

EFFECTS OF LAUNDRY VARIABLES ON THE
FLAMMABILITY AND SHRINKAGE OF VINYLON/POLYESTER FABRIC

by

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INTRODUCTION

In the United States each year between 150,000 and 250,000 persons are injured and between 2,000 and 3,000 die from ignited textiles (20). Because of these injuries and deaths, Congress passed the Flammable Fabrics Act in 1953, amended it in 1967 to cover more areas of textile items, and the Department of Commerce enacted two children's sleepwear standards in 1971 and 1974.

The first specific area to be covered by the acts was carpeting in 1967 (5). Children's sleepwear then became an important area for standards and the Standard for the Flammability of Children's Sleepwear, DOC-FF 3-71, came into effect to cover children's sleepwear sizes 0-6X. These standards were expanded in the Standard for the Flammability of Children's Sleepwear Sizes 7 through 14, DOC-FF 5-74, to cover children's sleepwear sizes 7-14.

The DOC-FF 3-71 standards require that the fabric to be tested be able to withstand fifty launderings and pass the vertical flame test for 1) char length and 2) residual flame time.

Several studies have investigated the effects of laundering variables on the flammability of fabrics. Pacheoco, et al (16), employing the DOC-FF 3-71 testing procedure, discovered that different laundry detergents had differing effects on textile flammability. It was found that fabrics laundered with phosphate-based detergents (which are banned in certain areas of the country) retain their flame retardant properties better than fabrics laundered with citrate-based or carbonate-based detergents.

Vandermass, et al (22), using the same procedure, found that fabric construction affects the flame retardant properties of a fabric. They found that with acetate (or triacetate) and polyester blended fabrics,

the heavier and denser the fabric, the less flame retardant it was. This occurs because the heavier fabric cannot shrink away from the flame as readily as lighter weight fabrics. In other fabric types, however, the reverse of this has been found true.

A committee of the American Association of Textile Chemists and Colourists formulated guidelines for studying the effects of laundering on flammability. They pointed out that not all laundry variables could be tested. Each person's laundering technique is different from everyone else's and different variables cause differing results. Not only do detergents with different bases affect the flame-retardancy but also bleaches cause differing effects, fabric softeners often reduce the flame resistance, and differing water hardnesses cause different effects on the fabric's flammability. All these variables may cause problems for the consumer and definitely do cause problems for the manufacturer who must make care labels for their products (7).

Fabric flammability is a worldwide problem and, therefore, an international task force undertook the job of creating a glossary of terms for flammable fabrics in four languages: English, French, German and Italian (6). These terms will serve as international guidelines for interpreting standards and for writing legislation and evaluating hazards. Following are a few of the terms the committee defined:

1. After glow time--The time the specimen continues to glow after it has ceased to flame.
2. Char Length--Length of totally or partly burned material after exposure of a specimen to a flame.

3. Ease of ignition--Time necessary during which an ignition source has to be applied to a specimen in order to obtain its ignition.
4. Flame resistance--The ability of textile material to resist, during a stated period of time, the action of a flame.
5. Flame retardance--The property of material or a treatment applied to a material, of retarding or annullating the propagation of flame.
6. Flammable--Capable of combustion in the gaseous phase generally with emission of light and heat during or after the application of an ignition source.
7. Ignition time--Time (in seconds) during which a material is exposed to an ignition source.
8. Self extinguishing--Incapable of undergoing sustained combustion after removal of ignition source.

Flammability testing is a worldwide issue. The fact that the preceding terms were formulated by a worldwide task force shows the importance of flammability testing on a global extent. However, flammability standards have become a burden to some segments of the textile industry and there have been numerous complaints against these standards. Some people in the textile industry believe that the technology of flame retardant fabrics and finishes is still too rudimentary to provide a wide range of flame retardant apparel fabrics. Textiles can be made to comply with the standards but flame retardant fabrics cannot be produced in all weights, colors, and textures that the market demands. Some also believe that the standards set up by the government are too rigorous and the testing requirements too burdensome. The textile industry believes there is definitely a need for the standards but they believe the testing procedures should be set at a more reasonable level in order to encourage (rather than discourage) this industry (3).

Knit shrinkage is also an important aspect in the longevity of use of children's sleepwear (1). Because many fabrics made for children's sleepwear are knit in structure, the distortion of the garment brought about by shrinkage often causes the consumer to get rid of the garment before it is worn sufficiently to warrant destruction under normal circumstances.

Purpose of Study

This study was undertaken to investigate the interactions of several laundering variables upon the flammability of fabrics suitable for children's sleepwear which must comply with the Federal flammability standard DOC-FF 3-71. Water hardness, types of detergents, and types of flame retardant fibers have been shown to affect flame retardant characteristics of several fabrics. Also, many fabrics made for children's sleepwear are knit in structure, therefore, shrinkage of the fabric plays a definite part in the longevity of use the garment will receive. For these reasons this study investigated the interaction of the fabric, a 75 per cent vinyon/25 per cent polyester blend with the following variables:

1. Water hardness

- 150 ppm (parts per million)
- 300 ppm

2. Detergents

- phosphate-base
- citrate-base
- carbonate-base

Objectives

This study was undertaken to investigate the following objectives:

1. To determine effects of differing water hardness (150 ppm and 300 ppm) on flame retardancy of the fabric (i.e. meeting Federal flame retardant standard DOC-FF 3-71.
2. To determine effects of several different detergent types (phosphate-base, citrate-base, and carbonate-base) on the flame retardancy of the fabric.
3. To determine by scanning electron microscope (SEM) and atomic absorption spectrometry any calcium deposit left on the fabric after subsequent launderings.
4. To determine the amount of shrinkage occurring in the fabric after subsequent launderings.

Hypotheses

Certain hypotheses were set up to determine at the .05 significance level the flammability, calcium deposition, and shrinkage of the fabric.

1. There will be no significant difference between 150 ppm (parts per million) and 300 ppm water hardness on the flame retardance (i.e. ability to meet Federal flammability standard DOC-FF 3-71) on the fabric.
2. There will be no significant difference among phosphate-base, citrate-base, and carbonate-base detergents on the flame retardancy of the fabric.
3. There will be no significant difference among the various detergents and water hardnesses on the calcium deposition on the fabric.
4. There will be no significant amount of shrinkage in the fabric after subsequent launderings.

Definition of Terms

Definitions were obtained from "Children's Sleepwear: Notice of Amendment to Flammability Standard to Provide for Sampling Plan", Federal Register, July 21, 1972, "Guidelines for Evaluating the Effects of Laundering on the Flammability of Sleepwear and Fabrics" by Fortess, et al, and Textile Testing by John H. Shinkle.

1. Char length-- the distance from the original lower edge of the specimen exposed to the flame to the end of the tear or void in the charred, burned, or damaged area.
2. Children's sleepwear--any product of wearing apparel up to and including size 6X, such as nightgowns, pajamas, or similar related items, such as robes, intended to be worn primarily for sleeping. Diapers and underwear are excluded from this definition.
3. Water hardness--the concentration of multivalent metal salts, such as calcium and magnesium salts, in water which form insoluble precipitates with soap, carbonate and silicate anions. Water hardness concentration is expressed as calcium carbonate in parts per million (ppm). Hard water has 164-260 ppm calcium carbonate.
4. Residual Flame Time--the time from removal of the burner from the specimen to the final extinction of molten material or other fragments flaming on the base of the cabinet.
5. Specimen--an 8.9 x 25.4 centimeter section of fabric.
6. Sample--five test specimens.
7. Flame retardant fabric--any fabric containing non-combustible fibers in such a proportion in order that the fabric not be combustible (or be self extinguishing) after the source of combustion is removed (i.e. vinyon).
8. Shrinkage--the linear amount a fabric will contract in either the wales or courses direction when laundered. It is expressed as the per cent of its original measurement.
9. Total dimensional change--the total shrinkage or stretch in the length and width of a test specimen after laundering and tumble drying.

10. Restored dimensional change--the residual dimensional change in per cent as measured under tension.
11. Wales direction--the direction of the cloth which parallels one wale.
12. Courses direction--the direction of the cloth which parallels one course.

REVIEW OF LITERATURE

Many of the major retail chains are becoming involved in the flame-retardant apparel movement because of the possibilities of future legislation that might cover all-items of textile merchandise (19). Sears, Roebuck and Company, J.C. Penney Company and Montgomery-Ward and Company expanded their merchandise lines for fall, 1975, to include apparel and sleepwear for both children and adults.

Montgomery-Ward placed on the market several flame retardant items including women's sleepwear, children's sleepwear, girls' blouses, dresses, tops, and slips. They also included a "test item" that is a girls' dress in both flame-retardant and non-flame-retardant materials. These two dresses were identical except for the flame-retardant treatment and the harsher hand which resulted from the treatment. The prices were identical so it really was a test to see if consumers would ignore the harsh hand that sometimes accompanies fabrics with flame-retardant finishes (19).

Sears, Roebuck has a full line of flame-retardant children's wear for sizes 3-14. In addition to sleepwear, the lines include playsets, girls' dresses and tops and boys' shirts, sweaters, and pants (19).

J.C. Penney has had a complete flame-retardant children's sleepwear program for the past three years. They added girls', women's and men's apparel for the fall and Christmas season, 1975. Boy's wear was also added for the Christmas holiday, 1975 (19).

Consumers are also concerned about shrinkage of these garments since many of the fabrics used for children's sleepwear are knits. Shrinkage has been a problem with knits which is attributed to the interlooping in the knit structure. The loops are elongated in the knitting and finishing processes. When the fabric is laundered the loops reorient themselves to their original shape which causes the fabric to lose its shape. The fabric usually shrinks in the lengthwise direction and "grows" in the crosswise direction. Because of this distortion in the fabric, the knit garment often loses its shape after laundering (1).

Flammable Fabrics Acts

Burns associated with flammable fabrics take the lives each year of an estimated 3,000 persons and injure approximately 200,000 persons. The three highest risk groups are children, the aged, and the handicapped.

The children who are burned are frequently playing with matches or playing near fires. They generally do not appreciate the danger associated with fire and are unable to protect themselves. The aged frequently fail to see the source of combustion. The greater reduction in their motor skills and their inability to see well often directly accompany the extent and severity of their burns. The handicapped are often unable to remove themselves from the source of the fire and are less able to extinguish the flame themselves or get help (8). Because of these high risk groups and the possibility of anyone being injured or killed in an accident involving flammable

fabrics, several laws were enacted and many others are being considered for consumer protection.

In 1953, the first flammable fabrics act was created to eliminate brushed rayon "torch" sweaters and long rayon pile cowboy chaps from the market. Further amendments were found necessary so, in 1967, the act was expanded to provide for more comprehensive fire safety regulations for wearing apparel, blankets, all household and personal fabrics, textiles, and furnishings such as curtains, draperies, carpets, and upholstery (8).

The Standard for the Flammability of Children's Sleepwear, DOC-FF 3-71, for children's sleepwear sizes 0-6X was issued by the Department of Commerce in 1972, and became effective on July 29, 1973. Later a need was found to cover not only sizes 0-6X but also children's sleepwear sizes 7-14 (children aged 6-12). The Standard for the Flammability of Children's Sleepwear Sizes 7 through 14, DOC-FF 5-74, went into affect May 1, 1975, and is very similar to the previous standard (DOC-FF 3-71) (15).

The reason for the new standard was that the Department of Commerce found that children between the ages of six and twelve are as susceptible to sleepwear fires as those under six. The National Bureau of Standards found that kitchen range fires are especially predominant in this age group. Girls are involved even more frequently than boys (15).

Other wearing apparel and textile articles are currently covered by flammability standards, or standards are being considered to encompass many areas of textile items. Standards were set up

for sweatshirts in 1968 because these shirts were being worn napped side out. A notice of findings that standards might be necessary to cover children's, infants', and toddlers' dresses was issued in 1970 and a similar notice was issued for children's underwear (9).

Many home furnishings are also covered by existing standards or standards are being developed for them. Currently under consideration are standards for bedspreads, blankets, curtains and drapery fabrics, upholstery and slipcover fabrics. Home furnishings that are now covered by flammability standards are rugs and carpets and mattresses and mattress pads. However, the sale of non-complying mattresses will be allowed indefinitely as long as the mattress is accompanied by a negative label (9).

Many state and local governments have also enacted flammable fabrics acts that cover articles not included in the Federal acts. Some of these acts made standards more stringent than even the standards enacted by the Department of Commerce. For example, Colorado has given the state health department the authority to "prohibit the sale of fabrics which have resulted in injury or death and represent a fire hazard due to the product's rapid rate of flammability; and to regulate, define, and establish methods of determining flammability of fabrics." (10)

Many states, including California, Illinois, Louisiana, Massachusetts, Michigan, Minnesota, New Jersey, New York, Pennsylvania, Rhode Island, South Carolina, and Wisconsin, have enacted or are considering standards that cover the flammability of camping equipment such as tents and/or sleeping bags. In addition, Massachusetts

requires that all public school children be educated on the prevention and treatment of fabric related burn injuries (10).

Children's clothing, above and beyond that covered by national standards, is included in many of the state and local flammable fabrics standards. California, Massachusetts, New Hampshire, New Mexico, and Texas all have laws and standards covering the flammability of children's clothing (not just children's sleepwear). New Hampshire has also enacted a law that gives the state the power to remove from the market all fabrics suspected of being highly flammable and the prohibition can continue until the item is proven to be safe (10).

The Consumer Product Safety Commission published a notice which prohibits the importation for sale of any goods which do not comply with the specified flammable fabrics acts. This notice does not apply to those goods to be exported except for those goods to be exported to markets that are installations of the United States. The notice prohibits the exportation of any non-complying goods that were not intended for exportation at the time of their manufacture (i.e. non-complying goods being sold in the United States market cannot be exported after having been discovered by the Federal Trade Commission). In certain instances persons subject to the act of selling non-complying goods may be allowed to re-work the violative goods in order to bring them into conformity with the law. Otherwise, non-conforming goods should be destroyed according to the notice (4).

Acts and standards are necessary in order to help the consumer avoid clothing flammability hazards. Burning textiles and clothing

are hazardous for the following reasons:

1. "Persons whose clothing caught on fire were four times more likely to die from burn related injuries than those whose clothing had not caught fire.
2. Persons whose clothing caught on fire were burned over nearly twice as much body surface as burn-injured persons whose clothing had not caught fire.
3. Burns that result from clothing catching fire are generally more extensive and more severe than other types of burn injuries." (8)

Laundry Detergents and Flammability

On October 1, 1964, the British Home Office issued regulations on the sale of children's sleepwear. The garments made of flame-retardant fabrics and flame-retardant yard goods were sold with printed cards giving washing instructions. These cards recommended eight brand name detergents and warned against the use of soap flakes or soap powders in the laundering of the flame-retardant articles. It was pointed out that the use of soap could leave flammable deposits, particularly when the wash water was hard (2).

Problems exist when laundering fabrics treated with flame retardant finishes in non-phosphate, carbonate-base detergents and in soaps. These detergents and soaps cause a reduction in the protective qualities of certain flame-retardant fabrics. The flame-retardant chemicals lose their effectiveness because soap combines with hard water and leaves a deposit of stearate salts on the fabric. These salts are extremely flammable as are the crystalline carbonate salts deposited on the fabric when it is washed in non-phosphate, carbonate-base detergents and hard water. The flame-retardancy of

the fabric can be restored in many cases by laundering it several times in a phosphate-base detergent or by the use of a cup of vinegar in the final rinse cycle. Labels with flame-retardant garments should give explicit instructions for their care (11).

Current Testing on Flame-Retardance

Much has been completed in the area of testing on flame-retardant fabrics but many facets still remain for further exploration. Laundry variables have been found to affect the flame-retardancy of a fabric (16). Density of the fabric and the type of fabrication used to form the textile has also proved to be a factor in its flame-retardant characteristics (22).

Pacheo and Carfagno (15) discovered that the flame retardant properties of garments treated with a commercially available finish were destroyed after, at most, twenty-five launderings with either an alkali-built soap or a carbonate-base detergent. The same fabric when washed fifty times in a phosphate-base detergent did not lose its flame-retardant properties. Insoluble calcium deposits were found to be the reason for the loss of flame-retardancy in the cases where a soap and a carbonate-base detergent were used. It was found that the flame-retardant properties could be restored to the fabric after subsequent launderings in a phosphate-base detergent.

Vandermaas, Holmes, and Zybko (19) found that fabric weight and density, finishes used on the fabric, and garment construction are all very important to the flame-retardant properties of a fabric. As they state, "it is important to realize that although each pro-

cessing step may have only a small affect on flammability when veiwed alone, the cumulative effect may be significant." Using acetate and Arnel tricetate fabrics, they found that fabrics made of these fibers were suitable for children's sleepwear and were able to pass the DOC-FF 3-71 standards. Warp knit fabrics made of a blend of acetate and polyester are ideal for children's sleepwear. Spun blends of flame-retardant Arnel and polyester when made into circular knits pass the standard whereas similar 100 per cent polyester fails. Further, not only does Arnel improve the flame-retardancy of the polyester but it also adds softness and absorbency, while the polyester provides for strength and durability. For the woven market there is considerable interest in the flame-retardant properties of treated Arnel because of the difficulty in treating cotton flannels.

Many laboratories are testing the flammability of fabrics but not every fabric can be tested using every laundry variable available. Testing should continue because textiles play a major role in ingition accidents and in the propagation of fire and the damage to human life and property. Once a textile material has started to burn, it is very likely that the process of combustion will continue and, unless artificially stopped, will lead to a major disaster (12).

Vinyon

Vinyon is a synthetic fiber that is inherently flame retardant (it is not combustible). The fiber forming substance is any long chain synthetic polymer composed of at least 85 per cent by weight vinyl chloride units ($-\text{CH}_2 - \text{CHCl}-$) and a co-polymer of vinyl acetate (14, 18).

Molecular weights range from 10,000 to 28,000 to give the necessary strength to the fiber without causing it to be insoluble (14). The fiber is polymerized into large molecules by heating the two substances with a catalyst (18). Vinyon is dissolved in acetone and extruded into warm air. The filaments are cold drawn (14).

The uses of vinyon vary considerably. Due to its resistance to chemicals, it is used in protective clothing for chemical workers. It is resistant to water and is used in fishing lines and nets. However, due to its low moisture absorption, vinyon is not used extensively for apparel and especially not underwear. Because of its unusual properties, vinyon has been used for purposes which most textiles are unsuitable. But these same properties have prevented vinyon's use for the more common textile purposes (14).

The major advantage vinyon has over other textile materials is that it does not burn. However, its major defect is that it begins to melt at 150°C. (14, 18).

Polyester fibers are any long chain polymers composed of at least 85 per cent by weight of an ester of dihydric alcohol and terephthalic acid ($p\text{-HOOC} - \text{C}_6\text{H}_4 - \text{COOH}$). (18)

Shrinkage

All fabrics have a tendency to lose their dimensional stability. One important dimensional change occurs when a fabric is washed. Shrinkage occurs especially if the fabric had been stretched in finishing (1, 17).

Relaxation shrinkage occurs after washing if, during manufacture, the fabric was subjected to tension under varying degrees of temperature and humidity. During the finishing process, the fabric is temporarily "set" in a stretched condition. With the hot and wet conditions of laundering, the fabric relaxes, the yarns reorient themselves and, thus, shrinkage occurs (1).

Shrinkage is not complete in one laundering (although most shrinkage will occur after only one laundering). A total of at least five treatments are necessary to achieve total shrinkage (17).

Permissible shrinkage varies with the fiber type, fabric construction and with the use the fabric is to be put. In general, no more than five per cent shrinkage in either direction is acceptable (17).

Many knit goods show a high initial dimensional change with laundering but are restored to near normal measurements by tension occurring during drying, pressing, or wearing. Knit shrinkage testing indicates the ability of fabrics to return to their original size under tension.

PROCEDURES

This research investigated the interaction of water hardness and detergents on the flammability of a 75 per cent vinyon/25 per cent polyester fabric. Calcium deposition on the fabric was also examined as a per cent of the total weight of the laundered fabric.

The fabric used was a tubular terry knit, vinyon/polyester blend. The physical characteristics are shown in Table 1.

Table 1 -- Physical Characteristics of Fabric

Weight	196.3 grams/ square meter
Courses	28 loops/ inch
Wales	19 loops/ inch
Method of Construction	Single, terry knit
Fiber Content	75% vinyon/ 25% polyester

The fabric was cut into fifty swatches, fourteen of which were 99 x 30.5 centimeters (cm) and thirty-six were 148.5 x 30.5 cm and then laundered according to the procedure in American Association of Textile Chemists and Colourists (AATCC) method The Appearance of Durable Press Fabrics after Repeated Home Launderings, 124-1969.

Laundering Plan

Two of the fourteen samples (99 x 30.5 cm) were not laundered, these provided for the control group in the vertical flame test. The remaining samples were divided into groups to be laundered using the laundering variables (detergent type and water hardness) to be studied. Two of the large samples were laundered under each

condition and removed after 50 washings. The smaller swatches, six for each condition, were removed after 5, 10, 20, 30, 40, and 45 launderings. The large swatches provided for ten specimens each (a total of 20 specimens under each conditions) and the small swatches provided 15 specimens each (these were necessary if the samples washed 50 times had not passed the Federal standards. The small swatches would have been cut into specimens and subjected to the vertical flame test to determine exactly when the fabric lost its flame retardant properties.)

A Sears Kenmore washing machine was used for the laundering cycles, with a fourteen minute hot ($60 + 3^{\circ}\text{C}$) wash and a warm rinse. The samples were then dried in a Sears Kenmore vented dryer for thirty minutes at a "Permanent Press" setting.

The water hardness in the laundering facilities was zero parts per million (ppm), consequently a water hardening agent was added to the wash cycle before each laundering. This hardening agent was obtained by dissolving 203 grams (g) of magnesium chloride ($\text{MgCl}_2 - 6\text{H}_2\text{O}$) and 441 g of calcium chloride ($\text{CaCl}_2 - 2\text{H}_2\text{O}$) in one liter of distilled water.

Three different based detergents were used with two differing water hardnesses in the test. The laundering plan was as follows:

<u>Detergent Used</u>	<u>Amount of Detergent Used</u>	<u>Water Hardness</u>
Phosphate-base	90 g	150 ppm (minimum) (medium hard water)
Phosphate-base	90 g	300 ppm (very hard water)
Citrate-base	90 milliliters	150 ppm
Citrate-base	80 ml	300 ppm

Laundry plan continued--

<u>Detergent Used</u>	<u>Amount of Detergent Used</u>	<u>Water Hardness</u>
Carbonate-base	90 g	150 ppm
Carbonate-base	90 g	300 ppm

Vertical Flame Test

The swatches were cut into 8.9 x 25.4 cm. specimens for the vertical flame test. The specimens were then mounted on specimen holders consisting of two U-shaped steel plates designed to allow the specimen to be suspended in a vertical position and to prevent curling of the specimen when the flame was applied.

After mounting, the specimens were placed in a circulating air oven designed to remove all moisture. The specimens remained in the oven for a thirty minute period and were then removed to an air-tight, moisture-tight dessicator where they cooled for not less than thirty but not more than sixty minutes.

After cooling, the specimens were tested by the vertical flame method in a test chamber specified by the DOC-FF 3-71 standards. The specimen was suspended in the cabinet and subjected to the flame.

A 3.8 cm. high flame was placed directly under the vertically positioned specimen and was removed after an ignition time of $3.0 \pm .2$ seconds. The residual flame time was measured and, after the specimen cooled, the char length of the specimen was measured. A weight (113.4 g.) was positioned on the corner of the burned fabric to cause the fabric to tear. The tear was measured to determine the char length.

Atomic Absorption Spectrometry and Microscopic Appearance

Three hundred mg. of fabric was baked for one hour in a circulating air oven and cooled in a desiccator. Ten ml. of distilled water was added, and the mixture was boiled for ten minutes on top of a hot plate. The solution was filtered through a sintered glass funnel and rinsed twice with distilled water. The amount of calcium in the solution was measured using the atomic absorption spectrometer and compared with standards to determine the percentage of calcium deposited on the fabric. Standards of one per cent, two per cent, and three per cent were made by dissolving calcium carbonate in de-ionized distilled water and an acid solution.

The fabric was also examined under a scanning electron microscope (SEM) to determine the amount of calcium deposited on the fabric and to determine exactly which fiber type attracted the calcium deposition to a greater extent. Photoelectronmicrographs were taken of the fabric with a polaroid camera connected to the microscope (Appendix)

Shrinkage

Many knit goods show a very high initial dimensional change in laundering but are restored to near normal measurements by tensions occurring during drying, pressing, or wearing. The knit shrinkage gauge (Model #7374) indicates the ability of the fabrics to return to their original size under tension. The gauge measures the shrinkage after restoration of the fabric under tension.

ASTM's test method for dimensional change of knitted fabrics in

laundering and dimensional restorability of the laundered fabric was the method used to determine the shrinkage of the fabric.

Two samples of the fabric were cut (sample A and sample B), each a sixteen inch square. Each was marked with two concentric circles, the outer one having a fourteen inch diameter and consisting of twenty equidistant dots and the inner one a ten inch diameter. The inner circle was marked along the line of the courses and three-quarters of an inch to either side of this diameter and also along the wales and to either side of this diameter (Figure I). The samples were then laundered as specified by AATCC Method 124-1969 (the same conditions used in the test for flammability).

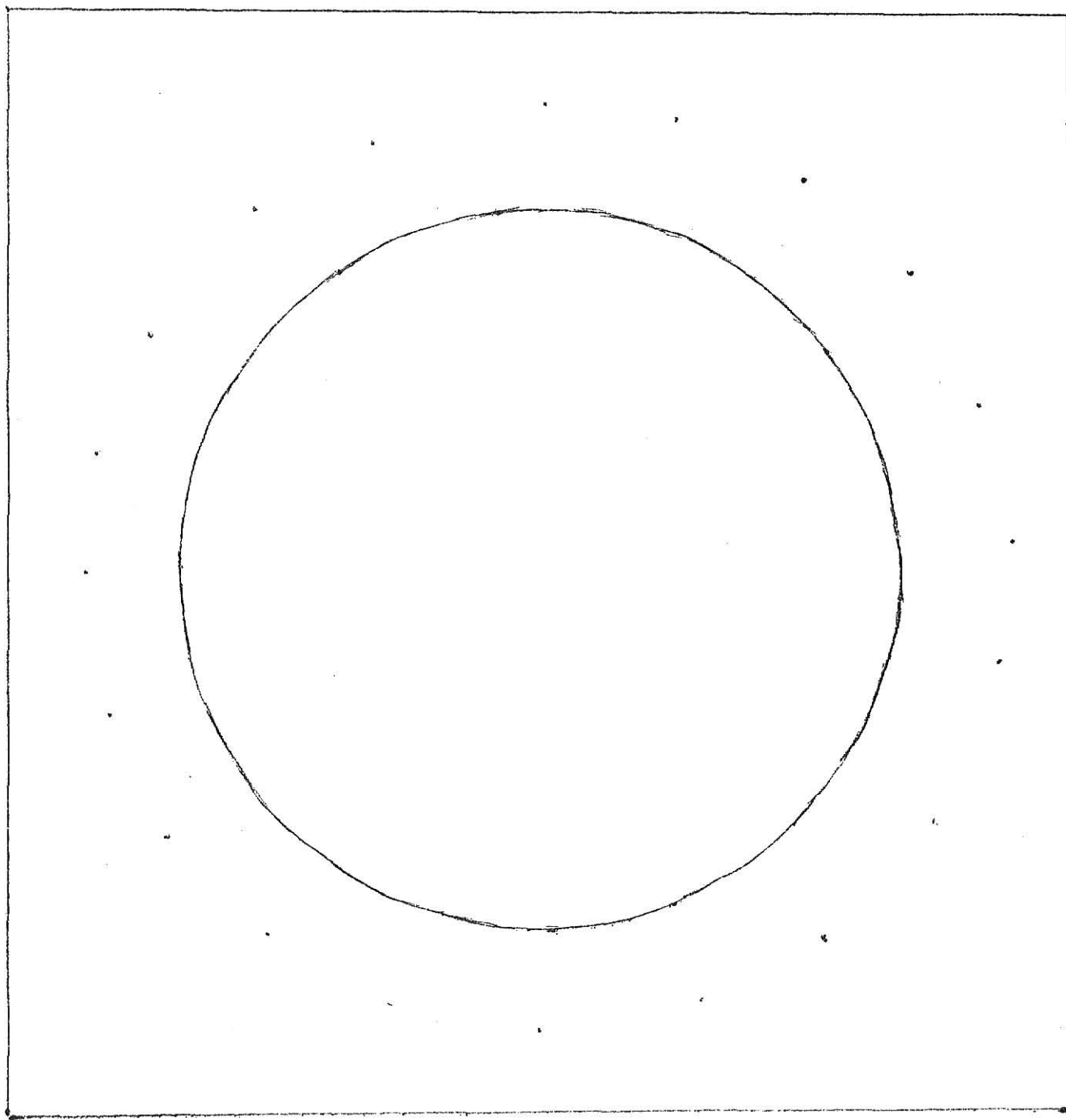
The samples were removed after each laundry cycle and were allowed to equilibrate at 70° F, 65 per cent Relative Humidity (standard atmosphere) for twenty-four hours. The samples were first measured for total dimensional change by measuring the lines of the courses and wales while the fabric was under no tension and determining the percentage of change to the nearest one-half per cent.

The samples were placed on the knit shrinkage gauge (model #7374) and measured for restored dimensional change. Mounting of the test specimen was performed by placing each of the twenty previously marked dots over a corresponding pin. The fabric was "stretched" into position and the inner circle was again measured along the wales and courses. This measurement determined the percentage shrinkage after restorative tension was applied to the fabric.

**THIS BOOK
CONTAINS
NUMEROUS PAGES
WITH DIAGRAMS
THAT ARE CROOKED
COMPARED TO THE
REST OF THE
INFORMATION ON
THE PAGE.**

**THIS IS AS
RECEIVED FROM
CUSTOMER.**

Figure I--Procedure for marking knit shrinkage samples, sixteen inch squares of fabric, marked with concentric circles of fourteen and ten inch diameters.



RESULTS AND DISCUSSION

Residual Flame Time and Char Length

Those samples that had been laundered for fifty cycles in a water hardness of 300 ppm were subjected to the vertical flame test first. This was done as recommended by Fortess, et al (6, p.9) who stated, "In order to alleviate extra work, the most stringent combinations should be considered first, i.e. high water hardness and carbonate or silicate detergent or soap. If these conditions are insufficient to result in failure according to the Government standards, then laundering at less stringent conditions would be less deleterious and, perhaps, not needed. If, however, the initial conditions cause failure, laundering at other less stringent conditions will be mandatory."

All of the specimens passed the Federal flammability standards. Whether laundered in a phosphate-base (Dash Detergent), citrate-base (Liquid All Detergent), or carbonate-base (Sears Low Phosphate Detergent) detergents, none of the specimens had a residual flame time of greater than 0 seconds nor a char length of greater than 0 centimeters. None of the specimens combusted, they withdrew from the source of ignition, and when the flame was removed there was no after glow. When the weight was positioned on the specimen to determine its char length, the fabric did not tear. The fabric had hardened into a black char upon ignition.

Calcium Deposition

Each one of the specimens contained less than one per cent calcium deposition. This deposition was tested on the fabrics after five,

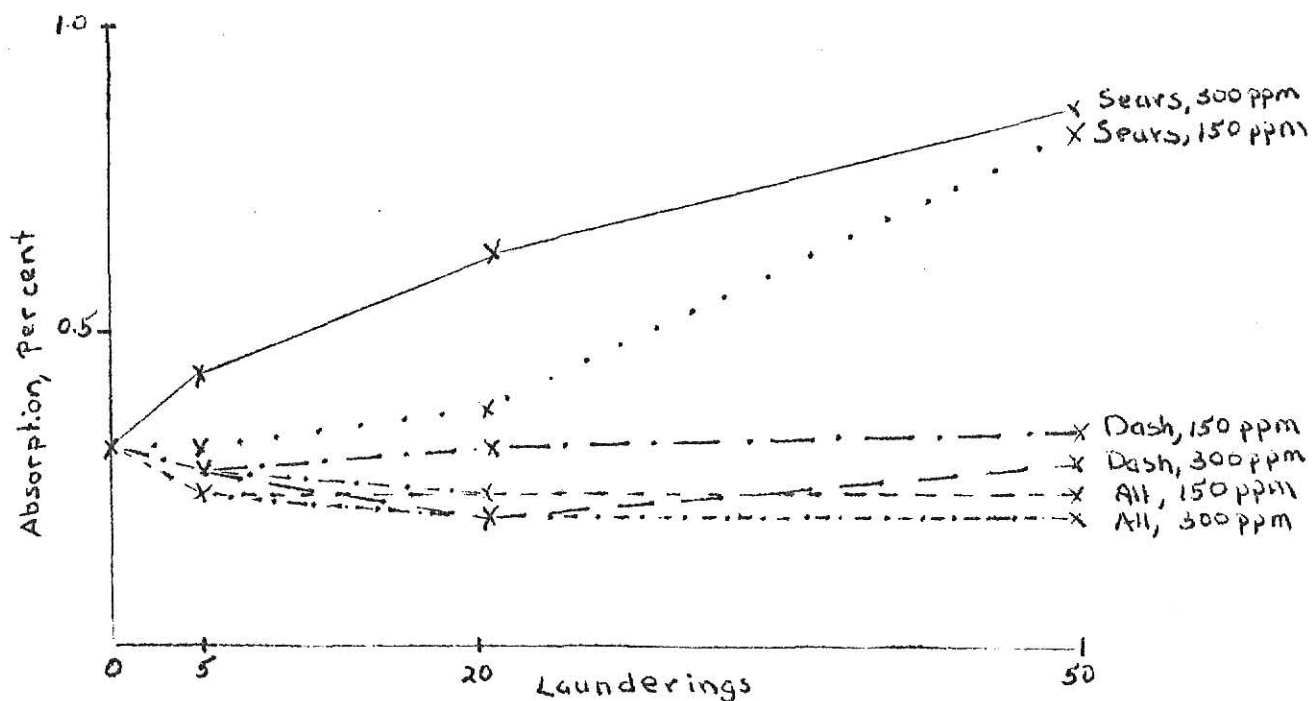
twenty, and fifty launderings. None showed an extensive amount of calcium deposition. The amount of deposition is presented in Table II and is presented graphically in Figure II.

Table II--Calcium deposition on fabric (Atomic Absorption Spectrometry).
Expressed as percentages.

Detergent	Water Hardness	Calcium Deposition		
		Number of Washings		
		5	20	30
Sears	300 ppm	.50 \pm .02	.68 \pm .04	.83 \pm .02
Sears	150 ppm	.42 \pm .01	.45 \pm .04	.80 \pm .05
All	300 ppm	.32 \pm .03	.30 \pm .03	.20 \pm .03
All	150 ppm	.32 \pm .01	.28 \pm .05	.24 \pm .05
Dash	300 ppm	.32 \pm .01	.28 \pm .03	.29 \pm .04
Dash	150 ppm	.35 \pm .02	.38 \pm .03	.33 \pm .01

Using the analysis of variance table, no significant difference was found within the various detergent types regardless of the water hardness and the number of washings.

Figure II--Calcium deposition on fabric



Shrinkage

After laundering in Liquid All Detergent, shrinkage was measured in both the course and wales direction. There was more shrinkage along the line of the courses than along the line of the wales. A great deal of shrinkage occurred after one washing (courses--7 per cent, wales--1 per cent) but shrinkage levelled off in subsequent launderings (after seven launderings--courses--9 per cent, wales--1.5 per cent, and after then launderings--courses--10 per cent, wales--1.5 per cent). These measurements are presented in Table III and Figure III.

Under restored dimensional change it was found that the fabric could be fairly well restored to its original size and shape while under tension. After one laundering, only 2 per cent shrinkage was measured along the courses and only 1 per cent occurred along the wales. After 10 launderings, the fabric was restorable to within 2 per cent of its original size along the courses and to within 2 per cent along the line of the wales. These measurements are presented in Table IV and Figure IV.

Discussion of Results

The fabric used in this study proved to be satisfactory for children's sleepwear. It passed the vertical flame test set up in the DOC-FF 3-71 and did not show a significant amount of calcium deposition on the fabric after laundering. Also, the fabric showed little exhibition of dimensional change that could not be restored after applying tension to be fabric.

Table III--Average Total Dimensional Change of the
Two Samples (Expressed as Per Cents)

<u>Number of Washings</u>	<u>Courses</u>	<u>Wales</u>
0	0	0
	**	
1	-7	-1
2	-7	-1
3	-8.5	-1
4	-9	-1
5	-8	-1
6	-10	-1
7	-9	-1
8	-10	-1.5
9	-9	-2
10	-10	-1.5

**significant at the 0.05 level using the t-test.
No significance was shown after subsequent
launderings.

Figure III. Average Total Dimensional Change of Two Samples

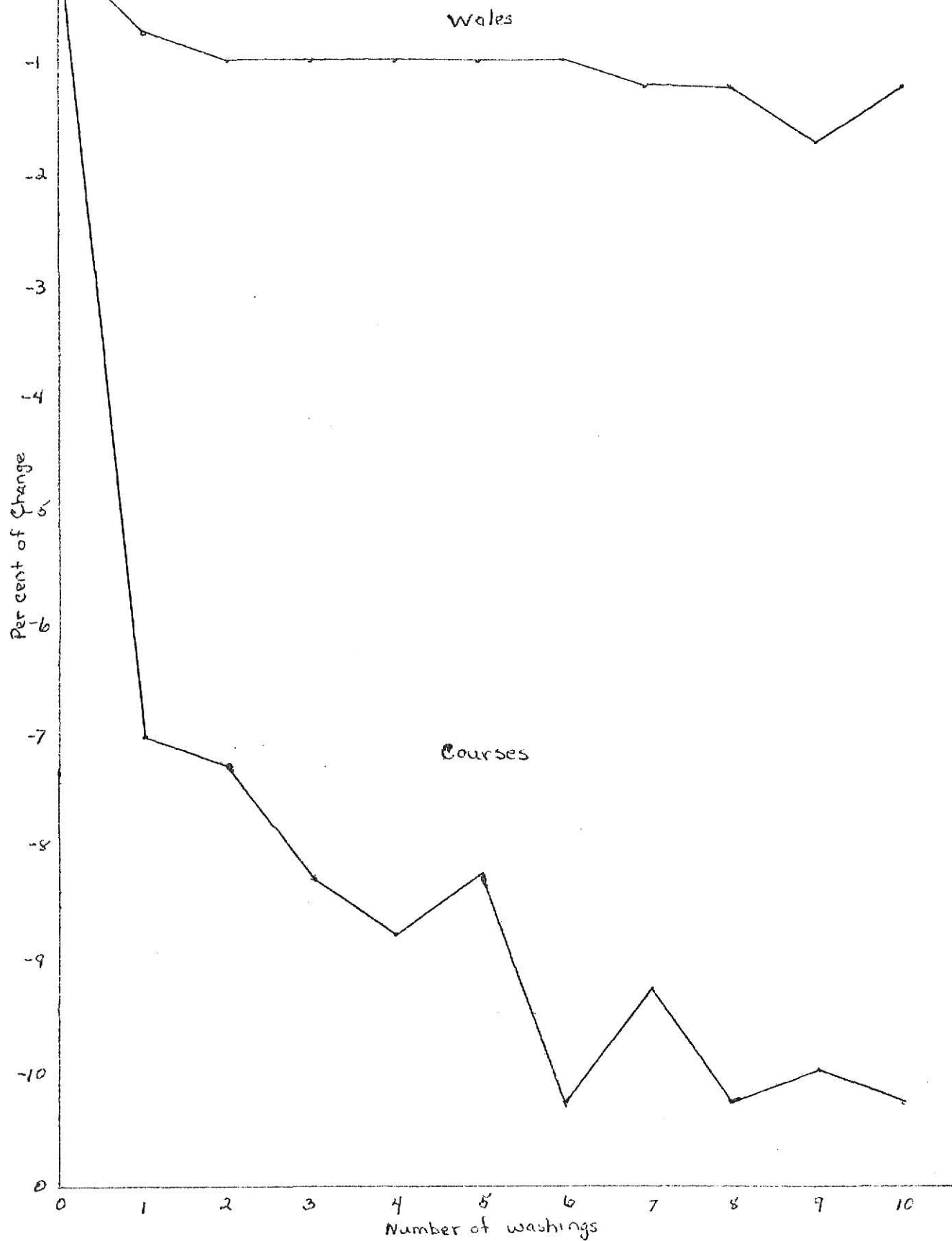
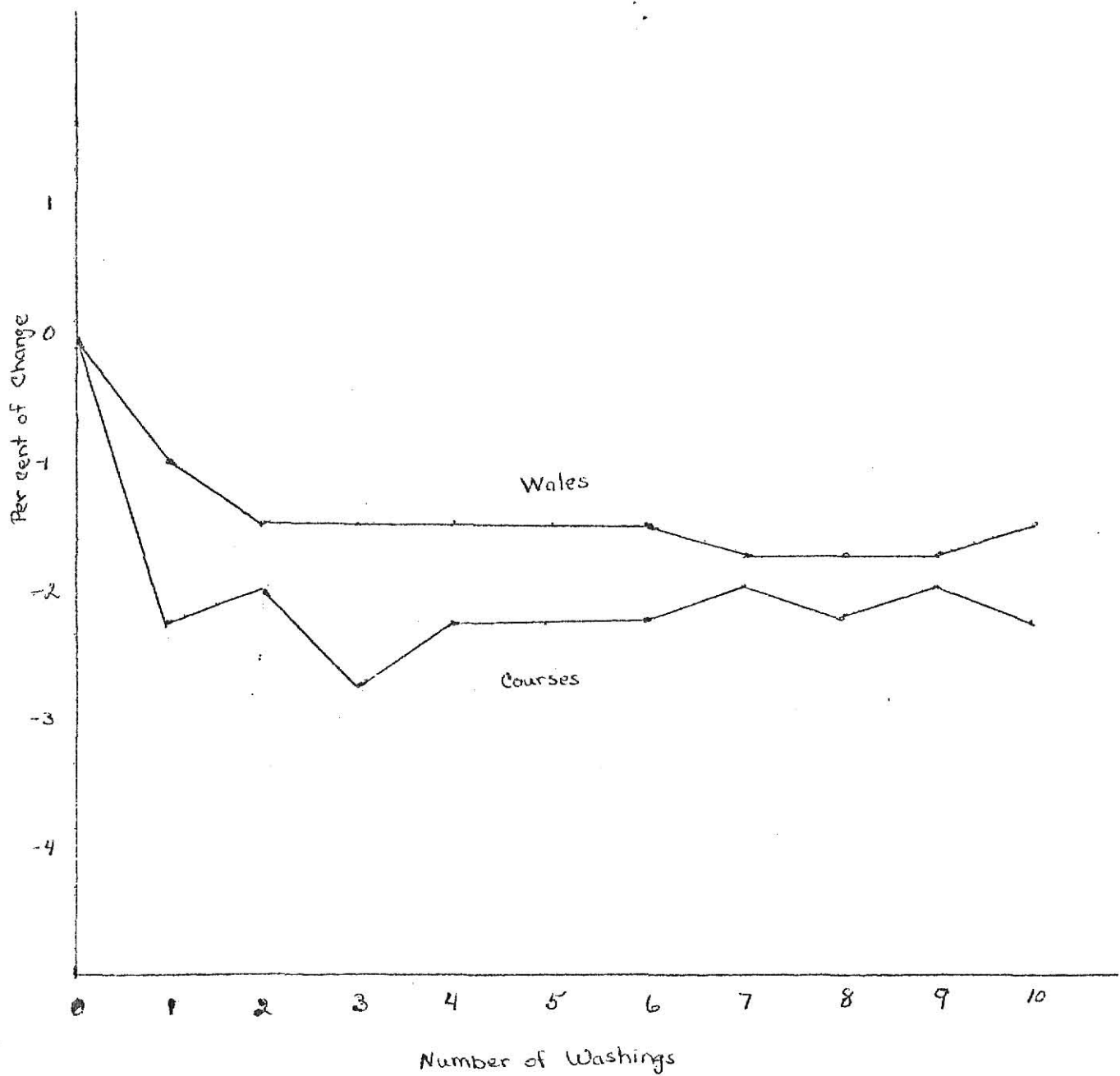


Table IV--Average Restored Dimensional Change of
the Two Samples (Expressed as Per Cents)

<u>Number of Washings</u>	<u>Courses</u>	<u>Wales</u>
0	0	0
1	-2	-1
2	-2	-1.5
3	-2.5	-1.5
4	-2	-1.5
5	-2	-1.5
6	-2	-1.5
7	-2	-1.5
8	-2	-1.5
9	-2	-1.5
10	-2	-2

No significant difference was shown under restored tension, using the t-test, after subsequent launderings.

Figure IV. Average Restored Dimensional Change of Two Samples



CONCLUSIONS AND SUMMARY

The fabric used in this study, a 75 per cent vinyon/25 per cent polyester tubular terry knit, was yellow in color before laundering. The fabric did not fade through subsequent launderings, however, when laundered in the blue Liquid All Detergent the fabric turned a shade of green. Although this was not investigated, it was probably due to the blue pigments in the detergent coming off on the fabric and, thus, changing the color. The hand of the fabric did not change in subsequent launderings. When ignited, the fabric did not burn but it emitted an odor. This odor was not evaluated but it was definitely an acrid odor (this odor could be a disadvantage to the fabric if it is harmful to people's health).

Investigation proved this fabric to be satisfactory for children's sleepwear according to those standards set up in the DOC-FF 3-71. It did not flame upon ignition, there was no afterglow, and the fabric did not melt or drip as many of the synthetic fabrics do. No significant calcium deposition was found on the fabric after being washed fifty times in very hard water with a carbonate-base detergent (the most stringent conditions used in this study). In addition, little calcium was observed on the fabric when it was examined under SEM. Also, the fabric showed no significant dimensional change that could not be restore after applying tension to the fabric.

Recommendation for Further Study

1. Mehkeri and Romanowski (12) evaluated the rate of flame spread in a vertically suspended fabric. It was concluded that the vertical flame test did not give reliable enough data to determine whether a fabric is flame-retardant or not. They recommended a more rigorous procedure for evaluating the danger which results from the flammability of a textile fabric. The acceleration of the flame front, not the burning time of a known length of fabric, is a much better indicator of the possible danger presented by a flammable fabric. A new instrument was also proposed that would measure burning time more precisely by the addition of intermediate "stations" along the fabric. The researcher is permitted to investigate and to establish a constant for the "compensated acceleration" of the flame front (i.e.--it can be determined exactly in which section of the vertically suspended specimen the fabric is more flammable--whether at ignition time or after sufficient flame spread). This is an innovative way to measure fabric flammability and should be examined to determine if this is a more realistic test than the vertical flame test now used in the DOC-FF 3-71 standard.

2. Miller, et al (13) found that the presence of moisture contributes to the flammability of a fabric and should be taken into consideration. The present evaluation techniques do not involve the monitoring and controlling of moisture conditions during testing. The presence of moisture may produce inaccurate conclusions regarding the flammability of the fabric and, subsequently, the hazard potential of the fabric.

There are several affects that moisture, present either in the fabric or in the atmosphere of the text environment, may have on the flammability characteristics of the textile materials. In general, materials such as cotton, polyester and nylon burn more slowly in the presence of moisture. Rayon, however, in upward burning, burns faster in a wet atmosphere. Moisture is an important factor in fabric flammability and is not taken into consideration in the DOC-FF 3-71 standard, which prescribes a bone-dry state for the fabric. More testing needs to be performed on fabrics in the presence of moisture (either in the atmosphere or in the fabric itself) in order to provide a more realistic examination of fabric flammability.

3. Further study needs to be done comparing (a) flame retardant fabrics made up of inherently flame-retardant fibers and (b) fabrics treated with flame retardant finishes. Flame retardant finishes work in a different way from inherently flame retardant fibers. Finishes may not be permanent and not able to stay on the fabric through the number of launderings necessary for Federal standards. Flame retardant fibers are permanent but can lose their retardancy if washed under conditions that leave a large amount of calcium deposition on the fabric. This study is important to determine the better and longer lasting flame retardant fabric.

4. Fabric softeners are used by consumers to a great extent and yet little research has been performed to determine the effects these softeners have on the flame retardance of the fabrics.

Research is necessary to determine if fabric softeners have a detrimental effect on the flame retardancy of fabrics. If they do, it is necessary to determine why flame retardancy is lost (whether the fabric softeners wash away the flame retardance or leave a residue on the fabric that causes the fabric to lose its flame retardance).

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APPENDIX

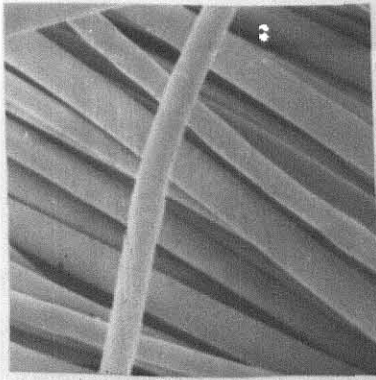
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- D. SEARS HEAVY DUTY LAUNDRY DETERGENT
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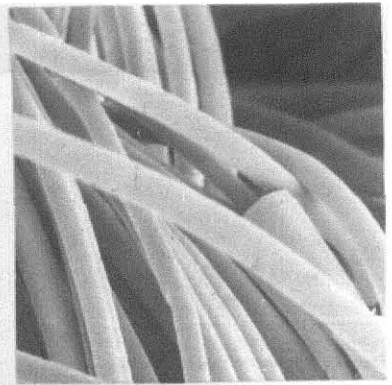
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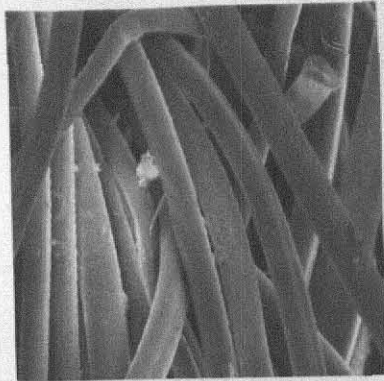
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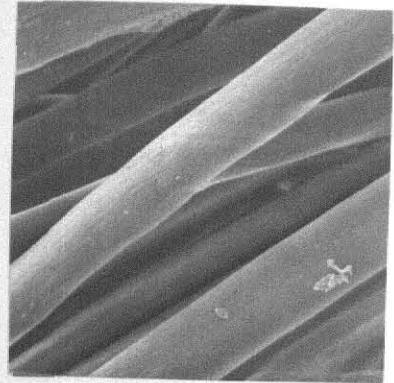
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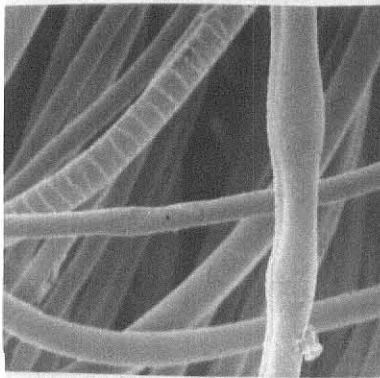
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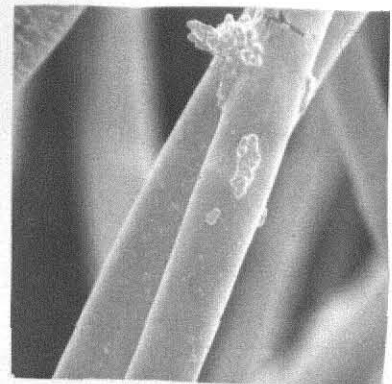
C.



D.



E.



F.

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EFFECTS OF LAUNDRY VARIABLES ON THE
FLAMMABILITY AND SHRINKAGE OF VINYLON/POLYESTER FABRIC

by

BARBARA A. OLIVER

B.S., Kansas State University, 1973

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

1976

The effects of laundry variables were studied on the flammability and shrinkage of a 75 per cent vinyon/25 per cent polyester terry knit fabric. Laundry variables included detergent type (citrate-base, carbonate-base, and phosphate-base) and water hardness (150 ppm and 300 ppm).

The specimens were subjected to the vertical flame test as described in the Standard for the Flammability of Children's Sleepwear, DOC-FF 3-71. Calcium deposition was measured on the fabric using atomic absorption spectrometry and photomicrographs. Shrinkage was measured using the American Standard Test Method for dimensional change of knitted fabrics in laundering and dimensional restorability of the laundered fabric.

Only those samples washed 50 times in water hardness of 300 ppm were subjected to the vertical flame test. These specimens had zero residual flame time, no afterglow, and zero char length. Therefore, it was determined that the specimens washed fewer times and under less stringent conditions would also meet the standards set up in the DOC-FF 3-71. No significant calcium deposition was found on the fabric after 5, 20, or 50 launderings under all conditions.

The fabric did shrink significantly after one laundering but did not shrink significantly after subsequent launderings. Its dimensional stability was restorable under tension of the knit shrinkage gauge (model #7374).