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Title: EFFECTS OF WASH WATER TEMPERATURES AND DRYING METHODS ON THE DIMENSIONAL STABILITY AND SURFACE APPEARANCE OF FILAMENT POLYESTER DOUBLE KNIT FABRICS

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With the increased production and use of double knit fabrics made from textured filament polyester, homemakers have become concerned over procedures for care that can be successfully carried out in the home. The purpose of this study was to determine what effects wash water temperatures and drying methods have on the dimensional stability and surface appearance of filament polyester double knit fabrics.

Changes in general physical properties, dimensional change, and surface appearance of four fabrics were studied after ten launderings at three wash water temperatures with two drying methods. Shirts made from two fabrics were worn by nursery school children, laundered ten times, and rated for pilling and snagging. All filament

polyester double knit fabrics in this study shrank more when washed in hot water and when dried in the tumble dryer than when washed in warm or cool water and horizontally screen dried. Shrinkage was continuous after five and ten launderings, although at a decreasing rate. All four fabrics had better appearance when laundered in warm or cool wash water and when tumble dried after ten launderings than when washed in hot water and horizontally screen dried.

Data indicated that resistance to pilling as tested in the Random Tumble Pilling Tester and snagging on shirts worn and laundered ten times were more dependent upon fabric characteristics and wearing conditions than on laundering conditions. Fabrics won consumer acceptance by parents of nursery school children who participated in the wear study.

Effects of Wash Water Temperatures and Drying Methods on Dimensional Stability and Surface Appearance of Filament Polyester Double Knit Fabrics

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INTRODUCTION

By 1975, knitters of yardgoods predict that double knit fabrics will account for a substantial 25 to 30 percent of men's slacks and sport jackets. At the same time the demand for double knit fabrics in women's dresses and suits is expected to continue. In addition, new growth in rainwear, coats, children's dresses and home sewing is a particularly promising outlet for double knit fabrics (29). Tailored knits are qualifying for men's clothing in this era of travel and masculine fashion awareness that leans toward comfort and casual good looks (22).

A survey of double knit fabric producers shows that production of double knit yardgoods reached 215 million pounds in 1969. This represents a 53 percent increase over the 145 million pounds produced in 1968 (29). Knitwear output is expected to increase by 50 percent during the decade of the 1970's (35).

To illustrate the significance of polyester fiber, in 1969 producers of double knit yardgoods used more textured polyester yarn than all other fibers and yarns combined (29). With the trend toward lighter weight fabrics, finer deniers and finer cuts, polyester has been the fastest growing fiber because of the vast range of performance characteristics that can be engineered into it. Polyester has been claimed to have more technical versatility than other manmade fibers (34).

The homemaker's concern for the care and maintenance of knitted polyester garments is only beginning. The output of the knitting industry is at least 25 percent of the textile production of the United States. The percentage grows each year because fabrics can be produced faster and cheaper by knitting than by any other means.

With the advantage of polyester being its ease of care, homemakers will be doing more of the laundering in the home rather than having garments dry cleaned. According to a study conducted at Iowa State University by Elizabeth Henry, recommended care instructions, fabric design, comfort of fit and degree of stretchability were among the features of knit garments important to the greatest number of the 50 faculty women surveyed. Over half of the respondents laundered knitted garments at home (15). In this same study, one of the items considered "very important" was adequate instructions on care. Data indicated that the professional women needed increased knowledge of correct laundry procedures and care practices. Manufacturers' labels lacked this desired information (15).

Personal experience of the author reveals that snagging and progressive shrinkage are some of the problems encountered by the consumer as a result of wear and home laundering if proper procedures are not followed. This experience prompted the present study of polyester double knit fabrics.

In studying consumer-oriented information on the care and performance of polyester double knit fabrics the author found that this information was limited in literature and on labels accompanying garments and yardage. This finding is supported by Miss Henry's study (15). In view of the importance of polyester fibers and their use in double knit fabrics, consumers need to know about caring for these fabrics at home. This research is based on the need for more information on home care of polyester double knit fabrics.

Statement of Problem

The purpose of this study was to determine the effects of wash water temperatures and drying methods on the dimensional stability and surface appearance of filament polyester double knit fabrics. Pilling, snagging and wrinkling were the surface effects considered.

The study was conducted to test the following hypotheses:

1. Initial dimensional changes will be greater at higher wash water temperatures than at lower wash water temperatures.
2. Initial dimensional changes will be greater with tumble drying than with horizontal screen drying.
3. Progressive or subsequent dimensional changes will be

greater at higher wash water temperatures than at lower wash water temperatures.

4. Fabrics will have a smoother appearance when laundered in lower wash water temperatures rather than higher wash water temperatures.

5. Fabrics dried in a tumble dryer will have a better appearance than those dried on a horizontal screen.

6. Higher wash water temperatures and tumble drying will create more pilling than lower temperatures and horizontal screen drying.

7. Resistance to snagging and pilling will be less dependent on laundering conditions to which the fabric is subjected than on the fiber length, yarn texture, fabric construction and conditions of wear.

8. Acceptable performance in wear will make polyester double knit fabrics desirable to men, women and children alike.

Limitations

The limitations of this study include the use of only 100 percent textured filament polyester double knit fabrics. Three wash water temperatures, 20°, 40° and 60° C $\pm$ 2° C and two drying procedures, horizontal screen and tumble, were the limitations of the laundry procedures.

The extent of the physical testing was limited by the amount of yardage donated by fabric mills. Based on information gathered in a survey of homemakers, pilling, snagging and wrinkling were the surface effects evaluated. The author considers these effects as highly influential features in consumer acceptance of and satisfaction with garments and home furnishings constructed of 100 percent filament polyester double knit fabrics.

Definitions

Course. The series of successive loops lying crosswise of a knitted fabric (28).

Dacron. A registered trademark for a polyester fiber product of E. I. DuPont de Nemours and Co. Inc. (28).

Dimensional stability. Resistance to changes in fabric dimensions, either extension or shrinking (3).

Double knit. Refers to a number of fine rib fabrics knitted on a machine equipped with two sets of needles so that the cloth is a twice knitted fabric in which, by the action of the double set of needles, the two sides of the cloth are interlocked (24).

Filament. "An individual strand that is indefinite in length. Yarns are made by twisting together several continuous filaments" (11, p. 60).

Pill. "Bunches or balls of tangled fibers on the surface of a fabric which are held to the surface by one or more fibers" (3, p. 287).

Snag. A yarn or yarns that have been caught by a foreign object pulling a loop to the surface of the fabric.

Standard atmosphere. "Air maintained at a relative humidity of 65 $\pm$ 2 percent and at a temperature of 70 $\pm$ 2° F" (3, p. 381).

Texturing. A means whereby stretch and bulk are combined with the performance of thermoplastic yarn through the permanent introduction of crimps, loops, coils, or crinkles into otherwise smooth, continuous filaments (37).

Thermoplastic. "A chemical fiber which becomes malleable when subjected to heat and whose form can be permanently changed by heat" (11, p. 60).

Trevira. A registered trademark for polyester textile fiber which has a five-sided filament cross section engineered by Hystron Fibers, Inc. to give supple hand, luster and a broad range of deniers to knit fabrics (18).

Wale. A column of loops running lengthwise in a knitted fabric (28).

Wicking. "The ability of a fabric or fiber to pick up moisture and have it travel along the fiber, although not actually absorbed by the fiber" (32, p. 230).

Wrinkle. An undesirable fabric deformation, usually a sharp or rounded short fold. The distinction between a wrinkle and a crease is not clear; generally, short and rounded irregular deformations are referred to as wrinkles while longer and sharper ones are called creases (3).

REVIEW OF LITERATURE

A survey of journals, technical reports, household magazines and books reveals very little information on the effects of wear or home care on 100 percent filament polyester double knit fabrics. The emphasis on production and marketing indicates the recency of polyester fibers in knitted fabrics in the filament form.

Polyester Fiber

Groundwork for the discovery of polyester was laid in the United States during the 1930's by the pioneer research into high polymers conducted by the late Dr. Wallace H. Carothers at DuPont. Dr. Carothers published his research findings on polyester but elected to continue his work in the polyamides and discovered nylon. DuPont researchers continued work on polyester and acquired American patent rights for the development of Dacron. In 1951, Dacron was displayed for the press in New York. By 1953, DuPont's first plant was in full production. By the end of 1968 there were 128 polyester plants in the world, with 23 in the United States (11).

In the spring of 1968, Trevira Star, a pentalobal polyester was introduced in knitwear. The fiber producing technique gives a broad range of deniers so that the fiber is suitable for many lightweight, worsted-like fabrics (18).

Polyester filament is generally considered to be the most versatile man-made fiber since man first conceived of imitating silk. This versatility explains not only the diverse uses of polyester fibers from double knit dresses to tire cord, but the number and variety of effects it can create.

Polyester filament comes in bright, semi-dull and dull variations which are controlled by the cross-sectional shape of the fiber. The trilobal and pentalobal cross-sections will reflect light differently from the standard round, rod-shaped polyester (18). Fabric made from the pentalobal filament is characterized by a distinctive lustrous appearance and a more silk-like hand compared to round cross-section filaments. The round cross-section gives a semi-dull appearance while the pentalobal is brighter (33).

"The outstanding characteristic of polyesters is their ability to resist wrinkling and to spring back into shape when creased" (32, p. 23). The low moisture absorption of polyesters makes them wash-and-wear fabrics because they dry quickly. Water-borne stains lie on the surface and are easily cleaned off (6). It is claimed that, if polyester is properly heat set, it will not shrink or stretch when subjected to boiling water, hot cleaning fluids or ironing temperatures that are lower than the heat setting temperatures (above 385^{o} F). Polyesters that have not been heat set may shrink at elevated temperatures (21).

Texturing the filament yarns has the advantage of producing loft and/or stretch in a fabric, opacity, and porosity which makes them more comfortable to wear. Textured filament yarns do not pill as easily as yarns made from staple fiber. The dominant process used throughout the world is the false twist method of texturing filament yarns (11).

Double Knit Fabrics

Double knit is a term that has recently come into use in the industry as a result of the ascent of the knit dress. Although not a standard technical knitting term, double knit refers to various types of fine rib structures that look like twice-knitted jersey fabric. The cloth has the appearance, front and back, of the face of jersey fabric; that is, the two sides of the cloth are interlocked or inter-knitted to create the impression of a double knitted plain jersey material (24; 28).

Advantages of double knit fabric over plain jersey cloth are greater dimensional stability by virtue of the double construction, easier cutting because the edges do not curl and less clinging due to more body in the heavier fabric (28).

Laundering Methods

The principal advantages of polyester fibers are their durability, ease of care and high resistance to fiber or fabric damage that may be incurred during home care practices.

For textured filament polyester fabrics, a warm wash water temperature of 120° F or 40° C is recommended. The gentle cycle and mild soap or detergent give the best results. Fabric softener may be used to reduce static electricity and give a softer hand (10).

As polyester is a thermoplastic fiber, it is likely to crease at temperatures above $50\text{-}60^{\circ}$ C. After cooling in this condition, creases which persist can be removed only by ironing. Ideal conditions to greatly reduce creasing would be to progressively cool the rinse water from the washing temperature down to cold-water temperature while continuing to agitate the fabric. This, of course, is not practical in home laundering conditions, but it is possible to follow the hot wash with a warm rinse to achieve a reasonable compromise (5).

Turning all garments wrong-side-out during laundering will reduce surface pilling that might occur on the right side of the fabric (16).

Normal liquid detergents are good grease and oil emulsifiers but have poor soil-suspending properties. They are inadequate for washing heavily soiled articles, as the soil may be re-deposited on the fiber. Synthetic fibers in particular are prone to the deposition of soil from such washing conditions. A better result is obtained when using either soap or a built detergent (5).

The spin-drying of hot, wet articles, followed by rinsing in cold water, is to be avoided as is prolonged spinning which has a strong cooling effect. Tumble drying in hot air helps to remove creases formed during washing. After the garments are dry, tumbling should be continued for 5-10 minutes without heat to allow progressive cooling (5).

Testing Knitted Fabrics

The Good Housekeeping Institute has established standards for shrinkage, color fastness and strength of knit goods. For instance, knitwear must have a minimum bursting strength of 25 pounds in order to quality for advertising in Good Housekeeping Magazine and for use of the Consumers' Guaranty Seal. All claims for the knitgoods must be substantiated. Knits are rated for appearance by the Institute using the plastic replicas of wrinkling patterns developed by the American Association of Textile Chemists and Colorists. A rating of five is required after tumble drying (35).

The specific problems which the National Knitted Outerwear Association encounters with knitted fabrics are dimensional stability and elasticity both in mechanical stressing and in the first washing. A fabric is expected to keep its surface appearance even after wear. Pilling should not occur at all or only after relatively long wearing (8).

Bursting strength has its widest application to knit fabrics, which do not lend themselves to the usual test for tensile strength of woven fabrics. The bursting test measures the composite strength of both walewise and coursewise directions simultaneously and indicates the extent to which a fabric can withstand a bursting force with pressure being applied perpendicular to the surface of the fabric (13).

The Scott Ball Burst attachment is fitted to a pendulum tester with a constant rate of traverse in such a way that the downward movement of the traverse forces the fabric against a one-inch ball. The load necessary to burst the fabric is the bursting strength.

PROCEDURES

Selection of Fabrics

In addition to the personal experiences of the author, the advantages of textured filament polyester yarns in double knit ready-to-wear led to the selection of 100 percent filament polyester fabrics for the study of performance in home laundering.

Inquiries were sent to yardage manufacturers concerning the availability of filament polyester double knit fabrics in plain colors with plain surfaces. As a result, four fabrics were donated by fabric mills. These included two Dacron, one Trevira and one unknown brand of filament polyester double knit fabric.

Fabric I is a navy Dacron double knit fabric, fabric II is a brown diagonally ribbed double knit of Dacron, fabric III is also a diagonally ribbed double knit of Trevira and fabric IV is a cream double knit with a novelty design made from an unknown brand of filament polyester (Figure 1).

Selection of Properties to be Measured

As a basis for selecting laundering variables informal visits with homemakers in Owyhee County, Idaho were made to determine laundering and care problems they had with the polyester double knit garments they had purchased. Questions were asked concerning types

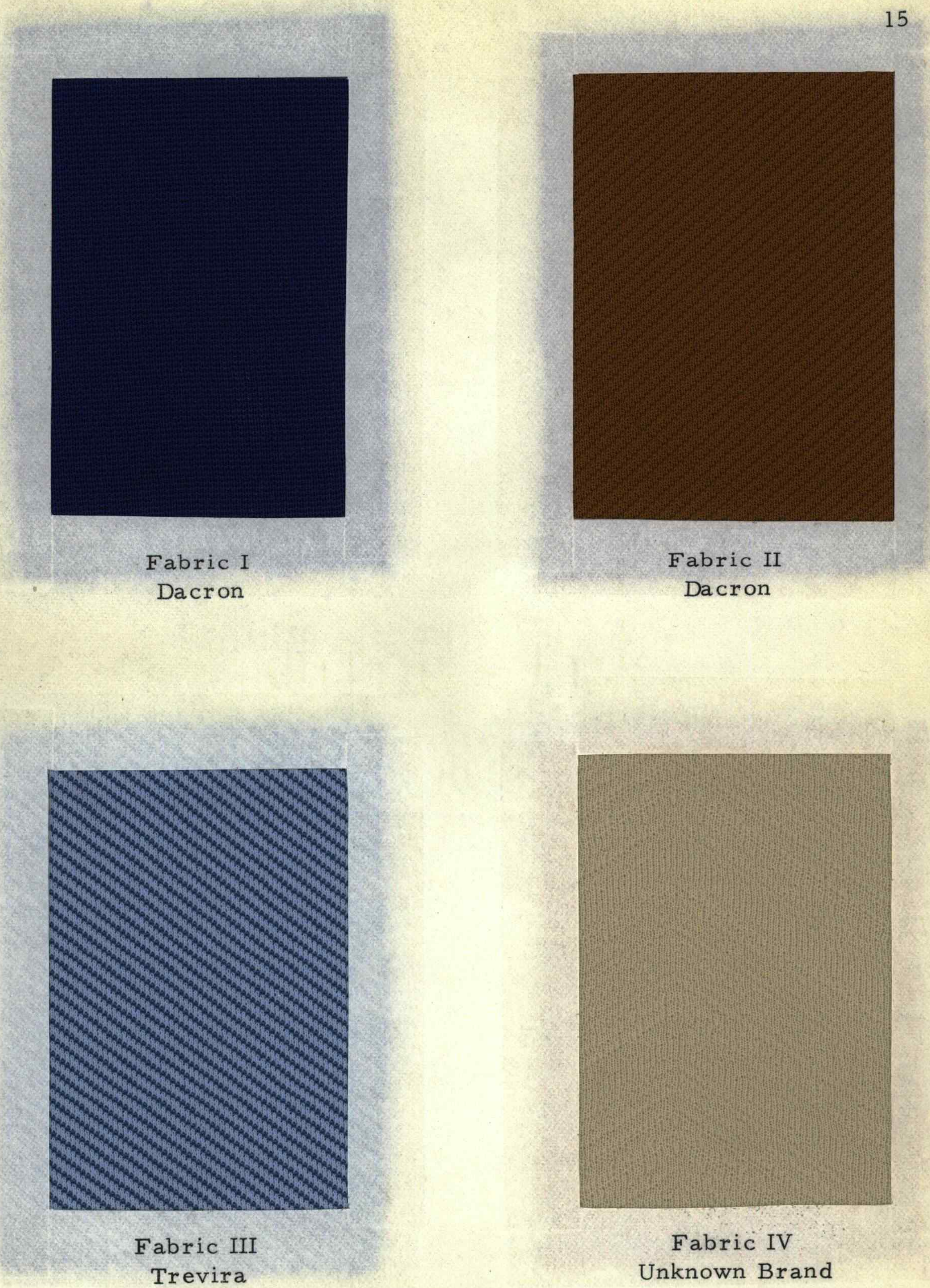


Figure 1. Polyester Double Knit Fabrics Used in this Study.

of laundry equipment commonly used in home laundering.

Informal conversations with merchants in specialty and department stores in Corvallis, Oregon were held to determine if consumers were bringing problems back to the merchant and, if so, what problems predominated in the care and wear of polyester double knit fabrics.

Fiber Identification

Microscopic and chemical tests were conducted to verify fiber content of the four fabrics used in this study. Slides of cross-sections and longitudinal fibers were viewed under the microscope and compared with photomicrographs of man-made textiles (19).

A solubility test in hot meta-cresol was performed to confirm the fiber content of the four double knit fabrics, which were found to be polyesters. Boiling dimethyl formamide was used to distinguish between the types of polyesters used. Kodel is insoluble in boiling dimethyl formamide (19).

General Physical Properties

Wale and course count, weight, bursting strength and thickness were investigated using procedures of the American Society for Testing and Materials (hereafter referred to as ASTM) (3). All tests were conducted under standard atmospheric conditions of temperature and humidity, 65 $\pm$ 2 percent and 70^{o} $\pm$ 5^{o} F (3). With a yarn counter, wales and courses were counted for two inches on five random samples of each fabric. The mean numbers of wales and courses per inch were calculated and reported (3).

In accordance with ASTM Designation D1910-64, five squares of fabric were randomly cut by means of a two-inch square die and weighed on a torsion balance. Two such weights in grams of 20 square inches were taken for each fabric. These weights were converted into ounces per square yeard (3).

The Randall and Stickney Thickness Gauge was used to measure the thickness in inches of five randomly selected samples, each in two places, giving ten measurements for each fabric.

ASTM Designation D231-62 was followed for bursting strength of knitted fabrics by means of the Scott Tester with the Ball Burst attachment. The rate of transverse was 12 inches per minute. The pressure was registered in pounds. Four conditioned four and one-half inch square specimens of each fabric were tested. A mean of the four measurements was calculated for each fabric.

Performance of Fabrics

Laundering Procedures

Laundry procedures were adapted from ASTM Designation D1905-68, Standard Method of Test for Dimensional Changes in Woven or Knitted Textiles (3). Eighteen 16-inch squares were cut randomly, no nearer the selvage than ten percent of the fabric width, from each length of the four fabrics. After conditioning in a standard atmosphere, each square was marked with a ten-inch circle in the center. Laundry-proof military uniform marking paint and ball-point tube textile paint were used to mark each specimen to insure markings that would withstand moisture, temperature and agitation through ten laundering periods. Six specimens of each fabric weighing 35 ounces plus knitted filler fabric weighing 13 ounces were used to make up the wash load of three pounds.

To determine the importance of proper care procedures some laundry procedures more severe than recommended were used. Three wash water temperatures, 60°, 40° and 20° C $\pm$ 2° were used for the hot, warm and cool launderings. One-half cup of all-purpose synthetic detergent was used in all wash loads. The water for the six-minute wash period was seven inches deep. Super agitation and spin speed were used throughout the laundering tests in an automatic oscillating washing machine. Two temperatures were used for the rinse, 40° and 20° C. The rinse cycle included eight spin-spray rinses with a two-minute agitated, eight and one-half inch deep rinse.

Twelve specimens of each fabric were tumble dried in an electric tumble dryer starting with a cold drum at the regular speed wash-and-wear cycle. This included 20 minutes of tumbling at 120° F and ten minutes with no heat for the cool-down period. To avoid wrinkling, specimens were tumbled while being removed from the dryer immediately upon completion of the automatic cycle.

Twelve specimens, three of each fabric, were flat dried on horizontal screens elevated two inches from the counter to allow for air circulation. This method of drying was chosen because the 1969 Book of ASTM Standards recommended this procedure even though line drying was applicable to some knitted fabrics (3).

Dimensional Stability

Still following the ASTM Designation D1905-68, Standard Method of Test for Dimensional Changes in Woven or Knitted Textiles, measurements of conditioned specimens were taken between corresponding points in each direction in a direct line along the previously marked central wale and course and three-fourths inch on each side of the central wale and course. Measurements were taken before laundering and after the first, fifth and tenth laundering intervals to determine initial and progressive changes. The percentage dimensional change was recorded as an average of the three readings in each direction on each specimen.

The relationship of factors affecting dimensional change was analyzed on the computer using the analysis of variance.

Fabric Appearance After Laundering

The procedure for studying fabric appearance after laundering was adapted from the 1967 Technical Manual of the American Association of Textile Chemists and Colorists (hereafter referred to as AATCC), using test method 88A-1964, Appearance of Fabrics in Wash-and-wear Items After Home Launderings, as a guide. Each fabric specimen was subjected to the same home laundering procedure as for the dimensional stability measurements, which included hot, warm and cool wash water temperatures and horizontal screen and tumble drying methods.

The AATCC durable press replicas of wrinkled fabric were used for evaluation. Overhead lighting procedures were used for general appearance because the effects of pattern and designs could mask wrinkles under low-angle lighting (1). The lighting equipment included two 40-watt four-foot fluorescent tubes. The fixture was mounted 24 3/8 inches from the wall and seven feet nine inches from the floor (1).

Resistance to Pilling

Three bias specimens 4 3/16 inches square were cut from each of the 16-inch squares used in previous tests. These specimens were used in sets of three for the procedures adapted from the ASTM

Standard Test for Pilling Resistance and Other Surface Effects of Textile Fabrics, Designation D1375-67 (3).

Unlaundered conditioned specimens of each fabric and the specimens of fabrics laundered ten times in hot water and tumble dried and conditioned were subjected to simulated wear by a random rubbing motion produced by tumbling the specimens in a cylindrical chamber lined with mildly abrasive cork for 30-, 60- and 120-minute intervals. Small amounts of short-length cotton fiber were placed in each chamber with the three specimens and renewed after each 30-minute tumbling period. After each 30-minute run, each specimen was removed and any loose cotton fiber cleaned off with a vacuum cleaner with a brush attachment. Cork liners were discarded after being used one hour on each side.

Three judges made a rank order evaluation comparing the amount of fiber damage on the four fabrics visible under the stereoscopic microscope. One specimen of each of the four laundered and unlaundered fabrics tumbled for 120 minutes was randomly selected to make a set of four samples which were ranked on a scale from one to four, the sample having the least fiber damage receiving a score of one. The remaining specimens were placed in order of increasing fiber damage, receiving scores of two, three and four. This evaluation was completed only after the tenth laundering interval.

Resistance to Snagging

The test for resistance to snagging was conducted on 12 pullover, crew-neck shirts constructed of fabrics II and III. Short zippers were inserted in shoulder seams for ease in putting the shirts on the four-year-old nursery school boys who participated in the wear study.

One shirt of each fabric was laundered ten times but not worn, and one shirt of each fabric was neither worn nor laundered. Each of the remaining ten shirts of each fabric was laundered in hot wash water at 60° C and cool rinse water at 20° C in a pulsator action washing machine after each eight-hour wear period. Regular pulsation speed and gentle spin speed were used. Three-fourths cup of all-purpose detergent and one-third cup of disinfectant were used in the wash water for each laundering. Ten shirts or the equivalent were washed in each three-pound load. Each shirt was turned wrong-side-out for the wash cycle.

Ten shirts or the equivalent were dried in the electric tumble dryer on the permanent press cycle set for 25 minutes, which allowed a ten-minute cool-down period at the end of the cycle. Each shirt was right side out for the drying cycle.

After ten wearings and ten launderings, each shirt was evaluated for snagging by a panel of professional home economists under lighting conditions prescribed by AATCC, including the use of two eight-foot, cool white, fluorescent lamps (2; 38).

The total numbers of snags were counted on the front, back and sleeves of each shirt at as close a range as each panel member wished to be. A rating scale from one to five was used to score the shirts according to the number of snags, which ranged from none to eight or more. No snags received a rating of five while eight or more received a rating of one.

RESULTS AND DISCUSSION

Survey of Homemakers and Merchants

The informal survey conducted among the homemakers in Owyhee County, Idaho indicated that the problems most often encountered as a result of wear or laundering of polyester double knits were shrinkage, pilling and snagging. They reported continuous shrinkage as one of the most annoying problems. When asked what type of laundry equipment and features of that equipment they had available to them, the author found both washers and dryers commonly used but not many variables in temperature settings or cycle action on either piece of equipment. All-purpose synthetic detergents were most commonly used in the family laundry.

Laundering conditions for this study were selected on the basis of this information even though they did not conform exactly to the general guides recommended by equipment manufacturers for laundering knitted garments. On the basis of this survey and personal experience, dimensional stability, resistance to pilling, fabric appearance and resistance to snagging were the properties selected for study.

Local merchants indicated that no problems had been brought to their attention concerning the customer satisfaction with polyester double knits in relation to wear or care practices.

Identification of Fibers

Cross-sectional and longitudinal views of each fiber under the microscope indicated that all fibers tested were polyester when compared to illustrations in DuPont's bulletin X-156, Identification of Fibers in Textile Materials (19). Solubility tests in hot meta-cresol further confirmed that all four fibers were polyesters. Boiling dimethyl formamide indicated that none of the four fabrics was knitted of Kodel polyester.

General Physical Properties

A comparison of general physical properties indicated all fabrics were similar in wale and course counts but varied as much as three ounces per square yard in weight (Table 1).

Table 1. Physical Measurements of Original Fabrics.

Property	Fabric I	Fabric II	Fabric III	Fabric IV
Wales per inch	28	29	32	27
Courses per inch	56	58	57	60
Weight in ounces per square yard	15.7	14.7	12.5	14.1
Thickness in inches	.045	.034	.035	.032
Bursting strength in pounds	*	282	*	259

*Strength beyond capacity of instrument.

Fabric I is Dacron double knit which has excellent strength, as it did not break within the 300-pound capacity of the Scott Ball Burst Tester. Fabric I is the thickest and heaviest of the four fabrics and has the fewest courses per inch. Fabric II has very high strength and is knitted of Dacron polyester. Fabric III is knitted in a diagonally ribbed pattern of Trevira polyester. While this fabric was the next to the thickest, it was over two ounces per square yard lighter than the next heavier fabric. Fabric IV had the lowest bursting strength, the breaks occurring across the walewise direction. It was also the thinnest, had the fewest wales per inch and the greatest number of courses per inch. The brand of polyester was unknown in fabric IV.

Performance of Fabrics

Dimensional Stability

Effects of Wash Water Temperature. Wash water temperature was the most statistically significant variable in the shrinkage of both walewise and coursewise directions of the four polyester double knit fabrics tested at all laundering intervals (Table 2).

The average percentage of walewise and coursewise shrinkage of the four polyester double knit fabrics laundered in hot, warm and cool wash water is compared in Figure 2. The most obvious effect noted from the figure is that the use of hot wash water resulted in

Table 2. Analysis of Variance of Factors Affecting Dimensional Stability of Polyester Double Knit Fabrics.

Source of Variation	d. f.	1 Laundering		5 Launderings		10 Launderings	
		F ratio coursewise	F ratio walewise	F ratio coursewise	F ratio walewise	F ratio coursewise	F ratio walewise
Water temperature (W)	2	23.03**	94.85**	67.594**	226.219**	42.716**	64.011**
Drying method (D)	1	11.99**	38.20**	20.172**	83.125**	30.011**	56.011**
Fabric (F)	3	2.07	5.98**	11.953**	19.000**	5.989**	7.606**
W x D	2	.30	11.34**	1.640	10.688**	2.409	4.223*
W x F	6	1.11	4.66**	2.453*	3.500**	2.420*	.989
D x F	3	3.46*	1.63	.391	4.219*	1.568	3.160*
W x D x F	6	2.14	3.41**	1.344	6.781**	1.750	.181
Error	48						
Total	71						

*5% level of significance.

**1% level of significance.

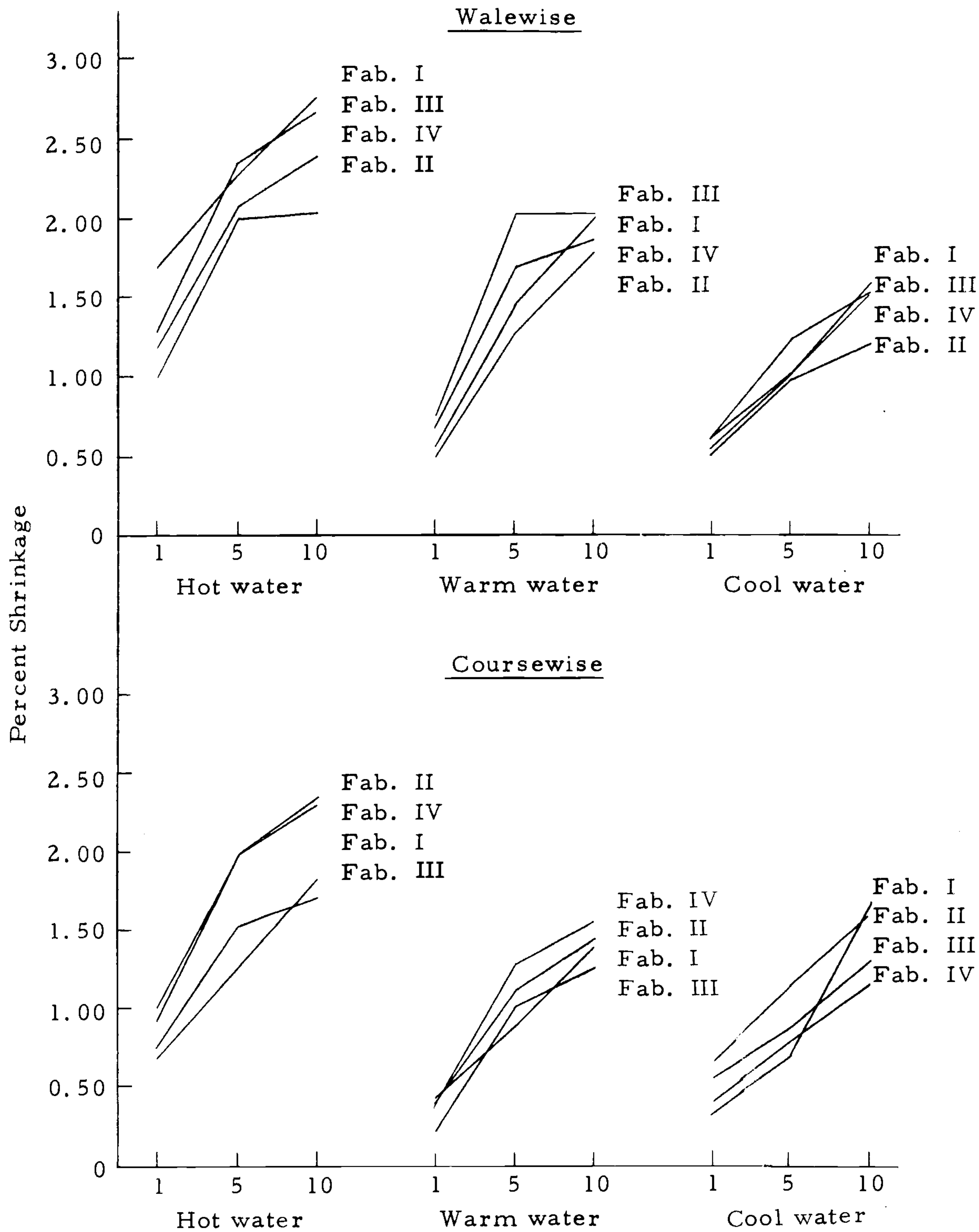


Figure 2. Percentage Shrinkage Affected by Wash Water Temperatures at One, Five and Ten Launderings.

considerable shrinkage of all four fabrics at all laundering intervals. There was less difference, however, in initial shrinkage of fabrics between warm and cool wash water. As an example of the significance of wash water temperature in shrinkage, fabric I laundered one time in hot wash water shrank 0.61 inch per yard in length and 0.25 inch per yard in width; whereas, the same fabric laundered one time in cool wash water shrank 0.21 inch per yard in length and 0.11 inch per yard in width.

On the basis of this result, hypothesis 1, which states the initial dimensional changes will be greater at higher wash water temperatures than at lower wash water temperatures, has been accepted.

Another effect shown by Figure 2 is that generally there was more shrinkage between one and five launderings in hot or warm wash water than between five and ten launderings. The one exception was fabric I for which there was a very nearly equal amount of shrinkage between all laundering intervals in hot wash water. In most cases in all fabrics under all laundering conditions there appeared to be progressive shrinkage but at a lower rate after the fifth laundering in hot and warm wash water. This was less true when fabrics were laundered in cool wash water rather than hot or warm. Hypothesis 3 states that progressive shrinkage will be greater at higher wash water temperatures than at lower wash water temperatures. The result of this test supports that hypothesis. It is interesting to note however, that the rate of shrinkage of these four fabrics was significantly greater during early laundering in hot and warm wash water. Shrinkage while laundering in cool wash water was less in percentage and at a gradual rate at all laundering intervals.

Effects of Drying Method. The method by which the four fabrics were dried was a statistically significant variable in both the walewise and coursewise directions at all laundering intervals (Table 2).

The percentage shrinkage was greater in tumble drying than with horizontal screen drying, but there were differences of only about 0.50 percent. For practical purposes this difference is not important when considered in relation to other factors in laundering procedures.

Shrinkage of the four polyester double knit fabrics in the walewise and coursewise directions is compared in Figure 3. With the exception of fabric II, the dimensional changes were more pronounced in the walewise direction than the coursewise direction in both horizontal screen and tumble drying.

The initial walewise shrinkage ranged from 0.59 percent to 0.83 percent under screen drying conditions, and tumble drying caused initial shrinkage ranging from 0.75 to 1.08 percent. The range of initial shrinkage in the coursewise direction of the four fabrics that were screen dried was from 0.20 percent to 0.59 percent, while the

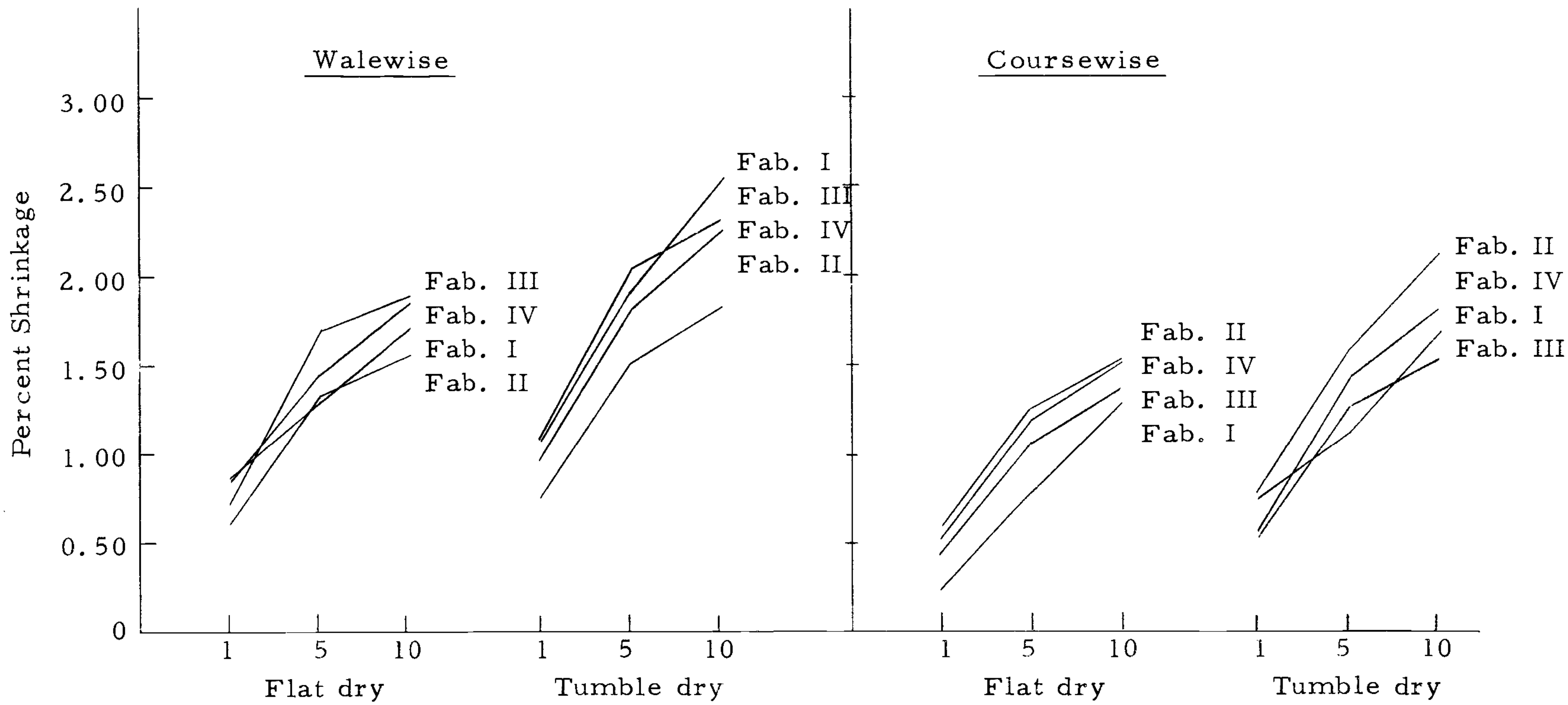


Figure 3. Effect of Drying Method on Shrinkage at One, Five and Ten Launderings.

range of initial dimensional change in tumble drying was 0.54 to 0.75. In inches this means up to 0.30 inch per yard in length and 0.21 inch per yard in width would be lost in screen drying, while up to 0.39 inch per yard in length and 0.27 inch per yard in width would be lost in initial laundering with tumble drying.

The trend toward progressive shrinkage is well illustrated in Figure 3. Even though there was more shrinkage between one and five launderings than between five and ten by both drying methods, the tumble dried fabric shrank more in the walewise direction than the horizontally dried fabric, except for fabric II. Fabric II shrank very nearly the same amount in the coursewise as in the walewise direction when screen dried, while tumble drying created more shrinkage in the coursewise than the walewise direction.

On the basis of these results hypothesis 2 with respect to tumble drying creating greater shrinkage than horizontal screen drying appears to be valid.

Effect of Fabric. Fabric appears to be a statistically significant variable at the 1.0 percent level after five and ten launderings in both directions, but the interactions of fabric with wash water temperature at one and five launderings were significant at the 1.0 percent level in the walewise direction and at the 5.0 percent level at five and ten launderings in the coursewise direction. On the basis of statistical analysis, differences between these fabrics were less important than the use of correct wash water temperature and drying methods in caring for polyester double knit fabrics.

Statistical Analysis of Dimensional Stability. The interaction of drying method and wash water temperature was statistically significant at the 1.0 percent level in the walewise direction at one and five laundering intervals but less significant after ten launderings. This interaction was not significant in the coursewise direction. The interaction of drying method with fabric was significant only at the 5.0 percent level in the walewise direction at five and ten launderings and the crosswise direction after one laundering (Table 2).

The interaction of wash water temperature, drying method and fabric was significant at the 1.0 percent level in the walewise direction after one and five launderings but not after ten launderings or in the coursewise direction.

Fabric Appearance After Laundering

Effect of Wash Water Temperature. Wash water temperature and drying method are statistically significant variables in the appearance of these four fabrics after one, five and ten laundering intervals (Table 3).

The effect of wash water temperature on fabric appearance is compared in Figure 4, with the score of five representing the

Table 3. Analysis of Variance of Factors Affecting Appearance of Fabrics.

Source of Variation	d. f.	F ratio (1 laund.)	F ratio (5 laund.)	F ratio (10 laund.)
Water temperature (W)	2	69.772**	18.313**	87.125**
Drying method (D)	1	9.890**	88.346**	26.574**
Fabric (F)	3	.512	11.248**	1.600
Judges (J)	2	2.114	1.785	.343
W x J	4	.443	.541	.457
W x F	6	4.565**	6.621**	7.140**
D x W	2	9.861**	12.718**	6.970**
D x F	3	.215	7.005**	1.879
D x J	2	.308	.648	.800
F x J	6	.785	.190	1.389
W x D x F	6	3.895**	4.876**	1.970
W x D x J	4	.498	.559	.087
W x F x J	12	.287	.448	.589
D x F x J	6	.241	.364	.234
W x D x J x F	12	.278	.400	.392
Error	144			
Total	215			

*Significant at 5.0% level.
**Significant at 1.0% level.

smoothest or best fabric appearance, and one, the most wrinkled as compared to the AATCC durable press replicas for evaluating fabric appearance after home laundering. All fabrics had better appearance at all laundering intervals with the use of warm or cool wash water than with hot wash water. There was relatively little difference in fabric appearance between warm and cool wash water except in fabrics II and IV after five and ten launderings.

With the exception of fabric IV laundered in cool wash water, all fabrics laundered in all wash water temperatures had better appearance after one laundering than after five, but seemed to improve in some cases after the fifth laundering. Fabric I is the only one of the four fabrics that did not show improvement in appearance between the fifth and the tenth launderings when washed in hot and cold water. This result might indicate a softening of the fabric after repeated launderings which would result in less prominent creases and folds.

The results of this analysis support hypothesis 4 in that the four fabrics had a smoother appearance when washed in lower water temperatures than at a high temperature.

Effects of Drying Method. Figure 5 illustrates the statistically significant effect of drying method on fabric appearance (Table 3). While a similar trend toward a more wrinkled appearance after five launderings can be seen in Figures 4 and 5, the difference between drying methods does not seem great enough to be of practical

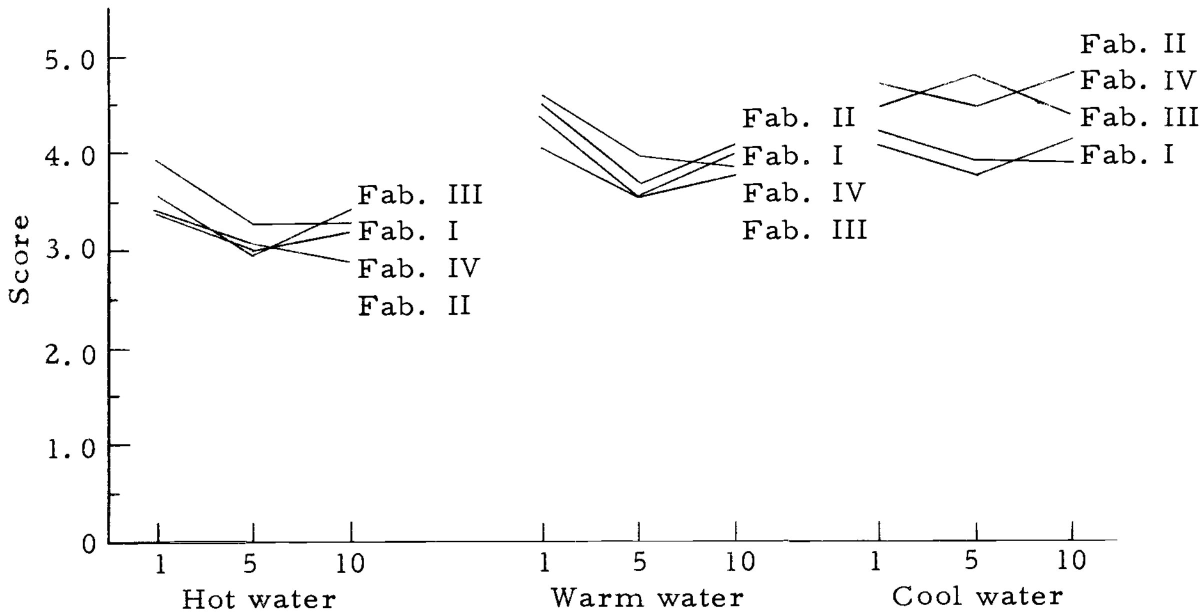


Figure 4. Fabric Appearance Affected by Wash Water Temperature at One, Five and Ten Launderings.

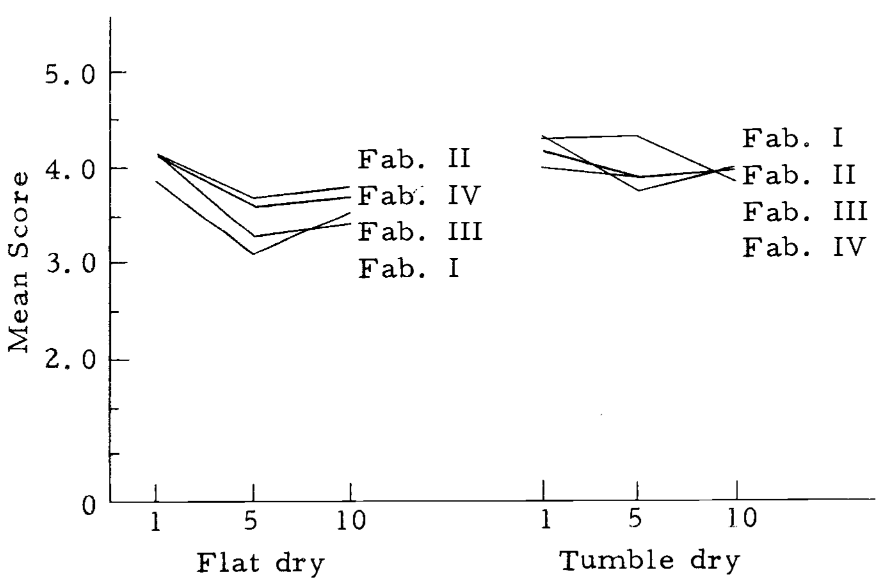


Figure 5. Fabric Appearance Affected by Drying Method at One, Five and Ten Launderings.

significance.

According to these results hypothesis 5, that fabrics dried in a tumble dryer may be expected to have a smoother appearance than those dried on a horizontal screen, has a basis for validity.

Statistical Analysis of Fabric Appearance After Laundering. By observing the differences in mean ratings, wash water temperature was the most important of the variables affecting the appearance of the fabric after one and ten launderings while drying method was especially significant at five launderings (Table 3).

The significant interactions noted at all laundering intervals were drying method with wash water temperature and wash water temperature with fabrics. The interaction of fabric and drying method was significant at the 1.0 percent level only after five launderings. Drying method, fabric and wash water temperature interacted significantly at the 1.0 percent level only after one and five launderings.

Resistance to Pilling

There was no visible pilling of the four laundered and unlaundered fabrics. Only slight fuzzing was visible to the naked eye on all fabrics after 120 minutes of tumbling in the Random Tumble Pilling Tester.

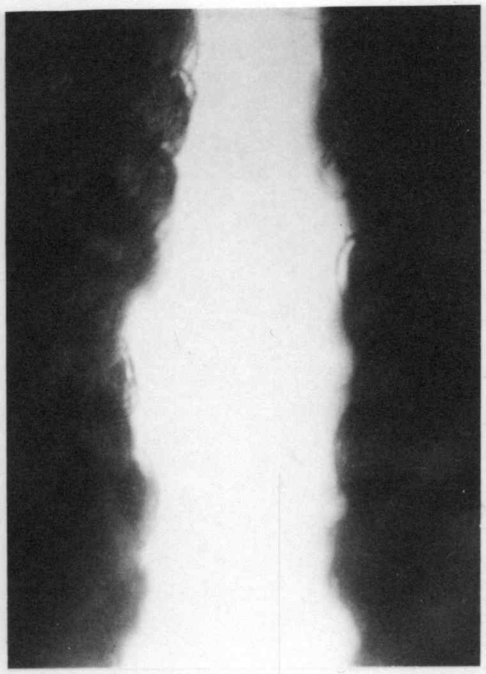
Some damage or distortion of the fibers in both the laundered and unlaundered fabrics was visible under the stereoscopic microscope as recorded on the photomicrographs (Figure 6). Therefore, laundering variables alone were not fully responsible for the fiber distortion of these polyester double knit fabrics. This fact lends to the rejection of hypothesis 6 which states that higher wash water temperature and tumble drying will create more pilling than lower wash water temperature and horizontal screen drying.

When comparing performance on the basis of subjective rank ordering of the four fabrics after random pilling, fabric III appears to have performed better than the other three fabrics when unlaundered. All fabric rankings were as low or lower for the laundered than the unlaundered fabrics except fabric I. After laundering, compared to fabric II, III and IV, fabric I showed less fiber displacement of fibers within the yarn or damage on the basis of judging (Table 4), and appearance in the photomicrographs (Figure 6). Fabric II showed consistently lower rankings than the other three fabrics both laundered and unlaundered.

On the basis of this information, hypothesis 6 has been rejected because neither laundered or unlaundered fabrics formed pills on the surface.

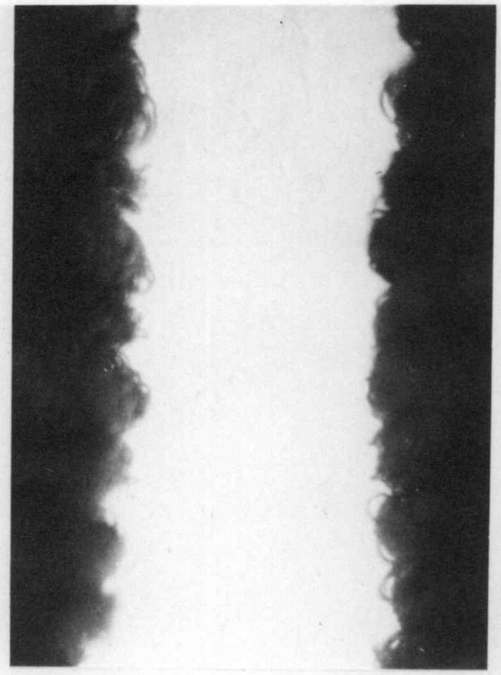
Resistance to Snagging

The shirts that were worn and laundered ten times showed significantly more snagging than those that were not worn (Table 5).



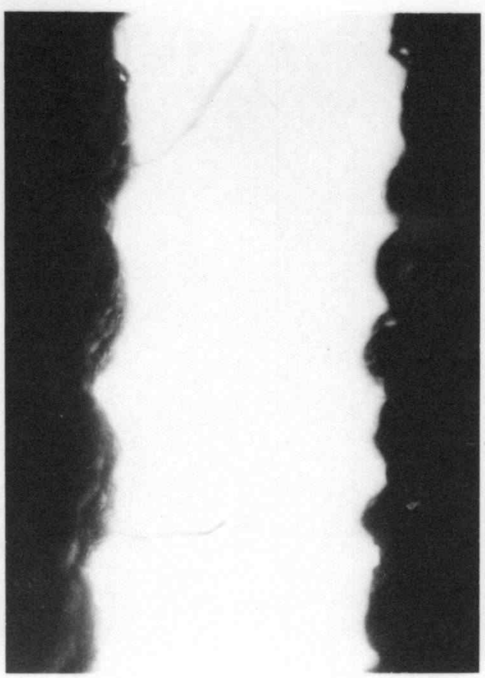
Unlaundered Laundered

Fabric I



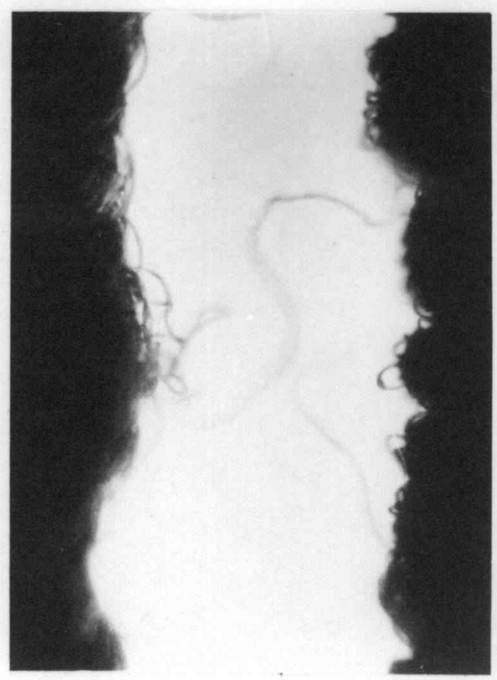
Unlaundered Laundered

Fabric II



Unlaundered Laundered

Fabric III



Unlaundered Laundered

Fabric IV

Figure 6. Photomicrographs of original and laundered polyester double knit fabrics after tumble pilling.

Table 4. Frequency of Rating of Pilling of Laundered and Unlaundered Polyester Double Knit Fabrics.

Rank	Fabric I No. of votes	Fabric II No. of votes	Fabric III No. of votes	Fabric IV No. of votes
		Unlaundered		
1	0	0	6	3
2	4	0	3	2
3	5	1	0	3
4	0	8	0	1
		Laundered		
1	5	0	1	3
2	2	0	7	0
3	2	1	1	5
4	0	8	0	1

Of the 24 shirts constructed of fabrics II and III, the worn shirts had significantly more snags than the original shirts that were either laundered or unlaundered and not worn (Table 6). There were not significant differences in snagging of shirts on the basis of fabric or launderings.

Resistance to snagging, then, will be less dependent on laundering conditions than on fabric characteristics, fiber length, or wearing conditions as stated in hypothesis 7.

During the wear study, the author observed slight pilling on the inside of the hems of the shirts where they rubbed against garments worn underneath such as slacks or jeans. There was no pilling on the outside of the shirts.

By means of a questionnaire sent to parents of the nine nursery school children who participated in this wear study, information concerning the acceptability of these two polyester double knit fabrics was gathered (Appendix E). Nine parents thought both fabrics II and III had better resistance to snagging than other double knit fabrics they had purchased. Only three thought that either fabric had lower resistance to snagging than other double knit fabrics. Other fabric properties in question--resistance to pilling, fuzziness, general appearance and smoothness--were all considered the same as or better than for other double knit fabrics.

Table 5. Analysis of Variance of Resistance to Snagging of Two Polyester Double Knit Fabrics Laundered Ten Times.

Source of Variation	d. f.	F Ratio
Worn vs not worn (W)	1	12.563**
Unlaundered vs laundered (L)	1	.083
Fabric (F)	1	.000
Judges (J)	2	.723
W x J	2	.733
W x F	1	.276
L x J	2	.051
L x F	1	.332
F x J	2	.245
Error	58	
Total	71	

**Significant at 1.0% level.

Table 6. Rating of Resistance to Snagging of Polyester Double Knit Fabrics Laundered Ten Times.

Source of Variation	Fabric II	Fabric III
Worn	3.1	2.7
Not worn	4.5	5.0
All shirts	3.3	3.1

All of the fathers surveyed except one liked the fabrics in the two shirts, and all except two would purchase a shirt of these fabrics. Of those who would not buy a shirt of these fabrics, the reason they gave was that the fabrics were a little rough and scratchy.

All of the boys except one liked the shirts of both fabrics. All of the mothers would buy shirts of either fabric for her husband, but two of the husbands said they would not buy a shirt of either fabric.

It was hypothesized that acceptable performance in wear will make polyester double knit fabrics desirable to men, women and children alike. It can be seen from these results that hypothesis 8 has a basis for validity. Even though there were only two fabrics in the sample, the reactions of the parents were sufficient to support the hypothesis.

SUMMARY AND RECOMMENDATIONS

Summary

The purpose of this study was to determine the effects of wash water temperatures and drying methods on the dimensional stability and surface appearance of filament polyester double knit fabrics.

The four polyester fabrics were laundered in hot, warm or cool wash water and dried in a tumble dryer or on a horizontal screen. Percentage dimensional change was determined after one, five and ten laundering periods. Fabric appearance was evaluated by a panel of professional home economists who compared each specimen with the AATCC durable-press replicas of wrinkled fabrics. Resistance to pilling was evaluated by the same panel of home economists who gave rank order scores to the four polyester double knit fabrics that were laundered and unlaundered.

After each of ten eight-hour wear periods, pullover shirts were laundered in hot water and dried in a tumble dryer. Evaluation consisted of counting the snags on each of the 24 shirts and assigning a rating based on the total number on each shirt.

Wash water temperature was the most important factor affecting the dimensional stability and fabric appearance. Drying method was a somewhat important factor affecting dimensional stability and fabric appearance. There was statistical evidence that differences among fabrics had relatively little effect on dimensional stability or changes in fabric appearance.

This study verified the observation that these four polyester double knit fabrics will shrink most when laundered in hot wash water--up to 2.75 percent. In contrast, maximum shrinkage of these polyester double knit fabrics was less than 1.75 percent when laundered ten times in cool wash water. The differences in initial shrinkage in warm and cool wash water were not of practical significance.

Appreciably more shrinkage occurred in the walewise than the coursewise direction at hot and warm wash water temperatures. The dimensions of these four polyester double knit fabrics were more dimensionally stable after the fifth and tenth launderings in warm or cool water than in hot water.

Fabric appearance was better after laundering in warm or cool wash water and drying in a tumble dryer than in hot water and horizontal screen drying. The resistance of these four fabrics to pilling and snagging seemed to have no relation to wash water temperature or method of drying.

Recommendations to the Consumer

On the basis of this study, pre-treating filament polyester double knit fabric in warm wash water and drying in a tumble dryer is recommended as up to 1.25 percent shrinkage might have already occurred before the garment would be subjected to subsequent launderings. Even though the dimensional changes were somewhat greater with tumble drying, fabric appearance is sufficiently better to sacrifice some dimensional stability in the pre-treatment.

Since conditions of wear seemed more important than laundering procedures in relation to resistance to pilling and snagging of filament polyester double knit fabrics, the recommended method of laundering garments is the same as that for treatment of fabrics before cutting.

The author recommends the use of cool wash water for ready-made garments because total shrinkage is not as great as in hot or warm wash water even after ten launderings. Warm or cool wash water results in a better surface appearance of fabric after ten launderings.

Recommendations for Further Study

All properties of filament polyester double knit fabrics in relation to laundering were not measured in this study. The results of the following additional investigations may have significance to the homemaker in purchasing, constructing and caring for fabrics or garments for the home and family.

1. A comparison of fabric appearance after home laundering using spin speed and drying temperatures as variables in

addition to wash water temperature and drying method;

2. a comparison of performance of varied qualities or grades of filament polyester double knit fabrics under laundering conditions;
3. the relationship of static electricity build-up and ease of soil retention in polyester double knit fabrics;
4. finishes used on polyester double knits and their effects on dimensional stability, static electricity, oil-borne stains and long term care and wear performance;
5. the results of steam treatment and pressing on shrinkage and appearance of polyester double knit fabrics;
6. a comparison of polyester double knit fabrics of similar construction; or
7. the development of a suitable laboratory method for testing resistance of double knit fabrics to snagging.

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APPENDICES

APPENDIX A

Percentage Shrinkage of Fabrics Affected by Wash Water Temperature.

No. of	Hot Water				Warm Water				Cool Water			
Launderings	I	II	III	IV	I	II	III	IV	I	II	III	IV
						Walewise						
1	-1.69	-0.99	-1.28	-1.17	-0.55	-0.50	-0.75	-0.69	-0.58	-0.53	-0.58	-0.50
5	-2.25	-2.00	-2.34	-2.08	-1.44	-1.25	-2.00	-1.67	-1.03	-0.97	-1.22	-1.06
10	-2.75	-2.03	-2.67	-2.39	-2.00	-1.80	-2.03	-1.88	-1.58	-1.20	-1.56	-1.53
						Coursewise						
1	-0.70	-1.00	-0.74	-0.92	-0.42	-0.39	-0.22	-0.33	-0.31	-0.64	-0.54	-0.39
5	-1.25	-1.97	-1.56	-1.94	-0.89	-1.11	-1.00	-1.25	-0.69	-1.14	-0.86	-0.78
10	-1.83	-2.32	-1.72	-2.30	-1.39	-1.47	-1.27	-1.56	-1.67	-1.61	-1.33	-1.14

APPENDIX B

Percentage Shrinkage of Fabrics in Relation to Drying Method.

No. of Launderings	Flat Dried				Tumble Dried			
	I	II	III	IV	I	II	III	IV
				Walewise				
1	-0.83	-0.59	-0.67	-0.59	-1.06	-0.75	-1.08	-0.98
5	-1.26	-1.30	-1.69	-1.43	-1.89	-1.52	-2.02	-1.78
10	-1.68	-1.56	-1.85	-1.63	-2.54	-1.80	-2.31	-2.24
				Coursewise				
1	-0.20	-0.59	-0.41	-0.56	-0.74	-0.76	-0.59	-0.54
5	-0.78	-1.24	-1.04	-1.22	-1.11	-1.57	-1.24	-1.43
10	-1.26	-1.50	-1.35	-1.50	-1.67	-2.10	-1.54	-1.83

APPENDIX C

Mean Ratings of Fabric Appearance After Laundering in Relation to Wash Water Temperature and Drying Method.

No. of	Hot Water				Warm Water				Cool Water			
Launderings	I	II	III	IV	I	II	III	IV	I	II	III	IV
1	3.9	3.4	3.5	3.4	4.4	4.5	4.1	4.6	4.2	4.7	4.1	4.5
5	3.3	3.1	3.0	3.0	3.6	3.7	3.6	4.0	3.9	4.5	3.8	4.8
10	3.3	2.9	3.4	3.2	4.0	4.1	3.8	3.9	3.9	4.8	4.1	4.4

No. of	Flat Dried				Tumble Dried			
Launderings	I	II	III	IV	I	II	III	IV
1	4.1	4.1	3.8	4.1	4.2	4.3	4.0	4.3
5	3.3	3.7	3.1	3.6	3.9	3.8	3.9	4.3
10	3.4	3.8	3.5	3.7	4.0	4.0	4.0	3.9

APPENDIX D

PARENT EVALUATION
(Mother's)

Name ____________________
Shirt fabric ________________
Date ____________________

MOTHER

Rate this fabric in the following areas as you compare it to other knit fabrics you have purchased.

	better	same	worse
General overall appearance			
Fabric smoothness (wrinkles, etc.)			
Absence of pills			
Absence of snagging			
Fuzziness			

As a parent, have you been satisfied with the wearing qualities of the shirts of the above fabric? Yes _____ No _____ Why? ____________
____.

Do you like the fabric of these shirts? Yes _____ No _____
Why? ____.

Would you purchase a similar shirt for your son? Yes _____ No ____
Why? ____.

Would you purchase a shirt of similar fabric (style not necessarily the same) for your husband? Yes _____ No _____ Why? ______________
____.

Did your son like these shirts and enjoy wearing them? Yes _____
No _____ Why? ____.

Did your son wear the shirts tucked into his trousers?
Always _____ Usually _____ Seldom _____ Never _____

Any comments that you may have or that your son has made about the shirts (use back of page if necessary).

(Father's)

Name ______________________
Shirt fabric __________________
Date _______________________

FATHER

Rate this fabric in the following areas as you compare it to other knit fabrics you have purchased.

	better	same	worse
General overall appearance			
Fabric smoothness (wrinkles, etc.)			
Absence of pilling			
Absence of snagging			
Fuzziness			

Do you like the fabric shown above? Yes _____ No _____ Why? ___
____.

Would you purchase a shirt of similar fabric (style not necessarily the same) for yourself? Yes _____ No _____ Why? ____________
____.

Do you find the feel of the fabric objectionable? Yes _____ No _____
Why? ____.

Any comments that you may have or that your son has made about the shirts.

APPENDIX E

Summary of Parents' Evaluation of Two Polyester Double Knit Shirts

Evaluation		Fabric II		Fabric III	
		Mother	Father	Mother	Father
Appearance	Better	3	4	6	4
	Same	3	2	2	2
	Worse				
Smoothness	Better	4	4	7	4
	Same	2	2	1	2
	Worse				
Pilling	Better	3	3	5	3
	Same	3	3	3	3
	Worse				
Snagging	Better	5	4	5	4
	Same	1	2	1	2
	Worse	1		2	
Fuzziness	Better	5	4	5	4
	Same	1	2	3	2
	Worse				
Wear	Yes	6		8	
	No				
Changes	Yes			1	
	No	6		7	
Fabric	Yes	6	6	7	7
	No		1		
Son buy ?	Yes	5			
	No	1			
Husband buy ?	Yes	6	5	8	5
	No		2		2
Son like ?	Yes	5		7	
	No	1		1	
Fabric objectionable ?	Yes		3		1
	No		4		6