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I am submitting herewith a thesis written by Carolyn Elaine Trotter Ashley entitled "The Effect of Selected Home Laundry Detergents on Aesthetic Properties and Flammability of Commercially Available Children's Sleepwear." I recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Textiles and Clothing.

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THE EFFECT OF SELECTED HOME LAUNDRY DETERGENTS ON AESTHETIC PROPERTIES AND FLAMMABILITY OF COMMERCIALLY AVAILABLE CHILDREN'S SLEEPWEAR

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ABSTRACT

The objectives of this study were to evaluate the effects of three detergents on the aesthetic properties and flammability of three commercially available children's sleepwear garments after repeated laundering under home laundry conditions. A 3 X 3 X 7 X 2 factorial design was developed to test the effects of three independent variables (detergents, laundry intervals, and fabrics) on six dependent variables (color change, hand, shape retention, pilling, flame time, and char length). The experimental design included three detergents (Tide, All, and Sears), three fabrics (100 percent nylon, 100 percent cotton, and 80 percent acetate/20 percent polyester), seven laundry intervals, and two replications.

Subjective ratings served as a basis for evaluating the effects of the detergents and repeated laundering on the aesthetic properties of pilling, hand, and shape retention of the three flame resistant fabrics. The Hunter Color Difference Meter was used to evaluate the color change of the fabrics as affected by the detergents and repeated launderings. The effect of these independent variables on the flame resistance characteristics was evaluated by the flammability test specified in the Children's Sleepwear Standard, DOC FF 3-71.

An analysis of variance using the SAS program was conducted for each of the measurements studied.

Results indicated that the flammability and the aesthetic properties of pilling, hand, and shape retention of the nylon garments were not

significantly affected by the detergents with repeated home laundering. However, both detergents and launderings were found to have a significant effect on the color change of the nylon fabric type, resulting in a moderate degree of fading.

The flammability of the acetate/polyester sleepwear was not significantly affected by detergents and laundering, but all aesthetic variables were significantly affected. Severe fading and pilling occurred, as well as unacceptable changes in hand and shape retention properties of the acetate/polyester garments.

For the cotton flannelette garments, the aesthetic properties of pilling and shape retention were not significantly affected by detergents and laundering. However, these variables were found to have a significant effect on the color and hand properties and flammability of the cotton garments. Although the cotton fabric became whiter with repeated laundering, properties of hand and flammability were found unacceptable when laundered in the no-phosphate detergent.

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CHAPTER I

INTRODUCTION AND STATEMENT OF PROBLEM

Fire has been both friend and foe to man since its discovery. Man's ability to control fire has determined how useful fire can be. With advanced technology, man has developed new controls for preventing fire. In an attempt to make clothing fires less hazardous, efforts have been intensified in the last decade to develop improved flame retardant finishes for fabrics.

Although injuries and deaths due to fires have long been a source of concern, accurate information as to how many people are actually affected by clothing fires has been difficult to assess. In 1968, it was estimated by the Department of Health, Education, and Welfare that there were 150,000-250,000 injuries and 3,000-5,000 deaths a year involved in the ignition of clothing (50). However, the National Electronic Injury Surveillance System recently released information which indicated that only 15,600 persons received medical treatment annually for textile-related burns, 9,700 of which involved articles of clothing. The National Center for Health Statistics has also recently reported only 517 deaths caused annually by the ignition of clothing (41).

Other important implications must be considered when looking at flammability in terms of human loss. The costly results of psychological, physical, and financial scars may be extensive. Many

survivors who suffer second and third degree burns are permanently disabled or disfigured. Medical and surgical treatment and lengthy hospitalization can add financial burdens to the victims and their families. Among physicians and surgeons, there is a belief that flame resistant clothing can drastically reduce the extent and severity of clothing burn injuries (27).

The first tangible evidence of governmental concern for clothing fires was passage of the Flammable Fabrics Act of 1953. It was initiated to eliminate materials which had unusually rapid flame spreads. The scope of this Act was broadened considerably in 1967 when the ammended Flammable Fabrics Act was passed. Its provisions were expanded to include not only apparel fabrics but also interior furnishings as well, and allowed the Secretary of Commerce to issue new or revised standards to protect the public from unreasonable risk (15, 27, 30, 32).

Studies of burn injury statistics compiled as specified by the amended Act led to a finding of need by the Department of Commerce for the further regulation of children's wear including sleepwear, underwear, and dresses through sizes 6x. On July 29, 1971, a standard for children's sleepwear was adopted which provided a two-year period of cautionary labeling, after which all sleepwear sizes 0-6x had to comply. Recognizing the need for extended flammability protection for children, the Consumer Product Safety Commission in May 1974 issued Standard FF 5-74 for the flammability of children's sleepwear sizes 7-14. The recent standard is almost identical to that of the FF

3-71 (0-6x) with revisions included concerning the measurement of residual flame time and relative humidity conditions for sample conditioning (45).

These measures taken to protect the consuming public have posed complex technological problems for fiber, fabric, and apparel manufacturers. In finishing a fabric for flame resistance, changes in either the physical characteristics or chemical properties are involved. Some deterioration in desirable aesthetic properties is often evident and an increase in cost is apparent when the flame retardant finishes are used (38).

A major concern of the textile industry is the effect of hard water and no-phosphate detergents on the flame resistant properties of treated fabrics. Studies have shown that these properties may be impaired by 25 or fewer launderings if no-phosphate detergents or soaps are used in only moderately hard water, with detrimental effects increasing with harder water levels (24, 28, 30, 33, 43). Though the DOC FF 3-71 Standard warns against the use of certain cleaning agents, such as no-phosphate detergents, there is a problem in complying with these recommendations in some localities because of restrictive legislation on the sale of phosphate detergents (5).

In an effort to meet the rigid requirements of the 1971 Flammability Standard, much research of necessity has concentrated on creating garments that meet the Standard. Sometimes the end products do not have the aesthetic properties desired by consumers.

Complaints have been voiced by some consumers concerning the stiff hand, pilling, shrinkage, and color changes which occurred with the laundering of treated sleepwear garments. Consequently, more information is needed on the effects of laundry products on flame resistant sleepwear garments. This study was designed to provide information regarding comparative analysis of the effect of three detergents on the aesthetic properties and flammability of commercially available children's sleepwear garments after progressive launderings under home laundry conditions.

I. OBJECTIVES

The objectives of this research were:

1. To evaluate selected aesthetic properties of three commercially available children's sleepwear garments as affected by detergent composition, after repeated launderings under home laundry conditions:
   A. Color change
   B. Shape retention
   C. Hand
   D. Pilling
2. To evaluate the effects of laundering with three detergents containing different levels of phosphate on the three commercially available children's sleepwear garments:
   A. Tide - a higher phosphate commercial formulation with 8.7 percent phosphorus.

B. All - a medium level phosphate built detergent containing 6.2-8.2 percent phosphorus.

C. Sears' Heavy Duty Laundry Concentrate - a carbonate built detergent.

II. ASSUMPTIONS

1. The commercial detergents selected were representative of those three types currently available on the market.
2. The commercial children's sleepwear garments evaluated were representative of those currently available on the market.
3. The laundering conditions used were comparable to those used in actual home launderings.
4. Children's sleepwear garments are laundered most frequently by washing machines.
5. Children's sleepwear garments are washed approximately 30 to 50 times before they are outgrown or discarded.

III. HYPOTHESES

1. There will be no significant difference in the effect of the three detergents on the flame resistance for each of the selected children's sleepwear garments, when laundered in water of medium hardness level.
2. There will be no significant difference in the effect of the three detergents on the color value for each of the selected

children's sleepwear garments, when laundered in water of medium hardness level.

4. There will be no significant difference in the effect of the three detergents on the property of hand for each of the selected children's sleepwear garments, when laundered in water of medium hardness level.
5. There will be no significant difference in the effect of the three detergents on the amount of pilling for each of the selected children's sleepwear garments, when evaluated at specified intervals during laundering.

IV. LIMITATIONS

1. Tide, All, and Sears' Heavy Duty Laundry Concentrate were the only detergent formulations studied.
2. One hundred percent cotton, 100 percent nylon, and 80 percent acetate/100 percent polyester were the only fabrics evaluated.
3. A medium water hardness level was the only level used.

V. DEFINITION OF TERMS

The following terms regarding flammability, appearance properties, and detergency are defined according to usage in the context of this study:

Afterglow - the continuation of glowing parts of a specimen after flaming has ceased (44).

Char Length - the distance from the original lower edge of the specimen exposed to the flame, in accordance with the specific procedure, to the end of the tear or void in the charred, burned, or damaged area (44).

Children's Sleepwear - any product of wearing apparel up to and including size 6x (44) and sizes 7 to 14 (45), such as nightgowns, pajamas, or similar or related items, such as robes, intended to be worn primarily for sleeping or activities related to sleeping. Diapers and underwear are excluded from this definition.

Color Value - that property of a color which is distinguished as light or dark; luminosity; brilliance (53).

Detergent - a laundry product designed to remove, emulsify, dissolve, and suspend oil in a washing solution. Home laundry usage currently limits meaning to synthetic, non-soap compounds which are distinguished principally by not forming lime curd in hard water. Synthetic detergent and detergent are used interchangeably. Technically, soaps are detergents, but in the current usage are not referred to as such (49).

Flammability - includes ease of ignition, ability to support combustion, and rate of burning (25).

Flame Resistant Fabric - refers to a fabric which does not support combustion after the igniting flame is removed. Charring of the area in contact with the flame is expected (23).

Flame Retardant - the quality of a substance which suppresses, reduces, or delays markedly the combustion of certain materials (23).

Hand - the way a fabric feels; harshness versus softness (18).

Inflammable or Flammable - textiles which can be set on fire easily and that support combustion (46).

Non-flammable - textiles which will not burn easily and do not support combustion (46).

Pilling - the balling up of fiber ends on the surface of fabrics (18).

Residual Flame Time - the time from removal of the burner from the specimen to the final extinction of molten material or other fragments flamming on the base of the cabinet (44).

Sample - five test specimens (44).

Shape - the outline of a garment when spread flat and smoothed out by hand into its preferred configuration.

Specimen - an 8.9 X 25.4 cm (3.5 X 10 inch) section of fabric (as specified by the DOC FF 3-71 Standard) (44).

Test Criteria - the maximum char length and residual flame which an item may exhibit in order to comply with this standard (44).

CHAPTER II

REVIEW OF LITERATURE

Comsumer information on the effects of detergents on flame resistant children's sleepwear is limited. Therefore, this study was designed to provide information to consumers on the effects of three home laundry detergents on the aesthetic properties and flammability of three commercially available children's sleepwear garments. Topics that will be discussed include definition of flame resistant textiles, flammability legislation, development of flame retardancy, methods of achieving flame retardancy in fibers and fabrics: flame retardant finishes, addition of flame retardant chemicals to fiber spinning dope, and inherently flame resistant fibers; variables affecting durability of flame retardancy, and the effect of flame retardants on fabrics.

I. DEFINITION OF FLAME RESISTANT TEXTILES

Almost all textile fibers are organic polymers, most of which decompose below 300° Centigrade. Most of the fibers are flammable and ignite under favorable conditions (21). Consequently, textiles are inherently flammable, and the concept of a "flameproof fabric" is ill-founded and is based on specious reasoning. There are only various degrees of flame retardancy (35).

One prevalent definition of a flame resistant textile item is one "which does not support combustion after the igniting flame is removed" (23). Similarly, a textile item is considered glow-resistant if it does not continue to glow upon removal of the ignition source. Usually, textiles may be flame resistant, but not glow-resistant. A textile product is thus said to be fire-resistant when both flame- and glow-resistance are exhibited (39). The American Association of Textile Chemists and Colorists' definition of fire-resistance also includes the resistance of the item to smoldering (1).

The flameproofing of textiles, or creating items that are completely retardant to burning, charring, and decomposition, has not been achieved. Consequently, a flame resistant fabric will either resist or discontinue burning once the source of ignition is removed (39).

II. DEVELOPMENT OF FLAME RETARDANCY

Man's desire and need to diminish the flammability of readily combustible items goes back to the prehistoric era, but efforts to impart flame-resistance to textiles is of relatively recent origin. In 1638, clay and plaster of Paris were used as a flame retardant for canvas. An Englishman, Obadiah Wyld, patented a process, in 1735, for flameproofing cellulosic fabrics by treating them with an aqueous solution of alum, iron sulphate, and borax. Almost a century later, in 1820, Gay-Lussac recommended treating linen and jute with

a solution containing ammonium sulphate, ammonium chloride, and borax. These types of finishes drastically reduced ignitability and combustibility, but they were not fast to leaching or washing (26). In the 1930's, a new method for producing durable weatherproof flame-retardant finishes on heavy cellulosic fabrics was developed. Chlorinated paraffins or polymers with a high chlorine content were used to evenly spread and fix metal oxides, particularly antimony oxide, over the surface of the fabric. During World War II, this flame-retardant finish was extensively used in treating tenting and tarpaulins to retard burning (10).

Research and development of flame retardant finishes have been increasing at a faster rate during the past twenty years. The early developments in this period were concerned primarily with cellulosic fabrics. With the introduction of synthetics and blends evolved the necessity to develop flame retardants for these fabrics. Thus, various new techniques and flame retardant finishes have been developed to impart flame-resistance to both natural and man-made textiles. The majority of flame retardant finishes contain phosphorus, nitrogen, and halogen (21). Other compounds may contain elements such as antimony and boron (50).

III. FLAMMABILITY LEGISLATION

Due to several fatal and near-fatal accidents involving brushed rayon cowboy suits and sweaters, the U.S. Congress passed the Flammable Fabrics Act of 1953. This initial Legislation was aimed at eliminating

flash-burning fabrics from the market, which it was successful in doing.

Statistics accumulated in the early 1960's showed that the 1953 Act had done little to reduce the total number of fabric-burn injuries. Thus, the 1967 Amendments to the Flammable Fabrics Act gave the government power to take immediate action against fabrics shown to be unduly hazardous. The scope of coverage was broadened to include all articles of wearing apparel and home furnishings. It also provided for the establishment of new standards when the Secretary of Commerce verified a need to protect consumers against foreseeable risks caused by fire accidents (42).

As a result of data collected in accordance with the 1967 Amendments, the Secretary of Commerce, on July 29, 1971, issued the "Standard for the Flammability of Children's Sleepwear" (DOC-FF-3-71) (11). This Standard required that by July 29, 1973, all children's sleepwear, sizes 0-6x, must pass the vertical flame test before appearing on the market. The test procedure specifies the application of a flame to a bone-dry fabric specimen in a vertical position for three seconds. An item meets the acceptance criteria if the average char length of five specimens does not exceed seven inches; no individual specimen has a char length of ten inches, and no specimen has a residual flame time greater than ten seconds (30).

Until July 29, 1972, garments which did not meet these standards were labeled, "Flammable: should not be worn near sources of fire."

However, as of July 29, 1973, any children's sleepwear items, including pajamas, nightgowns and robes, which did not meet the standards were removed from the market (36).

Recognizing the need for extended flammability protection for children, the DOC-FF-5-74 Standard was issued by the Consumer Product Safety Commission. As of May 1975, children's sleepwear sizes 7 to 14 had to pass flammability standards. The major differences in this latest standard from the DOC-FF-3-71 Standard are the exclusion of the residual flame time and bone dry conditioning criteria (45).

IV. METHODS OF ACHIEVING FLAME RESISTANCE IN FIBERS AND FABRICS

In the development of fabrics to meet the requirements of the government standards for flammability, three main approaches have been used: application of flame retardant chemical finishes to fabrics, addition of flame retardant chemicals to polymers prior to their extrusion, and the use of fibers which are inherently resistant to fire (14, 16, 21, 37). The physical and chemical properties of a fiber and fabric determine the method used for achieving flame resistance in a fabric. The amount and chemical nature of the flame retardant compounds are important when considering the usage of flame retardant finishes (34).

Flame Retardant Finishes

An increasing number of effective flame retardant finishes are being applied to textiles. Several types of fibers effectively

treated with finishes include cotton, cotton/polyester, polyester and rayon. The type of finish selected for different types of fabrics is often determined by the specific end-use of the textile. Therefore, no one finish is appropriate for all fabrics and for all end-uses (7).

Flame retardant finishes are broadly classified as non-durable, semi-durable, and durable. The durability of a finish is distinguished by its fastness to laundering (42).

Non-durable flame retardant finishes are basically inexpensive, efficient for those fabrics not requiring laundering or bleaching, and generally do not adversely affect desirable fabric properties (42). These non-durable finishes consist of mixtures of two or more inorganic salts, such as borates, ammonium phosphate, and ammonium sulfamate. Though these finishes have found only limited usage, such flame retardant treatments can be valuable for home use where temporary flame resistance is sought for such items as draperies and upholstery padding (7).

The semi-durable flame retardant finishes are not easily soluble in water and can withstand bleaching and a certain amount of mild laundering. A typical semi-durable finish, such as the urea phosphate class, may stay in the fabric, but the flame-resistance characteristics will be lost through ion-exchange with calcium in hard water. This type of finish may be entirely satisfactory for some household products and even a few clothing items (42).

The first durable flame retardant finish capable of commercial development was developed at the U.S.D.A.'s Southern Regional Research

Laboratory during the 1950-1960 decade. Phosphorus-containing resins used on cotton fabrics were found to impart good flame-resistance and were durable to repeated launderings. It was, however, found that the hand, drape, flexibility and color of fabrics treated with the new durable flame retardant finish were adversely affected (7). Since then, intense efforts have continued to develop fully satisfactory finishes, having characteristics of permanence, retention of mechanical and chemical properties, and non-toxicity. Even so, there is a persistent problem of attaining durability, aesthetic qualities and safety at the same time (35).

Addition of Flame Retardant Chemicals to Fiber Spinning Dope

Early research work conducted by textile scientists had shown that the flame retarding approach of a topical finish to some fabrics of man-made fibers could not produce the required flame retardancy characteristics without destroying desirable fiber and fabric properties. Particular problems developed in successfully printing and dyeing some fabrics of man-made fibers that had been treated with a flame retardant finish. It became necessary, therefore, to develop a new approach to flame retarding fabrics (29).

Through research conducted during the last two decades, it was discovered that flame resistant, self-extinguishing polyester fibers can be produced by adding certain amounts of aryl bromide and aryl phosphate to the fiber spinning dope. Dispersion of the flame retardant in the fiber does not seriously change or degrade the

properties of the polyester fiber, and there is no decrease in the serviceability of fabrics after many launderings and drycleanings (37).

Several other man-made fibers have been modified by this approach. Flame resistant nylon, rayon, polypropylene, acetate and triacetate are some of the fibers presently being produced, with different forms of these fibers being possible, also (9, 37, 40).

Inherently Flame Resistant Fibers

Although all fibers burn under certain conditions, some fibers have more inherently flame resistant properties than others. This classification of inherently flame resistant fibers includes nylon, glass fibers, acrylics, modacrylics, acetate, wool, and silk, with each having varying degrees of flame resistance. Though these are among the more flame resistant textile fibers, some require additional treatment for specific end-uses.

The inherently flame resistant fibers are becoming more and more a key factor in the development of flame resistant products for the market. Because many of these fibers have serious limitations in cost, physical or chemical properties, absorbency and comfort, or in utility, no single all-purpose fiber has been discovered in this category which might have over-all acceptance in a wide variety of end-uses (3).

V. VARIABLES AFFECTING DURABILITY OF FLAME RESISTANT FABRICS

In flame-resistant clothing, the fabric is designed to protect the wearer from flames, and therefore must be non-burning. However, true flame protection puts more demands on the fabric than simply to be non-burning - the fabric must retain its ability to protect the wearer. It has been proven by many researchers in the area of flammability, that certain variables can have an adverse effect on flame resistant fabrics (2, 5, 6, 20, 22, 24, 28, 30, 52).

Two of the most prominent factors affecting the performance of flame resistant fabrics are varied laundering procedures and the hardness of the water used in laundering. The durability of flame retardant fabrics is dependent upon the interaction of these variables, as well as others.

Laundry Variables

Fire-resistant fabrics are capricious in their response to laundering. Flame-retardant properties of the commercially available sleepwear garments of various fiber contents may be seriously impaired by 25 or fewer launderings if improper laundering procedures are used. Proper laundering procedures have been established by the American Association of Textile Chemists and Colorists, which includes such methodology as using a phosphate-based detergent and medium water hardness, as well as avoiding the use of chlorine bleach, soap, and fabric softeners (22, 28).

The effect of different types of cleaning agents used on flame-retardant fabrics has been studied in depth. Results from laboratory testing have shown that the use of non-phosphate detergents (carbonate-based, in particular) can impair flame resistant properties of numerous fabrics. These adverse effects are due to alkaline hydrolysis, ion exchange and/or deposition of calcium carbonate (22). Thus, the flame-resistance of the fabric surface is blocked. Fabrics found to fail the flammability test after being laundered in a carbonate-built, non-phosphate detergent included acetate, acetate/polyester, cotton and nylon (5).

Although the DOC-FF-3-71 Standard (44), specifies the use of a high-phosphate detergent for laundering, it would be difficult for consumers to buy detergents of high-phosphate content in some localities. Federal, state, and municipal standards limiting the composition of laundry detergents have outlawed high-phosphate detergents in many areas (24).

In addition to non-phosphate detergents, alkali-built soap has been found to have a detrimental effect on some flame retardant fabrics. Research studies have shown that the lost flame retardancy is due to deposition of flammable searate salts on the fabric. In some cases, flammability lost through soap curd deposition can be restored by additional launderings with phosphate detergents (5, 24, 28).

Further studies have shown that flame retardant fabric is generally degraded, to some extent, when exposed to sunlight. It is

estimated that about half of the American population dry their clothes with tumble dryers, with the remainder line-drying their clothes in the sunlight. Thus, flame resistant fabrics in household and apparel goods must be resistant to sunlight, as well as the hot temperatures of tumble drying, to assure that these goods remain flame-resistant through repeated launderings. The use of a small amount of pigment can protect some flame retardants from the destructive action of sunlight (6, 33).

Heat, as applied in the pressing of clothing, also decreases the effectiveness of some flame retardants. While the process of pressing is taking place, the ester groups of the alkyl phosphonates are hydrolyzed at the pressing temperature which produces sites for ion exchange. This chemical reaction may be irreversibly detrimental to the flame retardant properties of fabrics (6, 33).

Other laundry variables which frequently affect flame resistant fabrics adversely include chlorine or perborate oxygen bleach and fabric softeners. The use of bleach on colored flame resistant fabric is not recommended, due to unusual fading effects (13). Furthermore, certain fabric softeners may build up on the fabric to an extent that the garment's flame retardant characteristics are impeded and the garment becomes flammable (47). Hence, precaution must be taken to avoid the use of these laundry products when washing flame resistant items.

Hardness of Water

A very important factor, with respect to the durability of flame retardant fabrics to laundering, is the level of water hardness (expressed in parts per million - ppm). Water, in most regions of the United States, contains calcium and magnesium ions. These ions can be picked up from the wash water, by the flame resistant fabrics during laundering. Chemicals in the flame retardant finishes combine with phosphate from detergents or fatty acids from soap. This ion deposition results in impairment of the flame resistant properties of the fabric. The concentration of calcium and magnesium ions (water hardness) influences, to some extent, the amount of ion deposition and, thus, the degree of flame retardancy degradation (6, 20, 33).

For consumers who live in regions with characteristic hard water, water softening agents or equipment can be used to diminish these adverse effects as related to flame retardant fabrics.

VI. EFFECTS OF FLAME RETARDANTS ON FABRICS

Most flame retardant finishes affect both the physical properties and the aesthetic values of fabrics. Treated fabrics may show changes in hand, texture, color, absorbency, comfort, dimensional stability, tensile and tear strength, pilling, or dye fastness. Although the only performance criterion required is that the treated fabrics pass the vertical-flame test after at least 50 launderings, consumers demand good performance in the aesthetic and physical properties of the fabric, also (3, 39).

Since the engineering of fibers with specific structures and properties frequently results in compromising other properties, it is not surprising that the flame retardant property cannot be simply superimposed on the desirable properties of a cellulosic, polyamide, polyester, or other natural and man-made fibers. Because the treated fibers must pick up 10 to 20 percent of the flame retardant to achieve a significant shift to flame retardancy, serious problems are encountered in preserving the desirable properties of the fibers (40).

It has been found that certain fibers are more easily finished to produce desired fabric qualities than other. Particular difficulty has been encountered with satisfactorily treating cotton fabrics. The flame retardant finishes for cotton may be durable to laundering, but they often cause limitations of stiffness, reduced tear strength, and harsh hand in the fabric. Finishers say this is due to the combination of high chemical add-ons required to arrive at non-burning characteristics. Research is continuing to improve flame retardant finishes for cotton (7, 8, 37).

Another problem encountered is that the after-treatment of fibers for flame retardancy will generally affect the ease of dyeing and the dye fastness properties of the fabric. Flame retardants are usually alkaline or acidic, and it would be unusual for alkalinity or acidity not to affect a direct color. The adverse effects can range from slight to full color value changes, when the fabrics are laundered (40, 55).

Children's sleepwear garments often have a brushed surface. This adds softness to the fabric and produces a pleasing hand, as well as promoting insulation properties of the fabric. In general, such a brushed surface is prone to pill in garment wear and in washing. It has been found, however, that the pilling appearance of flame resistant sleepwear fabric is often worse than that of the untreated fabric (32). Among treated fabrics, the pilling performance of flame resistant synthetic fabrics is more intensified than for all others. With the higher tenacity synthetic fibers, pills remain attached to the fabric surface creating an undesirable appearance. Textile researchers have explained that pilling in treated sleepwear fabrics cannot be eliminated until the condition is improved in many other untreated fabrics (4, 32).

Various other problems have been reported by consumers. Some flame retardant treatments have caused allergic reactions in consumers, as well as eye irritation while ironing the treated sleepwear. Still others have caused white fabrics to turn yellow and have reduced the abrasion resistance of fabrics (3, 54). Consumers have also complained of an objectionable odor associated with some treated sleepwear. In the last few years, many of these problems have been eliminated with improved flame retardant treatments.

Current flame retardant finishes have been found to impart desirable properties to fabrics, such as wrinkle-resistance, mildew-resistance, and rot-resistance (7). The goal of researchers is to continue improving flame retardant treatments, so as to provide

flame resistant fabrics which would meet most of the aesthetic and physical qualities desired by consumers, as well as meeting all flammability standards.

CHAPTER III

PROCEDURE

The purpose of this study was to determine the effects of three home laundry detergents on the aesthetic properties and flammability of three commercially available children's sleepwear garments after repeated launderings under home laundering conditions. Procedures cover research design, fabrics, specimens, detergents, laundry/drying procedures, reflectance readings, flammability testing, judging, and statistical analysis.

I. RESEARCH DESIGN

A 3 X 3 X 7 X 2 factorial design was developed to test the effects of three independent variables (detergents, laundry intervals, and fabrics) on six dependent variables (color change, hand, shape retention, pilling, flame time, and char length). The experimental design included three detergents (Tide, All, and Sears'), three fabrics (100 percent nylon, 100 percent cotton, and 80 percent acetate/20 percent polyester), seven laundry intervals (0, 5, 10, 20, 30, 40, and 50), and two replications.

II. FABRICS

A market survey was taken to determine the three most prominent fabrics in children's sleepwear garments on the Knoxville market in the

fall of 1974. All garments chosen were labeled as being constructed of flame resistant fabric. A general description of the garments is given in Table 1. (See Appendix A for analysis of fabrics for flammability finishes).

The garments were coded in relation to the type of detergent applied to each. Two garments of each fabric were set aside to be used as control garments during later evaluations.

III. SPECIMENS

Five specimens of 8.9 X 25.4 centimeters (3.5 X 10 inches) size were cut from each of the garment types (by fiber content) after 0, 5, 10, 20, 30, 40, and 50 laundry intervals. Specimens were then coded in relation to the type of detergent applied to each.

IV. DETERGENTS

Three commercially available home laundry detergents with three different levels of phosphorus were selected for testing, The phosphorus content and the identification codes for detergents were:

Detergent Identification

Detergent	Phosphorus Content	Code Number
Tide	8.7%	I
All	6.2-8.2%	II
Sears' Heavy Duty Laundry Concentrate	0% (Carbonate-based)	III

All three detergents were of powder form.

TABLE 1

DESCRIPTION OF FABRICS

FIBER CONTENT	CONSTRUCTION	WEIGHT	GARMENT SIZE	MERCHANT	COLOR	CODE LETTER
100% Cotton	woven	5.10 oz/yd^2	6X	Sears	white	fabric C
100% Nylon	knit	2.64 oz/yd^2	16	Penney's	yellow	fabric A
80% Acetate/ 20% Polyester	brushed knit	2.74 oz/yd^2	14	Grant's	pink	fabric B

V. LAUNDRY/DRYING PROCEDURE

Garments were laundered under simulated home laundering conditions, as specified in the AATCC Test Method 124-1974 (1). All garments used for testing were subjected to this test method as a preliminary laundering before initial launderings of this experiment began. A Sears' Kenmore washer and dryer, models 20620 and 701860, respectively, were used.

Three 4-pound laundry loads, each consisting of three garments of each of the two fabrics, 100 percent nylon and 20 percent polyester/ 80 percent acetate, and four garments of the 100 percent cotton fabric, were laundered 50 times in each of the three specified detergents. A completely randomized block design was used. A block consisted of one wash and dry cycle of all fabrics, with each detergent. The three detergents were randomized within each block, with 50 blocks required to complete one replication. Consultation with a statistician revealed that two replications were sufficient to substantiate the veracity of the results.

Averages for the water hardness level during each month of laundering were obtained from the Knoxville Utilities Board (see Appendix B for listing).

VI. REFLECTANCE READINGS

All specimens were checked for degree of whiteness and color value by the Hunterlab Model D25D2 Digital Color Difference Meter. Reflectance

readings were taken of the five specimens cut from the garments, in each detergent, at 0, 5, 10, 20, 30, 40, and 50 laundry intervals. The five specimens from each fabric were tested collectively. To obtain consistent readings, each of the five specimens were folded in half, and arranged so that ten layers of fabric were placed under the light. One reading was taken on each side of the five folded specimens. The readings were recorded and averaged to obtain one value for each group of five specimens. The data were used in the statistical analysis for color change.

Readings were taken on the L,a,b scale of the Hunter Color Difference Meter. This scale gives measurements of color in units of approximate visual uniformity throughout the specimen being evaluated, Thus, L measures lightness and varied from 100 for perfect white to zero for black, approximately as the eye would evaluate it. The a reading measures redness when plus, gray when zero, and greenness when minus. The b reading measures yellowness when plus, gray when zero, and blueness when minus (10). The following scales illustrate the measurement values designating color and whiteness.

Measurement Values of Reflectance Readings

L readings

83.0 84.0 85.0 86.0 87.0 88.0 89.0 90.0 91.0 92.0 93.0 94.0

whiteness

a readings

-2.50 -2.00 -1.50 -1.00 -0.50 0.00 0.50 1.00 1.50 2.00 2.50

greenness gray redness

b readings

-2.50	-2.00	-1.50	-1.00	-0.50	0.00	0.50	1.00	1.50	2.00	2.50
	blueness				gray				yellowness	

Before taking each group of readings, the Color Difference Meter was calibrated using the standard plate closest to each of the fabrics in reflectance. The white, pink, and yellow standards' readings are given in Table II.

VII. FLAMMABILITY TEST

All specimens were tested for flammability according to the Children's Sleepwear Standard DOC FF 3-71 (11). The char lengths and burning rates were recorded and averaged, for each group of five specimens, at each of the specified laundry intervals.

VIII. JUDGING

After all laundry procedures and laboratory testing had been conducted, a panel of three judges was chosen, from a field of ten in a preliminary judging, to evaluate aesthetic properties of the specimens. All specimens were judged for hand and pilling properties. The pilling properties were judged according to the illustrative rating steps of the American Society of Testing Materials (ASTM) Standard Number D 1375-72 (1). For evaluating hand properties, judges were told to rate the specimens from one to five as to their harshness versus softness, respectively. The specimens were placed behind a screen and each judge evaluated the specimens by their tactile senses, using both hands.

TABLE II

HUNTER STANDARD READINGS FOR YELLOW, PINK, AND WHITE

Reading	Calibration	Standard Value
L	White	94.5
a	White	-1.1
b	White	2.2
L	Pink	67.1
a	Pink	22.3
b	Pink	11.5
L	Yellow	78.2
a	Yellow	-2.4
b	Yellow	22.6

Garments from the zero and fiftieth laundry intervals, for each fabric and detergent combination, were judged for shape retention. For evaluating shape retention, judges were told to rate the garments from one to five as to their acceptability for wearing as sleepwear. Each garment to be judged was placed against a stationery control garment of the same fabric type. (See Appendix C for sample rating sheet).

IX. STATISTICAL ANALYSIS

A 3 X 3 X 7 X 2 factorial analysis of variance with interaction of fabric content, type of detergent, and number of launderings were calculated for flame time, char length, color change, hand, pilling, and shape retention, using the SAS program for analysis. Because the cotton fabric was so different, in respect to the variables tested, from the other two fabrics, many factors appeared to be significant. Therefore, the data for flame time, char length, hand, pilling, and shape retention were reanalyzed by an analysis of variance with the cotton fabric data deleted, and the latter were analyzed separately. The data for color change were then analyzed separately for each fabric. Data were considered to be significant at the .05 probability level and highly significant at the .001 level.

CHAPTER IV

RESULTS AND DISCUSSION OF DATA

Reported in this chapter are the color change, pilling, hand, shape retention, and flammability properties of the three commercially available children's sleepwear garments, as affected by three home laundry detergents.

I. COLOR CHANGE

Data revealed that the color values of each fabric were affected by repeated launderings. Reflectance data (L,a,b) were obtained using the Hunter Color Difference Meter and were analyzed separately for the three fabrics. Both main effects, detergent and laundering, were found to have significant or highly significant effects on the three color variables for each of the fabrics studied. Statistical analyses for these are shown in Tables III, IV, and V for Fabrics A, B, and C, respectively.

100 Percent Nylon

Fabric A was a yellow nylon tricot, having initial color values of 88.9, -10.9, and 37.8 for L, a, and b, respectively. Hunter color value L is a measure of the ability of the fabric to reflect light. Higher values of L imply greater light reflectance and hence show fading of a dye. Hunter color value a is a measure of the relative redness or greenness of the fabric, with positive values implying redness and

TABLE III

ANALYSIS OF VARIANCE OF COLOR CHANGE FOR NYLON

Source	df	F-ratio	Probability > F
A. Reflectance Variable L			
Detergent	2	21.66464	0.0001***
Laundering	6	17.14900	0.0001***
Detergent X Laundering	12	0.96323	n.s.*
B. Reflectance Variable a			
Detergent	2	13.45816	0.0004***
Laundering	6	20.64946	0.0001***
Detergent X Laundering	12	0.50555	n.s.*
C. Reflectance Variable b			
Detergent	2	3.94355	0.0351**
Laundering	6	161.55546	0.0001***
Detergent X Laundering	12	1.31210	n.s.*

*not significant

**significant

***highly significant

TABLE IV

ANALYSIS OF VARIANCE OF COLOR CHANGE
FOR ACETATE/POLYESTER

Source	df	F-ratio	Probability > F
	A. Reflectance Variable L		
Detergent	2	20.26378	0.0001***
Laundering	6	28.69453	0.0001***
Detergent X Laundering	12	0.75055	n.s.*
	B. Reflectance Variable a		
Detergent	2	7.33404	0.0043**
Laundering	6	77.66311	0.0001***
Detergent X Laundering	12	0.68238	n.s.*
	C. Reflectance Variable b		
Detergent	2	76.40614	0.0001***
Laundering	6	42.97101	0.0001***
Detergent X Laundering	12	2.70948	n.s.*

*not significant

**significant

***highly significant

TABLE V

ANALYSIS OF VARIANCE OF COLOR CHANGE FOR COTTON

Source	df	F-ratio	Probability > F
	A. Reflectance Variable L		
Detergent	2	5.79944	0.0103**
Laundering	6	14.93792	0.0001***
Detergent X Laundering	12	0.86572	n.s.*
	B. Reflectance Variable a		
Detergent	2	128.87091	0.0001***
Laundering	6	33.04788	0.0001***
Detergent X Laundering	12	8.16704	0.0001***
	C. Reflectance Variable b		
Detergent	2	226.07714	0.0001***
Laundering	6	130.94584	0.0001***
Detergent X Laundering	12	9.15556	0.0001***

*not significant

**significant

***highly significant

and negative values greenness. Hunter color value b is a measure of relative yellowness or blueness of the fabric, with yellowness being positive and blueness negative. A change in a from a negative to a less negative number is also an indication of a fading of the yellow dye as is a change from a positive to a less positive value of b. Changes in L, a, and b with repeated launderings are shown in Figure 1 for Fabric A; different detergents are also shown in this figure.

The data show that there were only slight changes in the values of L for this fabric. Detergent II showed virtually no change, while detergents I and III both gave slight increases in L indicating little fading. All detergents showed definite shade changes, however. The Hunter a values were shifted to the less green values with detergent II causing the greatest shift and detergent I the least. The Hunter b values also showed a shift to the lesser yellow value with detergent III causing the greatest shift and detergents I and II a less severe shift. The interaction between detergent and laundering was found not significant (Table III, page 33).

80 Percent Acetate/20 Percent Polyester

Fabric B was a pink knit, having initial color values of 78.9, 31.9, and 0.8 for L, a, and b, respectively. Changes in L, a, and b with repeated launderings are shown in Figure 2 for Fabric B; different detergents are also shown in this figure.

The data reveal that there were severe changes in the values of L for this fabric. All detergents showed great increases in L indicating

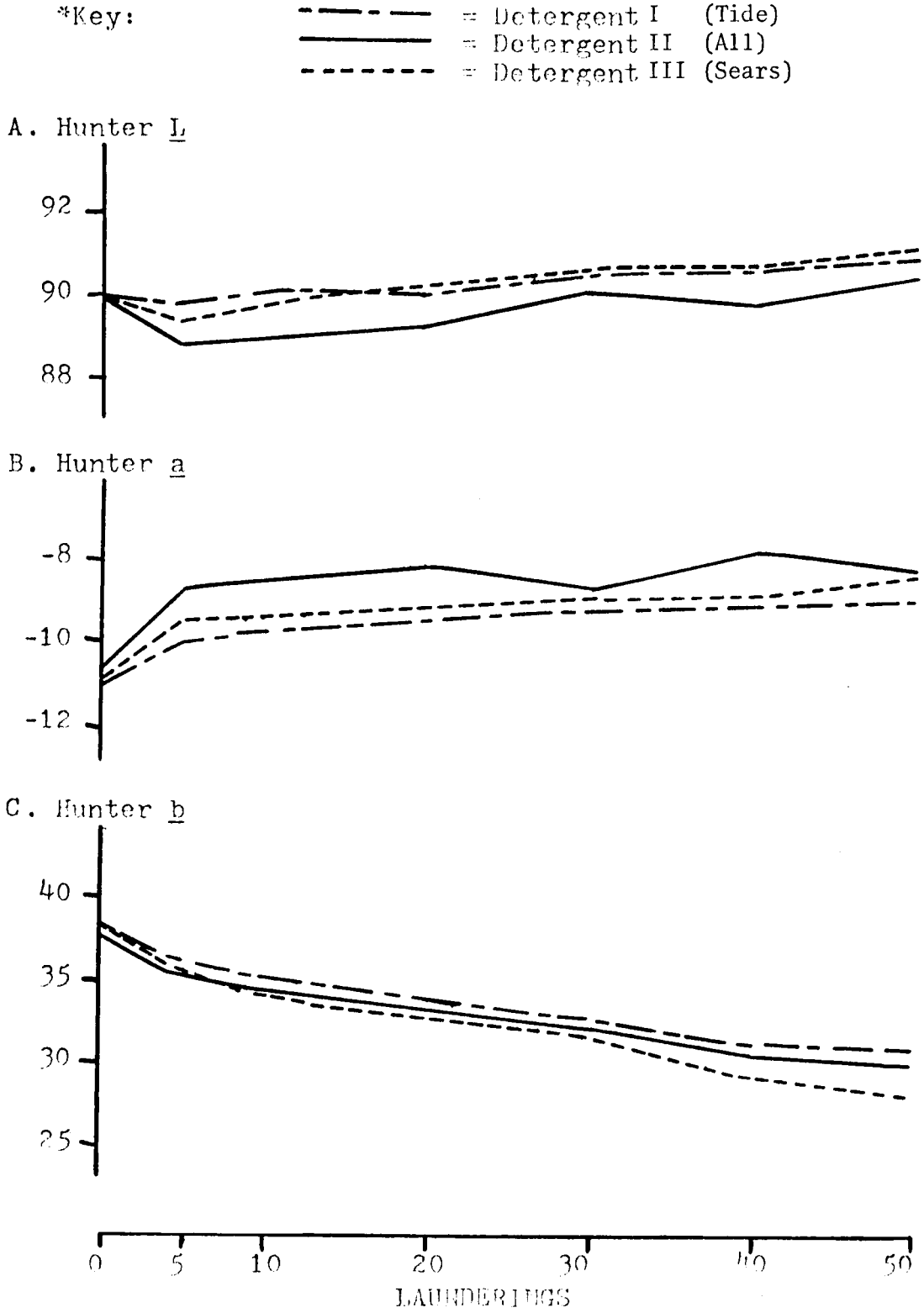


Figure 1. Variation of Hunter L,a,b With Launderings and Detergents for Nylon*

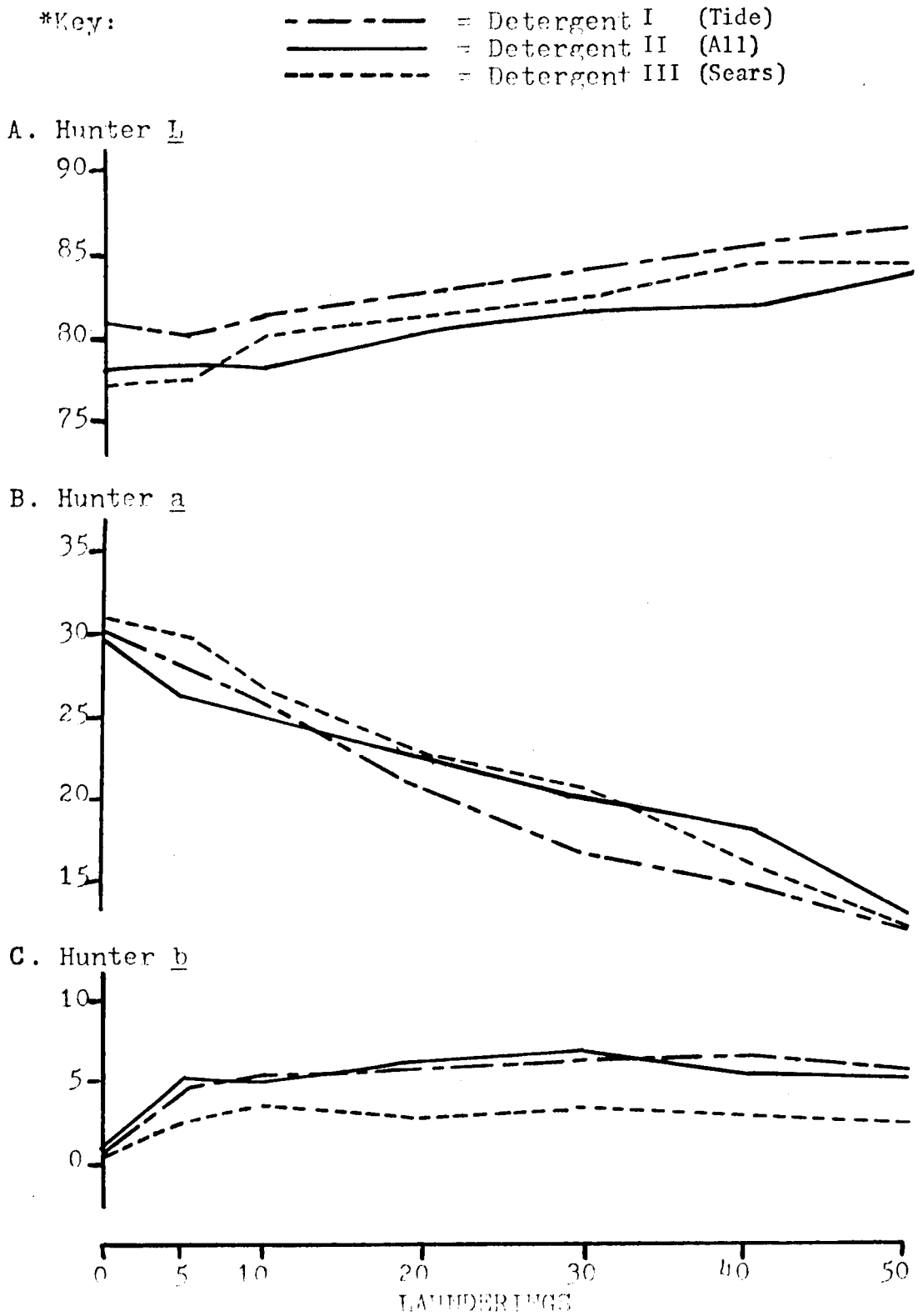


Figure 2. Variation of Hunter L,a,b With Launderings and Detergents for Acetate/Polyester*

severe fading. The Hunter a values were sharply shifted to a lesser red value with detergent I causing the greatest shift and detergent II the least. The Hunter b values also showed a shift to a greater yellow value, with detergents I and II causing the greatest shift and detergent III a less severe shift. The interaction between detergent and laundering was not found significant (Table IV, page 34).

100 Percent Cotton

Fabric C was a white flannelette, having initial color values of 93.8, 1.1, and -0.3 for L, a, and b, respectively. Changes in L, a, and b with repeated launderings are shown in Figure 3 for Fabric 3; different detergents are also shown in this figure.

The data revealed only moderate changes in the values of L for this fabric. All detergents showed moderate increases in L, with detergent III showing the greatest change. These changes indicate an increased whiteness of the fabric. Only slight changes were noted in the values for a. Detergent II showed virtually no change, while detergents I and III both gave slight increases, indicating a slight shift to a lesser green value. The Hunter b values also showed a shift to a greater blue value, with detergents I and III causing the greatest shift and detergent II a less severe shift. The interaction between detergents and laundering was found not significant for L, but was highly significant for a and b (Table V, page 35).

*Key:

= Detergent I (Tide)
= Detergent II (All)
= Detergent III (Sears)

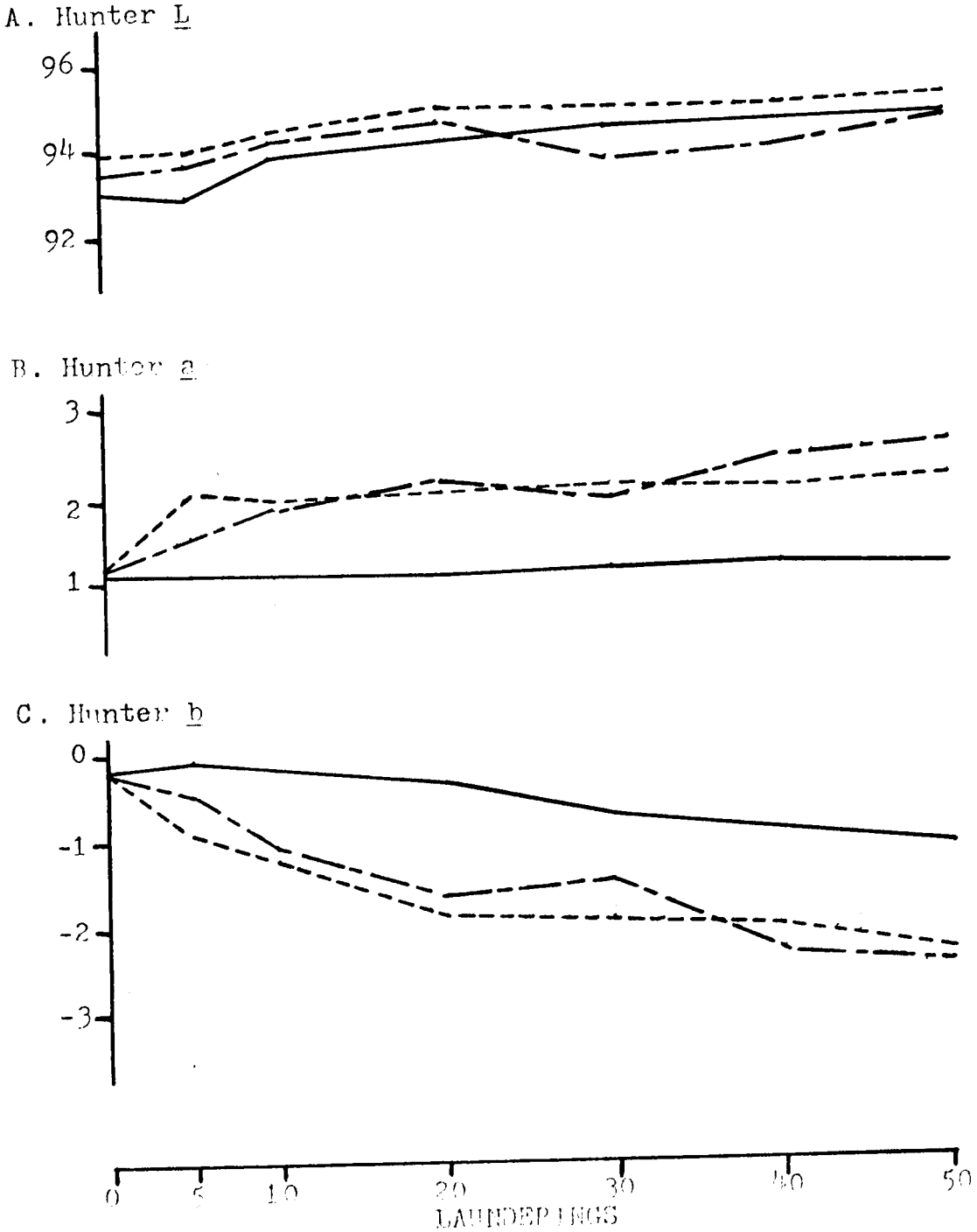


Figure 3. Variation of Hunter L,a,b With Launderings and Detergents for Cotton*

II. PILLING

Data revealed that the degree of pilling, as affected by repeated launderings, varied for each of the fabrics (Tables VI and VII). Rating results of the tested specimens ranged from Class "5" (no pilling) to Class "1" (severe pilling) depending on the fabric (Figure 4). Although there is no standard minimum requirement, it would seem desirable that specimens should not receive ratings lower than Class "3" (moderate pilling).

A fabric comparison showed no evidence of pilling recorded for the nylon specimens at any laundering intervals. Ratings for the cotton specimens showed only moderate pilling, with a gradual increase in the number of pills between the fifth and twentieth laundering intervals. There was no variation of effect among detergents on the cotton fabric. The acetate/polyester blend had considerable pilling after the initial laundering interval. Thus, the nylon fabric exhibited excellent resistance to pilling, with the acetate/polyester fabric having poor pill resistance.

III. HAND

The hand of the specimens was rated by the judges according to a scale of harshness versus softness. Data revealed that the hand of the specimens was significantly affected by repeated launderings, with the hand becoming harsher with laundering (Tables VIII and IX). The change in hand of the cotton specimens was greater and more undesirable than that of the other two fabrics (Figure 5). The fabric became very harsh

TABLE VI

ANALYSIS OF VARIANCE OF PILLING FOR
NYLON AND ACETATE/POLYESTER

Source	df	F-ratio	Probability > F
Detergent	2	0.54684	n.s.*
Fabric	1	1607.46611	0.0001***
Laundering	6	26.82790	0.0001***
Interactions:			
Fabric X Detergent	2	0.75616	n.s.*
Laundering X Detergent	12	1.18619	n.s.*
Fabric X Laundering	6	27.52842	0.0001***
Fabric X Detergent X Laundering	12	1.07428	n.s.*

*not significant

***highly significant

TABLE VII

ANALYSIS OF VARIANCE OF PILLING FOR COTTON

Source	df	F-ratio	Probability > F
Detergent	2	8.22583	n.s.*
Laundering	6	2.43084	n.s.*
Detergent X Laundering	12	0.37353	n.s.*

*not significant

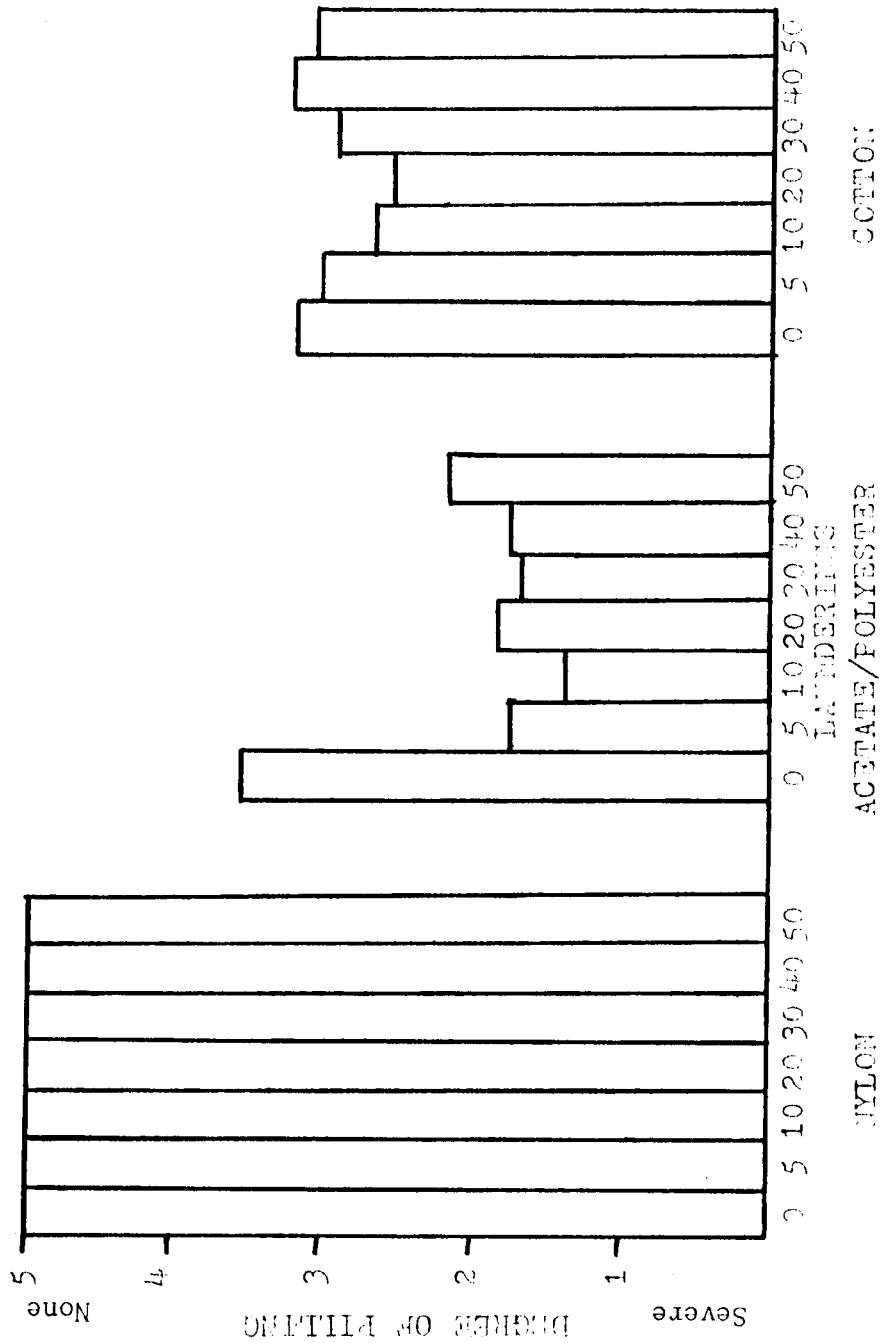


Figure 4. Degree of Pilling as a Function of Launderings for the Three FR Fabrics

TABLE VIII

ANALYSIS OF VARIANCE OF HAND FOR
NYLON AND ACETATE/POLYESTER

Source	df	F-ratio	Probability > F
Detergent	2	0.33168	n.s.*
Fabric	1	151.33193	0.0010**
Laundering	6	4.39965	0.0022**
Interactions:			
Fabric X Detergent	2	0.19380	n.s.*
Laundering X Detergent	12	0.69021	n.s.*
Fabric X Laundering	6	3.48163	0.0080**
Fabric X Detergent X Laundering	12	0.43606	n.s.*

*not significant

**significant

TABLE IX

ANALYSIS OF VARIANCE OF HAND FOR COTTON

Source	df	F-ratio	Probability > F
Detergent	2	610.22935	0.0014**
Laundering	6	8.20358	0.0006***
Detergent X Laundering	12	1.08381	n.s.*

*not significant
**significant
***highly significant

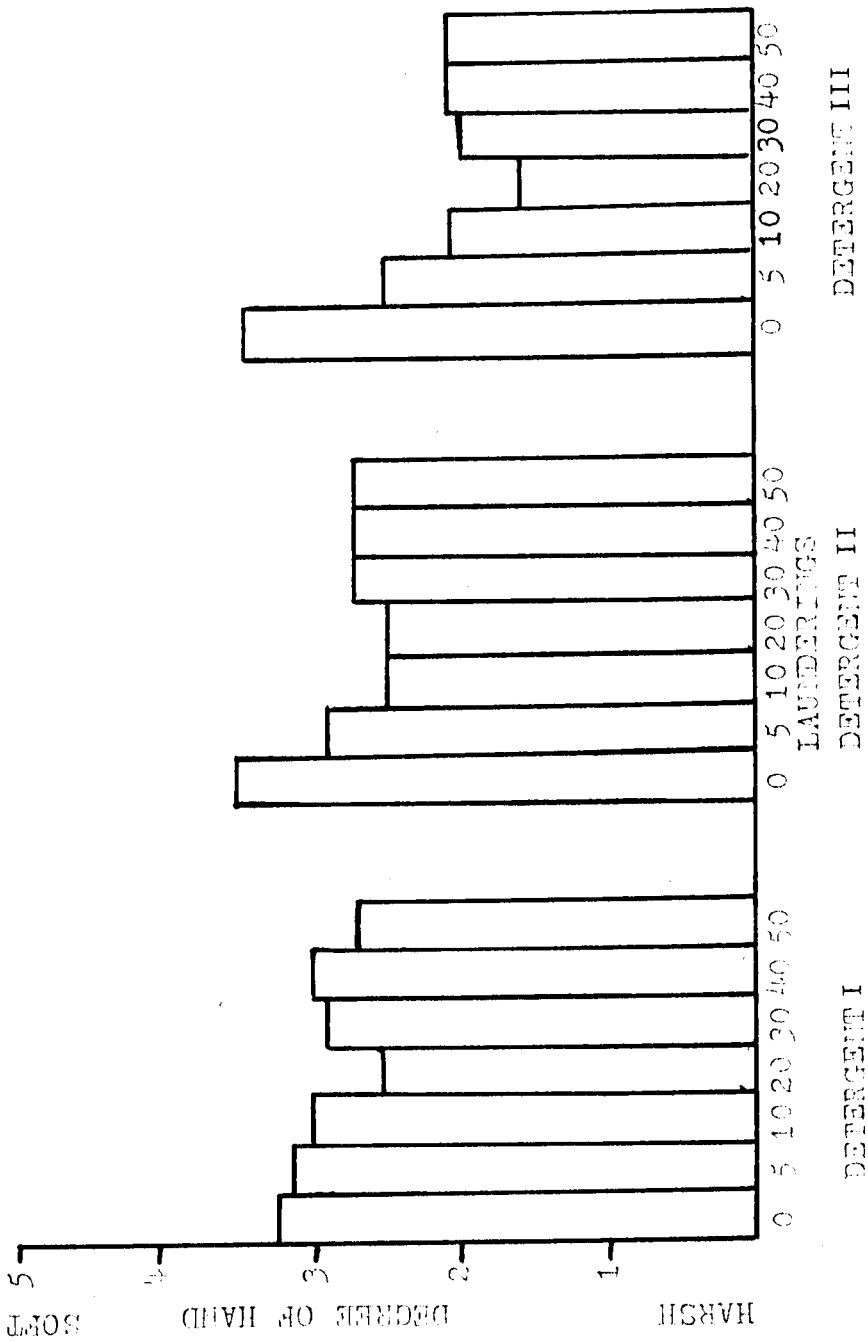


Figure 5. Degree of Hand as a Function of Launderings and Detergents for Cotton

with repeated laundering. Detergent I had the most detrimental effect on the hand of the cotton fabric. For the acetate/polyester specimens, there was a moderate change in hand after the fifth laundering interval, with the specimens being rated as harsher with progressive laundering. The hand of nylon specimens was not significantly affected by laundering (Figure 6).

IV. SHAPE RETENTION

The garments of each fabric and detergent combination were judged for shape retention characteristics at the zero and fiftieth intervals. Data revealed that the effect of laundering on the shape retention of the acetate/polyester and nylon garments was highly significant (Table X). The cotton garments were not significantly affected by detergent or laundering (Table XI). The acetate/polyester garments were affected most detrimentally, with an average mean rating change in shape retention of 2.6 degrees (Figure 7). This was a change from an "Acceptable" to an "Unacceptable" rating. (See Appendix C.) The average mean rating change in shape retention for the cotton and nylon garments was less than 1.0 degree for each, being a change from an "Acceptable" to a "Less Acceptable" rating.

V. FLAMMABILITY

An item meets the acceptance criteria of DOC FF 3-71 when the residual flame time of an individual specimen does not exceed ten seconds, the average char length of the specimens which comprise a

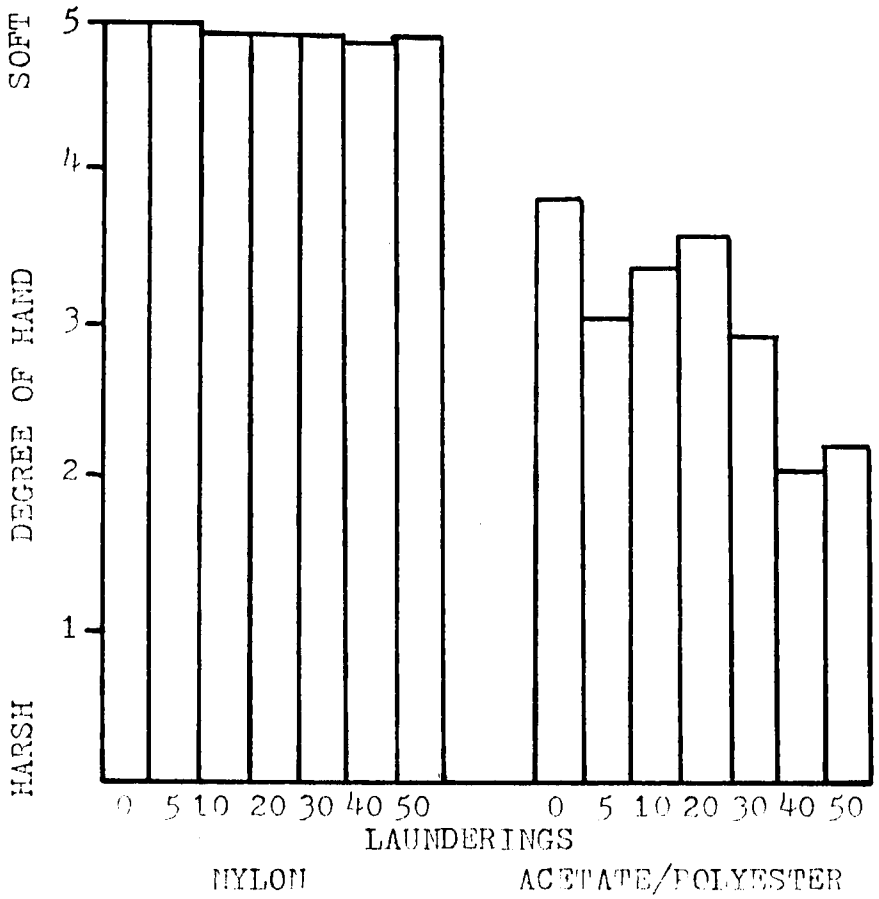


Figure 6. Degree of Hand as a Function of Launderings for Nylon and Acetate/Polyester

TABLE X

ANALYSIS OF VARIANCE OF SHAPE RETENTION FOR NYLON AND ACETATE/POLYESTER

Source	df	F-ratio	Probability > F
Detergent	2	0.02564	n.s.*
Fabric	1	49.47059	0.0049**
Laundering	6	201.19048	0.0001***
Interactions:			
Fabric X Detergent	2	1.82353	n.s.*
Laundering X Detergent	2	0.04762	n.s.*
Fabric X Laundering	6	40.04762	0.0007***
Fabric X Detergent X Laundering	12	1.47619	n.s.*

*not significant
**significant
***highly significant

TABLE XI

ANALYSIS OF VARIANCE OF SHAPE RETENTION FOR COTTON

Source	df	F-ratio	Probability > F
Detergent	2	0.30233	n.s.*
Laundering	6	5.50000	n.s.*
Detergent X Laundering	12	0.59091	n.s.*

*not significant

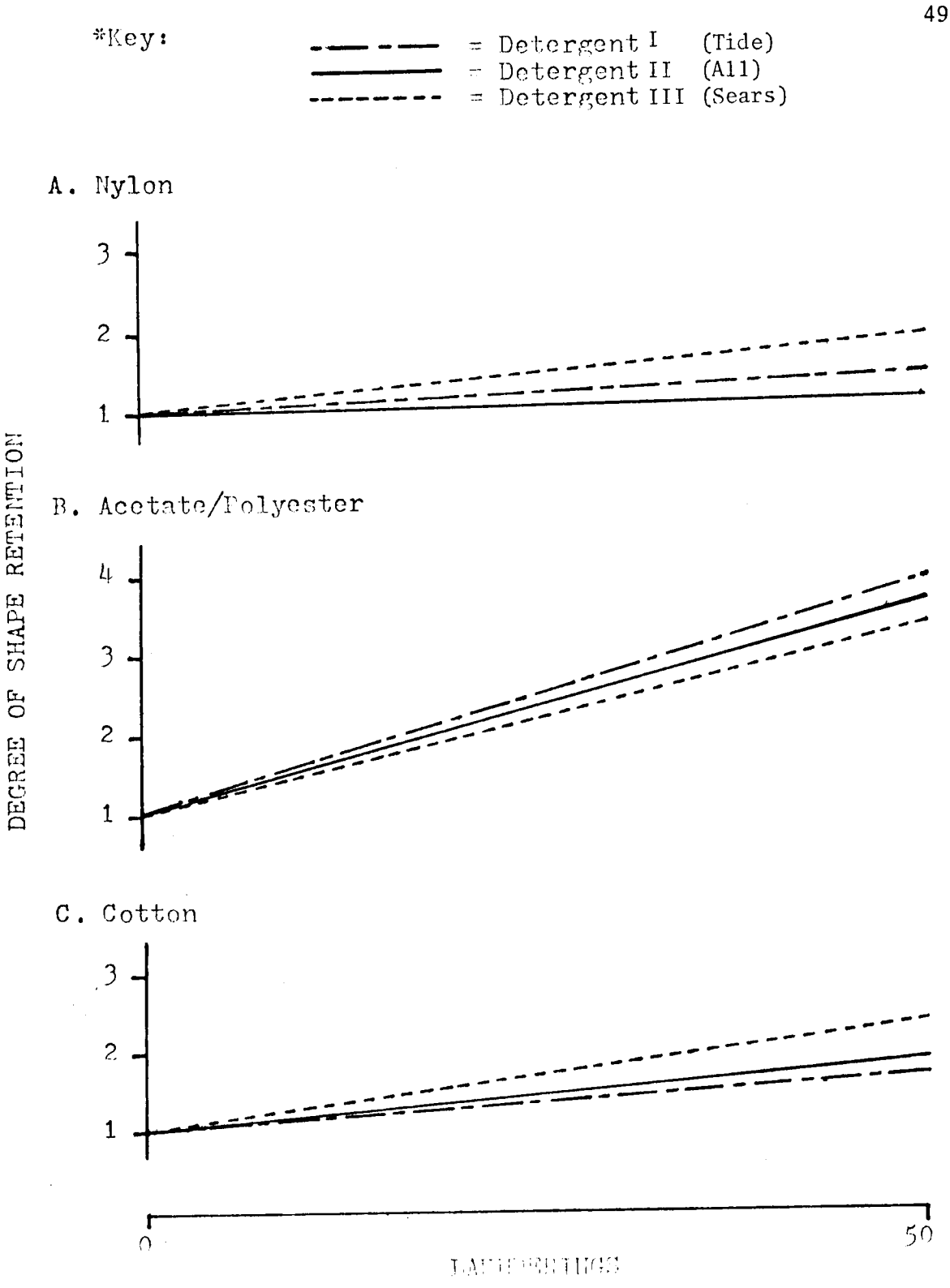


Figure 7. Degree of Shape Retention as a Function of Launderings for the Three FR Fabrics

sample do not exceed 17.78 centimeters (7 inches), and the char length of an individual specimen does not exceed 25.4 centimeters (10 inches).

The nylon fabric and the acetate/polyester blend when laundered in the no-phosphate, medium phosphate, and high phosphate detergents passed the DOC FF 3-71 vertical flammability test throughout the fifty laundering intervals. Results are shown in Figures 8 and 9. In the analyses of flame time and char length for these two fabrics, there were no significant interactions between detergent and laundering (Tables XII and XIV). The cotton fabric, when laundered in the no-phosphate detergent, failed to meet the flammability standard when tested after five launderings because of both excessive residual flame time and char length. In the analyses of flame time and char length for the cotton fabric, there was a highly significant interaction between detergent and laundering (Tables XIII and XV).

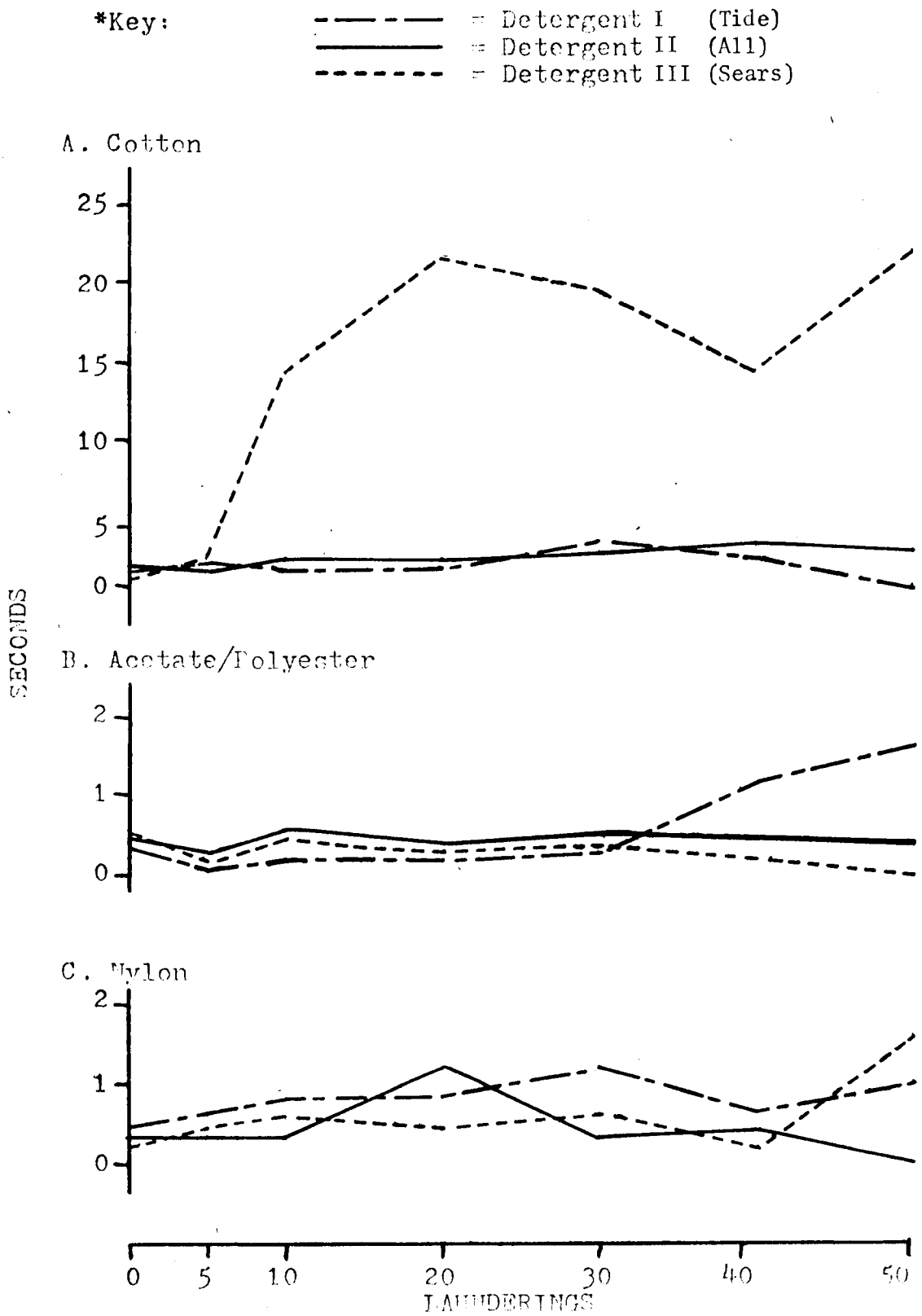


Figure 8. Flame Time as a Function of Launderings and Detergents for the Three FR Fabrics

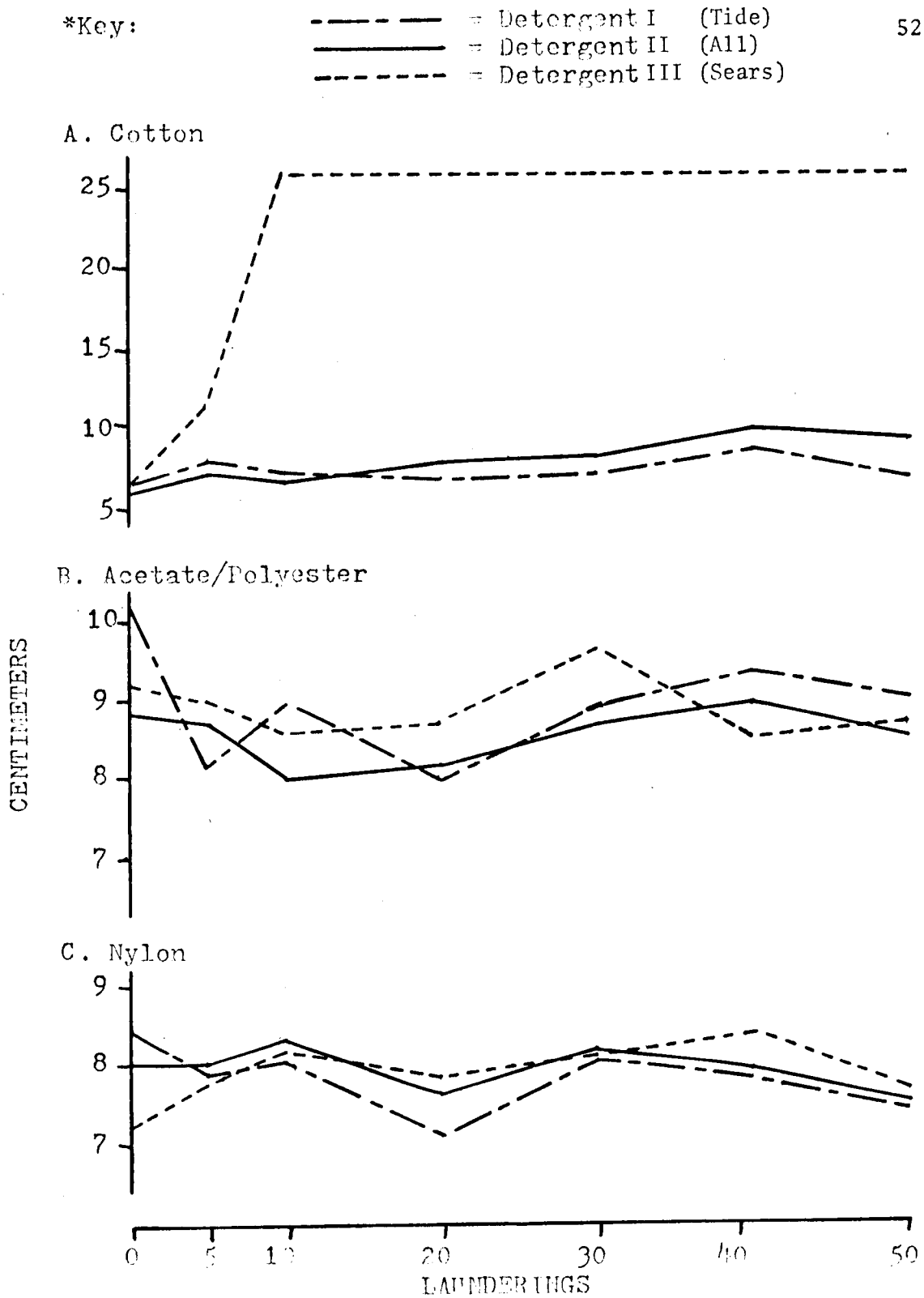


Figure 9. Char Length as a Function of Launderings and Detergents for the Three FR Fabrics

TABLE XII

ANALYSIS OF VARIANCE OF FLAME TIME FOR
NYLON AND ACETATE/POLYESTER

Source	df	F-ratio	Probability> F
Detergent	2	0.16161	n.s.*
Fabric	1	2.77219	n.s.*
Laundering	6	1.71104	n.s.*
Interactions:			
Fabric X Detergent	2	6.59517	n.s.*
Laundering X Detergent	12	0.30661	n.s.*
Fabric X Laundering	6	0.63097	n.s.*
Fabric X Detergent X Laundering	12	1.35310	n.s.*

*not significant

TABLE XIII

ANALYSIS OF VARIANCE OF FLAME TIME FOR COTTON

Source	df	F-ratio	Probability > F
Detergent	2	378.17846	0.0022**
Laundering	6	7.45646	0.0005***
Detergent X Laundering	12	5.89923	0.0005***

**significant

***highly significant

TABLE XIV

ANALYSIS OF VARIANCE OF CHAR LENGTH FOR
NYLON AND ACETATE/POLYESTER

Source	df	F-ratio	Probability > F
Detergent	2	0.70539	n.s.*
Fabric	1	49.43762	0.0049*
Laundering	6	1.90657	n.s.*
Interactions:			
Fabric X Detergent	2	3.16098	n.s.*
Laundering X Detergent	12	0.72218	n.s.*
Fabric X Laundering	6	0.49865	n.s.*
Fabric X Detergent X Laundering	12	0.46001	n.s.*

*not significant

TABLE XV

ANALYSIS OF VARIANCE OF CHAR LENGTH FOR COTTON

Source	df	F-ratio	Probability > F
Detergent	2	708.15701	0.0013**
Laundering	6	39.45529	0.0001***
Detergent X Laundering	12	26.82324	0.0001***

**significant
***highly significant

CHAPTER V

SUMMARY AND CONCLUSIONS

The objectives of this research were to evaluate the effects of three home laundry detergents on the aesthetic properties and flammability of three commercially available children's sleepwear garments, after repeated laundering under home laundering conditions. These procedures included three detergents of varying phosphorus content: Tide, All, and Sears' Heavy Duty Laundry Concentrate. The sleepwear fabric types studied were 100 percent nylon, 80 percent acetate/20 percent polyester, and 100 percent cotton. The garments were tested at seven laundry intervals: 0, 5, 10, 20, 30, 40, and 50. Two replications of the laundering procedures and laboratory testing were completed.

Subjective ratings served as a basis for evaluating the effects of the detergents and repeated laundering on the aesthetic properties of pilling, hand, and shape retention of the three flame resistant fabrics. The Hunter Color Difference Meter was used to evaluate the color change of the fabrics as affected by the detergents and repeated launderings. The effect of these independent variables on the flame resistance characteristics was evaluated by the flammability test specified in the Children's Sleepwear Standard, DOC FF 3-71 (11).

An analysis of variance involving fabric, detergent type and laundry intervals was run for each of the aesthetic properties measured, as well as for flammability characteristics.

I. EFFECT OF DETERGENTS AND LAUNDERING ON COLOR CHANGE

In the analysis of variance conducted on color change, both main effects, detergent and laundering, were found to have significant or highly significant effects on the three Hunter Color variables for each of the fabrics studied. These color changes were an indication of fading characteristics of the yellow nylon fabric and the pink acetate/polyester fabric.

Comparing the fabrics, the acetate/polyester blend showed the greatest changes in color value, indicating severe fading of the pink dye. Although there were only slight changes in the whiteness values for the nylon fabric, definite shade changes indicated a moderate degree of fading of the yellow dye, also. The white cotton fabric became slightly whiter with repeated laundering, and a shift to a greater blue color value was also indicated.

It is noteworthy that no one detergent was found to affect the color variables for each fabric in the same way. The data indicated a significant variation of effect among detergents on each fabric. Therefore, the detergents behaved differently on each fabric, for each Hunter Color variable.

II. EFFECT OF DETERGENTS AND LAUNDERING ON PILLING

The degree of pilling, as affected by repeated launderings, varied for each of the fabrics. There was no evidence of pilling for the

nylon fabric, at any laundering interval. Data for the cotton fabric indicated a moderate degree of pilling and the acetate/polyester fabric data showed severe pilling after the initial laundering interval. There was no variation of effect among detergents on the fabrics.

As previously noted, there is no standard minimum requirement, but it would seem desirable that fabrics should not receive ratings lower than Class "3," moderate pilling. Thus, the pill resistance of the acetate/polyester fabric was rated as undesirable after the initial laundering. An explanation could be that the pills on the acetate/polyester fabric did not break off through laundering since both of the fiber components are very strong. Polyester fabrics also tend to pick up and hold lint, as was common with the acetate/polyester fabric in this study. Thus, such pilling results in a rough, unsightly fabric appearance which is undesirable for wearing apparel.

III. EFFECT OF DETERGENTS AND LAUNDERING ON HAND

The hand of the fabrics was significantly affected by repeated launderings. The nylon fabric exhibited the best hand properties of the three fabrics, retaining its soft hand with repeated laundering. There was a moderate change in hand of the acetate/polyester fabric, from a "Less Soft" rating to a "Harsh" rating. This change may be partially explained by the severe pilling of the fabric with repeated laundering, as was previously discussed. The change in hand of the cotton fabric was greater and less desirable than that of the other

two fabrics, becoming very harsh with repeated laundering. The Sears' carbonate base detergent had the most detrimental effect on the hand of the cotton fabric. Thus, the cotton garments, when washed in a carbonate base (no-phosphate) detergent were judged unacceptable for wearing by children.

IV. EFFECT OF DETERGENTS AND LAUNDERING ON SHAPE RETENTION

In the analysis of variance conducted on shape retention, data revealed that the effect of laundering on the shape retention of the nylon and acetate/polyester garments was highly significant. Nylon garments were only slightly affected, with the acetate/polyester garments being affected most detrimentally. The cotton garments were not significantly affected by either main effect. Therefore, the acetate/polyester garments were the only ones found unacceptable for wearing by children, after repeated home laundering.

V. EFFECT OF DETERGENTS AND LAUNDERING ON FLAMMABILITY

The flammability behavior of each fabric type, under the specified laundering conditions of the study, was most important in evaluating the acceptance of the sleepwear garments for wearing by children. Data revealed that the nylon fabric and the acetate/polyester blend, when laundered in each of the detergents, passed the specified standard throughout the fifty laundering intervals. The cotton fabric, when laundered in the high- and medium-phosphate detergents, met the specified

standard but after ten launderings with the no-phosphate detergent, failed in flame time and char length. Therefore, all garments tested were acceptable for wearing by children, with the exception of the cotton garments laundered in no-phosphate detergent.

VI. CONCLUSIONS

Conclusions based on the data will be drawn relative to the formal null hypothesis.

Hypothesis 1

There will be no significant difference in the effect of the three detergents on the flame resistance for each of the selected children's sleepwear garments, when laundered in water of medium hardness level.

Sears' Heavy Duty Laundry Concentrate was found significantly different from the other two detergents in its effects on the cotton fabric in the study. Therefore, Hypothesis 1 was rejected.

Hypothesis 2

There will be no significant difference in the effect of the three detergents on the color value for each of the selected children's sleepwear garments, when laundered in water of medium hardness level.

All three detergents were found to have significant effects on each of the three fabrics, with repeated laundering. Therefore, Hypothesis 2 was rejected.

Hypothesis 3

There will be no significant difference in the effect of the three detergents on the shape retention for each of the selected children's sleepwear garments, when laundered in water of medium hardness level.

The effect of repeated laundering on the shape retention of the acetate/polyester garments was found to be highly significant. Therefore, Hypothesis 3 was rejected.

Hypothesis 4

There will be no significant difference in the effect of the three detergents on the property of hand for each of the selected children's sleepwear garments, when laundered in water of medium hardness level.

It was found that the hand of the acetate/polyester and cotton garments was significantly affected by repeated laundering. Therefore, Hypothesis 4 was rejected.

Hypothesis 5

There will be no significant difference in the effect of the three detergents on the amount of pilling for each of the selected children's sleepwear garments, when laundered in water of medium hardness level.

The effects of repeated laundering on the amount of pilling of the acetate/polyester garments were found to be highly significant. Therefore, Hypothesis 5 was rejected.

VII. RECOMMENDATIONS

Although the garments tested in this study were representative of those on the market in the fall of 1974, the flame retardant fibers and finishes are ever-changing, due to improved technology in the flammability field. Consequently, recommendations can be based only on the data gathered for garments of this study.

Garments made of the inherently flame resistant fiber performed better through laundering than those made of flame retardant-treated fibers. Evidence revealed that the untreated 100 percent nylon garments performed markedly better than the two treated garment types. Of these two types, the 80 percent acetate/20 percent polyester garments showed poor serviceability, as far as aesthetic properties. The 100 percent cotton garments performed better than the former, but were unacceptable when laundered in the no-phosphate detergent. These cotton garments failed the flammability test after ten launderings and were therefore considered unsafe for wearing by children.

It may also be concluded that the initial labeling of fiber content, care procedures, and price on children's sleepwear are not necessarily guides to the performance of the garments. Thus, the findings of this study point up the dilemma of consumers when selecting sleepwear garments for their children.

VIII. RECOMMENDATIONS FOR FURTHER STUDY

1. Further investigation is needed to test the effects of detergents on the aesthetic properties and flammability of children's sleepwear currently on the market.

2. Further laboratory studies would provide a better performance evaluation of the garments if a wear period were incorporated.

3. Further investigation is needed to test other flame resistant clothing as it appears on the market.

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APPENDIXES

APPENDIX A

ANALYSIS OF FABRIC SPECIMENS FOR FLAMMABILITY FINISHES

Fabric	% Nitrogen	% Bromine	% Phosphorus	Approximate Type of Finish
Cotton	1.93	—	2.10	THPOH Ammonia or Pyrovatex
Nylon	—	0.028	—	None
Acetate/ Polyester	0.064	3.93	0.290	TRIS Di-bromo-propylphosphate

Fabric specimens were chemically analyzed at the following laboratory:

Galbraith Laboratories, Inc.
2323 Sycamore Drive
Knoxville, Tennessee 37921

APPENDIX B

WATER HARDNESS LEVELS; MONTHLY AVERAGES

January	91	June	88
February	93	July	90
March	78	August	86
April	86	September	86
May	85	October	70

This information was received from:

Knoxville Utilities Board
Bureau of Water
626 Gay Street
Knoxville, Tennessee 37901

APPENDIX C

SAMPLE RATING SHEET

HAND

1	2	3	4	5
Very Harsh	Harsh	Neither Harsh Nor Soft	Less Soft	Soft

PILLING

1	2	3	4	5
				No Pilling

SHAPE RETENTION

1. Acceptable - Little change in size with practically no shape distortion
2. Less Acceptable - Some change in size with no shape distortion
3. Unacceptable - Some change in size with moderate shape distortion
4. More Unacceptable - Large change in size with moderate shape distortion
5. Most Unacceptable - Large change in size with great shape distortion

VITA

Carolyn Elaine Trotter Ashley was born in Norfolk, Virginia, on September 15, 1953. She graduated from Brunswick High School, Brunswick, Georgia, in 1971. Undergraduate studies were pursued at Georgia Southern College where, in 1974, she received a Bachelor of Science in Education degree, majoring in Home Economics.

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On August 31, 1975, she was married to Eric Holmes Ashley.