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COTTON AND COTTON MODACRYLIC BLENDED BATTING FIRE BLOCKING BARRIERS FOR SOFT FURNISHINGS TO MEET FEDERAL AND STATE FLAMMABILITY STANDARDS

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Abstract

The U.S. Consumer Product Safety Commission and the state of California's Bureau of Home Furnishings and Thermal Insulation are developing mandatory flammability standards to address open flame ignition of mattresses, filled top-of-the bed products, and upholstered furniture (i.e., soft furnishing products). There are mandatory and voluntary cigarette ignition standards in the U.S. for mattresses and upholstered furniture. Boric acid treated cotton batting has been used in mattresses and upholstered furniture for years because it can prevent or reduce cigarette and open flame ignitions. There are many new developments with cotton batting for use as fire-blocking barriers that have dimensional stability/integrity, and resiliency (e.g., thermal bonded and blend products) and could be used as a drop in component fire blocking barrier for soft furnishings. Some new developments with FR-cotton and cotton/modacrylic blended batting are discussed.

Introduction

There are mandatory and voluntary cigarette ignition standards in the U.S. for mattresses (16 CFR 1632) (U.S. CPSC) and upholstered furniture (voluntary standards of the Upholstered Furniture Action Council [UFAC]) (UFAC, 1990). California has mandatory open flame standards for upholstered furniture (TB 117 [CA TB117] and TB133 [CA TB133]) and mattresses (TB 121[CA TB121] and TB 129 [CA TB129]). The United Kingdom has a cigarette ignition and open flame standard for upholstered furniture and mattresses (BS 5852). The U.S. Consumer Product Safety Commission (CPSC) (U.S. CPSC, 2001, 2001a, 1997) and the California Bureau of Home Furnishings and Thermal Insulation (CA BHFTI) (CA BHFTI; CA 2002, 2003, 2003a), are considering/developing open flame ignition standards for these soft furnishing products and for bedclothing/top of the bed products (e.g., mattress pads, comforter, quilts, bedspreads, pillows). What is used and how it is used to meet the various new FR-standards for soft furnishings will depend on several factors: performance, cost, and meeting consumer expectations. The American consumer will expect these textile home furnishings products to remain unchanged in terms of aesthetics, price, performance, and care requirements.

Upholstered Furniture/Mattress/Filled Bedclothes Definitions

The 2001 CPSC draft standard defines “upholstered furniture” subject to the standard as any seating product that has a contiguous upholstered (fabric + filling) seat and back (U.S. CPSC, 2001a). A sleeper sofa with cushions and an upholstered seatback is considered furniture by this definition. The mattress portion of a sleeper sofa is covered by the existing mandatory mattress and mattress pad regulations, which list what products are covered [16 CFR 1632.1(a) Definitions]. It also excludes sleeping bags, pillows, mattress foundations, waterbeds, air mattresses, etc. [see 16 CFR 1632.1(a)(2)]. The CA BHFTI considers sleeper sofas both furniture and mattresses. For CPSC, futons, unless they meet the furniture definition, are covered only under mattress standards. CA BHFTI added futons to their mattress standard in 1984. CA BHFTI also considers futons that are used for seating as furniture; so futons would have to meet the Federal mattress standard (16 CFR 1632) and TB 106 as well as TB 117 and the new TB 603. [Futons have 3 components: mattress, mattress cover, frame. The mattress cover would not be covered by CA BHFTI standards: and the frame is usually wood, metal or plastic and thus is not covered by CPSC or CA standards.]

"Filled" top of the bed products include mattress pads, comforters, pillows, quilts, and decorative pillows. While the CA BHFTI is limited by their statute to regulating only filled bedding, the CPSC can consider all bedclothes, including sheets and blankets when crafting a future flammability regulation.

Mattresses/Foundation (Box Springs)/Bedclothing

U.S. CPSC. There is a U.S. federal standard for the Flammability of Mattresses and Mattress Pads (16 CFR 1632) that requires mattresses and mattress pads to be resistant to cigarette ignition. This federal standard administered by CPSC preempts any state standard unless the state has requested and is granted exemption from preemption by CPSC. Under the Fed-

eral Flammable Fabrics Act (FFA; 15 U.S.C. §1203) Section 16, a federal standard on one aspect of fire preempts any aspect [i.e., if the standards are designed to address the same risk of occurrence of fire, unless it is identical to the federal standard, then the state standard is preempted and the state has to file a petition for exemption from preemption (16 CFR 1061, Application for Exemption from Preemption) once the standard is final (U.S. CPSC, 1983), if they want to enforce their standard; this petition goes through notice and comment rulemaking].

In October 2001 the CPSC issued an Advanced Notice of Proposed Rulemaking (ANPR) (U.S. CPSC, 2001) that started their formal rulemaking process to develop a federal flammability standard to address open-flame ignition of mattresses. The ANPR is for a rulemaking for mattresses only, with the potential ignition source representing burning bedding (large open flame) (U.S. CPSC, 2001). A CPSC staff-briefing package is expected in early 2004 and a proposed standard could be published in 2004. The CPSC staff is preparing a briefing package on the issue of small open-flame ignition of textile bedclothes (top of the bed textiles). The CPSC staff briefing package, expected in 2004, will include staff recommendations on whether the Commission should go forward with a formal rulemaking to develop a federal open-flame flammability standard for textile bedding products.

The CPSC could propose/promulgate an open-flame standard for mattresses and possibly for bedding in 2004.

CA BHFTI. Legislation (Assembly Bill 603) directing the CBHF to develop an open-flame standard for residential mattresses/box springs (foundation) and "top of the bed" textile products, if those products are determined to contribute to mattress fires, was signed into law August 2001. AB 603 requires the CA BHFTI to have an open-flame standard for mattresses/box springs sold in California by January 1, 2004. The CA BHFTI completed a standard to address open-flame ignition of mattresses/box springs in 2003 ("TB 603") (CA, 2003). The effective date is scheduled to be 1/1/05. The test method uses the dual burners developed by NIST (Shields and Ohlemiller, 1998; Ohlemiller, 2003; Ohlemiller, et al., 2000; Ohlemiller and Gann, 2002). The ignition source proposed is designed to mimic the local heat flux imposed on a mattress/foundation by burning bedclothes. It consists of two T-shaped burners (CA, 2003). According to CPSC, the existing federal standard would preempt the TB 603 (U.S. CPSC, 1983). Rather than file for exemption from preemption CA filed comments on Oct. 6, 2003 with CPSC urging that CPSC adopt TB603 as the federal standard (http://www.bhfti.ca.gov/tb603_cpsc_comment.pdf).

The CA BHFTI has determined that a flammability standard for "filled" top of the bed products (such as mattress pads, comforters, pillows, quilts, decorative pillows, and padded headboards) is warranted. The CA BHFTI is expected to open their formal rulemaking process on open flame ignition of filled bedding in 2004. There will be a 45-day comment period followed by at least two public hearings in California. A typical rulemaking by the CA BHFTI lasts one year. The implementation date for the bedding standard is not known. The proposed standard ("TB-604") (CA, 2003a) is likely to contain two test methods: 1. Filling Materials (Natural and Synthetic) Component Test – Open-flame Resistance (Option A as a component; Option B in the composite); and 2. Loose Filling Materials (Natural and Synthetic) Component Test – Open-Flame Resistance. NIST did a study on the effect of "improved" filled bedding textiles on the fire performance of bed assemblies, which indicated that mattress pads may be the only relevant textile bedding item to the protection of currently available mattresses from open flame ignitions (Ohlemiller and Gann, 2003).

Upholstered Furniture

U.S. CPSC. In response to a petition from the National Association of State Fire Marshals (NASFM), in 1994 CPSC published (6/15/94) an advanced notice of proposed rulemaking (ANPR) to address risks associated with ignition of upholstered furniture by small open flame sources (matches, lighters, and candles). CPSC addressed the other requests in the petition by the NASFM by deciding that a large open flame standard was not appropriate and delayed the decision on whether a mandatory standard is needed for cigarette ignition resistance. The focus of the CPSC draft standard for small open flame ignition, issued in briefing packages in 1997 and 2001, is upholstery fabric (U.S. CPSC, 1997, 2001a).

Since the NASFM has withdrawn their 1994 petition, a decision on a mandatory standard for cigarette resistance would require a separate rulemaking. On Oct. 23, 2003 (68 FR 60629; "Ignition of Upholstered Furniture by Small Open Flames and/or Smoldering Cigarettes"), CPSC published a new ANPR to address both ignition of upholstered furniture by small open flames and/or smoldering cigarettes in the same rulemaking.

UFAC has a voluntary standard that addresses cigarette ignition and has been subject to review by CPSC (UFAC, 1990). The UFAC voluntary standard has been in use in the U.S. since the late 1970s and could become a mandatory standard if CPSC promulgates a mandatory standard for cigarette ignition as well as open flame ignition.

The CPSC, before proposing any rule or promulgating a final rule for flammability standards for residential upholstered furniture, has to consider studies by EPA (on dermal penetration, and a significant new use rule [SNUR] for FR-chemicals scheduled for proposal), NIOSH (workplace exposure/safety), and CPSC (durability, full scale chair tests, lab round-robin

tests, and others). The CPSC decision to determine whether to propose mandatory standards for small open flame and cigarette ignition could be made in 2004.

A petition from NASFM, asking CPSC to require warning labels that polyurethane foam in upholstered furniture poses a fire hazard, was denied in March 1999 as unnecessary.

Toxicity of Flame-Retardants In 1998-99 CPSC considered the toxicity issue of flame retardant chemicals used on upholstered furniture and the U.S. National Academy of Sciences (NAS) (National Research Council, 2000) studied the potential toxicological risks of sixteen flame-retardant chemicals that would potentially be used to meet the CPSC's draft proposed regulation for upholstered furniture flammability. The NAS study (4/27/00) found that 8 fire retardant chemicals likely to be used on residential upholstered furniture need further study and that 8 pose only minimal risk [including the 2 chemicals that could be used for topical treatments on cotton, phosphonic acid ester (Pyrovatex®) and tetrakis (hydroxymethyl) phosphonium salts (Proban®)]. However, it is important to recognize that none of these chemicals can be used alone successfully on all fibers or blends and the most commonly used backcoating agents are used with antimony oxide, which is on the list of products that the NAS listed for further study. Antimony oxide is presently under a toxicological review in Europe. If the antimony oxide is incorporated inside the fiber/polymer and there is no exposure then it would not be of concern.

CA BHFTI announced in November 1999 that they are undertaking a full review and update of their mandatory upholstered furniture standard (TB 117). A draft standard for review and comment was released 2/02 (CA, 2002). It contains composite and component tests methods for fabric and filling materials. A proposed rule could be published in 2004, which would be finalized in 1 year. [At the request of the National Cotton Batting Institute (NCBI), the CA BHFTI did a separate rulemaking to remove the afterglow requirements for testing cotton batting in TB 117, Section B, Part 1 and a final rule was issued in July 2000, removing this requirement for cotton batting (CA TB117).] Other states (e.g., LA, TX, OH) are considering adopting the current TB 117 at the request of NASFM.

This paper discusses some new developments with FR-cotton and cotton/modacrylic blend batting that could assist manufacturers in meeting the open and cigarette flame ignition standards for mattresses/box springs (foundation), bedclothing and upholstered furniture that are likely to be promulgated in the near future.

What is Cotton Batting?

The raw materials used in cotton batting consist of cotton gin motes (also referred to as “regins”), cotton linters (rarely used at present because of cost and availability), raw cotton (100% cotton and cotton by-products), and cotton textile mill by-products (that usually contain some polyester). “Shoddy”, reconstituted fiber from fabric cuttings and other textile mill yarn, slasher, and fabric waste that most often contains some synthetic fiber (mostly polyester) is also used. Gin motes are fibers that are removed at the lint cleaning process during ginning and are usually further processed to remove cotton plant parts. Linters are fuzz fibers, less than 0.5 in. long that are not removed during ginning but are removed at the cottonseed oil mill. Linters are not used very much these days unless specified. Raw cotton is the fiber that textile mills use. Textile mill by-products, which encompass a wide range of fiber materials that are unusable for textile products (usually because of length) are the primary raw material used. The trend in textile mills is to combine more of their waste fiber by-products and this trend leads to fewer varieties of textile mill wastes. Textile mill by-products usually contain some synthetic fibers.

Cotton Batting Uses in Mainstream Soft Furnishings (Mattresses/ Futons, Bedding, Upholstered Furniture)

Cotton batting may take many forms as supplied to the mattress, futon, bedding, and furniture industry. It can be supplied as batts, in rolls, stitched or sewn to netting and other materials. Cotton batting can be a thermal bonded high loft and/or needle punched product that is made flame and cigarette (smolder) ignition resistant either by using boric acid as the flame retardant or/and by blending with inherently flame resistant fibers [e.g., enhanced FR modacrylic (e.g., Protex®), inherently flame resistant polyester, or melamine-based fiber (e.g., Basofil®)]. It is an improved product that can be used as a drop-in component fire-blocking barrier in mainstream soft furnishings (i.e., mattresses, bedding, and upholstered furniture).

FR-cotton batting has the potential to be used to meet the various future flammability requirements. How it actually will be used to meet the potential flammability test methods will be evolving over the next few years. FR-cotton battings can be used as surface or interior products.

In the mattress industry, smolder and flame resistant cotton batting can be used as a fire blocking barrier in the top panel directly under cover fabrics and under a sacrificial layer of polyester batting (Figure 1) to pass open-flame mattress regulations (e.g., TB 603) or just under a cover fabric as well as in inner padding layers as insulators, cushioning padding and filling. FR-cotton batting or a batting of FR-cotton blended with a FR-synthetic fiber (e.g., FR-enhanced modacylic) can be used in the side panel of the mattress (Figure 2) under the ticking to pass open-flame mattress regulations (e.g., TB603). Some mattresses

are produced with cotton batting as the only filling material with the spring unit. In futons, batts are used as layering components to fill out the futon.

In the upholstered furniture industry cotton batting is used as padding in seat backs, arms, cushions, and as deck padding. To help upholstered furniture pass the various flammability tests, cotton batting products can be used under fabrics as a fire-blocking barrier. In filled bedclothes (mattresses pads, comforters, quilts, etc.) cotton batting can serve as the filling alone or in combination with other materials.

Preparation of FR-Cotton Batting: Cigarette (Smolder) and Open Flame Resistant

Boric Acid Treatment

The process developed by USDA in the early 1970's of adding boric acid to cotton to produce smolder and flame resistant cotton batting has been improved in recent years so that boric acid no longer dusts–out or leaches-out of the batting (Wakelyn et al., 2003). U.S Borax (2002) and Wakelyn et al. (2003) have reviewed the toxicity of boric acid. It poses only minimal risk to consumers of soft furnishings.

Boric acid (about 10% on the weight of the product) is added to the raw materials in the willow or mixing machine prior to garnetting along with 2-3% oil and a surfactant. The oil helps control dust and also acts as a carrying agent that allows the boric acid to adhere to the fibers. The surfactant is added to aid the oil by reducing the surface tension on the fibers and allows the oil and fibers to bond with the boric acid. To further achieve even distribution, the boric acid is ground to a very fine particle size prior to application to further enhance adherence to the fibers. The garnetted batting contains evenly distributed boric acid and there is little or no dust-out or leach-out of the boric acid.

To produce a thermal bonded batting about 5-20% low melt polyester is added to the cotton fiber and fibers are blended in the willow prior to garnetting. The resulting batting is then heat treated, forming thermal bonded batting. This can be high loft or compacted by a needle punch process.

The untreated and FR-cotton batting that was evaluated for resistance to open flame and cigarette ignition was produced by Jones Fiber Products. The smolder ignition and open flame ignition testing for FR-cotton batting reported in the results section was performed by Jones Fiber Products using the test methods indicated. FR-cotton batting passes very harsh smolder resistant and open flame ignition tests (see results).

Fiber Blend Products

To make the batting smolder and flame resistant, as well as durable to wet treatments, about 10-40% inherently flame resistant fiber such as enhance FR modacrylic (e.g., Protex®), inherently flame resistant polyester, and melamine (e.g., Basofil®) can be blended with the "cotton" fibers/by-products with or without a low melt polyester (5-20%). In this way the various batting products can be produced for use as fire blocking barriers or as filling material.

Blending with cotton enhances the properties of modacrylic fibers, which char and do not melt. Modacrylic fiber will shrink from the flame without cotton but remain in place when mixed with cotton. Protex® modacrylic fiber (manufactured by Kaneka Corporation of Japan), which was used in the cotton blend battings tested in this research, is an enhanced flame retardant fiber version of standard modacrylic fiber. It is an inherently fire retardant fiber that is produced by adding antimony oxide to the polymer melt before melt spinning. No deterioration in flame retardancy is evident after repeated washing or the passage of time and it is resistant to both acids and alkali. Protex® chars in the presence of flame with no dripping or melting, like other modacrylic fibers.

The limiting oxygen-index (LOI) testing results were provided by Kaneka Corp. of Japan. Jones Fiber Products prepared the cotton/modacrylic (Protex®-PBX) fiber blend batting that was evaluated using TB604 test methods and the cotton and FR-cotton/modacrylic (Protex®-PBX) batting that was evaluated using TB603 test methods. The CA BHFTI provided the TB604 testing results. The TB603 test results were provided by Kaneka Corp. of Japan.

Properly prepared FR-cotton batting and cotton/modacrylic blended batting can pass harsh smolder resistant and open flame tests. Cotton and FR-cotton rich blends with Protex®-PBX modacrylic fiber performed well in a variety of flammability tests (see results).

Flammability Tests Applicable to Cotton Batting (Test Methods)

Product flame resistant is test method dependent, i.e., one should specify what test the soft furnishing/fabric/barrier/filling material passes. There are many mandatory federal and state, as well as voluntary national and international standards, for the flammability of soft furnishings (smolder/cigarette resistance; small and large open flame). The current smolder test methods use a standard cigarette but a substitute standard ignition source is being developed by CPSC to replace the standard cigarette

and Gann (2003) has discussed the ignition strength of cigarettes. Large open flame standards for mattress/box springs use burners that mimic burning bedclothes (e.g., as in TB 603 [CA 2003]), other large flame sources (e.g., an 18 kW flame for 3min. as in TB 129 [CA TB 129]), or a trash can full of burning paper (as in TB 121 [CA TB 121]). Small open flame sources usually are representative of matches, cigarette lighters, and candles (e.g., a butane or propane flame for 15 or 20 sec.) and are used in upholstered furniture tests and potentially for testing the flammability of bedding or filling products.

Mattress/Foundation (Box Springs)

Smolder/Cigarette:

- 16 CFR 1632 [Federal CPSC] *Standard for the Flammability of Mattresses and Mattress Pads* (U.S. CPSC 16 CFR 1632) [ignition source 18 lighted cigarettes (9 in the bare mattress tests and 9 in the 2-sheet tests); cigarettes from natural tobacco, 85 ± 2 mm long, diameter of 0.3 ± 0.02 inches, weight 1.1 g ± 0.1 g) in a draft protected environment on a full scale mattress in a horizontal position]
- TB 106 *Federal Standard 16 CFR 1632* (CA TB106)
- (TB 26 *Requirements for Record Keeping and Prototype Test of Mattresses*)

Open Flame:

- (Final standard due in 2004) TB 603 *Requirements and Test Procedure for Resistance of a Mattress/Box Spring Set to a Large Open-Flame* (CA 2003) (for mattresses/ box spring ignition source NIST Dual Flame Burner Test Protocol to be used [2 T-burners, top burner HR 19kW (heat flux 65 kW/m^2) 70 sec., side burner HR 10kW (heat flux 45 kW/m^2) 50 sec.]; Peak HRR of the mattress set must not exceed 200 kW; total HR <25 megaJoules first 10 min. [secondary ignition/preflashover fire – heat, smoke, toxic gas]; test duration 30 min.)
- TB 121 *Flammability Test Procedure for Mattresses for Use in High Risk Occupancies* (CA TB121) [for typical institutional mattress, not intended to be used for residential mattresses; full scale test; mattresses conditioned at 70 ± 5°F, R.H. < 55%; ignition source -- galvanized metal container with 10 double sheets of loosely wadded newspaper (23 x 28 in. ~ 18.5 ± 0.5g), ignite newspaper with a match and allow combustion to continue until either all combustion has ceased or at least 10% by weight of the mattress consumed; P/F criteria – mattress fails if >10% weight loss in first 10 min., if temperature of 500ºF or > at the thermocouple above the test mattress at any time during test, if CO concentration exceeds 1000 ppm at any point in the test room at any time during the test]
- TB 129 *Flammability Test Procedure for Mattresses for Use in Public Buildings* (CA TB129) (ignition source T-burner [205 mm {about 8 in.}] 17.8 kW flame [2050 ± 50 kJ/mol] for 180 sec. side ignition; Product fails if: 1. Weight loss due to combustion of ≥ 1.36 kg in the first 10 min. of the test, or 2. Peak HRR of ≥ 100 kW, 3. Total HR of ≥ 25 MJ in the first 10 min. of the test.)
- CPSC ANPR, *Standard to Address Open-Flame Ignition of Mattresses/Bedding* (U.S. CPSC, 2001) (no test method proposed yet)

Furniture

Smolder/Cigarette:

- UFAC (voluntary) *Filling/Padding Component Test Method—1990 Part A – For Slab or Garneted Materials* (UFAC) (cigarette test) Vertical and horizontal panels are assembled on 3 specimen holders, using the UFAC Standard Type 1 mattress ticking as the cover fabric. A lighted cigarette is placed in the crevice formed by the abutment of the vertical and horizontal panels in each test assembly, and is then covered by sheeting fabric. The cigarettes are allowed to burn their full lengths unless an obvious ignition occurs. Test observations are recorded. A minimum of 3 test specimens is required for each sample tested. Ignition source is cigarettes without filter tips made from natural tobacco, 85 ± 2 mm long (3.3 ± 0.1 in) long and with a packing density of 0.27 ± 0.02 g/cm^3 (0.16 ± 0.01 oz/in3) and a total weight of 1.1 ± 0.1 g. Sheeting material is 100% cotton white bed sheeting, weight 125 ± 28 g/m2, and not treated for flame retardants, cut into 127 x 127 mm (5.0 x 5.0 in.) squares; cover fabric is 100% cotton mattress ticking conforming to federal specification CCC-C-436E, cloth, ticking, twill, cotton: UFAC Standard Type 1 fabric.
- UFAC (voluntary) *Barrier Test Method—1990* (UFAC) (cigarette test) Vertical and horizontal panels are assembled on a small-scale test assembly using UFAC standard polyurethane foam as the substrate. The Standard UFAC Type II cover fabric is used as the covering. The barrier material to be tested is placed between the cover fabric and the polyurethane substrate in both vertical and horizontal panels. A lighted cigarette is allowed to burn its entire length unless an obvious ignition occurs. Test observations and measurements are recorded. A minimum of 3 individual specimens is required for each barrier sample tested. Ignition source is cigarettes without filter tips made from natural tobacco, 85 ± 2 mm long (3.3 ± 0.1 in) long and with a packing density of 0.27 ± 0.02 g/cm^3 (0.16 ± 0.01 oz/in3) and a total weight of 1.1 ±0.1 g. Sheeting material is 100% cotton white bed sheeting, weight 125 ± 28 g/m^2, and not treated for flame retardants, cut into 127 x 127 mm (5.0 x 5.0 in.) squares; cover fabric is 100% bright regular rayon, scoured, 20/2, ring spun, basket weave construction, 271 ± 12 g/m^2; UFAC Standard Type II Cover Fabric. Polyurethane foam substrate: polyether type polyurethane foam containing no inorganic fillers or flame-retardants, having a density of 24.0 ± 1.6 kg/m^3.

- TB 116 *Requirements, Test Procedures and Apparatus for Testing the Flame Retardance of Upholstered Furniture* (CA TB116) (3 cigarettes from natural tobacco, 85 ± 2 mm long, diameter of 0.3 ± 0.02 inches, weight 1.1 g ± 0.1 g)

Open Flame:

- (Draft) CPSC *Upholstered Furniture Flammability Regulatory Options* (test for the *seating area* and *dust cover* – ignition source small butane flame, 20 sec.; max. flaming 2 min.; max. smolder 15 min. *Alternate seating barrier* – ignition source BS 5852 Crib #5; max. flaming 10 min.; max. smolder 60 min.) (U.S CPSC, 2001a; US CPSC, 1997).
- (Draft) Fabric Coalition *National Furniture Flammability Proposal* (Sept. 24, 2003) (D. Pettey, 2003) All furniture would be required to be assembled using foam compliant to CA BHFTI "TB-117 Plus" as specified in the 2/02 draft revision of TB-117 (10). Cover fabrics are tested using 45 degree (TB-117) testing apparatus; cover fabrics are required to meet either of the following two criteria, after exposure to a 5.0 second small open flame – for "Class 1" the fabric fails to ignite, or self-extinguishes and the average flame spread time is slower than 30.0 seconds; for "Class 2" fabrics an appropriate fire blocking system would be required. Foam requirements remain "TB-117 Plus". Cigarette ignition resistance: ASTM E-1353. Furniture to be assembled with Class A barriers, when constructed with Class 2 cover fabrics.
- TB 117 *Requirements, Test Procedure and Apparatus for Testing the Flame Retardance of Resilient Filling Materials Used in Upholstered Furniture* (CA TB117) [upholstery fabrics – both surfaces of fabric tested to determine compliance (Class 1) with 16 CFR 1610; filling material – vertical or 45º angle test depending on the material (12 in. x 3 in. x normal thickness cotton batting sample has to pass a vertical flame test; 16 CFR 1610 flame source, 12 sec. flame middle bottom edge ignition; max. char length shall not exceed 8 in. and average char length of 10 specimens shall not exceed 6 in.; no afterglow requirement)
- (Draft revision 2/2002) TB 117 *Flammability Test Procedure and Apparatus for Testing the Flame and Smolder Resistance of Upholstered Furniture* (CA, 2002) (a series of component and composite tests for filling materials and fabric with P/F criteria 4% weight loss in 10min. for most products)
- TB133 *Flammability Test Procedure for Seating Furniture for Use in Public Occupancies* (CA TB133) [finished product or full scale mock-up of the furniture can be tested; ignition source: square gas burner (250 x 250 mm), propane gas flow volume ~13 l/min for 80±2 sec.; test criteria: fails if the following are exceeded in a room test if oxygen consumption calorimetry is used – max. RHR ≥ 80 kW, total HR ≥ 25 MJ in first 10 min., > 75% opacity at the 4-ft smoke opacity monitor, CO conc. ≥ 1000 ppm for 5 min., if room instrument used – temperature increase of ≥ 200°F at ceiling thermocouple, of ≥ 50ºF at 4-ft thermocouple, weight loss due to combustion ≥ 3 lb in first 10 min., opacity and CO criteria same as for calorimetry)

Bedclothes

Open Flame:

- (Draft October 22, 2003) TB 604 *Test Procedure and Apparatus for Testing the Flame Resistance of Filled Bedclothing* (CA, 2003a) [Flat filling material: sample of filling material enclosed in 50% cotton/50% polyester standard casing fabric; specimen on a horizontal cement board on a weighing device and ignited on one corner with a small open flame (35 mm high butane gas flame for 20 sec.), specimen fails if the gross (fabric and fill) weight loss of any of the triplicate samples exceeds 25.0% in 6 min.; Pillow/Cushion and loose-filling materials: test pillow (same standard fabric) same test with specimen failure if gross (fabric and fill) weight loss of any triplicate sample exceeds 20.0% in 6 min.]

Results of FR-Testing: Burning Properties of Cotton Batting

Untreated Cotton Batting

Normally when cotton burns the fire takes the form of smoldering. Untreated cotton batting may flame, usually along the surface of the product only. After the surface fibers burn, smoldering usually encompasses the product. Under normal conditions, untreated cotton batting does not result in large flames like that of a fire from crumpled newspaper or a wood fire. Because cotton smolders when it burns the rate of combustion is slow compared to other padding products (e.g., untreated polyurethane foam). The slow combustion is a critical element that allows egress time for humans to react to the fire scenario. Time is a major factor in safety during fires. Cotton does not melt and drip when burning as do thermoplastic fiber such as polyester or nylon.

Smoldering Ignition: Boric Acid Treated Cotton Batting

Test Method. ASTM D5238-98 ("sandwich batt" test) (ASTM) is a very harsh cigarette test that is more severe than 16 CFR 1632 and the UFAC padding test. Layers of cotton batting are built up in a sandwich around a lighted cigarette that is allowed to burn entirely. The layers of cotton act as an insulator and allow heat from the cigarette to increase to very high temperature, making this a very severe test.

Results. Properly prepared boric acid treated FR-cotton batting passes the test -- the result is a pear-shaped burn, with the cigarette burning from the small end to the large end of the char (see Figure 3).

Open Flame Ignition: Boric Acid Treated Cotton Batting

Properly prepared boric acid treated FR-cotton batting performs well in open flame ignition tests that are more severe than any of the current or potential open flame tests.

Test Method. Boric acid treated cotton batting was tested using a modified TB 117 vertical open flame test (CA, 2002) -- the ignition source was modified from a 1.5 in. high flame to a 4 in. high flame and the burn time was extended from 12 sec. to 10 minutes.

Results. The piece of cotton batting tested only charred and flaming ceased when the ignition source was stopped (see Figure 4).

Test Method. Boric acid treated cotton batting was also tested using a modified version of the draft proposed revised TB 117 test method (CA, 2002) in a horizontal fashion. In this test the flame source was increased from a British source 1 with a 45 ml flow rate to a British source 3 with a 350 ml flow rate and the length was extended from 20 sec. to 10 minutes (see Figure 5).

Results. The cotton batting only charred and did not burn through (see Figure 6).

Test Method and Results. Mattresses made with boric acid treated FR-cotton batting as the primary barrier material have passed

- TB 129 (ignition source T-burner [205 mm {about 8 in.}] 17.8 kW flame [2050 ± 50 kJ/mol] for 180 sec; Product fails if: 1. Weight loss due to combustion of ≥ 1.36kg in the first 10 min. of the test, 2. Peak HRR of ≥100 kW, 3. Total HR of ≥ 25 MJ in the first 10 min. of the test.) (CA TB129)

and the

- TB 603 (for mattresses/ box spring -- ignition source NIST dual flame burners, top 65 kW flame for 70 sec., side 45 kW flame for 50 sec.; Peak HRR of the mattress set must not exceed 200kW, Total HR < 25 MJ first 10 min.; test duration 30 min.) (CA, 2003).

Open Flame Ignition Testing for Modacrylic Blended Cotton Batting

Test Method and Results. Enhanced FR**-**Modacrylic (Protex®-PBX)/cotton blended batting

Limiting Oxygen-Index (LOI). Test method ASTM D2863-77 was used. Two grams of fibers are opened; the fibers are twisted and folded in half making a bundle of fibers; 5 cm of the bundle of fibers is tested. Figure 7 is a graph showing the LOI (Horrocks et al., 1989) results of modacrylic (Protex®-PBX)/cotton blend fibers and modacrylic (Protex®-M)/cotton blend fibers. Protex®-PBX is the type of modacrylic that has been used to blend with cotton for nonwovens and Protex®-M modacrylic is more typically used with cotton for textile related applications. It can be seen that cotton/modacrylic (Protex®-PBX) blends are above 29 and cotton/modacrylic (Protex®-M) blends are above 31 until the blend level is <80/20 (cotton/modacrylic); then the LOI rapidly drops off. It is not known if LOI data have much meaning for predicting the flammability of soft furnishings. (These data were prepared and supplied by Kaneka Fibers of Japan, 2003. These data represent testing by Kaneka and are not guaranteed.)

Draft TB 604 (Filling for Bedding). [Small Scale] CA BHFTI tested various flat filling materials and pillows with a 20 sec corner ignition on a cement board (CA, 2003a). Cotton fiber blend batting (untreated cotton blended with enhanced FR-modacrylic and low melt polyester) performed very well in these tests compared to other batting materials and passed the draft test for comforters (P/F 25% weight loss in 6 min.) and pillows (P/F 20% weight loss in 6 min.) (See C-5 in Fig. 8 and P-5 in Fig. 9; these Figures are provided by John McCormick of CA BHFTI, 2003).

In full scale testing (for development of Draft TB604) on a mattress by the CA BHFTI (using a bottom edge ignition to the sheet for 20 sec. over a twin mattress), a comforter+pillow+mattress pad where the filling material was the same cotton/FR-enhanced modacrylic fiber blend batting, the peak HRR (kW) was 10.4 and 3.6 in the duplicate tests. This was the best of the experimental battings tested (data from John McCormick, CA BHFTI, 2003). Full-scale comforter only and pillow only tests were also run. The cotton/modacrlic fiber blended batting performed very well in these tests also (see Table 1; these data are provided by John McCormick of CA BHFTI, 2003).

TB 603. Enhanced FR-modacylic/FR-cotton (10% boric acid)/low melt PET (40/45/15 and 30/55/15) passed the TB 603 NIST burner test (see Table 2) if the batting weight was > 289 g/m^2 (~8.5 oz/yd^2) but it passed only if FR-cotton was used. This batting may be useful in the mattress side panel to meet TB 603 (Figure 2). (These data are prepared and supplied by Kaneka Fibers of Japan, 2003.)

Summary

In summary, engineered cotton batting properly treated with boric acid (~10% or >) or/and blended with inherently flame resistant fibers (e.g., enhanced FR-modacrylic, FR-PET) is cigarette (smolder) resistant and open flame resistant and can be

used like any other padding material. It is an improved product that can be used as a drop in component fire blocking barrier in mainstream soft furnishings (i.e., mattresses, bedding, and upholstered furniture). Cotton batting -- boric acid treated or blended -- should be helpful in meeting the various cigarette resistance and open flame resistance regulations for mattresses, futons, and upholstered furniture.

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Table 1. Bedclothing R & D Tests: Full Scale Tests for Development of TB-604.

Test No.	Product Tested	PHRR (kW)	Time to PHRR	Total HR (MJ) @ 10 minutes	Total Time
C-1	Twin size comforter	91.6	7:23	21.1	21.1
C-2	"	81.8	10:41	10.9	15.8
C-3	"	50.8	6:00	8.0	8.7
C-4	"	7.8	24:14	0.0	1.1
C-5	"	25.4	30:18	0.0	1.9
C-6-1	"	12.4	2:31	0.9	1.3
C-6-2	"	24.2	2:58	3.1	4.8
P-1	Standard bed pillow	103.7	7:08	12.5	13.4
P-2	"	28.9	11:50	0.4	3.7
P-3	"	32.3	6:39	2.1	2.1
P-4	"	0.6	33:11	0.0	2.7
P-5	"	0.5	2:21	0.0	4.8
P-6	"	5.8	14:40	0.0	0.2

Key: 1. Conventional PET batting; 2. Improved synthetic batting 1; 3. Improved synthetic batting 2; 4. Improved synthetic batting 3; 5. Cotton fiber blend batting; 6. Feather and down
Source: John McCormack, CA BHFTI, Oct. 22, 2003.

Table 2. Cotton/Modacrylic Blends TB603 NIST Burner Test.

Fiber Blend Ratio (%)				Weight		Weight Loss	Non-Woven	Ignition to	
PBX	FR Cotton	Cotton	Low Melt PET	g/m²	oz/yd²	(%)	Void	Urethane	Result
40	45		15	193	5.7	4	Void	No	×
30	55		15	290	8.6	1.2	No	No	o
40	45		15	289	8.5	4.8	No	No	o
40		45	15	307	9.1	3.4	Void	No	×
30	55		15	323	9.5	4.3	No	No	o
40	45		15	310	9.1	3.1	No	No	o

Key: PBX = Enhance FR-Modacrylic (Protex®); FR-cotton = Boric Acid (~10%) treated cotton batting; Melt PET = low melt polyester; x = failed, o = passed

Source: Kaneka Fibers of Japan, 2003.

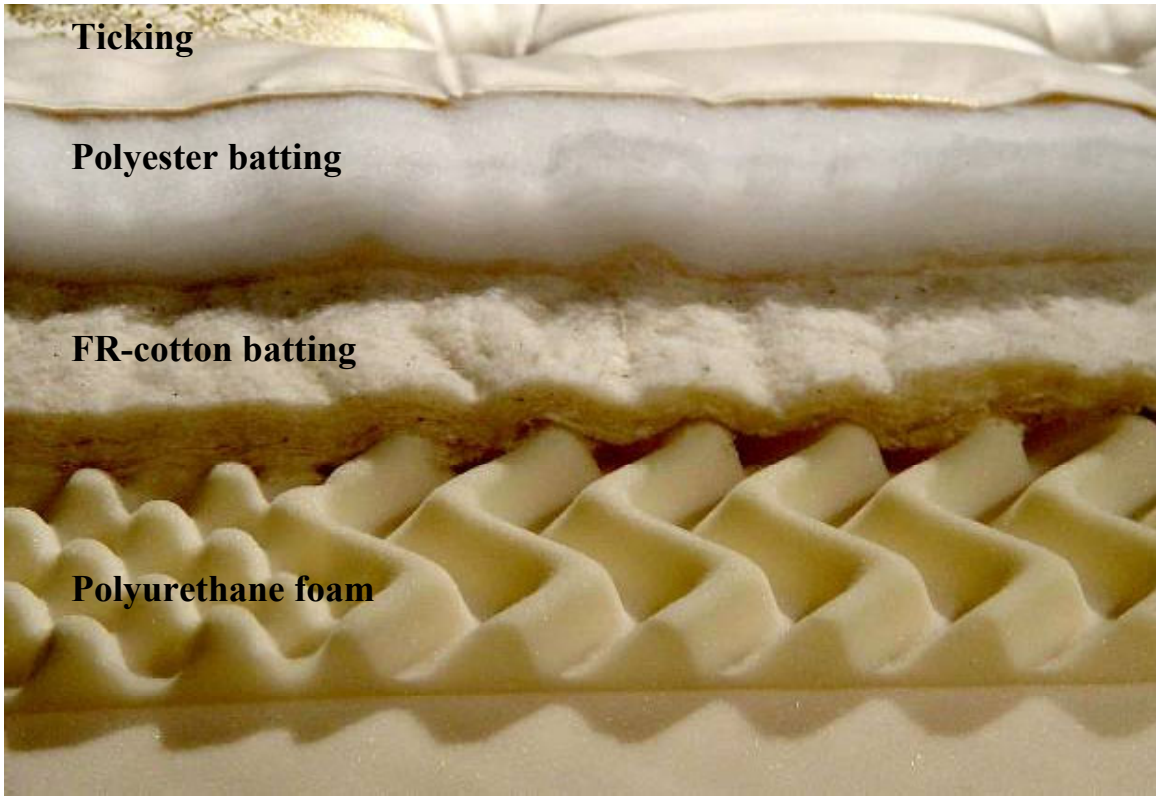

Figure 1. Cotton Batting (under a polyester layer) as a Fire Blocking Barrier Top Panel in a TB603 Compliant Mattress.

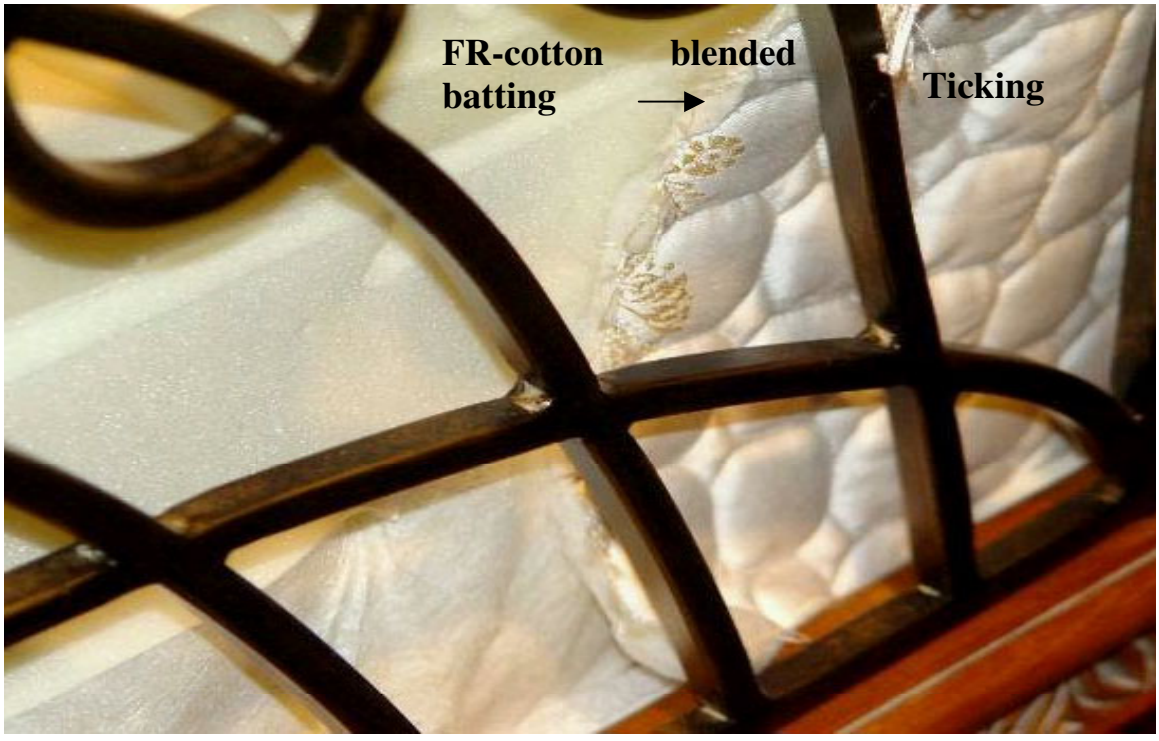

Figure 2. Cotton Batting as a Fire Blocking Barrier Side Panel in a TB603 Compliant Mattress.

Figure 3. Test Method (ASTM D5238-98) – Smolder Ignition.

Figure 4. CA TB 117; 4" High Flame – 10 minutes.

Figure 5. CA TB 117 Draft Proposed Revision; 350 ml flow rate – 10 minutes.

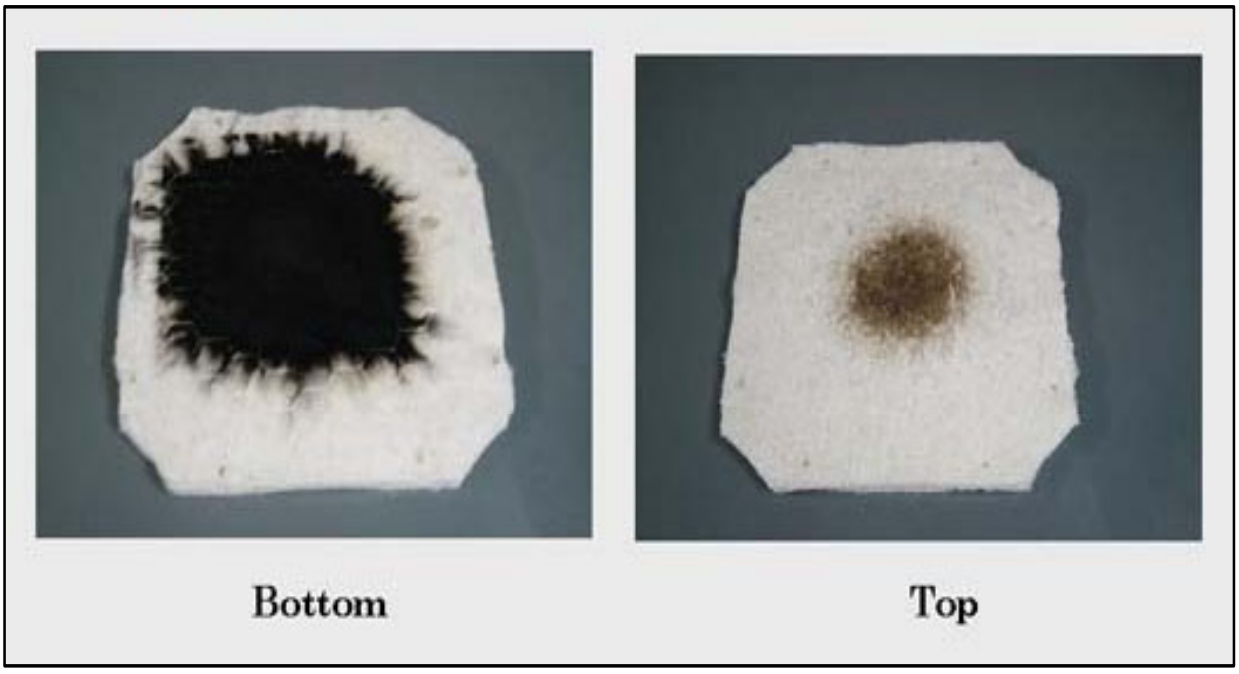

Figure 6. CA TB 117 Draft Proposed Revision; 350 ml Flow Rate – 10 minutes.

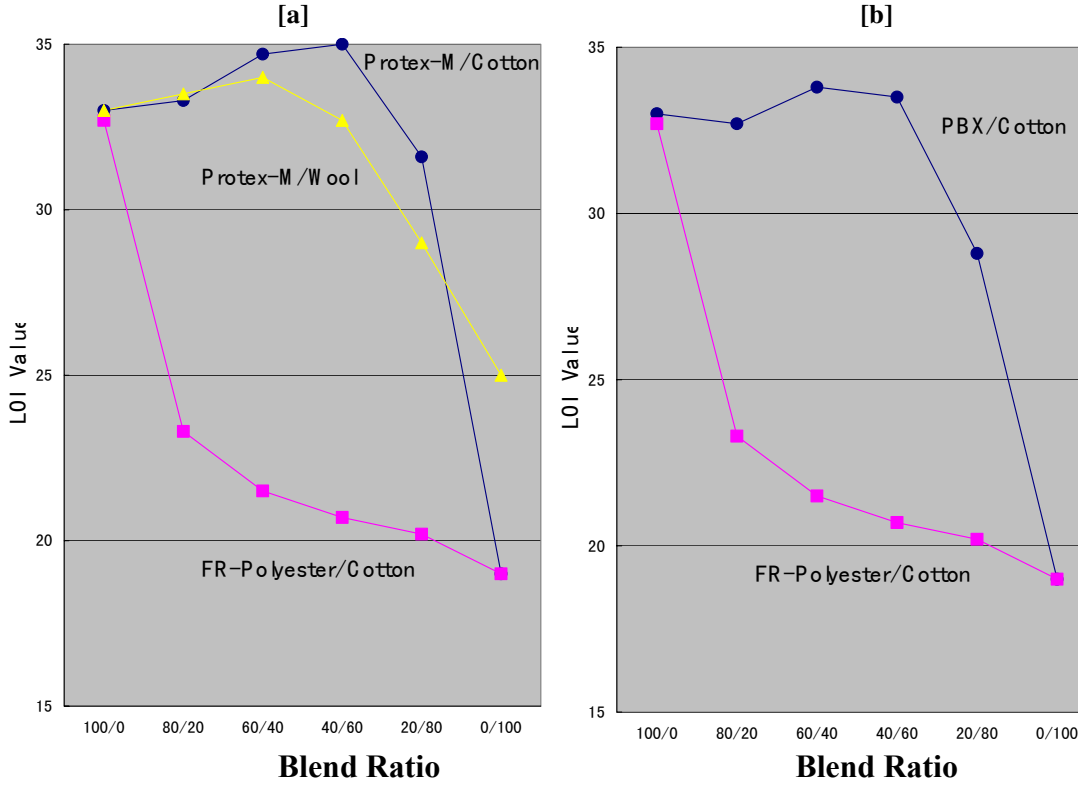

Figure 7. LOI Values of [a] Modacrylic (Protex®-M)/Cotton Fiber Blends and [b] Modacrylic (Protex®-PBX)/ Cotton Fiber Blends (*Source*: Data prepared and supplied by Kaneka Corp of Japan, 2003 and is not guaranteed.)

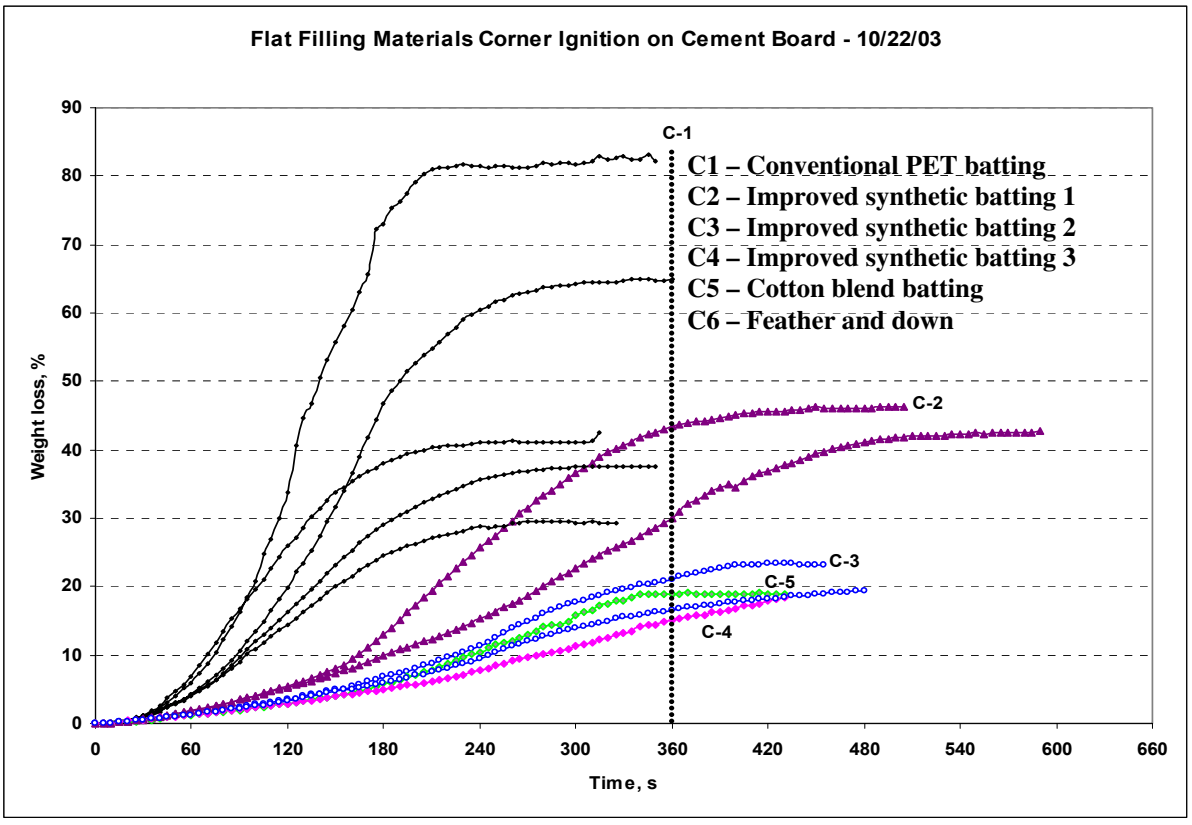

Figure 8. CA TB 604 [Small Scale Test] (P/F: 25% weight loss in 6 minutes).

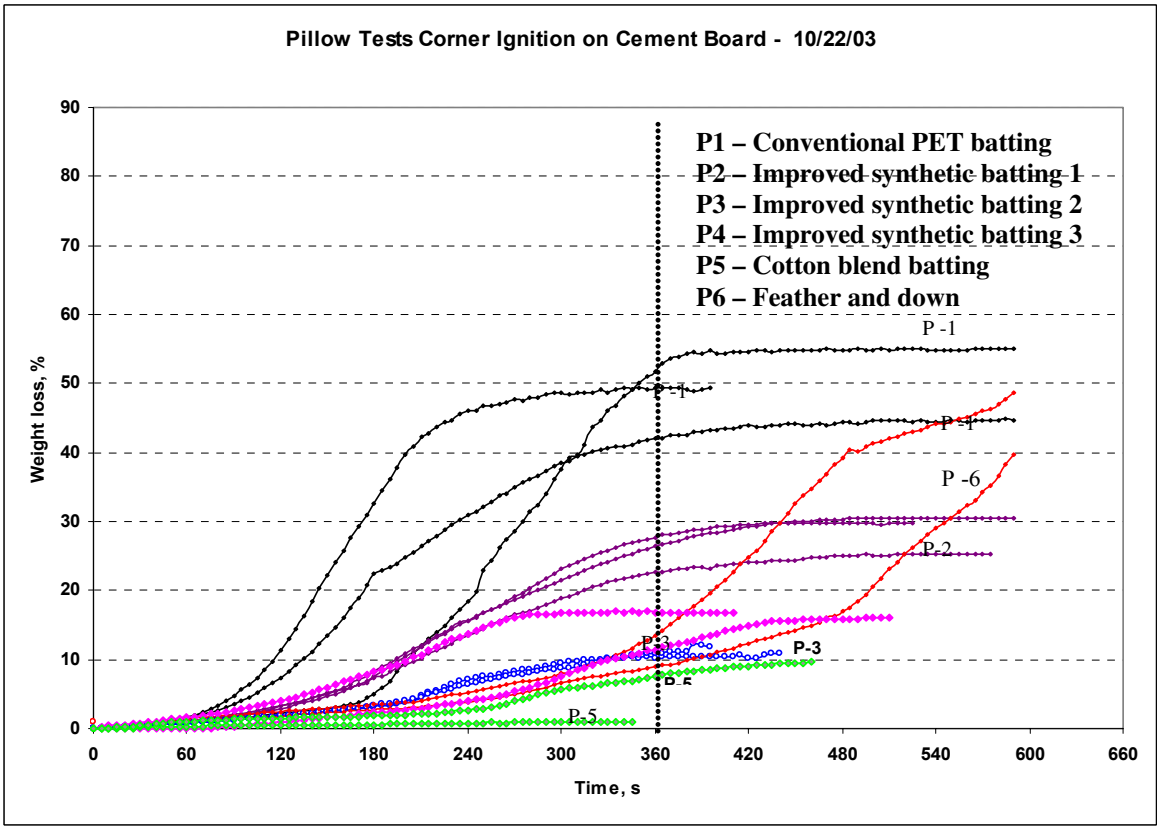

Figure 9. CA TB 604 [Small Scale Test] (P/F: 20% weight loss in 6 minutes).