EFFECT OF FABRIC SOFTENERS ON SELECTED COTTON AND COTTON-BLEND FABRICS AFTER A SERIES OF LAUNDERINGS

by

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INTRODUCTION

Fabric softeners have recently been made available for home laundering and their use has been widely promoted through the advertising media. These fabric softeners, as used in home laundering, are viscous fluids which are added to the final rinse. According to the promotional information, many desirable properties of fabrics result from or are improved by the use of softeners. As laundering is an important activity in most homes, it seems important to determine the effectiveness of fabric softeners. The purpose of this study is to test the null hypothesis that the use of fabric softeners has no significant effect, after a series of launderings, on certain physical properties of cotton and cotton-blends.

The Nature of Fabric Softeners

Silk, the aristocratic fiber of the past, has a luxury look and feel; it has a soft, pliable hand and drapes nicely. Silk, however, has been somewhat replaced by many man-made and resin-treated fibers. The softness of these fibers is much less than desirable. The size and twist of the yarns and the fabric construction affect the softness and hand. Chemical additives can improve this hand. The most important additives are compounds classified as cationic fabric softeners, which basically are true ionizable organic salts. These will ionize completely in dilute aqueous solution and will migrate to the surface of the fiber (3).

The fabric softeners, which are retailed for home laundering, are dialkyl quaternary ammonium salts in an alcohol and water solution. Some are tinted and perfumed to enhance aesthetic appeal. The dialkyl quaternary ammonium salts have two components; one is hydrophobic and the other is hydrophilic. The dialkyl or fatty portion will not mix with water because it is hydrophobic. So that the compound will mix with water, a hydrophilic portion is combined with the fatty portion. The part of the quaternary ammonium salt which has an affinity for moisture has a negative electrical charge and the part which repels moisture has a positive electrical charge. When the salt is dissolved in a water solution, the positive electrical charge is predominant; consequently, the quaternary ammonium salts are referred to as cationics as they are positively charged.

Most clothing fabrics have a negative charge. When garments are rinsed in water to which a cationic fabric softener has been added, the negative charge of the fabric attracts the fabric softener. The softener forms a coating on each fiber surface (19). Thus, cationic fabric softeners are lubricants of high spreading and penetrating power which improve the hand of a fabric as the yarn or filament slippage is increased (3).

As the softener lubricates each individual fiber, the strength of the fiber is increased because of the lessening of abrasive effects. This same lubricating ability is present on the yarns and, therefore, improves the strength of the fabric as yarn abrasion is lessened. As the yarns in the fabric are more flexible, sewability is increased as the needle can push the yarns aside more easily and not cause breakage of the threads (3).

Quaternary ammonium salts are effective as anti-static agents, especially on hydrophobic materials. As two different fabrics are rubbed together, the friction causes a build-up of static electricity on the surfaces; this accumulates on natural as well as the man-made fibers. At room and body temperatures, the natural fibers contain some moisture which serves as conduction material, so any electrical charge is quickly grounded. The fabrics of man-made fibers which have been rinsed in a fabric softener, can retain a higher moisture content; this is because the hydrophilic portion of the quaternary salt, which coats the fibers, has the same affinity for water as natural fibers. This moisture retaining property is present even after excessive drying in an automatic dryer (19).

For optimum conditions for drying with a minimum of wrinkling, good mechanical action is needed so there will be good continuous flexing of the material. A static accumulation on the fabrics prevents good mechanical action. As fabric softeners lessen the build-up of static electricity, less wrinkling results (18).

The quaternary ammonium salts--in proportion of one part salt to 20,000 parts water--will kill common disease-causing organisms within ten minutes. Fabrics treated with these salts will prevent the transfer of the organism, Staphylococcus aureus, which causes boils. These salts also are effective against Bacillus ammonia-genes the indirect cause of diaper rash for infants (19). Some salts possibly have a germicidal effect on E. coli and M. pyrogenes (3).

The Development of Fabric Softeners

The quaternary salts, now used as fabric softeners, were first prepared in the early 1900's, but remained laboratory curiosities for 30 years. About 1935, interest in their use was revived because of their high germicidal activity. In the late 1930's, the textile industry began to use these cationic compounds, but not for softening fabrics. Many new compounds have since been synthesized and used for many purposes relating to textiles (3).

Fabric softeners were first used by rayon processors to impart smoothness and to improve draping qualities of these cellulosic fabrics. The application of these cationic surfactants is now one of the most widely used final operations to improve hand, drape, and cutting and sewing properties of fabrics of cellulosic fibers. The importance of these additives has been increased because the fabrics made of man-made fibers, which are hydrophobic, need an anti-static finish. Hundreds of fabric softeners for commercial use have been described in patent literature, but only a few are available and used by the textile industry (16).

Cationic fabric softeners are now being used by some commercial laundries as "plus factors" for their customers. Some qualities associated with the use of cationics in commercial laundering are softening, "lofting," easier shakeout of large pieces, reduced wrinkling and linting, shorter drying and ironing time, less static electricity on man-made fibers, and less mildew on cellulosic fibers (3).

In 1957, over 15 different brands of fabric softeners were on the consumer market for home laundering use. The effects of their use, as promoted by the distributing concerns, vary some; but are essentially the same as the effects of using the basic quaternary ammonium salts. The cationic additives also vary some in composition. The basic quaternary ammonium compounds are generally 5 to 15 per cent of the formulation (15). Several automatic washing machines are now equipped with dispensers for the release of these preparations and other laundry aids into the water at the appropriate time.

Fibers Used in This Study

Cotton is the most used fiber for fabric construction. This fiber has many qualities which contribute to easy launderability. The fiber has a high wet strength and good resistance to alkalis. It has high electrical resistance and, therefore, does not pill. However, it does tend to crease easily and become rumpled, and it has a tendency to be attacked by mildew-causing fungi (10). Resin finishes, which change the structure of the cellulose, add resiliency and body to cottons so that the fabrics tend to resist creasing and soiling (7).

Dacron is the du Pont Company's trade name for a polyester fiber, which is a condensation product of ethylene glycol and dimethyl terephthalate. Fabrics made from this fiber have excellent dimensional stability, outstanding resilience, good resistance to soaps and synthetic detergents under ordinary laundering conditions, and high wet and dry strength. Dacron has a tendency to accumulate static electricity (11).

Arnel is a triacetate fiber produced by the Celanese Corporation. It is the most hydrophobic cellulosic fiber. Arnel has good dimensional stability and moderate strength; it is resistant to dilute laundering alkalis under mild conditions and will resist wrinkling as the fabrics are given a heat-setting treatment. The accumulation of static electricity tends to be high (12).

Any fabric in which two or more fibers are mixed or combined is a blend. Fibers may be blended by mixing them together in a staple form and then spinning the staple into a yarn. Fibers may be combined by twisting different yarns together or weaving different yarns into a single piece of fabric. When fabrics are properly blended, the desirable qualities of one fiber tend to eliminate the undesirable properties of other fibers by compensating for them (22).

The new emphasis on "wash and wear" fabrics has resulted in a trend toward the blending of many old and new fibers. Some desired qualities from blending are interesting textures and hand, better colorfastness, and an optimum resistance to wrinkling during laundering and when in wear-use.

According to Salvin (14), the contribution of Arnel to cotton-Arnel blends includes a wrinkle-prevention factor, which results from its high modulus, especially in hot humid conditions. Blends with Arnel are dimensionally stable. If the fabrics are properly dyed, there is a high degree of light- and colorfastness.

The styling effects and hand of fabrics of Arnel-cotton blends have appealed to the consumers.

One of the most important blends of cotton with man-made fibers is that of 65 per cent Dacron and 35 per cent cotton. The fabric made from this blend is extremely popular with consumers because of the "ease of care" properties of minimum wrinkling and easy launderability (10).

REVIEW OF LITERATURE

The literature reveals that very little research has been done on the effects of fabric softeners as used in home laundering.

The Philadelphia section of the American Association of Textile Chemists and Colorists reported the secondary effects of cationic fabric softeners as used under mill conditions. Different types of softeners were applied to Acrilan, Arnel, cotton, rayon, and wool. The testing was to determine relative effects on the fabric properties of tear strength, seam strength, electrical resistance, ageing, heat, and color change resulting from the latter two and ultraviolet light. The effect of softener application to Arnel generally increased the tear strength. The quaternary ammonium types of softeners were effective anti-static agents. Also, these types of softeners showed desirable protection against ultra-violet light bleaching of Arnel. The application of the quaternary ammonium types of softeners on cotton resulted in a good general increase in tear strength and some increase in softness (Sollenberger, 16).

According to Sollenberger (16), who reported the study, there has been a tendency for textile finishers to use a high concentration of softening material to obtain improved softness. This may cause actual stiffness in the fabric because the softening material is a solid tacky wax in pure form. Fabric softeners may produce effects on the material varying from silk-like to suede-like, depending on fabric construction and the softener composition. On knitted fabrics, an application of high amounts may result in an extremely soft nap.

According to Du Brow and Linfield (3), a one-tenth per cent concentration of softener to basic fabric is recommended because over-treatment tends to make the fabric water-repellent and greasy. Intervening washings tend to remove the excessive cationic buildup. The result of detergents in washing may also inactivate certain softener advantages, especially as an organism growth inhibitor.

Ward (19) stated that a small amount of fabric softener is needed for rinsing as all of the softener is attracted and retained by the fabric, and none is discarded with the rinse water.

According to wash and wear tests conducted by a producer of a widely distributed fabric softener and reported by White (20), the garments rinsed in a fabric softener generally needed less ironing than those garments not rinsed in water containing a fabric softener. When used on all cotton garments, the softener improved the appearance but did not eliminate the need for ironing.

The use of the fabric softener on the all cottons made stiff finishes more comfortable to the wearer. When the fabric softener was used on wash and wear man-mades or man-made blends, the static electricity was usually eliminated and the ironing was faster and easier. Wrinkles, in some cases, were completely eliminated when the garments were dried in an automatic dryer. Those garments which were rinsed with a fabric softener and line dried were comparable to garments that were given no softener treatment and were dried in a dryer.

The consumer market has whole-heartedly accepted the principle of "easy care" for fabrics and garments. This has resulted in the development of fabrics which are classed as "wash and wear." Williams (21) related that the ideal wash and wear garment or fabric is one that presents the ultimate in appearance, after repeated washings and dryings. This ideal of appearance is hard to define. Appearance is a mental concept, dependent on the observer's experiences, opinions, and mental disposition when he sees an object. Objective and subjective test methods have been the concern of many associated with wash and wear fabrics.

Photographic standards for the subjective evaluation of appearance have been developed by the Monsanto Chemical Company, E. I. du Pont de Nemours & Company, and Eastman Chemical Products, Inc. According to Stass (17), the use of any one of these three standards is a step in the right direction for evaluation judgments. Stass' conclusions are that the Eastman Chemical Products' photographs are very realistic. The photographs developed by

Monsanto Chemical show extensive wrinkling and many consumers would not accept any of the standards as wearable. Another disadvantage is that the fabrics have to be judged with special lighting. The photographs developed by du Pont are not actual size. They appear less wrinkled than the actual fabrics because the reduction of the photographs resulted in a muting of the wrinkles. Stass believes that the worst rating could be rated as "wash and wear," and the photographic standards do not cover the category into which a large amount of fabrics would fall.

The Wash and Wear Committee of the American Association of Textile Chemists and Colorists has accepted an evaluation technique based on five two-dimensional standards as developed by the Monsanto Chemical Company. This is the AATCC Tenative Test Method 88-1958. According to Williams (21), the comparison of two-dimensional standards with the three-dimensional test specimens is not too desirable. A set of five plastic three-dimensional standards has been developed recently by Monsanto Chemical. The results of using these standards indicated marked improvement over the photographic standards in the evaluation of wash and wear fabrics.

According to Kaswell (9), the problem of relating subjective evaluations to quantitative objective measurements is probably impossible. Subjective evaluations vary from person to person when judging such properties as drape, hand, luster, and wrinkling. In the objective measurements of wrinkling, fabrics are creased under specific load, direction, and time conditions; these conditions are not present in the actual use of fabrics. A wrinkling apparatus, the Celanese Wrinkle Tester, was made by the AATCC Creasing Properties Committee. This instrument wrinkles 8-inch by 8-inch fabric samples in a random but reproducible manner. The wrinkled fabrics are then subjectively ranked according to five qualitative-subjective criteria and a weighted numerical index of wrinkle resistance is calculated. The five criteria are wrinkle density, profile, sharpness of creasing, degree of mussiness, and randomness. Results are based on the over-all subjective opinion of relative rank and a weighted score method based on the five criteria. In the test reported by Kaswell, excellent correlation existed between the rank evaluation of the Monsanto and Cyanamid methods of crease recovery measurements. Excellent correlation existed between the qualitative-subjective weighted score and the Monsanto quantitative-objective angle of recovery method. The Celanese Wrinkle Test Method was not accepted by the AATCC as a standard, because it was believed that the textile industry must have an objective test method so that results could always be measured in a prescribed manner.

According to Bogarty et al. (1), the measurement of the hand of fabrics has been a controversial subject for many years. After numerous attempts to develop instruments for measuring factors relating to hand, none has been used with success. At the present, there are no satisfactory techniques for objective evaluation of hand.

"Hand," as defined by Hoffman and Beste (8), "is the impression which arises when fabrics are touched, squeezed, rubbed, or otherwise handled." Hand may be expressed as soft, crisp, firm, hard, harsh, cold, warm, boardy, dead, lively, waxy, dry, etc. Hand has many component characteristics which include stiffness expressed as firm, crisp, or soft; compliance as harsh, compliant, or limp; liveliness or springiness as opposed to a dead feel; weight; leanness or bulk; compressibility; thickness; waxiness; friction; covering power which includes fuzz and nap; and contour retention and resilience.

The sensitivity of the human hand and the discriminating ability of the individual to express hand as a single value will probably not be matched by any mechanical apparatus. All individuals have the ability to rate the feel of fabrics, although the observers' opinions may vary. This was evidenced in judgment tests reported by Bogarty et al. (1).

Bogarty also discussed methods of evaluating hand. One common method of evaluating hand is the intercomparison among a group of fabrics; these fabrics are rated at the same time and arranged in relative order of softness. A variation of this method involves the use of one of the fabrics in the group as "standard" and ranking is relative to the one fabric.

Another type of hand evaluation consists of offering fabrics one at a time for judgment; there is no physically present fabric standard. Previous impressions and experience are the sole basis for judgment. This sort of evaluation is common in everyday evaluation of clothing items.

METHOD OF PROCEDURE

Procedures formulated by Committee D-13 of the American Society for Testing Materials (2); the Federal Specification, Textile Test Methods CCCT-191b (4); and the Research Committee of the American Association of Textile Chemists and Colorists (13) were followed for the analyses of fabrics.

Selection of Fabrics and Fabric Softeners

Three broadcloth fabrics, suitable for garments which would be laundered frequently, were selected for this study. The fabrics were purchased as all cotton, Dacron and cotton, and Arnel and cotton. Two replicas, one pink and one pastel blue, were purchased for each fabric. The term "replica" is used, henceforth, to denote the color lot of the particular fabric. The selection of the fabrics was made on the basis of similar thread counts and color tints.

The all cotton broadcloth was ordered from the Sears, Roebuck and Company store in Kansas City, Missouri. The fabric was described as "crease resistant" in the order catalog. The Dacron and cotton broadcloth was also purchased through the Sears, Roebuck and Company store. The Arnel and cotton fabric was purchased from the local J. C. Penney retail store.

Two fabric softeners, Sta-Puf and Nu-Soft, were used in this study. These two softeners are the most widely promoted ones available on the consumer market. The softeners were purchased at a local retail supermarket.

Laundry Procedure

Fabrics were divided into three groups for separate laundering: 1) control, 2) Sta-Puf rinse, and 3) Nu-Soft rinse. The laundering was done in an automatic home-type horizontal axis washer. Each group of fabrics was washed for five minutes in water containing 30 grams of neutral soap flakes and at a temperature of 120° F. (± 2° F.). City water with a hardness of about 65 ppm was used. White cotton terry towels were used to increase the wash load to six pounds; a different lot of towels was used for each laundry group. The fabrics were allowed to complete the laundering cycle; this included three rinses of about two minutes each and the spin-dry process. No adjustment of water temperature was made for the rinses. After the water for the final rinse had run into the washer, the fabric softener was added. The amount of fabric softener used was in accordance with directions on the label of each fabric softener container. One-half cup of Sta-Puf was used for fabrics of group 2 and one bottle cap-ful of Nu-Soft was added to the final rinse of fabric group 3. No softener was added to the control group.

Each group of fabrics was dried in an automatic dryer for 30 minutes with no heat; after drying, the fabrics were laid flat. The towels were dried separately.

There was an interval of at least 24 hours between subsequent launderings. Portions of each fabric were withdrawn for analysis after 1, 5, 10, and 20 launderings.

Determinations of Fabric Properties

The fabrics, before laundering, were analyzed to determine fiber content, percentage of nonfibrous material and sizing, weight per square yard, direction and amount of twist, yarn number, thread count, dry and wet breaking strengths by the ravel strip method, crease recovery, and pilling resistance.

The measurements of wet and dry breaking strengths were also made after 1, 5, 10, and 20 launderings. Crease recovery and pilling resistance were measured after 20 launderings. Dimensional stability was determined after 1, 5, 10, and 20 launderings. The comparison of colorfastness was made between the fabrics which had been laundered 20 times and specimens as washed in the Launder-Ometer by AATCC Test Method 36-54, No. II.

Subjective evaluations of hand and appearance were made of fabrics before laundering and after 1, 5, 10, and 20 launderings by a panel of five persons.

Procedures recommended by A.S.T.M. were used to determine fiber content and percentage of nonfibrous material and sizing, Designation D-629-56T; count, amount and direction of twist, breaking strength by the ravel strip method, Designation D-39-49; recovery from creasing by the angle of recovery method using the Monsanto apparatus, Designation D-1295-53T; and pilling resistance, Designation D-1375-55T, using the appearance retention Method. The weight per square yard was determined by Test Method 5041 of Federal Specification. The yarn number was determined by the use of the Roller-Smith Universal Yarn Numbering balance.

All objective determinations were made under standard conditions of temperature and relative humidity.

Three sets of specimens for each fabric were used to determine dimensional stability. These specimens were 15-inch squares which were turned and machine edge-stitched; a darker shade of thread was used to mark a 10-inch square on each specimen. After the specimens were steam pressed without tension, measurements were made for the dimensional stability.

These same fabric specimens, before pressing, were used for the evaluation of appearance and hand.

Subjective Evaluations

The hand and appearance were subjective evaluations done by a panel of five persons who are engaged in textile research or study. Each panel member evaluated the same set of specimens throughout the study.

The photographic standards devised by the du Pont laboratories (18) were used as standards for the evaluation of appearance. The rating system ranged from 5, perfect performance, to 1, poor performance. The photographic standards are of reduced size and have a reference rectangle on the photograph for comparison of size. These standards were mounted on gray paper. For the evaluation, a set of specimens was arranged alphabetically, with both colors adjacent, in groups according to fiber content. These were laid flat on a table covered with white paper. Natural light from east windows and overhead fluorescent lighting were used. The panel member observed the specimens from an angle which would not obstruct the effect of the natural light on the specimens and recorded her impressions.

For the evaluation of hand, a set of five standards was assembled with the assistance of persons who have done extensive work with textiles. The rating system of '1', softest hand, to '5', least soft hand, was used. All five standards were white cotton broadcloth or broadcloth-like fabrics which had never been laundered. The '1' standard was soft, resilient, pliable, and silk-like to touch; it was the softest cotton broadcloth fabric which was available. The '5' standard was stiff, wiry, and harsh to touch. Standards '2', '3', and '4' were of varying degrees of softness between '1' and '5'. The standards were of about one-fourth yard swatches which were anchored in manila folders.

For the evaluation, the panel member was blindfolded with a device used for light blinding to facilitate sleeping. The standards were arranged on a table directly before the panel member. The 18 fabric specimens, arranged in an unplanned random order, were individually handed to the panel member for comparison with the standards. The impressions were recorded by the person conducting the test. Any pertinent comments relating to the hand of the fabrics also were recorded.

Analysis of Data

Analyses of variance were made of the data relating to hand, appearance, breaking strengths, and crease recovery to determine the significance of the effect of the fabric softeners as related to inherent fabric differences and the number of launderings.

Comparative judgments were made of data relating to dimensional stability, pilling, and colorfastness.

FINDINGS AND DISCUSSION

All of the fabrics analyzed in this study were of a plain weave and were classed as broadcloths (Plate I).

Physical Analyses of Fabrics

The fabrics, before laundering, were analyzed for determinations of fiber content, percentage of nonfibrous material and sizing, weight per square yard, direction and amount of twist, yarn number, thread count, dry and wet breaking strengths, crease recovery, and resistance to pilling. These determinations of initial qualities were the combined averages of both colors of the fabrics of all-cotton, Dacron-cotton blend, and Arnel-cotton blend. Results of these analyses appear in Table 1.

Fiber Content. The results of chemical analyses showed that the cotton fabric was 100 per cent cotton; the Dacron-cotton fabric was 65 per cent Dacron and 35 per cent cotton; and the Arnel-cotton fabric was a blend of 80 per cent Arnel and 20 per cent cotton.

Percentage of Nonfibrous Material and Sizing. The percentage of nonfibrous material and sizing present in the cotton fabric was 2.6 for the blue and 2.3 for the pink. The Dacron-cotton

EXPLANATION OF PLATE I

The broadcloths used in this study are as follows:

Fig. 1. Blue cotton fabric.

Fig. 2. Pink cotton fabric.

Fig. 3. Blue Dacron-cotton fabric.

Fig. 4. Pink Dacron-cotton fabric.

Fig. 5. Blue Arnel-cotton fabric.

Fig. 6. Pink Arnel-cotton fabric.

PLATE I

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Fig. 5

Fig. 6

blend fabric had 1.2 per cent of sizing for the blue and 1.3 per cent of sizing for the pink. The nonfibrous material present in the Arnel-cotton fabric was 1.4 per cent for the blue and 1.5 per cent for the pink.

Weight per Square Yard. All of the fabrics were of about the same weight. Both pink and blue replicas of the all-cotton fabric weighed 3.4 ounces per square yard. The two colors of the Dacron-cotton blend had a weight of 3.2 ounces per square yard. The blue Arnel-cotton fabric, weighing 3.4 ounces per square yard, was slightly heavier than the pink fabric, which weighed 3.3 ounces per square yard.

Direction and Amount of Twist. All of the fabrics were constructed of yarns which had a "Z" twist for both warp and filling, except the filling yarn of the pink Dacron-cotton blend, which was "S" twisted.

The "S" twisted filling yarn of the pink Dacron-cotton fabric had more twists per inch than the other yarns with 22.7 twists per inch compared with the blue fabric which had 14.2 twists per inch. The other yarns were generally consistent between the two colors. The Dacron-cotton warp had 17.7 twists per inch for the blue and 17.9 twists per inch for the pink. The yarns of the all-cotton fabrics had twists of 20.5 and 21.9 per inch of the warp and 12.3 and 12.1 twists per inch for the filling; blue and pink fabric, respectively. Yarns of the Arnel-cotton fabric were less tightly twisted than yarns of the other fabrics; the blue and pink warp had 8.9 and 9.6 twists per inch and the filling had 4.0 and 3.8 twists per inch.

Yarn Number. The yarn numbers varied somewhat among the different fabrics and between the two replicas of the Dacron-cotton blend. The filling yarns of the all-cotton fabric were number 36; the warp was number 32 and 34 for the blue and pink, respectively. The Arnel-cotton blend yarns were numbers: 40, blue warp; 41, pink warp; 22, blue filling; and 24, pink filling. The warp yarn, number 38, of the pink Dacron-cotton blend was coarser than the blue yarn, which was number 47; the reverse was true for the filling yarns, because the blue yarn was number 44 and the pink yarn was finer with a number of 58.

Thread Count. Both replicas of the all cotton and the Arnel-cotton fabrics had almost identical counts within their groups. The thread count per inch of the all-cotton fabric was 103 warp and 55 filling for the blue and 104 warp and 55 filling for the pink. The Arnel-cotton fabric had a thread count per inch of 95 warp and 62 filling for the blue and 95 warp and 60 filling for the pink. The thread count per inch of the Dacron-cotton fabric was 70 for the filling of both colors; the blue warp was more tightly woven with 135 threads per inch compared with 120 threads per inch for the pink.

Breaking Strength. All of the fabrics, except the Arnel-cotton blend filling, showed greater wet breaking strength than dry breaking strength. The blue Dacron-cotton blend fabric tended to be stronger than the pink. Both color lots of the all cotton and the Arnel-cotton were of similar strengths.

Pilling Resistance. Neither color lot of the all-cotton or Arnel-cotton fabrics showed any tendency to form pills when subjected to an abradant for 5 minutes with 0.9 pounds of pressure per square inch. The Dacron-cotton fabric showed a low pilling tendency for both colors.

Crease Recovery. The fabrics of the Dacron-cotton blend fibers had a higher percentage of crease recovery than the other fabrics. Fabrics of all cotton and Arnel-cotton fibers had a similar crease recovery, about 50 per cent warpwise and 60 to 66 per cent fillingwise. Both colors tended to be rather consistent in percentage of recovery; the one exception was the pink Dacron-cotton filling, which had a 9 per cent greater recovery than the blue Dacron-cotton filling. According to Fischer (5), a 75 per cent crease recovery is considered good.

Effect of Fabric Softeners on Fabrics after Laundering

The fabrics were analyzed for the effect of fabric softeners on hand, appearance, wet and dry breaking strengths, and dimensional stability after 1, 5, 10, and 20 launderings. After 20 launderings, determinations were made of pilling and crease recovery. Colorfastness to laundering was determined by comparison between specimens which had been laundered once in the Launder-Ometer and the fabrics which had been laundered 20 times.

Hand. The Dacron-cotton fabrics had a slightly softer hand before laundering than the Arnel-cotton fabrics. The cotton fabric was evaluated as being about '1' point harsher than the

Table 1. Physical properties of fabrics before laundering.

Fabric	All cotton Blue	All cotton Pink	Dacron-cotton Blue	Dacron-cotton Pink	Arnel-cotton Blue	Arnel-cotton Pink
Fiber content						
Per cent cotton	100	100	35	35	20	20
Per cent Dacron			65	65		
Per cent Arnel					80	80
Percentage of non-fibrous material	2.6	2.3	1.2	1.3	1.4	1.5
Price per yard	44¢	44¢	77¢	77¢	98¢	98¢
Fabric structure						
Weight-oz./sq.yd.	3.4	3.4	3.2	3.2	3.4	3.3
Threads per inch						
Warp	103	104	135	120	95	95
Filling	55	55	70	70	62	60
Yarn structure						
Number						
Warp	32	34	47	38	40	41
Filling	36	36	44	58	22	24
Twist						
Direction						
Warp	Z	Z	Z	Z	Z	Z
Filling	Z	Z	Z	S	Z	Z
Turns per inch						
Warp	20.5	21.9	17.7	17.9	8.9	9.6
Filling	12.3	12.1	14.2	22.7	4.0	3.8
Breaking strength-lbs.						
Warp						
Dry	45.9	46.0	62.2	70.9	40.6	38.9
Wet	56.4	57.6	62.8	71.4	45.0	43.3
Filling						
Dry	17.7	18.6	28.7	23.8	21.5	24.0
Filling	21.2	21.8	31.3	25.9	13.2	13.9
Crease recovery - %						
Warp	51	50	71	73	48	50
Filling	60	60	70	79	62	66
Filling[1]	None	None	Low	Low	None	None

[1] As compared with evaluation standards: None (0-2 pills) and Low (3-9 pills).

other fabrics. There was no significant difference between replicas of any of the fabrics before laundering. The means of the subjective ratings of the fabrics before laundering and after 1, 5, 10, and 20 launderings appear in Table 2.

Table 2. Subjective ratings of the hand of the fabrics before laundering and after 1, 5, 10, and 20 launderings.[1]

	Number of launderings									
	0		1		5		10		20	
Treatment	Blue	Pink	Blue	Pink	Blue	Pink	Blue	Pink	Blue	Pink
Cotton										
Control	3.8	3.4	3.2	3.6	3.4	3.4	3.2	3.8	3.0	3.6
Sta-Puf	3.6	4.0	3.4	3.2	3.2	3.2	3.0	3.4	3.4	3.6
Nu-Soft	3.8	3.8	3.4	3.2	3.2	3.2	3.2	3.4	3.0	3.2
Dacron-cotton										
Control	2.6	2.6	2.2	2.6	2.0	2.2	2.2	2.0	1.4	1.8
Sta-Puf	2.6	2.8	1.4	1.6	1.6	1.8	1.6	2.0	1.4	2.2
Nu-Soft	2.4	3.0	1.6	2.0	1.6	2.0	1.6	2.0	1.4	1.8
Arnel-cotton										
Control	2.4	3.0	2.2	2.6	2.0	2.0	2.0	2.4	2.0	2.6
Sta-Puf	2.6	2.6	1.8	2.8	1.6	2.4	1.6	1.8	2.2	2.2
Nu-Soft	3.2	2.6	2.0	2.4	1.8	2.4	1.6	2.2	2.0	2.2

[1] Based on standards ranging from 1: soft, resilient, pliable, and silk-like to touch to 5: stiff, wiry, and harsh to touch.

All of the fabrics tended to increase in softness after laundering. The blue specimens of each fabric tended to have a softer hand, after laundering, than did the pink. After the subsequent launderings, the Dacron-cotton fabrics tended to increase in softness more than the other fabrics. The relative softness of the Dacron-cotton fabrics remained the best; the Arnel-cotton fabrics were next softest; and the cotton fabrics were evaluated somewhat less soft than the other fabrics after each of the series of launderings.

Sta-Puf and Nu-Soft had only a slight, but equal, softening effect on each type of fabric.

The analysis of variance of the subjective ratings of the hand of the fabrics, as shown in Table 3, shows a significant difference at the 5 per cent level of the effect of laundering on the fabrics. The differences relating to the interactions of color and laundering, laundering and treatment, fabrics and treatment, and laundering, fabrics, and treatment are of no significance.

Table 3. Analysis of variance of the subjective ratings of the hand of the fabrics.

Source of variation	Degrees of freedom	Mean squares
Laundering (L)	4	1.4354
Color (C)	1	1.7362
Fabrics (F)	2	16.9014
Treatment (T)	2	.1914
LxC	4	.0539 ns
LxF	8	.1198 *
LxT	8	.1064 ns
FxT	4	.0544 ns
LxFxT	16	.0378 ns
Remainder	40	.0513
Total	89	

* Significant at P = .05.

The means of the subjective ratings of the hand of the fabrics before and after laundering are shown in Table 4. There was a significant difference between before laundering and after any laundering of all fabrics. There was no apparent effect due to additional launderings on the cotton fabrics. The Dacron-cotton and Arnel-cotton tended to become slightly softer with additional launderings; however, this was not generally consistent.

Table 4. Means of the subjective ratings of the hand of the fabrics before and after laundering.[1]

Number of launderings	Fabrics		
	Cotton	Dacron-cotton	Arnel-cotton
0	3.73	2.67	2.73
1	3.33	1.90	2.30
5	3.33	1.87	2.03
10	3.33	1.90	1.93
20	3.28	1.67	2.20

[1] Sd is 0.26.

Appearance. Before laundering, the Dacron-cotton fabric was evaluated as having the best appearance; the Arnel-cotton fabric was slightly less; the all-cotton fabric had the least desirable appearance. There was generally no difference between replicas of any of the fabrics.

The subjective ratings of the appearance of the fabrics before laundering and after each series of launderings appear in Table 5. After 1 laundering, the appearance of all fabrics was rated as much lower than before laundering; this was true for all treatments. All fabrics tended to retain the lower ratings after each laundering series. Nu-Soft tended to improve slightly the appearance of the cotton fabric after 5 and 10 launderings; Sta-Puf had no apparent effect on the cotton fabric. After 20 launderings, both softeners tended to improve the appearance of the Dacron-cotton fabric; this was not evident after 5 or 10 launderings. The effect of the fabric softeners on the appearance of Arnel-cotton was not noticeable after any of the launderings. The blue replicas of all fabrics tended to be rated as having a better appearance than the pink.

Table 5. Subjective ratings of the appearance of the fabrics before laundering and after 1, 5, 10, and 20 launderings.[1]

	Number of launderings									
	0		1		5		10		20	
Treatment	Blue	Pink	Blue	Pink	Blue	Pink	Blue	Pink	Blue	Pink
Cotton										
Control	3.4	3.2	1.2	1.2	1.2	1.2	1.4	1.2	1.8	1.8
Sta-Puf	2.8	3.6	1.4	1.6	1.4	1.2	1.8	1.4	1.6	1.2
Nu-Soft	3.6	3.4	1.4	1.0	2.2	2.0	2.0	2.0	1.8	1.4
Dacron-cotton										
Control	4.2	4.2	2.6	2.6	2.0	1.8	1.4	1.6	1.8	1.8
Sta-Puf	4.0	4.0	2.0	2.0	2.0	2.0	1.6	1.6	2.6	2.6
Nu-Soft	4.0	3.8	2.4	2.4	1.6	1.6	2.0	1.8	2.4	2.2
Arnel-cotton										
Control	3.8	3.8	1.2	1.2	1.0	1.0	1.4	1.4	1.2	1.2
Sta-Puf	4.0	4.0	1.2	1.0	1.4	1.2	1.6	1.4	1.4	1.4
Nu-Soft	3.8	3.6	1.2	1.0	1.2	1.4	1.6	1.2	1.4	1.4

[1] Based on photographic standards ranging from 5, best performance, to 1, poor performance.

The analysis of variance, Table 6, reveals there was no significant difference due to the interaction of laundering and color. The difference due to the interaction of laundering and treatment was significant at the 5.0 per cent level; the difference due to the interaction of the fabrics and treatment was significant at the 1.0 per cent level; and the difference due to laundering and fabrics was significant at the 0.1 per cent level. The differences due to the interactions of laundering, fabrics, and treatment showed a significance at the 0.1 per cent level.

Table 6. Analysis of variance of the subjective ratings of the appearance of the fabrics.

Source of variation	Degrees of freedom	Mean squares
Laundering (L)	4	16.5282
Color (C)	1	.1604
Fabrics (F)	2	3.3524
Treatment (T)	2	.1631
LxC	4	.0127 ns
LxF	8	.4136 ***
LxT	8	.0642 *
FxT	4	.1038 **
LxFxT	16	.1366 ***
Remainder	40	.0232
Total	89	

* Significant at P = .05.
** Significant at P = .01.
*** Significant at P = .001.

Breaking Strength. The means of the dry and wet breaking strength of the fabrics before laundering and after 1, 5, 10, and 20 launderings appear in Table 7.

The relative position of the fabrics based upon warpwise dry breaking strength was Dacron-cotton, having the greatest strength, cotton, and Arnel-cotton having the least strength. This order remained throughout the launderings with the exception of cotton and Arnel-cotton fabrics. These had comparable strengths after 10 launderings. The pink fabrics tended to be stronger than the blue. The fabrics had a general tendency to decrease in strength

Table 7. Breaking strength, in pounds, of fabrics before laundering and after 1, 5, 10, and 20 launderings.

Fabric and treatment	No. of launderings	Blue Warp Dry	Blue Warp Wet	Blue Filling Dry	Blue Filling Wet	Pink Warp Dry	Pink Warp Wet	Pink Filling Dry	Pink Filling Wet
Cotton Control	0	45.9	56.4	17.7	21.1	46.0	57.6	18.6	21.8
	1	38.8	44.2	15.2	17.9	42.9	45.8	16.8	19.3
	5	39.5	48.8	13.4	17.9	46.6	58.2	17.6	23.0
	10	31.9	46.2	15.8	19.0	37.1	61.0	15.7	23.2
	20	43.6	45.2	17.2	18.0	48.0	63.0	20.7	25.0
Cotton Sta-Puf	0	45.4	41.4	14.6	16.6	46.0	57.6	18.5	18.8
	1	40.2	51.4	13.8	18.8	44.1	58.4	14.5	24.0
	5	44.2	43.6	16.8	16.9	43.5	52.4	19.6	21.5
	10	34.3	43.8	17.9	18.4	34.2	56.8	17.6	23.3
	20	38.0	44.4	18.5	20.3	45.0	50.8	18.2	22.4
Cotton Nu-Soft	0	43.2	45.5	15.8	17.5	46.0	57.6	18.0	25.7
	1	46.6	45.2	18.5	12.0	51.8	54.4	23.2	18.2
	5	45.4	46.0	16.3	20.9	45.9	61.2	21.0	24.8
	10	36.0	46.4	15.9	15.2	40.2	58.4	17.0	20.6
	20	43.2	47.0	15.4	19.5	46.0	58.0	17.1	23.1
Dacron-cotton Control	0	62.2	62.8	28.7	31.3	70.9	71.4	23.8	25.9
	1	61.2	62.4	29.4	29.8	69.4	71.0	23.5	26.1
	5	60.3	64.0	28.0	30.0	65.7	71.0	22.3	26.1
	10	46.7	60.2	27.1	29.3	61.6	66.4	22.1	25.5
	20	55.0	58.6	26.5	29.7	59.9	65.6	21.6	25.2
Dacron-cotton Sta-Puf	0	65.2	61.8	29.3	34.3	71.6	72.8	21.0	27.7
	1	62.5	64.2	29.2	30.5	67.6	72.0	21.5	24.5
	5	61.8	66.2	27.9	30.2	68.5	69.4	21.0	24.6
	10	61.2	66.8	27.7	30.7	67.6	71.2	23.4	22.8
	20	62.0	62.8	28.7	30.6	67.4	71.0	21.2	24.7
Dacron-cotton Nu-Soft	0	61.0	62.8	27.9	31.3	72.2	71.4	26.4	25.9
	1	61.4	63.4	25.9	30.8	69.4	71.2	24.7	27.0
	5	62.0	65.4	26.2	30.8	66.1	70.6	24.8	25.5
	10	60.5	61.4	26.3	30.5	68.6	71.0	23.6	28.1
	20	57.4	62.4	24.8	29.3	65.2	69.8	24.3	26.1
Arnel-cotton Control	0	40.6	45.0	21.5	13.9	38.9	43.3	24.0	13.2
	1	33.1	39.5	23.0	15.2	35.9	38.6	21.4	14.3
	5	35.0	41.1	22.2	15.8	36.9	43.9	21.9	15.8
	10	33.1	40.4	21.6	15.7	33.2	42.4	21.6	15.2
	20	38.4	40.8	21.2	14.5	40.4	41.6	20.0	14.1
Arnel-cotton Sta-Puf	0	32.0	45.0	21.4	13.9	38.1	43.3	23.3	13.2
	1	36.0	42.4	21.4	14.0	33.6	45.3	22.8	14.7
	5	35.6	41.3	22.0	14.6	37.2	44.0	22.0	14.9
	10	32.0	40.4	21.6	14.5	36.3	42.6	22.5	15.2
	20	39.6	41.4	20.9	14.4	40.4	43.4	22.1	15.1
Arnel-cotton Nu-Soft	0	38.1	45.0	22.9	13.9	38.0	43.3	22.9	13.2
	1	40.4	43.0	22.9	15.0	41.0	42.7	22.1	14.8
	5	35.8	42.3	23.5	15.6	38.4	41.9	23.2	15.4
	10	32.6	42.2	18.5	15.0	29.3	44.2	15.8	14.2
	20	34.4	42.2	21.3	14.9	38.2	42.8	20.6	14.0

after subsequent launderings; however, there were some inconsistencies related to different treatments and fabrics. The control group of Dacron-cotton fabrics showed a steady decrease in strength, which was significant after 5 launderings. The Dacron-cotton fabrics treated with Sta-Puf decreased in strength after the first laundering, but retained this level after additional launderings. The Nu-Soft group had no appreciable loss in strength until after 20 launderings. All treatment groups of the cotton had a sharp decrease in strength after 10 launderings; after 20 launderings, the original strength was almost regained. The Nu-Soft group was somewhat greater in strength than the control or Sta-Puf groups of the cotton. The Nu-Soft treatment tended to increase the strength of Arnel-cotton until after 5 launderings; this group was significantly lower in strength than the control or Sta-Puf groups.

The Dacron-cotton fabrics had greater wet warp breaking strength throughout all treatments. Before laundering, the cotton and Arnel-cotton fabrics were similar in strength; the cotton fabric was stronger than Arnel-cotton after additional launderings. There was a significant difference between the two colors; the blue wet warp strength decreased significantly after 10 and 20 launderings, while the pink retained or increased in strength after 5 launderings. The cotton and Arnel-cotton fabrics which were given no treatment, decreased significantly in strength after 1 laundering; after 5 launderings, the strength was the same as the original. This strength remained through additional launderings. The cotton treated with Sta-Puf increased in strength after

1 laundering, dropped significantly with additional launderings, but had more than the original strength after 20 launderings. There was no change in strength of cotton and Arnel-cotton fabrics which were treated with Sta-Puf. The strength of Dacron-cotton and Arnel-cotton fabrics treated with Nu-Soft were not significantly changed after laundering; the cotton fabric increased in strength after the first laundering and retained this higher strength even after 20 launderings.

The dry breaking strength of the blue, fillingwise, of all fabrics was consistently higher than for the pink. The Dacron-cotton fabrics had greatest strength. The Arnel-cotton fabric was somewhat stronger than the all-cotton fabric; this tendency remained throughout the launderings, except that the Nu-Soft treatment group of Arnel-cotton was similar to cotton after 10 launderings. The Nu-Soft treated cotton, after 1 laundering, was significantly higher than fabrics given other treatments. Fillingwise, the dry cotton tended to decrease in strength, but regained its initial strength after 20 launderings; this was true for all treatments. The Dacron-cotton and Arnel-cotton fabrics tended to decrease gradually in strength, but this decrease did not become significant until after 20 launderings.

There was no significant difference between the two colors of fabrics as to wet breaking strengths of the fabrics fillingwise. The Dacron-cotton fabrics had the greatest strength, all cotton was next in strength, and Arnel-cotton was considerably weaker. The effect of laundering on the fabrics was the most significant of any of the interactions. After 1 laundering, the Sta-Puf treatment tended to increase the strength of cotton and decrease the strength of Dacron-cotton; this tendency was not evident after additional launderings. The Nu-Soft treatment produced rather erratic results; the strength of the cotton fabric decreased sharply after 1 laundering. Nu-Soft tended to have no significant effect on either cotton or Dacron-cotton fabrics.

The analysis of variance of breaking strength is recorded in Table 8. No significance in the interaction of laundering and color of dry warp breaking strength was shown; all other interactions were significant at the 0.1 per cent level. All interactions relating to wet breaking strengths of the fabrics warpwise were significant at the 0.1 per cent level.

Fillingwise, the dry breaking strengths showed no significant effect of the interactions of fabrics and color or fabrics and treatment. The interaction of laundering and fabrics was significant at the 1.0 per cent level and the interaction of laundering and treatment was significant at the 0.1 per cent level. At the 0.1 per cent level, the interaction of laundering, fabrics, and treatment was significant. The variance of the laundering and fabrics was significant at the 0.1 per cent level for the wet filling breaking strengths. This level of significance applied to the interaction of laundering, fabrics, and treatment. Other interactions were of no significance.

Table 8. Analysis of variance of dry and wet breaking strengths of warp and filling of the fabrics.

Source of variation	Degrees of freedom	Mean squares: Warp-dry	Mean squares: Warp-wet
Launderings (L)	4	514.7469	16.1310
Color (C)	1	1556.4480	3069.6224
Fabrics (F)	2	31560.1055	22648.3240
Treatment (T)	2	87.3300	4.6048
LxC	4	4.7149 ns	97.9999 ***
LxF	8	132.3956 ***	55.5833 ***
LxT	8	56.3424 ***	112.4844 ***
FxT	4	87.4079 ***	139.9899 ***
LxFxT	16	41.5075 ***	67.5598 ***
Remainder	400	11.6560	13.0915
Total	499		
		Filling-dry	Filling-wet
Launderings (L)	4	25.1782	12.1082
Color (C)	1	74.5828	8.4872
Fabrics (F)	2	2446.4682	6961.5618
Treatment (T)	2	2.0514	1.8320
LxC	4	5.0941 ns	3.0595 ns
LxF	8	12.9278 **	27.7854 ***
LxT	8	29.0618 ***	10.9511 ns
FxT	4	8.7088 ns	7.4078 ns
LxFxT	16	19.2280 ***	25.8306 ***
Remainder	400	4.8825	6.9204
Total	499		

** Significant at P = .01.
*** Significant at P = .001.

Crease Recovery. The percentages of crease recovery of the fabrics are given in Table 9. The warpwise crease recovery of the Dacron-cotton, before laundering, was about 20 per cent higher than the Arnel-cotton or cotton fabrics. These two fabrics had about 50 per cent crease recovery before laundering.

The fillingwise crease recovery of the Dacron-cotton fabrics was higher than the Arnel-cotton fabrics; the Arnel-cotton fabric had a higher recovery from creasing than the all-cotton fabric, but this difference was about half of the difference between Dacron-cotton and Arnel-cotton fabrics. The pink Dacron-cotton, fillingwise, tended to be considerably higher in recovery than the blue; this tendency was present in a lesser degree in the Arnel-cotton.

After 20 launderings, the Dacron-cotton fabrics retained the higher percentage of crease recovery warpwise. The percentage of recovery, after 20 launderings, was similar for Arnel-cotton and cotton fabrics. The fabrics treated with Nu-Soft tended to have a higher recovery; this tendency of recovery was comparable to the fabrics before laundering. Fabrics that were given no treatment or treated with Sta-Puf generally had a consistent percentage of recovery warpwise. Warpwise, the pink fabrics tended to lose more ability to recover from creasing than did the blue.

Fillingwise, the fabrics retained the following order of crease recovery: Dacron-cotton fabrics were highest followed by Arnel-cotton and the cotton fabrics. The tendency of the pink to recover from creasing was lowered to some extent after 20 launderings. There appeared to be no differences among the treatment groups of any of the fabrics after laundering.

The analysis of variance warpwise showed no significant effect of the interactions of laundering and fabrics, of fabrics and treatment, and of laundering, fabrics, and treatment. There was a significant difference at the 5.0 per cent level due to the interactions of laundering and color and of laundering and

Table 9. Percentage of crease recovery of fabrics before laundering and after 20 launderings.

Fabric	Number of launderings	Warp Blue	Warp Pink	Filling Blue	Filling Pink
Cotton					
As purchased	0	51	50	60	60
Control	20	49	47	53	46
Sta-Puf	20	50	47	46	45
Nu-Soft	20	52	48	48	48
Dacron-cotton					
As purchased	0	71	73	70	79
Control	20	63	69	65	66
Sta-Puf	20	71	71	70	69
Nu-Soft	20	75	74	69	74
Arnel-cotton					
As purchased	0	48	50	62	66
Control	20	47	42	57	57
Sta-Puf	20	44	43	52	52
Nu-Soft	20	51	50	62	60

treatment. The analysis of variance fillingwise revealed no significance of the interactions of laundering and treatment, fabrics and treatment, and laundering, fabrics, and treatment. There was significance at the 5.0 per cent level of the cross effect of laundering and fabrics. The interaction of laundering and color revealed a significance at the 1.0 per cent level. The analysis of variance of crease recovery is shown in Table 10.

The analysis of the means of the percentage of crease recovery, warpwise, as shown in Table 11, revealed there was no significant difference between color replicas before laundering or after 20 launderings. There was a significant difference between pink fabrics before and after laundering; the blue fabrics showed no such significance. There was a significant difference before

Table 10. Analysis of variance of per cent of crease recovery of filling and warp of fabrics.

Source of variation	Degrees of freedom	Mean squares Warp	Mean squares Filling
Launderings (L)	1	37.8225	650.2500
Color (C)	1	.1225	44.8900
Fabrics (F)	2	2054.1158	963.6634
Treatment (T)	2	21.3925	20.2534
LxC	1	18.0625 *	68.8900 **
LxF	2	1.2658 ns	32.3633 *
LxT	2	21.3925 *	20.2533 ns
FxT	4	4.6958 ns	8.3366 ns
LxFxT	4	4.6958 ns	8.3367 ns
Remainder	16	3.6612 ns	6.2750
Total	35		

* Significant at P = .05.
** Significant at P = .01.

Table 11. Percentage of crease recovery, warpwise, as color and treatment are related to laundering.

Number of launderings	Color[1] Blue	Color[1] Pink	Treatment[2] Control	Treatment[2] Sta-Puf	Treatment[2] Nu-Soft
0	56.47	58.00	57.23	57.23	57.23
20	55.83	54.53	53.02	54.37	58.17

[1] SD = 1.91.
[2] SD = 2.34.

laundering and after 20 launderings of the fabrics which were treated with Sta-Puf or given no treatment. The fabrics treated with Nu-Soft showed no significant difference before laundering and after laundering.

According to the analysis of fillingwise crease recovery, as shown in Table 12, there was a significant difference between colors before laundering and between percentages of recovery before and after laundering of each color. The difference among the fabric groups both before laundering and after 20 launderings was rather great.

Table 12. Percentage of crease recovery of fabrics, fillingwise, as color and fabrics are related to laundering.

Number of launderings	Color[1]		Treatment[2]		
	Blue	Pink	Cotton	Dacron-cotton	Arnel-cotton
0	63.73	68.73	59.90	74.40	64.40
20	58.00	57.47	47.83	68.80	56.57

[1] SD = 2.50.
[2] SD = 3.07.

Dimensional Stability. The dimensional loss of the fabrics is recorded in Table 13. The dimensional stability of the fabrics warpwise was generally not good, regardless of treatment. After 1 laundering, the dimensional loss of all fabrics was less than 2.5 per cent. The loss after 5 launderings varied from 2.5 per cent to 3.0 per cent for all fabrics. The range of loss after 10 launderings was from 3.0 per cent to 4.0 per cent. The percentage loss, after 20 launderings, was from 3.5 to 5.0. The two colors of the fabrics of Dacron-cotton blend varied somewhat; the pink fabric was consistently more stable. Both colors of the Dacron-cotton fabric which had been treated with either Sta-Puf or Nu-Soft tended to shrink less than the control group. The Arnel-cotton fabric which had been treated with Nu-Soft tended to have greater dimensional loss, after 20 launderings, than did the groups which were given no treatment or a Sta-Puf treatment.

The fillingwise dimensional loss was generally less than the warpwise loss. The all cotton and Dacron-cotton fabrics had a shrinkage of less than 2.5 per cent after all launderings. The blue cotton fabrics of all three treatment groups had no appreciable dimensional loss; the pink replica had a shrinkage of approximately 2.0 per cent after 20 launderings. Both colors of Dacron-cotton fabrics had a shrinkage of less than 1.0 per cent after 20 launderings; this was true for all treatment groups. The fabric of Arnel-cotton had a loss of 1.0 to 1.5 per cent after the first laundering; the shrinkage of these fabrics increased to 3.7 and 3.8 per cent for the blue and 2.6, 2.7, and 3.2 per cent for the pink. There was no noticeable differences in the dimensional stability of fabric fillings which had been given either Sta-Puf, Nu-Soft, or control treatment.

Pilling Resistance. All of the cotton fabrics and the control and Nu-Soft treated groups of the Dacron-cotton fabrics showed no change in pilling propensity from before laundering to after 20 launderings. The pilling rate of the Sta-Puf treated Dacron-cotton fabric changed from 'Low', before laundering to 'None', after the series of launderings. The control group of Arnel-cotton fabric increased from 'None' to a 'Low' rating of pilling while the Nu-Soft treated group increased from 'None' to a 'Moderate' rating. There was a fuzzy surface on the Sta-Puf treated group of the Arnel-cotton fabric, but it did not form any pills after the series of launderings. There was no

Table 13. Dimensional loss, in per cent, of fabrics after 1, 5, 10, and 20 launderings.

Fabric	1 Blue	1 Pink	5 Blue	5 Pink	10 Blue	10 Pink	20 Blue	20 Pink
					Warp			
Cotton								
Control	2.0	2.0	3.0	2.7	3.0	3.0	4.0	3.9
Sta-Puf	2.0	2.0	2.7	3.0	3.0	3.3	3.3	3.7
Nu-Soft	2.5	2.5	2.8	3.0	3.5	3.0	3.8	4.0
Dacron-cotton								
Control	2.0	2.0	3.0	2.8	4.0	3.5	5.0	4.5
Sta-Puf	2.0	1.5	3.0	2.5	3.5	3.0	4.4	3.7
Nu-Soft	2.0	1.7	3.0	3.0	3.7	3.0	4.4	4.0
Arnel-cotton								
Control	2.0	2.0	3.0	3.0	3.0	3.0	3.7	3.8
Sta-Puf	2.0	2.3	3.0	3.0	3.5	3.3	3.5	3.5
Nu-Soft	2.5	2.5	3.0	3.0	3.5	3.3	4.0	4.0
					Filling			
Cotton								
Control	0.0	1.0	0.0	1.8	0.2	1.8	0.2	2.2
Sta-Puf	0.0	1.3	0.0	1.5	0.0	1.5	0.0	1.8
Nu-Soft	0.0	1.0	0.0	1.5	0.0	1.7	0.0	1.7
Dacron-cotton								
Control	0.5	0.5	0.5	0.8	1.0	1.0	0.8	1.0
Sta-Puf	0.2	0.2	0.5	0.7	0.2	0.5	0.7	0.8
Nu-Soft	0.2	0.2	0.5	0.7	0.0	0.5	0.0	0.8
Arnel-cotton								
Control	1.5	1.3	2.5	2.3	3.5	2.8	3.8	2.6
Sta-Puf	1.0	1.0	2.8	2.0	3.0	2.8	3.7	2.7
Nu-Soft	1.5	1.2	3.0	2.0	2.8	2.5	3.7	3.2

noticeable difference between color lots of any of the fabrics. These evaluations were made by three persons, and all three observations were the same as recorded in Table 14.

Table 14. Evaluations of pilling of fabrics before laundering and after 20 launderings.

Treatment	Before laundering: Blue	Before laundering: Pink	After 20 launderings: Blue	After 20 launderings: Pink
Cotton				
Control	None	None	None	None
Sta-Puf	None	None	None	None
Nu-Soft	None	None	None	None
Dacron-cotton				
Control	Low	Low	Low	Low
Sta-Puf	Low	Low	None	None
Nu-Soft	Low	Low	Low	Low
Arnel-cotton				
Control	None	None	Low	Low
Sta-Puf	None	None	None[1]	None[1]
Nu-Soft	None	None	Moderate	Moderate

[1] Evaluated as having a fuzzy surface.

The cotton fabric had no tendency to pill, regardless of treatment. The control group of Dacron-cotton fabric showed no change in pilling; the Sta-Puf group showed an improvement in pilling resistance, but the Nu-Soft group retained the same pilling tendency. The fabric of Arnel-cotton blend fibers had varying tendencies to pill after laundering, depending on the treatment; the control group had a greater tendency to pill, the Sta-Puf group did not pill but became slightly fuzzy, and the Nu-Soft group had a tendency to pill moderately.

Colorfastness to Laundering. None of the fabrics showed any appreciable color change after 20 launderings when compared with the specimens which were laundered once in the Launder-Ometer. The specimens which were washed in the Launder-Ometer showed no appreciable change in color and no appreciable staining of the attached white cloth. All of the fabrics appeared to be colorfast to commercial and domestic laundering at a temperature of 120° F.; the effect of the fabric softeners on the fabrics accordingly was of no significance.

SUMMARY AND CONCLUSIONS

The purpose of this study was to test the null hypothesis that the use of fabric softeners, Sta-Puf and Nu-Soft, had no significant effect, after a series of launderings, on fabrics of all cotton, Dacron and cotton blend, and Arnel and cotton blend with respect to hand, appearance, dry and wet breaking strengths, crease recovery, dimensional stability, pilling, and colorfastness to laundering.

The properties of the cotton and Arnel-cotton fabrics were found to be relatively consistent between color groups. The Dacron-cotton fabrics were similar, except for significant differences in thread count, direction and amount of twist, and crease recovery of the filling and the breaking strengths of both warp and filling.

Sta-Puf and Nu-Soft had only a slight effect on the softness of the hand of the fabrics; there was more softening of the Dacron-cotton fabrics. The effect of laundering was more significant than the effect of the fabric softeners on the hand.

The effect of fabric softeners on the fabrics was not consistent, but the softeners generally did not improve the appearance of the fabrics.

The effect of fabric softeners on the breaking strength was quite varied. For the dry warp, Nu-Soft increased the strength of cotton some and the strength of the Dacron-cotton was increased until after 20 launderings. The Arnel-cotton fabric treated with Nu-Soft had a higher strength after 1 and 5 launderings, but lower after 10 and 20 launderings. Sta-Puf increased the dry strength of the Dacron-cotton fabric warpwise. Sta-Puf also increased the wet strength of cotton warpwise and had a slight effect on Dacron-cotton warpwise. Nu-Soft had a slight effect on increasing the wet strength of Dacron-cotton and had a slightly greater effect than Sta-Puf on the cotton strength.

Neither fabric softener had any significant effect on the dry or wet breaking strengths of the fillings.

The Nu-Soft treatment generally did not affect the crease recovery of the fabrics, warpwise, while the other methods of treatment lessened the crease recovery of the fabrics. The crease recovery, fillingwise, was not affected by any method of treatment.

The use of fabric softeners appeared to have no effect on the dimensional stability of the fabrics fillingwise. Fabrics of Dacron-cotton appeared to shrink less warpwise when treated with either softener. The fabrics of Arnel-cotton had a tendency to have a greater shrinkage warpwise when treated with Nu-Soft.

The Dacron-cotton and Arnel-cotton fabrics treated with Sta-Puf had a higher resistance to pilling. Nu-Soft increased the pilling of the Arnel-cotton fabric and showed no effect on the

Dacron-cotton fabric. The cotton fabric had no tendency to pill by any treatment.

None of the fabrics of either color showed any appreciable color change after 20 launderings. As all of the fabrics were considered colorfast to laundering, the effect of fabric softeners was not significant.

The null hypothesis was rejected with respect to hand, warpwise breaking strengths, pilling, warpwise crease recovery, and warpwise dimensional stability. This rejection was made due to the factors of a slight softening of hand of all fabrics and better warpwise dimensional stability and an increase of dry and wet warpwise breaking strengths for cotton and Dacron-cotton fabrics. Sta-Puf apparently reduced pilling tendencies of the blended fabrics, but Nu-Soft had an effect of increasing pilling of the Arnel-cotton blend. Nu-Soft tended to improve crease recovery of all fabrics warpwise. The null hypothesis was accepted with respect to appearance, colorfastness to laundering, dry or wet breaking strengths, crease recovery, or dimensional stability of the fabrics fillingwise and wet warpwise strength of the Arnel and cotton fabric.

The results of this study showed that the effect of using fabric softeners varied with the different fabrics analyzed; however, Sta-Puf and Nu-Soft were found not to be consistent as causative agents of effect.

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EFFECT OF FABRIC SOFTENERS ON SELECTED COTTON AND COTTON-BLEND FABRICS AFTER A SERIES OF LAUNDERINGS

by

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The purpose of this study was to test the null hypothesis that the use of fabric softeners, Sta-Puf and Nu-Soft, had no significant effect, after a series of launderings, on cotton and cotton-blend fabrics with respect to hand, appearance, dry and wet breaking strength, crease recovery, dimensional stability, pilling, and colorfastness to laundering.

Three broadcloth fabrics composed of all cotton, a blend of Dacron and cotton, and a blend of Arnel and cotton were selected for the study. Replicas of each fabric, one pink, one blue, as purchased, were analyzed for fiber content, percentage of non-fibrous material and sizing, weight per square yard, direction and amount of twist, yarn number, thread count, dry and wet breaking strength, crease recovery, and pilling resistance. There was no significant difference between color lots of either the cotton or Arnel-cotton fabrics. The two colors of the Dacron-cotton were similar, except for differences in direction and amount of twist, yarn number, thread count, and crease recovery of the filling and breaking strengths of both warp and filling.

The fabrics were divided into three groups for either Sta-Puf, Nu-Soft, or control treatment for a series of 20 launderings. The softeners were added to the final rinses in laundering of two groups. No softener was added to the control group. Portions of each fabric were withdrawn after 1, 5, 10, and 20 launderings for various analyses.

Analyses of variance were made of data relating to hand, appearance, breaking strength, and crease recovery. The fabric softeners had a slight softening effect on the hand of the fabrics, but the softeners did not generally improve the appearance of the fabrics. The effect of Nu-Soft was significant for increasing dry and wet warpwise breaking strength of cotton fabrics, while Sta-Puf caused a significant increase of the wet strength. Both softeners had a tendency to increase slightly the strength of the warp of the Dacron-cotton fabrics. Neither softener had any significant effect, fillingwise, on either dry or wet strength. Nu-Soft generally improved the warpwise crease recovery of the fabrics, but neither softener had any effect on crease recovery of the filling.

The remaining conclusions were based on comparative judgments. Sta-Puf appeared to reduce pilling of the blended fabrics, but Nu-Soft apparently increased the pilling tendency of the Arnel-cotton fabrics. The Dacron-cotton fabric which was treated with the softeners appeared to have better warpwise dimensional stability; however, Nu-Soft had a tendency to increase shrinkage of the warpwise Arnel-cotton blend. Neither softener had any noticeable effect on the color of the fabrics.

The results of this study showed that the effect of using fabric softeners, Sta-Puf and Nu-Soft, varied with the different fabrics analyzed; however, Sta-Puf and Nu-Soft were found to be not consistent as causative agents of effect.