THE EFFECT OF A SELECTED HOME LAUNDRY FABRIC SOFTENER UPON THE ABSORBENCY AND SOFTNESS OF DIAPER CLOTH

Thesis for the Degree of M. A.

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ABSTRACT

THE EFFECT OF A SELECTED HOME LAUNDRY FABRIC SOFTENER UPON THE ABSORBENCY AND SOFTNESS OF DIAPER CLOTH

by Betty J. Richter

Fabric softeners recently have become available for use in the home laundry process. According to the promotional information, certain fabric properties are enhanced through improved performance of the fabric following regular softener applications. Unfortunately, the resulting disadvantages have not been publicized as extensively.

The purpose of this study was to investigate the effect of fabric softeners on the properties of absorbency and softness of diaper cloth. Specific objectives were: (1) To determine the level of fabric absorbency at specified treatment intervals; (2) To determine the level of fabric softness at specified treatment intervals; (3) To determine the optimum number of softener treatments which will produce positive absorbency and improved fabric hand.

Since the properties of absorption and hand or softness were expected to show distinct changes as a result of fabric softener application to a fabric, the following null hypotheses were formulated: Fabric rate of absorption will be unchanged as a result of the application of a fabric softener. The hygroscopic property of a fabric will

be unchanged following application of a fabric softener. The softness of a fabric will be unchanged with softener application.

The diaper cloth specimens were divided into control and experimental groups. The former received a plain water rinse (treatment I) in the final cycle of the laundry procedure, while the latter received application of a fabric softener (treatment II). Appropriate objective measurements for rate of absorption and fabric hygroscopicity[1] were observed for each sample at specified intervals following completion of the 0, 1, 3, 6, 10, 15, 20 and 30 laundry cycles.

The subjective evaluation to appraise fabric softness was performed by a panel of 22 judges. Tests were designed to establish the least soft...most soft ordering of softener treated specimens, and to determine if the use of a fabric softener improved the hand or softness of diaper cloth as opposed to laundry procedures without application of a fabric softener.

Each of the null hypotheses was rejected as a result of statistical analysis of the collected data. The rate of absorption for diaper cloth specimens differed according to the type of treatment received, the number of laundry cycles and the interaction of treatment and laundry

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[1]Hygroscopicity refers to the quantitative capacity of a fabric for liquid intake.

cycles. Tests revealed that no difference could be expected to occur as a result of differing treatments; however, fabric hygroscopicity did increase with repeated launderings irrespective of the type of treatment received. Fabric softness was found to improve with application of a fabric softener.

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By

Betty J. Richter

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CHAPTER I

INTRODUCTION

Fabric softeners are a relatively new addition to the home laundry process although they have been used by the textile industry for over 25 years (9, 34). These products lubricate the fibers and enable them to slide readily past each other as the fabric is flexed. One of their advantages is that they give to some fabrics a pleasant, soft feel or hand.

Many fabrics sold today have been treated with softening agents by the manufacturer, but after a few launderings these chemicals gradually are lost from the fabric. Today, it is possible for the homemaker to maintain the original softness of a fabric by using a fabric softener designed for application during the laundry process. In addition to improved softness, manufacturers have boasted claims that these softener products will:

Improve fabric hand.

Eliminate the static electricity which makes fabrics cling.

Reduce wrinkling.

Reduce soiling.

Reduce color change.

Lubricate the fabrics for ease in ironing.

Retard bacterial growth.

improve wear (4, 10, 32).

In contrast to the claimed advantages of fabric softeners, certain disadvantages have not been highly publicized; upon repeated application of a fabric softener, a waxy coating produced by the accumulation of softener on the fibers can interfere with the fabric's ability to absorb liquids (10). Fabric softeners are used on washable items, particularly on towels and diapers. These items are generally thought to be more desirable when they are soft, although they are used primarily as absorptive fabrics. Consequently, concern has been expressed over the relationship of fabric absorbency to other textile properties.

Research effort presently is being directed toward the development of improved methods, materials and formulations to decrease softener buildup and simultaneously provide adequate softening. As yet very little information has been published in this area. Since a problem does exist and concern has been expressed, the following study has been designed to investigate the effect of fabric softeners on the properties of absorbency and softness of diaper cloth. The objectives of the study are:

1. To determine the level of fabric absorbency at specified treatment intervals.

2. To determine the level of fabric softness at specified treatment intervals.

3. To determine the relationship between fabric absorbency and softness at the specified treatment intervals.

In order to evaluate the performance of a home laundry softener on the absorbency and softness of diaper cloth, the following null hypotheses were formulated: The properties of absorption and hand or softness will not be expected to show distinct changes as a result of fabric softener application to a fabric.

A. Fabric rate of absorption will be unchanged as a result of the application of a fabric softener.

B. The hygroscopic property of a fabric will be unchanged following application of a fabric softener.

C. The softness of a fabric will be unchanged with softener application.

CHAPTER II

REVIEW OF LITERATURE

Introduction

The introduction of new synthetic fibers and, more recently, the wash and wear fabrics has necessitated the use of substances to counteract some of the adverse characteristics inherent in these fabrics. A soft, pliable hand and drape is now being produced in many of the synthetics and resin-treated fabrics through the use of recently developed chemical additives. These products have been synthesized in a variety of forms, including anionic, nonionic and cationic, of which cationic is the most important. The cationic fabric softeners are true organic salts which ionize completely in dilute aqueous solution (9). The basic principle involved in the use of the cationic is the attraction of unlike substances to one another (22). Most fabric surfaces are known to be negatively charged and, therefore, possess an ability to attract positively charged substances, in this case the fabric softeners.

The two major chemical groupings within the classification of fabric softeners are the tertiary salts and the quaternary ammonium salts. Although quaternary salts were used in the early part of the century, these salts remained laboratory curiosities until the 1930's. The initial use of these cationic softeners was as an inhibitor of bacterial growth (9). Nearly 10 years later the rayon industry recognized the potential of cationic softening agents and began to use these softeners on fabrics designed for wearing apparel in order to impart softness and improve drapability. Textile manufacturers, commercial laundries, diaper services and, most recently, the homemakers are presently using the cationic fabric softeners for many purposes relating to textiles.

Fabric Softeners

Fabric softeners may be described as surface-active agents, more commonly referred to as "surfactants." These terms are used to describe any substance whose presence in small amounts alters the energy relationship at the interfaces (surfaces) of a given system. In general, these materials consist of two parts, one that is oil soluble and another which is soluble in water (30). Thus, the surfactant is capable of reacting under numerous circumstances.

Generally, these lubricating softeners are divided into two classifications--the nonsubstantive type which are nonionic or anionic in nature and do not attach directly to the surface, and the substantive softeners which are based on the formation of a cation capable of attaching itself to the surface of a material (29). The substantive or cationic fabric softeners are more effective than the nonsubstantive ones. Because the latter are not bonded to fabric surfaces, they are more easily removed in the laundry process than the former substantive type of softening agent.

The retail textile softeners presently on the market are dialkyl quaternary ammonium compounds (4, 34). As quaternaries, these substances are nitrogen based salts which are highly active agents capable of forming monomolecular films. In solution, the softener dissociates to form a large cation and a small anion. The configuration of this cation and its orientation at interfaces produces the property of surface activity (4).

Cationic surfactants have been described by Sollenberger (29) as materials which dissolve or disperse in water, concentrate and orient at interfaces, and ionize in such a way that the cation includes a hydrophobic hydrocarbon chain containing from 8 to 25 carbon atoms. A straight hydrocarbon chain is recommended by Nuessle (24) as having greater softening efficiency than a branched one. Also, the longer saturated alkyl chains, from 16 to 18 carbon atoms, are preferred for softening (9, 24), even though they are known to have reduced solubility in water.

Dialkyl quaternary ammonium salts are dispersed in an alcohol and water solution (5). The alcohol functions as a solvent for the quaternary ammonium salt, while the water acts as a dispersive agent in the rinse water. These substances consist of molecules whose components are well balanced between a hydrophobic chain and a hydrophilic functional group (9). The dialkyl or fatty portion is hydrophobic and will not combine with water, while the hydrophilic component attached to the dialkyl portion possesses the ability to be dispersed in water. The hydrophobic portion of the quaternary ammonium salt carries a positive electrical charge; the hydrophilic, a negative one. In an aqueous solution the hydrophobic ions are attracted to negatively charged surfaces such as cotton and other textiles. The ionic bonds formed between the cations of the softener and the anionic fabric surface leave the hydrocarbon chain as a tightly held film capable of lubricating the surface of the fabric. "The cations . . . penetrate and cover each individual fiber, smooth out all of their irregularities and rough surfaces which tend to have adhesive or binding qualities, separate the fibers, make them more pliable, and eliminate unwanted friction." (25) "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." (16)

Physically, fabric softeners are tinted viscous liquids. They frequently possess a faint ammonium odor which has been partially masked by the use of perfume (29). A typical formula for a cationic fabric softener is: "75% cationic surface-active agent (usually a quaternary ammonium chloride or sulfate), 18% isopropanol and 7% water." (26) "Active ingredient percentage in the finished softener usually ranges from 3 to 8%." (26)

Fabric softeners are intended to be used in the final rinse and should not be allowed to mix with soaps, detergents, water softeners, bleaches or other laundering compounds. Should one of the above mentioned products remain on the fabric or in the rinse and a fabric softener be applied, an insoluble curd could occur as a result of a chemical reaction between the product and the fabric softener (19).

The amount of softener recommended by one manufacturer for use in the home laundry may be quite different than the suggested quantities of another because certain trade products are known to be more concentrated than others. For the standard home laundry load, the recommended quantity is based upon the weight of fabric being treated.

Cationic fabric softeners are relatively effective in small quantities. It is advised (27) that no more than a two or three per cent solution based on the actual fabric weight be used; Du Brow and Linfield (9) recommend an amount as small as one-tenth of one per cent. The latter (9), as well as Schwartz (27), warn against the use of an excess of softener or over-treatment. Excess usage could impart an undesirable greasy or oily hand to the fabric capable of increasing the water repellent property of the material and eventually result in a decrease of fabric absorbency.

Fabric Hand

According to Sollenberger (29), softness is the measurement of the effect of finishing agents on the hand of fabrics. The published work on this subject is controversial in nature and suggests that fabric hand "is a complex of many properties which are integrated in the course of a subjective judgment." (8) Hoffman and Beste (14) have described the somewhat intangible quality of hand as meaning "the impressions which arise when fabrics are touched, squeezed, rubbed or otherwise handled." These authors also point out that the handling of cloth may convey visual as well as tactile impressions. Derby (31) defined "hand" as the way the cloth feels when drawn through or held in the hands of the observer who consciously or unconsciously makes an evaluation on a comparative basis. "Thus hand is the psychological response to the nervous and muscular stimuli induced by certain physical properties of the fabric." (31)

Traditionally, fabric hand has been evaluated on a subjective basis, although, objective test instruments have been designed to measure certain properties related to hand. The American Society for Testing Materials (2) advocates the use of the Planoflex apparatus which gives a measure of distortion angle and the Friction Meter which records the coefficient of kinetic friction. A third instrument, the Handle-Ometer, has been developed to measure the combined properties of flexibility and surface friction. According to Bogaty, Hollies and Harris (8), these objective techniques are limited since each instrument measures only a portion of the property-complex related to fabric hand.

Because of the inadequacy of these instruments to determine objective values of fabric hand comparable to those obtained through subjective judgment, the research in the area of hand evaluation continues to employ the latter less rigorous, more encompassing type of evaluation as the primary means of determining fabric hand.

Without exception, the studies which deal with evaluation of fabric hand (3,8,16,23,29) recognize that the human hand is a sensitive instrument, capable of detecting small differences in fabric quality.

Binns (6) has carried out extensive research and determined that all individuals possess an ability to relate the feel of fabrics. In the course of his work, Binns (7) compiled a list of descriptive adjectives used by a group of observers in subjective descriptions of fabric hand.

The most common procedure of evaluation of fabric hand was developed by Binns (6), and has been used by Sollenberger (29) and Karhoff (16). The method employed by Binns involved comparison among groups of materials and the arrangement in a relative order of softness. Under this method all of the samples were offered to a panel for rating at the same time. A variation in this procedure was reported by Bogaty, Hollies and Harris (8), which involved the ranking of a series of fabrics relative to a specifically designated reference standard. They also suggest (8) an alternative method in which fabrics are offered one at a time for judgment. "Thus, if an innate ability for such judgments does exist in the observers, they should be able to express a judgment without immediate reference to a physically present material standard." (8) The advantages of this latter method are the greater number of samples which may be evaluated and the reduced probability of obtaining "nonlinear" arrays of fabrics.

For the experiment by Bogaty, Hollies and Harris (8) in which fabrics were offered one at a time, analysis of variance revealed that "fabrics differ significantly in handle and independently, the observers differ in the magnitude of their ratings." No consistent relationship between technical proficiency and ability to make correct judgments was found in this study. A single judgment by one observer could not be considered meaningful as errors were made by all observers. This fact was also found to be true in the work done by Ackley (3). However, it has been pointed out by both Bogaty, Hollies and Harris, and Ackley (8,3) that, if several samples are examined and the order of preference noted, the resulting distribution of observations would cluster in such a way as to permit the establishment of a definite trend.

From the study by Bogaty, Hollies and Harris (8), based on judgment of paired samples, it was concluded for the fabrics used in the study that "the judgment of pairs or the inclusion of a standard for reference offers no clear advantage in ability to discriminate with respect to harshness (hand)." It was further suggested that paired judgments may be more confusing to the observer because of the complex nature of fabric hand.

Sollenberger (29) has attempted to correlate subjective evaluations of fabric hand with objective measures as determined by the Handle-Ometer instrument. In general, the Handle-Ometer results obtained for different softener concentrations were in agreement with the subjective findings; however, the results for different softener types did not agree (29). The discrepancy in this case was felt to be a result of weighting effects of some softeners and the failure of the instrument to recognize adequately surface smoothness. Since both of these properties were recognized as playing an important role in the evaluation of fabric hand, the attempt to determine fabric hand objectively was discontinued.

In the Ackley study (3), the property of pliability in relation to hand was determined. Although an A.S.T.M. recommended instrument[1] has been designed to measure this quality, the objective measure was not utilized and results were based completely upon subjective evaluation. It was found that "the pliability of a fabric is not necessarily proportional to the amount of softening agent employed." (8)

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[1]The Planoflex.

After the peak of effectiveness is reached, the continued application of the softener has the effect of reducing fabric pliability (3). However, in the evaluation of smoothness, once the maximum limit is reached, subsequent use of a softener will not alter fabric smoothness.

The results of subjective tests to determine fabric hand have been expressed in varied terminology. For example, Bogaty, Hollies and Harris (8) chose the general term "harshness" which was in turn related to surface prickliness as well as the additional components of stiffness and compactness. Ackley (3) discusses pliability, smoothness, and fullness; Hoffman and Beste (14) have recognized such additional properties as crispness, firmness, hardness and wiryness. Although these descriptive terms may be useful, a more quantitative and reproducible measure would be preferred so that objective results could be obtained which would correlate with results from subjective human evaluation of fabric hand.

Fabric Absorbency

The term "absorbency," as used in the literature (10,13,20), infers the rate as well as the quantity of liquid intake. For the purpose of this study, "absorbency" will be used only when both of these components are implied. Subsequent reference to rate will always be in the term "rate of absorbency"; while the word "hygroscopicity" will refer to the quantitative capacity of a fabric for liquid intake.

Objective tests have been developed (2,15) to measure the properties of fabric absorption. In a study performed by Grimes and Dillin (13), the rate of fabric absorption was found to increase as the materials underwent laundry treatment. This increase seemed to be caused, not so much by the removal of any soluble sizing or finishing agents, as by the shifting of the yarns within the fabric to allow more uniform spaces between yarns. In general, unfinished laundered fabrics were more absorbent and possessed a higher degree of hygroscopicity than did finished fabrics.

Other research (10,20), specifically involved with laundering and application of cationic softeners, both commercial and industrial, reports the formation of a waxy coating which has the tendency to build up on the fibers with repeated use until its accumulation gradually interferes with the absorptive property of the fabric. More specifically, Linfield, Sherrill, Davis and Raschke (20) conclude that, "the (hygroscopic) capacity of treated fabrics was unaffected by the softener whereas the rate of absorption of water is a function of the amount of cationic softener." (20) Linfield and associates found that the absorption rate is roughly a logarithmic function of the concentration of softener on the fabric. Furthermore, the hygroscopic capacity is unaffected by the presence of varying amounts of fabric softener (20).

CHAPTER III

METHODS OF PROCEDURE

Pretest

Originally this study was designed to test the effect of a selected home laundry fabric softener on the hygroscopic property of terry cloth. The design of the pilot study involved the treatment of 36 three-inch by three-inch true grain samples of medium weight white cotton terry cloth which were bound with white cotton. The samples were divided into three groups, each of which received either laundry treatment according to AATCC Standard Test Method 36-1961 (1), or laundry treatment with the addition of one of two selected commercially available home laundry softeners. The AATCC Static Absorption Method 21-1961 (1) was used to measure hygroscopicity after the 0, 1, 5, and 10 laundry cycles[2] treatment. Results from the pilot study showed that differences did not exist between the two softener treated groups. However, differences were observed between the mean absorbency of the control and the softener treated groups. Compared to the expectation as determined by the untreated control group, application of a fabric softener tended to decrease the hygroscopic property of the fabric.

[2]Laundry cycle as used in this study refers to a wash period followed by two separate rinses.

Several changes were made in the final design as a result of the pilot study. Diaper cloth was substituted for the terry cloth because (1) there is more surface uniformity in the diaper fabric, and (2) a larger sample size necessary for additional testing could be handled more easily in a lighter weight fabric. Several methods of finishing the edge of the samples were tried (glue, adhesives, and saran) before the decision was made to leave the sample edges unfinished. Bias tape and thread could not be used as either or both might absorb some of the softener and in turn influence the test measurements under observation. Also, a decision was made to use only one softener; to increase the sample size; and to include measurements after the 0, 1, 3, 6, 10, 15, 20 and 30 laundry cycles. An additional test to measure rate of absorption was added to the final design of the study.

A pretest designed to study the procedure for subjective softness evaluation was administered to 23 undergraduate textile students. Seven sets of three softener treated samples were presented to the members of the panel, who were asked to rank the sets according to a continuous scale from most soft through least soft. Panelists were allowed to make judgments based on any number of samples within each set. In addition to ranking the samples, each panelist was asked to complete a questionnaire concerning the test procedure (see Appendix A, p. 50). Tabulation of pretest results indicated a preference for single sample sets. Analysis of the softness rankings indicated a significant agreement in softness rating among members of the panel.

Selection of Fabric

Prior to the selection of the diapers, the department stores and diaper service agencies in the East Lansing and Lansing, Michigan, area were asked which type of diaper was most preferred by their customers. The 26-ounce heavyweight gauze diapers available at J. C. Penney Company, Incorporated, were selected for use as test fabrics. The diapers were 21 inches by 40 inches and were purchased for $2.98 per dozen.

Selection of Fabric Softener

The two fabric softeners used in the pilot study were products of Procter and Gamble and A. E. Staley.[3] The former softener was known to contain optical brighteners; therefore, the latter product which did not contain fluorescent additives was selected for this study. The softener was purchased at a local retail supermarket.

Verification of Fabric Properties

Physical characteristics of the original fabric were determined by the following test methods: yarn number, twist per inch, thread count and weight per square

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[3]"Downy" is the trade name of the Procter and Gamble softener; "Sta-Puf," the A. E. Staley product.

yard. Additional tests on the fabric included moisture content and verification of the fiber. Unless otherwise stated, all tests were conducted under standard conditions of temperature (70° ± 2° F) and relative humidity (65% ± 2%). Standard procedures of the American Society for Testing Materials, the Federal Specification Textile Test Methods CCCT-191b, and the American Association of Textile Chemists and Colorists were used in the analysis of the fabric. The arithmetic mean, based on the appropriate number of replications, was used to report all measured values.

Fiber Content.--Burning, microscopic examination and solubility with 70% H_2SO_4 were used to verify the fiber content of the fabric.

Yarn Number.--Yarn number is expressed as a weight-length ratio of the number of units of length per unit of weight. Five yarns from each of the warp and filling were ravelled, measured to exactly 36 inches and rolled into individual balls. Each ball was then placed on the specimen holder of a Universal Yarn Numbering Balance for weighing. The yarn number was read directly from the scales on the balance.

Twist Per Inch.--The untwist/twist method of Federal Specifications 4052 (11) was used to determine the yarn twist per inch. Forty different 15-inch yarns, 10 from the warp and 30 filling were ravelled from the woven cloth. One end of the specimen was placed in the nonrotating clamp of the Suter Twist Tester. The other end was then secured in the open rotatable clamp. The distance between the clamps was set at 10 inches; a one-gram load was applied at the center of the specimen and yarn height at the point of load was noted. The cycle counter was set on zero and the proper twist direction selected before the yarn was untwisted and retwisted to its original length and height. Twist per inch was obtained by dividing the total number of turns as indicated on the counter by twice the distance between the clamps.

$$\text{Twist per inch} = \frac{\text{Number of turns}}{(2)\ (10\ \text{inches})}$$

Thread Count.--The number of warp and filling yarns per inch were counted according to Federal Specifications Method 5050 (11). The fabric was laid smoothly and without tension over a light box. A Suter Mechanical Pick Counter was used to determine five separate counts in both the warp and filling. Special care was taken not to include the same warp or filling yarns in any of the tests.

Weight Per Square Yard.--A three-inch by three-inch metal die was used to cut five specimens from different combinations of warp and filling yarns for purposes of determining weight per square yard, according to Federal Specification Test 5041 (11). Test squares were oven-dried and weighed under standard conditions to the nearest .001 gram. Conversion to weight in ounces per square yard was calculated, using the following formula:

$$\text{Ounces per square yard} = \frac{\text{Weight of sample in grams x 45.72}}{\text{Sample area in square inches}}$$

Moisture Content--AATCC Tentative Test Method 20A-1959T (1) was used to determine the moisture content of three fabric samples. Metal weighing cans were placed uncovered in a drying oven controlled to 105°-110° C. for a period of one hour. The lids were replaced on the cans, which were then transferred to a desiccator and allowed to cool to room temperature. Thirty minutes was found to be sufficient for cooling. Weights were then recorded for each of the cans. The cycle of heating, cooling and weighing was repeated a sufficient number of times until the weight of the containers was constant to within $\pm$ .001 grams.

Test specimens were placed in the containers, covered and weighed. The dry weight of the specimen, designated weight A, was determined by subtracting the weight of the empty container from the container and specimen weight.

The specimen and uncovered container were placed in the oven for 90 minutes. The specimen-containing cans were cooled to room temperature in a desiccator. Weights were taken and the procedure was repeated for 20-minute heating intervals until a constant weight of within $\pm$ .001 grams was attained. The weight of the empty can was subtracted from the constant specimen-can weight to obtain the oven-dry weight, designated weight B. Moisture content was calculated as follows:

$$M = \frac{A - B}{A} \times 100$$

The moisture regain was obtained from the following equation:

$$R = \frac{A - B}{B} \times 100$$

Where:

M = moisture content per cent
R = moisture regain per cent
A = average specimen air-dry weight
B = average specimen oven-dry weight

Preparation of Fabric Samples

Twelve five-inch by eight-inch samples were cut from each of 14 diapers. The samples were coded to ensure at least one and no more than two samples from each diaper in a 20-member sample set. Each set was then randomly divided into two sub-sets; one sub-set served as a control and underwent laundry with plain rinse (treatment I), while the remaining ten samples in the set were treated with a fabric softener, in addition to receiving laundry treatment (treatment II).

Laundry Procedure

All test specimens were laundered in the Atlas Launder-Ometer according to the following procedure (18): Individual fabric specimens were placed in half-pint glass jars which contained 10 stainless steel balls and 100 cc. of .02 per cent neutral soap solution (12). The specimen-containing jars were preheated, sealed and clamped into the rotating mechanism of the machine where they were allowed to revolve for a period of 15 minutes in a water bath at 160° F. The samples were then transferred to a second set of jars which contained 200 ml. of distilled water and rinsed for two minutes at the same temperature. The latter procedure was repeated for a second rinse with either plain water or a softener solution of concentration recommended by the manufacturer. Specimens were allowed to air dry on Fiberglas screens before the entire procedure was repeated. Sets of ten samples each were removed after completion of 1, 3, 6, 10, 15, 20 and 30 cycles of laundering.

Test for Rate of Absorption

The "Wick-Up Method," as formulated by Holland (15), and employed by Grimes and Dillin (13), was used to measure the rate of absorption of 10 replicates for each of the eight specified laundry cycles of treatment I or II. Strips measuring approximately one inch by six inches were cut from the treated samples and conditioned for a period of not less than four hours before being tested.

A small clamp was attached to one end of each sample before the strip was suspended one inch below the surface of a five per cent aqueous solution of Pontacyl Rubine R. The height of wicking in centimeters was recorded at 15, 30, 60, 90 and 120 second intervals. Results were noted in centimeters' rise per time interval.

Test for Fabric Hygroscopicity

A measure of water penetration into a fabric can be obtained by employing the AATCC Static Absorption

Standard Test Method 21-1961 (1). Three-inch by three-inch squares were cut by means of a metal die from each of the test specimens. The samples were conditioned for a minimum of four hours before being tested. Metal weighing cans were oven-dried and weighed to a constant measurement of $\pm$ .001 gram. Single specimens were placed in the cans and weighed to the nearest .001 gram. The weight of each dry specimen was then computed by subtracting the weight of the can from the combined weight of the specimen and can.

A sinker was secured to one side of the specimen and dropped into an immersion tank containing distilled water at 27° $\pm$ 1° C. The specimen was allowed to remain immersed for 20 minutes, removed from the bath and quickly passed through a motorized laboratory wringer. Blotting paper as recommended by the test procedure was not used for this test because the paper could absorb an excessive amount of water, and thus lead to a misleading measurement of fabric hygroscopicity. The test specimen was reweighed, as was the can. A wet sample weight was calculated by subtracting the weight of the can from the weight of the specimen and can. The percentage of water held in the fabric was obtained by finding the difference between the two specimen weights, dividing by the original dry weight and multiplying by 100.

$$H = \frac{W - D}{D} \times 100$$

Where:

H = per cent hygroscopicity
W = wet specimen weight
D = dry specimen weight

Hygroscopicity values were calculated for each of the 10 replicates of the eight levels of treatments I and II.

Subjective Evaluations

A panel composed of 11 members of the Textiles, Clothing and Related Arts faculty and 11 students was used to evaluate fabric hand. All judgments were performed on an individual basis in a room controlled to standard conditions. Samples were cut to uniform size and were preconditioned overnight. Instructions for the test and an evaluation form were provided as each panelist entered the testing room. Panel members were asked to evaluate sample sets according to a relative judgment procedure and a method of paired judgments.

Relative Judgment.--The sample set consisted of eight specimens each of which had received treatment II for one of the 0, 1, 3, 6, 10, 15, 20 or 30 cycles. Samples were coded in nonsense symbols and arranged at random on a table covered with black felt. Panelists were asked to rank the samples on a continuous scale ranging from most soft to least soft (see Appendix B, p. 51). The entire procedure was repeated on three successive days in order to establish a measure of individual consistency of judgment. Replicate sample sets identified by a different code were used for the subsequent tests.

Paired Judgment.--Seven samples which had received treatment I and a comparable set which had undergone treatment II were paired for the purpose of determining softness differences according to treatment. Treatment I and II specimens were arranged in a random manner within cycle sub-sets. Each set was coded, then placed in order of increasing number of laundry cycles on the table for panel evaluation. The code "R" and "L" indicating right and left placement within a sub-set was used to designate each sample. Faculty panelists were asked to record their judgments on Form A; students, Form B (see Appendix C, pp. 52-53).

Analysis of Data

Analyses of variance were performed on a Control Data Corporation 3600 computer for all data relating to fabric absorbency (33). The data obtained from the subjective tests were analyzed using appropriate non parametric statistical methods. Kendall's (17) coefficient of concordance and Lyerly's (21) method for determining the average Spearman rank correlation coefficient of N sets of ranks were used in the analysis of the relative judgment data.

CHAPTER IV

DISCUSSION OF RESULTS

Fabric Verification Tests

Samples of the original fabric were analyzed according to standard textile testing procedures. The fiber content yarn structure, fabric structure and moisture content of diaper cloth were determined. Results from the fabric property verification tests are summarized in Table I (see p. 27).

The fiber content of this particular brand of diapers was verified to be 100 per cent cotton. Average weights obtained from the test for yarn number indicate the use of a similar weight of yarn, 34 grams, in both the warp and filling.[4] Twist per inch was slightly less in the warp direction, 19, than in the filling, 22. All the yarns of the warp had received a Z directioned twist, while the filling yarns consisted of both S and Z twisted yarns. For the 30 consecutive yarns tested, no particular ordering of S and Z twist in the filling yarns structure could be established. The average thread count per square inch of the plain weave fabric was 44 x 35; weight per square yard was recorded as 3.4 ounces; and the moisture content and

[4]The 40-inch lengthwise direction of the diaper was designated as the warp; the 21-inch width, the filling.

TABLE I. Verification of fabric properties: average recordings of diaper cloth properties as determined by standardized tests

Test	Result of Test
Fiber content	100% cotton
Yarn structure	
Yarn number	
Warp in ounces	34
Filling in ounces	34
Twist per inch	
Warp	19 (Z)[1]
Filling	22 (S and Z)[1]
Fabric structure	plain weave
Thread count per inch	
Warp	44
Filling	35
Weight per square yard in ounces	3.4
Percentage moisture content	6.2
Percentage moisture regain	6.6

[1]Direction of twist indicated in parentheses.

moisture regain were determined to be 6.2 per cent and 6.6 per cent respectively.

Analysis of Fabric Rate of Absorption

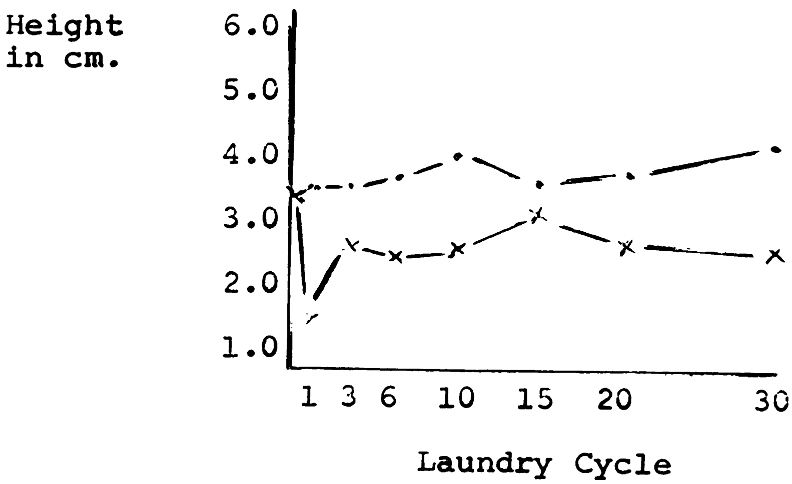
Measurements of the rate of absorption were taken for treatment I and treatment II specimens after completion of the 0, 1, 3, 6, 10, 15, 20 and 30 laundry cycles. The height of wicking for each of the 10 replicates for a given treatment at each of the specified laundry cycles was recorded for time intervals of 15, 30, 60, 90 and 120 seconds. Average rate of absorption heights are given for each treatment, specified cycle and time interval (see Appendix D, Table II, p. 54).

Analyses of variance were performed on the rate of absorption data.

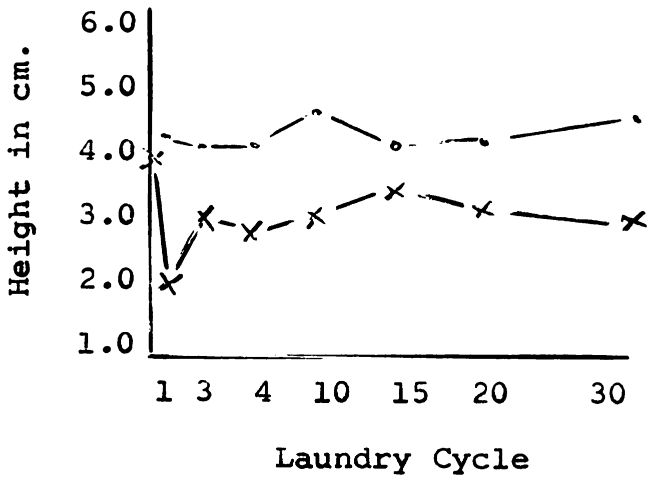
Differences between Treatments.--Highly significant differences in rate of absorption between the plain rinse (treatment I) and softener treated (treatment II) diaper cloth specimens were noted at each of the specified time intervals and laundry cycles (see Appendix D, Tables III, IV, V, VI and VII, pp. 55-57). Without exception, the treatment I rate of absorption measurements exceeded the recordings obtained for treatment II. The largest significant difference between treatments occurred at the first laundry cycle (Graph I, pp. 29-30). After this initial cycle, the differences between treatments decreased progressively at each of the 3, 6, 10 and 15 launderings; an increase was observed for the subsequent cycles.

GRAPH I. Rate of absorption: average heights in centimeters for plain rinse (treatment I) and softener treated (treatment II) diaper cloth specimens after laundry cycles of 0, 1, 3, 6, 10, 15, 20 and 30 for each of five specified time intervals

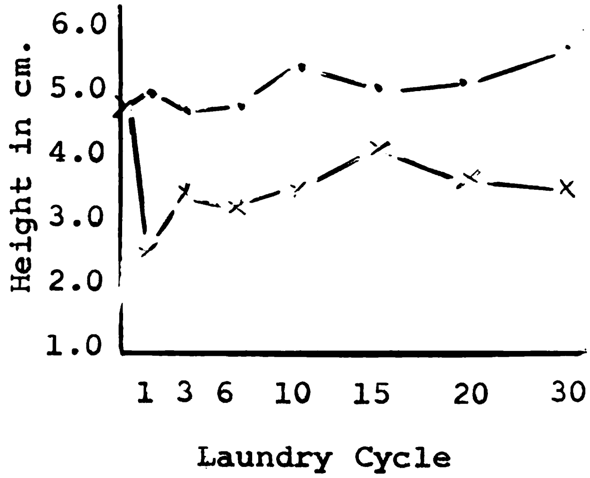
A. Fifteen Seconds Time Interval



B. Thirty Seconds Time Interval



C. Sixty Seconds Time Interval

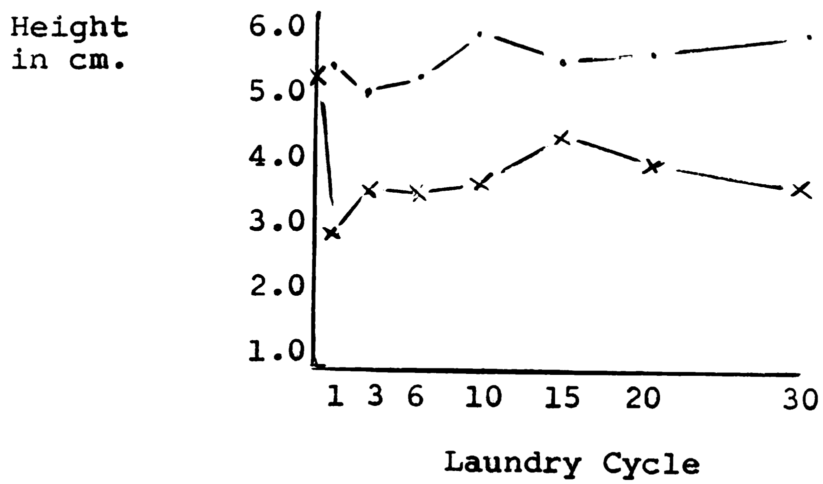


. - . Treatment I

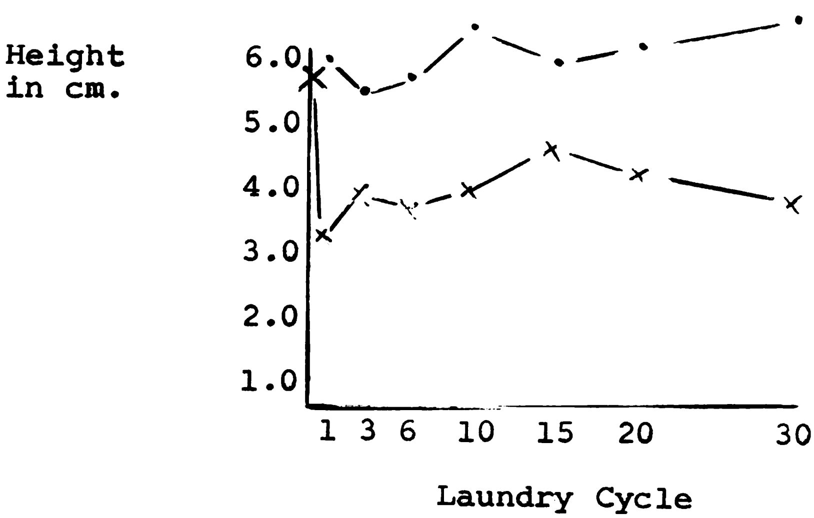
x - x Treatment II

GRAPH I. Continued

D. Ninety Second Time Interval



E. One hundred-twenty Second Time Interval



. - . Treatment I

x - x Treatment II

A positive linear relationship would be expected to occur for both treatment I and II between the recorded height of wicking and each specified time interval since the observed data is a cumulative measure of rate of absorption. It was interesting to note that the average rate of increase during the first 120 seconds of wicking for treatment I was greater than for treatment II (Graph II, pp. 32-33).

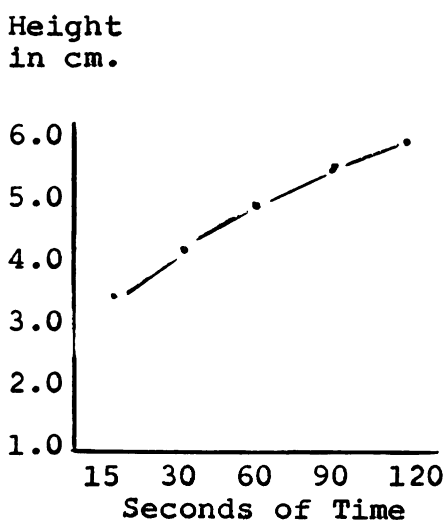
Differences among the specified laundry cycles.--Highly significant differences in rate of absorption among the 0, 1, 3, 6, 10, 15, 20 and 30 launderings were observed for both treatment I and treatment II (see Appendix D, Tables III, IV, V, VI, VII, pp. 55-57). The range of the variances for the plain rinse specimens was smaller than the observed range of variances for the softener treated ones.

For treatment I the rate of absorption after subsequent launderings remained similar to the values recorded for the zero cycle treatment. As the number of launderings increased beyond the sixth cycle, the rate of absorption of the diaper specimens tended to exceed the values obtained for the initial specimens.

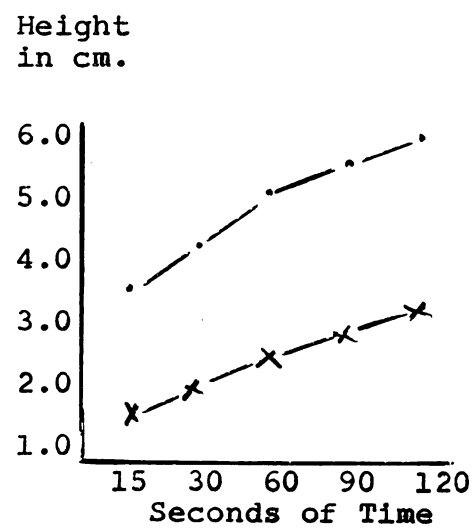
The rate of absorption was highest for treatment II specimens at the zero or untreated cycle; the lowest observed values occurred after completion of the first laundry cycle. After the initial laundering of the treatment II specimens the observed differences between each of the specified number of laundry cycles decreased. Although the

GRAPH II. Rate of absorption: average heights in centimeters for plain rinse (treatment I) and softener treated (treatment II) diaper cloth specimens at time intervals of 15, 30, 60, 90 and 120 seconds for each specified number of laundry cycles

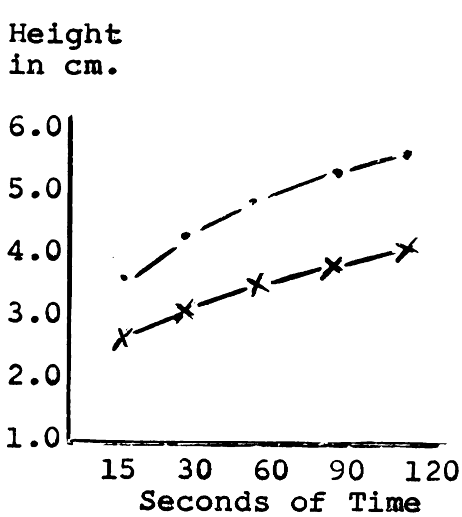
A. Laundry Cycle Zero



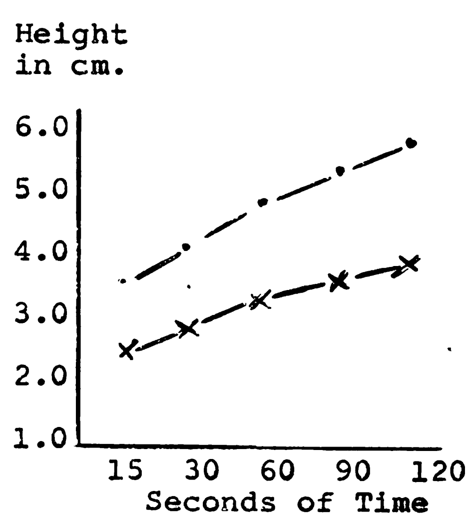
B. Laundry Cycle One



C. Laundry Cycle Three



D. Laundry Cycle Six

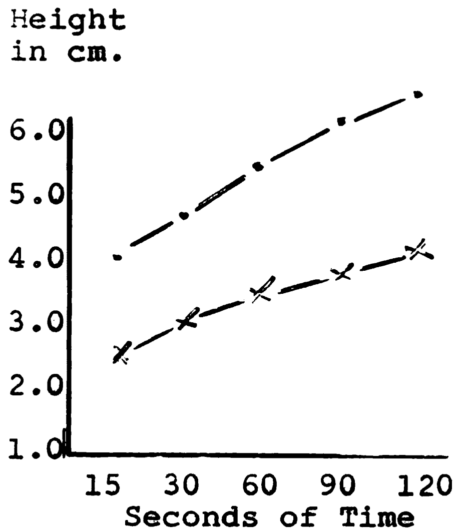


. - . Treatment I

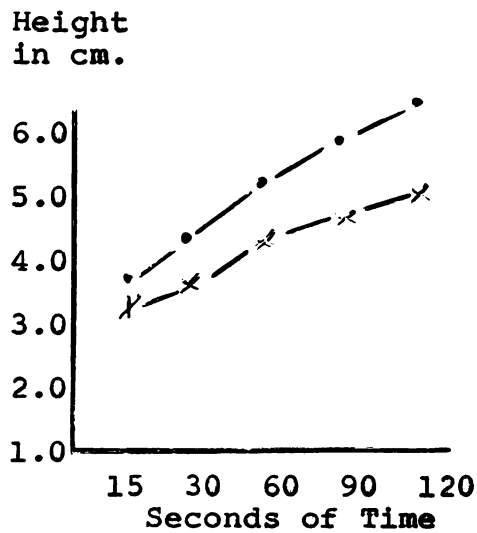
x - x Treatment II

GRAPH II. Continued

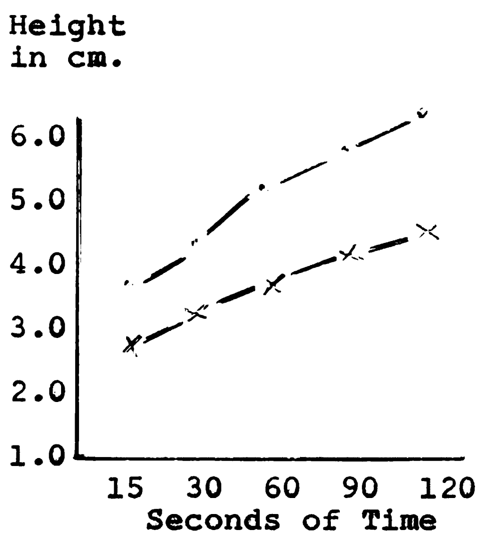
E. Laundry Cycle
Ten



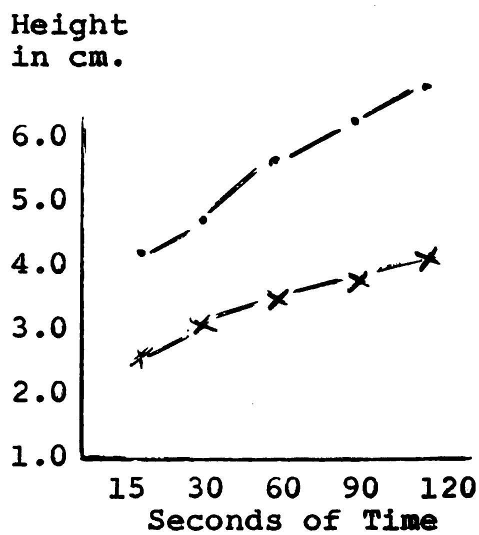
F. Laundry Cycle
Fifteen



G. Laundry Cycle
Twenty



H. Laundry Cycle
Thirty



. – . Treatment I

x – x Treatment II

average rate of absorption for treatment II increased with increasing numbers of launderings, the initial rate of absorption for the untreated specimens was never attained in subsequent measurements.

The interaction between treatment and specified number of laundry cycles was highly significant (see Appendix D, Tables III, IV, V, VI and VII, pp. 55-57). The observed variance of wicking heights can then be explained by the variation due to differences in treatments, differences in specified number of launderings, and by the interaction of treatments and cycles.

Analysis of Fabric Hygroscopicity

A measure of fabric hygroscopicity was obtained for treatment I and treatment II specimens after completion of the 0, 1, 3, 6, 10, 15, 20 and 30 laundry cycles. Mean hygroscopic weights are recorded for each treatment and specified laundry cycle (see Appendix D, Table VIII, p. 58).

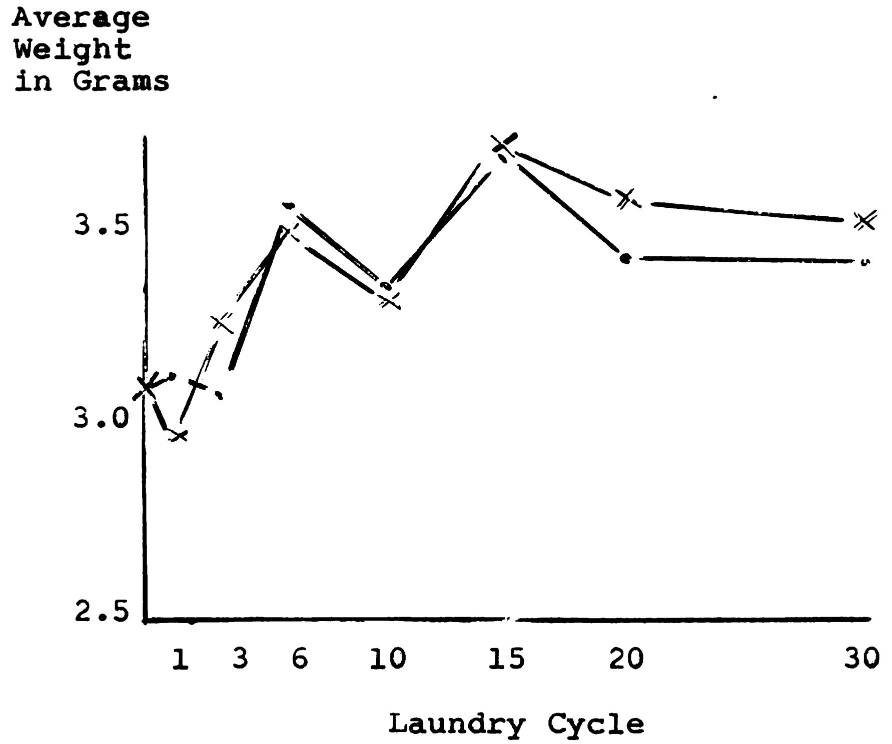
Differences between treatments.--No significant difference in fabric hygroscopicity was found between the plain rinse (treatment I) and softener treated (treatment II) diaper cloth specimens (see Appendix D, Table IX, p. 59). The results of this test verify the findings of Linfield and associates (20); in their study the absorptive capacity of treated fabrics was unaffected by application of a cationic fabric softener. In fact, hygroscopicity was not at all affected by the presence of large amounts of softener on the fabric (20).

<u>Differences among the specified laundry cycles</u>.--Highly significant differences in fabric hygroscopicity among the specified 0, 1, 3, 6, 10, 15, 20 and 30 launderings were observed for both treatment I and treatment II (see Appendix D, Table IX, p. 59). Graph III (see p. 36) illustrates that as the diaper cloth specimens received increasing numbers of launderings from 0 to 15 cycles the hygroscopic property of the fabric also increased; additional launderings as observed after the 20 and 30 cycles showed a decrease in hygroscopicity. Another interesting phenomenon that may be seen from Graph III is the irregularity of increase for the recorded data. A review of the literature disclosed no information which might help to explain this observation. Perhaps these fluctuations occurred as a result of moisture accumulation on the wringer rollers. Use of blotter paper, as recommended in AATCC Static Absorption Test Method 21-1961 (1), might have alleviated this problem. Until further investigation is pursued no statement can be made in an attempt to explain this unusual observation.

The test for interaction between the softener treatments and the number of laundry cycles was statistically significant (see Appendix D, Table IX, p. 59). However, it should be pointed out that, although statistically significant, this finding does not have any practical interpretation or significance.

Hygroscopicity measures the amount of liquid retention

GRAPH III. Hygroscopicity: average weight in grams for plain rinse (treatment I) and softener treated (treatment II) diaper cloth specimens after each of the 0, 1, 3, 6, 10, 15, 20 and 30 laundry cycles



. - . Treatment I

x - x Treatment II

at equilibrium; whereas, the rate of absorption represents the initial intake of liquids before equilibrium has been reached. Thus, a measure of hygroscopicity necessarily includes rate of absorption.

Analysis of Subjective Evaluation

Since fabric softness is based largely on personal standards, the subjective evaluation of fabric hand is considered to be the preferred method of discerning softness. The data obtained from both the relative judgment and the paired judgment tests consisted of symbolic rankings. To enable analysis of the data, the nonsense symbols were converted to a numerical scale at the time of tabulation.

Relative Judgment.--The Kendall coefficient of concordance, W (17), was used to test the ability of each individual to rank the specimens consistently, and to ascertain the ability of the panelists to agree among themselves. In every case the χ^2 test for significance of the W values was significant at or beyond the .98 level of confidence (see Appendix D, Table XI, p. 61). Thus, it may be inferred that individuals who participated in this study ranked the three replicate sets of specimens in relative order and that the panel as a group exhibited the ability to rate the specimens in a similar manner. Under the assumptions of the Kendall test, recognition of panel agreement suggests that the rankings were based upon a similar reference rather than implying that the responses were necessarily correct.

A method developed by Lyerly (21) was used to test the agreement of panelists' rankings against a criterion ranking defined as the increasing number of launderings each specimen had received. A highly significant value of ρ = .717 was computed. In this study it may be inferred that the order of ranking by the panelists corresponds highly to the increasing number of laundry cycles. As the specimens undergo additional launderings, the property of fabric hand also improves.

Further indication of agreement between the panelists' rankings and the criterion ranking may be obtained by ordering the sums of the former rankings. Graph IV, p. 39, shows a continuous increase of softness with successive launderings. It is interesting to note that errors[5] were made by all panelists. Not once did an individual rank the specimens in criterion order.

Paired Judgment.--The frequency distribution of panel evaluation to discern fabric softness (see Appendix D, Table XII, p. 62) indicates that panelists exhibited nearly complete agreement in their choices of the most soft specimen. Five panelists were observed to have committed a total of seven errors.[5] Thus, panelists consistently rated the softener treated specimens (treatment II) more soft than the specimens which had received a plain rinse (treatment I). The softness of diaper cloth was found to increase with application of a fabric softener.

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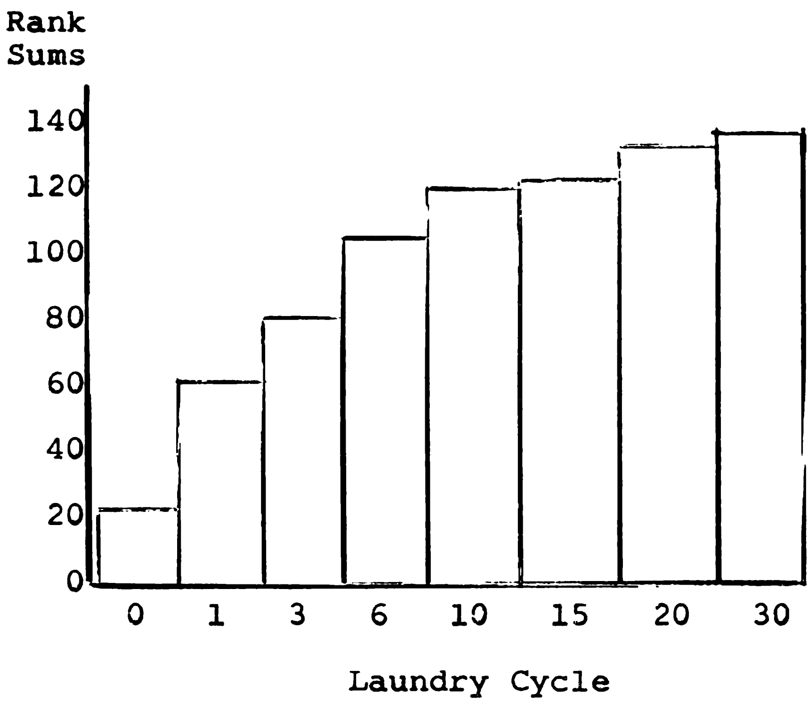
[5]An error was defined as an individual making a judgment opposed to the composite rating of the group.

GRAPH IV. Fabric softness: summed rankings of panelist's order of preference from least soft through most soft based on the average response per individual for softener treated specimens representing each of the 0, 1, 3, 6, 10, 15, 20 and 30 laundry cycles



Upon completion of the subjective tests panelists were asked: "Do you believe you are sensitive to fabric softness differences?" Only two individuals felt they could not discriminate among the specimens; while six members of the panel, all faculty, qualified their responses. The remaining 14 panelists felt they were sensitive to softener differences. The inquiry as to the effect of specimen appearances indicated that judgments on the average were influenced by the appearance of the fabric. The least soft specimen, zero level sample, was most often cited as being obvious. In general, panelists indicated that the least soft specimen was used as a reference for judging the remaining specimens in the set.

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

This study was designed to investigate the effect of a home laundry fabric softener on the absorption and softness of diaper cloth. The specific objectives were: (1) To determine the level of fabric absorbency at specified treatment intervals; (2) To determine the level of fabric softness at specified treatment intervals; (3) To determine the optimum number of softener treatments which will produce positive absorbency and improved fabric hand.

The null hypotheses to be tested were stated in the following manner: The properties of absorption and hand or softness will not be expected to show distinct changes as a result of fabric softener application to a fabric. Fabric rate of absorption will be unchanged as a result of the application of a fabric softener. The hygroscopic property of a fabric will be unchanged following application of a fabric softener. The softness of a fabric will be unchanged with softener application.

Each diaper cloth specimen received one of two treatments during the laundry process. The control group received a plain water rinse (treatment I) for the final cycle in the laundry procedure, while the experimental group (treatment II) received application of a fabric softener. Rate of absorption and hygroscopicity measurements were observed for each sample at specified intervals following completion of the 0, 1, 3, 6, 10, 15, 20 and 30 laundry cycles.

Fabric softness was determined subjectively by a panel of judges. Tests were designed to establish the least soft...most soft ordering of softener treated specimens, and to determine if the use of a fabric softener improved the hand or softness of diaper cloth as opposed to laundry procedures without application of a fabric softener.

Conclusions

Results obtained from analysis of data collected are to be interpreted as applicable only to this unique, specific combination of variables. Upon completion of this study the following conclusions were drawn:

1. There is a highly significant difference between the rate of absorption for diaper specimens which have received fabric softener treatment and untreated specimens. The immediate intake of a liquid substance was greater in every case for the plain rinse specimens than for the softener treated ones.
2. There is a difference between the rate of absorption for diaper specimens which have undergone varying numbers of launderings under treatment I and treatment II. The initial intake of a liquid substance was greatest after the tenth treatment for the control group and after the fifteenth for the softener treated one.

3. There is no difference in fabric hygroscopicity for diaper specimens which received either treatment I or treatment II. Under both treatments diaper specimens exhibited comparable ability to retain liquid substances.
4. There is a significant difference between fabric hygroscopicity of diaper specimens which have undergone varying numbers of laundry cycles. Specimens from both treatment I and treatment II exhibited greatest hygroscopicity at the fifteenth level of treatment. Beyond this level, the amount of absorption decreased.
5. There was complete agreement between the panelist's composite preferential rankings of diaper specimen softness and the order of increasing number of laundry cycles. Every panelist ranked the 0 level specimen least soft. On the average, specimens which had received additional launderings were ordered by the panelists according to an increasing number of laundry cycles; the 30 cycle specimens were considered most soft.
6. There is a highly significant relationship between softener application and softness of diaper specimens. Seventy-seven per cent of the panelists exhibited the ability to discriminate the softener treated specimens over the control for every treatment level. Application of a fabric softener did improve the hand or softness of diaper cloth.

The null hypothesis A, fabric rate of absorption will be unchanged as a result of the application of a fabric softener, was rejected based on the foregoing conclusions. The null hypothesis B, the hygroscopic property of a fabric will be unchanged following application of a fabric softener, was rejected. Although no difference between treatments was observed, hygroscopicity does increase with repeated launderings irrespective of the presence of softener application. The null hypothesis C, the softness of a fabric will be unchanged with softener application, was rejected. Softness does improve with application of a fabric softener.

Recommendations

The possibilities for further research based on fabric softeners and their use appears to be unending. From the research point of view, there is interest in developing a "miracle" product which would combine the household laundry detergent, bleach, brightener, disinfectant and softener into a single product. However, until this product becomes reality it would be of interest to determine the relationship which exists between fabric softeners and additional laundry additives. Suggestions for further research are:

1. To study the effects of different concentrations of a fabric softener on various physical properties of a fabric.
2. To investigate the relationship between fabric softeners and washing temperature, water hardness, detergent concentration and bleaches.

3. To determine the effect of softener application on fabrics of different fiber content.
4. To investigate the initial use of fabric softener treatment after several launderings or for specific alternate intervals of application.

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APPENDICES

APPENDIX A

PANEL EVALUATION PRETEST

Name: ______________________________

Major: ______________________________

How much contact do you have with fabrics

a) In clothing construction?

	Little	Some	Average	A great deal
a) In clothing construction?	___	___	___	___
b) In home use?	___	___	___	___
c) In school or work?	___	___	___	___

In the following blanks rank the samples from right to left.

Most soft . . . . Least soft

___ ___ ___ ___ ___ ___ ___

Did the appearance of the samples affect your judgment in the ranking of the samples?

Yes ___ No ___

Are the samples large enough to handle?

Yes ___ No ___

Would you have preferred only one sample to a group instead of three?

One ___ Three ___

Do you believe you are sensitive to fabric differences?

Yes ___ No ___

APPENDIX B

RELATIVE JUDGMENT

Name: ______________________________

Date: ____________________

I. The sets of eight samples have been treated with a fabric softener and coded by a nonsense symbol.

In the following blanks rank the samples from left to right according to their degree of softness.

most soft . . . . least soft

___ ___ ___ ___ ___ ___ ___ ___

APPENDIX C

Form A

I. Each member within the following sets of samples has received the same total number of treatments. One member of each set was treated with a fabric softener while the remaining one received only plain water rinses.

In the following blanks rate each set of samples separately as to their degree of softness.

Sample Set Number

	1	3	6	10	15	20	30
Most soft							
Least soft							

II. Did the appearance of the samples affect your judgment in the ranking of the samples?

Yes ___ No ___

If yes, in what way was your decision influenced?

III. Do you believe you are sensitive to fabric softness differences?

Yes ___ No ___

APPENDIX C

Form B

I. Each member within the following sets of samples has received the same total number of treatments. One member of each set was treated with a fabric softener while the remaining one received only a plain water rinse.

In the following blanks rate each set of samples separately as to their degree of softness.

Sample Set Number

	1	3	6	10	15	20	30
Most soft							
Least soft							

II. Indicate how much contact you have with fabrics.

	Very little	Some	Average	A great deal
a) In home use	___	___	___	___
b) At school	___	___	___	___
c) At work	___	___	___	___
d) In other activities	___	___	___	___

III. Did the appearance of the samples affect your judgment in the ranking of the samples?

Yes ___ No ___

If yes, in what way was your decision influenced?

IV. Do you believe you are sensitive to fabric softness differences?

Yes ___ No ___

APPENDIX D

TABLE II. Rate of absorption: average heights in centimeters for plain rinse (treatment I) and softener treated (treatment II) diaper cloth specimens at given time intervals for the specified number of laundry cycles

Treatment	Laundry Cycles	Time Intervals in Seconds				
		15	30	60	90	120
Original Specimen	0	3.57	4.15	4.89	5.47	5.92
	1	3.69	4.33	5.16	5.69	6.11
	3	3.67	4.19	4.84	5.21	5.66
I	6	3.71	4.20	4.89	5.40	5.82
Plain	10	4.14	4.77	5.54	6.13	6.62
Rinse	15	3.63	4.26	5.12	5.72	6.24
	20	3.70	4.34	5.19	5.83	6.38
	30	4.11	4.74	5.57	6.12	6.70
	1	1.66	2.09	2.63	3.01	3.41
	3	2.74	3.06	3.49	3.79	4.11
	6	2.51	2.91	3.29	3.69	3.92
II	10	2.63	3.10	3.53	3.82	4.13
Softener	15	3.19	3.65	4.16	4.52	4.86
	20	2.74	3.19	3.70	4.12	4.43
	30	2.60	3.03	3.49	3.82	4.10

APPENDIX D

TABLE III. Analysis of variance for rate of absorbency at the fifteen seconds time interval

Source	Sum of Squares	Degrees of Freedom	Mean Square	F value
Treatments	48.0706	1	48.0706	1335.2944**
Levels	10.2619	7	1.4660	40.7222**
Treatments x Levels	12.6159	7	1.8023	50.0639**
Within cell variation	5.1810	144	.0360	
Total	76.1294	159		

TABLE IV. Analysis of variance for rate of absorbency at the thirty seconds time interval

Source	Sum of Squares	Degrees of Freedom	Mean Square	F value
Treatments	63.7563	1	63.7563	1837.3573**
Levels	12.1407	7	1.7344	49.9827**
Treatments x Levels	13.5247	7	1.9321	55.6801**
Within cell variation	4.9980	144	.0347	
Total	94.4197	159		

**Significant at .001

APPENDIX D

TABLE V. Analysis of variance for rate of absorbency at the sixty seconds time interval

Source	Sum of Squares	Degrees of Freedom	Mean Square	F value
Treatments	95.3266	1	95.3266	2389.1378**
Levels	15.1224	7	2.1603	54.1429**
Treatments x Levels	16.6759	7	2.3823	59.7068**
Within cell variation	5.7450	144	.0399	
Total	132.8699	159		

TABLE VI. Analysis of variance for rate of absorbency at the ninety seconds time interval

Source	Sum of Squares	Degrees of Freedom	Mean Square	F value
Treatments	118.1641	1	118.1641	3061.2461**
Levels	19.5864	7	2.7981	72.4896**
Treatments x Levels	18.2834	7	2.6119	67.6658**
Within cell variation	5.5530	144	.0386	
Total	161.5869	159		

**Significant at .001

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TABLE VII. Analysis of variance for rate of absorbency at the one-hundred twenty seconds time interval

Source	Sum of Squares	Degrees of Freedom	Mean Square	F value
Treatments	140.8126	1	140.8126	3583.0178**
Levels	22.8339	7	3.2620	83.0025**
Treatments x Levels	20.0029	7	2.8576	72.7125**
Within cell variation	5.6650	144	.0393	
Total	189.3144	159		

**Significant at .001

APPENDIX D

TABLE VIII. Hygroscopicity: average weight in grams for plain rinse (treatment I) and softener treated (treatment II) diaper cloth specimens after each of the 0, 1, 3, 6, 10, 15, 20 and 30 laundry cycles

Treatment	Laundry Cycles							
	0	1	3	6	10	15	20	30
I Plain Rinse	3.1114	3.1618	3.0535	3.5425	3.3583	3.6842	3.3820	3.3425
II Softener	3.1114	2.9033	3.2974	3.4858	3.3218	3.6957	3.5292	3.4375

APPENDIX D

TABLE IX. Analysis of variance on fabric hygroscopicity

Source	Sum of Squares	Degrees of Freedom	Mean Square	F value
Treatments	.0295	1	.0295	.5630
Levels	6.8341	7	.9763	18.6317**
Treatments x Levels	.8054	7	.1151	2.1966*
Within cell variation	7.5474	144	.0524	
Total	15.2164	159		

*Significant at .05

**Significant at .01

APPENDIX D

TABLE X. Fabric softness: panelist's order of preference from least soft through most soft based on the average response per individual for softener treated specimens representing each of the 0, 1, 3, 6, 10, 15, 20 and 30 laundry cycles

	Least Soft........................Most Soft							
Panel Member	Laundry Cycles 0	1	3	6	10	15	20	30
a	1	2	4	3	5	7	6	8
b	1	5.5	2	7	8	4	5.5	3
c	1	2	5.5	3	5.5	4	7	8
d	1	3	2	7	5.5	5.5	8	4
e	1	2	5	7	4	3	8	6
f	1	2	3	4.5	7	4.5	6	8
g	1	2	4	3	6	7.5	7.5	5
h	1	5	4	2	3	6.5	6.5	8
i	1	3.5	6	8	5	7	3.5	2
j	1	3.5	2	7	3.5	8	5.5	5.5
k	1	2	4	7	5.5	5.5	8	3
l	1	2	3	4.5	6.5	4.5	6.5	8
m	1	2.5	4.5	4.5	2.5	6	7	8
n	1	2	7	3	8	5.5	4	5.5
o	1	2.5	2.5	4	5.5	7	5.5	8
p	1	2	3	4	6	7	5	8
q	1	7.5	2.5	4	2.5	6	5	7.5
r	1	2	3	6	4.5	4.5	8	7
s	1	2	3	4	8	6.5	5	6.5
t	1	2	3	4	7	5	7	7
u	1	3	2	7	8	6	4	5
v	1	2.5	5.5	4	5.5	2.5	7.5	7.5
Sum	22.0	62.5	80.5	107.5	122.0	123.0	136.0	138.5
Group Preference	1	2	3	4	5	6	7	8

APPENDIX D

TABLE XI. Coefficient of concordance and chi square values of panelists' rankings obtained from subjective evaluation of fabric softness

Panel Member	w value	^{2} value	Panel Member	w value	^{2} value
a	.72	11.52	l	.77	12.32
b	.77	12.32	m	.52	8.32
c	.77	12.32	n	.77	12.32
d	.52	8.32	o	.80	12.80
e	.74	11.84	p	.69	11.04
f	.72	11.52	q	.85	13.60
g	.53	8.48	r	.66	10.56
h	.62	9.92	s	.86	13.76
i	.55	8.80	t	.75	12.00
j	.72	11.52	u	.68	10.88
k	.90	14.40	v	.53	8.48
Composite panel	.49	82.32			

^{2} .98 = 7.82 d.f. = 2 $\quad$ ^{2} .999 = 46.80 d.f. = 21

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TABLE XII. Fabric softness: frequency distribution of panel evaluation to discern fabric softness between plain rinse (treatment I) and softener treated (treatment II) diaper cloth specimens after each of the 0, 1, 3, 6, 10, 15, 20 and 30 laundry cycles

		Sample Set According to Level of Treatment							
		1	3	6	10	15	20	30	Total
Specimen Discerned More Soft	Plain Rinse Treatment I	1	1	1	0	0	2	2	7
	Softener Treatment II	21	21	21	22	22	20	20	147
		22	22	22	22	22	22	22	154

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