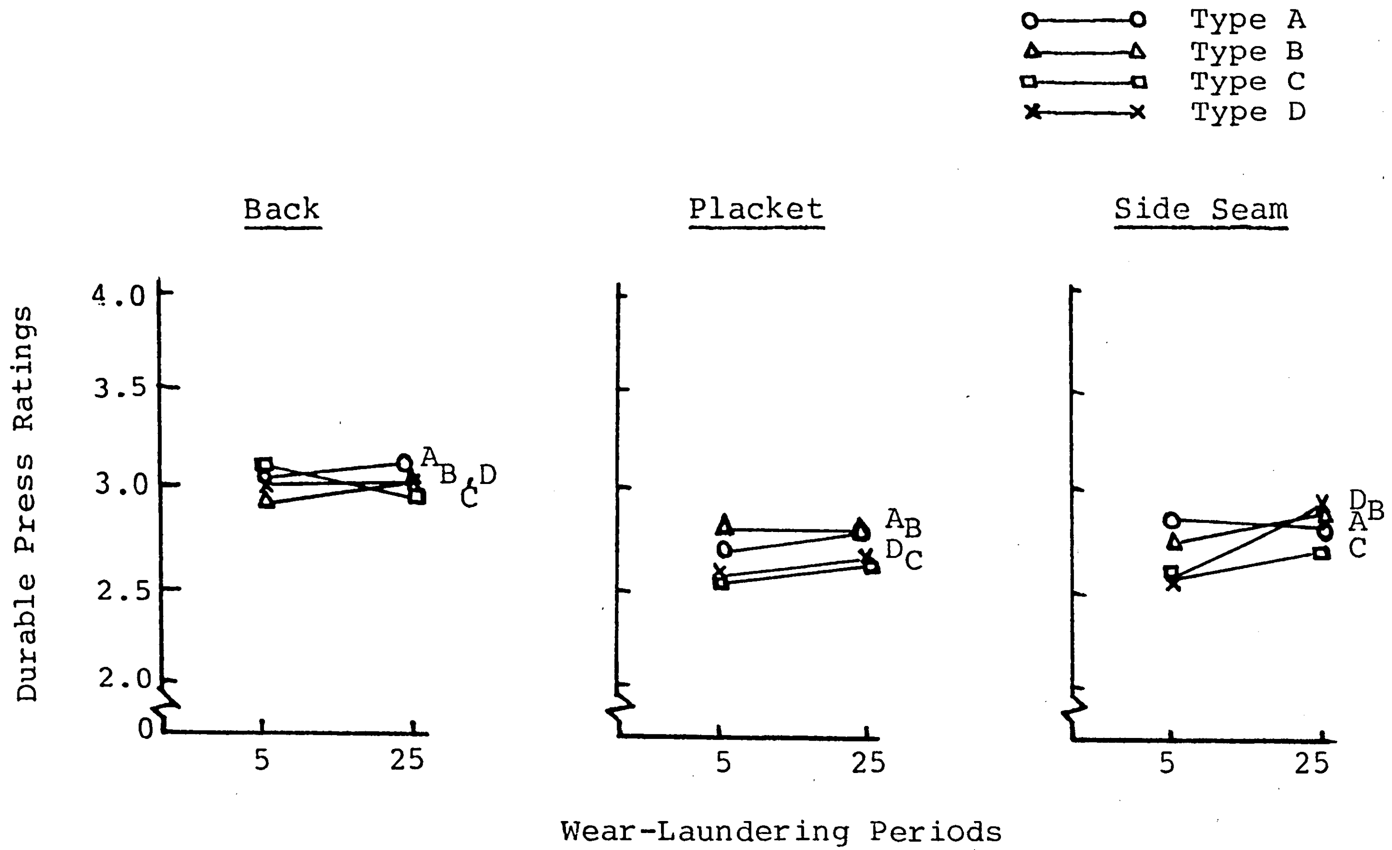

Fig. 1. Mean durable press values of the back, placket, and side seam areas of blue shirts at 5 and 25 wear-laundering periods.

wear-launderings, Type C received the lowest rating at 2.96. Again, Type C was rated lowest when evaluating the placket at both the 5 (2.56) and 25 (2.68) wear-laundering periods, as well as the lowest value (2.70) on the side seams after 25 wearings and launderings.

The two-way analysis of variance of durable press values of the shirts after 5 and 25 wear-laundering periods is shown in Table 3. Only the placket evaluations had significance at the alpha=0.05 level in relationship to type with a 3.82 F-ratio. There would appear to be a significant difference between the placket mean values and the type of finishing application method used.

The two groups of shirts finished by the minimum application methods were fairly consistent in having higher mean values. This is evident in Table 4 in which Type B shirts (minimum application) were ranked first by the Newman Keuls' comparison test of the marginal means of the shirts after 5 and 25 wear-laundering periods. Type A (Sanfor-Set, minimum application) was ranked second, with Type D (pad-dry-cure) and Type C (Sanfor-Set, pad-dry-cure) ranked third and last, respectively. Table 4 shows that there was no significant difference between the shirt types with regard to durable press appearance.

TABLE 3

TWO-WAY ANALYSIS OF VARIANCE OF DURABLE PRESS VALUES OF THE BLUE SHIRTS AFTER 5 AND 25 WEAR-LAUNDERING PERIODS

Source of Variance	d.f.	Mean Square	F-Ratio	Probability of F
BACK				
Type	3	0.07	1.57	0.20
Error	76	0.05		
Laundry	1	0.00	0.11	0.74
Laundry-Type	3	0.10	2.72	0.05
Error	76	0.04		
PLACKET				
Type	3	0.46	3.82*	0.01
Error	76	0.12		
Laundry	1	0.32	2.80	0.10
Laundry-Type	3	0.04	0.38	0.76
Error	76	0.12		
SIDE SEAM				
Type	3	0.13	1.31	0.28
Error	76	0.10		
Laundry	1	0.03	0.32	0.57
Laundry-Type	3	0.12	1.43	0.24
Error	76	0.09		

*Indicates significance at the $\alpha = 0.05$ level.

TABLE 4

NEWMAN KEULS' COMPARISONS OF THE MARGINAL MEANS OF THE BLUE SHIRTS AFTER 5 AND 25 WEAR-LAUNDERING PERIODS (DURABLE PRESS VALUES)

	Shirt Type			
	B	A	D	C
Mean Value	2.85	2.79	2.66	2.62

Note: There was not a significant difference between the shirt types underlined by the same line.

The marginal means used in Table 4 are the averages of the shirt type means of the two evaluation periods. Thus, the 2.85 marginal mean for Type B is an average of the readings taken after 5 and 25 wear-launderings.

Shrinkage

Evaluations with regard to shrinkage of the shirts were determined on three shirts of each of the four types. The shirts were measured for shrinkage at four different locations--length down the center back, chest across the center front, sleeve, and collar. The fabric squares were measured both in the warp and filling directions in order to determine percentage of shrinkage by direction.

The means and standard deviations of shrinkage of the blue shirts and of the fabric squares both in the warp and filling directions are shown in Table 5. Figure 2 depicts

TABLE 5

MEANS AND STANDARD DEVIATIONS OF SHRINKAGE ON THE LENGTH, CHEST, SLEEVE, AND COLLAR OF THE BLUE SHIRTS AND ON THE FABRIC SQUARES (WARP AND FILLING DIRECTIONS) AT 5 AND 25 WEAR-LAUNDERING PERIODS

Fabric and Shirt Type	Shirts*				Fabrics	
	Length	Chest	Sleeve	Collar	Warp	Filling
MEAN VALUES						
After 5 Launderings						
Sanfor-Set, Minimum Application	1.11	0.89	0.98	1.50	1.07	1.33
Minimum Application	0.56	0.31	0.37	1.39	0.90	1.23
Sanfor-Set, Pad-Dry-Cure	1.23	0.82	0.91	1.50	1.30	1.40
Pad-Dry-Cure	0.94	1.53	1.05	1.38	0.77	1.53
After 25 Launderings						
Sanfor-Set, Minimum Application	2.30	0.51	1.74	2.97	1.50	1.33
Minimum Application	0.84	0.66	0.85	2.28	1.07	1.33
Sanfor-Set, Pad-Dry-Cure	1.64	1.31	1.56	2.47	1.43	1.50
Pad-Dry-Cure	1.24	1.45	1.36	2.01	1.07	1.67
STANDARD DEVIATIONS						
After 5 Launderings						
Sanfor-Set, Minimum Application	0.20	0.73	0.37	0.48	0.06	0.17
Minimum Application	0.16	0.43	0.40	0.39	0.10	0.06
Sanfor-Set, Pad-Dry-Cure	0.91	0.33	0.33	0.32	0.44	0.15
Pad-Dry-Cure	0.17	0.78	0.68	0.12	0.15	0.15
After 25 Launderings						
Sanfor-Set, Minimum Application	1.00	0.45	0.14	0.25	1.33	1.33
Minimum Application	0.27	0.58	0.46	0.24	1.23	1.33
Sanfor-Set, Pad-Dry-Cure	0.66	0.87	0.20	0.39	1.40	1.50
Pad-Dry-Cure	0.08	0.78	0.09	0.42	1.53	1.67

Note: *Represents the measurements of three shirts from each of the four shirt types.

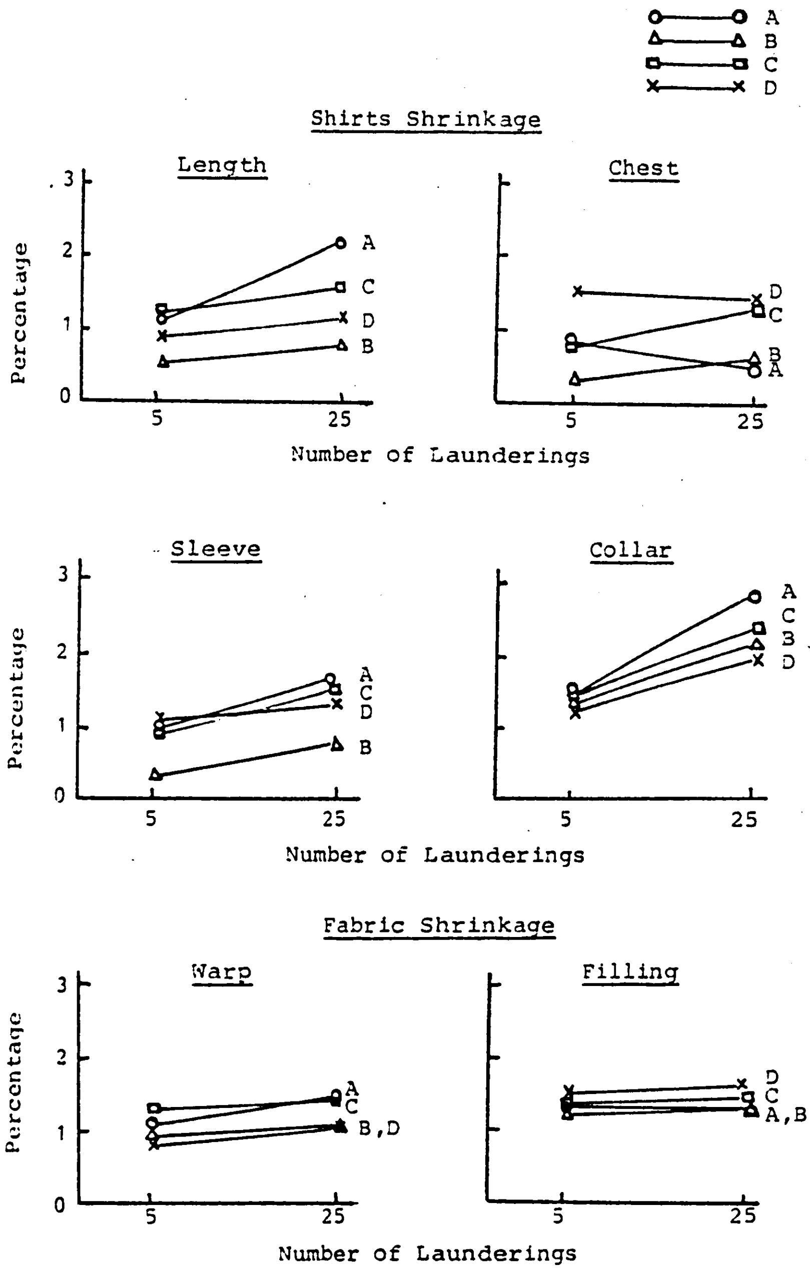

Fig 2. Mean values of shrinkage of the length, chest, sleeve and collar of blue shirts and fabrics after 5 and 25 wear-laundering periods.

the shrinkage data. After 5 wear-laundering periods the shirts with minimum application finishing method (Type B) had less shrinkage (under 1.0 percent) in the length, chest, and sleeve than did the other finishing techniques. The Sanfor-Set, pad-dry-cure method (Type C) shirts had the greatest shrinkage in length (1.23 percent). The pad-dry-cure (Type D) shirts had the greatest shrinkage in the chest (1.53 percent) and sleeve (1.05 percent) of the four types.

The mean shrinkage after 25 wear-launderings was greatest for the shirts finished with the Sanfor-Set, minimum application (Type A) in length (2.3 percent), sleeve (1.74 percent), and collar (2.97 percent) but was lowest in chest shrinkage (0.51 percent). The minimum application finished shirts (Type B) were lowest in shrinkage for length and sleeve with less than 1.0 percent. The shirts finished with the pad-dry-cure method (Type D) shrank more in the chest (1.45 percent) than the other methods but were lowest in shrinkage of the collar with 2.01 percent.

The fabric squares had greater shrinkage in the filling direction at the 5 and 25 wear-laundering periods with one exception (Type A). The pad-dry-cure application (Type D) had the greatest shrinkage in the filling direction at both evaluation periods, although it had less shrinkage in the warp direction. After 25 wear-laundering periods Type D was tied for lowest shrinkage with Type B, with averages just under 1.5 percent.

Table 6 presents the results of two-way analysis of variance of shrinkage of the fabric squares after 5 and 25 wear-laundering periods. Warp and filling directions show a significant difference at the alpha=0.05 level with regard to laundry period; and in the warp direction, significant difference was found also between shirt types.

TABLE 6

TWO-WAY ANALYSIS OF VARIANCE OF SHRINKAGE OF THE FABRIC SQUARES AFTER 5 AND 25 LAUNDERING

Source of Variance	d.f.	Mean Squares	F-Ratio	Probability of F
Warp Direction				
Type	3	0.29	7.02*	0.01
Error	8	0.04		
Laundry	1	0.40	11.44*	0.01
Laundry-Type	3	0.03	0.81	0.52
Error	8	0.04		
Filling Direction				
Type	3	0.12	3.44	0.07
Error	8	0.03		
Laundry	1	0.04	14.29*	0.00
Laundry-Type	3	0.00	1.71	0.24
Error	8	0.00		

*Indicates significance at the $\alpha = 0.05$ level.

Table 7 records the results of analysis using Newman-Keuls' Comparisons of the marginal means of shrinkage of the fabrics after 5 and 25 wear-laundering periods in the warp direction. Fabric Type D (pad-dry-cure) had the least shrinkage followed by Type B (minimum application). There was no significant difference between the marginal means on shrinkage between Types D and B as each was less than 1.0 percent. Type A (Sanfor-Set, minimum application) and Type C (Sanfor-Set, pad-dry-cure) were similar in shrinkage with slightly over 1.0 percent shrinkage recorded.

TABLE 7

NEWMAN-KEULS' COMPARISONS OF THE MARGINAL MEANS OF SHRINKAGE OF FABRICS AFTER 5 AND 25 LAUNDERINGS IN THE WARP DIRECTION

	Fabric Type			
	D	B	A	C
Mean Value	0.92	0.98	1.28	1.37

Note: There was not a significant difference in the fabric types underlined by the same line.

Table 8 shows the results of two-way analysis of variance of shrinkage on the length, chest, sleeve, and collar of the shirts after 5 and 25 launderings. A significant difference was found at the alpha=0.05 level

TABLE 8

TWO-WAY ANALYSIS OF VARIANCE OF SHRINKAGE ON THE LENGTH, CHEST, SLEEVE, AND COLLAR OF THE SHIRTS AFTER 5 AND 25 LAUNDERINGS

Source of Variance	d.f.	Mean Square	F-Ratio	Probability of F
Length				
Type	3	1.13	2.29	0.16
Error	8	0.49		
Laundry	1	1.79	15.14*	0.00
Laundry-Type	3	0.29	2.44	0.14
Error	8	0.12		
Chest				
Type	3	1.17	1.55	0.28
Error	8	0.76		
Laundry	1	0.05	0.66	0.44
Laundry-Type	3	0.24	3.08	0.09
Sleeve				
Type	3	0.68	3.43	0.07
Error	8	0.20		
Laundry	1	1.81	20.41*	0.00
Laundry-Type	3	0.06	0.67	0.60
Error	8	0.09		
Collar				
Type	3	0.32	1.60	0.26
Error	8	0.20		
Laundry	1	5.89	161.22*	0.00
Laundry-Type	3	0.19	5.13	0.03
Error	8	0.04		

*Indicates significance at the $\alpha = 0.05$ level.

for length, sleeve, and collar with regard to laundry period only.

Figure 2 depicts the percentage of shrinkage on the four areas of the shirts as well as fabric shrinkage by yarn direction. It is interesting to note the relationship between warp shrinkage of the fabrics and warp measurements of the shirts (length, sleeve, and collar). In both instances the two Sanfor-Set fabrics (Types A and C) were greatest in shrinkage after 25 wear-launderings. In the filling direction, the chest shrinkage by fabric type was related to fabric shrinkage as Types D, C, B, and A were in the same order.

Although shrinkage was not a problem with the shirts or fabrics, the greatest shrinkage was found in the collars of the shirts. A factor could be the interfacing used in the collars.

Breaking Strength

The breaking strengths of 20 shirts of each of the four types were calculated after 25 wear-laundering periods. Results from these determinations are recorded in Tables 9 through 11 and in Figure 3.

Means and standard deviations of breaking strength values of the shirts after 25 wear-laundering periods are shown in Table 9, while the means are depicted in Figure 3. The shirts finished with the Sanfor-Set, minimum application (Type A) had the highest breaking strength values in the warp direction with 39.1 pounds recorded. Type D (pad-dry-cure) was second strongest with 38.8 pounds, Type C (Sanfor-Set, pad-dry-cure) ranked third with 36.8 pounds, and Type B (minimum application) shirts were fourth with 34.8 pounds.

TABLE 9

MEANS AND STANDARD DEVIATIONS OF BREAKING STRENGTH VALUES OF BLUE SHIRTS AFTER 25 WEAR-LAUNDERING PERIODS IN THE WARP AND FILLING DIRECTIONS (VALUES IN POUNDS)

Shirt Type	Mean Values	Standard Deviations
WARP DIRECTION		
Sanfor-Set, Minimum Application	39.1	2.21
Minimum Application	34.8	5.13
Sanfor-Set, Pad-Dry-Cure	36.8	2.52
Pad-Dry-Cure	38.8	4.79
FILLING DIRECTION		
Sanfor-Set, Minimum Application	18.8	1.37
Minimum Application	17.5	2.27
Sanfor-Set, Pad-Dry-Cure	19.8	2.00
Pad-Dry-Cure	21.7	1.90

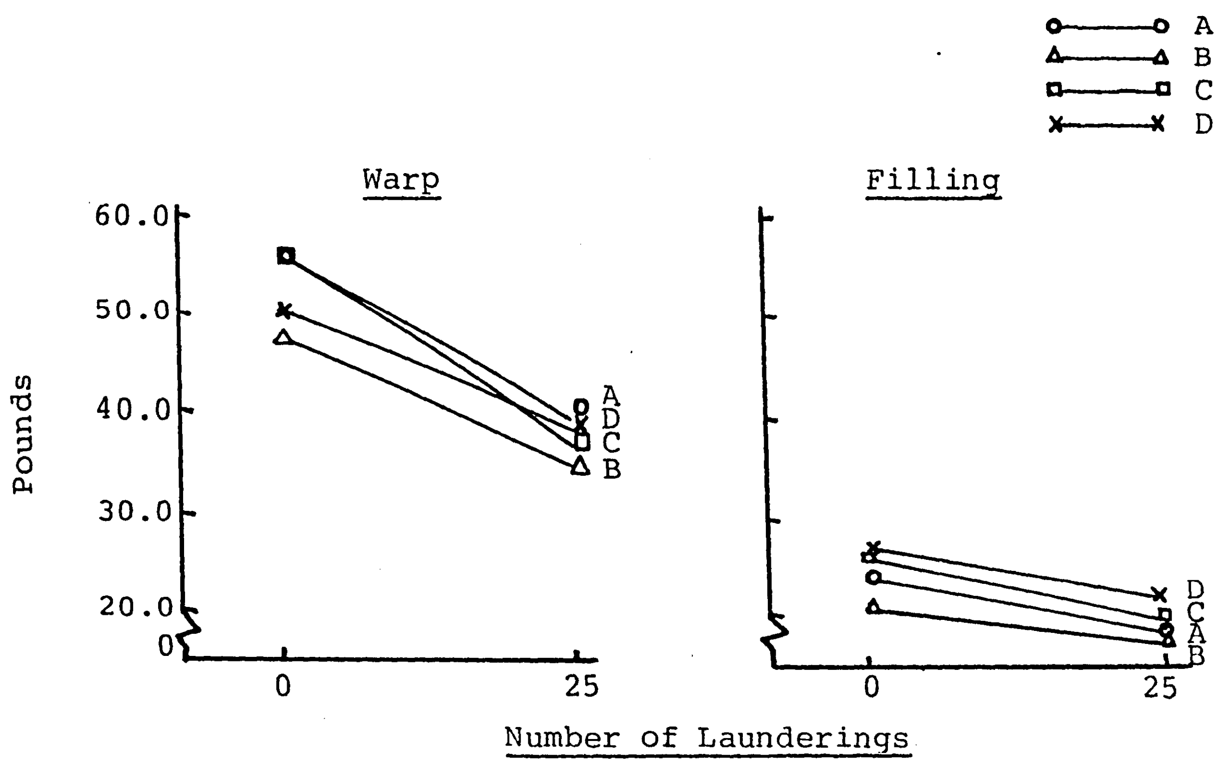

Fig. 3. Mean breaking strength values of blue shirts after 25 wear-laundering periods in the warp and filling directions.

In the filling direction, Type D shirts had the highest breaking strength (21.7 pounds). Type C was second strongest (19.8 pounds), Type A was third (18.8 pounds) and Type B had the lowest breaking strength (17.5 pounds). The breaking strengths of all four shirt types were higher in the warp direction than in the filling, as expected.

When an analysis of variance was applied to the data, the results, shown in Table 10, indicated that significant differences were present between the shirt groups (types).

TABLE 10

ONE-WAY ANALYSIS OF VARIANCE OF BREAKING STRENGTH VALUES OF BLUE SHIRTS AFTER 25 WEAR-LAUNDERING PERIODS IN THE WARP AND FILLING DIRECTIONS

Source of Variance	d.f.	Mean Squares	F-Ratio	Probability of F
Warp Direction				
Between Groups	3	76.01	5.06*	0.00
Within Groups	73	15.01		
Total	76			
Filling Direction				
Between Groups	3	59.43	16.18*	0.00
Within Groups	76	3.67		
Total	79			

*Indicates significance at the $\alpha = 0.05$ level.

These differences existed between the groups both in the warp and filling directions after 25 wear-launderings.

Table 11 presents the Newman-Keuls' Comparisons of the breaking strength values.

TABLE 11

NEWMAN-KEULS' COMPARISONS OF BREAKING STRENGTH VALUES OF BLUE SHIRTS AFTER 25 WEAR-LAUNDERING PERIODS IN THE WARP AND FILLING DIRECTIONS

	Shirt Type			
	A	D	C	B
Warp Direction				
Mean Value	39.1	38.8	36.8	34.8
	D	C	A	B
Filling Direction				
Mean Value	21.7	19.8	18.8	17.5

Note: There was not a significant difference in the shirt types underlined by the same line.

The shirt types are also ranked in order of breaking strength values. There was no significant difference in the breaking strength values, in the warp direction, between shirt Type A, Type D, or Type C. Also, no significant difference existed between Type C and B. In the filling direction, there was no significant difference between shirt Types C and A, but significant differences did exist in the breaking strength of the other shirt types. Shirt Type A had the highest breaking strength in the warp direction and Type D had the highest breaking strength in the filling direction. In both yarn directions, Type B had the lowest breaking strength.

Tearing Strength

Tearing strength determinations for the blue shirt were calculated initially and after 25 wear-laundering cycles. Data which were obtained from an analysis of the tearing strength are recorded in Tables 12 through 14, and depicted in Figure 4.

The means and standard deviations of tearing strength values of the blue shirts are recorded in Table 12. The mean tearing strength values for Type C (Sanfor-Set, pad-dry-cure) shirts were highest both in the warp (1.85 pounds) and filling (1.32 pounds) directions. In the warp direction, Type D (pad-dry-cure) was second strongest (1.79 pounds) with Type A (Sanfor-set, minimum application) third (1.69 pounds) and last was Type B (minimum application) (1.54 pounds). Therefore, those shirts finished with the pad-dry-cure finishing application method were stronger in warp tearing strength than those finished with minimum

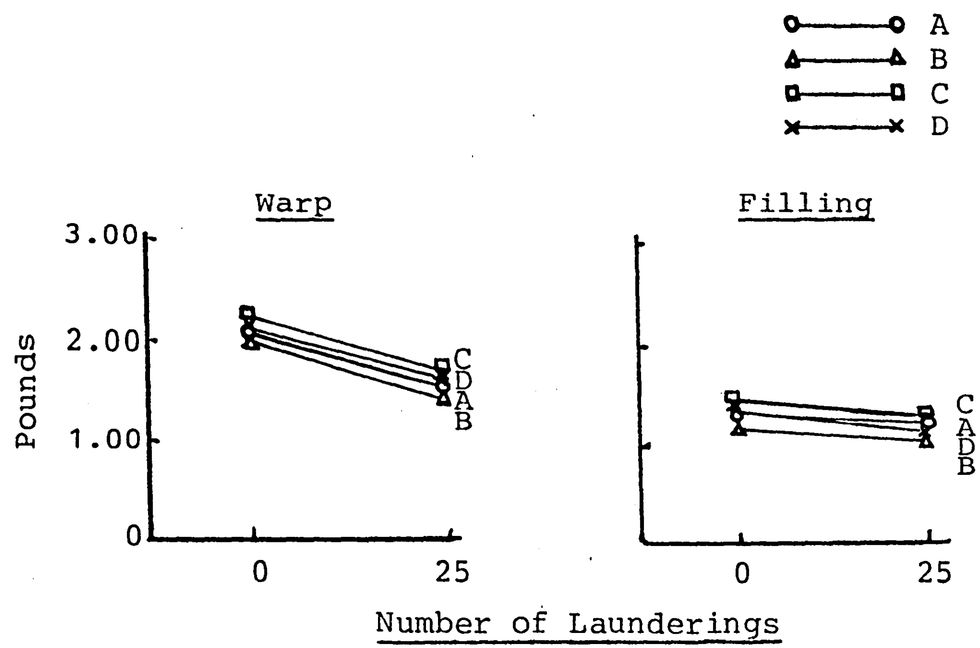

Fig. 4. Mean tearing strength values of blue shirts after 25 wear-laundering periods in the warp and filling directions

application. In the filling direction those shirts finished with Sanfor-Set were stronger.

TABLE 12

MEANS AND STANDARD DEVIATIONS OF TEARING STRENGTH VALUES OF BLUE SHIRTS AFTER 25 WEAR-LAUNDERING PERIODS IN THE WARP AND FILLING DIRECTIONS

Shirt Type	Mean Values	Standard Deviations
Warp Direction		
A Sanfor-Set, Minimum Application	1.69	0.16
B Minimum Application	1.54	0.16
C Sanfor-Set, Pad-Dry-Cure	1.85	0.21
D Pad-Dry-Cure	1.79	0.15
Filling Direction		
Sanfor-Set, Minimum Application	1.23	0.07
Minimum Application	1.05	0.11
Sanfor-Set, Pad-Dry-Cure	1.32	0.09
Pad-Dry-Cure	1.15	0.08

Table 13 shows that there was a significant difference at the 0.05 level in tearing strength values between groups (types) both in the warp and filling directions.

The results of Newman-Keuls' Comparisons of tearing strength values of the blue shirts after 25 wear-laundering periods in the warp and filling directions are shown in Table 14. The Newman-Keuls' data identify the various shirt types and their ranking in tearing strength both

TABLE 13

ONE-WAY ANALYSIS OF VARIANCE OF TEARING STRENGTH VALUES OF BLUE SHIRTS AFTER 25 WEAR-LAUNDERING PERIODS IN THE WARP AND FILLING DIRECTIONS

Source of Variance	d.f.	Mean Square	F-Ratio	Probability of F
Warp Direction				
Between Groups	3	0.36	11.86*	0.00
Within Groups	73	0.03		
Total	76			
Filling Direction				
Between Groups	3	0.26	32.35*	0.00
Within Groups	73	0.01		
Total	76			

*Indicates significance at the $\alpha = 0.05$ level.

TABLE 14

NEWMAN-KEULS' COMPARISONS OF TEARING STRENGTH VALUES OF BLUE SHIRTS AFTER 25 WEAR-LAUNDERING PERIODS IN THE WARP AND FILLING DIRECTIONS

	Shirt Type			
Warp Direction	C	D	A	B
Mean Values	1.85	1.79	1.69	1.54
Filling Direction	C	A	D	B
Mean Values	1.32	1.23	1.15	1.05

Note: There was not a significant difference in the shirt types underlined by the same line.

in warp and filling directions. Those underlined were not significantly different from the other types. In the warp direction, shirt Type C tearing strength was not significantly different from Type D, but was significantly different from Types A and B. Shirt Type D was not significantly different from Types C or A, but was different from Type B. In the filling direction, each shirt type was found to be significantly different from the other types, with tearing strengths ranging from 1.32-1.05 pounds.

Abrasion Resistance

Abrasion resistance was determined by the Accelerated Method by determining the fabric weight before and after abrasion--with abrasion expressed in percentage of fabric loss. The results of the statistical analysis of the data, such as the mean and standard deviations, one-way analysis of variance and Newman-Keuls' comparisons of the percentage of weight loss due to abrasion, are presented in Tables 15 through 17.

A summary of the means and standard deviations of the percentage of fabric loss due to abrasion of the blue shirts after 25 wear-laundering periods is shown in Table 15. Type A, the Sanfor-Set, minimum application method of finishing, experienced the lowest percentage of fabric loss (12.1 percent) due to abrasion. The finishing method with the greatest amount of fabric loss due to abrasion was Type D, pad-dry-cure with 19.4 percent. Type B (minimum application) and Type C (Sanfor-Set, pad-dry-cure) fell between the two with 16.5 percent and 14.4 percent, respectively. A graphic presentation of the means is shown in Figure 5.

TABLE 15

MEAN AND STANDARD DEVIATIONS OF PERCENT OF FABRIC LOSS DUE TO ABRASION ON THE BLUE SHIRTS AFTER 25 WEAR-LAUNDERING PERIODS

Shirt Type	Mean Values	Standard Deviations
Sanfor-Set, Minimum Application	12.1	2.37
Minimum Application	16.5	1.47
Sanfor-Set, Pad-Dry-Cure	14.4	2.13
Pad-Dry-Cure	19.4	2.03

Table 16 shows the results of a one-way analysis of variance of the percentage of weight loss due to abrasion on the blue shirts after 25 wear-laundering periods. A significant difference existed between the shirt types at the 0.05 alpha level.

The results of the Newman-Keuls' comparisons of the percentage of weight loss due to abrasion on the blue shirts after 25 wear-laundering periods are shown in Table 17.

TABLE 16

ONE-WAY ANALYSIS OF VARIANCE OF PERCENT OF WEIGHT LOSS DUE TO ABRASION ON THE BLUE SHIRTS AFTER 25 WEAR-LAUNDERING PERIODS

Source of Variance	d.f.	Mean Square	F-Ratio	Probability of F
Between Groups	3	187.14	45.47*	0.00
Within Groups	73	4.12		
Total	76			

*Indicates significance at the $\alpha = 0.05$ level.

TABLE 17

NEWMAN-KEULS' COMPARISONS OF PERCENT OF WEIGHT LOSS DUE TO ABRASION ON THE BLUE SHIRTS AFTER 25 WEAR-LAUNDERING PERIODS

	Shirt Type			
	A	C	B	D
Mean Values	12.1	14.4	16.5	19.4

Note: There was not a significant difference between the shirt types underlined by the same line.

Shirt Type A was ranked first, followed by Type C, Type B, and Type D. A significant difference existed between the four shirt types with regard to percentage of weight loss due to abrasion, as evidenced by the absence of lines underscoring the means.

Figure 5 pictures the percentage of fabric loss due to abrasion by fabric type. Types A and C, with the Sanfor-Set finish, exhibited the best abrasion resistance. The role of minimum application or pad-dry-cure finishing was not as apparent as the role of Sanfor-Set with regard to the cotton shirts' abrasion resistance.

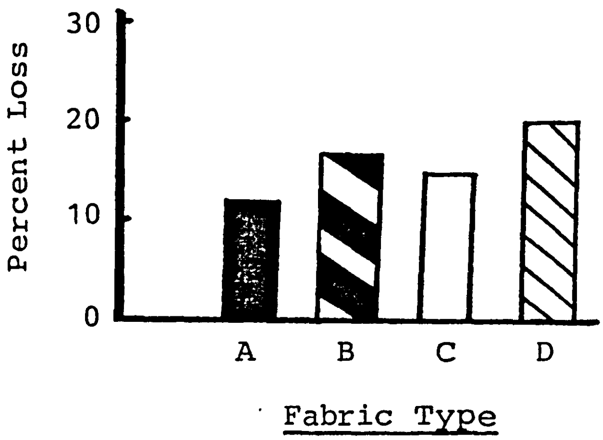

Fig. 5. Means of percentage of fabric loss due to abrasion on the blue shirts after 25 wear-laundering periods.

Color Evaluation

Evaluations with regard to color were determined on the four experimental shirt types. The color differences were measured by comparing initial color readings with color readings following 25 wear-launderings. The Hunterlab Color Difference Meter was used to determine color loss due to repeated wearings and launderings.

Means and standard deviations of the color differences on the blue shirts after 25 wear-laundering periods are shown in Table 18.

TABLE 18

MEANS AND STANDARD DEVIATIONS OF COLOR DIFFERENCE (DELTA E) ON THE BLUE SHIRTS AFTER 25 WEAR-LAUNDERING PERIODS

Shirt Type	Mean Values	Standard Deviations
Sanfor-Set, Minimum Application	1.2328	0.2644
Minimum Application	1.6633	0.4161
Sanfor-Set, Pad-Dry-Cure	1.4537	0.4858
Pad-Dry-Cure	2.2849	0.6650

No. 1 is the highest ranking.

The shirt type with the lowest color loss was Type A (Sanfor-Set, minimum application), followed by Type C Sanfor-Set, pad-dry-cure) and Type B (minimum application). Shirt Type D, or the pad-dry-cure finishing application method had the greatest color loss. These results are graphically depicted in Figure 6 which shows the color difference values of the four fabrics with number 1 representing the best score, or the least amount of color difference following 25 wearings and launderings.

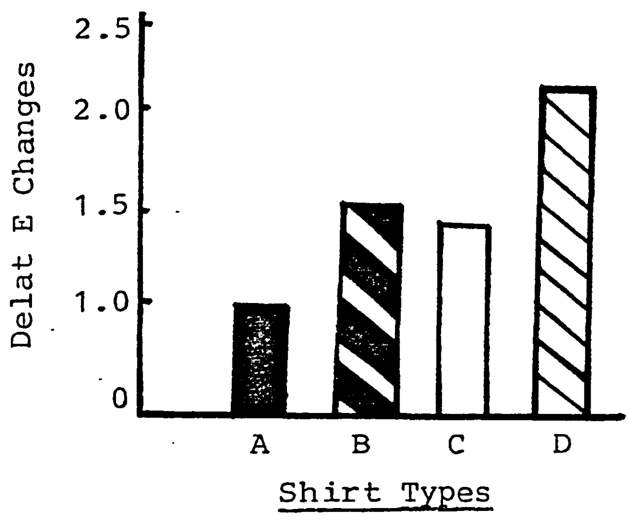

Fig. 6. Means of color difference (Delta E) on the blue shirts after 25 wear-laundering periods.

Table 19 shows the results of a one-way analysis of variance of color difference after 25 wear-laundering periods. At the alpha=0.05 level there was a significant difference between the fabric types due to wearing and laundering.

TABLE 19

ONE-WAY ANALYSIS OF COLOR DIFFERENCE (DELTA E) OF THE BLUE SHIRTS AFTER 25 WEAR-LAUNDERING PERIODS

Source of Variance	d.f.	Mean Square	F-Ratio	Probability of F
Between Groups	3	1.2313	5.34*	0.01
Within Groups	20	0.2303		
Total	23			

*Indicates significance at the $\alpha = 0.05$ level.

Newman-Keuls' comparisons of color difference of the experimental shirts after 25 wear-laundering periods are shown in Table 20.

TABLE 20

NEWMAN-KEULS' COMPARISONS OF COLOR DIFFERENCE (DELTA E) OF THE BLUE SHIRTS AFTER 25 WEAR-LAUNDERING PERIODS

	Shirt Type			
	A	C	B	D
Mean Values	1.2328	1.4537	1.6633	2.2849

Note: There was no significant difference between the shirt types underlined by the same line.

The rankings of the four fabric types shows Type A and C, the two Sanfor-set finished fabrics, as experiencing the least color loss. This analysis also shows there was no significant difference between shirt Types A, B, and C, but there was a significant difference between the color loss of these three types and Type D.

Broken Yarns

Wear failure, defined as broken yarns observed on the collar, cuffs and placket, was recorded initially and after 15, 20, and 25 wear-launderings. Broken yarns were observed by placing each shirt on a dark table and examining with a 4" diameter magnifying glass and a mounted magnifying lens attached to a high intensity light. The location and the number of broken warp and filling yarns were recorded on drawings of each shirt. Special attention was given to the collar, cuffs, and placket. Pens with different colored ink were used to identify the broken yarns found at the various evaluation periods.

Data which resulted from these evaluations are recorded in Tables 21 through 27. A graphic illustration of the means of broken yarns of the eighty blue shirts observed at 0, 15, 20, and 25 wear-launderings in both warp and filling directions are shown in Figure 7.

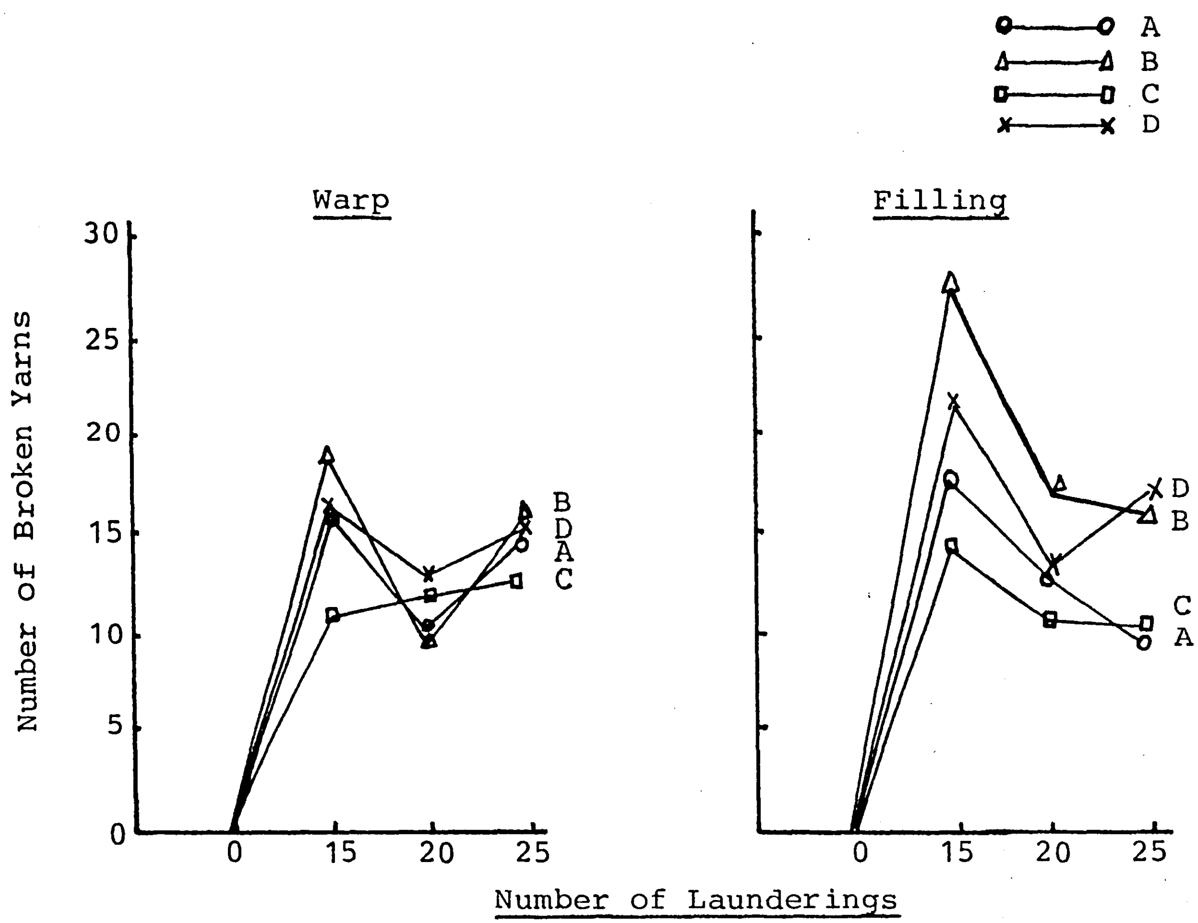

Fig. 7. Mean number of broken yarns of the blue shirts at 0, 15, 20, and 25 wear-launderings in the warp and filling directions.

Means and standard deviations of broken yarns of the blue shirts initially and after 15, 20, and 25 wear-laundering periods are shown in Table 21. The results are shown by yarn direction and as grand totals. The Sanfor-Set, pad-dry-cure (Type C) finished shirts had the lowest number of broken yarns (72.9), and Type B (minimum application) experienced the greatest number of broken yarns with 111.2. Type A (Sanfor-Set minimum application) had 84.4 broken yarns counted on the 20 shirts, while the shirts with the pad-dry-cure finish, Type D, had 101.6 broken yarns. Most of the broken yarns occurred at the collar points, cuff edges, and bottom corner of the placket, probably attributed to abrasion at these areas.

Table 22, one-way analysis of variance, shows significant differences were found at the 0.05 level, between the four fabric types in the filling direction. The Newman-Keuls' comparison test was used to rank the filling data and determine which fabric types were significantly different. Table 23 shows these data as well as ranking of fabric types when warp and filling yarns were totaled. The two Sanfor-Set fabrics, Types C and A, were ranked #1 and #2, respectively, as they had the fewest broken yarns. The pad-dry-cure (Type D) was third while minimum application (Type B) had the most broken yarns.

TABLE 21

MEANS AND STANDARD DEVIATIONS OF BROKEN YARNS OF THE BLUE SHIRTS INITIALLY AND AFTER 15, 20, AND 25 WEAR-LAUNDERING PERIODS

Shirt Type	Warp Direction				
	Number of Launderings				
	0	15	20	25	Total
MEAN VALUES					
Sanfor-Set, Minimum Application	0.5	16.0	10.4	14.8	41.7
Minimum Application	1.2	19.2	9.8	16.2	46.3
Sanfor-Set, Pad-Dry-Cure	0.2	11.0	12.1	12.7	36.0
Pad-Dry-Cure	1.3	16.2	13.2	15.8	46.6
STANDARD DEVIATIONS					
Sanfor-Set, Minimum Application	1.15	8.38	4.64	11.99	15.71
Minimum Application	3.12	8.94	5.15	94.9	12.55
Sandor-Set, Pad-Dry-Cure	0.70	4.86	8.88	9.68	14.69
Pad-Dry-Cure	2.39	7.28	5.29	10.61	12.68

Shirt Type	Filling Direction				
	Number of Launderings				
	0	15	20	25	Total
MEAN VALUES					
Sanfor-Set, Minimum Application	1.0	17.8	13.2	10.0	42.0
Minimum Application	1.4	28.2	17.4	16.8	63.8
Sanfor-Set, Pad-Dry-Cure	0.4	14.4	11.3	10.8	36.9
Pad-Dry-Cure	1.4	21.5	14.2	17.9	55.0
STANDARD DEVIATIONS					
Sanfor-Set, Minimum Application	1.98	9.06	10.10	8.81	18.44
Minimum Application	2.95	15.71	14.62	11.70	27.00
Sanfor-Set, Pad-Dry-Cure	1.18	6.84	10.03	11.12	15.41
Pad-Dry-Cure	2.41	7.81	9.33	11.77	22.90

Average Broken Yarns Per Shirt Type

Shirt Type	Mean Values	Standard Deviations
Sanfor-Set, Minimum Application	84.4	30.42
Minimum Application	111.2	34.78
Sanfor-Set, Pad-Dry-Cure	72.9	28.66
Pad-Dry-Cure	101.6	32.10

TABLE 22

ONE-WAY ANALYSIS OF VARIANCE OF TOTAL NUMBER OF BROKEN YARNS ON THE BLUE SHIRTS AFTER 25 WEAR-LAUNDERING PERIODS (WARP AND FILLING)

Source of Variance	d.f.	Mean Square	F-Ratio	Probability of F
WARP DIRECTION				
Between Groups	3	491.05	2.52	0.06
Within Groups	76	195.28		
Total	79			
FILLING DIRECTION				
Between Groups	3	3005.35	6.56*	0.00
Within Groups	76	457.78		
Total	79			
TOTAL OF WARP AND FILLING				
Between Groups	3	5882.43	5.90*	0.00
Within Groups	76	996.88		
Total	79			

*Indicates significance at the $\alpha = 0.05$ level.

TABLE 23

NEWMAN KEULS' COMPARISONS OF TOTAL NUMBER OF BROKEN YARNS ON THE BLUE SHIRTS AFTER 25 WEAR-LAUNDERING PERIODS (FILLING AND/OR WARP)

	Shirt Type			
	C	A	D	B
Filling Direction				
Mean Value	36.9	42.0	55.0	63.8
Total of Warp and Filling				
Mean Value	72.9	84.4	101.6	111.2

Note: There was not a significant difference between the shirt types underlined by the same line. There was no significant difference in the warp direction.

The data summarized in Table 24, two-way analysis of variance, show the greatest significant differences occurred between initial and 15 wear-laundering evaluation period, with significant differences also occurring between the four fabric types and between type and laundering period. After 20 launderings a significant difference did not exist between fabric types. At the end of the study (25 launderings) only the laundering periods contributed to significant differences in broken yarns. A follow-up with the Newman-Keuls' test (Table 25) ranks the fabric types.

TABLE 24

TWO-WAY ANALYSIS OF VARIANCE OF BROKEN YARNS ON THE BLUE SHIRTS INITIALLY AND AFTER 15, 20, AND 25 WEAR-LAUNDERING PERIODS (IN THE WARP DIRECTION)

Source of Variance	d.f.	Mean Square	F-Ratio	Probability of F
Initially and 15 Launderings				
Type	3	146.40	4.84*	0.00
Error	76	30.27		
Laundry	1	8791.22	285.89*	0.00
Laundry-Type	3	90.24	2.93*	0.04
Error	76	30.75		
15 and 20 Launderings				
Type	3	85.22	2.26	0.09
Error	76	37.69		
Laundry	1	714.02	12.36*	0.00
Laundry-Type	3	196.38	3.40*	0.02
Error	76	57.77		
20 and 25 Launderings				
Type	3	36.19	0.50	0.68
Error	76	72.21		
Laundry	1	479.56	6.26*	0.01
Laundry-Type	3	62.49	0.82	0.49
Error	76	76.54		

*Indicates significance at the $\alpha = 0.05$ level.

Significant differences were found after 15 launderings only. The rank order is identical to Table 23 but with fewer significant differences.

TABLE 25

NEWMAN KEULS' COMPARISONS OF THE MARGINAL MEANS OF BROKEN YARNS ON THE BLUE SHIRTS INITIALLY AND AFTER 15, 20, AND 25 WEAR-LAUNDERING PERIODS (IN THE WARP DIRECTION)

	Shirt Type			
	C	A	D	B
Between 0 and 15 Launderings				
Mean Values	5.60	8.25	8.78	10.18

Note: There was not a significant difference between the shirt types underlined by the same line.
There was no significant difference between the 15 and 20 or the 20 and 25 wear-laundering periods.

Table 26 reports the results of a two-way analysis of variance of broken yarns on the blue shirts initially and after 15, 20, and 25 wear-laundering periods in the filling direction. A significant difference was found at the $\alpha = 0.05$ level between shirts, laundry periods, and laundry period/shirt type after 15 wear-launderings. The 15 and 20 laundering interval shows significance with regard to shirt types and laundry period. No significant difference was found between the 20 and 25 laundering periods with regard to any of the variables.

TABLE 26

TWO-WAY ANALYSIS OF VARIANCE OF BROKEN YARNS ON THE BLUE SHIRTS INITIALLY AND AFTER 15, 20, and 25 WEAR-LAUNDERING PERIODS (IN THE FILLING DIRECTION)

Source of Variance	d.f.	Mean Square	F-Ratio	Probability of F
<u>Initially and 15 Launderings</u>				
Type	3	401.41	6.38*	0.00
Error	76	62.88		
Laundry	1	15073.81	294.12*	0.00
Laundry-Type	3	297.21	5.80*	0.00
Error	76	51.25		
<u>15 and 20 Launderings</u>				
Type	3	706.35	5.50*	0.00
Error	76	128.37		
Laundry	1	1651.22	15.47*	0.00
Laundry-Type	3	114.64	1.07	0.36
Error	76	106.71		
<u>20 and 25 Launderings</u>				
Type	3	376.71	2.44	0.07
Error	76	154.20		
Laundry	1	0.90	0.01	0.92
Laundry-Type	3	80.98	0.89	0.45
Error	76	90.87		

*Indicates significance at the $\alpha = 0.05$ level.

Newman-Keuls' comparisons of the marginal means of the broken yarns counted in the filling direction are seen in Table 27. No significant differences occurred between the 20th and 25th wear-laundering periods. The shirts were ranked in identical order, Types C, A, D, and B, as ranked in Table 25 for warp direction data.

TABLE 27

NEWMAN KEULS' COMPARISONS OF THE MARGINAL MEANS OF BROKEN YARNS ON THE BLUE SHIRTS INITIALLY AND AFTER 15, 20, AND 25 WEAR-LAUNDERING PERIODS (IN THE FILLING DIRECTION)

	Shirt Type			
	C	A	D	B
Between 0 and 15 Launderings				
Mean Value	7.38	9.40	11.45	14.80
Between 15 and 20 Launderings				
Mean Value	12.85	15.52	17.88	22.75

Note: There was not a significant difference between the shirt types underlined by the same line.
There was no significant difference between the 20 and 25 wear-laundering periods.

An observation of Figure 7 emphasizes the findings of the greatest number of broken yarns after 15 wearings and launderings of the shirts. It is noted, however, that wear failure was not a problem during the study as the largest mean number of broken yarns was only 111.2--an average counted on 20 shirts which had been worn and laundered 25 times.

Panel Evaluation

The appearance of the experimental shirts was evaluated by a panel of three observers. Six shirts of each of the four fabric types were evaluated at the conclusion of the 25 wear-laundering periods with regard to hand (crispness, smoothness, and softness) and appearance (color, wrinkle recovery, cuffs, collar, and placket). The results of these observations are presented in Tables 28 and 29.

During the evaluation process, those shirt types receiving a number 5 rating were considered "excellent"; no shirts were rated lower than a 3--"satisfactory." Rank 4 was "good" appearance.

The mean values and standard deviations of the panel's evaluation of hand are presented in Table 28. The table shows the initial evaluations as well as those following 25 wear-launderings. The evaluations were only slightly different in the ratings of the crispness or smoothness of the four shirt types with softness receiving a slightly wider range. In general, the evaluation of hand was rated between 3 (satisfactory) and 4 (good). When the three areas of crispness, softness, and smoothness, were averaged by

TABLE 28

MEANS AND STANDARD DEVIATIONS OF PANEL EVALUATIONS OF HAND OF THE BLUE SHIRTS INITIALLY AND AFTER 25 WEAR-LAUNDERING PERIODS

Shirt Type	Means		Standard Deviations	
	Number of Launderings			
	0	25	0	25
Crispness				
Sanfor-Set, Minimum Application	4.1	3.9	0.17	0.17
Minimum Application	4.0	4.1	0.70	0.17
Sanfor-Set, Pad-Dry-Cure	3.8	3.9	0.50	0.72
Pad-Dry-Cure	4.4	3.8	0.23	0.17
Softness				
Sanfor-Set, Minimum Application	3.5	4.2	0.40	0.17
Minimum Application	3.6	3.8	0.51	0.50
Sanfor-Set, Pad-Dry-Cure	4.1	3.8	0.17	0.17
Pad-Dry-Cure	3.8	3.3	0.40	0.35
Smoothness				
Sanfor-Set, Minimum Application	3.9	4.1	0.17	0.17
Minimum Application	4.1	3.9	0.51	0.35
Sanfor-Set, Pad-Dry-Cure	3.9	3.8	0.35	0.50
Pad-Dry-Cure	3.7	3.9	0.85	0.72

No. 5 = highest ranking

Averages of the three areas
evaluated by fabric type:

Type A - 4.06
Type B - 3.93
Type c - 3.83
Type D - 3.66

fabric type, shirt Type A (Sanfor-Set, minimum application) received the highest ranking with a 4.06. Shirt Type B (minimum application) followed, but dropped to a 3.93. The lowest rating was Type D with a 3.66 average.

Table 29 identifies the means and standard deviations of the panel evaluations with regard to appearance. Panel evaluations of color, wrinkle recovery, cuffs, collar, and placket are summarized in the table. The appearance ratings were not as high after laundering as the hand ratings, as none were rated a 4 (good), while some appearance ratings were as low as 2 (poor). When the five appearance areas were averaged all fabric types received a "satisfactory" rating except Type D (pad-dry-cure), which received a 2.96 or "poor" rating. The best-rated fabric type was Type B with a 3.30, followed by Type A and Type C, respectively.

Significant differences were not determined because ratings were so similar. Since all the shirts were 100 percent cotton these similarities could be expected. The two shirt types with minimum application finishing were rated higher in appearance and hand than the two types finished with the pad-dry-cure method. The major differences in appearance occurred between laundering periods of the

TABLE 29

MEANS AND STANDARD DEVIATIONS OF PANEL EVALUATIONS OF APPEARANCE OF THE BLUE SHIRTS INITIALLY AND AFTER 25 WEAR-LAUNDERING PERIODS

Shirt Type	Means		Standard Deviations	
	Number of Launderings			
	0	25	0	25
Color				
Sanfor-Set, Minimum Application	4.3	2.9	0.35	0.35
Minimum Application	4.4	3.1	0.23	0.35
Sanfor-Set, Pad-Dry-Cure	3.1	2.3	0.17	0.00
Pad-Dry-Cure	3.7	2.3	0.58	0.00
Wrinkle Recovery				
Sanfor-Set, Minimum Application	3.9	3.4	0.35	0.23
Minimum Application	3.5	3.3	0.40	0.35
Sanfor-Set, Pad-Dry-Cure	3.7	3.4	0.00	0.23
Pad-Dry-Cure	4.0	2.8	0.00	0.50
Cuffs				
Sanfor-Set, Minimum Application	4.4	3.0	0.23	0.30
Minimum Application	4.6	3.2	0.23	0.40
Sanfor-Set, Pad-Dry-Cure	4.3	3.6	0.35	0.80
Pad-Dry-Cure	4.4	3.1	0.23	0.35
Collar				
Sanfor-Set, Minimum Application	4.3	3.1	0.58	0.35
Minimum Application	4.3	3.2	0.35	0.17
Sanfor-Set, Pad-Dry-Cure	4.3	3.1	0.35	p.35
Pad-Dry-Cure	4.6	3.1	0.23	0.17
Placket				
Sanfor-Set, Minimum Application	3.9	3.6	0.51	0.51
Minimum Application	4.2	3.7	0.17	0.35
Sanfor-Set, Pad-Dry-Cure	4.3	3.5	0.35	0.68
Pad-Dry-Cure	4.2	3.5	0.17	0.40

Averages of the five areas evaluated by fabric type:

Type A - 3.20
Type B - 3.30
Type C - 3.18
Type D - 2.96

shirts and not between the fabric types. The lowest rating was recorded for color evaluations, while the best rating was reported for appearance of the placket after 25 wear-launderings.

CHAPTER V

SUMMARY

The study was concerned with a comparative evaluation of 80 men's light blue broadcloth dress shirts of 100 percent cotton finished by four different application methods.

The four finishing techniques were coded as follows:

Type A - Sanfor-Set, minimum application
Type B - Minimum application
Type C - Sanfor-Set, pad-dry-cure
Type D - Pad-dry-cure

Twenty shirts of each of four finishing techniques were used. The overall objective of the study was to evaluate the wear life performance of the various finishing techniques through 25 wear-laundering periods.

The shirts were worn by a panel of 20 male white-collar workers employed at the Texas Woman's University. Each subject was assigned four shirts--one of each of the four types.

During the course of the study the shirts were evaluated with regard to parameters considered important to the consumer. At various intervals of wearing and laundering, the shirts were evaluated with respect to their appearance, shrinkage, and wear failure (number of broken yarns).

Initially and after 25 wear-laundering periods the shirts were evaluated with regard to tensile strength, tearing strength, abrasion resistance, color evaluation, and panel evaluation of hand and appearance.

A summary relative to the findings of the study follows.

Durable press appearance values, obtained at each evaluation interval, were found to be similar for the four shirt types. Since all of the shirts were 100 percent cotton the similarities were expected. The two shirt types finished with the minimum application method (Types A and B) rated better than those finished by the pad-dry-cure method (Types C and D), although not significantly better. The marginal means ranged from 2.85 to 2.62, with 5.0 representing the smoothest appearance. The shirt backs were rated smoothest of the three areas evaluated, followed by side seams and plackets, respectively.

Shrinkage percentages were determined on three shirts of each of the four types by measurements taken on the chest, sleeve, collar, and back length of the shirts after five and 25 wear-launderings. Significant differences were found in shrinkage, except in the chest measurements, between laundering periods rather than fabric types. Shrinkage of the shirts was minimal as percentages averaged less than 2.0 percent after 25 launderings. The shrinkage of fabric squares of each fabric type averaged just under 1.5 percent each direction when warp and filling measurements were averaged. The two Sanfor-Set finished fabrics (Types A and C) had greater shrinkage after 25 launderings than the fabrics without Sanfor-Set (Types B and D).

An analysis of breaking strength values found all four fabric types to lose strength in the warp and filling directions after 25 wear-launderings, with the greatest strength loss in the warp direction. Warp strengths ranged from 34.8 to 29.1 pounds, while in the filling, strengths ranged from 17.5 to 21.7 pounds. In both instances, Type B (minimum application) was lowest in breaking strength values.

A comparison of the four fabric types concerning tearing strength found Type C (Sanfor-Set, pad-dry-cure) was ranked highest in both directions with Type B (minimum application) significantly lower than the other three fabrics. Tearing strength values ranged from 1.54 to 1.85 pounds in the warp direction with filling strength ranging from 1.05 to 1.32 pounds after the shirts were subjected to 25 wear-launderings.

Abrasion resistance was determined by calculating the percentage of fabric loss by weighing fabrics of each shirt type before and after abrasion. A significant difference was found between the four shirt types after 25 wear-laundering periods. Type A (Sanfor-Set, minimum application) had the best resistance to abrasion with a 12.1 percent fabric loss, followed by Type C with a 14.4 percent, Type B having a 16.5 percent loss, and Type D with the poorest score of 19.4 percent. The Sanfor-Set finished fabrics exhibited the best abrasion resistance, significantly so at the 0.05 level.

Color loss, due to repeated wearings and launderings, was determined by comparing original color readings with color values at the end of the study. Types A and C, Sanfor-Set finished fabrics, experienced the least color loss. Type B was third best in color retention with Type D significantly lower than the other three fabrics. Color loss was not considered a problem as values ranged from 1.2328 to 2.2849 with Delta E number 1 representing the best score.

Wear failure, the number of broken yarns observed on selected areas of the shirts, was recorded initially and following 15, 20, and 25 wear-launderings. The greatest number of broken yarns occurred after 15 launderings. The Sanfor-Set finished fabrics had the fewest number of broken yarns with a total of 72.8 for Type C and 84.4 yarns counted in Type A. The pad-dry-cure finished shirts (Type D) averaged 101.6 and minimum application (Type B) shirts had an average of 111.2 broken yarns.

A panel of three observers evaluated six shirts of each of the four fabric types with regard to hand (crispness, softness, and smoothness) and appearance (color retention, wrinkle resistance, cuffs, collar, and placket). The panel rated the minimum application finished fabrics (Types A and B) to have better hand and appearance than the pad-dry-cure fabrics. The hand evaluations were rated higher than the evaluations of appearance for each of the fabric types.

An overall summary of the findings was developed by assigning a rank of No. 1 to the shirt with the best score in each of the properties evaluated after the shirts had been worn and laundered 25 times. A rank of 2 was given to the shirt type having the second highest score, with 3 and 4 assigned for the lowest scores, respectively. In this manner, the shirt with the greatest number of 1 and 2 scores would have the lowest total which represents the best overall performance. The overall summary was developed by collapsing over the significant differences that existed between the shirt types with regard to the various properties evaluated. Table 30 shows the Newman Keuls' rankings of each shirt type, with lines identifying significant differences.

TABLE 30

SUMMARY OF THE RANKINGS OF ALL SHIRT TYPES WITH REGARD TO PROPERTY EVALUATED BY COLLAPSING OVER SIGNIFICANT DIFFERENCES

	Ranking (Order of Standing)			
Property Evaluated	1	2	3	4
Durable Press	B	A	D	C
Shrinkage: Fabrics	D	B	A	C
Tensile Strength				
(warp)	A	D	C	B
(filling)	D	C	A	B
Tearing Strength				
(warp)	C	D	A	B
(filling)	C	A	D	B
Abrasion Resistance	A	C	B	D
Color Difference	A	C	B	D
Broken Yarns				
(warp and filling)	C	A	D	B
Panel Evaluation:				
Hand	A	B	C	D
Appearance	B	A	C	D

Note: There was not a significant difference between the shirt types underlined by the same line.

A - Sanfor-Set, Minimum Application
B - Minimum Application
C - Sanfor-Set, Pad-Dry-Cure
D - Pad-Dry-Cure

When each fabric type was assigned a total number, as explained above, the points received by each, were:

Type A - 20 points
Type B - 32 points
Type C - 26 points
Type D - 31 points

The best overall performance was achieved by Type A--Sanfor-Set with minimum application. It was the only fabric to avoid a last place (4) rating. Type A ranked number 1 in warp tensile strength, abrasion resistance, color change, and hand. It was second best in durable press, filling tearing strength, broken yarns, and appearance, with only three properties ranked as third best--shrinkage, filling breaking strength and warp tearing strength.

Of the other three fabric types Type B received the highest number or poorest performance. Type B was rated last in five properties--warp and filling tensile strength, warp and filling tearing strength and broken yarns.

A closer look at the standings of the two Sanfor-Set finished fabrics (Types A and C) revealed that they were superior in performance. They received highest rankings in breaking and tearing strength, abrasion resistance, color difference, and broken yarns.

In conclusion, the overall performance of the 80 shirts, which were included in the final analysis, was considered to be satisfactory from the viewpoint of the 20 men who wore the shirts 25 times. The subjects expressed no displeasure concerning comfort or appearance during the study, although the wearing of a blue shirt every day did become tiring to some. This study concluded that all cotton shirts were judged to be highly acceptable.

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