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10 July, 1998

Ms. Rockelle Hammond
Office of the Secretary
US Consumer Product Safety Commission
Washington, DC 20207

Re: Post Hearing Comments of the National Cotton Council -- *Flame Retardant Chemicals (63 FR 18183; April 14, 1998)*

Dear Ms. Hammond:

These post-hearing comments are submitted by the National Cotton Council (NCC) in response to CPSC's April 14, 1998 notice of extension of comment period and request for comments on flame retardant chemicals that may be suitable for use in upholstered furniture (63 FR 18183). NCC is the central trade organization of the American cotton industry. NCC members include producers of over 75% of the US cotton and cotton processing industries.

We have reviewed the October 28, 1997 CPSC staff briefing package on regulatory options on upholstered furniture flammability and attended the May 5-6, 1998 public hearing. The hearing raised questions beyond the toxicology of flame retardant chemicals that need to be addressed. Several major areas of concern that NCC would like to comment on are:

- The small open flame standard that CPSC proposes in the briefing package is different than the UK standard BS-5852. The CPSC standard may require different FR systems. Thus, just because UK manufacturers indicate that they have systems for most upholstery fabrics to meet BS-5852 it does not mean that they also can meet the "potential" CPSC standard. Much research and development will be necessary to determine if the industry can meet the CPSC "potential" standard.
- The need for adequate toxicological testing by the chemical suppliers and well-defined approval methodology of flame retardant chemicals for use on upholstered furniture.

- Consideration of environmental and worker health and safety issues for FR chemicals and the impact on small businesses.

I. CPSC standard is different than BS-5852 and may require different FR-systems

The small open flame standard proposed in the CPSC briefing package (pp. 36-40; Tab G) is different than BS-5852. The CPSC standard is for prevention of ignition not prevention of flame progression. BS-5852 allows fabrics that are composed of 75% or more natural fiber to be untreated if barriers and interliners are used. Barriers (inert and active) and interliners cannot be used to make a fabric meet the potential CPSC standard. BS-5852 requires FR-filling material and has a different pass/fail criteria than the potential CPSC standard. The potential CPSC standard requires not only that the fabric not burn but also that the fabric act as a protective barrier to prevent ignition of the flammable filling material .

At the May 5-6, 1998 hearing there was an upholstery fabric representative from the UK, who indicated that most fabrics could be treated to pass BS-5852 and suggested, without offering data, that they could also meet the potential CPSC standard. Representatives from the Fire Retardant Chemicals Association (FRCA) also oversimplified the treatment process and capabilities. For example, on the first day representatives for FRCA talked in favor of the ease and effectiveness of fabric chemical treatments and were backing away from backcoatings; on the second day, however, FRCA representatives seemed to favor backcoatings and were backing away from fabric treatments.

The US textile industry is as innovative as any in the world and has much technology available for making textiles that can meet most existing FR-standards, which are less stringent that the potential CPSC standard. For cotton, for example, durable systems are available to meet sleepwear standards and make protective clothing. However, specifically how to meet the potential CPSC standard for upholstery fabrics is not presently known. The US upholstery industry is a fashion-driven business. There are numerous style changes in a year. Over 6,000 to 7,000 different fabrics are normally offered by upholstery fabric suppliers to the furniture industry and these can be in various colors.

Many issues need to be addressed. For example,

1. lightweight polished cotton and silk cannot be backcoated (even in the UK);
2. technology for FR-treatments for cotton/polyester fabrics is not available (unless one fiber is less than about 10-15%);
3. lightweight cotton and synthetic fabrics may not be able to provide, even after FR-treatments, enough insulation to prevent involvement of the flammable filling material after a 20 second flame; and

4. since cigarette and open flame resistance are controlled by different mechanisms, light weight and some heavy weight cotton fabrics that are smolder resistant before treatment for open flame resistance may not be after treatment.

FR-fabric treatments are available for cotton fabrics to meet some FR-standards but they are complicated. These treatments can affect the aesthetics of the product, are costly, and their effectiveness for meeting the potential CPSC standard is not known. There are two commercial durable topical fabric treatments for cotton: the phosphonium salt precondensate/ammonia cure process and reactive phosphourous based flame retardants (see P. J. Wakelyn, W. Rearick and J. Turner, Cotton and Flammability, *American Dyestuff Reporter 87(2)*, 13-21, 1998). Much of this technology was developed by the USDA in the 1960's and 70's.

The phosphonium salt system can be several different chemicals: tetrakis (hydroxymethyl) phosphonium (THP) salts either prereacted with urea or another nitrogenous compound (precondensate) or without reaction with the nitrogenous material. These products can be sold in the US as Retardal® or Proban®. The precondensate/ammonia system requires pad application to the fabric, ammoniation to ensure adequate polymer formation, oxidation to make the polymer insoluble, and washing. This forms an insoluble polymer in the fiber which is durable to washing. All of these steps must be done correctly and this can affect the color, strength, abrasion resistance and other qualities of the fabric.

Reactive phosphourous based flame retardants (e.g., Pyrovatex® or Amgard®; N-methyol dimethyl phosphonopropionamide), which react with the hydroxyl groups of cellulose, are applied by a pad/dry/cure process in the presence of a phosphoric acid catalyst. Reactive phosphorus flame retardants are the main FR-agents used for cotton upholstery fabrics in the UK. The chemical manufacturers recommend that higher add-on levels of chemical are necessary since the finish can hydrolyze and loose effectiveness. Afterwashing is generally required with an alkali followed by rinsing and drying. Usually 4 to 5 stages of washing and two of drying are required. This helps reduce fabric strength loss. This process can cause more fabric strength and abrasion resistance loss than the precondensate and there can be durability problems (see R. B. LeBlanc, *Textile Chemist and Colorist 29(2)* 19-20, 1997). In addition, chlorine bleach, high acidity, softeners, and stain and water repellents can reduce the effectiveness of reactive phosphorus based flame retardants and suppliers also recommend that these agents not be used for fabrics less than 5-6 oz./yd^2.

Backcoating is the major method for making upholstery fabrics that pass BS-5852. There is very little experience with backcoatings in the US for producing FR upholstery fabrics. However, as many as 50-60% of US upholstery fabrics can be backcoated with a very light resin treatment to prevent raveling or to add strength but upholstery fabric manufacturers try to stay away from backcoating fabrics as much as possible. FR-backcoatings for upholstery fabrics to meet BS-5852 usually contain brominated fire retardants and antimony oxide in a resin system (e.g., acrylic or styrene-butadine resin) that is much heavier that the light backcoats presently used for non-FR purposes. FR-backcoating is done in the US for automotive fabrics to meet MVSS 302, but this test is not very severe; these fabrics would not pass BS-5852 or the potential CPSC standard. Products like halogenated phosphate esters with antimony trioxide in a liquid latex emulsion are used for this purpose.

Most US upholstery fabrics exported to the UK are not FR-treated. The FR-treatments are done in the UK. Very little, if any FR-treated cotton upholstery fabric is currently in production in the US to meet BS-5852. There are a few backcoated fabrics which are manufactured by one or two companies, but these backcoat treatments are not effective for all US upholstery fabrics. For example, fabrics that are greater than 70% cellulosic are not able to be produced to pass BS-5852.

There are only three US companies, using topical fabric treatments, that currently produce FR-treated cotton fabrics for any end use. These companies use the precondensate/ammonia system; no US companies presently use reactive phosphorous-based flame retardant systems. About 85% of the FR-fabrics produced in the US are by one company, mainly for protective clothing/ woven workwear. FR-fabrics represents only about 0.2% of cotton and cotton blend fabrics produced in the US. The US textile industry would essentially have to develop new FR-finishing capabilities and new processes for the almost infinite variety of currently used US upholstery fabrics, depending upon weight, fiber types, fabric formation, and dyes. This would necessitate large capital expenditures which many small textile businesses would not be able to incur. It is uncertain, therefore, whether the US textile industry will produce many of these FR-treated fabrics or whether most will be produced outside of the United States.

The USDA, Southern Regional Research Center in New Orleans is doing research on FR-cotton but it most likely will be a some time before there are new or improved systems available.

In summary, there are many questions to be answered regarding cotton and cotton blend fabrics and the potential CPSC standard. The topical fabric treatments are costly, complicated and the effectiveness is not known, since they have not been tested. What is the durability? Are they effective for 5 years, 10 years, the life of the product? Cheaper, effective durable treatments and treatments for lightweight cotton fabrics and cotton/ polyester fabrics are necessary. It is unlikely that companies will invest in much research and development until they know what standard has to be met. It could take three or four years to develop systems. In addition, not all the upholstery fabrics presently used in the US will be able to be treated, which could affect the fashion and aesthetic of US furniture. For example, rough surfaces, puckered surfaces, washed cotton look, double cloth woven jacquards, matelasse, and fancy textured yarn fabrics like chenilles, cannot be backcoated or topically finished and still retain their fashion.

II. Toxicological testing and approval methodology

1. General

The fiber and textile industries look to the chemical suppliers to do adequate testing/ evaluation of the chemicals used to finish textiles. The toxicity testing of FR chemicals by the chemical suppliers should satisfy the requirements of the Federal Hazardous Substances Act (FHSA) for products that have been treated and the EPA Toxic Substances Control Act (TSCA) for any new, new use, or existing chemicals. In addition, NCC suggests that CPSC and EPA consider the Organization for Economic Cooperation and Development (OECD), Screening Information Data Set (SIDS) basic test as a screening-level for health and environmental toxicity that should be conducted on chemicals and a basis for approval under the CPSC administered FSHA and the EPA TSCA. The SIDS criteria calls for the following testing for high-production-volume chemicals:

acute toxicity
chronic toxicity
developmental and reproductive toxicity
neurotoxicity
mutagenicity
carcinogenicity
ecotoxicity
environmental fate

At present available toxicological data are incomplete and the approval methodology for FR-chemicals is inconsistent due to lack of test data. This more complete data set (OECD-SIDS) would provide some confidence to both the textile and furniture manufacturer and the consumer that the chemicals used on FR-treated upholstered furniture will not present a human health or environmental risk.

A recent publication by US EPA, "What Do We Know about the Safety of High-Production-Volume Chemicals?" discusses the "1997 Baseline of Hazard Information that is Readily Available to the Public" and the need for a full set of basic toxicity information (OECD SIDS basic tests) on all HPV chemicals.

2. Europe and Flame Retardants:

On March 25-27, 1998 the SIDS (Screening Information Data Sets) Initial Assessment meeting was held in Sidney, Australia. The purpose was to review screening-level health and environmental test data. The data were either assembled or generated by the members of the OECD that participate in the SIDS program.

One of the outcomes of the meeting was expressed concern for the testing needs of three brominated flame retardants (see Table 1 below) that would be potentially used in backcoatings (BNA Occup. Safety and Health Reporter, p. 1816, May 20, 1998). The group recommended testing one of the three chemicals using longer-term studies than called for in the SIDS screening-level health and environmental test data. This chemical would serve as an example for the related substances and the need for additional testing would be determined after a review of initial data. In 1993 an EU regulation prescribing a testing and assessment scheme was adopted that requires extensive testing beyond the screening level of SIDS for high production volume chemicals.

Table 1:

Chemical	**CAS No.**
Bis (pentabromophenyl) ether	1163-19-4
Diphenylether, pentabromo	32524-81-9
Diphenylether, octabromo	32536-52-0

3. European Union Ecolabelling Initiative:

The European Union (EU) is developing an "Eco-Label" for textiles. The primary objective of eco-labelling is to limit the impact of products on the environment. The latest draft states:

> **Flame Retardants:** No use of flame retardant substances or preparations containing substances that are classified by the manufacturer, or can be classified on the basis of available data as dangerous for the environment according to Commission Directive 67/548/EEC, as last amended by Commission Directive 97/69/EC.
>
> *Alternative*
>
> or No use of brominated flame retardants or antimony oxides
>
> or No use of halogenated flame retardants or antimony oxides

The use of different brominated flame retardants (BFRs) and in particular polybrominated biphenyls (PBBs) and polybrominated diphenylethers (PBDEs/PBDPOs), has and continues to raises various concerns in the European Union. These concerns may be generally summarized as follows: First, some BFRs are characterized by a low degree of biodegradability and a high degree of bioaccumulability. If these characteristics are combined with a certain level of toxicity, e.g., for aquatic organisms or mammals, that would indicate that they could be classified as dangerous for the environment, and represent, potentially at least, a long-term danger. Secondly, these products are not 100% pure, but contain various amounts of impurities such as different furans and dioxins. Moreover, halogenated substances in general are known to contribute to the formation of dioxins if they are incinerated in conditions that are not optimal. Antimony oxides, which are usually added in conjunction with BFRs to increase their effectiveness, are also known to contribute to the formation of dioxins during non-optimal incineration. Thirdly, some studies suggest that BFRs may act as endocrine disrupters.

On the basis of these and other general and specific concerns, various proposals for phasing-out certain classes of BFRs have been made in recent years. A proposal for a European Directive was made in 1992 but was never adopted. Some countries, such as Austria, Switzerland, and Canada, have adopted legislation prohibiting PBBs.

In 1995, US and European manufacturers of certain BFRs proposed a voluntary commitment to the OECD SIDS program. Among other proposals, the manufacturers proposed to contribute to the risk analyses related to PBBs and PBDEs/PBDPOs, and to minimize the level of impurities of decabromodiphenyl ether and octabromodiphenyl ether. Within the PBDEs, they would only manufacture or import/ export deca-, penta-, and octa-bromodiphenyl ethers, and within the PBBs only decabromobiphenyl. The commitment did not cover hexabromocyclododecane.

One main problem facing the EU decision makers is the lack of a clear risk assessment on the dangers related to the manufacture and use of BFRs. It is not very precise to classify whole families of substances together; one must generally examine each specific substance used. Decabromodiphenyl ether, octabromodiphenyl ether and pentabromodiphenyl ether are now currently undergoing risk analysis under Regulation 793/93, to determine whether they are dangerous to the environment according to Directive 67/548, and whether reduction measures are called for. The results of these three risk assessments are not expected until the end of 1998 at the earliest. Risk analyses for hexabromocyclododecane and tetrabrombisphenyl A are scheduled for later.

In addition to the risks associated with the manufacture and application of BFRs in association with antimony oxides, for the EU the main potential environmental concerns related to their presence in furniture could be summarized as introducing hazardous substances to landfills, as restricting the possibilities of recycling or incineration with energy recovery, and as contributing to the formation of dioxins. (The World Health Organization (WHO) in late May recommended lowering the daily intakes of dioxin to 1-4 picograms form 10 picograms per kilogram of body weight and tightening regulations).

A second essential question for the EU is: Are there alternatives to BFRs? Information on this point is as yet incomplete, but for textile components the answer is yes, with the range of phosphate-based chemicals and preparations available. Do the alternatives to BFRs have less environmental impact? Again there has been no clear comparative study. Nevertheless, the phosphate-based compounds used for textiles are generally held to be intrinsically less hazardous. The potential environmental impact of most concern would be the contribution to eutrophication via the waste water from the sites applying these FRs.

III. Environmental, Health and Safety Issues for Textile Manufacturers

Any US company wanting to produce FR-fabrics for furniture will have to meet environmental (EPA) and workplace (OSHA) regulatory requirements, which will add to the cost of doing business. CPSC needs to consider these costs and requirements, as well as the cumulative impact of incremental increases in regulatory costs, in their determination of the economic and technological feasibility of any regulation that is promulgated.

In their analysis of the costs of a potential new regulation CPSC staff did not consider these additional costs incurred to produce FR-treated upholstery fabrics. In addition, CPSC did not do an analysis to determine if the potential new regulation will have a significant impact on a substantial number of small entities as required by the Regulatory Flexibility Act.

Some of the environmental, health and safety regulations for the flame retardant textile processes (backcoating and topical treatments) are:

<u>OSHA (workplace)</u>

- Process Safety Management Standard (29 CFR 1910.119) (if ammonia or other listed chemicals are used in the process)
- Hazard Communication Standard (29 CFR 1910.1200) (MSDS, training)
- PELs for Ammonia (29 CFR 1910.1000 Table Z-1), Formaldehyde (29 CFR 1910.1048), other chemicals (29 CFR 1910.1000) (monitoring, engineering controls, recordkeeping)
- Safety and Health Management Program (written program, training, etc.)

Furthermore, the textile industry has concerns with the dermal effects of handling these materials throughout processing. Worker practices, training and personal protective equipment could be required.

<u>EPA (environmental)</u>

- (Air) Clean Air Act (42 US Code 7401 et seq.)
    - NAAQS for Ozone (because of VOCs emitted which can undergo photochemical oxidation in the astmosphere to form ozone); EPA finalized a more severe standard in 1997. This will cause more areas to be nonattainment and could prevent new FR-finishing facilities.
    - Hazardous Air Pollutant (HAP); Maximum Available Control Technology (MACT) standard for textile finishing due by Nov. 2000
    - Chemical Accident Prevention, Section 112(r) (40 CFR 68)
    - Federal Permits ("Title V" permit) (40 CFR 70)
    - State Air Permits

- (Water) Clean Air Act (33 US Code 1251 et seq.)
  - NPDES permits (40 CFR 122) (for effluents including metals, COD, BOD, TSS); FR-finishing may not be allowed in some areas because of effluent restrictions.
  - Storm Water Permits
  - State Water Permits

- (Solid Waste) RCRA (42 US Code 6901 et seq.)
  - If the product is a hazardous waste or the process produces hazardous waste a state solid waste permit could be required; this will affect recycling efforts and disposal of products.

- Emergency Planning and Community Right-to Know (42 US Code 11001 et seq.)
  - Toxic Release Inventory (TRI) (40 CFR 372)

We appreciate the Consumer Product Safety Commission's consideration of theses comments. Please do not hesitate to call if you have any questions or need additional information.

Sincerely,

P/ Wakelyn

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Senior Scientist, Environmental Health and Safety

Attachments:
1. Cotton and Flammability. *American Dyestuff Reporter* 87(2) 13-21 (1998).
2. Cotton and Flammability, Fire Safety and Technology Conf. March 22-25, 1998, Atlanta, GA.

COTTON AND FLAMMABILITY[1,2]

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INTRODUCTION

Cotton, like all textile fibers, will burn. Whenever cotton is in the presence of oxygen and the temperature is high enough to initiate combustion (360-420°C), untreated cotton will either burn (flaming combustion) or smolder (smolder combustion) (1). The degree of flammability depends on many factors including the fabric construction (see Table 1). Laundering can affect the effectiveness/durability of flame retardant treatments (e.g., chlorine bleach and high acid condition can cause hydrolysis of some reactive phosphorus treatments). Fabrics have different flammability requirements depending on the particular end use. Many of these requirements are met by cotton fabrics without the use of special flame retardant finishes.

Resistance to burning is one of the most useful properties that can be imparted to cotton fibers and textiles. Some end uses for cotton in textile items for apparel, home furnishings, and industrial, can depend on its ability to be treated with chemical agents (flame retardants) that confer flame resistance (FR). End uses requiring flame retardant finishes include protective clothing (e.g., foundry workers apparel and fire fighters uniforms), children's sleepwear, furnishing/upholstery, bedding, carpets, curtain/drapes, and tentages. In the U.S., the market for chemically modified flame resistant cotton fabrics is about 16 million square yards per year (2), which is less than 0.2 percent of total cotton consumption in the U.S. The variable manufacturing cost of a flame retardant treatment is about $1-3

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[1] *The statements, recommendations and suggestions contained herein are based on experimental data and other information believed to be reliable. However, no guarantee is made of their accuracy, and the information is given without warranty, express or implied, as to its use or application by others. Likewise, no statement contained herein shall be construed as an authorization or recommendation for the use of a product or process in the infringement of any existing patent, nor does the use of any trade name or trademark constitute endorsement of the particular product.*

[2] *Parts of this paper have been presented and published elsewhere.*

per yard, depending on fabric weight and other factors (2). This can be a major limitation. The flammability and flame resistance of cotton have been studied extensively and several comprehensive reviews of the subject are available (3-9).

Government regulations, insurance company requirements, building codes, and voluntary standards dictate where and when flame-resistant textiles must be used. Also in today's litigious environment, textile producers are becoming increasingly concerned with the liability to which they may be exposed if someone accuses their product of causing an injury or fatality. This paper gives a brief overview and update of the present state of cotton and flammability.

REGULATIONS

In the United States, federal textile flammability regulations are promulgated and enforced by the U.S. Consumer Product Safety Commission (CPSC). If there is a federal standard, CPSC has preemption over state and city regulations. Presently, federal standards developed pursuant to the Federal Flammable Fabrics Act, cover general wearing apparel, children's sleepwear, carpets, and mattresses. The state of California has developed mandatory standards for upholstered furniture and independent standard setting organizations (e.g., ASTM, NFPA, ISO)[3] and trade and industrial associations (e.g., UFAC, BIFMA)[3] have developed voluntary standards for upholstered furniture and other products. The 1996 Annual Book of ASTM Standards Vol. 07.02 (p. 474) contains a summary of the various test methods which should be consulted for details of the specific test method.

Worldwide there are a large number of flammability regulations and these vary from country to country. In the U.S., regulations as well as building codes covering products such as upholstered furniture, and other internal furnishings can vary from state to state and even city to city. It should be noted that flammability of materials is defined by test methods and the logic behind the test methods is not always obvious. These test methods include open flame tests with different ignition sources, ignition times and vertical or 45° angle placement of the fabric, as well as cigarette and pill ignition tests. The details of these various tests can determine what fibers or fabrics are acceptable for a given end use and who wins or loses the business. Companies participating in textile markets where flammability issues are important are well advised to participate in the industry groups or associations that interact with the regulators and standard setting organizations.

[3] ASTM = American Society for Testing and Materials; NFPA = National Fire Protection Association; ISO = International Organization for Standardization; UFAC = Upholstered Furniture Action Council; BIFMA = Business and Institutional Furniture Manufacturing Association

Cotton bales being shipped by vessel and other methods to textile mills are incorrectly considered by some regulations to be a hazardous flammable solid. Cotton bales that are compacted to 14 lbs/ft^3 or greater pass the severe California Standard (TB 129) for mattresses for public occupancy and cotton dry or wet does not spontaneous combust. Cotton can only spontaneously combust if it is heavily contaminated with oil (e.g., oily rags). Recently, this test information from recent studies was used as the basis to remove baled cotton from the IMO IMDG Code Class 4.1 (flammable solid).

FLAME RETARDANT PROCESSES AND CHEMISTRY FOR COTTON SUBSTRATES

Introduction

The chemical treatment used to impart flame resistance to untreated cotton depends on many factors. Is the finish intended to be durable or non-durable? Is the treatment to prevent burning or smoldering? What is the construction of the textile to be treated (e.g., a highly napped surface which can be readily ignited or a dense, heavy construction which burns only under extreme conditions)? Is the textile 100% cotton or does it contain some percentage of thermoplastic man-made fibers, e.g., polyester? There can be human and ecotoxicity concerns. In addition, consumers want the textile product to continue to retain its comfort and aesthetic properties.

Flame retardants in the U.S. market for all end uses can be grouped into six categories: bromine based, antimony oxide, phosphorus based, chlorine based, alumina trihydrate and other as noted in Table II (10). For cotton normally phosphorus-based, and N, and halogen containing chemicals are used. These finishes promote char formation. Cotton and other cellulosics form chars when exposed to a flame. Synthetics, such as polyester and nylon, shrink away from the flame or melt. This is why blends of cotton and polyester are difficult to make flame resistant and can result in more severe fires.

For textiles, the January 1998 *American Dyestuff Reporter* features a buyers' guide listing approximately 30 suppliers of flame retardant chemicals and over 150 products (11).

Non-Durable Treatments

Early attempts at flameproofing cellulosic materials typically involved non-durable to laundering, water soluble chemicals, most of which were inorganic salts. They were and are applied by various means including immersion, padding or spraying. Two bibliographies on the subject contain nearly 700 references including over 400 patents (6).

A number of non-durable finishes have been developed for various industries. Most are based on borax ($Na_2B_4 \cdot 10\ H_2O$), boric acid (H_3BO_3), diammonium phosphate [$(NH_4)_2 HPO_4$], ammonium polyphosphate or sodium phosphate dodecahydrate (Na_3PO_4 - $12H_2O$) (9). These agents are applied from water solutions to the textile, followed by squeezing to reduce the wet pick up, and finally by drying. While such treatments are removed by conventional laundering, most can withstand several nonaqueous launderings with dry-cleaning solvents and still remain effective. These non-durable finishes are recommended for 100% cotton textiles. Combinations of flame retardants with resin systems can improve durability. For cotton/polyester blended textiles, a reagent such as ammonium bromide, which decomposes with heat and becomes active in the gaseous phase, should be added to the agents mentioned above for greater effectiveness (9).

The efficiency of these salts depends on their ability to impart to the substrate resistance to both afterflaming and afterglow. These two characteristics are different and generally unrelated phenomena which occur by different mechanisms. Consequently, many good afterflaming inhibitors do not provide good afterglow resistance and vice versa. Boric acid, for example, has been widely used on certain cotton substrates because it is a good cost effective water soluble glowproofing agent but has little ability to prevent afterflaming of fabric. However, cotton batting treated with boric acid (target range 9.0-11.5% by weight) passes TB 117; the CPSC mattress test (16 CFR 1632); and the UFAC filling test (12). The ammonium salts of phosphoric acid are among the best examples of the relatively few inorganic compounds which are able to produce effective resistance to both afterflaming and afterglow.

The temporary or non-durable flame retardant finishes have been used on products that will not be laundered such as draperies and upholstery. Many of the more common water soluble type retardants will hydrolyze or decompose at temperatures in the range 135-149°C. This must be considered in mill processing or ironing/pressing if these materials are applied in commercial laundering. Mixtures of borax and boric acid will lose hydrated water at 127-134°C, and consequently lose effectiveness (6).

Durable Treatments

Most of the emphasis today is on flame retardant treatments which are durable to multiple launderings. The specific regulation specifies the details. There have been many techniques for imparting durable flame resistance properties to cellulosic substrates described in the published literature (4,7,8,13). However, there are relatively few that are used in practice today, either due to commercial availability, cost of the chemicals, safety concerns (including dermatitis and other human and environmental toxicity), process control issues, and process costs or other reasons. Durable flame retardants are more complex, more expensive and more difficult to apply than non-durable treatments (7). The main flame retardant finishes used on cotton are phosphorus-based (14); the mechanism of phosphorus-based flame retardant finishes on cotton is complex and has been described (15, 16). These finishes promote char formation. This paper will be limited to systems which are widely available and used to produce commercial textiles.

"Precondensate[4]" /NH_3 Process: This flame-retardant agent which conveys flame resistance exists as a polymer in the fibrils of cotton fibers and is not combined chemically with OH groups in the cotton fiber. This process imparts durable flame resistance to a range of fabric weights and constructions of 100% cotton fabrics when applied under proper application procedures. It produces fabrics with a good hand and strength retention. However, some dye shades can be affected. Proper application of precondensates to cotton fabrics requires:

- Adequate fabric preparation
- Proper padding/uniform application
- Proper phosphorus add-on relative to fabric properties
- Appropriate moisture control prior to ammoniation
- Control of the ammoniation step to ensure adequate polymer formation
- Effective oxidation and washing of the treated fabric

Application of the formulation (precondensate, sodium acetate, nonionic surfactant) can be done with conventional pads. For optimum performance the precondensate formulation must be uniformly distributed within the fibers. Multiple dips and nips work well for this purpose.

Control of fabric moisture before ammoniation is a critical factor. Moisture levels between 10% and 20% generally will provide successful results, but optimum levels should be determined for each fabric. This determination can be made gravimetrically or with commercially available moisture meters. Uniform drying is important and oven temperatures should be checked across the width and length and corrected as needed. Overdrying tends to retard reaction with ammonia, while underdrying tends to form a less durable FR polymer. Chemical curing is accomplished by exposing the moist, precondensate-padded fabric to anhydrous, gaseous ammonia. For commercial applications, a continuous ammonia cure system is used. The modern systems are compact and carefully engineered for safety and efficiency after many years of experience. The details are available from suppliers.

[4] Precondensate is the designation for a tetrakis(hydroxymethyl)phosphonium salt pre-reacted with urea or another nitrogenous material. The reaction products are complex oligomers; exact compositions are proprietary information of chemical suppliers. The precondensate treatment using ammonia gas to polymerize the procondensate in the fiber is the largest commercial use of flame retardants in the U.S. (14).

The final steps in the process are oxidation of the phosphorus polymer, washing of the fabric to remove unreacted chemicals, and adjustment of the fabric pH. Oxidation can be done on either batch or continuous equipment using hydrogen peroxide.

After treatments of ammonia cure FR cotton fabrics, such as top softening, wrinkle resistant, and water repellency are similar to those for non-FR fabrics. These final finishing steps should be done after the fabric has been oxidized, properly washed and dried.

Treatment of blends of cotton and man-made fibers by this process can sometimes be done successfully. Specific formulations for blends must be determined empirically, and may require higher add-on to get durability, since the finish is designed to be insolubilized within the cotton fiber.

Fume handling and disposal is important at certain stages of the precondensate/ammonia process. Formaldehyde and ammonia are the chemicals most often involved. Trace amounts of phosphorus chemical with their characteristic odor can be handled in any system designed to exhaust formaldehyde and ammonia. Adequate ventilation is essential in the bath preparation area, over the pad and throughout the drying frame (including entrance and exit ends). Disposal of exhausts into the atmosphere may not be permissible; scrubbing to remove excessive amounts of chemicals may be required (17).

<u>Reactive Phosphorus Based Flame Retardants</u>: These are compounds (e.g., N-methylol dimethyl phosphonopropionamide (MDPPA)) that react with OH groups of cellulose, the main constituent of cotton fiber. These compounds can be used for cotton alone and for cotton blends with low synthetic fiber content. The finish promotes char formation (15, 16). The finish is usually applied to the fabric after the coloring stage. The depth of dyeing and method of printing can affect whether the reactive phosphorus compound will react with the cellulose to give an even, through treatment. The reactive phosphorus based flame retardants typically are applied by a pad/dry/cure method, in the presence of phosphoric acid catalyst. Some chemical manufacturers recommend that higher add on levels of chemical are necessary to produce a durable flame resistant fabric that can withstand multiple launderings, since laundering can sometimes hydrolyse and remove some of the finish. The finish is sometimes applied with a methyolated melamine resin to increase bonding/fixation of the agent to cellulose, which enhances the flame retardancy (7). Afterwashing is generally required often with an alkali such as soda ash followed by further rinsing and drying. Usually 4 to 5 stages of washing and two dryings are required. This helps to reduce fabric strength loss (7).

A reactive phosphorous based process has the advantage of not requiring specialized equipment such as an ammonia cure unit and has less affect on dyes. However, this process can cause more strength loss than the precondensate and there can be a durability problem in some wash treatments if the instructions of the chemical supplier are not followed (18). Chlorine bleach, high acidity, softeners, and powdered detergents can reduce the effectiveness of reactive phosphorus based flame retardants. Some suppliers of these flame retardants recommend that these agents not be used for fabrics less than 5-6 oz/yd^2 and not to use softeners. The use of these chemicals are allowed under European Ecotex labeling criteria.

Other

Fiber Blends: A more recent approach to flame-resistant cotton-containing fabrics involves the use of core-spun yarns (19,20). These are specialized yarns that are made from two components. One component is a central core usually made from a man-made synthetic like polyester or nylon or a nonflammable core like fiberglass. The other component is a cotton cover that is wound around the central core to form the yarn. The core yarn is woven or knitted into an appropriate textile, then treated with a finish to make the cotton cover flame resistant. When the core yarns are spun so as to restrict their synthetic content to 40% or less, the flame-retardant treatment of the cotton component alone will frequently make the array flame resistant. The need for a separate flame-retardant treatment of the polyester or nylon component is no longer required. If fiberglass is the core yarn no flame retardant treatment may be necessary.

Fleece, sherpa and other raised surface garments that contain 5-50% polyester or acrylic generally will pass the CPSC general wearing apparel standard (16 CFR 1610) without FR finishes, depending on their construction and weight. At least 15% synthetic fiber in the raised surface face fabric is normally required to produce a Class 1 fabric under 16 CFR 1610. Fleece garments of 100% cotton with no FR finish are also marketed. However, the formation of the yarns and fabrics is very important for untreated 100% cotton or high cotton blend fleece fabrics to pass 16 CFR 1610. A low-level flame retardant treatment or other treatments to the face fabric can also be helpful.

It has been reported (21) that naturally colored brown cotton has some increased flame resistant properties over conventional white cotton. This is most likely due to an increased nitrogen content. The nitrogen level may also be beneficially increased by blending with nylon, wool, or applying selective nitrogen containing chemicals.

Fire blockers, barriers, intumescent systems

As discussed above in this section most commercially available flame retardant compounds for cotton contain phosphorus, nitrogen and/or halogen (Cl, Br). The phosphorus moieties act in the condensed phase as char formers. Nitrogen-containing compounds alone have little flame retardant effect, except when present with phosphorus, where they have a synergistic effect creating enhanced char formation. Recently it has been reported that if intumescent systems, 1. ammonium polyphosphate, melamine, pentaerythritol, and 2. melamine phosphate and dipentaerythritol, are dispersed about flame resistant cotton fibers, their effectiveness is increased (22). More char is formed and the char is more resistant to oxidation. These systems may be effective for back coating fabrics or for cotton composite barriers. Back coated fabrics, compacted FR-cotton batting, and other cotton-containing barriers are also used to meet flammability standards.

RESEARCH NEEDS

There is a need for suppliers of FR cotton fabric and cotton yarn in the US. These materials could be used in products such as fleece and other niche areas, including other fabrics with raised surfaces, and possibly upholstery. The issue is more one of the complexity and expense of the flame retardant treatment process rather than technical feasibility. The durable flame retardants mentioned above can be applied to fiber, yarn, or fabric but the process and equipment details and associated costs and environmental consequences (23) need to be determined/developed. The same processing systems that work well to produce quality flame retardant cotton fabrics can also work for fiber or yarn but the equipment needs are obviously different. This potentially could be a significant business for someone willing to invest in the applied research to work out the details.

Some research needs include:

1. cheaper, durable chemicals, which impart both flame resistance and wrinkle resistance, without causing appreciable strength loss or reduced abrasion resistance
2. treatments that result in low smoke and toxic gas emissions
3. environmentally-friendly finishes that can be applied simply as a low add-on without affecting aesthetic properties of the fabric
4. improved ecotoxicology (replacement of brominated FR compounds and antimony compounds, since brominated FR agents potentially can form dioxins and furans and are potential ozone depleting chemicals; antimony compounds have incorrectly been linked with sudden infant death syndrome)
5. coatings/back coatings
6. FR barriers/fire blockers
7. cotton stock (fiber) treatments

SUMMARY

The biggest change in flame resistance of cotton in the last 20 years is improved application systems. The basic chemistry and agents are essentially the same, e.g., precondensate and reactive phosphorous compounds for durable treatments and boric acid for cotton batting. The conditions for application of precondensate/ammonia have been optimized and the ammoniator reactor has been improved. Systems for applying the reactive phosphorous compounds have also been improved and adapted for surface treatments. Systems for boric acid treatment of cotton batting have been improved so that batting with more even application of the chemical and with no dusting out can be obtained. It is expected that there will be continued improvement in application systems (7, 22).

Finally, it should be remembered that all textile products burn and that it is necessary to be careful around ignition sources. Public information and education programs are important for preventing textile related fires.

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Table 1. Major Factors that Influence Ignition of Cotton (1)

- airflow
- relative humidity of the fabric
- amount of oxygen available
- physical factors/construction (fabric geometry, density, thickness, and weight)
- chemical factors (inorganic impurities, alkali metal ions, e.g., K, Na, Ca and salts of Fe, Cr, Pb can induce smoldering)
- heat source
- how fast the cotton is heated
- treatments for open flame resistance can affect smolder resistance (fabric weight important)
- evenness/throughness of treatment

Table II. U.S. Flame-Retardants Market

Bromine-based	32%
Chlorine-based	17%
Phosphorus-based	17%
Antimony oxide	20%
Alumina trihydrate	11%
Other (includes, magnesium hydroxide and boron-, molybdenum- and nitrogen-based)	3%

1995 demand = $718 million
2000 (est.) demand = $925 million

Source: *Chemical and Engineering News*, Feb. 24, 1997, 19-20 and Business Communications Co.

Cotton And Flammability—Overview Of New Developments

By P.J. Wakelyn, Ph.D., William Rearick,
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Abstract

Resistance to burning is one of the most useful properties that can be imparted to cotton fibers and textiles containing cotton. Processes presently used to impart flame resistance (FR) characteristics to cotton yarns and fabrics for the various end uses (e.g., protective clothing, children's sleepwear, carpets, upholstery, bedding, etc.) are discussed, as well as research needs.

Introduction

Cotton, like most textile fibers, is combustible. Whenever cotton is in the presence of oxygen and the temperature is high enough to initiate combustion (360-420°C), untreated cotton will either burn (flaming combustion) or smolder (smolder combustion).[1] The degree of flammability depends on the fabric construction. Fabrics have different flammability requirements depending on the particular end use. Practically all of these requirements are met by cotton fabrics without the use of special flame retardant finishes.

Resistance to burning is one of the most useful properties that can be imparted to cotton fibers and textiles. Some end uses for cotton in textile items for apparel, home furnishings, and industrial, can depend on its ability to be treated with chemical agents (flame retardants) that confer flame resistance (FR). End uses requiring flame retardant finishes include protective clothing (e.g., foundry workers apparel and fire fighters uniforms), children's sleepwear, furnishing/upholstery, bedding, carpets, curtain/drapes, and tentages. In the US, the market for chemically modified flame resistant cotton fabrics is about 16 million square yards per year,[2] which is less than 0.2 percent of total cotton consumption in the US. The variable manufacturing cost of a flame retardant treatment is about $1-2 per yard, depending on fabric weight and other factors.[2] This can be a major limitation. The flammability and flame resistance of cotton have been studied extensively and several comprehensive reviews of the subject are available.[3-6]

Government regulations, insurance company requirements, building codes, and voluntary standards dictate where and when flame-resistant textiles must be used. Also in today's litigious environment, textile producers are becoming increasingly concerned with the liability to which they may be exposed if someone accuses their product of causing an injury or fatality. This article provides a brief overview and update of the present state of cotton and flammability.

Regulations Examined

In the United States, federal textile flammability regulations are promulgated and enforced by the US Consumer Product Safety Commission (CPSC). If there is a federal standard, CPSC has preemption over state and city regulations. Presently, federal standards developed pursuant to the Federal Flammable Fabrics Act, cover general wearing apparel, children's sleepwear, carpets, and mattresses (Table IA, IB).

The state of California has developed mandatory standards for upholstered furniture and independent standard setting organizations (e.g., ASTM, NFPA, ISO)[3] and trade and industrial associations (e.g., UFAC, BIFMA[3]) have developed voluntary standards for upholstered furniture and other products. Table IA, IB lists some of these standards that apply to the various textile end uses. These should be consulted for details of the test method. The 1996 Annual Book of ASTM Standards Vol. 07.02 (p. 474) contains a summary of the various test methods.

Worldwide, there are a large number of flammability regulations and these vary from country to country. In the US, regulations as well as building codes covering products such as upholstered furniture, and other internal furnishings can vary from state to state and even city to city. It should be noted that flammability of materials is defined by test methods and the logic behind the test methods is not always obvious. These test methods include open flame tests with different ignition sources, ignition times and vertical or 45° angle placement of the fabric, as well as cigarette and pill ignition tests.

The details of these various tests can determine what fibers or fabrics are

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***Note**—Philip J. Wakelyn, Ph.D., is affiliated with the National Cotton Council, Wash., DC; William Rearick and John Turner, Ph.D., with Cotton, Inc., Raleigh, NC.*

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acceptable for a given end use and who wins or loses the business. Companies participating in textile markets where flammability issues are important are well advised to participate in the industry groups or associations that interact with the regulators and standard setting organizations.

Flame Retardants: Processes And Chemistry For Cotton Substrates

Introduction

The chemical treatment used to impart flame resistance to untreated cotton depends on many factors. Is the finish intended to be durable or non-durable? Is the treatment to prevent burning or smoldering? What is the construction of the textile to be treated (e.g., a highly napped surface which can be readily ignited or a dense, heavy construction which burns only under extreme conditions)? Is the textile 100% cotton or does it contain some percentage of thermoplastic man-made fibers, e.g., polyester? In addition, there can be problems of ecological concern.

Flame retardants in the US market for all end uses can be grouped into six categories: bromine based, antimony oxide, phosphorus based, chlorine based, alumina trihydrate and other as noted in Table II[10]. For textiles, the January 1997 American Dyestuff Reporter featured a buyers' guide listing approximately 30 suppliers of flame retardant chemicals and over 150 products.[11]

Non-Durable Treatments

Early attempts at flameproofing cellulosic materials typically involved water soluble chemicals, most of which were inorganic salts. They were and are applied by various means including immersion, padding or spraying. Two bibliographies on the subject contain nearly 700 references including over 400 patents.[8]

A number of non-durable finishes have been developed for various industries. Most are based on borax ($Na_2B_4O_7 \cdot 10H_2O$), boric acid (H_3BO_3), diammonium phosphate [$(NH_4)_2HPO_4$], ammonium polyphosphate or sodium phosphate dodecahydrate ($Na_3PO_4 \cdot 12H_2O$)[9]. These agents are applied from water solutions to the textile, followed by squeezing to reduce the wet pick up, and finally by drying. While such treatments are removed by conventional laundering, most can withstand several nonaqueous launderings with dry-cleaning solvents and still remain effective. These non-durable finishes are recommended for 100% cotton textiles. Combinations of flame retardants with resin systems can improve durability. For cotton/polyester blended textiles, a reagent such as ammonium bromide, which decomposes with heat and becomes active in the gaseous phase, should be added to the agents mentioned above for greater effectiveness.[9]

The efficiency of these salts depends on their ability to impart to the substrate resistance to both afterflaming and afterglow. These two characteristics are different and generally unrelated phenomena which occur by different mechanisms. Consequently, many good afterflaming inhibitors do not provide good afterglow resistance and vice

[3] *ASTM=American Society for Testing and Materials; NFPA=National Fire Protection Association; ISO=International Organization for Standardization; UFAC=Upholstered Furniture Action Council; BIFMA=Business and Institutional Furniture Manufacturing Association.*

versa. Boric acid, for example, has been widely used on certain cotton substrates because it is a good cost effective water soluble glowproofing agent but has little ability to prevent afterflaming of fabric. The ammonium salts of phosphoric acid are among the best examples of the relatively few inorganic compounds which are able to produce effective resistance to both afterflaming and afterglow.

The temporary or non-durable flame retardant finishes have been used on products that will not be laundered such as draperies and upholstery. Many of the more common water soluble type retardants will hydrolyze or decompose at temperatures in the range 135-149°C. This must be considered in mill processing or ironing/pressing if these materials are applied in commercial laundering. Mixtures of borax and boric acid will lose hydrated water at 127-134°C, and consequently lose effectiveness.[†]

Durable Treatments

Most of the emphasis is currently on flame retardant treatments which are durable to multiple launderings. The regulations specify the details. There have been many techniques for imparting durable flame resistance properties to cellulosic substrates described in the literature.[4,7,8,12] However, there are relatively few that are practiced today, either due to commercial availability of the chemicals, safety concerns, process control issues or other reasons. Durable flame retardants are more complex, more expensive and more difficult to apply than non-durable treatments.[7] The main flame retardant finishes used on cotton are phosphorus-based;[13] the mechanism of phosphorus-based flame retardant finishes on cotton is complex and has been described.[14,15] This article will be limited to systems which are widely available.

"Precondensate" /NH3 Process: The flame-retardant agent which conveys flame resistance exists as a polymer in the fibrils of cotton fibers and is not combined chemically with OH groups in the cotton fiber. This process imparts durable flame resistance to 100% cotton fabrics when applied under proper application procedures. It produces fabrics with a good hand and strength retention. Proper application of precondensates to cotton fabrics requires:

- *Adequate fabric preparation*
- *Proper padding/uniform application*
- *Proper phosphorus add-on relative to fabric properties*
- *Appropriate moisture control prior to ammoniation*
- *Control of the ammoniation step to ensure adequate polymer formation*
- *Effective oxidation and washing of the treated fabric*

A generalized precondensate* formulation, applicable to a range of fabric weights and constructions, is a follows:

	% By Weight
Precondensate	*20.0 to 50.0*

* *Precondensate is the designation for a tetrakis(hydroxymethyl)phosphonium salt pre-reacted with urea or another nitrogenous material. The reaction products are complex oligomers; exact compositions are proprietary information of chemical suppliers. The precondensate treatment using ammonia gas to polymerize the precondensate in the fiber is the largest commercial use of flame retardants in the US.*[13]

† *The amount of anhydrous sodium acetate is 4% of the amount of precondensate used. Some precondensates are available with the sodium acetate already combined.*

Sodium acetate (anhydrous)	*0.8 to 2.0*[5]
Nonionic surfactant	*0.2*
Water	*79.0 to 47.8*

Application of the formulation can be done with conventional pads. For optimum performance--the precondensate formulation must be uniformly distributed within the fibers. Multiple dips and nips work well for this purpose.

Control of fabric moisture before ammoniation is a critical factor. Moisture levels between 10% and 20% generally will provide successful results, but optimum levels should be determined for each fabric. This determination can be made gravimetrically or with commercially available moisture meters. Uniform drying is important and oven temperatures should be checked across the width and length and corrected as needed. Overdrying tends to retard reaction with ammonia, while underdrying tends to form a less durable FR polymer.

Chemical curing is accomplished by exposing the moist, precondensate-padded fabric to anhydrous, gaseous ammonia. For commercial applications, a continuous ammonia cure system is used. The modern systems are compact and carefully engineered for safety and efficiency after many years of experience. The details are available from suppliers.

The final steps in the process are oxidation of the phosphorus polymer, washing of the fabric to remove unreacted chemicals, and adjustment of the fabric pH. Oxidation can be done on either batch or continuous equipment using hydrogen peroxide. For batch processing 10% hydrogen peroxide (50% active solution) based on the weight of the fabric, at 54° to 60°C with a 20:1 liquor-to-fabric ratio can be used. Ten minutes dwell in a rope washer or equivalent is normally sufficient to complete conversion of the phosphorus to the pentavalent, or durable, state and to remove traces of odor. Rinsing with warm water or dilute (2% to 5%) sodium carbonate solution completes the wash. The final pH of the fabric should be in the range of five to eight. For open-width, continuous oxidation, 10% hydrogen peroxide (50% active solution) on weight of the fabric, is padded at room temperature onto the fabric. Sufficient "sky-time" to allow 30 to 60 seconds exposure of the goods to this solution is needed before rinsing and pH adjustment. Continuous washing requirements are dependent on the fabric weight and construction and the amount of unfixed polymer to be removed. The final pH of the material should be the same as for batch processing.

After treatments of ammonia cure FR cotton fabrics, such as top softening, wrinkle resistant, and water repellency are similar to those for non-FR fabrics. These final finishing steps should be done after the fabric has been oxidized, properly washed and dried.

Treatment of blends of cotton with man-made fibers by this process can sometimes be done successfully. Specific formulations for blends must be determined empirically, and may require higher add-on to get durability, since the finish is designed to be insolubilized within the cotton fiber.

Fume handling and disposal is important at certain stages of the precondensate/ammonia process. Formaldehyde and ammonia are the chemicals most often involved. Trace amounts of phosphorus chemical with their characteristic odor can be handled in any system designed to exhaust formaldehyde and ammonia. Adequate ventilation is essential in the bath preparation area, over the pad and throughout the drying frame (including entrance and exit

Table IA: Flammability Standards for Textiles[6]

(CPSC) Flammable Fabrics Act 16 CFR 1605. 1608 1609 (text)

General wearing apparel
- (CPSC) 16 CFR 1610, Standard for the flammability of clothing textiles
- ASTM D1230 Standard Test Method for Flammability of Apparel Textiles--16 CFR 1610 updated
- NFPA 702 Flammability of wearing apparel
- ISO 6940: 1984 Textile Fabrics - Burning Behavior - Determination of Ease of Ignition of Vertically Oriented Specimens
- ISO 6941: 1984 Textile Fabrics - Burning Behavior - Determination of Flame Spread Properties of Vertically Oriented Specimens
- ISO 10047: 1993 Textiles - Determination of Surface Burning Time of Fabrics

Sleepwear
- (CPSC) Standard for the flammability of children's sleepwear:
  16 CFR 1615, Sizes 0 through 6X (FF3-71)
  16 CFR 1616, Sizes 7 through 14 (FF5-74)

Carpet
- (CPSC) 16 CFR 1630, Standard for the surface flammability of carpets and rugs (FF 1-70)
- (CPSC) 16 CFR 1631, Standard for the surface flammability of small carpets and rugs (FF 2-70)
- ASTM D2859 Test Method for Flammability of Finished Textile Floor Covering Materials–16 CFR 1630 and 1631
- ISO 6925: 1982 Textile Floor Coverings - Burning Behavior - Tablet Test at Ambient Temperature.

Mattress
- (CPSC) 16 CFR 1632, Standard for the flammability of mattresses and mattress pads (FF 4-72)
- CA TB 129 Flammability Test Procedure for Mattresses for Public Buildings [not a mandatory CA standard]
- CA TB 121 Flammability Test Procedure for Mattresses for Use in Public Occupancies [not a mandatory CA standard]
- ASTM E 1590 Standard Test Method for Fire Testing of Mattresses
- NFPA 267 Standard Method of Test for Fire Characteristics of Mattresses and Bedding Assemblies Exposed to Flaming Ignition Source
- ASTM D5258 Standard Test Method for Smoldering Combustion Potential of Cotton-Based Batting [for mattresses and upholstered furniture]

6 See ASTM D 4723, p. 474, 1996 Annual Book of ASTM Standards Vol. 07.02, for summary of test methods.

ends). Disposal of exhausts into the atmosphere may not be permissible; scrubbing to remove excessive amounts of chemicals may be required .[16]

Reactive Phosphorus Based Flame Retardants: These are compounds (e.g., N-methylol dimethyl phosphonopropionamide (MDPPA)) that react with cellulose, the main constituent of cotton fiber. These compounds can be used for cotton alone and for cotton blends with low synthetic fiber content. The finish promotes char formation. The finish is usually applied to the fabric after the coloring stage. The durability of the finish makes treated fabric acceptable for curtains, upholstery, bed linen and protective clothing. The reactive phosphorus based flame retardants typically are applied by a pad/dry/cure method, in the presence of phosphoric acid catalyst. The finish is sometimes applied with a methyolated melamine resin to increase bonding/fixation of the agent to cellulose, which enhances the flame retardancy.[7] Afterwashing is generally required often with an alkali such as soda ash followed by further rinsing and drying. This helps to reduce fabric strength loss.[7] A reactive phosphorous based process has the advantage of not requiring specialized equipment such as an ammonia cure unit and has less affect on dyes. However, this process can cause more strength loss than the precondensate and there can be a durability problem in some wash treatments if the instructions of the chemical supplier are not followed.[17]

Other

Fiber Blends: A more recent approach to flame-resistant cotton-containing fabrics involves the use of core-spun yarns.[18,19] These are specialized yarns that are made from two components. One component is a central core usually made from a man-made synthetic like polyester or nylon or a non-flammable core like fiberglass. The other component is a cotton cover that is wound around the central core to form the yarn. The core yarn is woven or knitted into an appropriate textile, then treated with a finish to make the cotton cover flame resistant. When the core yarns are spun so as to restrict their synthetic content to 40% or less, the flame-retardant treatment of the cotton component alone will frequently make the array flame resistant. The need for a separate flame-retardant treatment of the polyester or nylon component is no longer required. If fiberglass is the core yarn no flame retardant treatment may be necessary.

Fleece, sherpa and other raised surface garments that contain 5-50% polyester or acrylic generally will pass the general wearing apparel standard (16 CFR 1610) without FR finishes, depending on their construction and weight. Fleece garments of 100% cotton with no FR finish are also marketed. However, the formation of yarns and fabrics is very important for untreated 100% cotton fleece fabrics to pass 16 CFR 1610.

It has been reported[20] that naturally colored brown cotton has increased flame resistant properties over conventional white cotton. This is most likely due to an increased nitrogen content. The nitrogen level may also be beneficially increased by blending with nylon, wool, or applying selective nitrogen containing chemicals.

As discussed, in this section are the most commercially available flame retardant compounds for cotton contain phosphorus and nitrogen. The phosphorus moieties act in the condensed phase as char formers. Nitrogen-containing compounds alone have little flame retardant effect, except when present with phosphorus, where they have a synergistic effect creating enhanced char formation. Recently it has been reported that if intumescent systems, 1. ammonium polyphosphate, melamine, pentaerythritol, and 2. melamine phosphate and dipentaerythritol, are dispersed about flame resistant cotton fibers, their effectiveness is increased.[21] More char is formed and the char is more resistant to oxidation. These systems may be effective for back coating fabrics or for cotton composite barriers.

Product Categories

FR Apparel/Protective Clothing

Cotton is reported as maintaining a 50% market share of the total US industrial flame resistant apparel market.[2] The main competition for cotton is aramid and more exotic fibers. For industrial workwear FR cotton provides equal or better protection at roughly one-third the price of Nomex.[8,22] Flame resistant apparel for protective clothing includes uniforms for the petroleum and petrochemical industries, metal workers, and utility workers, protective apparel (flight uniforms) for space shuttle astronauts,[23] and military apparel (the Navy uses FR-cotton coveralls for engineering room personnel). Most industrial FR apparel is probably produced by the precondensate/ammonia process but actual market data is difficult to obtain. There are ASTM, NFPA and ISO standards for protective clothing (see Table IA, IB).

There are workplace requirements for electrical power workers. The Occupational Safety and Health Administration (OSHA) rule for Electrical Power Generation, Transmission and Distribution: Electrical Protective Equipment (29 CFR 1910.269[24]) states "The employer shall ensure that each employee who is exposed to the hazards of flames or electrical arcs does not wear clothing that, when exposed to flames or electrical arcs, could increase the extent of injury that would be sustained by the employee" [29 CFR 1910.269(1)(6)(iii)]. Further, the standard also discourages the use of fabrics made of most synthetic fibers, alone or in blends: "Clothing made from the following types of fabrics, either alone or in blends, is prohibited by this paragraph, unless the employer can demonstrate that the fabric has been treated to withstand the conditions that may be encountered or that the clothing is worn in such a manner as to eliminate the hazard involved: acetate, nylon, polyester, rayon" [29 CFR 1910.269 (1)(6)(iii)]. The standard specifically states that cotton of 11 oz/yd^2 or more will not ignite and therefore, meets the requirements of 29 CFR 1910.269 (1)(6)(iii) under the arc test conditions.[24,25] Lighter weight cotton fabrics have to be treated to meet most of the end-uses covered under this standard, unless the employer has determined "that the clothing worn will not ignite under the electric arc and flame conditions possible at the employee's actual workplace. This can be through employer-run tests of the actual clothing to be worn or through reliance on such tests run by others".[25] OSHA is also considering adding an "Appendix C-Clothing" to their compliance guidelines for enforcement of 29 CFR 1910.269[26] to explain further their interpretation of "the ignition threshold of 100 percent natural cotton". The "Electrical Power" rule has created additional markets for FR cotton industrial apparel.

Children's Sleepwear

Several major mills were producing flame resistant cotton for children's sleepwear in the 1970's. Because of chronic toxicity concerns (cancer) with the flame retardant agent used for polyester,[27] regulations were changed in 1978 to allow thermoplastic fibers which melt drip (e.g., polyester) to pass the vertical flame test required by the CPSC Children's Sleepwear Standards (16 CFR 1615 and 1616). Since FR-cotton could not compete with non-flame retardant treated polyester and the public concern about finishes on garments for children, there has not been much cotton used for children's sleepwear in the US The higher cost of FR-cotton sleepwear also has had a negative impact on sales. However, FR-cotton sleepwear is presently marketed in some upscale department and specialty stores. Both precondensate/ammonia and MDPPA reactive phosphorus flame retardant finishes are used for FR-cotton sleepwear. With the recent changes in the children's sleepwear regulations, cotton is coming back into use for tight-fitting garments and infant wear, since these garments meet the requirements of the amended standards (16 CFR 1615 and 1616) without a flame retardant treatment.

Due to environmental concerns, the high phosphate detergents that were used in the 1970's are no longer allowed for use in the United States. Investigations currently underway at the CPSC indicate that the old high phosphate detergents appear not to remove the FR-properties of cotton garments and may even help to maintain the FR-properties. Today's consumer uses low or non-phosphate detergents and low water temperatures (below 105°F) which may cause some FR-garments to fail the vertical flame test (required by the children's sleepwear flammability standards) after laundering. However, the use of non-phosphate detergents do not necessarily harm FR durability as long as softened water is used. When non-phosphate detergents are used in hard water, deposits (e.g., calcium stearate and carbonate) can build up on the fabric, which harms FR-performance, particularly with regard to afterflame and afterglow.[7,28] Liquid non-phosphate detergents readily dissolve in water whereas solid non-phosphate detergents in cold hard water can more readily leave deposits, which can harm FR-performance.

Fleece/sherpa (garments with raised fiber surface)

Fleece goods are an area where untreated 100% cotton has generally been excluded because of the requirement of passing 16 CFR 1610 (a 45° angle test). The increase in demand for 100% cotton apparel has spurred interest in 100% cotton fleece goods. There has recently been a very limited number of commercial 100%-cotton fleece fabrics in the market which pass 16 CFR 1610. Judging from the FTIR and NIR analysis, these fabrics do not contain flame retardants. It may be that heavier, denser fabrics with denser naps are what is required for fleece to pass this test without flame retardants. Another option, which has been considered for making 100% cotton fleece practical, is surface spraying on the side which is to be napped, either before or after napping, using a reactive phosphorus based flame retardant. It should be technically feasible and will probably only require a very low level of flame retardant, but may require the afterwash and second drying step.

Table IB:

Upholstered Furniture

- CA TB 116 Requirement, Test Procedures and Apparatus for Testing the Flame Retardance of Upholstered Furniture (cigarette test; mock-up or full chair)
- CA TB 117 Requirements, Test Procedures and Apparatus for Testing the Flame Retardancy of Resilient Filling Materials Used in Upholstered Furniture (open flame test, 45° / and vertical; component test)
- CA TB 133 Flammability Test Procedure for Seating Furniture for Use in High Risk and Public Occupancies
- UFAC (voluntary standards) - 83 UFAC Test Methods - six individual tests: Fabric Classification Test Method; Interior Fabric Test Method; Barrier Test Method; Filling/Padding Component Test Method; Weltcore Test Method; Decking Material Test Method
- NFPA 260A Standard Method of Test and Classification System for Cigarette Ignition Resistance of Components of Upholstered Furniture (Similar to UFAC-83)
- NFPA 260B Standard Method of Test for Determining Resistance of Mock-up Upholstered Furniture Material Assemblies to Ignition by Smoldering Cigarettes

Blankets

- ASTM D4151 Standard test flammability of blankets

Curtains and Drapes (films or other textiles)

- NFPA 701 Standard Methods of Fire Tests for Flame-Resistant Textiles and Films
- ISO 6940: 1984 Textile Fabrics - Burning Behavior - Determination of Ease of Ignition of Vertically Oriented Specimens.
- ISO 6941: 1984 Textile Fabrics - Burning Behavior - Determination of Flame Spread Properties of Vertically Oriented Specimens.

Protective Clothing

- ASTM D 4108 Test Method for Thermal Protective Performance of Materials for Clothing by Open-Flame Method
- NFPA 1971 Protective Clothing for Structural Fire Fighting
- ASTM F 1506 Textile Materials for Wearing Apparel for Use by Electrical Workers Exposed to Momentary Electric Arc and Related Thermal Hazards
- ISO 6942:1993 Clothing for Protection Against Heat and Fire - Evaluation of Thermal Behavior of Materials and Material Assemblies When Exposed to a Source of Radiant Heat.

Cellulose Insulation

- (CPSC) 16 CFR 1209 Interim Safety Standard for Cellulose Insulation (cigarette test for smoldering combustion and test for small open-flame sources such as matches or candles; corrosiveness to copper, aluminum or steel if exposed to water)
- (CPSC) 16 CFR 1404 Cellulose Insulation (potential fire hazard labeling)

Upholstery

Currently in the US there are no mandatory federal regulations for upholstery fabrics going into residential end uses. However, there are voluntary standards (UFAC) and the state of California has regulations. The CPSC has a rulemaking underway to determine if a standard is necessary to address the risk of small open flame for furniture. CPSC has developed a small open flame test that is being evaluated. It appears that this would be the equivalent of a vertical flame test for upholstery fabrics. If this ultimately became law, it would require flame retardant treatments for most upholstery fabrics.

Residential furniture in California has to meet the requirements of CA TB 117 (open-flame test for resilient filling materials and fabric). This is a component test where the fabric has to meet a test similar to the 45° angle general wearing apparel test and the batting/filling has to meet a 45° angle open flame test if synthetic and a vertical flame test if natural (e.g., cotton) batting. Most cotton upholstery fabrics over 2 oz/yd² do not have to be treated to pass TB 117. Cotton batting would normally be treated with boric acid (target range 9.0-11.5% by weight) to pass TB 117; this batting will also pass the CPSC mattress test (16 CFR 1632) and the UFAC filling test.[29]

Upholstery for furniture going into high-risk public occupancies in California is required to pass a composite full-scale furniture test (California Bulletin 133). In the full-scale flammability testing of furniture, cotton fabrics have been shown to perform poorly without a fire blocker layer, but they performed well when a fire blocker was used under the upholstery. These cotton fabrics probably did not have any FR treatment.[30] It is not known if it is necessary to include a fire blocker layer if flame retardant treated cotton upholstery is used. This may be dependent on fabric construction as well as furniture construction.

In the UK, the fire properties of household furniture are controlled by government regulation, with the intent to ensure all furniture is cigarette and match resistant and that the only foams allowed are combustion modified. Separate requirements are set for covers and fillings. US products exported to the UK have to meet these standards. Reactive phosphorous FR-treatments of upholstery fabric, back coatings and barriers are used to meet the match resistance requirement.

Carpets

Research into carpets has been ongoing at Cotton Incorporated for many years. The flammability test (16 CFR 1630, Standard for the Surface Flammability of Carpets and Rugs), which is required for residential carpeting, is referred to as the "pill test". In this test a methenamine pill is put on the carpet sample, ignited, and the pass/fail criterion is based on the spread of the flame. It has been found that high density cotton carpets generally do not require a flame retardant treatment to pass the test, whereas low density cotton carpets do. However, there are many factors such as construction, which have an influence.[31,32] Research has demonstrated that very low levels (less than 1% on the weight of the fiber) of reactive phosphorus based flame retardants can be applied directly by spray in conjunction with fluorochemicals near the end of the carpet manufacturing process. A formulation containing five percent fluorocarbon, five percent catalyst, and five percent reactive phosphorus based flame retardant is sprayed or foamed on the carpet at about a 15% add-on based on the dry weight of the fiber. The solution may be sprayed on dry or wet carpet. The carpet is dried at appropriate temperatures.

Table II: US Flame-Retardants Market.

Bromine-based	32%
Chlorine-based	17%
Phosphorus-based	17%
Antimony oxide	20%
Alumina trihydrate	11%
Other (includes, magnesium hydroxide and boron-, molybdenum- and nitrogen-based)	3%

1995 demand = $718 million
2000 (est.) demand= $925 million

Source: Chemical and Engineering News, Feb. 24, 1997, 19-20 and Business Communications Co.

Cotton Based Home Insulation

Cotton batting has made in-roads in the building insulation market in recent years. Cotton-content by-products, such as gin motes, textile card waste, or apparel manufacturers cutting waste are available and can be used. Specialized equipment is required to apply the flame retardant chemicals (which are proprietary) to the cotton batting properly. CPSC has regulations (16 CFR 1209 and 1404) for cellulose insulation.

Research Needs

There is a market need for suppliers of FR cotton fiber and cotton yarn. These materials could be used in products such as fleece and other niche areas, including other fabrics with raised surfaces, and possibly upholstery. The issue is more one of the complexity and expense of the flame retardant treatment process rather than technical feasibility. The durable flame retardants mentioned above can be applied to fiber or yarn but the process and equipment details and associated costs need to be determined/developed. The same processing systems that work well to produce quality flame retardant cotton fabrics can also work for fiber or yarn but the equipment needs are obviously different. This potentially could be a significant business for someone willing to invest in the applied research to work out the details.

Some specific research needs[33] include:

1–cheaper, durable chemicals, which impart both flame resistance and wrinkle resistance, without causing appreciable strength loss or reduced abrasion resistance
2–treatments that result in low smoke and toxic gas emissions
3–methods to fix THP type FR agents
4–environmentally-friendly (e.g., formaldehyde-free) finishes that can be applied simply as a low add-on without affecting aesthetic properties of the fabric
5–improved ecotoxicology (replacement of brominated FR compounds and antimony compounds, since brominated FR agents potentially can form dioxins and furans and antimony compounds have incorrectly been linked with sudden infant death syndrome)
6–evaluate intumescent coating systems
7–coatings/back coatings
8–FR barriers
9–cotton stock (fiber) treatments

Conclusions

The biggest change in flame resistance of cotton in the last 20 years is improved application systems. The basic chemistry and agents are essentially the same, e.g., precondensate and reactive phosphorous compounds for durable treatments. The conditions for application of precondensate/ammonia have been optimized and the ammonia-tor reactor has been improved. Systems for applying the reactive phosphorous compounds have also been improved and adapted for surface treatments. Systems for boric acid treatment of cotton batting have been improved so that batting with more even application of the chemical and with no dusting out can be obtained. It is expected that there will be continued improvement in application systems.[7]

In closing it should be remembered that most all textile products burn and that it is necessary to be careful around ignition sources. Public education is important for preventing textile related fires.

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July 16, 1998

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Subject: Flame Retardant Chemicals That May Be Suitable For Use In Upholstered Furniture, 63 Fed. Reg. 13017 (March 17, 1998)

The Society of the Plastics Industry, Inc. (SPI) is pleased to provide comments on the referenced Commission proceeding on behalf of its Polyurethane Division. SPI is a trade association of more than 2,000 members representing all segments of the plastics industry in the United States. SPI's business units and committees are composed of plastics processors, raw material suppliers, machinery manufacturers, moldmakers and other industry-related groups and individuals. Founded in 1937, SPI serves as the "voice" of the plastics industry. SPI's Polyurethane Division is comprised of chemical producers, systems formulators, and manufacturers of machinery and auxiliary equipment used in the polyurethane industry.

Summary of SPI Comments

SPI's purpose in these brief comments is to provide a perspective on the upholstered furniture flammability issue. SPI does not have expertise regarding flame retardant toxicity. However, we do have a long-standing history of supporting fire testing and fire safety. SPI has long been a leader in supporting appropriate tests, application recommendations, and detection and suppression devices to reduce the risk of injury or death due to fire. In the important area of flame-retardants, SPI emphasizes that it is the Commission's responsibility to ensure that any eventual proposal adheres to sound risk assessment principles. SPI believes that the touchstone of any fire test or requirement, including those mandated by CPSC, is to demonstrate that it has a real relationship to an identified risk relative to a particular product involved.

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Flammability is a Composite, Not a Component, Issue

The current focus is on the application of flame retardant chemicals to specific components of upholstered furniture – primarily upholstery fabrics. The CPSC protocol includes component tests of fabrics used in skirts and dust covers as well as a composite seating mockup. SPI has a long-standing position of supporting composite, small scale testing that can be correlated with full-scale results. It is well documented that the fire performance of individual components does not necessarily predict performance when combined.

For several decades, SPI has consistently maintained that any meaningful standard applicable to upholstered furniture, whether voluntary or mandatory, must be based on the performance of the finished product and not the performance of the individual components that make up the finished product.

Standards Must Reduce Real World Risks

CPSC's request for comments focuses on the ability of upholstered furniture to resist ignition from a small open flame source, such as a match or a cigarette lighter. SPI has previously expressed concern about whether the fire incidents identified by the Commission are adequately defined and linked to the small open flame ignition test proposed. SPI continues to believe that this is a pivotal issue.

It is important to establish that application of flame retardant chemicals to fabric will address meaningful risk without creating new risks or compromising physical or cigarette smoldering performance. It is also important to confirm that the scenarios involved in the formation of test requirements (e.g., the behavioral patterns associated with children playing with cigarettes, matches, lighters, and other sources of ignition) remain relevant.

As required for any major rulemaking, CPSC must perform a cost benefit analysis, which demonstrates that the benefit to be achieved will outweigh the cost of compliance. Given the decline in smoking, and thus the related use and availability of cigarette ignition materials and with the recent adoption of the cigarette lighter standard, we question the appropriateness of CPSC in inclusion of reduction of cigarette-related fire deaths in its cost benefit analysis, which establishes a need for an open flame ignition standard.

SPI would suggest that at this juncture, a well-defined informational and educational campaign may be the most cost effective means to communicate the dangers presented by unsafe use of sources of small open flames by children.

Any standard, which does not result in a reduction of an established risk, does not contribute to a positive resolution of this issue.

Respectfully Submitted,

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