United States
CONSUMER PRODUCT SAFETY COMMISSION
Washington, D.C. 20207

MEMORANDUM

DATE: April 3, 1997

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

Through : Andrew G. Ulsamer, Ph.D., Associate Executive Director, AGU Directorate for Laboratory Sciences

FROM : Frank A. Vitaliti, Division of Engineering Laboratory FAV

SUBJECT: Evaluation of the Cigarette and Open Flame Ignition Resistance of a Flame Retardant Backcoated Fabric

This memorandum reports the results of testing to determine the cigarette ignition resistance and time to small open flame ignition of a 100% olefin woven fabric with a flame retardant (FR) backcoating. The fabric was provided by the manufacturer. The test results for the fabric are compared to those of a previously tested FR backcoated fabric.

BACKGROUND

Thermoplastic fabrics, such as olefins, have a high degree of resistance to cigarette ignition, but tend to melt away and/or burn when exposed to an open flame exposing the filling materials below.[1] The test fabric adds a new dimension to thermoplastic ignition behavior by virtue of its FR backcoating.

TEST PROGRAM

The Fabric Classification Test Method[2], part of the Upholstered Furniture Action Council (UFAC) Voluntary Program was used to evaluate the cigarette ignition resistance of the subject upholstery fabric. The fabric to be tested is placed over polyurethane foam using a small scale mockup is shown in Figure 1.

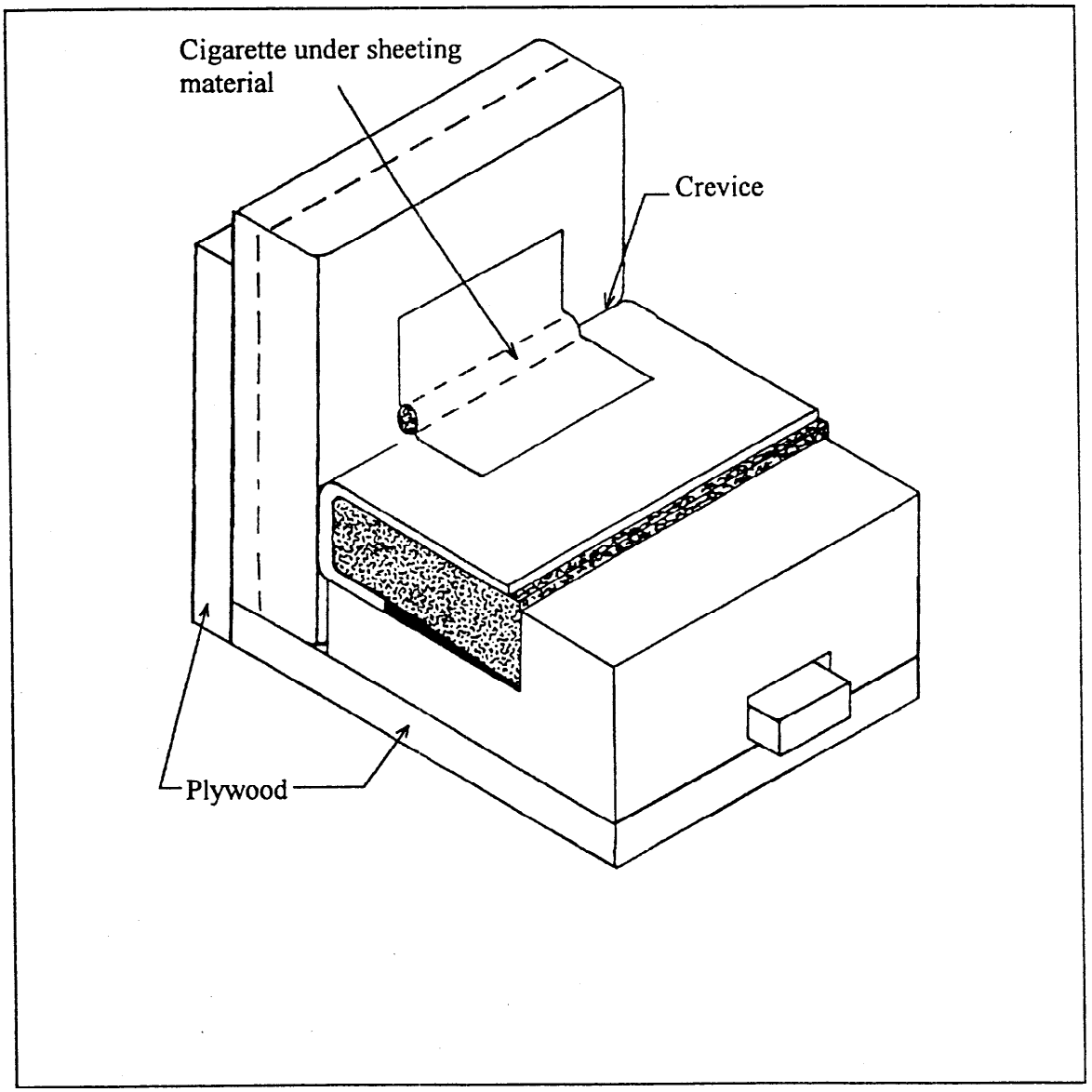


Figure 1 UFAC test mockup

The mockup consists of two square pieces of wood, each nominally 8 inches by 8 inches by 0.75 inches thick and joined at one edge is used. Vertical and horizontal panels containing the upholstery fabric over a standard foam substrate are placed in the mockup. Unfiltered Pall Mall cigarettes are lighted and used as the ignition source. The cigarette is placed in the crevice formed at the intersection of the two

panels and covered with a 5 inch by 5 inch piece of unlaundered cotton sheeting fabric. A minimum of three test specimens are tested. Fabrics with a vertical char of less than 1.75 inches above the mockup crevice are Class I. All other fabrics are Class II and are required by UFAC to have an approved barrier between the cover fabric and conventional polyurethane foam in the horizontal seating surface.

The conditioning requirements specified in the UFAC Fabric Classification Test Method were followed. Test specimens were conditioned for at least 4 continuous hours prior to testing at a temperature of 21± 3°C (70± 5°F) and 50 to 60% relative humidity.

The time to open flame ignition test uses the seat mockup specified in the draft test protocol[3] developed by CPSC staff (see Figure 2).

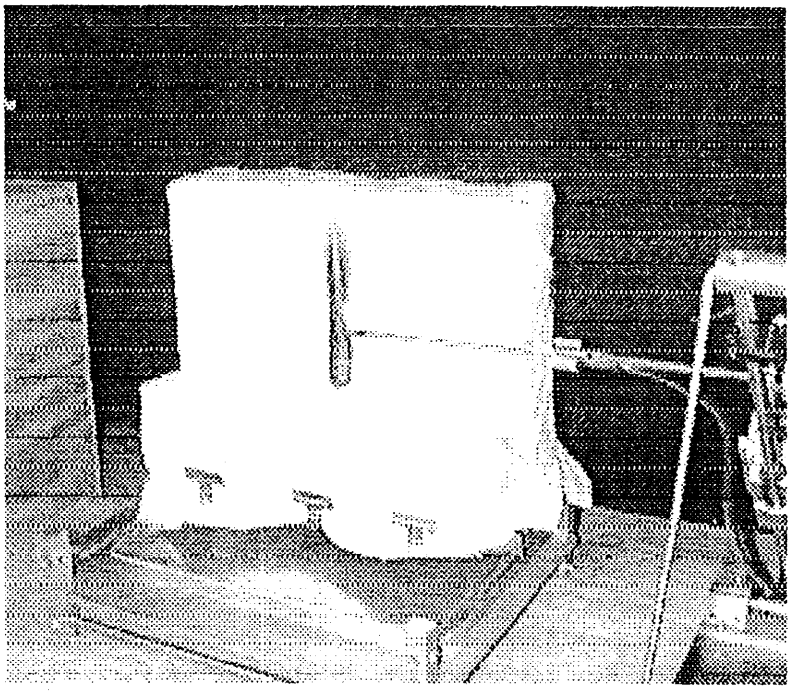


Figure 2 Open Flame Seat Mockup

The small butane flame is delivered to the test material using a test fixture that accurately places the flame in the crevice of the seat for a preselected amount of time.

The conditioning requirements specified in the protocol were followed. Standard materials and test specimens were conditioned for at least 24 continuous hours prior to testing at a temperature of 25 ± 2°C and between 40 and 55% relative humidity.

RESULTS

The fiber content of the fabric, its resistance to smoldering (cigarette) and small open flame ignition are presented in Table 1.

Cigarettes placed on the 100% olefin fabric burned their entire length with a vertical char length of 0.9 inches or less. The upholstery fabric is thus classified as a UFAC Class I.

In the open flame test, the fabric started to melt at 3 seconds, exposing the filling material (foam) underneath. The longer the flame was applied (up to 24 seconds), the greater the area of foam exposed, but neither foam nor fabric ignited. The fabric and foam both ignited when the open flame was held for 25 seconds, and self-extinguished in 3 out of 4 trials. This fabric and the foam ignited more consistently at 29 to 30 seconds and self-extinguished in 50% to 75% of trials. At 31 seconds the fabric ignited and continued to burn beyond 120 seconds in 3 out of 4 trials. The foam also ignited at 29 to 31 seconds.

Initially the olefin prevented the foam from igniting, even though the fabric melted away. The foam appeared to ignite only after a sufficient area is exposed. A certain amount of exposed foam surface area appears to be necessary to sustain an ignition. When the foam ignited, it continued to burn rapidly upwards and ignited the fabric.

In comparison, the interlab[4] FR backcoated fabric, which has a high cellulosic content (60% rayon, 36% polyester, and 4% cotton), ignited at 30 seconds and self-extinguished in 12 seconds. In addition and most importantly, the interlab fabric chars instead of melting away, and helps to protect the filling material underneath the fabric. The cellulosic/thermoplastic blend fabric thus offers greater protection against open flame ignition than the thermoplastic fabric.

The standard foam commonly used in upholstered furniture with a density of 1.5 lbs/ft^3, without any fabric installed, was also tested for open flame ignition resistance. The bare foam ignited repeatedly at 2 seconds and self-extinguished between 4 and 5 seconds. At 3 seconds the foam ignited and continued to burn beyond 120 seconds.

TABLE 1

SMOLDERING IGNITION AND SMALL FLAME RESISTANCE

FABRIC	RESISTANCE TO SMOLDERING (CIGARETTE) IGNITION	RESISTANCE TO SMALL OPEN FLAME
100 % Olefin (FR back-coated)	cigarettes burned the entire length, char ≤ 0.9 inches	did not ignite from 3 to 24 sec., fabric melted away and exposed foam did not ignite
		ignited at 25 to 29 sec., self-extinguished 75% of trials, or continued to burn beyond 120 sec.
		ignited at 30 sec., self-extinguished 50% of trials, or continued to burn beyond 120 sec.
		ignited at 31 sec., self-extinguished 25% of trials, or continued to burn beyond 120 sec.

CONCLUSION

The FR backcoated olefin fabric tested for smoldering cigarette ignition was found to be resistant to cigarette ignition (UFAC Class I). The olefin fabric and foam began to ignite in the open flame test after 25 second of flame exposure and did not always self-extinguish. In trials with increasingly high flame exposures above 25 seconds, the melting away of the fabric allowed the foam underneath to become involved in the fire which then appeared to ignite the fabric.

REFERENCES

1. NBS Monograph 173, "Fire Behavior of Upholstered Furniture", Vytenis Babrauskas and John Krasny, November 1985.

2. UFAC Test Methods, Upholstered Furniture Action Council, 1990.

3. "Bench Scale Test Method For Upholstered Furniture Ignition Resistance To Small Open-Flame Sources", Draft, September 1996, Consumer Product Safety Commission.

4. Memorandum to Dale Ray from Linda Fansler, LSEL, Ignition Time Tests for Interlaboratory Evaluation Fabrics, September 25, 1996, Consumer Product Safety Commission.

United States
CONSUMER PRODUCT SAFETY COMMISSION
Washington, D.C. 20207

MEMORANDUM

DATE: April 4, 1997

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

Through : Andrew G. Ulsamer, Ph.D., Associate Executive Director, Directorate for Laboratory Sciences AGU

FROM : Frank A. Vitaliti, Division of Engineering Laboratory FAV

SUBJECT: Cigarette Ignition Resistance For A Range Of Upholstery Fabrics With And Without Fire Blocker Backings And Fabrics From Full Scale Chair Tests

This memorandum reports the results of tests to determine the cigarette ignition resistance of a range of upholstery fabrics. Two sets of fabrics were evaluated. The first set consisted of five upholstery fabrics with and without an aramid fire blocker backing and a flocked fiber on Kevlar®, all of which had been previously tested for open flame ignition resistance in the bench scale test.[1] The second set consisted of eight upholstered furniture fabrics previously tested as part of the full scale open flame tests.[2] The upholstery fabrics with and without the fire blocker and Kevlar® were supplied by one manufacturer. The other upholstery fabrics were purchased for the full scale open flame phase of the Upholstery Furniture Project.

TEST PROGRAM

The objective of the test program was to evaluate the cigarette ignition resistance of these 19 upholstery fabrics. The fabric type and characteristics are described in Tables 1 and 2.

The Fabric Classification Test Method[3], part of the Upholstered Furniture Action Council (UFAC) Voluntary Program, was used to evaluate the cigarette ignition resistance of the these upholstery fabrics.

The conditioning requirements specified in the UFAC Fabric Classification Test Method were followed. These require that standard materials and test specimens be conditioned for at least 4 continuous hours prior to testing at a temperature of 21± 3°C (70± 5°F) and 50 to 60% relative humidity.

This test method uses a mockup (Figure 1) to establish the performance level of upholstery cover fabrics in contact with polyurethane foam with respect to cigarette ignition resistance.[3] The mockup consists of two square pieces of wood, each nominally 8 inches by 8 inches by 0.75 inches thick and joined at one edge. Vertical and horizontal panels containing the upholstery fabric over a standard foam substrate are placed in the mockup. Unfiltered Pall Mall cigarettes are used as the ignition source and are placed in the crevice formed at the intersection of the two panels. The cigarette is covered with a 5 inch by 5 inch piece of unlaundered cotton sheeting fabric during the test. A minimum of three test specimens are required for each upholstery fabric to be classified. Fabrics with a vertical char of less than 1.75 inches above the mockup crevice are Class I: All other fabrics are Class II (and require an approved barrier between the cover fabric and conventional polyurethane foam in the horizontal seating surface).

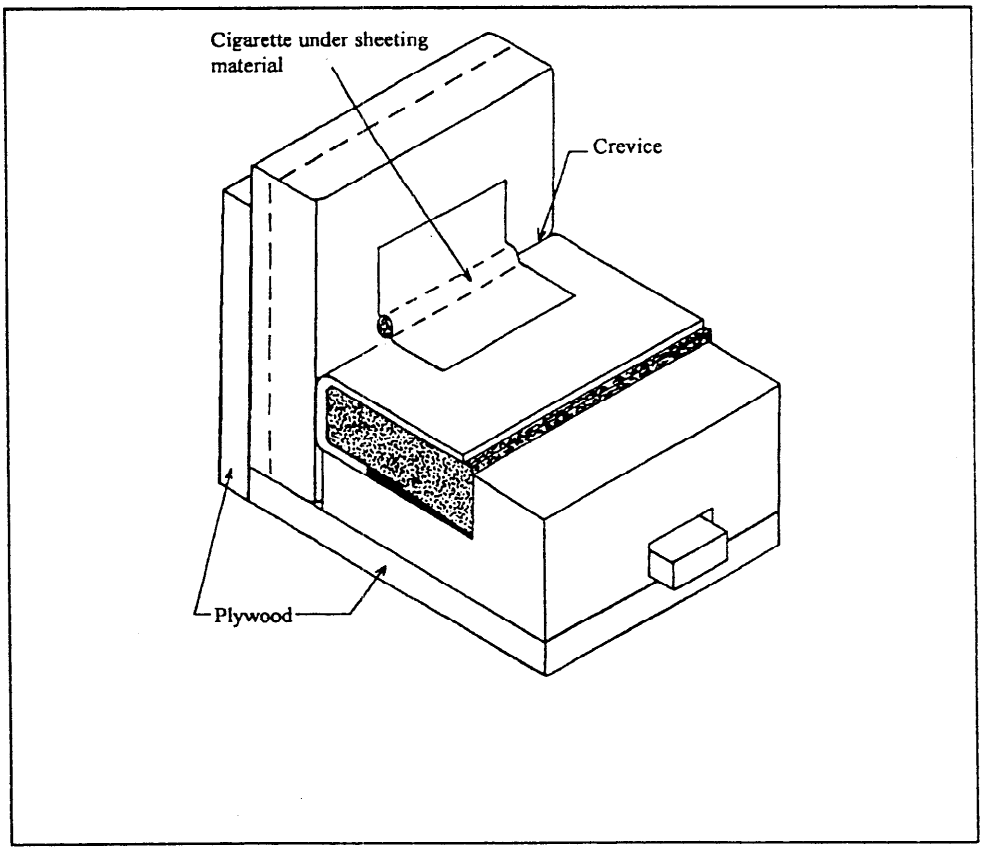


Figure 1 UFAC test mockup

RESULTS

The fiber content of each of the two sets of fabrics and their resistance to smoldering (cigarette) ignition are presented in Table 1 (fire blocker set) and Table 2 (full scale open flame set). The cigarettes placed on all fabrics in both sets burned their entire length. The vertical chars for all the fabrics were 1.1 inches or less. All nineteen upholstery fabrics were thus UFAC Class I.

The thermoplastic fabrics with fire blocker (in Table 1) melted away, exposing the Kevlar® fire blocker layer underneath, whereas the thermoplastic fabrics without fire blocker exposed the foam. The vertical chars were less on fabrics with fire blocker than on fabrics without fire blocker. The difference in vertical chars varied from 0.1 to 0.6 inches.

The microfiber velvet nylon with fire blocker (Fabric No. Ia) had the least vertical char (0.0 inches) while the olefin without fire blocker (Fabric No. IV) had the greatest vertical char (1.1 inches).

The one cellulosic fabric in Table 1 (Fabric No. Va) had a vertical char of 0.6 inches, while the same fabric without the fire blocker (Fabric No. V) yielded a char of 1.0 inches. Both are similar to vertical chars of the thermoplastic fabrics with and without a fire blocker.

In the small open flame time to ignition tests[1] of the same fabrics in Table No. 1, nine of the 11 fabrics tested ignited in 12 seconds or less. Fabric No. I, a nylon fabric without the fire blocker ignited in 21 seconds while Fabric No. Ia (the same fabric with the fire blocker) ignited when the flame was applied for 24 seconds. Neither fabric self-extinguished after igniting.

The fabrics in Table 2 had vertical chars ranging from 0.5 to 1.0 inches. These results indicate there is no apparent correlation between fabric weight, construction or fiber content and the resistance of these fabrics to cigarette ignition. The results are similar to those observed for the fabrics in Table 1 (except for the microfiber velvet nylon with fire blocker).

In the full scale small open flame tests[2] of the same fabrics in Table 2, seven of the eight ignited when a 35 mm butane flame was applied for 15 seconds or less. The remaining cotton fabric on Chair No. 7 ignited in a range greater than 15 seconds but less than or equal to 20 seconds, and did not self-extinguish. Although this fabric appeared to resist small open flame the longest, the char produced by the cigarette ignition test was within the same range as the rest of the fabrics in Table 2.

TABLE 1

CIGARETTE IGNITION TESTS OF UPHOLSTERY FABRICS WITH AND WITHOUT FIRE BLOCKER

FABRIC NO.	FIBER CONTENT	FABRIC CONSTRUCTION	FABRIC WEIGHT (oz/yd^2)	RESISTANCE TO SMOLDERING (CIGARETTE) IGNITION (char in inches)
I	Nylon: thermplstic.	microfiber velvet	7.2	cigarettes burned entire length, char $\leq$ 0.6
Ia	Nylon w/ FB*	microfiber velvet	11.5	cigarettes burned entire length, char = 0.0
II	Nylon: thermplstic.	woven jacquard	6.9	cigarettes burned entire length, char $\leq$ 0.5
IIa	Nylon w/ FB*	woven jacquard	11.3	cigarettes burned entire length, char $\leq$ 0.4
III	Polyester: thermplstic.	jacquard	7.4	cigarettes burned entire length, char $\leq$ 0.7
IIIa	Polyester w/ FB*	jacquard	12.1	cigarettes burned entire length, char $\leq$ 0.5
IV	Olefin: thermplstic.	woven	5.8	cigarettes burned entire length, char $\leq$ 1.1
IVa	Olefin w/ FB*	woven	10.1	cigarettes burned entire length, char $\leq$ 0.8
V	Cotton: cellulosic	printed woven	5.1	cigarettes burned entire length, char $\leq$ 1.0
Va	Cotton w/ FB*	printed woven	9.6	cigarettes burned entire length, char $\leq$ 0.6
VI	Nylon on Kevlar®**	nylon flocked on aramid	5.0	cigarettes burned entire length, char $\leq$ 0.7

* FB = Fire Blocker

** Kevlar® = Fire Blocker

thermplstic. = thermoplastic

TABLE 2

CIGARETTE IGNITION TESTS OF UPHOLSTERY FABRICS FROM FULL SCALE OPEN FLAME CHAIRS

CHAIR NO.	FIBER CONTENT	FABRIC CONSTRUC-TION	FABRIC WEIGHT (oz/yd^2)	RESISTANCE TO SMOLDERING (CIGARETTE) IGNITION (char in inches)
1	cotton-rayon: cellulosic blend	woven-damask	8.4	cigarettes burned entire length, char $\leq$ 0.8
2	polyester-olefin: thermoplastic blend	woven with napped pattern	10.8	cigarettes burned entire length, char $\leq$ 0.7
4	polyester-cotton: thermplstic.& cellul. blend	woven-dobby	7.4	cigarettes burned entire length, char $\leq$ 0.5
5	cotton-rayon & polyester: cellulosic & thermplstic. blend	woven-plain	8.5	cigarettes burned entire length, char $\leq$ 0.7
6	polyester-cotton: thermplstic.& cellul. blend	woven-damask	8.6	cigarettes burned entire length, char $\leq$ 0.6
7	cotton: cellulosic	woven-damask	13.0	cigarettes burned entire length, char $\leq$ 0.6
8	cotton: cellulosic	woven-damask	7.5	cigarettes burned entire length, char $\leq$ 0.8
9	cotton: cellulosic	woven-basketweave	9.4	cigarettes burned entire length, char $\leq$ 1.0

CONCLUSION

All 19 fabrics tested for smoldering cigarette ignition were found to be UFAC Class I fabrics. The fabrics with the fire blocker tended to char less than those without the fire blocker. Only one fabric (the nylon with fire blocker) did not produce any char.

The cotton fabrics tested (with weights ranging from 5 to 13 oz/yd^2) had similar resistance to smoldering ignition from cigarettes.

In previous small open flame tests, two of these 19 fabrics (the nylon microfiber velvet) resisted ignition for 21 and 24 seconds.

REFERENCES

1. Memorandum To Dale Ray From Frank A. Vitaliti, LSEL, Ignition Time Tests For A Range Of Upholstery Fabrics With And Without Fire Blocker Backings, February 4, 1997, Consumer Product Safety Commission.

2. Memorandum To Dale Ray From Linda Fansler, LSEL, Final Report: Upholstered Furniture Flammability Testing: Full Scale Open Flame Data Analysis, February 26, 1996, Consumer Product Safety Commission.

3. UFAC Test Methods, Upholstered Furniture Action Council, 1990.

United States
CONSUMER PRODUCT SAFETY COMMISSION
Washington, D.C. 20207

MEMORANDUM

DATE: March 31, 1997

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

Through: Andrew G. Ulsamer, Ph.D., Associate Executive Director, AGU
Directorate for Laboratory Sciences

FROM : Linda Fansler, Division of Engineering Laboratory LF

SUBJECT: Analysis of Flame Height/Gas Flow

Gas flow rate, outlet pressure and flame height for the butane flame used in the upholstered furniture testing program were monitored to establish that a relatively consistent flame height can be maintained when the gas flow rate and outlet pressure are specified.

BACKGROUND

As part of the upholstered furniture project, a draft test protocol was developed to evaluate the small open flame ignition resistance of three locations on upholstered furniture. The protocol, entitled "Bench Scale Test Method For Upholstered Furniture Ignition Resistance To Small Open Flame Sources"[1], specifies that a small flame be applied to mockups representing three locations on upholstered furniture, the skirt, dust cover and seating area.

The draft protocol specifies a butane gas ignition source. Consultants[2] and information in the literature[3], have indicated that a specified gas flow rate is critical in delivering a consistent flame to the specimen. When the gas flow rate is specified and maintained, the heat flux delivered will be consistent for a given flame height. The flame height, gas flow rate, and outlet pressure were monitored during routine tests[4] conducted in August 1996 to verify the relationship with the burner setup specified in the draft test protocol.

[1] Superscript refers to references on page 4.

TEST PROGRAM

The objective of this program was to determine the relationship between the flame height and the butane gas flow rate and outlet pressure of the test setup. The gas flow rate was monitored using a self-contained mass flowmeter with a range of 0 to 200 ml, calibrated for nitrogen. The flow rate of the butane gas was calculated using the conversion factor of 0.2822[5] to obtain the equivalent gas flow rate of 45 ± 2 ml/min. The specified outlet pressure of 0.4 psi was achieved with a dual stage regulator and a high accuracy needle valve. A burner tube having a 5/16 inch outside diameter with a 0.035 inch wall thickness, was connected by flexible tubing to a cylinder containing butane gas. These test conditions resulted in a flame height of approximately 35 mm.

The burner setup was initially turned on before testing began and allowed to "warm up" before data were recorded. The outlet pressure was set to 0.4 psi and a gas flow range of 157 ± 7 ml/min (equal to 45 ± 2 ml/min of butane) was supplied by the mass flowmeter. The flame height was measured periodically throughout the testing using a flame height gage constructed by the Engineering Laboratory. These three parameters were monitored, adjustments were made if necessary and the system was allowed to stabilize before testing continued.

A test fixture that automatically controls the placement of the flame and the time that the flame is applied was used for all tests.

RESULTS

The results of these tests are presented in Table 1. After an initial "warm up" period, (during which air was being purged from the gas line), it was determined that a butane flame of approximately 34 to 35 mm could be maintained when the gas flow rate and outlet pressure met the specifications in the draft protocol. The small variations in test room temperature and humidity monitored on these two test days did not appear to influence results.

Holding the pressure constant at 0.4 psi resulted in a flame height of 35 mm while the flow rate varied between 156 and 166 ml/min, a variation of about 6%. Similarly at a flame height of 34 mm with a pressure of 0.4 psi, the flow rate varied from 155 to 158 ml/min, about a 2% variation in flow rate. These differences in flow rate may reflect some imprecision in flame height measurements as well as insensitivity of the flame height to small changes in flow rate.

TABLE 1
FLOW RATE/FLAME HEIGHT/OUTLET PRESSURE

DAY	TIME	FLOW RATE (ml/min)	FLAME HEIGHT (mm)	PRESSURE (psi)	TEMP. °F	% RH
8-23-96	9:50	165	~25	0.4	70	60
	10:00	159	~30	0.4	70	60
	10:20	157	~32	0.4	69	60
	10:45	158	35	0.4	69	58
	11:15	160	35	0.4	68	59
	11:40	159	35	0.4	69	60
	12:25	161	35	0.4	68	59
	1:25	157	34	0.42	67	58
	1:45	156	35	0.4	68	59
	2:25	153	33	0.38	68	59
	2:42	157	35	0.4	68	59
	4:20	164	35	0.4	66	62
	4:50	162	35	0.4	68	64
	5:15	162	35	0.4	68	66
	5:35	163	35	0.4	68	62
	5:45	163	35	0.4	67	63
8-27-96	10:50	163	35	0.4	70	58
	11:10	157	35	0.4	68	58
	11:30	155	34	0.4	70	59
	12:05	158	34	0.4	70	56
	12:35	157	34	0.4	70	55
	1:00	157	34	0.4	70	55
	1:10	156	34	0.4	70	55
	1:45	158	34	0.4	69	55
	2:20	162	35	0.4	69	55
	3:10	163	35	0.4	69	54
	3:20	162	35	0.4	69	54
	3:50	166	35	0.4	70	54
	4:07	154	33	0.4	70	54

CONCLUSION

This limited study indicates that using a gas flow rate of 45 ± ml/min and outlet pressure of 0.4 psi (as specified in the draft protocol), a butane flame with a height of approximately 35 mm can be consistently delivered to the test specimen. The small variations in test room temperature and humidity on the two test days did not influence results.

REFERENCES

1. "Bench Scale Test Methods For Upholstered Furniture Ignition Resistance To Small Open-Flame Sources", draft, February 1996, Consumer Product Safety Commission, Directorate For Engineering Sciences.

2. Meeting at the CPSC Engineering Laboratory with consultants to the Upholstered Furniture Project, July 1996.

3. BS 5852 Fire Tests For Furniture, Part 2 Methods Of Test For The Ignitability Of Upholstered Composites For Seating By Flaming Sources, March 1982.

4. Memorandum To Dale Ray From Linda Fansler, LSEL, Ignition Time Tests With Flame Resistant Foams and Polyester Batting, October 3, 1996, Consumer Product Safety Commission.

5. Information provided by Matheson Gas Products, Office of Equipment Engineering Technical Services, Montgomeyville, PA.

United States
CONSUMER PRODUCT SAFETY COMMISSION
Washington, D.C. 20207

MEMORANDUM

DATE: April 30, 1997

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

Through: Andrew G. Ulsamer, Ph.D., Associate Executive Director, AGU
Directorate for Laboratory Sciences

FROM : Linda Fansler, Division of Engineering LF

SUBJECT: Chemical Identification of Flame Retardant Polyurethane Foam and Upholstery Fabrics Backcoated With Flame Retardants

Attached are two reports describing the laboratory analysis conducted by the Directorate for Laboratory Sciences, Division of Chemistry (LSC) to determine the presence of flame retardant (FR) chemicals in polyurethane foam and upholstery fabric. This memorandum summarizes the findings of the laboratory analysis.

Thirteen polyurethane foams taken from the chairs used in the small open flame tests at the Division of Engineering (LSE) were analyzed for the presence of flame retardant chemicals. Flame retardant chemicals must be added to polyurethane foam to meet the flammability standards in the State of California and the United Kingdom.

The small open flame tests conducted by LSE indicated that some of the foams from the "California" chairs did not meet the requirements for flammability issued by the State of California. Flame retardant chemicals were detected in four of the six foams that did not meet the flammability requirements for "California" foam.

Although the small open flame tests conducted by LSE did not indicate a problem with the "United Kingdom" foams, one foam was analyzed for the presence of melamine. Melamine foams are often used in furniture manufactured for the United Kingdom market. The addition of melamine chemicals increases the flame resistance of foam. Melamine was detected in the "United Kingdom" foam.

In small open flame tests conducted by LSE two fabrics, an olefin and a cellulosic/thermoplastic blend, ignited but had the potential to self-extinguish. LSC analyzed the backcoatings on these two upholstery fabrics to determine the type of FR chemicals present and whether migration through to the surface could occur.

The backcoatings of both fabrics contained antimony trioxide, a flame retardant treatment. Small amounts (0.01%) of antimony trioxide could be extracted from the backcoated fabrics with a 0.1 N dilution of hydrochloric acid, water and 0.9% of NaCl. No antimony trioxide was extracted with hexane.

Attachments

cc: W. Porter, LSC
S.-B. Chen, LSC

UNITED STATES GOVERNMENT

MEMORANDUM

U.S. CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, D. C. 20207

TO : Linda Fansler, LSEL
THROUGH : Warren K. Porter, Jr., Director, LSHL
FROM : Shing-Bong Chen, Chemist, LSHL

APR 28 1997

SUBJECT: Migration of Flame Retardant in Fabrics of Upholstered Furniture

Two pieces of fabric were investigated in this study, one is Polyolefin with FR back coating and the other one is Polyester(36%), Rayon(60%) and cotton(4%) with FR back coating. The type of FR used is not known, but could be either organo-phosphate, borate or antimony trioxide.

1. The fabrics were digested with concentrated nitric acid and the digest were analyzed using ICP. The elements of interest are Phosphorus (P) for organo-phosphate, Boron (B) for borate and Antimony (Sb) for antimony Trioxide. The data show they contain traces of Phosphorus (< 0.03 %) and Boron (<0.02%).

2. The fabrics were then extracted with hydrochloric acid in different concentrations for Antimony analysis. The results are in Table 1. Reagent grade antimony trioxide is very soluble in 4N HCl and can be completely recovered with the acid extraction. It was found that Polyolefin and Polyester contain 1.16% and 2.50% of Antimony respectively when extracted with 4N HCl. Only 0.01% of Antimony extracted with 0.1 N HCl from both of fabrics. This represents 0.76% extraction of the total antimony trioxide (1.16%) extracted with 4N HCl from the polyolefin fabric, 0.56 % of the total antimony trioxide(2.50%) from the polyester fabric. It also found that only 0.01% of Antimony were extrcted with 0.9% of NaCl solution or water and 0% with hexane solvent.

Table 1. Antimony Trioxide Extraction with Various Media

Fabric	Extractant	% by wt. of Sb	% by wt. of Sb extracted with 4N HCl
Polyester	4N HCl	2.50	
Polyester	2N HCl	2.01	
Polyester	0.1N HCl	0.01	0.56
Polyester	0.9% NaCl	0.01	
Polyester	water	0.01	
Polyester	hexane	0.00	
Polyolefin	4N HCl	1.16	
Polyolefin	2N HCl	0.83	
Polyolefin	0.1N HCl	0.01	0.76

UNITED STATES GOVERNMENT

MEMORANDUM

U.S. CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, D. C. 20207

JAN 13 1997

TO : Linda Fansler, LSEL
THROUGH : Warren K. Porter, Jr., Director, LSHL
FROM : Shing-Bong Chen, Chemist, LSHL

SUBJECT: Chemical Identification of Flame Retardant in Polyurethane Foams

I. Background

In support of the small open flame ignition phase of the Upholstered Furniture Project, the Division of Health Sciences Laboratory (LSHL) recently chemically analyzed 13 polyurethane foams to determine if flame retardant (FR) chemicals were present. These foams were taken from chairs used in the small open flame tests at the Division of Engineering Laboratory (LSEL)[1].

Chairs 1 through 9 were made to meet the existing small open flame standards in the State of California. Chairs 10 through 18 were made to meet the existing small open flame standard in the United Kingdom. A FR foam is necessary to meet the flammability requirements in both California and the United Kingdom. The small open flame tests conducted at LSEL indicated that some of the foams from the "California" chairs did not meet the requirements for flammability. The foam in the "UK" chairs were protected by fire blocking barriers and did not ignite during testing.

This report describes the results and the methods that were used to analyze for fire retardants in polyurethane foam. A Fourier Transform Infrared Spectrophotometer (FTIR) and Gas Chromatograph/Mass Spectrometry (GC/MS) were used in this analysis. Twelve foams from "California" chairs and one foam from a "UK" chair were analyzed.

II. Method

There are hundreds of Flame Retardants (FR) on the market. Different FRs may require different approaches for sample preparation and instrumental analysis. The methods used in this study follow:

a. Extraction -

California Foam (Chairs 1 - 9) - methylene chloride, 40 grams, was added to a 0.5 grams of the sample in a covered glass container. After sitting for 10-15 minutes, the foam is compressed and the methylene chloride decanted for subsequent analysis.

United Kingdom foam (Chairs 10-18) - Water, 100 milliliters, was added to 1.0 grams of the sample in a beaker and boiled for one hour. The foam was compressed and the hot extract decanted. The white crystals formed after evaporation of the water.

b. Infrared analysis -

The IR spectra of FR were obtained using a Mattson Polaris FTIR system.
California Foams - A thin film on a NaCl window was prepared by the evaporating of solvent from the extract.

United Kingdom foams - A KBr pellet of FR was prepared.

c. Gas Chromatograph/Mass Spectrometry(GC/MS) -

The Total Ion Chromatogram (TIC) was obtained using a HP-6890 GC-MSD system. A diluted methylene chloride or water solution was injected and separated by GC. The mass spectrum of each chemical was then obtained by Mass Spectrometry. The compound identification was done by using search program against NBS and Wiley Library data bases of chemicals mass spectra.

GC conditions -
Column - J & W DB-1, 0.25 mm ID, 30 m, 0.1 um
Oven Temperature - 200°C(2 mins)/ 20°C/min /280°C (Chairs 1-9)
100°C(2 mins)/ 20°C/min /240°C (Chairs 10)
Injector Temperature - 275° C
Carrier Gas - Helium, 1.0 ml/min
Injection - 1 ul splitless injection, 50 ml/min purge

III. Results

The test results of 12 California foam samples, Table 1, show the major FR components present. The Total Ion Chromatogram (TIC) of extract from the side foam of chair no.1 (Fig. 1) gave three major peaks, a library search of mass spectra confirms that the extract is a mixture of triphenyl phosphate, tetrabromodiphenyl oxide and pentaboromodipheny oxide. The TIC of extract of the foam from the seat of chair no.3 (Fig. 2) gives only one major peak, which is identified as tris(1,3-dichloroisopropyl) phosphate (FYROL FR-2) by mass spectrum. The IR spectrum (Fig. 3) of FR from chair no.2 matches a standard spectrum (Fig. 4) of the FR additive DE-60FS supplied to LSHL by Great Lakes Chemical Corporation. This suggests that DE-60F is a mixture of triphenyl phosphate, tetrabromodiphenyl oxide and pentaboromodipheny oxide.

In order to show the use of melamine as FR in United Kingdom polyurethane foam, one United Kingdom foam sample was analyzed for FR. Polyurethane foam from chair no.10 was extracted with hot water. The resulting crystals were confirmed to be melamine by GC/MS. The IR spectrum (Fig. 5) of the crystal also matches closely with Aldrich Library spectrum of 99% pure melamine(Fig. 6).

IV. Conclusion

LSHL has successfully identified the presence or absence of Flame Retardant additives in 13 polyurethane foams used in upholstered furniture. The California foams contain either FYROL FR-2 (1,3-dichloroisopropyl phosphate) or DE-60F (a mixture of triphenyl phosphate, tetrabromodiphenyl oxide and petabromodiphenyl oxide) as flame retardants. The United Kingdom foams contain melamine as flame retardant.

The IR and GC/MS methods developed for identifing FR are greatly superior to X-ray fluorescence (XRF) technique that only give total bromine or chlorine. An additive can be identified by the comparison the IR spectrum of an unknown additive to a spectrum of a known additive. In the case of mixed additives such as DE-60F, the GC/MS method positively identifies each chemical. A measurement of total bromine or chlorine by XRF does not give structural information of individual chemicals.

V. Reference

1. Upholstered Furniture Flammability Testing: Full Scale Open Flame Data Analysis, February 26, 1996, Consumer Product Safety Commission.

Table 1. The Identification of Flame Retardant in Polyurethane Foams

Chair no.	Location	Type of Additive	# Small Open Flame Test Results
1	side	DE-60F	Passed
2	seat	DE-60F	Failed
3	seat	FYROL FR-2	Passed
4	seat	DE-60F	Passed
4	back	* N.D.	Failed
5	seat	DE-60F	Failed
6	seat	FYROL FR-2	Passed
7	seat	DE-60F	Failed
7	side	DE-60F	Failed
8	seat	DE-60F	Passed
8	armrest	N.D.	Failed
9	seat	DE-60F	Passed

* Not Detected

\# Passed or failed California TB 117, Upholstered Furniture Flammability Testing: Full Scale Open Flame Data Analysis, February 26, 1996, Consumer Product Safety Commission.

File : C:\HPCHEM\1\DATA\PU1B-2-5.D
Operator : chen
Acquired : 17 Sep 96 9:12 am using AcqMethod FR
Instrument : GC/MS Ins
Sample Name: PU 1b, side, extract, 29-700 ions
Misc Info : 1ul splitless, 50 purge, 200(2)/20/280(24)
Vial Number: 1

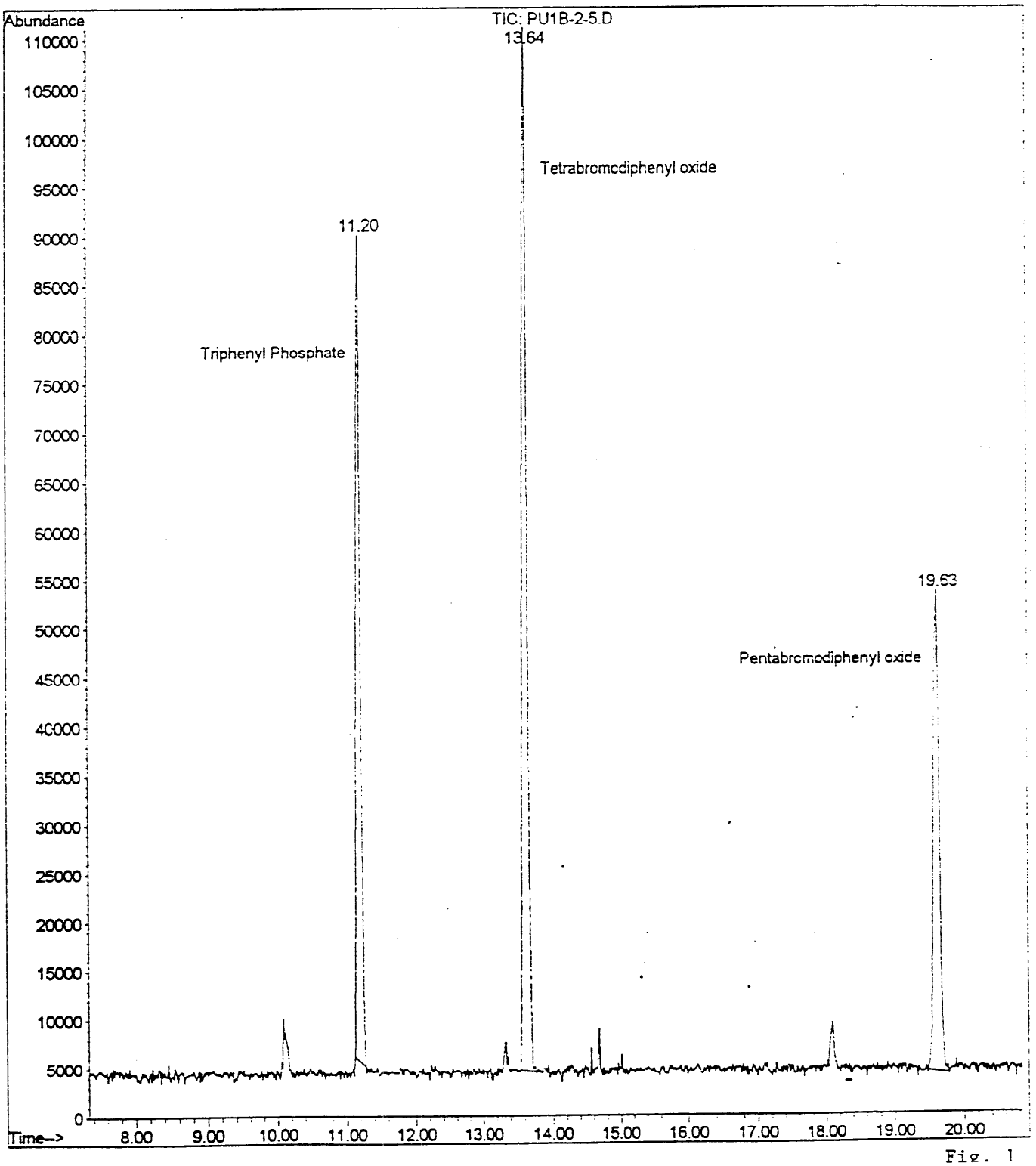


Fig. 1

File : C:\HPCHEM\1\DATA\PU3A-1.D
Operator : chen
Acquired : 12 Sep 96 12:56 pm using AcqMethod FR
Instrument : GC/MS Ins
Sample Name: PU chair 3a, seat, #1, extract
Misc Info : 1 ul, splitless, 50 purge, 200(2)/20/280
Vial Number: 1

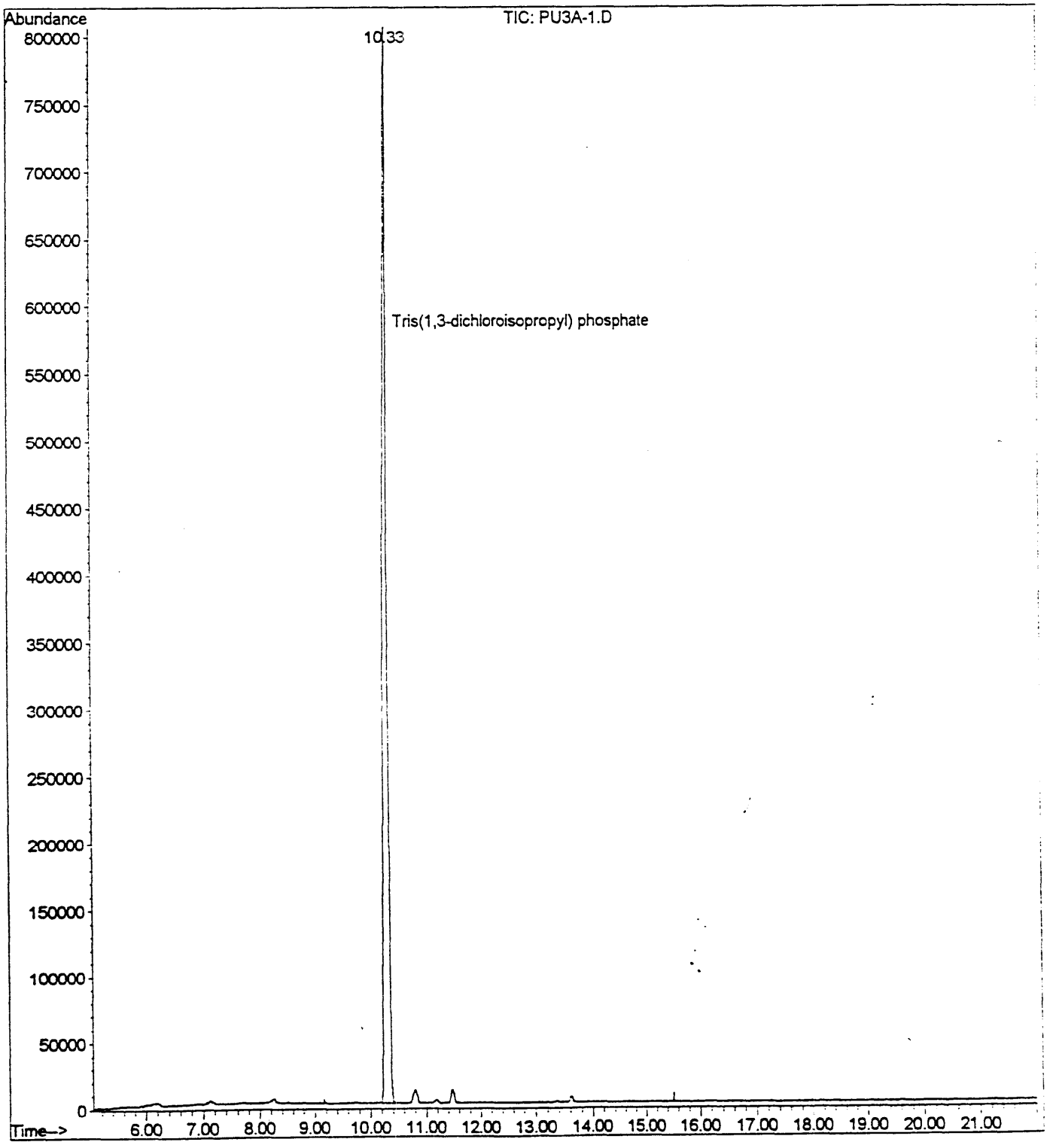
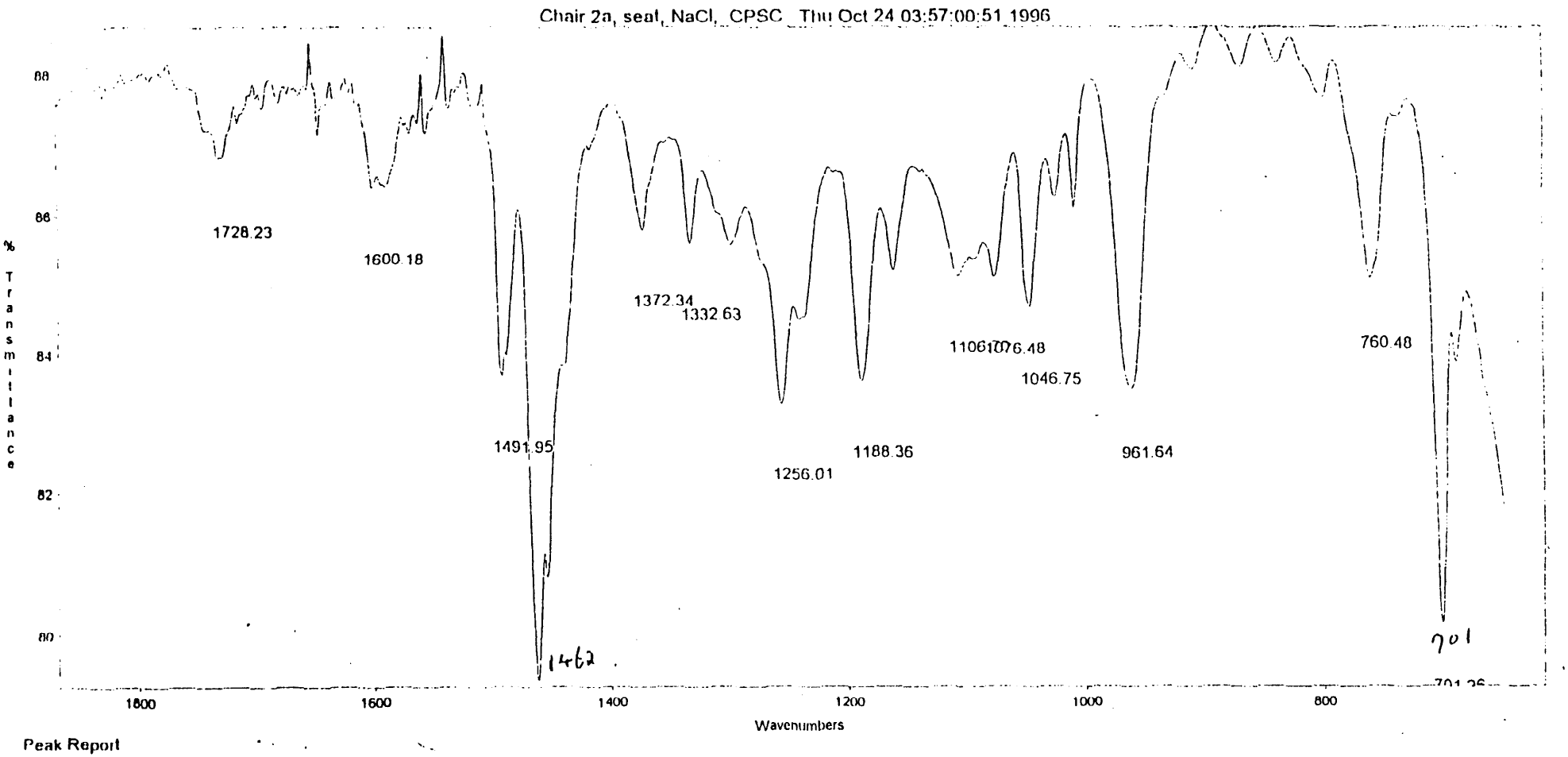


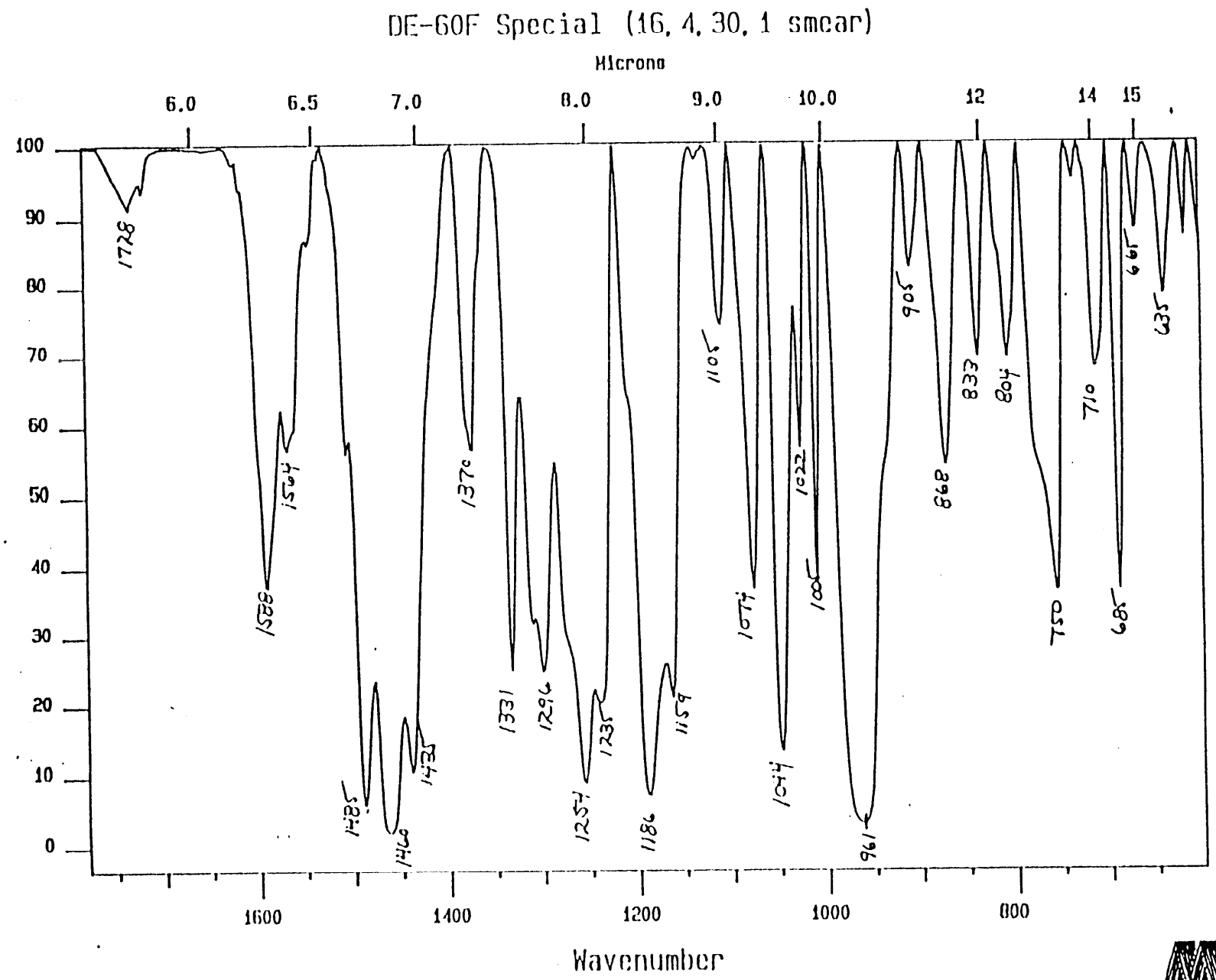
Fig. 2



Peak Report
File: C:\FIRST\DATA\FOAM\FR2A.RAS
Title: Chair 2a, seat, NaCl, CPSC Thu Oct 24 03:57:00:51 1996
Filter: Three Point Center of Gravity

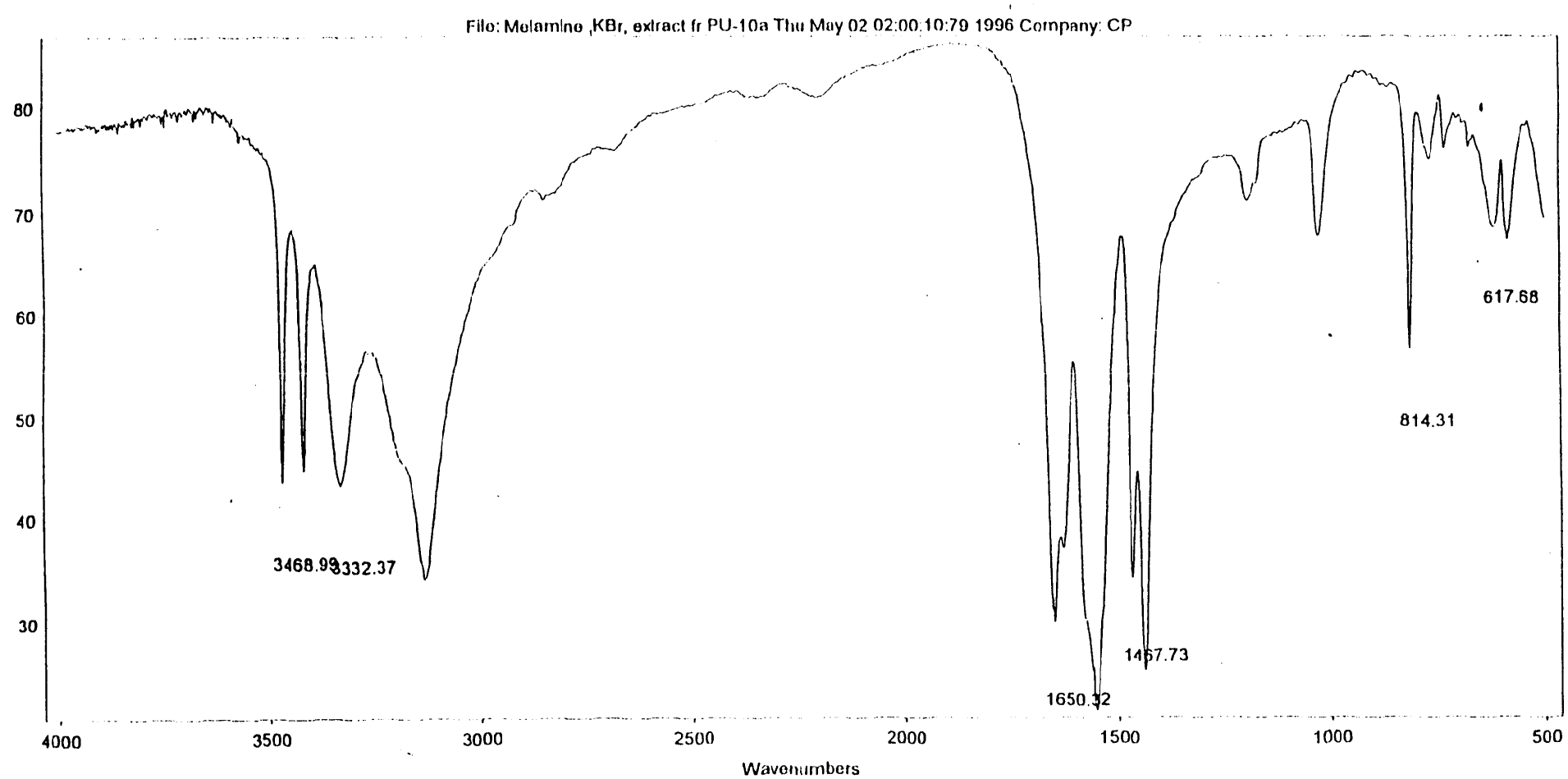
cm-1	%T	cm-1	%T	cm-1	%T	cm-1	%T
1728.23	86.79	1600.18	86.39	1491.95	83.69	1462.24	79.32
1372.34	85.78	1332.63	85.59	1256.01	83.29	1188.36	83.62
1106.70	85.12	1076.48	85.10	1046.75	84.67	961.64	83.51
760.48	85.09	701.26	80.14				

Fig. 3



DE-60FSpec.ran

Fig. 4

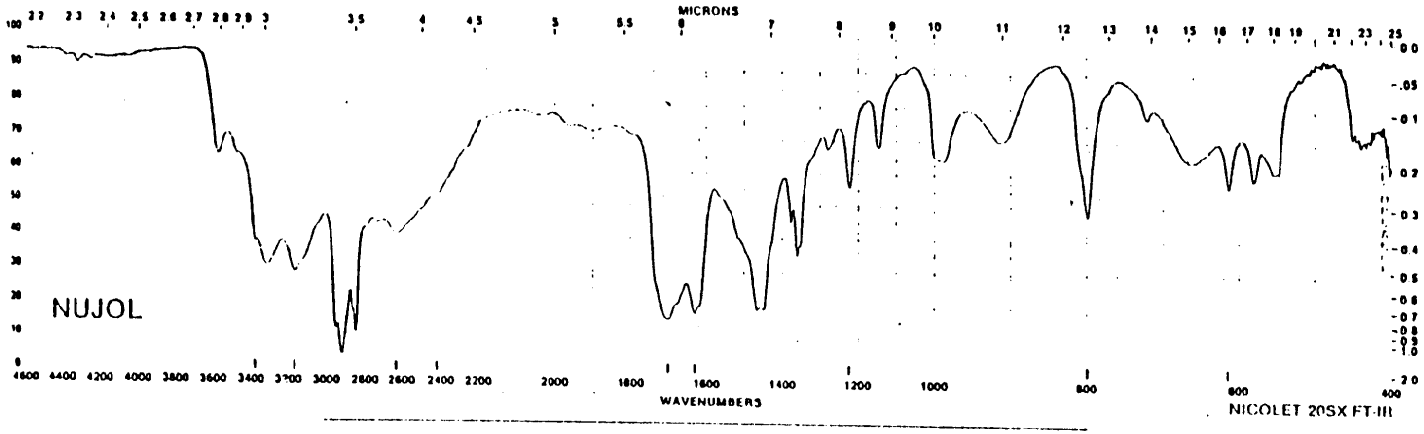


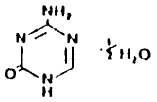
Peak Report
File: C:\FIRST\DATA\FOAM\MELAMINE.RAS
Title: File: Melamine ,KBr, extract fr PU-10a Thu May 02 02:00:10:79 1996 Company: CP
Filter: Three Point Center of Gravity

cm-1	%T	cm-1	%T	cm-1	%T	cm-1	%T
3468.99	43.52	3332.37	43.16	1650.32	29.86	814.31	56.64
617.68	68.64	1551.76	21.07	1467.73	34.27	1438.28	25.02

2635.6 1620.9 613.8

B





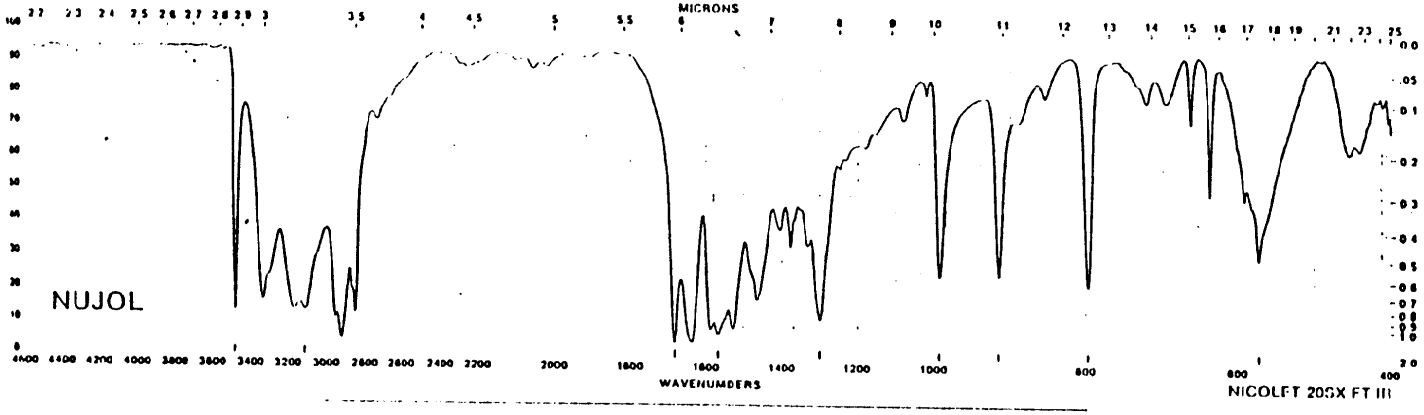
C3330-1 *CAS [3397-62-4]*
2-Chloro-4,6-diamino-1,3,5-triazine, 97%

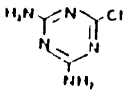
FW 145.55
mp >320°C

IR III, 1381F

3407.1	1566.9	915.6
3118.9	1298.9	797.9
1682.7	993.9	573.3

C





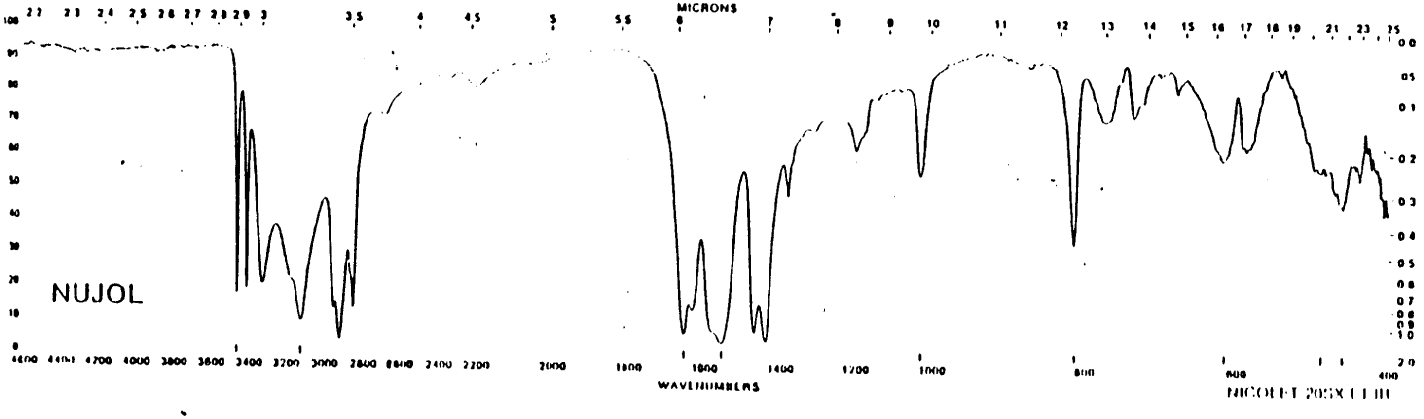
M265-9 *CAS [108-78-1]*
Melamine, 99%

FW 126.12
mp >300°C

IR III, 1382B
Merck 10,5627

3469.4	1553.3	617.4
3132.8	1030.5	489.3
1653.7	814.2	461.5

D



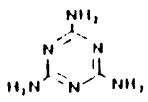


Fig. 6

United States
CONSUMER PRODUCT SAFETY COMMISSION

Washington, D.C. 20207

MEMORANDUM

DATE: June 19, 1997

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

Through: Andrew G. Ulsamer, Ph.D., Associate Executive Director, AGU
Directorate for Laboratory Sciences

FROM : Linda Fansler, Division of Engineering LF

SUBJECT: Inherently Flame Resistant Fabrics And Intumescent Barrier Fabrics

The Directorate for Laboratory Sciences conducted tests on fabrics received from three manufacturers. These fabrics were reported to have flame resistant properties and were evaluated for small open flame and cigarette ignition resistance.

BACKGROUND

A total of eight fabrics were received from three manufacturers. Four of the fabrics were from manufacturer A and were described by the manufacturer as "100% cotton fabrics made from naturally flame resistant cotton fiber". Three of the fabrics were from manufacturer B and were described by the manufacturer as "seating barriers, active barrier - works to extinguish flame". The remaining fabric was received from manufacturer C and was also described as an "active fire barrier".

Laboratory staff evaluated these fabrics using the test protocol in the CPSC draft standard[1] for small open flame ignition resistance, the Upholstered Furniture Action Council (UFAC) Fabric Classification Test Method[2] and a modified version of the UFAC procedure using the CPSC small open flame seating area mockup. One of the fabrics was also evaluated as a dust cover using the test protocol in the CPSC draft standard.

TEST PROGRAM.

The fabrics (see Tables 1,2 and 3 for descriptions), were evaluated for time to ignition from a small butane flame using the CPSC draft test protocol. The butane flame was delivered to the seating area test mockup using a test fixture[3] that accurately placed

[1] Superscript refers to reference numbers on page 7.

the flame in the crevice of the mockup or the underside of the dust cover specimen for a preselected amount of time. Flame application times were varied until the minimum time to ignition was established or the fabric met the 20 second flame application time criteria as specified in the CPSC draft standard.

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

The fabrics were evaluated for cigarette ignition resistance using three protocols. In the first protocol, the UFAC Fabric Classification Test Method was used. The test fabric was placed over standard UFAC foam using a small wooden seat mockup placed inside an enclosure. The lit cigarette was placed in the crevice and covered with a piece of unlaundered sheeting fabric. Char measurements were recorded; fabrics with a vertical char of less than 1.75 inches above the mockup crevice are considered UFAC Class I fabrics.

The conditioning requirements specified in the UFAC test protocol were followed. Test specimens and standard foam were conditioned for at least 4 continuous hours prior to testing at a temperature of 21 ± 3°C and 50 to 60% relative humidity.

In the second and third protocols used to evaluate resistance to smoldering (cigarette) ignition, modified versions of the UFAC protocol were used. The fabrics were placed over the standard foam specified in the CPSC draft protocol using the seating area test mockup without the UFAC test enclosure. In both protocols, the lit cigarette was placed in the crevice. In the second protocol, the cigarette was covered with a piece of unlaundered sheeting fabric while in the third protocol, the burning cigarette was not covered. Char measurements were recorded both in the horizontal and vertical directions.

The conditioning requirements specified in the UFAC test protocol were followed. Test specimens and standard foam were conditioned however, for at least 24 hours prior to testing at a temperature of 21 ± 3°C and 50 to 60% relative humidity.

RESULTS

The results of the tests on fabrics received from manufacturer A are presented in Table 1. The four fabrics received from manufacturer A were labeled as 100% cotton. Two of the fabrics were 4.4 oz/yd^2 and two of the fabrics were 9.4 oz/yd^2 (Table 1). Both lightweight fabrics ignited in 5 seconds and the heavier weight fabrics ignited in 11 to 12 seconds and in 10 to 12 seconds. Once ignited, all fabrics continued to burn and did not self-extinguish. All four fabrics were UFAC Class II fabrics with either obvious ignitions and/or vertical char length measurements greater than 1.75 inches.

Table 1 also presents both the horizontal and vertical char measurements for the tests using cigarettes placed on the CPSC Seat mockup. The horizontal measurements are presented because these fabrics smoldered in the horizontal direction. The char lengths, both vertical and horizontal, are very similar for all fabrics when tested with cigarettes

covered with the sheeting fabric. In the uncovered tests, however, the horizontal measurements are similar (smoldering progressed along the horizontal axis until it reached the edge of the mockup) but the vertical results show considerable variation.

TABLE 1
SMALL OPEN FLAME AND SMOLDERING IGNITION TESTS OF FABRICS REPORTED TO BE INHERENTLY FLAME RESISTANT

FABRIC IDENTIFICATION	TIME TO IGNITION (sec)	CHAR LENGTHS (inches)				
		UFAC (covered, vertical)	CPSC Seat Mockup (covered)		CPSC Seat Mockup (uncovered)	
			vertical	horizontal	vertical	horizontal
muslin, 4.4 oz/yd^2	5	≤ 4.0*	≤ 3.4*	≤ 3.3*	0.4	3.4*
muslin, 4.4 oz/yd^2	5	≤ 0.7*	≤ 2.2*	≤ 3.4*	≤ 6.0*	3.5*
canvas, 9.4 oz/yd^2	11 to 12	≤ 4.0*	≤ 3.1*	≤ 3.3*	≤ 1.5	≤ 3.5*
denim twill, 9.4 oz/yd^2	10 to 12	≤ 2.4*	≤ 3.0*	≤ 3.4*	≤ 1.9	≤ 3.6*

* had one or more obvious smoldering ignitions

Table 2 presents results from testing of the three fabrics from manufacturer B. These were labeled as barrier fabrics containing either corespun cotton or fire retarding fibers (unidentified) covering a glass core. There were two variations of the fabric containing corespun cotton covering a glass core. The difference was the presence of a peel and stick backing application on one of these two corespun cotton over glass core fabrics. Manufacturer B also provided information indicating that these two fabrics were coated with a flame retardant chemical that is "intumescent in its vapor phase" (i.e., the chemical causes the fabric to swell). The third fabric, containing the fire retarding (FR) fibers also "swells, blocking the flames from the fuel source", according to information provided by manufacturer B. All three of these fabrics are intended as barriers and as such were tested with a rayon/polyester/cotton blend upholstery fabric weighing 10.2 oz/yd^2 using the CPSC Seat mockup. The fabric had an ignition time of 7-10 seconds.

All three barrier fabric/upholstery fabric combinations ignited with a 20 second flame application time as specified in the CPSC draft standard, but self-extinguished within seconds. Upon close observation, the barrier/upholstery fabric interface bubbled during combustion, as might be expected of an intumescent substance.

All three barrier fabric/upholstery fabric combinations were UFAC Class I with vertical char measurements less than 1.75 inches. The cigarettes placed on the mockups containing

the peel and stick version of the corespun cotton covering a glass core did not remain lit. As specified in the UFAC protocol, a total of three cigarettes were placed on each of three mockups for a combined total of nine cigarettes that self-extinguished on the UFAC mockups.

The horizontal and vertical char measurements were also recorded for the tests using cigarettes placed on the CPSC Seat mockup. The char lengths for both the vertical and horizontal directions, covered and uncovered, were similar for two of the fabrics, the glass core covered with FR fibers and the non-peel and stick corespun cotton covering a glass core. The cigarettes placed on the mockups containing the peel and stick version of the corespun cotton covering a glass core did not remain lit. A total of three cigarettes were placed on each of three mockups covered with sheeting and three mockups uncovered, for a combined total of 18 cigarettes that self-extinguished during testing.

The fabric containing FR fibers over a glass core was also tested as a dust cover. Results of this time to ignition testing are also presented in Table 2. The barrier fabric was tested alone and in combination with two traditional dust cover fabrics, a cotton/polyester woven dust cover fabric and a olefin nonwoven dust cover fabric. By itself the barrier fabric met the 20 second flame application time criteria; the fabric ignited but self-extinguished within seconds. When tested in combination with the woven and nonwoven dust cover fabrics, the criteria in the CPSC draft standard was met; the barrier/dust cover fabrics ignited with a 20 second flame application but self-extinguished.

TABLE 2
SMALL OPEN FLAME AND SMOLDERING IGNITION TESTS
OF THREE INTUMESCENT BARRIER FABRICS

FABRIC IDENTIFICATION	TIME TO IGNITION (sec)	CHAR LENGTHS (inches)				
		UFAC (covered, vertical)	CPSC Seat Mockup (covered)		CPSC Seat Mockup (uncovered)	
			vertical	horizontal	vertical	horizontal
SEAT MOCKUP FR fibers/glass w/uph. fabric	20/SE	≤ 0.7	≤ 0.6	≤ 0.6	≤ 0.3	not recorded
cotton/glass w/FR coating, w/uph. fabric	20/SE	≤ 0.6	≤ 0.7	≤ 0.4	≤ 0.4	≤ 0.2
cotton/glass w/FR coating w/peel & stick backing, w/uph. fabric	20/SE	cigarettes did not stay lit; a total of three cigarettes were placed at each location for a combined total of 27 cigarettes self-extinguishing				
DUST COVER FR fibers/glass	20/SE					
FR fibers/glass w/woven dust cover fabric	20/SE					
FR fibers/glass w/nonwoven dust cover fabric	20/SE					

SE = self-extinguished
NOTE: for seat mockup tests, barrier fabrics were tested with an upholstery fabric.

Table 3 presents the results from tests on the barrier fabric from manufacturer C. This fabric was labeled as a "fire barrier" (no fiber content information provided) that is not FR-treated but has the ability to "release a fire fighting agent" to slow the progression of combustion of upholstery fabric (Table 3). As the fabric is a barrier fabric, it was tested with a rayon/polyester/cotton blend upholstery fabric weighing 10.2 oz/yd^2. The time to ignition was 10 seconds with no self-extinguishment. A nine

second flame application time also resulted in ignition but the test specimen self-extinguished. Results of the UFAC Fabric Classification test indicate that this barrier fabric/upholstery fabric combination is a UFAC Class I with vertical char measurements of less than 1.75 inches. Test results using the CPSC Seat mockup are similar with no differences between covered and uncovered test results.

TABLE 3
SMALL OPEN FLAME AND SMOLDERING IGNITION TESTS OF A INTUMESCENT BARRIER FABRIC

FABRIC IDENTIFICATION	TIME TO IGNITION (sec)	CHAR LENGTHS (inches)				
		UFAC (covered, vertical)	CPSC Seat Mockup (covered)		CPSC Seat Mockup (uncovered)	
			vertical	horizontal	vertical	horizontal
barrier fabric w/uph. fabric	10	≤ 0.7	≤ 0.7	≤ 0.3	≤ 0.8	≤ 0.4

NOTE: for seat mockups test, barrier fabric was tested with an upholstery fabric.

CONCLUSION

The four fabrics received from manufacturer A did not meet the small open flame criteria in the CPSC draft standard. These fabrics did not perform as well as others tested at the Engineering Laboratory.[4] In addition, the fabrics smoldered profusely during tests with lit cigarettes.

Three of the barrier fabrics (manufacturer B) when combined with an easily ignitable (7-10 seconds) upholstery fabric,[4] met the criteria in the CPSC draft standard. Although the barrier/upholstery fabric combinations ignited in 20 seconds, the flame application time specified in the CPSC draft standard, self-extinguishment occurred within seconds. These fabrics also performed well in the cigarette ignition tests. Lit cigarettes placed on mockups containing the peel and stick barrier/upholstery fabric combination did not remain lit.

In contrast, although resisting cigarette ignition, one of the barrier fabrics (manufacturer C) did not offer much improvement in small open flame resistance when combined with an easily ignitable upholstery fabric whose time to ignition is 7 to 10 seconds.[4] The ignition times for these mockups were 10 to 12 seconds, which are similar to time to ignition results obtained during tests of other upholstery fabrics.[4]

REFERENCES

1. Draft CPSC Small Open Flame Standard, R. Khanna, ESME, July 1997, Consumer Product Safety Commission.

2. UFAC Test Methods, Upholstered Furniture Action Council, 1990.

3. Furniture Flammability Fixture, Operation Manual, Version 1.1, Consumer Product Safety Commission, Directorate For Laboratory Sciences, June 1997.

4. Draft Memorandum To Dale Ray From Linda Fansler, LSE, Summary Of Upholstered Furniture Tests, May 22, 1997, Consumer Product Safety Commission.

United States
CONSUMER PRODUCT SAFETY COMMISSION

Washington, D.C. 20207

MEMORANDUM

DATE: September 19, 1997

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

Through: Andrew G. Ulsamer, Ph.D., Associate Executive Director, AGU
Directorate for Laboratory Sciences

FROM : Linda Fansler, Division of Engineering LF
Shing-Bong Chen, Division of Chemistry SBC

SUBJECT: FR Backcoated and Non-FR Backcoated Upholstery Fabrics

The Directorate for Laboratory Sciences has conducted tests on fabrics received from a textiles coating manufacturer and a textile testing laboratory, both in the United Kingdom. The fabrics included both fabrics with flame retardant (FR) backcoatings and fabrics without FR backcoatings. The fabrics were evaluated for small open flame and cigarette ignition resistance and the presence of flame retardant chemicals.

BACKGROUND

A total of thirty-one fabrics were received from the above sources. Twenty-one of the fabrics were labeled as containing an FR backcoating. However, chemical analysis showed that 10 of these fabrics labeled as containing an FR backcoating were not so treated. The remaining ten fabrics were labeled as non-FR. Five of the FR backcoated fabrics had corresponding fabrics that were not FR backcoated. All of the fabrics appeared to be remnants, which may explain why there were discrepancies in whether the fabric had an FR backcoating or not. This also raises questions as to what other finishes and/or fabric treatments may have been applied.

Laboratory staff evaluated these fabrics using the test protocol in the CPSC staff's draft standard[1] for small open flame ignition resistance, the Upholstered Furniture Action Council (UFAC) Fabric Classification Test Method[2] and a modified version of the UFAC procedure using the CPSC small open flame seating area mockup. Due to the limited amount of fabric available for testing, some of the fabrics were not tested

[1] Superscript refers to reference numbers on page 10.

to each protocol. The fabrics were also analyzed to determine if flame retardant chemicals were present and if those chemicals were likely to migrate from out of the fabric.[3]

TEST PROGRAM.

The fabrics (see Tables 1 and 2 for a description of each fabric) were evaluated for time to ignition from a small butane flame using the CPSC draft test protocol. The butane flame was delivered to the seating area test mockup using a test fixture[4] 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 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.

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 prior to testing at a temperature of 25 $\pm$ 2°C and between 40 and 55% relative humidity.

For fabrics evaluated for cigarette ignition resistance, two protocols were used. In the first protocol, the UFAC Fabric Classification Test Method was used. The test fabric was placed over standard UFAC foam using a small wooden seat mockup placed inside an enclosure. The lit cigarette was placed in the crevice and covered with a piece of unlaundered sheeting fabric. Char measurements were recorded; fabrics with a vertical char of less than 1.75 inches above the mockup crevice are considered UFAC Class I fabrics.

The conditioning requirements specified in the UFAC test protocol were followed. Test specimens and standard foam were conditioned for at least 4 continuous hours prior to testing at a temperature of 21 $\pm$ 3°C and 50 to 60% relative humidity.

In the second protocol used to evaluate resistance to smoldering (cigarette) ignition, a modified version of the UFAC protocol was used. The fabrics were placed over the standard foam specified in the CPSC draft protocol using the seating area test mockup but without a UFAC-type test enclosure. The lit cigarette was placed in the crevice and the cigarette was covered with a piece of unlaundered sheeting fabric. Char measurements were recorded both in the horizontal and vertical directions.

The conditioning requirements specified in the UFAC test protocol were followed in both instances. Test specimens and standard foam were conditioned however, for at least 24 hours prior to testing at a temperature of 21 $\pm$ 3°C and 50 to 60% relative humidity.

To determine the presence of FR chemicals, the fabrics were either digested with concentrated nitric acid for antimony (Sb) or extracted with 4 N hydrochloric acid for phosphorus (P), and the solution was analyzed using an Inductively Coupled Plasma Spectra-Meter (ICP). Antimony is present as antimony trioxide, while phosphorus is present as organo-phosphate. The percent by weight of either phosphorus or antimony was determined for each fabric. To determine the potential for migration, the fabrics were extracted with hydrochloric acid in different concentrations, normal (0.9%) saline solution, water and hexane. Hexane was used to represent organic solvents found in cleaning fluids.

RESULTS

The flammability test results, % by weight of the FR backcoating and fabric weights for these fabrics are presented in Tables 1 and 2. The fabric weights were determined for the thirty-one fabrics using a "Sutter Method Yield Scale". The fabric weights ranged from 5.6 to 14.2 oz/yd^2 for the fabrics treated with FR backcoatings and 4.5 to 21.2 oz/yd^2 for the non-FR backcoated fabrics.

FLAMMABILITY

Table 1 presents the results of the flammability tests on the paired FR backcoated fabrics and non-FR backcoated fabrics and the type and amount of FR backcoating present. Three of the five FR backcoated fabrics (Fabrics A1, D1, and E1), met the 20 second flame application time criteria as specified in the draft standard. Fabrics A1 and E1 also ignited and self-extinguished following a 30 second flame application. Fabric D1 did not ignite when the butane flame was applied for up to 30 seconds. The times to ignition of the FR backcoated fabrics that did not meet the 20 second flame application time criteria, (Fabrics B1 and C1), were similar to those of their corresponding non-FR backcoated fabrics. Both fabrics contained relatively low amount of antimony (see below).

UFAC tests were not conducted on these fabrics due to insufficient samples. This was also true in the case of the CPSC Seat Mockup tests for Fabrics A1 and C1. Of those fabrics tested in the CPSC Seat Mockup protocol, only Fabric B1 had a cigarette that ignited during the test. The other fabrics had vertical and horizontal chars from $\leq$ 0.3 to $\leq$ 0.7 inches.

CHEMICAL

All five backcoated fabrics contained antimony in amounts ranging from 1.11 to 1.94 % by weight (Table 1). The two fabrics with the least amount of antimony present, (Fabrics B1 and C1), did not meet the 20 second flame application time criteria. Although, there was not much difference in the amount of antimony present between Fabrics B1 (1.28%) and E1 (1.30%), Fabric E1 was heavier weight (twice as heavy) and also had a textured surface, which could also have contributed to its resistance to the application of the small open flame for 20 seconds.

TABLE 1
SMALL OPEN FLAME AND SMOLDERING IGNITION TEST RESULTS FOR PAIRED FR AND NON-FR BACKCOATED UPHOLSTERY FABRICS

FABRIC IDENTIFICATION	TIME TO IGNITION (sec)	20 SECOND FLAME APPLICATION	CHAR LENGTHS (inches)		
			UFAC (covered,vertical)	CPSC Seat Mockup (covered) vertical	CPSC Seat Mockup (covered) horizontal
Fabric A1, FR backcoated, 1.94 % antimony, 5.6 oz/yd^2	3 to 5 / self-extinguished	ignited and self-extinguished (ignited and self-extinguished at 30 s)	did not test, not enough fabric provided	did not test, not enough fabric provided	
Fabric A2, non-FR backcoated, 4.5 oz/yd^2	6 / did not self-extinguish	ignited and did not self-extinguish	did not test, not enough fabric provided	≤ 0.5	≤ 0.5
Fabric B1, FR backcoated, 1.28% antimony, 7.7 oz/yd^2	7 to 8 / did not self-extinguish	ignited and did not self-extinguish	did not test, not enough fabric provided	0.8*	0.5*
Fabric B2, non-FR backcoated, 6.7 oz/yd^2	7 to 9 / did not self-extinguish	ignited and did not self-extinguish	did not test, not enough fabric provided	0.6	≤ 0.5
Fabric C1, FR backcoated, 1.11% antimony, 7.7 oz/yd^2	7 / did not self-extinguish	ignited and did not self-extinguish	did not test, not enough fabric provided	did not test, not enough fabric provided	
Fabric C2, non-FR backcoated, 7.0 oz/yd^2	7 to 8 / did not self-extinguish	ignited and did not self-extinguish	did not test, not enough fabric provided	0.5	≤ 0.3
Fabric D1, FR backcoated, 1.57% antimony, 10.8 oz/yd^2	> 30	did not ignite (did not ignite at 30 s)	did not test, not enough fabric provided	≤ 0.6	≤ 0.4
Fabric D2, non-FR backcoated, 7.3 oz/yd^2	3 to 4 / did not self-extinguish	ignited and did not self-extinguish	did not test, not enough fabric provided	≤ 0.7	≤ 0.6
Fabric E1, FR backcoated, 1.30 % antimony, 14.2 oz/yd^2	20 / self-extinguished	ignited and self-extinguished (ignited and self-extinguished at 30 s)	did not test, not enough fabric provided	≤ 0.5	≤ 0.4
Fabric E2, non-FR backcoated, 11.4 oz/yd^2	10 to 11 / did not self-extinguish	ignited and did not self-extinguished	did not test, not enough fabric provided	≤ 0.7	≤ 0.5

* 1 of 3 cigarettes tested ignited

The other fabrics tested in this study were six FR backcoated upholstery fabrics and 15 non-FR backcoated fabrics. None of these fabrics samples were paired. Results of this testing are presented in Table 2. The amounts and types of FR present are also included in Table 2.

FLAMMABILITY

Four of the fabrics with FR backcoatings, (Fabrics H, I, J, and K), ignited and consistently self-extinguished even when the flame was applied for up to 20 seconds. Of the remaining FR backcoated fabrics, Fabric F ignited and self-extinguished, but did not always self-extinguish within the 120 second limit and Fabric G ignited and did not always self-extinguish when a 20 second flame was applied. Chemical analysis (see below) showed that Fabric F contained antimony (3.6%) while Fabric G contained phosphorus (2.26%).

All six FR backcoated fabrics were UFAC Class I fabrics with vertical char length measurements less than 1.75 inches.

Two of the non-FR backcoated fabrics (Fabrics X and Y) did not ignite with a 20 second flame application. Fabric Y also resisted ignition at 30 seconds of flame application. Both fabrics were heavy weight fabrics. Although not meeting the criteria in the CPSC draft standard, three other non-FR backcoated fabrics showed improvement when the 20 second butane flame was applied. Fabric U ignited and did not always self-extinguish within the 120 second limit. Fabric W also ignited with a 20 second flame application, but did not always self-extinguish and Fabric Z sometimes ignited and did not self-extinguish. The remaining ten non-FR backcoated fabrics ignited between 8 and 16 seconds and did not self-extinguish.

UFAC tests were done on 11 of these fabrics, all six of the FR backcoated fabrics and five of the non-FR backcoated fabrics. All of these fabrics were UFAC Class I fabrics with a vertical char less than 1.75 inches. CPSC Seat Mockup tests were done on 11 of these fabrics. Three of the fabrics (Fabrics F, H, and Y), had at least one cigarette ignition. The char measurements for the remaining eight fabrics ranged from $\leq$ 0.3 to 0.9 inches.

Table 2 also presents both the horizontal and vertical char measurements for the tests using cigarettes placed on the CPSC Seat mockup. There was not enough of two of the six FR backcoated fabrics, (Fabrics I and K), to conduct this test. Two of the FR backcoated fabrics (Fabrics G and J) that were tested, had vertical and horizontal char length measurements of $\leq$ 0.7 inches. The remaining two FR backcoated fabrics (Fabrics F and H), had 1 or more cigarettes that ignited during the test. All six cigarettes ignited during the tests on Fabric F. Fabric H, however, had one cigarette out of six that ignited during the test. The non-igniting cigarettes had vertical and horizontal char length measurements of $\leq$ 0.7 inches. As stated above, both fabrics passed the UFAC tests.

CHEMICAL ANALYSIS

The fabrics reported to have an FR backcoating treatment were analyzed to determine the type and amount of FR present. Fabric G contained 2.26 % by weight of phosphorous. The remaining five backcoated fabrics contained antimony trioxide in amounts ranging from 1.42 to 3.62% by weight (Table 2). Although Fabric F contained the highest percentage of FR treatment, 3.62% by weight of antimony, it ignited and did not always self-extinguish within the specified limit, when the butane flame was applied for 20 seconds.

Fabrics P to R and T to Z were reported by the source to contain FR backcoating treatments. Flammability results and chemical analysis determined that these fabrics do not contain FR backcoatings.

TABLE 2
SMALL OPEN FLAME AND SMOLDERING IGNITION TEST RESULTS OF FR BACKCOATED AND NON-FR BACKCOATED FABRICS

FABRIC IDENTIFICATION	TIME TO IGNITION (sec)	20 SECOND FLAME APPLICATION	CHAR LENGTHS (inches)		
			UFAC (covered,vertical)	CPSC Seat Mockup (covered) vertical	CPSC Seat Mockup (covered) horizontal
Fabric F, FR backcoated, 3.62% antimony, 6.9 oz/yd^2	10 to 12 / self-extinguished	ignited and self-extinguish, but not always within the 120 sec limit	≤ 0.8	obvious ignitions, 6 cigarettes	
Fabric G, FR backcoated, 2.26% phosphorus, 8.4 oz/yd^2	10 to 12 / self-extinguished sometimes	ignited and did not always self-extinguish	≤ 0.7	≤ 0.5	≤ 0.3
Fabric H, FR backcoated, 2.74% antimony 9.1 oz/yd^2	10 to 12 / self-extinguished	ignited and self-extinguished	≤ 0.6	0.7*	≤ 0.4*
Fabric I, FR backcoated, 1.94% antimony, 11.0 oz/yd^2	10 to 12 / self-extinguished	ignited and self-extinguished	≤ 0.6	did not test, not enough fabric provided	

Fabric J, FR backcoated, 1.42% antimony, 11.6 oz/yd^2	19 to 20 / self-extinguished	ignited and self-extinguished	≤ 0.6	0.6	0.3
Fabric K, FR backcoated, 2.61% antimony, 12.8 oz/yd^2	16 to 17 / self-extinguished	ignited and self-extinguished	≤ 0.6	did not test, not enough fabric provided	
Fabric L, non-FR backcoated, 6.4 oz/yd^2	9 / did not self-extinguish	ignited and did not self-extinguish	0.8	0.6	0.4
Fabric M, non-FR backcoated, 6.9 oz/yd^2	8 to 10 / did not self-extinguish	ignited and did not self-extinguish	≤ 0.6	≤ 0.7	0.4
Fabric N, non-FR backcoated, 7.2 oz/yd^2	8 to 9 / did not self-extinguish	ignited and did not self-extinguish	0.6	0.6	≤ 0.4
Fabric O, non-FR backcoated, 8.9 oz/yd^2	11 / did not self-extinguish	ignited and did not self-extinguish	≤ 0.7	0.5	≤ 0.3
Fabric P, non-FR backcoated, 9.4 oz/yd^2	10 to 12 / did not self-extinguish	ignited and did not self-extinguish	did not test, not enough fabric provided	did not test, not enough fabric provided	
Fabric Q, non-FR backcoated, 10.1 oz/yd^2	11 / did not self-extinguish	ignited and did not self-extinguish	did not test, not enough fabric provided	≤ 0.7	≤ 0.5
Fabric R, non-FR backcoated, 10.4 oz/yd^2	16 / did not self-extinguish	ignited and did not self-extinguish	did not test, not enough fabric provided	did not test, not enough fabric provided	
Fabric S, non-FR backcoated, 11.1 oz/yd^2	13 / did not self-extinguish	ignited and did not self-extinguish	0.7	0.7	0.4
Fabric T, non-FR backcoated, 11.4 oz/yd^2	11 to 12 / did not always self-extinguish	ignited and did not self-extinguish	did not test, not enough fabric provided	did not test, not enough fabric provided	
Fabric U, non-FR backcoated, 12.6 oz/yd^2	16 to 17 / did not self-extinguish by the 120 sec limit	ignited and did not self-extinguish by the 120 sec limit	did not test, not enough fabric provided	did not test, not enough fabric provided	
Fabric V, non-FR backcoated, 15.0 oz/yd^2	15 to 17 / did not self-extinguish by the 120 sec limit	ignited and did not self-extinguish	did not test, not enough fabric provided	did not test, not enough fabric provided	
Fabric W, non-FR backcoated, 15.2 oz/yd^2	5 / self-extinguished	ignited and did not always self-extinguish	did not test, not enough fabric provided	did not test, not enough fabric provided	

Fabric X, non-FR backcoated, 16.9 oz/yd^2	21 to 25 / did not self-extinguish	did not ignite	did not test, not enough fabric provided	did not test, not enough fabric provided	
Fabric Y, non-FR backcoated, 17.3 oz/yd^2	did not ignite at 20 or 30 seconds	did not ignite	did not test, not enough fabric provided	0.6**	0.9**
Fabric Z, non-FR backcoated, 21.2 oz/yd^2	19 to 20 / did not self-extinguish	sometimes ignited and did not self-extinguish	did not test, not enough fabric provided	did not test, not enough fabric provided	

*1 of 6 cigarettes tested ignited
** 2 of 3 cigarettes tested ignited

EXTRACTION

Table 3 presents the results of the analysis of the FR backcoatings to determine whether migration through to the front surface could occur. Ten of the FR backcoated fabrics contained antimony trioxide, a flame retardant treatment. Small amounts (0 to 0.2 %) of antimony could be extracted from all backcoated fabrics with a 0.1 N dilution of hydrochloric acid, water, 0.9% of NaCl or hexane. Fabric G contained phosphorous and substantial amounts of phosphorous (1.7%) were extracted with 0.1N HCl but relatively little with hexane, water or 0.9% NaCl.

TABLE 3
% ANTIMONY (OR PHOSPHORUS) EXTRACTED FROM BACKCOATED FABRICS

FABRIC	A	B	C	D	E	F	G*	H	I	J	K	extract w/
	1.94	1.28	1.11	1.57	1.30	5.98	1.92	3.37	1.98	2.67	2.53	4 N HCl
	0.01	0.01	0.01	0.01	0.01	0.01	1.70	0.00	0.00	0.01	0.00	0.1 N HCl
	0.01	0.02	0.02	0.01	0.01	0.01	0.13	0.00	0.00	0.00	0.00	0.9% NaCl
	0.01	0.01	0.01	0.01	0.01	0.00	0.04	0.00	0.00	0.00	0.00	water
	0.00	0.00	0.00	0.01	0.00	0.00	0.17	0.00	0.00	0.00	0.00	hexane

* % phosphorus

CONCLUSIONS

Seven of the 11 FR backcoated fabrics met the 20 second flame application criteria in the draft standard by self-extinguishing within the 120 second limit. One of the FR backcoated fabrics ignited and did not always self-extinguish within the specified limit after a 20 second flame application and another ignited and did not always self-extinguish. The two remaining FR fabrics ignited and did not self-extinguish in under 10 seconds. Three of these fabrics contained antimony and one contained phosphorus as the FR. The amount of antimony varied by a factor of three indicating that other factors might have been involved. Two non-FR fabrics also met the small open flame criteria. All fabrics appeared to be remnants raising some questions concerning what treatments they may have been exposed to.

Of the seven FR backcoated fabrics which passed the open flame test, five were also subjected to the CPSC cigarette test (Fabrics Al, Dl, El, H, I, J, and K). Four fabrics (Fabrics D1, E1, H and J) had no cigarette ignitions and one, Fabric H had 1 out of 6 cigarettes that ignited. Fabric H, however, passed the UFAC test. An additional fabric (Fabric F), which failed both the open flame test and the CPSC cigarette test also passed the UFAC test.

Migration of the FR chemicals from backcoated fabrics was minimal in that less than 0.02% of antimony trioxide could be extracted. The one phosphorus based FR treatment exhibited substantial extraction with 0.1N HCl but relatively less with the other extractants.

REFERENCES

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