(2) Cigarette Tests

Twenty-three of the 27 UK chairs did not ignite when evaluated with lit cigarettes. Four chairs, chairs numbered 3, 12, 25, and 26, had one or more cigarettes igniting. Two of the chairs with ignitions, chairs numbered 12 and 25, were covered with 100% cellulosic upholstery fabrics. Chair number 3 was covered with two upholstery fabrics; both the upholstery fabrics on the back and seat cushions were 100% cellulosic. The upholstery fabric covering the side of the chair was a cellulosic/thermoplastic blend, a 50/50 blend of cotton and polyester fibers as reported by the source[4] that provided the chair to CPSC staff. The label on UK chair number 26 indicated that the fabric was a cellulosic/thermoplastic blend with a high, (82%), cotton content.

The side/seat crevice test location had the greatest number of cigarette ignitions, seven total, with three of the four chairs with ignitions igniting in that test location. The welt edge was the other test location where cigarette ignitions occurred in two of the four chairs igniting from cigarettes. Eleven other chairs with welt cords present did not ignite from lit cigarettes.

Chair number 3 had three ignitions along the welt cord edge at the side/seat crevice location, and three ignitions along the welt cord at the front welt edge location. Chair number 12 also had three ignitions along the front welt edge. Chair number 25 had three ignitions in the side/seat crevice test location and chair number 26 had one ignition in the same test location.

Two of the four chairs had polyester fiberfill in the seat cushion and either polyester fiberfill or polyurethane foam in the side as the filling materials directly under the upholstery fabric in the side/seat crevice test location. The other two chairs had feathers in the seat cushion and a non-woven nylon fiber pad in the side as the filling materials directly under the upholstery fabric.

The two welt cords involved in the cigarette ignitions in chairs numbered 3 and 12 consisted of a twisted paper core encased in thermoplastic yarns. Borate was detected in the two paper welts. Borate was also detected in some of the other welt cords that did not ignite from lit cigarettes. Table 5 presents the results of the full-scale cigarette ignition tests.

TABLE 5

Full-Scale Cigarette Ignition Test Results

Chair No.	Fiber Content	Fabric Wt. (oz/yd^2)	Cigarette Ignition Results (per no. of cigarettes)	Locations of Ignition (per no. of cigarettes)	Welt Cord Present
UK 1	cotton	12.5	none of 7 cigarettes ignited	---	no
UK 2	rayon/polyester	10.8	none of 11 cigarettes ignited	---	yes
UK 3	linen/cotton polyester/cotton	9.8 9.8	6 of 10 cigarettes ignited	side/seat crevice-3 welt edge - 3	yes
UK 4	polyester/cotton	10.7	none of 10 cigarettes ignited	---	yes
UK 5	polyester/cotton	10.5	none of 10 cigarettes ignited	---	yes
UK 6	cotton	6.7	none of 11 cigarettes ignited	---	yes
UK 7	rayon/polyester	16.3	none of 7 cigarettes ignited	---	no
UK 8	polyester	16.7	none of 7 cigarettes ignited	---	no
UK 9	cotton/polyester/ nylon	7.3	none of 7 cigarettes ignited	---	no
UK 10	cotton/polyester/ nylon	8.2	none of 7 cigarettes ignited	---	no
UK 11	polyester/cotton/ nylon	12.7	none of 9 cigarettes ignited	---	yes
UK 12	cotton cotton	9.5 7.7	3 of 10 cigarettes ignited	welt edge - 3	yes
UK 13	polyester/acrylic	11.3	none of 7 cigarettes ignited	---	no
UK 14	polyester/cotton/ rayon/acrylic	16.7	none of 8 cigarettes ignited	---	yes
UK 15	cotton/polyester/ nylon	10.0	none of 7 cigarettes ignited	---	no
UK 16	cotton/polyester	14.0	none of 7 cigarettes ignited	---	no
UK 17	cotton/polyester	12.5	none of 11 cigarettes ignited	---	no
UK 18	rayon/polyester/ acrylic	17.3	none of 10 cigarettes ignited	---	no
UK 19	polyester/nylon	12.5	none of 10 cigarettes ignited	---	yes
UK 20	polyester/cotton	12.0	none of 7 cigarettes ignited	---	no
UK 21	polyester/cotton	12.0	none of 10 cigarettes ignited	---	yes
UK 22	polyester/acrylic	12.5	none of 7 cigarettes ignited	---	no
UK 23	cotton/acrylic	13.3	none of 11 cigarettes ignited	---	yes
UK 24	cotton/linen/ nylon	9.5	none of 9 cigarettes ignited	---	yes
UK 25	cotton	12.5	3 of 10 cigarettes ignited	side/seat crevice-3	yes
UK 26	cotton/nylon	11.2	1 of 10 cigarettes ignited	side/seat crevice-3	yes
UK 27	cotton	7.0	none of 10 cigarettes ignited	---	yes

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b. Mockup Tests

(1) Small Open Flame

(a) Dust Cover Tests

Only three dust cover mockups were constructed for the first 15 UK chairs, as the dust cover fabric was the same on all 15 chairs. Test results from the three specimens tested represented UK chairs numbered 1 to 15. No ignitions occurred on the three dust cover specimens tested.

For the remaining 12 UK chairs only seven mockups could be constructed due to the amounts of fabric remaining after the full-scale testing. Of these seven mockups tested, an ignition occurred only with the dust cover from UK chair number 22. Table 6 presents this test data for those ten dust cover mockups tested.

TABLE 6

Dust Cover Mockup Test Results

Chair Number	Fiber Content	Dust Cover Mockup Results
UK 1	polypropylene	no ignition
UK 10	polypropylene	no ignition
UK 13	polypropylene	no ignition
UK 16	jute	no ignition
UK 17	olefin	no ignition
UK 18	olefin	no ignition
UK 19	polypropylene	no ignition
UK 21	olefin	no ignition
UK 22	olefin	ignited
UK 23	polyester/cotton	no ignition

(b) Mockup Tests With Standard Foam

All of the upholstery fabrics found on the 27 UK chairs were tested on a mockup with the standard foam. UK chairs numbered 3 and 12 were covered with two different upholstery fabrics. A total of 29 mockups were constructed and tested with the small open flame applied by the *Furniture Flammability Fixture.*

Seven of the mockups ignited when the flame was applied for 20 seconds. Four of these mockups representing UK chairs numbered 1, 3a, 10 and 13 had ignitions at all three flame applications. Three of the mockups representing UK chairs numbered 3b, 8, and 19 had ignitions at one flame application location. Table 7 presents the results of the mockup tests.

(c) Mockup Tests With UK Foam

A total of 22 mockups were constructed using upholstery fabrics either, (1) purchased separately, (2) taken from the actual chair or (3) acquired fabric from the same lot as used on the actual chair, and foam with a density meeting the specifications in *the Furniture and Furnishings (Fire) (Safety) Regulations 1988.*

Five of the 22 mockups ignited during testing. Mockups representing UK chairs numbered 1 and 3a ignited at all three-flame applications. The mockups representing UK chairs numbered 19 and 22 ignited at two flame applications and the mockup representing UK chair number 13 ignited at one flame location. The other 17 mockups did not ignite. Table 7 presents the results of this testing.

(2) Cigarette Tests

Thirteen mockups were constructed with upholstery fabric and standard polyurethane foam and tested using lit cigarettes as the ignition source. Eight of the 13 mockups ignited. All three cigarettes ignited on six of the 13 mockups, those representing UK chairs numbered 3, 5, 6, 10, 25, and 26. Two of the three cigarettes ignited on the mockups representing UK chairs numbered 1 and 27. The other five mockups had no ignitions from lit cigarettes. Table 7 presents the results of the cigarette mockup tests.

TABLE 7

Mockup Test Results

Chair Number	Small Open Flame Test Results			Cigarette Mockup Results
	Mockup Standard Foam	Mockup UK Foam	Source of Fabric for UK Foam Test	Mockup Standard Foam
UK 1	3 ignitions	3 ignitions	purchased separately	2 ignitions
UK 2	no ignitions	no ignitions	purchased separately	no ignitions
UK 3	3 ignitions (fabric a) 1 ignition (fabric b)	3 ignitions (fabric a) ---	purchased separately ---	3 ignitions (fabric a)
UK 4	no ignitions	no ignitions	purchased separately	no ignitions
UK 5	no ignitions	no ignitions	purchased separately	3 ignitions
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
UK 7	no ignitions	---	---	---
UK 8	1 ignition	---	---	---
UK 9	no ignitions	no ignitions	purchased separately	---
UK 10	3 ignitions	no ignitions	purchased separately	3 ignitions
UK 11	no ignitions	---	---	no ignitions
UK 12	no ignition (fabric a) no ignition (fabric b)	--- no ignition (fabric b)	--- purchased separately	---
UK 13	3 ignitions	1 ignition	purchased separately	---
UK 14	no ignitions	no ignitions	purchased separately	---
UK 15	no ignitions	no ignitions	purchased separately	---
UK 16	no ignitions	---	---	---
UK 17	no ignitions	no ignitions	taken from chair	---
UK 18	no ignitions	no ignitions	taken from chair	---
UK 19	1 ignition	2 ignitions	---	---
UK 20	no ignitions	---	taken from chair	---
UK 21	no ignitions	no ignitions	taken from chair	no ignitions
UK 22	no ignitions	2 ignitions	taken from chair	---
UK 23	no ignitions	no ignitions	taken from chair	---
UK 24	no ignitions	no ignitions	fabric from chair lot	no ignitions
UK 25	no ignitions	no ignitions	fabric from chair lot	3 ignitions
UK 26	no ignitions	no ignitions	fabric from chair lot	3 ignitions
UK 27	no ignitions	no ignitions	fabric from chair lot	2 ignitions

8. DISCUSSION

a. Small Open Flame

(1) Seating Area Tests

Statistical analysis[7] shows that the seating area test results were consistent across the 27 chairs for each of the small open flame tests. This indicates that these small open flame tests were conducted consistently by LS staff. Twenty-two of the 27 UK chairs or 81% had corresponding results in both full-scale and mockup tests. Sixteen of the 22 correlated chairs did not ignited in both full-scale and mockup tests. Six of the 22 chairs had one or more ignitions in both the full-scale and mockup tests.

However, the seating area results of the small open flame full-scale chair tests and the mockup tests were not always identical. Six of the 27 chairs or 22% ignited in the full-scale tests and did not ignite in one or both of the mockup tests, (standard foam and UK foam). The reasons for these differences may include the limited number of tests performed and/or that the fabrics on these chairs are borderline, meaning that they sometimes pass and sometimes fail, non uniform fabric/filling material contact, or amount of FR chemicals present in the fabric backcoating. In one case, UK chair number 10 was covered with upholstery fabric that did not contain flame retardant chemicals in the backcoating while the extra fabric purchased separately for use with the UK foam contained flame retardant chemicals in the backcoating. Another possible influence on the full scale results is the presence of polyester fiberfill directly below the upholstery fabric that is not present in the mockup constructions.

(2) Dust Cover Tests

A comparison of dust cover results for 22 of the 27 chairs could be made. In five of the 27 chairs much of the dust cover fabric itself was consumed during the full-scale test and mockup tests could not be conducted. Fifty-five percent (12) of the 22 chairs had similar full-scale and mockup results. Eleven chairs had dust cover fabrics that did not ignite in either full-scale or mockup tests. One chair ignited in both full-scale and mockup dust cover tests. Forty-five percent (10) of the 22 chairs tested in both full-scale and mockup tests ignited in full-scale but not in the mockup tests.

In general, this mockup test may not represent the dust cover area of the chair as the mockup test procedure applies the flame to the middle of a 12-inch square test specimen of dust cover fabric. While the *Draft Standard for Upholstered Furniture*, states that interior materials that are within one inch of the dust cover should also be tested if the dust cover melts or splits, this may not be practical with some materials found close to the dust cover contributing to the ignition, such as strings, straps or interior fabrics stapled directly to the wood frame. In addition, the wood frame itself is capable of sustaining the ignitions.

b. Cigarette Tests

There was only enough fabric to construct mockups representing 13 of the 27 chairs. Test results for ten (77%) of the 13 mockups were similar to the comparable full-scale tests. Three full-scale/mockup combinations did not have comparable results. UK chairs numbered 1, 6 and 27 did not ignite in full scale but did in the mockup tests. The upholstery fabrics on these chairs were 100% cellulosic.

These cigarette test results and comparisons between full-scale and mockups should be interpreted cautiously as the cigarette mockup test was developed by LS staff as a screening test. The resistance of upholstered furniture to smoldering ignition is dependent on the interaction between the lit cigarette and both the fabric and filling material directly beneath the fabric. In the bench scale tests, the mockups were tested with standard non-flame resistant polyurethane foam. According to the literature,[8] polyester fiberfill ranks higher than non-flame resistant polyurethane foam for cigarette ignition resistance and cellulosic fabrics in general are less resistant to smoldering ignition from lit cigarettes.

9. CONCLUSIONS

a. Seating Area

The relationship between the draft test protocol and the flammability performance of full-scale upholstered chairs is correlated as follows:

- Eighty-one percent (22) of the 27 UK chairs had corresponding results in both full-scale and Draft Standard mockup seating area tests.

- Fifty-nine percent (16) of the 27 UK chairs did not ignite when tested to both the seating area full-scale and Draft Standard mockup protocols.

- Eighty-seven percent (14) of the 16 UK chairs resisting ignition in both seating area tests, also resisted ignition from cigarettes.

For many upholstery fabrics, predictions of likely flammability performance on upholstered chairs can be made using the test procedure in the draft test protocol. However, there are other factors besides the presence of FR upholstery fabrics that may influence the likelihood of ignition for some furniture and or upholstery fabrics. These other factors may include, number of flame applications, amount of FR chemicals present in the backcoating, or the type of filling material directly underneath the upholstery fabric. Additional studies were conducted in the summer of 2000 to further characterize these influencing factors. The results of this work are found in Cobb and Tao, *Evaluation of UK Chair Test Data*, October 2000.

b. Dust Cover

In the 22 UK chairs tested in both full-scale and to the mockup protocol in the *Draft Standard for Upholstered Furniture*, 41% (9) did not ignite in the dust cover test location. This difference in corresponding results is likely due to the draft test protocol's limited representation of dust cover constructions found in the actual chairs.

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: October 23, 2001

TO : Dale Ray, Project Manager, Upholstered Furniture
Directorate for Economic Analysis

THROUGH: Andrew G. Stadnik, Associate Executive Director for Laboratory Sciences

FROM : Linda Fansler, Division of Electrical Engineering

SUBJECT : Alternate Barrier Tests

INTRODUCTION

This memorandum contains a summary of testing done by the U.S. Consumer Product Safety Commission's (CPSC) laboratory to support the development of an alternate test procedure to the small open flame seating area test in the draft upholstered furniture standard.[1] The alternate test procedure uses a small wooden crib as the ignition source and is based on a similar test in a British Standard.[2] Barrier fabrics and materials were also evaluated with small open flame and cigarette ignition sources. Twelve barrier fabrics/materials were evaluated during the test program.

BACKGROUND

In 1997, CPSC staff published an advance notice of proposed rulemaking containing a draft flammability performance standard for upholstered furniture. The draft *Standard for Upholstered Furniture*[1] evaluates the ability of upholstery fabric and materials to resist ignition when subjected to a small open flame source. The performance requirement calls for the cessation of combustion and limited flame progression on the test specimen following a 20-second flame exposure.

In the recently revised draft *Standard for Upholstered Furniture,*[3] CPSC staff is considering including an alternate test method that allows for limited fire growth when a fire resistant barrier fabric or material is used in furniture assemblies. The test method, called the Alternate Barrier Test, would be conducted in lieu of the small open flame test. The proposed Alternate Barrier Test is based on a similar test found in the British Standard BS 5852, *Methods of Test For Assessment of Upholstered Seating by Smouldering and Flaming Ignition Sources.*[2] A wooden crib is used as the ignition source and although the test specimen is allowed to ignite, any flaming present must cease within ten minutes. At one hour into the test, smoke and glowing embers must not be present.

[1] Draft Standard For Upholstered Furniture, R. Khanna, Engineering Sciences, October 1997, CPSC.
[2] BS 5852:1990, Methods of Test for Assessment of the Ignitability of Upholstered Seating by Smouldering and Flaming Ignition Sources, British Standards Institution, London.
[3] Draft Standard For Upholstered Furniture, R. Khanna, Engineering Sciences, **revised** February 19, 2001.

The purpose of a fire resistant barrier is to prevent filling materials from becoming involved in an ignition. The barrier, also known as an interliner is placed between the upholstery fabric and filling materials and is either a separate layer or laminated directly onto the back of the upholstery fabric. In most cases a barrier does not prevent the upholstery fabric from becoming involved in the ignition.

Although CPSC staff has conducted flammability tests[4] on full-scale furniture and mockups with fire resistant barriers, this was very limited testing and the barriers were only subjected to the small open flame test and criteria in the published draft *Standard for Upholstered Furniture.*[1] This memorandum outlines CPSC staff expansion of this limited testing to support the inclusion of an Alternate Barrier Test in the draft furniture standard.

EXPLORATORY TESTS

A limited number of exploratory tests were first conducted to gain a better understanding of the fire behavior of the wooden crib ignition source. These exploratory tests were conducted with a combination of two barrier fabrics and six upholstery fabrics.

The two barriers used in the exploratory tests were a woven cotton fabric treated with flame resistant chemicals to resist ignition and an aramid nonwoven fabric that is inherently resistant to flame. These two barrier fabrics were combined with up to six cover fabrics, including three flame resistant (FR), fabrics and three non-FR fabrics. Two ignition sources were used, the small open flame and a wooden crib.[5]

The small butane flame ignition source was used to establish a baseline for the cover and barrier fabric combinations. Some of the small flame tests were stopped at 2 minutes (the flaming condition criteria found in the draft furniture standard), while other exploratory small flame tests continued beyond 2 minutes. This extended observation time allowed CPSC laboratory staff to gain insight into the severity of flaming, smoke production and total combustion time produced by a fully involved burning mockup.

The exploratory tests using the crib as the ignition source established the wood crib as a more severe ignition source when compared to the small butane flame. In addition, CPSC laboratory staff observed that the wood crib simulated the additional flaming and smoldering present when the cover fabric was involved in the ignition.

As a result of the exploratory tests with a variety of cover fabrics, the staff decided to evaluate barriers with the wooden crib ignition source using a standard FR polyester cover fabric specified in the British Regulations.[6] The FR polyester was chosen to investigate any differences provided by a standardized cover fabric.

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[4]Test results documented in 1997 Upholstered Furniture Briefing Package and Technical Report: Summary of Flammability Tests Upholstered Furniture Project (1998-2000), L. Fansler, October 2000, CPSC.
[5] These wooden cribs were constructed of bass wood and hobby glue by CPSC laboratory staff following the dimensional specifications in BS 5852.
[6] The Furniture and Furnishings (Fire) (Safety) Regulations 1988, Department of Trade and Industry, United Kingdom.

Overall, the results of the exploratory tests indicated that fire resistant barrier fabrics can provide protection to the foam underneath but not all barrier/cover fabric combinations may be effective.

TEST PROGRAM

Building on the exploratory testing, CPSC laboratory staff developed a plan to evaluate barrier fabrics and materials to support the inclusion of an Alternate Barrier Test in the draft *Standard for Upholstered Furniture*. The plan identified three ignition sources to use in evaluating the alternate test being developed; the number 5 wooden crib specified in BS 5852, the small butane flame specified in the draft *Upholstered Furniture Standard*, and the Pall Mall cigarette specified in the Mattress Standard.[7]

In addition to the standard FR polyester cover fabric, seven upholstery fabrics were included in the small open flame and cigarette portion of the test program. The cover fabrics used in this study were:

1. 100% inherently FR polyester, plain weave, 6.5 oz/yd^2 (British Regulation standard FR cover fabric),
2. 56% rayon, 34% polyester, 10% cotton, jacquard weave, 10 oz/yd^2,
3. 100% cotton, twill weave, 11.5 oz/yd^2,
4. 60% acetate, 40% cotton, plain weave taffeta, 3.5 oz/yd^2,
5. 100% cotton, plain weave, 6.5 oz/yd^2,
6. 100% silk, plain weave, 3.7 oz/yd^2,
7. 100% cotton pile weave corduroy, 9.0 oz/yd^2, and
8. 57% acrylic, 31% polyester, 12% olefin, plain weave, chenille yarns, 8.0 oz/yd^2.

A variety of fire resistant barrier fabrics and materials were also included in the testing. Three of the barrier fabrics, all 100% cotton, were purchased from sources in the United Kingdom (UK), where barrier fabrics are commonly used in residential furniture. The other nine barriers were obtained through sources in the United States. The barrier fabrics and materials used in this study were:

A. 100% cotton, woven, 6.5 oz/yd^2
B. 100% cotton, woven, 6.0 oz/yd^2
C. 100% cotton, woven, 7.0 oz/yd^2
D. 100% aramid, 1.5 oz/yd^2
E. 100% aramid, 3.0 oz/yd^2
F. melamine/aramid blend, 1.5 oz/yd^2
G. melamine/aramid blend, 3.0 oz/yd^2
H. 100% novoloid, 2.4 oz/yd^2
I. 100% novoloid, 3.7 oz/yd^2
J. 100% novoloid, 5.6 oz/yd^2
K. melamine/modacrylic/polyester blend, 4.0 oz/yd^2
L. melamine /modacrylic/polyester blend, 14.0 oz/yd^2

The selection of cover fabrics and barriers were randomized during these tests. In addition, the run sequences among the various cover fabric/barrier combinations were also randomized.

[7] 16 CFR Part 1632 Standard For The Flammability of Mattresses And Mattress Pads.

The cotton barrier fabrics from the UK were reported to contain a chemical treatment to make them resistant to fire. Some soaking experiments were also done to determine the extent to which the chemical treatments were bound to the fabrics when the fabrics were exposed to either a 30-minute or a 24-hour water soak.

SUMMARY AND DISCUSSION OF RESULTS

A. Wooden Crib Tests

Barrier A

Barrier A is a 100% cotton plain weave fabric weighing 6.5 oz/yd^2. This barrier fabric was obtain through a source in the UK and was reported to be chemically treated to resist flaming ignition. At the time of purchase CPSC staff was informed that this cotton barrier fabric met the criteria of the schedule 3, crib number 5 test as specified in the British Regulations.[5] A schedule 3, crib number 5 barrier fabric should provide protection to the filling material beneath. As Table 1 shows, this did not happen for several replicate test runs; all of the mockups covered with Barrier A ignited. Approximately 2 minutes into the test the barrier split exposing the foam to the flames. The mockups were manually extinguished using a pressurized carbon dioxide tank. The mockups constructed with the standard FR polyester cover fabric performed the same as those mockups without the cover fabric.

A chemical analysis[8] was done to determine why Barrier A did not perform as expected; (i.e. did not provide protection to the filling material). Based on the CPSC laboratory staff's analysis, it appears that Barrier A was not treated with flame retardant chemicals.

TABLE 1
Wooden Crib Test Results – Barrier A

Barrier A	Results	Results after Soaking (24 hours)
without the standard FR polyester cover fabric	ignited, foam involved, manually extinguished **(5 replicates)**	ignited, foam involved, manually extinguished **(1 replicate)**
with the standard FR polyester cover fabric	ignited, foam involved, manually extinguished **(3 replicates)**	not tested

Barriers B and C

Barriers B and C were both obtained from a second UK source. At the time of purchase, CPSC staff requested barrier fabrics meeting the criteria of the schedule 3, crib number 5 test as specified in the British regulations.[5] The results (Table 2) show that Barrier B (6.0 oz/yd^2) performed similar to Barrier A. All the mockups constructed with Barrier B ignited. The foam became involved and had to be manually extinguished.

[8] Memorandum to L. Fansler, LSE from D. Cobb, LSC, "Chemical Analysis of Barrier Fabrics," October 2001, CPSC.

The results of wooden crib tests with Barrier C were basically the same with two exceptions. One mockup each with and without the standard FR polyester cover fabric ignited and self-extinguished. In addition, limited tests with both Barriers B and C barrier fabrics soaked for either 24 hours or 30 minutes resulted in sustained ignitions.

Chemical analysis[9] determined that these two barrier fabrics may have been chemically treated but the treatment was essentially water extractable and may not have been applied correctly to bind to the fabric.

TABLE 2
Wooden Crib Test Results – Barriers B and C

Condition	RESULTS		Results after Soaking*	
	Barrier B	Barrier C	Barrier B	Barrier C
without the standard FR polyester cover fabric	ignited, foam involved, manually extinguished **(5 replicates)**	**4 reps** ignited foam involved, manually extinguished **1 rep** ignited, foam melted, self-exting.	ignited, foam involved, manually extinguished (both 24 & ½ hour soaks)	ignited, foam involved, manually extinguished (both 24 & ½ hour soaks)
with the standard FR polyester cover fabric	ignited, foam involved, manually extinguished **(3 replicates)**	**2 reps** ignited, foam involved, manually extinguished **1 rep** ignited, foam melted, self-exting.	not tested	not tested

*** Soaking = 1 rep each for 30 minutes and 1 rep each for 24 hours**

Barriers D and E
Barriers D and E are 100% aramid, nonwoven fabrics weighing approximately 1.5 and 3.0 oz/yd^2 respectively. Barrier D, the lighter weight aramid barrier, was only used in exploratory tests. In the limited exploratory tests, Barrier D did not perform consistently so a decision was made to use just the 3.0-oz aramid, Barrier E, in the alternate barrier test program.

Aramid fibers are generally fire resistant. Of the six mockups covered with Barrier E, five ignited and self-extinguished. The sixth mockup ignited and the foam became involved so the mockup was manually extinguished. Table 3 presents the results of this testing.

TABLE 3
Wooden Crib Test Results – Barrier E

Barrier E	Results
without the standard FR polyester	**2 reps** ignited, foam melted, self-extinguished
with the standard FR polyester cover fabric	ignited, foam melted, self-extinguished **(3 replicates)**

Barriers F and G

Barriers F and G from the same U.S. manufacturer are melamine and aramid blend nonwoven fabrics. Barrier F weighs approximately 1.5 oz/yd^2 while Barrier G weighs approximately 3.0 oz/yd^2. Barrier G performed consistently; igniting and self-extinguishing when tested with and without the FR polyester cover fabric. Barrier F ignited and self-extinguished without the FR polyester cover fabric but two mockups with the FR polyester cover fabric had sustained ignitions. Table 4 presents the results of this testing.

TABLE 4
Wooden Crib Test Results – Barriers F and G

Condition	RESULTS	
	Barrier F	**Barrier G**
without the standard FR polyester cover fabric	ignited, foam melted, self-extinguished **(3 replicates)**	ignited foam melted, self-extinguished **(3 replicates)**
with the standard FR polyester cover fabric	**2 replicates** ignited, foam involved, manually extinguished **1 replicate** ignited, foam melted, self-extinguished	ignited, foam melted, self-extinguished **(3 replicates)**

Barriers H, I and J

Barriers H, I and J were obtained from the same source and are novoloid nonwovens of differing weights. The three barrier fabrics weighed approximately:

- Barrier H – 2.4 oz/yd^2
- Barrier I – 3.7 oz/yd^2
- Barrier J – 5.6 oz/yd^2

Only preliminary tests on the novoloid barrier fabrics have been completed. These tests include only one replicate each without the standard FR polyester cover fabric. The two lighter weight fabrics, Barriers H and I, ignited and self-extinguished. Barrier J ignited and the foam became involved. At the time of these tests in early June 2001, additional yardage of Barrier H, I and J were not available. A recent conversation with the US supplier revealed that the German manufacturer of the novoloid barrier fabrics is again supplying their customers. CPSC staff has received additional yardage of Barrier I and plans to begin testing later in October 2001.

Barrier K

Barrier K is a melamine/modacrylic/polyester blend batt. This barrier material performed well in the crib ignition tests. Table 5 presents the results of this testing. Although Barrier K ignited, this barrier consistently self-extinguished within 3 to 10 minutes of testing.

TABLE 5
Wooden Crib Test Results – Barrier K

Barrier K	Results
without the standard FR polyester cover fabric	ignited, foam melted, self-extinguished **(3 replicates)**
with the standard FR polyester cover fabric	ignited, foam melted, self-extinguished **(3 replicates)**

Barrier L

Barrier L is a melamine/modacrylic/polyester blend fiber batt. All six mockup tests (Table 6) with and without the standard FR polyester cover fabric, ignited and self-extinguished.

TABLE 6
Wooden Crib Test Results – Barrier L

Barrier L	Results
without the standard FR polyester cover fabric	ignited, foam melted, self-extinguished **(3 replicates)**
with the standard FR polyester cover fabric	ignited, foam melted, self-extinguished **(3 replicates)**

Summary of all Crib Test Results

Overall, seven of the 11 barriers tested without the standard FR polyester cover fabric passed the tests using a wooden crib ignition source. For purposes of this testing, a pass is when there are no ignitions in the three mockups tested. One barrier, the 3-oz aramid was variable, passing in two of the three mockups tested. All three cotton barriers had ignitions.

Of the eight barriers tested with the standard FR polyester cover fabric four passed and two failed when two of the three mockups tested had sustained ignitions. Two other barriers failed with obvious ignitions to the mockups. Table 7 has a summary of these results.

The results with and without the standard FR polyester cover fabric are consistent except for Barriers C, E, and F. Barrier C failed the majority of the time and Barrier E passed the majority of the time. Barrier F, the lighter weight melamine/aramid nonwoven blend, passed without the standard FR cover fabric, but failed in 2 of 3 mockup tests with the standard FR polyester cover fabric.

TABLE 7
Summary of Crib Test Results

Barriers	Test Results	
	Without FR polyester cover fabric	**With FR polyester cover fabric**
A 100% cotton (FR treated?)	failed: obvious ignition	failed: obvious ignition
B 100% cotton (FR treated)	failed: obvious ignition	failed: obvious ignition
C 100% cotton (FR treated)	failed: obvious ignition **(4 of 5 tests)**	failed: obvious ignition **(2 of 3 tests)**
E 100% aramid	variable: **(2 of 3 tests)**	passed
F melamine/aramid blend	passed*	failed: **(2 of 3 tests)**
G melamine/aramid blend	passed	passed
H 100% novoloid	passed: **(1 test)**	NT
I 100% novoloid	passed: **(1 test)**	NT
J 100% novoloid	passed: **(1 test)**	NT
K melamine/modacrylic/ polyester blend	passed	passed
L melamine/modacrylic/ polyester blend	passed	passed

* For this testing a pass means no ignitions for the three mockups tested. NT = not tested

B. Small Open Flame Tests

A small butane flame was used as the second ignition source in this testing. For this testing, mockups were constructed with

1. the barrier fabrics and up to eight upholstery fabrics,
2. the barrier fabrics alone, and
3. to establish a baseline, the upholstery cover fabrics alone.

Table 8 presents the results of the cover fabric tests. Six, of the eight cover fabrics ignited and the foam became involved. Two fabrics resisted ignition.

TABLE 8
Small Open Flame Test Results – Eight Cover Fabrics

COVER FABRIC	TEST RESULTS (3 replicates)
std. FR polyester	ignited, foam melted, self-extinguished
cellulosic/thermoplastic blend	ignited, foam involved, manually extinguished
cotton twill	ignited, foam involved, manually extinguished
cotton corduroy	ignited, foam involved, manually extinguished
silk	smoke only, self-extinguished
acrylic/olefin/nylon blend*	ignited, foam involved, manually extinguished **(2 reps.)**
acetate/cotton taffeta	ignited, foam involved, manually extinguished
cotton print	ignited, foam involved, manually extinguished

*Mockups constructed with the acrylic blend cover fabric had flaming drips and flaming to the edge of mockup.

Barrier A

Barrier A was tested by itself and with the eight cover fabrics. Table 9 presents the results of this testing. Barrier A prevented the foam from becoming involved in the majority of the tests, (21 of 27 tests). In the six tests where ignitions occurred, the flames on the cover fabric were large and intense enough to sustain the ignition until the foam ignited at which time the mockups were manually extinguished using pressurized carbon dioxide.

TABLE 9
Small Open Flame Test Results – Barrier A

COVER FABRIC	TEST RESULTS (3 replicates)
no cover fabric	smoke only, self-extinguished
std. FR polyester	smoke only, self-extinguished
cellulosic/thermoplastic blend	**2 reps** ignited, foam involved, manually extinguished **1 rep** ignited, foam melted, self-extinguished
cotton twill	did not ignite
cotton corduroy	ignited, foam melted, self-extinguished
silk	smoke only, self-extinguished
acrylic/olefin/nylon blend*	ignited, foam involved, manually extinguished
acetate/cotton taffeta	**2 reps** ignited, foam melted, self-extinguished **1 rep** ignited, foam involved, manually extinguished
cotton print	ignited, foam melted, self-extinguished

*Mockups constructed with Barrier A and the acrylic blend cover fabric had flaming drips and flaming to the edges of the mockup in 1 minute.

Barriers B and C

The results (Table 10) of the small open flame tests with Barriers B and C were similar to the results of Barrier A. The majority of the mockups covered with Barriers B and C did not have sustained ignitions. Both barrier fabrics had 23 of the 27 mockups that did not ignite. All six of the mockups constructed with the acrylic blend cover fabric and either Barrier B or Barrier C ignited and continued to burn intensely. In addition, a mockup constructed with Barrier B and the cotton print cover fabric and another mockup constructed with Barrier C and the cellulosic/thermoplastic blend upholstery fabric both had sustained ignitions.

TABLE 10
Small Open Flame Test Results – Barriers B and C

COVER FABRIC	TEST RESULTS (3 replicates)	
	Barrier B	**Barrier C**
cellulosic/thermoplastic blend	ignited, foam melted, self-extinguished	**2 reps** ignited, foam melted, self-extinguished **1 rep** ignited, foam melted, manually extinguished
cotton twill	did not ignite	did not ignite
cotton corduroy	ignited, foam melted, self-extinguished	ignited, foam melted, self-extinguished
silk	smoke only, self-extinguished	smoke only, self-extinguished
acrylic/olefin/nylon blend*	ignited, foam involved, manually extinguished	ignited, foam involved, manually extinguished
acetate/cotton taffeta	ignited, foam melted, self-extinguished	ignited, foam melted, self-extinguished
cotton print	**2 reps** ignited, foam melted, self-extinguished **1 rep** ignited, foam involved, manually extinguished	ignited, foam melted, self-extinguished

*Mockups with either Barrier B or C and the acrylic blend cover fabric had flaming drips and flaming to the edges of the mockup at 1 minute.

Barrier E

Only five cover fabrics were used with Barrier E due to the limited amount of Barrier E fabric available. However, as shown in Table 11, this barrier consistently provided protection to the filling material when tested by itself or combined with a cover fabric.

TABLE 11
Small Open Flame Test Results – Barrier E

COVER FABRIC	TEST RESULTS (3 replicates)
no cover fabric	smoke only, self-extinguished
std. FR polyester	smoke only, self-extinguished
cellulosic/thermoplastic blend	NT
cotton twill	NT
cotton corduroy	ignited, foam melted, self-extinguished
silk	smoke only, self-extinguished
acrylic/olefin/nylon blend*	ignited, foam melted, self-extinguished **(2 replicates)**
acetate/cotton taffeta	NT
cotton print	NT

*Mockups with Barrier E and the acrylic blend cover fabric had flaming drips and flaming to the edges of the mockup at 1 minute. NT = not tested

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Barriers F and G

Six mockups covered with Barriers F and G had sustained ignitions. One of these ignitions occurred on a mockup covered with the acrylic blend cover fabric. This mockup ignited at the back of mockup when the foam became involved from a flaming, dripping piece of cover fabric. The other sustained ignitions occurred from the front of the mockup when the barrier split exposing the foam to the flames. The results of Barriers F and G are in Table 12.

TABLE 12
Small Open Flame Test Results – Barriers F and G

COVER FABRIC	TEST RESULTS (3 replicates)	
	Barrier F	**Barrier G**
no cover fabric	ignited, smoke only, self-extinguished	ignited, smoke only, self-extinguished
std. FR polyester	ignited, smoke only, self-extinguished	ignited, smoke only, self-extinguished
cellulosic/thermoplastic blend	**2 reps** ignited, foam melted, self-extinguished **1 rep** ignited, foam involved, manually extinguished	ignited, foam melted, self-extinguished
cotton twill	**2 reps** ignited, foam involved, manually extinguished **1 rep** ignited, foam melted, self-extinguished	**2 reps** ignited, foam involved, manually extinguished **1 rep** ignited, foam melted, self-extinguished
cotton corduroy	ignited, foam melted, self-extinguished	ignited, foam melted, self-extinguished
silk	NT	NT
acrylic/olefin/nylon blend*	**2 reps** ignited, foam melted, self-extinguished **1 rep** ignited, foam involved, manually extinguished**	ignited, foam melted, self-extinguished
acetate/cotton taffeta	ignited, foam melted, self-extinguished	ignited, foam melted, self-extinguished
cotton print	ignited, foam melted, self-extinguished	ignited, foam melted, self-extinguished

*Mockups with either Barrier F or G and the acrylic blend cover fabric had flaming drips and flaming to the edges of the mockup at 1 minute. NT = not tested

**Mockup ignited when foam in the vertical panel ignited from the back of the mockup, possibly from a flaming dripping piece of upholstery fabric.

Barriers H, I and J

Due to limited quantities of Barriers H, I and J available to CPSC staff only one small open flame test each using Barriers H and J were performed. Both fabrics were tested without cover fabrics. The fabrics charred but did not sustain combustion when the small butane flame was applied. Additional yardage of Barrier I was ordered and testing will begin later in October 2001.

Barrier K
Barrier K did not have sustained ignitions when tested by itself or with four of the seven cover fabrics. However, seven mockups ignited and had sustained ignitions. Ignitions occurred on the mockups covered with the cellulosic/thermoplastic, cotton twill and cotton corduroy cover fabrics. Table 13 presents the results of the testing.

TABLE 13
Small Open Flame Test Results – Barrier K

COVER FABRIC	TEST RESULTS (3 replicates)
no cover fabric	ignited, smoke only, self-extinguished
std. FR polyester	ignited, smoke only, self-extinguished
cellulosic/thermoplastic blend	**1 rep** ignited, foam melted, self-extinguished **2 reps** ignited, foam involved, manually extinguished
cotton twill	ignited, foam involved, manually extinguished
cotton corduroy	**1 rep** ignited, foam melted, self-extinguished **2 reps** ignited foam involved, manually extinguished
silk	NT
acrylic/olefin/nylon blend*	ignited, foam melted, self-extinguished
acetate/cotton taffeta	ignited, foam melted, self-extinguished
cotton print	ignited, foam melted, self-extinguished

*Mockups with Barrier E and the acrylic blend cover fabric had flaming drips and flaming to the edges of the mockup at 1 minute. NT = not tested

Barrier L
Small open flame testing of Barrier L has not started as of mid October. Plans are to begin this testing later in October.

Summary of all Small Open Flame Tests

In general barriers that did well in the crib test did not always provide protection to the foam in the small open flame tests. Mockups covered with either the cellulosic/thermoplastic, cotton twill or cotton corduroy tended to have sustained ignitions. This was true for Barriers F and G, Barrier K. Barrier E did not ignite with the cotton corduroy cover fabric however, it was not tested with the cellulosic/thermoplastic blend or the cotton twill cover fabrics.

Although the small open flame test procedure is designed to test the ability of mockups to self-extinguish, generally, the barriers did not accomplish this, the fuel load of the burning cover fabric was such that the barrier could not always provide protection to the foam.

C. Cigarette Tests

The third ignition source used in this test program was a lit non-filtered cigarette. Mockups were constructed with

1. the barrier fabrics and up to eight upholstery fabrics,
2. the barrier fabrics alone, and
3. to establish a baseline, the upholstery cover fabrics alone.

Table 14 presents the results of the cover fabric tests. None of the eight cover fabrics ignited from a lit cigarette.

TABLE 14
Cigarette Ignition Test Results – Eight Cover Fabrics

COVER FABRIC	TEST RESULTS (3 replicates)
std. FR polyester	NT
cellulosic/thermoplastic blend	di
cotton twill	did not ignite
cotton corduroy	did not ignite
silk	did not ignite
acrylic/olefin/nylon blend	did not ignite
acetate/cotton taffeta	did not ignite
cotton print	did not ignite

NT = not tested

Barrier A
Mockup tests with smoldering cigarettes as the ignition source were done with Barrier A in combination with the variety of cover fabrics. Ignitions occurred on the mockups constructed with the heavier cotton cover fabrics, the twill and corduroy, and Barrier A. Table 15 presents the results of the cigarette tests.

TABLE 15
Cigarette Ignition Test Results – Barrier A

COVER FABRIC	TEST RESULTS (3 replicates)
no cover fabric	did not ignite
std. FR polyester	did not ignite
cellulosic/thermoplastic blend	did not ignite
cotton twill	ignited, foam involved, manually extinguished
cotton corduroy	**2 reps** did not ignite, **1 rep** ignited, foam involved, manually extinguished
silk	did not ignite
acrylic/olefin/nylon blend	did not ignite
acetate/cotton taffeta	did not ignite
cotton print	did not ignite

Barriers B and C

The results (Table 16) of the cigarette ignition tests on mockups constructed with Barriers B and C were similar to the results of Barrier A. Ignitions occurred only on the mockups constructed with the cotton corduroy and Barriers B and C.

TABLE 16
Cigarette Ignition Test Results – Barriers B and C

COVER FABRIC	TEST RESULTS (3 replicates)	
	Barrier B	Barrier C
no cover fabric	did not ignite	did not ignite
std. FR polyester	did not ignite	did not ignite
cellulosic/thermoplastic blend	did not ignite	did not ignite
cotton twill	did not ignite	did not ignite
cotton corduroy	ignited, foam involved, manually extinguished	**2 reps** ignited, foam involved, manually extinguished **1 rep** did not ignite
silk	did not ignite	did not ignite
acrylic/olefin/nylon blend	did not ignite	did not ignite
acetate/cotton taffeta	did not ignite	did not ignite
cotton print	did not ignite	did not ignite

Barrier E

Only a few cigarette ignition tests could be completed using Barrier E, due fabric limitation. Mockups constructed with Barrier E did not ignite when tested with lit cigarettes. These results are presented in Table 17. One of the mockups constructed with Barrier E and the cotton corduroy ignited when the lit cigarette was used as the ignition source.

TABLE 17
Cigarette Test Results – Barrier E

COVER FABRIC	TEST RESULTS (3 replicates)
no cover fabric	did not ignite
std. FR polyester	did not ignite
cellulosic/thermoplastic blend	NT
cotton twill	NT
cotton corduroy	**1 rep** ignited, **1 rep** did not ignite (only **2 replicates** tested)
silk	did not ignite
acrylic/olefin/nylon blend	NT
acetate/cotton taffeta	NT
cotton print	NT

NT = not tested

Barriers F and G

Cigarette ignitions occurred only on the mockups constructed with the cotton corduroy and Barrier F and G. Table 18 presents the results of these tests.

TABLE 18
Cigarette Test Results – Barriers F and G

COVER FABRIC	TEST RESULTS (3 replicates)	
	Barrier F	**Barrier G**
no cover fabric	did not ignite	did not ignite
std. FR polyester	did not ignite	did not ignite
cellulosic/thermoplastic blend	did not ignite	did not ignite
cotton twill	did not ignite	did not ignite
cotton corduroy	ignited, foam involved, manually extinguished	ignited, foam involved, manually extinguished
silk	NT	NT
acrylic/olefin/nylon blend	did not ignite	did not ignite
acetate/cotton taffeta	did not ignite	did not ignite
cotton print	did not ignite	did not ignite

NT = not tested

Barriers H, I and J

No cigarette tests were done with Barriers H, I and J. Additional yardage of Barrier I was ordered and testing will begin later in October.

Barrier K

Five mockups covered with Barrier K ignited from the lit cigarette ignition source. The cover fabrics for these five mockups were the cotton twill and the cotton corduroy. Table 19 presents the results of this testing.

TABLE 19
Cigarette Test Results – Barrier K

COVER FABRIC	TEST RESULTS (3 replicates)
no cover fabric	did not ignite (2 reps tested)
std. FR polyester	did not ignite (2 reps tested)
cellulosic/thermoplastic blend	did not ignite
cotton twill	3 reps ignited
cotton corduroy	3 reps ignited
silk	NT
acrylic/olefin/nylon blend	did not ignite
acetate/cotton taffeta	did not ignite
cotton print	2 reps did not ignite, 1 rep ignited

Barrier L
Cigarette ignition testing is planned for late October 2001.

Summary of all Cigarette Ignition Tests

None of the cover fabrics ignited from a lit cigarette when tested by itself. Most of the cover fabrics also did not ignite when tested with the barriers. An exception to this was the cotton corduroy. At least one mockup covered with the cotton corduroy and each of the barriers ignited from the lit cigarette. The mockups covered with the cotton twill cover fabric and barriers A and K also ignited. Two of the mockups covered with the cotton print cover fabric and barrier K also ignited.

CONCLUSIONS (based on testing so far)

- Fire resistant barriers are currently available that provide protection to the foam padding in CPSC laboratory mockup tests. Four barriers consistently passed the crib ignition tests when tested without a cover fabric. However, some fire resistant barrier fabrics including those that passed the crib ignition tests did not prevent the filling materials from becoming involved in the fire when combined with certain cotton and acrylic blend cover fabrics.

- For some barriers, the standard FR polyester fabric may have affected wood crib test results, although this testing is very limited and the significance of any such effect is undetermined.

- Cigarette mockup tests indicate that barriers provide protection to the foam for some cover fabrics. One cellulosic cover fabric ignited when combined with all barrier fabrics in the mockup tests.

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: June 2, 2000

TO : Dale Ray, Project Manager, Upholstered Furniture
Directorate for Economic Analysis

THROUGH: Andrew G. Stadnik, AED Laboratory Sciences
Robert T. Garrett, Director Division of Electrical Engineering

FROM : Linda Fansler, Division of Electrical Engineering LF

SUBJECT : Sensitivity Issues and Other Factors Influencing the Flammability of Upholstery Fabrics

PURPOSE

This memorandum provides a discussion of the work done by the U.S. Consumer Product Safety Commission's (CPSC) Directorate of Laboratory Sciences (LS) staff to evaluate the sensitivity of the draft furniture flammability test protocol[1] and the test fixture[2] described in the draft protocol to various conditions and deviations from protocol requirements.

After the Commission briefing in December, 1997 by the CPSC, and subsequent public comment period, several issues regarding the sensitivity of the draft upholstered furniture test protocol and test fixture to a number of physical variables were raised. These issues mainly concerned the repeatability and reliability of the draft test protocol and test fixture to a number of physical factors and conditions. As a result, LS staff identified a set of studies designed to evaluate the robustness of the test protocol and fixture design. The effects of the following 14 variables were evaluated:

1. seat back angle,
2. flame angle,
3. flame placement,
4. flame size,
5. flame application time,
6. fabric tension,
7. soaking procedure,
8. filling materials,
9. spilled beverages,
10. soiling,
11. cleaning agents,
12. fabric finishes,
13. fire barriers, and
14. borderline fabrics.

[1]Superscript refers to references on page 7.

In the course of assessing these factors, LS tested a total of 160 upholstery fabrics using the draft test protocol and mockup test fixture. Although not a random sample of upholstery fabrics, the set included 54 flame-retardant (FR) backcoated, 15 FR-treated, 12 inherently flame-resistant, 6 laminated with a FR-fire-blocker, and 73 non-flame resistant upholstery fabrics. From prior CPSC studies of the test protocol documented in the December 1997 briefing package, upholstery fabrics must be treated or backcoated with flame-retardant chemicals or contain inherently flame-resistant fibers (wool, polyvinyl, leather etc.) to meet the criteria of the draft test protocol.

SENSITIVITY OF DRAFT TEST PROTOCOL

The following sections present the results of the LS staff's analysis of the different variables and their effects on the sensitivity of the draft test protocol and test fixture.

1. Seat Back Angle

The draft test protocol specifies a seating area mockup test frame with a 90° angle at the seat back junction. Although the seat back angle is fixed, modifications were made to the test frame and tests were conducted with the angle changed to 95° and 85°. Results of this testing[3] indicate that a small change to the angle of the seat back junction did not make a measurable difference in small open flame results for the fabrics tested. If an upholstery fabric did not meet the criteria on a mockup with a 90° seat back angle, it also did not meet the test criteria when the seat back angle was either 95° or 85°. This was also true with fabrics meeting the test criteria in the draft test protocol with one exception. Another fabric in this study had variable results and did not always meet the test criteria at any of the seat back angles studied in this test.

Although this limited testing did not indicate that a small change to the seat back angle influenced the outcome of the testing, the seat back angle issue is not a relevant factor that may affect the test results using the specified test mockup frame. This issue requires no further sensitivity analysis. A deliberate attempt must be made to alter the seat back angle and therefore the draft test protocol would not be followed as it is currently written.

2. Flame Angle

The Furniture Flammability Fixture is designed so that the approach of the burner tube is at 45° to the crevice of the seating area mockup. The burner tube travels downward in an elevated path until it reaches the crevice location. This approach angle is fixed by the mechanism and only a deliberate effort would alter the flame approach angle, therefore an analysis of the sensitivity of the approach of the flame angle is not necessary.

3. Flame Placement

The draft test protocol states that the burner tube is "*placed evenly along the vertical and horizontal intersection of the crevice*". The test fixture operations manual[2] has detailed instructions how to make adjustments to properly align the burner to achieve the correct position as described in the draft protocol. The test fixture was recently redesigned to simplify the adjustments necessary to properly align the burner in the crevice of the mockup. Again small variations in the flame placement are not factors influencing the outcome of the test results. Proper burner placement can be achieved by following the draft test protocol and the furniture fixture manual. Further sensitivity analysis of this issue is unnecessary.

4. Flame Size

The draft test protocol states that a flame height of 35 mm (1.4 in) can be achieved when the pressure and flow meet the specifications given. In a limited study[4] conducted by LS staff, a 35-mm flame was consistently delivered to the test specimen. Observations made by laboratory staff during the initial startup of the gas flow system determined, that a 35-mm flame was present when the pressure was set to 0.4 psi and the flow to 45 ml/min. In addition, the gas flow system at the Engineering Laboratory is checked periodically to assure that the gas flow is maintained at 45 ± 2 ml/min.

The method and the gage used to determine the height of the flame are somewhat imprecise. Although a tolerance is not given in the draft test protocol, differences in flame height during testing may range from 36 to 34 mm with no discernible affect on the test results. Considering the measurement limitations, the sensitivity of the flame size may not be a factor affecting the outcome of the test results.

5. Application Time

The draft test protocol states that the butane flame is applied for 20 seconds. This flame application time was chosen for two reasons.[5] The British Standard, BS 5852, *Fire Tests for Furniture*, specifies a 20 second flame application and LS tests[6] indicate that a 20 second exposure time differentiates between upholstery fabrics which readily ignite and sustain combustion, and fabrics that are more resistant. "*The draft test protocol is intended to address flame exposure from child play and inadvertent contact, but not intentional acts to initiate a fire.*"[5] Child fire play information suggests that focused, intentional behavior is needed to maintain a small open flame source in one location for more than 20 seconds.[5]

The timer on the fixture uses a microprocessor running a stable, high frequency clock, a very accurate method, to time the flame exposure on the test mockup. The test fixture was redesigned with a set flame application time of exactly 20 seconds. A deliberate attempt must be made to manually alter the flame application time, which would mean that the draft test protocol would not be followed as written. Therefore, no sensitivity analysis is necessary.

6. Fabric Tension

The draft protocol states that the upholstery fabric is mounted on the mockup test frame over standard polyurethane foam. The edges of the fabric are clipped to the edges of the mockup frame with the fabric under even tension. Even tension results in the fabric and foam being in direct, intimate contact with no air pockets present and a gap in the crevice area no bigger than 1/8 inch. By following the directions given in the draft test protocol, a seating area mockup can be constructed. If the fabric is pulled too tight the foam deforms and a gap is created at the crevice. If the fabric is too loose, the fabric and foam are not in direct contact and air gaps are present. Because the visual cues are so obvious, evaluating sensitivity to deviation is unnecessary.

7. Soaking Procedure

In a limited study,[7] nine-upholstery fabrics were soaked in 1 gallon of water following the specifications in the draft test protocol. The upholstery fabrics were dried and then conditioned for 24 hours before being subjected to the flammability procedure in the draft test protocol. Those fabrics that met the criteria in the draft protocol before soaking also met the criteria after soaking.

The intent of the water soaking procedure is to remove any nondurable fire retardant finishes used on upholstery fabrics. However what is not clear from the language in the draft test protocol is when this provision of the standard is applicable. Further work to evaluate the sensitivity effects on soaked upholstery fabrics is unnecessary, however clarification to the draft protocol is warranted.

8. Filling Materials

The effects of filling materials[8] were also examined; nine filling materials commonly found in upholstered furniture and three upholstery fabrics were used in a limited study. Although the draft test protocol allows for the use of actual filling materials found in finished furniture items in place of the standard foam, differences in flammability results were observed in some cases when substitutions were made. A FR backcoated upholstery fabric that met the criteria when tested with the standard foam, ignited with four other kinds of filling materials including latex foam, shredded foam and polyester fiberfill. A 100% cotton, non-flame resistant fabric ignited when tested with both standard foam and FR treated foam.

For some upholstery fabrics, filling materials may play a larger role in the resistance of ignition from a small open flame. Additional testing to evaluate the sensitivity effects of filling materials may be necessary to understand their role in resisting small flame ignition when combined with FR backcoated or treated upholstery fabrics.

EFFECTS OF EXTERNAL AGENTS/CONDITIONS

LS also looked into external conditions that may influence test results. These external conditions can occur in normal use of upholstered furniture and may include such factors as soiling and or cleaning upholstery fabrics, spray-on additives, etc. These external conditions are not controlled by using the draft test protocol, however some of these conditions were simulated in the laboratory, and the effects on the flammability of upholstery fabrics were observed.

9. Spilled liquids

A limited study was done to examine the effects of the residue left on upholstery fabrics from spilled beverages. The small open flame ignition resistance of three fabrics was tested before and after soaking in two kinds of beverages.[9] There was minimal change in the ignition and burning characteristics of two fabrics. A third fabric showed a minor decrease in ignition resistance from one of the beverages.

10. Soiling

A study[10] was done by the LS staff to determine whether upholstery fabrics meeting the criteria in the draft test protocol loose their flame resistance after becoming soiled with a fatty acid solution simulating oils from food and the human body. No significant effect of this fatty acid treatment was found on the three fabrics studied.

11. Cleaning Agents

Tests were conducted[11] to examine the effect of commercial cleaning products on the flammability of upholstery fabrics meeting the criteria of the draft test protocol. Three upholstery fabrics were used: a naturally flame-resistant fabric, a FR-treated fabric and a fabric with a FR-backcoating. Three cleaning methods were used. Results indicate that there are no significant effects on the flammability of these upholstery fabrics after being cleaned.

12. Effect of Fabric Finishes

The effect of stain repellents and a fire retardant spray-on additive were studied using commercial products.[12] The stain repellent products did not affect whether the three upholstery fabrics met or failed to meet the criteria of the draft test protocol. The spray-on fire retardant allowed two non-flame resistant upholstery fabrics to meet the criteria. However, after following the soaking procedure in the draft test protocol, the two fabrics treated with the spray-on fire retardant ignited and continued to burn.

OTHER FACTORS THAT WERE EVALUATED

13. Effects of Fire Barriers

Tests by the LS staff have investigated four kinds of fire barriers including laminated fire-blockers placed between the fire and foam.[13,14,15] In this limited testing, some of the upholstery fabrics showed improved flammability performance when tested with a barrier, other fabrics did not. The presence of a barrier or fire-blocker does not guarantee that an upholstery fabric will meet the criteria in the draft test protocol.

14. Identification of 'Borderline' Upholstery Fabrics
The draft test protocol and furniture fixture has been used to test a variety of upholstery fabrics. Using the draft protocol and furniture fixture, staff has identified some FR-backcoated upholstery fabrics with inconsistent flammability characteristics. The draft test protocol specifies that the butane flame is applied to each upholstery fabric three times for a duration of 20 seconds each. Upholstery fabrics that produce inconsistent results are considered 'borderline' fabrics. 'Borderline' fabrics sometimes meet and other times do not meet the criteria in the draft test protocol. Modifications to the draft test protocol may include increasing the number of upholstery fabric specimens tested to identify these 'borderline' fabrics in a more reliable manner.

CONCLUSIONS

The draft test protocol was designed to achieve a specific outcome. Factors that may affect the test results are important to consider and eliminate if possible. Several key issues were examined to evaluate the draft protocol for factors influencing test results. LS staff concluded that with one exception issues identified as potential influences on test results are well controlled by the draft test protocol and fixture specifications and do not influence the outcome of the test results.

The role of the filling material may be more significant that presently understood. The literature on upholster furniture flammability research[16] indicates that in general, resistance to small open flame sources is dependent more on fabric than on the filling material beneath the fabric. Limited testing by LS staff indicates for some FR backcoated upholstery fabrics, certain filling materials may influence ignition resistance.

In addition to sensitivity factors, other factors outside the scope of the draft test protocol may also have an effect on the flammability performance of upholstery fabrics. Certain external conditions resulting from daily use were also examined for their effects on the flammability performance of upholstery fabrics tested using the draft test protocol. In general, simulated external conditions did not affect the flammability performance of upholstery fabrics meeting the criteria of the draft test protocol.

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14. Memorandum to Dale Ray, EC, from L. Fansler, LS, *Inherently Flame Resistant Fabrics And Intumescent Barrier Fabrics*, June 1997, CPSC.

15. Memorandum to Dale Ray, EC, from D. LaRue, LS, *Small Open Flame Ignition Test Results Of Flame Resistant Upholstery Fabrics and Intumescent Barrier Fabrics*, May 2000, CPSC.

16. *Fire Behavior of Upholstered Furniture*, NBS Monograph 173, V. Babrauskas and J. Krasney, U.S. Department of Commerce, National Bureau of Standards, November 1985.

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: May 25, 2000

TO : Dale Ray, Project Manager, Upholstered Furniture
Directorate for Economic Analysis

THROUGH: Andrew G. Stadnik, AED Laboratory Sciences
Robert T. Garrett, Division Director, Electrical Engineering

FROM : Linda Fansler, Division of Electrical Engineering LF

SUBJECT : Effects of Variations To The Seat/Back Geometry

The Directorate for Laboratory Sciences conducted tests varying the angle of the seat/back crevice junction on the seating area mockup frame. Small variations to the seat/back crevice were made to determine effects on the flammability of upholstery fabric. This memorandum discusses the results of this testing.

BACKGROUND

The Draft Standard for Upholstered Furniture[1] specifies a seating area mockup test frame with a 90° angle at the seat/back crevice. Many tests have been conducted using this seating area test frame and standard polyurethane foam to evaluate the flammability performance of flame-resistant upholstery fabrics. However, all upholstered furniture does not have a perfect right angle at the seat/back crevice junction. Some upholstered chair back cushions recline slightly and others because of the filling material, often polyester fiberfill, angle inward towards the seat cushion at the crevice junction.

Tests were conducted to investigate any potential change to the flammability performance of six upholstery fabrics when the seating area test frame's seat/back geometry was varied. Modifications were made to the seat/back angle of the test frame and, in addition to 90°; tests were conducted with the seat/back crevice angle at 95° and 85°.

TEST PROGRAM

Six upholstery fabrics were used in this testing. The fabrics included two non-flame resistant fabrics and four flame resistant backcoated upholstery fabrics. Seating area mockups were constructed with the standard foam specified in the *Draft Standard for Upholstered Furniture*

[1]Superscript refers to references on page 4.

and each of the upholstery fabrics. *The Furniture Flammability Fixture*[2] was used to apply the ignition source, a small butane flame to the crevice of the seat mockups for 20 seconds. However, as these tests were exploratory in nature, the flame was applied multiple times to each seat mockup instead of one 20 second flame application per mockup as specified in the *Draft Standard.* Ignition was defined as occurring when the fabric tested ignited and did not self-extinguish within the two-minute observation period. The burning characteristics of each fabric were recorded including the time in seconds for afterflame, afterglow and smoldering as well as the occurrence of an ignition. CO_2 was used to extinguish any ignitions.

The upholstery fabrics and standard foam were conditioned following the specifications in the *Draft Standard for Upholstered Furniture* with the exception of the soaking procedure, which was not done. The fabrics and foam were placed in the conditioning area for at least 24 hours immediately before the tests. Conditions were maintained at $25 \pm 2^\circ$ C ($77 \pm 6^\circ$ F) and between 40 and 55% relative humidity. Tests were conducted in a draft-protected room equipped with an exhaust fan to evacuate the room of smoke and fumes at the completion of a test.

The seat/back angle on the seating area test frame was modified in the following manner.

1. The bolts holding the horizontal and vertical panels of the seat frame together were removed, and replaced with two small C-clamps.
2. The horizontal and vertical panels were adjusted until the desired angle was created, and then the C-clamps were tightened.
3. The new seat/back angle was verified.

RESULTS AND DISCUSSION

The results of this testing are presented in Table 1. This was a set of exploratory tests therefore the number of 20-second flame applications on each upholstery fabric at each seat/back angle varied. The majority of the 20-second flame application tests were conducted with only one or two trials at the different seat/back angles for each fabric. However, limited, as this testing was the results are fairly consistent.

Non-Flame Resistant Upholstery Fabrics

There were two non-flame resistant fabrics used in this testing. Fabric UF 19, a 100% cotton twill fabric ignited when the flame was applied and did not self-extinguish. Ignitions occurred when the seat/back angle was set at 95°, 90°, or 85°. Fabric UF 22, a cellulosic/thermoplastic blend fabric also ignited with the 20 second flame application and did not self-extinguish. Although this fabric was not tested at 95°, there is no reason to believe that the flammability results would differ from those at 90° and 85°.

Flame Resistant Backcoated Fabrics
There were four flame resistant backcoated upholstery fabrics tested. Fabric UF 4, a cellulosic/thermoplastic blend fabric had mixed results. Based on prior testing, this upholstery fabric was 'borderline', meaning it sometimes ignited and other times it did not ignite. With the seat/back angle set at 90°, this fabric ignited about a quarter of the time. No ignitions occurred with a 95° seat/back angle and one ignition occurred out of two tests when the seat/back angle was set at 85°.

Fabric UF 5, a 100 % olefin plain weave fabric also had slightly mixed results. The fabric did not ignite when the seat/back angle was set at either 90° or 95°, but one flame application out of seven did ignite at 85°. Fabrics UF 18 and 21, which are both FR backcoated, had more consistent test results. Fabric UF 18, a rayon/polyester/cotton blend fabric did not ignite when the seat/back angle was set at either 90°, 95°, or 85°. UF 21, a 100% olefin twill weave fabric also did not ignite with any of the variations to the seat/back angle.

TABLE 1

20 SECOND FLAME APPLICATION TESTS AT DIFFERENT SEAT/BACK ANGLES

Fabric Identification	Seat/Back Angle	No. of Ignitions	Total No. of 20 Second Flame Applications/No. of Mockups
UF Number 19 Cotton twill 12.0 oz/yd^2 non-FR backcoated	90°	2	2/2
	95°	2	2/2
	85°	2	2/2
UF Number 22 Rayon/Polyester/Cotton 10.3 oz/yd^2 non-FR backcoated	90°	1	1/1
	95°	NA	NA
	85°	1	1/1
UF Number 4 Rayon/Polyester/Cotton 11.0 oz/yd^2 FR backcoated	90°	5	13/7
	95°	0	2/2
	85°	1	2/2
UF Number 5 Olefin plain weave 8.8 oz/yd^2 FR backcoated	90°	0	1/1
	95°	0	1/1
	85°	1	7/2
UF Number 18 Rayon/Polyester/Cotton 11.9 oz/yd^2 FR backcoated	90°	0	1/1
	95°	0	1/1
	85°	0	1/1
UF Number 21 Olefin twill weave 9.5 oz/yd^2 FR backcoated	90°	0	14/8
	95°	0	6/2
	85°	0	2/2

CONCLUSIONS

Results of this testing indicate that in general a slight change to the angle of the seat back junction did not make a measurable difference in small open flame results for the fabrics tested. Two non-flame resistant upholstery fabrics ignited when the mockup test frame seat/back angle was 90°, 95° or 85°. Two flame resistant backcoated fabrics did not ignite when the seat/back angle was either 90°, 95° or 85°. One flame resistant backcoated upholstery fabric considered 'borderline', continued to have inconsistent results with the two modified seat/back angles. Another fabric was considered 'borderline', but not enough repeat tests were done to be able to make a definitive conclusion about this fabric.

REFERENCES

1. *Draft Standard For Upholstered Furniture*, R. Khanna, ES, October 1997, CPSC.

2. *Furniture Flammability Fixture, Operations Manual*, Directorate for Laboratory Sciences, June 1997, CPSC.

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

May 24, 2000

TO : Dale Ray, Project Manager, Upholstered Furniture
Directorate for Economic Analysis

THROUGH: Andrew G Stadnik, Associate Executive Director,
Directorate for Laboratory Sciences
Jim Hyatt, Director,
Division of Mechanical Engineering, Laboratory Sciences

FROM : William Rowe, Division of Mechanical Engineering

SUBJECT : Effects of Tap Water Soaking on Upholstery Fabric Flammability

Background:
The Directorate for Laboratory Sciences evaluated the effect of the water soak procedure in the draft CPSC standard for upholstered furniture[1] on a representative sample of upholstery fabrics with known flammability characteristics.

Procedure:
1. The samples were cut to the standard size for flammability testing and were immersed in 1 gallon (3.79×10^{-3} m^3) of tap water at room temperature for 24 hours. The samples were then air dried for 24 hours. The samples were then conditioned in a chamber at a temperature of 77±6°F (25±2°C) a relative humidity of 40-55% for 24 hours. In three instances, the available fabric was too narrow for a full size sample. In those cases, the amount of water was reduced so the ratio of fabric area to water volume was the same as for a full with sample.
2. The samples were mounted on the seating area mock up and a standard butane flame was applied for 20 seconds.

[1] Draft Standard of Upholstered Furniture, in Briefing Package on Upholstered Furniture Flammability, U.S. Consumer Product Safety Commission, October 1997. Tab G

Results:

The draft standard for upholstered furniture flammability requires that visible flame, smoldering, and smoke resulting from the application of a 20 second butane flame cease within 120 seconds after the flame is removed. The results are shown in Table 1.

Table 1 Comparison of Original State and Soaked Fire Retardant Fabrics

Fabric Identification	20 Second Flame Application	
	Original State	1 Gal Tap Water
UF 19 100% Cotton, No FR treatment	Ignited and burned 120+ sec.	Ignited and burned 120+ sec.
UF5 100% olefin, FR backcoated	1 of 7 did not self extinguish in 120 sec.	1 of 6 did not self extinguish in 120 sec.
UF 18 60% Rayon, 36% polyester and 4% cotton FR backcoated	1 did not ignite, and 1 did not self extinguish.	5 did not ignite, and 1 did not self extinguish.
UF 12 100% cotton, FR treated	Smoldered 20 sec.	Smoldered 20 sec.
UF 15 100% cotton, FR treated	Smoldered 1 sec	Smoldered 15 sec.
UF 16 100% cotton, FR treated	Did not ignite	Smoldered 6 sec.
UF 11 100% cotton, FR treated	Smoldered 21 sec.	Smoldered 19 sec.
UF 32 88% cotton, 12% nylon, FR treated	Smoldered 16 sec.	Smoldered 18 sec.
UF 13 100% cotton, FR treated	Smoldered 14 sec.	Smoldered 11 sec.

Discussion:

The draft standard has a pass/fail criterion. The upholstery fabric must self extinguish within 120 seconds. Presoaking in one gallon of tap water and drying prior to administering the flame test did not affect whether or not an upholstery fabric passed or failed the test.

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: June 6, 2000

TO : Dale Ray, Directorate for Economic Analysis,
Project Manager Upholstered Furniture

THROUGH: Andrew G. Stadnik, Associate Executive Director,
Directorate for Laboratory Sciences
Robert T. Garrett, Director, RTGarrett
Division of Electrical Engineering, Laboratory Sciences

FROM : Andrew J. Bernatz Electrical Engineering Technician LSE AJB

SUBJECT : Effects of Beverages on the Flammability of Upholstery Fabrics

The U.S. Consumer Product Safety Commission (CPSC) Directorate for Laboratory Sciences (LS) evaluated the small open flame ignition resistance of three upholstery fabrics soaked with two types of beverages. Tests were conducted on fabrics received from three textile manufactures. Each fabric was identified with a universal code number (UF No. 4, 20, and 21) which applies for all CPSC Upholstered Furniture Project test programs.

Fabrics with and without flame retardant (FR) backcoatings were included in the study. Chemical analysis by LS staff verified that two of the fabrics contained an FR backcoating, while the remaining fabric did not. The two FR backcoated fabrics consisted of olefin and a fabric blend of rayon/polyester/cotton that weighed 9.5 and 11.0 oz/yd^2 respectively. The non-FR backcoated fabric was a wool that weighed 10.5 oz/yd^2.

All fabrics were first tested in their original condition. The fabrics were then tested after soaking in two different beverages: a national brand cola, and hot coffee with creamer and sugar. Each fabric specimen was folded into thirds and placed into an 11" x 14" photographic processing tray. Approximately 2 liters (2.1 quarts) of beverage were poured over the fabric specimen. The saturated fabric remained in the liquid for 4 hours and was then dried.

LS staff evaluated these fabrics using the basic methodology in the test protocol in the CPSC Draft Standard for Small Open Flame Ignition Resistance.[1] The fabrics were evaluated for time to ignition from a small butane flame using the CPSC draft standard for the seating area test. Each piece of fabric was tested over the standard polyurethane foam in the seating area mock-up. The flame was applied to a specimen at different locations and decreasing flame exposure times from 20 seconds until no ignition was observed for three tests. Then the flame application times were increased from the time when no smoke was observed until three ignitions occurred. Ignition is defined as the presence of any visible flaming, glowing or smoldering after removal of the test flame. This method was used to establish the time to ignition for all of the specimens.

Materials and Methods

A study was conducted to determine the easiest and most appropriate method to remove the excess liquid from the test specimen. Method A involved placing the saturated test specimen between two laundered[2] 100% cotton towels and blotting. Method B involved putting the fabric specimen through an Atlas Laboratory wringer with 8 lbs force applied to the top roller by means of hanging weights from the control arm. After the excess liquid was removed, the test specimens were placed flat on laundered 100% cotton towels to dry and then conditioned for 24 hours at a temperature of 25±2°C and between 40% and 55% relative humidity

This study consisted of six trials using one fabric and one beverage. Three trials used the blotting method and three used the wringer method. Both methods produced consistent test results. However, the blotting method (Method A) required more time and care to ensure even removal of excess liquid from all areas of the specimen. Consequently, the wringer method (Method B) was used on the remaining test specimens.

Results and Discussion

<u>NON-FR BACKCOATED FABRIC</u>

In all trials of soaked and dried specimens, and all but one trial of a specimen in original condition, Fabric UF No. 20, the non-FR backcoated fabric, met the flammability performance criteria as specified in the draft test method. The fabric ignited when the butane flame was applied for 20 seconds, but self-extinguished. The time to ignition for all trials was between 5 and 9 seconds. In one trial of a specimen in original condition, the fabric ignited and continued burning. See Table 1 for test results.

[1] Superscript refers to references on page 7

TABLE 1
SMALL OPEN FLAME IGNITION TESTS FOR ORIGINAL STATE AND LIQUID APPLICATIONS NON-FR BACKCOATED FABRIC

FABRIC IDENTIFICATION	ORIGINAL CONDITION	LIQUID TYPE	TIME TO IGNITION (seconds)	20-SECOND FLAME APPLICATION
Fabric UF No.20 100% Wool 10.5 oz/yd^{2}, Blue-Gray, Jacquard Weave	X		5-7*	Ignited and self-extinguished 15 out of 16 trials, ignited and continued to burn beyond 120 seconds 1 trial
		Cola/Blot	5-6*	Ignited and self-extinguished 3 out of 3 trials
		Cola/Wringer	6-7*	Ignited and self-extinguished 3 out of 3 trials
		Coffee, Creamer & Sugar/ Wringer	6-9*	Ignited and self-extinguished 7 out of 7 trials

* Self-Extinguished With Just Smoke Only

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FR BACKCOATED FABRICS

The FR backcoated, Olefin Fabric, UF No.21, ignited in all trials and self-extinguished. There was little difference between the time to ignition for specimens in their original condition or those which had been soaked and dried. The time to ignition for specimens in original condition was 3 to 4 seconds and 2 to 4 seconds for soaked.

Fabric UF No.4, a Cellulosic/Thermoplastic blend with a FR backcoating, were tested in their original condition they failed to self-extinguished in one-third of the trials. Specimens which had been soaked and dried self-extinguished in all trials. The application of the two beverages slightly decreased this fabric's time to ignition. The time to ignition for specimens in original condition trials was between 6 and 9 seconds and between 4 and 6 seconds for the soaked and dried specimens. Of the two beverages, the coffee with the creamer and sugar appeared to have the greatest effect on the performance of the fabric. Specimens soaked in the coffee/creamer/sugar did not self-extinguish in approximately three quarters of the trails while specimens soaked in cola did not self-extinguish in approximately one third of the trials. See Table 2 for test results.

TABLE 2
SMALL OPEN FLAME IGNITION TESTS FOR ORIGINAL STATE AND LIQUID APPLICATIONS FR BACKCOATED FABRICS

FABRIC IDENTIFICATION	ORIGINAL CONDITION	LIQUID TYPE	TIME TO IGNITION (seconds)	20-SECOND FLAME APPLICATION
Fabric UF No.21 Backcoated 100% Olefin 9.5 oz/yd^2, Green, Twill Weave	X		3-4*	Ignited and self-extinguished 15 out of 15 trials
		Cola/ Wringer	2-4*	Ignited and self-extinguished 12 out of 12 trials
		Coffee, Creamer & Sugar/ Wringer	2-3*	Ignited and self-extinguished 12 out of 12 trials
Fabric UF No.4 FR Backcoated 60% Rayon 35% Polyester 4% Cotton 11.0 oz/yd^2, Blue, Dobby Weave	X		6-9*	Ignited and self-extinguished 8 out of 12 trials, did not self-extinguish in 4 trials
		Cola/ Wringer	4-6*	Ignited and self-extinguished 9 out of 14 trials, did not self-extinguish in 5 trials
		Coffee, Creamer & Sugar/ Wringer	4-5*	Ignited and self-extinguished 3 out of 12 trials, did not self-extinguish in 9 trials

* Self-Extinguished With Just Smoke Only

Conclusions

These tests were conducted to determine if residue from the spillage of two different types of beverages on upholstery fabrics would affect the fabrics resistance to ignition from a small open flame ignition source. There was minimal change in the ignition and burning characteristics of fabrics UF No. 20 and No. 21 when specimens were tested in both original condition and after drying from a soaking with cola or a combination of coffee, creamer and sugar. There was a slight decrease in time to ignition of specimens of fabric UF No. 4 when tested in the soaked and dried condition as compared to the original condition. A greater percentage of the UF No. 4 specimens failed to self-extinguish when tested after drying from soaking in a combination of coffee, creamer and sugar than failed after drying from a soaking in cola or when tested in the original conditional.

References

1. Draft standard for Small Open Flame Ignition Resistance of Upholstered Furniture, R. Khanna, ESME, October 1997, Consumer Product Safety Commission.

2. American Association of Textile Chemists and Colorists Test Method Version 124: "Appearance of Durable Press Fabric After Repeated Home Launderings" - 1996.

United States
CONSUMER PRODUCT SAFETY COMMISSION

Washington, D.C. 20207

MEMORANDUM **DATE:** May 25, 2000

To:	Dale Ray, Directorate for Economic Analysis, Project Manager Upholstered Furniture
Through:	Andrew G. Stadnik, Associate Executive Director, Directorate for Laboratory Sciences
Through:	Robert T. Garrett, Director, Electrical Engineering Division
From:	Joseph J. Puskar, Electrical Engineering Division Andrew J. Bernatz, Electrical Engineering Division

Subject: Ignition Tests of Filling Materials Currently Found in Upholstered Furniture

Ignition tests were conducted using three fabrics with filling materials commonly found in upholstered furniture. The three fabrics tested were a cellulosic/thermoplastic blend flame retardant (FR) backcoated fabric, a 100% olefin FR backcoated fabric, and a cotton fabric. Nine filling materials were tested: latex foam, untreated cotton batting, shredded polyurethane foam, woven bag containing feather/fiber blend, nonwoven bag containing feather/fiber blend, resinated polyester fiber, non-resinated polyester fiber, interior fabric with non-resinated polyester fiber, and FR foam.

BACKGROUND

As part of the upholstered furniture project, staff from the Directorate for Engineering Sciences (ES) developed a draft test protocol to evaluate small open flame ignition resistance of two locations on upholstered furniture. The protocol, entitled "Draft Standard For Small Open Flame Ignition Resistance of Upholstered Furniture"[1], specifies that a small butane flame be applied to mockups representing the seating area and the dust cover. A test fixture that automatically controls the placement of the flame and the time the flame is applied was used for these tests. The test fixture was designed and constructed by staff at the Engineering Laboratory (LSE).

Previously LSE conducted limited small open flame testing to determine the effects on fabric ignition in seating area mockup tests of: 1) flame retardant treated foam and conventional non-FR foam as the filling material and

[1]Superscript refers to references on page 8

2) combining polyester batting with non-FR foam[2]. Three upholstery fabrics were used in this testing:

1. Fabric Code UF-4: A cellulosic/thermoplastic blend made of 60% rayon, 35% polyester, and 4% cotton. The fabric was FR backcoated and had a weight of 11 oz/yd^2.
2. Fabric Code UF-21: A twill weave, 100% olefin, FR backcoated fabric having a weight of 9.5 oz/yd^2.
3. Fabric Code UF-19: A 100% cotton twill fabric with no FR backcoating having a weight of 12.0 oz/yd^2.

UF-4 and UF-21 were two of the upholstery fabrics included in the first interlaboratory evaluation[2,3]. LSE conducted these additional tests to increase the understanding of the effects of different filling materials on the small open flame ignition of upholstered furniture.

Many types of filling material are used in upholstered furniture in addition to non-FR foam. TABLE 1 lists the filling materials tested by LSE with the cellulosic/thermoplastic fabric and with the olefin fabric.

TABLE 1
FABRIC/FILLING MATERIAL TEST COMBINATIONS

FILLING MATERIAL	FABRIC		
	Cellulosic/thermo-plastic Blend	Olefin	100% Cotton Twill
Latex Foam	T	T	N.T.
Untreated Cotton Batting	T	T	N.T.
Shredded Polyurethane Foam	T	T	N.T.
Woven Bag Containing Feather/fiber Blend	T	T	N.T.
Nonwoven Bag Containing Feather/fiber Blend	T	T	N.T.
Resinated Polyester Fiber	T	T	N.T.
Non-resinated Polyester Fiber	T	N.T.*	N.T.
Interior Fabric w/Non-resinated Polyester Fiber	T	N.T.*	N.T.
FR Foam	N.T.	N.T.	T

T = Tested. N.T. = Not Tested. N.T.* = Insufficient filling material.

FR treated foam is also used in some instances in upholstered furniture, for example, residential furniture made to meet the regulations in the State of California[6] or the United Kingdom[7]. Although resistance to a small open flame may depend more on the fabric than the filling material, self-extinguishment after small flame ignition of upholstery fabrics is more likely with an FR treated foam than a non-FR foam[8]. The 100% cotton twill fabric was tested only with a FR foam taken from chairs intended to meet existing open flame standards in the State of California (Technical Bulletin 117)[6]. The FR foam was polyether polyurethane having a density of 1.83 lb/ft^3.

TEST PROGRAM

The objective of this test program was to determine if the fabric/filling material combinations listed in TABLE 1 met the small open flame ignition resistance as specified in the ES draft test protocol.

The fabrics and filling materials were evaluated for ignition using the ES draft test protocol[1]. The draft protocol specifies a 20 second flame application on each of three mockups during which the fabric must not ignite or, if an ignition occurs, must self-extinguish within 120 seconds. Ignition can include afterflame, afterglow, or smoldering. A butane flame was delivered to the seating area test mockup using a test fixture that accurately placed the flame in the crevice of the mockup for 20 seconds. While the CPSC Draft Protocol specifies one 20 second flame application per mockup, LSE conducted multiple flame applications to each mockup. In addition to the 20 second flame applications, different flame application times were conducted to determine the time to ignition for the fabric and filling material combination. In this report only the 20 second flame applications results were considered. In most tests only one mockup was used due to a limited supply of test fabric and/or filling material. Each flame application is considered one trial. Flame applications were usually started one inch from the mockup edge and one inch away from the last ignition char.

In addition to the flame application times, other observations were recorded, including afterflame, or afterglow/smoldering times and whether the specimen self-extinguished. Afterflame is the time that the fabric continues to produce a flame after the ignition source is removed. Afterglow/smoldering is the time that a fabric continues to glow or produce smoke after the removal of the ignition source. Self-extinguishment of a fabric occurs when any visible flaming, glowing or smoldering ceases at any time during the observation period after the ignition source is removed.

The conditioning requirements specified in the draft protocol were followed. All test specimens were conditioned for at least 24 hours at 25 ± 2°C and between 40 to 55% relative humidity. The fabrics were not soaked as specified in the CPSC Draft Protocol.

RESULTS

The test results are presented in Tables 2, 3, and 4. In the tables, a different number of mockups were tested for each filling material/fabric combinations due to the limited amount of materials that were on hand. The total number of flame applications to the mockup is higher than the number of 20 second flame applications to the mockup because other informational ignition tests were also conducted on the same mockup. These additional tests are not reported on in this memo.

Table 2 shows the ignition results for the UF-4 (cellulosic/thermoplastic blend) fabric with the standard foam filling material and with each of the eight test filling materials. When the UF-4 fabric was tested with the standard foam[4], it did not always meet the requirements of the draft test protocol. A total of thirteen 20 second flame application trials were performed. Twelve trials (92%) either did not ignite or ignited and self-extinguished within 120 seconds with a 20 second flame application. One trial ignited and continued to burn beyond 120 seconds.

For the UF-4 fabric two filling material and fabric combinations met the requirements of the draft test protocol: woven bag containing feather/fiber blend and nonwoven bag containing loose polyester fiber fill. One hundred percent of the trials conducted on these filling materials ignited and self-extinguished within 120 seconds during the 20-second flame application test.

The latex foam filling material with a 90% self-extinguishment rate performed about the same as the standard foam. However, it did not meet the draft test protocol requirements. Eighteen out of twenty 20 second flame application trials ignited and self-extinguished within 120 seconds. The other two trials ignited and continued to burn beyond 120 seconds.

Five filling materials underperformed the standard foam: untreated cotton batting (67% self-extinguishment rate), interior fabric and non-resinated polyester fiber over 1.5" standard foam (60% self-extinguishment rate), resinated polyester fiber filling (60% self-extinguishment rate), shredded polyurethane foam (20% self-extinguishment rate), and non-resinated polyester fiber filling (40 % self-extinguishment rate). None of these five filling materials met the draft test protocol requirements.

TABLE 2
20 SECOND OPEN FLAME TEST RESULTS FOR UF-4 FABRIC

FILLING MATERIAL	NO. OF MOCKUPS	TOTAL NO. OF FLAME APPLICATIONS TO MOCKUPS	NO. OF 20 SEC. FLAME APPLICA-TIONS TO MOCKUPS	IGNITION AFTER 20 SECOND FLAME Y/N	SELF-EXTINGUISHMENT AFTER 20 SECOND FLAME	
Standard Foam[4]	7	62	13	10 Y 1 Y 2 N	10 Y 1 N ------	92% Passed
Latex Foam	3	32	20	18 Y 2 Y	18 Y 2 N	90% Passed
Unt. Cotton Batting	1	10	9	6 Y 3 Y	6 Y 3 N	67% Passed
Shredded Polyurethane Foam	1	5	5	1 Y 4 Y	1 Y 4 N	20% Passed
Woven Bag Containing Feather/Fiber Blend	1	14	6	6 Y	6 Y	100% Passed
Nonwoven Bag W/Loose Polyester Fill	1	10	4	4 Y	4 Y	100% Passed
Resinated Polyester Fiber Filling	1	13	5	3 Y 2 Y	3 Y 2 N	60% Passed
Non-resinated Polyester Fiber Filling	1	14	5	2 Y 3 Y	2 Y 3 N	40% Passed
Int. Fabric & Non-Resinated Polyester Fiber Over 1.5" Std. Foam	1	11	5	3Y 2Y	3 Y 2 N	60 % Passed

Table 3 shows the ignition results for the UF-21 (olefin twill weave) fabric with the standard foam filling material and with each of the six test filling materials. Ten 20-second flame application trials did not ignite when the olefin fabric was tested with the standard foam[5]. Five other 20 second flame application trials ignited and self-extinguished within 120 seconds. The UF-21 fabric with the standard foam filling material met the draft test protocol requirements 100% of the time. Two other filling material and fabric combinations also met the requirements of the draft test protocol in 100% of the tests: woven bag containing feather/fiber blend and untreated cotton batting. The 20-second flame application trials for these two filling materials ignited and self-extinguished within 120 seconds.

The other four filling materials tested did not meet the requirements of the draft test protocol. The shredded polyurethane foam and the resinated polyester fiber filling over 1.5" standard foam passed only 50% of the tests. The latex foam and the nonwoven bag containing loose polyester fill passed 0% of the tests.

TABLE 3
20 SECOND OPEN FLAME TEST RESULTS FOR UF-21 FABRIC

FILLING MATERIAL	NO. OF MOCKUPS	TOTAL NO. OF FLAME APPLICATIONS TO MOCKUPS	NO. OF 20 SEC. FLAME APPLICA-TIONS TO MOCKUPS	IGNITION AFTER 20 SEC. FLAME Y/N	SELF-EXTINGUISHMENT AFTER 20 SECOND FLAME	
Standard Foam[4]	8	63	15	5 Y 10 N	5 Y ----	100% Passed
Latex Foam	1	8	1	1 Y	1 N	0% Passed
Untreated Cotton Batting	1	13	7	7 Y	7 Y	100% Passed
Shredded Polyurethane Foam	1	6	6	3 Y 3 Y	3 Y 3 N	50% Passed
Woven Bag Containing Feather/Fiber Blend	1	13	5	5 Y	5 Y	100% Passed
Nonwoven Bag Containing Loose Polyester Fill	1	10	3	3 Y	3 N	0% Passed
Resinated Polyester Fiber Filling Over 1.5" Std. Foam	1	6	6	3 Y 3 Y	3 Y 3 N	50% Passed

Table 4 shows the ignition results for the UF-19 (100% cotton twill) fabric with the standard foam filling material and with the California FR foam. The UF-19 fabric over the California FR foam performed about the same as the cotton fabric over the standard foam. When the UF-19 fabric was tested over the standard foam, it ignited and did not self-extinguish within 120 seconds during one 20 second flame application trial. When the UF-19 fabric was tested over the California FR foam one of the 20-second flame application trials self-extinguished within 120 seconds. The other 20 second flame application trials continued to burn beyond 120 seconds. Neither the UF-19 fabric with the standard foam (0% pass rate) nor with the FR foam (20% pass rate) met the draft test protocol requirements.

TABLE 4
20 SECOND OPEN FLAME TEST RESULTS FOR UF-19 FABRIC

FILLING MATERIAL	NO. OF MOCKUPS	TOTAL NO. OF FLAME APPLICATIONS TO MOCKUPS	NO. OF 20 SEC. FLAME APPLICA-TIONS TO MOCKUPS	IGNITION AFTER 20 SEC. FLAME Y/N	SELF-EXTINGUISHMENT AFTER 20 SEC. FLAME	
Standard Foam[2]	2	21	2	2 Y	2 N	0 % Passed
California FR Foam	1	10	5	1 Y 4 Y	1 N 4 N	20 % Passed

CONCLUSION

Two of the eight filling materials tested with the UF-4 (cellulosic/thermoplastic blend) fabric met the requirements of the draft test protocol: woven bag containing feather/fiber fill and the nonwoven bag containing loose polyester fill. The other six filling materials and the standard foam did not consistently meet the requirements of the draft test protocol for the 20-second flame application test.

Two of the six filling materials tested (and the standard foam previously tested) with the UF-21 (olefin twill weave) fabric met the requirements of the draft test protocol: woven bag containing feather/fiber fill and untreated cotton batting. The other four filling materials did not meet the requirements of the draft test protocol for the 20-second flame application test.

The UF-19 (100% cotton twill) fabric over the California FR foam performed about the same as the fabric over the standard foam; however, neither the standard foam nor the FR foam met the requirements of the draft test protocol for the 20-second flame application test.

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UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: May 26, 2000

TO : Dale Ray, Directorate for Economic Analysis,
Project Manager Upholstered Furniture

THROUGH: Andrew G. Stadnik, Associate Executive Director,
Directorate for Laboratory Sciences
Robert T. Garrett, Director,
Division of Electrical Engineering, Laboratory Sciences

FROM : Weiying Tao, Textile Technologist, Division of Electrical Engineering

SUBJECT : Effect of Soiling on the Flammability of Upholstery Fabrics

Introduction

This study was to determine whether soiling of different upholstery fabrics affects the flammability performance of the fabrics to small open flame exposures. Six samples of used upholstery fabrics were collected from two upholstery shops and chemical analyses were performed to identify the soils on these dirty fabrics.[1] Major chemicals found on these dirty fabrics were dodecanoic acid (lauric acid), tetradecanoic acid (myristic acid), hexadecanoic acid (palmitic acid) and octadecanoic acid (stearic acid), which are all classified as "fatty acids" due to their organic makeup and might come from food and body fluids.

Three new upholstery fabrics were soiled with a mixture of these fatty acids. The flammability of both soiled and unsoiled fabrics was tested using the test protocol in the U.S. Consumer Product Safety Commission (CPSC) Staff's Draft Standard for Small Open Flame Ignition Resistance.[2] It was found that fabrics soiled with fatty acids yielded longer mean combustion time than the unsoiled fabrics in most cases. However, the fabrics still self-extinguished within 20 seconds. Soiling with these fatty acids did not affect the flammability performance of the fabrics based on the pass/fail criteria in the draft standard.

Materials and Methods

Three new upholstery fabrics were chosen for preparing soiled fabrics. These fabrics were also used in the interlaboratory (IL) study.[3] They were fabric IL2 (100% wool, 10.99 oz/yd^2), fabric IL3 (88%cotton/12% nylon sateen with flame retardant treatment, 10.33oz/yd^2), and fabric IL4 (92%cotton/8%rayon chenille, 19.83 oz/yd^2). Five grams of each fatty acid (palmitic acid, stearic acid, myristic acid, and lauric acid) were mixed and dissolved in 200ml of ethanol solution. Each fabric specimen (40"x27.5") was sprayed with 10 ml of the mixed solution (with a total of one gram of fatty acid mixture).[1] Specimens were also sprayed with 10ml of pure ethanol as solvent control since ethanol was used as a solvent for the fatty acids.[1] Specimens were dried and conditioned before testing. The specimens were conditioned for at least 24 hours at a temperature of 25±2°C and between 40 and 55% relative humidity, as specified in the protocol.

Table 1 shows the experimental design. Three specimens were cut from each of 5 consecutive blocks of the fabric rolls and randomly assigned to 3 conditions as listed in Table 1. Specimen size was 40"x 27.5" to fit on the CPSC small open flame seating area mockup. Each trial consisted of 3 consecutive burn tests on the specimen. Thus, there were 3 burns on each of 5 specimens in each given condition, which resulted in 15 total burns for each condition.

Table 1. Experimental Design

Trial	Block	Condition*
1	1	0
2	1	1
3	1	2
4	2	1
5	2	0
6	2	2
7	3	1
8	3	2
9	3	0
10	4	1
11	4	0
12	4	2
13	5	0
14	5	1
15	5	2

*Condition 0 = Control (fabric as received)
Condition 1 = Ethanol (fabric with ethanol alone)
Condition 2 = Fatty acid (fabric with fatty acid suspended in ethanol)

The flammability was tested using the test protocol in the CPSC Staff's Draft Standard for Small Open Flame Ignition Resistance.[2] Per the draft standard, a butane flame was applied in the crevice of the seating area test mock-up using a test fixture that accurately placed the flame in the test position for the required time of 20 seconds.[4] The draft standard specifies that the fabric must not ignite or ignition must self-extinguish within 120 seconds. Ignition can be afterflame, afterglow, or smoldering.

Results and Discussion

Fiber content, fabric weight, fabric construction, and finish, in general affect fabric flammability. Test results of fabric flammability for each fabric at three different conditions are shown in Table 2. The data in Table 2 show that the wool and cotton/nylon sateen flame retardant treated fabrics self-extinguished as expected because the wool fabric has natural flame resistance and the sateen is a flame retardant treated fabric containing nylon. Ethanol treatment alone had no effect on fabric flammability for all three different fabrics. The fatty acid soiling increased the mean combustion time for the wool and cotton/nylon sateen fabrics, however, the combustion still self-extinguished within 20 seconds.

For the cotton/rayon chenille fabric, inconclusive results were obtained for all three conditions because ignition did not always self-extinguish. The fabric weight and construction may have contributed to the result. Heavy plain surface fabrics generally have good small flame ignition resistance. However, this is a heavy 100% cellulosic fabric with a raised fiber surface and the raised fibers are not evenly distributed at the fabric surface. Ignition would probably self-extinguish in areas with less raised fibers and not self-extinguish in areas with more raised fibers. This may have affected the testing results. Further study would be needed to clearly understand such an inconclusive result. Overall, fatty acid soiling did not affect fabric resistance to small open flame for all three fabrics.

Table 2. Flammability of Each Fabric at Three Different Conditions

Fabric	Condition	Flame Application Time (sec.)	Ignition (Y/N)	Self-Extinguish (Y/N)	Mean Combustion Time (sec.)
IL2, 100% Wool (10.99 oz/yd^2)	0	20	Y	Y	11
	1	20	Y	Y	11
	2	20	Y	Y	17
IL3, 88/12 cotton/nylon sateen, FR treated, (10.33 oz/yd^2)	0	20	Y	Y	17
	1	20	Y	Y	16
	2	20	Y	Y	20
IL4, 92/8 cotton/rayon chenille (19.83 oz/yd^2)	0	20	Y	4 of 15 tests did not self-extinguish[1]	N/A*
	1	20	Y	3 of 15 tests did not self-extinguish[2]	N/A*
	2	20	Y	4 of 15 tests did not self-extinguish[3]	N/A*

*For these fabrics, ignition did not self-extinguish and had to be extinguished with CO_2 in some cases.

[1]11 of 15 tests self-extinguished (mean combustion time for these 11 tests was 21 seconds)

[2]12 of 15 tests self-extinguished (mean combustion time for these 12 tests was 20 seconds)

[3]11 of 15 tests self-extinguished (mean combustion time for these 11 tests was 27 seconds)

Conclusions

A mixture of palmitic acid, stearic acid, myristic acid, and lauric acid was used to soil three different upholstery fabrics. The effect of fatty acid soiling on the flammability of upholstery fabrics was evaluated. The ignition self-extinguished for both soiled and unsoiled 100% wool and cotton/nylon sateen flame retardant treated fabrics although mean combustion time was increased. Inconclusive results were obtained for both soiled and unsoiled cotton/rayon chenille fabric because the ignition did not always self-extinguish. No significant effect of fatty acid smoldering was trapped in the crevice of the seating area test mock-up in some cases, which is unusual. The variation could be much smaller if those cases were not included.

Table 3. Flammability of Each Fabric Before and After Cleaning

Fabric	Condition	Mean Combustion Time*(sec.)	Range of Combustion Time (sec.)	Coefficient of Variation** (CV%)
cotton/rayon/ polyester FR back coated (IL5)	1(Professional cleaning)	21	17 - 25	12
	2(Home cleaning-A)	20	18 - 23	8
	3(Home cleaning-B)	19	17 - 21	8
	0(Control-uncleaned)	21	19 - 24	7
cotton/nylon Proban treated (IL3)	1	28	16 - 75	69
	2	22	17 - 51	49
	3	21	17 - 30	23
	0	24	17 - 64	66
100% wool (IL2)	1	12	11 - 14	8
	2	12	10 - 14	12
	3	12	10 - 16	15
	0	12	10 - 14	11

*Means are not significantly different at α=0.05 for the same fabric at different conditions.
**CV is a relative measure of variation.

The flammability results are consistent with the results of chemical analyses (Table 4). It is seen from Table 4 that the amount of antimony and DB on fabric IL5 at different cleaning conditions was not significantly different. The amount of phosphorus on fabric IL3 before and after cleaning was not statistically different either. These results indicated that one time cleaning had no significant effect on fabric flammability. One time cleaning did not remove or diminish the flame retardant chemicals on the fabrics.

The small open flame testing results also indicated that the fabric flammability was not affected if there were any cleaning products deposited on the fabrics after cleaning. This is clearly demonstrated in the flammability data of the 100% wool fabric (Table 3). The ignition self-extinguished at 12 seconds consistently both at its original state and after different cleanings for the wool fabric.

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: May 31, 2000

TO : Dale Ray, Directorate for Economic Analysis,
Project Manager Upholstered Furniture

THROUGH: Andrew G. Stadnik, Associate Executive Director,
Directorate for Laboratory Sciences
Robert T. Garrett, Director, Electrical Engineering, Laboratory Sciences
Jim Hyatt, Director, Mechanical Engineering, Laboratory Sciences
Warren Porter, Director, Chemistry, Laboratory Sciences

FROM : Weiying Tao, Division of Electrical Engineering
George Sushinsky, Division of Mechanical Engineering
Bharat Bhooshan, Division of Chemistry
David Cobb, Division of Chemistry

SUBJECT : Cleaning and Wear Effects on Upholstery Fabric Flammability

SUMMARY

The objectives of this study were to determine the effects of cleaning and wear on upholstery fabric flammability and to examine the durability of flame retardant (FR) back coating of fabrics. Flame retardants are commonly used to treat upholstery fabrics to achieve the required flammability performance of the fabrics. Thus as part of the U.S. Consumer Product Safety Commission's (CPSC's) efforts to develop a flammability standard for upholstery fabric, it was necessary to study the effects of cleaning and wear on upholstery fabric flammability to ensure the effectiveness or durability of flame retardant treatment through its potential life. In addition, cleaning products remaining on the fabrics may also affect fabric flammability. In this study, selected upholstery fabrics were cleaned using both professional and home spray cleaning methods. A flame retardant back coated fabric was also pounded repeatedly with a constant force before and after cleaning to simulate sitting (wear). Small open flame tests and chemical analyses were performed to determine whether cleaning and pounding affect flammability and remove or diminish flame retardant chemicals on the fabrics. It was found that cleaning and pounding had no significant effects on the flammability of the upholstery fabrics studied.

EXPERIMENTAL

Upholstery Fabrics

Three different upholstery fabrics that resist small open flame ignition at their original states were included in this study. These three fabrics were also used in the interlaboratory (IL) study.[1] They were fabric IL2 (100% wool fabric), fabric IL3 (cotton/nylon Proban treated fabric), and fabric IL5 (cotton/polyester/rayon flame retardant back coated fabric). The fabrics selected for the study represented fabrics with different FR treatments and fabrics without FR treatments. These three fabrics were cleaned using both professional and home spray cleaning methods to study the cleaning effect on flammability. Fabric IL5 was also pounded with a constant force according to a modified ASTM test method to determine the durability of flame retardant back coating and the combination effect of cleaning and wear on fabric flammability.

Fabric Cleaning

1) Experimental Design

Table 1 shows the experimental design for fabric cleaning. Both professional and home spray cleaning methods were used in this study to determine the effect of cleaning on fabric flammability. One popular professional wet cleaning method was selected to clean the upholstery fabrics. Professional dry cleaning was not used in this study due to its lack of popularity in the market place. Two different, commonly found commercial home foam cleaners were used to clean the fabrics following manufacturer's instructions. All fabrics were cleaned once.

For each fabric, four specimens were cut from three consecutive blocks (portions) of fabric from the same roll (4x3=12 pieces of fabric total) and randomly assigned to four different conditions (cleaning methods) as listed in Table 1. Specimen size was 102cm x 70cm (40in x 27.5in) to fit on the CPSC small open flame seating area mockup. The experimental design was a randomized groups design with four conditions and three specimens (independent observations) per condition. Each specimen consisted of three consecutive flammability tests plus different chemical analyses performed after all the flammability tests were completed. There were total of nine flammability tests for each condition. One-way ANOVA (analysis of variance) was used for statistical analyses.

Table 1. Experimental Design

Trial	Block	Condition (Cleaning Method)
1	1	2 (Home cleaning-A)
2	1	0 (Uncleaned-control)
3	1	1 (Professional cleaning-wet)
4	1	3 (Home cleaning-B)
5	2	0
6	2	3
7	2	2
8	2	1
9	3	3
10	3	2
11	3	1
12	3	0

2) Cleaning Procedures

One professional and two home cleaning methods were used for this study. Professional cleaning was done by a local professional furniture cleaning operator. Home cleaning was done by the laboratory staff following foam cleaner manufacturer's instructions. Each fabric specimen was laid on the specimens of standard foam that would be used for flammability testing, and then cleaning was applied. Both the fabric specimens and foams were labeled and tested together afterward to determine the cleaning effect. Following were the cleaning procedures used:

i) Professional Cleaning

- Spray an even layer of cleaner onto the fabric;
- Brush the fabric and then vacuum;
- Spray an even layer of softener (neutralizer) onto the fabric, vacuum and air dry.

ii) Home Cleaning-A

- Spray a light, even layer of foam cleaner onto the fabric;
- Spread foam evenly with a clean, damp cloth and wipe gently;
- Vacuum when completely dry.

iii) Home Cleaning-B

- Vacuum fabric thoroughly to remove loose dirt;
- Place brush head of foam applicator on fabric and release small amount of foam;
- Spread foam evenly with vigorous, overlapping circular motion;
- Remove excess foam with a clean damp cloth;
- Allow fabric to dry completely, then vacuum.

Wear Testing (Constant Force Pounding)

At least 10 ASTM standards were reviewed to determine if standard test procedures exist for assessing back coating durability of upholstered furniture fabrics. Relevant sections of British Standard BS 4875 were also examined because researchers have used test methods established in BS 4875-85 "Strength and Stability of Furniture" for durability testing of furniture.[2]

Based on the above information and to facilitate testing issues, the following test was proposed to assess the durability of flame-retardant back coating of fabrics. This test is a combination of ideas from ASTM D 3574 - 95 Standard Test Methods for Flexible Cellular Materials - Slab, Bonded, and Molded Urethane Foams - Test I_3 - *Dynamic Fatigue Test by* Constant Force Pounding (Sections 95 to 99), and BS 4875-85 Strength and Stability of Furniture Part 1 - Methods for Determination of the Strength of Chairs and Stools - Section 7.4 - *Test 4: seat and back fatigue test,* with certain modifications. Figure 1 shows the test configuration. Materials and test procedures used for the study are described below:

Figure 1. Wear Testing (Constant Force Pounding)

1) Materials

Fabrics:

The upholstery fabric was placed over a foam pad and compressed under a flat perforated wood platen to achieve about a 20 percent reduction in the thickness of the foam pad. The fabric was stapled to the base platen to maintain the fabric and foam in position. The finished structure resembled a cushion 380mm x 380mm x 51mm (15in x 15in x 2in) in size.

Perforated base platen:

- approximately 380mm x 380mm x 10mm (15in x 15in x 0.38in)
- plywood with an A/B surface against the padding
- Perforations of approximately 6.5-mm (1/4-in) diameter holes on 20mm (3/4 in) centers over a minimum central area of 350mm x 350mm (13.8in x 13.8in).

Seat Construction:

Fabric over 2-inch thick polyether type, polyurethane foam pad.

Impactor:

A flat impactor, described in ASTM D3574, was used to produce large shear effects on the material at the edges of the impactor. The impactor was covered by a piece of denim fabric as shown in Figure 1.

Each material was conditioned for at least 12 hours at 23 ± 2°C and 55 ± 5 percent relative humidity according to ASTM D3574. Tests were conducted under similar environmental conditions in the laboratory.

2) Procedure

A specimen was placed under the test impactor. It was pounded for 200,000 cycles. The test load was 750 ± 20 N (169 ± 4.5 lb_f) at a frequency of 70 cycles per minute.

3) Pounding/Cleaning Combination Methods

The wear testing (constant force pounding) was only applied to fabric IL5 (cotton/polyester/rayon FR back coated fabric). Nine specimens were cut from the fabric roll and randomly assigned to three different conditions (pounding/cleaning combinations) as listed in Table 2. There were three specimens (independent observations) per condition. Each specimen consisted of three consecutive flammability tests plus different chemical analyses performed after all the flammability tests were completed. There were nine flammability tests total for each condition. The results were compared with the data from the fabric at its original state. The flame retardant back coating durability and the combination effect of cleaning and wear on flammability were analyzed.

Table 2. Pounding/Cleaning Combination

Condition	Methods
4	Pounding only
5	Pounding + Professional Cleaning
6	Pounding + Professional Cleaning + Pounding

Fabric flammability was tested using the test protocol in the CPSC Staff's Draft Standard for Small Open Flame Ignition Resistance with certain modifications.[3] A revised test fixture used in the interlaboratory study was used in this study.[1] The specimens were conditioned for at least 24 hours at a temperature of 25 ± 2°C and a relative humidity between 40 and 55 percent before testing. A butane flame was applied in the crevice of the seating area test mock-up using the revised test fixture that accurately placed the flame in the test position for a desired amount of time. A flame application time of 20 seconds was used as specified in the CPSC staff's draft standard. The draft standard specifies that the fabric must not ignite or ignition must self-extinguish within 120 seconds to pass the test. Ignition can be afterflame, afterglow, or smoldering.

As part of a blind-test procedure, the test specimens for each experiment on a given fabric were tested randomly. The observer recording test observations did not know the block or condition of the specimens during testing. The same blind-test method was employed for both flammability testing and chemical analyses.

Chemical Analyses

Chemical analyses were performed to identify the chemicals on the fabrics to determine whether the cleaning and/or pounding remove or diminish the flame retardants from the fabrics. Fabric IL3 (cotton/nylon Proban treated fabric) was analyzed for phosphorus (P) content. Fabric IL5 (cotton/polyester/rayon flame retardant back coated fabric) was analyzed for antimony (Sb) and decabromo diphenyl ether (DB) contents. Chemical analysis was not performed on fabric IL2 because this is a 100% wool fabric without flame retardant treatment.

1) Phosphorus

A 40-50 mg weight of fabric specimen was digested with 2 ml of concentrated nitric acid in a test tube. The solution was diluted to 10 ml with deionized water and then analyzed using an inductively coupled plasma (ICP) atomic emission spectrometer to quantitatively determine the amount of phosphorus on the fabric. Six specimens from each condition were analyzed. The instrument conditions used were as follows:

Torch gas flow:	High flow
Auxiliary gas flow:	1 liter/minute
Nebulizer pressure:	34 psi
Wavelength:	214.94 nm
Pump Speed:	100 rpm
RF setting:	1150

2) Antimony

Antimony was extracted from the fabric by placing a 20-30 mg weight of sample in a test tube with 10 ml of 4N hydrochloric acid at room temperature for about 24 hours. An inductively coupled plasma atomic emission (ICP) spectrometer was used to analyze and quantify antimony in the extract. Six specimens from each condition were analyzed. Following were the instrument conditions:

Torch gas flow:	High flow
Auxiliary gas flow:	1 liter/minute
Nebulizer pressure:	34 psi
Wavelength:	206.833 nm
Pump Speed:	100 rpm
RF setting:	1150

3) Decabromo Diphenyl Ether

Decabromo diphenyl ether (DB) was extracted from fabric samples by placing a 20-30 mg weight of sample in a test tube to which 5 ml of tetrahydrofuran (THF) were added. The test tubes were placed on a shaker and gently agitated for 48 hours at room temperature.

The extracts were analyzed using high pressure liquid chromatography (HPLC) to quantify the amount of DB. The conditions used were as follows:

Column:	Symmetry C18 2.1x100mm
Eluant:	100% acetonitrile
Flow:	0.4 ml/min
Detector:	Photodiode Array (UV-Vis)
Wavelength:	228 nm
Volume Injected:	4μl

The retention time of DB was about 5.0 minutes. DB content was calculated by measuring the peak areas of standards and samples at this retention time, and performing linear regression of peak area versus amount of DB injected. Nine specimens from each condition were analyzed.

RESULTS AND DISCUSSION

Effects of Cleaning

Flammability tests and chemical analyses were performed for each fabric in its original state and after cleaning. To test statistical significance of the differences among these conditions, multiple comparison was computed using ANOVA. The flammability test results and the chemical analysis data are shown in Tables 3-4 respectively. The data presented in this memo are preliminary. In-depth statistical analyses were done by EPHA. During the small open flame tests, no major afterflame or afterglow occurred, but smoldering was observed for all fabrics. All fabrics ignited but self-extinguished within 120 seconds. The data in Table 3 show that the mean combustion time for the same fabric at different cleaning conditions was not significantly different. For fabric IL3, a large variation of the smoldering time occurred because the smoldering was trapped in the crevice of the seating area test mock-up in some cases, which is unusual. The variation could be much smaller if those cases were not included.

Table 3. Flammability of Each Fabric Before and After Cleaning

Fabric	Condition	Mean Combustion Time*(sec.)	Range of Combustion Time (sec.)	Coefficient of Variation** (CV%)
cotton/rayon/ polyester FR back coated (IL5)	1(Professional cleaning)	21	17 - 25	12
	2(Home cleaning-A)	20	18 - 23	8
	3(Home cleaning-B)	19	17 - 21	8
	0(Control-uncleaned)	21	19 - 24	7
cotton/nylon Proban treated (IL3)	1	28	16 - 75	69
	2	22	17 - 51	49
	3	21	17 - 30	23
	0	24	17 - 64	66
100% wool (IL2)	1	12	11 - 14	8
	2	12	10 - 14	12
	3	12	10 - 16	15
	0	12	10 - 14	11

*Means are not significantly different at α=0.05 for the same fabric at different conditions.
**CV is a relative measure of variation.

The flammability results are consistent with the results of chemical analyses (Table 4). It is seen from Table 4 that the amount of antimony and DB on fabric IL5 at different cleaning conditions was not significantly different. The amount of phosphorus on fabric IL3 before and after cleaning was not statistically different either. These results indicated that one time cleaning had no significant effect on fabric flammability. One time cleaning did not remove or diminish the flame retardant chemicals on the fabrics.

The small open flame testing results also indicated that the fabric flammability was not affected if there were any cleaning products deposited on the fabrics after cleaning. This is clearly demonstrated in the flammability data of the 100% wool fabric (Table 3). The ignition self-extinguished at 12 seconds consistently both at its original state and after different cleanings for the wool fabric.

Table 4. Flame Retardant Chemicals on the Fabrics Before and After Cleaning

Fabric	Condition	Antimony (%) (CV%)	DB (%) (CV%)	Phosphorus (%) (CV%)
cotton/rayon/ polyester FR back coated (IL5)	1	2.28 (2.56)	5.04 (6.52)	NA (Not Applied)
	2	2.29 (6.28)	4.82 (4.95)	NA
	3	2.33 (4.25)	4.96 (5.28)	NA
	0	2.36 (7.69)	5.14 (3.89)	NA
cotton/nylon Proban treated (IL3)	1	NA	NA	2.82 (1.28)
	2	NA	NA	2.8 (1.61)
	3	NA	NA	2.97 (6.26)
	0	NA	NA	2.87 (3.81)

Means in columns are not significantly different at $\alpha=0.05$.

Effects of Pounding and Cleaning

There were no differences noted by visual inspection of the backcoatings of the fabric IL5 after the wear tests (constant force pounding) compared to new (untested) fabrics. Tables 5-6 provide the small open flame test and chemical analysis results showing the combination effect of cleaning and pounding. It is seen from Table 5 that the fabric ignited but self-extinguished at 21 to 22 seconds for the control and the pounded/cleaned fabrics. There were no significant differences in the mean combustion time between the control fabric and the fabrics with different combinations of pounding and cleaning.

Table 5. Flammability of FR Back Coated Fabric Before and After Pounding/Cleaning

Fabric	Condition*	Mean Combustion Time** (sec.)	Range of Combustion Time (sec.)	CV%
cotton/rayon/ polyester FR back coated (IL5)	0	21	19 - 24	8
	4	21	19 - 24	10
	5	21	20 - 24	7
	6	22	19 - 23	6

*Condition 0 = Control (fabric as received)
Condition 4 = Pounding only
Condition 5 = Pounding + Professional Cleaning
Condition 6 = Pounding + Professional Cleaning + Pounding
**Means are not significantly different at $\alpha=0.05$.

Table 6 shows that there were no significant differences in the amount of DB present on the fabrics between the control and the pounded/cleaned fabrics. The presence of antimony decreased slightly after pounding plus cleaning. However, this slight decrease of antimony on the fabric did not affect fabric flammability as shown in Table 5. There is no significant effect of pounding/cleaning on the fabric flammability although there is a slight loss of antimony from the fabric.

Table 6. Flame Retardant Chemicals on FR Back Coated Fabric Before and After Pounding/Cleaning

Fabric	Condition	Antimony (%) (CV%)	DB (%) (CV%)
cotton/rayon/ polyester FR back coated (IL5)	0	2.36/a (7.69)	5.14/a (3.89)
	4	2.23/a (4.5)	5.19/a (5.19)
	5	2.14/b (5.93)	5.16/a (8.22)
	6	2.14/b (5.89)	4.91/a (7.34)

Means with the same letter in columns are not significantly different at $\alpha=0.05$.

CONCLUSIONS

Three different upholstery fabrics were cleaned using both professional and home spray cleaning methods. The flame retardant back coated fabric was also pounded with a constant force before and after cleaning to simulate wear (sitting). Small open flame testing and chemical analysis were performed for all fabric conditions to determine the effects of cleaning/wear on the flammability of upholstery fabrics. The results indicated that neither the combustion time nor the presence of flame retardant chemicals on the fabrics was affected by one-time cleaning. Although the amount of antimony present on the flame retardant back coated fabric decreased slightly after pounding plus cleaning, the mean combustion time of the fabric still remained the same as the control fabric. Cleaning and wear had no significant effect on the flammability of the upholstery fabrics.

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3. Draft Standard for Small Open Flame Ignition Resistance of Upholstered Furniture, R. Khanna, ESEM, October 1997, Consumer Product Safety Commission.

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: May 10, 2000

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THROUGH: Andrew G. Stadnik, Associate Executive Director, Laboratory Sciences
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SUBJECT : Small Open Flame Ignition Test Results of "Over-the-Counter" Fabric Finishes

The U.S. Consumer Product Safety Commission's (CPSC's) Directorate of Laboratory Sciences (LS) has conducted tests on upholstery fabrics treated with three "over-the-counter" fabric finishes. Two of them are fabric protectants by different manufacturers that repel spills and stains. The other finish is a "spray-on" fire retardant that claims to raise the ignition temperature of combustible materials and make them harder to burn. Each finish was tested for small open flame ignition.

BACKGROUND

Upholstery fabric numbers 19, 22, and 28 were tested with each fabric protectant applied according to the manufacturer's directions to see how the protectant affected the flammability properties of the fabric. Each fabric was also tested without any protectant to compare the results. Fabrics 19 and 22 are non-fire resistant-treated fabrics and Fabric 28 has a fire resistant backcoating applied to the fabric.

Fabrics 19 and 22 were also tested with the "spray-on" fire retardant to see how well it made the fabric fire resistant. Two different tests were performed. First, the fabric was sprayed with the fire retardant according to the manufacturer's directions, and then tested. The second test was the same as the first except that after the fire retardant was applied, the fabric was soaked in water for 24 hours and then dried to evaluate the durability of the fire retardant finish.

All testing followed the test protocol in the CPSC staff's Draft Standard for Small Open Flame Ignition Resistance of Upholstered Furniture[1].

TEST PROGRAM

The fabrics were evaluated for time to ignition using the CPSC draft test protocol for small open flame ignition. A butane flame was delivered to the seating area test mockup using a test fixture[2] that accurately placed the flame in the crevice of the mockup for a preselected amount of time. Flame application times were varied until the minimum time to ignition was established or the fabric met/or exceeded the 20-second flame application time criteria as specified in the CPSC staff's draft standard. The draft standard specifies a 20-second flame application during which the fabric must not ignite or if an ignition occurs must self-extinguish within 120 seconds. Ignition can include afterflame, afterglow or smoldering.

The conditioning requirements for temperature and humidity specified in the protocol were followed. The standard foam and test fabrics were conditioned for at least 24 continuous hours before testing. They were conditioned at a temperature of 25 ± 2°C and between 40 and 55% relative humidity.

RESULTS

Table 1 presents the results of the Small Open Flame Ignition Tests on the fabrics treated with the three "over-the-counter" fabric finishes. Some testing beyond the scope of the draft protocol was done to further categorize the performance of the fabric finishes. Flame application times greater than 20 seconds shown on the table are the longest tested flame application times when the fabric self-extinguished within the requirements of the draft test protocol.

Protectant: Fabrics 19 and 22 ignited and continued to burn beyond 120 seconds with and without the protectant applied. However, the time to ignition decreased for both fabrics treated with the protectant. With the applied protectant, the time to ignition of Fabric 19 decreased from 16 to 18 seconds to 5 to 7 seconds and Fabric 22 decreased from 7 to 10 seconds to 4 to 6 seconds.

Fabric 28 ignited and self-extinguished with and without the fabric protectant after the standard 20-second flame application. However, the fabric ignited and self-extinguished without the protectant after a 35-second flame application but did not self-extinguish with the protectant after a 30-second flame application. Time to ignition did not change when the fabric protectant was applied.

Fire Retardant Spray: Fabrics 19 and 22 ignited and self-extinguished with a 20-second flame application after the fire retardant spray was applied. Fabric 19 also ignited and self-extinguished with a 90-second flame application. Fabric 22 also ignited and self-extinguished with a 35-second flame application. Although both fabrics continued to meet the 20-second flame application criteria, the time to ignition decreased after the spray was applied. Fabric 19 decreased from 16 to 18 seconds to 6 to 7 seconds and Fabric 22 decreased from 7 to 10 seconds to 3 to 4 seconds.

Neither fabric passed the small open flame ignition test when treated with the fire retardant finish and then soaked in water for 24 hours. They both ignited and continued to burn beyond 120 seconds. The time to ignition increased after soaking but was still less than the ignition time of the untreated fabrics.

TABLE 1
SMALL OPEN FLAME IGNITION TESTS OF "OVER-THE-COUNTER" FABRIC FINISHES

FABRIC IDENTIFICATION	FINISH	TIME TO IGNITION (seconds)	20-SECOND FLAME APPLICATION
UF No. 19	None	16-18	ignited and continued to burn beyond 120 seconds (2 trials)
100% cotton	Protectant 1	5-7 and self-extinguished	ignited and continued to burn beyond 120 seconds (2 trials)
(12 oz/yd^2)	Protectant 2	<1 and self-extinguished	ignited and self-extinguished 2 out of 5 trials
	Fire Retardant Spray	6-7 and self-extinguished	ignited and self-extinguished (3 trials); also ignited and self-extinguished after a flame application of 90 seconds (1 trial)
	Fire Retardant Spray and Soaked in Water for 24 hours	7-8 and self-extinguished	ignited and continued to burn beyond 120 seconds (4 trials)
UF No. 22	None	7-10	ignited and continued to burn beyond 120 seconds (1 trial)
56% rayon 34% polyester	Protectant 1	4-6 and self-extinguished	ignited and continued to burn beyond 120 seconds (2 trials)
10% cotton	Protectant 2	3-4 and self-extinguished	ignited and continued to burn beyond 120 seconds (5 trials)
(10.3 oz/yd^2)	Fire Retardant Spray	3-4 and self-extinguished	ignited and self-extinguished (3 trials); also ignited and self-extinguished after a flame application of 35 seconds (1 trial)
	Fire Retardant Spray and Soaked in Water for 24 hours	7-9 and continued to burn beyond 120 seconds	ignited and continued to burn beyond 120 seconds (3 trials)
UF No. 28	None	2-3 and self-extinguished	ignited and self-extinguished (2 trials); also ignited and self-extinguished after a flame application of 35 seconds (1 trial)
	Protectant 1	2-3 and self-extinguished	ignited and self-extinguished (5 trials); ignited and continued to burn beyond 120 seconds after a 30-second flame application (1 trial)