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I am submitting herewith a thesis written by Kathleen R. Wachter entitled "An Evaluation of Selected Commercial Cationic Fabric Softeners on the Flammability and Absorbency of Selected Flame Retardant Fabrics." 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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AN EVALUATION OF SELECTED COMMERCIAL CATIONIC FABRIC SOFTENERS ON THE FLAMMABILITY AND ABSORBENCY OF SELECTED FLAME RETARDANT FABRICS

A Thesis

Presented for the

Master of Science

Degree

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ABSTRACT

The objectives of this research were to evaluate the effect of four cationic softeners, identified in the appendix, at selected concentrations on the flame resistance and absorbency of six flame retardant fabrics. The six fabrics used were cordelan, nylon, cotton, polyester, modacrylic, and acetate. The study was designed to evaluate interactions of softener type, levels of softener, and fabrics on the flame retardancy, sinking time, and wicking of the six flame retardant fabrics.

Fabric samples were cut from commerical fabrics. After cutting and edge stitching, each individual group of fabrics was washed with AATCC #124 detergent and tumble dried. Softeners were applied to the fabrics at the required levels by a pad-dry technique using a Butterworth laboratory padder. Test specimens were cut from fabric samples and conditioned for testing. Specimens for the flame test were conditioned according to DOC FF 3-71 standards. The sinking time test, adapted from the Diaper Institute, utilized specimens conditioned in a controlled environment prior to testing. A ten minute time limit was established for sinking. The wicking was adapted from Weirick's Absorbency Test and was conducted with specimens under ambient room conditions. Readings were taken at one, five, and ten minute intervals in both warp and fill directions.

The warp and fill values were averaged together for data analysis only at the ten minute interval.

Evaluations for flame retardancy, sinking time, and wicking were based on an analysis of variance using a Wang Programmable Calculator. Results indicated that there was no effect of softener on the flame resistance of the six fabrics studied. However fabric absorbency as measured by wicking and sinking time was effected by the softeners applied, either becoming more absorbent with increasing concentration as some of the synthetics exhibited, or became less absorbent as exhibited by the cotton fabric.

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CHAPTER I

INTRODUCTION

Fire was one of man's earliest and greatest discoveries and has contributed significantly to man's existence. People who are not alert to the hazards of fire may needlessly be exposed. Clothing flammability constitutes one of these hazards and as a result many die each year and others are permanently scarred due to unfortunate exposure to flame.

Prior to 1953 flammable clothing constituted such a hazard that a committee was established by the National Retail Merchants Association and the American Association of Textile Chemists and Colorists (AATCC) to study the flammability of clothing (2). Today, deaths from burns rank third behind auto accident deaths and deaths from falls. However, not all burn deaths are the direct result of ignition of textile products.

In following years laws were passed for regulation of flammable clothing. As a result of these laws, research has found fibers and finishes that are flame resistant, durable, nontoxic, and of reasonable cost for both the producer and the consumer. Research, despite earlier problems, may now concentrate on cost reduction in fibers and finishes; and hence will continue to provide the impetus for newer and more functional finishes and fabrics thereby eliminating some of the problems arising from environmental and

ecological concerns. Flame resistant (FR) fabrics used for this study are cordelan, a matrix of 50% vinal and 50% vinyon; 100% nylon, 100% cotton flannelette, 100% polyester, 65% SEF modacrylic/ 35% polyester, and 80% acetate/20% polyester.

In finishing a fabric for flame resistance, changes in either the physical characteristics or chemical properties are involved. Sometimes the end product does not have the aesthetics that a potential customer would desire. Therefore, unless differences in quality can be eliminated in the fiber stage finishes must be applied. Softeners are a type of finish often used to improve aesthetic qualities and reduce problems in dyeing and finishing.

Softeners have been used by the industry since the 1930's. They were important in the fixing or setting of dyes. Previously dyes tended to distribute unevenly when applied to the fabric (8, 32). In the mid 50's softeners were offered for sale on the retail market. The initial response was negative; yet with the increasing acceptance of synthetic detergents in the home, new ways had to be implemented to obtain the softness and smoothness which previously had been obtained by the use of soap based products. The softeners were promoted as increasing softness and easing ironing chores for the housewife (29).

Softening agents can be composed of cationic, anionic, or nonionic compounds. The type of softener chosen depends on the

charge exhibited by the fabric in water. The largest offering of softeners for the home market are cationic. The softeners are offered in concentrate or nonconcentrate forms and are primarily used in the rinse cycle. The softeners used in this study are identified in the appendix. Some nonionic softeners are offered which can be added in the wash phase of the laundry cycle. Caution is advised because of possible reaction between detergent and nonionic softener.

The softener molecule, when solubilized in water, is composed of a hydrophobic end and a hydrophilic end (25). The positively charged hydrophilic end, in water, is attracted to the negatively charged fabric surface. Because of the attraction between the softener and the fabric, there is the possibility of a build-up of softener. This may decrease fabric absorptive capacity over a period of time (30). If it decreases the absorptive capacity, it may also decrease the flame resistance of the fabric.

Because it is known that there is some retention of the fabric softener, one may question its effect on fabric absorbency and fabric flammability. A garment should be able to absorb moisture that is generated by the body and allow the skin to breathe. If the fabric exhibits water repellent properties, the moisture from the skin will not be absorbed.

A fabric's absorptive mechanism depends upon the physical characteristics of the material itself. A natural fabric (e.g., cotton) will differ from a synthetic (e.g., polyester) in

its uptake of moisture. Some fabrics may absorb moisture on the surface while none is absorbed into the fiber (17). To test these ideas adaptations of the Diaper Institute sink time and the Weirick's wicking absorbency are used.

While softeners give desirable aesthetics otherwise not possible, the flammability of the fabric should be considered in relation to softeners. The fabric softener may or may not reduce the flame resistance of a FR fabric. There has been a lack of information in published literature on an FR fabric's flammability when softeners have been applied.

The interrelationship of these factors may be seen when examined collectively. The objectives of this research are to investigate:

1. Fabric flammability, initially, and after treatment with cationic softeners.

2. Fabric absorbency initially, and after softeners have been applied.

Statement of the Problem

Softeners are used to enhance the aesthetic qualities that consumers consider when purchasing a garment. The consumer uses softeners to make the care of garments easier, to attain the improved characteristics of hand, and to prevent the occurrence of negative properties (e.g., static build-up and wrinkling). If the consumer consistently uses the softener each time the garment

is laundered, desirable aesthetics may be affected. If a build-up occurs, the flammability may be changed. It may be possible that the fabric is no longer flame resistant. This could be a very important consideration since these FR finishes have been developed for the consumers protection. With these finishes, water repellency and flammability are undesirable even when softeners are used. There has been little published literature on the effect of differing concentration levels of softeners on the flame resistance and absorptive capacity of these fire retardant fabrics.

Need for the Study

Since softeners were first introduced to the home market, there has been a gradual increase in their use. As a result of the static build-up problem with today's synthetic fabrics, softener use has increased. The FR finishes that have been developed for producing flame resistant fabrics have led to some undesirable characteristics such as stiff fabrics, and malodorous finishes. To counteract these problems, homemakers may add softeners to reduce the stiff, harsh feel and the perfume in the softeners may mask the odor resulting from finishing.

It has been hypothesized that, in time, a build-up of softener occurs. Exactly how much has not been determined. If there is a build-up, it may affect the absorbency. The level of softener may influence the water repellency and flame resistance of a fabric. This study will investigate these properties so that both consumers and manufacturers may become more informed.

Assumptions

1. The concentration range of: 0%, 0.1%, 0.5%, 1.0% bracket the probable levels that may be applied in home laundry resulting from build-up of fabric softeners.

2. Cationic softeners are most often used in home laundering.

3. The types of softeners chosen are representative of those most frequently used.

Limitations

1. The application procedure for softeners does not simulate home laundry conditions.

2. Application by padding may give uneven distribution of the softener on the fabric.

3. The study is limited to six flame resistant fabrics and four commercially available cationic fabric softeners.

Objectives

1. To determine the effects of four concentration levels of the four fabric softeners on flammability characteristics of the six FR fabrics.

2. To determine the difference between the four softeners and their effect on the flammability characteristics of the six FR fabrics.

3. To determine the effects on absorbency resulting from the four concentration levels of the four softeners.

Definitions

The following terms are defined according to usage in this study:

Fire retardant finish—a topical application of chemicals to fabrics thereby increasing flame resistance. This finish may be durable or nondurable (22).

Flame resistant fabrics—those treated with chemicals or coating to resist flame. Abbreviated in the text as FR (23).

Flammability—when exposed to flame, a fabric catches fire easily (23).

CHAPTER II

REVIEW OF LITERATURE

Flammability

The problem of flammability has been around since fire was first discovered. As early as the 1700's people were experimenting with ways to make fabrics less flammable. Cotton was the first fabric to be researched for flame resistance (2). Aenishanslin (1) discusses finishes developed in the 30's to give flame retarding properties.

Impetus for flame resistant fabrics began after the Cocoanut Grove Nightclub fire in November, 1942 (24). Other incidents that helped to bring flammability into focus were the rayon "torch" sweaters and cowboy chaps. These articles of clothing were highly flammable needing only a spark from a fire to burst into flame.

Acts and Amendments

It was not until 1953 that a formal act was passed that afforded some protection from the extremely flammable clothing of previous burning incidents. The act of 1953 was employed quite extensively until 1967 when an amendment to the law was signed by President Johnson. The amended law included household goods in addition to personal apparel, and became effective one year later (19). The 1967 amended law enabled the Secretary of Commerce to

initiate standards for the public good. The Health, Education and Welfare department could investigate and keep records of burn injuries (16). An Information Council on Fabric Flammability was formed at this time to investigate the flammability problem and offer solutions. Since then, automobile interiors, airplane interiors, rugs, carpets, mattresses and bedding material have been required to comply with standards on flammability.

The Flammable Fabrics Act for Children's Sleepwear sizes 0-6X was instituted in 1971 with regulations for testing of the fabrics. In May 1973 the act was expanded to include children's sleepwear sizes 7-14.

Fabric Characteristics

Under the proper conditions, all fabrics will burn, char, or melt. Some fabrics are easier to ignite than others. Actual wear conditions can also influence a fabric's combustibility (12). Baker (2) has classified fabrics from highly flammable to nonflammable as follows:

1. Cellulosics—cotton, linen, rayon.
2. Man-made—polyester, nylon, acrylic.
3. Animal—silk, wool.
4. Metallics—asbestos, glass, steel.

Other factors such as yarn, weave, fabric weight, and garment design may cause differences in burning characteristics. The blends in use today profoundly affect burning rates.

It is possible to make some fabrics flame resistant with a finish and others by changing their physical characteristics in the melt or dope stage by changing the chemical composition of the fiber. In both instances, end-use performance and aesthetics may be changed creating new problems for both dyer and finisher. Baum suggests the use of additives known to be flame resistant (3). Chemicals such as antimony, bromine, or chlorine have been used. These chemicals are added in the melt or dope stage to synthetics. Topically finishing known flammable fabrics is another possible solution. Phosphorus compounds are often used for the natural fabrics (e.g., cotton, linen). Developing durable flame resistant finishes for fabrics, natural or synthetic has been a problem. Research to produce better fibers and finishes has continued. Synthetics, in particular polyester, seem to be a better alternative for FR fabrics (7).

Developing Flame Resistance

Various ways are possible for developing a flame resistant fabric which meets the standards for flammability. Ways (13) that are possible include:

1. Application of flame resistant chemicals in finishing a fabric.
2. Addition of FR materials in the melt or dope stage prior to extrusion.
3. Use of inherently flame resistant fibers whose chemistry promotes flame retardancy.

Flame resistant chemicals as topical finishes are most often applied to cotton as research was conducted in this area first.

Phosphorus compounds have been used with best results on cotton, but may be used on other cellulosics (1, 11).

Inherently flame resistant synthetics are used in blends with flammable fibers to produce moderately flame resistant fabrics. For some time this approach was an acceptable alternative to use of a flammable fabric alone (13).

Softeners

Softeners were discovered in the early twentieth century and have been used in industry since the 1930's (5, 8, 9, 10, 15, 31). In the early development, the softeners primary purpose was as a dye fixative for direct dyes to combat migration. Softeners were later developed to help repair the damage that occurred during processing and to improve wear and abrasion properties (15).

Initially, the home consumer resisted purchasing softeners on the retail market (10). Many ways of promoting softeners including give aways were tried to sell a product that would reduce ironing while making the fabrics more aesthetically pleasing (31). One favorable factor for the softener industry was the introduction of synthetic detergents to replace soap. Soaps used prior to synthetic detergents coated the fabric giving it a smooth hand. This coating made ironing easier because the surface was smoother. Now smoothness was eliminated by synthetic detergents which did not coat the fabrics. Hence the consumer found that the softener improved the hand and reduced wrinkling.

Means have been used to finish fabrics for flame resistance with a change in some end-use performance properties. Customer satisfaction has been affected because some of the finishes left the handle, drape, smoothness, texture, of the fabric lacking in desirable properties. Softeners have often been employed to help combat this tendency.

Formulation of Softeners

Softeners today may be anionic, cationic, or nonionic compounds. The cationic softeners may be purchased in dilute or concentrate formulations. The typical formulation (10, 31) for the cationics currently offered on the retail market are: cationic softener, 3-8%; rewetting agent, 0.2-2.0%; viscosity additive, 0.1-1.0%; fluorescent dye, 0.05-0.3%; perfume, dye, water, water, bacteriostats, to 100%. Some of the ingredients that can produce softener action are "dihydrogenated tallow dimethyl ammonium chloride, ethoxylated dialkyl dimethyl ammonium sulfate, or imidazolinium derivatives" (32). Bacteriostat and whitening properties have been postulated but this interpretation is open to speculation.

The longer alkyl chain lengths ($C_{16}$to C_{18}) give much better softening properties than those molecules containing twelve or fewer carbons (10, 14). Of the groups containing these longer alkyl chain lengths, the quaternaries may consist of dialkyl dimethyl ammonium chloride with the alkyl group coming from the

hydrogenated ethoxylated analogues (14). To date there has been no explanation for a softeners mode of attachment to a fabric.

The softener action on the fabric is a hard one to assess. One suggested mechanism may be that when the quaternary ammonium compound is dissolved in water it separates into an uncharged hydrophobe end attached to a positively charged hydrophile end which contains nitrogen. Fabric placed in the solution exhibits a negative charge (26), causing the positively charged hydrophile end of the softener to be attracted to the negatively charged fabric. The hydrophile end adheres to the surface of the fabric and leaves the hydrophobe tail of the softener attached (27,28).

Softener Action

Cationics are substantive to some fabrics and laundering does not appreciably inhibit their action (30, 32). The cationic softener promotes smoothness properties and reduces friction between the fibers (10). The hydrophobic arrangement of the outer surface results in the fabric's water resistance. This may occur if the softener was used consistently.

The fabric structure influences how the softener is deposited onto the fabric (10). Softeners generally act on the fabric's surface with the fiber at the interface (5). Good aesthetic appeal is obtained with this type of attraction and the film that congregates at the surface of the fabric (15). As a result, small amounts of cationic softener are required to obtain the desired aesthetics.

Absorbency

"Absorbency in textiles is the quality of taking up a fluid in the manner of a sponge" (4). Man has long been concerned with comfort in clothing. To be comfortable allowances should be made for absorbency, water imbibition, and the ability to maintain thermal body heat (21). High absorbent capability will contribute greatly to the physiological comfort of the wearer. A hindrance for some textile fabrics (e.g., synthetics), is that they do not absorb the moisture from the body.

Problems and Theories Associated with Absorbency

With this problem in mind the question arises as to how the water is absorbed by the garment to maintain proper body temperature, while soaking up excess perspiration. Several theories have been hypothesized about the mechanism of moisture absorption and vapor permeability (4, 20). According to Buras et al.(4), the walls of the fiber support capillary movement of moisture until the complete surface is wet. Several other factors affect the water transport such as the fibers themselves, the twist, construction, arrangement of the fiber (random vs. compact), fiber size, roughness of yarns, water contact angle, crimp, blending of fibers and yarns. These variables may play a significant role in determining water absorption for a given fabric (4, 17).

Knight (20) postulates that water transfer by fibers occurs in fabrics. If the spaces between the fibers are small enough,

it is conceivable that absorption may take place through the spaces only.

Capillary penetration appears as the mechanism by which a fabric holds moisture. There is also an influence by the fibers from the way they are processed into yarns (17). A rough texture may not be suitable for clothing end-use if the arrangement of the fibers is not even. Evenness of the fibers is required to promote absorption. Another reason for capillary penetration is postulated by Hollies (17) who states that open spaces between fibers contain an energy potential.

Laundering will improve absorbency due to compaction, expansion and friction in the laundering cycle (4). This promotes the fabrics wetting more rapidly because the capillary action into small spaces thus formed is faster than in large spaces where it may not occur at all (4).

Studies Conducted on Absorbency

The theories relating to water imbibition aid the understanding of the effects on the absorptive capacity of fabrics treated with a softener. If as hypothesized, there is a coating on the fabric by the softener then there would be a decrease in the absorptive capacity overtime because smaller spaces are available to absorb the moisture. In assessing characteristics that will be of benefit to the consumer, the effect of softeners on the absorbency of fabrics under actual wear conditions would be of practical concern.

Since cationics are known to be substantive, building on the fabric over time, there would appear to be a repellent effect on the fabric when moisture is introduced. Shenai and Mulla (30) in a study on the effect of a cationic softener on cotton fabric concluded that the ascendency of deionized water onto the fabric, when timed, will give an estimate of the content of the softener on the fabric. Therefore, if there is a build-up of softener, the uptake of deionized water onto the fabric would decrease and directly affect the aesthetic quality of the garment for the potential consumer.

Linfield et al. (21), found softeners did not decrease absorbency at low concentration levels. As the concentration level increased the absorption that did occur was at a much slower rate.

A study by the Northern Piedmont Section (28) concerned repeated applications of softeners and its effect on absorbency of terry towels. Three tests for absorbency were conducted. The Weirick's (wicking) Absorbency test, Fieldcrest's Water Absorbency test, and Sink Time test. The Weirick's and Sink Time tests were more reliable in calculating absorption than the Fieldcrest which measures the time necessary for a one by one inch square to sink. Two types of terry towels were used, rayon/cotton and all cotton. While use of the softeners showed visible evidence of build-up, due to a greasy feel, there was no serious loss of absorbency.

DuBrow and Linfield (8) state that over time if an excess of softener should be used, moisture repellency may occur leaving the fabric nonabsorbent.

Mehra et al. (25), showed that rewettability for softened samples with a 0.1% softener concentration, decreased substantially after the first wash and thereafter leveled off.

Hughes and Koch (18) attempted to determine the number of washings required to remove all traces of a 0.1% softener that had been applied to a dry towel. Removal was not complete after two additional launderings without softener.

CHAPTER III

PROCEDURES

This chapter outlines the procedures that were used to prepare specimens, apply softeners, determine wet pick-up, prepare specimens for testing, conduct tests and analyze data gathered.

Fabrics

The flame retardant fabrics used for this study were purchased commercially. All were intended by their manufacturers for use in children's sleepwear. A general description of the fabrics is given in Table I.

Preparation of Specimens

Samples of adequate size to prepare all the needed test specimens were cut from each roll of purchased fabric. These samples measured eleven inches by thirteen inches for cotton and polyester, with the remaining samples measuring twelve inches by fourteen inches to allow for shrinkage in laundering and drying. These samples were numbered consecutively when cut; a total of forty-four samples was cut from each fabric. Two samples from each fabric were used to develop the technique of applying softeners. Six of the fabrics were used as untreated controls. The remaining thirty-six samples were used to provide three samples of each fabric at each level of application of the four fabric softeners.

TABLE I

DESCRIPTION OF FABRICS

FABRIC	FIBER CONTENT	CONSTRUCTION	WEIGHT	COLOR
Cordelan	Cordelan Matrix Fiber	Knit	4.6 oz/yd^2	Print
Nylon	100% Nylon	Brushed Knit	2.3 oz/yd^2	White
Cotton	100% Cotton Flannelette	Woven	4.8 oz/yd^2	Yellow
Polyester	100% Polyester	Knit	4.5 oz/yd^2	Blue
Modacrylic	65% SEF/35% Polyester	Napped Knit	8.1 oz/yd^2	White
Acetate	80% Sayfr Acetate/ 20% Polyester	Brushed Knit	2.6 oz/yd^2	White

After the samples were cut and numbered, they were assigned to a softener number (I, II, III, IV) and a particular softener level (0%, 0.1%, 0.5%, 1.0%). Placement of the samples in the experimental design was done with the assistance of a table of random numbers. Thereafter each fabric was assigned to the same block according to the sample number. The cut rectangles were stitched with colored thread to indicate the softener (I, II, III, IV) to be used. The corners were clipped to indicate softener level application. One corner clipped indicated a 0.1% concentration; two corners clipped indicated a 0.5% softener concentration; and three corners clipped indicated a 1.0% softener concentration. No corners were clipped on the control samples.

Each individual set of fabric samples was washed with 90 grams of AATCC detergent according to AATCC-124-1973 and tumbled dried. This procedure was repeated for each of the six sets of fabrics.

The individual fabric samples were then weighed and the weight was recorded to the nearest 0.1 milligram.

Technique

The two extra samples from each fabric were used to develop the technique. After weighing these samples in the dry state, they were padded with distilled water and run at various pressures through a Butterworth laboratory padder. A wet weight was recorded for the padded sample. The wet pick-up for distilled water was calculated according to the following formula:

$$\% \text{ wet pick-up} = \frac{\text{wet weight - dry weight}}{\text{dry weight}} \times 100$$

This process was replicated for each of the six fabrics. The fabrics were machine dried after each padding. Several trials utilized various pressures. Best results were obtained between thirty pounds per square inch and thirty-six pounds per square inch. After a wet pick-up had been determined for distilled water, two drops of Triton GR-5, a wetting agent, were added to the distilled water and the specimens were padded with the solution and reweighed. Percentage wet pick-up with the Triton GR-5 wetting agent was calculated, using the preceding formula.

Results obtained for the padding with the surfactant solution were used to determine wet pick-up for subsequent addition of softeners.

Preparation of Softeners

Four commercially available cationic softeners were chosen for testing, and are identified in the appendix. All four softeners were concentrated formulations.

The active content of the solids for each softener was determined by pipetting 5.0 ml of the softener onto a tared watchglass, and the weight of softener solution recorded. These specimens were oven dried at a temperature of 81°C to constant weight. An average dry solids content was calculated as follows:

$$\% \text{ active solids} = \frac{\text{dry weight}}{\text{wet weight}} \times 100$$

Preparation of Pad Bath

The solids content was calculated for each of the four softeners. A pad bath was formulated to give a desired softener level based on the fabric weight of each specimen group.

Separate pad baths were calculated for cordelan and polyester based on their wet pick-ups with distilled water containing Triton GR-5. The pad baths for the remaining samples were calculated on the basis of 100% wet pick-up.

The formula used to calculate pad bath concentration was as follows:

$$\frac{\text{X g softener}}{\text{weight of the fabric (g)}} \times 100 = 0.1\% \text{ (or } 0.5\% \text{ or } 1.0\%)$$

A specified quantity of distilled water was added to the calculated amount of softener for each pad bath. Pad baths of four hundred milliliters water each was used for the cordelan and the polyester. A pad bath of 1200 ml was calculated for the remaining four fabrics. The softener pad baths were designed to have a hundredfold excess of solution so that the concentrations would remain constant as padding of various samples was completed.

After the samples were padded with the softener solution, the specimens were hung and allowed to air dry. After drying the samples were cut into test specimens for flammability, wicking, and sink time absorbency tests.

Preparation of Specimens for Testing

The test for flammability was conducted according to DOC FF 3-71 specifications (6).

The Sink Time Absorbency Test was adapted from the Diaper Institute, using a four inch square folded to one inch and then dropped into 800 ml of distilled water (21). A ten minute time limit was established for the specimens to sink. The time required for the specimen to sink was recorded in seconds. Three replications for each softener and softener level were recorded and averaged.

The Wicking Absorbency test utilized a one inch by eight inch piece of fabric (28). A warp and a fill specimen were cut. The specimens were suspended by tape from a rod and weighted with a clip at the bottom. The eight inch strip was then immersed one-half inch into the distilled water to which a water soluble red coloring had been added to facilitate measurement. Readings for the wicking specimens were taken at one minute, five minute, and ten minute intervals with the height of the water column being recorded in inches.

Statistical Analysis

After all testing had been completed and recorded, averages for each of the tests, (flame test, sink time absorbency, and wicking absorbency warp and fill) were calculated and graphs prepared showing the average effect of the softener at the four levels of concentration and four softeners for each fabric.

Analysis of variance was calculated using a Wang Computer Programmable Calculator 600-14-TP to determine interactions between fabric, levels of softener and wicking, and sink time.

CHAPTER IV

PRESENTATION OF DATA AND DISCUSSION OF RESULTS

Data are presented on the effects of the six FR fabrics, four softeners, and four softener levels in relation to the effect on flammability, the effect on sink time absorbency and the effect on wicking absorbency.

Flammability

The first point to be considered was the effect of softener on flammability as determined by the vertical forced ignition test, DOC FF 3-71. Figures 1-4 show the dependent variable, average char length in inches as a function of level of applied softener. Each figure represents a different softener; the char lengths for the six fabrics are shown. Analysis of variance for the data shown in Figures 1-4 showed that the fabric softeners, and level of applied softener had no effect on fabric flammability. The fabrics themselves had different levels of flammability (probability > .999) but were unaffected by the add-on of softener. No significant interactions between fabric and softener or level of softener were observed. Since the levels of softener add-on were greater than those expected to build up on the fabrics in laundering, it appears that a softener could be used in home laundering with no adverse effects on the flame retardant properties of these fabrics.

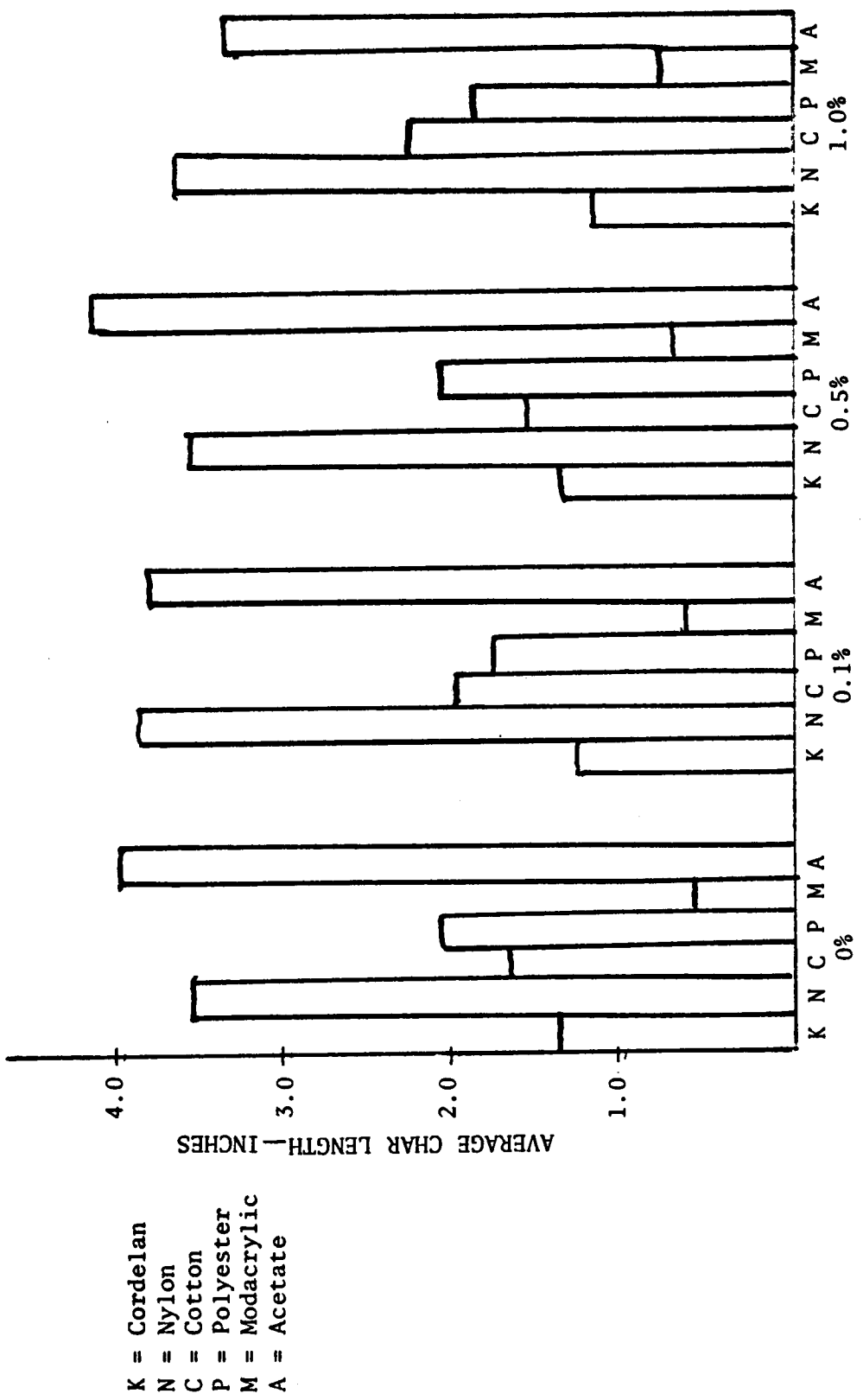


Figure 1. Char Length As a Function of Add-on for Softener I for Six FR Sleepwear Fabrics.

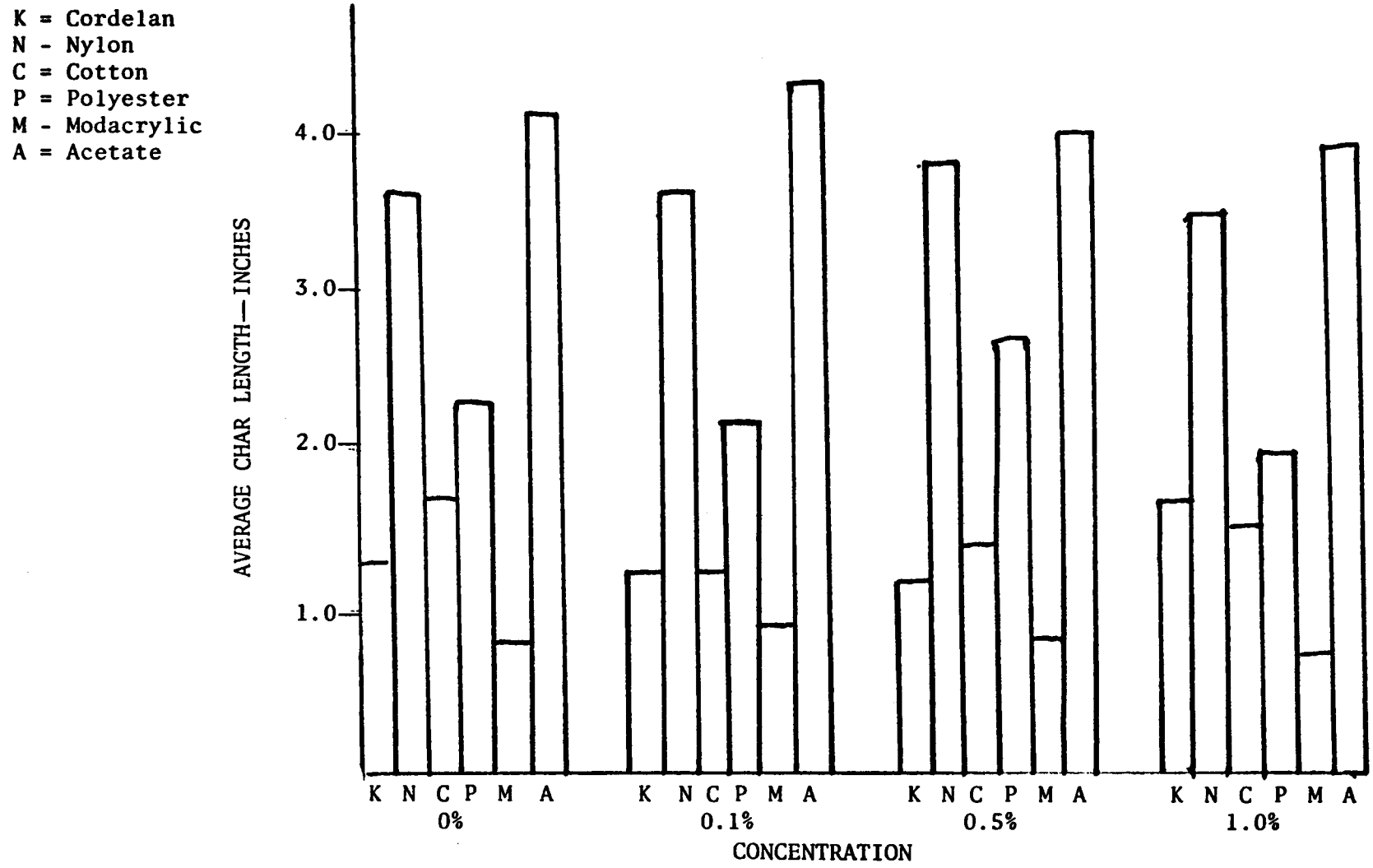


Figure 2. Char Length As a Function of Add-on for Softener II for Six FR Sleepwear Fabrics.

K = Cordelan
N = Nylon
C = Cotton
P = Polyester
M - Modacrylic
A = Acetate

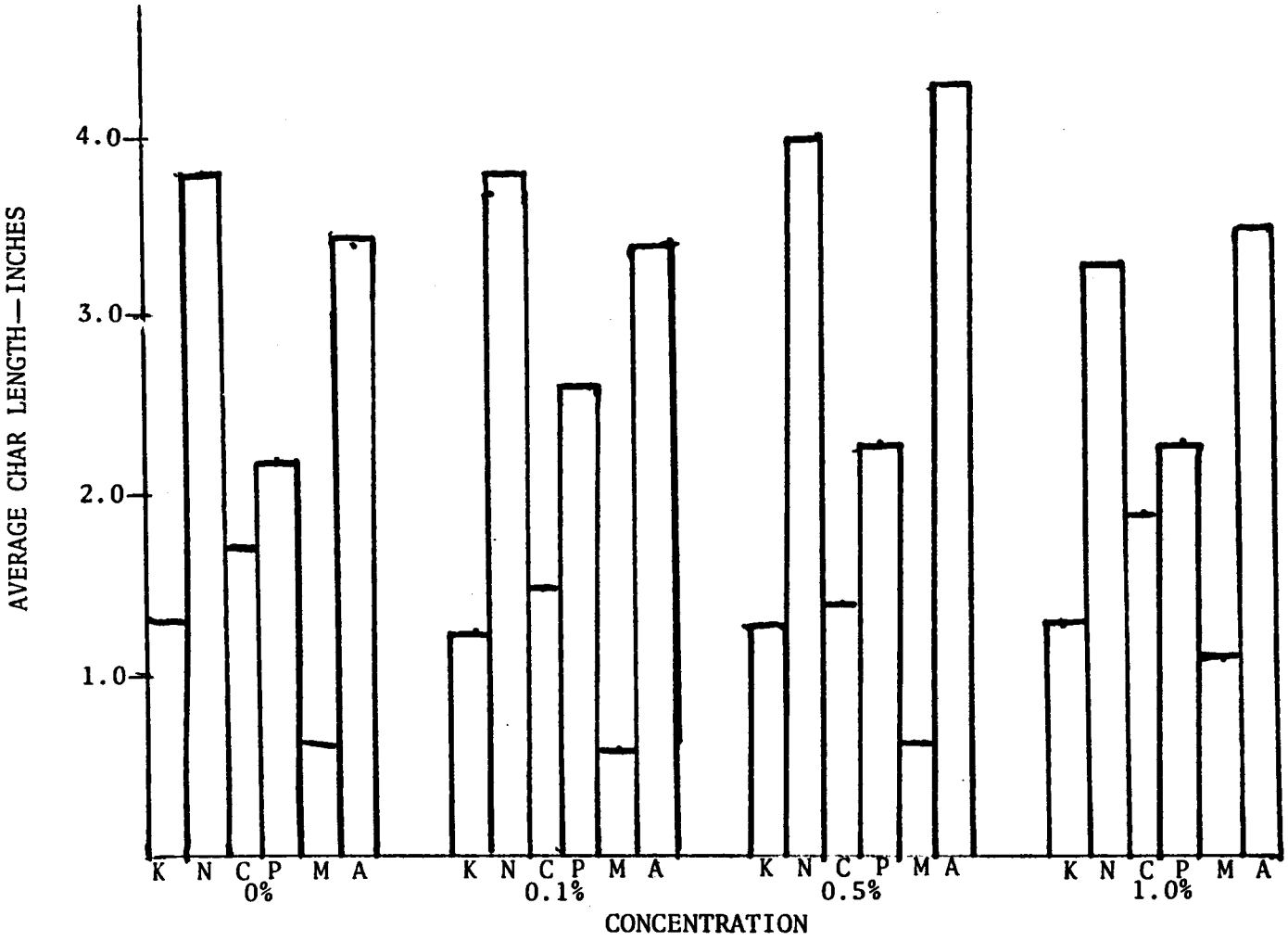


Figure 3. Char Length As a Function of Add-on for Softener III for Six FR Sleepwear Fabrics.

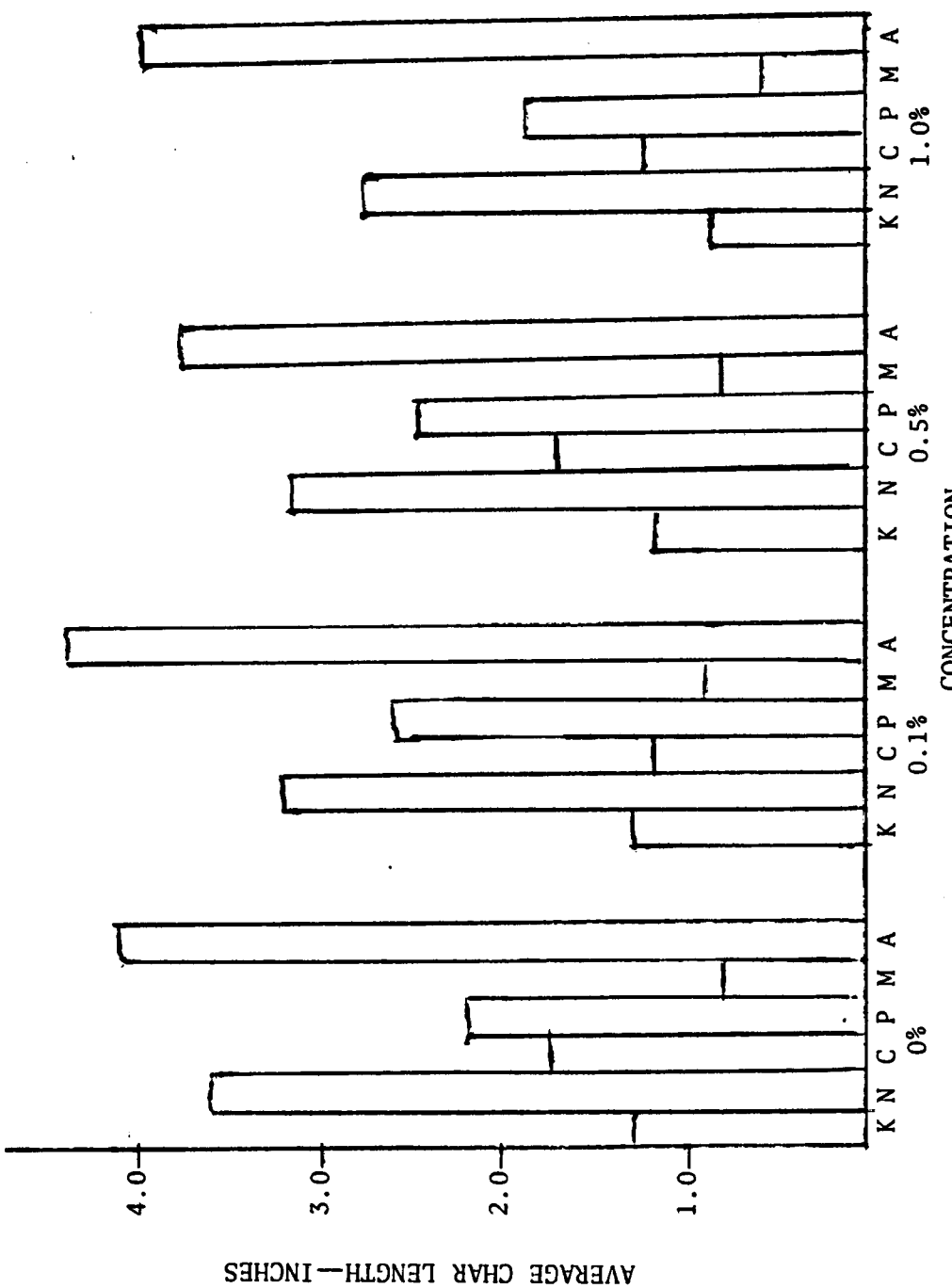


Figure 4. Char Length As a Function of Add-on for Softener IV for Six FR Sleepwear Fabrics.

The flame test results verified the manufacturers claims for all six FR fabrics. Individual flame characteristics were noted for several fabrics. The nylon continued to flame on the side of the fabric after the removal of the burner flame. The cotton flared in the initial burn, but would self-extinguish with heavy smoke moving to the top of the fabric specimen.

Figure 1 shows the effect of softener I on the char length of the six fabrics for the concentration levels stated. Overall the net effect of this softener on the FR fabrics was no significant influence on the flame retardant properties.

The individual fabrics exhibited unique characteristics when exposed to flame. The nylon continued to flame on the side of the fabric. While not increasing the char length, softener increased the flame time. At succeeding levels the tendency to flame on the side or end of the fabric continued.

The cotton at the high softener concentration level had the flame skip the fabric leaving 0.12 inch untouched by flame and proceeded to burn 1.5 inches more. These results suggest a nonuniform application of softener to the fabric.

Figure 2 shows that softener II does not affect the FR properties of the six fabrics. As the concentration level is increased, four of the six fabrics show a slight decrease in char length, substantiating the conclusion of no significant damage to flammability by the higher concentrations.

For softener II the acetate and nylon exhibited side flame tendencies when the flame was withdrawn in contrast to the nylon for softener I. The modacrylic flame skipped the fabric leaving 0.12 inch of fabric melted. Cordelan exhibited burn spots in the fabric surrounding the initial burn length.

Therefore, softener II, while not causing failure of the six FR fabrics, introduced individual tendencies in burning not found when testing the controls under the same conditions.

Figure 3 shows no significant differences in char length for softener III and the six fabrics, but does show a slightly reduced char length for two of the fabrics at the higher concentration levels.

Individual flaming tendencies were more noticeable at the lower concentration of softener III. Cotton flashed before extinguishing with heavy smoke given off after extinction. The modacrylic continued to flame but did not increase char length after the flame was removed. Nylon continued to flame on the side after the ignition source was removed.

Figure 4 represents softener IV which showed an initial increase for most of the fabrics at the low concentration. There was a decrease for all fabrics at the higher concentration levels. Softener IV slightly decreased all char lengths relative to the control while softeners I, II, III, do not affect the fabrics in this manner.

The nylon fabric at the high concentrations flamed on the side increasing flame time but not char length. Cotton's flame with softener IV tended to move up the fabric without charring the fabric

beyond a certain level. Cordelan and modacrylic exhibited spacing and skipping from the ignition source.

Overall it would be safe to use the four commercial fabric softeners at higher concentration levels with no significant decrease in flame retarding properties.

Sink Time

The sink time test results are shown in Figures 5-10. The dependent variable, average sink time in seconds, is shown as a function of softener concentration. Each figure represents one FR fabric; all softeners are shown at the levels applied.

The test results indicated that the individual fabrics react differently with each of the four softeners, whereas in the flame test the fabrics did not vary significantly with each softener. In the following analysis the softeners did influence sinking time over varying concentration levels.

The control fabrics, except for cotton and acetate, were nonabsorbent as determined by this test. For the cordelan fabric (Figure 5) all softeners tend to increase absorbency, but softener II does so to a lesser extent than do the other three. At levels likely to be encountered during home laundering, no softeners are effective in increasing absorbency of the cordelan.

For the nylon fabric (Figure 6) all softeners except softener I caused a sharp increase in absorbency as shown by the greatly reduced sink time. Softener III continued to reduce sink time at higher levels,

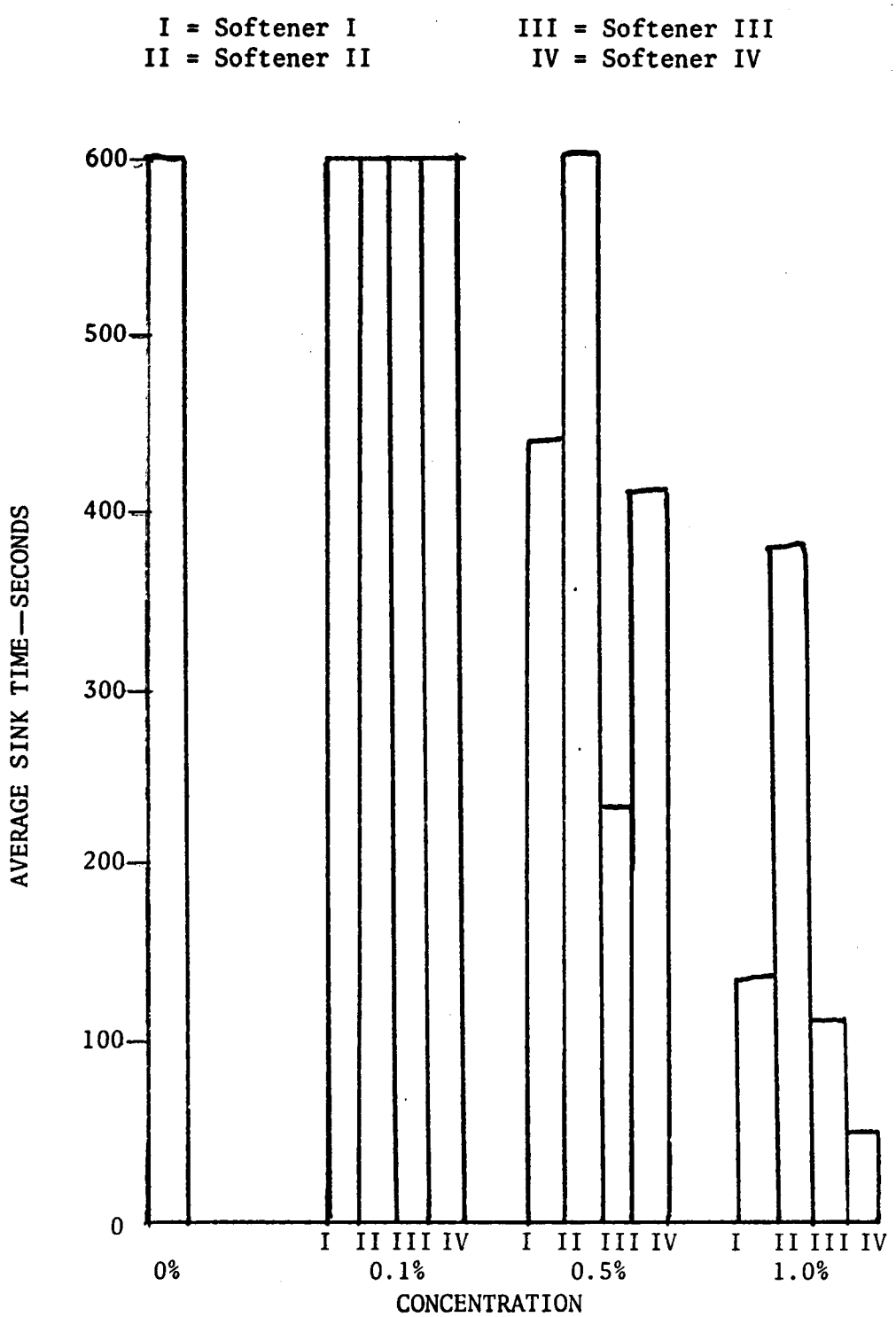


Figure 5. Effect on Sink Time of Softener I, II, III, IV for Cordelan

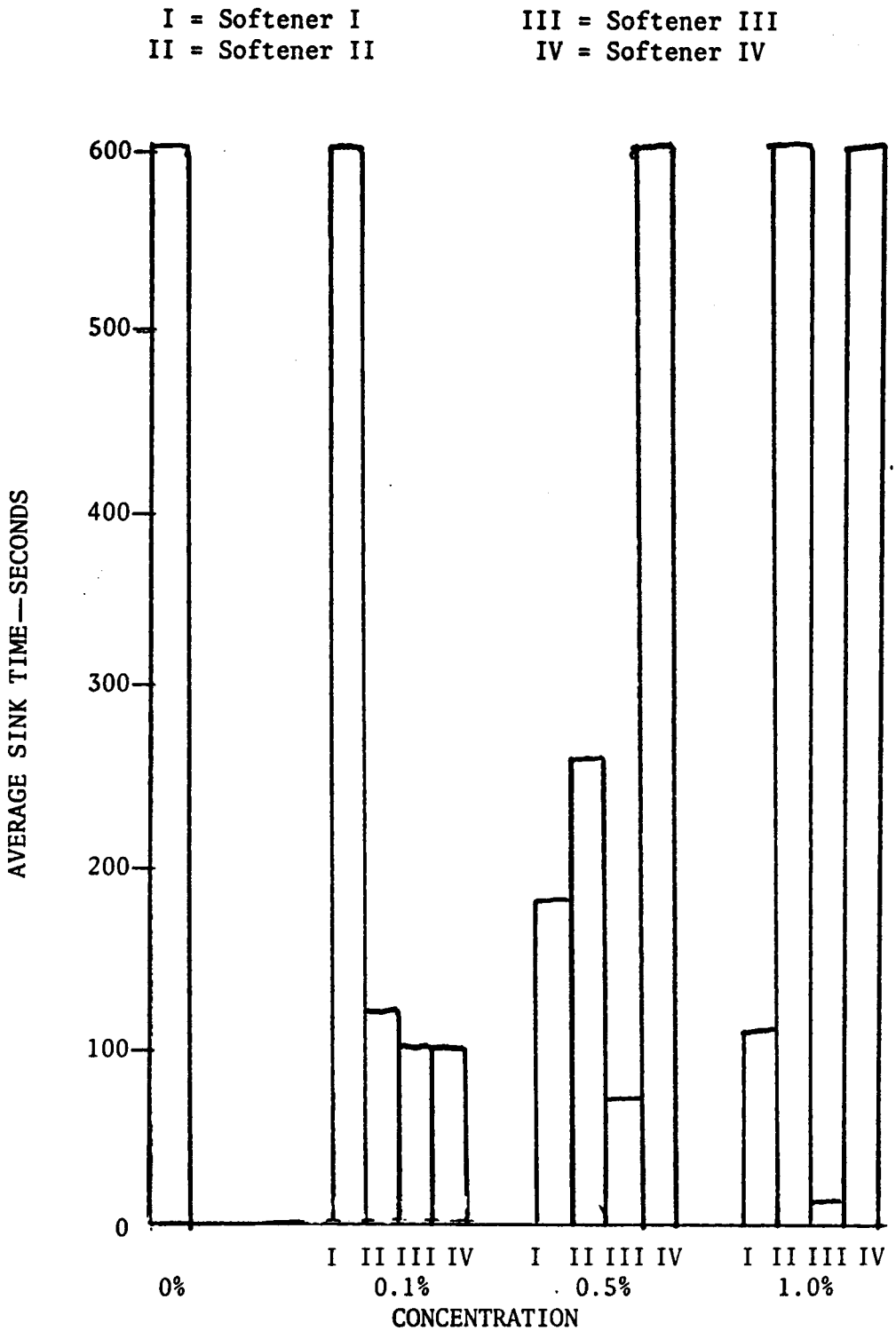


Figure 6. Effect on Sink Time of Softener I, II, III, IV for Nylon

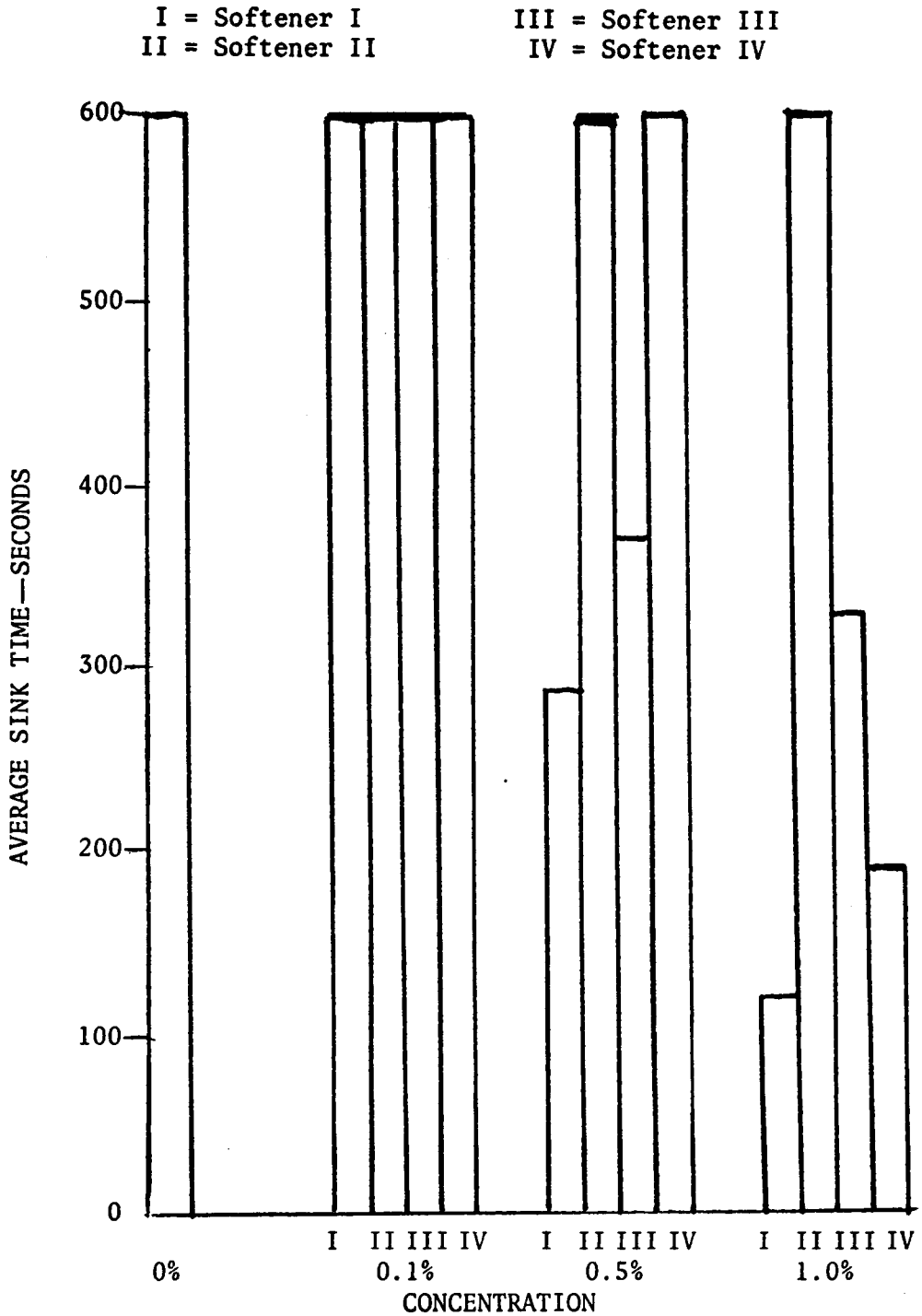


Figure 7. Effect on Sink Time of Softener I, II, III, IV for Modacrylic

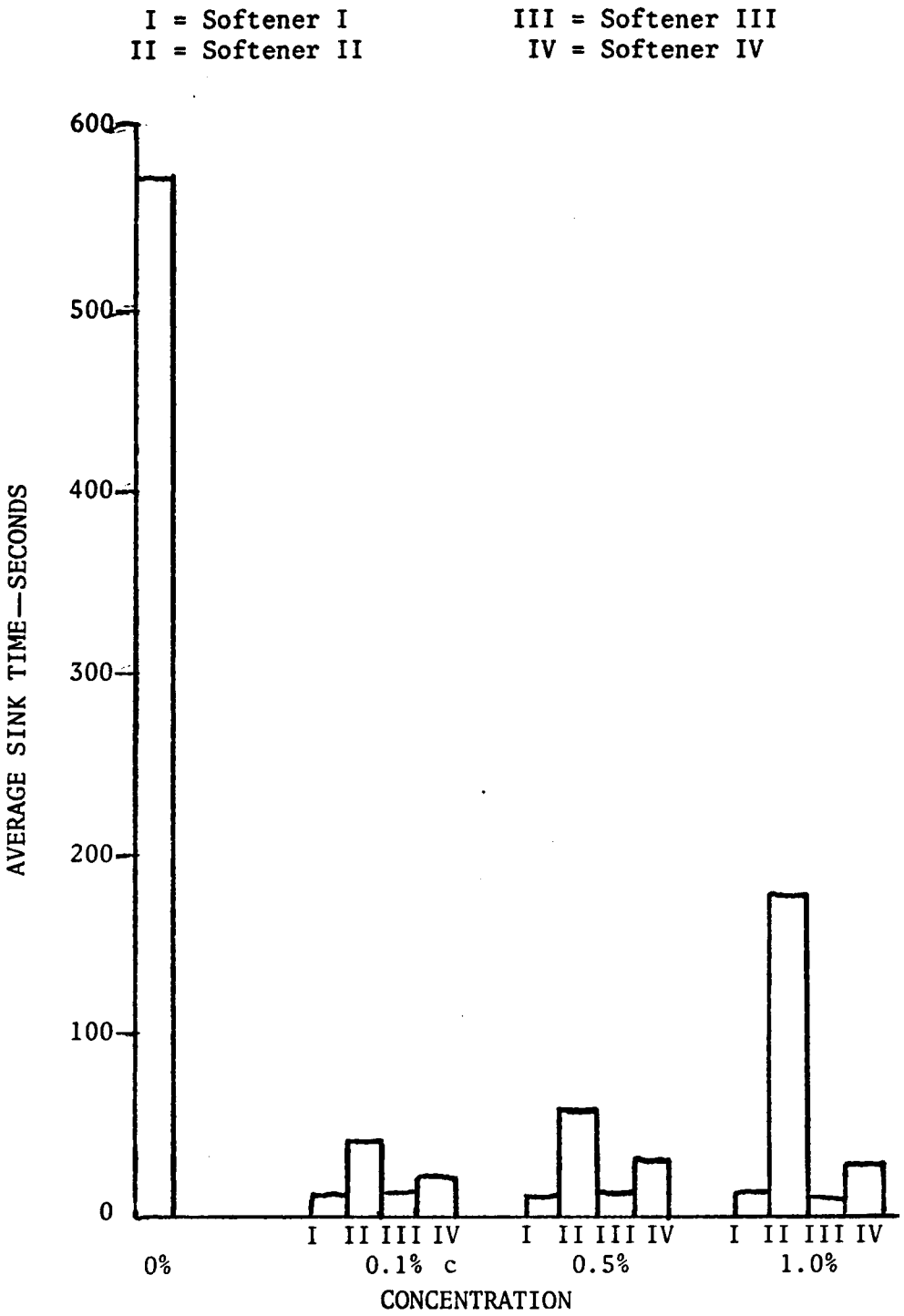


Figure 8. Effect on Sink Time of Softener I, II, III, IV for Polyester

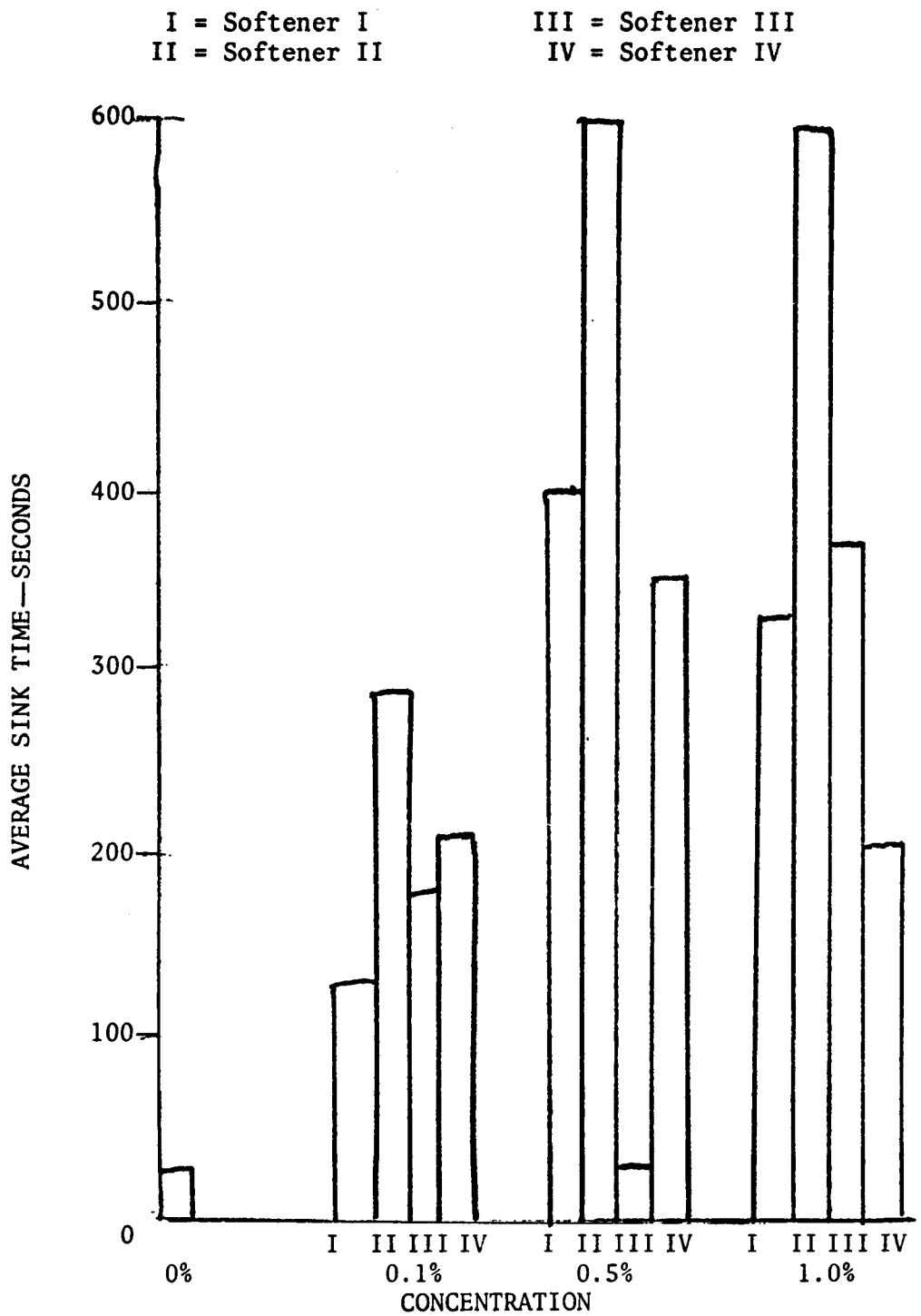


Figure 9. Effect on Sink Time of Softener I, II, III, IV for Cotton

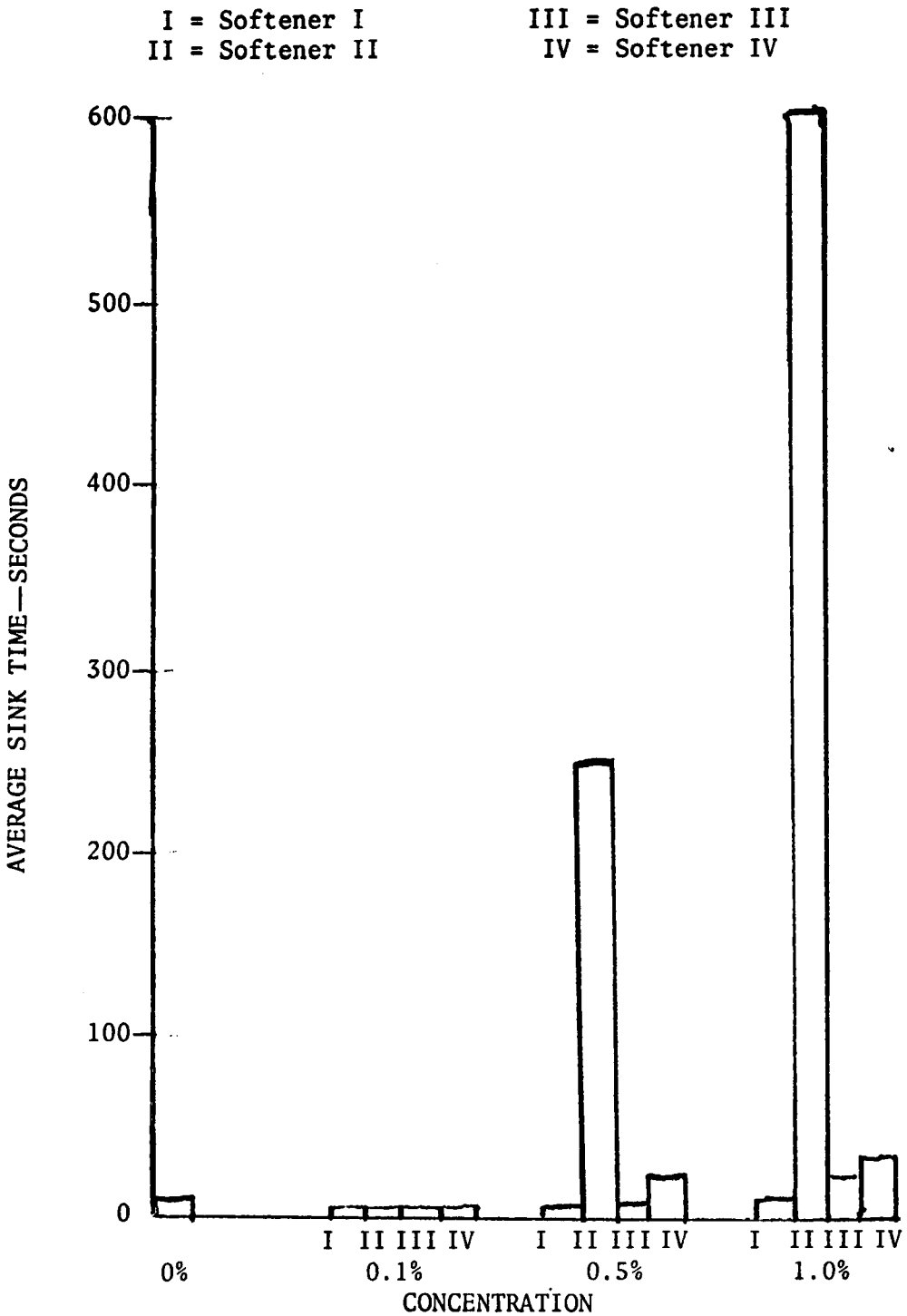


Figure 10. Effect on Sink Time of Softener I, II, III, IV for Acetate

but softeners II and IV did not. Softener I was effective in reducing sink time only at levels higher than expected during home laundering.

The modacrylic fabric (Figure 7) showed behavior similar to that of the cordelan fabric, in that low levels of applied softener did not reduce sink time. Higher levels of softeners I, III, and IV did cause some reduction in sink time but softener II was ineffective at all levels. Softener II was also least effective for the cordelan.

Results for the polyester fabric are shown in Figure 8. All softeners showed a considerable decrease in sink time and hence an increase in absorbency at the lowest level applied (0.1%). Application of higher levels of softeners I, III, and IV did not cause any change in sink time, but higher levels of softener II caused a decrease in absorbency. Polyester fabric more closely resembled nylon in its behavior than the cordelan or the modacrylic.

Figure 9 shows results obtained for the cotton fabric. The fabric was initially highly absorbent and application of all softeners caused a reduction in absorbency as indicated by longer sink times. Softener II was the least effective in this respect, causing the most rapid loss in absorbency and, at high levels, rendering the fabric water repellent.

Acetate (Figure 10) was similar to cotton with respect to initial sink time. Unlike cotton as the concentration levels increased the absorbency remained essentially unchanged except with softener II which caused a decrease in absorbency, especially at the higher levels.

Generally, softener I increased absorbency at the higher levels for cordelan, nylon, modacrylic, and polyester, and decreased the absorbency for cotton. The sink time for the acetate fabric was not affected by softener I. At the 0.1% level, cordelan and modacrylic were not made more absorbent; polyester and nylon were made more absorbent; the high absorbency of cotton was reduced; and the high absorbency of acetate was unaffected.

Softener II was the least effective of the four softeners, generally not improving the absorbency of the nonabsorbent fabrics and causing greatest losses on absorbency for the absorbent fabrics. It was the only softener which made acetate nonabsorbent. Softener III increased absorbency for cordelan and nylon at all levels over the untreated control. Acetate was unaffected. Polyester was made absorbent at the 0.1% level. Further increases in level caused no further effect. Modacrylic sink time was reduced only at the highest level applied. Cotton was made less absorbent at all levels applied. Softener IV increased the absorbency of modacrylic at higher levels. The absorbency of polyester and of nylon was greatly increased at the 0.1% level. Higher levels caused a reversal for nylon but did not affect polyester. This softener also produced no effect on sink time for acetate. Cotton's absorbency decreased over the control at all levels.

Wicking Absorbency

The distance distilled water ascended in ten minutes is shown in Figures 11-16 for each fabric. The height shown is the average of the

I = Softener I
II = Softener II
III = Softener III
IV = Softener IV

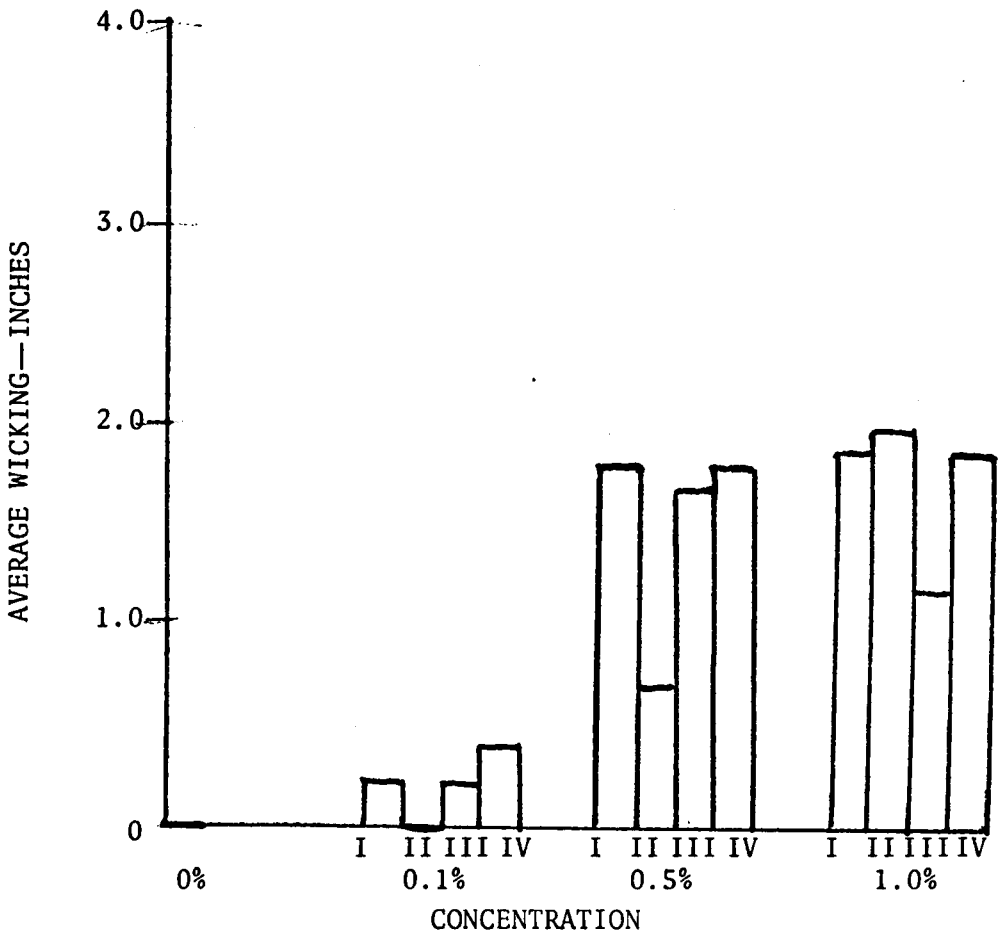


Figure 11. Effect on Wicking Absorbence As a Function of Add-on for Softener I, II, III, IV for Cordelan

I = Softener I
II = Softener II
III = Softener III
IV = Softener IV

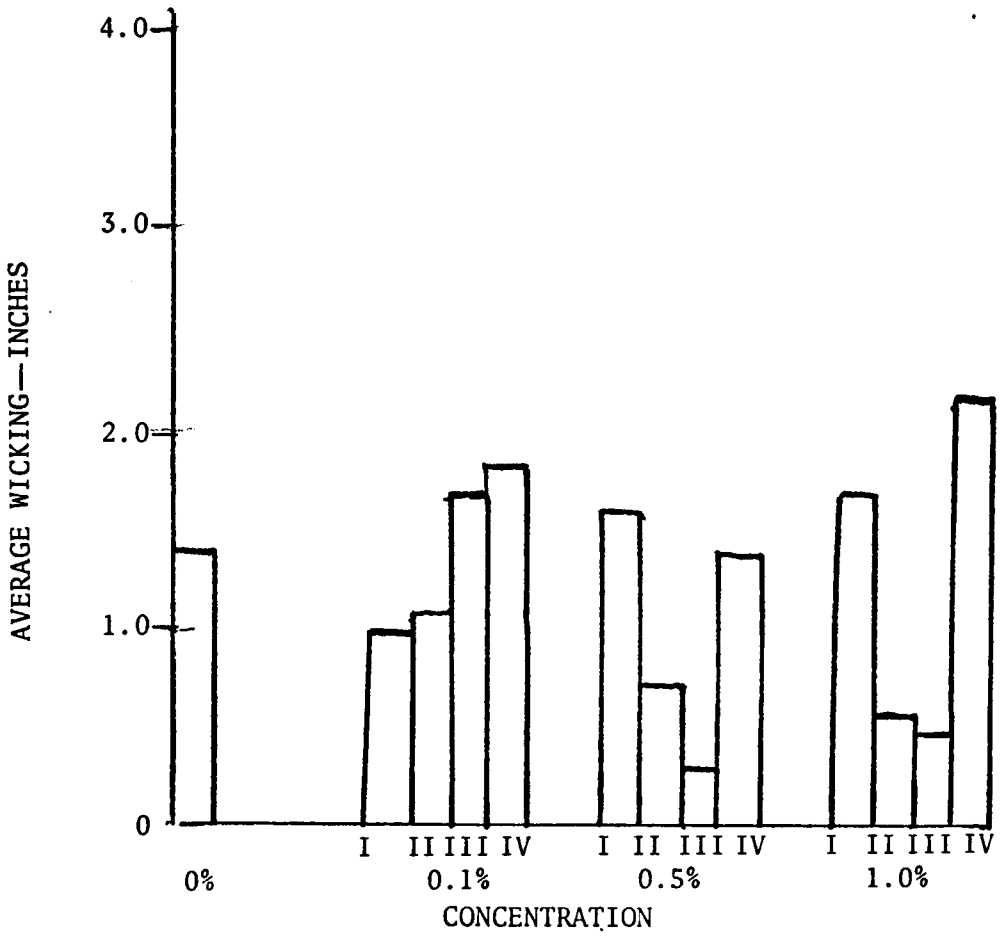


Figure 12. Effect on Wicking Absorbence As a Function of Add-on for Softener I, II, III, IV for Nylon

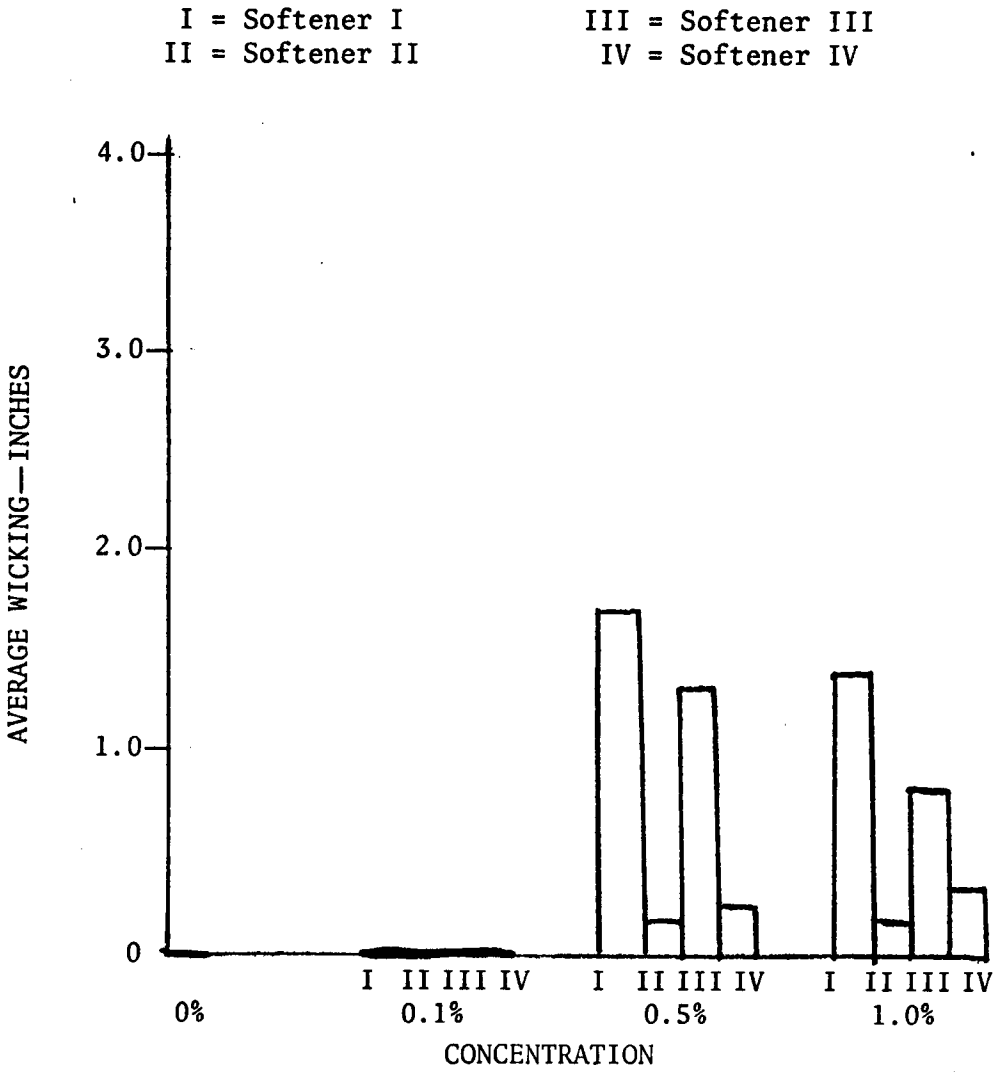


Figure 13. Effect on Wicking Absorbence As a Function of Add-on for Softener I, II, III, IV for Modacrylic

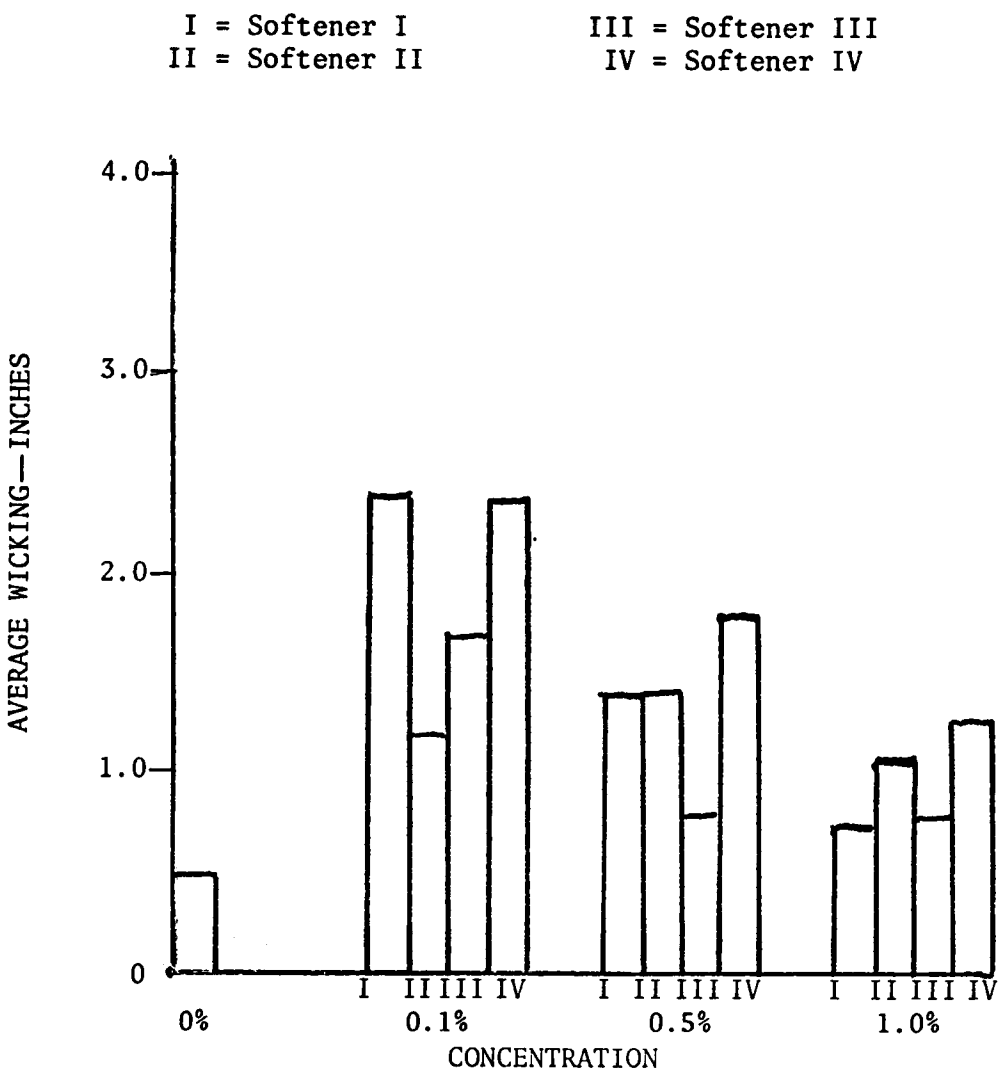


Figure 14. Effect on Wicking Absorbence As a Function of Add-on for Softener I, II, III, IV for Polyester

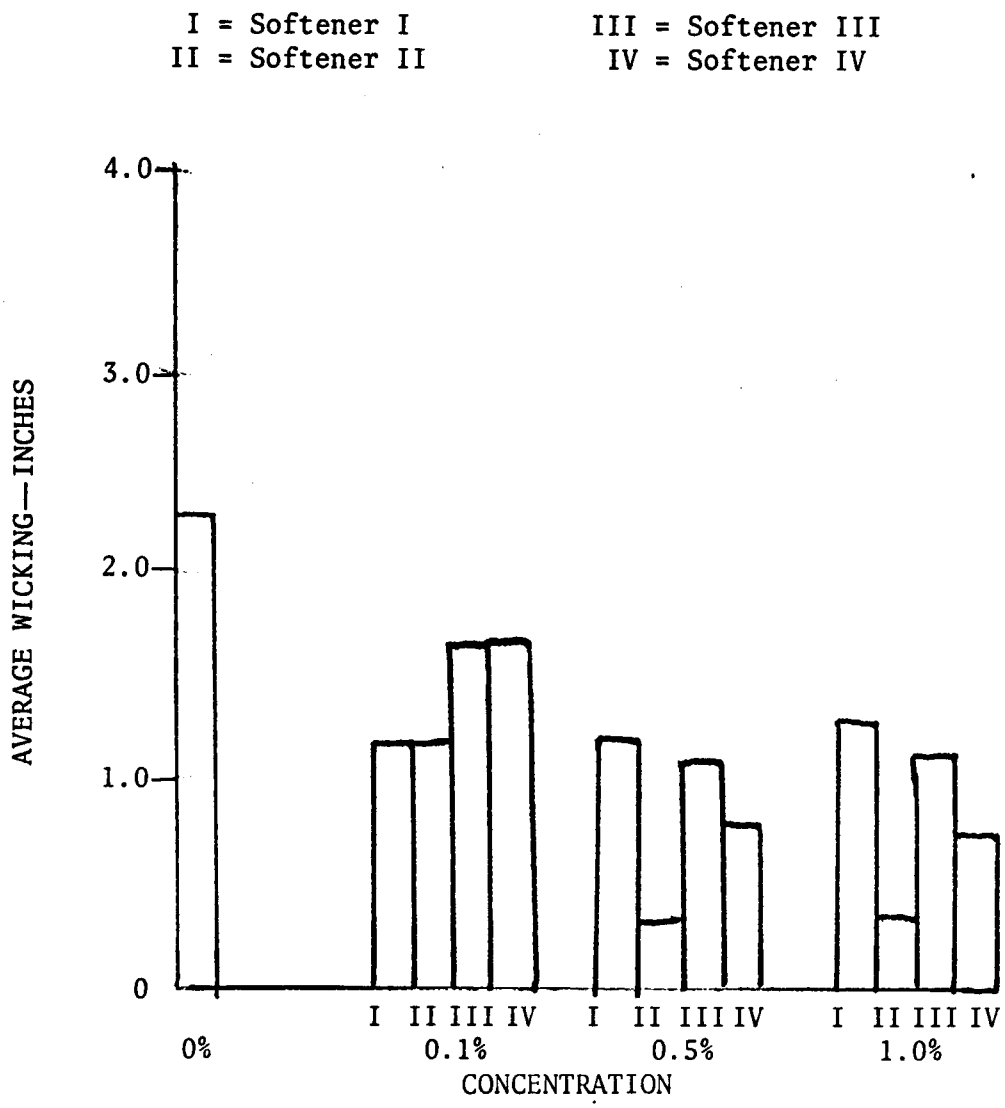


Figure 15. Effect on Wicking Absorbence As a Function of Add-on for Softener I, II, III, IV for Cotton

I = Softener I
II = Softener II
III = Softener III
IV = Softener IV

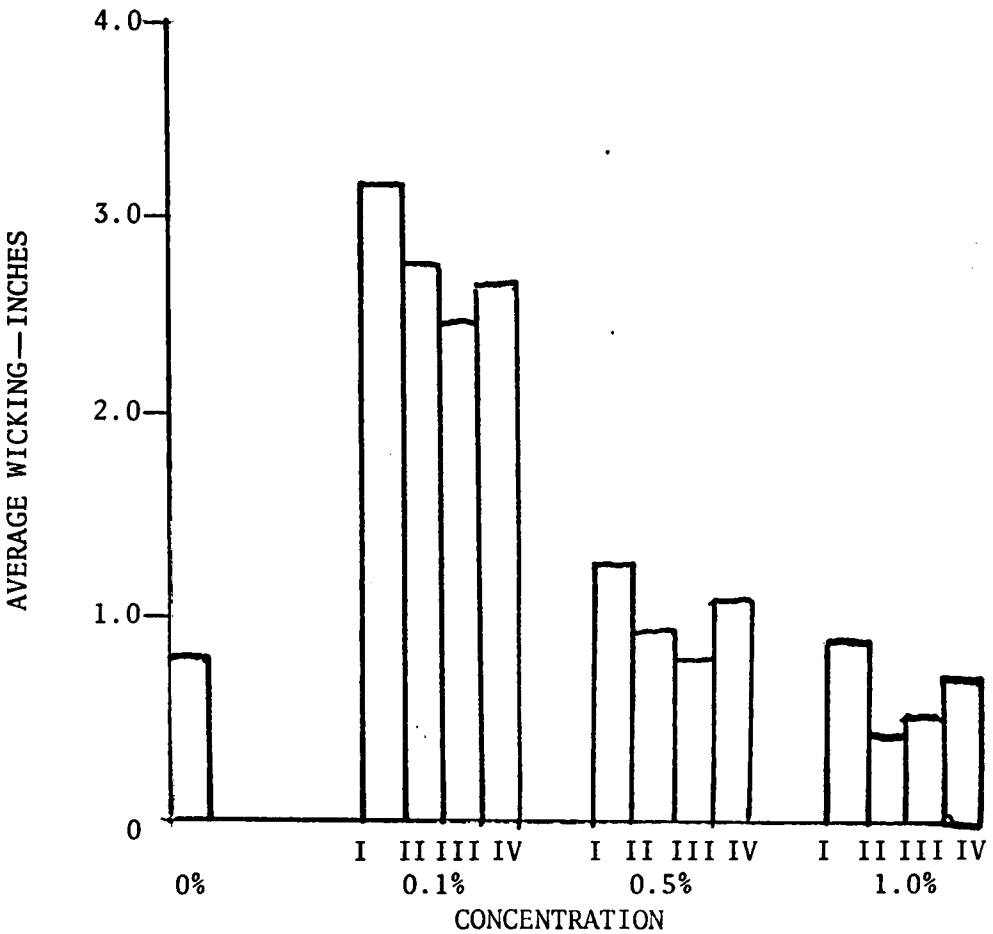


Figure 16. Effect on Wicking Absorbence As a Function of Add-on for Softener I, II, III, IV for Acetate

warp and fill directions (or wale and course directions for the knits). Averages were used because the separate results for warp and fill gave essentially the same results. Each figure shows all four softeners at the various levels applied.

Analysis of variance showed that all effects and interactions were significant (probability > .999) indicating that each individual softener interacts differently with each of the six FR fabrics.

The results for the cordelan fabric are shown in Figure 11. At low levels, only softener IV caused increased wicking, but at higher levels all softeners caused an increase in wicking absorbency.

The results for the nylon fabric are shown in Figure 12. This fabric was fairly absorbent initially in this test; softeners II and III caused a reduction in absorbency while softeners I and IV may have caused a slight increase.

The results for modacrylic fabric are shown in Figure 13. As in the sink time test results, this fabric behaved most like cordelan. Softeners II and IV caused little if any increase in wicking, while softeners I and III were effective but only at high concentrations.

The results for the polyester fabric are shown in Figure 14. All softeners caused an increase in absorbency at the 0.1% level; this effect was reduced at higher levels of applied softener.

The cotton fabric (Figure 15) exhibits the highest initial absorbence of all fabrics studied. All softeners applied at all levels reduced the absorbency of this fabric. Softeners II and IV caused the greatest loss in absorbency.

The results for acetate (Figure 16) showed a marked increase in absorbency at the 0.1% level for all softeners, then a decrease at the higher levels. In this test the acetate fabric behaved most like the polyester. At the highest level applied the fabric was less absorbent than the untreated control. All softeners seemed to exhibit the same general effect on acetate in this test.

The softeners at various concentrations interacted individually with each fabric. While decreasing the wicking for the natural fabric, some softeners proved deleterious to some synthetic fabrics while the inverse occurred on other synthetic fabrics.

Softeners may enhance the wicking of some fabrics at a low level of softener application and decrease wicking at a higher level of application.

CHAPTER V

SUMMARY AND CONCLUSIONS

The objectives of this research were to evaluate the characteristics of four commercial cationic softeners on the flame retardancy, sink time absorbency, and wicking absorbency of six FR fabrics based on a control group and treated samples.

The samples were cut from commerically purchased bolts of fabric; all fabrics were claimed to be flame resistant by the manufacturer. The samples were washed with AATCC #124 detergent and tumble dried.

Pad bath concentrations for the softeners were calculated from the average active dry solid content for the softener and wet pick-up based on the fabrics padded with Triton GR-5 in distilled water. Distilled water was used for the pad bath with the softener.

Char length in inches for the flame test, sink time in seconds, and wicking in inches were measured to determine the effect of softeners on the fabrics. An analysis of variance involving fabric, softener type, and level of applied softener was run for each of the properties measured.

Relationship of Average Char Length by Softener

For the flame test the FR fabrics were the only significant variable (probability > .999). All main effects and other interactions, were found to be nonsignificant. All the specimens passed the flame

retardancy test indicating that the level of softener as well as the softener itself had no significant effect.

The fabrics were significant indicating that each fabric exhibited its own properties in burning. An explanation could be that the softener itself may have adhered only to the surface of the fabric, thereby leaving the inside of the fiber chemically unchanged, while not influencing the burning characteristics of the fabric.

Relationship of Sink Time

The analysis of variance conducted on sink time found all effects and interactions to be significant, indicating that specific softeners had different effects on different fabrics. It has been noted that except for cotton and acetate the control fabrics were relatively nonabsorbent. As the levels of softener increased the natural fabric tended to decrease its absorbency related to initial sink time. Another observation was that some synthetics, notably modacrylic, became more absorbent, especially at the higher concentrations of softener. This may be due in part to a reduction in the surface tension of the water in the vicinity of the softened fabric specimens. Since the softener itself is water soluble, the higher the concentration, the more softener can be desorbed by the water while the accompanying reduction in surface tension permitted the fabric to sink.

The individual softeners themselves reacted differently on the six fabrics. Softener II overall inhibited the absorption for most of the fabrics while softener III tended to increase the absorbency for some

fabrics. Surface tension may be a cause or the absorption of a particular softener by the individual fiber at a specified concentration, may have exhibited this tendency.

Relationship of Wicking Absorbency

The wicking absorbency evaluation found significant results (probability > .999) for all main effects and interactions, as in the case of the sink time results. In this respect the sink time and wicking tests proved to be consistent tests.

The wicking test indicated that the individual softener and level of softener affected each fabric differently. Some fabrics, notably the modacrylic, would not wick with softener II or IV, yet with softener I it would readily wick at the higher concentrations.

Overall the wicking by a particular fabric was increased by the use of a softener over the initial control. This indicates that a softener does not decrease absorption at higher levels, thus disputing what has been said in the literature about high concentrations of softener on a fabric. Consideration should be given to interactions between the fabric and softener which would indicate how well a fabric absorbs.

The cordelan presented a problem in wicking because of the print. The water would not absorb where the fabric was printed at the lower levels, but as concentration increased this tendency was not as evident.

In conclusion the use of softener at a high concentration does not affect the flame retardancy of a fabric. The absorbency of the fabric

was dependent on the type of softener, concentration level of the softener, and the fabric. Desirable characteristics can be given to the consumer despite what has been stated in the literature. Softener II tended to be the least effective softener in relation to absorbency.

Recommendations for Further Study

In an effort to control as many variables as possible this set of experiments did not duplicate home laundry procedures. Therefore, in the future, the use of a known softener concentration could be applied under home laundry conditions in relation to a commercial detergent to determine the interaction of concentration with home laundry practices. This study also utilized distilled water. In the future, tap water should be included to determine what, if any, effect this may have on flame retardancy and the absorbency of flame retardant fabrics. The use of ready-made sleepwear may be utilized rather than purchased bolts. The ready-to-wear manufacturer may apply finishes that would influence the testing of these fabrics.

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APPENDIX

APPENDIX

TABLE 2

IDENTIFICATION OF FABRIC SOFTENERS

NUMBER	BRAND	MANUFACTURER
I	Coconut nuSoft	Best Foods, A division of CPC International Inc. Engelwood Cliffs, N.J. 07632
II	Final Touch	Lever Brothers Company New York, N.Y. 10022
III	Sta-Puf	A.E. Staley Mfg. Co. Oak Brook, Ill 60521
IV	Downy	Proctor & Gamble Cincinnati, Oh 45202

VITA

Kathleen R. Wachter was born July 12, 1949 in Jeffersonville, Indiana. She attended the local grade school and Providence High School, Jeffersonville, Indiana, graduating from high school in 1967. The following two years she attended Spalding College, Louisville, Kentucky, and Spencerian Business College, also in Louisville. She received a Diploma in Merchandising from Spencerian in June 1969.

After working for the J.C. Penney Co., Clarksville, Indiana and the U.S. Census Bureau in Jeffersonville, Indiana, for several years, she enrolled in Purdue University, Lafayette, Indiana in February 1972. She earned the B.S. degree in Textiles-Merchandising in May 1974.

The following September she enrolled in graduate school at the University of Tennessee, Knoxville, to work towards the Master of Science degree in Textiles and Clothing. While at the University she became a member of Omicron Nu and a student member of the American Association of Textile Chemists and Colorists. In December 1975 she was awarded the Master of Science degree.