

Fabric Hand: Designer Evaluation of Upholstery Weight  
Fabrics Treated With Commercial Flame Retardants

by

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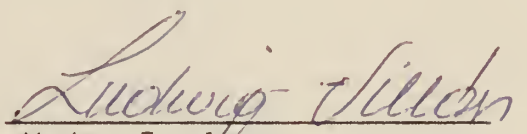
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## INTRODUCTION

Flammability of textile products is one of the major challenges posed to scientists and technologists at the present time. The U.S. national projection for fires related to textiles per year based on averages computed for 1977-1978 is 214,800. These fires were responsible for 3,500 deaths and 8,800 injuries, and up to \$656 million dollars in direct losses and \$2 billion dollars in fire related expenditures. Although all fibers and textile products may be involved in the starting of fires and/or materially contributing to the flame, mattresses, upholstered furniture, and bedding are even more prominent with regard to the number of fires. Tovey and Katz concluded that most textile fires "start because someone misused a source of heat or misused the material ignited. But this does not relieve the textile industry from the responsibility for working to reduce the flammability of textile products" (1).

Historically, flame retardant finishes for textiles are not a new idea. As long ago as 1735, an Englishman, Obadiah Wyld, patented a process for flameproofing cellulosic fibers by treating them with an aqueous solution of alum, iron sulphate, and borax. There are several other works on fireproofing of textiles during

1638-1800, however, it appears that the first systematic study was carried out by a French chemist, Gay-Lussac, who was commissioned by King Louis XVIII for protection of Parisian theater curtains. Gay-Lussac found a number of inorganic fire retardant chemicals (ammonium chloride, ammonium phosphate, and borax) very effective on hemp and linen fabrics (1).

It is now agreed that the early attempts of fire retarding fabrics were crude, and those treatments did not prove adequate or provide desirable properties. The treated cloth was stiff, and protective coatings either softened in heat or became very brittle in cold days. In spite of the inherent faults of these earlier processes, they were in use for many years and in principle are still in use today (2).

Flame retardant finishes are those which appreciably slow combustion once the source of heat is removed (1). It is this finish which is of primary concern to most designers and manufacturers. Today's interior designer must be able to advise his/her client on matters related to flame retardants and the consequences of chemicals applied to natural fibers. In dealing with flame retardants, one of the major concerns is the direct result of chemical treatment on the tactile appearance of fabrics.

There has been limited research conducted on the tactile qualities of natural fibers with chemical additives. To better understand client preferences and to offer guidelines for designers, the proposed study will examine upholstery weight fabrics in light of tactile changes, following the custom commercial application of flame retardant finishes.

## STATEMENT OF THE PROBLEM

This investigation was designed to address one major issue. The purpose of this study was:

1. To evaluate upholstery weight fabric for tactile changes, following the custom commercial application of flame retardant finishes.

The study was concerned with the following questions:

1. Can interior designers perceive differences in fabric hand between untreated upholstery weight fabric and those treated with commercial flame retardant finishes?

2. Is there a measurable difference in flexural rigidity between untreated upholstery weight fabric and those treated with commercial flame retardant finishes?

### Hypotheses

In order to answer questions, 1 and 2 of this study and for the purpose of testing, six null hypotheses were formulated. If relationships were noted at the 0.05 level, the hypotheses were rejected. These hypotheses are:

1. There are no significant differences in hand within selected cottons, linens, wools, and silks.

2. There are no significant differences in hand within selected cottons, linens, wools, and silks when treated with flame retardant finishes.

3. There are no significant differences in flexural rigidity within selected cottons, linens, wools, and silks.

4. There are no significant differences in flexural rigidity within selected cottons, linens, wools, and silks when treated with flame retardant finishes.

5. There are no significant interactions of the fabric direction and treatments in regard to hand for each of the select fabrics.

6. There are no significant interactions of the fabric direction and treatments in regard to flexural rigidity within selected cottons, linens, wools, and silks.

## REVIEW OF LITERATURE

### History

Historically, the development of flame retardants for textiles has passed through four stages. The first stage, which stemmed initially from trial and error experiments and later from systematic studies, resulted in water soluble or nondurable flame retardants. The second involved deposition of insoluble retardants inside the fabric. This was a natural outgrowth of the work on water soluble retardants and insoluble deposits which has been carried on concurrently since about 1850. The third significant advance was the use of mixtures of halogenated organic materials and insoluble metal salts and oxides (2). This innovation was introduced in the 1930's and provided new fire retardants that were of considerable importance to the military forces during World War II (3). The fourth and most promising stage, which began in the late 1930's, was based on chemical modification of the cellulosic molecules with the fire retardant (2).

The earliest known pamphlet concerning a treatment to impart flame retardants was published over 300 years ago in 1638 by Nicolas Sabatini. He pointed out the need for flame retardants in theaters, theater decorations and

scenery, and recommended that clay and gypsum be mixed with colors used to paint theaters and scenery to render them resistant to flame.

This early flame retardant was improved with time, but in principle, it was unchanged for years. The first noteworthy recorded attempt to impart flame resistance to cellulose was accomplished in England in 1735 by Obadiah Wyld, who was granted a patent for a flame retardant mixture containing alum, ferrous sulphate, and borax (4).

Interest in flame retardants was renewed when Gay-Lussac was commissioned by King Louis XVIII of France to investigate the possibilities of imparting flame resistance to linen and jute textiles. He obtained flame resistance on these fabrics by using mixtures of ammonium phosphate, ammonium chloride, and borax (16).

Some 39 years later, in 1859, Versmann and Oppenheim invented a process for flame retardant textiles by precipitating stannic oxide in the fiber (13).

The first laundry resistant flame retardant finish for fabric is said to have been the work of William Henry Perkins in 1902. Perkins' process was an improvement on the older method of precipitating stannic oxide in the flannelette. After numerous trials, he concluded that fabric so treated was permanently flame resistant and no amount of washing with hot soap and water would remove the

flame retardant.

Perkins called his process Non Flam. It added two cents a yard to the cost of the fabric. This process was extended to lace curtains, muslin, and other fabrics. In 1913, for the benefit of the public, he allowed his patent to be revoked so that any manufacturer could use it (5)

Although it was originally indicated that the effectiveness of the Perkin process lasted about 20 washings without loss in fire retardance, recent work has shown a large loss after only a few regular washings in present day laundering equipment. Leatherman modified the Perkin's approach which led to the chlorocarbon metallic oxide treatment (19).

The advent of World War II saw the development of the first commercial fire retardant system which could be called durable. This system was based on a fire retardant composed of antimony oxide and chlorinated organic compounds. During World War II, 700 million yards of cotton fabrics, mostly duck for military tents and tarpaulins, were processed with the so-called FWWMR finish (fire, water, weather, and mildew resistant). As late as the 1970's this finish has still been the most important durable fire retardant finish run on a commercial scale in terms of total yardage produced (16). For the past decade, flammability has been one of the most talked about



subjects in the textile industry, and it is likely that it will continue to be of great interest for some time to come (22).

### Legislation

In 1951, following a number of deaths from garment fires, flammable fabrics were viewed for the first time as a general consumer problem. This brought about the Flammable Fabrics Act of 1952, regulating flammability of textile products purchased directly by consumers (6). The Act covered items that were imported or were in interstate commerce (8).

Further developments led to the Ammended Flammable Fabrics Act of 1967, which gave the U.S. Government authority and duty to "set mandatory flammability standards as needed to protect people against unreasonable risk." It also authorized investigation of deaths and injuries, research, and development of test methods and devices. The Act related to standards applicable to wearing apparel and interior furnishings for homes, offices, and places of assembly or accomodation (7).

The philosophy has subsequently changed with the passing of the Consumer Product Safety Act and the establishment of the Consumer Product Safety Commission (CPSC) in 1972. According to this Act, the government is

empowered to issue standards protecting the public from unreasonable hazards even without prior interaction with industry (8).

In 1976, a draft for a proposed flammability standard for upholstered furniture was submitted to the Consumer Products Safety Commission by the National Bureau of Standards (9). The furniture manufacturers, in anticipation of this type of action, formed the Upholstered Furniture Action Council (UFAC) in 1974. The purpose of UFAC was to oppose the governmental standards through the development of voluntary standards and test methods (10).

UFAC maintained that it could develop a program which would fulfill CPSC safety requirements and yet be more cost effective. Estimates of the increase in retail prices which would result from implementation of the governmental standard ranged from \$114 to \$174 million dollars as compared with an increase of \$30 million dollars for the UFAC plan.

UFAC further maintained that governmental regulations would not only impose direct costs on the public in terms of retail price hikes and reduced fabric selection, but also in direct costs to taxpayers. These indirect costs would accrue from the expense of government regulation and enforcement.

After much debate on the issue and review of the proposed UFAC standards, the CPSC agreed in 1983 to continue work toward a voluntary program. A program was designed to insure that 90% of upholstered furniture would be resistant to cigarette ignition (14).

In addition to the establishment of standardized test methods and minimum performance levels, UFAC stated that education of interior designers, retailers, and the public was a vital element in the success of their voluntary program (10). To date, property damage, loss of life, and the aging population within the United States continue to motivate the government's interest in maintaining flame retardant standards for upholstered furniture.

#### Flame Retardants

In understanding flammability, Schulz indicates that there are four theories which provide the basis for flame retardant treatments of textiles:

- (1) Chemical Theory - based on the fact that certain chemicals alter the decomposition of cellulose, and favor the formation of smaller amounts of tars and flammable gases, while increasing the proportion of non-volatile carbonaceous materials.

- (2) Thermal theory- based on ideas that, the heat supplied may be absorbed by exothermic processes during change of flame retardants, or the heat may be removed by conduction along fibers.
- (3) Coating theory- based on the fact that fiber coated with an impermeable glassy coating such as borax, boric acid, and antimony oxide, confers flame retardance.
- (4) Gas theory- based on fact that when a flame retardant treated textile reaches the temperature of combustion, the textile releases an inert gas that interferes with flame development by starving a fire of oxygen (30).

Usually a flame retardant chemical or mixture affects flammability in more than one of these ways.

Hundreds of different chemicals have been investigated for use on textiles. Some are not suitable because of objectionable characteristics, such as moisture absorption, deterioration under high temperature, drying or pressing, toxicity, corrosiveness, or because they adversely affect color, feel, flexibility, tensile strength, and the life of the fabric. Also, a few flame retardants have been identified as being possibly

carcinogenic (15). Flame retardant treatments currently being used to treat cellulosic and proteins are shown in Table 1.

Table 1

Flame Retardant Chemicals For Cellulosics and Proteins

---

Fiber	Flame Retardant Chemical
Cellulosic	Phosphonium Salt Precondensate
	Polyphosphate
	Inorganic Salt
	Organic Phosphate
Proteins	Halogenated Organic Compound
	Phosphate Blend

---

## Cellulosics

Cellulose and cellulosic products are considered flammable because they are readily ignited and rapidly consumed after ignition.

Cellulosic fibers still amount to over half of the fibers used in most countries, and therefore the reduction of the flammability of cellulosic products is of great importance.

When cellulose is heated to the temperature of decomposition, it yields volatile, flammable gases, as well as liquid and tarry products which may also volatilize and ignite, leaving a char consisting mainly of carbon. The slow oxidation of this char is responsible for the afterglow, which is as great a fire hazard as the flaming of the volatile products. The flame retarding treatment essentially reduces the proportion of the volatile products to the amount of char formed. An efficient flame retardant finish therefore must satisfy two requirements:

- (1) Reduce the formation of flammable tar and gaseous products.
- (2) Prevent the afterglow of the increased amount of char.

Substantial chemical add-ons are generally required to attain a satisfactory flame retardant effect. Consequently, the flame retarding treatment of cellulose is expensive and generally impairs the physical properties of the substrate. Although many processes are documented in the scientific and patent literature to reduce the flammability of cellulose and cellulosic products, their usage has been limited because of the high costs and undesirable side effects (29).

Flame retardants used on cellulose are usually classified according to their permanence and effectiveness in providing resistance to open flame ignition. The majority of flame retardants provide the following degrees of durability (17).

#### Nondurable

In the past, as in the present, great interest has focused upon water soluble chemicals as flame retarding agents. They can impart only temporary protection, since the effect of the treatment is destroyed not only by laundering, but also by rain and perspiration. Periodic reprocessing is thus necessary to maintain flame retardancy (29).

According to Schulz, the deposition of any nondurable substance onto the cellulose substrate in sufficient

amount will suppress the propagation of flame. Since organic materials are commonly considered flammable, mostly inorganic salts and acids have been suggested as flame retardants (30). In practice, only a few very efficient agents, or mixtures of such, are used which are capable of imparting a high degree of resistance to both afterflaming and afterglowing. These two characteristics are attained by different mechanisms, and many effective flame retardants fail to reduce the afterglow.

Cellulosic materials treated with water soluble inorganic salts must be dried carefully, since fast drying might cause crystallization of the chemicals on the surface, and drying at too high a temperature might result in the decomposition of ammonium salts by loss of ammonium (29).

The nondurable, water soluble inorganic flame retardants can be divided into three main groups (30).

The retardants in Group I melt at relatively low temperature and subsequently resolidify in the form of a solid foam produced by the evolution of decomposition products. The solid foam serves as a barrier between the flame and the substrate.

The most important examples of this group are boric acid and its salts. Boric acid itself imparts only moderate levels of flame retardancy, but applied in large



amounts it prevents afterglow. Its sodium salt, borax, imparts better protection against flame propagation, but does not suppress the afterglow.

A solution of ammonium sulfate, ammonium phosphate, boric acid, and borax is suggested for the nondurable flame retardant treatment of cellulosic textiles.

The flame retardants in Group II consist of inorganic acids, acidic salts, and salts capable of releasing acids on heating. The importance of furnishing free acid groups at the time of combustion is illustrated by the relative effectiveness of orthophosphoric acids and their sodium salts. When the acid anhydride is balanced by an equivalent amount of alkali oxide in the residue, the salt does not exhibit flame retardant properties. Flame retardants in this group include sulfamic acid, phosphoric acid, and metallic acids.

The flame retardants in Group III are inorganic compounds which decompose or sublime on heating, producing large amounts of nonflammable gases or vapors. Carbonates, halides, ammonium salts, and highly hydrated salts are characteristic members of this group (11).

#### Semi-Durable

Based on the findings of Reeves, Drake, and Perkins semi-durable fire retardants are those that resist removal

by one and up to about 15 launderings. Such retardants are adequate for many end-use products such as drapes, upholstery, and mattress ticking. If they are sufficiently resistant to sunlight or can be easily protected from actinic degradation, this type retardant is also useful for outdoor textile products such as beach umbrellas, tents, and cover fabric (7).

Most of the effort to develop semi-durable retardants has been for cellulose and based on a combination of phosphorus and nitrogen compounds. These materials are usually insoluble salts of amphoteric cations and anions - stannates, tungstates, aluminates, borates, and phosphates of zinc, tin, aluminum, and easily reducible metallic oxides (11).

Application of insoluble salts is a means of attaining semi-durable flame resistance. Flame retarding effects of the simple inorganic salts are based on their capability of decomposing in heat and releasing a strong acid or an alkali which is responsible for the reduction of flame propagation. Generally these thermally unstable salts of weak acid/strong base or of strong acid/weak base are very soluble in water (29).

## Durable

Durable flame retardants provide the desired degree of retardancy for the useful life of the textile product. This can mean durability for 50 or more laundry cycles and usually signifies durability to at least 15 cycles. Durability to laundering or other cleaning methods is just one of the several criteria a fire retardant must meet to be satisfactory and acceptable for use in fabrics for specific textile products. Other factors which must be considered include strength retention, stiffness, and discoloration of the treated material. Other criteria that can sometimes disqualify a finish are ion exchange properties, odor, and sensitivity to acid or base. Until now, the successful and potentially acceptable fire retardants for cotton are of three general types: (1) metal oxides (2) water soluble monomers, which penetrate the fiber react and polymerize or copolymerize with an appropriate monomer and, in some systems, simultaneously react with the cellulose and (3) preformed polymers which are deposited on the surface of the fibers and subsequently are either further polymerized or fused to provide durability (7).

## Methods Of Application

In treating cellulose, commercially available flame retardant chemicals may be applied by immersion or foam. Immersion is the most effective way for applying fire retardants to textiles. Immersion provides the greatest uniformity of treatment and the most precise add-on. These features are essential for the production of goods with a known degree of safety. Immersion consists of (a) padding fabric through a liquor of the retardant, and (b) drying. It is important that the fabric be thoroughly wet with the liquor to provide uniformity of finish in the fabric and adequate add-on. Proper fabric preparation of facile wetting is preferred to the use of wetting agents in the treating liquor. If a wetting agent is required for adequate wetting with the retardant liquor, it should be one that decomposes during the subsequent drying set to avoid subsequent re-wetting and migration of retardant. Drying of the padded fabric should be at temperatures of less than about 130<sup>0</sup> C for many retardants; however, some commercial products can be dried at much higher temperatures.

Low wet pickup systems for fabric finishing are now in widespread use in the textile industry. Of the low wet pickup systems, those using foams have generated the most

interest in the United States (23). Wright reports, the two major systems are the Valfoam system developed by United Merchants and the FFT system developed by Union Carbide (24). The former uses stable foams which are collapsed by mechanical action after they have been applied to the fabric, while the latter uses unstable foams which collapse on contact with the fabric.

Where stable foams are employed, several modes of foam application can be used, the choice being dictated by the construction and weight of the fabric (25). For lightweight fabrics, the foamed finish is applied to both sides of the fabric using horizontal pad (23). The wet pickup is controlled primarily by the blow ratio of the foam. With highly absorbent fabrics where two-sided application leads to excessive wet pickups, the foam is applied to one side of the fabric. For medium weight, tightly constructed fabrics, a knife over roll application is preferred. This is especially useful with low absorbency fabrics (26).

The driving force for developing the foam systems was the reduced energy consumption in fabric finishing. The Valfoam process is being used to apply durable press resins, hand builders, finishes to control shrinkage, and softeners to cotton and polyester/cotton blend fabrics. In commercial practice, the foam process has yielded

savings as high as 70 to 80% in the drying step (28); however, there are other advantages to foam finishes. It is versatile, reduces waste effluent, requires low capital expenditure, increases output per range, uses chemicals more efficiently, and creates novel effects (27).

## Proteins

Proteins are a class of naturally occurring compounds of high molecular weight. They are extremely widespread in nature, being one of the essential constituents of the tissues of plants and animals. In general, proteins fall into two groups - fibrous and globular. In the fiber field proteins such as wool, silk, mohair, etc., are of great value, while those found in milk or groundnuts are capable of being transformed into fibers (12).

### Wool

Until recently very little systematic research had been done relating to the flammability of wool fabrics, mainly because wool is fairly regarded as slower burning than most other textiles (12).

Wool is regarded as a safe fiber from the point of view of flammability. It may be ignited if subjected to a sufficiently powerful heat source, but will not usually support flame and continues to burn or smolder for only a

short time after the heat source is removed. This is connected with the chemical and morphological structure of the wool fiber which has a high amino and amido nitrogen and moisture content.

The natural flame resistant properties of the wool fiber are connected with its relatively high nitrogen and moisture content, high ignition temperature, low heat of combustion, low flame temperature, and high limiting oxygen index. Another important property of wool fibers is that when ignited it does not melt and drip. Wool burns more slowly than untreated cotton in compressing air, and its ignition temperature stays high and practically constant as the pressure is increased (11).

Although wool is regarded as a safe fiber, higher degrees of flame retardance can be required to meet specific and severe flammability standards.

Lewin, Atlas, and Pearce conclude that there have been four stages in the development of flame retardant treatments for wool:

- (1) Nondurable treatments mainly based on inorganic borates and/or phosphates for purposes such as theater curtains and aircraft furnishings.

- (2) Development of a durable flame retardant treatment based on a tetrakis (hydroxymethyl) phosphonium chloride (THPC) treatment to meet the F.A.R. specification for wide-bodied jets.
- (3) Development of inexpensive and durable treatments based on titanium and zirconium complexes to meet the requirements of the U.S. tablet tests for carpets in 1970.
- (4) Subsequent improvement of the Zirpro titanium and zirconium treatments and the development of Zirpro multipurpose finishes, to allow wool products to meet a wide range of flammability standards. During this time, other flame retardant treatments were also developed, based on organochlorine, organobromine, sulfur-containing, and organophosphorous compounds (11, 12).

#### NONDURABLE AND SEMI-DURABLE TREATMENTS

A number of inorganic compounds such as ortho- and metaphosphoric acids, sulfuric and sulfamic acids, ammonium borate, potassium hydroxide, and potassium carbonate, when padded on to wool, were found to impart



nondurable flame retardancy to wool. Add-ons of 6-10% of phosphoric acid and cyanamide impart semi-durable flame retardance to wool (12).

#### ZIRCONIUM AND TITANIUM COMPLEXES

A successful treatment, which is now applied on large-scale basis, was developed by the International Wool Secretariat and described in detail in a number of papers by L. Benisek (33, 34). This treatment is based on the exhaustion of negatively charged titanium or zirconium complexes on to positively charged wool fibers in acid conditions, during and after drying. Treatment from a long liquor bath at 60<sup>0</sup>C for 30 minutes is the most common application technique, although application by pad-batch-rinse-dry and other techniques is possible. Zirpro wool products can meet most stringent flammability requirements before and after washing at 40<sup>0</sup>C and/or dry cleaning. The Zirpro treatments can be combined with other easy-care finishes for wool.

Application techniques are shown in Table 2.

Table 2

Application Techniques For Flameproofing Wool

---

1. Exhaustion Technique - Low temperature or boil  
Loose stock, tops, yarn packages, yarn in hank,  
fabrics, knitted garments, sheepskins.  
Machinery - common dyeing machinery
  
  2. Pad - Batch - Rinse - Dry Technique  
Fabrics  
Machinery - pad mangle, tenter, winch
  
  3. Pad - Steam - Rinse - Dry Technique  
Tops, fabrics, carpets  
Machinery - for continuous pad - steam dyeing
  
  4. Dip-Nip-Batch-or Dry-Rinse-Dry Technique  
Sheepskins, loose stock
- 

Silk

Silk is a natural protein which contains a large amount of nitrogen and is not very flammable. Phosphates, borates, and nitrogen compounds are used to impart improved flame resistance. Silk is said to burn and fuse

rather like wool, but without creating such unpleasant smell. The difference is probably due to the absence of sulfur in the fiber. Little quantitative information is available, but silk decomposes rapidly at 170<sup>0</sup>C, a lower temperature than wool, because of the absence of cross links. The treatments given for wool are also effective on silk (7).

### Fabric Hand

Chemical finishes which have been introduced to flame retard fibers often affect fabric hand (18). Fabric handle is concerned with the feel of the material and so depends on the sense of touch (28). Fabric hand is influenced by flexibility (pliable to soft), compressibility (soft to hard), surface contour (rough to smooth), surface friction (harsh to slippery), and thermal character (warm to cool). Several of these characteristics can be measured objectively by standard test procedures. However, in describing the overall property of hand, consumers depend primarily on subjective evaluation (13).

### Evaluation Techniques

The assessment of fabric hand involves two major classes of variables: people as judges with certain traits

and fabrics as stimuli with certain physical properties (20).

Previous studies suggest using a semantic differential scale for analyzing subjective measures of fabric hand. The semantic differential scale, also known as the bipolar adjective scale, typically is a seven point scale that pairs an adjective with its opposite. It is used to describe or evaluate a particular situation or experience. The crux of the method, lies in selecting the sample of descriptive polar terms. Ideally, the sample should be as representative as possible of all the ways in which meaningful judgements can vary, and yet be small enough in size to be efficient in practice (38).

In using the semantic differential, the four polar word pairs chosen to describe the properties of fabric hand include:

Roughness	Smoothness
Stiffness	Flexibility
Compactness	Openness
Coldness	Warmth

In measuring the physical properties of fabric hand, the Drape - Flex Stiffness Tester is used most often. A rectangular strip of fabric, 6 in. x 1 in. is mounted on a

horizontal platform in such a way that it overhangs, like a cantilever, and bends downward. See Figure 1. From the length "l" and the angle "O" a number of values are determined (33). In performing this test, bending length, flexural rigidity, and overall flexural rigidity can be determined.

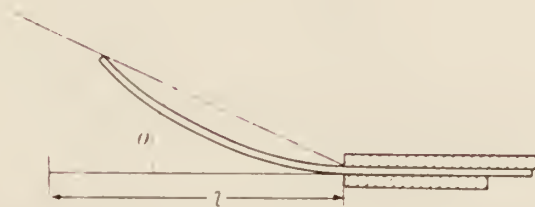


Figure 1. Fabric Stiffness, Cantilever Principle.

## DEFINITION OF TERMS

1. Afterglow - Glowing combustion in a material after cessation (natural or induced) of flaming (34).
2. Combustion - Self - catalyzed exothermic reaction involving fuel and oxidizer.
3. Finish - Compound or combination of compounds added after conversion to end product. May be covalently bound or deposited.
4. Fire Resistance - Capacity of a material or structure to withstand fire without losing its functional properties.
5. Fire Retardance - The resistance to combustion of a material when tested under specified conditions (34).
6. Flame Propagation - Spread of flame from region to region in a combustible material.
7. Flames - Combustion processes in the gas phase accompanied by emission of visible light.
8. Flame Resistance - The property of a material whereby flaming combustion is prevented, terminated, or inhibited following application of a flaming or non -

flaming source of ignition, with or without subsequent removal of the ignition source (34).

9. Flame Retardant - Chemical compound capable of imparting flame resistance to (reducing the flammability of) a material to which it is added.

10. Flammability - Those characteristics of a material that pertain to its relative ease of ignition and relative ability to sustain combustion (34).

11. Hand - The "feel" of a fabric; the qualities that can be ascertained by touching it. The hand of fabrics is influenced by flexibility (pliable to stiff), compressibility (soft to hard), extensibility (stretchy to nonstretchy), resilience (springy to limp), density (compact to open), surface contour (rough to smooth), surface friction (harsh to slippery), and thermal character (cool to warm) (13).

## PROCEDURE

### Test Fabrics

The fabrics to be evaluated in this particular study were commercially available and of upholstery weight.

A majority of the test fabrics were donated by textile manufactures, the remainder purchased from various suppliers. The test fabrics were divided into four categories with each category containing three test fabrics. In categorizing, no attempt was made to control other textile parameters (Table 3). Category I: 100% cotton, Category II: 100% linen, Category III: 100% wool, and Category IV: 100% silk. Under each category, the fabrics were further divided into three subgroups; A, B, and C. "A" and "B" both represented fabric treated by different flame retarding companies, while "C" was untreated.

### Treatment of Fabrics

The fabrics classified as group "A" were treated with a durable saline solution. This specific saline solution demonstrates resistance to 20 solvent cleanings with no loss in fire retardancy. In using this finish, it was also observed that shrinkage took place. The degree of shrinkage depended on fabric construction. The average



Table 3

## CONSTRUCTION CHARACTERISTICS OF SELECTED TEST FABRICS

<u>Cotton</u>	<u>Weight</u>
1. Twill Weave	22.96 oz/yd <sup>2</sup>
2. Plain Balance Weave	5.99 oz/yd <sup>2</sup>
3. Plain Balance Weave	8.64 oz/yd <sup>2</sup>
 <u>Linen</u>	
1. Woven Pile (Warp Pile)	9.99 oz/yd <sup>2</sup>
2. Plain Balance Weave	7.98 oz/yd <sup>2</sup>
3. Crepe Weave (Plain Weave)	10.95 oz/yd <sup>2</sup>
 <u>Wool</u>	
1. Plain Balance Weave	15.60 oz/yd <sup>2</sup>
2. Twill Weave	16.12 oz/yd <sup>2</sup>
3. Plain Balance Weave	26.90 oz/yd <sup>2</sup>
 <u>Silk</u>	
1. Crepe Weave	6.57 oz/yd <sup>2</sup>
2. Basket Weave	8.94 oz/yd <sup>2</sup>
3. Woven Pile (Filling Pile)	9.73 oz/yd <sup>2</sup>

shrinkage factor was 3%.

The fabrics classified as Group "B" were treated with a metallic salt-base solution. This flame retardant finish is classified as a semi-durable treatment since it resist removal for one to about 15 launderings.

In treating the fabrics, the immersion technique was used. Protein fibers were treated with a weaker percentage of the metallic salt- base solution than that used in cellulosic treating. Once immersed, the fabrics were then padded and put through a tenter frame. After passing through the tenter frame, the fabrics were then dried.

In using this treatment, shrinkage was observed but did not appear to be of great effect.

### Subjective Measurements

Sensory evaluation of hand was conducted using a semantic differential consisting of four pairs of polar terms. This was suggested by Brand (36) to better convey the sensory meaning of hand expressions. Hoffman (37) indicated that the semantic differential is one of the more sophisticated ways of finding out what a person liked and why, and that the instrument could be applied to measure the aesthetic appeal of textiles.

Polar words were selected to represent the four major modes of fabric deformation in handling a fabric: bending, frictional, thermal, and compressional deformation.

TABLE 4

#### SEMATIC DIFFERENTIAL IN ORDER OF PRESENTATION

Polar Adjective Pair	Physical Properties Represented
Roughness/Smoothness	Frictional
Stiffness/Flexibility	Bending
Openness/Compactness	Compressional
Warmth/Coldness	Thermal

In evaluating subjective measurements, a randomized panel of 12 judges from the interior design field made qualitative assessments of 36 test fabrics. The designers represented the Midwest Geographic area.

Each judge individually assessed each of the 36 test fabrics. A 6 in. x 6 in. specimen, one for each judge, was randomly selected and cut from each fabric category. See Figure 2.

In evaluating fabric hand, the controller demonstrated the method to be used. The sample was to be held lightly between the thumb and forefinger of one hand and bent to form an arc. The Judges were then asked to handle one fabric at a time behind a screen so that they could feel and handle it freely. In rating the fabric, each polar pair was presented in the following situation:

polar term x \_\_\_:\_\_\_:\_\_\_:\_\_\_:\_\_\_:\_\_\_:\_\_\_: polar term y  
(1) (2) (3) (4) (5) (6) (7)

Using a 7 pt. scale, a check-mark was then placed to which best describes the fabric.

- |                     |                 |
|---------------------|-----------------|
| (1) Extremely X     | (5) Slighty Y   |
| (2) Quite X         | (6) Quite Y     |
| (3) Slighty X       | (7) Extremely Y |
| (4) Neither X nor Y |                 |

It took less than 30 minutes on the average for a judge to finish the entire judging task.

## OBJECTIVE MEASUREMENTS

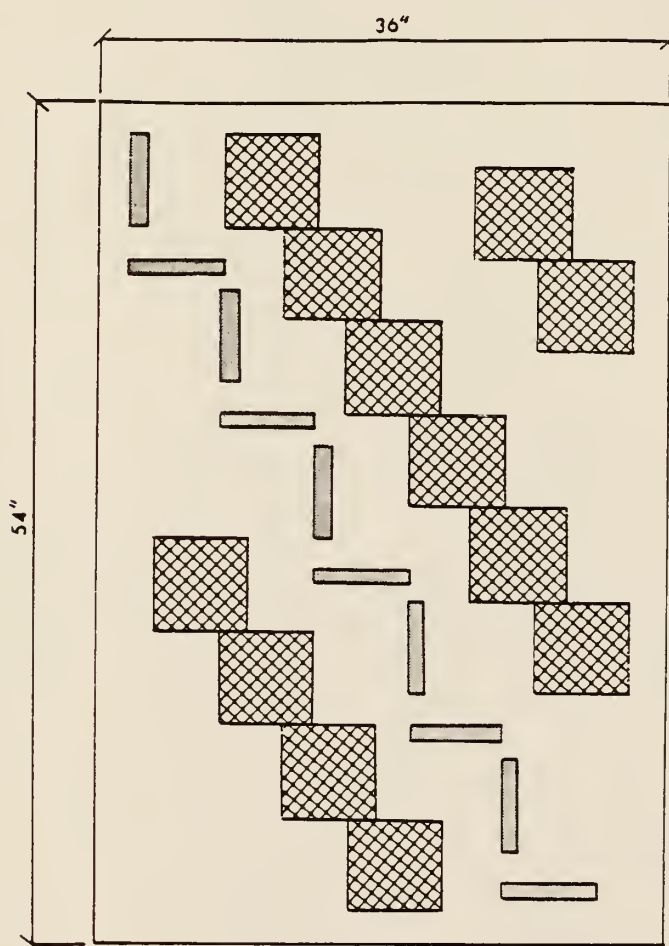
Fabric stiffness was evaluated by following ASTM Test Method D 1388, "Standard Test Method For Stiffness of Fabrics (Option A)" In measuring stiffness, the Drape - Flex Stiffness Tester was used. A rectangular strip of fabric, 6 in. x 1 in. was mounted on a horizontal platform on which a weight was placed so that the leading edges of fabric and weight coincide. Holding the weight in a horizontal plane, both the specimen and weight were slid slowly and steadily until the leading edges projected beyond the edge of the platform. The length of overhang was measured when the tip of the specimen reached the level of the two inclined lines. Using the provided scale the length of overhang was recorded to the nearest centimeter (35).

In performing this procedure, eight specimens were randomly selected and cut from each fabric category and group. Four specimens were cut with the long direction parallel to the warp and four with the long direction parallel to the filling. The specimens were cut in such a way that the warp specimens did not contain the same warp yarns for the warp direction tests and the filling specimens did not contain the same filling yarns. Fabric within 10% of the selvages or ends were not used.

See Figure 2. Four readings were taken from each specimen in which bending length and flexural rigidity were determined.

All tests were carried out in an atmosphere maintained at a temperature of 70°F ( $\pm 2^\circ$ ) and 65% relative humidity ( $\pm 2^\circ$ )

Figure 2. Sampling Plan



KEY:



Subjective Testing



Objective Testing

## STATISTICAL ANALYSIS

Data obtained from both subjective and objective testing were analyzed statistically by using an analysis of variance procedure. A Two Way Table Of Means was performed on the data if F was significant. The level of confidence used in all statistical tests was 0.05.

## RESULTS AND DISCUSSION

This investigation was designed to study upholstery weight fabric in light of tactile changes following the custom commercial application of flame retardant finishes. Measurements were taken subjectively by a panel of interior designers, and objectively by the Drape - Flex Stiffness Tester.

Sensory evaluation of fabric hand was conducted using a semantic differential scale consisting of four pairs of polar terms. The terms were selected to represent the four major modes of fabric deformation in handling a fabric: surface contour (rough to smooth), flexibility (pliable to stiff), density (compact to open), and thermal (warm to cool).

Data obtained from the seven point semantic differential scale was analyzed statistically by analysis of variance. Summaries of the analyses are reported in Tables 5, 6, 7, and 8. Post hoc analyses were performed when interactions were found to be significant. Fisher's Least Significant Difference Tests were used for this purpose. If there were no interactions, A Table of Overall Means was used. Significance was noted at the 5% level.



Table 5

## ANALYSIS OF VARIANCE FOR SELECTED COTTONS

Source of Variation	DF	Mean Squares and Significances Of				
		Rough/ Smooth	Flexible/ Stiff	Open/ Compact	Warm/ Cold	
Judges	11	5.26*	7.01*	4.25*	6.25*	
Test Fabrics	2	70.19*	16.36*	5.68*	7.62	
Treatments	2	4.78	9.08*	3.34*	13.59*	
J x TF	22	1.97*	2.52	0.94	2.40*	
J x T	22	2.25*	1.94	0.71	2.58*	
TF x T	4	2.56	4.94*	0.68	0.98	
J x TF x T	44	1.06	1.68	1.10	1.07	
Total	107					

\*Significance at the 5% level

J = Judges  
T = Treatment  
TF = Test fabrics

Table 6

## ANALYSIS OF VARIANCE FOR SELECTED LINENS

Source of Variation	DF	Mean Squares and Significances Of				
		Rough/ Smooth	Flexible/ Stiff	Open/ Compact	Warm/ Cold	
Judges	11	6.13*	4.73*	5.73*	7.34*	
Test Fabrics	2	14.81*	29.25*	1.81	4.62	
Treatments	2	2.68	19.44*	1.18	5.20	
J x TF	22	3.08*	2.08	0.90	1.84	
J x T	22	2.59*	1.76	0.62	1.85	
TF x T	4	1.65	2.78	0.15	0.23	
J x TF x T	44	1.42	1.63	0.66	1.98	
Total	107					

\*Significance at the 5% level

J = Judges  
T = Treatment  
TF = Test Fabrics

Table 7

## ANALYSIS OF VARIANCE FOR SELECTED WOOLS

Source Of Variation	DF	Mean Squares and Significances Of				Warm/ Cold
		Rough/ Smooth	Flexible/ Stiff	Open/ Compact		
Judges	11	1.78*	8.49*	5.10*	8.79*	
Test Fabrics	2	7.82*	73.68*	38.03*	7.68*	
Treatments	2	2.82*	30.56*	11.58*	6.51	
J x TF	22	0.90	1.11	1.25	1.81	
J x T	22	1.56*	2.45*	2.29*	1.67	
TF x T	4	1.26	9.87*	2.82	0.87	
J x TF x T	44	0.80	1.22	1.25	1.82	
Total	107					

\*Significance at the 5% level

J = Judges  
T = Treatments  
TF = Test Fabrics

Table 8

ANALYSIS OF VARIANCE FOR SELECTED SILKS

Source Of Variation	DF	Mean Squares and Significances Of				
		Rough/ Smooth	Flexible/ Stiff	Open/ Compact	Warm/ Cold	
Judges	11	3.79*	5.74*	10.70*	7.76*	
Test Fabrics	2	11.38*	6.03	3.25	11.70*	
Treatments	2	9.15*	38.36*	3.11	2.79*	
J x TF	22	1.96	1.84	2.34*	2.21	
J x T	22	1.19	1.26	1.60	0.81	
TF x T	4	0.30	2.30	1.19	3.27	
J x TF x T	44	1.20	2.47	1.13	1.44	
Total	107					

\*Significance at the 5% level

J = Judges  
T = Treatments  
TF = Test Fabrics

### Roughness/Smoothness

The surface contour or frictional property of fabric hand can be described as either rough or smooth. Rough fabrics are those which are coarse and uneven, whereas smooth fabrics are defined as even in consistency and without raised areas or indentations.

Scale ratings were scored by attributing lower values to roughness and higher values to smoothness.

#### Cotton

In terms of roughness/smoothness there is evidence of only one interaction between test fabrics and flame retardant finishes (Table 9). The judges, in testing selected cottons, rated only one fabric and only Treatment B to be rougher than the untreated and those with Treatment A.

Within Group 1, Treatment B left the selected cottons significantly rougher than did Treatment A. The judges did not perceive differences between Treatment A and the untreated.

There were no significant differences detected in roughness/smoothness associated with flame retardant treatments and fabrics under Groups 2 and 3.

Table 9

Two Way Table Of Means For Roughness/Smoothness  
Of Selected Cottons

Treatment	TEST FABRICS		
	G1	G2	G3
A	2.58	5.33	3.92
B	1.75	5.25	4.17
C	3.41	5.50	4.58

\*Significance at the 5% Level

G = Group  
 G1 = 22.96 oz/yd<sup>2</sup> fabric  
 G2 = 5.99 oz/yd<sup>2</sup> fabric  
 G3 = 8.64 oz/yd<sup>2</sup> fabric

Commercial Applicator A = Durable Saline Solution  
 Commercial Applicator B = Metallic Salt Solution  
 C = Untreated

## Linen

Concerning roughness and smoothness there were no interactions between the sources of linens and flame retardant treatments applied, hence it is appropriate to discuss overall means.

Table 10

Table Of Overall Means For Roughness/Smoothness  
Of Selected Linens

Test Fabric	Mean	Treatment	Mean
G3	4.47	B	4.53
G1	4.47	C	5.00
G2	5.58	A	5.00

\*Significance at the 5% level

G = Group

G1 = 9.99 oz/yd<sup>2</sup> fabric

G2 = 7.98 oz/yd<sup>2</sup> fabric

G3 = 10.95 oz/yd<sup>2</sup> fabric

Commercial Applicator A = Durable Saline Solution

Commercial Applicator B = Metallic Salt Solution

C = Untreated

As shown in Table 10, the selected linens in Groups 1 and 3 were perceived as rougher than those in Group 2. There were no detectable effects of applying flame retardants on the roughness/smoothness of the fabrics studied

## Wool

When evaluating wool for roughness and smoothness, the judges did not perceive any interaction between test fabrics and flame retarding treatments. Since an interaction did not occur, overall means were examined (Table 11).

Table 11

Table Of Over All Means For Roughness/Smoothness  
Of Selected Wools

Test Fabric	Mean	Treatment	Mean
G1	1.56	B	1.56
G3	1.61	A	1.89
G2	2.39	C	2.11

\*Significance at the 5% level

G = Group

G1 = 15.60 oz/yd<sup>2</sup> fabric

G2 = 16.12 oz/yd<sup>2</sup> fabric

G3 = 26.90 oz/yd<sup>2</sup> fabric

Commercial Applicator A = Durable Saline Solution

Commercial Applicator B = Metallic Salt Solution

C = Untreated

The results indicate that test fabrics under Groups 1 and 3 were rougher than those in Group 2.

There were no differences among flame retardant treatments that cannot be assigned to sampling variations.



## Silk

Flame retardant treatments and the selected samples of silk did not interact in regard to roughness and smoothness, so overall means were appropriate to study (Table 12).

Table 12

Table Of Overall Means For Roughness/Smoothness  
Of Selected Silks

Test Fabric	Mean	Treatment	Mean
G1	2.36	B	2.50
G2	2.78	A	2.67
G3	3.47	C	3.44

\*Significance at the 5% level

G = Group

G1 = 6.57 oz/yd<sup>2</sup> fabric

G2 = 8.94 oz/yd<sup>2</sup> fabric

G3 = 9.73 oz/yd<sup>2</sup> fabric

Commercial Applicator A = Durable Saline Solution

Commercial Applicator B = Metallic Salt Solution

C = Untreated

The particular silks in Groups 1 and 2 were perceived significantly rougher those in Group 3.

Fabrics in which treatments A and B had been applied, definitely became rougher as compared to the untreated.

## Summary

In summary, the judges perceived the treated silk and one of the treated cotton fabrics to be rougher than that of the untreated. The performance of Treatments A and B depended on the particular fabric type. Treatment A was considered rough on silk, whereas Treatment B was evaluated rough on both Group 1 cotton and all of the silks. There were no significant effects by flame retardant treatments on wool and linen fabric.

### Flexibility/Stiffness

A fabric that is considered flexible maintains the property of bending without breaking. The property of bending without breaking is a necessary characteristic of textile fibers. To create yarns and fabrics that can be creased, that have the quality of drapability and the ability to move with the body, that give when sat upon, and, in general, that permit freedom of movement, fibers used must be bendable, pliable, or flexible. Many substances in nature resemble fibrous forms, but because they are stiff or brittle, they do not make practical textile fibers.

It is further accepted that a fiber must flex or bend repeatedly in order to be classified pliable or flexible.

As with other properties, fibers of different types vary in their degree of pliability. The degree of flexibility determines the ease with which fibers, yarns, and fabrics will bend and is important in fabric durability (13).

Stiffness or rigidity is the opposite of flexibility. It is the resistance to bending or creasing.

Scale readings were scored by attributing lower values to flexibility and higher values to stiffness.

### Cotton

Reviewing flexibility/stiffness, the judges imply that an interaction does occur between test fabrics and flame retardant chemicals. See Table 13.

In Groups 1 and 2, the data shows that Treatment B leaves the selected cottons stiffer than the untreated. The judges did not perceive a difference between test fabrics that were untreated and those with Treatment A.

As apparent in Group 3, Treatment A left the selected cottons stiffer than the untreated. There were no interactions with Treatment B. This indicated there were differences within fabric groups, causing them to take finishes different.

Table 13

Two Way Table Of Means For Flexibility/Stiffness  
Of Selected Cottons

Treatment	Test Fabrics		
	G1	G2	G3
A	5.42	4.17	5.08
B	6.17	4.83	4.58
C	4.67	3.33	3.75

\*

\*Significance at 5% level

G = Group

G1 = 22.96 oz/yd<sup>2</sup> fabric

G2 = 5.99 oz/yd<sup>2</sup> fabric

G3 = 8.64 oz/yd<sup>2</sup> fabric

Commercial Applicator A = Durable Saline Solution

Commercial Applicator B = Metallic Salt Solution

C = Untreated

## Linen

In terms of flexibility/stiffness there were no interactions between the selected samples of linen and the flame retardants applied (Table 14).

Table 14

Table Of Overall Means For Flexibility/Stiffness  
Of Selected Linens

Test Fabric	Mean	Treatment	Mean
G3	2.06	B	2.25
G1	2.56	C	2.53
	*		*
G2	3.81	A	3.64

\*Significance at the 5% level

G = Group

G1 = 9.99 oz/yd<sup>2</sup> fabric

G2 = 7.98 oz/yd<sup>2</sup> fabric

G3 = 10.95 oz/yd<sup>2</sup> fabric

Commercial Applicator A = Durable Saline Solution

Commercial Applicator B = Metallic Salt Solution

C = Untreated

The data indicates that the selected linens in Group 2 were stiffer than those in Groups 1 and 3.

Fabrics in which Treatment A had been applied were evaluated stiff when compared to the untreated and those applied with Treatment B.

## Wool

In evaluating wool, the judges definitely sensed an interaction between test fabrics and flame retardant treatments. There is an indication that in Groups 2 and 3 fabrics in which Treatment B had been applied were significantly stiffer when compared to the untreated and those with Treatment A.

The data from Table 15 implies that in Group 1 flame retardant treatments did not effect fabric flexibility.

Table 15

Two Way Table Of Means For Flexibility/Stiffness  
Of Selected Wools

Treatment	Test Fabric		
	G1	G2	G3
A	6.33	3.42	3.92
B	6.25	5.17	5.92
C	6.42	2.00	3.50

\* Significance at 5% level

G = Group

G1 = 15.60 oz/yd<sup>2</sup> fabric

G2 = 16.12 oz/yd<sup>2</sup> fabric

G3 = 26.90 oz/yd<sup>2</sup> fabric

Commercial Applicator A = Durable Saline Solution

Commercial Applicator B = Metallic Salt Solution

C = Untreated

Within Group 2, test fabrics in which Treatment A and B had been applied were stiff when compared to the untreated.

Concluding from the results in Group 3, Treatment A produced the same degree of flexibility as the untreated, whereas test fabrics in which Treatment B had been applied were perceived as stiff.

### Silk

It was found that flame retardant treatments did not affect the flexibility/stiffness of the various test fabrics. Hence, it is appropriate to study over all means (Table 16).

As shown in Table 16, there is a significant difference between test fabrics 1 and 2. Test fabrics under Group 2 are stiffer than those in Group 1.

Test fabrics in which Treatment A and B had been applied were considered stiff when compared to the untreated. Treatment B was worse than Treatment A in this respect.

Table 16

Two Way Table Of Means For Flexibility/Stiffness  
Of Selected Silks

Test Fabric	Mean	Treatment	Mean
1	3.39	C	2.83
3	3.67	A	3.53
2	4.19	B	4.89

\*Significance at the 5% level

G = Group

G1 = 6.57 oz/yd<sup>2</sup> fabric

G2 = 8.94 oz/yd<sup>2</sup> fabric

G3 = 8.64 oz/yd<sup>2</sup> fabric

Commercial Applicator A = Durable Saline Solution

Commercial Applicator B = Metallic Salt Solution

C = Untreated

#### Summary

Overall, the data indicates that the application of flame retardants stiffens fabric hand. However, the performance of Treatments A and B depended on the particular fabric type. Treatment A, comprised of a durable saline solution, was perceived stiff on the selected cottons in Group 3, whereas in Groups 1 and 2 it was the application of Treatment B which stiffens fabric hand.



In terms of flexibility/stiffness on selected linens, the judges noted Treatment A to be the stiffest.

Evaluating the selected wool fabrics, significant differences were seen within Groups 2 and 3 under which Treatment B, metallic salt solution had been applied.

Silk fabrics treated by both commercial applicators A and B were considered stiff when compared to the untreated.

#### Openness/Compactness

Openness and compactness are words which refer to the compressional properties of fabric hand. A compact fabric can be perceived as fibers firmly pressed together, whereas an open piece of fabric is just the opposite.

Scale ratings were scored by attributing lower values to openness and higher values to compactness.

#### Cotton

In evaluating the particular cotton fabrics, the judges did not indicate a significant interaction between test fabrics and flame retarding treatments. See Table 17.

The test fabrics from Groups 2 and 3 were evaluated to be more compact than those in Group 1.

The flame retardant treatment applied by Commercial Applicator B resulted in a more compact fabric.

Table 17

Table Of Overall Means For Openness/Compactness Of Selected Cottons

Test Fabric	Mean	Treatment	Mean
1	5.39	C	5.58
3	5.92	A	5.72
2	6.17	B	6.17

\*Significance at the 5% level

G = Group

G1 = 22.96 oz/yd<sup>2</sup> fabric  
 G2 = 5.99 oz/yd<sup>2</sup> fabric  
 G3 = 8.64 oz/yd<sup>2</sup> fabric

Commercial Applicator A = Durable Saline Solution  
 Commercial Applicator B = Metallic Salt Solution  
 C = Untreated

Linen

There were no interactions between the selected linens and the applied flame retardant treatments.

Therefore, overall means were studied (Table 18).

The data indicates the selected linens in Group 2 to be more compact than those in Group 3.

There were no detectable effect of applying flame retardants on the openness/compactness of the fabrics studied.

Table 18

Table Of Overall Means For Openness/Compactness Of Selected Linens

Test Fabric	Mean	Treatment	Mean
3	5.42	C	5.47
1	5.69	B	5.67
2	5.86	A	5.83

\*Significance at the 5% level

G = Group

G1 = 9.99 oz/yd<sup>2</sup> fabric

G2 = 7.89 oz/yd<sup>2</sup> fabric

G3 = 10.95 oz/yd<sup>2</sup> fabric

Commercial Applicator A = Durable Saline Solution

Commercial Applicator B = Metallic Salt Solution

C = Untreated

#### WOOL

In terms of openness/compactness there is definitely an interaction between test fabrics and flame retarding chemicals. The judges in testing selected wools, perceived interactions in Groups 2 and 3. See Table 19.

Table 19

Two Way Table Of Means For Openness/Compactness  
Of Selected Wools

Treatment	Test Fabric		
	G1	G2	G3
A	6.42	4.75	3.75
B	6.33	5.50	5.25
C	5.75	4.33	3.75

\*Significance at the 5% level

G = Group

G1 = 15.60 oz/yd<sup>2</sup> fabric

G2 = 16.12 oz/yd<sup>2</sup> fabric

G3 = 26.90 oz/yd<sup>2</sup> fabric

Commercial Applicator A = Durable Saline Solution

Commercial Applicator B = Metallic Salt Solution

C = Untreated

Under Group 2, Treatment B changed the openness of the fabric by making it more compact.

The results for Group 3 are much the same as for Group 2, however in this case, Treatment B is more compact than both the untreated and those under Treatment A.

## Silk

There were no significant differences found in perceptions regarding the openness/compactness of selected silk fabrics (Table 20).

Table 20

Table Of Overall Means For Openness/Compactness Of Selected Silks

Test Fabric	Mean	Treatment	Mean
3	4.89	C	5.00
2	5.31	A	5.11
1	5.47	B	5.56

\*Significance at the 5% level

G = Group

G1 = 6.57 oz/yd<sup>2</sup> fabric

G2 = 8.94 oz/yd<sup>2</sup> fabric

G3 = 9.73 oz/yd<sup>2</sup> fabric

Commercial Applicator A = Durable Saline Solution

Commercial Applicator B = Metallic Salt Solution

C = Untreated

There were no significant differences in openness/compactness attributable to either the test fabrics or to the treatments used.

## Summary

In evaluating the particular categories of natural fiber textiles, the judges noted that the treated cotton and two of the wool fabrics were more compact in structure than the untreated. When significant differences were found, test fabrics in which Treatment B had been applied were evaluated more compact than the others.

### Warmth/Coldness

Thermal properties of fabric hand can be described as either warm or cold. Generally, fabrics which feel warm are lofty and have considerable surface fuzz. Cool fabrics are described as being dense (lack bulk) and have a smooth, clear finish.

Scale ratings were scored by attributing lower values to warmth and higher values to coldness.

### Cotton

In terms of thermal properties, the selected cotton fabric did not receive significant interaction between test fabrics and flame retarding treatments. See Table 21.

Cotton fabrics from Group 1 were judged to be cooler than those in Group 2. Selected cottons in which

Treatment B had been applied were cooler when compared to the untreated.

Table 21

Table Of Overall Means For Warmth/Coldness Of Selected Cottons

Test Fabric	Mean	Treatment	Mean
1	3.81	C	3.64
3	4.33	A	4.36
2	4.72	B	4.86

\*Significance at the 5% level

G = Group

G1 = 22.96 oz/yd<sup>2</sup> fabric  
 G2 = 5.99 oz/yd<sup>2</sup> fabric  
 G3 = 8.64 oz/yd<sup>2</sup> fabric

Commercial Applicator A = Durable Saline Solution  
 Commercial Applicator B = Metallic Salt Solution  
 C = Untreated

### Linen

Linen in terms of warmth/coldness did not receive an interaction between test fabrics and flame retardant treatments. Since an interaction did not occur, overall means were determined (Table 22).

Table 22

Table Of Over All Means For Warmth/Coldness  
Of Selected Linens

Test Fabric	Mean	Treatment	Mean
1	3.56	C	3.61
2	4.11	A	3.92
3	4.22	B	4.36

\*Significance at the 5% level

G = Group

G1 = 9.99 oz/yd<sup>2</sup> fabric

G2 = 7.98 oz/yd<sup>2</sup> fabric

G3 = 10.95 oz/yd<sup>2</sup> fabric

Commercial Applicator A = Durable Saline Solution

Commercial Applicator B = Metallic Salt Solution

C = Untreated

Test fabrics under Group 3 were perceived cooler than those in Group 1.

Linen fabrics which have been subjected to flame retardant Treatment B were evaluated cooler than the untreated fabric.

#### Wool

There is no interaction between test fabrics and flame retardant chemicals. As seen in Table 23, we look



at over all means.

Table 23

Table Of Over All Means For Warmth/Coldness  
Of Selected Wools

Test Fabric	Mean	Treatment	Mean
3	2.94	C	3.11
2	3.31	A	3.14
1	3.86	B	3.86

\*Significance at the 5% level

G = Group

G1 = 15.60 oz/yd<sup>2</sup> fabric

G2 = 16.12 oz/yd<sup>2</sup> fabric

G3 = 26.90 oz/yd<sup>2</sup> fabric

Commercial Applicator A = Durable Saline Solution

Commercial Applicator B = Metallic Salt Solution

C = Untreated

The wool fabric under Group 1 was perceived cooler than that of Group 3.

It is evident that Treatment B increased the coolness of wool and was significantly different than Treatment A. Treatment A was not found to have an effect on warmth/coolness.

## Silk

Reviewing warmth/coldness, the judges imply that an interaction does occur between test fabrics and flame retardant chemicals. See Table 24.

Table 24

Two Way Table Of Means For Warmth/Coldness  
Of Selected Silk

Treatment	Test Fabrics		
	G1	G2	G3
A	4.58	4.58	3.00
B	4.50	4.75	3.83
C	4.58	3.33	3.50

\*Significance at the 5% level

G = Group

G1 = 6.57 oz/yd<sup>2</sup> fabric

G2 = 8.94 oz/yd<sup>2</sup> fabric

G3 = 9.73 oz/yd<sup>2</sup> fabric

Commercial Applicator A = Durable Saline Solution

Commercial Applicator B = Metallic Salt Solution

C = Untreated

In Group 2, the judges indicated that treatment B significantly decreases the warmth of silk fabrics when

compared to the untreated.

In Group 3, Treatment B decreases the warmth of selected silks when compared to Treatment A.

#### Summary

In conclusion, the judges noted that in all fabric categories, except for silk, those in which Treatment B had been applied were perceived cooler in thermal property than the untreated. In testing silk, the judges considered fabrics with Treatment B cooler than the control in Group 2 and in Group 3 cooler than those receiving Treatment A.

#### Objective Testing

In measuring the physical properties of fabric hand, the Drape - Flex Stiffness Tester was used. A rectangular strip of fabric, 6 in. x 1 in. was mounted on a horizontal platform in such a way that it overhangs, and bends downward. The length of overhang was then recorded from which flexural rigidity was determined.

Data obtained from objective measurements were analyzed statistically by analysis of variance. A summary of the analyses are reported in Tables 25, 26, 27, and 28.

In testing all of the twelve fabrics, there was a definite interaction between the three treatments (A, B,

and C) and the direction of the yarns (warp vs filling). Since interactions occurred, Two Way Table Of Means were reported on all of the data. All means shown in the tables are based on five samples. Differences are seen between treatments as well as yarn direction. Significance was noted at the 5% level.

Table 28

ANALYSIS OF VARIANCE FOR SELECTED SILKS

Source Of Variation	DF	Mean Squares and Significances Of		
		SILK 1	Silk 2	Silk 3
Treatment	2	9,181,993	46,503,538	20,796,739
W vs F	1	1,795,333	16,216,387	19,859,462
T x W vs F	2	3,123,848*	10,533,079*	8,553,045*
Samples	24	101,523	266,524	284,346
Total	29			

\*Significance at the 5% level

W = Warp  
 F = Filling  
 TF = Treatment

Table 26

ANALYSIS OF VARIANCE FOR SELECTED LINENS

Source Of Variation	DF	Mean Squares and Significances Of		
		Linen 1	Linen 2	Linen 3
Treatment	2	2,729,770	2,909,029	99,634,338
W vs F	1	78,069	2,317,227	419,181,944
T x W vs F	2	70,489*	129,798*	78,787,243*
Samples	24	9,909	21,567	436,190
Total	29			

\*Significance at the 5% level

W = Warp  
 F = Filling  
 TF = Treatment

Table 27

## ANALYSIS OF VARIANCE FOR SELECTED WOOLS

Source Of Variation	DF	Mean Squares and Significances Of		
		Wool 1	Wool 2	Wool 3
Treatment	2	289,054,070*	122,365,690	864,789,186
W vs F	1	78,236,766*	3,072,780	38,027,489
T x W vs F	2	2,931,578*	6,842,485*	38,967,900*
Samples	24	1,279,286	412,426	844,328
Total	29			

\*Significance at the 5% level

W = Warp  
 F = Filling  
 TF = Treatment

Table 25

## ANALYSIS OF VARIANCE FOR SELECTED COTTONS

Source Of Variation	DF	Mean Squares and Significances Of		
		Cotton 1	Cotton 2	Cotton 3
Treatment	2	1,612,725,691	23,113,281	8,069,897
W vs F	1	934,438,684	13,446,675	28,578,762
T x W vs F	2	239,204,353*	1,614,890*	4,640,626*
Samples	24	2,424,703	20,698	111,937
Total	29			

\*Significance at the 5% level

W = Warp  
 F = Filling  
 TF = Treatment



Cotton

Table 29

Two Way Table Of Means For  
Flexural Rigidity of Cotton 1

Treatment	Filling (mg·cm)	Warp (mg·cm)
A	12,930.810	5,799.599
B	40,605.214	17,146.096
C	6,523.703	3,597.830

\*Significance at the 5% level

Commercial Applicator A: Durable Saline Solution  
Commercial Applicator B: Metallic Salt Solution  
C: Untreated

As shown in Table 29, the results suggest that in both warp and filling direction, Treatments A and B significantly stiffens fabric hand. The results also show that fabrics in which Treatment B had been applied are much stiffer than those with Treatment A.

Significant differences are seen between warp and filling direction. Within all fabrics the filling direction has shown to be stiffer than warp.

Table 30

Two Way Table Of Means For  
Flexural Rigidity Of Cotton 2

Treatment	Filling (mg·cm)	Warp (mg·cm)
A	495.852 *	1,264.584 *
B	2,588.623 *	4,846.823 *
C	857.695 *	1,847.728 *

\*Significance at the 5% level

Commercial Applicator A: Durable Saline Solution  
 Commercial Applicator B: Metallic Salt Solution  
 C: Untreated

The data from Table 30 indicates that the particular cotton samples became stiffer with the application of Treatment B and less stiff or more drapable after applying Treatment A. This was true for both warp and filling direction.

Within all treatments, significant differences are seen in yarn direction with warp being stiffer than filling.

Table 31

Two Way Table Of Means For  
Flexural Rigidity Of Cotton 3

Treatment	Filling (mg·cm)		Warp (mg·cm)	
A	1,178.972	*	3,577.680	}
B	828.775	*	3,863.874	
C	595.454		1,017.798	

\*Significance at the 5% level

Commercial Applicator A: Durable Saline Solution  
Commercial Applicator B: Metallic Salt Solution  
C: Untreated

Results from Table 31 indicate that in the filling direction there were no interactions between flexural rigidity and Treatments A and B. However, interactions are seen in the warp direction. Fabrics with the application of Treatments A and B became much stiffer.

In terms of yarn direction, warp vs filling, differences were seen between Treatments A and B. Data indicates warp direction stiffer than filling, however in the control sample there were no differences among warp and filling direction. When compared to filling direction, the warp appears to be taking the finish in a more stiffening manner.

Linen

Table 32

Two Way Table Of Means  
For Flexural Rigidity Of Linen 1

Treatment	Filling (mg·cm)	Warp (mg·cm)
A	256.204 *	289.515 *
B	1,257.712 *	967.774 *
C	179.124	129.673

\*Significance at the 5% level

Commercial Applicator A: Durable Saline Solution  
Commercial Applicator B: Metallic Salt Solution  
C: Untreated

According to the results from Table 32, Treatment B significantly stiffened fabric hand. There were no differences observed between the untreated fabrics and Treatment A.

As far as differences between warp and filling direction, there is only one. This difference is seen with the warp and filling yarns under Treatment B. Yarns in the filling direction appear to be stiffer than those in the warp direction.

Table 33

Two Way Table Of Means For  
Flexural Rigidity Of Linen 2

Treatment	Filling (mg·cm)		Warp (mg·cm)	
A	534.585	*	1,205.299	}
	*		*	
B	1,308.604	*	1,988.408	
	*		*	*
C	472.289	*	752.965	

\*Significance at the 5% level

Commercial Applicator A: Durable Saline Solution  
 Commercial Applicator B: Metallic Salt Solution  
 C: Untreated

As seen in Table 33, fabrics in which Treatment A had been applied were comparable in flexural rigidity to that of the untreated. However, fabrics in which Treatment B had been applied were significantly stiffer than the control and those applied with Treatment A. In the warp direction, both treatments, A and B, stiffened fabric hand.

Measurable differences are seen between warp and filling direction. Within all fabrics the warp direction has shown to be stiffer than filling both initially and after application of both treatments.

Table 34

Two Way Table Of Means For  
Flexural Rigidity Of Linen 3

Treatment	Filling (mg·cm)		Warp (mg·cm)
A	4,150.916 *	*	193.428
B	14,784.061 *	*	797.919
C	4,710.217	*	189.772

\*Significance at the 5% level

Commercial Applicator A: Durable Saline Solution  
Commercial Applicator B: Metallic Salt Solution  
C: Untreated

The data in Table 34 indicates that in the filling direction Treatment A and the control were comparable in terms of stiffness. Fabrics in which Treatment B had been applied were stiffer in the filling direction than the others. There were no differences among treatments seen in the warp direction.

In terms of warp vs filling, differences are seen under each of the treatments and initially in the control. The filling direction was stiffer than warp.

Wool

Table 35

Two Way Table Of Means For  
Flexural Rigidity Of Wool 1

Treatment	Filling (mg·cm)	Warp (mg·cm)
A	13,694.917 *	16,982.346 *
B	18,542.312 *	22,824.478 *
C	8,871.312 *	10,990.098 *

\*Significance at the 5% level

Commercial Applicator A: Durable Saline Solution  
Commercial Applicator B: Metallic Salt Solution  
C: Untreated

As evident from Table 35, the application of Treatments A and B has measurably stiffened fabric hand. This was true for both warp and filling. According to the results, fabrics with Treatment B are stiffer than those with Treatment A.

As far as yarn direction, significant differences are noted for all fabrics with the warp direction stiffer than filling both initially and after treatment.

Table 36

Two Way Table Of Means For  
Flexural Rigidity Of Wool 2

Treatment	Filling (mg·cm)	Warp (mg·cm)
A	2,013.849	1,673.576
B	5,978.526	8,528.704
C	851.695	562.033

\*Significance at the 5% level

Commercial Applicator A: Durable Saline Solution  
 Commercial Applicator B: Metallic Salt Solution  
 C: Untreated

Results from Table 36 show that flame retardants, once again, stiffened fabric hand. In both warp and filling direction, fabrics with Treatments A and B became stiffer. Of the two treatments, Treatment B proved to be the worst in stiffening the fabric.

In comparing warp direction to that of filling, there is only one interaction at the 5% level. This interaction is seen under Treatment B where the warp is stiffer than filling.



Table 37

Two Way Table Of Means For  
Flexural Rigidity Of Wool 3

Treatment	Filling (mg·cm)	Warp (mg·cm)
A	5,229.764 *	4,588.950 *
B	* 23,862.914	* 17,111.359 *
C	3,579.466	4,215.614

\*Significance at the 5% level

Commercial Applicator A: Durable Saline Solution  
Commercial Applicator B: Metallic Salt Solution  
C: Untreated

Data from Table 37 indicates that in the filling direction Treatments A and B significantly stiffen fabric hand. In the warp direction it was only Treatment B which increased fabric hand.

In yarn direction, significant differences were seen under Treatment B, with the filling direction stiffer than warp.

Silk

Table 38

Two Way Table Of Means For  
Flexural Rigidity Of Silk 1

Treatment	Filling (mg·cm)		Warp (mg·cm)	
A	659.676 *		960.449	}
B	3,066.579 *	*	1,298.318 *	
C	337.951		337.653	

\*Significance at the 5% level

Commercial Applicator A: Durable Saline Solution  
Commercial Applicator B: Metallic Salt Solution  
C: Untreated

As evident from Table 38, Treatment B in the filling direction has stiffened fabric hand. In the warp direction, both Treatments were significantly stiffer than that of the untreated.

In terms of yarn direction, differences are seen under Treatment B with the filling direction stiffer than warp. This suggests the filling yarns of the fabric were more effected by the treatment than the warp.

Table 39

Two Way Table Of Means For  
Flexural Rigidity Of Silk 2

Treatment	Filling (mg-cm)	Warp (mg-cm)
A	304.929	563.684
B	2,223.549	6,063.943
C	227.399	539.562

\*Significance at the 5% level

Commercial Applicator A: Durable Saline Solution  
 Commercial Applicator B: Metallic Salt Solution  
 C: Untreated

As evident in Table 39, Treatment B, in both filling and warp has significantly stiffened fabric hand.

Under Treatment B, measurable differences were seen between warp and filling direction. With the application of Treatment B, yarns in the warp direction were more highly effected than filling thus causing the warp yarns to gain stiffness.

Table 40

Two Way Table Of Means For  
Flexural Rigidity Of Silk 3

Treatment	Filling (mg·cm)		Warp (mg·cm)
A	191.802		721.961
	*		*
B	1,112.949	*	4,875.722
	*		*
C	243.766		832.571

\*Significance at the 5% level

Commercial Applicator A: Durable Saline Solution  
Commercial Applicator B: Metallic Salt Solution  
C: Untreated

According to the results from Table 40, Treatment B significantly stiffened fabric hand. This was true in both warp and filling direction. Fabrics in which treatment A had been applied were comparable in flexural rigidity to that of the untreated fabrics.

In terms of yarn direction, differences are seen under Treatment B with the warp direction stiffer than filling.

## Summary

In summary, the selected cottons in Group 1 were significantly stiffened in both warp and filling direction as a result of Treatments A and B. As originally, the filling direction remained stiffer than the warp direction. In Group 2, an interesting thing happened, the selected cottons in both warp and filling direction became less stiff or more drapable when Treatment A was applied. However, Treatment B stiffened the fabric hand in both fabric directions. As initially, the warp direction of the fabric remained stiffer than the filling. According to measurements, selected cottons in Group 3 were stiffened only in the warp direction with Treatments A and B. In yarn direction, the warp became significantly stiffer than the filling.

In looking at selected linens within Group 1, Treatment B stiffened both the warp and filling direction. Treatment B had a much more stiffening effect on the filling than on the warp direction of the fabric. In Group 2, Treatment B again significantly stiffened both warp and filling direction. As originally, the warp direction remained stiffer than the filling. The linens in Group 3 were stiffened by Treatment B in the filling direction. Initially these fabrics were stiffer in the

filling as compared to warp. This effect remained constant throughout Treatments. Treatment A stiffened only one group of fabrics (Group 2) and in one fabric direction (warp).

Results indicate Treatments A and B to significantly stiffen the selected wools in Group 1. As initially, the warp direction remained stiffer. In Group 2, flame retardants, A and B, once again stiffened fabric hand. The fabrics were stiffened in both warp and filling direction. Within this group, Treatment B had a much more stiffening effect on warp direction than filling. The selected wools in Group 3 were significantly stiffened in the filling direction with the application of Treatments A and B. In warp direction it was only Treatment B which increased the stiffness of fabric hand. In yarn direction, Treatment B caused greater stiffening in filling direction than in the warp direction.

The selected silks in Group 1 were stiffened by Treatment A only in the warp direction, whereas the application of Treatment B stiffened the silk in both warp and filling direction. Treatment B had a much more stiffening effect on the filling than on the warp direction of the fabric. In Group 2, Treatment B stiffened both warp and filling direction. As initially, Treatment B had a much more stiffening effect on warp than

## COMPARISON OF SUBJECTIVE AND OBJECTIVE MEASURES

In looking at flexibility/stiffness of fabric hand, both subjective and objective measures agree that the application of flame retardants may stiffen fabric hand. However, varying fabrics and varying commercial application methods have different stiffening effects.

According to physical flexural rigidity tests, stiffening effects by Treatments A and B were evident in warp and/or filling direction of selected cottons in Groups 1, 2, and 3. Only the stiffening effect of Treatment B was detectable by the designers subjective evaluation of flexibility/stiffness for the Group 1 fabrics.

In the case of selected linens, there was little agreement between physical and subjective measurements. In measuring flexural rigidity, physical tests indicate that in Group 1, Treatment B stiffened the linens in both fabric directions. In Group 2, Treatment A stiffened the linens only in the warp direction, while Treatment B stiffened the fabrics in both warp and filling direction. The selected linens in Group 3 were stiffened in the filling direction by the application of Treatment B. Designers were unable to perceive any of these effects.

All three wool fabric groups were measured as stiffened in one or both directions by Treatments A and B. Designers were unable to perceive any of these effects.

The silk fabrics were measured as stiffened by Treatment B in both directions of all fabrics and stiffened in the warp direction of the Group 1 fabrics by Treatment A. Designers perceived a stiffened effect by Treatments A and B in all groups of fabric including groups 2 and 3 which did not have a physically measurable effect by Treatment A.

In conclusion, comparing subjective measures to that of objective measures it is important to note that although differences are perceived, objective measurements indicate a higher degree of stiffness. This degree of stiffness can be seen between the treated fabrics and those which were untreated. Also, objective measures indicate that more fabric categories were affected by flame retarding treatments than subjective measures.



## CONCLUSIONS

This investigation was designed to address one major issue. The issue was:

1. To evaluate upholstery weight fabric for tactile changes, following the custom commercial application of flame retardant finishes.

Two questions were generated regarding this issue. The concluded results of this study will be discussed in answer to these questions.

The questions were:

1. Can interior designers perceive differences in fabric hand between untreated upholstery weight fabric and those treated with commercial flame retardant finishes?
2. Is there a difference in flexural rigidity between untreated upholstery weight fabric and those treated with commercial flame retardant finishes.

When interior designers were asked to evaluate test fabrics in terms of roughness/smoothness, they perceived the treated silks and one treated cotton fabric to be rougher than that of the untreated. Treatment A was considered rough on silk, whereas Treatment B was evaluated rough on Group 1 cotton and all silks. The designers did not perceive any effect of treatment on the wool and linen fabrics.

In evaluating flexibility/stiffness, the designers indicated that the application of flame retardants often stiffens fabric hand. The performance of Treatments A and B depended on the particular fabric type. Treatment A, comprised of a durable saline solution stiffened one group of selected cottons and linens, whereas Treatment B (metallic salt solution) stiffened the other two groups of cottons as well as two groups of wools. According to subjective evaluation, the designers perceived all silk fabrics stiffer as a result of Treatments A and B.

When rating openness/compactness, interior designers perceived the treated cottons and two of the wool fabrics to be more compact in structure than the untreated. In all cases, when differences were found, Treatment B caused the compacting not Treatment A.

In terms of warmth/coolness, the designers indicated that in all fabric categories, except silk, those in which Treatment B had been applied were perceived cooler in thermal property than the untreated.

In answer to the second question, this particular study did find a difference in flexural rigidity between untreated upholstery weight fabric, and those treated with commercial flame retardants. It was evident that the selected test fabrics were often stiffened by the application of flame retardants. Fabrics receiving

Treatment B, comprised of a metallic salt solution were often stiffer than both the untreated and those with Treatment A.

In yarn direction, data shows that in some fabrics one direction was significantly stiffer than the other. Depending on the particular fabric, Treatments A and B stiffened the warp and filling yarns in varying amounts.

## RECOMMENDATIONS FOR FURTHER STUDY

This study examined upholstery weight fabrics in light of tactile changes following the custom commercial application of flame retardant finishes. Also studied were subjective scales of fabric hand in relationship to objective scales of measurement. Suggestions for further research includes:

1. Examine the effects of color change once flame retardant chemicals have been applied.
2. Further research should be conducted to examine the shrinkage that takes place as a result of flame retardant chemicals.
3. Further research should be conducted to determine if there is a difference between male and female perception of upholstery weight fabrics following the custom commercial application of flame retardant finishes.

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## APPENDIXES

APPENDIX A

LIST OF CONTACTS  
FOR FABRIC DONATION

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1. Ametex  
261 Fifth Avenue  
New York, New York  
(212) 696-0535
  
2. Amoco Fabric Company  
550 Interstate North Parkway  
Atlanta, Georgia 30099  
(404) 955-0935
  
- \*3. Architex  
625 W. Jackson  
Chicago, Illinois 60606  
(800) 621-0827
  
4. Arc Com Fabrics  
33 Ramland S.  
Orangeburg, New York 10962  
(800) 223-5466
  
5. Artlee Fabrics  
100 New South Road  
Hicksville, New York 11801  
(800) 645-7230
  
6. Laura Ashley  
300 D. St. SW  
Washington, D.C. 20024  
(800) 621-2989
  
7. Barclay Fabrics  
9115 Pennsauken, New Jersey 08110  
(800) 257-8344

Note: \* Denotes Fabric Suppliers

8. Basset McNab Company  
1032 Arch Street  
Philadelphia, PA 19107
  
9. Lee Behren Silk  
245 Newtown Road  
Plainview, New York 11803  
(516) 249-3100
  
10. Gretchen Bellinger  
330 E. 59th Street  
New York, New York 10022  
(212) 688-2850
  
11. Biscayne Fabrics  
P.O. Box 370489  
Miami, Florida 33137
  
12. Boussac of France, Inc.  
979 Third Street  
D and D Building  
New York, New York 10022  
(212) 421-0534
  
- \*13. Brunschwig and Fils Inc.  
979 Third Avenue  
New York, New York 10021  
(212) 838-7879
  
- \*14. Henry Calvin Fabrics  
290 Division Street  
San Francisco, California 94103  
(415) 863-1944
  
15. Camouflage Fabrics and Wallcoverings  
129 West Avenue #34  
Los Angeles, California 90031  
(213) 223-5251

16. Manuel Canovas  
979 Third Avenue  
New York, New York 10022
17. Carleton V Ltd  
979 Third Avenue  
New York New York 10022
- \*18. Carnegie Fabrics  
110 North Center Avenue  
Rockville Centre, New York 11570  
(516) 678-6770
19. Henry Cassen Fabrics  
245 Newtown Road  
Plainview, New York 11803  
(516) 249-3100
20. Ronald Charles Associates  
3900 North Miami Avenue  
Miami, Florida 33127
- \*21. China Seas Inc.  
21 East Fourth Street  
New York, New York 10003  
(212) 752-2890
22. Clarence House  
211 East 58th Street  
New York, New York 10022  
(212) 752-2890
23. Coral Of Chicago  
2002 South Calumet Avenue  
Chicago, Illinois  
(800) 621-5250
24. Coraggio Textiles  
P.O. Box 3332  
Bellevue, WA 98009  
(800) 624-2420

25. Molly Corbett Fabrics  
1429 Leavenworth Street #303  
San Francisco, California 94109
26. Ian Crawford Inc.  
979 Third Avenue  
D and D Building  
New York, New York 10022  
(212) 243-6250
27. David and Dash  
2445 North Miami Avenue  
Miami, Florida 33137  
(305) 573-8000
- \*28. Deschemaker  
979 Third Avenue  
New York, New York 10022  
(212) 319-5730
29. Design Tex  
56-08 37th Avenue  
Woodside, New York 11377
- \*30. Donghia Textiles  
483 Broadway  
New York, New York 10013  
(212) 925-2777
31. Duralee Fabrics  
1775 Fifth Avenue  
Bayshore, New York 11706
32. Finlandia Fabrics  
P.O. Box 185  
Exton, PA 19341  
(800) 532-0362

33. Glant Fabric Corporation  
P.O. Box 84228  
Seattle, Washington 98124  
(206) 628-6235
  
34. Grayson Fabrics  
410 West First Street  
P.O. Box 382  
Roselle, New Jersey 07203  
(800) 645-5146
  
35. Greef Fabrics Inc.  
150 Midland Avenue  
Port Chester, New York 10573
  
36. Guadalupe Hand Print Fabrics  
P.O. Box 877  
Boerne, Texas 78006
  
37. Harleys Fabric  
1313 North 108th Avenue  
Tulsa, Oklahoma 74158  
(800) 331-3235
  
38. Harrinton Textile  
499 East Walnut Street  
North Wales, PA 19454
  
- \*39. S. Harris and Company Inc.  
991 Francisco Street  
P.O. Box 2856  
Torrance, CA 90509
  
40. Heirloom  
500 Old Thomasville Road  
High Point, North Carolina 27261
  
41. Hinson and Company  
27-35 Jackson Avenue  
Long Island City, New York 11101



42. Horton Fabrics  
8517 Directors Row  
Dallas, Texas 75247  
(800) 527-5229
  
43. Hoy Designer Textiles  
3131 Western #318  
Seattle, Washington 98121  
(206) 283-7556
  
44. I.C.F. Inc.  
305 East 63rd Street  
New York, New York 10021  
(212) 750-0900
  
- \*45. International Fabrics  
232 Swathmore Avenue  
P.O. Box 1448  
High Point, North Carolina 27261  
(800) 334-7399
  
46. Lee Jofa Inc.  
800 Central Blvd.  
Carlstadt, New Jersey 07072  
(201) 438-8444
  
47. Morton Jonap LTD  
12 Midland Avenue  
Hicksville, New York 11801  
(516) 931-6777
  
48. Judith Kindler Textiles  
208 Utah Street  
San Francisco, California 94103  
(415) 861-1603
  
49. Knoll International  
655 Madison Avenue  
New York, New York 10028  
(212) 207-2200

- \*50. Kravet Fabrics  
225 Central Avenue S  
Bethpage, New York 11714  
(800) 645-9068
  
- 51. Boris Kroll Fabrics  
979 Third Avenue  
New York, New York 10022  
(212) 755-6200
  
- 52. LaLune Collection  
241 Broadway Street  
Milwaukee, WI 53202  
(414) 271-1172
  
- \*53. Jack Lenor Larson Inc.  
41 East 11th Street  
New York, New York 10003  
(212) 674-3993
  
- 54. Lazarus  
9303 East 46th Street  
P.O. Box 47090  
Tulsa, Oklahoma 74147  
(918) 622-7700
  
- 55. Maharam Fabrics  
8600 West 95th St. Overland Park  
Kansas City, Kansas 66212  
(913) 381-5333
  
- 56. Naco Fabrics  
145 Plant Avenue  
Hauppauge, New York 11788  
(800) 645-5146
  
- 57. R. and M. Enterprises  
2355 Rusmar  
P.O. Box 1270  
Cape Girardeau, MO 63701  
(314) 334-0517

58. Rodolph  
P.O. Box 1249  
Sonoma, California 95476
  
59. Scalamandre Silks  
2400 Market Street  
Philadelphia, PA 19103  
(212) 980-3888
  
60. Robert Scott and Associates  
8727 Melrose Avenue  
Los Angeles, California 90069
  
61. Silk Dynasty Inc.  
382 First Street  
Los Altos, California 94022  
(415) 394-3649
  
62. Stratford Hall Inc.  
495 South Calhoun Street  
Fort Worth, Texas 76104  
(817) 332-1465
  
63. Stroheim and Roman  
10 West 20th Street  
New York, New York 10011  
(212) 691-0700
  
64. Westgate Fabrics  
1000 Fountain Parkway  
Grand Prairie, Texas 75050  
(214) 647-2323
  
65. H. Lynn White Inc.  
8208 Nieman Road  
Lenexa, Kansas 66214

APPENDIX B

MATERIALS PROVIDED  
FOR SUBJECTIVE TESTING

FABRIC HAND SCALE

Instructions to Designers:

The purpose of this study is to examine upholstery weight fabrics in light of tactile changes, following the custom commercial application of flame retardant finishes. On the following pages are several adjectives that can be used to describe "fabric hand" or how the fabric feels to you. You are to rate the fabric according to adjectives presented in the following scales.

In using the scale if you feel that the fabric is very closely related to one end of the scale, you should place your check-mark as follows:

soft  X :\_\_\_\_\_:\_\_\_\_\_:\_\_\_\_\_:\_\_\_\_\_:\_\_\_\_\_:\_\_\_\_\_:\_\_\_\_\_:hard

or

soft \_\_\_\_\_:\_\_\_\_\_:\_\_\_\_\_:\_\_\_\_\_:\_\_\_\_\_:\_\_\_\_\_:\_\_\_\_\_ X :hard

If you feel that the fabric is quite closely related to one or the other end of the scale (but not extremely), you should place your check-mark as follows:

flat \_\_\_\_\_: X :\_\_\_\_\_:\_\_\_\_\_:\_\_\_\_\_:\_\_\_\_\_:\_\_\_\_\_:\_\_\_\_\_: textured

or

flat \_\_\_\_\_:\_\_\_\_\_:\_\_\_\_\_:\_\_\_\_\_:\_\_\_\_\_:\_\_\_\_\_ X :\_\_\_\_\_: textured

If you feel that the fabric is only slightly related by the adjective at one end or the other end of the scale you should place your mark as follows:

flimsy \_\_\_\_\_:\_\_\_\_\_ : X : \_\_\_\_\_: \_\_\_\_\_: \_\_\_\_\_: \_\_\_\_\_: firm

or

flimsy \_\_\_\_\_:\_\_\_\_\_ : \_\_\_\_\_: \_\_\_\_\_: X : \_\_\_\_\_: \_\_\_\_\_: firm

If you feel that the fabric can be described as neutral, or if the scale is completely irrelevant or unrelated to the fabric, then you should place the checkmark as follows:

thick \_\_\_\_\_:\_\_\_\_\_ : \_\_\_\_\_: X : \_\_\_\_\_: \_\_\_\_\_: \_\_\_\_\_: thin

- IMPORTANT:
- 1) Place your check-mark in the middle of the spaces.
  - 2) Do not omit any.
  - 3) Do not put more than one check-mark on a single scale.

FABRIC HAND SCALE

According to the instructions on the separate page,  
place a check between each pair of adjectives at the  
location that best describes the particular fabric.

Sample 1A(C)

Roughness \_\_\_\_:\_\_\_\_:\_\_\_\_:\_\_\_\_:\_\_\_\_:\_\_\_\_:\_\_\_\_: Smoothness  
Flexibility \_\_\_\_:\_\_\_\_:\_\_\_\_:\_\_\_\_:\_\_\_\_:\_\_\_\_:\_\_\_\_: Stiffness  
Openness \_\_\_\_:\_\_\_\_:\_\_\_\_:\_\_\_\_:\_\_\_\_:\_\_\_\_:\_\_\_\_: Compactness  
Warmth \_\_\_\_:\_\_\_\_:\_\_\_\_:\_\_\_\_:\_\_\_\_:\_\_\_\_:\_\_\_\_: Coldness

Fabric Hand: Designer Evaluation of Upholstery Weight  
Fabrics Treated With Commercial Flame Retardants

by

STEPHANIE ANN WATSON

B.S., Kansas State University, 1984

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AN ABSTRACT OF A THESIS

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requirements for the degree

MASTER OF SCIENCE

College of Human Ecology

Kansas State University  
Manhattan, Kansas

1987



## ABSTRACT

Today's interior designer must be able to advise his or her client on matters related to flame retardants and the consequences of chemicals applied to natural fibers. In dealing with flame retardants, one major concern to designers is the direct result of chemical treatment on the tactile appearance of a fabric. To better understand client preferences and to offer guidelines for designers, the purpose of this study was to investigate upholstery weight fabrics for tactile changes, following the custom commercial application of flame retardant finishes. Fabrics tested were upholstery weight cottons, linens, wools, and silks. Measurements were taken both subjectively and objectively.

In conducting subjective testing, a seven point semantic differential scale was used. Findings were based on a factorial equation involving twelve judges, thirty - six test fabrics, and two flame retardant treatments.

In setting up the semantic differential scale, polar terms were selected to represent the four major modes of fabric deformation in handling a fabric: frictional, bending, compressional, and thermal deformation.

Rough and smooth were polar adjectives used to describe surface contour or frictional properties. The

judges perceived the all of the silks and Group 1 cotton to be rougher than that of the untreated.

In describing bending properties of fabric hand, adjectives flexible and stiff were used. The data suggests that the application of flame retardans stiffen fabric hand. Treatment B more so than Treatment A.

When describing compressional properties of fabric hand, polar adjectives open and compact were used. The judges noted that cotton and wool fabrics in which Treatment B had been applied were more compact in structure than the untreated.

Thermal properties of fabric hand can be described as either warm cold. The judges noted that in all fabric categories, except silk, those in which Treatment B had been applied were perceived cooler in thermal property than the untreated.

Measurements for objective testing were taken utilizing the Drape - Flex Stiffness Tester.

Results indicate that the selected test fabrics were stiffened by the application of flame retardants. Treatment B, comprised of a metallic salt solution was consistently stiffer than both the untreated and those with Treatment A.