A TEST METHOD FOR SMOLDER RESISTANCE OF UPHOLSTERED FURNITURE

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CHAPTER I

INTRODUCTION

The Flammable Fabrics Act (17), as amended in 1967, granted an enforcing agency the right to establish flammability standards when a need for such standards was found and proven. The Consumer Product Safety Commission (CPSC) is currently the agency directed to promulgate such regulations.

In the past, consumer concerns for safe textile products have led to a number of standards being imposed on textile products to reduce death, injury, and property damage. Reports from the National Electronic Surveillance System (EISS) and the Flammable Fabrics Accident Case Testing System (FFACTS) to the CPSC, citing cases of death and injury due to fires involving upholstered furniture, led to the first formulation of the proposed regulation of upholstered furniture flammability, Upholstered Furniture Flammability Standard PFF 6-76 (60).

The CPSC, in cooperation with the National Bureau of Standards (BS), had developed a draft of a flammability standard designed to address the problem of furniture flammability and the major hazard associated with it--

ignition by cigarettes. The Commission then issued a "Notice of Finding that a Flammability Standard or Other Regulation May be Needed and Institution of Proceedings" (61). During the time between the publication of both the finding of a need and the draft of the Proposed Upholstered Furniture Flammability Standard, PFF 6-76, much data were collected by the commission regarding 1) the cost of such a standard to industry and the consumer, 2) the impact of such a standard on industry and the consumer, and 3) a refinement of the regulatory procedures necessary for producing a workable standard. In September 1977, the Commissioners of CPSC reviewed the draft of the Standard for Upholstered Furniture Flammability, and the data presented by various industries involved with the manufacturing of upholstered furniture, and the publication of a revised draft, PFF 6-78, was the result (35).

Briefly, the proposed standard (revised draft, PFF 6-78) consists of two tests--one to classify fabrics and one to classify combinations of fabrics, filling materials, and constructions. Upholstery fabric would be classified into one of four categories (A, B, C, and D), with Class A fabrics the most resistant to ignition by cigarettes and Class D fabrics the least resistant. Under the CPSC standard for fabric classification, the following fabrics are typical examples of each class:

Class A - Wools, wool blends, vinyl plastics and heavy-weight synthetics (nylon, olefin, polyester, and acrylic)

Class B - medium-weight synthetics and some light-weight or tightly woven cellulosics (cotton, rayon, and linen)

Class C - medium-weight cellulosics (rayon)

Class D - heavy-weight cellulosics.

Based on the data collected at the time of the proposed standard, Class D fabrics comprised 25 to 35 percent of the upholstered furniture market, Class C, 20 to 25 percent of the market, Class B, 25 to 30 percent of the market and Class A, the least flammable fabrics, only 10 to 15 percent of the market. The synthetic fibers and wool fibers combined represented only 10 to 15 percent of the market while cellulosic fibers comprised the remaining 85 to 90 percent of the fibers used in 1977 (20).

While the CPSC standard does not propose to eliminate fabrics from the market, some of the currently used fabrics would require chemical treatments, fabric finishing techniques, or the use of special construction and filling materials to meet the proposed standard. Rather than perform the extra steps and incur added costs to meet the proposed standard, the furniture industry will probably select fabrics which are already in the A and B classes. If such were the case, a mandatory standard could cause changes in both the available fabrics for consumer selection as well as an increase in cost if flame resistant procedures were necessary.

Of the estimated 250 million yards of fabric used for upholstery, the CPSC estimates that 14 percent, mostly cellulosics, could be replaced by synthetic substitutes. The upholstered furniture fabric suppliers have estimated the actual amount to be well above this prediction (49).

The CPSC estimated the total cost of this regulation to the public to be between $57 million and $114 million annually in added purchase costs. This would add 15 to 25 percent to the retail price per furniture piece. Some of these costs are already being passed on to the consumer by the furniture industry in anticipation of the regulatory procedures (55). If a mandatory standard is promulgated by CPSC, the furniture industry will be faced with the addition of testing, record keeping, and increases in costs brought about by the regulatory procedures.

Objectives of the Study

The CPSC proposed a mandatory flammability standard for upholstered furniture after determining a need for such a regulation. The upholstered furniture industry submitted a counterproposal to CPSC in the form of a voluntary program to be carried out by the furniture manufacturers (5, 23).

Researchers (9, 10, 24) have indicated that the smolder resistance of furniture is a function of total systems, rather than individual components making up the furniture. Based on the results of research, the real need for and purpose of a flammability standard for upholstered furniture is to define total systems which can perform in a smolder resistant manner, including any specific limitations of combinations of systems to assure performance in a fire safe manner. Therefore, the purposes of this study were:

1. To devise an alternative flammability test method for upholstery fabrics that defines conditions under which upholstery fabrics can perform in a fire safe manner; and

2. To incorporate the resultant test method into a procedure which will specify fabric/batting combinations that do perform in a fire safe manner in relation to the end-use of the product.

CHAPTER II

REVIEW OF LITERATURE

The history of consumer concern for textile flammability in this country dates back to a series of fire disasters during the 1940's and 1950's when several fire incidents involving textiles caused a number of deaths and injuries. Some of these occurred in public places such as the Coconut Grove night club in Boston and a circus tent fire in Hartford, Connecticut, but the fires, involving individuals, which received much publicity and generated concern were those fires due to children's brushed rayon cowboy chaps and women's high pile rayon sweaters. A number of children were injured and died in separate incidents when wearing cowboy chaps of brushed rayon and there were a series of burn incidents resulting from the ignition of brushed rayon sweaters made to simulate angora wool. The latter incidents that brought about the term "torch like" fabrics (26, 33).

The "torch like" fabrics led to the formation of the Flammable Fabrics Act in 1953 (18). Since that time various acts and governmental agencies have been involved with protecting consumers against hazards that evolved from the use of textile products (19, 28, 43, 51).

The Flammable Fabrics Act, which is a rather broad act, became a law on June 30, 1954. The original act covered the regulation of highly flammable fabrics for apparel, and in 1967 this act was broadened to cover additional fabrics including textile products for use in household interiors. In 1967 the Flammable Fabrics Act, under the jurisdiction of the Department of Commerce, was amended (6), giving more power to the enforcing agency. Section 14(a) of the amended act states:

> The Secretary of Health, Education, and Welfare in co-operation with the Secretary of Commerce shall conduct a continuing study and investigation of deaths, injuries and economic losses resulting from accidental burning of products, fabrics or related materials. The Secretary of Health, Education, and Welfare shall submit annually a report to the President and to the Congress containing the results of the study and investigation.

The time that elapses between the issuance of a need for regulations and the issuance of a regulation is often quite long (33). Part of this is due to the time involved in developing test methods and the negotiations between government and industry to clarify the standards prior to the issuance of a public law (27, 28).

Part of the problem involves the confusion between a test method and a standard. A test method is used to classify items on a graduated scale, such as the faharenheit temperature scale. A standard on the other hand, is a set of criteria for determining how products should perform in a test (32, 33). The primary requisite for a test method for determining the flammability or flame resistance of textiles is that the method in some way should be related to the hazard or hazardous situation under question. The primary requisite of a fabric flammability standard is that the pass/fail requirements correlate with realistic ignition and burning situations (14, 22). A perfect correlation would represent an ideal situation, although not always easily attained (37, 53, 54).

The development of CS 191-53 represents a systematic method of developing a standard. Following the deaths and injuries involving brushed rayon fabrics in the 1940's and 1950's, it was decided that certain easily ignited, rapidly burning fabrics should be eliminated from the apparel markets in the United States. A simple, accurate and reproducible test method to measure rate of burning and ease of ignition was developed for general wearing apparel. The pass/fail criteria of the 45° angle test procedure, as outlined in CS 191-53, was set so fabrics which were considered unreasonably hazardous were eliminated and those fabrics which were of normal flammability passed the standard.

Under the terms of the amended Flammable Fabrics Act, the Federal government issued six flammability standards, after reports to the President and the Congress indicated a need, covering a variety of textile products. A summary of these standards (25) appears in table 1. Initially, the standards were established by the Department of Commerce and enforced by the Federal Trade Commission (FTC). With the creation of the Consumer Product Safety Commission in 1967, both responsibilities were then transferred to this agency (17).

Fires in which textiles are the first to ignite result in more deaths and injuries than fires involving any other class of materials. The term "textile fires" is used to denote fires in which a textile product was the first item to ignite. There are some instances in which a textile product was first to ignite, but did not contribute materially to the fire. There are, however, some incidents where textiles were responsible for generating the most flame and smoke, although they were not the first to ignite. The former incidents were considered to be a textile fire, while the latter incidents were not considered textile fires (36, 56).

Statistics for the years 1977-78, as compiled by the National Fire Incident Reporting System (NFIRS) and the United States Fire Administration (USFA), indicated that the national average of dollar losses due to textile fires was $512 million or 16 percent of the total economic losses

TABLE 1

FEDERAL STANDARDS IMPLEMENTING THE FLAMMABLE FABRICS ACT

Effective Date	Standard	Application	Test Method
1954	General flammability standard for wearing apparel. CS 191-53	Applies to most articles of clothing.	Fabric placed in a holder at a 45° angle.
1971	Large carpets and rugs. DOC FF 1-70	Applies to carpets that have a dimension greater than 6 feet.	Specimens 9x9" are exposed to a methanamine tablet.
1971	Small carpets and rugs. DOC FF 2-70	Applies to carpets that have no dimension greater than 6 feet.	Same as for large carpets and rugs.
1973	Mattresses (and mattress pads) DOC FF 4-72	Ticking filled with resilient material intended for sleeping.	Cigarettes are allowed to burn, chars are measured.
1972	Children's Sleepwear Sizes 0-6x DOC FF 3-71	Nightgowns, pajamas, or other items intended to be worn for sleeping.	Vertical forced ignition.
1975	Children's Sleepwear Sizes 7-14 DOC FF 5-74	Nightgowns, pajamas, or other items intended to be worn for sleeping.	Vertical forced ignition.

due to fires. Textile related fires accounted for 2,827 injuries, or 32 percent of the total, and 579, or 47 percent of the deaths even though textile related fires accounted for only 21 percent of all fires (56, 62). In textile fires, mattresses, upholstered furniture, and bedding lead the list in textile items first to ignite. Nearly one half of all the fire related fatalities and one third of all fire related injuries can be attributed to textile related fires. Fires involving upholstered furniture accounted for 44 percent of the deaths in textile related fires. The main source of ignition was smoking materials (36).

The dollar value of life and of the pain of injury is difficult to assess, although Dardis and others (11, 34, 47) have developed cost-benefit analysis models to examine the value of implementing new flammability standards as well as the benefits evolved from the implementation of the Standard for Children's Sleepwear. The objectives of such models and analyses are 1) to assist in selecting the most cost effective consumer protection program and 2) to determine whether the implementation of the program is justified. In general the cost of a safety standard includes the cost of the resources necessary to develop and monitor the standard as well as the costs to the consumer due to product regulation. The consumer costs involve increases in price, reduction in items from which to choose, and in some instances a reduction in the product wear life. The benefits provided by a safety standard are estimated by two major approaches:

1) the reduction in accidents, including the direct and indirect costs accidents would have on livelihood, and
2) willingness of consumers to pay for the risk reduction.

A necessary part of the development of a standard is a cost-benefit analyses to determine the dollar ratio involved in the implementation of a standard. The lower the ratio, the higher the benefit derived, and at the level of 0.75, the consumer is getting $1.00 in protection for every $0.75 in expenditure.

The most important considerations in a cost-benefit analysis are to examine the data concerning burn incidents, costs required to implement regulatory procedures, and alternative consumer programs in comparison to the property and personal injury losses to the consumer. A cost-benefit analysis can put a dollar value on life, but the problems associated with pain and suffering are not something readily assessed with a monetary value and are therefore excluded from the analysis (47).

Data contributed by NEISS and FFACTS substantiated the need for an upholstered furniture flammability regulation, and the notice of a need for regulation of the flammability of upholstered furniture was first published in November, 1972, in the <u>Federal Register</u> (61). The Proposed Standard for Flammability of Upholstered Furniture, PFF 6-76 as developed by the National Bureau of Standards under the direction of the CPSC, was divided into two parts. Fabrics were first classified by an NBS test or a prototype apparatus which is similar to a small chair, and second a mock-up test apparatus is used to test all the components being considered for use in a particular furniture piece.

The fabric classification portion of this standard is based on the char length produced by a lighted cigarette placed on the upholstery fabric. The classification procedures are as follows:

1. Class A:

   char length is < 1.5 inch on glass fiber board
   < 1.5 inch on cotton batting

2. Class B:

   char length is < 1.5 inch on glass fiber board
   ≤ 1.5 inch on cotton batting

3. Class C:

   char length is ≥ 1.5 inch on glass fiber board
   < 3.0 inch on glass fiber board

4. Class D:

   char length is ≥ 3.0 inch on glass fiber board

Three specimens for each fabric sample are cut and mounted on the fabric test assembly (prototype) over glass fiber board as shown in figure 1. A lighted cigarette is placed at the abutment of the horizontal (seat) and vertical (back) panels, covered with a square of cotton sheeting and secured with one straight pin. If all three specimens produce a char length less than 1.5 inch, excluding the average cigarette size (3.3 inches in the lengthwise direction and 0.3 inch in the diameter or crosswise direction), the fabric is again tested, but with cotton batting in the vertical panel and glass fiber board in the horizontal panel. If the char produced on cotton batting is less than 1.5 inches, excluding the cigarette size on all three samples, the fabric receives a Class A rating. The fabric receives a Class B rating if one of the char lengths is equal to 1.5 inches or greater, or if the batting exhibits combustion. When the char length is equal to or greater than 1.5 inches and less than 3 inches on glass fiber board, the fabric receives a Class C rating. If one of the three test specimens ignites or the char length is 3.0 inches or greater on glass fiber board the fabric receives a Class D rating.

Classification of the fabrics is made when the results of the cigarette burns are the same, that is, the cigarettes burn their entire length, or all three cigarettes

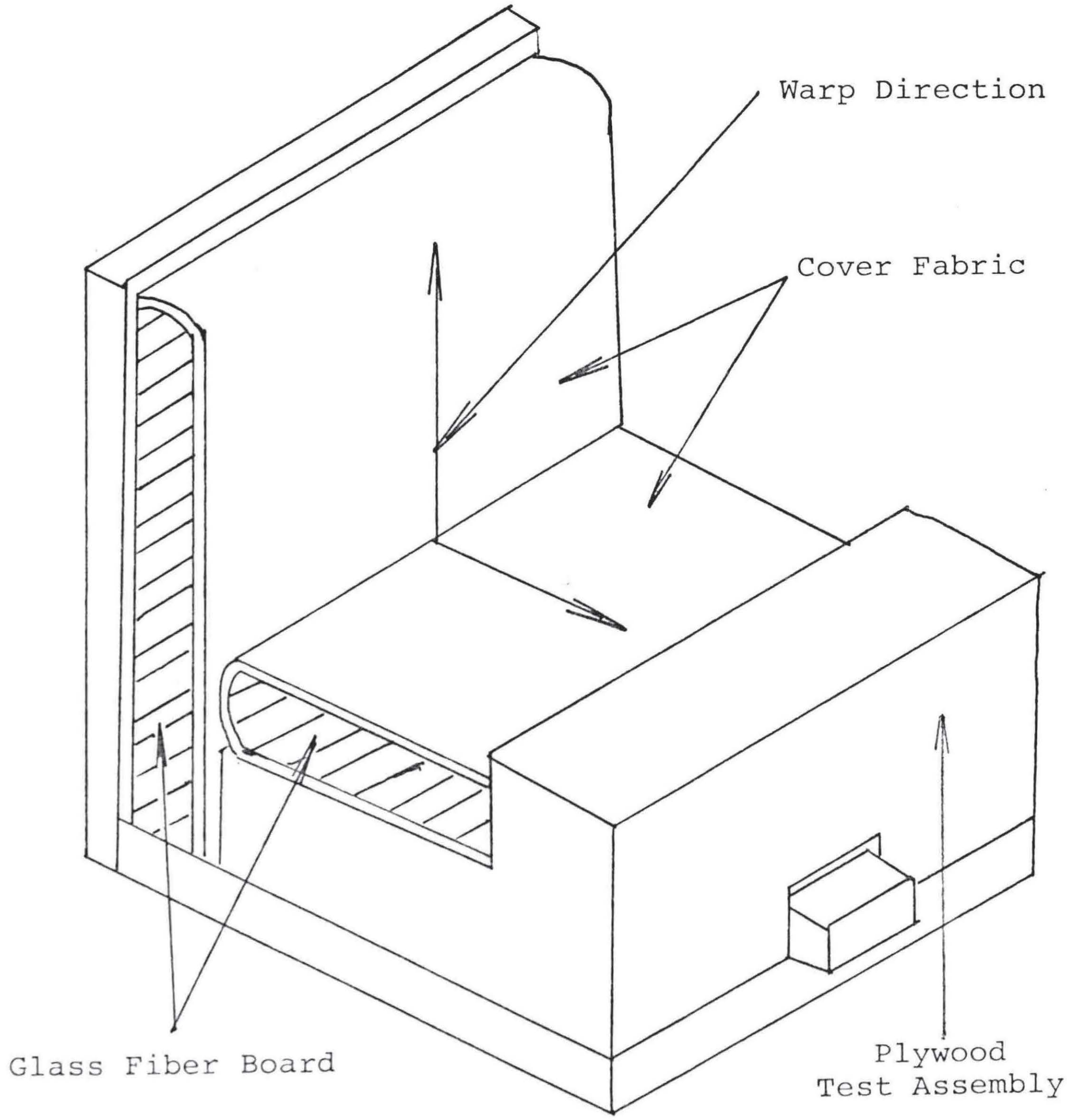

Fig. 1. NBS sample holder for upholstery fabric test

extinguish before burning their entire length. Class C and D fabrics are not barred from furniture production, but they would encounter difficulty in passing the second part of the test procedure, the mock-up test.

The mock-up test (figure 2) consists of using an assembly of all components considered for use for a particular piece of upholstered furniture. The test procedure requires lighted cigarettes to be placed over all surface construction components such as cording, quilting, thread, et cetera. Sheeting squares are then placed over these lighted cigarettes and the char lengths are again used for classification, except this time the criteria is pass/fail. Any char length of greater than 3 inches is considered to be a failure. The mock-up test was not included in this study.

The Upholstered Furniture Action Council (UFAC) is a federation of five or more associations that represent approximately 70 percent of the upholstered furniture producers in the United States. UFAC was formed, in 1972, to represent the upholstered furniture industry for the purpose of presenting alternatives for the mandatory regulation of upholstered furniture flammability. The voluntary plan they developed sought to eliminate the testing and record keeping involved with mandatory regulations (5, 23).

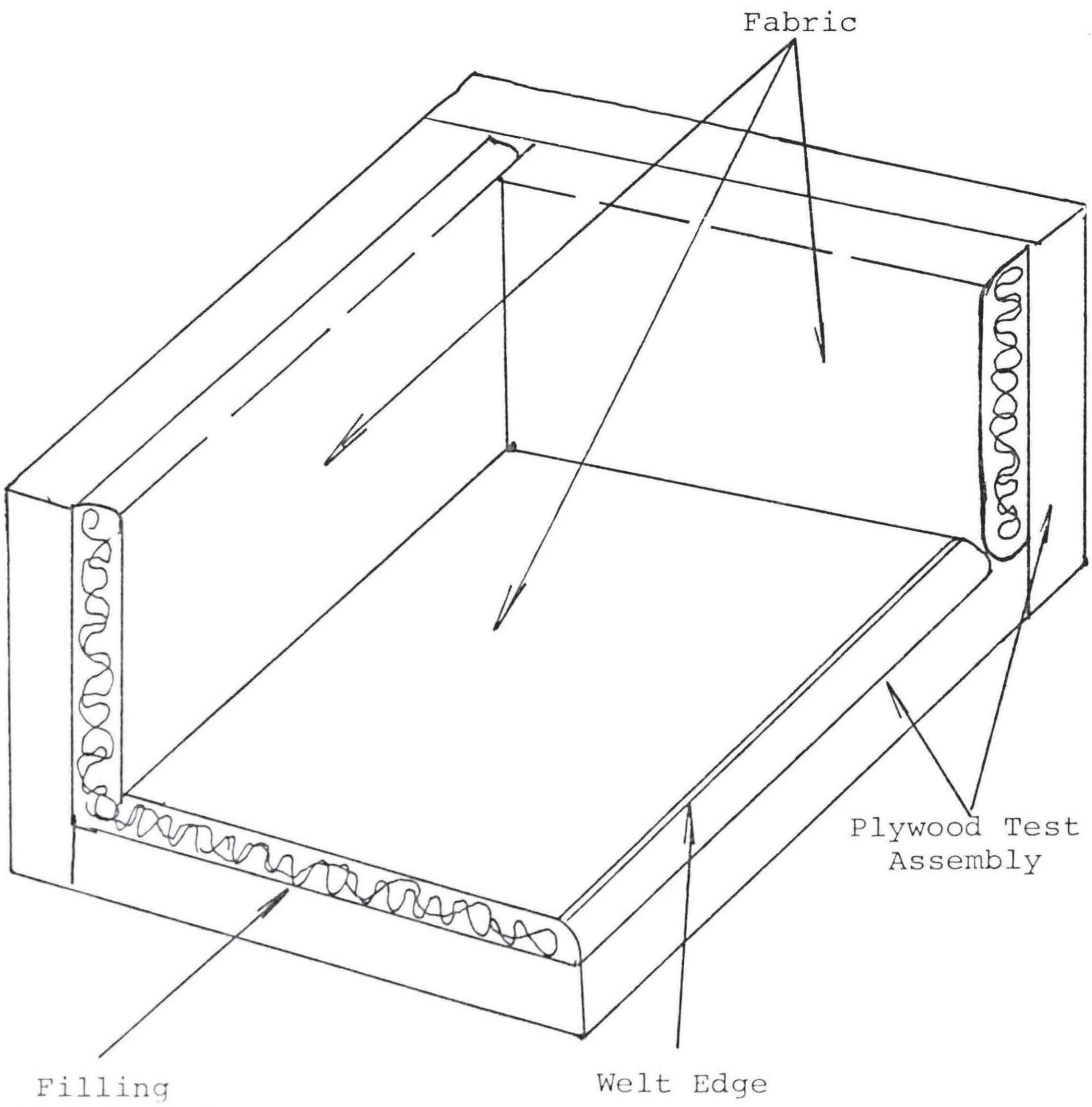

Fig. 2. NBS furniture mock-up test assembly

The UFAC voluntary plan (57) differed from the proposed CPSC mandatory regulation in a number of ways. First, upholstery fabric are divided into two classes as follows:

Class I: Fabrics containing 50 percent or more thermoplastic fibers, plus any other fabrics that perform equally as well when measured by a laboratory test.

Class II: All other fabrics.

Second, the UFAC plan indicated that fabric suppliers would certify the fabrics as either Class I or Class II. This method of fabric classification would eliminate classification of fabrics by tests, as proposed by CPSC. Third, the voluntary plan of UFAC proposed the elimination of ignition prone welt cords, and fourth, it proposed the elimination of untreated cotton batting as a substratum in immediate contact with the covering fabric (57). Fabrics composed of less than 50 percent thermoplastic fiber would be eliminated, and thus cotton, linen, rayon, and many blends containing these fibers would be categorized as Class II fabrics. Under the UFAC plan many of the currently used upholstery fabrics could be eliminated from the market merely because of their lack of thermoplastic fiber content (23).

Under the UFAC voluntary plan, furniture manufacturers would attach a UFAC hangtag (label) to furniture, indicating the furniture was produced under UFAC guidelines in compliance with the voluntary standards. The UFAC plan for using hangtags was devised to combine the two concepts of fabric rating and of furniture construction criteria of the voluntary plan. The hangtag is proported to make the consumer aware that the item of furniture is safer because of the UFAC recommended construction criteria and also to warn the consumer of the dangers of ignition of upholstered furniture from a burning cigarette regardless of the safety improvements of the UFAC Criteria. The hangtags are available to the furniture manufacturers from UFAC at a nominal cost (57).

In anticipation of the implementation of an upholstered furniture flammability standard in 1976, labels were at times placed on the deck (the flat surface under the loose cushions) of some furniture pieces. The following statement is an example of a label attached to some of the furniture for sale in retail stores in 1976 (57):

CAUTION SMOKERS

> Smoldering cigarettes can cause upholstered furniture to catch fire. If you feel drowsey you are urged not to smoke while seated or reclining. The Upholster Furniture Action Council issues this warning in the interest of public safety.

The original voluntary plan as proposed by UFAC was not entirely acceptable to the CPSC. Therefore, UFAC formulated additional assurances of compliance as requested by the CPSC. To substantiate that the UFAC construction criteria were met and that furniture pieces bearing the UFAC hangtag were in compliance with the construction criteria as outlined by UFAC, five tests were added to the voluntary action program. These tests were as follows:

1. A welt cord test.
2. A decking materials test.
3. A filling materials test.
4. A barrier test.
5. A fabric classification test.

The test apparatus used for the UFAC test is the same as the NBS prototype test apparatus except for the substrata, which is a polyurethane foam in both the vertical and horizontal panels of the testing apparatus. Following the UFAC negotiations with CPSC, the UFAC hangtag was changed and the hangtags attached to complying furniture in 1979 were as follows:

> The manufacturer of this upholstered furniture certifies that with this cover fabric and filling material, the item is made in accordance with $UFAC_{CM}$ construction criteria that are engineered to reduce, but not necessarily eliminate, ignition by a burning cigarette by insulating or modifying certain materials or combinations of materials, traditionally used in upholstered furniture manufacturing, that are most susceptible to ignition.
>
> Keep your family and furniture safe from fires caused by careless smoking. Even with modern $UFAC_{CM}$-recommended materials and methods, smoldering cigarettes and other heat or fire sources can cause upholstery furniture fires.
>
> For the protection of your family, $UFAC_{CM}$ recommends that you have at least one

> smoke detector in your home. An early warning of fire, starting from any cause, can help protect you and your family. (57)

One major change that occurred as a result of the UFAC voluntary proposal was the substitution of polyurethane foam for the untreated cotton batting in the deck and sides of upholstered furniture (59). Products made with polyurethane foam pass existing flammability standards for carpets and mattresses (9), but polyurethane foam has some severe draw backs for use in residential applications (63). Polyurethane foam, when exposed to sufficient temperatures, will burn and produce potentially hazardous gases. The use of polyurethane foam has increased 220 percent (59) since the proposed standard for upholstered furniture was first published. However, the CPSC staff and commission will need some time to collect and analyze the data to determine the problems associated with the toxicity of burning foam.

In November 1979, the CPSC voted unanimously to allow UFAC a one-year trial period for utilizing the voluntary program to reduce furniture flammability (16, 58). The staff of CPSC had not concluded its analysis of the voluntary program in January of 1981; therefore, the voluntary program will continue to remain in effect until further action is taken by the CPSC (7).

The State of California always has been somewhat faster than the federal government in passing regulations for textile flammability. The California State standard was in effect for children's sleepwear prior to the federal sleepwear standard (33) and the regulation of upholstered furniture flammability has existed in California since May of 1966 (28).

The State of California established a plan for the testing of upholstery fabric and filling materials as individual components and not as an integral unit (50). Furniture which is produced or manufactured to be sold in California must meet the criteria as set forth by that state. The California testing procedure plan was presented to the CPSC for approval and incorporating into the proposed federal standard, but the plan was rejected by the CPSC (5).

To gain an understanding of the complexities of establishing a flammability standard for upholstered furniture, consideration of many factors is involved. Damant and Young (10) conducted extensive research in 1977 on the classification of fabrics used as upholstered furniture coverings. Results of this study revealed significant differences between the smolder resistance of fabric/substrata combinations.

The nature of the substrata (furniture filling material) critically influences the flammability characteristics of the finished furniture pieces. Further, fabric weight, dyes, finishes, weaves, fibers, and backcoatings all may influence the way in which a particular fabric becomes involved in smoldering combustion (9). However, the choices available for filling materials on the other hand are rather limited. The most commonly used filling materials are 1) cotton batting, 2) several types of polyurethane foam, and 3) polyester fiberfill (38).

Knoepfler and Neumeyer (31) have indicated that cotton batting, while inexpensive, is capable of sustaining a smoldering combustion reaction even after the original source of ignition is removed, whether the source is an open flame or a burning cigarette. Large quantities of smoke and toxic gases result from the burning of mattresses as indicated by results of research conducted by Keating, Knoefler, McSherry and Wadsworth (29), and the burning characteristics of mattresses are similar to those exhibited by upholstered furniture. Attempts have been made to flame retard cotton batting (30, 46), but such procedures are expensive and have not been entirely satisfactory. Cotton batting products, unless chemically modified, can be extremely hazardous because of their tendency to readily support and propagate smoldering combustion (9, 31).

A number of studies (3, 13) have been conducted to examine and evaluate the effectiveness of adding backcoatings to cotton, as well as other fiber upholstery fabrics in an effort to impart smolder resistance. Several compounds have been evaluated as possible smolder resistant additives to be incorporated into latex backcoatings. Upholstery fabric is typically backcoated to prevent seam slippage, provide dimensional stability, and improve wear-ability. The addition of a smolder resistant backcoating can be effective in reducing fire hazards when the back-coating material can withstand the heat of an ignition source and prevent ignition of the substrata.

Backcoating of fabrics restricts the amount of air penetration of the fabric and increases fabric weight. In the research performed by Donaldson (13) relative to examining air permeability of fabrics, results revealed that the ability of a fabric to resist air penetration also was an important factor in determining smolder resistance, although backcoating was not the only factor influencing smolder resistance. High permeability is allowable when the substrata is treated with a flame retardant substance. The addition of backcoating substances increases fabric weight and fabric weight also influences smolder resistance in some fabrics (3).

Heavy synthetic fabrics are more resistant to ignition than are heavy cellulosic fabrics, which are less resistant (13). Fabric construction, including compactness of weave and finishes, influences the ability of a fabric to withstand ignition. Heavier fabrics require backcoatings and an increase in flame retarding chemicals in order to inhibit smoldering ignition as compared to medium or light weight fabrics. Donaldson, also, found that as the fabric weight of cellulosics increased the char areas produced by lighted cigarettes also increases (12).

The problem of imparting smolder resistance to upholstered furniture is a composite of many factors including both fabrics and substrata. Currently, there are a limited number of materials available for use as filling materials for upholstered furniture, but there are a variety of cover fabrics. It is not uncommon for a manufacturer to offer as many as 400 cover fabrics, and in some instances swatch books provide as many as 4000 cover fabrics from which a consumer may make selections (20).

As noted in the August 1981 issue of a furniture industry trade publication (45), the upholstery fabrics most often selected by consumers were: 1) velvets, 2) cotton prints, and 3) jacquard weaves. The fibers utilized in these fabrics were cotton, nylon, olefin, and blends which included acrylic and rayon. A number of these fabrics were mainly cellulosic fiber fabrics which would not meet the specifications of the UFAC plan of classification according to thermoplastic fiber content.

Recognizing that fires involving upholstered furniture and bedding are often related to smoking materials, several bills have been introduced in Congress to develop a standard to reduce to five minutes the burn time of a cigarette placed on a flat surface. However, cigarette makers find neither the previous bills nor HR 6675, introduced in 1981, to be acceptable to them. To produce a cigarette that would self-extinguish could possibly reduce the incidents of fires resulting from cigarette ignition, but to produce a cigarette with such a capacity would require the addition of chemicals to cigarettes and would possibly increase the hazards of cigarettes to smokers (4).

Krasny (1) indicated that screening tests for textile flammability should be conducted in the orientation at which the textile is most likely to be used. Consequently, the prototype test designed by NBS, simulating a small upholstered furniture piece, fulfills this criteria. The use of a cigarette as the ignition source appears to be the most realistic method for evaluating the smolder resistance of upholstered furniture, since smoking materials are the most common ignition source for this type of textile related fire.

The use of unfiltered cigarettes, as specified by the PFF 6-78 test procedure for upholstered furniture flammability, is the best method for assessing the smolder resistance of upholstered furniture. Olsen and Bollinger (42) found that covered cigarettes produced higher temperatures than uncovered cigarettes to complete the burn, therefore, indicating the stringency of both the proposed test method and the use of sheeting to cover the lighted cigarette.

Based on the research reviewed, evidence exists that there is a need for a realistic test method to examine smolder resistance of upholstered furniture. Such a test method should incorporate fabric and substrata currently available for the manufacture of upholstered furniture.

CHAPTER III

PROCEDURE

The purposes of this research were to devise a flammability test method and fabric classification procedure and to determine performance differences between certain fabrics/substratas combinations when tested by the devised test method. Some fabrics which can perform in a smolder resistant and safe manner under certain conditions will be eliminated from the market by either the CPSC proposed standard or the UFAC voluntary plan for upholstered furniture flammability (5, 38). An alternative plan for testing fabric/substrata materials more realistic to end use could prevent the elimination of many of the currently used fabrics from the marketplace.

Fabrics Tested

After preliminary flammability tests were performed on 27 typical upholstery fabrics, thirteen fabrics, available from a commercial upholstery fabric supplier, were selected as the fabrics to be tested in this research. The fabrics were selected as representative of upholstery fabrics currently on the market and were not limited to fabrics that performed in a particular manner during the preliminary flammability tests. The sample fabrics contained natural and manmade fibers and a wide range of blends. The percentage fiber content is shown in table 2.

Physical Properties of Fabrics Tested

Yarn

The number of yarns per inch were determined for all fabrics in accordance with the ASTM Test Method D 1910-70 (2). An Alfred Suter pick counter was used to count the number of yarns per inch in five locations in both the warp and filling directions. In any fabric where the individual yarns were not readily distinguishable, the ravel yarn count method was performed as outlined in the above test method. An average of five counts was calculated and recorded for both the warp and the filling directions.

Fabric Weight

The fabric weight was determined for all fabrics in accordance with ASTM Designation D 1910-70 (2). Fabric specimens were cut 6" x 6" (15 cm x 15 cm), conditioned and weighed on a Mettler analytical balance in accordance with the specified procedure.

Fabrics were tested in received condition, meaning that no special treatment, such as washing or dry cleaning,

TABLE 2

PERCENTAGE FIBER CONTENT OF FABRICS TESTED

Fabric Number	Generic Fiber				
	Nylon	Wool	Rayon	Cotton	Olefin
1	100				
2[a]	45	55			
3		100			
4	17		83		
5			100		
6			81	19	
7			76	24	
8[b]			42	54	
9			36	64	
10				100	
11	26		50	24	
12				100	
13					100

[a]Sample number 2 contained a flame retardant finish.

[b]Sample number 8 contained 4 percent of a nonspecified classification.

was performed prior to testing. Fabrics were conditioned for each test performed as specified by the testing procedure.

Oxygen Index

The Oxygen Index (OI), formerly called the Limiting Oxygen Index test, was performed in accordance with the ASTM Test Method D 2863-76 "Standard Method for Measuring the Minimum Oxygen Concentration to Support Candle-Like Combustion of Plastics" (2). Five specimens 1 1/2" x 5 1/2" (3.8 cm x 14 cm) were cut from each sample fabric and placed in a specimen holder designed to support specimens vertically in the center of a test column. Each specimen was ignited by methane gas delivered by means of a small glass tube with a small orifice (1 to 3 mm in diameter). The ignition flame was from 6 to 25 mm long. A hand held stop watch was used to ascertain the burn time. The average consumed oxygen of each specimen was calculated and the oxygen consumed was recorded. The corrected concentration of oxygen and nitrogen was obtained prior to the ignition of the fabric as specified in the test procedure. The entire top edge of the specimen was ignited prior to removal of the flame and before starting the timer. Sections 8.6 through 8.9 of ASTM D 2863-76, test method, which pertain to fabrics, were followed to obtain correct oxygen consumption of the burning fabrics.

Air Permeability

Ten specimens, cut from each fabric tested in the dimensions of 4" x 4" (10 cm x 10 cm) containing different yarns in each specimen, were utilized in testing by Federal Test Method Standard No. 191, Method 5452 (15), the permeability of fabric to air. The actual area of the fabric through which air was forced was 1.10 square inch. No special sample conditioning was required. The individual specimens were mounted on a Gurley No. 4418 Densometer as indicated in the operating instructions of the instrument. The inner cylinder was raised to its highest position and a stop watch was used to determine the time necessary for the air to pass through the fabric speciman. The average air permeability of each sample fabric was calculated to the nearest second on the results of the ten specimens and reported.

Vertical Flammability Test
Children's Sleepwear Standard FF 6-74

The Children's Sleepwear test is a vertical test of fabric flammability using a 1 1/2 inch (5 cm) methane gas flame applied for one half its length to the base of the fabric specimen for three seconds. Initially, the test consisted of determining both the char length (seven inches maximum) and flaming melt drip (residual flame) on the floor of the test chamber (maximum ten seconds). Currently measurement of the residual flame has been discontinued. A total of ten specimens 3" x 10" per fabric sample were cut: five in the warp direction and five in the filling direction. The specimens were conditioned, as specified by the test method, in a forced draft oven for 30 minutes at 105° F (40° C) and then cooled in a dessicator for 30 minutes prior to testing. The flame impingement time was three seconds. An average of the char lengths of the ten specimens was calculated.

Mushroom Apparel Flammability Test, MAFT Test, Proposed Standard for the Flammability of General Wearing Apparel

In the MAFT ignition test (44, 48), the surface of the fabric is exposed to an open flame for 0.5 and 1.0 seconds. The methane gas ignition source is supplied by a number 18 hypodermic needle. The flame is about 7/8 inch (2.2 cm) long. The ignition source was positioned so the fabric touched a hook extending 3/8 inch (0.9 cm) beyond the orifice of the hypodermic needle. A solenoid controlled valve automatically regulates the gas flow for the required ignition time.

The flame impingment is 4 inches (10 cm) above the bottom edge of the fabric, thereby allowing the flame to spread in all directions, not only upward as in other fabric edge ignition tests. Time of ignition for this heat transfer test are 3 seconds and 12 seconds. If the specimen does not ignite at the 3 second exposure time, ignition is again attempted in a different area for 12 seconds. The assumption is that fabrics which ignite in 3 seconds will also ignite in 12 seconds. Therefore only the first test need be performed. Fabrics which fail to ignite in 12 seconds are considered sufficiently safe to be placed in fabric Class I unless the critical test value is exceeded. At any time the value of 0.42 joules/cm^2.s is exceeded on the recorder, the fabric is classed as a failure. In the case of ignition, the speciman shall be allowed to burn until either the fabric self-extinguishes or the heat transfer rate of 0.42J/cm^2.s is exceeded as specified in the Test Method Criteria.

Classification of fabrics using the MAFT test apparatus is as follows:

Class of Fabric	Length of Time to Ignite	Maximum Heat Transfer
1	regardless of ignition time	0.42 $J/cm^2.s$
2	greater than one second	0.42 $J/cm^2.s$
3	1.0 second or less	0.42 $J/cm^2.s$
4	0.5 second or less	0.42 $J/cm^2.s$

Four specimens 12.5" x 24.0" (30 cm x 60 cm), two warp and two filling, were cut for each fabric and conditioned at room temperatrue of at least 60° F (15° C) and a relative humidity of less than 67 percent. An ignition test and heat transfer rate test were performed on the fabric surface. Flame impingement times for the ignition test were 0.5 and 1.0 seconds. The heat transfer test flame impingement times were 3.0 and 12.0 seconds. The rate of heat transfer was measured by 20 thermocouples contained in a copper cylinder and top plate of the MAFT testing assembly. An electronic signal processor received the outputs of the thermocouples and converted the rate of heat transfer to $joules/cm^2.s$. The rate was plotted and the highest rate was considered as the heat transfer measurement for the speciman. The ignition time tests were not indicative of acceptable upholstery fabric performance thus performance of the specimens did not warrant testing beyond the 3 second heat transfer test.

UFAC Classification of Fabrics

The fabrics in the sample were classified (57) as either Class I, those fabrics containing 50 percent or more thermoplastic (synthetic) fiber or performing as well (57), and as Class II fabrics, containing less than 50 percent thermoplastic fiber. Fabrics with a flame retardant finish would be considered as performing as well (57) regardless of fiber content and therefore would be considered to be Class I.

Proposed Standard for the Flammability of Upholstered Furniture PFF 6-78

Fabric Prototype Test

The fabric prototype test, as designed by NBS, was used for testing the smolder resistance of fabrics, and char lengths obtained during this test were compared to the char lengths obtained during a modified prototype test.

The Proposed Standard for the Flammability of Upholstered Furniture (PFF 6-78) consisted of the following two tests for the classification of upholstery fabrics.

1. Glass Fiber Board Test: Three fabric specimens per sample were placed on a prototype assembly. The specimens were wrapped over glass fiber board and placed in the support system. A lighted cigarette was placed at the abutment of the horizontal and vertical panels and covered

with cotton sheeting. Char length measurements were taken and recorded.

2. Cotton Batting Test: When char lengths of less than 1.5 inch on glass fiber board resulted, the second part of the prototype test was performed. Three specimens per sample were cut in the required dimensions outlined in PFF 6-78. The fabric was attached to the prototype by staples over the cotton batting in the vertical panel in a taut manner to prevent folds or the influence of air entering and creating a draft or tunnel effect. Fabric was wrapped over the glass fiber board in a horizontal position as described in the first portion of the test. Again, a lighted cigarette was placed at the abutment of the horizontal and vertical panel following the same requirements for the cigarette, sheeting, and measuring techniques as used for the glass fiber board test.

The fabric specimens, cotton sheeting, cotton batting, and glass fiber board were conditioned for 48 hours prior to testing in an atmosphere of less than 55 percent relative humidity and a temperature greater than 65° F (18° C). Fabric specimens were suspended to allow the circulation of air on all sides. The fabric test assembly is shown in figure 3.

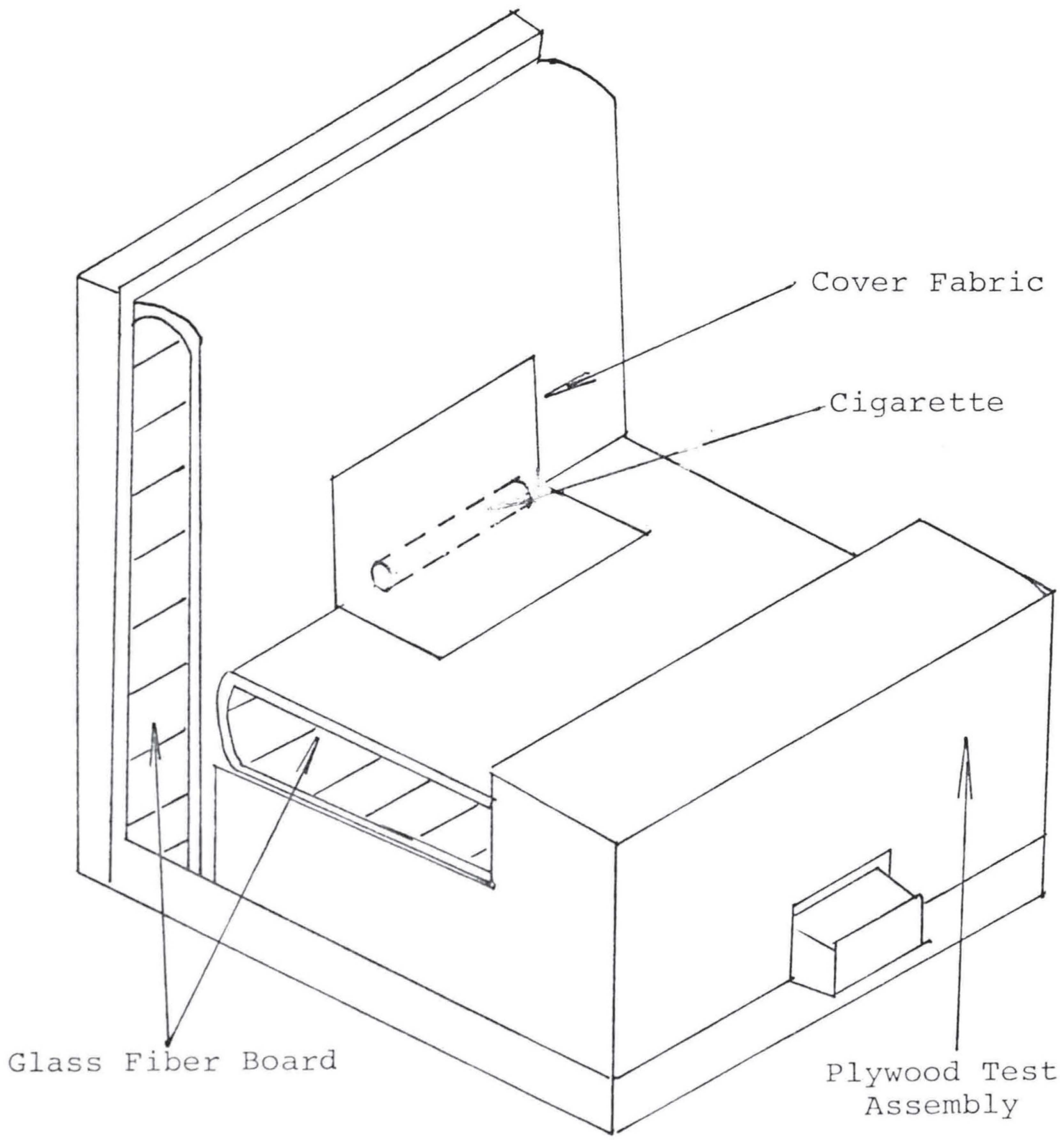

Fig. 3. NBS sample holder for upholstery fabric test with cigarette and sheeting.

A summary of the fabric prototype test procedure recommended by the DOC draft of the Proposed Standard for the Flammability of Upholstered Furniture (PFF 6-78) follows.

1. Fabric specimens for the glass fiber board test: Three specimens per sample are cut 8" x 8" (20 x 20 cm) for the vertical panel across the width of the fabric and 8" x 12" (20 x 30 cm) for the horizontal panels across the width of the fabric.

2. Fabric specimens for the cotton batting test: Three specimens per sample are cut 8" x 8" (20 cm x 20 cm) for the vertical panels and 12" x 12" (30 cm x 30 cm) for the horizontal panels across the width of the fabric.

3. Ignition Source: The cigarettes (Pall Mall) must be without filter tip and made from natural tobacco 3.4 $\pm$ 0.1 inch (85 $\pm$ 2 mm) long, with a diameter of 0.3 $\pm$ 0.1 inch (85 cm) with a packing density of 0.270 $\pm$ 0.020 g/cm^3 and a total weight of 1.1 $\pm$ 0.1 g. The cigarette may not burn longer than 0.16 inch (4 mm) before placement.

4. Cover fabric: The sheeting cover fabric is untreated cotton sheeting, which has been laundered and tumbled dried at least once. Squares 5" x 5" (12 cm x 12 cm) are cut after the fabric has been washed and dried.

5. Cotton batting: The cotton used must be approximately 2.0 inches (5 cm) thick and shall not be treated with any substance that imparts fire retardency. The batting shall be a blend of cotton staple and linters, all new (unused) material, and shall contain a minimum of 25 percent cotton staple. Cotton batting is cut in 12" x 12" squares (30 x 30 cm).

6. Glass fiber board: The glass fiber board pieces for the vertical (back) panel and the horizontal (seat) panels are cut in 6" x 8" (15 cm x 20 cm) and 12" x 12" (30 cm x 30 cm) pieces with the smaller of the pieces being used in the horizontal position. The glass fiber board pieces are not be be used for more than five tests.

At least three cigarettes must either burn their entire length or self-extinguish before burning their entire length. Then the test assembly is taken apart, the cigarette ashes are removed, and char lengths of both the horizontal and vertical panels are measured. Both the length and width of the char produced are measured on each fabric piece, a total of four measurements. The total length of the char minus 3.3 inches, the average length of a cigarette, equaled one considered char length, and the total depth (width) minus 0.3 inch, the average diameter of a cigarette, equaled the other considered char length.

Only the longest of the four measurements per specimen is recorded. If the char length of each of the three specimens is less than 1.5 inch on the glass fiber board test, the test was continued with the second portion of the test, the cotton batting test.

Modified Prototype Test

Before divising a modification of the CPSC testing procedure and classification of fabrics,an attempt was made to apply a flame retardant to selected areas of upholstery fabrics. The flame retardant was composed of borax, boric acid and diammonium phosphate in various ratios. The flame retardant was not permanent, but allowed the testing of flame retarded fabric over untreated cotton batting. The results were not indicative of further research. There was a limited commercial availability of borax, boric acid, and diammonium phosphate.

An attempt was also made to flame retard certain areas of fabrics prior to placement on the NBS test assembly, for example, six inches above and below the abutment of the back and seat, and in a variable pattern on the fabric. Neither of these methods warranted further research and were also abandoned. This localized application was performed to reduce chemical costs.

The NBS prototype test was modified by the substitution of polyester fiberfill for cotton in the vertical panel of the test assembly. Results of preliminary tests indicated that polyester fiberfill reduced the smoldering time of the lighted cigarettes and also reduced the char lengths produced by the smoldering cigarettes.

The second step in the modification of the NBS prototype test assembly was to wrap polyester fiberfill around the cotton batting used in the vertical panel. This method proved moderately effective in protecting the cotton batting from smoldering, but the glass fiber board in the horizontal position allowed the fabric to smolder, causing char lengths which lowered the fabric classification. Further problems encountered were 1) finding the proper thickness of fiberfill to use and 2) ascertaining that the fiberfill would remain in the proper position during the life of the finished furniture piece.

Consequently, in the final modification of the NBS prototype, the cotton batting in the back position was replaced entirely with fiberfill and the glass fiber board in the seat position was also replaced with polyester fiberfill. Since the polyester fiberfill did not have the rigidity of glass fiber board and could not be used without some method of stabilization, the addition of a solid material was necessary to stabilize the fiberfill. $Masonite_{TM}$ (8), a tough, dense, moisture-resistant fiberboard made from wood fibers exploded under high steam pressure (21), was cut in the dimensions of 5" x 6" (12 cm x 15 cm), slightly narrower than the 6" x 6" (15 cm x 15 cm) glass fiber board. A piece of polyester fiberfill was cut 6" x 6" x 2" (15 cm x 15 cm x 5 cm) from a grade one polyester fiberfill batt and wrapped over the $Masonite_{TM}$, then placed in the seat portion of the NBS test assembly. Figure 4 shows the complete modification of the test assembly. This modified prototype retains the severity of the covered cigarette placed on the fabric while incorporating the components available for actual furniture construction.

The modified prototype test utilized the same testing apparatus, cotton sheeting, cigarette specifications, and the same fabric dimensions as did the cotton batting portion of the Proposed Standard for the Flammability of Upholstered Furniture (PFF 6-78). The main difference between the two test methods was the substitution of polyester fiberfill in place of the cotton batting in the vertical (back) panel and the addition of a stabilizing board and polyester fiberfill in the horizontal (seat) position to replace the glass fiber board.

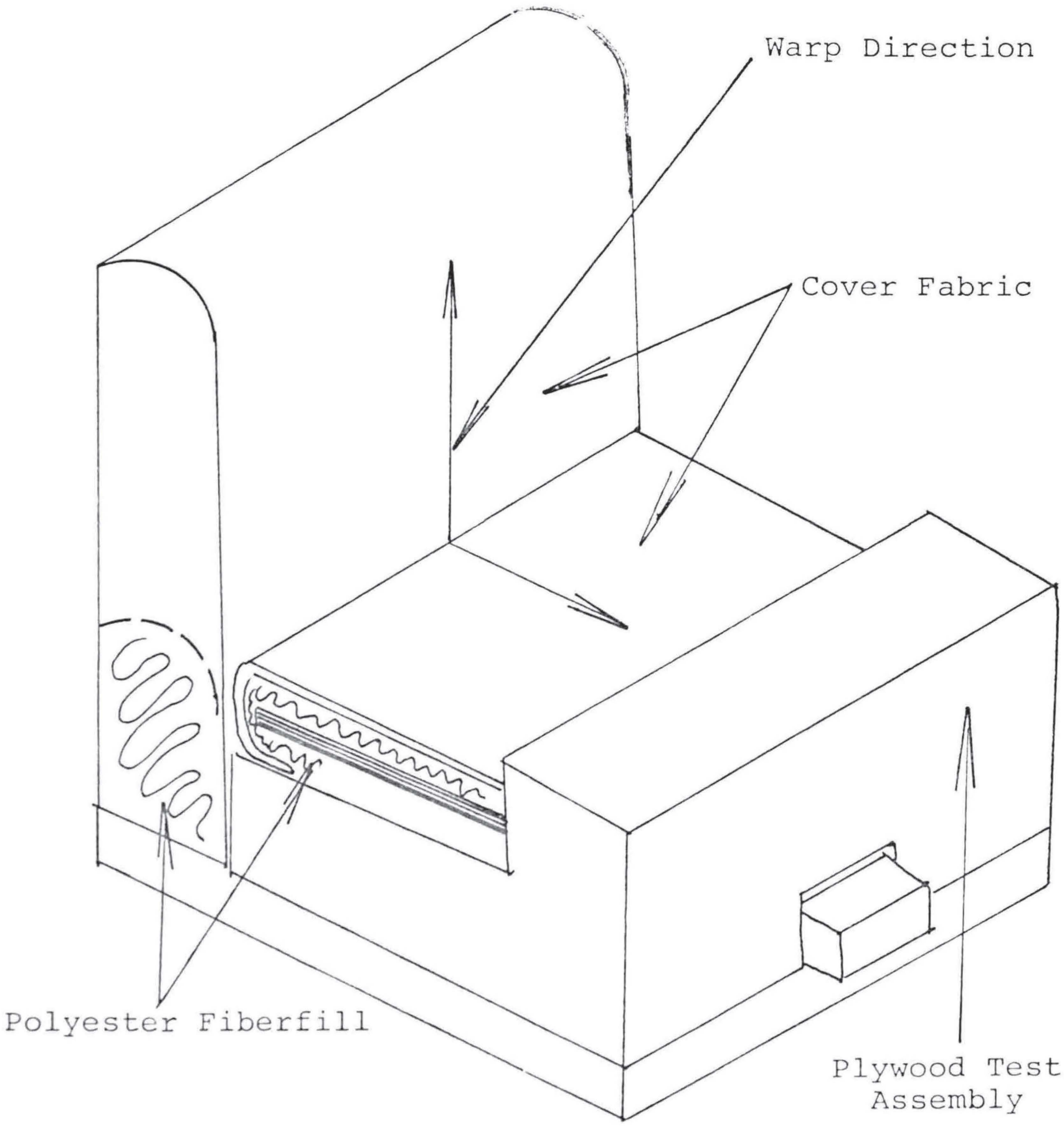

Fig. 4. Modified upholstery fabric test assembly

Statistical Treatment of the Data (41)

The char lengths of each fabric that resulted from the NBS prototype test were compared with the char lengths that resulted from the modified prototype test by using a Student's t-test. The t-test was applied as a significant test of difference between char lengths. A total of thirteen t-tests were conducted to make the char length comparisons.

Five variables (fabric weight, permeability, fabric construction [backcoating], oxygen index, and fiber content by thermoplastic classification) were utilized in the statistical analyses. Multiple regression and correlation analysis were performed to determine which of the five variables exerted the greatest effect on the char lengths produced by a smoldering cigarette. A stepwise regression analysis was utilized to select the best subset of characteristics that influence char lengths.

The five selected variables were compared to the char lengths produced by lighted cigarettes placed on the CPSC prototype and compared to those produced by a lighted cigarette placed on the modified prototype. All statistical tests were based upon $\alpha = 0.05$ level of significance (39).

CHAPTER IV

RESULTS

This research was attempted to devise an alternative test method for examining the smolder resistance of upholstered furniture fabrics containing synthetic, natural fibers and blends, using a substrata similar to that used in actual furniture construction. Correlations between open flame and smolder resistance tests were made to evaluate any relationships which might exist between these two types of tests.

Physical Properties of Fabrics Tested

Yarn Count

The number of yarn per inch was determined for all fabrics in accordance with the ASTM Test Method D 1910-70. Several fabrics in the sample required the use of the ravel yarn count method. An average of five counts in both the warp and filling directions was calculated and the results are recorded in table 3.

Fabric Weight

Fabric weight was determined for all fabrics in accordance with ASTM D 1910-70. Fabric weights for the

TABLE 3

PHYSICAL PROPERTIES OF THE FABRICS TESTED

Fabric Number	Mean Weight[a] oz/yd^2 (gm/m^2)	Mean Yarn Count[b] yarns/in	Weave Type
1	12.75 (432.30)	6 x 7	Plain
2	11.75 (398.39)	15 x 15	Plain
3	19.95 (676.42)	14 x 8	Basket
4	12.42 (421.11)	144 x 53	Dobby
5	18.36 (622.51)	39 x 39	Plain
6	23.01 (780.18)	83 x 36	Jacquard
7	16.38 (555.38)	43 x 27	Plain (rib)
8	16.76 (568.36)	80 x 14	Plain (rib)
9	10.93 (370.59)	63 x 63	Jacquard
10	22.35 (757.80)	9 x 8	Plain
11	23.32 (790.68)	10 x 13	Plain
12	9.30 (315.32)	54 x 44	Velvet
13	14.36 (486.89)	12 x 13	Plain

[a]ASTM D 1910-70.

[b]ASTM D 1910-70.

sample fabrics ranged from 9.3 oz/yd^2 to 23.35 oz/yd^2, the average weight of the fabrics tested was 16.26 oz/yd^2, and the median weight was 16.38 oz/yd^2. Fabrics with backcoatings were noted and no attempt was made to classify backcoating materials. (Backcoating was used as a part of the analysis of data, under the fabric construction variable and will be discussed under the Oxygen Index Test.)

Researchers (10, 24) have indicated that there is a significant relationship between the fabric weight, as well as the compactness of yarns in fabric construction, to the burning characteristics. Very light fabrics and very heavy fabrics do not perform as well as medium weight fabrics, depending upon the fiber content of the fabric being tested. The assessment and evaluation of cause and effect are difficult to evaluate for the sample in this study because of the interrelationships which exist among the variety of fabric contents examined. Weights of fabrics tested are recorded in table 3.

Oxygen Index

The Oxygen Index test (OI) was performed in accordance with ASTM D 2863-76. The OI test provides a means of quality control and provides the researcher with data for examining flame retardants and flammability characteristics of blended fiber fabrics, but it is in itself not a flammability standard.

Upholstery fabrics with backcoatings performed in a more flame resistant manner than did the non-backcoated fabrics when tested by the OI method. There was no significant correlation between fabric weight and oxygen consumption index. However, fabrics without backcoatings were below an OI of 17.4 while fabrics with backcoatings were consistently above an IO of 17.4 burn time. Average OI results for the individual fabrics are listed in table 4.

Air Permeability

Ten fabric specimens were cut and tested on a Gurley No. 4418 Densometer using the Federal Test Method Standard No. 191, Method 5452 procedure. For the purpose of statistical analysis, the results were not averaged.

The permeability of fabrics measured the ability of air to pass through a fabric either because of the weave compactness or due to the addition of a backcoating. Donaldson (12, 13) found that air permeability may be affected by a number of factors such as:

1. Construction or finishing techniques can effect air permeability by causing a change in air flow paths through a fabric;

TABLE 4

RESULTS OF THREE FLAMMABILITY TESTS

Fabric	Oxygen[a] Index (Average Oxygen Consumed)	FF 6-74[b] (inches)	MAFT[c] (3 sec) (J/cm^2.sec)
1	18.9	BEL[d]	0.05
2	20.4	2.25	0.04
3	21.0	BEL	0.40
4	17.3	BEL	EXT[e]
5	17.5	BEL	0.08
6	17.1	BEL	EXT
7	17.1	BEL	0.04
8	16.9	BEL	EXT
9	17.0	BEL	EXT
10	19.3	BEL	0.02
11	18.9	BEL	0.04
12	16.8	BEL	EXT
13	18.5	BEL	0.04

[a] = ASTM D 2863 - 76.

[b] = Vertical Flammability Test Children's Sleepwear Standard.

[c] = Mushroom Apparel Flammability Test, Proposed Standard for the Flammability of General Wearing Apparel.

[d] = BEL = burned entire length.

[e] = Estinguish (test terminated).

2. Yarn twist affects air flow since as the twist increases, the diameter decreases and density of yarn increases, thus reducing the cover factor and increasing air permeability;

3. Yarn crimp and weave influence the shape and area of the interstices between yarns.

Vertical Flammability Test Children's Sleepwear Standard FF 6-74

A total of ten fabric specimens per sample fabric were cut, five in the warp and five in the filling direction. The fabrics were tested by applying an open flame to the base of the fabric specimen as outlined in the test procedure. Twelve of the thirteen fabrics tested burned the entire length (B.E.L.) of the fabric speciman. Only one fabric the flame retardant treated fabric had a measurable char length. Apparel fabrics burning in the same manner as exhibited by these upholstery fabrics would be excluded from use in apparel constructions. The vertical flammability test results are reported in table 4.

Mushroom Apparel Flammability Test, MAFT Test, Proposed Standard for the Flammability of General Wearing Apparel

The Mushroom Apparel Flammability Test (MAFT), a proposed test for flammability of general wearing apparel, was conducted according to the procedure outlined in the proposed standard using only the 3 second heat transfer test. The MAFT test results for the fabric samples are presented in table 4. By definition, fabrics fail the MAFT test when a reading greater than 0.42 $J/cm^2 \cdot s$ was obtained. Some of the fabrics tested did not exhibit the 0.42 $J/cm^2 \cdot s$ failure criteria temperature. The first sample fabric which did not reach the critical temperature was allowed to smolder for 30 minutes before the test was stopped and the smolder extinguished. After this initial experience, other fabrics exhibiting the same smolder pattern and lacking the critical temperature were extinguished after 5 minutes smoldering time. Samples that were terminated were considered as a failure. In view of this the MAFT test data were not entered in the statistical analysis.

In view of the data obtained on the above tests (see table 4) there appears to be no significant correlation between the results of the open flame and smolder resistance tests for the sample fabrics. This indicated that the smolder resistance to cigarette ignition is the best procedure for classifying the upholstery fabrics. The findings in the comparison concur with other published research (10, 24), which also indicated there was little correlation between test methods.

UFAC Classification of Fabrics

The fabrics in the sample were classified as either Class I, those fabrics containing 50 percent or more synthetic fiber or performing as well (57), and Class II fabrics containing less than 50 percent synthetic fiber.

Only two of the fabrics tested were 100 percent synthetic fiber in composition. Seven of the fabrics were blends of natural and synthetic. These seven fabrics would be Class II under the USAC classification method. Also the two 100 percent cotton and one 100 percent rayon fabrics would be Class II. The 100 percent wool fabric could possibly be a Class I in the UFAC classification method, but for the purpose of this study, it was left in the Class II category. One fabric, composed of 55 percent wool and 45 percent nylon, had a flame retardant finish and therefore was placed in the Class I category. If this fabric did not have a flame retardant finish the percentage of synthetic fiber (45 percent nylon) would not qualify the fabric for the Class I category. Upholstery fabrics containing 65 percent wool and 45 percent nylon, without a flame retardant finish, perform well while reverse blends (65 percent nylon and 45 percent wool) obtained lower CPSC classifications (52). The UFAC classification of fabrics appears in table 5, along with the fabric classification by the CPSC and Modified test methods.

TABLE 5

CLASSIFICATION OF UPHOLSTERY FABRICS TESTED

Fabric	UFAC Fabric Class	CPSC Fabric Class	Modified Test Fabric Class
1	I	B	B
2	I	A	A
3	II	A	A
4	II	C	B
5	II	D	B
6	II	D	B
7	II	D	D
8	II	D	B
9	II	D	D
10	II	D	D
11	II	C	B
12	II	D	B
13	I	B	B

Proposed Standard for the Flammability of Upholstered Furniture PFF 6-78

Fabric Prototype Test

Fabrics were conditioned, and were tested on both the glass fiber board and cotton batting substrata as outlined in the procedure for fabric classification under the Proposed Standard for the Flammability of Upholstered Furniture PFF 6-78. The char lengths produced by the sample fabrics were used to classify fabrics according to the test procedure outlined in the above proposal. Figure 5 shows this fabric classification procedure.

The averaged char length for each of the fabric samples was compared with the char lengths obtained by the modified prototype test using like fabric samples. Each test was performed on fabric specimens cut from the same piece of fabric.

Modified Prototype

Results of previous research in the Texas Woman's University flammability laboratory and by other researchers, as indicated in the Review of Literature, have implied that a modified test method could be of value in defining the performance of a particular fabric/batting system in a simulation more realistic to the end use of the product. The real purpose of any standard of this type is to assure

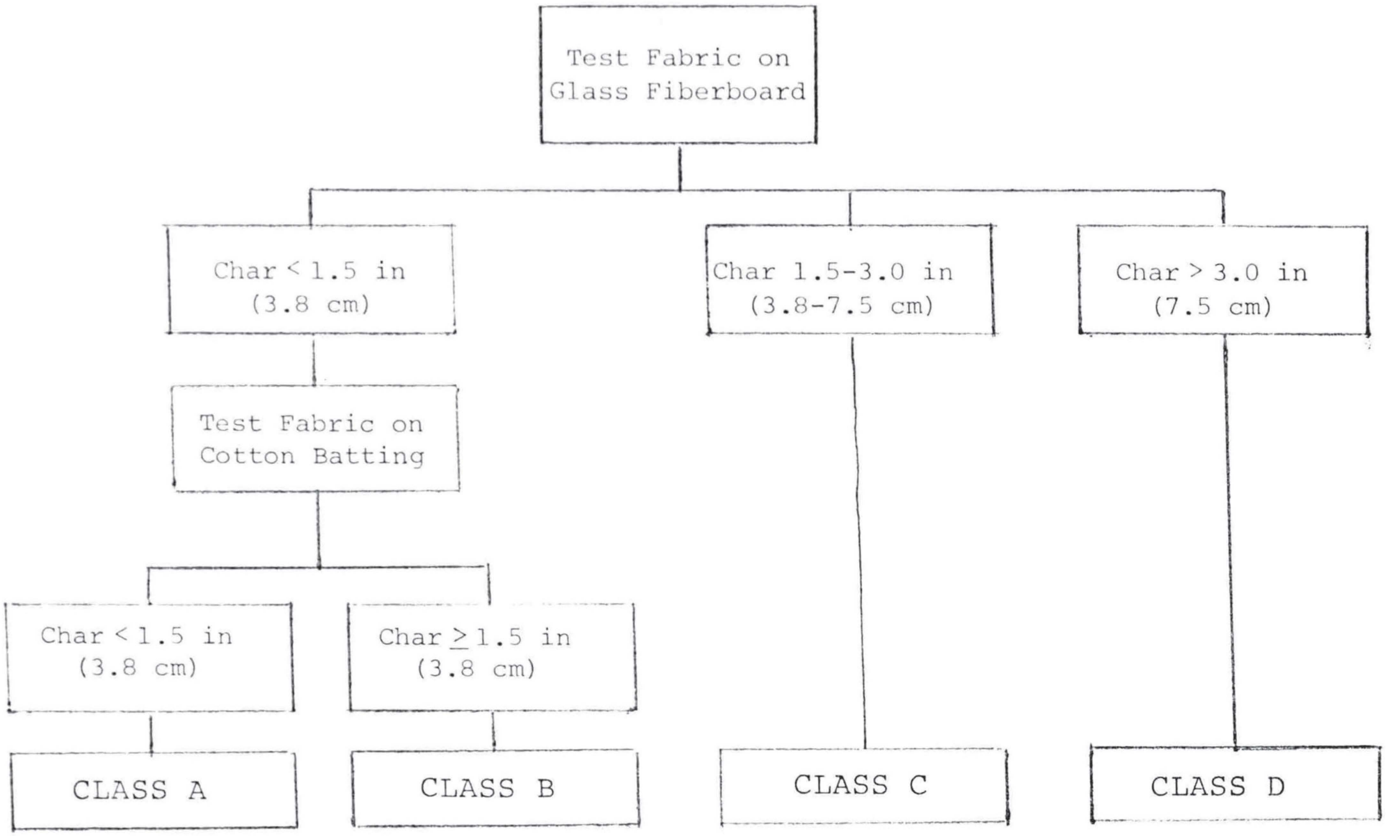

Fig. 5. CPSC upholstery fabric classification test

fire safety in the end product. The objective of this research was to devise a test method and a scheme which would assure fire safety and at the same time act as a qualifier of fabric/batting systems rather than an eliminator of fabrics.

The test apparatus and specifications for cigarettes are the same in both test schemes. The apparatus which allows a simulation of a seat and back of an upholstered chair (NBS prototype test apparatus) was used, and a lighted cigarette was placed in the crevice at the abutment of the seat and back of the simulated chair. The most obvious modification in the modified test procedure was the substitution of polyester fiberfill as the substrata and the resulting test scheme. Figure 6 shows the modified test scheme.

Results of the CPSC, UFAC, and the modified tests are summarized in table 5. Many similarities existed between results of the CPSC tests and the modified tests. Fabric samples number 1, 2 and 3 performed the same in both test classifications, and were considered safe fabrics. Fabrics 7, 9, and 10 failed both classification methods and were Class D fabrics. Fabrics 4, 5, 6, 8, 11, and 12 performed much better when tested by the modified test method and received a higher classification than obtained under

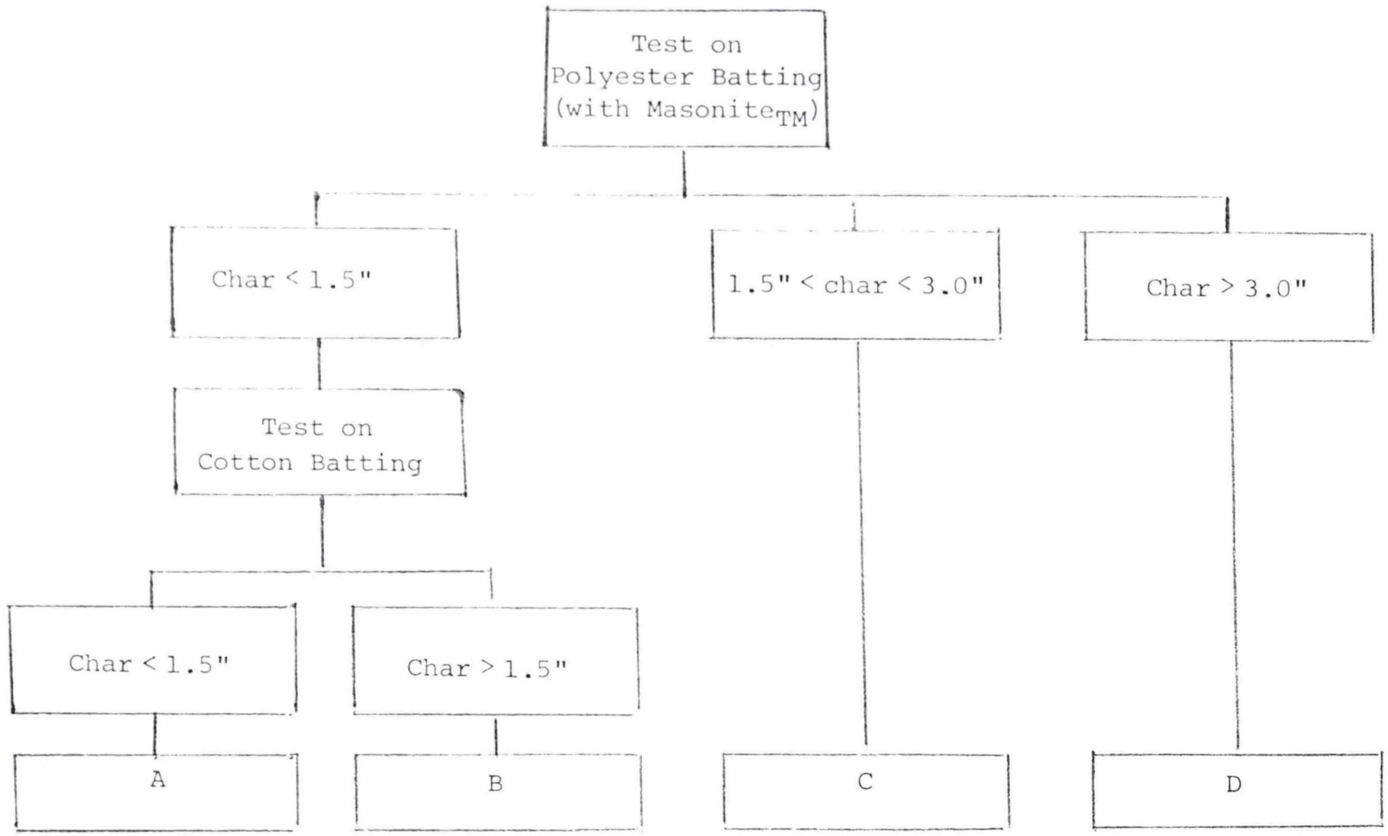

Fig. 6. Upholstery Fabric Classification by Modified Test Procedure

the CPSC testing procedure. Fabric 13, a 100 percent synthetic fiber fabric with a backcoating dropped from a Class A under the CPSC fabric classification to a Class B under the modified method of classification. The fabric classification under the CPSC and modified test procedure is shown in figure 7.

Several fabrics retained the same classifications under both test methods, but several fabrics changed classifications, as noted above. It is seen that fabrics which are not safe are still excluded, as indicated by a D classification. The two cotton fabrics composed of 100 percent cotton were both classed as D fabrics under the CPSC proposal, but the cotton velvet (number 12) was able to perform as a Class B fabric under the modified test proposal. The 100 percent cotton fabric that remained a Class D smoldered extensively, gave off copious amounts of smoke and fumes, and would not be recommended as a fire safe upholstery fabric. However, the 100 percent cotton velvet showed a greatly reduced evolution of smoke and fumes during the tests, and performed well under the modified test procedure. This fabric would perform as a fire safe fabric when used in constructions containing polyester fiberfill. One major difference also noticeable in comparing these two cotton fabrics was the fact that the

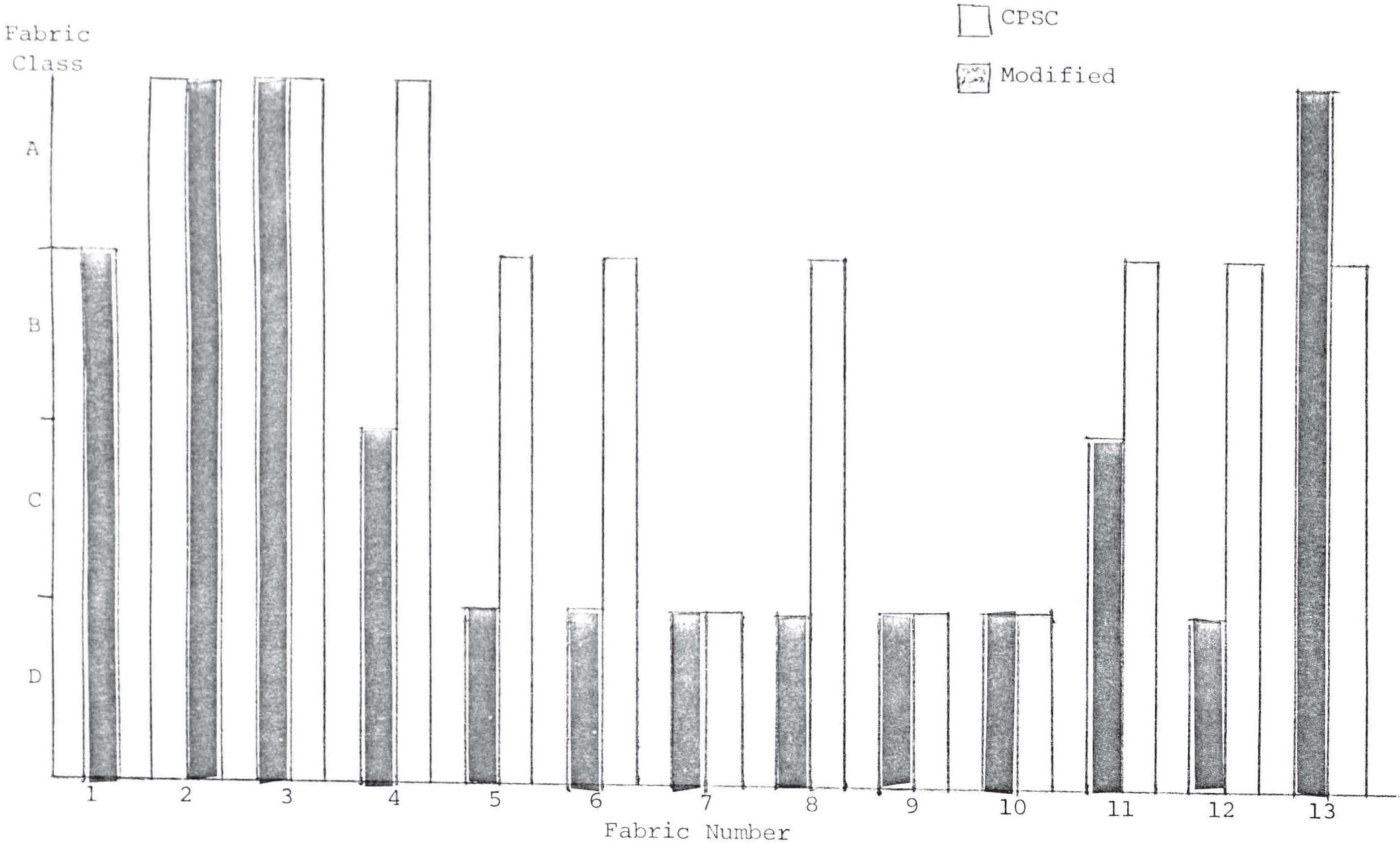

Fig. 7. Fabric classification by the CPSC and modified test methods

fabric which was classified as a D fabric was heavily backcoated and did not have the same yarn construction as the velvet fabric.

The one fabric (number 13) that obtained a lower classification on the modified test as opposed to the CPSC fabric classification was a 100 percent olefin fiber fabric backcoated with olefin. This fabric in other substrata combinations could possibly perform well.

The modified test scheme indicates that a test can be designed to define systems of fabric/batting combinations that can function in a fire safe manner, and which will not necessarily exclude currently used upholstery fabrics from use, particularly the natural fiber fabrics. A Class A fabric would be recommended for use with polyester or cotton batting, a Class B fabric would be recommended for use with polyester fiberfill batting and with cotton batting with a caution noted. Class C fabric would be recommended for use with polyester fiberfill batting only and a Class D fabric would not be recommended for use.

Statistical Results of Data

Char lengths produced on the NBS prototype were compared to char lengths produced on the modified test assembly. A series of thirteen individual t-tests were conducted to compare these char lengths.

In general, all test results within fabric and test procedures were identical, resulting in small, if any, experimental variation in char length for the purpose of the t-tests. This indicates that the mechanical techniques of the testing procedure were highly replicable and that any differences in mean char lengths were clear cut distinctions between the test procedures being evaluated. The significant differences between char lengths based on results of the CPSC and modified tests are reported in table 6. Probabilities on the t-tests were all well beyond the 0.01 level.

Multiple regression was used to analyze the relationships between the selected variables: test (CPSC vs. Modified), char length, fiber content, permeability, fabric weight, construction, and Oxygen Index. A stepwise regression to select the best subset of characteristics which influence char lengths was obtained.

Table 7 shows the mean values and standard deviations of the selected variables to be included in the multiple regression. The multiple regression correlation coefficients are shown in table 8. Char length is related to the type of test indicating that the chars produced on the modified test fabrics were smaller than those produced on similar fabrics tested by the CPSC procedure. Fiber

TABLE 6

SIGNIFICANT DIFFERENCES BETWEEN CHAR LENGTHS BASED ON TEST METHOD

Fabric Number	Test Method	Number of Replications	Mean Char Length Inches	t[a] Value	Probability
1	CPSC	3	6.0	(VL)[a]	0[b]
	MOD	3	0.6	0.00	
2	CPSC	3	0.4		
	MOD	3	0.4+	-1.00	0.37 NS
3	CPSC	3	0.4	(VL)	1.00 NS
	MOD	3	0.4	-0.0	
4	CPSC	3	6.0	(VL)	0
	MOD	3	0.5	0.0	
5	CPSC	3	6.0	(VL)	0
	MOD	3	0.6	0.0	
6	CPSC	3	6.0	(VL)	0.00
	MOD	3	0.6	163.0	
7	CPSC	3	6.0	(VL)	0
	MOD	3	0.6	0.0	
8	CPSC	3	6.0		
	MOD	3	0.8	16.48	0.00
9	CPSC	3	6.0		
	MOD	3	6.0	0.0	1.00
10	CPSC	3	6.0		
	MOD	3	6.0	0.0	1.00
11	CPSC	3	6.0	(VL)	
	MOD	3	0.4	169.0	0
12	CPSC	3	6.0	(VL)	
	MOD	3	0.6	93.53	
13	CPSC	3	6.0	(VL)	
	MOD	3	0.9	152.00	0

[a](VL) = Lack of variability resulting in artificially large t-values.

[b] 0 indicates that a calculation of probability was not possible due to the lack of variability, but differences are obvious.

TABLE 7

MEAN VALUES AND STANDARD DEVIATIONS OF VARIABLES
(n = 78)

Variable	Mean	Standard Deviation
Test[a]	1.50	0.50
Char Length[b]	3.28	2.75
Fiber Content[c]	1.76	0.43
Permeability[d]	11.08	34.67[h]
Fabric Weight[e]	16.28	4.66
Construction[f]	0.54	0.50
Oxygen Index[g]	18.15	1.37

[a] = CPSC (1), Modified (2).

[b] = CPSC Pff 6-78 Char length in inches.

[c] = UFAC classification Class 1 or 2.

[d] = Federal Test Standard No. 191, Method 5452 - seconds.

[e] = ASTM D 1910-70 oz/yd^2.

[f] = Backcoated (1), Non-backcoated (0).

[g] = ASTM D 2863-76.

[h] = There were extreme high and low readings among the fabrics in the sample.

TABLE 8

CORRELATIONS FOR DIFFERENCES BETWEEN TEST TYPES AND SELECTED VARIABLES
(N = 78)

Source of Variation	Test	Char Length	Fiber Content	Permea- bility	Fabric Weight	Construction	Oxygen Index
Test	1.00	-0.682					
Char Length		1.00	0.204	0.269	0.020	-0.162	-0.307
Fiber Content			1.00	0.174	0.431	-0.465	-0.336
Permea- bility				1.00	0.378	0.213	0.194
Fabric Weight					1.00	0.296	0.269
Construc- tion						1.00	0.786
Oxygen Index							1.00

df - 76 for a single pairwise correlation

Char length is related to the type of test (CPSC - Modified).

Fiber content no correlation or relationship to char length.

Permeability slight influence on char lengths.

Fabric weight and construction had no correlation with char lengths produced.

Oxygen Index very slight (higher the OI the shorter the char) influence on char lengths.

Fiber content - construction - fabric weight are mildly related to char length.

contents, thermoplastic or nonthermoplastic, have no relation to the char lengths produced by either test method. Permeability has a slight influence on char length. None of the independent variables selected had a significant influence on any of the chars.

Results of the analysis of variance (tables 9 and 10) again showed that the char lengths produced on the upholstery fabrics are the most significant in evaluating upholstery fabric. The $F_{6,71}$ at $\alpha = 0.05$ is significant at the confidence level of 95 percent. The modified test procedure was statistically significant at the 0.05 level. The stepwise regression once again showed the test method, CPSC vs. modified, as the most significant variable. Oxygen Index and permeability were significant influences on the lengths of the chars produced. Significant differences ($\alpha = 0.05$) were revealed between the different char lengths produced by the CPSC and modified test method.

TABLE 9

ANALYSIS OF VARIANCE FOR CHAR LENGTHS IN RELATION TO TESTED FABRIC CHARACTERISTICS

Dependent Variable: Char Length

Independent Variables	
	Test
	Oxygen Index
	Fiber Content
	Permeability
	Fabric Weight
	Construction

Analysis of Variance	Df	Sum of Squares	Mean Square	F
Regression	6.0	394.179	65.696	25.02*
Residual	71.0	184.425	2.625	

$F_{6,71} = 2.25$

*Significant at $\alpha = 0.05$ level.

TABLE 10

ANALYSIS OF VARIANCE (STEPWISE REGRESSION) FOR DEGREE OF FABRIC PROPERTIES INFLUENCE ON CHAR LENGTHS

Independent Variable[a]	B	Standard Error B	F
Test	-03.712	0.3625	104.855*
Oxygen Index	-00.984	0.2151	20.954*
Permeability	00.026	0.0057	20.714*
Construction	01.240	0.7028	3.115
Fiber Content	00.652	0.6504	1.008
Fabric Weight	-00.049	0.0563	0.770

(Constant) 25.418 $F_{6,71} = 3.98$

*Significant at $\alpha = 0.05$ level.

[a]Dependent variable = char length

Formula: CL = 25.42 - 3.71 (T) --0.98 (OI) + 0.03 (P) +

1.24 (C) + 0.65 (FC) - 0.05 (FW)

The higher the OI the shorter the char length.

The greater the permeability the greater the char length.

Minimal influence by construction.

Backed fabrics have longer char lengths.

CHAPTER V

SUMMARY AND CONCLUSIONS

The purpose of this study was to develop and evaluate an alternative test for upholstered furniture flammability which will define systems that can perform in a fire safe manner. The data obtained from the fabric flammability tests indicated that by using substrata more representative of end use situations, currently used fabrics need not be eliminated from the marketplace. However, caution notes would be necessary for some fabric/batting combinations.

The results of the laboratory tests indicated there was no correlation between the various flammability test methods. The lack of sufficient correlation between flammability testing methods is in agreement with the findings of other researchers as cited in the review of literature.

The experimental results show that the modified test method does not exclude all natural fiber fabrics from use. The fabric classification as proposed by UFAC would exclude the use of natural fiber fabrics, by the classification of fabrics on the basis of synthetic (thermoplastic) fiber content.

Fabrics which were not safe were still excluded under the modified test scheme, as indicated by a D classification. The two 100 percent cotton fabrics were both classed as D fabrics under the CPSC proposal, but the cotton velvet was able to perform as a Class B fabric under the modified test procedure. The 100 percent cotton fabric that remained a Class D smoldered extensively, gave off copious amounts of noxious smoke and fumes and would not be recommended as a fire safe upholstery fabric. Each of these cotton fabrics would be eliminated under the UFAC and CPSC classification methods. However, the 100 percent cotton velvet did perform well under the modified test procedure and did not emit the same amount of smoke and fumes as experienced when testing the other cotton fabric. The cotton velvet fabric would perform in a fire safe manner when used in constructions containing polyester fiberfill batting substrata.

The modified test procedure couples the practicality of using substrata materials that are common to the industry while still retaining some of the severity of the CPSC proposal for testing flammability of upholstery fabrics. The CPSC staff proposal classifies fabrics on performance under test conditions, recommending only the most smolder resistant fabrics be used in all furniture constructions. However, the modified proposal recommends that only the most smolder resistant combinations of fabric and batting be used for furniture construction. The addition of the influence of the polyester fiberfill batting to the modified test allows a wider choice of fabric/batting combinations to be made available to the manufacturer, while still maintaining a comparable degree of fire safety. By uses of the suggested guidelines, fabrics previously considered hazardous may be smolder resistant and usable while still maintaining a high degree of safety. Therefore, many of the natural and cellulosic fiber fabrics now being used for upholstered furniture may not necessarily be eliminated from the market. To attempt to produce upholstered furniture which was fire proof would be unrealistic and it must be realized that there is a difference between fire safe and fire proof. Asbestos is a fire proof fiber, yet the use of such a fiber in upholstery fabric would be highly unlikely as well as dangerous to the consumer. The consumer must also take some responsibility in the use of smoking materials, and consumer education programs have been instigated by both the CPSC and UFAC to make consumers more aware of fire hazards involving textile products.

More extensive evaluation of textile flammability requires the testing of flame resistant textiles with both open flame and smoldering ignition sources. Many fire retardant systems which are effective in flaming ignition are not effective against smoldering ignition. For example, some polyurethane foams and fabrics which pass open flame tests have been found to smolder and ignite when a burning cigarette is placed on them (40). The modified prototype test, the use of polyester fiberfill, and the test scheme proposed in this study incorporate some of the severity of the CPSC proposed standard for upholstered furniture flammability while using components realistic to the product end use.

Some upholstery fabrics are heavily backcoated for yarn stabilization and these backcoatings could affect smolder resistant properties. The backcoated fabrics examined in this research did perform better than the non-backcoated fabrics when tested by the Oxygen Index, although backcoating had little effect on smolder resistance.

The Proposed Standard for Upholstered Furniture Flammability (PFF 6-78) requires that, prior to final construction approval, a mock-up test be performed. Considering that the modified test includes actual construction components to some extent, the adoption of this modified test could eliminate or modify the need for the mock-up test. The elimination of the amount of testing required would greatly reduce cost.

Recommendations

As a result of this study, the following areas are suggested as possible topics for future study.

1. Investigation of fabric backcoating and the addition of chemicals to inhibit smoldering combustion.
2. Study of fabric/batting combinations, including the many construction possibilities that were not covered in this research.
3. Investigation into the hazards involved with the emission of toxic fumes from polyurethane foam.
4. Investigation of the mock-up component classification, as compared to the modified prototype test and classification, with consideration for the possibility of eliminating the mock-up test.
5. Study of the role played by backcoating of synthetic fibers as compared to the backcoatings applied to cellulosic fibers when tested with this modified prototype test.
6. Investigation of the uses of specific blends of fibers when tested by the modified prototype test.

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