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MEMORANDUM

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Subject: Toxicity of Flame Retardant Chemicals (FR's) used in Upholstery Fabrics and the Toxicity of the Smoke from FR-treated Fabrics (ANPR, FR, 59: # 114, June 15, 1994, pp. 30735 ff)

I. Background

Full-scale tests for the ignition resistance of upholstered furniture were conducted by the U.S. Consumer Product Safety Commission in 1995-1996. These tests revealed that cover fabrics play an important role in the ignition of upholstered furniture (Fansler et al., 1996) and that use of flame-retarded (FR) fabric may significantly increase the ignition resistance of the furniture. For this reason, the staff is evaluating the possible use of FR treatments to increase the ignition resistance of the fabrics to meet the flammability standards which are being developed. The use of FR's in the fabrics, however, raises two important questions:

Question #1. Could FR's be used to flame retard upholstery fabric to meet a flammability standard without posing a hazard?

Question # 2. Could the smoke generated by the FR-treated fabrics cause more harm to the consumers than the smoke generated by the non-FR fabric in the case of residential fire?

The first question is relatively more important than the second. For a flame retardant to pose a hazard, it would have to be either acutely or chronically toxic

and there would have to be exposure. The fire retardant would have to migrate out of the fabric and penetrate the skin of an individual using the furniture. The amount of fire retardant that was bioavailable (both migrating out of fabric and penetrating the skin) would have to be at a level that would cause a toxic response. The definition of "toxic" that pertains to acute toxicity is found at 16 CFR §1500.3(c)(1). A definition of "toxic" that pertains to chronic toxicity is found at 16 CFR §1500.3(c)(2). A summary of the guidelines for determining chronic toxicity can be found at 16 CFR §1500.135.

Combustion toxicity research has demonstrated that the primary toxicant from combustion is carbon monoxide (CO). Any toxicant produced by combustion of the fire retardant would be produced in small amounts relative to the amounts of CO produced from combustion of a whole piece of furniture. It is therefore unlikely that the smoke generated by the FR-treated fabrics would cause more harm to consumers than the smoke generated by the non-FR fabric.

II. Discussion

Question #1. Could FR's be used to flame retard upholstery fabric to meet a flammability standard without posing a hazard?

Response:

To answer the first question, the FR's identified as being used in upholstery fabrics in the European Report (1992) and in an acid extraction study conducted by the CPSC laboratory staff (which identified organophosphates, borate and antimony trioxide in the fabric; Chen, 1997) were examined for acute and chronic adverse health effects of concern and degree of exposure. Not all of these FR chemicals are necessarily candidates for use in meeting a possible CPSC small open flame standard.

Boric Acid (CAS # 10043-35-3)

Boric acid is an inorganic acid, stable in air and soluble in water at 0.1 M with a pH of 5.1. It is widely used in cosmetics, hair colors and pharmaceuticals. The Cosmetics, Toiletry, and Fragrance Association (CTFA) recommended a safe upper limit (for toxic effects) of 5% boric acid as an additive in cosmetics. They also recommended that boric acid at that level not be used on infants or injured skin (CTFA, 1983).

Absorption of boric acid through intact skin is very low, but it is greatly increased through abraded, denuded, or burned skin and through mucous

membrane. Dermal studies with ointments, solutions and powders containing boric acid have been conducted in infants with or without diaper rash or with burns (Mulinos et al., 1953; Vignec and Ellis, 1954; Johnston et al., 1955) and in adult patients with burns (Draize and Kelly, 1959; Schuppli et al., 1971) or vaginitis (Swate and Weed, 1974). The studies showed a poor absorption of boric acid in subjects with normal intact skin but the absorption was significant in infants with diaper rash or burns, and in adult patients with burns. Thus, dermal penetration of boric acid is likely to be very low from the upholstered furniture covered with boric acid treated fabrics except for persons whose damaged skin touches the fabric.

Boric acid has a very low acute toxicity (oral LD_{50} in rats 5.14 g/kg, Merck Index, 1996; >4,000 mg/kg, Weir and Fisher, 1972). The major health hazards associated with boric acid exposure are reproductive and developmental effects. Testicular atrophy and dystrophic changes occurred in rats given boric acid in feed for 14 days or 90 days at about 1 g/kg/day and sterility in rats occurred at about 700 mg/kg/day given in feed for 14 days (no viable sperm in males and decreased ovulation in females; Weir and Fisher, 1972). The no-effect level in the 90 day study was about 100 mg/kg/day (Weir and Fisher, 1972).

Boric acid caused developmental effects in rats below the maternally toxic dose level and at maternally toxic dose levels in mice (0.1, 0.2, or 0.4% boric acid in feed throughout gestation). The developmental effects included enlarged lateral ventricles of the brain, and shortening of rib XIII in rats; and an increased incidence of a rudimentary rib XIII (a malformation) and a decreased incidence of rudimentary or full rib(s) at lumbar 1 (an anatomical variation) in mice. In rats, the no-observable-adverse-effect level (NOAEL) for maternal toxicity was 78 mg/kg (0.1%), while in mice 248 mg/kg (0.1%) approached the maternal NOAEL (Heindel et al., 1992).

A 2-year cancer bioassay (NTP, 1987) in $B6C3F_1$ mice showed no evidence of carcinogenicity at doses of 2,500 or 5,000 ppm (in feed), however the survival of the treated animals was lower than that for the control group (control 40/50, low dose 30/50, high dose 22/50) which may have reduced the sensitivity of the study. The study showed testicular atrophy and interstitial cell hyperplasia in the high dose male mice.

The NOEL for developmental effects in male rats was 100 mg/kg/day and the NOEL for maternal toxicity in rats was 78 mg/kg/day. Using a safety factor of 100, the acceptable exposure limit would be 0.78 to 1 mg/kg (NOAEL/100). For a 60 kg adult this would be 60 mg. Since the dermal penetration of boric acid is very poor (undetectable), a dose of 60 mg boric acid is not expected to penetrate the skin every day.

Decabromodiphenyl Oxide (DB; CAS # 1163-19-5)

DB is a completely brominated aromatic that is a white to off-white powder. No dermal penetration studies were found on DB. DB has a low acute toxicity (Norris et al., 1973, 1975; Kociba et al., 1975). Doses up to 2,000 mg/kg given orally in corn oil failed to produce any sign of acute toxicity in rats. Repeated oral doses of up to 800 mg/kg produced no overt indication of toxicity during a 30-day study. Repeated application of DB in petrolatum to human skin three times a week for three weeks did not produce any adverse effects (Norris et al., 1973, 1975). DB caused no teratogenic effects in rats (1,000 mg/kg orally, days 6-15 of gestation; Norris et al., 1973, 1975).

In a 2-yr oral (feeding) cancer bioassay study in F344/N rats and $B6C3F_1$ mice, *some evidence of carcinogenicity* was observed for male and female rats. DB caused an increased incidence of neoplastic nodules in the liver at a 25,000 ppm dose in males and at a 50,000 ppm dose in both sexes (NTP, 1986). *Equivocal evidence of carcinogenicity* was found for male mice (hepatocellular adenomas and carcinomas combined) and *no evidence of carcinogenicity* was found in female mice (25,000 or 50,000 ppm; NTP, 1986). Utilizing the methodology of CPSC's Federal Hazardous Substances Act (FHSA) guidelines, DB does not meet the FHSA definition of "toxic" for carcinogenicity.

Based upon the limited available data DB does not appear to be either acutely or chronically toxic.

Hexabromocyclododecane (HBCD, CAS # 3194-55-6)

HBCD has a very low acute toxicity; the oral LD_{50} value in rats is >10,000 mg/kg and the dermal LD_{50} value in rabbit is >8,000 mg/kg (Dynamac Corp.1988). No dermal penetration studies were found in the literature.

Murai et al., (1985) found no reproductive developmental effects in rats (0, 0.01, 0.1, or 1.0 % HBCD in diet from day 0 to day 20 of pregnancy). No chronic studies were located.

In conclusion, HBCD has a very low acute dermal and oral toxicity. While there is limited data on the chronic effects of HBCD, the existing data do not indicate any chronic effects. Based upon limited data, HBCD would not be considered toxic.

Antimony Trioxide (Antimony Oxide, CAS # 1309-64-4; 1317-98-2; 12412-52-1)

Antimony trioxide (AT) occurs in nature as the minerals valentinite and senarmontite. AT is not a flame retardant. It is used in combination (as a synergist, typically at 2-10% by weight of fabric) with organochlorine and brominated compounds to diminish the flammability of a wide range of plastics and textiles (IARC, 1989).

No dermal penetration studies were found in the literature. AT is only slightly soluble in water and insoluble in organic solvents (IARC, 1989). The absorption of AT from the gastrointestinal (GI) tract was studied in three rats. AT (200 mg) was given as a suspension in water by gavage to rats and the urine collected for eight subsequent days showed a total of 3.2% of the dose in urine (Gross et al., 1955). This indicates some absorption of AT from the GI tract. Since no fecal excretion, blood levels and tissue distribution of AT were monitored in this study, no conclusion can be drawn about the major route of excretion or the absorption rate from the GI tract. The acute dermal, subcutaneous, and oral LD_{50} values of AT are > 2,000 mg/kg in rabbit, 7,900 mg/kg in rats, and >34,600 mg/kg in rats, respectively (RTECS). These values indicate that AT has a low acute toxicity.

Most of the human data come from studies of smelter workers which showed that inhalation of smelter dust containing AT caused pneumoconiosis (IARC, 1989) in some of these workers. The pneumoconiosis was generally symptomless (NIOSH, 1978).

AT caused an increased incidence of lung tumors in female Fischer rats (CDF from Charles River) in an inhalation study. Female rats (49-51/group) were exposed to 0, 1.6 ± 1.5, or 4.2 ± 3.3 mg/m^3 of AT, 6 hour/day, 5 days/week for 13 months (Watt, 1983). Twelve months after the end of the treatment, 13 control, 17 low-dose and 18 high-dose rats were sacrificed and selected tissues were examined. Lung tumors localized in the bronchioloalveolar region occurred in 14/18 high-dose group rats ($p < 0.01$). Another inhalation study in rats (Wistar) showed lung tumors in the females, but not in the males or the controls (0, or 45 mg/m^3, 7 hour/day, 5 day/week for 52 week ; Groth et al., 1986). According to the CPSC's guidelines for chronic hazards, there is sufficient evidence for the carcinogenicity of AT in experimental animals. AT is a probable human carcinogen and meets the FHSA's definition of "toxic."

Acid extraction study of two upholstery fabrics was conducted by the CPSC staff (Chen, 1997). Hydrochloric acid (4N HCl) extraction of polyolefin and polyester fabrics showed that the fabrics contained 1.16% and 2.5% of antimony trioxide, respectively (The reagent grade antimony trioxide is very soluble in 4N HCl and can be completely recovered with the 4N HCl acid extraction). The

amount of AT which may leach out in a very dilute acid medium (0.01N HCl) and become available to a consumer was found to be very low (0.01%). Consumer exposure to AT is expected to be very low because it is tightly bound in the fabric as indicated by its very poor extraction in dilute acid medium (0.01%). While AT does not meet the definition for "toxic" for an acute toxicant, it does meet the definition of "toxic" for carcinogenicity. However, based upon the amount of AT that leaches out of fabric, bioavailability would be limited.

Tris (1,3-dichloroisopropyl)phosphate (TDCP, Fyrol FR-2; CAS # 13674-87-8)

TDCP is similar in structure to tris (2,3-dibromopropyl) phosphate (TRIS) and would be expected to have similar bioavailability from similar treated fabrics. TDCP can be absorbed dermally by both rats and rabbits when directly applied to shaved skin and it penetrates the skin two-fold better than TRIS. Like TRIS, TDCP is excreted primarily in the urine of both rats and rabbits (Ulsamer, 1980). A skin penetration study revealed that 4.63% (0.926 mg) of the C^{14}TRIS (20 mg) on dry fabric penetrated the rabbit skin in 96 hours (Ulsamer, et al., 1978). In this study TRIS was surface coated by immersing the fabric in the radioactive TRIS solution in 1,1,1-trichloroethane and allowed to air dry. If fabric is similarly surface coated with TDCP, it is likely that it would migrate out of the fabric and through skin as TRIS did. The bioavailablity of an FR from a fabric depends upon the FR binding to the fiber: the stronger the binding, the lower the bioavailablity. Since the method of FR treatment for upholstery fabrics may differ greatly from the method for apparel fabrics, the bioavailability would probably differ as well. A surface coated upholstery fabric would be expected to behave like a surface coated apparel fabric, while TDCP applied as a back-coat is likely to behave very differently.

TDCP is moderately toxic by the oral route; the oral LD_{50} value in rats is 2,830 mg/kg. The dermal LD_{50} is 23,900 mg/kg using occlusive techniques (Mellon Institute Report, cited by Ulsamer, et al., 1980). TDCP would not be considered "toxic" by the dermal route of exposure.

In a two year toxicity/carcinogenicity study (TDCP in feed; 0, 5, 20, 80, mg/kg/day; 60 rats/sex/dose for 2 years) in Sprague Dawley rats, the incidence of hepatocellular carcinoma was significantly increased in males in the high-dose group (control, 1/60; 80 mg/kg, 7/60; $p < 0.05$; Stauffer Chemicals Co., 1981). The incidence of total liver tumors (neoplastic nodules plus hepatocellular carcinoma) was significantly increased in both sexes of the high-dose group as compared to controls (Control, 3/60, 80 mg/kg, 23/60 males, and 13/60 females, $p < 0.05$). Utilizing the methodology of CPSC's chronic hazard guidelines, TDCP is a probable human carcinogen and meets the FHSA's definition of "toxic."

The CPSC staff previously evaluated the cancer risk from TDCP in mattress foam (Mishra, 1985). Aqueous extraction data were used to estimate exposure. Dermal penetration data with TRIS were used as a surrogate for estimating bioavailability. It was assumed that a person would sleep on a mattress containing 8.5% TDCP in the foam for an average of 6 hours per day for four years, with one-quarter body surface area (skin) in direct contact with the mattress (worst case). The lifetime cancer risk for all liver tumors was estimated to be 0.59 per million. If TDCP levels and water extractability of TDCP are the same for foam mattresses and fabric, it is expected that the lifetime cancer risk for liver tumors would be similar.

Tris(2-chlorethyl) Phosphate (TRCP, CAS # 115-96-8)

There are no dermal penetration studies available on TRCP, however, based on the chemical structure similarity to Fyrol FR-2, it is likely to have similar dermal penetration to that of Fyrol FR-2 (see TDCP). TRCP is rapidly absorbed following oral administration since peak plasma levels are attained in five minutes. The major route of excretion is in urine (greater than 90% of the dose) with approximately 6% of the dose in feces, and a trace amount exhaled as CO_2 (NTP, 1991).

There are very few studies available on the toxic effects of TRCP. It is "toxic" by oral administration to rats with an oral LD_{50} of 1230 mg/kg (RTECS). The dermal LD_{50} value in rabbit is > 20 ml/kg (>20,000 mg/kg; RTECS). TRCP would not be considered "toxic" by the dermal route of exposure.

Organophosphates are known to cause anticholinesterase effects, but the anticholinesterase activity of TRCP is minimal and it may not cause delayed neurotoxicity associated with many organophosphates (NTP, 1991). TRCP causes lesions in the hippocampal area of the brain of treated rats when administered at 200mg/kg and higher doses and is a neurotoxin (private communication, Dr. H.B. Matthews). It is not likely that such doses would be achieved through contact with TRCP fire retarded upholstery fabric. In a study in hens, TRCP failed to show behavioral or histopathological evidence of delayed neurotoxicity (10 ml/kg; Sprague et al., 1981).

The National Toxicology Program (NTP) conducted a 2-year gavage study on TRCP in F344/N rats and $B6C3F_1$ mice (0, 44, or 88 mg/kg, in rats and 0, 175, or 350 mg/kg in mice, 5 days/week for 104 week by gavage in corn oil, 60 animals/sex/dose; NTP, 1991). There was *clear evidence of carcinogenicity* for male and female rats as shown by an increased incidence of renal tubule adenomas (controls,1/50 , 88 mg/kg, 24/50 males, 5/50 females). There was *equivocal evidence of carcinogenicity* in male and female mice. Utilizing the methodology of CPSC's guidelines, TRCP is a probable human carcinogen and meets the definition of "toxic" under the FHSA. The hazard posed to humans based on carcinogenicity

would depend on the amount of TRCP that migrated out of the fabric and the amount that penetrated the skin.

Since the dermal acute toxicity is so much lower than its oral toxicity it does not appear that very much TRCP would penetrate the skin and be bioavailable.

Urea (CAS # 57-13-6)

Urea does not meet the definition of "toxic" under FHSA; the oral LD_{50} value in rats is 8,471 mg/kg (RTECS). There are no chronic toxic effects found in the literature associated with urea. Though it is not a flame retardant, it is, however, often present with other FR's. Since urea is a natural by-product of protein metabolism in the body, is present in the blood in high concentrations, is excreted by the kidney in the urine in large amounts, and, therefore, is not considered "toxic" under the FHSA.

Phenol Isopropylated Phosphate (PIP, CAS # 68937-41-7)

PIP has a low acute toxicity; the oral LD_{50} value in rats is more than 5,000 mg/kg, and the dermal LD_{50} in rabbit is more than 2,000 mg/kg (no information on higher doses; RTECS). There are no chronic toxic effects found in the literature that are associated with PIP. PIP has a low delayed neurotoxicity and a low skin penetration capacity (European Report, 1992; no data given). Based on the limited available information, PIP would not be considered "toxic" under the FHSA.

Ammonium Bromide (AB, CAS # 12124-97-9)

Ammonium bromide (AB) meets the definition of "toxic" under the FHSA; the oral LD_{50} in rats is 2700 mg/kg (RTECS). No dermal penetration or chronic studies were found in the literature. Though AB has anticonvulsant and sedative properties, these properties are not relevant to its use as an FR. Since AB can ionize into ammonium and bromide ions, it is unlikely to penetrate the skin.

Phosphorothioic acid, O,O-dimethyl ester, O-ester with p-hydroxybenzenesulfonamide (Proban, CAS # 115-93-5)

Proban meets the definition of "toxic" under the FHSA; the oral LD_{50} in rats is 160 mg/kg and the dermal LD_{50} in rabbit is >2500 mg/kg (RTECS). No other dermal penetration or chronic toxicity data were found in the literature. Proban is a large chemical molecule and, thus, is likely to have a low skin penetration. This may account for its low dermal toxicity relative to oral toxicity. If this is the case, Proban would not be expected to be bioavailable.

Phosphonic Acid, [2-{(hydroxymethyl)carbamoyl} ethyl]- dimethyl ester (9Cl) (Pyrovatex; CAS # 20120-33-6)

The toxicity information available on Pyrovatex is limited to acute toxicity in rats. The oral LD_{50} in rats is 13,000 mg/kg which indicates that the chemical does not meet the definition of "toxic" under the FHSA (RTECS). There are no skin penetration studies or dermal LD_{50} value available.

Ammonium Polyphosphate (AP, CAS# 68333-79-9)

No toxicity information was available in the computerized data bases (RTECS, MEDLINE,TOXLINE). However, the European Report (1992) states that AP is often used in the backcoating of fabric and can be considered harmless. Since the molecule is large, its migration to the top of the fabric would be limited. In addition, AP is a charged molecule and is not expected to be absorbed through the skin to any significant extent. For these reasons, the statement in the European Report appears reasonable.

Ammonium Sulfamate (AS; CAS # 7773-06-0)

AS would be considered "toxic" under the FHSA; the oral LD_{50} value in mice and rats is 3,100 and 4,400 mg/kg (Gupta et al., 1979). No dermal penetration studies or dermal acute toxicity studies were found. A 90-day study in rats (0, 100, 250, or 500 mg/kg/day, dissolved in distilled water, by gavage) showed no significant changes in relative organ weights, histology of liver, or blood neutrophil count as compared with controls. No studies related to chronic effects were found in the literature.

In conclusion, there is very little toxicity information available to evaluate the safety of AS in upholstery fabric. Further exposure data (dermal penetration studies and extraction of AS from fabric) are required.

Tetrakis (hydroxymethyl)phosphonium compound with urea (CAS # 2710-4-30-9)

No toxicity information was available in the computerized data bases (RTECS, MEDLINE,TOXLINE) on this tetrakis-urea compound. The European Report (1992) described this compound as biologically active, showing acute systemic toxic effects and having a potential to cause skin, eye, and respiratory tract irritation. There are also doubtful teratogenic effects, described by the chemical producer (data not published). The tetrakis-urea compound is chemically transformed to an insoluble material when applied to the fabric. The insoluble material is reported to be inert and not dangerous (HS staff has no information on

this). Because the European Report did not provide adequate toxicity information, the HS staff can not evaluate the conclusions reached in the report.

Fire Retarded Polyurethane Foam

While the question being answered refers specifically to fire retardants used to treat fabric to meet a possible flammability standard, polyurethane foam used in upholstered furniture is also treated with fire retardants. These fire retardants have also been examined for their toxicity.

Laboratory analysis (Chen, 1997) has shown that fire retarded polyurethane foams used in California contain either Fyrol FR-2 or DE-60F (a mixture of triphenyl phosphate, tetrabromodiphenyl oxide and pentabromodiphenyl oxide) as flame retardants. Toxicity information on Fyrol FR-2 has been discussed earlier. No toxicity information on tetrabromo- and pentabromodiphenyl oxide was found in the literature. Both diphenyl oxides are expected to have a toxicity pattern similar to that of decabromodiphenyl oxide because of their similarity in chemical structure; the toxicity of decabromodiphenyl oxide was discussed earlier.

Triphenyl Phosphate

Triphenyl phosphate would not meet the definition of "toxic" for acute effects under the FHSA, based on the rabbit skin LD_{50} value of > 7900 mg/kg (RTECS). Triphenyl phosphate has not been shown to be carcinogenic (RTECS).

Melamine

Melamine is the fire retardant used in the United Kingdom to treat polyurethane foam. Without additional work, a determination of whether melamine meets the definition of "toxic" for acute effects under the FHSA, can not be made. The dermal LD_{50} for rabbits is reported to be >1 gm/kg (RTECS). Melamine was carcinogenic for male F344/N rats, causing transitional cell carcinomas in the urinary bladder. With one exception, urinary bladder stones were observed in male rats that had transitional-cell carcinoma. Melamine was not carcinogenic for female F344/N rats or male or female $B6C3F_1$mice in a National Toxicology Program study (Tech Rep. 245, 1983). Mice and rats were treated with 2,250 or 4,500 ppm melamine in the diet. Since melamine was only carcinogenic to one sex of one species it does not meet the definition of "toxic" under the FHSA. Based upon limited toxicity information, melamine is not "toxic" under the FHSA.

In summary, the majority of FR's reviewed above were either not "toxic" or did not appear to be bioavailable. However, toxicity information is lacking on most of the fire retardants, a determination about a lack of toxicity is based on limited data in many cases, and it is not clear how much if any exposure there is.

Therefore, additional exposure information would aid staff in determining what if any risk is posed to humans.

Question # 2. Could the smoke generated by the FR-treated fabrics cause more harm to the consumer than the smoke generated by the non-FR fabric in the case of residential fire?

Response:

Studies (Babruskas et al., 1988; Hilado and Furst, 1976; CPSC, 1987) on the toxicity of smoke generated by home furnishing materials and other materials commonly found in a household were reviewed by the HS staff. The smoke generated by an FR-treated material in the case of fire is likely to have the pyrolytic byproducts (toxic gases) of the FR which may add to the overall toxicity of the smoke. For example, ammonium bromide may generate hydrogen bromide on pyrolysis. Chlorinated organophosphate may generate, hydrochloric acid (HCl), carbon monoxide (CO) and carbon dioxide (CO_2). Nitrogenous chemicals like urea, may produce hydrogen cyanide (HCN). Construction materials may also produce HCN if they contain nitrogen based materials like polyurethane foam. The production of these gases also depends upon the air supply. If the air supply is abundant then there would be more production of CO_2 and NO_2 than CO and HCN. If furniture has polyurethane foam which is a nitrogenous material and may constitute a major portion of the combustible materials in the furniture, then the relative contribution of HCN from a urea containing FR-treated fabric to overall HCN generation could be very small. Combustion toxicity research has demonstrated that the primary toxicant from combustion is carbon monoxide (CO). Any toxicant produced by combustion of the fire retardant would be produced in small amounts relative to the amounts of CO produced from combustion of a whole piece of furniture. The reviewed studies were designed to evaluate the total toxicity as measured by lethality of the smoke in test animals, along with measurements of concentrations of toxic gases, e.g., CO, HCN.

Babruskas et al., 1988 [NBS (NIST) Special Publication 749]

This study was not designed specifically to compare toxic fumes generated by FR and non-FR fabrics alone in the case of fire. However, it provides general background information on the overall hazard to the consumer from FR-treated and non-FR-treated materials for a variety of materials commonly found in a household. The items included in the study were TV cabinet housing, business machine housing, upholstered chairs, cable array, and circuit boards. Based on two criteria - flashover and the carbon monoxide fractional effective dose (CO-FED; CO toxicity/total toxicity from all gases), the study showed that FR materials gave better fire performance (lower toxicity and better escape time) to the consumer than the non-FR materials. In large-scale tests (room tests) the escape time was

10-fold better for FR tests than for the non-FR tests on the basis of the toxicity criteria. On the basis of flashover criteria, the escape time was more than 15-fold better for the FR tests than for the non-FR tests. This enhanced fire performance seen in the study for the FR materials, should by no means be expected from all FR materials according to the authors. The staff agree with the authors because a new flame retardant chemical or a new upholstery material that has never been tested for toxicity before may behave in an unpredictable manner. For this reason it is still necessary to test and evaluate all new FR-treated materials.

The study was global in nature (included a variety of household materials and a upholstered chair) not specific for upholstery fabric, therefore, a direct reference to upholstery fabric can not be drawn. However, the amount of fabric in furniture is likely to be very small relative to other components of the furniture and other materials in a room. Thus, the contribution to the overall smoke toxicity by an FR-treated fabric is likely to be insignificant. On the other hand, the FR-treated fabric may delay the ignition and thereby may even reduce the overall production of the smoke and the resulting hazard from the smoke.

Hilado and Furst, 1976

In this study, 70 different types of cushion materials were tested; 12 of them were upholstery fabrics. Although there were two FR-treated fabrics in the study, no non-FR-treated fabrics of the same type were included as controls for comparison. The objective of the study was to rank the materials in order of toxicity of the smoke each produced. No effort was made to compare a specific material with or without FR treatment to determine if the FR treatment caused a change in the toxicity. The study is, however, relevant because it provides information on the toxicity of various FR- and non-FR-treated fabrics as well as filling materials used in upholstered furniture.

Briefly, the test procedure involved pyrolyzing (combusting) the test specimen (1 gm) in a heating chamber connected to an exposure chamber (4.2 L), exposing the test animal (4 mice/test) to the smoke and recording the time to first sign of incapacitation in minutes (Ti) and time to death in minutes (Td).

For all 12 fabrics tested, average Ti values (two or three experiments) ranged from 4.52 min for a 99/1 wool/spandex fabric to 14.82 min for a fiberglass base fabric. The corresponding average Td values ranged from 5.80 min for the wool material to 24.60 min for the fiberglass material. Low Ti or Td values indicate high toxicity. Thus, the wool blend was most toxic and the fiberglass base fabric was least toxic. The 100% nylon face with 20% polyurethane foam 80% acrylic back (Td, 6.72), polyester (Td, 9.36-10.63), and largely wool fabrics (Td, 5.8 - 8.92) exhibited the shortest Td values. There were two FR-treated fabrics in the study. The average Ti and Td values were 12.56 and 15.32 min, respectively, for one FR-

treated fabric (vinyl 80%, and 20% nylon blend fabric; no back coating). The corresponding Ti and Td values for the second FR-treated fabric (expanded vinyl fabric; backing removed) was 7.62 and 17.49 min, respectively. Another fabric which was also an expanded vinyl fabric (chemically similar but not a control sample; backing removed) without FR treatment showed Ti and Td values of 7.69 and 15.64 min, respectively; similar to the FR fabric.

The data are limited to one set of FR- and non-FR-treated fabrics which may not be directly comparable. This study provides no information about the difference in the toxicity of the smoke generated by FR versus non-FR fabrics. The study shows that the fabric type is an important factor in determining the toxicity of the smoke produced during combustion.

CPSC, 1987 Study

The CPSC's Health Sciences Laboratory (CPSC, 1987) conducted a systematic investigation of the toxicity of the smoke generated by a large number of commonly used upholstering materials. The toxicity index used was the LC_{50} dose, which is defined as the concentration of a toxic agent or a mixture of agents that kills 50% of the test animals.

The study showed that the presence of flame retardant chemicals in filling materials (fibers and foams) seems to increase the toxicity of the smoke somewhat in the flaming mode[1] of combustion in some experiments. However, the toxicity of the smoke from the non-flame-retarded polyurethane foam (PUF # 32) and comparable flame retarded polyurethane foam (PUF 32X) were similar in other experiments. Thus, no clear-cut general conclusion can be drawn from the study about the effect of FR treatment on the toxicity of smoke.

Possible Release of Hydrogen Cyanide Gas and Bromofurans

It has also been pointed out that the smoke from fabric treated with nitrogen-containing FR's and other chemicals, like urea, may be of concern because these chemicals can produce HCN (a toxic gas) when the treated fabric is ignited in a residential fire. The actual relative increase of smoke toxicity due to generation of HCN from a nitrogen containing chemical like urea would depend upon the amount of other HCN producing FRs in the fabric, and the proportion of other HCN producing nitrogenous construction materials, like polyurethane foam in the furniture. If the amount of urea is low, then its contribution to the overall

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[1]In the flaming mode combustion, the sample holding cup in the heating furnace is kept at 25^0 above autoignition temperature (the lowest temperature at which the material spontaneously flamed).

generation of HCN by other materials in the furniture would be low and the resulting increase in the toxicity hazard due to urea would be low. Further the toxicity of the resulting HCN from combustion of a nitrogen-containing FR is likely to be low compared to the toxicity of the CO produced by combustion of the piece of furniture.

It has also been pointed out that brominated biphenyl compounds may generate bromofurans (toxic chemicals) as a result of combustion in a fire (no details given; European Report, 1992). Data do not exist to determine the extent to which bromofurans may be produced, however, the toxicity of bromofurans generated from a biphenyl FR is likely to be low compared to the toxicity of the CO produced by the piece of furniture.

Toxicity of Smoke from Melamine-Containing Foams

Toxicity of smoke from melamine-containing foams following combustion is, however, of concern. Melamine-containing foams when combusted were found to produce about ten-fold higher levels of hydrogen cyanide (HCN), a potent toxic gas, as compared to control foams not containing melamine (Levin, 1992). Since upholstered furniture is likely to contain large amounts of foam as a cushion, the increased generation of HCN by a melamine-containing foam could be significant in a residential fire. The smoke containing high levels of HCN is likely to cause an increased level of injuries and deaths in the occupants of the residence.

III. Conclusions

Question #1. Could FR's be used to flame retard upholstery fabric to meet a flammability standard without presenting a hazard?

For a flame retardant to pose a hazard, it would have to be acutely or chronically toxic, the flame retardant would have to migrate out of the fabric or foam under reasonably foreseeable use conditions, and it would have to penetrate the skin (become bioavailable) at a level that would cause a toxic response. While some of the flame retardants reviewed were not chronically or acutely toxic, this determination in many cases was based upon extremely limited toxicity information. The following chemicals do not appear to be toxic:
1) decabromodiphenyl oxide, 2) hexabromocyclododecane, 3) urea, 4) phenyl isopropylated phosphate, 5) Pyrovatex, 6) triphenyl phosphate, and 7) melamine. The following chemicals have either no toxicity data or limited toxicity data but are not expected to be bioavailable: 1) Proban, 2) ammonium polyphosphate, and 3) tetrakis (hydroxymethyl) phosphonium compound with urea. Boric acid and ammonium bromide are toxic but do not appear to be bioavailable and ammonium sulfamate is acutely toxic but there is no information on bioavailability. Antimony

trioxide, Tris (1, 3-dichloroisopropyl)phosphate (TDCP, Fyrol FR-2), and Tris (2-chloroethyl) phosphate are all probable human carcinogens and thus, chronically toxic. The cancer risk assessment based on the extreme exposure case indicated that the TDCP-treated upholstery fabrics is not likely pose a risk to humans. Since TRCP is chemically similar to TDCP, TRCP in upholstery fabrics would also probably not pose a risk. Based on the low extractability of AT from two fabrics, HS staff believe that AT in these upholstery fabrics is likely not to be bioavailable.

These conclusions are based upon limited data in many cases. Additional data on the amount of FR chemicals in upholstery fabric and polyurethane foam and the ability of the FR chemical to migrate out of the fabric or foam would enable us to more accurately predict whether a particular FR chemical treated fabric would be considered a hazard to humans. If FR chemicals migrate out of treated fabric and foam, then additional data on whether they penetrate the skin would also be useful in predicting the degree of hazard they pose to humans.

Question # 2. Could the smoke generated by the FR-treated fabrics cause more harm to the consumer than the smoke generated by the non-FR fabric in the case of residential fire?

In the CPSC study, flame retardant chemicals in filling materials (fibers and foams) appears to increase the toxicity of the smoke in the flaming mode of combustion, however other combustion tests did not show such an increase. Since, no data are available specifically comparing the toxicity of smoke from FR treated and control fabric, no firm conclusions can be made. However, the overall information on other household materials including an upholstered chair indicate that any increase in toxicity of smoke specifically contributed by the FR treated fabric is likely to be very small compared to the CO produced by combustion of the entire piece of furniture. It is more likely that the delay in ignition due to FR treated fabric would outweigh any possible contribution of the FR treated fabric to the overall toxicity of the smoke.

For fire retarded polyurethane foams, there is one study that indicates that melamine treated polyurethane foam produces about ten-fold higher levels of HCN than control foams not containing melamine. Smoke containing these higher levels of HCN could cause increased injuries and deaths.

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DEPARTMENT OF HEALTH & HUMAN SERVICES Public Health Service

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August 22, 1997

Dr. Marilyn L. Wind
Director, Division of Health Sciences
Consumer Product Safety Commission
Suite 600
4330 East-West Highway
Bethesda, MD 20814

Dear Dr. ~~Wind.~~ Marilyn

At Dr. Lucier's request, I have reviewed the draft memorandum prepared by the staff of the Consumer Product Safety Commission (CPSC) for the chronic toxicity of flame retardants that have potential for use on fabrics in upholstered furniture. I think your staff should be complemented for a very thorough review of the subject and for their careful consideration of the "pros and cons" of recommending flame retardants for use in upholstered furniture. Due to their very thorough consideration of flame retardants my following comments and suggestion regarding the chronic toxicity that may be associated with flame retardant use are relatively minor.

1. You mention in your letter that the standard would address risks associated with small open flames. Should this standard not be inclusive of smoking materials, e.g., cigarettes, as well?

2. Page 7, paragraph 4
It is mentioned that TRCP is a poor inhibitor of actylcholine esterase. That is true of all the organophosphate flame retardants mentioned. This is due to the fact that they do not have a good "leaving group" that permits the phosphorylation of actylcholine esterase. TRCP, never-the-less, is a neurotoxin, causing lesions in the hippocampal area of the brain of treated rats when administered at 200 mg/kg and higher doses. However, such doses are not likely to be achieved on contact with treated upholstery.

3. Page 10, paragraph 2
Whereas I agree that the majority of flame retardants reviewed are probably not hazardous when used in upholstered furniture it should be noted that there was no mention of efficacy or applicability. That is, are these chemicals equally effective flame retardants? Further, can they all be applied to upholstery and expected to remain on the fabric? Equally well? Also, some of the compounds mentioned, decabromodiphenyl oxide and hexabromocyclododecane, appear to have the potential to bioaccumulate in the environment when the furniture or upholstery is discarded. They may also be released into the environment as a result of their manufacture and application. Should possible adverse environmental effects be a consideration?

4. Page 13, last paragraph
Some of the flame retardants recommended appear to be considered safe because they have not been subjects of adequate testing. Should testing be requested of the manufacturers or through a Federal Agency?

Again, I would like to complement your staff at CPSC for a very thorough job. My suggestions for improvement are minor, but I hope you find them of use.

Sincerely,

SKIP

H. B. Matthews, Ph.D.
Head, Chemistry

cc:
Dr. George Lucier

U.S. Department
of Transportation
**Federal Aviation
Administration**

Mike Monroney
Aeronautical Center

P.O. Box 25082
Oklahoma City, Oklahoma 73125

August 15, 1997

Marilyn L. Wind, Ph.D.
Director
Division of Health Sciences
U.S. Consumer Product Safety Commission
Washington, D.C. 20207

Dear Dr. Wind:

I carefully reviewed the draft memorandum entitled "Toxicity of flame retardant chemicals (FR's)...the smoke from FR-treated fabrics." In general, my review revealed that the memorandum is thoroughly prepared and is based on sound scientific information. The information incorporated in the draft is supported by literature citations and the conclusions made are scientifically logical. Nevertheless, there are some specific, but minor, points which I thought worth mentioning.

1. Page 3, Paragraph 2: Author should consider incorporating the reference of ***Am Ind Hyg Assoc J*** **30**, 470 (1969). In this paper, the oral LD_{50} in rats is given as 5.14 g/kg; thus, the paragraph may need some modification. Also, refer to the latest Merck Index.

2. Page 4, Paragraph 3: The conclusion of not being "toxic" is for carcinogenicity only or for other types of toxicity, too. The conclusion needs further elaboration.

3. Page 5, Paragraph 2, Line 6: Consider modifying the sentence starting with "Since" as "Since no fecal excretion, blood levels and tissue distribution of AT were monitored...."

4. Page 8, Last Paragraph, Sentences 1 & 2: Since the dermal LD_{50} determination is the consequence of the absorption of an agent through the skin, the second sentence should be modified by including "other" between "No" and "dermal."

5. Page 10, Paragraph 1: It is not clear whether the transformed product's insolubility is related to water. Since the product is a polymer, it can be logically inferred that the insolubility is related to water, not to organic solvents. This aspect should be clarified.

6. Page 10, Last Paragraph, Line 13: Insert "CO and" between "than" and "HCN."

7. Page 11, Paragraph 1, Line 15: Should "author" be "authors," as well?

8. Page 13, Paragraph 1: Since the toxicity of smoke from a fabric treated with a fire retardant will **also** be dependent upon the chemical nature of the retardant, the conclusion should be generalized. Therefore, the authors should consider changing the sentence by adding "-cut general" just after "clear."

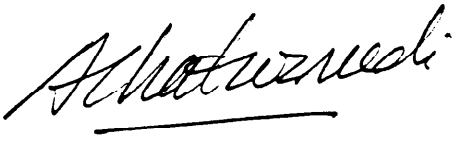
9. Page 13, Paragraph 2, Line 4 from bottom: Insert "considerably" between "be" and "low."

10. At certain places in the margins of the draft, some editorial changes are suggested. Authors should consider them appropriately.

The draft memorandum and the hazard guidelines are being returned herewith. I am also enclosing a complimentary copy of the special issue of ***Toxicology*** on the **International Colloquium on Combustion Toxicology** for your perusal. The information given in the issue might be of your and your colleagues' interest, particularly the information on smoke toxicity.

If I can be any further assistance, please feel free to contact me. I can be reached in the Toxicology and Accident Research Laboratory (AAM-610), Aeromedical Research Division, FAA Civil Aeromedical Institute, at 405-954-6250.

Sincerely,



A. K. Chaturvedi, Ph.D.
Team Coordinator,
Biochemistry Research
Adjunct Professor, University of
Oklahoma College of Pharmacy

Enc: As above

G

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

MEMORANDUM

DATE: October 3, 1997

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

THOUGH: for Andrew G. Stadnik, AED Engineering Sciences NVM
Nicholas V. Marchica, Director, Mechanical Engineering NVM

FROM : Rikki Khanna
Fire Protection Engineer
Directorate for Engineering Sciences

SUBJECT: Transmittal of documents: Draft Standard, Technical Basis Document, and Response to ANPR Comments

This memorandum forwards the subject documents for the Upholstered Furniture Project.

Attachment(s)

Draft Standard
Technical Basis Document
Response to ANPR Comments

DRAFT STANDARD FOR UPHOLSTERED FURNITURE

Standard for Small Open Flame Ignition Resistance of Upholstered Furniture

Subpart A - The Standard

Sec.
1 Purpose, Scope and Applicability.
2 Referenced Documents
3 Definitions.
4 General Requirements.
5 Test Apparatus
6 Atmospheres for Testing and Conditioning
7 Test Sample Preparation
8 Seating Area Test Procedure
9 Dust Cover Test Procedure

Appendix A Solving Gas Flow Problems
Appendix B Furniture Flammability Fixture Construction Drawings
Appendix C Figures

§ 1 Purpose, Scope and Applicability

(a) *Purpose.* This draft standard prescribes requirements for testing small open flame ignition resistance of upholstered furniture before the sale in commerce or the introduction in commerce of any upholstered furniture which is subject to the standard. The standard prescribes test methods to determine the flammability performance of the upholstered furniture seating area in § 8 and dust cover in § 9 when exposed to a small open flame.

(b) *Scope.* All upholstered furniture, as defined in § 3 manufactured or imported after the effective date of this standard are subject to requirements of this standard.

(c) *Applicability.* The requirements for testing prescribed by this standard are applicable to each "manufacturer" as that term is defined in § 3 of upholstered furniture or its components, that are manufactured for sale in commerce.

§ 2 Referenced Documents

(a) BS 5852: Fire Tests for Furniture, Part 2, British Standards Institute - 1982.

§ 3 Definitions

In additions to the definitions given in Section 2 of the Flammable Fabrics Act as amended (15 U.S.C. 1191), the following definitions apply for the purposes of this standard.

Afterflame The time for which a material continues to produce a visible flame after the ignition source has been removed.
Afterglow The time for which a material continues to glow after the removal of an external ignition source and after the cessation of flaming of the material.
Barrier A material that is intended to reduce the ignitability of upholstery.
Combustion An exothermic, self-sustaining reaction involving a solid or liquid, and or gas phase fuel. It can occur through flaming, glowing or smoldering.
Cover Fabric The outermost layer of fabric or related material used to enclose the main support system and upholstery filling used in the furniture item.
Dust Cover The outermost layer of non-structural material on the underside of the finished item of upholstered furniture.
Glow Combustion characterized by incandescence, without visible flame.
Ignition Initiation of combustion. It is perceived by the presence of any visible flaming, glowing, or smoldering after removal of the test flame.
Manufacturer An individual plant or factory at which upholstered furniture and/or it's components are produced or assembled.
Seating Area The intersection of the vertical and horizontal surfaces of upholstered furniture that are intended for seating purposes.
Self-Extinguishment The termination of any visible combustion within 2 minutes

of the test flame removal before the specimen is consumed.
Small Open-Flame A flaming ignition source that simulates the heat output of a match, candle, or cigarette lighter.
Smolder Combustion characterized by smoke production, without visible flame or glowing.
Specimen A specific portion of a material or a laboratory sample upon which a test is performed.
Upholstered Furniture A unit of interior furnishing with a resilient surface covered, in whole or in part, with fabric or related material, that is intended for use or may be expected to be used in homes, and is intended or promoted for sitting or reclining upon.

§ 4 General Requirements

(a) *Summary of test method.* The test method measures the ability of upholstered furniture to resist ignition when subjected to a small open-flame source (e.g. match, candle, or cigarette lighter). The surfaces to be tested are the seat/back or side intersection of the seating area and the dust cover. Materials used in upholstered furniture seating area construction are to be tested by constructing a small scale mock-up consisting of a cover fabric, any barrier materials used in the finished item between the cover fabric and filling, and standard polyurethane foam.

Dust cover materials are to be tested as individual components. Passing dust covers that do not melt or split when tested in accordance with § 9 can be used in any furniture construction of the assembled product. Interior materials within 1 inch (25.4 mm) measured vertically of a passing dust cover material that are exposed if the dust cover melts or splits, must also be tested in accordance with § 9 and pass.

The manufacturer has the option of constructing the seating area mock-up with the actual filling materials used in the finished product instead of the standard foam.

(b) *Criteria for Seating Area Test.* When testing the seating area mock-up in accordance with § 8, the test sample passes if:

i. All three specimens cease all modes of combustion within two minutes after flame removal.
ii. Any form of combustion does not extend to any edge of the mock-up.

(c) *Criteria for Dust Cover Test.* When testing the dust cover mock-up in accordance with § 9, the test sample passes if:

i. All three specimens cease all modes of combustion within two minutes after flame removal.
ii. Any form of combustion does not extend to any edge of the specimen.

§ 5 Test Apparatus

(a) Specimen Holders and Frame: The specimen holders consist of metal frames used to mount the test specimens in the test fixture.

Specimen Holders and Mock-up Frame Dimensions

Test Location	Length/Height Max/Min	Width Max/Min	Depth Max/Min
Dust Cover	10.1 in (257 mm) 9.9 in (251 mm)	10.1 in (257 mm) 9.9 in (251 mm)	N/A
Seating Area Back Frame[1]	11.9 in (302 mm) 11.7 in (297 mm)	17.8 in (452 mm) 17.6 in (447 mm)	N/A
Seating Area Base Frame[1]	N/A	17.8 in (452 mm) 17.6 in (447 mm)	6.0 in (152 mm) 5.8 in (147 mm)

[1] Seating Area Mock-up frame is based in BS 5852, 1979.

(b) Seating Area Mock-up: The test frame shall consist of two rectangular frames hinged together and capable of locking at a right angle to each other. The frames shall be made of 1 in. x 1 in. (25 mm x 25 mm) steel angle 1/8 in. (3 mm) thick, and shall securely hold platforms of steel mesh set 0.25 ± 0.05 in. (6 ± 1 mm) below the front face of each test frame.

(c) Clips: Clips are used to secure the specimens to the holders.

(d) Gas: The gas shall be C.P. Grade, 99.0 % purity.)

(e) Burner : Two burner tubes which consists of stainless steel tube with the following dimensions:

Burner Tube Dimensions

Test Location	Inside Diameter. Max/Min	Outside Diameter Max/Min	Length Max/Min
Dust Cover	0.239 in (6.07 mm) 0.235 in (5.97 mm)	0.317 in (8.05 mm) 0.307 in (7.80 mm)	6.05 in (154 mm) 5.95 in (151 mm)
Seating Area	0.239 in (6.07 mm) 0.235 in (5.97 mm)	0.317 in (8.05 mm) 0.307 in (7.80 mm)	11.05 in (154 mm) 10.95 in (151 mm)

The burner tubes are connected by flexible tubing to a cylinder containing butane gas.

(f) Gas Supply System: Consists of a pressure gage, flowmeter, fine control valve, and cylinder regulator providing an outlet pressure of 2.75 kPa (0.4 psi). The flowmeter shall be calibrated to supply the butane gas at a rate of 45 ± 2 ml/min (2.75 in^3/min) at 25° C (77° F). Under the above

conditions, the burner should produce a flame approximately 35 mm (1.4 in) in height.

(g) Gas Flow Control: It is essential that the gas flow rate to the burner complies with the flow rate specified. Some difficulties have been reported with the supply and measurement of the gas, particularly where the gas cylinder has to be stored in an environment cooler than the defined test conditions and/or some distance from the test specimen.

(h) Test Fixture: A test fixture fabricated in accordance with the requirements of Appendix B shall be used to deliver the test flame to the samples. See **Figure 1**.

§ 6 Atmospheres for Conditioning and Testing

(a) Test Enclosure: The test enclosure shall consist of either a room with a volume greater than 20 m^3 (706 ft^3) (which contains adequate air for testing), or a smaller enclosure with adequate airflow. Inlet and extraction systems shall provide an air flow rate of less than 0.2 m/s (.66 ft/s) in the proximity of the test specimen to provide adequate air without disturbing burning behavior.

(b) Water Soak Procedure: This procedure shall be performed prior to conducting the seating area test in § 8. The intent of the Water Soak Procedure is to remove any nondurable fire retardant finishes used in cover fabric samples that may be affected by exposure to water. A specimen of the seating area cover fabric is to be totally submerged in 1 gallon (3.2 liters) of tap water at room temperature for 24 hours.

i. The cover fabric specimen is to be placed in a container of sufficient size to completely submerge the cover fabric sample.

ii. After the immersion period, the sample is to be thoroughly air dried and conditioned per § 6 (c).

(c) Conditioning : The specimens to be tested shall be conditioned for at least 24 hours immediately before the tests in the following atmosphere:
- Temperature: 25 ± 2° C (77 ± 6° F)
- Relative Humidity: 40 - 55 %

(d) Testing Initiation: The test shall be performed in an atmosphere having a temperature between 10° - 30° C (50° - 86° F) and a relative humidity between 20% to 70%. If the test room does not meet the conditions of § 6(c), then testing shall be initiated within **10 minutes** after the specimens are removed from the conditioning room. Otherwise recondition

samples per Section § 6(c).

§ 7 Test Sample Preparation

1. Seating Area Samples: The sample materials should be removed from any packaging prior to conditioning. The test materials shall be the cover fabric and any barrier materials (if applicable) used in the finished product and standard polyurethane foam as the filling material. A specimen of the seating area mock-up is described below. A seating area sample consists of three specimens.

   Cover Fabric and Barrier Materials The cover fabric and barrier material size needed for each test is 40 ± 0.2 in (1016 ± 5 mm) x 27.5 ± 0.2 in (699 ± 5 mm). The cover fabric (and any barrier material) specimens shall have triangular cut-outs 22.5 in (572 mm) from one end on both sides. The size of these cut-outs shall be approximately 2.1 ± 0.2 in (55 ± 5 mm) x 5.25 ± 0.2 in (140 ±5 mm) high. See **Figure 2**.

   (a) Foam* Two pieces, one 18.0 ± 0.2 in x 11.75 ± 0.2 in x 3.0 ± 0.2 in (458 ± 5 mm x 305 ± 5 mm x 76 ± 5 mm) thick, and the other (18.0 ± .2 in x 3.25 ±.2 in x 3.5 ± .2 in (458 ± 5 mm x 83 ± 5 mm 76 ± 5 mm) thick are required for each test. The foam shall be polyether type non-FR polyurethane with a density of 1.5 to 1.8 lb/ft^3 and firmness of 25-30 IFD. See **Figure 3**.

   (b) Position seat mock-up in the upright position. Insert end of cover fabric (and any barrier material) such that the larger 22.5 in (572 mm) dimension of the material is placed on the vertical (back) portion of the seat mock-up.
   Next, insert the smaller 17.5 in (445 mm) dimension of the fabric (and any barrier material) from behind around the hinged bar. Both fabric (and any barrier) ends shall be pulled taught and laid across the horizontal seating surface.

   (c) Place larger foam against crevice and on top of horizontally placed fabric (and any barrier material), and the vertical back of the seat mock-up.

   (d) Wrap the larger dimension fabric (and any barrier material) around the foam to the back of the seat mock-up and fasten with metal clips.

   (e) Position smaller dimension of fabric (and any barrier material) and place smaller foam flush on front edge of seat frame with 75 mm

*As stated in **§ 4** the manufacturer has the option of constructing the seating area mock-up with the actual filling materials used in the finished product instead of the standard foam.

(17.7 in) dimension vertical. Wrap both fabrics around entire contour of seat foam. Insert larger foam between the wrapped fabric and the vertical back of the seat mock-up.

(f) Fasten all fabric edges (and any barrier material) to the top, bottom, and sides of each frame using metal clips. Ensure that the fabric is secured and under even tension. Pull fabric taught to eliminate air pockets between fabric and foam, but do not create a gap larger than 1/8" along the crevice. See **Figure 4**.

2. Dust Cover Material Samples: The dust cover materials should be removed from any packaging prior to conditioning. One specimen measuring no less than 12 ± 0.2 in x 12 ± 0.2 in (305 ± 5 mm x 305 ± 5 cm) should be used for each dust cover test. A test sample consists of three specimens. See **Figure 5**.
   (a) Secure dust cover sample with metal clips in the specimen holder to avoid wrinkles in the fabric. Pull sample taught around the edges to avoid any dipping or sagging. See **Figure 6**.

§ 8 Seating Area Test Procedure

1. Sample Positioning

   (a) Install the seat mock-up on the test fixture rails, align and adjust such that the horizontal burner tube rests evenly along the vertical and horizontal intersection of the crevice. See **Figure 7**.

2. Ignition Source Application:

   (a) Light the gas emerging from the longer 11 in (279 mm) burner tube, adjust the gas flow rate (specified in § 5) and allow the flame to stabilize for at least 2 minutes. (Ensure the flame height is approximately 35 mm (1.4 in)
   (b) Actuate the Furniture Flammability Fixture(FFF) to apply the lit burner tube axially along the crevice between the seat and back for **20 seconds**. The flame shall not be less than 2.1 in (50 mm) from the nearest side edge.
   (c) Repeat the Seating Area Test on the remaining two specimens.

3. Test Observations:

Record the following observations for 2 minutes after the test flame is removed:

(a) Record the ignition/non-ignition of the mock-up
(b) Record the afterflame, afterglow, and smolder time of the mock-up
(Note: If the flaming progresses to top or any other edge of the sample within 2 minutes, stop the test, and record "failure")
(c) Record Self Extinguishment (Yes/No)

§ 9 Dust Cover Test Procedure

1. Sample Positioning

(a) Place the specimen horizontally in its holder in the FFF and adjust the burner tube by placing the 35 mm flame gage on the tube, until the tip of the gages touches the center of the dust cover specimen. See **Figure 8**.

2. Ignition Source Application:

(a) Light the gas emerging from the shorter 152 mm (6.0 in) burner tube, adjust the gas flow rate (specified in § 5) and allow the flame to stabilize for at least 2 minutes. Ensure the flame height is approximately 35 mm (1.4 in).
(b) Actuate the FFF to apply the vertically lit burner flame at the bottom center of the specimen for **20 seconds**.

(c) Repeat dust cover test on the remaining two specimens.

3. Test Observations

Record the following observations for 2 minutes after the test flame is removed:

(a) Record the ignition/non-ignition of the dust cover
(b) Record the afterflame, afterglow, and smolder time of the dust cover specimen.
(Note: If the flaming progresses to any edge of the sample within 2 minutes, stop the test, and record "failure")
(c) Record the presence of any dripping of dust cover material
(d) Record Self Extinguishment (Yes/No)

APPENDIX A-Solving Gas Flow Problems

The rate of butane gas flow to the burner tube must conform to the specified flow rate. Any deviation from the specified rate will affect the heat energy imparted to the test specimen. Difficulties can occur with the supply and measurement of butane when either the cylinder is stored in an environment cooler than defined test conditions or when greater than 10 feet distance exists from the test fixture. In such cases, a 5 to 10 feet maximum length of tubing between the FFF and tank both inside the controlled environment (15 - 30° C (50 - 86° F) can help the butane gas to stay in equilibrium. Otherwise flowing butane through a length of metal tubing immersed in a water bath maintained at 25° C (77° F) is adequate so that the flow can correct for temperature variations.

Accurate setting and measurement of the butane flow rate is also essential. A digital reading flow meter needs to be checked when initially installed, and also at regular intervals during testing. One method capable of measuring the absolute butane flow at the burner tube is accomplished by . This can be done by connecting the burner tube with a short length of tubing (about 7 ID mm (.276 in)) to a soap bubble flow meter. The upward passage of a soap film meniscus in a glass tube of calibrated volume (e.g. a burette) over a know period of time gives an absolute measurement of the flow. Fine control valves which can each be preset to one of the desired butane flow rates, with simple switching means from one to the other are helpful.

APPENDIX B Furniture Flammability Fixture Construction Drawings

APPENDIX C Figures

Figure 1 - Test Fixture

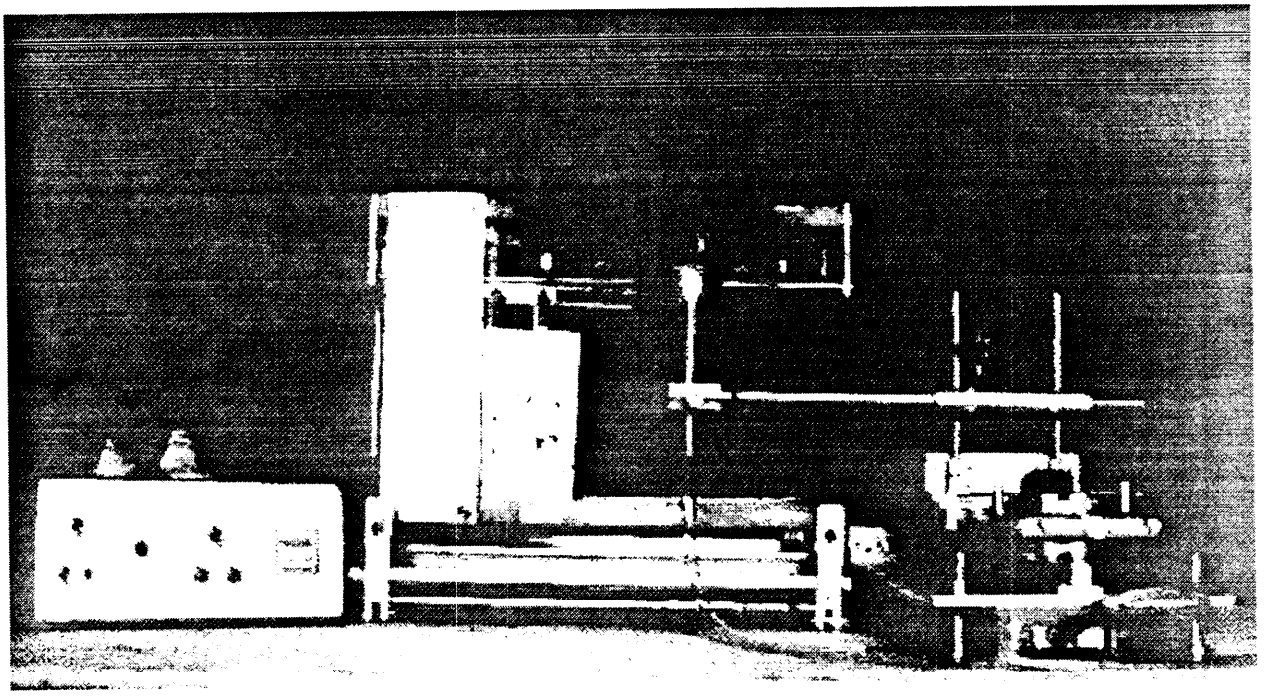


Figure 2 - Cover Fabric/Barrier Material Specimen

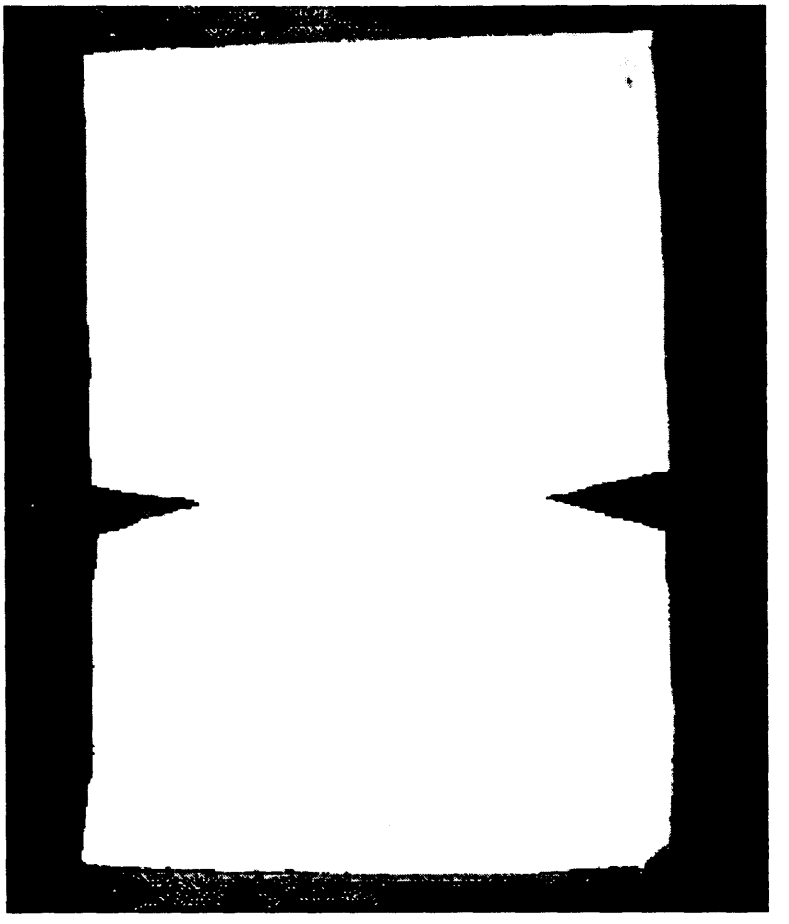


Figure 3 - Foam Specimens

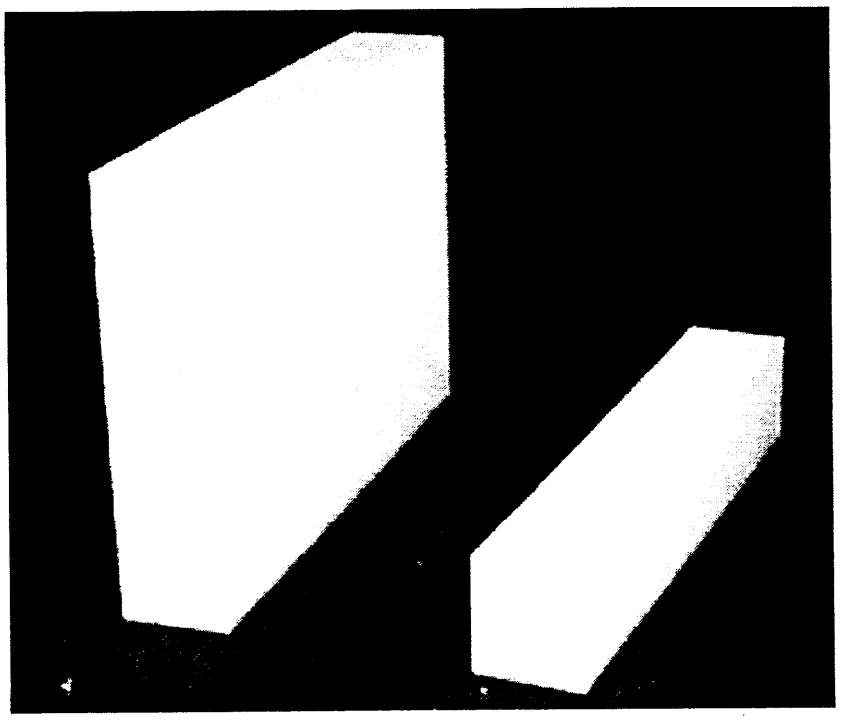


Figure - 4 Seating Area Mock-Up

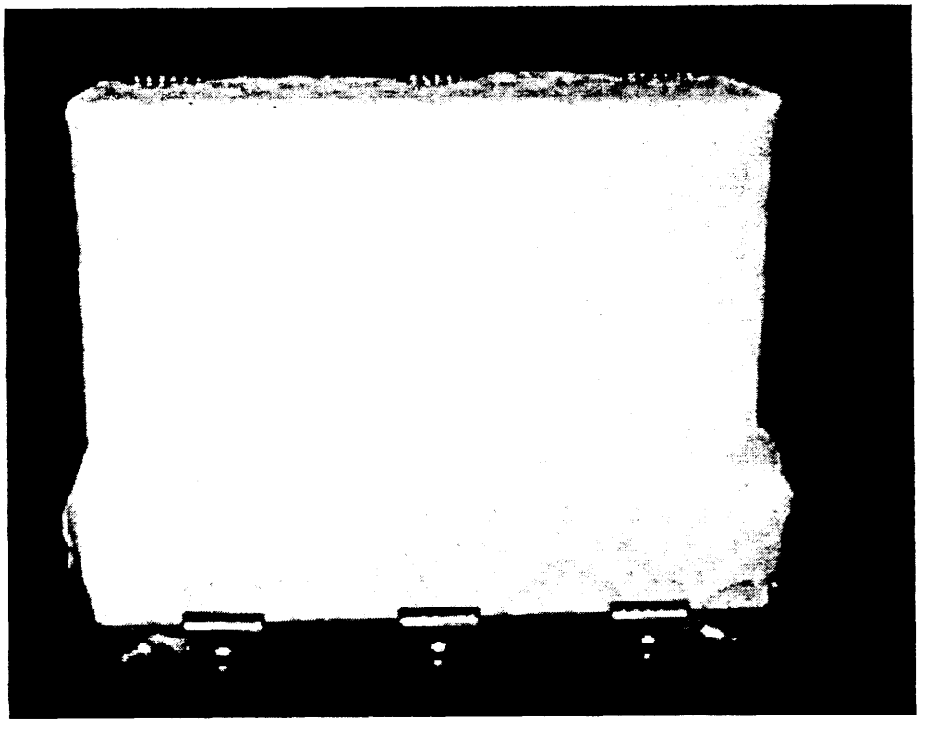


Figure - 5 Dust Cover Specimen

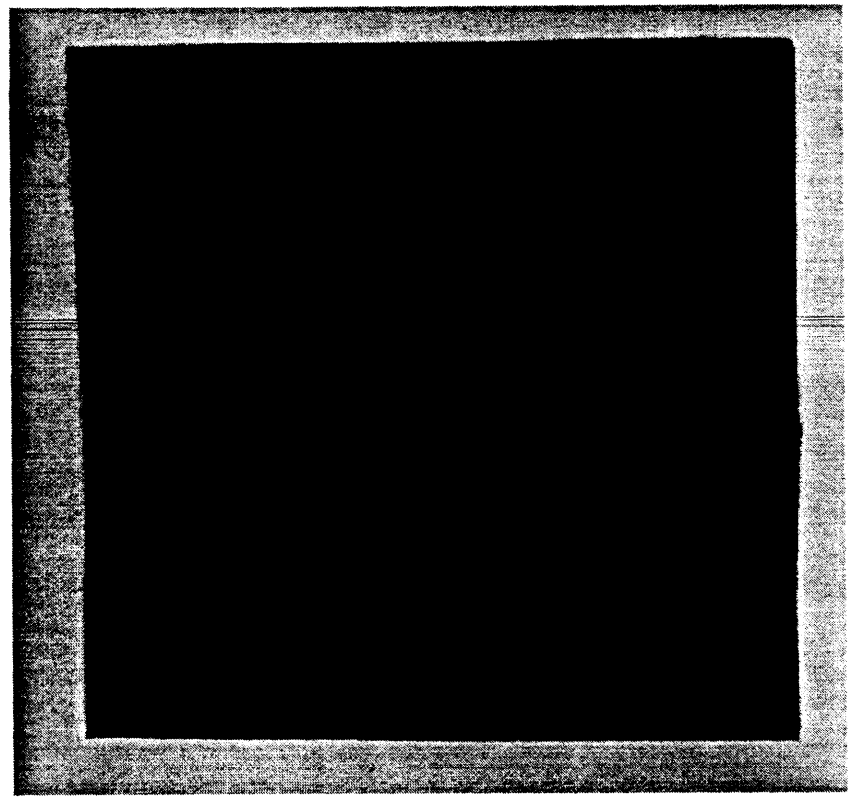


Figure 6 - Dust Cover Specimen in Holder

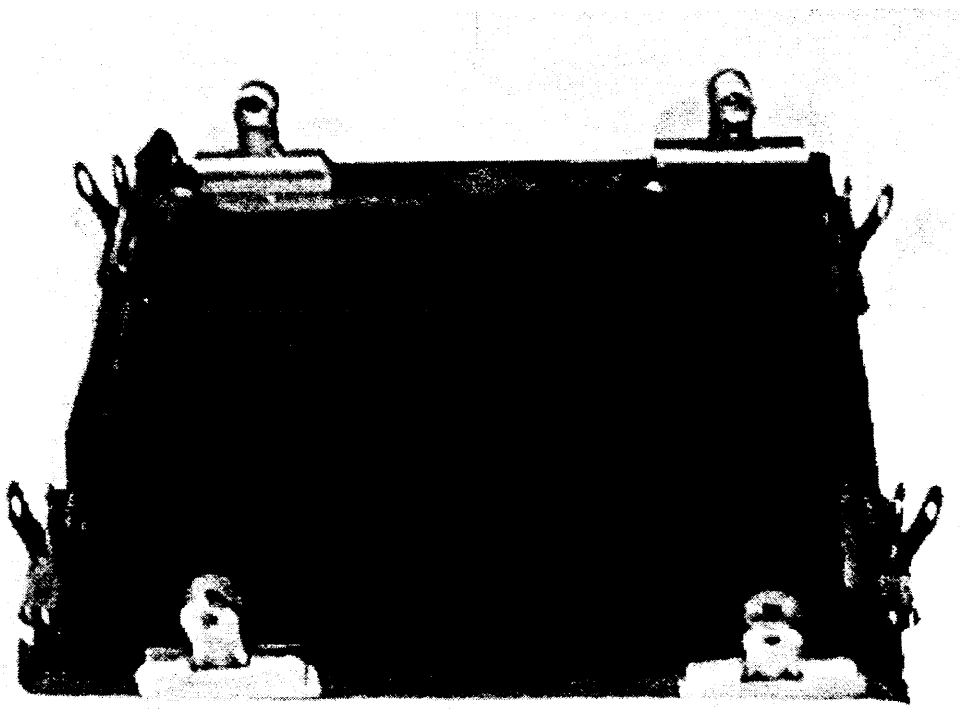


Figure 7 Seating Area Mock-Up Positioned in Test Fixture

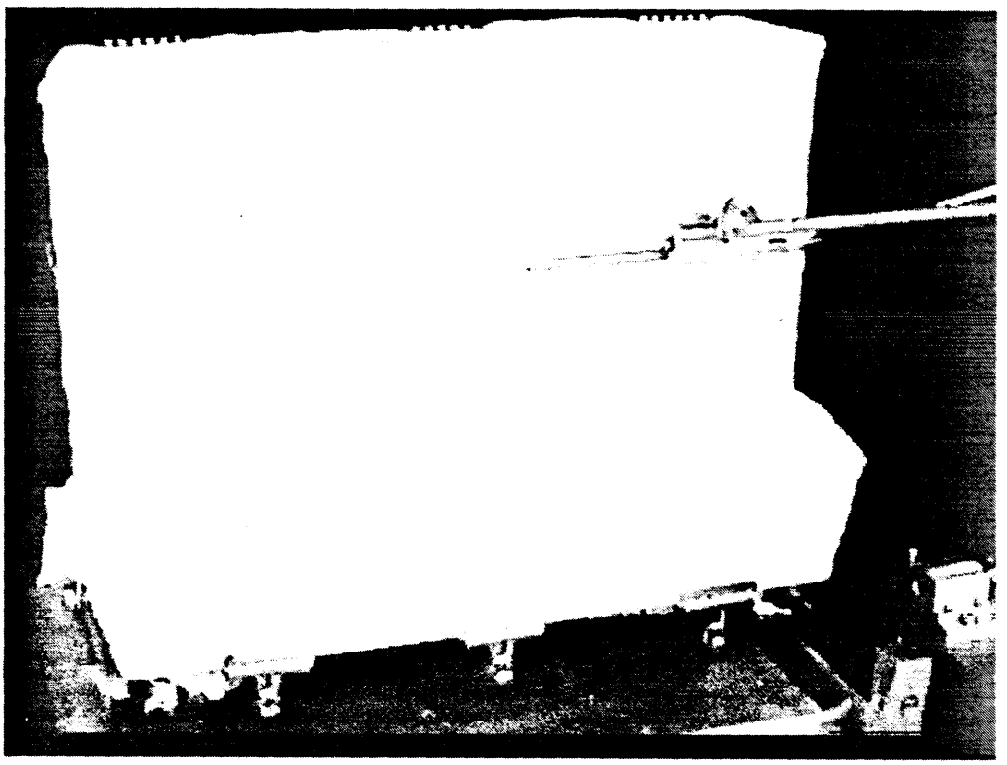
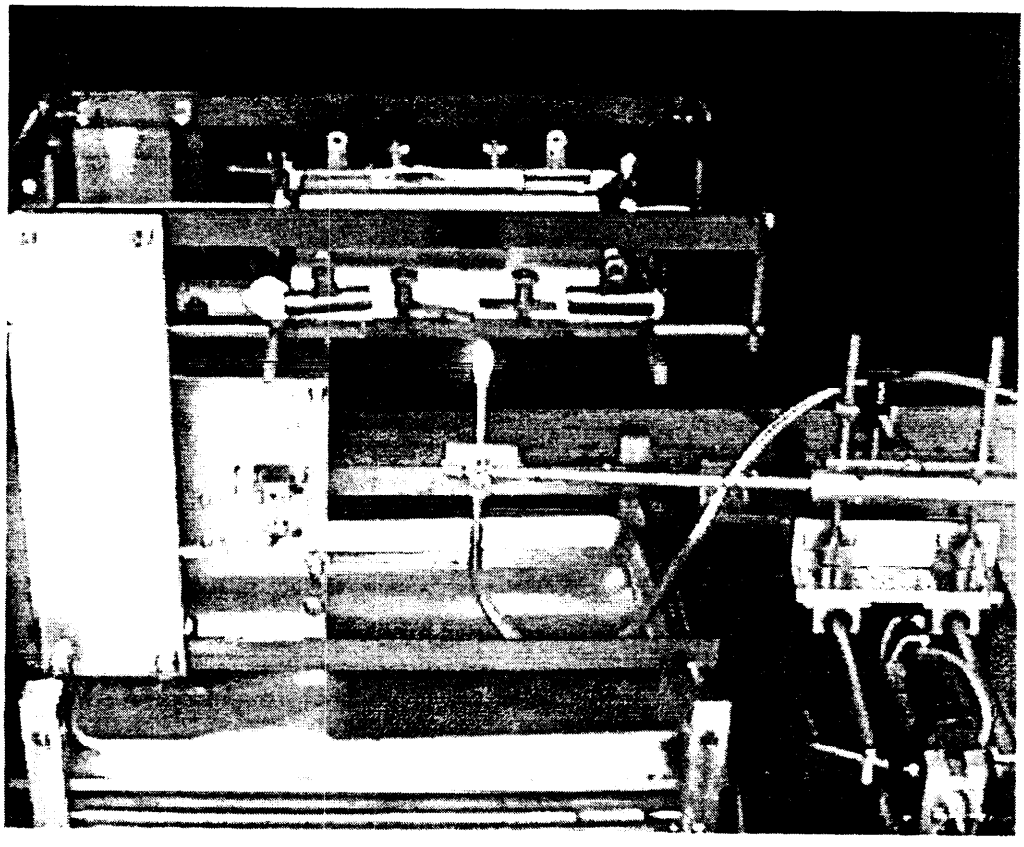


Figure 8 - Dust Cover Positioned in Test Fixture



Technical Basis Report for the Draft Performance Standard for the Flammability of Upholstered Furniture

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CONTENTS

List of Figures

1. Potential Open Flame Ignition Locations Identified in Field Study
2. Seating Area Mock-Up
3. Dust Cover Mock-Up
4. Furniture Flammability Fixture

List of Tables

1. Comparison of Heat Fluxes of Typical Furniture Ignition Sources
2. Average 35 mm Butane Flame Temperatures

Abstract

1. Introduction
2. Standard Approach
3. Scope of Standard
4. CPSC Flammability Apparatus and Test Method
5. Acceptance Criteria

TECHNICAL BASIS FOR THE DRAFT STANDARD FOR THE FLAMMABILITY OF UPHOLSTERED FURNITURE

ABSTRACT

On June 1994, the Commission granted a petition from the National Association of State Fire Marshals, and began the development of a performance standard for small open flame ignition of upholstered furniture. This report discusses the rationale for the technical approach of the performance test method, the experimental set-up for the test method, and other requirements of the draft standard. Mock-ups of two test locations of upholstered furniture, the seating area and dust cover are subjected to a standard test flame for a set duration and orientation. The acceptance criteria involves measurements of continued combustion and flame progression on the specimen over time after removal of the ignition source.

The performance test provisions in the draft standard were derived from (1) a comprehensive testing program including full scale and mock-up specimens representing a range of flammability performance, (2) a review of actual small open flame upholstered furniture fire incidents (3) quantification of flame characteristics of known ignition sources and, (4) test fixture testing to assess the practicability of the standard. These provisions address the risk of deaths and injuries resulting from accidental small open-flame upholstered furniture fires. This report summarizes the technical basis for the standard.

1.0 INTRODUCTION

This report by the Consumer Product Safety Commission (CPSC) staff describes the technical basis of a draft upholstered furniture flammability standard. The draft standard is intended to address the risks presented by the small open flame ignition of upholstered furniture.

The CPSC draft standard was developed using the British Standard, "BS 5852, Fire Tests for Upholstered Furniture, Part 2", as a basis with additional input from laboratory studies, field investigations, meetings, and comments from interested parties. Presentations were made to various industrial groups representing the fiber, textile, and upholstered furniture industries. CPSC personnel have also visited textile and furniture manufacturing facilities. All suggestions have been considered in the development of the apparatus, test method, acceptance criteria, and other provisions in the draft standard.

2.0 SCOPE OF COVERAGE

The scope of the draft standard is limited to residential upholstered furniture items that present an unreasonable risk of death or injury from ignition by small open flames that may come in contact with such items in an inadvertent manner such as from fire play by young children and accidental dropping of small open flame sources by older persons. The applicable products are identified as:

•Chairs and sofas or other furniture intended for seating with upholstered seats and backs or sides manufactured or imported after the effective date of the standard

•Items with dust covers - any fabric or other nonstructural material attached to keep dirt/dust from accumulating in the item's interior

• Non-rigid seating items which may be formed with seating and back support, such as bean bag chairs

•Office furniture intended for sale or use by consumers

The following products are not within the scope of the draft standard:

•Items without both upholstered horizontal seating surfaces and upholstered sides or backs

•Items without both cover upholstery and filling material

•Non-residential or contract furniture

•Futons, futon covers and slipcovers

•Mattresses and bedding

•Outdoor furniture

3.0 STANDARD APPROACH

3.1 Open Flame Ignition Prevention

The CPSC staff's draft standard is based on preventing sustained combustion of upholstered furniture resulting from small open flame exposure. National fire data[1] for 1994 show that open flame ignition of upholstered furniture results in 3,800 fires, 540 injuries, and 160 deaths when furniture is the first item ignited. Of these, small open flame sources were responsible for 460 injuries and 100 deaths. The draft standard is intended to lessen the likelihood of those fires in which upholstered furniture is the first item ignited. If the sustained combustion of upholstered furniture is prevented, flames will be unlikely to produce sufficient heat to ignite nearby combustibles or generate toxic smoke.

Analysis of the national fire data[2] shows that a majority of the fire incidents in the scope of the project involved childplay with matches and cigarette lighters as the primary cause of small open flame upholstered furniture fires. An effective approach to address this fire scenario is to prevent sustained combustion of upholstered furniture by requiring that the upholstery fabrics not support combustion after exposure to a small open flame source. This should reduce the likelihood of ignition and the transition from ignition to the initiation of sustained combustion of the upholstered item. This approach would decrease the number of fires caused by childplay or other activities where matches or cigarette lighters are the ignition source.

[1] "1994 Residential Fire Loss Estimates", Directorate for Epidemiology and Health Sciences
[2] "Small Open Flame Ignitions of Upholstered Furniture", Final Report, Directorate for Epidemiology and Health Sciences, September 1997

3.2 Alternate Approach

An alternate approach considered by CPSC staff to address upholstered furniture flammability is to apply heat release rate requirements to furniture. The heat release rate is the rate at which energy is liberated during combustion. The heat release rate approach is predicated on the theory that by limiting the heat release from combustibles, one can limit rapid fire growth and provide more escape time for occupants prior to reaching **untenable** conditions. By limiting the heat release rate of materials, a fire involving these materials may develop more slowly, allowing more escape time for occupants, and possibly preventing **flashover conditions**. On this basis, the Model Building Codes have adopted heat release requirements for building materials and furnishings for high-risk occupancies.

3.3 Basis for CPSC Approach

CPSC staff feels that controlling the heat release rate is not the most effective method of reducing the risk of death and injury from ignition of furniture in a residential fire scenario. In fires, many deaths or serious injuries can result from incapacitation due to toxic combustion products inhalation. Controlling heat release rates does not prevent the generation of toxic combustion products that can present serious life safety concerns in upholstered furniture fires. Heat release rate requirements are most relevant to high risk occupancies where fire protection systems (i.e. fire sprinklers, fire alarms) are installed to provide additional safety in the form of slow fire growth. For residential applications, preventing sustained combustion of upholstered furniture is more likely to prevent deaths and injuries and would obviate the need for addressing smoke toxicity, rapid heat release, or other factors. Therefore, CPSC staff believes adoption of heat release requirements would not reduce fire fatalities as effectively as a standard that lessens the likelihood of ignition of upholstered furniture in residential fire scenarios.

Existing flammability standards that apply a similar approach have been successful. Examples of such standards include the voluntary Upholstered Furniture Action Council Program, Standard for the Flammability of Mattresses and Mattress Pads (FF 4-72), Standard for the Flammability of Children's Sleepwear (FF 5-74), and BS 5852 Fire Tests for Upholstered Furniture.

Untenable conditions- when the temperatures and smoke concentrations reach levels that are unacceptable for life safety

Flashover - stage of a fire when the enclosure becomes fully involved and all combustibles in the enclosure ignite.

4.0 TEST METHOD AND APPARATUS

The parameters of the test method were chosen to combine simulation of real-life upholstered furniture fires using a reasonable, repeatable, and concise laboratory test method. The CPSC staff's test method is based on the match flame test of the BS 5852 Fire Tests for Furniture Standard, and input from field data of small open flame upholstered furniture fires. Two significant differences in the CPSC draft sandard and the BS 5852 Standard are the addition of the dust cover test and use of a mechanized apparatus to provide consistent flame delivery to the test specimens. The Field data[2] show that besides the seating area, the dust cover location was the most common location involved in upholstered furniture fires.

In order to reliably characterize **full scale** flammability behavior of furniture, the test method applies a furniture mock-up **bench scale** approach, where the upholstery fabric and any fire resistant barrier materials to be used in the finished product are tested in combination with a standard foam filling material. The fabric and barrier material over standard foam approach was chosen due to testing[3] showing that commonly used filling materials had virtually no effect on the ability of furniture to limit combustion resulting from small open flame exposure. The study also concluded that cover fabrics are the primary determinant of ignition performance. Therefore it would obviate the need to evaluate the contribution of filling materials in the test approach.

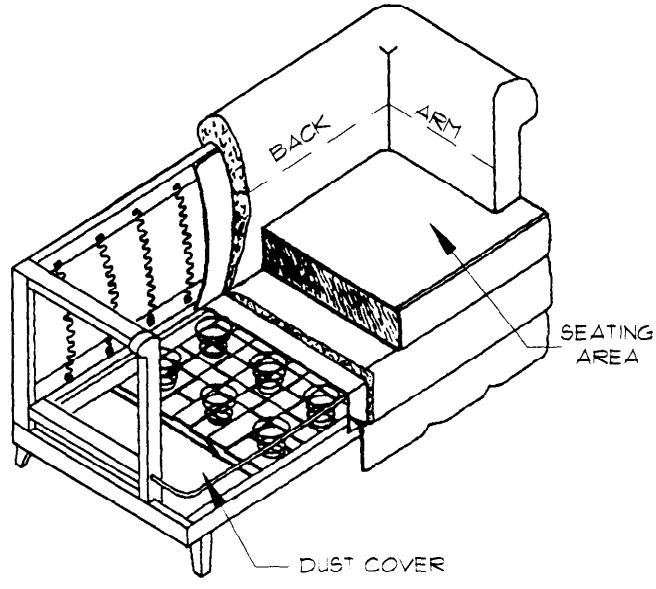
Staff recognizes that a full scale test may be more representative of the actual product performance. However, the mock-up bench scale approach reasonably represents ignition performance of finished products since the cover fabric was concluded to be the primary determinant of ignition. In addition, the mock-up bench scale approach will reduce the economic impact of a flammability standard on industry. The work leading to the major parameter choices is described in this report.

4.1 Test Locations

The two test locations were chosen from information obtained from actual fire incidents involving upholstered furniture. Most of the small open flame upholstered furniture fires resulted from childplay with matches or cigarette lighters. In-depth investigations[2] revealed the most prominent locations where ignitions of upholstered furniture were most likely to occur: the seating area and to a lesser extent, dust cover. These locations are shown in Figure 1. Small scale mock-ups of the two identified ignition locations are made for testing purposes.

bench scale- a test method in which the smaller scale mock-up of the end-product is evaluated.
full scale- a test method in which the end-product or full size mock-up of the product is evaluated.
3 - Upholstered Furniture Flammability Testing: Full Scale Open Flame Data Analysis, February 26, 1996

Figure 1 : Potential Open Flame Ignition Locations Identified in Field Study



4.2 Specimens

4.2.1 Seating Area

Data from fire incidents[2] support that the seating area is the portion of upholstered furniture where ignition is most likely to occur. The seating area test evaluates fire performance in a vertical/planar intersection test geometry which represents the seat/back and seat/arm junction of finished upholstered items. The test flame is delivered to the crevice via the CPSC Furniture Flammability Fixture. Consideration was given to selecting the flat seat cushion as the test location, however, a flat cushion would not account for the upward flame spread that may occur if the back of the chair is ignited. The crevice location allows for the evaluation of both the seat/back and seat/arm locations shown in Figure 1.

The seating area mock-up, shown in Figure 2, consists of two metal frames hinged and locked at right angles, upholstery/filling materials, and any barrier or lining materials intended to impart fire resistance used in the actual construction of the chair. The seating area specimen size and configuration were chosen to represent a small-scale mock-up of the geometry typical of an upholstered furniture seating area. The seating area mock-up is similar to the test frame used in the BS 5852 Standard. The CPSC test method varies slightly from the BS 5852 mock-up in that the way the seating area mock-up is assembled such that the crevice is more

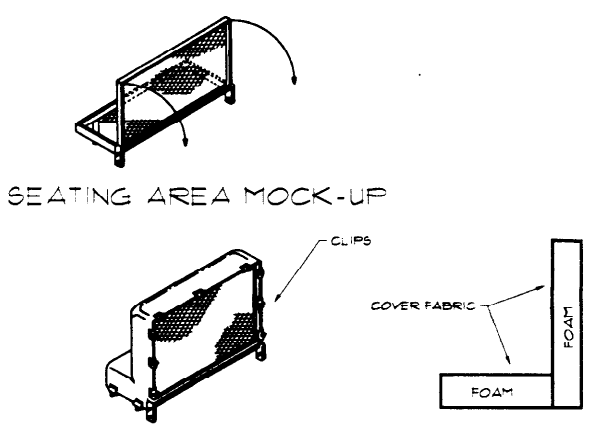
reflective of actual furniture. Staff recognizes that the BS 5852 seat mock-up approach is a simplified geometry of the finished item seating area and this approach seems reasonable since there is too much variation in upholstered seating constructions to address every possible geometry.

Prior to testing, the top surface of seating area fabric samples are subjected to a soaking procedure to ensure any fire retardant treatments are not compromised when exposed to water or normal wear which may occur during use of the product.

The General Requirements of the draft standard limit the allowable combustion time and flame spread on the sample. These requirements are intended to lessen the likelihood of small open flame ignited fires originating in the seating area of upholstered furniture. Details on the selection of requirements and acceptance criteria are discussed later in this report.

Laboratory testing[4] has demonstrated that the technology is available to meet the requirements of the Seating Area Test. These include the use of naturally flame resistant fabrics, chemical flame retardant fabrics treatments or backcoating, and use of fire resistant barriers. Either one or combination of these technologies can be used to meet the requirement of the draft standard.

Figure 2: Seating Area Mock-Up



4 - Memorandum from Linda Fansler to Dale Ray, "Summary of Upholstered Furniture Tests", October 10, 1997

4.2.2 Dust Cover Test

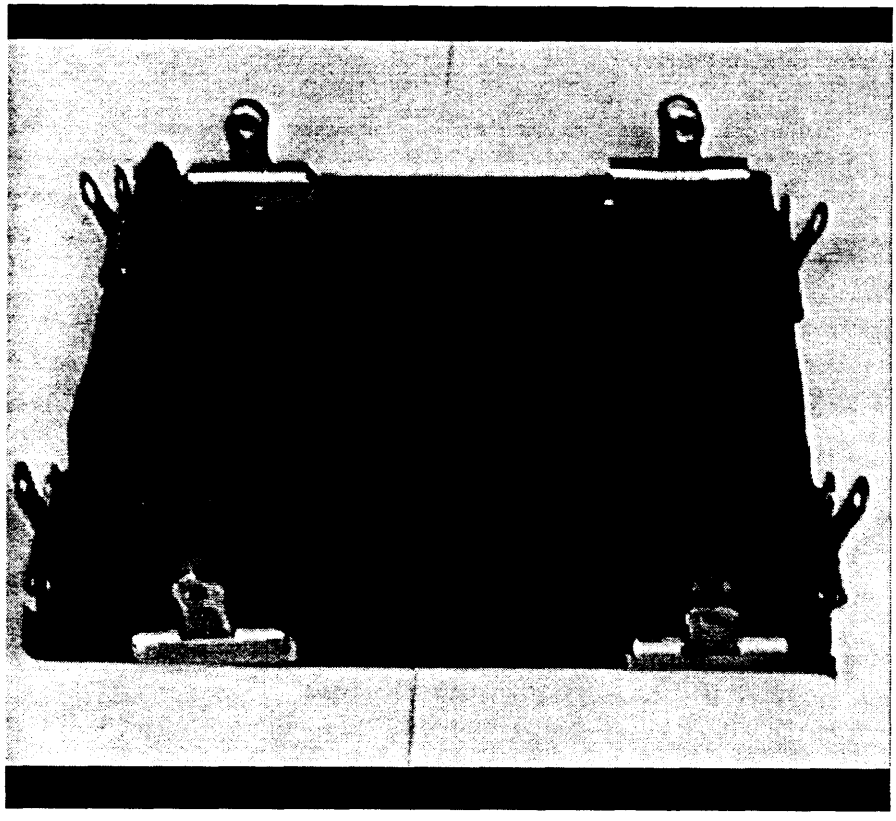
Fires involving ignition of the dust cover have also been identified in the fire data. The dust cover is the outermost material underneath the chair. The dust cover test evaluates fire performance in a horizontal test geometry.

The dust cover mock-up, shown in Figure 3, also consists of a square metal frame in which a dust cover specimen is placed. The dust cover specimen is tested by itself since there is substantial variation in furniture constructions; some products may have no combustible material above the dust cover. The primary intent of the Dust Cover Test is to ensure that materials used as dust cover fabrics or directly above dust covers do not support combustion when exposed to a small open flame source.

The General Requirements in the draft standard limit the allowable combustion time and flame spread of the dust cover mock-up samples. Some dust cover materials tend to melt away or split and expose interior materials when subjected to a small open flame. Interior materials within 1 inch above passing dust cover materials that are exposed if the dust cover melts away or splits, must also pass the Dust Cover Test. Staff believes that exposed interior materials within 1 inch above the dust cover may ignite from exposure to a small open flame source and involve the entire upholstered item. Therefore, interior materials should be resistant to small open flame ignition when used with dust covers that tend to melt away or split when exposed to a small open flame. These requirements are intended to lessen the likelihood of fires originating in the dust cover location from spreading and involving the entire finished item. Details on the selection of requirements and acceptance criteria are discussed later in this report.

Laboratory testing[4] has demonstrated that the technology is available to meet the requirements of the Dust Cover Test. These include the use of naturally flame resistant fabrics, chemical flame retardant fabrics treatments, and use of fire resistant barriers. Either one or combination of these technologies can be used to meet the draft standard.

Figure 3: Dust Cover Mock-up



4.3 Ignition Source

The ignition source is a butane diffusion flame intended to represent a small open flame source such as a match, cigarette lighter, or candle flame that may be present in residences. These types of ignition sources were identified in the Field Study[2] as the primary small open flame ignition sources.

The burner tube consists of a stainless steel tube with an outside diameter of approximately 8.0 mm and a wall thickness of 1.0 mm. The gas supply system consists of a pressure gage, flowmeter, fine control valve, and cylinder regulator providing an outlet pressure of 27.5 mbar (0.4 psi). The flow meter supplies butane gas at a constant rate of 45 ml/min at 25° C. Under the specified conditions, the flame height is approximately 35 mm.

Laboratory testing[5] has shown that the heat flux of the butane test flame is approximately 164 kW/ m^2. Comparisons between this test flame and other small open flame ignitions sources were made and are outlined in the Table 1.

---

[5] Memorandum to Dale Ray from John Murphy and Larry Mulligan "Heat Flux and Temperature Measurements of 35 mm Butane Flame, Cigarette Lighters, Candles, and Matches", June 13, 1997.

As can be seen from the table below, the burner assembly produces a slightly higher amount of energy than can be expected from typical small open flame ignition sources. When characterizing the heat flux at different locations of the test flame, a second smaller diameter heat flux gage was used in addition to the heat flux gage used with the typical ignition sources. The smaller diameter gage measured values higher than the larger diameter gage. Therefore, in order to compare the heat flux produced by the test flame to typical ignition sources, only data from the larger diameter heat flux gage were used.

The heat output provides approximately 6 percent higher heat flux than cigarette lighters. Staff feels that the test flame is reasonable since it is similar to other small open flame ignition sources and variable times from sources such as candles and cigarette lighters can account for any differences.

Table 1: Comparison of Heat Fluxes of Typical Furniture Ignition Sources

OPEN FLAME SOURCE	HEAT FLUX $(kW)/m^2$	MAX. TEMP (C)
Kitchen Match	135	554
Cigarette Lighter	155	651
Tapered Candle	143	570
Votive Candle	124	560
Methanamine Pill	134	560
Test Flame	164	751

The draft standard requires the tip of the flame to be impinged on the dust cover specimen since the temperatures near the tip of the butane test flame are greatest in this location as found from laboratory testing.[5]

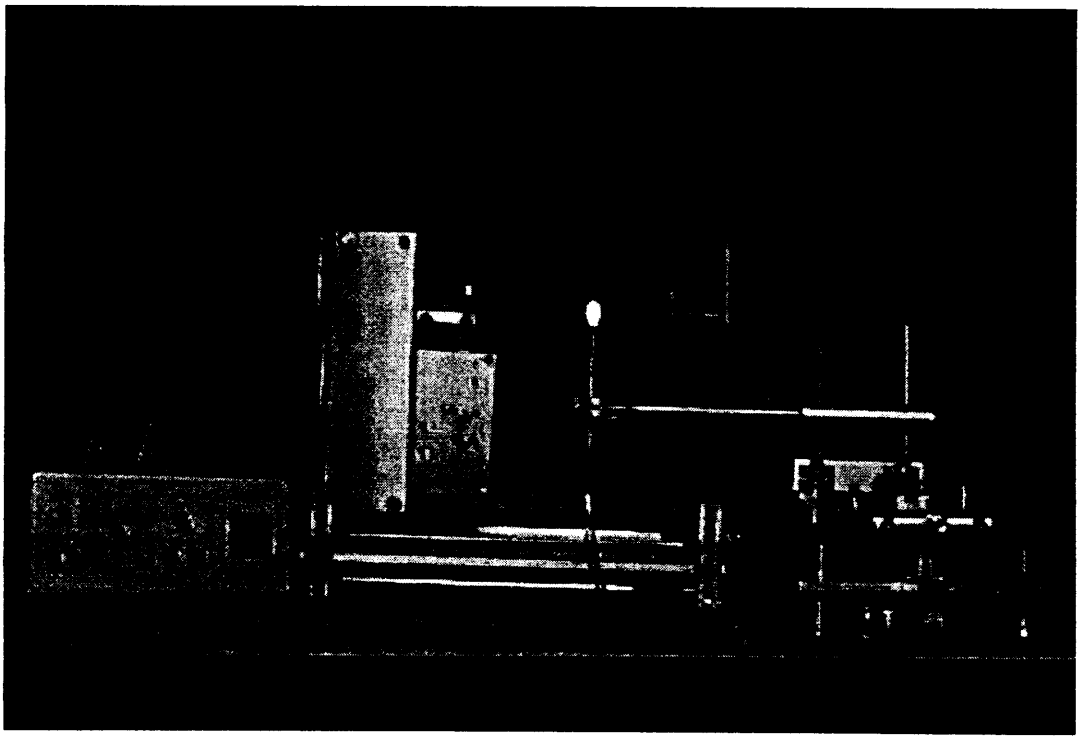
Table 2: Average 35 mm Butane Flame Temperatures

HEIGHT ABOVE BURNER TUBE	LEFT THERMOCOUPLE (C)	CENTER THERMOCOUPLE (C)	RIGHT THERMOCOUPLE (C)
10	587 ± 5	492 ± 5	540 ± 6
15	610 ± 40	550 ± 20	570 ± 30
20	590 ± 20	520 ± 20	540± 30
25	650 ± 60	550 ± 60	570 ± 70
30	660 ± 50	720 ± 10	720 ± 20
35	650 ± 50	710 ± 40	660 ± 80
40	670 ± 30	690 ± 10	630 ± 40
45	580 ± 60	640 ± 60	580± 70
50	560 ± 40	580 ± 60	500 ± 100

4.4 Flammability Test Fixture

A Flammability Test Fixture, shown in Figure 4, was developed to provide an automated test apparatus capable of delivering the test flame to the specimen in a repeatable and reproducible manner. The major components of the test fixture are the actuator, the mock-up assembly, and the control box. The actuator is a mechanical assembly that uses an electric linear drive to deliver the flame to the test specimen. The mock-up assembly consists of the framework that holds the two mock-ups in position. Finally, the control system contains functions to start the test and adjust the flame exposure time. Engineering Shop drawings of the Flammability Test Fixture are provided in the Appendix of the draft standard. For more detailed description of the Flammability Test Fixture refer to the "Operation Guide."

Figure 4: Furniture Flammability Fixture



[6] Furniture Flammability Operations Manual, June 1997

4.5 Flame Exposure Time

The flame exposure time is a critical element of the test procedure that impacts the performance of the specimen. CPSC staff has chosen a **20 second** flame exposure time for the draft standard. The 20 second flame exposure time is based on (1) laboratory experiments which support that a 20 second exposure time differentiates between fabrics which readily ignite and sustain combustion, from fabrics which are more ignition resistant and (2) child fire play information which suggests that the focused, intentional behavior is needed to maintain a small open flame source in one location for more than 20 seconds.

CPSC laboratory testing[4] was conducted to characterize flammability performance of various upholstery fabrics using the seating area mock-up when tested[4] with a variety of flame impingement times ranging from 5 to 25 seconds. These tests show that most conventional upholstery fabrics readily ignited when exposed to the test flame for up to 20 seconds and continued to burn until the specimens were extinguished by test personnel. Therefore, the 20 second flame exposure is a good line of demarcation between fabrics which readily ignite and sustain combustion, from those which are more resistant to ignition or self extinguish when exposed to small open flame sources.

The 20 second flame exposure time is also used in the BS 5852 Standard, Part 2 Match Flame Test. The 20 second flame exposure time in BS 5852 is based on experimental work[7] conducted in the U.K. to characterize burn times of matches. In the U.K. study, various type of matches were tested with 15 composites in 6 different orientations using the BS 5852 type rig. The study concluded that 20 seconds was within the upper 85% of match burn times.

Laboratory experiments[8] were conducted by CPSC staff to characterize the burn times of typical small open flame ignition sources including matches and cigarette lighters. The results of the CPSC experiments indicate that there is extreme variability in match burn times depending on factors such as the type, orientation, and moisture content of matches. The average burn times ranged from 10 to 57 seconds. Cigarette lighters exhibited burn times which ranged from 200 to 960 seconds. Based on the results of CPSC's evaluation of small open flame ignition sources, flame exposure time in the draft standard cannot be based on experimental measure of flame duration alone, due to the wide variability of results.

The draft standard is intended to address flame exposure from child play and inadvertent contact, but not intentional acts to initiate a fire. The incident data[2] indicate the most frequent probable cause of upholstered furniture small open flame ignited fires is fire play by young children. Fire play is defined as a playful activity with no significant motivation toward fire setting behavior[9]. There are some motor and cognitive challenges for a young child to maintain a flame at a specific position

unintentionally for 20 seconds. Therefore, the child who engages in this focused behavior is persistent beyond that which is typical of mere fire play, and represents an intentional act.

Although typical small open flame ignition sources may be capable of burning longer than 20 seconds, the behavior expected in child play and other inadvertent or accidental scenarios suggests that a 20 second flame exposure time would be reasonable for the draft standard. Also, testing of upholstery fabrics indicates that 20 seconds represents a demarcation point in fabric performance, and further supports selecting the 20 second exposure time.

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[7] "Standard Flaming Ignition Sources for Upholstered Composites, Furniture and Bed Assembly Tests", K.T. Paul, Journal of Fire Sciences.
[8] Memorandum to Dale Ray from John Murphy and R. Khanna "Match Burn Times, November 9, 1995.
[9] "Abilities of Young Children to Operate Butane Cigarette Lights", Comsis Corporation, March, 1988.

5.0 ACCEPTANCE CRITERIA

The performance requirements set forth in the draft standard are intended to reduce the societal impact of small open flame upholstered furniture fires. The General Requirements in the draft standard calls for the cessation of combustion (flaming, smoldering, etc.) and limit the flame progression on the test specimen within 2 minutes of flame removal following a 20 second flame exposure. Staff feels that 2 minutes allowable combustion time is appropriate to assess the propensity of furniture materials to self extinguish once combustion of the samples has begun. Any form of combustion that persists beyond 2 minutes can result in the transition to full involvement of the upholstered item and result in serious life safety hazard by involving other nearby combustible items. The goal of this approach is to prevent sustained combustion of upholstered furniture.

The staff decisions for the requirements of the draft standard are based on a review of existing furniture flammability standards, an analysis of current methods in furniture flammability technology, a review of field incidents, and a comprehensive testing program. After a review of the existing furniture flammability standards, staff concluded that the performance requirements set forth in BS 5852 which essentially require the cessation of any form of combustion on samples within 2 minutes after flame removal, would be most effective in reducing the fire hazard associated with upholstered furniture.

To assist in the development of the draft standard, staff assessed whether current technology available to the industry complies with the draft standard by conducting a series of laboratory studies described in this report and through discussions with textile product finishers. Staff concludes that current technology is available to the industry to meet the requirements of a small open flame standard. These include the use of naturally flame retardant fibers, flame retardant chemical treatments and backcoatings, and the use of some types fire blockers between the fabric and filling materials. Either one or a combination of current techniques can be used to meet the performance requirements set forth in the draft standard.

Staff conducted a series of laboratory tests[4] to confirm that the requirements set forth in the draft standard provide an improved level of safety from small open flame ignition of furniture. Mock-ups representing upholstery fabrics used in the current residential furniture market afforded little or no resistance to small open flame ignition. Once ignited, they continued to burn readily until they were completely consumed. Mock-ups containing one of the available flame resistant technologies demonstrated improved performance. For these samples, most ignited but self extinguished after the test flame was removed. The flame progression in the test specimens was a concern to staff as rapid flame progression in a full scale upholstered item may result in full involvement of the furniture item or ignition of nearby combustibles. To address this hazard, the draft standard requires that the flame progression must not reach the edge of the specimens. Staff concluded that

the best performance measure for the hazard criteria was to limit the allowable combustion time and flame progression of the test specimen. The furniture industry could readily incorporate one or more of the available flame retardant technologies to meet the draft standard requirements.

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

MEMORANDUM

DATE: June 17, 1997

TO: Dale Ray
Project Manager
Directorate for Economic Analysis

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

FROM: John Murphy, JRM
Mechanical Engineer,
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for Larry Mulligan, AGU
General Engineer,
Directorate for Laboratory Sciences

SUBJECT: Comparative heat flux and temperature measurements for various open flame sources.

INTRODUCTION/BACKGROUND

The ignition source for the CPSC draft standard is a butane diffusion flame with a measured height of 35 mm (1.4 in). To characterize the 35mm butane flame, heat energy output and temperature profiles were measured using heat flux transducers and thermocouples. Comparisons were also made between the heat energy output and the temperature of the butane flame and other common small open flame ignition sources such as cigarette lighters, candles, matches, and methenamine tablets (A standard flame source for carpet testing). This memo reports the results of this study.

Method

Heat Flux

Two different models of Schmidt-Boelter thermopile heat flux transducers were used to take the heat flux measurements. One was a model 64-10sb-36-20K with a smooth body and flange. The diameter of the copper body on this transducer is about 25 mm (1 in.) The other one was a model 8-1.5-10SB-4-0-36-20680K. The body of this transducer is 13 mm(0.5 in) in diameter. The lower end of the transducer is reduced in diameter to 3 mm (0.125 in) forming a probe that is 38 mm (1.5 in) long. Both transducers are water cooled with a K-type thermocouple to monitor the body temperature of the transducer. The transducers have a rated capacity of 113.6 kilowatts/meter^2 (10 Btu/ft^{2}sec). Readings can be taken from zero to 150% of the rated capacity.

The heat flux transducers were mounted so that the measurement surface of the transducer was horizontal and positioned over the flame. Water was circulated through the transducers during testing. The temperature of the water was controlled so that the body temperature of the transducer was maintained at 50 ± 2°C. This was done to avoid condensation on the sensing surface during measurements.

Heat flux measurements were performed on a tapered candle, a votive candle, a cigarette lighter, a methenamine tablet, and kitchen matches. These measurements were taken with the transducer located at the tip of the flame. Other measurements were made at 4 mm increments along the central axis of the burner tube.

The transducers were cleaned with a moistened tissue in-between readings to prevent a soot build-up caused by being placed over the flame. The measurements were taken with the transducer suspended from a ring stand without any surrounding structure.

Flame Temperature

The temperature of the butane flame was measured at various locations in the flame. This required precise positioning of the thermocouple. To achieve this, three K-type thermocouple (enclosed for rigidity in ceramic tubes) were fitted into a machined holding block. This block was then securely mounted, via a matched machined spline and groove onto a Mitutoyo Digimatic Height Gage. The thermocouple were arranged so that the two outermost were aligned with the outside edge of the burner tube, the third was located above the center of the burner tube. Measurements were taken every five millimeters and repeated several times on different days to assess the distribution of temperatures within the flame.

Results/Discussion

Heat flux data for several common flame sources are listed in Table I. Measurements were taken using the small diameter heat flux transducer positioned at the tip of the flame. The 35 mm butane flame heat flux is closest to that for the cigarette lighter but is somewhat greater than those for the other flame sources. All flame sources are reasonably similar.

The heat flux profile of the 35 mm butane flame is presented in Table II. The geometry of the heat flux transducer had a large influence on the measured values. The large diameter transducer suspended in a ring stand measured a heat flux that was one half the heat flux measured by the small diameter transducer. It is known that the measurement procedures such as the orientation of the transducers, the size of the sensing surface, the mounting used to support the transducers, and especially the geometry of the test setup significantly affects the final readings, To determine the precise reason for this difference would require additional work. The data show that the presence of the heat transducer in the flame disturbs the properties of the flame. The measured heat flux is different when the transducer impinges into the flame as opposed to when the transducer is near the tip of the flame. As a result, the heat flux of the disturbed flame can be very different from

the heat flux of an undisturbed flame or of the flame during testing. The highest heat fluxes occurred within four millimeters on either side of the flame tip.

The average flame temperatures and the standard deviations are shown in Table III. The highest temperatures of the butane flame were measured at 30 mm above the tube. The temperatures were only slightly lower at 35 or 40 mm above the burner tube. Maximum temperatures at heights below 30 mm are at the outer positions, whereas at greater heights, the maximum temperature is along the vertical center line of the flame. There was clearly some flame movement as shown by the changes in temperature observed.

The tube was not mounted in the interlaboratory test fixture, which might shield the flame from some air currents.

Temperature measurements of a butane cigarette lighter are shown in Table IV. As with the heat flux measurements the cigarette lighter temperatures were somewhat lower than for the butane flame. The flame height is also somewhat lower than for the butane flame. The flame height is also somewhat lower than the 35 mm butane flame as judged by the temperature readings.

Table 1 measurements of some common household ignition sources

Item	Heat Flux as measured by small diameter transducer in ring stand kilowatt/meter^2
8" Tapered Candle	143 ± 1
Votive Candle	124 ± 6
Cigarette Lighter	155 ± 2
Methenamine Tablet	134 ± 9
Match	135 ± 19
35 mm Butane Flame	164 ± 3

Table II Measurements of Heat Flux at Different Heights in 35mm Butane Flame

Height above Burner Tube (millimeters)	Heat Flux as measured by large diameter transducer in ring stand (kilowatt/meter2)	Heat Flux as measured by small diameter transducer in ring stand (kilowatt/meter2)
7	3 ± 1	
11	11 ± 1	5.7
15	25 ± 1	45 ± 3
19	41 ± 1	61 ± 3
23	54 ± 1	76 ± 7
27	65 ± 2	98 ± 10
31	76 ± 0	132 ± 10
35	**80 ± 1**	**164 ± 3**
39	73 ± 2	164 ± 3
43	65 ± 2	129 ± 8
47	65 ± 1	112 ± 11

Table III Average 35 mm Butane Flame Temperatures

Height above Vertical Tube (mm)	Left Thermocouple Temperature (C)	Center Thermocouple Temperature (C)	Right Thermocouple Temperature (C)
10	587±5	492±5	540±6
15	610±40	550±20	570±30
20	590±20	520±20	540±30
25	650±60	550±60	570±70
30	660±50	720±10	720±20
35	650±50	710±40	660±80
40	670±30	690±10	630±40
45	580±60	640±60	580±70
50	560±40	580±60	500±100

Table IV Flame Temperature of Cigarette Lighter

Height above Vertical Tube (mm)	Left Thermocouple Temperature (C)	Center Thermocouple Temperature (C)	Right Thermocouple Temperature (C)
5	367	435	574
10	480	533	628
15	599	583	642
20	651	605	649
25	619	567	624
30	558	489	555

Conclusions

Measurements of the heat flux of several common household ignition sources such as candles, cigarette lighters, and kitchen matches, show some variation but are reasonably similar. The heat flux values of the household sources are also reasonably similar to those of the 35 mm butane flame.

The maximum heat flux, for all ignition sources, generally occurred near the tip of the flame, as expected, but allowed some flexibility for flame placement with little effect on heat flux.

Measurement of the temperature of a cigarette lighter and the 35 mm butane flame indicates that both have reasonably similar maximum temperatures. The maximum temperature of the 35 mm butane flame is near the tip of the flame but allows some flexibility in placement of the flame. Both heat flux and temperature data clearly indicate that the tip of the flame is preferable to allowing the flame to impact the fabric closer to the burner tube.

cc:
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