THE COLORFASTNESS AND DIMENSIONAL STABILITY OF COTTON SWEAT SHIRTS

by

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CHAPTER I

INTRODUCTION

The modern trend in fashion, and therefore clothing, has been toward more relaxed, flexible garments. At the same time there is, however, an increased demand for a casual, well-groomed appearance. This direction in clothing is indicated by an increased consumption of knit wear.

Statistical data available through the U. S. Department of Commerce, Bureau of Census (42, 43) lists the total production and shipment of knit outerwear products in 1955 as having a quantity of 30,315,000 dozen and in 1960 as having a quantity of 37,743,000 dozen. This represents an increase of almost one-fourth over the knit outerwear products of 1955. Knit outerwear sport shirts represented a quantity of 18,659,000 dozen of the total knit outerwear products in 1955 and a quantity of 21,806,000 dozen of the total in 1960.

Knit outerwear products are grouped by the U. S. Department of Commerce, Bureau of Census (41, 42, and 43) into the following four categories: sweaters, jackets, jerseys and pullover as one; knit outerwear sport shirts as two; swimwear and sport shorts as three; and the knit outerwear products not specified by kind as four. Knit outerwear sport shirts include knit outerwear shirts such as polo, tennis, basque, "T", and sweat shirts.

Despite this increased demand and consumption of knit outerwear goods, particularly in shirts, little research has been conducted on knit outerwear. Questions as to colorfastness, wearability and dimensional stability in knit clothing, for the most part, have not been investigated thoroughly. The major purpose of this study was to evaluate colorfastness and dimensional stability of sweat shirts made of a heavy all cotton napped fabric.

Knit wear is generally considered to be clothing fabricated either directly from knitting machines as the most "T" shirts and sweat shirts, or indirectly made from knit fabrics as in the cases of sweaters, jerseys, and jackets.

According to Picken's The Language of Fashion, the sweat shirt is "a collarless, highnecked, pullover sweater; often with fleece inside and fine-ribbing outside, used by athletes" (32). Webster's New World Dictionary of the American Language has defined sweat shirt as "a heavy, long sleeved cotton jersey, worn as by athletes to absorb sweat during or after exercise" (17). The Sears, Roebuck and Company Mail Order Catalog describes sweat shirts as "shirts having flat-knit cotton outside, cotton fleece self-lining with ribbed neck, cuffs and bottom" (33), it also has named sweat shirts as "cotton knit sport tops".

The various descriptions of sweat shirts mentioned have indicated that the original end uses of sweat shirts have been placed mainly in sports or athletics. It was not until recently, that the traditional "dirty old grey sweat shirt" has emerged from its drab cocoon and developed into an important outerwear for campus and leisure as well as for sports. This trend is well established especially among the lively moderns (31). The young people's attitudes toward sweat shirts have changed and their uses have consequently been expanded. Today, sweat shirts are used as play clothes, working clothes, casual wear, leisure time outfits as well as sport wear. The rapid increase in the popularity of sweat shirts has led to the manufacture of sweat shirts with a much greater variety in color, style and design to meet individual consumer demands. Bold abstract prints, classic prints and lettering are most likely to be seen on sweat shirts as a decorative feature.

A fashion count of college co-eds conducted over a three-week period showed that an average of 20.3 per cent of the co-eds were wearing sweat shirts. The fashion counts were conducted alternately between three freshmen women's residence halls at Kansas State University, Manhattan, Kansas, during the hours from 7:30 P.M. to 8:30 P.M. on Mondays and Thursdays and from 1:00 P.M. to 2:00 P.M. on Saturdays. The percentage of 20.3 indicated that the sweat shirt is definitely one of the major items of clothing in the co-ed's wardrobe, which is used for after class leisure wear, for play or work wear, and for study hour wear as well as for casual weekend wear.

According to Swanson's (37) and Finlayson's (12) studies, factors relating to the satisfaction with sweaters are: color, fit, comfort, fiber, and fabric, appearance, style, beauty, ease of care, approval of friend, and price, with price being the least important and with appearance being the most important. These factors are also true with respect to sweat shirts.

During interviews with co-eds who owned sweat shirts and during observations in the same three freshmen dormatories, some facts related to sweat shirts were noticed. Some of the major advantages of sweat shirts, from the standpoint of the girls, are those of comfort, absorption, and warmth. Some of the disadvantages are poor stability of color and a noticeable change in dimensions after a period of wearing and laundering. Since sweat shirts are such a popular item in the co-ed's wardrobes, their durability is of importance.

Color change and dimensional change of sweat shirts are important factors to be considered in the acceptability of sweat shirts. Differences in laundering and drying conditions, differences in wearing conditions, the effects of sunlight, daylight, humidity and perspiration, and differences in finishing processes could all contribute to undesirable changes in the color and dimensions of sweat shirts.

Because of the facilities available and time limitations, only selected factors causing changes in color and dimensions of sweat shirts were studied in this project. Although very little research has been done on sweat shirts, several studies have been done in the area of knit wear which were somewhat related to the factors of concern in this study. Some of these projects were the study of dimensional stability of cotton "T" shirts by Freeburg (16) and the study of acceptability of sweaters by Dunham (8).

The objectives of this study were: To study the effects of sunlight, laundering and drying on the colorfastness of sweat shirts made of 100 per cent cotton, and to study the effects of laundering and drying on the dimensional stability of sweat shirts made of 100 per cent cotton. The sweat shirts used in this study were available on the open market at time of the initiation of this project (spring, 1963).

The following hypotheses were proposed as guides for the study:

1. There is no significant difference between the colors of 100 per cent cotton sweat shirts initially and after 40 Standard Fading Hours (SFH) of exposure in the Fade-Ometer.
2. There is no significant difference between the colors of 100 per cent cotton sweat shirts initially and after 15 home launderings followed by screen dryings.
3. There is no significant difference between the colors of 100 per cent cotton sweat shirts initially and after 15 home launderings and tumbler dryings.
4. There is no significant difference between the dimensions of 100 per cent cotton sweat shirts initially and after 15 home launderings followed by screen dryings.
5. There is no significant difference between the dimensions of 100 per cent cotton sweat shirts initially and after 15 home launderings and tumbler dryings.

CHAPTER II

REVIEW OF LITERATURE

To the present time, sweat shirts have been constructed mainly from 100 per cent cotton yarns. Cotton is an inexpensive natural fiber, which imparts a great degree of comfort to its products. Comfort of the cotton sweat shirts was one of the major advantages mentioned by the girls who were interviewed.

Properties that account for the comfort of the cotton sweat shirts are: cotton is very absorbent; it is static free; it is fresh and easy to care for; it is strong and durable; it has a pleasant hand; and it is stretchable to a certain extent (27, 36).

Construction of Sweat Shirts and Their Fabrics

A knit fabric is a fabric consisting of a series of inter-loopings from one or more parallel yarns. Wales and courses are the two basic units used in constructing a knit fabric. Each chain of loops running lengthwise in the fabric is called a wale and each chain of loops running crosswise in the fabric is called a course. Knitting may be done by hand or by machine. Two basic types of knitting machines are flat and circular machines. Knit fabric can be classified into two basic types, the filling-knit and the warp-knit. Filling-knit fabric in which yarns generally run crosswise, is characterized by horizontal stretch, and can be made on either a flat or a circular machine. Most knit fabrics are filling-knits. Warp-knit fabric, in which yarns generally run lengthwise, is stronger and more resistant to snags and runs than is filling-knit. It can be made only on a flat machine. Knitted cotton fabrics range from loose, open construction to close knitted construction. Knitted cotton are elastic, form-fitting, absorbent and do not wrinkle easily. The interlock machine, one type of knitting machine, makes a closely knitted fabric with somewhat less elasticity than the usual rib-knit. It makes knit outerwear fabrics that are used widely for play suits, polo shirts, sweaters, blouses, and sports shirts (1, 24, and 26).

Variations in knit fabrics may be achieved by varying the type of knit, the fiber content of yarns, and the type of yarn construction, and by using different finishing techniques (39).

Sears, Roebuck and Company Mail Order Catalog (33) has described that sweat shirts are constructed of flat-knit bodies and sleeves with rib-knit cuffs, necks, and bottoms. A flat-knit fabric is a filling-knit made on a flat knitting machine. Flat-knit fabric is capable of being fashioned or shaped in the knitting process and is characterized by having a smooth surface appearance. It is also known as a plain or a jersey-knit. Rib-knit, one type of filling-knit, is a combination of plain and purl stitches which shows wales on both sides of the fabric and is particularly elastic in the crosswise direction (1, 24, and 26).

Different parts of the sweat shirts can be shaped by full-fashioning or simple cutting methods, and then sewed together to form garments. According to Johnstone (21) as National Cotton Council of America (26), full-fashioning is done by knitting various parts of a garment, sleeves, front, and back, as flat strips on full-fashioned knitting frames which automatically drop or add the correct number of stitches so as to narrow or widen the strips at the edges of certain places. By increasing or decreasing the number of stitches it is possible to make fashioning marks that may be formed by the rows of knit stitches which come together at an angle, or the rows may be parallel to each other at the joining place. These fashioning stitches are commonly located around the armscyes, they can be also placed around the necklines, on the sides of the sleeve seams, and on the underarm seams. The shaped-as-knit pieces of a full-fashioned knit garment will not ravel. The manner in which parts of knit garments are shaped and joined together may serve as a guide for judging the quality of knit garments. Since fashion marks are a sign of quality of knit garments, stitches that look like fashion marks, but are inserted for appearance only, may be found in cut-and-sewed knit garments (21).

Full-fashioned seams are joined together by looping or overlocking. By the looping method, pieces are machine stitched close to the edges forming a fine, soft, elastic, flat seam which is comfortable. By the overlocking method, two bound-off edges are joined together, with stitches similar to a button hole stitch, forming a seam that is neither as flat nor as flexible as a looped seam. The cut-and-sewed seams must be stitched securely and covered, using overlock stitches or seam coverings such as straight tape to keep cut edges from raveling (21).

Sweat shirts with different styles of necklines are available on the market. The most common ones are plain-round necks, boat necks, "V" necks, hoops, open collars with zippered fronts, shawl collars, and roll collars. Among these the plain-round neck has been the most popular neck style chosen by co-eds, as revealed by a fashion count.

There are, in general, two ways of finishing a plain-round neck in sweat shirts and other knit wear such as sweaters, "T" shirts, etc. These are single-looped and double-looped neck finishes. A single-looped neck finish has only one thickness of ribbing which is bound off on the outer edge. A double-looped neck finish has double thicknesses of ribbing with a fold on the outer edge. A double-looped neckline has less stretch than a single-looped neckline, but it keeps the shape of the neckline better. An elastic thread, yarn, or band may be placed within the fold to help maintain the shape of the neckline (21).

Sleeves of sweat shirts come in various lengths such as long, three-quarter, and short. Sleeve cuffs may be finished with rib-knit or simply with machine stitches. The rib-knitted cuffs may be single-looped or double-looped as in the case of neck finish. Most of the sweat shirt bottoms are finished with rib-knit or simple cut-and-sewed hems. Other types of finishing around the bottom may be found as different styles demand.

Dimensional Stability of Knit Goods

Although the need for standard test methods for measuring the amount of dimensional change in knit fabrics occurring during laundering had emerged before 1950, it was not until that time that substantial efforts were made. In 1951, the first step was taken to develop a test method by the Task Group (38) which was a committee organized by the ASTM (American Society for Testing Materials), U. S. Bureau of Standards. The test method for cotton knit fabrics developed and submitted by the Task Group was adopted by the ASTM as a tentative method, Designation: D 1231-52T, in June 1952. It became a standard ASTM test method for cotton knit fabrics, Designation: D 1231-54, in 1954 (3).

In Fletcher and Roberts (15) study of the rearrangement of the structures of plain, rib, and interlock knit fabrics during laundering, using the standard method for the laundering of woven fabrics to launder the knit fabrics, they found that the course per wale spacing followed no regular pattern, even before laundering. This irregularity indicated that distortion in the structure of unlaundered knit fabrics is obviously inherent in their manufacture. Also as a result of laundering, there was significantly more shrinkage present in the tightly knitted fabric than there was in the loosely knitted fabric. Therefore changes occurring in the dimensions of knit fabrics during laundering are due to a rearrangement of fabric structure. They further indicated that spiraling effects are common in circular-knit fabrics since there can be no crosswise alignment of circular knit goods and since tension is automatically controlled during the knitting process in the lengthwise direction only. Changes in fabric structure therefore may occur in the fabric when it is released from the tension of the knitting machine.

According to Fletcher and others (13), dimensional changes of knit goods during laundering varies with the type of construction and the number of courses per inch. The greatest change takes place during the first laundering. A study of the relationship of loop shape to dimensional change in laundering of plain-knit cotton "T" shirts by Fletcher and Roberts (14), revealed that the change in dimensions during laundering of cotton "T" shirts depends on the ratio of w/p (width of the loop, w / length of the loop, p). Size of yarns, weight per square inch, and bursting strength were not related to the dimensional change. A linear relationship was found between the dimensional changes in length and width and the w/p ratio. Those with ratios greater than one changed the least in dimensions and seldom stretched. The loops were shortened by laundering and the width of loops became greater than the length.

According to Fletcher and Roberts' study (15) which compared the effects of tumbler drying and screen drying on cotton knit fabrics, tumbler drying tended to consolidate the loop construction of knit fabrics, and the dimensional change was different from that of screen drying. The shrinkage in length of tumble dried fabric ranged from 15 to 36 per cent as compared to 11 to 30 per cent of screen dried fabric. In width, there was 6 to 44 per cent stretch with tumbler drying as compared with 3 per cent shrinkage and 63 per cent stretch with screen drying. Most knit fabrics shrank from 20 to 25 per cent in area with tumbler drying, but only 10 to 15 per cent with screen drying. These results indicated, in general, that there was greater dimensional change in area with tumbler drying than with screen drying. Also the results of the study by Fletcher and Roberts (14), showed that the lengthwise shrinkage was greatly increased with tumbler drying.

According to Smith (34), tumbler drying of knit fabrics after washing usually adds 5 per cent more shrinkage than that of screen drying. However, the construction of the fabric must also be taken into consideration, as an 8 per cent shrinkage might be considered poor for certain knit goods but good for others. The Task Group (38) stated in the reports on knit fabrics that shrinkage of knit fabrics is desirable for some garments. Fabrics with zero shrinkage were not acceptable for such garments as "T" shirts and a substantial shrinkage in the length was not desirable in fabrics used for women's skirts. According to Smith (34), the minimum or maximum shrinkage specifications for washing knit goods still remains uncertain. Most of the relaxation shrinkage control processes used in manufacturing knit fabrics are aimed toward producing a fabric with 3 to 5 per cent shrinkage based on screen drying. Perhaps the minimum shrinkage control of knit goods would be a combination of mechanical shrinkage control in conjunction with a resin treatment in the production of knit fabrics. Although methods have long been used for removing shrinkage at the finishing plant once and for all with woven cotton goods, it was only recently that there has been any successful method for controlling shrinkage of cotton knit goods. The newest method developed for making washable cotton knit fabrics (29) has had the claim made for it that it will control the lengthwise shrinkage of cotton knit fabrics to only 1 per cent and will retain about the same dimensions during the useful life of the fabric.

Change in Color

There are many factors which may contribute to the amount and the character of color change of textile materials under the action of light and atmosphere. According to Galle (18), some of the most important factors causing changes are: (1) intensity and spectral distribution of the radiant energy in sunlight and skylight, (2) duration of exposure, (3) variations in intensity in a 24 hour period, (4) humidity, and (5) temperature.

There is a cumulative effect of light combined with atmospheric contaminants which does not occur when various factors are applied individually. In many cases peculiarities in fading have been attributed to moisture sensitivity (28).

Research developments committee of the American Association of Textile Chemists and Colorists (AATCC) on colorfastness to light report on "A Critical Evaluation of Some of the Various Methods of Conducting Lightfastness Tests" (28) indicated that the present carbon-arc-lamp method (or Fade-Ometer Exposure method) produces results which agree closely with the results of the Sunlight Exposure method. By the latter method, samples are exposed under glass only between the hours of 9 A.M. and 3 P.M. on sunny days. The report also stated that a much better correlation with daylight exposures can be obtained by modifying the Fade-Ometer so that it can be operated on a cycle of 3.8 hours of light at a black panel temperature of 145°F followed by a period of one hour during which the carbon-arc-lamp is turned off, and a relative humidity (R.H.)

of 85 to 95 per cent is maintained in the test chamber.

According to Graber (19), samples exposed in Fade-Ometers with black panel temperature over 175°F showed a considerably faster rate of fading with a greater tendency to be scorched or burned than did those in Fade-Ometers with black panel temperatures below 175°F. Also no abnormal color change or fading was noticed between spring and summer outdoor tests and between the various Fade-Ometer tests when the black panel temperatures were below 175°F.

The colorfastness of dyed fabrics to washing is one of the important end-use properties of a textile. The test procedures used must be independent of the fiber content (35). The research developments committee of the AATCC on colorfastness to washing (35) reported that the use of synthetic detergents or fluorescent dyes in the washing process have a negligible effect on the test result of colorfastness to washing of textiles.

Various methods are available for the evaluation of color changes. Some of the most common ones are the multifiber test fabric and the color transference chart which have made possible a better evaluation of staining, the International Grey Scale (IGS) which is a simple method for measuring small color changes accurately (35), and the spectrophotometric specification of color which is a simple but accurate objective method (20).

Color Specification

Color is a common household word. The response or sensation resulting from looking at a colored object depends to a considerable extent upon the nature of the surrounding color field and the nature of the field to which the observer has previously been exposed. In general, a physical method of color specification is used rather than a chemical method. The specifications for colored objects must be based on accurate objective measurements such as that provided by the spectrophotometric specification of color (20).

In order to place the measurement and specification on a scientific basis, the International Commission on Illumination (I.C.I.) adopted a standard which by means of instrumental measurements provides a highly precise method for evaluating and analyzing color, controlling color systems, and for correlating results obtained in different laboratories (4).

Colors can be expressed in terms of wavelength. The unit of length used to specify the wavelength of visible radiation is the millimicron (mu) and 25,400,000 mu is equivalent to one inch in length. Each color has its specified spectral region such as violet at 400 to 450 mu, blue at 450 to 500 mu, green at 500 to 570 mu, yellow at 570 to 590 mu, orange at 590 to 610 mu, and red at 610 to 700 mu (20).

In general, no two persons' color responses are the same, but the differences are very small unless a person suffers from some degree of color blindness. The color vision of normal human observers is tridimensional, that is a mixture of the three primary colors (red, green, and blue) and only one set of the three primaries will produce a color match. Any given color can be specified in terms of the relative amounts of three primary colors defined by the Commission International d'Eclairage (C.I.E.). The amounts of the three C.I.E. primaries are designated by X, Y, and Z - the tristimulus values. X, Y, and Z values can be calculated from a spectrophotometric curve or from point-by-point data from a spectrophotometer. The results obtained will not only depend on the curves but also on the type of illumination under which the sample is to be observed. Illuminant C, a source having the spectral distribution of energy, is one of the international standards for illumination to be used for the purpose of colorimetry and is the best representative of average daylight which has been used most widely. Other illuminants, such as Illuminant A which is a source having an energy distribution similar to that of a gas-filled tungsten lamp and Illuminant B which is a source having an energy distribution similar to average noon sunlight and being intermediate between Illuminant A and C, are used under special conditions (4, 20).

Although tristimulus values, X, Y, and Z, are specifications of colors, the use of these does not allow one to indicate the nature of the color difference between samples when a difference exists. More information is supplied if the color is specified in terms of dominant wavelength, purity and brightness (or visual efficiency), or trichromatic coefficients x and y and tristimulus value Y. These parameters can be understood better because they relate closely to the three psychological attributes - hue, saturation, and value (20).

Trichromatic coefficients of a color are the ratio of any one of the tristimulus values to the sum of the tristimulus values. Quality of color is defined by these three coefficients.

$$x = \frac{X}{X+Y+Z} \qquad y = \frac{Y}{X+Y+Z} \qquad z = \frac{Z}{X+Y+Z}$$

and $x+y+z = 1$

Only two of the three coefficients are independent since the sum of x, y, and z must equal unity regardless of the tristimulus values - X, Y, and Z. Trichromatic coefficients x and y have generally been selected for the purpose of establishing a color specification.

Dominant wavelength is defined as wavelength of spectral region with which each color is most closely identified when illuminated by daylight, or it may be defined as a wavelength of spectrum color required to give a color match for an unknown sample. The dominant wavelength indicates what hue the color will be and what part of the spectrum will have to be mixed with the neutral standard. Purity is a measurement of the saturation of the dominant wavelength with respect to the illuminant and it indicates the degree of approach of the unknown color to the spectrum color so designated or it is simply a ratio of the amounts of two parts making up the combination. Purity is computed by determining on the chromaticity diagram (20) the relative distances of sample points and the corresponding spectrum point from the illuminant point. Brightness or visual efficiency (Y) is computed by determining the value of tristimulus value Y for a surface. Brightness also depends upon the spectral quality of the illuminant, hue, and purity. The Y value is the luminance if the color exists in a self-luminous area; the reflectance, if the color belongs to an opaque object; or the transmittance, if it belongs to a transparent object (20, 22, and 25).

When light falls on an object, a portion of light is reflected, a portion is absorbed, and the rest is transmitted. An object is said to be opaque when the transmitted portion is negligible and an object is said to be transparent when the transmitted portion is too large to be ignored. Many objects which are ordinarily assumed to be opaque have a measurable transmission factor. This is true in the cases of textile fabrics, paper and films of paint, ink, lacquer or enamel. For such materials, information concerning the opacity can be acquired by measuring the diffuse reflection factors with both white and black backings. This type of measurement demonstrates that opacity is a function of wavelength, even in case of nearly white materials (20).

Colorimeters are instruments which synthesize an equivalent stimulus (20). A tristimulus colorimeter is a visual colorimeter, in which the comparison field is illuminated by three lights of different fixed colors. The intensity of each light can be independently adjusted. The purpose of the visual colorimeter is to obtain three C.I.E. primaries as a specification of color in a direct and simple way (22). Since color matchings conducted from a tristimulus colorimeter sample only a very small area of the color samples, the application of tristimulus colorimeters in industrial product-control problems have been relatively discouraging, but because of the ease of calibration and the simplicity of the theory (Grassmann's law) it is a rather useful visual research tool (22).

A spectrophotometer is an instrument used to measure the fundamental properties of an object with respect to color. It must have a built-in illuminating device to be applicable to studies of the color reflectance of objects. The quantities measured by the spectrophotometer depend upon the illuminating and viewing conditions. For transparent objects, the illuminating quantity is spectral transmittance, and for opaque objects, it is spectral reflectance. Readings obtained with a spectrophotometer are independent of an observer's eyes. Spectrophotometry is the experimental procedure for determining the energy distribution of a source of light. Although tristimulus values do not provide as much information as trichromatic coefficients do, they can be derived from spectrophotomatic data by a computation procedure. They do provide a fundamental basis for a language of color. One of the useful applications of spectrophotometry is the color identification of an unknown colored object (20, 25).

The Bausch and Lomb "Spectronic 20" Spectrophotometer with self-contained reflectance unit can be used as a colorimeter, a spectrophotometer, or a reflectometer (30). The instrument can measure colors of small areas on patterned or vari-colored textiles, wall paper, plastic, ceramic, etc. It can be used for a colorimetric analysis. Any 20 mu band in 400 to 700 mu for transmittance or reflectance measurement can be selected from the instrument. A point of light of the chosen wavelength is focused on the surface of the sample and the white integrating sphere "adds up" all the reflected light and converts it into a per cent reflectance or transmittance reading. A magnesium carbonate block supplies a 100 per cent standard and a white porcelain disc inside the cover of the integrating sphere as a working standard is calibrated against the carbonate block. Not only solid samples but powder and liquid samples as well may be measured with this instrument by containment in glass cells.

As a basis for color specification, a spectrophotometric curve or table of data is not adequate. For adequate color specification with tolerance, the spectrophotometric data must be converted into a form of tristimulus specification by means of methods discussed later and by means of a standard observer, a standard coordinate system, and a standard illuminant. Any given color then can be specified in terms of the relative amounts of three C.I.E. primaries needed to produce that color (20).

There are two commonly used methods available for determining the tristimulus values, the weighted ordinate method and the selected ordinate method. The selected ordinate method is used most frequently because of its convenience. This method involves the use of a simple adding device. It is often used for color measurement for ceramics, plastics, textiles, paints, dyes, paper, ink, leather goods, and other industries in which uniformity of color is required. Depending on the accuracy required and shape of the spectrophotometric curve, the number of selected ordinates are chosen. Ten selected ordinates give significant information, but thirty selected ordinates are recommended for most work. As the number of selected ordinates is increased, proportionally smaller color differences can be reliably measured. This method can be applied to either transparent or opaque samples. In the selected ordinate method, tristimulus values X, Y, and Z are obtained by adding the measured reflectances or transmittances at specified wavelengths and then these are multiplied by listed correction factors. Bausch and Lomb "Spectronic 20" Spectrophotometer is provided with a specially designed chart called a B & L Trichromatic Coefficient Computing Form for Illuminant C which will convert the per cent reflectance readings from the instrument directly at each of ten wavelength settings from 415 to 685 mu into tristimulus values X, Y, and Z without the application of the respective multiplying factors (30).

The tristimulus values then are converted into trichromatic coefficients x, y, and z. These chromatic coefficients are then interpolated into graphical chromaticity diagram (a x, y diagram) for the determination of dominant wavelength and purity of color. The brightness or visual efficiency is equal to the stimulus value Y. A chromaticity diagram in which each point represents the chromaticity, is independent of the luminance of a color. In Hardy's (1936) "The Handbook of Colorimetry," a key diagram and a set of large scale chromaticity diagrams are provided. By means of these diagrams, a relationship of one color to the other, or a comparison of the same color before and after treatment, is immediately available (4, 6, and 20).

CHAPTER III

METHOD OF PROCEDURE

The colorfastness and the dimensional stability of sweat shirts made of 100 per cent cotton were determined and evaluated by both objective and subjective methods. The effects of sunlight, laundering (followed by screen drying), and laundering followed by tumbler drying upon the colorfastness of sweat shirts were measured separately. The effects of laundering and laundering followed by tumbler drying on the dimensional stability of sweat shirts were measured also.

The tests conducted in this study were done according to Federal Specification Methods ccc-T-191b (10), Standards on Textile Materials set up by the ASTM (American Society for Testing Materials) Committee D-13 (2), the Commercial Standards CS 146-55 (44), Federal Standard DDD-S-751 (11), and Standards set up by the AATCC (American Association of Textile Chemists and Colorists) (5).

Selection of Sweat Shirts

According to the results of a three-week fashion count and of interviews, three brands of 100 per cent cotton sweat shirts and three colors of each brand were selected on the local open market.

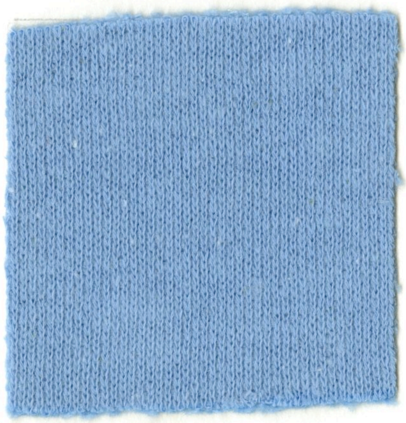
The three brands selected were designated as brand A, B, and C. Three lots of each brand were selected, the lots being designated by the different colors, black, navy blue, and light blue. Four sweat shirts of each lot and brand were purchased, making a total of thirty-six sweat shirts. Sweat shirts were constructed of plain filling knit and various parts of the sweat shirts were simply cut and sewed together. All had plain round double-looped necklines and long sleeves except for those of brand C in which only short sleeves were available. Sweat shirts of brand A and B were of the same size, XL (extra large), and those of brand C were of size, L (large), since XL was not available. Sweat shirts of brand A cost $2.69 per shirt and had white letters decorating the front of the sweat shirts. No care instructions for the garments were provided by the manufacturer. Sweat shirts of brand B had a price of $2.98 and were decorated with white designs on the front of each shirt. Simple care instructions for the garments were provided by the manufacturer. Sweat shirts of brand C had a price of $1.69 and there were no designs on them. Simple care instructions for the garments were provided by the manufacturer. Samples of sweat shirts of all brands as purchased are shown in Plates I, II, and III.

The sweat shirts were divided into four sets, each set being composed of one sweat shirt of each brand and lot. One set was used as purchased in the analysis of the fabrics and the construction of the sweat shirts. In addition it was used in evaluating the colorfastness of the sweat shirts to sunlight. A second set, not treated, was used as a standard for subjective evaluation. A third set, laundered and screen dried, was used to determine the effect of laundering on the colorfastness and on the dimensional stability of the sweat shirts, and a fourth set was laundered and tumble dried to determine the effect of laundering and tumbler drying on the colorfastness and one the dimensional

PLATE I SAMPLES OF SWEAT SHIRTS (BRAND A)

BLACK

NAVY BLUE

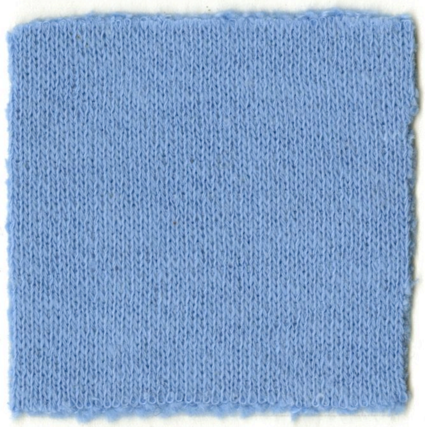


LIGHT BLUE

PLATE II SAMPLES OF SWEAT SHIRTS (BRAND B)

BLACK

NAVY BLUE

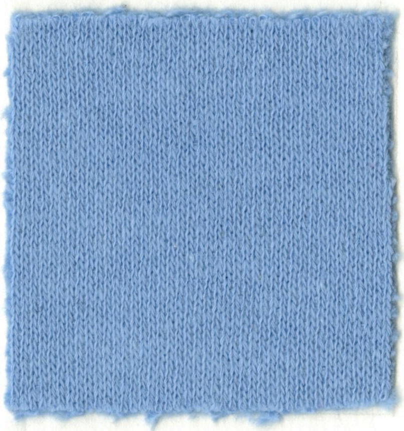


LIGHT BLUE

PLATE III SAMPLES OF SWEAT SHIRTS (BRAND C)

BLACK

NAVY BLUE



LIGHT BLUE

stability of the sweat shirts.

Analysis of Sweat Shirts and Fabrics

The fabric of the sweat shirts of each brand and lot, as purchased, was analyzed as to density and type of knit, according to Federal Specifications Method 5070 (10), and as to weight, according to Federal Specifications Method 5041 (10). The construction of the sweat shirts was also analyzed as to the type of seam, stitch, and stitching, according to Federal Standard DDD-S-751 (11). The finishings of necklines, sleeves and bodies were noted also.

Laundering Procedure

Sweat shirts to be laundered (followed by screen drying), and the ones to be laundered and tumble dried, were subjected to the same laundering procedure. Sweat shirts to be laundered and the ones to be tumble dried of the same lot of three brands A, B, and C were laundered together, making a total of six sweat shirts of the same lot in the same washing load. Because of the weight and the bulkyness of the sweat shirts, a total of six sweat shirts completed a washing load. The initial dry weight of the washing load of the black lot was 5.06 pounds, the navy blue lot was 4.81 pounds and that of the light blue lot was 4.83 pounds.

A three ring agitator type automatic washer (Frigidaire's three ring washer, "Imperial" model, WIAR-61, by General Motors) was used for the series of launderings. The machine had an operating cycle of 30 minutes, and it was operated with settings of "normal soil" for the washing cycle, "regular non colorfast" for the fabric selector, and "automatic" for the cold water selector. These settings were those recommended by the handbook for the operation of the washer. The complete operating cycle included: soil, 5 min.; lint away wash, 10 min.; spin, 2 min.; fill, 3 min.; lint away rinse, 5 min.; and dry, 5 min. As recommended by the handbook for the operation of the washer, a sufficient amount of low-suds synehetic detergent (3/4 cup) was used to give adequate running suds. The washer was allowed to complete the full operating cycle. The average water temperature during the washing cycle was $44 \pm 2^{\circ}$ C and the hardness of the water was 10 ppm. The total hardness of laundering water was determined with the taylor Total Hardness Set, using the EDTA method (40), based on a titration with a standard solution of disodium ethylene diamine tetraacetate. The water at the beginning of the cycle had an average pH of 8.41. The water and detergent mixture at the end of agitation had an average pH of 8.97, and the water after the last rinsing had an average pH of 8.62.

Sweat shirts, to be laundered only, of the same lot of three brands were screen dried by placing them on horizontal screens at room temperature allowing air to circulate freely about them until the shirts were completely dried. Care was taken not to distort the sweat shirts in any way.

Sweat shirts, to be tumble dried, of the same lot of three brands were dried together, making a total of three sweat shirts of the same lot in each load to be dried. The tumble drier (Frigidaire's Wrinkles-Away

Dryer, "Imperial" model, DIAF-61, by General Motors) had an operating cycle of 53 minutes, when set on "Bulky - automatic drying." The drying cycle was that recommended by the handbook for operation of the drier. Sweat shirts to be tumble dried were allowed to complete the operating cycle in the drier. Tumble dried sweat shirts were removed from the drier and placed on a flat surface and allowed to cool to room temperature. Hereafter, when fabrics or sweat shirts are referred to as being tumble dried, this is taken to mean that they had also been laundered by the above mentioned procedure. The sweat shirts were laundered and dried a total of 15 times.

Colorfastness to Sunlight

Fabric strips of the sweat shirts of each lot and brand were exposed in the Fade-Ometer in accordance with AATCC method 16A-1957 (5) in order to determine colorfastness of the fabrics. Specimen were exposed for a total of 40 Standard Fading Hours (SFH), thus conforming to the hours set by the Hatch Textile Research, Textile Technologists and Testing Laboratory for the Minimum Fade-Ometer Tolerances considered as satisfactory for normal use of textile products (9).

Four specimen of the fabric of each sweat shirt were prepared and assigned to one of the various time lengths of Fade-Ometer exposure which were 5, 10, 20, and 40 SFH. The black panel temperature during the continuous operation cycle was $145 \pm 5^{o}F$ (28).

The color change of the fabric of the sweat shirts due to sunlight was determined by the B & L Spectronic Colorimeter 20 with Reflectance

Attachment (30). Ten readings at specified wavelengths were taken at each of the three locations on each specimen, making a total of thirty readings for each fabric. Separate readings were taken on the original fabric and after 5, 10, 20, and 40 SFH of exposure in the Fade-Ometer.

Colorfastness to Laundering and to Tumbler Drying

Color change of sweat shirts due to launderings and dryings was determined by the use of Bausch and Lomb Spectronic Colorimeter 20 with Reflectance Attachment (30). The three selected positions of the sweat shirts for reflectance reading were: lower front, front shoulder, and upper back. Ten readings were taken in each selected position at ten specified wavelengths, making a total of thirty readings for each sweat shirt. Readings were taken as purchased and again after 1, 5, 10, and 15 launderings and dryings in the same positions of the sweat shirts which had been laundered and screen dried and those which were laundered and tumble dried.

Dimensional Stability of Fabrics

A 10-inch square was marked on each sweat shirt. Markings were placed at the corners and at the center of each edge of the square. Two sweat shirts, one to be laundered and one to be laundered and tumble dried, of each lot and brand were so marked with fine sewing thread. The lengthwise distances were parallel to the wales and the crosswise distances were perpendicular to the wales, thus conforming to ASTM Designation D 1470-57T (2). The distances were measured after 1, 5, 10, and 15 launderings or tumbler dryings.

Dimensional Stability of Sweat Shirts

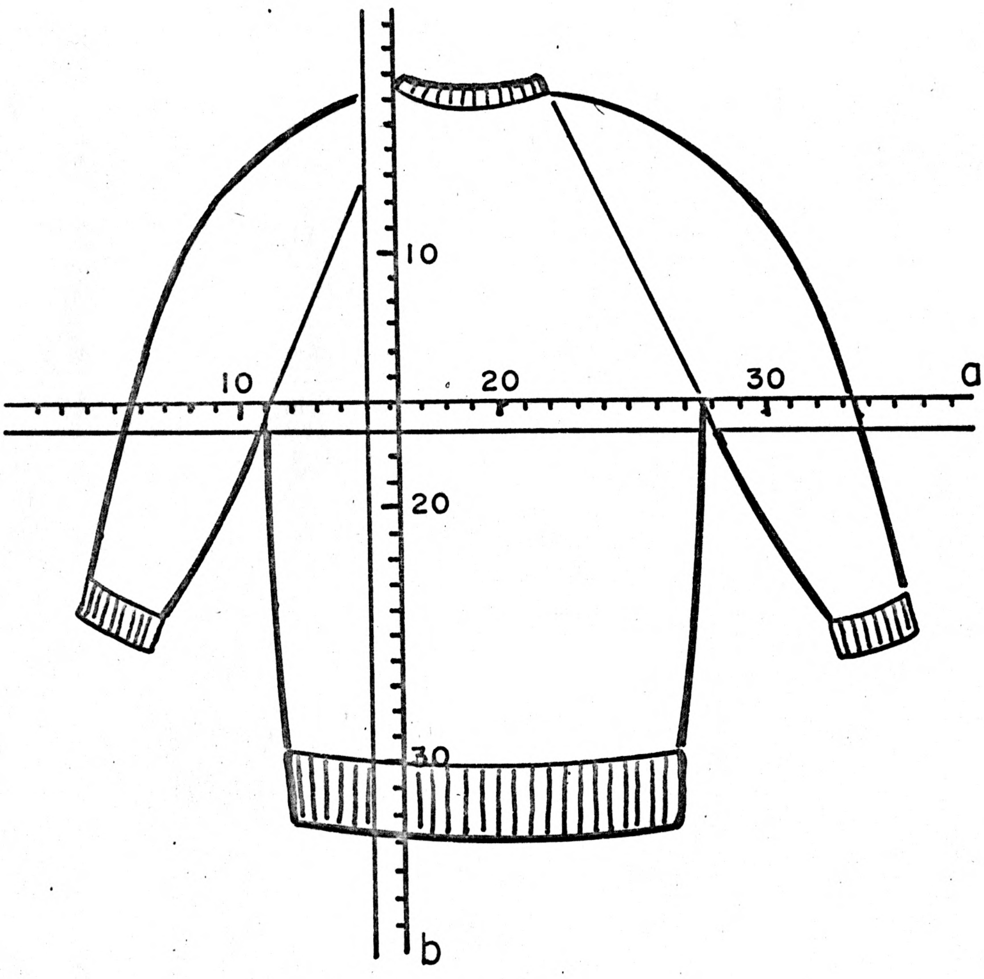
Two measurements, lengthwise and crosswise, of the sweat shirts of each lot and brand, being laundered and being laundered and tumble dried, were taken as measure of the overall dimensions of the sweat shirts. These measurements conformed to Commercial Standard CS 146-55 (44). The two measurements of each treated sweat shirt were taken as purchased and after 1, 5, 10, and 15 treatments. Sweat shirts were measured lengthwise from the shoulder seam next to the neck opening to the bottom of the sweat shirts and crosswise below the armscyes (Figure 1).

Method of Evaluation

Objective Evaluation

The objective evaluations were: the readings taken to determine colorfastness of the sweat shirts before and after Fade-Ometer Exposure; the readings taken to determine colorfastness of the sweat shirts before and after launderings, and before and after tumbler dryings; the measurements taken to determine dimensional stability of the fabrics which had been laundered (followed by screen dryings), and laundered and tumble dried; and the measurements taken to determine dimensional stability of the laundered and of the tumble dried sweat shirts.

FIGURE I



Two measurements as a measure of overall dimensions of 'sweat shirts:

a. Crosswise measurement

b. Lengthwise measurement

Colorfastness to Sunlight, to Laundering, and to Tumbler Drying. Using the B & L Trichromatic Coefficient Computing Form for Illuminant C (30) and the chromaticity diagram given in Hardy's (1936) "The Handbook of Colorimetry" (20), color was expressed in terms of dominant wavelength (mu), purity (%), and brightness (%). Related detailed information has been discussed on pages 20 and 21. The amount of color change which the sweat shirts underwent after 5, 10, 20, and 40 SFH of exposure in the Fade-Ometer and the amount of color change which the sweat shirts underwent after 1, 5, 10, and 15 launderings and dryings were determined. The variations between the sweat shirts which were laundered and those which were laundered and tumble dried were analyzed in order to determine whether it was the launderings and/or the tumbler dryings that affected a color change.

The statistical significance of the color change was determined by the analysis-of-variance and the multiple range test at a five per cent level of significance (7, 23).

Dimensional Stability of Sweat Shirts and Fabrics. The percentage change in dimensions which the fabrics and the sweat shirts underwent after 1, 5, 10, and 15 launderings and dryings were determined. The variations between the fabrics and between the sweat shirts, which had been laundered and tumble dried, were analyzed in order to determine whether it was the launderings and/or the tumbler dryings that affected the changes in dimension of the fabrics and the sweat shirts.

The statistical significance of the dimensional change was determined by the analysis of variance and the multiple range test at a five per cent rejection level (7, 23).

Subjective Evaluation

A panel, composed of five members, each of which was experienced in the field of textiles and clothing, evaluated the sweat shirts against the standard in each lot after 5, 10, 20, and 40 SFH for the amount of color change. They also evaluated the amount of color change and the amount of dimensional change of the sweat shirts after 1, 5, 10, and 15 launderings or tumbler dryings against the standard in each lot.

Colorfastness to Sunlight, to Laundering, and to Tumbler Drying. Two sweat shirts of the same lot and brand, one which had been laundered (follow by screen dryings) and the other which had been laundered and tumble dried, were evaluated against the standard under a day light lamp for the amount of color change. Each specimen of the fabrics after a certain number of SFH was evaluated under a day light lamp against the standard for the amount of color change due to sunlight.

Dimensional Stability of Sweat Shirts. Two sweat shirts of the same lot and brand, one which had been laundered only and the other which had been laundered and tumble dried, were evaluated against the standard, for the amount of dimensional change, by laying them flat without tension at the side of the standard on a flat surface.

The panel members did not know the treatments given to the specimens nor the brand of the specimens which they were examining. Each member was instructed to use her own judgment and was given as much time as needed to mark answers. The evaluation sheet forms are shown in the Appendix.

Dimensional change and color change were evaluated on a five-point rating scale, scaled as follows: "no change", "slight change", "moderate change", "more change than acceptable", and "excessive change". These evaluations were assigned a numerical score, with "no change" given a score of five, "slight change" a score of four, "moderate change" a score of three, "more change than acceptable" a score of two, and "excessive change" a score of one.

The numerical scores were then analyzed statistically as were those for objective evaluations for the significance of the amount of change in dimension and in color.

CHAPTER IV

FINDINGS AND DISCUSSION

Analysis of Sweat Shirts and Fabrics

The bodies and sleeves of the sweat shirts were plain filling-knit, while the ribbings of the necks, cuffs, and bottoms of the sweat shirts were a one-by-one rib-knit. None of the fabrics of the sweat shirts were balanced as to the number of wales and courses per inch. As is shown in Tables 1, 2, and 3, the number of courses exceeded the number of wales per inch in all cases. The number of courses per inch ranged from as few as 23.8 as in the cases of the black and the light blue sweat shirts of brand C to as many as 26.5 as in the case of the black sweat shirt of brand A. The number of wales per inch varied from a minimum of 19.3 as in the navy blue sweat shirt of brand B to a maximum of 22.0 as in the black sweat shirt of brand A. The black shirt of brand A was the most closely knitted, with 26.5 courses and 22.0 wales per inch and the navy blue shirt of brand B was the most loosely knitted, with 24.2 courses and 19.3 wales per inch.

All parts of the sweat shirts were cut-and-sewed together and all had plain round necks of double-looped design with seam types BSa-2, SSh-2 and BSb-2, and SSh-2 used in brands A, B, and C, respectively. All seams and stitches were classified according to Federal Standard DDD-S-751 (11). All of the sweat shirts were sewed with various combinations of stitch types 602 and 504, as is shown in Tables I, II, and III on pages 37, 38, and 39.

TABLE I

ANALYSIS OF SWEAT SHIRTS (BRAND A)

	Sweat Shirts		
	Black	Navy Blue	Light Blue
Fiber Content	Cotton	Cotton	Cotton
Weight (ounces/sq.yd.)	9.88	10.50	8.92
Density of Fabric			
Courses per inch (c)	26.5	25.7	25.3
Wales per inch (w)	22.0	20.8	21.7
w/c ratio	0.83	0.81	0.86
Type of knit			
Body and sleeves	plain	plain	plain
Ribbing	one-by-one rib	one-by-one rib	one-by-one rib
Seam Construction			
Armscye:			
Type of seam	FSa-1	FSa-1	FSa-1
Type of stitch	607	607	607
Stitches per inch	11	12.5	11.9
Waistline ribbing:			
Type of seam	FSa-1	FSa-1	FSa-1
Type of stitch	607	607	607
Stitches per inch	11.5	13.6	13.3
Shoulder:			
Type of seam	—	—	—
Type of stitch	—	—	—
Stitches per inch	—	—	—
Underarm:			
Type of seam	FSa-1	FSa-1	FSa-1
Type of stitch	607	607	607
Stitches per inch	10.5	11.8	11.3
Cuff ribbing:			
Type of seam	FSa-1	FSa-1	FSa-1
Type of stitch	607	607	607
Stitches per inch	13	14	14
Neckline ribbing:			
Type of seam	BSa-2	BSa-2	BSa-2
Type of stitch	602	602	602
Stitches per inch	10.5	10	10.3
Style			
Sleeve	Raglan, long	Raglan, long	Raglan, long
Neckline	plain round	plain round	plain round

TABLE II

ANALYSIS OF SWEAT SHIRTS (BRAND B)

	Sweat Shirts		
	Black	Navy Blue	Light Blue
Fiber Content	Cotton	Cotton	Cotton
Weight (ounces/sq.yd.)	11.09	9.26	10.40
Density of Fabric			
Courses per inch (c)	25.5	24.2	25.2
Wales per inch (w)	21.2	19.3	21.7
w/c ratio	0.83	0.80	0.87
Type of knit			
Body and sleeves	plain	plain	plain
Ribbing	one-by-one rib	one-by-one rib	one-by-one rib
Seam Construction			
Armscye:			
Type of seam	FSa-1	FSa-1	FSa-1
Type of stitch	607	607	607
Stitches per inch	11	11	10.5
Waistline ribbing:			
Type of seam	FSa-1	FSa-1	SSh-2
Type of stitch	607	607	602,504
Stitches per inch	13.1	13.6	10.8
Shoulder:			
Type of seam	—	FSa-1	—
Type of stitch	—	607	—
Stitches per inch	—	10.8	—
Underarm:			
Type of seam	FSa-1	FSa-1	FSa-1
Type of stitch	607	607	607
Stitches per inch	10	12	10.3
Cuff ribbing:			
Type of seam	FSa-1	FSa-1	FSa-1
Type of stitch	607	607	607
Stitches per inch	12.4	12.5	10.5
Neckline ribbing:			
Type of seam	SSh-2	BSb-a	SSh-2
Type of stitch	602, 504	602	602, 504
Stitches per inch	8.8	11.8	9.5
Style			
Sleeve	Raglan with gussets, long	Set-in, long	Raglan with gussets, long
Neckline	plain round	plain round	plain round

TABLE III

ANALYSIS OF SWEAT SHIRTS (BRAND C)

	Sweat Shirts		
	Black	Navy Blue	Light Blue
Fiber Content	Cotton	Cotton	Cotton
Weight (ounces/sq.yd.)	10.06	10.06	9.37
Density of Fabric			
Courses per inch (c)	23.8	24.5	23.8
Wales per inch (w)	21.7	21.0	21.0
w/c ratio	0.91	0.86	0.88
Type of knit			
Body and sleeves	plain	plain	plain
Ribbing	one-by-one rib	one-by-one rib	one-by-one rib
Seam Construction			
Armscye:			
Type of seam	FSa-1	FSa-1	FSa-1
Type of stitches	607	607	607
Stitches per inch	12	10.9	10.9
Waistline ribbing:			
Type of seam	SSh-2	SSh-2	SSh-2
Type of stitch	602, 504	602, 504	602, 504
Stitches per inch	9.8	10.5	9
Shoulder:			
Type of seam	--	--	--
Type of stitch	--	--	--
Stitches per inch	--	--	--
Underarm:			
Type of seam	FSa-1	FSa-1	FSa-1
Type of stitch	607	607	607
Stitches per inch	11	10.4	10.9
Cuff ribbing:			
Type of seam	FSa-1	FSa-1	FSa-1
Type of stitches	607	607	607
Stitches per inch	13.4	12.0	12.4
Neckline ribbing:			
Type of seam	SSh-2	SSh-2	SSh-2
Type of stitches	602, 504	602, 504	602, 504
Stitches per inch	11	9.5	9.4
Style			
Sleeve	Raglan, short	Raglan, short	Raglan, short
Neckline	plain round	plain round	plain round

The seams of the armscye, underarm and the cuff ribbing of brands A, B, and C sweat shirts, the waistline ribbing of brands A and B shirts, and the shoulder seam of the navy blue shirt of brand B were seam type FSa-1 and were sewed with stitch type 607. The waist ribbing seams of brand C sweat shirts were seam type SSh-2 and were sewed with stitch types 602 and 504 (Tables I, II, and III). The seams were stitched securely and covered with overlock stitches to keep the edges from raveling and were reinforced at the ends. None of the bodies of the sweat shirts had side seams.

The sleeves of all the sweat shirts were of the raglan style, except those of the navy blue shirt of brand B which were of the set-in style with shoulder seams. The raglan style sleeves in the black and light blue sweat shirts of brand B had gussets inserted at the underarms. All the sleeves were long with the exception of those of brand C sweat shirts which were short.

In all cases the ribbings were double-looped and the fiber content of the sweat shirts was cotton. The weight of the sweat shirt fabrics in ounces per square yard ranged from a minimum of 8.92 as in the case of the light blue shirt of brand A to a maximum of 11.09 as in the case of the black shirt of brand B (Tables I, II, and III).

Objective Evaluation of Colorfastness

The color change which was expressed in terms of dominant wavelength (mu), purity (%), and brightness (%), was determined by the use of the B & L Trichromatic Coefficient Computing Form for Illuminant C (30) and the chromaticity diagram (20). The hypotheses of no difference were tested at the five per cent level of significance, using the F distribution in a fixed effect, two-way classification, analysis-of-variance (7). The significant differences resulting from the analysis-of-variance test were further analyzed according to "The New Multiple Range Test" (23) for establishing significant differences among several means.

Colorfastness to Sunlight

All of the sweat shirts after exposure in the Fade-Ometer for 40 SFH showed some color changes as indicated in Table IV. A comparison between exposure times and a comparison between colors of all sweat shirts were statistically evaluated at a five per cent level of significance and the results are shown in Table V. The sweat shirts of brand A showed a significant amount of change in brightness of color in a comparison between exposure times as well as between colors. Those of brand B showed a significant change in purity of color in a comparison between colors, while brand C sweat shirts showed a significant change in brightness of color for a between colors comparison.

Further statistical analysis by the multiple range test for testing significant difference among means indicated that after 40 SFH the degree of color change in the brightness of the light blue sweat shirt of brand A showed the most significant change (Table V). Since there had been no significant difference between the colors in dominant wavelength and purity, the total color change as a result of exposure in the Fade-Ometer was limited to a change of visual efficiency (or brightness). The black

TABLE IV

NUMERICAL VALUES OF COLORS OF SWEAT SHIRTS, BEFORE AND AFTER 40 SFH OF EXPOSURE IN THE FADE-OMETER

		Dominant wavelength (mu)		Purity (%)		Brightness (%)	
Brand	Color	Before	After	Before	After	Before	After
	Black	480.8	483.5	9.00	7.66	8.33	6.73
A	Navy Blue	477.6	465.0	11.00	8.50	9.74	8.35
	Light Blue	479.2	479.0	25.0	23.80	36.24	38.15
	Black	456.3	460.3	12.60	5.17	9.20	6.00
B	Navy Blue	475.5	477.5	14.90	14.80	8.83	7.49
	Light Blue	478.0	477.0	26.60	26.10	33.42	32.57
	Black	480.7	466.0	14.00	8.15	7.16	5.20
C	Navy Blue	478.9	485.9	19.38	13.10	10.41	8.40
	Light Blue	478.8	480.1	28.00	23.80	32.35	35.56

TABLE V

OBJECTIVE EVALUATION OF COLORFASTNESS OF SWEAT SHIRTS TO 40 SFH OF EXPOSURE IN THE FADE-OMETER

I. Result of the analysis of variance

Brand	Comparison	Dominant wavelength	Purity	Brightness
A	Between Times	n.s.*	n.s.	0.95**
	Between Colors	n.s.	n.s.	0.95
B	Between Times	n.s.	n.s.	n.s.
	Between Colors	n.s.	0.95	n.s.
C	Between Times	n.s.	n.s.	n.s.
	Between Colors	n.s.	n.s.	0.95

II. Result of the multiple range test

	Comparison between exposure times (SFH)				Comparison between colors		
Brand	5	10	20	40	Black	Navy Blue	Light Blue
Purity							
B	—	—	—	—	0.95	n.s.	n.s.
Brightness							
A	n.s.	n.s.	n.s.	0.95	n.s.	n.s.	0.95
C	—	—	—	—	0.95	n.s.	n.s.

Note: *n.s.: Not significant at five per cent rejection level

**0.95: Significance level indicated

sweat shirt of brand B showed the most significant change in purity of color and the black sweat shirt of brand C showed the most significant change in brightness of color. Therefore, the total change in color of sweat shirts of brand B was limited to a change in the saturation of color (or purity of color) in the black sweat shirt, and the total color change in sweat shirts of brand C was limited to the change in visual efficiency of color in the black sweat shirt.

Although partial changes in colors after 40 SFH were noticed, no total color changes in dominant wavelength, purity, and brightness was found in any of the sweat shirts. Therefore, the hypothesis of no change in colors after 40 SFH of exposure in the Fade-Ometer was accepted on the basis of objective evaluation.

Colorfastness to Laundering

All of the sweat shirts after 15 launderings and screen dryings underwent some color change as indicated in Table VI. The sweat shirts of brand A, B, and C, as a result of analysis of variance, showed a significant amount of change in dominant wavelength in a comparison between colors as seen in Table VII. Those of brand B showed a significant change in purity of color in a comparison between the number of launderings and between the three colors. The comparison between colors of the sweat shirts of brands B and C yielded a significant change in brightness of color.

Further statistical analysis by the multiple range test (Table VII) showed that there was no significant difference among dominant wavelengths

TABLE VI

NUMERICAL VALUES OF COLORS OF SWEAT SHIRTS, BEFORE AND AFTER 15 LAUNDERINGS

		Dominant Wavelength (mμ)		Purity (%)		Brightness (%)	
Brand	Color	Before	After	Before	After	Before	After
	Black	486.4	484.3	7.00	5.75	6.90	7.87
A	Navy Blue	565.0	482.3	10.50	16.70	7.55	5.63
	Light Blue	481.0	479.0	26.70	25.60	37.51	39.13
	Black	482.5	470.5	11.00	8.30	6.92	5.55
B	Navy Blue	477.5	476.0	15.40	17.00	7.18	6.60
	Light Blue	478.3	480.0	27.80	35.00	33.33	40.21
	Black	450.0	474.3	8.80	10.00	6.26	4.63
C	Navy Blue	477.5	477.5	13.00	15.00	8.02	6.37
	Light Blue	479.3	481.3	26.20	23.70	35.13	39.20

TABLE VII

OBJECTIVE EVALUATION OF COLORFASTNESS OF SWEAT SHIRTS TO 15 LAUNDERINGS

I. Result of the analysis of variance

Brand	Comparison	Dominant wavelength	Purity	Brightness
A	Between Times	n.s.*	n.s.	n.s.
	Between Colors	0.95**	n.s.	n.s.
B	Between Times	n.s.	0.95	n.s.
	Between Colors	0.95	0.95	0.95
C	Between Times	n.s.	n.s.	n.s.
	Between Colors	0.95	n.s.	0.95

II. Result of the multiple range test

Brand	Comparison between the number of launderings				Comparison between colors		
	1	5	10	15	Black	Navy Blue	Light Blue
Dominant wavelength							
A	—	—	—	—	n.s.	n.s.	n.s.
B	—	—	—	—	n.s.	n.s.	n.s.
C	—	—	—	—	0.95	n.s.	n.s.
Purity							
B	n.s.	n.s.	n.s.	0.95	0.95	n.s.	n.s.
Brightness							
B	—	—	—	—	n.s.	n.s.	0.95
C	—	—	—	—	n.s.	n.s.	0.95

Note: *n.s.: Not significant at five per cent rejection level
**0.95: Significance level indicated

of sweat shirts of brands A and B, although as a whole in the analysis-of-variance evaluation the difference was significant. However, the black sweat shirt of brand C showed the most significant change in dominant wavelength of color after having been subjected to the series of launderings. After 15 home launderings followed by screen dryings significant changes at the five per cent level of significance were found in the black sweat shirt of brand B in a measurement of color purity and in the light blue sweat shirts of brands B and C in measurements of color brightness.

Since there had been no significant change between the colors in dominant wavelength, purity, and brightness of the sweat shirts of brand A, the total change in colors as a result of the laundering test was negligible. The total change in colors of brand B sweat shirts as a result of the series of launderings were limited to the change in saturation (or purity) of the black sweat shirt and visual efficiency (or brightness) of the light blue sweat shirt. The total change in colors of the brand C sweat shirts were due to the change in hue (or dominant wavelength) of the black sweat shirt and the visual efficiency of the light blue sweat shirt.

There were partial changes in colors after the series of treatment but no total changes in colors were found in any of the sweat shirts. Therefore, the hypothesis of no change in colors after 15 home launderings followed by screen dryings was accepted on the basis of objective evaluation.

Colorfastness to Laundering and Tumbler Drying

After 15 home launderings and tumbler dryings, all of the sweat shirts underwent a color change as can be seen in Table VIII. Only the sweat shirts of brand C showed a significant amount of change in dominant wavelength of color in a statistical comparison between colors by means of the analysis-of-variance (Table IX). Those shirts of brands A and C showed a statistically significant difference in purity in a between color comparison. In a comparison between the colors of the brands A, B, and C sweat shirts for brightness, all yielded a significant difference.

Further analysis in a test for differences among means, as indicated in Table IX, showed that there was no significant difference among dominant wavelengths for the sweat shirts of brand C, although as a whole the difference between dominant wavelengths for all brands of sweat shirts was significant. The navy blue shirt of brand A and the light blue shirt of brand C showed the most significant changes in purity of color. The navy blue shirt of brand A, the light blue shirt of brand B and the black shirt of brand C showed the most significant change in brightness of color after having been subjected to 15 launderings and tumbler dryings.

Since there had been no significant change between the colors in dominant wavelength of sweat shirts of brand A, the total change in color as a result of the test was due to the change in color saturation and visual efficiency of the navy blue shirt. The total change in color of brand B sweat shirts as a result of the laundering and tumbler drying was limited to the change in visual efficiency of the light blue sweat shirt. The total color changes of brand C sweat shirts were due to the change in

TABLE VIII

NUMERICAL VALUES OF COLORS OF SWEAT SHIRTS BEFORE AND AFTER 15 LAUNDERINGS AND TUMBLER DRYINGS

Brand	Color	Dominant wavelength (mu)		Purity (%)		Brightness (%)	
		Before	After	Before	After	Before	After
A	Black	470.0	465.0	12.00	10.8	4.95	5.06
	Navy Blue	479.5	473.0	8.80	12.5	8.45	5.85
	Light Blue	479.5	479.3	26.20	25.00	35.77	42.60
B	Black	477.5	466.0	10.00	6.75	6.59	5.92
	Navy Blue	478.0	474.3	16.00	22.20	7.74	5.47
	Light Blue	478.0	479.3	26.60	20.00	33.86	41.98
C	Black	482.5	476.3	11.00	7.70	7.40	4.92
	Navy Blue	479.5	482.1	16.30	12.30	7.72	7.58
	Light Blue	479.5	479.2	25.90	24.50	35.10	41.24

TABLE IX

OBJECTIVE EVALUATION OF COLORFASTNESS OF SWEAT SHIRTS
TO 15 LAUNDERINGS AND TUMBLER DRYINGS

I. Result of the analysis of variance

Brand	Comparison	Dominant wavelength	Purity	Brightness
A	Between Times	n.s.*	n.s.	n.s.
	Between Colors	n.s.	0.95**	0.95
B	Between Times	n.s.	n.s.	n.s.
	Between Colors	n.s.	n.s.	0.95
C	Between Times	n.s.	n.s.	n.s.
	Between Colors	0.95	0.95	0.95

II. Result of the multiple range test

Brand	Comparison Between Colors		
	Black	Navy Blue	Light Blue
Dominant wavelength			
C	n.s.	n.s.	n.s.
Purity			
A	n.s.	0.95	n.s.
C	n.s.	n.s.	0.95
Brightness			
A	n.s.	0.95	n.s.
B	n.s.	n.s.	0.95
C	0.95	n.s.	n.s.

Note: *n.s.: Not significant at five per cent rejection level
**0.95: Significance level indicated

color saturation of the light blue sweat shirt and the visual efficiency of the black sweat shirt.

No total color changes in dominant wavelength, purity, and brightness werefound significant after the series of treatment, although there were partial changes in color. Therefore, the hypothesis of no change in colors after 15 launderings and tumbler dryings was accepted on the basis of objective evaluation.

Objective Evaluation of Dimensional Stability

The hypotheses of no difference were tested at the five per cent level of significance, using the F distribution in a fixed effect, two-way classification, analysis-of-variance (7). The significant differences resulting from the analysis-of-variance test were further analyzed according to the procedure of "The New Multiple Range Test" (23) for testing a significant difference, if there is any, among several means.

Dimensional Stability of Fabrics to Laundering and to Tumber Drying

All of the fabrics of the sweat shirts after the series of launderings with screen dryings and the series of launderings and tumbler dryings underwent some dimensional changes (Table X). All of the fabrics showed shrinkage in the lengthwise direction but showed irregularity in dimensional changes in the crosswise direction. In the lengthwise direction of the fabrics, generally, the greatest change in dimensions took place during the first laundering and during the first tumbler drying. Similar results were also found in Fletcher's study (13).

TABLE X

PER CENT OF DIMENSIONAL CHANGES OF FABRICS AFTER SERIES OF LAUNDERINGS OR TUMBLER DRYINGS

Brand	Color	1		5		10		15	
		Crosswise	Lengthwise	Crosswise	Lengthwise	Crosswise	Lengthwise	Crosswise	Lengthwise
				Laundered					
	Black *	2.50	5.88	0.31	8.75	-2.81	9.81	-1.44	10.00
A	Navy Blue **	1.06	6.38	1.56	8.25	-2.50	10.44	-4.69	10.63
	Light Blue	-0.81	9.63	-3.94	13.88	-2.60	12.31	-6.14	15.13
	Black	-1.63	11.69	-2.19	13.63	-5.81	15.50	-5.44	15.44
B	Navy Blue	4.90	5.63	0.44	12.50	-1.25	12.13	-1.13	13.44
	Light Blue	-1.00	9.00	-3.00	9.81	-3.63	12.31	-2.69	12.19
	Black	-1.13	7.50	-3.50	10.44	-5.19	12.00	-6.25	10.81
C	Navy Blue	1.79	6.63	-0.73	8.03	-7.38	13.65	-6.44	11.56
	Light Blue	-1.88	6.88	-0.19	8.03	-3.94	11.78	-7.00	11.06
				Tumble Dried					
	Black	1.88	6.69	0.25	13.75	0.94	14.38	0	15.13
A	Navy Blue	4.18	11.25	3.03	15.31	2.40	13.88	2.31	17.00
	Light Blue	1.88	14.19	-0.19	19.19	1.50	18.88	0.44	20.00
	Black	2.31	12.50	-1.00	16.38	1.38	17.13	2.31	17.94
B	Navy Blue	6.88	11.25	4.90	17.63	5.25	18.38	4.56	20.19
	Light Blue	4.38	11.25	2.40	16.06	2.94	16.56	2.38	16.44
	Black	2.31	14.25	0	16.78	-2.3	17.75	-0.63	18.94
C	Navy Blue	2.50	11.25	0.31	15.53	-1.13	15.88	0.31	17.31
	Light Blue	2.31	11.75	0.94	16.06	1.15	17.13	1.88	18.44

Note: *No sign indicated shrinkage

**Minus sign (-) indicated stretch

No such indication was noticed in the case of crosswise dimensional changes. The lengthwise and crosswise shrinkage was greatly increased with the laundering and tumbler drying treatment and the crosswise stretch was greatly increased with laundering alone.

The shrinkage in length of the tumble dried fabrics after 15 dryings ranged from a minimum of 15.13 per cent in the fabric of the black sweat shirt of brand A to a maximum of 20.19 per cent in the fabric of the navy blue sweat shirt of brand B. On the other hand, for the fabrics laundered only, the shrinkage in length after 15 launderings ranged from a minimum of 10.0 per cent in the fabric in the case of the black sweat shirt of brand A to a maximum of 15.44 per cent in the fabric in the case of the black sweat shirt of brand B.

In width, there was a 4.56 per cent shrinkage in the fabric of the navy blue sweat shirt of brand B and a 0.63 per cent stretch in the fabric of the black sweat shirt of brand C after 15 launderings and tumbler dryings. These results can be compared with a 1.13 per cent stretch in the fabric of the navy blue sweat shirt of brand B and to a 7.0 per cent stretch in the fabric of the light blue sweat shirt of brand C for 15 launderings.

After the series of launderings and tumbler dryings, there was more lengthwise shrinkage in the loosely knitted fabric as in the case of the navy blue shirt of brand B than was in the tightly knitted fabric as in the case of the black shirt of brand A (Tables I, II, and III). No such trend was noticed in the cases of only laundered fabrics. The maximum crosswise shrinkage in the fabrics as a result of tumbler dryings and the minimum crosswise stretch in the fabrics as a result of launderings were both present in the loosely knitted fabric as in the case of the navy blue shirt of brand B.

There was more crosswise stretch in the fabric with less difference between the number of wales and the number of courses per inch (Tables I, II, and III). The light blue sweat shirt of brand C, after the series of launderings, and the black sweat shirt of brand C, after the series of tumbler dryings, showed more crosswise stretch.

No fabrics reached apparent stability in dimensions as a result of 15 launderings or 15 launderings and tumbler dryings. Launderings (followed by screen dryings) seemed to create more irregularity in the crosswise dimensional changes of the fabrics than did tumbler dryings. No fabric showed the same amount of dimensional change during the series of launderings and the series launderings with tumbler dryings. The launderings tended to create both more lengthwise shrinkage and more crosswise stretch than did the tumbler dryings. Therefore, the launderings alone had a greater effect on the dimensional changes of the fabrics than did the launderings followed by tumbler dryings. The tumbler dryings tended to compensate for the crosswise stretch in the fabrics resulting from the launderings by causing shrinkage in the width. In addition, the tumbler drying caused further lengthwise shrinkage.

The analysis-of-variance of the relative dimensional changes of all the fabrics laundered (followed by screen dryings) showed a significant change in dimensions in comparison between colors and between the number of launderings, with two exceptions. The two exceptions were the brand A fabrics in the comparison between colors in crosswise direction and in the fabrics of brand C in a comparison between colors in both lengthwise and crosswise dimensions (Table XI).

Similar statistical tests of the relative dimensional changes of all the fabrics of the tumble dried sweat shirts, yielded a significant change in dimensions in a comparison between colors and in a comparison between the number of tumbler dryings, with two exceptions. These exceptions were fabrics of brand B in a comparison between the number of dryings for a crosswise dimensional measurement and those fabrics of brand C in a comparison between colors for a crosswise dimensional measurement.

Further statistical analysis by the multiple range test for significant differences among means showed that significant changes in crosswise and lengthwise dimensions occurred in the fabrics of brand A and B after the first laundering and after the first laundering with tumbler drying except crosswise dimension of brand B fabrics (Table XI). Also there were significant changes in both crosswise and lengthwise dimensions in the sweat shirts of brand C after ten launderings and in crosswise dimension after the first laundering and tumbler drying. After 15 tumbler dryings, the relative lengthwise dimensional change of the sweat shirt of brand C also showed a statistical significance.

Since there were significant changes in dimensions of all sweat shirts during the series of treatments when measured objectively, the hypotheses of no significant dimensional change after 15 launderings and after 15 launderings and tumbler dryings were rejected.

TABLE XI

OBJECTIVE EVALUATION OF DIMENSIONAL STABILITY OF FABRICS TO 15 LAUNDERINGS AND TO 15 TUMBLER DRYINGS

I. Result of the analysis of variance

Brand	Comparison	Laundered		Tumble dried	
		Crosswise	Lengthwise	Crosswise	Lengthwise
A	Between Times	0.95**	0.95	0.95	0.95
	Between Colors	n.s.*	0.95	0.95	0.95
B	Between Times	0.95	0.95	n.s.	0.95
	Between Colors	0.95	0.95	0.95	n.s.
C	Between Times	0.95	0.95	0.95	0.95
	Between Colors	n.s.	n.s.	n.s.	0.95

II. Result of the multiple range test

Brand		Comparison between the number of launderings				Comparison between the number of launderings and tumbler dryings			
		1	5	10	15	1	5	10	15
A	Crosswise:	0.95	n.s.	n.s.	n.s.	0.95	n.s.	n.s.	n.s.
	Lengthwise:	0.95	n.s.	n.s.	n.s.	0.95	n.s.	n.s.	n.s.
B	Crosswise:	0.95	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Lengthwise:	0.95	n.s.	n.s.	n.s.	0.95	n.s.	n.s.	n.s.
C	Crosswise:	n.s.	n.s.	0.95	n.s.	0.95	n.s.	n.s.	n.s.
	Lengthwise:	n.s.	n.s.	0.95	n.s.	n.s.	n.s.	n.s.	0.95

Note: *n.s.: Not significant at five per cent rejection level

**0.95: Significance level indicated

Dimensional Stability of Sweat Shirts to Laundering and to Tumbler Drying

All of the sweat shirts after either a series of launderings (followed by screen dryings) or a series of tumbler dryings underwent some dimensional changes as indicated in Table XII. All of the sweat shirts showed a general trend in overall dimensional changes similar to those of the sweat shirt fabrics. The sweat shirts showed a lengthwise shrinkage with irregular crosswise dimensional change as a result of both treatments.

In general, the greatest change in lengthwise dimensions took place after the first treatments. Similar results were also indicated in Fletcher's study (13). No such indication was found in the case of crosswise dimensional change. The crosswise stretch and lengthwise shrinkage were greatly increased with launderings. The lengthwise shrinkage in the sweat shirts was greatly increased with tumbler dryings. After 15 launderings the lengthwise dimensions of the sweat shirts were reduced and the crosswise dimensions were increased. After 15 tumbler dryings, the lengthwise dimensions of the sweat shirts were also decreased while the crosswise dimensions showed no general trend toward change.

As a result of 15 tumbler dryings, the shrinkage in length of the tumble dried sweat shirts ranged from a minimum of 17.06 per cent in the navy blue sweat shirt of brand A to a maximum of 21.83 per cent in the light blue sweat shirt of brand A. This range can be compared to a minimum of 11.50 per cent in the black sweat shirt of brand A to a maximum of 16.56 per cent in the black sweat shirt of brand B when the

TABLE XII

PER CENT OF DIMENSIONAL CHANGES OF SWEAT SHIRTS AFTER SERIES OF LAUNDERINGS OR TUMBLER DRYINGS

		1		5		10		15	
Brand	Color	Crosswise	Lengthwise	Crosswise	Lengthwise	Crosswise	Lengthwise	Crosswise	Lengthwise
				Laundered					
	Black	* 0.57	7.38	-0.57	10.61	-1.43	11.30	-1.71	11.50
A	Navy Blue	** -0.14	6.42	-3.03	9.36	-0.65	11.51	-6.21	12.72
	Light Blue	0.30	8.84	-2.08	14.05	-2.67	14.83	-4.75	16.38
	Black	-0.85	10.04	-0.37	12.30	-3.68	14.83	-4.53	16.56
B	Navy Blue	-0.82	6.25	-4.25	10.24	-3.97	13.33	-4.82	12.28
	Light Blue	-1.72	7.66	-1.58	10.48	-3.45	12.30	-4.88	11.65
	Black	-0.58	8.21	-1.90	10.39	-4.24	12.25	-6.29	14.05
C	Navy Blue	-0.31	6.77	-2.89	9.86	-5.19	12.53	-7.08	12.25
	Light Blue	-2.37	7.00	-1.18	8.73	-3.55	10.80	-6.09	11.75
				Tumble Dried					
	Black	2.83	11.16	2.27	14.06	0.85	16.85	3.04	17.81
A	Navy Blue	4.35	10.82	4.13	14.64	1.40	16.18	2.08	17.06
	Light Blue	0.29	14.89	-0.29	19.07	-0.29	21.46	-0.29	21.83
	Black	0	11.47	-1.15	15.12	-0.86	16.88	-1.01	18.06
B	Navy Blue	2.58	16.82	0	17.25	-0.95	18.34	0	19.30
	Light Blue	-0.57	11.48	-0.85	16.07	-1.14	17.22	-1.56	17.33
	Black	1.34	14.84	-0.89	18.18	-2.97	20.26	-2.52	20.78
C	Navy Blue	3.14	13.26	1.97	17.14	0.94	19.16	1.10	19.40
	Light Blue	0.59	13.73	-0.59	16.78	-1.18	18.61	-1.18	19.39

Note: *No sign indicated shrinkage

**Minus sign (-) indicated stretch

sweat shirts were subjected to 15 launderings.

In width, there was a 2.52 per cent stretch in the black sweat shirt of brand C and a 3.04 per cent shrinkage in the black sweat shirt of brand A after 15 tumbler dryings as compared to a 1.71 per cent stretch in the black sweat shirt of brand A and to a 7.08 per cent stretch in the navy blue sweat shirt of brand C after 15 launderings.

No sweat shirts reached apparent stability in dimensions after having been subjected to 15 dryings by either treatments. On the other hand the tumbler dryings seemed to create more irregularity in the crosswise dimension than did the launderings. No sweat shirts showed the same amount of dimensional change either during the series of launderings or during the series of tumbler dryings. Therefore, both launderings and the tumbler dryings had effects on the dimensional stability of the sweat shirts. The launderings tended to cause more lengthwise shrinkage and crosswise stretch than did the tumbler dryings. Therefore, the launderings had a greater effect on the dimensional changes of the sweat shirts than the tumbler dryings. The tumbler dryings tended to overcome, to a certain extent, the crosswise stretch in the sweat shirts caused by the launderings and even increased shrinkage in both the width and the length of the sweat shirts.

As Table XIII indicated in the analysis-of-variance showed a significant amount of change in the crosswise dimension of all the laundered sweat shirts in a comparison between the number of launderings. In the lengthwise dimension, there was a significant difference in

TABLE XIII

OBJECTIVE EVALUATION OF DIMENSIONAL STABILITY OF SWEAT SHIRTS TO 15 LAUNDERINGS AND TO 15 TUMBLER DRYINGS

I. Result of the analysis of variance

Brand	Comparison	Laundered		Tumble Dried	
		Crosswise	Lengthwise	Crosswise	Lengthwise
A	Between Times	0.95	0.95	n.s.*	0.95**
	Between Colors	n.s.	0.95	0.95	0.95
B	Between Times	0.95	0.95	n.s.	0.95
	Between Colors	n.s.	0.95	n.s.	0.95
C	Between Times	0.95	0.95	0.95	0.95
	Between Colors	n.s.	0.95	0.95	0.95

II. Result of the multiple range test

Brand		Comparison between number of launderings				Comparison between number of launderings and tumbler dryings			
		1	5	10	15	1	5	10	15
A	Crosswise:	n.s.	n.s.	n.s.	0.95	n.s.	n.s.	n.s.	n.s.
	Lengthwise:	0.95	n.s.	n.s	n.s.	0.95	0.95	n.s.	n.s.
B	Crosswise:	0.95	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	Lengthwise:	0.95	0.95	n.s.	n.s.	0.95	n.s.	n.s.	n.s.
C	Crosswise:	n.s.	n.s.	0.95	0.95	0.95	0.95	n.s.	n.s.
	Lengthwise:	0.95	0.95	n.s.	n.s.	0.95	0.95	0.95	0.95

Note: *n.s.: Not significant at five per cent rejection level

**0.95: Significance level indicated

between the number of launderings and between colors. All of the tumble dried sweat shirts, with two exceptions, yielded a significant amount of change in both the crosswise and lengthwise dimensions in comparisons between the number of tumbler dryings and between colors. The exceptions related to the crosswise dimensions of brand A shirts in a comparison between the number of tumbler dryings and those of brand B in comparisons between colors and between the number of tumbler dryings.

Further statistical analysis in a test for the significant differences among the means indicated that there were significant changes in the crosswise dimension after 15 launderings and the lengthwise dimension after one laundering, and after one and five tumbler dryings in brand A sweat shirts (Table XIII). Significant changes occurred in the crosswise dimensions of the brand B sweat shirts after one laundering and in the lengthwise dimensions after one and five launderings and after one tumbler drying.

After 10 and 15 launderings and after one and five tumbler dryings, the crosswise dimensions of the brand C sweat shirts showed a significant change. The lengthwise dimensional changes of brand C sweat shirts showed significant changes after one and five launderings. It was also found that the changes in the lengthwise dimension of the brand C sweat shirts was independent of the number of tumbler dryings.

There were significant changes in dimensions of all sweat shirts during the series of treatments, therefore, the hypotheses of no change after 15 home launderings and after 15 home launderings and tumbler dryings were rejected, on the basis of objective measurements.

Subjective Evaluation

An impartial panel evaluated the sweat shirts after exposure in the Fade-Ometer, after a series of launderings, and after a series of launderings and tumbler dryings for the amount of color change. They also evaluated the sweat shirts after a series of launderings and after a series of tumbler dryings for the amount of overall dimensional change. The evaluations of the panel were statistically analyzed at a five per cent level of significance, using both the analysis-of-variance and the "New Multiple Range Test."

Colorfastness to Sunlight

The panel evaluations indicated that the color of the black sweat shirts of all brands was the least affected by the treatment. The rating after exposure in the Fade-Ometer for 40SFH fell between the rating scales of "no change" and "slight change" (Table XIV). The color of the navy blue sweat shirts of brands A and C were the most affected by the treatment. Their rating after exposure for 40 SFH fell below the rating scale of "more change than acceptable."

According to the analysis-of-variance and the multiple range test, the panel evaluations of the color change of all the sweat shirts in a comparison between colors were significant in the navy blue sweat shirts of brands A and C. When comparing between exposure times, there were significant color changes in sweat shirts of brands B and C only after 40 SFH (Table XV). Therefore, the hypothesis of no change in colors after 40 SFH of exposure in the Fade-Ometer was rejected on the basis of subjective

TABLE XIV

RESULTS OF SUBJECTIVE EVALUATION AVERAGE SCORES OF RATINGS

Number of Treatments	Brand A			Brand B			Brand C		
	Black	Navy Blue	Light Blue	Black	Navy Blue	Light Blue	Black	Navy Blue	Light Blue
A. Colorfastness to Sunlight									
5 hr.	5	3.8	5	5	5	5	5	3.6	4.8
10 hr.	5	2.2	4.6	5	4.6	4.4	5	2.4	4.6
20 hr.	5	1.4	4.0	4.8	3.6	3.8	4.6	1.4	3.8
40 hr.	4.6	1.0	3.8	4.4	2.4	3.6	4.6	1	2.2
B. Colorfastness to Laundering									
1st	4	4	4.4	4.4	4.6	4.4	4.4	4.4	4.6
5th	3.6	3.8	4.2	4.2	3.8	3.4	4.0	4.0	4.0
10th	3	3.6	4.0	3.4	3.6	3.2	3.6	3.2	3.4
15th	2.2	2.6	3.6	3.0	3.4	1.6	1.8	1.8	3.0
C. Colorfastness to Laundering and Tumbler Drying									
1st	4	4	4.2	4	4.2	4.8	4	4	4.6
5th	3.4	3.4	4.2	4	3.8	3.8	4	3.6	4.0
10th	2.8	3.2	3.4	3.4	3.4	3.0	3	2.6	3.2
15th	1.6	1.8	3.2	2.2	1.8	1.4	2.2	1.6	2.6

TABLE XV

SUBJECTIVE EVALUATION OF COLORFASTNESS OF SWEAT SHIRTS

I. Results of the analysis of variance

Brand	Comparison	Colorfastness to sunlight	Colorfastness to laundry	Colorfastness to laundry and tumbler drying
A	Between Times	n.s.*	0.95	0.95
	Between Colors	0.95**	0.95	0.95
B	Between Times	0.95	0.95	0.95
	Between Colors	n.s.	n.s.	n.s.
C	Between Times	0.95	0.95	0.95
	Between Colors	0.95	n.s.	0.95

II. Result of the multiple range test

Brand	Comparison between exposure times (SFH)				Comparison between colors		
	5	10	20	40	Black	Navy Blue	Light Blue
A. Colorfastness to sunlight							
A	—	—	—	—	n.s.	0.95	n.s.
B	n.s.*	n.s.	n.s.	0.95**	—	—	—
C	n.s.	n.s.	n.s.	0.95	n.s.	0.95	n.s.

TABLE XV (cont.)

Brand	Comparison between the number of launderings: 1	5	10	15	Comparison between colors: Black	Navy Blue	Light Blue
B. Colorfastness to launderings							
A	n.s.	n.s.	n.s.	0.95	0.95	n.s.	n.s.
B	n.s.	n.s.	n.s.	0.95	—	—	—
C	n.s.	n.s.	n.s.	0.95	—	—	—

Brand	Comparison between the number of launderings and dryings: 1	5	10	15	Comparison between colors: Black	Navy Blue	Light Blue
C. Colorfastness to launderings and tumbler dryings							
A	n.s.	n.s.	n.s.	0.95	n.s.	n.s.	n.s.
B	n.s.	n.s.	n.s.	0.95	—	—	—
C	n.s.	n.s.	0.95	0.95	n.s.	0.95	n.s.

Note: *n.s.: Not significant at five point rejection level

**0.95: Significance level indicated

evaluation.

Colorfastness to Laundering and to Tumbler Drying

The panel evaluations as indicated in Table XIV showed that the color of the light blue sweat shirt of brand A and navy blue sweat shirt of brand B were the least affected by the series of launderings. The rating after 15 launderings fell between "slight change" and "moderate change." The light blue sweat shirt of brand B and the black and navy blue sweat shirts of brand C were the most affected in color after 15 launderings. Their ratings fell below the value on the rating scale of "more change than acceptable."

When both statistical evaluations were used (Table XV), only the black shirt of brand A gave a significant change in a between colors comparison. The differences in colors of sweat shirts of all brands also were significant only after 15 launderings in a comparison between the number of launderings.

The evaluations of the panel (Table 14) showed that the color in the light blue sweat shirts of brand C was the least affected after 15 tumbler dryings. The rating was above the value on the rating scale of "moderate change." The black and navy blue sweat shirts of brand A, the navy blue and light blue sweat shirts of brand B, and the navy blue sweat shirt of brand C were the most affected in color after 15 tumbler dryings. Their rating fell below the value on the rating scale of "more change than acceptable."

According to the analysis-of-variance and the multiple range test, the panel evaluations for the amount of color change in the tumble dried shirts (Table XV) showed that the color changes in a comparison between the number of tumbler dryings were significant in brands A and B only after 15 tumbler dryings. A significant amount of color change, when compared between colors, occurred in the navy blue sweat shirt of brand C. This color change was significant both after 10 and after 15 tumbler dryings.

Since there were significant changes in colors after the series of treatments, the hypotheses of no significant change after 15 launderings and after 15 tumbler dryings were rejected on the basis of subjective evaluation.

Dimensional Stability of Sweat Shirts to Laundering and to Tumbler Drying

The panel evaluations indicated that the crosswise dimensions of the black sweat shirt of brand A and of the light blue sweat shirt of brand B, and the lengthwise dimensions of the navy blue sweat shirt of brand A were the least affected after 15 launderings. Their ratings were very close to the value on the rating scale of "slight change" (Table XVI). On the other hand, the crosswise dimension of the black sweat shirt of brand C and the lengthwise dimension of the black sweat shirt of brand B were affected the most after 15 launderings. Their ratings fell between "moderate change" and "more change than acceptable."

Statistical analysis of the panel evaluations for the amount of dimensional changes in the laundered sweat shirts (Table XVII) showed that there were significant amounts of dimensional change in brand A sweat shirts in width after 10 launderings and in length after the first

TABLE XVI

RESULTS OF SUBJECTIVE EVALUATION
AVERAGE SCORES OF RATINGS

	Brand A			Brand B			Brand C		
Treatment	Black	Navy Blue	Light Blue	Black	Navy Blue	Light Blue	Black	Navy Blue	Light Blue
A. Crosswise Dimensional Stability to Laundering									
1st	4.4	4.6	5	3.4	4	4	4	4	4.2
5th	4	4	4.2	4.2	3.8	3.8	3.6	3.6	3.8
10th	3.4	3.8	3.6	3.2	3.4	3.8	3.4	3.6	3.8
15th	3.8	3.6	3.2	3	3.2	3.8	2.6	3	3
B. Lengthwise Dimensional Stability to Laundering									
1st	3.8	4.2	3.8	3	3.8	3.8	3.6	3.2	3.6
5th	3	3.6	3.6	2.2	3.2	4.2	3.4	2.6	3.8
10th	2.8	3.2	3	2.6	2.2	3.2	3.2	2.6	3.6
15th	3	3.8	2.8	2.2	2.4	3.2	3.0	2.4	3
C. Crosswise Dimensional Stability to Laundering and Tumbler Drying									
1st	4.4	4.2	4	4.2	3.7	4	3.6	3	3.6
5th	3.8	3.8	3.8	4	4	3.6	3.6	3.6	3.8
10th	3.6	3.8	3.2	3.8	3	3.2	3.2	2.6	3.8
15th	2.6	2.8	2.4	3.4	2.6	3	2.4	2	3
D. Lengthwise Dimensional Stability to Laundering and Tumbler Drying									
1st	2.6	3.4	2	3.4	2.8	2.6	2	1.6	2
5th	2	2.6	2.4	3	1.8	2.2	2.2	1.4	2.4
10th	1.2	3	1.2	3.4	1.4	2	1.4	1.2	2.2
15th	1.6	2.2	1.2	2.6	1.2	1.8	1.2	1.2	1.6

TABLE XVII

SUBJECTIVE EVALUATION OF DIMENSIONAL STABILITY OF SWEAT SHIRTS

I. Result of the analysis of variance

Brand	Comparison	Laundered		Tumble Dried	
		Crosswise	Lengthwise	Crosswise	Lengthwise
A	Between Times	0.95	0.95	0.95	n.s.
	Between Colors	n.s.*	0.95**	n.s.	0.95
B	Between Times	n.s.	n.s.	0.95	0.95
	Between Colors	n.s.	0.95	0.95	0.95
C	Between Times	0.95	0.95	0.95	n.s.
	Between Colors	0.95	0.95	0.95	0.95

II. Result of the multiple range test

Brand		Comparison between number of launderings				Comparison between number of launderings and tumbler dryings			
		1	5	10	15	1	5	10	15
A	Crosswise:	n.s.	n.s.	0.95	n.s.	0.95	n.s.	n.s.	0.95
	Lengthwise:	0.95	n.s.	n.s.	n.s.	—	—	—	—
B	Crosswise:	—	—	—	—	n.s.	n.s.	0.95	n.s.
	Lengthwise:	—	—	—	—	0.95	n.s.	n.s.	n.s.
C	Crosswise:	0.95	n.s.	n.s.	0.95	n.s.	n.s.	n.s.	0.95
	Lengthwise:	n.s.	n.s.	n.s.	0.95	—	—	—	—

Note: *n.s.: Not significant at five per cent rejection level
**0.95: Significance level indicated

laundering. The amount of dimensional change of brand C sweat shirts in width both after one and 15 launderings and in length after 15 launderings also yielded a statistical significant change.

The panel evaluations indicated that the crosswise dimension of the black sweat shirt of brand B was affected the least after 15 tumbler dryings. The rating was above the value on the rating scale of "moderate change" (Table XVI). The navy blue sweat shirt of brand C was affected the most after the treatment. The rating was at the value on the rating scale of "more change than acceptable." In general, the lengthwise dimensions of all the sweat shirts were affected greatly by the tumbler dryings.

The subjective evaluations for the amount of dimensional change in the tumble dried sweat shirts when analyzed statistically by both the analysis-of-variance and the multiple range test, indicated that there were significant amounts of change in the width of the brand A sweat shirts both after one and after 15 tumbler dryings (Table XVII). The crosswise dimensional change after 10 tumbler dryings and the lengthwise dimensional change after one tumbler drying in brand B sweat shirts showed a statistical significance. The change in the width of the brand C sweat shirts after 15 tumbler dryings was also significant.

There were significant changes in dimensions of the sweat shirts after the series of treatments, therefore, the hypotheses of no significant change in dimensions after 15 launderings and after 15 tumbler dryings were rejected on the basis of subjective evaluation.

Acceptability of Sweat Shirts

There was poor agreement between the objective and subjective methods of evaluation used in determining the acceptability of the sweat shirts after a period of exposure in the Fade-Ometer, a series of launderings, or after a series of launderings and tumbler dryings.

Colorfastness to Sunlight, to Laundering, and to Tumbler Drying

After 40 SFH of exposure in the Fade-Ometer, the light blue sweat shirt of brand A showed a significant amount of color change in brightness, when evaluated objectively. When evaluated subjectively, the navy blue sweat shirt of brand C and the brand B sweat shirts of all three colors showed a significant change in colors.

After 15 launderings, only the black sweat shirt of brand B showed a significant change in purity of color, when evaluated objectively, while all of the laundered sweat shirts showed a significant change in colors when evaluated subjectively.

After 15 launderings and tumbler dryings, no sweat shirts yielded any significant amount of color change, according to objective measurement, however, the subjective evaluations indicated that all of the sweat shirts showed significant changes in colors. In the case of the brand C sweat shirts, all colors showed significant changes after only 10 tumbler dryings.

Objective and subjective methods of evaluation showed little agreement. Subjective evaluations fell below "more change than acceptable" in the following cases (Table VIII): after 40 SFH, the navy blue shirts of brands A and C; after 15 launderings, the light blue sweat shirt of brand B, and the black and navy blue shirts of brand C; after 15 tumbler dryings, the black and navy blue shirts of brand A, and the navy blue and light blue shirts of brand B, and the navy blue shirt of brand C. Subjective evaluations also revealed that there were more changes in the navy blue shirts of all the brands than in any other colors, both after the 40 SFH of exposure in the Fade-Ometer and 15 tumbler dryings. However, the objective evaluations showed that while there were partial color changes in some cases, there was no case in which a total color change had yielded a significance. Therefore, the subjective method of evaluation in the color changes of the sweat shirts after various treatments were more critical than the objective method of evaluation.

Dimensional Stability of Sweat Shirts to Laundering and to Tumbler Drying

After the series of launderings, the sweat shirts of all brands yielded a significant amount of overall dimensional change, when measured objectively, while only the brands A and C sweat shirts showed a significant change, when evaluated subjectively. After the series of tumbler dryings, the objective measurements indicated only the length of the brands A, B, and C sweat shirts and the width of the brand C shirts had a significant amount of dimensional change. However, the width of the tumble dried sweat shirts of all brands and the length of brand B sweat shirts had a significant change, when evaluated subjectively.

According to the subjective evaluations, only the dimensional change in length of all the tumble dried sweat shirts were judged below

TABLE XVIII

SWEAT SHIRTS SHOWING COLOR CHANGES, AFTER SERIES OF TREATMENTS, WHICH WERE SUBJECTIVELY RATED AS BELOW "MORE CHANGE THAN ACCEPTABLE"

Brand	Color	Treatment		
		40 SFH	15 Laundering	15 Tumbler Drying
	Black			X
A	Navy Blue	x		x
	Light Blue			
	Black			
B	Navy Blue			x
	Light Blue		x	x
	Black		X	
C	Navy Blue	x	x	x
	Light Blue			

the value on the rating scale of "more change than acceptable" after 15 dryings, with the exceptions of the navy blue sweat shirt of brand A and the black sweat shirt of brand B (Table XIX). In the case of the navy blue shirt of brand C, the rating for the lengthwise dimensional change was already below the acceptance level after only one tumbler drying.

The dimensional stability of the brand C sweat shirts in length, when evaluated both objectively and subjectively, was poor after the series of tumbler dryings. It can be noted in Table I, II, and III that the brand C sweat shirts as a whole had the least number of courses per

TABLE XIX

SWEAT SHIRTS SHOWING DIMENSIONAL CHANGES, AFTER SERIES OF TREATMENTS, WHICH WERE SUBJECTIVELY RATED AS BELOW "MORE CHANGE THAN ACCEPTABLE"

		Treatment			
		15 Laundering		15 Tumbler Drying	
Brand	Color	Crosswise	Lengthwise	Crosswise	Lengthwise
	Black				x
A	Navy Blue				
	Light Blue				x
	Black				
B	Navy Blue				x
	Light Blue				x
	Black				x
C	Navy Blue				x*
	Light Blue				x

Note: *Received this evaluation after only one tumbler drying

inch as compared to the others. Thus, a possible explaination for the excessive lengthwise shrinkage might be the fewer number of courses per inch in the fabric. A similar situation was noticed also in Fletcher and others' study (13). By the objective evaluation, the dimensional change in length of all the sweat shirts, in width of all the sweat shirts laundered only, and in width of brand C sweat shirts which were tumble dried were significant during the series of treatments. Therefore, the objective evaluations of the overall dimensions of the sweat shirts which had been subjected to launderings and to launderings and tumbler dryings were generally more critical than those of the subjective evaluations.

CHAPTER V

SUMMARY AND CONCLUSIONS

The modern trend in fashion and therefore clothing has been toward more relaxed, flexible garments. However, there is still an increased demand for a casual, well-groomed appearance. An increased consumption of knit wear illustrates this direction in clothing. Despite this increased demand and consumption of knit outerwear, particularly knit outerwear sports shirts such as sweat shirts, tennis shirts, polo shirts, "T" shirts, etc., little research related to the field of knit wear has been conducted.

It was not until recently, that the traditional "old grey sweat shirt" emerged from its drab cocoon and developed into an important outerwear for campus and leisure as well as for sports among the lively, young moderns. Questions as to colorfastness, wearability and dimensional stability of sweat shirts for the most part have not been studied.

The purpose of this study was to investigate the effects of laundering, drying, and sunlight on the colorfastness, and the effects of laundering and drying on the dimensional stability of sweat shirts made of 100 per cent cotton which were available on the market at the time of the initiation of this research (spring, 1963).

After being subjected to a 40 SFH of exposure in the Fade-Ometer, to 15 home launderings, or to 15 home launderings and tumbler dryings, colors of the sweat shirts were evaluated objectively and subjectively for the amount of changes. The fabrics and sweat shirts were measured also objectively as well as evaluated subjectively for the amount of dimensional changes after 15 home launderings or after 15 home launderings and tumbler dryings. The effects of various treatments to the acceptability of sweat shirts were observed as well.

The results of the objective and subjective evaluations indicated:

1. After 40 SFH of exposure in the Fade-Ometer, all the sweat shirts underwent a color change, but only the change in brightness of the light blue sweat shirt of brand A was significant at the five per cent rejection level, when measured objectively. On the other hand, the color changes of the navy blue sweat shirts of brands A and C were judged unacceptable, when evaluated subjectively.

2. After 15 home launderings followed by screen dryings, all the sweat shirts underwent a color change, but only the color change in purity of the black sweat shirt of brand B yielded a significant change, when measured objectively. On the other hand, the color change in the light blue sweat shirt of brand B and the black and navy blue sweat shirts of brand C were judged unacceptable by the panel.

3. The sweat shirts, after 15 home launderings and tumbler dryings, all underwent a color change, but no change was found significant as measured objectively. The subjective method of evaluation which judged the color changes occurring in the black and navy blue sweat shirts of brand A, the navy blue and light blue sweat shirts of brand B, and the navy blue sweat shirt of brand C as unacceptable.

4. Subjective evaluation revealed that the color of the navy blue sweat shirts of all the brands were affected the most both after the 40 SFH

of exposure in the Fade-Ometer and after 15 tumbler dryings.

5. For evaluating the amount of color change as to the degree of acceptance, the subjective method was more critical than the objective method. In general, the colors of the sweat shirts were affected to a certain extent by the sunlight. Colors of the sweat shirts were affected to a greater extent by the laundering than by the tumbler drying. Since no apparent stability in color change after the series of treatments was reached, an increase in the number of the time of treatments might be meaningful.

6. After 15 launderings and after 15 launderings and tumbler dryings, all of the fabrics of the sweat shirts underwent some dimensional changes. Significant changes in crosswise and in lengthwise dimensions occurred in the brand A fabrics after the first laundering and after the first tumbler drying. The changes in both crosswise and lengthwise dimensions of the brand B fabrics were significant after the first laundering, while only the change in length of the brand B fabrics was significant after the first tumbler drying. Also there were significant changes in both the width and the length of the brand C fabrics after 10 launderings. After the first tumbler drying, only the width of the brand C fabrics had a significant change, but after 15 dryings, the significant change was in the lengthwise direction.

All of the fabrics showed shrinkage in length but the change in width was irregular. The greatest changes in length took place during the first launderings and during the first launderings and tumbler dryings. No such indication was noticed in the crosswise dimensional change. The laundering tended to increase both the lengthwise shrinkage and crosswise stretch in the fabrics resulting from launderings by causing shrinkage in the width. In addition, the tumbler drying caused further lengthwise shrinkage.

The launderings seemed to create more irregularity in the crosswise dimensional changes of the fabrics than did the tumbler dryings.

7. There was more lengthwise shrinkage occurred in the loosely knitted fabric than there was in the tightly knitted fabric as a result of tumbler drying. The maximum crosswise shrinkage in the fabric resulting from the series of tumbler dryings and the minimum crosswise stretch in the fabric resulting from the series of launderings alone were both found in the loosely knitted fabric.

8. The dimensions of all the sweat shirts underwent some changes after 15 launderings and after 15 launderings followed by the tumbler dryings. By the objective evaluation, the laundered sweat shirts of all the brands showed a significant change in overall dimensions. The objective measurements also indicated that the changes in the length of the brands A, B, and C sweat shirts and in the width of the brand C sweat shirts were significant as a result of 15 tumbler dryings. On the other hand, only the lengthwise dimensional changes of the tumble dried sweat shirts of all the brands were judged unacceptable by the panel with the exceptions of the navy blue sweat shirt of brand A and the black sweat shirt of brand B.

In general, the greatest change in the lengthwise dimensions of the sweat shirts took place after the first treatments. However, there was no definite pattern of crosswise dimensional changes established. The excessive lengthwise shrinkage which occurred in the sweat shirts after the series of tumble dryings might be due to the fewer number of courses per inch in the sweat shirt fabric.

9. No fabrics or sweat shirts reached apparent stability in dimensions as a result of 15 launderings or launderings and tumbler dryings. The launderings tended to create both more lengthwise shrinkage and more crosswise stretch than did the launderings and tumbler dryings. Irregularity in the crosswise dimensional changes of the fabrics and of the sweat shirts were caused both by the launderings alone and by the tumbler dryings. The tumbler dryings tended to compensate for the crosswise stretch in the fabrics and the sweat shirts resulting from the launderings by causing shrinkage in the width. The dryings also caused further lengthwise shrinkage. In general, both treatments affected the dimensions of the sweat shirts and the fabrics. However, the launderings alone had a greater effect on the dimensional changes of the fabrics and sweat shirts than did the launderings followed by the tumbler drying.

10. For evaluating the amount of dimensional changes as to the acceptability of the sweat shirts, the objective methods of evaluation were more critical than the subjective methods of evaluation.

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APPENDIX I

Example of Statistical Analyses of Data

Statistical analysis of the crosswise dimensional stability of Brand C sweat shirts to 15 launderings and tumbler dryings.

Hypothesis 1: There was no significant difference between the crosswise dimensions of brand C sweat shirts initially and after 15 launderings and tumbler dryings.

Hypothesis 2: There was no significant difference between the crosswise dimensions of black, navy blue, and light blue sweat shirts of brand C during the series of launderings and tumbler dryings.

The hypotheses of no difference will be tested at the five per cent level of significance.

I. Analysis-of-variance, two-way classification, fixed effect, F test.

Number of tumbler drying	Black	Navy Blue	Light Blue	Ri	Mean
1	-0.58	-0.31	-2.37	-3.26	-1.09
5	-1.90	-2.89	-1.18	-5.97	-1.99
10	-4.24	-5.19	-3.55	-12.98	-4.33
15	-6.29	-7.08	-6.09	-19.46	-6.49
Cj	-13.01	-15.47	-13.19	-41.67 = G	

The sum of squares for estimating the population variance from the column means (Cj) = SSC is

$$SSC = \frac{\sum_{1}^{3} Cj^2}{4} - \frac{G^2}{12} = \frac{(-13.01)^2 + (-15.47)^2 + (-13.19)^2}{4} - \frac{(-41.67)^2}{12}$$

$$= 0.94020$$

The sum of squares for estimating the population variance from the row means (Ri) = SST is

$$SST = \frac{\sum^{4} Ri^2}{3} - \frac{G^2}{12} = \frac{(-3.26)^2 + (-5.97)^2 + (-12.98)^2 + (-19.46)^2}{3}$$

$$- \frac{(-41.67)^2}{12} = 53.11443$$

The total sum of squares = SS is

$$SS = (-0.58)^2 + (-1.90)^2 + (-4.24)^2 + (-6.29)^2 + (-0.31)^2 + (-2.89)^2$$

$$+ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots + (-6.09)^2 - \frac{(-41.67)^2}{12}$$

$$= 58.99963$$

The error sum of squares = SSE is
SSE = SS - (SST + SSC) = 4.94500

Analysis of variance

Comparison	Sum of squares	df	Mean square
Between times	SST = 53.11443	3	$\frac{SST}{3}$ = 17.70481
Between colors	SSC = 0.94020	2	$\frac{SSC}{2}$ = 0.47010
Error	SSE = 4.94500	6	$\frac{SSE}{6}$ = 0.82416
Total	SS = 58.99963	11	

$$FT = \frac{17.70481}{0.82416} = 21.48207 \qquad F_{.95}(3,6) = 4.76$$

Conclusion: They hypothesis 1 was rejected.

$$FC = \frac{0.47010}{0.82416} = 0.57039 \qquad F_{.95}(2,6) = 5.14$$

Conclusion: The hypothesis 2 was accepted.

II. The multiple range test, for further testing differences among several means in an analysis-of-variance.

Application steps:

Step 1. The data necessary to perform the test are: 1) the means; 2) the standard error, Sm=0.67; and 3) the degrees of freedom on which this Sm is based, $n_2 = 6$.

Step 2. The significant ranges obtained from the table - Significant Studentized Ranges for a 5% Level New Multiple Range Test, for samples of size p = 2, 3, and 4, are 3.46, 3.58, and 3.64, respectively.

The significant ranges are then each multiplied by the standard error, Sm = 0.67, to form what may be called Least Significant Ranges.

Step 3. The means are ranged in ranked order from left to right, as in the following table under Results.
The differences are tested in the following order: the largest minus the smallest, the largest minus the second smallest, up to the largest minus the second largest; then the second largest minus the smallest, the second largest minus the second smallest, and so on, finishing with the second smallest minus the smallest.
Each difference is significant if it exceeds the corresponding least significant range; otherwise it is not significant.

a). Standard Error of a Mean

$$Sm = \sqrt{\frac{0.82416}{3}} = 0.67 \qquad (n_2 = 6)$$

b). Least Significant Ranges

(2)	(3)	(4)
1.80	1.86	1.89

c). Results

15	10	5	1
-6.49	-4.33	-1.99	-1.09

(-1.99 and -1.09 are underscored by the same line.)

Note: Any two means not underscored by the same line are significantly different. Any two means underscored by the same line are not significantly different

APPENDIX II

Visual Evaluation of Sweat Shirts

Evaluation for Color Change

Sweat Shirt # ____________________

Type of Treatment ____________________

No. of Treatment ____________________

Date of Evaluation ____________________

Name of Evaluator ____________________

Check in one of the blanks below those terms which best suit your evaluation.

__________ No change

__________ Slight change

__________ Moderate change

__________ More change than acceptable

__________ Excessive change

Visual Evaluation of Sweat Shirts

Evaluation for Dimensional Change

Sweat Shirt # ______________________

Type of Treatment ______________________

No. of Treatment ______________________

Date of Evaluation ______________________

Name of Evaluator ______________________

		Lengthwise	Crosswise	Lengthwise	Crosswise
No Change					
Slight Change	+*				
	-*				
Moderate Change	+				
	-				
More change than acceptable	+				
	-				
Excessive Change	+				
	-				

* + = stretch

* - = shrink

THE COLORFASTNESS AND DIMENSIONAL STABILITY
OF COTTON SWEAT SHIRTS

by

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B. S., The National Taiwan University,
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Recently the consumption of knit wear in the United States has increased, however there has been limited research related to this field. It was only recently, that the "old grey sweat shirt" developed into an important outerwear for campus and leisure wear as well as for sports wear among the young moderns. The purpose of this study was to investigate the effects of sunlight, laundering, and drying on the colorfastness, and the effects of laundering and drying on the dimensional stability of sweat shirts made of 100 per cent cotton. The construction of sweat shirts and their fabrics, dimensional stability of knit goods, and color specification were reviewed.

According to the results of a three-week fashion count and interviews, three brands of cotton sweat shirts were selected. Three colors of each brand and four shirts of each color and brand were purchased. Sweat shirts were subjected to a total of 40 SFH of exposure in the Fade-Ometer, to 15 home launderings followed by screen dryings, or to 15 home launderings and tumbler dryings. After the various treatments, colors and dimensions of the sweat shirts were evaluated both objectively and subjectively for the amount of color change and for the amount of dimensional change.

The statistical significance of the changes in colors and dimensions were determined by the analysis-of-variance and the multiple range test at a five per cent level of significance. The agreement between the objective and subjective methods of evaluation used to determine the acceptability of the sweat shirts after the series of treatments was poor.

After 40 SFH of exposure in the Fade-Ometer, 15 launderings and after 15 tumbler dryings, no significant total change in colors was found in any of the sweat shirts, when measured objectively. On the other hand, changes in some of the sweat shirts after 40 SFH, 15 launderings, and after 15 tumbler dryings, were judged unacceptable by the panel. In general, the color of the sweat shirts were affected to a certain extent by the exposure in the Fade-Ometer. Colors of the sweat shirts were affected to a greater extent by the laundering than by the tumbler drying.

After 15 launderings and after 15 launderings and tumbler dryings, all of the sweat shirts showed a significant change in overall dimensions, when measured objectively. On the other hand, only the lengthwise dimensional changes of some of the tumble dried sweat shirts were judged unacceptable when evaluated subjectively.

All of the fabrics showed shrinkage in length but the change in width was irregular. Generally, the greatest change in length of the sweat shirts and the fabrics took place during the first laundering and the first tumbler drying. No such indication was found in the changes in width.

There was more lengthwise shrinkage occurring in the loosely knitted fabric than there was in the tightly knitted fabric as a result of tumbler drying. The excessive lengthwise shrinkage occurring in the sweat shirts after a series of tumbler dryings might be due to the fewer number of courses per inch in the fabrics.

No apparent stability in dimensions of sweat shirts was reached after the series of treatments. The laundering tended to create both more lengthwise shrinkage and more crosswise stretch than did the tumbler drying. Irregularity in the crosswise dimensional changes were caused both by the laundering and by the laundering and tumbler drying. The tumbler drying tended to compensate for the crosswise stretch, resulting from the laundering, by causing crosswise shrinkage. The dryings also caused further lengthwise shrinkage. Both treatments, generally, affected the dimensions of the sweat shirts and the fabrics. However, the laundering alone had a greater effect on the dimensional changes of the sweat shirts than did the tumbler drying alone.