THE EFFECT OF HOME LAUNDERING ON SELECTED PROPERTIES OF RESIN TREATED AND STARCHED BROADCLOTH AND PERCALE

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CHAPTER I

INTRODUCTION

The chief purpose of applying resin finishes to cotton is to enhance its inherent properties by imparting new characteristics such as dimensional stability, low soil retention, faster drying, shape retention, and fair appearance after laundering without pressing. In general, the goal is the production of a fabric that will require a minimum of care in use and laundering. Unfortunately, the minimum care performance properties are often accompanied by undesirable changes in other textile properties.

This study is primarily concerned with the effects of home laundering upon certain properties of a resin finished percale and broadcloth and a comparison of the behavior and performance of the resin finished cloths with that of untreated fabrics laundered without starching and with starching.

The objectives of this study were to:

1. Determine how a resin finished cotton fabric differed from the same fabric without a resin finish in the properties of air permeability, yarns per inch, reflectance, rate of absorption, ultimate absorption, breaking strength, stiffness and crease recovery.
2. Determine how repeated home laundering affected the properties and characteristics of the (a) resin finished, (b) untreated, and (c) untreated and starched fabrics.

CHAPTER II

REVIEW OF LITERATURE

Within the past several years, there has been an increasing interest in resin finished or minimum care fabrics. Evidence of this fact can be found in statistics on resin finished cotton which is being produced. In 1957 the total yardage of cottons treated for wrinkle resistance and minimum care properties was nearly 2,000,000,000 yards. (1). The statistics given above are considerably higher than those supplied by Borghetty (2) for 1955. For that year he states that 1,400,000,000 yards of cotton dress goods were treated with resins. Eight hundred million yards were treated with regular crush proof finishes, and 600,000,000 yards were treated for wash-and-wear. The combined total of the two surpassed the total yardage of all synthetic fibers.

It has been estimated that 800,000 bales of cotton which otherwise would have been stored as surplus were used for wash-and wear fabrics in 1958. (3). Although it is acknowledged that an ideal wash-and-wear fabric is still not in sight, some observers believe that resin finishes may account for 85 to 90 percent of all broadwoven goods finished for apparel and household uses when the remaining handicaps are overcome.

Wash-and-wear or minimum care garments as such were pioneered by synthetic fiber manufacturers. Considerable consumer interest was expressed, and the potential of this new market was realized by the cotton industry. Intensive research efforts were begun to produce an all-cotton wash-and-wear product. With the accumulated experience in the application of resin formers for dimensional stability and wrinkle resistance and with continued improvements in application techniques, the development of a minimum care cotton was brought about. As yet, however, no ideal wash-and-wear garment has been produced.

Although resin finishes have improved the wrinkle resistance and dimensional stability of cotton fabrics, their use generally results in losses in other important textile properties. (4).

Fynn (5) lists some of the disadvantages of resin finishes. Resin finishes may impart a stiffness or roughness to the fabric which may not be desirable. In laundering, resin treated fabrics often discolor, retain soils, stains, and oil spots, and otherwise fail to become clean. Of greater importance is the fact that resins invariably degrade strength, tear resistance, and abrasion resistance of all fabrics to which they are applied. If chlorine retaining resins are used on fabrics that are normally bleached in laundering, this degradation can continue to the point of tendering fabrics beyond use. Some resins also break down and produce disagreeable odors, especially in warm humid climates.

Two factors are important in making fabrics washable-and-wearable. These factors are (1) the basic fabric from the viewpoint of its construction and its fiber, and (2) the type of chemical finish which has been applied to resist moisture and soil. If a fiber does not possess a natural aversion to water, treatment with a resin will be necessary to attain this feature.

The resins used in the impregnation of cottons are actually reactive chemicals which are capable of forming resins or of reacting with the cellulose itself. There has been a great deal of discussion as to whether these reactive chemicals polymerize or react with the cotton. It seems probable that both reactions occur to varying degrees depending on application techniques and conditions. Fabric wrinkle resistance can be increased either by the polycondensation of thermosetting resins within a cellulose fiber or by the reaction of cellulose molecules with a cross-linking compound. Apparently cross-linking of cellulose through resin bridges is necessary for anti-creasing properties. To obtain maximum wrinkle resistance it is important to maintain the multifilamentous nature of the yarns. This property allows the individual fibers to change position during creasing and in this manner to relieve part of the applied stress of creasing. (6).

The ability of a fabric to absorb moisture is of great importance in the comfort of clothing. Fabrics which hinder the absorption and subsequent evaporation of moisture from the body tend to be clammy and uncomfortable for the wearer. Evaporation serves as a thermostat to regulate skin temperature, and it is essential if the human body is to be comfortable under both hot and cold environmental conditions. (7).

Since the application of a resin finish tends to decrease absorption of water by the fabric, air permeability becomes of increasing importance in insuring the comfort of the wearer. For fabrics composed of hydrophilic fibers, air permeability will not interfere with other factors of comfort such as moisture transfer and heat dissipation. In hydrophobic fabrics, the weave must be sufficiently open and the air permeability sufficiently high so that moisture can pass through the fabric interstices and evaporate. (8). Gregory (9) acknowledges that a wide range of permeability exists within which comfort is not affected so long as the fabric permits absorption and evaporation of moisture.

Two factors are important in absorbency: the rate of absorption and the total amount of liquid absorbed. Either or both of these factors can be measured.

A static immersion absorption test is proposed by the American Association of Textile Chemists and Colorists. (10). A sample of cloth is conditioned and weighed. It is then immersed in water and reweighed. The percent increase in weight is calculated.

Larose (11) has used a porous plate to measure water absorption. A plate is immersed in water which is under a slight head of water pressure. The sample is placed in contact with the moist plate, a glass slide and weight are put on top, and the sample is allowed to remain for varying periods of time. The increase in sample weight is calculated as a percentage.

Skinkle (12) gives several methods for determining the absorbency of fabrics. One test that is frequently carried out in industry is the sinking time of a patch of cloth. It is quick, simple to do, and requires no special apparatus. However, the results obtained cannot be successfully reproduced. A simple wick-up method may be used to determine the rate of absorption of a strip of cloth.

A device by which both the rate and the total amount of absorption can be measured has been used by Buras, Goldthwait, and Kraemer. (13). Like the Larose method, the sample is brought into contact with a porous plate that is under a slight head of water pressure. A system of flowmeters of varying capacities is employed to measure the maximum rate of absorption of the cloth, and a graduated buret is used to measure the total amount of water absorbed. The apparatus is rapid to use and easily operated, and it allows comparison of the rate and amounts of absorption for different fabrics in a readily understandable manner.

As mentioned earlier, air permeability is of importance in the comfort of clothing, especially when a finish which lowers the hygroscopy of the fabric is employed. Sieminski and Hotte (14) give three general methods for measuring the air permeability of a fabric. One method uses the time taken for the passing of a given volume of air through an area of the material. The air passes through a more permeable sample more quickly than it does through those that are less permeable. In the second method, the back pressure developed by passing air through the sample at a constant rate is considered. The greater the back pressure developed, the greater the resistance of the fabric to air flow, or the less permeable the sample. The third general method is the one most generally applied and the one used in this investigation. In this method a given pressure drop is maintained across the sample and the rate of flow of air through the sample is measured. The _ASTM Standards on Textile Materials_ (15) describes the apparatus and the procedure to be used in measuring air permeability by the third general method given above.

The feel or "hand" of a fabric is important in determining the appearance of a fabric and of the garments made from it. In judging the hand of a fabric, use is made of such sensations as stiffness or limpness, hardness or softness, and roughness or smoothness. An attempt to evaluate the hand of a fabric in the laboratory is difficult because there are no definitive limits for hand or for many of its components such as stiffness, compressibility, resilience, and so on. (16).

Several methods for measuring stiffness have been proposed. Pierce (17) proposed a heart-loop test, which consists of bending the ends of a strip of fabric together to form a loop and measuring this loop under the force of gravity, and the cantilever test. The cantilever test consists of allowing a strip of fabric to project a fixed distance from a horizontal platform and measuring the angle between the tip of the fabric and the platform.

Skinkle (12) discusses the device employed by MacNicholas and Hedrich which consists of folding a strip of fabric back on itself and measuring the height of the fold when compressed by various loads. The height of the fold is directly proportional to the stiffness of the fabric.

Schwarz (18) describes the Drape-o-meter, an instrument developed at the M. I. T. Textile Research Laboratory. This device tests bending deformation about a vertical axis.

Most of the bending tests described above allow two-dimensional distortion of the fabric. The Drapemeter, developed by the Fabric Research Laboratories, was designed to allow a fabric to deform three dimensionally. Such a technique allows for the interaction of warp and filling fabric stiffnesses. (8).

The Flexometer as described by Schiefer (19) measures the amount of work required to fold a pair of samples mounted between a fixed and a moving plate in such a way as to oppose the rotation of the moving plate toward the fixed one.

Dreby (20) has developed the Planoflex, which measures the distortion angle through which a fabric may be distorted in its own plane without wrinkling.

Abbott (16) has compared five methods of laboratory evaluation of stiffness with subjective evaluation of this property. A group of seventeen people arranged nineteen different fabrics of various constructions, weights, and fiber contents according to the stiffness of the fabrics. The laboratory methods which were compared with the subjective evaluation were the cantilever test, the heart-loop test, the Schiefer Flexometer, the Planoflex, and the M. I. T. Drape-o-meter.

Abbott found a reasonably well established relation between the subjective rating and the laboratory rating. However, the correlation of coefficients for flexural rigidity as determined by the cantilever test was higher than for the other laboratory methods. The cantilever test also required simple apparatus and was easily conducted. For these reasons it was suggested that this test be seriously considered as a standard laboratory test for stiffness.

The cantilever test is the preferred method for determining stiffness according to the ASTM. (15.) However, there is one major deviation from the procedure suggested by Peirce. (17). Instead of determining the bending length and flexural rigidity of a fixed length of cloth from its bending angle, the angle of dip is held constant at 42° and the length of overhang varies in direct proportion to the stiffness of the cloth.

The ability of a fabric to recover from wrinkles formed in use or in the laundering process is essential in minimum care garments. There are various ways of measuring resistance to wrinkling or to folding deformations that normally occur during its use.

Buck and McCord (21) describe various laboratory test methods for measuring crease recovery. One of the earliest methods of estimating wrinkle resistance was crumpling a specimen of cloth and then releasing it. The fabric was then examined visually to determine the extent of the recovery. Another test method, the T-B-L method, uses a fabric cutting 4 cm. long and 1 cm. wide which is folded across its narrow dimension, pressed under a weight, and allowed to recover while hanging over a horizontal wire at the crease. The distance between the two edges of the strip is measured. The greater the distance, the greater is the recovery of the cloth.

A small rectangular cutting is folded and placed under a weight in the mercury method. After removing the weight, the sample is placed on edge on the surface of the mercury and allowed to recover. Either the angle of creasing or the distance between the ends of the cutting can be measured.

A modification of the T-B-L method is found in the creasing-angle method, which involves measurement of the angle of crease rather than the distance between the two ends of a folded cutting.

The Monsanto method, a modification of the creasing angle method, is the method advocated by the ASTM. (15). Lawrence and Phillips (22) found a good correlation between results obtained with this instrument and subjective evaluation. The instrument is simple to operate and gives results which are adequate for most purposes.

CHAPTER III

THE EXPERIMENT

Introduction

Several tests were selected to determine differences that might exist between resin treated and untreated broadcloth and percale and to determine the effects of home laundering upon certain properties of resin treated, untreated, and starched untreated fabric. The tests performed were air permeability, yarns per inch, reflectance, rate of absorption, amount of absorption, breaking strength, stiffness, and crease recovery.

Percale and broadcloth were selected for this experiment since both fabrics are widely used for apparel. Both are frequently treated with resin finishes or are starched as part of the laundering process. The percale was an 80 square type, and the resin finished percale was treated with approximately 5 percent by fabric weight of a triazine type thermo-setting resin. The percale used for the untreated and starched fabric was the same fabric without a resin applied. The broadcloth had a yarn count of 154 x 72. The type of resin applied is not known, but the untreated cloth was mercerized and Sanforized. No other information about the fabric was available.

The fabrics were subjected to a series of thirty launderings with tests being made at three regular intervals.

Selection and Preparation of Test Samples

For both broadcloth and percale 88 samples were cut for the untreated and the resin treated fabrics, and 60 additional samples were cut from the untreated fabrics to be used as starched fabric. Fewer samples were needed for the starched fabrics since most measurements were not made on starched cloth until the tenth washing.

Because part of the fabric was treated with a resin finish, it is unlikely that the resin finished and untreated fabrics used in this experiment were taken from the same length of cloth. However, the resin treated and untreated fabrics in both broadcloth and percale were made to meet the same specifications.

The fabrics were torn from selvage to selvage into 12 inch strips. Each of these strips was then divided into three samples approximately 12 inches wide. No effort was made to keep a record of the original location of each sample in the strip of fabric. The edges of all samples except those to be tested before laundering were overcast to prevent ravelling.

The samples were assigned to the various tests at random. Since the untreated and the starched samples were taken from the same original fabric, only one set of random numbers was drawn and assigned for these two types of samples. A separate randomization was made for the resin finished fabric.

In order to simplify identification of the samples according to treatment, color and number codes were assigned to the various samples. Different colors of marking inks were used to facilitate rapid sorting of the three sets of samples after laundering.

Laundering Procedure

The samples were laundered together. As samples were removed for testing, they were replaced by other test samples of the same size and fabric so that the wash load remained the same throughout the series of 30 launderings.

An automatic agitator type washer was used for the launderings. The samples were washed for 10 minutes using water at 145 ± 2^{o} F. and 3/4 cup of a low sudsing detergent. The detergent was dissolved in hot water before it was added to the wash. After the wash period, the fabric was rinsed twice and damp dried.

After the final spin dry period, the samples were sorted. The resin finished and the untreated samples were dried for 15 minutes in a preheated dryer set at a medium heat setting. The starched samples were completely immersed in a starch solution consisting of six quarts of cold water and 2 1/2 cups of powdered corn starch. The samples were placed in the washer for a repetition of the final spin cycle to remove the excess starch solution. The starch solution was somewhat more concentrated than that recommended by the manufacturer for a medium starch. However, since the spinning process tends to remove more of the solution than other methods, it was considered advisable to increase the concentration of the starch. The samples were then dried for 10 minutes at the same temperature as the untreated and resin finished samples. The amount of starched cloth was not as great as that of the resin treated and untreated fabric; therefore, the drying time was reduced.

After 10, 20, and 30 launderings, samples which were to be tested were removed from the wash load, sprinkled and ironed. Approximately the same amount of distilled water was used each time to dampen the fabrics, and the samples were allowed to become uniformly moist before they were ironed. An ironer set for the same speed and temperature was used to iron the samples each time. Each sample was passed through the ironer twice, once in the warp and once in the filling direction.

Description of Apparatus and Test Procedures

A. Absorption Apparatus

An apparatus similar to that used by Buras, Goldthwait, and Kraemer (5) was used to determine the absorbency of the fabric tested. The apparatus consisted in part of a fritted glass funnel with a porous plate (A) connected by plastic tubing to three flowmeters (B). The remainder of the apparatus was made up of a concentrically coiled length of plastic tubing (C), a graduated buret (D), a supply bottle (E) for refilling the buret, and a polyethylene bag filled with lead shot.

The apparatus was arranged so that when the entire system of tubing and flowmeters was filled with distilled water the surface of the porous plate was moist. The porous plate of the funnel was placed approximately 1/4 inch lower than the coiled length of tubing to compensate for the capillary action which tended to retard the flow of water from the tubing through the plate. However, the difference in the heights of the funnel plate and the tubing was not great enough to allow water to stand on top of the plate.

Specimens the same diameter as the porous plate (3 1/4 ins.) were used to determine the absorbency of the cloth. A sample was placed on the plate, and the bag of lead shot was placed on the sample to insure even contact with the plate. One of the stopcocks that opens and closes the flowmeters was turned so that water could pass from the tubing through the open flowmeter, through the porous plate, and into the fabric. The flowmeter reading was taken when the float reached its highest point. From this reading and from calibration curves that had been plotted for each flowmeter it was possible to determine the maximum rate of absorption in cubic centimeters per minute. The total amount of moisture absorbed was determined by reading on the buret the number of milliliters of water required to refill the coiled tube. Two measurements were made on each sample.

B. Reflectance Apparatus

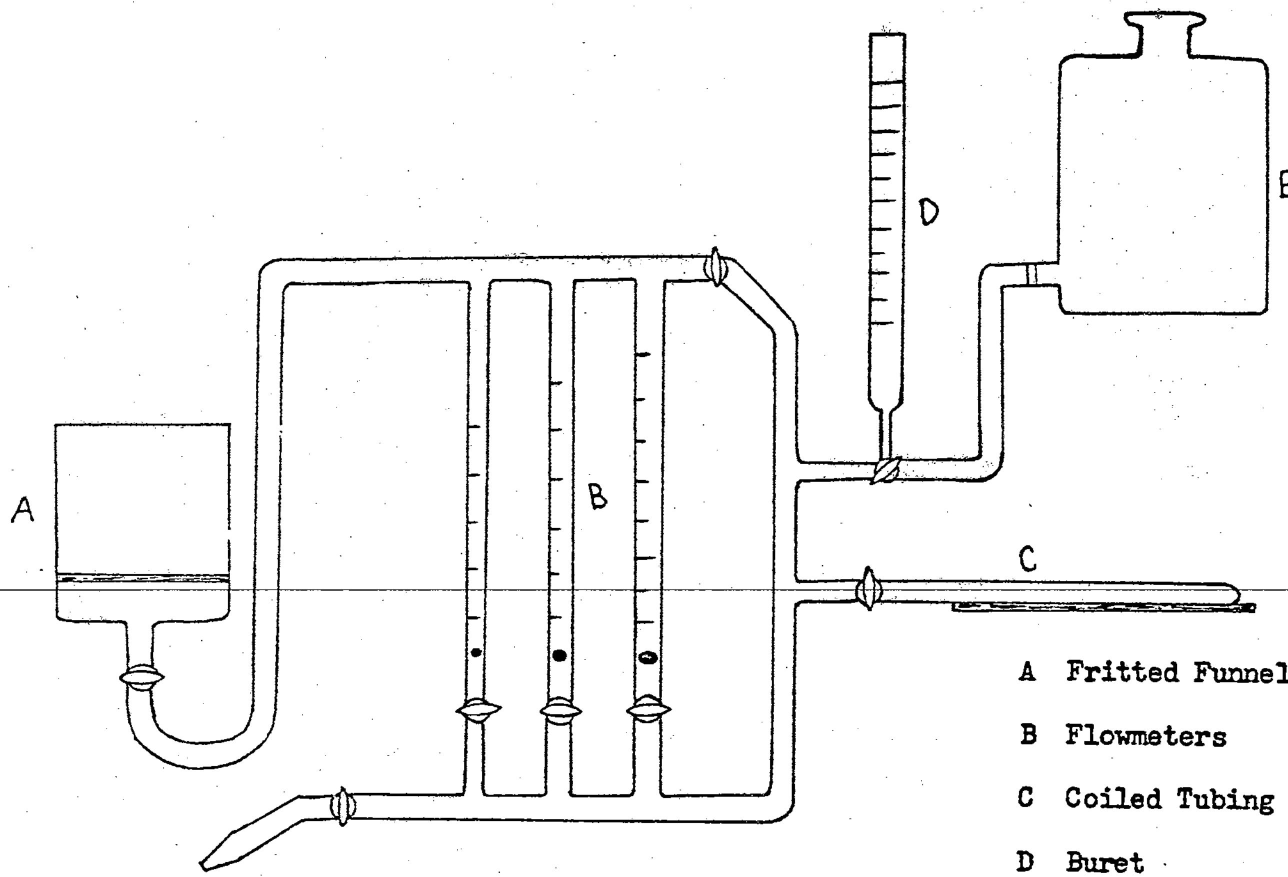
A Gardner Multi-Purpose Reflectometer, an apparatus similar to that discussed by Hunter (23, 24) as far as principles of construction and operation are concerned, was used to measure reflectance. This device employs three colored filters, green, blue, and amber, and a photoelectric cell which measures the amount of light reflected by the surface being tested. Magnesium oxide is used as a standard for comparisons and measurements of white or near-white surfaces, and the percent of light reflected with each filter by the surface being tested is compared with that reflected by magnesium oxide.

Frequently, white or near-white surfaces are rated for degrees of yellowness, and an equation is supplied by which a scale of yellowness can be made. Values increase from zero for magnesium oxide or other selected standards to positive values for yellowish surfaces and negative values for bluish surfaces. The degree of yellowness was used to measure reflectance in this study. Two measurements were made on each sample.

C. Air Permeability Apparatus

The Frazier Air Permeometer was used to measure air permeability.

Plate I



A Fritted Funnel

B Flowmeters

C Coiled Tubing

D Buret

E Supply Bottle

ABSORPTION APPARATUS

The apparatus consists of a suction fan which draws air through a known area of fabric, a circular orifice over which the fabric to be tested is clamped, a device for regulating the drop in pressure across the fabric, and a means of measuring the amount of air passing through the fabric.

The test specimen is to lie smooth and undistorted in its own plane between the clamp and the circular orifice. Conditioned air is then drawn through the predetermined area of the fabric and through the calibrated flow meter. The pressure drop across the fabric is to be maintained at a predetermined value, and the reading on the flow meter is to be recorded. The air permeability of the fabric was expressed as cubic feet of air per minute per square foot of fabric at a stated pressure drop. Nine measurements were made on each sample tested.

D. Other Apparatus and Procedures

Procedures of the American Society for Testing Materials (15) were used for tests on breaking strength, yarns per inch, stiffness, and crease recovery. Strips cut 1 1/4 x 6 inches were ravelled to 1 inch in width and tested on a Scott Tester, a pendulum type or constant-rate-of-traverse tester, to measure breaking strength. Three warp and three filling measurements were made on each sample of cloth. One measurement each in the warp and filling direction was made to determine the number of yarns per inch of the fabrics. The counts were taken near the center of the sample. The Cantilever test was used to make four measurements of warp and four of filling on each sample to determine stiffness, and the Monsanto method was used to measure crease recovery. Five warp and five filling measurements per sample were taken for crease recovery. Breaking strength measurements were made before laundering and after the completion of thirty launderings. Breaking strength tests were made only at the beginning and end of the experiment because it was believed that the effect of laundering would not be great enough to cause significant differences at each of the regular test intervals.

All tests were performed in a constant temperature and humidity laboratory. Conditions maintained were a temperature of $70 \pm 2^{\circ}$ F and a relative humidity of 65 ± 2 percent.

CHAPTER IV

DISCUSSION OF RESULTS

Several basic assumptions were used in the analysis of the data.

1. It is assumed that each measurement is made up of four components: the mean, the finish effect, the laundering effect and a random error or sampling variation.

2. The above effects are additive and independent.

Measurement = Mean + Finish + Laundering + Error

3. The error is from a normally distributed population with a mean of zero and a standard deviation.

Interaction is a measure of the failure of the above effects to be additive. When interaction is present, the main effects, specifically those of laundering and finish, are not additive. The components are related to and dependent on each other, and their effects can not be completely separated and distinguished.

Measurement = Mean + Finish + Laundering + (Finish x Laundering) + Error

Because of the large number of analysis of variance tables, they have been placed in an appendix. Reference is made to each in the discussion of results. In certain cases the means have been presented in graphic form, and in others they are a part of the analysis of variance tables.

Air Permeability

The analysis of variance for air permeability of broadcloth (Table I) shows that differences exist among the fabrics and that the differences may be attributed to finishes, laundering, and interaction between finishes and laundering. Laundering increased the permeability of the fabrics; however, it did not affect all finishes to the same extent as may be seen in Figure 1. The air permeability of the starched broadcloth increased sharply between 0 and 10 launderings, and it continued to increase at a more gradual rate with repeated laundering. After 10 launderings, the air permeability of the starched fabric was much higher than that of the resin finished cloth which was more permeable than the untreated broadcloth. The resin finished fabric was affected least by laundering, a gradual increase occurring between 0 and 30 launderings. The permeability of the untreated fabric increased most between 0 and 10 launderings.

Figure 2 illustrates changes in air permeability for percale, and the analysis of variance is recorded in Table II. There were differences due to laundering, finish, and interaction. The untreated fabric became less permeable with laundering, while the starched and resin finished percale became more permeable. The starched fabric was more permeable than the resin finished percale. The increase was rather rapid between 0 and 10 launderings, but a levelling trend occurred from 10 to 30 launderings. The decline in air permeability for the untreated fabric was greatest for the first 10 launderings, and although the permeability increased slightly after 10 launderings, it did not approach that of the fabric before laundering.

Reflectance

The analysis of variance for reflectance for broadcloth (Table III) shows that differences existed among the three finishes and that laundering affected the reflectance of the fabrics. There is also evidence

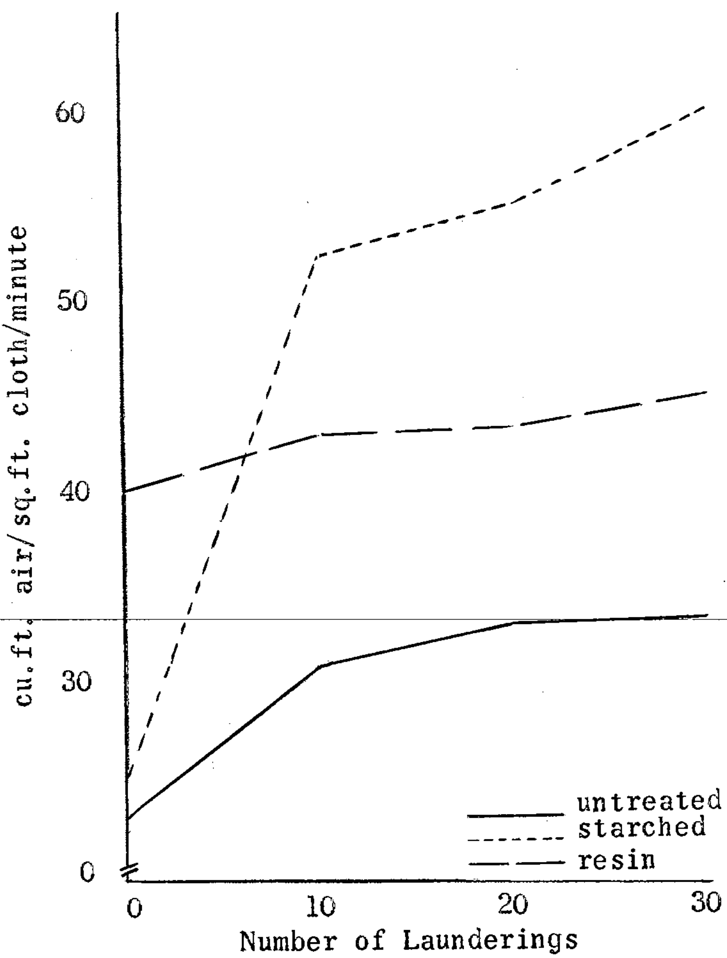


Figure 1. Air Permeability of Broadcloth

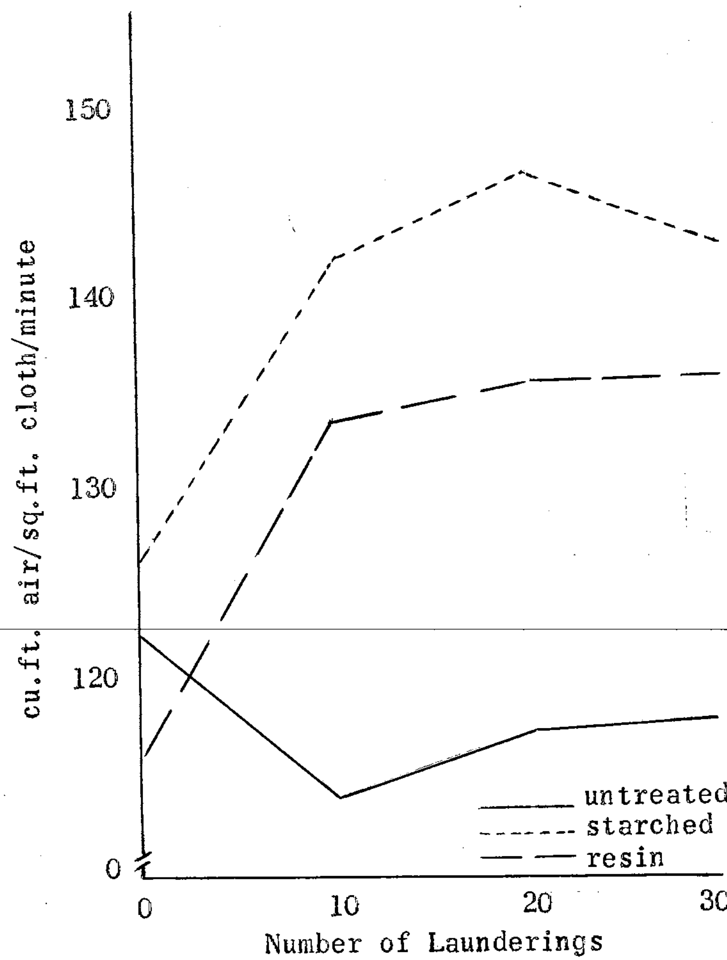


Figure 2. Air Permeability of Percale

of interaction between the finishes and laundering. Figure 3 shows that in the untreated, starched, and resin finished fabrics, the trend was for the fabric to become less blue and to approach the magnesium oxide standard more closely as the fabric was subjected to laundering. The resin treated fabric was less blue than either the untreated or starched fabric throughout the series of launderings. This difference was most obvious at 0 and 30 launderings. The untreated and resin treated fabrics were consistent in becoming less blue with laundering, while there were deviations in this trend in the starched broadcloth. In all fabrics, the greatest change occurred between 0 and 10 launderings.

The analysis of variance for reflectance of percale (Table IV) also shows differences due to finish, to laundering, and to interaction. It can be observed from Figure 4 that the change due to laundering was not as great as that for broadcloth. There was a trend for the percale of all finishes to approach the magnesium oxide standard more closely with repeated laundering, with the fabric becoming less yellow. At 0 and 10 launderings, there were only slight differences among the three finishes. However, at 20 and 30 launderings, the starched percale was considerably more yellow than the untreated and resin finished fabrics. The decrease in yellowness was consistent for the resin treated and untreated percale, but not for the starched fabric. The degree of yellowness increased for the starched fabric after 10 launderings, although it did not rise to the original value determined before laundering.

Yarns per Inch

The analysis of variance for warp yarns per inch in broadcloth is given in Table V. The differences among the fabrics can be attributed

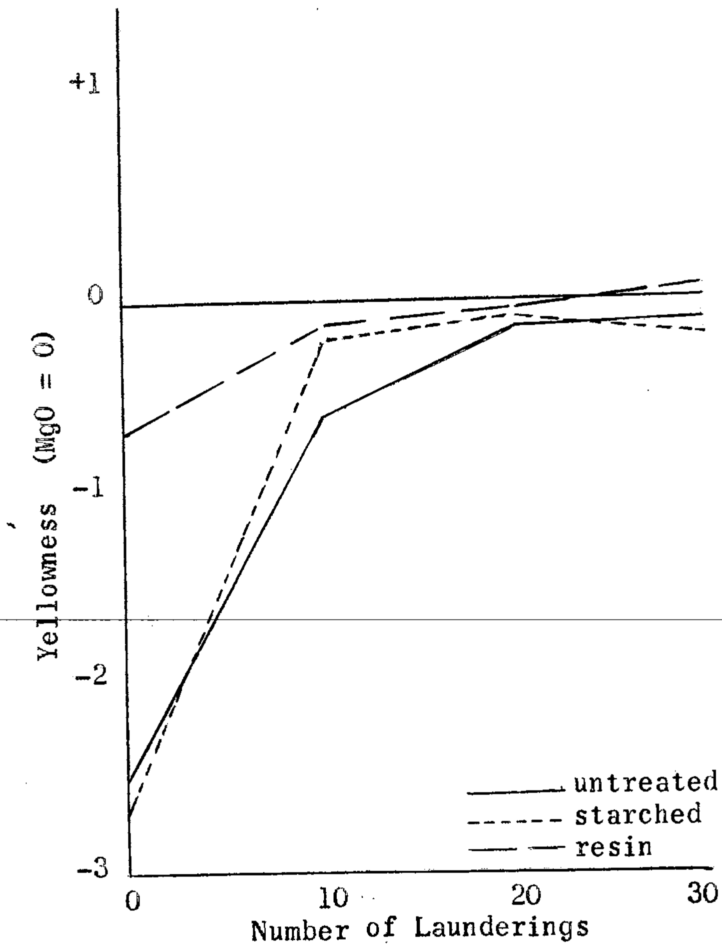


Figure 3. Reflectance of Broadcloth

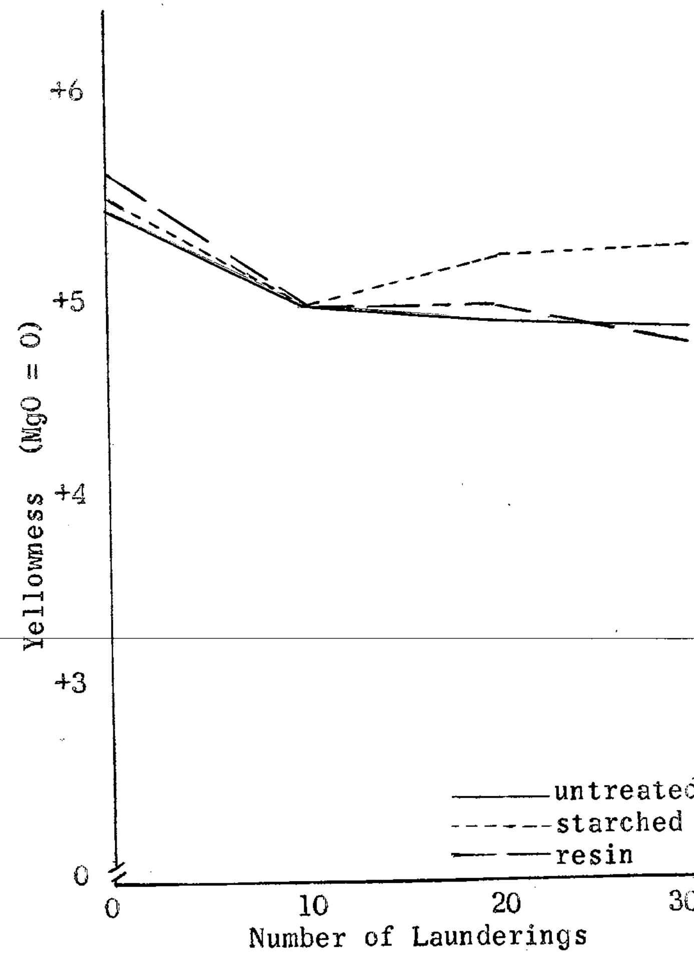


Figure 4. Reflectance of Percale

almost entirely to differences in finishes. The number of yarns per inch of untreated and starched broadcloth was essentially unchanged throughout the series of launderings. The resin finished cloth consistently had fewer warp yarns per inch and a more varied count between 0 and 30 launderings than the other fabrics. However, the difference was very small.

Table VI gives the analysis of variance for broadcloth filling yarns. Most of the variation that exists is due to differences among the finishes. Only a very small part may be attributed to the effect of laundering. As in the warp count of broadcloth, the untreated and starched fabrics had more yarns per inch than the resin finished broadcloth.

According to Table VII, variations in the number of warp yarns per inch of the percale fabrics were due to laundering, finishes, and interaction. The resin finished cloth had a smaller number of yarns per inch than the untreated and starched fabrics. Originally the untreated and starched fabrics were equal in number of yarns per inch. At the end of 30 launderings, however, the untreated fabric had a slightly higher count than the starched fabric.

Differences in yarns per inch in the percale filling yarns were due to laundering effect, finish effect, and interaction (Table VIII). Laundering produced a similar increase in count in both the untreated and starched percale and a slight decrease in the resin finished fabric.

When the difference in yarns per inch of the resin treated vs. untreated and starched broadcloth and percale is considered in relation to the total count, it is probable the difference in no case was great enough to affect the performance of the fabrics in use.

Stiffness

Laundering and finishing had significant effects on stiffness of broadcloth as may be seen in Table IX. From an examination of the means, the nature and extent of the differences can be determined. Most of the variation was due to difference in finish, the starched fabric being stiffest and the resin finished fabric being least stiff. The effect of laundering was small, but stiffness of the untreated and resin finished broadcloth tended to increase slightly with laundering.

The analysis of variance for stiffness measurements on broadcloth filling (Table X) shows differences due to finish, to laundering, and to interaction, finish being the most important factor. Laundering increased the stiffness of the untreated broadcloth slightly, but it appears to have had little or no effect on starched and resin finished fabrics. The resin finished cloth was least stiff, while the starched cloth was much stiffer than the resin finished and untreated fabrics.

Table XI shows that laundering, finish, and interaction effects account for variations in warp stiffness of the percale, finish being of primary importance. The starched cloth was much stiffer than the other fabrics, and the resin treated fabric was least stiff. Laundering was also of importance in changes in stiffness of the untreated cloth. Stiffness decreased with laundering. The behavior of the percale was similar to that of the broadcloth.

Stiffness also varied with the percale filling, and the effects of finish, laundering, and interaction are significant (Table XII). The largest part of the difference was due to the finish, the starched fabric being much stiffer than the resin finished and untreated percale, which differed only slightly in stiffness. Laundering tended to increase the filling stiffness of the untreated percale, but no such changes occurred in the starched and resin finished cloths.

Crease Recovery

The finish effect is most important in the analysis of variance (Table XIII) for warp crease recovery of the broadcloth, and the effects of laundering and interaction are also significant. The resin finished cloth had the highest recovery, while the starched cloth had the lowest. Laundering decreased the amount of recovery of the resin treated cloth, but it tended to increase that of the untreated fabric. These changes are shown in Figure 5.

According to Table XIV differences due to finishing, to laundering, and to interaction account for variations in the crease recovery of the broadcloth filling. By far the greatest part of the difference was due to finish, the crease recovery of the resin finished fabric being highest, and that of the starched cloth being lowest. Crease recovery of the untreated and starched fabrics appeared to be little affected by laundering, but the crease recovery of the resin finished cloth was decreased by laundering as was the case in the warp direction. This change was greatest for the first 10 launderings. Differences in crease recovery are shown in Figure 6.

Laundering, finish, and interaction effects are significant, as may be seen in Table XV, but the finish effect is responsible for the largest part of the variation. As in the broadcloth, the crease recovery for the resin finished cloth was highest and that for starched fabric lowest. Laundering tended to decrease the crease recovery of the untreated and resin finished percale, but the starched fabric was not

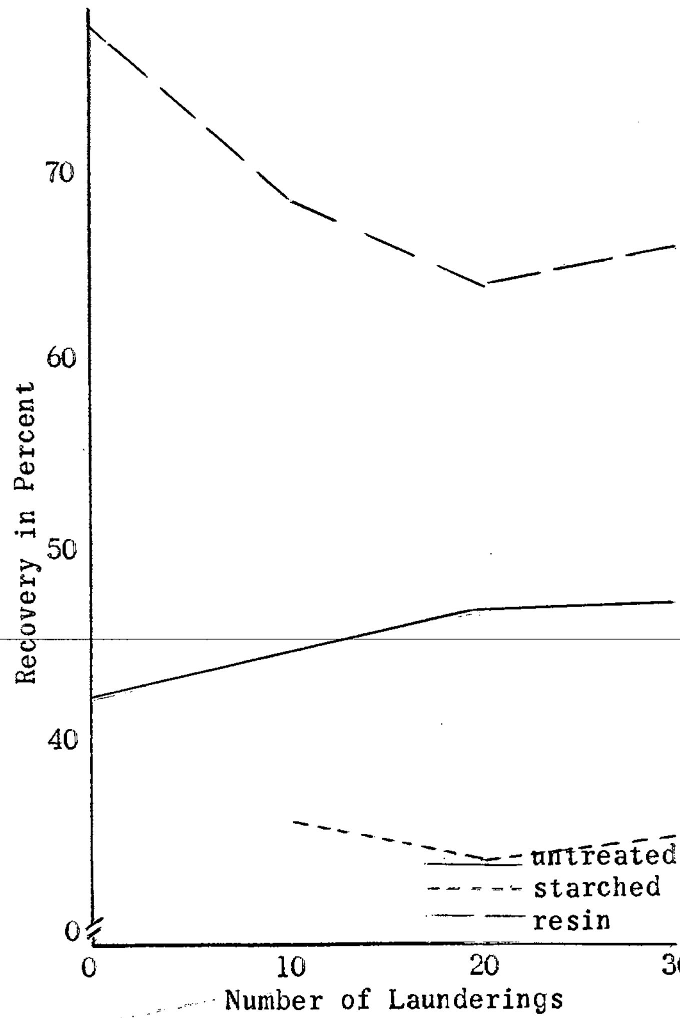


Figure 5. Crease Recovery of Broadcloth Warp

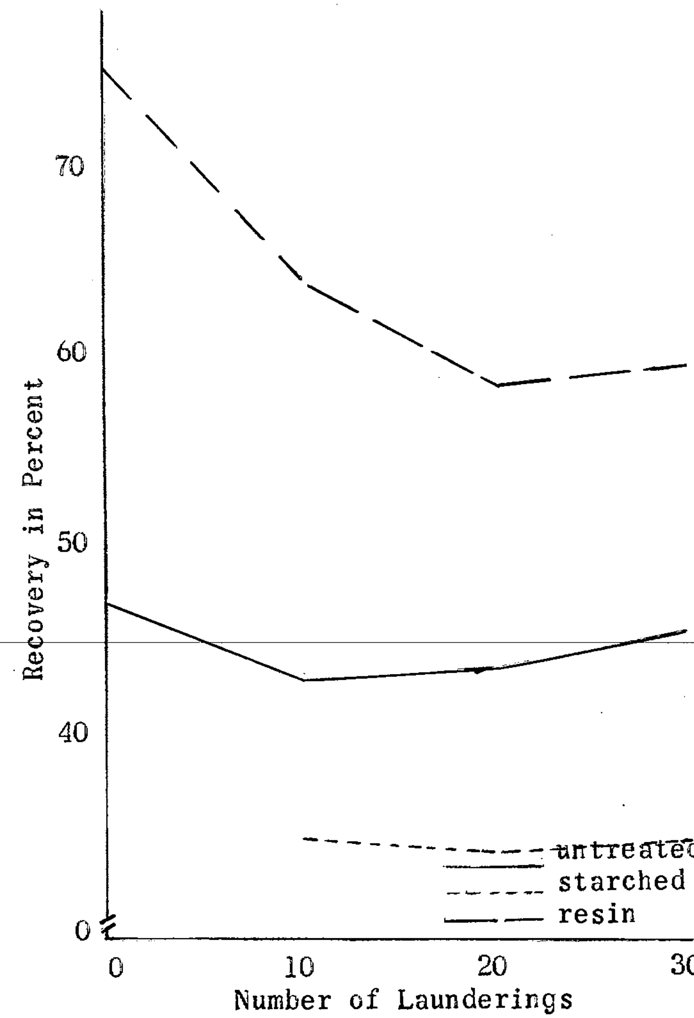


Figure 6. Crease Recovery of Broadcloth Filling

affected by laundering. Figure 7 shows the variations among the means of the finishes at the different laundry intervals.

The resin finished percale recovered more fully from creasing in the filling direction than the untreated and starched fabrics. The effect of the finish accounts for most of the variation, with smaller amounts due to laundering and interaction (Table XVI). Laundering had very little effect on the untreated and starched fabrics, but it lowered the crease recovery of the resin treated fabric, especially during the first 10 launderings. These changes are shown in Figure 8.

Amount of Absorption

Variations in the total amount of absorption for broadcloth are due to finish effects and interaction, finish effects being most important. The untreated fabric absorbed more water than the starched fabric, and the resin finish had the lowest amount of absorption. Although the analysis of variance (Table XVII) does not show the effect of laundering to be significant, an examination of the means indicates a possible increase in amount of absorption in the resin treated broadcloth due to laundering.

Laundering and finish effect are responsible for differences in the amount of absorption of percale fabrics, the finish effect being most important (Table XVIII). The untreated percale was most absorbent, and the resin finished fabric least absorbent as was also the case in the broadcloth. Absorption for untreated and resin finished percales increased with laundering, but there was no change in the starched cloth.

Rate of Absorption

Table XIX shows that the maximum rate of absorption for broadcloth was affected by laundering, finish, and interaction, with laundering

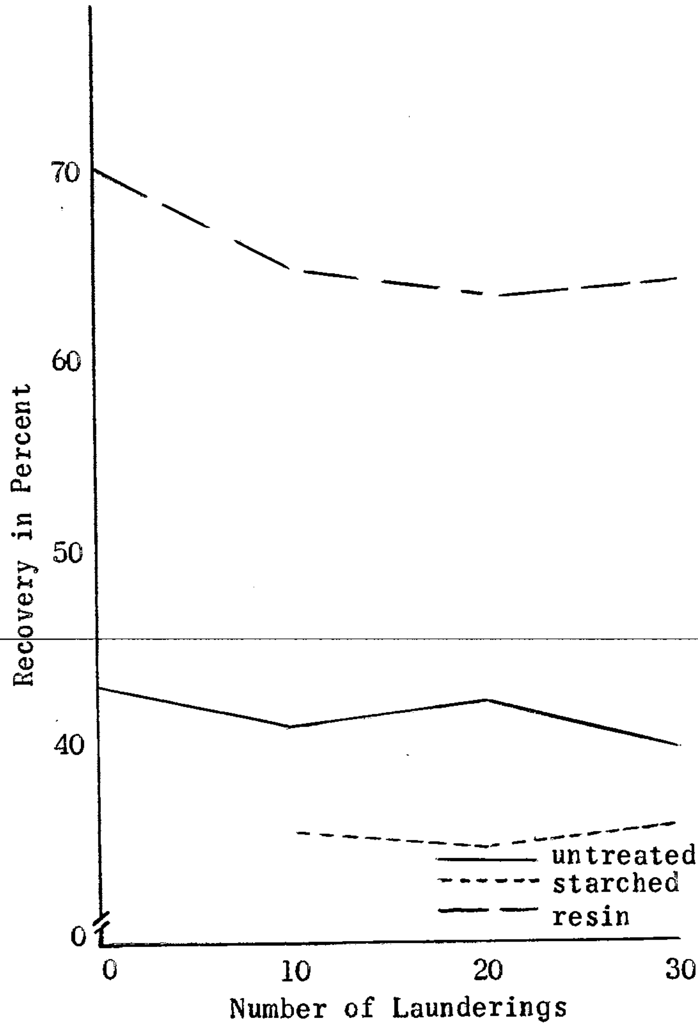


Figure 7. Crease Recovery of Percale Warp

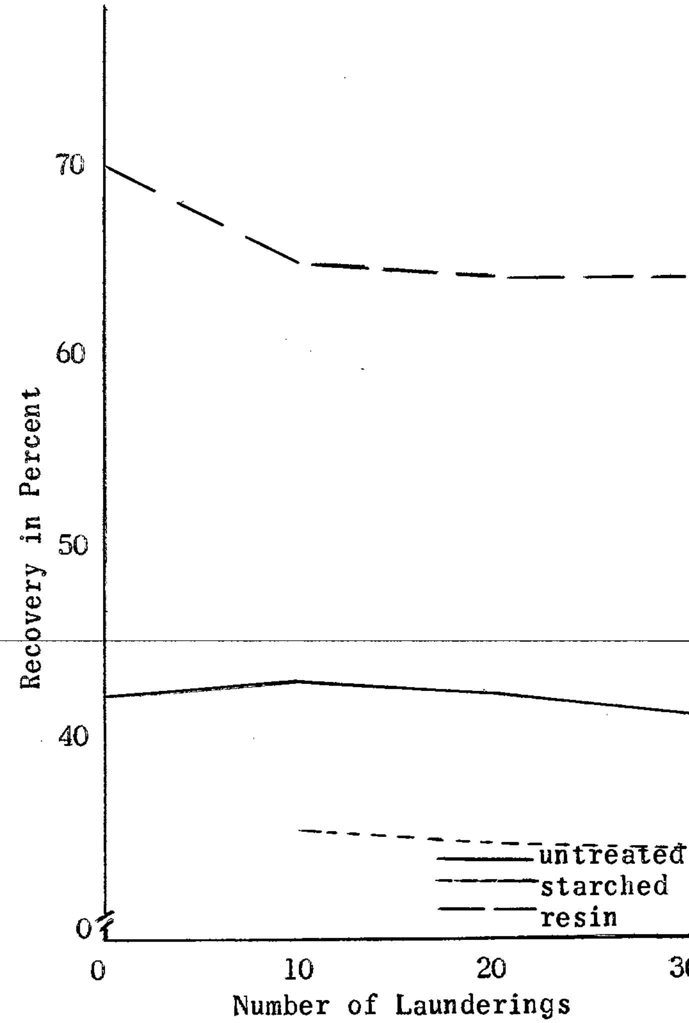


Figure 8. Crease Recovery of Percale Filling

being most significant. In tests made on the original fabric the resin treated fabric absorbed water more quickly than the untreated fabric. After 10 launderings, however, the untreated fabric had the highest rate of absorption, followed by the starched and resin finished broadcloth. Laundering increased the rate at which the untreated and resin finished cloth absorbed water, but the starched fabric was unaffected by laundering. After 10 launderings, the rate of absorption for the untreated cloth was unaffected by further laundering, but the rate for the resin finished cloth increased until the 20th laundering. Differences in rate of absorption are shown in Figure 9.

The finish had the greatest effect on the rate of absorption for percale, although laundering and interaction were significant factors as shown in Table XX. The resin finished cloth had the lowest rate of absorption, and the untreated cloth had the highest. As seen in Figure 10, laundering increased the rate of absorption for the untreated cloth but decreased it for the resin finished percale. The greatest changes occurred between 0 and 10 launderings. After 10 launderings the untreated cloth changed only slightly, but the rate of absorption for the resin finished fabric increased slightly with repeated launderings. However, it did not approach the original rate of absorption.

For both broadcloth and percale, the untreated fabric had the highest rate of absorption, while the resin finished fabric had the lowest except that the original resin finished broadcloth absorbed water more quickly than the untreated cloth. Laundering increased the rate of absorption for all fabrics except the starched fabrics and the resin treated percale.

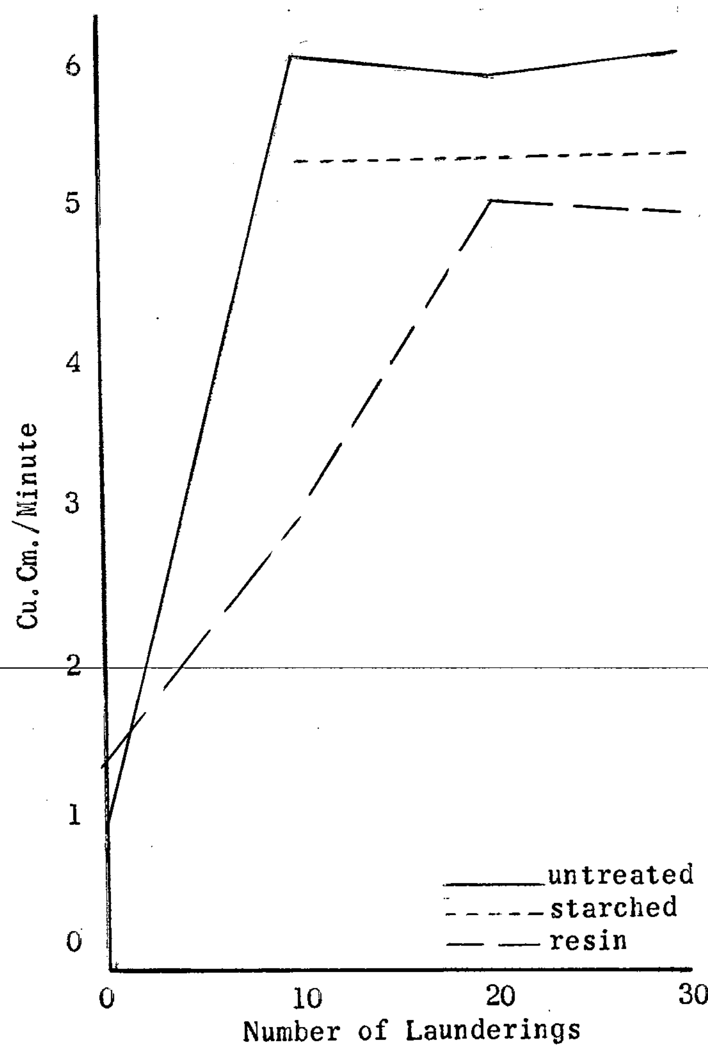


Figure 9. Maximum Rate of Absorption for Broadcloth

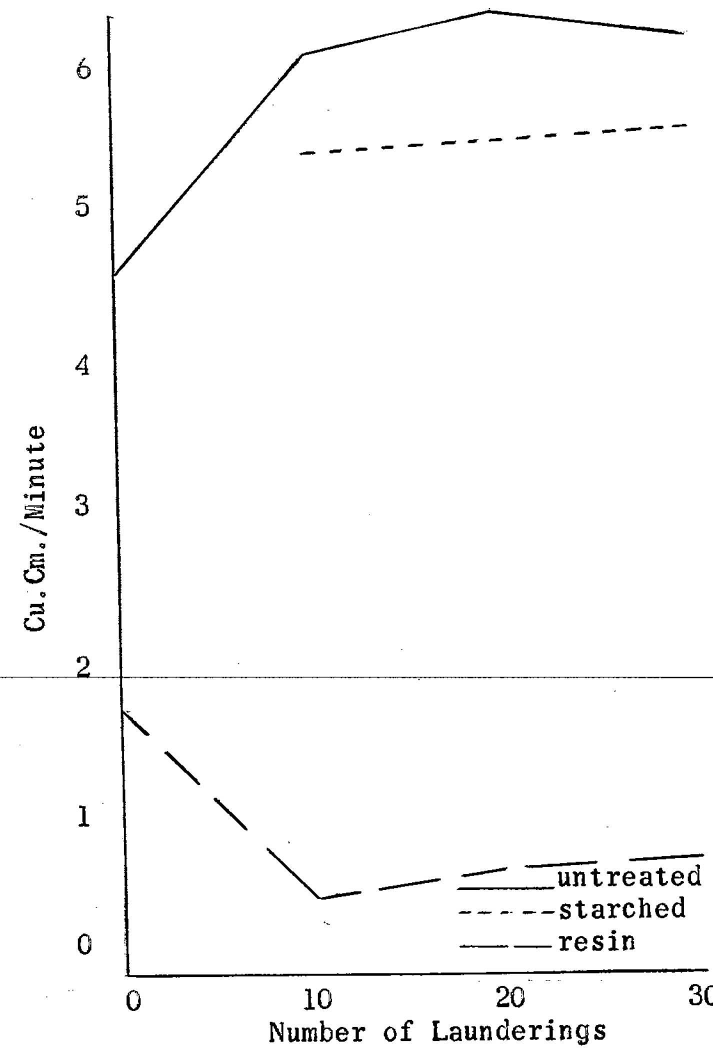


Figure 10. Maximum Rate of Absorption for Percale

Breaking Strength

Finish, laundering, and interaction effects were significant factors in changes in breaking strength of the broadcloth warp as indicated in Table XXI. The original resin finished fabric was 17.5 percent lower in strength than the untreated fabric. After thirty launderings the mean breaking strength for all fabrics was higher than the means for the unlaundered fabric.

Laundering and finish effects are responsible for variations in breaking strength of the broadcloth filling as shown in Table XXII. The resin finished fabric was 29 percent lower in strength than the original untreated fabric. As in the warp, the strength of the filling in all fabrics was higher at 30 launderings than in the original fabrics.

Table XXIII shows that variations in the breaking strength of the percale warp were due to finish effects and interaction. Of the two fabrics tested before laundering, the resin finished percale was 38 percent lower in strength than the unfinished fabric. After 30 launderings the untreated and starched fabrics were about 10 percent lower in strength than the original untreated percale, and the resin finished cloth was slightly stronger than before laundering.

The effect of finish is most important in accounting for the differences in breaking strength for the percale filling (Table XIV). There is also evidence that laundering affected breaking strength to some degree. Before laundering the resin finished percale was 37 percent lower in strength than the untreated fabric, and its strength was essentially unchanged throughout the series of launderings. The means of the untreated and starched fabrics show that strength was decreased slightly with laundering. No difference existed between the strength of the untreated and starched percale.

For both broadcloth and percale, the resin finished fabric was considerably lower in strength than the untreated fabric. Laundering increased the breaking strength of the broadcloth fabrics. The strength of the untreated and starched percale fabrics was reduced, and the resin treated percale filling was unchanged by laundering.

Starching had no effect on breaking strength since the means for the untreated and starched fabrics are approximately the same for each fabric.

Shrinkage was not responsible for the increase in strength of broadcloth as the number of yarns per inch did not change significantly with laundering. The differences in breaking strength as a result of laundering are of secondary importance when compared with differences due to finishes.

CHAPTER V

SUMMARY AND CONCLUSIONS

The effect of home laundering on various properties of resin treated and starched white broadcloth and percale was determined from results of tests performed on starched, untreated, and resin finished fabrics. The untreated fabric was included in order to provide a control for the experiment, the starched fabric being taken from the same original fabric as the untreated cloth.

The lengths of cloth used were cut into samples which were assigned to the various tests at random so that statistical analysis could be used to determine causes of variation among the fabrics.

All samples were laundered together in an automatic agitator type washer using water at 145 $\pm$ 2° F. and a low sudsing detergent, and the fabrics were dried in a tumbler type dryer. At each test interval, samples to be tested were removed from the wash load, dampened, and ironed. Tests were made before laundering and after 10, 20, and 30 launderings.

Tests made were: air permeability, reflectance, yarns per inch, stiffness, crease recovery, amount of absorption, rate of absorption, and breaking strength.

1. Laundering increased air permeability in all fabrics except the untreated percale. For both percale and broadcloth, the starched cloth was most permeable, and the untreated cloth was least permeable.

2. In the measurement of reflectance, all fabrics approached the

magnesium oxide standard more closely with laundering, the broadcloth becoming less blue and the percale becoming less yellow.

3. There was little change in yarns per inch. The resin treated fabrics had fewer yarns per inch than the untreated and starched fabrics. Although laundering caused some differences of statistical significance, there was no change great enough to be of practical importance in use and performance of the fabrics.

4. Starching increased the stiffness of both the percale and the broadcloth. Except for the percale filling, the untreated cloth was stiffer than the resin finished fabric before laundering. Laundering increased the stiffness of the untreated broadcloth and percale filling and of the untreated and resin finished broadcloth warp. The stiffness of the untreated percale warp decreased with laundering.

5. For all fabrics, crease recovery was highest for the 0-laundered resin finished fabrics and lowest for the starched fabrics. For all resin finished fabrics, crease recovery was reduced by laundering. The recovery of the untreated broadcloth warp was improved and that of the untreated percale warp was decreased by laundering.

6. The untreated fabrics absorbed the largest amount of water, and the resin finished cloths absorbed least. Laundering increased the rate at which all fabrics except the resin finished percale and the starched fabrics absorbed water.

7. Except for the 0-laundered broadcloth, the untreated fabrics absorbed water most rapidly and the resin finished cloth least rapidly at all test intervals. Laundering increased the rate at which all fabrics except the resin finished percale and the starched fabrics absorbed water.

8. For both fabrics, the resin finished cloth was lowest in breaking strength, and differences between the resin finished cloth and untreated cloth were greater for percale than for broadcloth. Starching did not affect the strength of the fabrics, and laundering did not produce any deterioration in strength except for a slight decrease in the strength of the untreated and starched percale fabrics.

9. For all tests, changes between 0 and 10 launderings were more pronounced than later changes. There was a tendency toward a levelling or stabilizing of test results at intervals after 10 launderings.

10. Test measurements indicate that little loss of the resin finish resulted from the laundering process, since the resin finished cloth did not change excessively with repeated launderings.

11. Although no attempt was made to compare the performance of the broadcloth and percale fabrics, the following similarities existed and are readily observable:

a. Air permeability was greatest for starched fabrics and lowest for untreated fabrics.

b. Starched fabrics were much stiffer than untreated and resin finished fabrics. Generally, the resin finished fabrics were least stiff.

c. Resin finished fabrics consistently had the highest crease recovery, while starched fabrics were lowest. Laundering produced a decrease in the recovery of the resin finished fabrics.

d. Laundering increased the maximum rate of absorption. The untreated fabric had the highest and the resin finished fabric the lowest rate of absorption.

e. Resin treated fabrics were lower in breaking strength than untreated and starched fabrics. Laundering had little or no deteriorating effect on breaking strength.

f. Yarn count was lower for resin finished fabrics than for untreated cloth.

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A P P E N D I X

TABLE I

ANALYSIS OF VARIANCE: AIR PERMEABILITY (BROADCLOTH)

Source of Variation	Degrees of Freedom	Mean Square
Total	143	
Pieces in Finish	33	10.701
Wash	3	2795.980**
Finish	2	3968.505**
Finish x Wash (Interaction)	6	811.814**
Error	99	2.082

** Denotes significance at the 1 percent level

TABLE II

ANALYSIS OF VARIANCE: AIR PERMEABILITY (PERCALE)

Source of Variation	Degrees of Freedom	Mean Square
Total	143	
Pieces in Finish	33	66.110
Wash	3	1007.418**
Finish	2	5318.286**
Finish x Wash (Interaction)	6	612.132**
Error	99	6.128

** Denotes significance at the 1 percent level

TABLE III

ANALYSIS OF VARIANCE: REFLECTANCE
(BROADCLOTH)

Source of Variation	Degrees of Freedom	Mean Square
Total	143	
Pieces in Finish	33	.0205
Wash	3	29.3388**
Finish	2	6.5842**
Finish x Wash (Interaction)	6	3.1977**
Error	99	.0164

** Denotes significance at the 1 percent level

TABLE IV

ANALYSIS OF VARIANCE: REFLECTANCE
(PERCALE)

Source of Variation	Degrees of Freedom	Mean Square
Total	143	
Pieces in Finish	33	.0248
Wash	3	2.2736**
Finish	2	.5195**
Finish x Wash (Interaction)	6	.2666**
Error	99	.0118

** Denotes significance at the 1 percent level

TABLE V

ANALYSIS OF VARIANCE: YARNS PER INCH OF WARP (BROADCLOTH)

Source of Variation	Degrees of Freedom	Mean Square
Total	143	
Pieces in Finish	33	2.269
Wash	3	1.823
Finish	2	137.505**
Finish x Wash (Interaction)	6	3.767*
Error	99	1.381

Means

Number of Launderings	Untreated	Starched	Resin
0	160.2	159.5	155.8
10	160.0	159.8	156.7
20	159.7	160.0	157.3
30	159.7	159.7	157.7

* Denotes significance at the 5 percent level

** Denotes significance at the 1 percent level

TABLE VI

ANALYSIS OF VARIANCE: YARNS PER INCH OF FILLING (BROADCLOTH)

Source of Variation	Degrees of Freedom	Mean Square
Total	143	
Pieces in Finish	33	1.063
Wash	3	.887**
Finish	2	306.330**
Finish x Wash (Interaction)	6	.260
Error	99	.220

Means

Number of Launderings	Untreated	Starched	Resin
0	73.8	73.7	69.0
10	73.2	73.2	69.0
20	73.7	73.4	69.2
30	73.5	73.6	69.2

** Denotes significance at the 1 percent level

TABLE VII

ANALYSIS OF VARIANCE: YARNS PER INCH OF WARP
(PERCALE)

Source of Variation	Degrees of Freedom	Mean Square
Total	143	
Pieces in Finish	33	.764
Wash	3	1.907**
Finish	2	77.645**
Finish x Wash (Interaction)	6	3.803**
Error	99	.303

Means

Number of Launderings	Untreated	Starched	Resin
0	89.8	89.6	86.2
10	89.4	88.8	87.6
20	89.1	88.8	87.5
30	89.2	88.4	86.6

** Denotes significance at the 1 percent level

TABLE VIII

ANALYSIS OF VARIANCE YARNS PER INCH OF FILLING
(PERCALE)

Source of Variation	Degrees of Freedom	Mean Square
Total	143	
Pieces in Finish	33	1.012
Wash	3	18.893**
Finish	2	28.430**
Finish x Wash (Interaction)	6	9.560**
Error	99	.272

Means

Number of Launderings	Untreated	Starched	Resin
0	77.1	77.0	78.0
10	79.0	78.8	77.1
20	79.6	79.3	77.5
30	79.9	79.7	77.3

** Denotes significance at the 1 percent level

TABLE IX

ANALYSIS OF VARIANCE: STIFFNESS OF WARP
(BROADCLOTH)

Source of Variation	Degrees of Freedom	Mean Square
Total	87	
Wash	3	6.7394**
Finish	2	86.6569**
Wash x Finish (Interaction)	5	.0219
Pieces in Finish (Error for finish)	21	.0080
Piece in Wash in Finish (Error for wash and interaction)	56	.0178

Means
(Length of Overhang in cm.)

Number of Launderings	Untreated	Starched	Resin
0	4.16	--	3.86
10	4.29	7.44	4.12
20	4.32	7.49	4.02
30	4.30	7.38	3.92

** Denotes significance at the 1 percent level

TABLE X

ANALYSIS OF VARIANCE: STIFFNESS OF FILLING
(BROADCLOTH)

Source of Variation	Degrees of Freedom	Mean Square
Total	87	
Wash	3	4.1233**
Finish	2	54.5816**
Wash x Finish (Interaction)	5	.0347*
Pieces in Finish (Error for finish)	21	.0126
Piece in Wash in Finish (Error for wash and interaction)	56	.0140

Means
(Length of Overhang in cm.)

Number of Launderings	Untreated	Starched	Resin
0	3.48	--	3.08
10	3.66	5.91	3.21
20	3.69	5.98	3.13
30	3.63	5.99	3.05

* Denotes significance at the 5 percent level

** Denotes significance at the 1 percent level

TABLE XI

ANALYSIS OF VARIANCE: STIFFNESS OF WARP
(PERCALE

Source of Variation	Degrees of Freedom	Mean Square
Total	87	
Wash	3	2.1486**
Finish	2	107.6665**
Wash x Finish (Interaction)	5	.9264**
Pieces in Finish (Error for finish)	21	.0247
Piece in Wash in Finish (Error for wash and interaction)	56	.0269

Means
(Length of Overhang in cm.)

Number of Launderings	Untreated	Starched	Resin
0	5.80	—	4.22
10	4.90	8.11	4.38
20	4.70	7.95	4.30
30	4.52	8.21	4.14

** Denotes significance at the 1 percent level

TABLE XII

ANALYSIS OF VARIANCE: STIFFNESS OF FILLING (PERCALE)

Source of Variation	Degrees of Freedom	Mean Square
Total	87	
Wash	3	4.5550**
Finish	2	36.2652**
Wash x Finish (Interaction)	5	.0558
Pieces in Finish (Error for finish)	21	.0161
Piece in Wash in Finish (Error for wash and interaction)	56	.0136

Means
(Length of Overhang in cm.)

Number of Launderings	Untreated	Starched	Resin
0	3.38	—	3.44
10	3.61	5.58	3.58
20	3.52	5.79	3.51
30	3.53	5.62	3.41

** Denotes significance at the 1 percent level

TABLE XIII

ANALYSIS OF VARIANCE: CREASE RECOVERY OF WARP
(BROADCLOTH)

Source of Variation	Degrees of Freedom	Mean Square
Total	87	
Wash	3	545.0493**
Finish	2	7981.2373**
Wash x Finish (Interaction)	5	147.2154**
Pieces in Finish (Error for finish)	21	5.1491
Piece in Wash in Finish (Error for wash and interaction)	56	5.1954

** Denotes significance at the 1 percent level

TABLE XIV

ANALYSIS OF VARIANCE: CREASE RECOVERY OF FILLING
(BROADCLOTH)

Source of Variation	Degrees of Freedom	Mean Square
Total	87	
Wash	3	866.6613**
Finish	2	5569.8159**
Wash x Finish (Interaction)	5	97.3372**
Pieces in Finish (Error for finish)	21	4.8170
Piece in Wash in Finish (Error for wash and interaction)	56	5.7680

** Denotes significance at the 1 percent level

TABLE XV

ANALYSIS OF VARIANCE: CREASE RECOVERY OF WARP (PERCALE)

Source of Variation	Degrees of Freedom	Mean Square
Total	87	
Wash	3	379.9188**
Finish	2	6758.9270**
Wash x Finish (Interaction)	5	19.1819**
Pieces in Finish (Error for finish)	21	3.7540
Piece in Wash in Finish (Error for wash and interaction)	56	3.2600

** Denotes significance at the 1 percent level

TABLE XVI

ANALYSIS OF VARIANCE: CREASE RECOVERY OF FILLING (PERCALE)

Source of Variation	Degrees of Freedom	Mean Square
Total	87	
Wash	3	329.8009**
Finish	2	7133.4004**
Wash x Finish (Interaction)	5	18.8971**
Pieces in Finish (Error for finish)	21	5.6990
Piece in Wash in Finish (Error for wash and interaction)	56	3.9279

** Denotes significance at the 1 percent level

TABLE XVII

ANALYSIS OF VARIANCE: TOTAL AMOUNT OF ABSORPTION
(BROADCLOTH)

Source of Variation	Degrees of Freedom	Mean Square
Total	87	
Wash	3	.0088
Finish	2	.1512**
Wash x Finish (Interaction)	5	.0208**
Pieces in Finish (Error for finish)	21	.0043
Piece in Wash in Finish (Error for wash and interaction)	56	.0033

Means
(mls.)

Number of Launderings	Untreated	Starched	Resin
0	.925	—	.694
10	.881	.800	.731
20	.888	.775	.838
30	.906	.794	.838

** Denotes significance at the 1 percent level

TABLE XVIII

ANALYSIS OF VARIANCE: TOTAL AMOUNT OF ABSORPTION (PERCALE)

Source of Variation	Degrees of Freedom	Mean Square
Total	87	
Wash	3	.0214**
Finish	2	.0686**
Wash x Finish (Interaction)	5	.0044
Pieces in Finish (Error for finish)	21	.0033
Piece in Wash in Finish (Error for wash and interaction)	56	.0022

Means (mls.)

Number of Launderings	Untreated	Starched	Resin
0	.931	--	.869
10	.981	.912	.900
20	1.025	.912	.988
30	1.031	.925	.925

** Denotes significance at the 1 percent level

TABLE XIX

ANALYSIS OF VARIANCE: MAXIMUM RATE OF ABSORPTION (BROADCLOTH)

Source of Variation	Degrees of Freedom	Mean Square
Total	87	
Wash	3	73.7069**
Finish	2	8.7550**
Wash x Finish (Interaction)	5	5.5565**
Pieces in Finish (Error for finish)	21	.0201
Piece in Wash in Finish (Error for wash and interaction)	56	.0215

** Denotes significance at the 1 percent level

TABLE XX

ANALYSIS OF VARIANCE: MAXIMUM RATE OF ABSORPTION (PERCALE)

Source of Variation	Degrees of Freedom	Mean Square
Total	87	
Wash	3	3.6536**
Finish	2	223.9785**
Wash x Finish (Interaction)	5	4.2290**
Pieces in Finish (Error for finish)	21	.0203
Piece in Wash in Finish (Error for wash and interaction)	56	.0205

** Denotes significance at the 1 percent level

TABLE XXI

ANALYSIS OF VARIANCE: BREAKING STRENGTH OF WARP
(BROADCLOTH)

Source of Variation	Degrees of Freedom	Mean Square
Total	59	
Wash	1	342.7322**
Finish	2	891.4558**
Wash x Finish (Interaction)	1	1.9763
Pieces in Finish (Error for finish)	33	15.632
Piece in Wash in Finish (Error for wash and interaction)	22	17.388

Means
(In Pounds)

Number of Launderings	Untreated	Starched	Resin
0	57.6	--	47.5
30	60.3	62.5	49.4

** Denotes significance at the 1 percent level

TABLE XXII

ANALYSIS OF VARIANCE: BREAKING STRENGTH OF FILLING
(BROADCLOTH)

Source of Variation	Degrees of Freedom	Mean Square
Total	59	
Wash	1	581.1776**
Finish	2	681.4420**
Wash x Finish (Interaction)	1	5.4002
Pieces in Finish (Error for finish)	33	2.0995
Piece in Wash in Finish (Error for wash and interaction)	22	2.0047

Means
(In Pounds)

Number of Launderings	Untreated	Starched	Resin
0	30.9	--	22.0
30	36.1	36.6	25.8

** Denotes significance at the 1 percent level

TABLE XXIII

ANALYSIS OF VARIANCE: BREAKING STRENGTH OF WARP (PERCALE)

Source of Variation	Degrees of Freedom	Mean Square
Total	59	
Wash	1	.3100
Finish	2	2346.1054**
Wash x Finish (Interaction)	1	149.7069**
Pieces in Finish (Error for finish)	33	6.9302
Piece in Wash in Type (Error for wash and interaction)	22	10.1272

Means (In Pounds)

Number of Launderings	Untreated	Starched	Resin
0	59.7	--	37.1
30	53.3	54.0	38.2

** Denotes significance at the 1 percent level

TABLE XXIV

ANALYSIS OF VARIANCE: BREAKING STRENGTH OF FILLING
(PERCALE)

Source of Variation	Degrees of Freedom	Mean Square
Total	59	
Wash	1	18.6368*
Finish	2	1229.6062**
Wash x Finish (Interaction)	1	6.9691
Pieces in Finish (Error for finish)	33	2.4884
Piece in Wash in Finish (Error for wash and interaction)	22	2.5250

Means
In Pounds)

Number of Launderings	Untreated	Starched	Resin
0	38.4	—	24.1
30	36.9	36.2	24.1

* Denotes significance at the 5 percent level

** Denotes significance at the 1 percent level

VITA

Mary Laverne Walsh

Candidate for the Degree of

Master of Science

Thesis: THE EFFECT OF HOME LAUNDERING ON SELECTED PROPERTIES OF RESIN TREATED AND STARCHED BROADCLOTH AND PERCALE

Major Field: Clothing, Textiles, and Merchandising

Biographical and Other Items:

Personal Data: Born September 21, 1937 near Okemah, Oklahoma, The daughter of Arthur W. and Margaret Walsh.

Education: Attended Okfuskee grade school and graduated from Okemah High School.
Undergraduate Study: East Central State College, 1955-1958.
Graduate Study: Oklahoma State University, 1958-1960.

Professional Experience: Graduate Assistant in textile research for the Department of Clothing, Textiles, and Merchandising, College of Home Economics, Oklahoma State University from 1958 to May, 1960.