2) Operation

This section describes the operation of the fixture in manual mode (for setting up) and in automatic mode (for running tests). An initial checkout procedure will incorporate descriptions of these modes. Also, adjustment procedures will be described. Before operating, ensure that the fixture has been assembled properly and is placed on a secure level surface without obstructions near the fixture. Begin with the Checkout.

Checkout!

Determine proper functioning of the fixture by performing the following 11 steps of the operational checkout. Refer to Figure 3, Control Panel.

1. Switch power off (the power switch LED light will be up).

2. Switch Manual/Automatic to Manual.

3. Plug into a nominal 120 Volt A/C power source.

4. Switch power on (LED will light).

Manual Mode Checkout

The purpose of manual mode is to check the test setup while maintaining control of movement. Perform steps 5 through 8 several times in forward and reverse sequences to check the motor and drive system.

5. Depress the In/Out switch towards the "In" position and hold – the burner and shield will rotate together towards the center of the platform opening.

6. Release the In/Out switch when the Burner Assembly stops. This is the test position for the burner.

7. Again, depress the In/Out switch towards the "In" position and hold - only the Shield Assembly will now rotate. The Shield Assembly will rotate and reveal the burner beneath, reach its limit and stop automatically. This is depicted in Figure 4.

8. Depress the In/Out switch towards the "Out" position and hold- the burner and shield will rotate together out from under the Main Assembly opening. At the extreme, the shield will stop and the burner will continue out from under the shield, reach its limit and stop. This is the setup position for the burner. This is depicted in Figure 5.

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Figure 4
Burner in Test Position
(Top View)

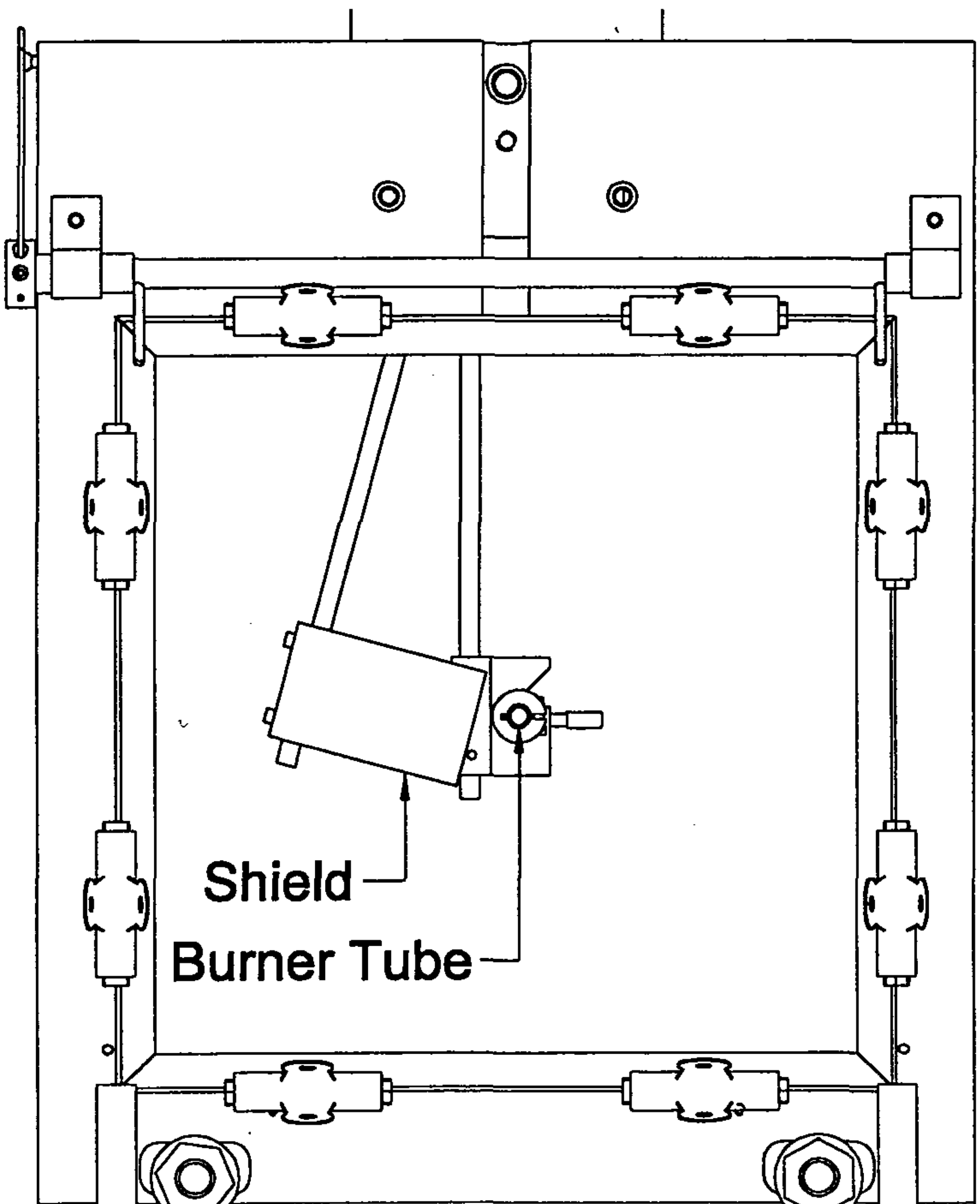

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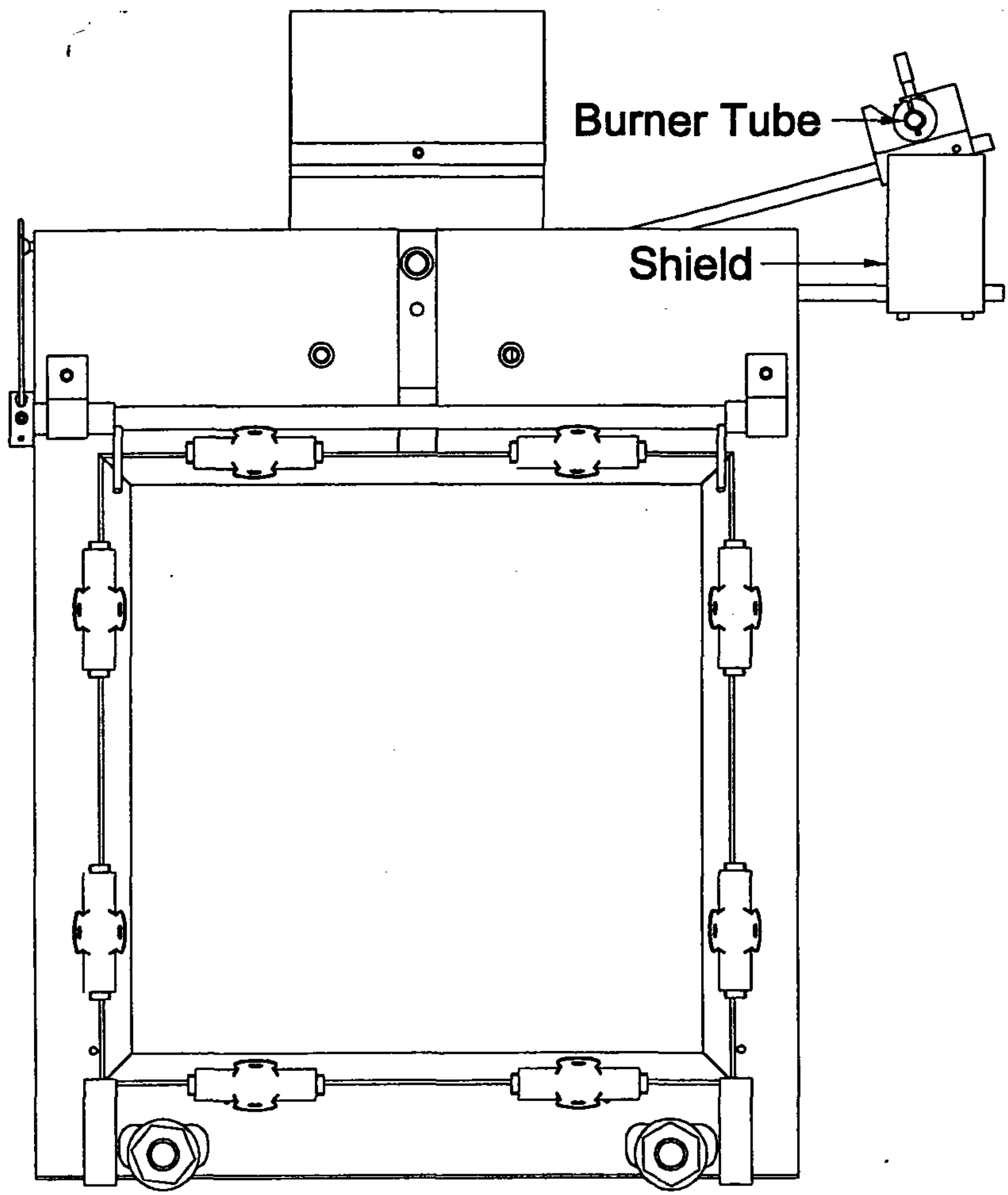
Figure 5
Burner in Setup Position
(Top View)



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Automatic Mode Checkout

Automatic mode is used to perform actual tests.

Warning: Whenever Auto is selected, the motor will automatically move the burner and shield.

9. Flip the Manual/Automatic switch to Automatic mode. When Automatic is selected a long tone will sound. Immediately following, the motor will move the burner and shield to the front, setup position, as described in step 8. At this position, four short tones will sound, indicating that the fixture is ready to run a test. (There are no tones in Manual Mode.)

10. Press the Start button. The following automatic sequence will occur:

    a. The burner and shield will advance to the test position (Figure 4) and stop. The shield will still cover the burner tube.

    b. After a 3-second pause to stabilize the flame, the shield will move-exposing the flame. The 20-sec flame-exposure begins.

    c. After the timed exposure, the shield will move to cover the burner and then the burner and shield will return to the setup position and stop. A four-tone signal will indicate readiness for more testing.

11. Abort button. The resetting feature allows the burner to be called back in Automatic Mode. Test this feature by pressing the Abort button while a (mock) test is in progress (i.e. during the Step 10 sequence).

Adjustments

Timer.

The time period of the flame exposure is fixed at 20 seconds[1] for tests that require a single time period. In this case, the 2-digit thumbwheel timer on the control panel is not active. This timer/display has a 1 to 99 sec range when active. Refer to the Technical Assistance section for more information.

Burner Offset.

Burner offset is measured from the top of the burner tube to the underside of the fabric specimen or, as a proxy, the top surface of the Main Assembly platform on which the fabric rests. The top surface was used for initial calibration with a burner offset set to 35 mm (1.38 in)[1] as shown in Figure 6. [The 35-mm offset equals the flame height specified in the draft standard]. For actual tests, the fabric at the test position of the tube shall be used and the offset confirmed. To achieve this offset, the burner position relative to the platform can be adjusted in two ways:

(1) Placement of the collar along the burner tube. Using the Collar Wrench provided (part 106), loosen the collar set screw (Figure 6) and move the collar into a position to achieve the 35-mm offset. Tighten the setscrew.

(2) Vertical positioning of the tube within the Burner Assembly slot. Loosen the knurled thumbscrew (Figure 6) of the Burner Assembly and slide the Burner Tube to achieve the 35-mm offset. Tighten the thumbscrew.

It is recommended that the "collar" method be used primarily because it is the more repeatable method. The "slot" method is convenient when variation in fabric sag reduces the burner offset below 35 mm. To be certain of the offset, check it each time using the Offset/Flame Gage (part 107).

[1] Refer to the CPSC draft standard. See End Note.

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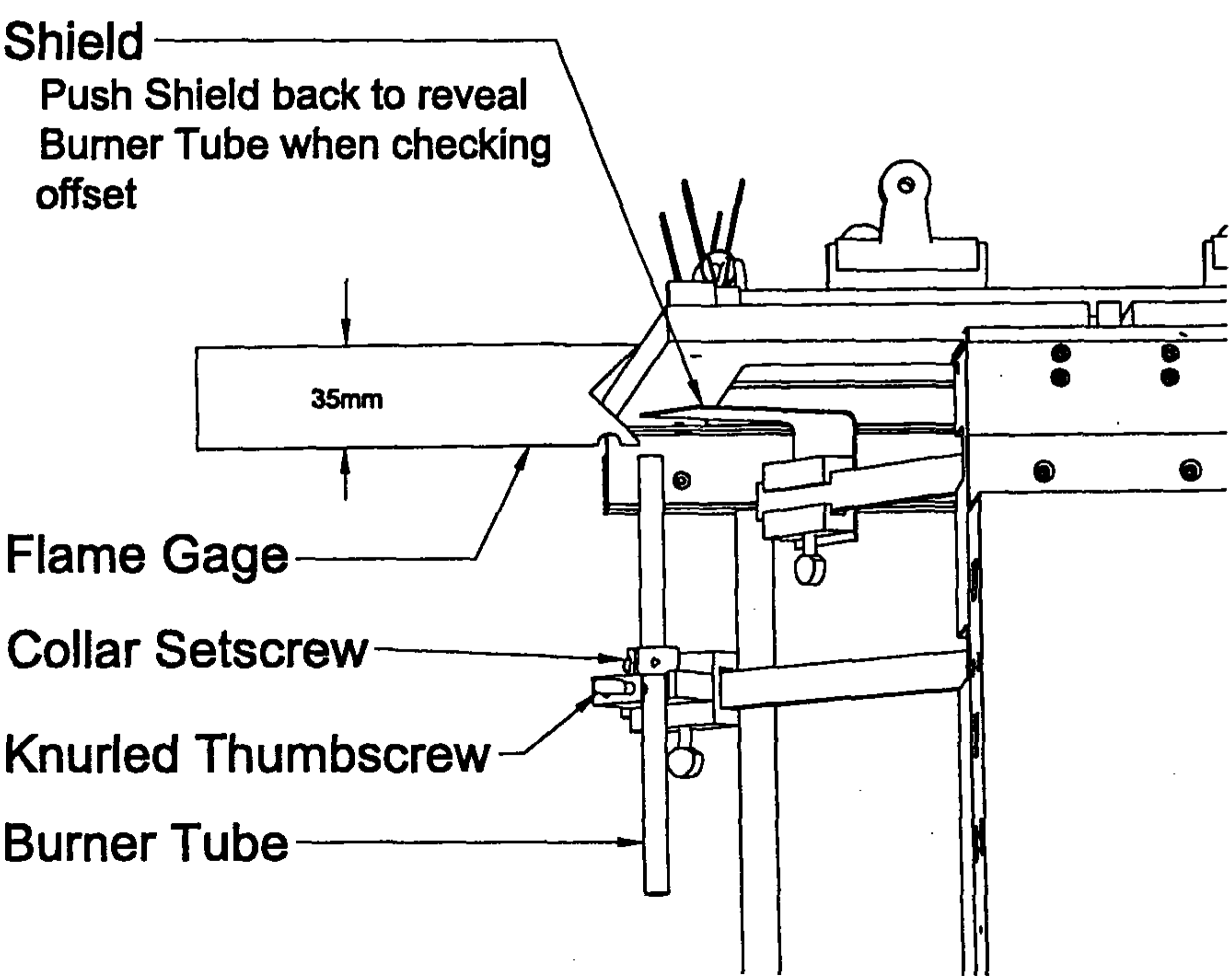
Figure 6
Checking Burner Offset



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Conducting a Test

Refer to the previous sections for details on operations and adjustments. At this point, a fabric specimen ("mockup") and a suitable gas with calibrated gas flow should be on hand[1]. Generally, the procedure to conduct a test is to setup the test without a flame, light the flame, and let the fixture automate the test.

1. Install a fabric mockup on the Main Assembly (Assembly, page 6).
2. Connect a flexible gas supply tube to the Burner Tube and provide a regulated gas supply[1]. The supply tube must be long enough to allow the Burner Tube to move freely through the test sequence.
3. Move the unlit burner to the test position using the Manual controls (Operation, page 7).
4. Check the Burner Offset using the Flame/Offset Gage. Make adjustments. (Adjustments page 9).
5. Return the burner to the setup position. (Operation, page 8).
6. Light the burner gas and let the flame stabilize[1].
7. Select Automatic Mode and press Abort. Pressing Abort ensures that the test sequence is initialized.
8. Press Start.
9. At the conclusion of the automatic sequence, perform observations and then apply fire suppression[1] if necessary.

[1] Refer to the CPSC draft standard. See End Note.

3) Maintenance and Troubleshooting

Maintenance

1. Clean burn residue from the Burner and Shield Assemblies, especially in places that might interfere with the assembly of these parts to the beams.

2. Clear burn residue from the platform, especially where the fabric mockup rests.

Troubleshooting

1. Problem: Shield contacts the Main Assembly platform. Solution: loosen the screws and slide the shield down until it has no more than a 0.1-in (2.5-mm) clearance.

2. Problem: Any instance in which the motor does not operate appropriately. Solution: Refer to the Technical Assistance section.

4) Specifications

Basic physical and environmental specifications/requirements:

Fixture Mass:	7.7 kg (17 lb)
Fixture Size:	432mm (17 in) X 483mm (19 in) X 305mm (12 in) [heightXwidthXdepth]
Mockup Size:	254-mm (10-in) square
Clip:	No.2 Bulldog clips, 57-mm (2.25-in) wide.
Burner Offset:	35 mm (1.38 in). This is specified in the draft standard.
Timer:	Set for 20-sec. Optional adjustment range 1-99 sec.
Power Required:	Nominal (90-130 VAC 50/60 Hz)
Environmental:	*Indoor-use only. Refer to the draft standard for additional* requirements[1]

5) Technical Assistance

Please refer technical questions to the following individuals.

Mark Eilbert, Mechanical Engineer — Mechanical Help: (301) 413-0182
Nelson Caballero, Electrical Engineer — Electrical Help: (301) 413-0183

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[1] Draft Standard For Upholstered Furniture, Standard for Small Open Flame Ignition Resistance of Upholstered Furniture, U.S. Consumer Product Safety Commission, October 1997. Refer to the CPSC draft standard for guidance and requirements for Dust Cover Tests including: mockup assembly, flame exposure times, flame stabilization, fire suppression, gas supply, test environment, and data collection.

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: October 13, 2000

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

THROUGH: Nicholas V. Marchica NVM
Mechanical Engineering Division Director
Directorate for Engineering Sciences

FROM : Rikki Khanna RK
Fire Protection Engineer
Directorate for Engineering Sciences

SUBJECT : Small Open Flame Upholstered Furniture Standard Development Approach

Standard Approach

The staff investigated several approaches in its standard development process to address the risk of small open flame initiated upholstered furniture fires. Most flammability standards attempt to reduce fire risk by limiting combustion parameters such as heat release rate (HRR)/mass loss, flame-spread, or ignition behavior. The relative safety provided by controlling these parameters depends on the specific fire scenario that needs to be addressed. For some fire scenarios, controlling one combustion parameter may be more effective than another. It is important to recognize that the level of protection provided by a safety standard is closely tied to the test method used to evaluate fire performance.

For small open flame upholstered furniture fires, the staff believes that ignition behavior is the most effective parameter as a basis of a national flammability standard. The ignition sources in these fires are relatively small. Upholstered furniture can be produced that resists ignition from these small open flames. The staff has demonstrated both economic and technical feasibility to produce upholstered furniture that will resist ignition from small open flames. Upholstered furniture fires result in the production of extremely lethal smoke and gasses. A very intense fire can occur in just a few minutes. Most of the deaths and injuries result from inhalation of toxic gases. Preventing the ignition of upholstered furniture could avert these deaths and injuries. This approach has been successfully applied in furniture flammability standards[1] administered by the United Kingdom.

[1] BSI 5852 - 1982, Part 2 Methods of test for the ignitability of upholstered composites for seating by flaming sources

Controlling the HRR/mass loss was another approach investigated by staff. HRR standards are applicable to fire scenarios where controlling fire growth and reducing the possibility of flashover are critical for life safety. This approach is ideal for large public occupancies such as movie theaters, hotel lobbies, etc. where slowing fire growth is essential to provide tenable conditions for safe egress of occupants. The state of California has adopted a standard[2] that uses this approach. Typically these fire scenarios involve larger ignition sources, equivalent to a wastebasket fire and ignition due to arson or incendiary acts. These ignition sources are not within the scope of the hazard the staff is attempting to address. Controlling HRR does not seem to be an effective approach for a residential fire scenario, since the production of toxic gases still produces a threat to occupants in these fires.

Flame-spread rate standards have been applied to the building materials industry to reduce the contribution of building materials in fires. Flame spread standards are probably the best known fire performance standards. The most widely used of these is the Steiner Tunnel Test[3]. The tunnel test was proposed when the need was recognized to develop a method to control burning characteristics of interior finish material. The purpose of the test is to determine the comparative burning characteristics of the material under test by evaluating the flame spread over its surface, when exposed to a test fire. The staff has adopted this approach in part, by requiring that the flame-spread does not reached edges of the test specimen.

Test Method Development

The difficulty in designing a test that will provide a basis for predicting performance under real fire conditions is obvious. Equally obvious is the impracticality of designing tests to represent all fire conditions. A test designed to represent a "typical" fire may not provide a reliable basis for predicting "real life" performance of all materials tested. Therefore, there is a constant search for improved test methods.

The most realistic test approach for any product involves testing the finished item as it is received and used. Many large, complex products, however--like upholstered furniture--are manufactured using materials and constructions that vary considerably, even from one production unit to the next. In fire and flammability testing, this means that full-scale test results are highly variable. Flame test series performed on different chairs, even from the same production run, with the same cover fabrics, can be expected to produce non-identical results. Even certain upholstery fabrics can be sufficiently complex to exhibit variable test performance.

In establishing a level of safety for the finished product that can be consistently demonstrated by manufacturers and testing labs, a common approach is to conduct smaller, bench-scale tests on samples that reasonably represent the physical characteristics of the finished product but are less subject to its inherent variability. A bench-scale test is an acceptable substitute for a full-scale test, provided the bench-scale test is repeatable and reproducible, and results between the two kinds of tests correlate reasonably well. Bench-scale testing is generally

[2] State of California Technical Bulletin 113, Flammability Test Procedure for Seating Furniture for Use in Public Occupancies.
[3] Test method contained in NFPA 255, *Method of Test of Surface Burning Characteristics of Building Materials* (ASTM E-84).

preferred to reduce testing costs, since manufacturers can often test components or small sub-assemblies, and destruction of the finished product is not necessary.

The principal test in the staff's draft small open flame standard is a bench-scale test. Mockups that represent upholstered furniture are constructed using fabric and a standard polyurethane foam filling material. A 35-mm butane flame is applied to the seat/back crevice of the mock-up for 20 seconds. After removal of the flame source, observations are made of the ignition behavior and flame-spread of the mock-up are made for 15 minutes. Samples pass the test if the mock-up is ignition resistant, i.e. – does not produce any visible form of combustion during the 15-minute observation time, or flame-spread does not reach the edges of the mock-up.

To support the development of the test method, staff conducted full-scale tests on actual finished items of upholstered furniture, including tests on furniture purchased from the U.K. made with FR-treated fabrics. The results of the full-scale tests were compared with the corresponding bench-scale tests for each chair tested in full-scale in a correlation study[4]. The correlation between full scale and mockup test results was reasonably good ($\tau = .68$), with no significant difference between mean passing ratios at the 95% confidence level. This correlation exists even with apparent anomalies in 5 of 27 samples, at least 3 of which appear to have ready explanations. Among all products tested by the staff, full scale and mockup ignition performance was the same in a substantial majority of tests. (It should be noted that, even among the small number of inconsistent results, the FR-treated chairs exhibited much less hazardous ignition behavior than that of conventional chairs made with non-FR fabrics.).

Another supporting study[5] was conducted to evaluate the repeatability and reproducibility of the bench-scale test method. ASTM E691-92[6] guidelines were used to assess the precision of the test method. The staff and 8 other laboratories were supplied test samples and written test procedures. The results of the interlaboratory study were consistent within and between all 9 laboratories.

Conclusion

The staff believes that controlling ignition is the most effective approach to reduce the risk of death or injury from small open flame ignited residential upholstered furniture fires. The bench-scale test method effectively evaluates the flammability performance of upholstered furniture and is suitable for adoption in a national flammability standard.

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[4] Full Scale/Bench Scale Test Study

[5] Interlaboratory Study of Upholstered Furniture Fabric Flammability Draft Test Method, 9/28/200

[6] ASTM E691-99 Standard Practice for Conducting an Interlaboratory Study to Determine the Precision of a Test Method

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: March 28, 2001

TO : Dale Ray, Upholstered Furniture Project Manager

THROUGH: Nicholas V. Marchica, Director, Division of Mechanical Engineering NVM
Directorate for Engineering Sciences

for Hugh McLaurin, Associate Executive Director NVM
Directorate for Engineering Sciences

FROM : Rikki Khanna, Fire Protection Engineer rk
Directorate for Engineering Sciences

SUBJECT : Modifications to Draft Standard for Small Open Flame Upholstered Furniture

BACKGROUND

This memorandum describes modifications made to the Standard for Small Open Flame Ignition Resistance of Upholstered Furniture (standard) since the October 1997 Briefing Package to the Commission. Since publication of the briefing package, CPSC staff has continued work that has led to substantial modifications to the draft standard in two basic areas. These modifications include revised criteria for ignition and the addition of an alternate barrier test.

CRITERIA FOR IGNITION

CPSC staff believes that the draft standard's criteria for ignition defined in the October 1997 Briefing Package to the Commission needed clarification. Previously, the standard required all forms of combustion of the furniture composite to cease within two minutes after removal of the ignition source. Laboratory tests found that two minutes is not enough time to adequately evaluate the ignition performance of the furniture composite. The ignition of furniture composites generally involves two separate modes of ignition. These are flaming[1] and progressive smoldering[2] ignition. Both are critical, but are different modes of ignition that should be addressed separately. Flaming ignition of the furniture composite is easier to detect than progressive smoldering. The requirements for flaming ignition have been expanded to: screen out samples that burn until they are essentially consumed; include flaming debris; and, accommodate the alternate barrier test performance requirements described later in this memorandum.

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[1] Undergoing combustion in the gaseous phase with the emission of light.
[2] Smoldering that is self-propagating, i.e. independent of the ignition source.

The requirements for flaming ignition (any one of which will result in a test failure) are:

1. Any test specimen that displays escalating flaming combustion behavior so that it is unsafe to continue the test and forcible extinction is required.
2. *Any test specimen that burns until it is essentially consumed within the test duration* (2 minutes for seating area test, 10 minutes for barrier test).
3. Any test specimen on which any flame front reaches the edges of the specimen or passes through the full thickness of the specimen within the duration of the test.
4. Any test specimen that continues to flame for more than 2 minutes after removal of the burner tube.
5. Any test specimen that continues to flame for more than 10 minutes after ignition of the crib (barrier test only).
6. Any test specimen from which debris causes an isolated floor fire not meeting the requirements of items 4 and 5.

In practice it has been found that there is a clear distinction between materials that char under the influence of the ignition source but do not propagate further (non-progressive) and those where smoldering develops in extent and spreads (progressive). By extending the observation time for the different modes of ignition, test personnel have more time to assess if the furniture composite will continue to support combustion. The requirements for progressive smoldering ignition (any one of which will result in a test failure) are:

1. Any test specimen that displays escalating smoldering combustion behavior so that it is unsafe to continue the test and forcible extinction is required.
2. Any test specimen that smolders until it is essentially consumed or that smolders to the extremities of the specimen (to either side or to the full thickness of the specimen) within the duration of the test (15 minutes for seating area test, 1 hour for barrier test).
3. Any test specimen that produces externally detectable amounts of smoke, heat or glowing 15 minutes after removal of the burner tube.
4. Any test specimen that produces externally detectable amounts of smoke, heat or glowing 60 minutes after ignition of the crib (barrier test only).
5. Any test specimen that on final examination shows evidence of charring within the filling (other than discoloration) more than 100 mm in any direction from the nearest part of the original position of the source (apart from upwards).

A final examination section has been added to the revised standard to assist test personnel in determining the presence of progressive smoldering. This revision requires that immediately after completion of the test, the specimen is to be dismantled and examined for progressive smoldering. If this is present, the specimen is to be manually extinguished and an ignition (test failure) is recorded for the relevant test.

NEED FOR ALTERNATE APPROACH

Throughout the standard development process, CPSC staff have considered alternate performance requirements. The application of current flame retardant technologies required to meet the draft standard may not be feasible for some upholstered furniture fabrics such that it is no longer feasible to continue their use. For these fabrics, the use of fire barriers is an approach that can provide an improved level of protection from the risk of small open flame ignition.

Fire Barrier Background

Fire barrier materials can offer increased design options for achieving acceptable fire performance. Fire barriers have been studied as a means of reducing cigarette ignitablity, open flame ignitability, and fire growth. Systemic engineering data are not available; however, enough studies have been reported to enable some generalizations.

Barriers can provide improved resistance to fabric ignition and flame spread from small open flame sources. Some are even effective against larger flame sources[3]. The ignition resistance of composites involving a readily ignitable fabric over a slow burning padding would gain little benefit from a barrier, but after an open flame ignition has occurred, a properly chosen barrier can be highly effective in reducing the heat release rate (HRR) of the padding. However, their effectiveness in reducing the amount of carbon monoxide (CO) and smoke production cannot be readily predicted.

The development of fire barriers in upholstered furniture applications was spurred by the requirements of the state of California and aircraft safety regulations.[4,5] These regulations contain performance criteria based on heat release from burning composites. Thus, the available data are geared to evaluate barrier performance with the goal of providing low peak HRR as well as low smoke and CO development.

Fire Barrier Mechanisms

For open flame behavior improvement, fire barriers have been classified using the following possible retardant mechanisms.

1. Transpiration cooling. This occurs if the fire barrier contains substances that gasify rapidly but are nonflammable. Typically, hydrated alumina, which release water vapor, can be used as filler for foams.
2. Re-radiation. This effect is noted for materials of low thermal conductivity and good high temperature stability.
3. Thermal insulation. This mechanism is effective if the fire barrier is thermally stable, of low conductivity and density, and, if cellular, of closed cell form. Effectiveness increases with thickness.

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[3] Krasny, J.F., Parker, W.J., Babrauskas, V. Fire Behavior of Upholstered Furniture and Mattresses (2001)
[4] Damant, G.H., and Nurbakhsh, S. Using California Technical Bulletin 133 to Measure Heat Release Rates of Seating Furniture, Fire and Flammability of Furnishings and Contents of Buildings, STP 1233, pp. 83-97, ASTM, Philadelphia, PA (1994)
[5] Kourtides, D.A., et al., Optimization of Aircraft Seat Cushion Fire Blocking Layers, DOT/FAA/CT-82/1 32, Federal Aviation Administration, Atlantic City, NJ (1983)

4. Reflection. Typically, aluminum foil or aluminized fabrics are useful for this, but this effect would be more noticeable if the reflective surface were on the outside than when it is in contact with other surfaces on both sides.
5. Local heat dissipation. A material of high density and thermal conductivity can limit small-scale ignitability by dissipating heat over a wide area. Cigarette ignitability can also be improved. Aluminum is a suitable material for this.
6. Barrier to pyrolyzates (products of thermal decomposition). A dense, nonporous substance is required for this. Additional benefits can be derived from limiting oxygen access to the thermal decomposition region from thermal cracking of the retained pyrolyzates.

Commonly used barriers can be grouped into 2 categories:

1. Barriers that provide improved open-flame properties if they do not split due to tension, but which sacrifice cigarette ignitability.

- FR cotton fabric has been tested for this purpose. The behavior appears to be typical of cellulosic fabric; increasing barrier weight improves the heat release rate behavior but worsens cigarette ignitability. Its effect on open flame ignitability is presumed to be small.

2. Barriers cigarette ignition behavior.

- Polychloroprene (neoprene) foam barriers. These are seen to offer an improved behavior in all three aspects (cigarette ignitability, open flame ignitability, and heat release rate). Performance is improved with barrier thickness (density is usually constant). A neoprene foam barrier was considered to be completely satisfactory even for the fire environment in aircraft; however, its weight precludes its use in that application. The neoprene foam barrier derives a signification fraction of its effectiveness from the action of the filler, aluminum trihydrate, in releasing water as a cooling mechanism.
- Fiberglass cloth. Quite widely used but unless coated, this is porous and not practical in larger thickness because of its brittleness. Its mechanical strength under heating can be usefully exploited in single or multi-layer constructions. Fiberglass cores with FR cotton wrappings or with PVC coating are used widely.
- Novoloid felt. This was seen to be effective in some full-scale chair tests where it reduced peak heat release rate.
- Aramid non-woven barriers are also used widely. Their performance is dependent on thickness.
- Intumescent barriers. These fabrics swell to several times their original thickness when exposed to fire. They insulate and protect filling materials from exposure to heat.

Fire Barrier Studies

Numerous studies to evaluate the flammability performance of barriers in furniture have been conducted. Papers describing primary results with barriers are discussed below. The relative performance of barriers can vary with cover fabric, filler materials, and intensity of the ignition source. This is evident in a study involving the Cone and furniture calorimeter results for eight fabrics, each paired with three barriers, over California Technical Bulletin (TB) 117 and medium level melamine foam.[6] In this case, the 60 and 180 second average HRR generally ranked a woven glass fiber barrier best, followed by a non-woven aramid fabric and a coated glass fabric (fabric weights were 120, 68, and 265 gm^{-2}).

A barrier which breaks open or which does not have sound bonding at the edges and seams (because of the use of sewing threads with low heat resistance) can readily let the padding become involved at an early stage and lose its protective value. Barriers are reported to reduce flame spread, but differences in flame spread behavior due to various barrier materials were found to be minor in two early studies.[7,8] In another study, 10 and 40 g wood cribs were ignited on large mock-ups of ordinary polyurethane covered with 60/40 wool/viscose fabric.[9] Three barriers, a FR polyurethane, a modified neoprene, and a Novoloid felt, greatly extended times to certain temperature and pyrolysis product levels in the room, with only minor difference between these barriers.

Barriers with open weaves may help with cigarette ignition resistance but permit pyrolysis gasses from the padding to enter the burning process.[10] Molten thermoplastic fabrics can penetrate porous barriers resulting in flames below the barriers.[5] Thermoplastic barriers were found ineffective in Cone Calorimeter tests.[11]

One paper describes the Ohio State University calorimeter results obtained with composites of nylon, polypropylene, and cotton fabrics over TB 117 and TB 133 (melamine treated) polyurethane, with and without various barriers.[8] The author emphasized that generalizations about such composites should not be made, but each system needs to be tested. Barriers generally improve the performance of composites containing TB 117 and TB 133 foams. But for thermoplastic fabrics used with a glass cloth barrier, the HRR at low irradiance was the same for both foams. This is explained by the collection on the glass cloth of the molten fabric material, which then burned. The type of foam did not effect the results. In a heavy cotton fabric/barrier/melamine foam composite, the flames almost extinguished but then re-ignition occurred, presumably due to the depletion of melamine. Cotton and polyester batting barriers acted like wicks for thermoplastic outer fabrics, and increased heat release.

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[6] Ohlemiller, T.J., and Shields, J.R., *Behavior of Mock-ups in the California Technical Bulletin TB 133 Test Protocol: Fabric and Barrier Effects*, NISTIR 5653, NIST, Gaithersburg, MD (1995)
[7] Prager, F.H. and Wood, J.F., *Full Scale Investigation of the Fire Performance of Upholstered Furniture*, Part I (RAPRA 4), International Isocyanate Institue (1979)
[8] Woolley, W.D., Ames, S.A., Pitts, A.I., and Buckland, K., The Ignition and Burning Characteristics of Fabric Covered Foams, *Fire Safety Journal*, 2:39-59 (1978/80)
[9] Gallagher, J.A., Interliner Effects on the Fire Performance of Upholstery Materials, *Journal of Fire Sciences*, 11:87-105 (1993)
[10] Grand, A.F., Priest, D.N., and Stansbury, H.W., II, Burning Characteristics of Upholstered Chairs, *Fire and Flammability of Furnishings and Contents of Buildings*, ASTM SP 1233:63-82, ASTM, Philadelphia, PA (1994)
[11] Villa, K.M., and Babrauskas, V., *Cone Calorimeter Rate of Heat Release Measurements for Upholstered Composites of Polyurethane Foam*, NISTIR 4652, NIST, Gaithersburg, MD (1991)

A Finnish study ranked barriers from worst to best fire resistant properties: FR polyurethane, pre-oxidized carbon fabric, and FR cotton fabrics; FR treated wool felt; glass fabric.[12] Plots of heat and smoke release rate and CO concentration for these barriers in a composite with a FR polyester fabric and polyurethane foam are given in the paper. The weight of the barrier and the flammability of the cover fabric played an important role in the rankings. Barriers were found necessary with larger ignition sources even for certain FR cover fabrics.

Alternate Fire Barrier Test

The CPSC staff incorporated an alternate barrier test to provide flexibility to the furniture industry, and preserve fabric choices while providing increase flammability performance for furniture products. The barrier test is based on the British Standards Institute 5852 standard[13] using the crib #5 ignition source. The purpose of the barrier is to limit the fire growth of the furniture composite. The test evaluates the ability of the barrier material to protect the internal filling of the furniture composite. Since the barrier material is not designed to prevent furniture ignitions, the ability of the barrier material cannot be adequately evaluated with a small open-flame ignition source. The performance of the barrier is critical when the furniture has already achieved a sustained ignition. Therefore, the ignition source should represent a sustained ignition. The ignition source selected for the barrier tests is a 40 x 40-mm wooden crib with a mass of approximately 17 grams. The performance criteria for the barrier test are for flaming and smoldering ignition.

CONCLUSION

Although the CPSC staff preference is to prevent the ignition of furniture, staff believes that the barrier approach can be effective in reducing upholstered furniture fires when applied with appropriate performance requirements. Some barriers can provide improved flammability performance against open flame sources as well as cigarette ignition resistance benefits. The draft standard requires that barriers prevent the ignition or substantially reduce the contribution of interior filling materials of furniture in fire scenarios. The alternate barrier test will provide flexibility to the furniture industry in meeting the requirements of the draft standard and afford consumers an adequate level of safety from small open flame and possibly cigarette ignitions.

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[12] Pakkala, L., and Ryynanen, T., Improving the Fire Resistance Properties of Upholstered Furniture, Research Note 1002, Technical Research Institute, Espoo, Finland (1989)
[13] Methods of test for Assessment of the Ignitability of Upholstered Seating by Smoldering and Flaming Ignition Sources – BS 5852: 1990

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: October 23, 2001

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

THROUGH: Hugh McLaurin
Associate Executive Director
Directorate for Engineering Sciences

Nicholas V. Marchica
Division Director, Mechanical Engineering
Directorate for Engineering Sciences

FROM : Rohit Khanna
Fire Protection Engineer
Directorate for Engineering Sciences

SUBJECT : Cigarette - Open Flame Relationship

INTRODUCTION

The purpose of this memorandum is to: 1) describe and relate the mechanisms of smoldering and flaming combustion of upholstered furniture and, 2) explain why the staff believes that the draft small open flame standard will reduce the cigarette ignition hazard. Smoldering and flaming are two different but equally important modes of combustion that need to be considered when assessing upholstered furniture flammability. Any upholstered item may be capable of one or both modes of burning. The ignition scenarios are likewise different. A smoldering furniture fire usually is initiated from a cigarette, whereas a flaming fire can be started with a variety of ignition sources such as matches, lighters, or other larger flaming sources. In addition, a smoldering fire may develop into a flaming fire later in its course, or a flaming fire may convert to a smoldering fire due to lack of oxygen. Therefore an effective upholstered furniture flammability standard needs to address both smoldering and flaming combustion since upholstered furniture is capable of either or both modes of burning.

TEXTILE CLASSIFICATION AND THERMAL PROPERTIES

Before discussing smoldering and flaming combustion of upholstered furniture, it is necessary to discuss classification and some important thermal properties as they relate to textiles. Textile fibers are either natural or manufactured (man-made), depending on origin. A *natural fiber* is any fiber that exists as such in natural states in a form that can readily be converted to yarns and fabrics. A *manufactured fiber* is any fiber derived by a process of manufacture from any substance, which, at any point in the manufacturing process, is not a fiber. The fibers in this class are produced from raw materials that may or may not have fibrous forms.

Fibers are either protein, cellulosic, mineral (inorganic), or synthetic. Sometimes the synthetic group is erroneously called the "thermoplastic group". Although many synthetic fibers are *thermoplastic* (soften when heated and harden when cooled), others do not. These designations are determined by the chemical nature of a fiber. *Protein fibers* are composed of polymers of amino acids; *cellulosic fibers*, of polymers formed from glucose (sugar). *Mineral* (inorganic) *fibers* may be composed of silica obtained from rocks or sand; *synthetic fibers*, of polymers that originate from small, organic molecules typically obtained from petroleum refining process[1].

Fibers are also grouped according to their behavior when exposed to heat sources. Fibers that melt or soften when exposed to heat are called thermoplastics. These are often, but not always synthetic fibers. Fibers that produce char when exposed to heat are termed cellulosics, since they typically contain cellulose. Cellulosics can be natural or man-made fibers. A fiber's tendency to melt or produce char impacts its flammability performance when exposed to smoldering and open flame ignition sources and will be discussed in detail later in this document. Table 1 shows some important thermal properties of various fibers used in upholstery fabrics. Fibers differ in the amount of heat they generate during burning, called *heat of combustion* and the amount of oxygen required for combustion to be sustained, called *limiting oxygen index*[2].

Table 1 – Thermal Properties of Fibers

Fiber	Density G/cm^3	Pyrolysis Temp C	Ignition Temp.[a] C	Limiting Oxygen Index %	Heat of Combustion MJ/kg	Melting Temp. C
Polypropylene	0.96	320 – 400	350 – 495	18 – 19	46.5	160 – 177
Nylon	1.14	300 – 400	390 – 510	20 – 21	33.1	216 – 260
Acrylic	1.17	250 – 500	465 – 500	18 – 19	31.8	...
Modacrylic	1.35	140 – 170	s.e.[b]	27 – 31	...	...
Polyester	1.34	285 – 305	390 – 508	20 – 22	23.9	252 – 292
Wool	1.31	130 – 300	570 – 600	24 – 25	20.5	...
Cotton	1.35	285 – 300	250 – 260	17 – 19	17.0	...
Rayon	1.50	177 – 230	420 – 570	17 – 19	17.0	...
Kevlar	1.44	475 – 495	s.e.[b]	28 – 32	...	...

a: by ASTM D 1929 b: self-extinguishing

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SMOLDERING COMBUSTION

Smoldering combustion is a relatively slow, non-flaming combustion process involving an oxidizer gas and a porous solid fuel. A common example of smoldering combustion is a lit cigarette. Smoldering can also occur with porous fuels such as polyurethane foam. When a porous fuel smolders for a long period of time, it can create a large volume of vaporized fuel, which is ready to react suddenly if a flow of oxidizer occurs, such as a breeze or gust of wind. Such an occurrence incites the fuel to make the transition to flaming combustion[3]. The propensity to undergo smoldering combustion is greater in cellulosic materials. Cellulosic materials contain finely divided fuel particles that provide a large surface area per unit mass of fuel, which facilitates mixing with oxygen. The porous nature of the fuel particles allows oxygen transport to the reaction zone by diffusion and convection. At the same time, these particles form effective thermal insulators that help slow heat losses enabling sustained smoldering combustion. The principle requirement for smoldering to occur is that the material must form a rigid char when heated[4]. Materials that produce non-rigid char or tarry fluids will tend not to smolder. When cellulosic materials smolder, the formation of rigid char occurs. Char is not a well-defined material, but it is considered higher in carbon content than the original fuel; its surface area per unit mass is also enhanced. Char has a rather high heat of oxidation and is susceptible to rapid oxygen attack at moderate temperatures. The attack of oxygen forms mainly carbon monoxide and carbon dioxide. The process is facilitated not only by the enhanced surface area but also by the presence of alkali metal impurities that are present in all cellulosic materials, which catalyze the oxidation process[5].

FLAMING COMBUSTION

Most organic (natural and synthetic) materials will ignite in the presence of oxygen when exposed to an external heating source. When organic materials ignite, flaming combustion occurs when there is sufficient fuel and oxidizer to support a sustained exothermic reaction. The primary difference between flaming and smoldering combustion is the rate at which the oxidation reaction occurs. In flaming combustion, the rapid reaction rate produces temperatures so high that visible light is emitted from the combustion reaction zone[6].

TRANSITION FROM SMOLDERING TO FLAMING

Smoldering and flaming are two different modes of combustion. However, the relationship between smoldering and flaming combustion is clear. Fires may begin as smoldering and at some point may convert to flaming. The mechanism by which this occurs is a complex process of gas flow and reaction chemistry that is not well understood. There are some characteristics of this process that can be generalized from studies on this topic. The transition to flaming occurs when the smoldering process reaches a critical value and the reactants are ignited by external means or spontaneously. Transition to flaming occurs in upholstered furniture only after smoldering has been present for some time. The limited studies that have been conducted suggest that the propagation of smoldering down through the material is necessary for the transition to flaming. As the smoldering wave reaches the underside of the cushioning material, a pathway is created through which oxygen can reach the reaction zone[7]. Several studies have been conducted that characterize the potential for smoldering upholstered furniture fires to transition to flaming. One study conducted by the California Bureau of Home Furnishings (BHFTI) placed cigarettes on 15 commercial chairs[8]. Nine chairs went to flaming. The average time to transition to flaming was 142 minutes. The range of times was 60-306 minutes, which indicates that the occurrence of the transition from smoldering to flaming is highly variable. Another series of tests conducted by the National Bureau of Standards (NBS) on 22 identical chairs yielded and average transition time of 44 minutes and a range of 29-63 minutes for the 12 chairs that went to flaming[9].

FLAMMABILITY PERFORMANCE OF UPHOLSTRY MATERIALS

There are many different materials used in the construction of upholstered furniture. Some of theses major components are:

1. Cover fabric
2. Interliners – fabric between the cover fabric and padding
3. Padding – there are different padding materials in the seat, sides, and back
4. Weltcords
5. Decking – another fabric and type of padding below the seat cushion
6. Frames
7. Springs
8. Stiffeners

During the ignition process, regardless of the heating source, the cover fabric and materials directly below the cover fabric - the padding, are important. Also, the geometry of upholstered plays a key role in the ignition process. Table 2 summarizes the results from a wide variety of experiments on smoldering and open flame ignition behavior of upholstered furniture[10]. It can be seen from Table 2 that some materials that have good smoldering ignition resistance do not have good open flame ignition resistance. The converse holds true as well.

Table 2 Upholstered Furniture Components Listed In Order of Ignition Resistance

Ignition Resistance	Cover Fabric	Padding	Interliners	Weltcords	Construction Geometry
A. Smoldering Ignition Resistance					
High	Wool, PVC	Specialty foams† Polyester batting	Aluminzed fabrics Neoprene sheets Vinyl coated glass Novoloid felts	Aluminized PVC Thermoplastics	Flat areas Flat areas near welt cords
	Cellulose/thermoplastic blends	SR PU SR batting Untreated PU	Cellulosic fabrics	Cellulosics	Tufts
	Light thermoplastics	Mixed fiber batting			Crevices
	Light cellulosics	Cellulosic batting			
Low	Heavy cellulosics				
B. Small Flame Ignition Resistance					
High	FR Wool	Specialty foams‡	Aluminized gas impermeable fabrics	Minor effects	Flat areas
	Wool, PVC coated cellulosics‡	FR cellulosic batting FR PU	Neoprene sheets		Vertical areas
	Thermoplastics	Cellulosic batting	Novoloid fabrics§		Corner areas
		Polyester batting	Aramid fabrics§		
		Untreated PU	Vinyl coated glass fabrics‡		
		Latex Foam	FR cellulosic fabrics§		
			Cellulosic fabrics§		
Low			Thermoplastic fabrics		

SR – smolder resistant; FR – flame resistant; PU – polyurethane foam.
† Neoprene; combustion modified, high resiliency PU.
‡ heavier materials have higher flame ignition resistance and generally higher heat release and lower flame spread rate.
§ Fabrics include woven, knitted, and nonwoven structures.

Cover Fabrics

Cover fabrics play an important role in the ignition behavior of upholstered furniture. Cover fabrics are usually the first component of upholstered furniture exposed to heat sources. Their performance when exposed to heating sources is heavily dependent on their fiber content. For smoldering ignition, thermoplastics exhibit good ignition resistance. Their high resistance to smoldering ignition is primarily due to the fact that they do not support char formation. Thermoplastic fibers typically melt away when subject to heating sources. The smoldering ignition resistance of thermoplastics increases with fabric weight because a large portion of the heat from cigarettes is consumed in melting the thermoplastic fibers. Cellulosic fabrics exhibit poor smoldering ignition resistance. When cellulosics are exposed to low smoldering ignition sources, the formation of rigid char occurs. If enough alkali metal ions are present in the cellulose, this char will propagate and sustain smoldering combustion. The propensity for smoldering ignition of cellulosic fabrics increases with fabric weight.

In open flame ignition performance, thermoplastic fabrics exhibit poor performance. When in contact with flames, thermoplastic fabrics melt away from heat sources. This behavior exposes the internal components (padding and foam) of furniture to flames. For cellulosic fabrics, exposure to flames produces a rapid production of char. This char initially has a positive benefit as it acts as an insulator and protects the internal components of furniture. With continued flame exposure, the protective char layer eventually becomes consumed, splits, or enough heat is transferred to ignite internal components. The open flame ignition resistance of cellulosic fabrics increases with weight.

The data shown in Table 3 summarizes several studies conducted by the California Bureau of Home Furnishings[11]-[16]. The data shows that by increasing the content of thermoplastic fibers, the propensity to ignite from cigarettes decreases. Fabrics containing 20 to 50% thermoplastic fibers rarely ignite from cigarettes.

Table 3 – Cigarette Ignition Resistance of Typical Fabric/Padding Composites

	Percent of Fabrics Igniting		
	100% Cellulose	Cellulosic/ Thermoplastic Blends	100% Thermoplastics
A: Mini Mock-Up Results			
Batting			
100% Cotton			
Untreated	100	82	9
FR	76	43	0
70/30 Cotton/Polyester	79	32	0
100% Polyester			
Non-resinated	33	7	0
Resinated	19	4	0
Foam			
Polyurethane			
Untreated	41	25	0
FR 1	86	54	0
FR 2	38	25	0
High Resiliency	83	57	0
Neoprene	93	39	0
Neoprene Interliner Over cotton batting	19	14	
Glass Fiberboard	100	54	0
B: Full-Scale Furniture			
Results on 171 furniture items (various filling materials)	Fabric weight <270 g/m^2: 67 > 270 g/m^2: 95	>70% Cellulose: 82 <70% Cellulose: 6	6
Specifications			
Batting:	Density Kg/m^3	Foam	Density Kg/m^3
100% Cotton, untreated	38	Untreated PU	20
FR Cotton, 12-15% Boric acid	38	FR PU1 (antimony trioxide and PVC)	37
70/30 cotton/polyester, bonded	37	FR PU2 (brominated biphenyl)	32
100% polyester, resinated with 28% acrylic resin	8	High Resiliency PU (brominated organophosphat)	42
100% polyester, non-resinated with poly scrim	8	Neoprene (4% antimony trioxide, 16% alumina trihydrate)	56

Finishes and back coatings also effect the flammability behavior of cover fabrics. There are a variety of finishes applied to fabrics to enhance the degree of comfort and protection. Flame retardant finishing treatments exist to improve flame and smolder resistance. Treatment of cellulosic fabrics with borax and boric acid can increase both open flame and smoldering ignition resistance[17]. Some flame retardant treatments for cellulosic fabrics utilize char formation as a method to achieve flame resistance. Such treatments may worsen smoldering ignition resistance since char production may result in propagation of smoldering combustion. There are many spray-on flame retardant treatments marketed to improve open flame and smoldering ignition resistance of fabrics. These products may provide some improvement in ignition behavior, but their effectiveness has not been fully established. Issues such as uniformity and permanency are reasons to doubt the performance of such treatments. Back coated fabrics are composed of two or more layers of a textile fabric and a polymer layer. The layers are bonded together by an adhesive or by the adhesive properties of one of the component layers. Staff testing of FR back coated fabrics has demonstrated that this can be an effective method of improving both open flame and smoldering ignition of upholstered furniture[18].

Padding

The two major types of padding material are PU foam and batting. The effect of padding material on cigarette ignition resistance is illustrated in Tables 2 and 3. If the heat from a smoldering ignition source can transfer from the cover fabric, the properties of padding materials can determine whether or not smoldering will propagate. Until 1975, there was a general belief that PU foams would not smolder. It is now understood that certain standard grade foams will smolder while some specialty foams will only smolder when in contact with a substantial smoldering source[19]. The rate of foam smolder propagation is likely to be slower since the maximum temperatures are less than 400°C in still air. This is substantially less than the temperatures generated during smoldering in cellulosics, which is about 600°C[20]. This may be one reason why most PU foams will only smolder when subjected to a continuous heating source. Specialty foams such as Neoprene and Combustion Modified High Resiliency PU foams exhibit good smoldering ignition resistance.

For small open flame ignition, PU foam has poor ignition resistance. PU foam's high heat of combustion (24 MJ/kg) and cellular structure accounts for its rapid burning. Methods exist to improve the small open flame ignition behavior and burning of PU foam. The addition of FR elements such as chlorine, bromine, or phosphorous improves small open flame ignition resistance to PU foam. Specialty foams such as Neoprene and Combustion Modified High Resiliency PU foams High resiliency (HR) foams exhibit good open flame performance. When exposed to flames, these foams typically melt away or form voids and air bubbles.

There are several types of batting materials used in upholstered furniture. These include cotton batting, blends of cotton and polyester, and all polyester batting. Polyester batting is more cigarette ignition resistant than ordinary PU, and untreated cellulosic batting less so (Table 2 and 3). Most cellulosic batting contains primarily cotton but other fibers are also used. Untreated cellulosic batting smolders readily. Treatment with boric acid crystals is the most common SR treatment for cotton batting; concentrations required are roughly 8 – 12%. The boric acid is not applied as a water solution, since an expensive drying would be required. It is important that the boric acid particles adhere to the batting and not separate during use. An admixture of thermoplastic fibers to cotton fibers increases cigarette ignition resistance for padding as well as fabrics.

Interliners/Fire Blockers

The Upholstered Furniture Action Council (UFAC) program[21] requires that all fabrics be tested, and those which are more ignition prone (Class II) must be used with a barrier material between the fabric and the padding in the seating area. The most common barrier material passing UFAC requirements, is polyester batting, which is also often used as padding to achieve certain appearance and comfort effects. However, many fabrics, especially heavy cellulosics, cause cigarette ignition even with UFAC approved polyester barriers. Other interliners, which are primarily used to improve flame resistance, are neoprene and CMHR PU sheets, glass fabrics, Nomex and Kevlar non-wovens, and aluminized fabrics; they are generally effective in increasing cigarette as well as open flame ignition resistance.

EFFECT OF GEOMETRY

For any composite of fabric and padding material, cigarette ignition resistance is higher in flat areas than in crevices[22]. Several factors such as re-radiation from two surfaces, chimney effect of air in the channel below the cigarette; and in the case of cellulosic fabrics, the increase in mass of cellulosic fibers and alkali ions due to multiple layers at the seams contribute to conditions to enhance smoldering. Most tests require testing in a 90° crevice. Smaller angle crevices, which could be formed by the cigarettes falling between the seat and back or sides of furniture, have been reported to have lower ignition resistance. Tufted areas may also have lower cigarette ignition resistance than flat areas and are usually tested separately, as are areas near the welt edge outside the crevices. If cigarettes rest inside the tufted indentation, ignition has been observed to be more frequent than in flat areas; however, if the burn cone tends to stick out into the air, and the rest of the cigarette rests on the flat area, the likelihood of ignition should be enhanced[23].

FLAME SPREAD

Flame spread has been the basis of flammability evaluation of building materials; however, little quantitative work has been done on the flame spread over upholstered furniture. General flame spread theory has not been much applied to upholstered items, primarily because of the variety of configurations and interaction between fabric and padding.

HEAT RELEASE RATE

During the last few years, the importance of the heat release rate for the prediction of flashover potential has been realized. Several methods to measure heat release have been suggested. One early technique is to directly measure the sensible enthalpy of the fire gas outflow. However, this requires corrections be made for losses to the room walls; these losses may vary widely for various wall materials, and depend on the heat release rate of the material being evaluated. Furniture calorimeters, i.e., large-scale instruments in which actual furniture can be tested have been developed by a number of laboratories. A bench-scale instrument, i.e., the cone calorimeter has been developed to measure heat release of a small sample of material. A method based on the Ohio State University (OSU) calorimeter has been used widely. The correlation between furniture calorimeter and cone calorimeter results has not been fully established. In addition, utilizing heat release rate as an acceptance criteria for small open ignited furniture fires will not fully address the hazard toxic combustion products in residential fires. For these reasons, staff believes that limiting allowable combustion for flaming and smoldering is the most effective method for reducing fire losses with residential furniture.

POTENTIAL CIGARETTE IGNITION BENEFITS

The provisions in the draft standard address the risk of small open flame ignition of upholstered furniture. In addition, substantial benefits will be achieved by reducing the risk of cigarette ignition. As discussed previously, upholstered furniture is capable of both flaming and smoldering combustion. The staff recognizes that these are two different physical combustion phenomena and has considered this in the development of the draft standard. Hence, staff believes the draft standard will be effective in addressing flaming and smoldering combustion of upholstered furniture.

The draft standard contains provisions to limit both flaming and smoldering combustion. Although the standard does not utilize a smoldering ignition source, the provisions account for smoldering combustion. A material's propensity to smolder is dependent on the physical and chemical properties of the material regardless of the ignition source. The properties of materials that effect smoldering combustion were discussed in detail earlier. Extensive data available on the relative ability of materials to support smoldering combustion was also reviewed.

The draft standard requires mock-up composites of fabrics to be used in upholstered furniture and standard untreated PU foam. After exposure to the small open flame ignition source, the composite is required to cease flaming combustion within 2 minutes and cease smoldering combustion within 15 minutes. Any flaming or smoldering beyond the specified time limits is considered a failure of the composite. Typically, fabrics that are prone to smolder may transition to flaming under certain conditions. Studies show that this transition can occur after 29 minutes. Therefore staff has limited allowable smoldering combustion of composites to 15 minutes. Staff believes that the requirements in the draft small open flame standard can address a large portion of cigarette ignited fires. Since the standard contains requirements to limit both flaming and smoldering combustion, substantial benefits from reducing the risk of cigarette ignited fire will be realized.

REFERENCES

[1] Hatch, Katherine, *Textile Science*, pp. 84-86, West Publishing Company, St. Paul, MN (1993)

[2] Kransy, John, F., Parker, William, J., Babrauskas, Vytenis, *Fire Behavior of Upholstered Furniture and Mattresses*, p 208, Noyes Publications, Norwich, NY (2001)

[3] Microgravity Combustion Science Discipline Brochure

[4] Drysdale, Dougal, *An Introduction to Fire Dynamics*, p 276, John Wiley and Sons (1992)

[5] Olemiller, Thomas, J., *Smoldering Combustion*, The SFPE Handbook of Fire Protection Engineering, p 1-352. NFPA, Quincy, MA (1988)

[6] Kanury, A. Murty, *Flaming Ignition of Solid Fuels*, The SFPE Handbook of Fire Protection Engineering, p 1-326. NFPA, Quincy, MA (1988)

[7] Drysdale, Dougal, *An Introduction to Fire Dynamics*, p 274, John Wiley and Sons (1992)

[8] McCormack, J.A., Damant, G.H., Williams, S.S., and Mikami, J.F., *Flaming Combustion of Upholstered Furniture Ignited by Smoldering Cigarettes*, BHFTI, North Highlands, CA (1980)

[9] Bukowski, R.W., *Investigation of the Effects of Heating and Air Conditioning on the Performance of Smoke Detectors in Mobile Homes*, NBSIR 79-1915, NBS, Gaithersburg, MD (1979)

[10] Babrauskas, Vytenis and Krasny, John, F., *Upholstered Furniture and Mattresses*, NFPA Handbook, p. 3-129. NFPA, Quincy, MA (1993)

[11] Kransy, John. F., Parker, William, J., Babrauskas, Vytenis, *Fire Behavior of Upholstered Furniture and Mattresses*, p 212, Noyes Publications, Norwich, NY (2001)

[12] Damant, G.H., and Young, M.A., Flammability Classification of Fabrics Used as Upholstery Furniture Coverings, *J. Consumer Products Flammability*, 4:60-113 and 329-345 (1977)

[13] Damant, G.H., Williams, S.S., and McCormack, J.A., *The Role of Fabric in the Cigarette Ignition of Upholstered Furniture*, Laboratory Report No. SP-83, Bureau of Home Furnishings, North Highlands, CA (1983)

[14] McCormack, J.A., Damant, G.H., and Williams, S.S., Cigarette Evaluation of 450 Pieces of Residential Upholstered Furniture, *J. of Fire Sciences*, 4:135-147 (1986)

[15] McCormack, J.A., and Damant, G.H., Flammability Studies of 700 Articles of Upholstered Furniture, *J. of Fire Sciences*, 6:121-138 (1988)

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: 17 October 2001

TO : Dale Ray, Upholstered Furniture Project Manager
Directorate for Economics

THROUGH: Susan Ahmed, Ph.D., Associate Executive Director
Directorate for Epidemiology

Russell Roegner, Ph.D., Director
Division of Hazard Analysis

FROM : Mark S. Levenson, Ph.D. ML
Division of Hazard Analysis

SUBJECT : Upholstered Furniture Compliance Testing Plan: Statistical Aspects

Background

The Consumer Product Safety Commission (CPSC) is presently considering a mandatory standard to reduce the hazard associated with small open-flame ignitions of upholstered furniture. Furniture subject to the standard would be required to resist small open-flame ignition. Furniture manufacturers would have the option of choosing between two methods for determining ignition resistance. The primary test method is a component test of the upholstery fabric.[1] Alternatively, manufacturers could choose to use a barrier material between the upholstery fabric and the filling. The barrier material would have to be ignition resistant as determined by a component test of the barrier.[2] CPSC is considering a testing plan that manufacturers would employ to establish compliance with the standard. This memo addresses the statistical aspects of the proposed plan. The plan is the same for both the upholstery fabric and the barrier material tests.

Compliance Testing Plan

The testing plan is based on a statistical sample of the material. First, units of the material are defined based on production considerations and material considerations to have uniform properties with regard to ignition resistance. Scientific knowledge and existing studies will be used for the definition. Second, samples from the unit are subjected to the

[1]See "Draft Standard For Small Open Flame Ignition of Upholstered Furniture" by R. Khanna, February 2001.
[2] See "Alternate Barrier Test" by L. Fansler, October 2001.

relevant test method. Finally, based on the test results of the samples, the compliance of the unit to the standard is determined.

The testing plan consists of three stages: Initial, Normal, and Reduced. A manufacturer tests units of a new class of material using the Initial Stage plan. After 5 units have been demonstrated to be compliant under this plan, the manufacturer may use the less stringent Normal Stage plan. In a similar manner, the manufacturer moves to the least stringent Reduced Stage plan. However, a failure of a unit at any stage requires the manufacturer to start the process over with the Initial Stage plan.

Each stage has a maximal size permissible for a material unit. This size is smallest for the Initial Stage and largest for the Reduced Stage. The sizes are based on scientific knowledge and existing studies. Additionally, the number of samples and corresponding tests decrease after the Initial Stage. In the Initial Stage, three samples are selected. Each sample will consist of four specimens. The resulting 12 specimens are tested providing 12 test results. If all the 12 tests pass, the unit is defined as compliant. If two or more tests fail, the unit is defined as non-compliant. If one of the tests fails, an additional sample of four specimens is selected. The four specimens are tested. If all four tests pass, the unit is compliant. If there are any failures, the unit is non-compliant. Normal and Reduced Stages are similar except only two initial samples of four specimens are selected. Guidance will be provided on selecting the samples to best represent the unit and minimize costs. Table 1 summarizes the three stages.

Table 1: Testing Plan Stages.

Stage	Maximal Unit Size (yds)	Initial Samples	Subsequent Samples	Specimens Per Sample	Compliance Criteria
Initial	1000	3	1	4	(a) No Failures in initial samples or (b) One failure in initial samples and no failures in subsequent samples
Normal	5000	2	1	4	(a) No Failures in initial samples or (b) One failure in initial samples and no failures in subsequent samples
Reduced	10,000	2	1	4	(a) No Failures in initial samples or (b) One failure in initial samples and no failures in subsequent samples

The probability of rejecting a unit under each of the three stages can be calculated. Figure 1 gives these probabilities as a function of the *Unit Compliance Proportion. The Unit Compliance Proportion* (UPC) is the proportion of specimens from the unit that would pass the test method if the entire unit were tested. UPCs very near one are intended by the standard. Under the Initial Stage plan, there is an 85% probability of rejecting a unit with an UPC of 0.8. The probability drops to 47% and 18% at UPCs of 0.90 and 0.95, respectively. The corresponding probabilities under the Normal and Reduced stages are 69%, 32%, and 11% for UPCs of 0.8, 0.90, and 0.95, respectively.

As mentioned above, after 5 passing units the sampling plan is relaxed to the next stage. Figure 2 provides the probability of failing at least one of 5 units for the three different stages as a function of UPC. Logically, passing 5 units is much more stringent than passing a single unit. Under the Initial Stage, there is a 96% chance of failing at least one unit in 5 for an UPC of 0.90. However, the probability decreases rapidly for higher UPCs. For the Normal and Reduced Stages, the probabilities are correspondingly lower. However, they are still quite high for UPCs less than 0.90.

Summary

The proposed compliance testing plan consists of three stages of statistical sampling. The first stage, Initial Stage, is designed to be stringent until a manufacturer's process of producing ignition resistant materials is established to be reliable. After the reliability is established as demonstrated by the consistent passing of units in the Initial Stage, the number of samples is decreased and the permissible size of the material units is increased in the Normal Stage. A final stage, Reduced Stage, is reached with even larger permissible units if additional units consistently pass. The testing of a unit under any of the stages allows for the possibility of a single failure among multiple tests, if further specified tests do not produce any additional failures.

Figure 1: Probability of Rejecting a Unit Under Initial, Normal and Reduced Stages

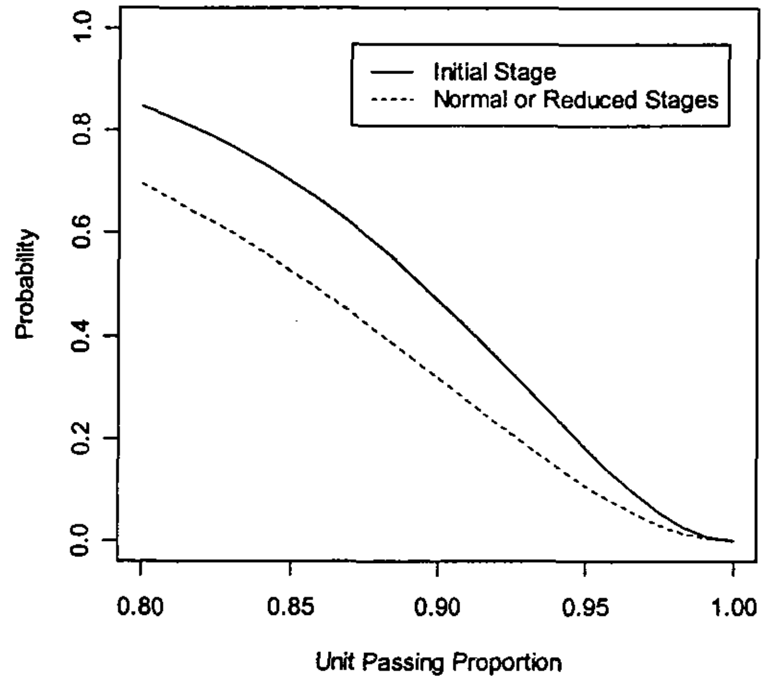
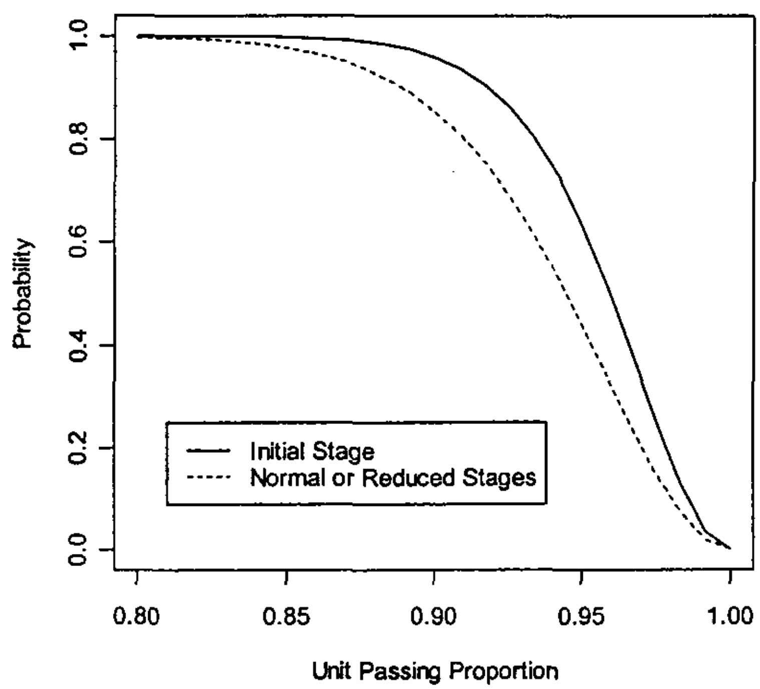


Figure 2: Probability of Failing at Least One of 5 Units Under Initial, Normal and Reduced Stages



TAB D

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: October 19, 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 : Summary of Upholstered Furniture Flammability Tests

During 1998 through 2000, Laboratory Sciences staff carried out a series of tests addressing flammability issues related to the small open flame and cigarette ignition resistance of upholstered furniture. Twelve individual reports were prepared describing the results of the tests. The attached technical report summarizes the major findings of each test.

Technical Report: Summary of Flammability Tests Upholstered Furniture Project (1998-2000)

Linda Fansler
Laboratory Sciences
10/19/00

The Directorate for Laboratory Sciences carried out a series of tests designed to better understand small open flame and smoldering (cigarette) ignition performance of upholstered furniture. This recent work (1998 to 2000) builds on information presented in the 1997[1] Upholstered Furniture Briefing Package. There are five major categories of tests: UK chairs, filling materials, flame resistant fabrics and barriers, sensitivity issues and cigarette ignition. This memorandum summarizes the major findings of each test.

UK CHAIRS

Twenty-seven upholstered chairs manufactured in the United Kingdom (UK) were tested[2] to evaluate the relationship between a full-scale upholstered chair's flammability performance and the results obtained using the mockup test procedure[3] in the staff's draft test protocol. The potential added benefit of cigarette ignition resistance was also studied. Two reports were written describing the UK chair study; these reports are references 2 and 4. The major findings of the UK chair study include:

- Eighty-one percent (22) of the 27 UK chairs had corresponding results in both full-scale and Draft Standard for Upholstered Furniture mockup seating area tests.
- Fifty-nine percent (16) of the 27 chairs did not ignite when tested to both the seating area full-scale and Draft Standard for Upholstered Furniture mockup test protocols.
- Eighty-seven percent (14) of the 16 UK chairs resisting ignition in both seating area tests, also resisted ignition from cigarettes.

[1]Superscript refers to references on pages 8 and 9.

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, other factors besides the presence of flame resistant upholstery fabrics that 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[4] that investigated some of these factors indicate that the amount of flame retardant chemical in backcoated fabrics is an important factor in determining whether a fabric will resist ignition from a small flame source. Fabrics with inadequate amounts of flame retardant chemicals may resist ignition in the mockup test procedure but ignite in full-scale, depending on the type of filling material directly beneath the upholstery fabric and/or the chair design. In addition, the number of tests (three flame applications) in the current draft test protocol tends to increase the possibility that borderline upholstery fabrics, those that sometimes resist ignition and other times ignite, aren't readily identified.

The recent study[4] also confirms that the fiber content and filling material directly beneath the upholstery fabric are less important than the concentration of flame retardant chemicals in backcoated and immersion treated upholstery fabric in determining whether an upholstered chair resists cigarette ignition. Flame resistant foam and other chemically treated filling materials appear to be important for some upholstery fabrics, especially cellulosic fabrics, in preventing cigarette ignition.

In addition to fiber content, limited data suggest that fabric construction and weight may also be important factors affecting cigarette ignition resistance of flame retardant immersion treated upholstery fabrics. Two fabrics with similar fiber content were examined; a heavier fabric with a pile construction ignited while a lighter fabric with a plain weave construction did not ignite when exposed to a lit cigarette.

FLAME RESISTANT FABRICS AND BARRIERS

As reported[1] in the 1997 Upholstered Furniture Briefing Package, typically upholstery fabrics must be treated or backcoated with flame retardant chemicals or contain inherently flame-resistant fibers (wool, polyvinyl, leather, etc.) to resist small open flame ignition and meet the criteria of the draft test protocol. Laboratory staff continued this investigation by testing[5] a variety of upholstery fabrics. Fifty upholstery fabrics from several sources were tested, including 16 untreated, 16 backcoated with flame-retardant chemicals, eight chemically fire resistant (immersion) treated, and ten inherently fire resistant fabrics. Further details of this study are found in reference 5.

- Twenty-nine of the 50 upholstery fabrics resisted ignition after exposure to a 20 second flame.
- Two of these fabrics that resisted ignition were not treated with flame retardant chemicals.

Some of the upholstery fabrics resisted ignition with flame application times beyond the 20 seconds as specified in the draft test protocol. These included eight fabrics backcoated with flame retardant chemicals, eight fabrics chemically treated to resist ignition, and four inherently resistant fabrics. Extended flame application times ranged from 25 to 120 seconds.

Barrier fabrics designed to be placed between the upholstery fabric and filling materials were also evaluated[5]. The barrier fabrics were chemically treated; the chemical causes the fabric to swell when exposed to heat. The combination of the barrier fabric with a non-fire resistant upholstery fabric did not always improve the flammability performance.

SENSITIVITY ISSUES

In response to public comments concerning the sensitivity or robustness of the staff's draft test protocol and fixture design, a series of tests[6] were conducted evaluating the effects of 14 variables. These variables included:

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.

Eight reports, references 6, 7, 9 to 14, were prepared discussing the sensitivity issues.

1. Seat Back Angle

Modifications were made to the mockup test frame so that the junction where the back and seat join was changed from the specified 90° angle. Tests were run with the seat back angle set at 95° and 85°. Although this limited testing[7] did not indicate that a small change to the seat back angle influenced the outcome of the testing, this factor only becomes an issue if a deliberate effort is made to alter the seat back angle.

2. Flame Angle and
3. Flame Placement

The approach angle of the flame is fixed by the design of the Furniture Flammability Fixture. The flame travels at a 45° angle to the crevice of the seating area mockup. Adjustments[8] can be made to properly align the burner in the crevice of the seating area test following the draft test protocol and test fixture operations manual. Laboratory staff does not consider these two issues to be influencing factors because they are both controlled.

4. Flame Size

The draft test protocol states that a flame height of 35mm (1.4 in) can be achieved when the gas pressure and flow meet the specifications given. This flame height is easily achievable. Although the method and gage used to determine the height of the flame are somewhat imprecise, the small variation of the flame size may not be a factor affecting the outcome of the test results.

5. Application Time
The flame application time is specified in the draft test protocol. The timer used on the test fixture is set with a flame application time of exactly 20 seconds. When the flame application time is altered, the draft test protocol is no longer being followed.

6. Fabric Tension
The draft test protocol states that the upholstery fabric is mounted on the mockup test frame over standard polyurethane foam under even tension. Uniform tension results in the fabric and foam being in direct, intimate contact with no air pockets. These are obvious visual clues to the test operator that the mockup is constructed according to the protocol.

7. Soaking Procedure
The intent of the water soaking procedure in the draft test protocol is to remove any nondurable fire retardant finishes used on upholstery fabrics. Laboratory staff tested[9] upholstery fabrics before and after the water soak and found those fabrics that met the criteria in the draft test protocol before soaking also met the criteria after soaking. However, the language in the draft test protocol needs clarification as to when this provision of the standard is applicable.

8. Filling Materials
In addition to the observations made concerning filling materials in the UK chair study, nine filling materials commonly found in upholstered furniture and three upholstery fabrics were tested in a limited study.[5] It appears that filling materials directly beneath upholstery fabrics may play a larger role in the ignition of some upholstery fabrics than previously thought. Both studies showed that the filling material may be an influencing factor that should be taken into consideration when evaluating upholstered furniture's resistance to small open flame ignition.

9. Spilled Liquids
A limited study[11] was done to examine the effects of the residue left on upholstery fabrics from spilled beverages. Of the three upholstery fabrics used in this study only one, a flame retardant chemically backcoated fabric showed a slight decrease in ignition and burning characteristics.

10. Soiling
No significant effects[12] on the flammability of three upholstery fabrics were found after they were soiled with simulated body and food oils. A mixture of four fatty acids was used to simulate the body and food oils. Laboratory staff concluded that soiling with these fatty acids did not affect the flammability performance of these upholstery fabrics based on the test criteria in the draft test protocol.

11. Cleaning Agents and Wear Effects
Cleaning and wear on upholstery fabric flammability and the durability of a flame-retardant chemical backcoating was examined[13] by Laboratory staff. A professional upholstery cleaner cleaned three upholstery fabrics using commercial products and equipment, and laboratory staff cleaned identical fabrics using a product designed for home use. One of the fabrics was also pounded repeatedly with a constant force before and after cleaning to simulate sitting (wear). Laboratory staff determined using both chemical analysis and flammability tests that cleaning and pounding had no significant effects on the flammability of the fabrics studied.

12. Effect of Fabric Finishes
The effect of consumer add-on protective fabric finishes was studied[14] by Laboratory staff. Two stain repellent products and a fire retardant spray-on additive were studied. The stain repellent products had no effect on flammability of two non-flame resistant upholstery fabrics and one fabric backcoated with flame retardant chemicals. The spray-on fire retardant additive improved the flammability performance of the two non-flame resistant upholstery fabrics; however, this product is water based and therefore must be reapplied after exposure to water.

13. Effects of Fire Barriers
Laboratory testing showed that barriers designed to prevent heat and or flame exposure from reaching the filling materials below the upholstery fabric do not always guarantee that an upholstery fabric will meet the criteria in the draft test protocol.[1,5]

14. Identification of 'Borderline' Upholstery Fabrics
Using the draft test protocol and furniture test fixture, Laboratory staff identified some flame retardant chemically backcoated upholstery fabrics with inconsistent flammability characteristics. These 'borderline' fabrics sometimes meet and other times do not meet the criteria in the draft test protocol. Increasing the number of upholstery fabric specimens tested will identify these 'borderline' fabrics more reliably.

Sensitivity Summary
The draft test protocol was designed to achieve a specific outcome. After examining these key issues, Laboratory staff conclude that with one exception (role of filling material), 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.

CIGARETTE IGNTION

In addition to the cigarette tests on the UK chairs, cigarette tests[15] were conducted on 40 other upholstery fabrics including both flame resistant and non-resistant fabrics. The fabrics were evaluated for cigarette ignition resistance using the test protocol in the Upholstered Furniture Action Council (UFAC) Fabric Classification Test Method[16] and or a modified version of the UFAC procedure using the small open flame seating area mockup. Reference 15 is a report containing the details of the cigarette tests.

The majority of the 40 fabrics tested resisted ignition from smoldering cigarettes. Twenty-five of the upholstery fabrics were evaluated with both test protocols. Of these 25 fabrics only one had inconsistent results; the fabric ignited in the CPSC modified test protocol but not in the UFAC protocol. This fabric was an 11-ounce flame retardant chemically backcoated cotton upholstery fabric. The non-resistant version of this fabric did not ignite in either test protocol.

Similar results were obtained with another 11-ounce cotton upholstery fabric although this fabric was only evaluated with the CPSC protocol. In the non-resistant version, the cotton fabric did not ignite but the version with the flame-retardant chemical backcoating ignited. These results concur with the UK chair tests, which showed that certain flame resistant treated cellulosic upholstery fabrics may resist small open flame ignition but ignite from smoldering cigarettes.

CONCLUSIONS

- There are upholstered chairs in the UK market that resist ignition from both small open flame and cigarette ignition sources.
- The amount of flame retardant chemicals in backcoated upholstery fabrics is an important factor in determining whether a fabric will resist ignition from a small flame source.
- Depending on the flame retardant chemical treatment level in the fabric, filling materials may play a role in determining small open flame ignition resistance of upholstered furniture.
- Some upholstery fabrics that meet the test criteria in the staff's draft test protocol also resist ignition with flame application times beyond 20 seconds.
- Barrier fabrics do not always improve flammability performance of non-fire resistant upholstery fabrics.
- The use of standard foam vs. actual filling materials found in an upholstered furniture item is the only sensitivity issue identified that has the potential to influence the outcome of tests performed following the draft test protocol.
- Cellulosic flame resistant treated upholstery fabrics may not always resist both small open flame and cigarette ignition. Flame resistant filling materials may be needed for certain flame resistant treated cellulosic upholstery fabrics to resist cigarette ignition.

REFERENCES

1. Memorandum to Dale Ray, EC, from L. Fansler, LS, *Summary of Upholstered Furniture Tests*, October 1997, CPSC.

2. Memorandum to Dale Ray, EC, from L. Fansler, LS, *UK Chair and Mockup Test Results*, October 2000, CPSC.

3. *Draft Standard for Upholstered Furniture*, R. Khanna, Directorate for Engineering Sciences, CPSC, October 3, 1997.

4. Memorandum to Dale Ray, EC, from D. Cobb, W. Tao, LS, *Impact of Flame Retardant Chemicals, Filling Materials and Fabric Type on Flammability Testing*, October 2000, CPSC.

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

6. Memorandum to Dale Ray, EC, from L. Fansler, LS, *Sensitivity Issues and Other Factors Influencing the Flammability of Upholstery Fabric*s, June 2000, CPSC.

7. Memorandum to Dale Ray, EC, from L. Fansler, LS, *Effects of Variations To The Seat/Back Geometry*, May 2000, CPSC.

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

9. Memorandum to Dale Ray, EC, from W. Rowe, *Effects of Tap Water Soaking on Upholstered Fabric Flammability*, May 2000, CPSC.

10. Memorandum to Dale Ray, EC, from J. Puskar, A. Bernatz, LS, *Ignition Tests of Filling Materials Currently Found in Upholstered Furniture*, May 2000, CPSC.

11. Memorandum to Dale Ray, EC, from A. Bernatz, LS, *Effects of Beverages on the Flammability of Upholstery Fabrics*, June 2000, CPSC.

12. Memorandum to Dale Ray, EC, from W. Tao, LS, *Effect of Soiling on the Flammability of Upholstery Fabric*s, May 2000, CPSC.

13. Memorandum to Dale Ray, EC, from W. Tao, G. Sushinsky, B. Bhooshan, D. Cobb, LS, *Cleaning and Wear Effects of Upholstery Fabric Flammability*, May 2000, CPSC.

14. Memorandum to Dale Ray, EC, from D. LaRue, LS, *Small Open Flame Ignition Test Results of "Over-The-Counter" Fabric Finishes*, May 2000, CPSC.

15. Memorandum to Dale Ray, EC, from G. Stafford, A. Bernatz, LS, *UFAC vs. CPSC Cigarette Tests of Upholstery Fabrics*, April 2000, CPSC.

16. *UFC Test Methods*, Upholstered Furniture Action Council, 1990.

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: May 30, 2000

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

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

Robert T. Garrett, Director, Division of Electrical Engineering

FROM : Dean L. LaRue, Electrical Engineer, Laboratory Sciences

SUBJECT : Small Open Flame Ignition Test Results of Flame Retardant Upholstery Fabrics and Intumescent Barrier Fabrics

SUMMARY

The U.S. Consumer Product Safety Commission's (CPSC) Directorate for Laboratory Sciences (LS) has conducted tests on fabrics received from two chemical manufacturers and four textile manufacturers. These fabrics included fabrics with fire resistant backcoatings, fabrics with fire resistant chemical treatments, fabrics with fire resistant properties, a fire resistant barrier fabric used with upholstery fabric, and untreated fabrics. All fabrics were evaluated for small open flame resistance. Thirty-four of the 50 different fabrics tested were fire resistant fabrics. Of these 34, 79% (27) did not ignite when tested to the draft test protocol. Two non-fire resistant fabrics also did not ignite. Of the 29 non-igniting upholstery fabrics, 69% (20) resisted ignition with extended flame application times ranging from 25 to 120 seconds. The combination of a fire resistant barrier fabric and a non-fire resistant upholstery fabric did not always improve flammability performance.

BACKGROUND

Fifty upholstery fabrics were received from the above sources. The fabrics had the following breakdown: 16 untreated, 15 fire resistant backcoated, one lightly fire resistant backcoated, eight chemically fire resistant treated, and ten inherently fire resistant fabrics. The fabrics with an "a" designation are the untreated version of the equivalent backcoated fabric. For example, fabric 1 is backcoated and 1a is the same fabric without the backcoating.

In addition to the upholstery fabrics, a barrier fabric was tested with several untreated upholstery fabrics. The barrier fabric is corespun cotton covering a glass core. The manufacturer provided two variations of the fabric. The difference between the two variations is that one of them has a "peel & stick" backing. In both variations the barrier fabric is placed between the upholstery fabric and foam, but the "peel & stick" version allows the barrier fabric to be adhered directly to the upholstery fabric. The manufacturer indicated that the fabrics are treated with a chemical that is "intumescent in its vapor phase" (i.e. the chemical causes the fabric to swell).

Laboratory staff evaluated these fabrics using the test protocol in the CPSC staff's draft standard for the small open flame ignition resistance of upholstered furniture[i]. However, the protocol was not followed entirely. The soaking procedure described in the protocol was not needed for this evaluation and a variable number of trials were used for many tests to attempt to characterize the fabrics based on their ignition resistance. Ignition resistance is the ability of the fabric to keep from igniting when exposed to an open flame. In addition, time to ignition of many of the fabrics was recorded for characterization purposes.

TEST PROGRAM

The fabrics were evaluated for time to ignition using the draft test protocol for small open flame ignition. A butane flame was delivered to the seating area test mockup using the CPSC designed test fixture[ii] that accurately placed the flame in the crevice of the mockup for a preselected amount of time. Flame application times were varied until the shortest flame exposure needed to cause 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 protocol 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.

Some testing beyond the scope of the draft test protocol was done to further categorize the fire resistance of the fabrics; maximum flame application times were established. A maximum flame application time is the time beyond 20 seconds that the fabric self-extinguished within the requirements of the draft test protocol.

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.

Fiber content was determined by either chemical or microscopic analysis. Fabric weights were measured for the fabrics using a "Sutter Method Yield Scale."

The results of these tests are summarized in Table 1. The column designated as 'I' indicates those fabrics with ignitions and the column designated as 'DNI' indicates those fabrics that did not ignite during testing. Further details on individual fabrics can be found in the tables numbered 1A through 7A in the appendix.

TABLE 1 – UPHOLSTERY FABRICS

Shaded areas indicate fabrics that did not ignite during testing.

FABRIC IDENTIFICATION	FIBER CONTENT	WEIGHT (oz/yd²)	METHOD OF FIRE RESISTANCE	I	DNI	EXTENDED TESTING (seconds)
UF No. 1	Cotton	13.0	backcoated		X	---
UF No. 1a	Cotton	10.0	untreated	X		
UF No. 2	*polyester/cotton*	*12.5*	backcoated		X	75
UF No. 2a	polyester/cotton	9.0	untreated	X		---
UF No. 6	cotton	16.2	backcoated		X	---
UF No. 6a	cotton	12.5	untreated	X		---
UF No. 7	cotton	12.7	backcoated		X	75
UF No. 7a	cotton	8.2	untreated	X		---
UF No. 8	polyester/rayon	14.0	backcoated		X	90
UF No. 8a	polyester/rayon	9.5	untreated	X		---
UF No. 9	polyester/rayon	12.5	lt. backcoated		X	90
UF No. 10	cotton/flax/acrylic	13.2	backcoated		X	60
UF No. 10a	cotton/flax/acrylic	9.7	untreated	X		---
UF No. 11	cotton	10.0	FR chemicals		X	120
UF No. 12	cotton	11.0	FR chemicals		X	90
UF No. 13	cotton	8.0	FR chemicals		X	50
UF No. 14	cotton	11.5	FR chemicals		X	90
UF No. 15	cotton	10.7	FR chemicals		X	90
UF No. 16	cotton	7.3	FR chemicals		X	50
UF No. 17	cotton	8.3	backcoated		X	---
UF No. 19	cotton	12.0	untreated	X		---
UF No. 21	olefin	9.5	backcoated		X	---
UF No. 22	rayon/polyester/cotton	10.3	untreated	X		---
UF No. 24	cotton/polyester/acrylic	11.7	backcoated		X	75
UF No. 24a	cotton/polyester/acrylic	8.5	untreated		X	---
UF No. 25	cotton/acrylic	9.2	backcoated		X	90
UF No. 25a	cotton/acrylic	6.5	untreated		X	---
UF No. 26	cotton	*11.0*	backcoated	X		---
UF No. 26a	cotton	9.0	untreated	X		---
UF No. 27	cotton	11.0	backcoated	X		---
UF No. 27a	cotton	8.5	untreated	X		---
UF No. 28	polyester/rayon/olefin	13.0	backcoated		X	35
UF No. 28a	polyester/rayon/olefin	9.7	untreated	X		---
UF No. 29	cotton	9.5	FR chemicals		X	90
UF No. 30	cotton/rayon	19.3	backcoated	X		---
UF No. 31	cotton/rayon	15.8	backcoated	X		---
UF No. 32	cotton/nylon	9.8	FR chemicals		X	120
UF No. 33	silk/PVC	5.0	inherent		X	35
UF No. 34	PVC/cotton	6.7	inherent	X		---
UF No. 35	PVC/cotton	7.5	inherent	X		---
UF No. 36	PVC	7.5	inherent		X	---
UF No. 37	PVC	7.5	inherent		X	25
UF No. 38	PVC	10.7	inherent		X	30
UF No. 39	wool/viscose/PVC	13.0	inherent		X	---
UF No. 40	PVC	13.5	inherent		X	40
UF No. 41	PVC	18.2	inherent		X	---
UF No. 42	polyester	8.0	inherent		X	---
UF No. 48	polyester	7.4	untreated	X		---
UF No. 50	olefin	5.8	untreated	X		---
UF No. 52	cotton	5.1	untreated	X		---

RESULTS

Two of the untreated fabrics (24a and 25a) did not ignite when tested to the draft test protocol. Both of these fabrics were blends containing cotton and acrylic fibers. In addition Fabric 24a also contained polyester fibers.

Overall the fire resistant fabrics performed well based upon the draft test criteria. The chemically treated fabrics performed best, followed by the inherently fire resistant fabrics. Ignition performance of the fabrics that passed did not appear to be affected by fabric weight and fiber content alone.

Eleven of the 16 fire resistant backcoated upholstery fabrics did not ignite when tested to the draft test protocol. Most of these 11 fabrics were also tested with flame applications beyond 20 seconds. Eight of these 11 fire resistant backcoated fabrics resisted ignition with flame application times ranging from 35 to 90 seconds before igniting and continuing to burn.

All eight of the chemically treated upholstery fabrics did not ignite when tested to the draft test protocol. In addition, all eight fabrics resisted ignition with flame application times well beyond the 20 seconds as specified in the draft test protocol. These fabrics resisted ignition from flame application times ranging from 50 to 120 seconds.

The inherently fire resistant upholstery fabrics also performed well when tested to the draft test protocol. Eight of the 10 inherently fire-resistant fabrics did not ignite. Extended ignition tests were done, on one-half of the fabrics meeting the criteria, resulting in ignition times ranging from 25 to 40 seconds.

The seven fire resistant fabrics that ignited when tested to the draft protocol were made of cotton fibers or a blend of cotton and either rayon or PVC. Fourteen of the upholstery fabrics meeting the criteria also contained cotton fibers or a blend of cotton and other types of fibers. As above, fabric weight and type were not the sole reasons for resisting igniting or igniting when tested to the draft protocol.

Overall the use of a barrier fabric with a non-fire resistant upholstery fabric did not guarantee an improved flammability performance. The barrier fabrics worked well with certain types of fabric but very poorly with others. For example, it worked well at extinguishing a small open flame with both a lightweight and a heavyweight 100% cotton fabric but did not work with a 100% olefin fabric. The two polyester fabrics that were tested produced mixed results. One was a lightweight (7.4 oz/yd^2) fabric that did not ignite in one of three trials. The other fabric was mediumweight (8.0 oz/yd^2) and resisted ignition in all trials. The mediumweight fabric also did not ignite without the barrier fabric as it contained inherently fire resistant fibers. The barrier fabric prevented ignition from occurring in 14 of 33 trials with the rayon/polyester/cotton blend when the flame was applied for 20 seconds.

Three different lots of each type of barrier fabric were tested; they did not show a substantial difference in performance. The "peel & stick" version of the barrier fabric performed slightly better than the "non-sticky" version.

CONCLUSIONS

- Of the 50 upholstery fabrics tested to the draft test protocol, 29 resisted ignition after exposure to a 20-second flame.
- Twenty-seven of the 29 non-igniting upholstery fabrics were fire resistant upholstery fabrics.
- Two of the 29 non-igniting upholstery fabrics were non-fire resistant upholstery fabrics.
- One hundred percent (8) of the chemically treated upholstery fabrics resisted ignition when tested to the draft protocol.
- Eighty percent (8 of 10) of the inherently fire resistant upholstery fabrics resisted ignition when tested to the draft test protocol.
- Sixty-nine percent (11 of 16) of the fire resistant backcoated upholstery fabrics did not ignite when tested to the draft test protocol.
- Twenty of the 29 non-igniting upholstery fabrics resisted ignition beyond the 20 seconds specified in the draft test protocol.
- Extended times to ignition for these 20 upholstery fabrics ranged from 25 to 120 seconds.
- Fifteen of the 20 upholstery fabrics resisted ignition at least three times longer that required, (i.e. 60 seconds or greater).
- Nine of the 20 upholstery fabrics resisted ignition at flame application times ranging from 90 to 120 seconds.
- Overall the use of a fire resistant barrier fabric in combination with a non-fire resistant upholstery fabric did not always improve the flammability performance.
- There are many upholstery fabrics available that can meet the draft protocol requirements.

APPENDIX

Untreated Fabrics

Table 1A presents the results of the small open flame ignition tests on the untreated upholstery fabrics. Two of these 11 fabrics, numbered 24a and 25a, resisted ignition when tested to the draft protocol. Both fabrics were cotton/acrylic blends. Fabric 24a was a medium weight cotton/acrylic/polyester blend. Fabric 25a was a lightweight cotton/acrylic blend. Fabric 10a was a heavyweight cotton/acrylic/flax blend but did not meet the criteria of the draft test protocol. Although it self-extinguished within 120 seconds, the fire damage spread to the top of the mockup before the ignition stopped. According to the definitions in the draft protocol, this is considered an ignition.

TABLE 1A
SMALL OPEN FLAME IGNITION TESTS OF UNTREATED FABRICS
Shaded areas indicate fabrics that did not ignite during testing.

FABRIC IDENTIFICATION	TIME TO IGNITION[1] (seconds)	NO. OF IGNITIONS/ TOTAL NUMBER OF 20 SECOND FLAME APPLICATIONS
UF No. 1a	3	2/2
UF No. 2a	3	2/2
UF No. 6a	6-7	2/2
UF No. 7a	4	2/2
UF No. 8a	5	2/2
UF No. 10a	2-3	2/2
UF No. 24a	3	0/3
UF No. 25a	3	0/3
UF No. 26a	5	2/2
UF No. 27a	4	2/2
UF No. 28a	5	2/2

[1] Self-extinguished.

Fire Resistant Backcoated Fabrics

Table 2A presents the results of the flammability tests on the fire resistant (FR) backcoated fabrics. Fabric numbers correspond to the untreated fabrics in Table 1A with an "a" following the same fabric number. Fabrics labeled 8, 9, and 8a (from Table 1A) are the same base fabrics but fire resistant backcoated, lightly fire resistant backcoated, and untreated, respectively. The remaining fabrics in Table 2A do not correspond to any other fabric. The fire resistant backcoating did not affect the time to ignition of the paired fabrics.

Eleven of the 16 fire resistant backcoated upholstery fabrics met the performance criteria of the draft test protocol by resisting ignition. Eight of the 11 non-igniting fabrics resisted ignition beyond the 20-second flame application specified in the draft test protocol. Fabrics 2, 7, 8, 9, 10, 24, 25, and 28 ignited and self-extinguished after being exposed to a flame for 35 to 90 seconds. These fabrics were medium to heavy weight cotton/acrylic, cotton/polyester, or rayon/polyester blends.

Five of the fire resistant backcoated fabrics ignited and sometimes did not self-extinguish when tested to the draft test protocol. Fabric 6 self-extinguished in two out of three trials while Fabric 30 self-extinguished in one of two trials with a 20-second flame application. Fabric 27 ignited and self-extinguished but not before the flames reached the top of the mockup. (According to the draft test protocol, if the flames reach the top of the mockup within 120 seconds, the fabric does not meet the criteria.) Fabrics 26 and 31 ignited and continued to burn in two trials each.

TABLE 2A
SMALL OPEN FLAME IGNITION TESTS OF FR BACKCOATED FABRICS

Shaded areas indicate fabrics that did not ignite during testing.

FABRIC IDENTIFICATION	TIME TO IGNITION[1] (seconds)	NO. OF IGNITIONS/ TOTAL NUMBER OF 20 SECOND FLAME APPLICATIONS	EXTENDED TESTING[2] (seconds)
UF No. 1	3-4	0/2	---
UF No. 2	2-3	0/2	75
UF No. 6	5-6	1/3	---
UF No. 7	3-4	0/2	75
UF No. 8	4-5	0/2	90
UF No. 9	4-5	0/2	90
UF No. 10	2-3	0/2	60
UF No. 17	---	0/1	---
UF No. 21	3-4	0/15	---
UF No. 24	2-3	0/2	75
UF No. 25	2-3	0/2	90
UF No. 26	3-4	2/2	---
UF No. 27	3-4	2/2	---
UF No. 28	2-3	0/2	35
UF No. 30	15	1/2	---
UF No. 31	14	2/2	---

[1] Self-extinguished.

[2] Ignited and self-extinguished after the indicated flame application time.

Chemically Treated Fire Resistant Fabrics

Table 3A presents the flammability test results for the chemically treated fire resistant fabrics. These fabrics were immersed in chemicals during the manufacturing process to make them fire resistant. All of the fabrics resisted ignition when tested to the draft test protocol. They either did not ignite or ignited and self-extinguished which is considered a non-ignition by definition. Smoldering occurred for 22 seconds or less before the fabrics self-extinguished. Fabrics 12, 14, 15, and 29 did not sustain ignition even with a 90-second flame application. Fabrics 13 and 16 did not ignite with a 20-second flame application and did not sustain ignition with a 50-second flame application. Fabrics 11 and 32 did not sustain ignition with a 120-second flame application. These fabrics were all medium to heavy weight cotton or a cotton/nylon blend.

TABLE 3A
SMALL OPEN FLAME IGNITION TESTS OF CHEMICALLY TREATED FIRE RESISTANT FABRICS

Shaded areas indicate fabrics that did not ignite during testing.

FABRIC IDENTIFICATION	TIME TO IGNITION[1] (seconds)	SMOLDERING TIME BEFORE SELF-EXTINGUISHING (seconds)	EXTENDED TESTING[2] (seconds)
UF No. 11	3-5	22	120
UF No. 12	---	8	90
UF No. 13	---	0	50
UF No. 14	---	5	90
UF No. 15	---	1	90
UF No. 16	---	0	50
UF No. 29	---	5	90
UF No. 32	5-7	15	120

[1] All self-extinguished.

[2] Ignited and self-extinguished after the indicated flame application time.

Inherently Fire Resistant Fabrics

Table 4A presents the flammability test results of the inherently fire resistant (FR) fabrics. Nine of these fabrics were either 100% polyvinyl chloride (PVC) fibers or a PVC blend. One of the fabrics was a 100% polyester fiber. Eight of ten inherently fire resistant fabrics resisted ignition for 20 seconds or longer when tested to the draft test protocol.

Four inherently fire resistant fabrics (33, 37, 38, and 40) ignited and self-extinguished with a 25 to 40 second flame application. Two other fabrics (36, and 41) did not ignite with a 20-second flame application. In five trials, Fabric 39 did not ignite in two and ignited but self-extinguished in the other three trials. Fabric 42 ignited but self-extinguished in two trials.

Two inherently fire resistant fabrics (34 and 35) did not resist ignition. Fabric 34, a cotton/PVC blend, ignited and continued to burn past 120 seconds three out of five trials. Fabric 35, also a cotton/PVC blend ignited and self-extinguished four out of five trials.

TABLE 4A
SMALL OPEN FLAME IGNITION TESTS OF INHERENTLY FR FABRICS

Shaded areas indicate fabrics that did not ignite during testing.

FABRIC IDENTIFICATION	TIME TO IGNITION[1] (seconds)	NO. OF IGNITIONS/ TOTAL NUMBER OF 20 SECOND FLAME APPLICATIONS	EXTENDED TESTING[2] (seconds)
UF No. 33	5-10	0/2	35
UF No. 34	---	3/5	---
UF No. 35	---	1/5	---
UF No. 36	21-23	0/1	---
UF No. 37	7	0/3	25
UF No. 38	---	0/1	30
UF No. 39	10	0/5	---
UF No. 40	9-12	0/3	40
UF No. 41	34-38	0/4	---
UF No. 42	1-2	0/3	---

[1] All self-extinguished.

[2] Ignited and self-extinguished after the indicated flame application time.

Fire Barrier Baseline Upholstery Fabrics

The upholstery fabrics in Table 5A were tested without a fire barrier interposed between the upholstery fabric and the standard foam specified in the draft test protocol. The results are included to establish a baseline for comparison. Most of these fabrics were only tested for time to ignition as most of the time these fabrics continued to burn. There were two exceptions to this, Fabrics 19 and 42. Fabric 19 ignited in one trial and Fabric 42, an inherently flame resistant polyester did not ignite in three trials.

TABLE 5A
PERFORMANCE OF FABRICS WITHOUT USING A FIRE BARRIER

Shaded area indicates fabrics that did not ignite during testing.

FABRIC IDENTIFICATION	TIME TO IGNITION[1] (seconds)	NO. OF IGNITIONS/ TOTAL NUMBER OF 20 SECOND FLAME APPLICATIONS
UF No. 19	16	1/1
UF No. 22	8-9	---
UF No. 42	1-2	0/3
UF No. 48	3-4	---
UF No. 50	2-3	---
UF No. 52	6	---

[1]Did not always self-extinguish.

"Non-sticky" Barrier Fabric

Table 6A presents the results of the small open flame ignition tests on the "non-sticky" barrier fabric, one that lacked an adhesive coating by which it could be fastened to the upholstery fabric. Three different sets of barriers (labeled Lots 1, 2, and 3) were used in this testing. Chemical analysis indicated that the barrier fabrics from the three lots were each treated with slightly different concentrations of antimony.

The earliest flammability tests, with the barrier fabric from Lot 1 under Fabric 22, produced very encouraging results but later tests could not duplicate them. Fabric 22, a heavy weight rayon/polyester/cotton blend initially resisted ignition when combined with the Lot 1 fire barrier. When the butane flame was applied for 20 seconds, the upholstery fabric ignited and self-extinguished. Nine months later, this test was repeated resulting in very different results; the upholstery fabric ignited and continued to burn. Despite careful review and examination, it has not been possible to determine the differences in test or material characteristics that affected the results.

Because of the extremely different results with the Lot 1 fire barrier; two other lots of the fire barrier were purchased for further testing. Various tests were conducted using these other two lots with Fabric 22 and other fabrics to try to determine the reason for the differing results using the Lot 1 fire barrier. There was not enough of the Lot 1 fire barrier remaining to do testing on other fabrics.

Chemical analysis before testing showed one and a half times the amount of antimony present in a piece of the Lot 1 barrier fabric than in a piece analyzed after flammability testing. Subsequent flammability tests on two other lots also showed varying results in spite of their having antimony levels nearly that found in the Lot 1 fire barrier. Overall, across all three lots of barrier fabric, Fabric 22 ignited and self-extinguished in six of the fifteen 20-second trials.

In addition to Fabric 22, the Lot 2 fire barrier was tested with additional fabrics (Fabrics 48, 50, and 52), to determine how the barrier fabric performed in combination with fabrics containing different fibers.

- Fabric 22 ignited and self-extinguished in three of seven trials.
- Fabric 48, a lightweight 100% polyester fabric, ignited and self-extinguished in one of three trials.
- Fabric 50, a lightweight 100% olefin fabric, ignited and continued to burn in all three trials. The flame had the tendency to burn horizontally along the crevice of the seat mockup without penetrating the fire barrier.
- Fabric 52, a lightweight 100% cotton fabric, ignited and self-extinguished in each of five trials.[1]

Using Lot 3 as the fire barrier, two additional fabrics, Fabrics 19 and 42, were tested in addition to Fabrics 22, 48, 50, and 52. These fabrics were added to determine if fabric weight changed the performance characteristics of the fire barrier.

- Fabric 22 ignited and self-extinguished in two of five trials.
- The results for Fabrics 48, 50, and 52 were identical to the results when Lot 2 was used.
- Fabric 19, a heavy weight 100% cotton fabric, performed differently than its lightweight counterpart, Fabric 52, igniting and self-extinguishing in five of six trials.
- Fabric 42, a medium weight 100% polyester fabric, performed better than its light weight counterpart, Fabric 48, by igniting and self-extinguishing each of six trials. Fabric 42 self-extinguished without the fire barrier (as shown in Table 5A).

[1] The number of trials for each fabric was determined by the amount of useable fabric remaining on the seat mockup after each trial. For example, a trial that ignites and self-extinguishes would not damage as much of the fabric compared to a trial that ignites and continues to burn. Therefore, if a fabric performed well with the fire barrier, more trials could be performed on the fabric.

TABLE 6A
SMALL OPEN FLAME IGNITION TESTS OF
THE "NON-STICKY" BARRIER FABRIC

Shaded areas indicate fabrics that did not ignite during testing.

BARRIER LOT [Antimony (ug/mg)]	FABRIC IDENTIFICATION	TIME TO IGNITION (seconds)	NO. OF IGNITIONS/ TOTAL NO. OF 20 SECOND FLAME APPLICATIONS	EXTENDED TESTING (seconds)
1 [42.99]	UF No. 22	---	0/1	35
1 [29.20]	UF No. 22	10-11	1/1	---
1 [29.12]	UF No. 22	---	1/1	---
2 [38.26]	UF No. 22	---	3/6	---
	UF No. 22	9-10	1/1	---
	UF No. 52	2-4	0/5	---
	UF No. 48	2-3	2/3	---
	UF No. 50	---	3/3	---
3 [37.05]	UF No. 22	2-5	2/5	---
	UF No. 52	3-5	0/5	25
	UF No. 48	3-4	2/3	---
	UF No. 50	---	3/3	---
	UF No. 19	7-9	2/5	---
	UF No. 42	6-7	0/6	35

"Peel & Stick" Barrier Fabric

Table 7A presents the results of the small open flame ignition tests on the "peel & stick" (P&S) barrier fabric. The same series of tests were performed as on the "non-sticky" version of the fire barrier, with a few exceptions. The two polyester fabrics, 42 and 48, were not tested using this fire barrier, and Fabric 19 was tested only with P&S Lot 2 as the fire barrier.

The antimony levels in the P&S fabrics recorded in Table 7A do not match the levels recorded on Table 6A because P&S Lots 1, 2, and 3 are not equivalent fabrics to the "non-sticky" Lots 1, 2, and 3.

With the P&S version of the fire barrier, Fabric 22 did not perform well in any of the tests; (although it did with the "non-sticky" version), and the results were variable. Using P&S Lot 1 as the fire barrier, Fabric 22 ignited and did not ignite in one trial, self-extinguished once, and ignited and continued to burn in the rest of the 20-second trails. When tested with P&S Lots 2 and 3, Fabric 22 performed at about a 50% success rate. It ignited and self-extinguished in five of nine trials using P&S Lot 2 and three of six trials using P&S Lot 3.

Fabric 52 was only tested with P&S Lots 2 and 3 of the fire barrier. It ignited and self-extinguished three out of five trials with P&S Lot 2. However, with P&S Lot 3, it ignited and self-extinguished in each of five trials.

Fabric 50 performed the same as it did with the "non-sticky" version of the fire barrier. It ignited and continued to burn beyond 120 seconds in all trials of each lot.

Fabric 19 ignited and self-extinguished in each of five trials and did not ignite in one trial using P&S Lot 2 as the fire barrier. With P&S Lot 3, it ignited and self-extinguished in each of six trials, which is a slight improvement over testing with the "non-sticky" barrier when it self-extinguished in five of six trials.

TABLE 7A
SMALL OPEN FLAME IGNITION TESTS OF THE "PEEL & STICK" BARRIER FABRIC

Shaded areas indicate fabrics that did not ignite during testing.

BARRIER LOT [Antimony (ug/mg)]	FABRIC IDENTIFICATION	TIME TO IGNITION (seconds)	NO. OF IGNITIONS/ TOTAL NO. OF 20 SECOND FLAME APPLICATIONS	EXTENDED TESTING[1] (seconds)
1 [31.19]	UF No. 22	---	---	24
	UF No. 22	13-15	1/1	---
	UF No. 22	14-15	1/2	---
1 [42.98]	UF No. 22	---	1/1	---
2 [30.47]	UF No. 22	---	4/9	---
	UF No. 52	3-5	2/5	---
	UF No. 50	---	3/3	---
	UF No. 19	10-12	1/7	---
3 [31.33]	UF No. 22	4-5	3/6	---
	UF No. 52	4-5	0/5	30
	UF No. 50	---	3/3	---
	UF No. 19	9-10	0/6	---

[1] Ignited and self-extinguished after the indicated flame application time.

Endnotes

[i] Draft Standard for Small Open Flame Ignition Resistance of Upholstered Furniture, R. Khanna, ESME, October 1997, Consumer Product Safety Commission.

[ii] Furniture Flammability Fixture, Operational Manual, Version 1.1, Consumer Product Safety Commission, Directorate for Laboratory Sciences, June 1997.

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

Date: October, 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	:	UK Chair and Mockup Test Results

1. INTRODUCTION

This report presents analysis of the test data and other information collected during the recent small open flame test program on 27 upholstered chairs from the United Kingdom (UK). Upholstered chairs manufactured in the UK were used in this test program as the staff of the U.S. Consumer Product Safety Commission (CPSC), are interested in the flammability performance of furniture designed to resist ignition from a small open flame. Furniture sold in the UK must meet a small open flame performance standard.[1] Flame retardant treatments and backcoatings are often applied to upholstery fabrics to meet the UK regulations. In addition, all polyurethane foam filling material is required by the UK Regulations[1] to be combustion modified, i.e. treated with flame retardant chemicals.

2. TEST PROGRAM

The objective of the test program was to gain a better understanding of the relationship between mockup and full-scale flammability performance of upholstered furniture. Both small open flame and cigarette ignition tests were performed on the 27 upholstered chairs and mockups representing these chairs following the protocol in the *Test Plan – Flammability Tests on UK Chairs*.[2] The chairs were obtained from the following sources.

- Fifteen chairs were manufactured in the UK and purchased from a UK test lab associated with a UK furniture manufacturer (1998-1999),
- Eight chairs were manufactured in the UK and purchased from a UK retail furniture store (1999-2000), and
- Four chairs were manufactured in the UK and purchased from an UK furniture manufacturer (1900-2000).

[1] Superscript refers to references on page 21.

3. TEST METHODS

a. Full-Scale Chair Tests

(1) Small Open Flame

The chairs were first tested with a small butane flame applied manually to the test areas following the procedure outlined in the *Test Plan – Flammability Tests on UK Chairs*. This test plan was used to assess the ability of full-scale furniture to resist ignition when subjected to a small open flame ignition source similar to a match, lighter or candle. The ignition source was applied three times to each test area. Each flame application was at least two inches away from a previous test and had duration of 20 seconds.

Two locations on each chair were tested: (1) the seating area and (2) the dust cover. The dust cover was defined as the fabric on the underside of the furniture. For the dust cover tests, the chairs were elevated 15 inches to allow the test operator to place the burner tube beneath the chair. For UK chairs numbered 1 to 15, the butane flame was applied to the underside of the chair once at each of three locations: two inches from the inside edge of the front of the chair frame and two inches from each inside edge of the side frame. For UK chairs numbered 16 to 27, a fourth test location was added; the flame was also applied to the center of the dust cover.

The seating area consisted of the upholstery fabric covered filling materials in the seat and back cushions and arms or sides. The butane flame was placed in the crevices between the seat and back and between the seat and side locations.

An ignition was recorded for an individual test location if any one of the following occurred,

1. the char reached a mark placed nine inches above the chair seating area crevice,
2. the flames reached the side of the chair frame during a dust cover test,
3. the flames spread from the dust cover fabric to other parts of the chair, or
4. after igniting, the test location did not self-extinguish within the two-minute observation period.

An ignition was defined by the presence of flames, smoke or glowing embers. CO_2 gas released from a tank through a nozzle was used to extinguish flames at the completion of each full-scale test.

(2) Cigarette Ignition

After the UK chairs were tested in full-scale with the small butane flame, the chairs were tested with lit cigarettes, again following the procedure outlined in the *Test Plan – Flammability Tests on UK Chairs*. Unfiltered Pall Mall® cigarettes were used as the ignition source. Three cigarettes were placed in the seat crevices, the front welt edges and seat cushions. Each cigarette was covered with sheeting fabric during the test. When the test cigarettes were positioned in the back/seat or side/seat crevices, they were allowed to drop down as far as they would naturally fall. The welt cord was tested as part of the full-scale chair test only when it was located in a box welt construction on the seat cushion. 264

An ignition was recorded for a test location if any one of the three cigarettes caused an obvious ignition or if the char from the cigarette extended more than three inches from the original location of the cigarette. The maximum char length was recorded for all cigarette test locations and was determined by measuring the length of the char on the vertical and horizontal test surfaces on the chair. The char lengths were measured to the nearest 0.1-inch from the nearest point of the original location of the cigarette. When the original position of a cigarette was disturbed due to extensive fabric degradation, an estimate of the maximum char length was made. Water was used to extinguish chair ignitions. The chair was allowed to dry to the touch before being disassembled for mockup testing.

b. Mockup Tests

(1) Small Open Flame

After the full-scale cigarette tests were completed, the 27 UK chairs were disassembled. Undamaged upholstery fabric was taken from each chair and sewn together to create test-specimen-size pieces of fabric. Seams were carefully positioned on the mockup frame as not to interfere with the placement of the ignition source. Additional upholstery fabric for 16 of the chairs was also purchased from the UK, and used in some of the mockup tests.

The dust cover fabric was also carefully removed from the bottom of each chair and cut into specimen size pieces. *The Furniture Flammability Fixture* as specified in the *Draft Standard for Upholstered Furniture*[3] was used to apply the small flame to the center of the dust cover mockup for 20 seconds.

The Furniture Flammability Fixture was also used to apply the small flame to the crevice of the seat mockup. The small butane flame, the same ignition source as used in the full-scale open flame tests, was applied for 20 seconds. The flame was applied three times to the crevice of each mockup at the following locations: two inches from the left edge, in the center of the mockup and two inches from the right edge of the mockup.

The burning characteristics of each fabric were recorded after the flame was removed. The time in seconds for afterflame, afterglow and smoldering as well as the occurrence of ignition was recorded. Ignition was defined as occurring when the fabric being tested did not self-extinguish or the char reached the top of the mockup within the two-minute observation period. Ignitions were extinguished with CO_2

(a) Mockup Tests With Standard Foam

The upholstery fabrics and standard polyurethane foam were used to construct a mockup representing the seating area of each chair. With the exception of mockups representing UK chairs numbered 24 to 27, the upholstery fabrics were taken from the actual chair. Additional fabric from the same lot as covering the actual chair was used to cover mockups representing UK chairs numbered 24 to 27. The polyurethane foam was the same as the foam specified in the *Draft Standard for Upholstered Furniture*, and had a density of 1.5 to 1.8 lb/ft^3 and a firmness of 25 to 30 IFD.

(b) Mockup Tests With UK Foam

Mockup tests were also performed using upholstery fabrics the same as found on the UK chairs and non-flame retardant UK polyurethane foam. The upholstery fabrics used for mockups representing UK chairs numbered 1 to 6, 9 to 10, and 12 to 15 were purchased separately[4] from the chairs and may not be the same lot as the fabrics used on the corresponding UK chairs. With the exception of UK chairs numbered 24 to 27, all other mockups tests were covered with upholstery fabrics taken from UK chairs. Mockups constructed representing UK chairs numbered 24 to 27 were covered with upholstery fabrics from the same lot as those used on the actual chair.

The UK foam met the specifications in *the Furniture and Furnishings (Fire) (Safety) Regulations 1988*[1]. This foam was less dense (1.24 to 1.36 lb/ft^3) than the standard foam specified in the *Draft Standard for Upholstered Furniture*.

(2) Cigarette Tests

Cigarette tests were also conducted on mockups constructed with upholstery fabrics taken from nine of the actual UK chairs and standard polyurethane foam. Only cigarette tests on nine of the upholstery fabrics were possible due to limits on the amount of available fabric. Fabric purchased from the same lot as covering the actual chair was used with four of the mockups: UK chairs numbered 24 to 27. Three lit cigarettes were placed in the crevice of each seating area mockup and covered with five-inch squares of sheeting fabric. The cigarettes were allowed to burn their full length. An ignition was recorded if any one of the three cigarettes caused an obvious ignition or if the char from the cigarette extended more than three inches from the original location of the cigarette. The maximum char length measurements were made and recorded exactly the same as in the full-scale chair tests. Water was used to extinguish mockup ignitions.

4. CONDITIONING AND TESTING FACILITIES

a. Full-Scale Chair Tests

The Test Plan required conditioning the chairs continuously for 48 hours before testing at a temperature of 25 $\pm$ 2°C (77 $\pm$ 6°F) and a relative humidity less than 55%. The chairs, cigarettes and five-inch sheeting squares were placed in areas maintained at these conditions prior to testing. Testing began within ten minutes of removal from the conditioning area. Hygrothermograph recordings of the conditioning and test areas were made, and the charts kept throughout the test program.

The chairs were tested in a draft-protected room equipped with an exhaust fan to evacuate the room of smoke and fumes produced during the testing. However, the exhaust fan was not turned on until the completion of a full-scale test.

b. Mockup Tests

Test specimens used to construct the mockups were conditioned following the specifications in the *Draft Standard for Upholstered Furniture* with the exception of the soaking procedure, which was not done. Fabrics, foam, cigarettes and the five-inch sheeting squares were placed in the conditioning area for at least 24 hours immediately before the tests. Conditions were maintained at 25 $\pm$ 2°C (77 $\pm$ 6°F) and less than 55% relative humidity. Testing began within ten minutes of removal from the conditioning area. Permanent records of the atmospheric conditions in both the conditioning and test areas were made.

The mockups were tested in the same draft protected room as the full-scale furniture. The mockups were placed on a table directly beneath the exhaust hood. The exhaust fan was turned on at the completion of a mockup test.

5. RECORDING OF DATA AND OBSERVATIONS

All data and observations for each full-scale and mockup test were recorded on data sheets and filed according to chair number. Color photographs were taken of each chair before testing. The full-scale chair and mockup tests were also videotaped.

6. MATERIALS IDENTIFICATION

Upholstery fabrics were weighed and the fiber contents determined qualitatively by microscopic examination. In some cases chemical analysis was also used to verify a fiber content. The filling materials below the upholstery fabrics were also examined; foam and fiber batting were analyzed using infrared spectrophotometric analysis, welt cords were identified visually and microscopically. Chemical analysis was used to determine the presence of borate, a flame-retardant often used in paper welt cords and cotton batting.

The amount and kind of flame-retardant chemicals present in both the upholstery fabrics and the filling materials (foam and fiber batting) was also determined. The procedure and results are explained in memorandums written by Laboratory Sciences (LS) Chemistry staff.[5,6]

7. FLAMMABILITY TEST RESULTS

a. Full-Scale Chair Tests

(1) Small Open Flame

(a) Seating Area

The seating area was tested in two locations. The burner was placed first in the junction created by the back/seat crevice and then in the junction created by the side/seat crevice. Eleven of the 27 UK chairs ignited in the seating area crevice locations. Table 1 shows the results of this testing.

TABLE 1

Full-Scale Seating Area Flammability Test Results

Chair No.	Fiber Content	Fabric Weight (oz/yd^2)	Flammability Test Results*
UK 1	cotton	12.5	6 ignitions
UK 2	rayon/polyester	10.8	no ignitions
UK 3 (2 fabrics)	linen/cotton and polyester/cotton	9.8 and 9.8	6 ignitions
UK 4	polyester/cotton	10.7	no ignitions
UK 5	polyester/cotton	10.5	1 ignition
UK 6	cotton	6.7	no ignitions
UK 7	rayon/polyester	16.3	no ignitions
UK 8	polyester	16.7	3 ignitions
UK 9	cotton/polyester/nylon	7.3	3 ignitions
UK 10	cotton/polyester/nylon	8.2	6 ignitions
UK 11	polyester/cotton/acrylic	12.7	no ignitions
UK 12 (2 fabrics)	cotton and cotton	9.5 and 7.7	4 ignitions
UK 13	polyester/acrylic	11.3	3 ignitions
UK 14	acrylic/polyester/cotton/rayon	16.7	1 ignition
UK 15	cotton/polyester/nylon	10.0	no ignitions
UK 16	cotton/polyester	14.0	no ignitions
UK 17	cotton/polyester	12.5	6 ignitions
UK 18	acrylic/rayon/polyester	17.3	no ignitions
UK 19	nylon/polyester	12.5	3 ignitions
UK 20	polyester/cotton	12.0	no ignitions
UK 21	polyester/cotton	12.0	no ignitions
UK 22	acrylic/polyester	12.5	no ignitions
UK 23	cotton/acrylic	13.3	no ign[illegible]
UK 24	cotton/linen/nylon	9.5	no ignitions
UK 25	cotton	12.5	no ignitions
UK 26	cotton/nylon	11.2	no ignitions
UK 27	cotton	7.0	no ignitions

* All chairs had a total of 6 flame applications per chair with the exception of chair number 13, which only had 5 flame applications due to the chair size.

Of the 11 chairs igniting in the seating area tests, four chairs numbered 1, 3, 10 and 17 ignited in all locations tested. The other seven chairs igniting had one or more ignitions each.

All but three of the 11 chairs that ignited contained some amount of cellulosic fiber. Chairs numbered 8, 13 and 19 were covered with fabrics made from 100% thermoplastic fibers. All of the 16 chairs not igniting were covered with upholstery fabrics containing either 100% cellulosic or a cellulosic/thermoplastic blend.

The fabric weights for the 11 chairs that had ignitions ranged from 16.7 oz/yd^2 to 7.3 oz/yd^2. The fabric weights for the 16 non-igniting chairs ranged from 16.3 oz/yd^2 to 6.7 oz/yd^2. The fabric construction for both the 11 UK chairs with ignitions and the 16 without ignitions included both raised surface and plain surface fabric constructions.

LS staff performed chemical analysis[5] to identify the presence of antimony (Sb), hexabromocyclododecane (HBCD) or decabromo diphenyl ether (DB), three chemicals present in flame retardant (FR) backcoatings. The presence of phosphorus was also determined by chemical analysis. Phosphorus is present in flame retardant treatments where the fabric is immersed into a solution containing FR chemicals. This analysis determined that all but one of the upholstery fabrics covering the 27 UK chairs contained FR chemicals. There was no FR chemicals found in the upholstery fabric on UK chair number 10. Table 2 presents the results of the chemical analysis to determine the presence of flame retardant chemicals on upholstery fabrics covering the UK chairs.

Three of the upholstery fabrics, (chairs numbered 1, 6, and 12), contained a combination of Sb and HBCD, two of which had ignitions. Seventeen of the upholstery fabrics contained a combination of Sb and DB, seven of which had ignitions. UK chair number 3 which ignited, had two upholstery fabrics; these fabrics contained either a combination of Sb and DB or Sb and HBCD. The upholstery fabric on UK chair number 23 contained only Sb and four upholstery fabrics contained only phosphorus, neither of these groups of upholstery fabrics had ignitions.

Chemical analysis indicated those UK chairs that did not ignite had greater amounts of FR chemicals present; 1.14% to 4.13% of Sb, and 4.1% to 10.7% of either HBCD or DB. Chemical analysis of the 11 chairs igniting in the seating area tests, indicated a range of Sb present from 0.28% to 3.95%, and a range of either HBCD or DB from 1.4% to 10.4%.

TABLE 2

Amount of FR Chemicals Present on Upholstery Fabrics

Chair Number/ Number of Ignitions	% Sb	%HBCD or % DB	% P
UK 1 / 6 ignitions	0.68	6.3 HBCD	---
UK 2 / no ignitions	2.12	6.6 DB	---
UK 3 /6 ignitions (2 fabrics)	0.63 (fabric a) 1.11 (fabric b)	5.0 HBCD (fabric a) 5.1 DB (fabric b)	---
UK 4 / no ignitions	3.71	8.3 DB	---
UK 5 / 1 ignition	3.79	7.2 DB	---
UK 6 / no ignitions	1.17	10.7 HBCD	---
UK 7 / no ignitions	1.81	6.4 DB	---
UK 8 / 3 ignitions	1.70	4.0 DB	---
UK 9 / 3 ignitions	0.49	3.4 DB	---
UK 10 / 6 ignitions	---	---	---
UK 11 / no ignitions	1.14	5.7 DB	---
UK 12 / 4 ignitions (2 fabrics)	2.20 (fabric a) 1.14 (fabric b)	10.4 HBCD (fabric b, back cushion) 8.4 HBCD (fabric b, seat cushion)	---
UK 13 / 3 ignitions	2.36	8.6 DB	---
UK 14 / 1 ignition	3.95	8.2 DB	---
UK 15 / no ignitions	2.02	4.3 DB	---
UK 16 / no ignitions	2.20	9.5 DB	---
UK 17 / 6 ignitions	1.66	6.3 DB	---
UK 18 / no ignitions	4.13	10.2 DB	---
UK 19/ 3 ignitions	0.28	1.4 DB	---
UK 20 / no ignitions	1.86	7.5 DB	---
UK 21 / no ignitions	2.37	7.3 DB	---
UK 22 / no ignitions	2.64	4.1 DB	---
UK 23 / no ignitions	3.28	---	---
UK 24 / no ignitions	---	---	1.25
UK 25 / no ignitions	---	---	1.51
UK 26 / no ignitions	---	---	1.44
UK 27 / no ignitions	---	---	1.35

Materials identification and chemical analysis determined that 13 of the 27 UK chairs had either polyester fiberfill or polyurethane foam directly under the upholstery fabric in the three parts of the chair, seat, back and side, forming the test locations, (i.e. back/seat crevice and the side/seat crevice locations). Eight of the 27 chairs had polyester fiberfill directly under the upholstery fabric in the seat, back and side areas of the chair. Only one chair had polyurethane foam in the seat, back and side areas and five chairs had other types of filling materials such as feathers and nylon-fiber pads or no filling materials directly below the upholstery fabrics. Table 3 presents the results of this analysis.

Of the 11 chairs igniting, five chairs had polyester fiberfill in the seat, back and side locations in the chair, five chairs had either polyester fiberfill or polyurethane foam in the seat, back and side locations, and one chair had either polyester fiberfill or no filling material directly under the upholstery fabric. Eight of the 11 chairs with ignitions had polyester fiberfill as the filling material directly under the upholstery fabric in the seat location. Ten of the 11 chairs with ignitions had polyester fiberfill as the filling material directly under the upholstery fabric in the back location. Seven of the 11 chairs with ignitions had polyester fiberfill directly under the upholstery fabric in the side location.

Chemical analysis[6] indicated that the polyester fiberfill present in these UK chairs were not FR treated as the fiberfill did not contain appreciable amounts of phosphorous. For the six instances where polyurethane foam was the filling material directly under the upholstery fabric in chairs with ignitions, chemical analysis determine that FR chemicals (phosphorus and melamine) were present. The amount of phosphorous ranged from 0.21% to 1.49% and the amount of melamine ranged from 0.73% to 14.89%.

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TABLE 3
Filling Materials Directly Under Upholstery Fabrics And FR Chemicals Present

Chair No.	Seat Filling Material	% and Type of FR	Back Filling Material	% and Type of FR	Side Filling Material	% and Type of FR
UK 1	polyester fiberfill	none	polyester fiberfill	0.01% P	polyester fiberfill	0.01% P
UK 2	polyurethane foam	0.81% P and 1.28% melamine	polyester fiberfill	0.01% P	polyester fiberfill	0.02% P
UK 3	polyester fiberfill	0.01% P	polyester fiberfill	0.01% P	polyester fiberfill	0.01% P
UK 4	polyester fiberfill	0.01% P	polyester fiberfill	none	polyester fiberfill	0.01% P
UK 5	polyester fiberfill	0.01% P	polyester fiberfill	0.01% P	polyester fiberfill	0.01% P
UK 6	polyester fiberfill	0.01% P	polyurethane foam	0.34%P and 11.4%melamine	polyurethane foam	0.64% P and 13.2%melamine
UK 7	polyurethane foam	0.89% P and 0.90% melamine	polyester fiberfill	0.01% P	polyester fiberfill	0.01% P
UK 8	polyester fiberfill	0.01% P	polyurethane foam	1.49% P and 1.1% melamine	polyester fiberfill	0.01% P
UK 9	polyester fiberfill	0.01% P	polyester fiberfill	0.01% P	polyester fiberfill	0.01% P
UK 10	polyester fiberfill	0.01% P	polyester fiberfill	0.01% P	polyester fiberfill	0.01% P
UK 11	polyester fiberfill	0.03% P	polyester fiberfill	none	polyurethane foam	0.99% P and 15.4%melamine
UK 12	polyester fiberfill	1.02% P	polyester fiberfill	0.01% P	polyurethane foam	0.80% P and 14.9%melamine
UK 13	polyurethane foam	1.11% P and 0.73% melamine	polyester fiberfill	0.01% P	polyester fiberfill	0.01% P
UK 14	polyurethane foam	0.92% P and 0.87% melamine	polyester fiberfill	none	polyurethane foam	0.54% P and 14.6%melamine
UK 15	polyester fiberfill	none	polyester fiberfill	none	polyester fiberfill	none
UK 16	polyester fiberfill	0.01% P	polyester fiberfill	none	polyurethane foam	0.65% P and 11.6%melamine
UK 17	polyester fiberfill	none	polyester fiberfill	none	no filling materials directly under fabric	---
UK 18	polyester fiberfill	none	polyester fiberfill	none	polyester fiberfill	---
UK 19	polyurethane foam	0.21% P and 11.2% melamine	polyester fiberfill	0.01% P	polyurethane foam	0.01% P
UK 20	polyurethane foam	0.21% P and 16.7% melamine	polyurethane foam	0.66% P and 12.8%melamine	polyurethane foam	0.19% P and 15.5%melamine
UK 21	polyester fiberfill	0.01% P	polyester fiberfill	none	polyurethane foam	none
UK 22	polyurethane foam	0.78% P and 0.89% melamine	polyester fiberfill	none	polyurethane foam	0.17% P and 8.9%melamine
UK 23	polyester fiberfill	none	polyurethane foam	0.85% P and 5.1% melamine	polyurethane foam	0.77% P and 17.7%melamine
UK 24	feathers	---	nylon pad	0.01 %P	nylon pad	0.01% P
UK 25	feathers	---	feathers	---	nylon pad	0.01% P
UK 26	feathers	---	feathers	---	nylon pad	0.01% P
UK 27	polyester fiberfill	none	polyester fiberfill	none	polyurethane foam	0.54% P and 8.7%melamine

(b) Dust Cover

Sixteen of the 27 dust cover fabrics ignited in full-scale tests. Other parts of the chairs such as interior fabrics and wood frames became involved in six of the dust cover ignitions (chairs numbered 1, 9, 12, 15, 19, and 24). The flames spread quickly to the edge of the chair in four dust cover ignitions, (chairs numbered 10, 14, and 20), and in six of the dust cover ignitions the dust cover fabric itself sustained the ignition (chairs numbered 21 to 23 and 25 to 27).

Of the sixteen igniting dust cover fabrics, 11 were 100% thermoplastic fabrics, four were made from jute fibers (burlap) and one was a thermoplastic/cellulosic blend fabric. The 11 non-igniting dust cover fabrics consisted of ten 100% thermoplastic fabrics and one burlap fabric. Table 4 presents the results of the dust cover testing.

TABLE 4

Full-Scale Dust Cover Flammability Test Results

Chair Number	Fiber Content/Fabric Wt. (oz/yd^2)	Test Results (ignition/applications)
UK 1	polypropylene / 1.5	1 / 1
UK 2	polypropylene / 1.5	0 / 3
UK 3	polypropylene / 1.5	0 / 3
UK 4	polypropylene / 1.5	0 / 3
UK 5	polypropylene / 1.5	0 / 3
UK 6	polypropylene / 1.5	0 / 3
UK 7	polypropylene / 1.5	0 / 3
UK 8	polypropylene / 1.5	0 / 3
UK 9	polypropylene / 1.5	1 / 3
UK 10	polypropylene / 1.5	1 / 3
UK 11	polypropylene / 1.5	0 / 3
UK 12	polypropylene / 1.5	1 / 3
UK 13	polypropylene / 1.5	0 / 3
UK 14	polypropylene / 1.5	1 / 3
UK 15	polypropylene / 1.5	2 / 3
UK 16	jute / 7.5	0 / 4
UK 17	olefin / 2.2	1 / 1
UK 18	olefin / 2.3	0 / 4
UK 19	polypropylene / 1.5	2 / 4
UK 20	olefin / 2.3	1 / 1
UK 21	olefin / 2.2	1 / 4
UK 22	olefin / 2.8	1 / 1
UK 23	polyester/cotton / 3.5	2 / 3
UK 24	jute / 6.5	1 / 1
UK 25	jute / 6.3	1 / 1
UK 26	jute / 7.3	1 / 1
UK 27	jute / 6.8	1 / 1