

THE EFFECTS OF LAUNDERING ON POLYESTER FABRICS
WITH DIFFERENT WATER HARDNESSES AND DETERGENTS

by

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INTRODUCTION

Man made fiber production in the United States has increased significantly in the past ten years. In 1976, man made fibers accounted for approximately 77 percent of the apparel market, 88 percent of home furnishings market, 82 percent of industrial uses market and 84 percent of other markets (luggage, medical, etc.). The major natural fibers (cotton, wool) in 1976 were used in 23 percent of apparel, 12 percent of home furnishings, 18 percent industrial uses and 16 percent other uses (9, p. 1).

The major man made fiber marketed for most of these uses and especially for apparel is polyester. Polyester was first marketed in the United States in the 1950's by du Pont under the trade name of Dacon. Acceptance for the fiber grew until the most popular synthetic fiber in 1970 was polyester. Polyester is known for its ability to blend well with other fibers and to impart its good qualities with the good qualities of other fibers (16, p. 64).

While the properties of polyester such as strength and comfort are important, the hydrophobicity (i.e., water hating property) of the fiber must be considered. Research has been performed related to the problems of laundering polyester fabrics (20, 21, 26, 32).

Narkar and Karmakar (26, p. 47) studied the loss in whiteness in polyester fabrics after the fabrics were worn and laundered repeatedly. They examined the reasons why polyester fabrics lose their whiteness and develop a yellow cast which is caused by unremoved organic and organic soils accumulating on the fabric.

Shimauchi and Mizushima (32, p. 462) found that the deposits of soil during laundering (redeposition) are found more often on polyester fabrics

than on cotton fabrics. They also noted that soil redeposition tests gave results close to actual consumer use if natural soils are used.

Kohler (20, p. 173) studied the variables of washing temperature, time, and detergent concentration with machine laundered fabrics. In a similar study, Komeda, Mino, Imamura and Tokiwa (21, p. 733) investigated the bath temperature, detergent concentration, mechanical action and water hardness factors that are present in washing conditions.

Water that is used in laundering contains ions of calcium and magnesium which may affect the laundering process. The concentration of metal ions in water is known as water hardness. Water hardness is defined as the total concentration of calcium and magnesium expressed as equivalent calcium carbonate either in parts per million or grains per gallon (6, p. 25).

Concern with the flammability and flame retardancy of fabrics has increased during the last few years. The textile industry has been involved in researching and developing products that have a reduced or no flammability. The use of flame retardant chemicals has increased significantly and the market for the chemicals was expected to reach 850 million pounds in 1975 (19, p. 14).

Flame retardant properties related to polyester fabrics are fairly new. Polyester fabrics may be treated with fire retardant finishes or be blended with fibers that may themselves be treated with fire retardant finishes. Experimentation in inherently fire retardant polyester fibers has been undertaken to provide consumers with better protection in this area (16, p. 64).

Many studies that have been conducted on polyester fabrics have dealt mainly with the removal of oily soil or stains, the mechanical properties of soiling that occur on polyester and the effects of optical brighteners on polyester fabric (5, 28, 32). The major focus of this study dealt with

possible weight gain/loss of fabrics after multiple launderings in different systems.

The rationale for this emphasis was based on a previous unpublished study (12) in which polyester fabric exhibited a weight loss after one laundering in a phosphate and non phosphate detergent. Although it was expected that there would be an increase in weight due to the deposition of detergent and hardness deposits on the fabric, this result did not occur. Consequently, it was postulated that a loss in weight would continue to occur with repeated launderings (12).

The purpose of this study, therefore, was to determine whether a weight loss would occur in a polyester fabric after repeated launderings with different water hardness levels and different detergents. The major experimental emphases were changes in weight, structural characteristics and color and/or whiteness.

OBJECTIVES

This study was undertaken to investigate the following objectives:

1. To determine the effects of multiple launderings (0, 5, 10, 15, 20) of polyester fabric on weight, color, and structural characteristics.
2. To determine whether the detergent (with optical brighteners or without optical brighteners) affected the retention of color/whiteness.
3. To visualize detergent or mineral deposits on the fabric surface by the use of a scanning electron microscope (SEM).

HYPOTHESES

1. There will be no significant differences in the weight of the samples before and after laundering for 0, 5, 10, 15, 20 cycles in two water hardnesses.

2. There will be no significant differences between American Association of Textile Chemists and Colourists (AATCC) Standard Detergent 124 (with optical brighteners) and AATCC Standard Detergent WOB (without optical brighteners) on the reflectance values of polyester fabrics after multiple (0, 5, 10, 15, 20) launderings in two water hardnesses.
3. There will be no observable fiber damage or deposition on the polyester fabrics after laundering for 0, 5, 10, 15, 20 cycles in two water hardnesses as evidenced by the scanning electron microscope.

REVIEW OF LITERATURE

REDEPOSITION STUDIES

The effectiveness of a detergent solution is important in the laundering and dry cleaning of fabrics. Detergents are synthetic agents that are present in a liquid bath and which clean the surface of a solid material. There are four types of detergents, namely, cationic (positively charged ions), anionic (negatively charged ions), nonionic (do not ionize) and ampholytic (ionize either positive or negatively) (28, p. 27).

Several variables in the detergent solution affect the effectiveness and cleansing capability of the detergent. Among these variables are the amount of detergent, amount of water, type of detergent, type of water and type of soil and fabric. For example, in a given procedure too little detergent does not hold soil in suspension while a strong detergent concentration may be a factor in redeposition (17, p. 495).

Redeposition is the process of removing soil from a fabric and then re-depositing it in such a form that the washed fabric is darker than the original fabric before laundering (14, p. 108). When a detergent is used with synthetic fibers such as polyester, there may be more of a tendency towards redeposition than when used with natural fibers such as cotton because of polyester's hydrophobicity (i.e. water hating, oil loving) characteristic (14, p. 108.)

Greying of fabrics may occur from several types of synthetic detergents because of the detergents ineffectiveness to function well in hard water. Redeposition may occur on fabrics from the ineffectiveness of detergents in keeping soil suspended. It also may occur from other sources such as high soiling, adverse temperatures (too hot or too cold), low solution volume and/or

low detergent concentration in hard water situations (14, p. 109).

Hunter (17, p. 494) noted that polyester fabrics have a tendency to grey from the redeposition of soil particles faster and more readily than other fibers. The redeposition process increased as the detergent concentration decreased. It was further noted that permanent press fabrics were more susceptible to this process.

Fort, Bellica and Sloan (10, p. 1) found that an organic sheath may be seen on the surface of the fibers with soil particles embedded in the sheath. This finding indicated that the redeposition of soil may not adhere directly to the fiber but to a substrate on the fiber which, in this case, would be an organic substance.

Two German scientists, Rufflin and Buhler (31, p. 192), noted that the choice of washing agent and the finish that was applied to the fabrics are indicated by the greyness of polyesters after laundering. The laundering tests in that study were done with air filter dust and mineral oil which served as a base for the dust.

FLUORESCENT WHITENING AGENTS

The amount of light that is reflected from the surface of hydrophobic fibers, such as polyester, differ after laundering than before laundering. Redeposition may cause a loss in reflectance at lower detergent concentration and is recognized as an increase in greyness (17, p. 495).

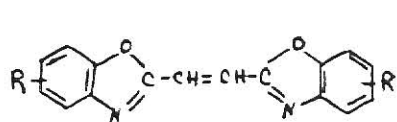
The mechanism by which fluorescent whitening agents operate is to convert the invisible ultraviolet light that strikes the brightener (a colorless, organic compound) on the fabric to a visible light. The reflected light from the fabric is blue-white, thus masking the yellow discoloration seen on fabrics. The result is that the fabric appears brighter and whiter. Fluorscent

brighteners are incorporated into detergents, soaps, softeners, and other laundry formulations (23, p. 75). According to Stensby (35, p. 497) the maximum reflection that can be obtained by using brighteners is 100 percent. In actual use, however, 92 to 95 percent is difficult to achieve.

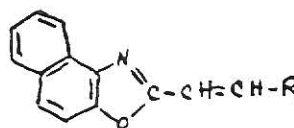
The introduction of optical brighteners into soaps and detergents for home use was established after World War II by Lever Brothers, Co. The first basic types of optical brighteners were either diamino stilbene disulfonic acid types for cotton or naphthyl triazole stilbene for cotton and nylon (38, p. 75). The brighteners used today include the first basic types as well as bleach stable brighteners and polyester brighteners which exhibit limited effectiveness on previously brightened polyester fabrics (36, p. 27).

The three most often used brighteners for polyester fibers are bisbenzoxazolyl (BBO), naphthoxazolyl (NOS), and naphotriazolyl (NTSA). These brighteners adhere to the fibers by first dissolving or dispersing in a liquor. The brighteners then will migrate throughout the surface of the fiber. The degree of dissolution of the brightener in the liquor and the rate at which migration occurs will have an effect on the working ability of the brightener (35, p. 49).

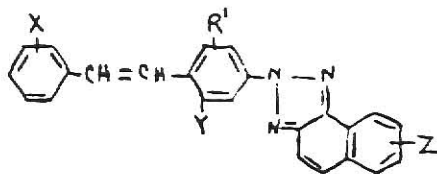
The following are the chemical formulas for the three polyester brighteners (BBO, NOS, NTSA):



Brightener BBO



Brightener NOS



Brightener NTSA

Stensby (30) found that NTSA was more effective in nonionic detergent solutions. He also discovered that a change in the pH of the solution caused a change in the affinity of the brightener for the aqueous base. The pH change also interfered with the degree of swelling that occurred in some fibers. BBO was found to be effective at high temperatures on polyester (above 160° F). Polyester fibers become softer at high temperatures above 160° F consequently, BBO may have penetrated the fibers more easily (35, p. 503).

WATER HARDNESS

Research studies dealing with hard water on fabrics have investigated the effects of differing water hardnesses on fiber properties, soiling, fabric degradation and deterioration of color. The water hardness studies (1, 3, 21) have incorporated the effects of detergents, pre-soaking laundry products, enzymes, and builders on soil redeposition occurring on fabrics. Many of the variables were investigated simultaneously rather than individually.

The presence of dissolved salts (calcium and magnesium) in water is known as water hardness. The United States Geological Survey expresses hardness as parts of calcium in a million parts of water (ppm). Water which contains less than 55 ppm is considered soft water, 55 ppm to 100 ppm is moderately soft water, 100 ppm to 200 ppm is moderately hard to hard water, and 200 ppm to 500 ppm is hard to excessively hard water (24, p. 25).

Water hardness produces insoluble soaps, which when exposed to detergents, interfere with the foaming properties and the detergency action of the detergent (34, p. 302). These insoluble soaps are the result of the calcium and magnesium mineral salts that are found in hard water. The salts react with the detergent and replace the sodium, in the detergent, with calcium or magnesium which are insoluble. The calcium and magnesium soaps may deposit onto fabrics and not

be carried away in the bath liquor and this occurrence is known as deposition (28, p. 39).

An increase in water hardness has been shown to render the detergent less effective in its cleaning ability (14, p. 55). Consequently, if the water is hard, it should be softened before washing for maximum cleaning potential by the detergent. Softening of the water may be accomplished by the addition of water softening agents in the wash water or by mechanical water softeners. The softeners remove the mineral salts that naturally occur in water. Softening the water compensates for the loss in cleaning power of the soaps or synthetic detergent without necessitating an increase in detergent concentration of the wash liquor (11, p. 354).

According to Cutler and Davis (8, p. 475) anionic detergents lose their cleaning ability in high water hardnesses (over 150 ppm) by binding with the metal salts to form insoluble particles that may be deposited onto fabrics. Because of this loss, sodium tripolyphosphate (STP) is added to synthetic detergents to help overcome the negative effects of hard water. The amount of sodium tripolyphosphate used is determined by the hardness of the water. Detergent action is not increased by the use of extra amounts of STP beyond that which is required for the binding of the metal salts into soluble complex es (form) (8, p. 479).

Nonionic detergents (no charge) are only slightly affected by water hardness, unlike the ionizing anionic detergents. Nonionic detergents are preferred because of their ability to clean effectively in hard water that is present in many homes (8, p. 479).

POLYESTER

Polyester is a fiber in which the fiber forming substance is any long

chain polymer composed of at least 85 percent by weight of an ester of dihydric alcohol and terephthalic acid ($p\text{-HOOC-C}_6\text{H}_4\text{-COOH}$) reactive sites. Polyester fibers are characterized by being strong, resistant to wrinkles and are easily washed and dried. These fibers have limitations in that they have low moisture absorption, poor affinity to dyes and tend to pill (37, p. 18).

Polyester fibers, because of their long smooth filaments, usually do not attract dirt. Particulate soils and stain wash out easily and the fibers are not readily susceptible to alkali conditions that may exist in the bath liquor (24, p. 15).

The surface of the polyester fiber allows only a minimum number of reactive sites, according to Bowers and Chantrey (5, p. 3), for ionic detergents that have been dissolved in an aqueous media. The fact of reduced reactive sites allows for nonionic detergents to work to a greater advantage than other detergent types.

FIBER FRACTURE

The breakdown of man made fibers or fiber fracture occurs most often at the intersection of the warp and weft yarns in woven fabrics according to Nikolaeva (27, p. 22). The type of fiber distortion at these points is varied. Included in fiber fracture are breaks as the result of fiber elongation over the other yarns, bending and friction of yarn on yarn or yarn on external sources. The rate of deterioration at these intersections occurs as frequently as 88 percent.

Frictional effects or mechanical deterioration known as abrasion occurs in most wet processing stages. This abrasion is the result of creasing, rubbing or actual abrasion of the fibers that visually may be seen on the surface of the fabric or may be seen as a loss in the life of the garment (7, p. 624).

Princen (29, p. 152) did research in the area of fiber fracture of polyester fibers. He found that when the polyester fiber is bent, lines at a 45 degree angle appear on the inside of the bend. Princen refers to these lines as kink bands and found that they were results of the fiber being compressed and are signs of later fiber reorientation. If the fiber is repeatedly bent at this point it will eventually be the point of fiber fracture or break.

In a different study, Handy (13, p. 529) found that when polyester is woven into fabric and constructed into dress shirts the most abrasive damage occurs in laundering. He further discovered that the ability of the fabric, in a blend, to resist this abrasion increased with the increase in polyester content of the fabric.

FLAMMABILITY

The last ten to twenty years has produced much research and development of fire retardant finishes. Early research was done concerning cellulose fabrics. The development of synthetics created a need for new fire retardant treatments (19, p. 14). Legislation developed a list of five flammability standards for carpets and rugs, small carpets and rugs, childrens sleepwear (sizes 0 to 6X), mattresses, childrens sleepwear (sizes 7 to 14) (4, p. 109).

The flammability tests measure the ignitability (ease of a fabric to become coinflamed) and combustibility (rate at which the flame travels) of fabrics. Fabrics that have a flame retardant finish are tested according to the AATCC 34-1969 Test Method. This test method measures the after flame (duration of flame on fabric), char length (vertical length of char) and after glow (duration of glowing). Fabrics that have not been treated with fire retardant finishes are tested according to the AATCC 33-1962 test method which measures the ignition temperature and the temperature of the flame (19, p. 14).

The Oxygen Index (OI) is a test for flammability that measures both fire retardant and untreated fabrics. The OI measures the minimum volume of oxygen in a slowly rising oxygen-nitrogen mixture that will sustain candle like burning of the polymer (19, p. 15).

Most fire retardant finishes contain either phosphorus, nitrogen, or bromides. Common fire retardant treatments available on the market for cellulose fibers and fyrol. Polyester fabrics may be treated with tris (dibromopropyl) phosphate or tris (2, 3, dibromopropyl) phosphate (TDBPP) (4, pp. 109-113).

Mobile Chemical Company (30) has produced a new phosphorus flame retardant for polyester fabrics called Antiblaze 19T which is a low viscosity flame retardant finish. Mobile found that Antiblaze 19T flame retardant met the DOC FF 3-71 standard for children's sleepwear, and the DOC FF 3-71 standard for laundering. The fire retardant finish was durable to 50 launderings at 140 degrees fahrenheit.

Antiblaze 19T flame retardant is applied to polyester by a padding procedure (30, p. 5). The application of the retardant may occur at the final processing stages or at an earlier point in the fabric manufacture. The fabric may be dyed, printed or yarn dyed in woven and knit structures. Color bleeding or discoloration of a white background does not occur with Antiblaze 19T so that the retardant may be applied to printed fabrics. Antiblaze 19T has been shown to be an effective flame retardant as measured by the Oxygen Index Method (30, p. 5).

PROCEDURE

SELECTION OF FABRIC

A laboratory study of two polyester fabrics (Fabric T and Fabric U) was conducted to determine the effects of laundering on the fabrics. The 100 percent polyester fabrics were similar in weave, threads per inch and width. The two fabrics differed only in that one was printed and had been treated with an Antiblaze 19T flame retardant finish (Fabric T) while the other fabric was in the unfinished or gray state (Fabric U). The physical characteristics of the fabrics are shown in Table 1.

TABLE 1. PHYSICAL CHARACTERISTICS OF FABRICS

	<u>Treated</u>	<u>Untreated</u>
Width	111.5 cm	113.5 cm
Yarns per cm: Warp	22.3/cm	22.0/cm
Yarns per cm: Weft	32.3/cm	33.3/cm
Weight	105.45g/m ²	98.32g/m ²
Construction	plain weave	plain weave
Fiber Content	100 percent polyester	100 percent polyester

Each fabric was cut into forty-eight samples, 5 x 15 centimeters (cm) for duplicate testing. The variables involved in this study included two polyester fabrics, two water hardness, and two detergents.

LAUNDRY SAMPLES

The 98 samples were laundered according to the procedure specified by the

American Association of Textile Chemists and Colourists (AATCC) Method 61-1975, Test Number IIA.

Prior to laundering the fabric samples were top stitched, 10 stitches per inch, on all four sides with a 0.5 x 2.54 cm label on the lower edge for identification. Two replicate samples were used for each water/detergent/cycle combination. The samples were evaluated after 1, 2, 3, and 4 cycles in the laundrometer. Each laundrometer cycle is equivalent to five cycles in a commercial washer (2).

The samples were placed under standard conditions (70° F temperature $\pm 2\%$) for 24 hours before the initial weight was measured. The samples were then exposed to the laundry treatment, again dried in standard conditions for 24 hours, and finally reweighed. The weight of each sample was taken twice and the two weights averaged.

Two control groups were kept for later comparison. One control group was not exposed to any launderings. The other control group, consisting of 32 samples (16 of each fabric), were laundered in two water hardnesses for four laundry cycles (5, 10, 15, 20).

The water hardness levels that were used were zero parts per million (ppm) and 300 ppm. The levels were obtained by a titration technique. The method was as follows: A water hardening agent was added to distilled water to make a stock solution (2000 ppm). The stock solution was later diluted to the necessary ppm (300). The hardening agent was obtained by dissolving 29.6 grams of magnesium sulfate ($\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$) and 26.4 grams of calcium chloride ($\text{CaCl}_2 \cdot 2\text{H}_2\text{O}$) in 15 liters of distilled water.

The water hardness was measured using an EDTA titration technique. A small amount of Mordant Black II dye and one ml (milliliter) of an ammonium

buffer (pH of 10) was added to 25 ml of the diluted water sample (300 ppm). The water sample was a pink color at this point. Ethylenediamine tetraacetic acid (EDTA) was titrated into the sample until the sample turned to a blue end point indicating that the calcium and magnesium ions were complexed (inactivated ions).

The water hardness of the sample is calculated in hardness as ppm of calcium carbonate (CaCO₃) using the number of milliliters of titrate that was needed to determine the blue end point.

$$\text{Hardness as ppm CaCO}_3 = \frac{\text{ml of titrate} \times 1000}{\text{ml of sample}}$$

AATCC standard detergent 124 with optical brighteners and AATCC standard detergent without optical brighteners were used. AATCC standard detergent 124 is both an anionic and nonionic detergent which contains fluorescent brightening agents and complex sodium phosphates to soften water (Table 2).

TABLE 2. AATCC STANDARD DETERGENT 124 FORMULATION

48 %	Sodium tripolyphosphate
14 %	Linear Alkylate Sulfonate-Sodium Salt
16 %	Sodium Sulfate
9.7%	Sodium Silicate
7.25%	Moisture and miscellaneous*
2.5%	Soap-high molecular weight
2.3%	Alcohol ethoxylate
.25%	CMC (Carboxyl methyl cellulose)

* Miscellaneous- .3% of mixed brightener system including balanced portions of Bis (triazinyl) Stilbenedisulfonate and triazolylstibenesulfonate.

The detergent and water hardness plan was as follows:

Detergent Used	Water Hardness
AATCC 124	0 ppm (soft water)
AATCC 124	300 ppm (very hard water)
AATCC WOB	0 ppm
AATCC WOB	300 ppm
none	0 ppm
none	300 ppm

COLOR DIFFERENCE

The Gardner Color Difference Meter Model AC-2A Series 200 was used to obtain color differences. Readings were taken at Rd, a, and b settings on each treated sample and the control group. Three warp and three filling readings were taken of each sample and averaged. For the treated polyester sample since it was a printed fabric, the pink background was read on the fabric.

The Rd value indicates the amount of light reflected by a sample when the light is applied at an angle of 45 degrees. The light is measured as it diffuses perpendicularly from the surface of the sample. A value of zero would indicate that the sample completely absorbed the light (black). A value of 100 would indicate that the sample completely reflected the light (white).

The values of a and b indicate redness or greenness and yellow or blueness. A plus value of a indicated red and a minus value of a indicates green. A plus value of b indicates yellow and a minus value of b indicates blue.

SCANNING ELECTRON MICROSCOPE

The scanning electron microscope was used to examine the fibers for deposits and fiber damage. Both control samples and samples laundered for four cycles were examined.

The samples were mounted on specimen holders and coated with gold-palladium alloy to reduce charging. A layer of liquid adhesive held the fabric sample onto the specimen holder. The edges were attached firmly to prevent the adhesive from obscuring the fibers in the center of the sample.

STATISTICAL ANALYSIS

Analysis of variance was performed for the experimental data. The 0.05 level of significance was selected. The data were analyzed using a four way analysis of variance.

RESULTS AND DISCUSSION

The results are divided into four major areas: 1) weight change, 2) Rd color values, 3) a color values, and 4) b color values. The variables discussed are shown in Appendix A.

WEIGHT CHANGE

The amount of weight loss was dependent on the interaction of the four variables, i.e., detergent, water, fabric, and number of cycles. The mean values for these variables are presented in Appendix B.

TABLE 3. ANALYSIS OF VARIANCE OF WEIGHT DIFFERENCE

FIRST ORDER INTERACTION					
Source of Variation	df	Sum of Squares	Mean of Squares	F ratio	Significance Level
Detergency	2	.002	.001	6.54	.00
Water	1	.000	.000	0.36	.55 ns
Fabric	1	.000	.000	2.50	.12 ns
Cycle	3	.003	.001	6.75	.00
SECOND ORDER INTERACTION					
Detergent x Water	2	.000	.000	0.15	.86 ns
Detergent x Fabric	2	.000	.000	1.26	.29 ns
Detergent x Cycle	6	.001	.000	1.18	.33 ns
Water x Fabric	1	.000	.000	0.30	.58 ns
Water x Cycle	3	.000	.000	0.39	.76 ns
Fabric x Cycle	3	.000	.000	0.06	.98 ns

ns-not significant at 0.05 level

The first order interaction of water and fabric were not significant at the 0.05 level seen in Table 3. The first order interactions of detergent and cycles were significant at the 0.05 level and below that level of significance also. None of the second order interactions of weight change were significant at the 0.05 level.

TABLE 4. MEAN WEIGHT LOSS IN GRAMS

Variables		Mean Value in Grams
Detergent		
	AATCC WOB	-.016
	AATC Dash	-.015
	Control	-.005
Cycles	1	-.007
	2	-.007
	3	-.013
	4	-.021

The mean weight loss from the initial weight to the final weight showed that the two detergents had a significant weight loss (Table 4). Samples that were laundered in detergent exhibited a greater mean weight loss (-.016 and .015) than samples that were laundered in water alone (-.005). The mean weight loss by cycle indicated that the longer the fabric was laundered the more weight was lost.

The weight loss between variables is not great but the fact that any loss at all occurred should be noted. The original samples weighed approximately 1.0 grams to .98 grams so that a .02 gram weight change is a large amount when compared to the original weight of the sample.

Rd COLOR VALUES

The color differences of the fabrics were dependent on the interaction of the variables of detergent, water, and number of cycles. The mean values for these variables are presented in Appendix C. Table 5 gives the analysis of variance for the Rd Color Values.

TABLE 5. ANALYSIS OF VARIANCE OF Rd COLOR VALUES

FIRST ORDER INTERACTIONS					
Source of Variation	df	Sum of Squares	Mean of Squares	F ratio	Significance Level
Detergent	2	53.35	26.67	129.44	.00
Water	1	3.43	3.43	16.15	.00
Fabric	1	1721.18	1721.18	8352.79	.00
Cycle	3	10.95	3.65	17.72	.00
SECOND ORDER INTERACTIONS					
Detergent x Water	2	17.08	8.54	41.45	.00
Detergent x Fabric	2	0.11	0.05	0.28	.75 ns
Detergent x Cycle	6	54.29	9.05	43.91	.00
Water x Fabric	1	0.08	0.08	0.41	.52 ns
Water x Cycle	3	2.59	0.86	4.19	.01
Fabric x Cycle	3	0.47	0.15	0.76	.52 ns

ns-not significant at 0.05 level

The first order interactions all were found to be significant at the 0.05 level of significance. As can be seen in Table 5, the most significant differences in the second order interaction occurred with water and number of cycles,

detergent and fabric, water and fabric, and fabric and cycle interactions.

The water-cycle interaction indicates that the reflectance increased from 61.6 percent after one cycle to 62.9 percent after four cycles. The fabrics washed in hard (300 ppm) water, however, showed an increase in percent reflectance after the first three cycles but then decreased in reflectance after the fourth cycle (Table 6).

TABLE 6. MEAN Rd VALUE (PERCENT) OF WATER-CYCLE AND DETERGENT-CYCLE INTERACTIONS

<u>Water</u>	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>
Soft	61.6	62.1	62.6	62.9
Hard	61.7	61.7	62.2	62.0
<u>Detergent</u>				
AATCC WOB	61.0	62.1	63.0	64.0
AATCC 124	62.0	62.4	63.3	63.3
Control	62.0	61.2	60.9	60.1

The detergent-cycle interaction presented in Table 6, showed an increase in reflectance with an increase in the number of cycles the samples were laundered in AATCC detergent without optical brighteners. The samples that were laundered in AATCC 124 Standard detergent showed an increase in reflectance with repeated launderings from 62.0 percent to 63.3 percent. The control (water only) samples, however, decreased in Rd value as the number of cycles increased.

TABLE 7. MEAN Rd VALUE (PERCENT) OF WATER-DETERGENT INTERACTION

<u>Detergent</u>	<u>Water</u>	
	<u>Hard</u>	<u>Soft</u>
AATCC WOB	62.6	62.4
AATCC 124	62.9	62.6
Control	60.3	61.8

The interaction of water with detergent, shown in Table 7, indicated that the detergent containing optical brighteners had a greater reflectance than either the AATCC standard detergent without optical brighteners or the control sample (no detergent). This occurrence was observed for the samples washed in soft water or hard water. The difference between the Rd values of samples in hard water and detergent without optical brighteners (62.6 percent) and those laundered with hard water and standard detergent 124 (62.9 percent) and hard water and control (60.3 percent) is small. This difference, while it exists statistically, is very slight.

Samples that were laundered in soft water and detergent with optical brighteners (62.6 percent) showed the greatest amount of reflectance. The samples that were laundered in soft water and detergent without optical brighteners (62.4 percent) and samples that were laundered in soft water only (61.8 percent) showed a lower percentage of reflectance.

The Rd color values produced varying values with different water types, detergent types, and cycle lengths. While a 0.05 significant level was determined in the discussed interactions, the variance of the values on closer evaluation did not appear to be extreme.

a COLOR VALUE

As stated earlier, a plus value of a is an indication of redness and a minus value of a is an indication of greenness. All of the samples that were tested had a plus value of a which indicated a tendency towards redness.

The difference in the value a was dependent upon the interaction of the variables of detergent, cycle number, and water type. The mean values of the variables are shown in Appendix D.

TABLE 8. ANALYSIS OF VARIANCE OF a COLOR VALUE

FIRST ORDER INTERACTIONS					
Source of Variation	df	Sum of Squares	Mean of Squares	F ratio	Significance Level
Detergent	2	1.01	.50	4.19	.02
Water	1	.50	.50	4.18	.04
Fabric	1	1120.59	1120.59	9308.78	.00
Cycle	3	5.04	1.68	13.95	.00
SECOND ORDER INTERACTIONS					
Detergent x Water	2	1.15	.58	4.80	.01
Detergent x Fabric	2	.32	.16	1.34	.27 ns
Detergent x Cycle	6	5.41	.90	7.50	.00
Water x Fabric	1	.89	.89	7.44	.00
Water x Cycle	3	1.98	.66	5.47	.00
Fabric x Cycle	3	3.61	1.20	10.01	.00

ns-not significant at 0.05 level

Table 8 indicates that the first order interactions of water (.04) and detergent (.02) was significant at the 0.05 level of significance. The first

order interactions of fabric and laundry cycle are significant at an even lower level.

The second order interaction of detergent-fabric did not have any significant difference at the 0.05 level but a significant difference was seen at all of the other interactions.

TABLE 9. MEAN a VALUES OF DETERGENT-WATER AND DETERGENT-CYCLE INTERACTION

<u>Water</u>	<u>Detergent</u>		<u>Control</u>
	<u>AATCC WOB</u>	<u>AATCC 124</u>	
Hard	5.5	5.7	5.5
Soft	5.6	5.7	5.7
<u>Cycles</u>			
1	5.6	5.4	5.3
2	6.2	6.0	4.9
3	5.6	5.7	6.1
4	5.6	5.7	4.9

The a value of 5.7 for soft water control and AATCC detergent 124 and an a value of 5.6 for soft water and detergent without optical brighteners is significant. The samples that were laundered in hard water and detergent without optical brighteners (5.5) and hard water and detergent with optical brighteners (5.7) showed little difference in a values. The control samples (no detergent) had the same a values (5.5). This difference in a values for that level are not totally significant. These significant interactions seen in Table 9 show that the a values do not vary to a large extent.

In the detergent by cycle interaction (Table 9), the interaction of AATCC WOB increases in the second cycle and then decreases back to the first cycle value. AATCC 124 detergent also exhibited increasing a values (5.4 to 6.0) in the second cycle. It then decreased (5.7) but not below the value of a for the first cycle (5.4). The control increased in a value in the second (5.6) and third (6.1) but decreased in the fourth cycle (4.9).

TABLE 10. MEAN a VALUE OF WATER-CYCLE AND FABRIC-CYCLE INTERACTIONS

<u>Water</u>	<u>Cycles</u>			
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>
Hard	5.2	6.1	5.7	5.3
Soft	5.7	5.8	5.9	5.6
<u>Fabric</u>				
Treated	8.7	9.7	9.1	8.7
Untreated	2.2	2.2	2.4	2.1

The water by cycle interaction (Table 10) shows an increase in a value after two cycles in both water types (6.1, 5.8) but after the third cycle the hard water level decreased in value (5.7). The soft water values increased after the third cycle (5.9) and then began to decrease, like the hard water values, at the fourth cycle (5.6).

The fabric-cycle interaction seen in Table 10 indicates an increase in a value for the treated sample after the first two cycles followed by a decrease in the a value. The untreated sample showed no change after the first two cycles (2.2) then the values increased (2.4) to be followed by a decrease (2.1). It must be noted here that the a values between the fabric types are different

due to different colors of the fabrics. In addition, the difference within each fabric type does not appear to be large enough to be considered a considerable change.

TABLE 11. MEAN a VALUE OF FABRIC - WATER INTERACTION

<u>Fabric</u>	<u>Water</u>	
	<u>Hard</u>	<u>Soft</u>
Treated	8.9	9.2
Untreated	2.2	2.2

Table 11 presents the mean a values that were obtained for the fabric and water interaction. The interaction showed that soft water had a greater amount of redness as indicated by an increased value (9.2) than hard water (8.9) in the treated sample. The untreated sample showed no difference in a value when washed in either hard or soft water. The difference that is seen between the treated and untreated fabrics is due to the fact that one sample was white and the other pink.

b COLOR VALUE

Values of b indicate the amount of yellow or blue color in a fabric. A plus (+) value of b indicates yellow color and a minus (-) value of b indicates blue color. The samples that were tested all had negative b values indicating a tendency toward blueness.

TABLE 12. ANALYSIS OF VARIANCE OF b VALUES

FIRST ORDER INTERACTIONS

Source of Variation	df	Sum of Squares	Mean of Squares	F ratio	Significance Level
Detergent	2	16.10	8.05	229.32	.00
Water	1	.98	.49	3.21	.08 ns
Fabric	1	72.22	72.12	2053.71	.00
Cycle	3	5.82	1.94	55.24	.00

SECOND ORDER INTERACTIONS

Detergent x Water	2	1.09	.54	1.52	.00
Detergent x Fabric	2	0.98	.49	13.94	.00
Detergent x Cycle	6	1.92	.32	9.12	.00
Water x Fabric	1	.02	.02	.59	.45 ns
Water x Cycle	3	.42	.14	3.97	.01
Fabric x Cycle	3	1.43	.48	13.57	.00

ns-not significant at 0.05 level

As can be seen in Table 12, all of the first order interactions were significant except for water alone ($F = 3.21$). Appendix E contains the mean values of b for the first level interactions.

TABLE 13. MEAN b VALUES OF DETERGENT-WATER AND DETERGENT-FABRIC INTERACTION

<u>Water</u>	<u>Detergents</u>		
	<u>AATCC WOB</u>	<u>AATCC 124</u>	<u>Control</u>
Hard	-8.2	-8.3	-7.1
Soft	-8.2	-8.2	-7.5
<u>Fabric</u>			
Treated	-9.0	-8.9	-8.3
Untreated	-7.3	-7.4	-6.3

The b values increased with the number of cycles washed (Table 13). b also exhibited greater values with the detergent with optical brighteners and detergent without optical brighteners then when laundered in water alone (control).

Table 13 also showed that AATCC detergent 124 in hard water exhibited a greater b value (-8.3) while AATCC detergent WOB and 124 in soft water had values as high (-8.2). The control sample had a greater b value (7.5) in soft water than in hard water (-7.1).

The treated samples, as indicated in Table 13, showed a different value of b in the three types of detergent treatments. The results showed that the treated sample WOB (without brighteners) had a greater b value (-9.0) than with the other detergent. The untreated samples indicated that AATCC 124 detergent had a greater b value (-7.4) than with the other detergent.

TABLE 14. MEAN b VALUES OF DETERGENT-CYCLE, WATER-CYCLE, AND FABRIC-CYCLE INTERACTIONS

<u>Detergent</u>	<u>Cycle</u>			
	<u>1</u>	<u>2</u>	<u>3</u>	<u>4</u>
AATCC WOB	-8.6	-8.2	-8.2	-7.7
AATCC 124	-8.2	-8.2	-8.2	-8.0
Control	-7.8	-7.4	-7.1	-6.8
<u>Water</u>				
Hard	-8.2	-7.9	-7.8	-7.4
Soft	-8.1	-7.9	-8.0	-7.6
<u>Fabric</u>				
Treated	-9.0	-8.7	-8.9	-8.3
Untreated	-7.3	-7.2	-6.8	-6.7

There was no large differences between cycle and detergent, cycle and water, or cycle and fabric (Table 14). The interaction between cycle and detergent indicated that all samples lost some of the blue color value after they were washed. The cycle and water interaction also indicated that a loss in b values was seen after repeated cycles. Both the treated and untreated samples indicated the loss in b values occurred after repeated cycles.

SCANNING ELECTRON MICROSCOPE

Scanning electron microscope observation did not show fiber damage nor hardness deposits. The AATCC standard detergent 124 and hard (300 ppm) water samples had very few deposits on the fiber surface. The few deposits that were seen had the appearance of particulate soil as illustrated by Hearle (15).

These samples also contained a few particles that could be classified as detergent deposits.

The fiber arrangement in the yarns showed displacement after four (20 launderings) cycles. The fibers that were displaced in the treated samples appeared to have torn, broken ends while control samples showed ends that appeared to be cut. The control sample appeared to have a more orderly arrangement of fibers in the yarns while treated samples had yarns that were displaced from their original position.

SUMMARY AND CONCLUSIONS

The objectives of this research were: 1) to determine if a weight change occurred when polyester fibers were laundered; and 2) to determine how the variables of water, detergent, and number of laundering cycles affected the characteristics of polyester fabrics.

Two fabrics were used in this study, a white 100 percent polyester gray fabric and a pink print of 100 percent polyester treated with a flame retardant finish. The variables included different water hardnesses, detergent types, and laundering cycles. Changes in color and in weight were measured.

The results of the study indicated that a weight change in the fabrics occurred after repeated launderings. Although the weight loss was minimal it nevertheless was apparent. Weight loss increased after four cycles and no significant increase was noted in the reflectance values.

Each of the fabrics showed very little color change after repeated launderings. The color values did not change with either increasing laundering cycles or differing detergent types significantly. The minimal change in color was evident for the R_d , a and b values.

These data may indicate that detergent and mineral deposits did not adhere to the fiber. This indication is somewhat substantiated by the fact that no mineral or detergent deposits were observed on the fabric with SEM analysis.

REJECTED HYPOTHESES

The following hypothesis was rejected:

1. There will be no significant difference in the weight of the sample before and after laundering for 0, 5, 10, 15, and 20 cycles in two water hardnesses.

ACCEPTED HYPOTHESES

The following hypotheses were rejected:

1. There will be no significant differences between American Association of Textile Chemists and Colourists (AATCC) Standard Detergent 124 (with optical brighteners) and AATCC Standard Detergent WOB (without optical brighteners) on the reflectance values of polyester fabrics after multiple (0, 5, 10, 15, 20) launderings in two water hardnesses.
2. There will be no observable fiber damage or deposition on the polyester fabrics after laundering for 0, 5, 10, 15, and 20 cycles in two water hardnesses as evidenced by the scanning electron microscope.

RECOMMENDATIONS FOR FURTHER STUDY

1. Flammability tests should be performed after repeated launderings to determine the effectiveness of the Antiblaze 19T flame retardant finish.
2. The physical characteristics (i.e., abrasion, strength, etc.) of the fabric without Antiblaze 19T flame retardant finish should be compared to the physical characteristics of the fabric with Antiblaze 19T flame retardant finish.
3. The effects of softeners and bleaches to the durability and flame retardancy of Antiblaze 19T flame retardant fabric should be determined.

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APPENDICES

APPENDIX A

CODE FOR VARIABLE FACTORS

Detergents (D)

WOB (AATCC Standard Detergent with no Optical brighteners)

124 (AATCC Standard Detergent with optical brighteners)

Control (no detergent added)

Waters (W)

S = Soft- Oppm water hardness

H = Hard- 300 ppm water hardness

Fabrics (F)

T = Treated (100% polyester fabric with Antiblaze 19T)

U = Untreated (100% polyester fabric without Antiblaze 19T)

Cycles (C)

1 = (denotes one 45 minute cycle in laundrometer: equivalent
to 5 launderings in a commercial washer)

2 = 10 launderings

3 = 15 launderings

4 = 20 launderings

APPENDIX B

MEAN VALUE OF WEIGHT DIFFERENCE

FIRST ORDER INTERACTIONS	
Variables	Mean weight difference in grams
<u>Detergent</u>	
AATCC WOB	-.016
AATCC 124	-.015
Control	-.005
<u>Water</u>	
Soft	-.013
Hard	-.012
<u>Fabric</u>	
Treated	-.015
Untreated	-.010
<u>Cycle</u>	
1	-.007
2	-.007
3	-.013
4	-.022

 SECOND ORDER INTERACTIONS

Variables	Mean weight difference in grams
<u>Detergent x Water</u>	
AATCC WOB x Soft	-.017
AATCC WOB x Hard	-.016
AATCC 124 x Soft	-.016
AATCC 124 x Hard	-.015
Control x Soft	-.007
Control x Hard	-.004
<u>Detergent x Fabric</u>	
AATCC WOB x Treated	-.021
AATCC WOB x Untreated	-.012
AATCC 124 x Treated	-.015
AATCC 124 x Untreated	-.016
Control x Treated	-.008
Control x Untreated	-.004
<u>Detergent x Cycle</u>	
AATCC WOB x 1	-.008
AATCC WOB x 2	-.013
AATCC WOB x 3	-.016
AATCC WOB x 4	-.029
AATCC 124 x 1	-.011
AATCC 124 x 2	-.007
AATCC 124 x 3	-.014

 SECOND ORDER INTERACTIONS (CONTINUED)

AATCC 124 x 4	-.029
Control x 1	-.003
Control x 2	-.003
Control x 3	-.010
Control x 4	-.007
<u>Water x Fabric</u>	
Soft x Treated	-.016
Soft x Untreated	-.010
Hard x Treated	-.021
Hard x Untreated	-.010
<u>Water x Cycle</u>	
Soft x 1	-.008
Soft x 2	-.010
Soft x 3	-.015
Soft x 4	-.020
Hard x 1	-.006
Hard x 2	-.006
Hard x 3	-.011
Hard x 4	-.023
<u>Fabric x Cycle</u>	
Treated x 1	-.010
Treated x 2	-.009
Treated x 3	-.016
Treated x 4	-.023

SECOND ORDER INTERACTIONS (CONTINUED)

Untreated x 1	-.004
Untreated x 2	-.006
Untreated x 3	-.011
Untreated x 4	-.020

APPENDIX C
MEAN VALUES OF Rd

FIRST ORDER INTERACTIONS	
Variable	Mean Rd Value Percent
<u>Detergent</u>	
AATCC WOB	62.51
AATCC 124	62.76
Control	61.06
<u>Water</u>	
Soft	62.30
Hard	61.92
<u>Fabric</u>	
Treated	57.87
Untreated	66.34
<u>Cycle</u>	
1	62.48
2	62.39
3	61.91
4	61.66

 SECOND ORDER INTERACTIONS

Variable	Mean Rd Value Percent
<u>Detergent x Water</u>	
AATCC 124 x Hard	62.90
AATCC 124 x Soft	62.61
AATCC WOB x Hard	62.57
AATCC WOB x Soft	62.44
Control x Hard	60.28
Control x Soft	61.85
<u>Detergent x Fabric</u>	
AATCC WOB x Treated	58.22
AATCC WOB x Untreated	66.79
AATCC 124 x Treated	58.55
AATCC 124 x Untreated	66.96
Control x Treated	56.85
Control x Untreated	65.28
<u>Detergent x Cycle</u>	
AATCC WOB x 1	61.20
AATCC WOB x 2	62.10
AATCC WOB x 3	62.96
AATCC WOB x 4	63.99
AATCC 124 x 1	61.96
AATCC 124 x 2	62.42
AATCC 124 x 3	63.33

 SECOND ORDER INTERACTIONS (CONTINUED)

AATCC 124 x 4	63.31
Control x 1	62.04
Control x 2	61.20
Control x 3	60.87
Control x 4	60.14
<u>Water x Fabric</u>	
Soft x Treated	58.03
Soft x Untreated	66.56
Hard x Treated	57.71
Hard x Untreated	66.12
<u>Water x Cycle</u>	
Soft x 1	61.62
Soft x 2	62.07
Soft x 3	62.60
Soft x 4	62.90
Hard x 1	61.70
Hard x 2	61.74
Hard x 3	62.18
Hard x 4	62.06
<u>Fabric x Cycle</u>	
Treated x 1	57.54
Treated x 2	57.60
Treated x 3	58.15
Treated x 4	58.20

SECOND ORDER INTERACTIONS (CONTINUED)

Untreated x 1	65.78
Untreated x 2	66.21
Untreated x 3	66.63
Untreated x 4	66.76

APPENDIX D

MEAN VALUES OF a

FIRST ORDER INTERACTIONS	
Variables	Mean <u>a</u> Value
<u>Detergent</u>	
AATCC WOB	5.75
AATCC 124	5.72
Control	5.52
<u>Water</u>	
Soft	5.73
Hard	5.59
<u>Fabric</u>	
Treated	9.08
Untreated	2.24
<u>Cycles</u>	
1	5.95
2	5.82
3	5.45
4	5.42

 SECOND ORDER INTERACTIONS

Variables	Mean <u>a</u> Value
<u>Detergent x Water</u>	
AATCC WOB x Soft	5.98
AATCC WOB x Hard	5.52
AATCC 124 x Soft	5.71
AATCC 124 x Hard	5.73
Control x Soft	5.52
Control x Hard	5.52
<u>Detergent x Fabric</u>	
AATCC WOB x Treated	9.15
AATCC WOB x Untreated	2.35
AATCC 124 x Treated	9.21
AATCC 124 x Untreated	2.22
Control x Treated	8.87
Control x Untreated	2.16
<u>Detergent x Cycle</u>	
AATCC WOB x 1	5.62
AATCC WOB x 2	6.21
AATCC WOB x 3	5.56
AATCC WOB x 4	5.80
AATCC 124 x 1	5.40
AATCC 124 x 2	6.06
AATCC 124 x 3	5.70
AATCC 124 x 4	5.70

 SECOND ORDER INTERACTIONS (CONTINUED)

Control x 1	5.34
Control x 2	5.58
Control x 3	6.19
Control x 4	4.95
<u>Water x Fabric</u>	
Soft x Treated	9.25
Soft x Untreated	2.22
Hard x Treated	8.91
Hard x Untreated	2.22
<u>Water Cycle</u>	
Soft x 1	5.66
Soft x 2	5.78
Soft x 3	5.92
Soft x 4	5.56
Hard x 1	5.25
Hard x 2	6.12
Hard x 3	5.71
Hard x 4	5.27
<u>Fabric x Cycle</u>	
Treated x 1	8.73
Treated x 2	9.70
Treated x 3	9.15
Treated x 4	8.73

SECOND ORDER INTERACTIONS (CONTINUED)

Untreated x 1	2.18
Untreated x 2	2.20
Untreated x 3	2.48
Untreated x 4	2.11

APPENDIX E

MEAN VALUE OF $\bar{b}$

FIRST ORDER INTERACTIONS	
Variables	Mean $\bar{b}$ Value
<u>Detergent</u>	
AATCC WOB	-8.17
AATCC 124	-8.18
Control	-7.31
<u>Fabric</u>	
Treated	-8.75
Untreated	-7.02
<u>Water</u>	
Soft	-7.92
Hard	-7.85
<u>Cycle</u>	
1	-8.20
2	-7.94
3	-7.88
4	-7.51

 SECOND ORDER INTERACTIONS

Variables	Mean <u>b</u> Value
<u>Detergent x Water</u>	
AATCC WOB x Soft	-8.16
AATCC WOB x Hard	-8.18
AATCC 124 x Soft	-8.11
AATCC 124 x Hard	-8.25
Control x Soft	-7.49
Control x Hard	-7.13
<u>Detergent x Fabric</u>	
AATCC WOB x Treated	-9.05
AATCC WOB x Untreated	-7.19
AATCC 124 x Treated	-8.91
AATCC 124 x Untreated	-7.44
Control x Treated	-8.29
Control x Untreated	-6.32
<u>Detergent x Cycle</u>	
AATCC WOB x 1	-8.57
AATCC WOB x 2	-8.17
AATCC WOB x 3	-8.23
AATCC WOB x 4	-7.71
AATCC 124 x 1	-8.21
AATCC 124 x 2	-8.22
AATCC 124 x 3	-8.26
AATCC 124 x 4	-8.02

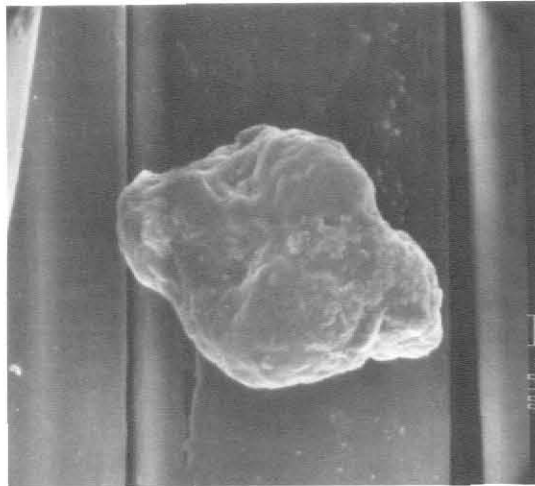
SECOND ORDER INTERACTIONS (CONTINUED)

Control x 1	-7.83
Control x 2	-7.43
Control x 3	-7.16
Control x 4	-6.80
<u>Water x Fabric</u>	
Soft x Treated	-8.77
Soft x Untreated	-7.07
Hard x Treated	-8.73
Hard x Untreated	-6.97
<u>Water x Cycle</u>	
Soft x 1	-8.13
Soft x 2	-7.98
Soft x 3	-7.98
Soft x 4	-7.58
Hard x 1	-8.27
Hard x 2	-7.91
Hard x 3	-7.78
Hard x 4	-7.44
<u>Fabric x Cycle</u>	
Treated x 1	-9.06
Treated x 2	-8.67
Treated x 3	-8.95
Treated x 4	-8.33

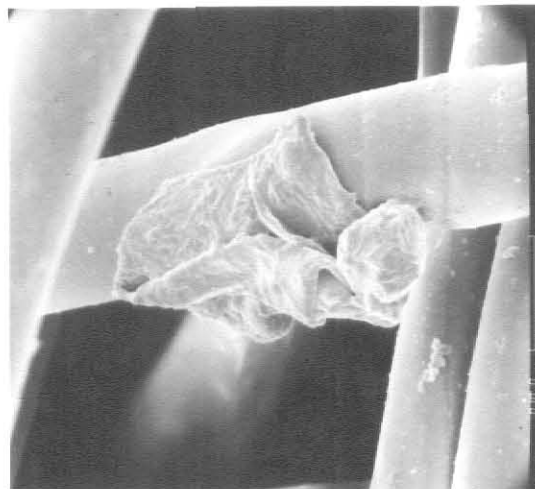
SECOND ORDER INTERACTIONS (CONTINUED)

Untreated x 1	-7.34
Untreated x 2	-7.21
Untreated x 3	-6.82
Untreated x 4	-6.70

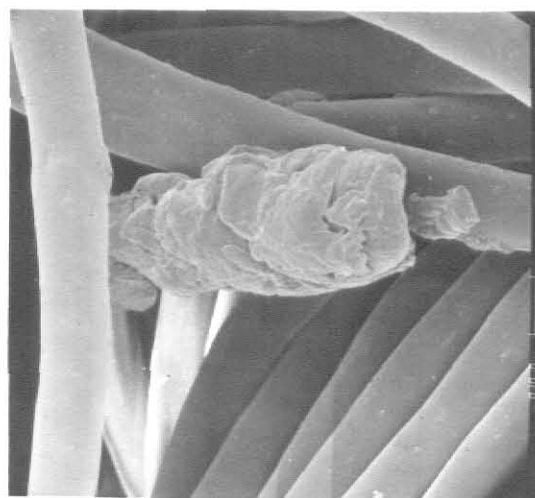
APPENDIX F
SCANNING ELECTRON MICROSCOPE PHOTOGRAPHS



AATCC 124 Detergent
300 ppm
20 Laundry Cycles



No Detergent
0 ppm
20 Laundry Cycles



Original Fabric

THE EFFECTS OF LAUNDERING ON POLYESTER FABRICS
WITH DIFFERENT WATER HARDNESSES AND DETERGENTS

by

REBECCA ANN GOOSEN

B.A., Central Michigan University, 1974

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Clothing, Textiles
and Interior Design

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1977

The effects of laundry variables on the weight change and color difference of a 100 percent unfinished polyester and a 100 percent fire retardant finished polyester fabric were studied. The laundry variables included the detergent type (with optical brighteners and without optical brighteners), laundrometer cycles (1, 2, 3, and 4) and water hardness (0 parts per million and 300 parts per million).

The specimens were examined with a Gardner Color Difference Meter Model AC-2A Series 200 to determine color change during laundering. The fabric was weighed before and after being subjected to the different treatments to detect any weight change. A scanning electron microscope was used to observe mineral or detergent deposition on the surface of the fabric after laundering.

An analysis of variance was performed to evaluate the reflectance values. The reflectance values changed marginally after repeated launderings. The fabrics showed a significant loss of weight at the 0.05 level with each of the specific treatments.

Examination of the fabric under scanning electron microscope (SEM) showed little evidence of detergent residue or mineral deposits on the fibers. In addition, the fabrics that were not laundered were similar in fiber and yarn conditions (i.e. slippage, degradation) to fabrics that were laundered as seen by SEM.