IV. UFAC TEST:

Prototype #1 sustained smouldering. Number 2 vertical char, less than 1/2". Number three sustained smouldering.

V. Thickness of mattress prior to test was approximately three inches and after 135,000 cycles of accelerated wear was still three inches, within the limits of measurement.

Summary

The accelerated wear testing and subsequent flammability evaluation made on the mattress submitted by Hogan and Associates indicated that mechanical action of wear during use will have a relatively minor effect on the boric acid concentration in the cotton batting of slab or solid core mattresses made by the process employed by Hogan and Associates.

Even after three years of actual use the 135,000 cycles of accelerated testing, the Hogan and Associates mattress easily passed the open flame vertical test specified by California Bulletin 117.

After three years of actual use and 135,000 cycles of accelerated wear the treated cotton batting in the Hogan and Associates mattress met the cigarette resistant requirements of California Bulletin 117.

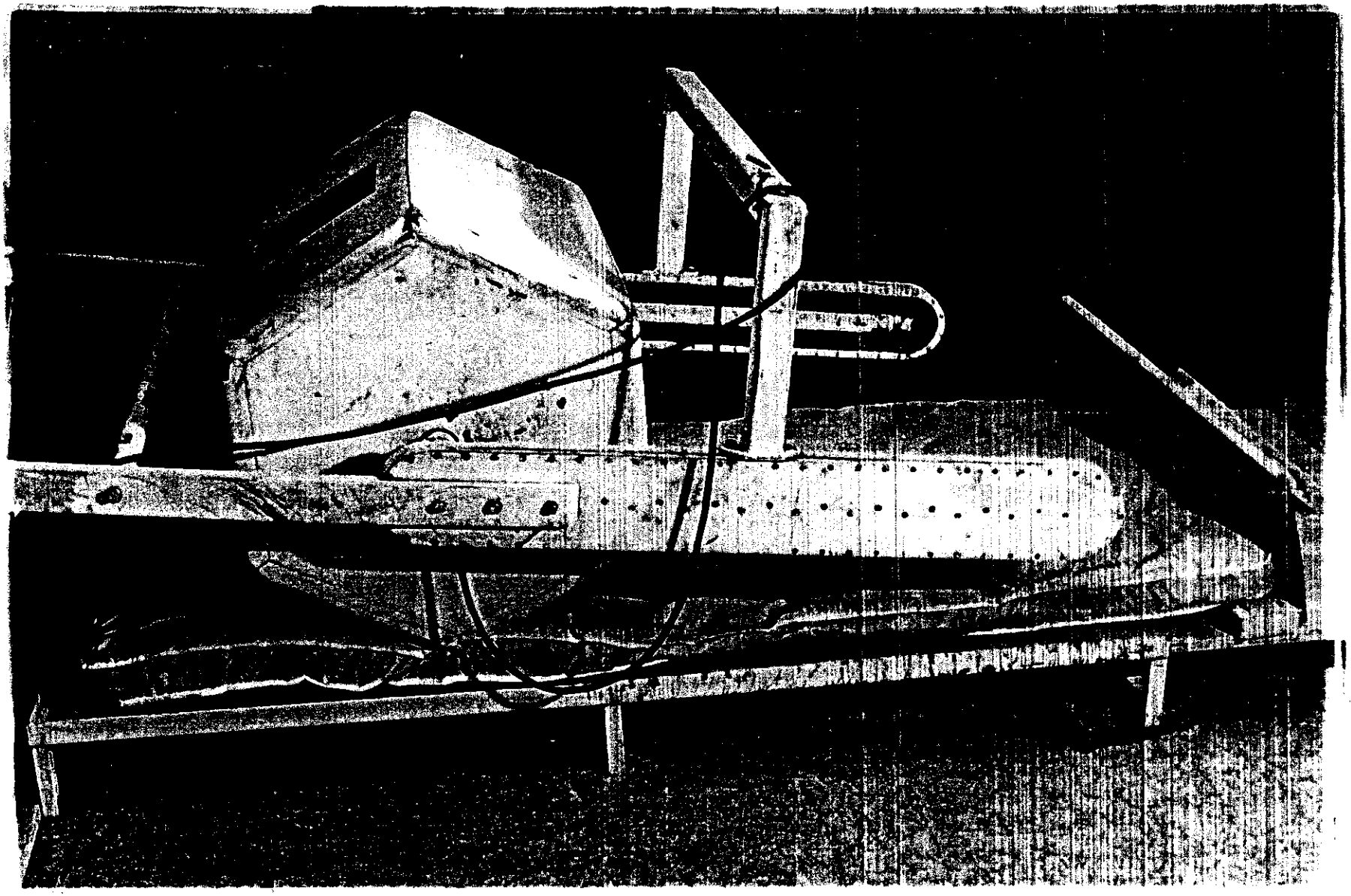
After three years of actual use and 135,000 cycles of accelerated wear the Hogan and Associates mattress easily passed the cigarette resistant requirements of FF 4-72, the Federal mattress flammability standard.

After three years of wear and 135,000 cycles of accelerated wear the treated cotton batting in the Hogan and Associates mattress did not meet the requirements of the UFAC prototype furniture test, using standard mattress ticking. It is possible that the initial boric acid levels were not high enough to meet this severe test, and that with higher initial boric acid levels the mattress filling material would meet the requirements of the UFAC even after the type of wear to which this test mattress was subjected.

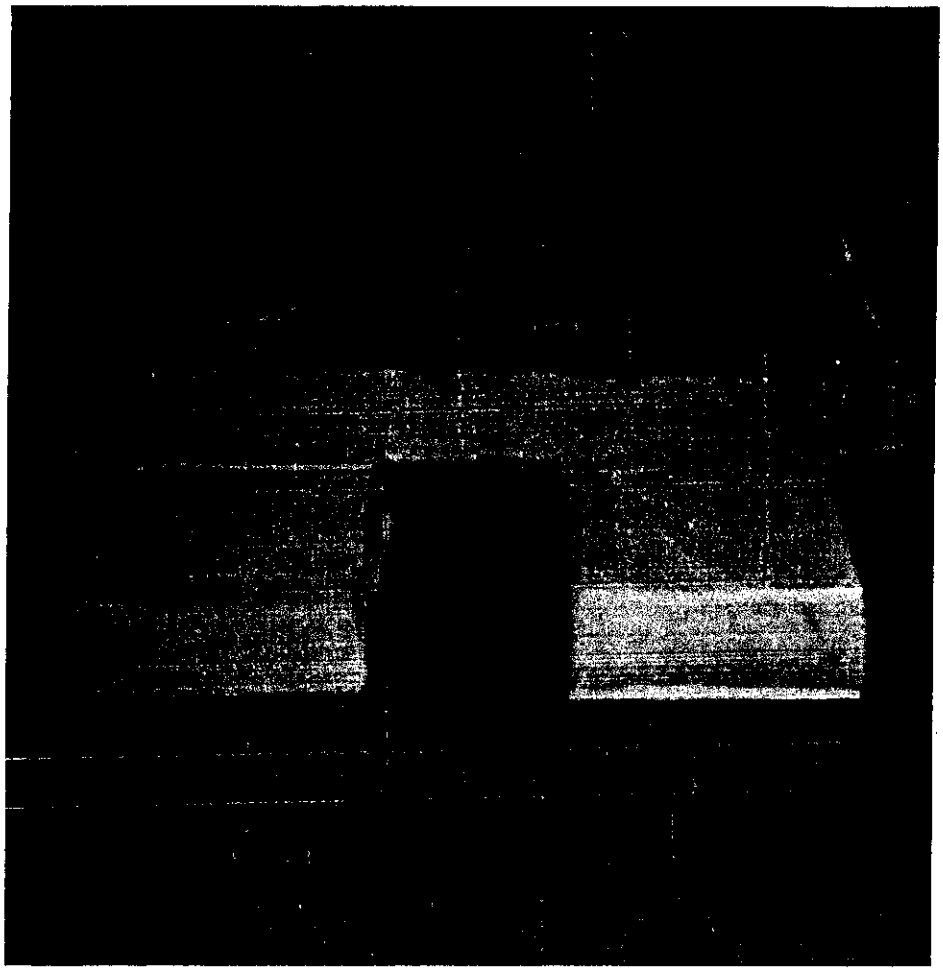
George S. Buck, Jr.
President

GSBjr:jj

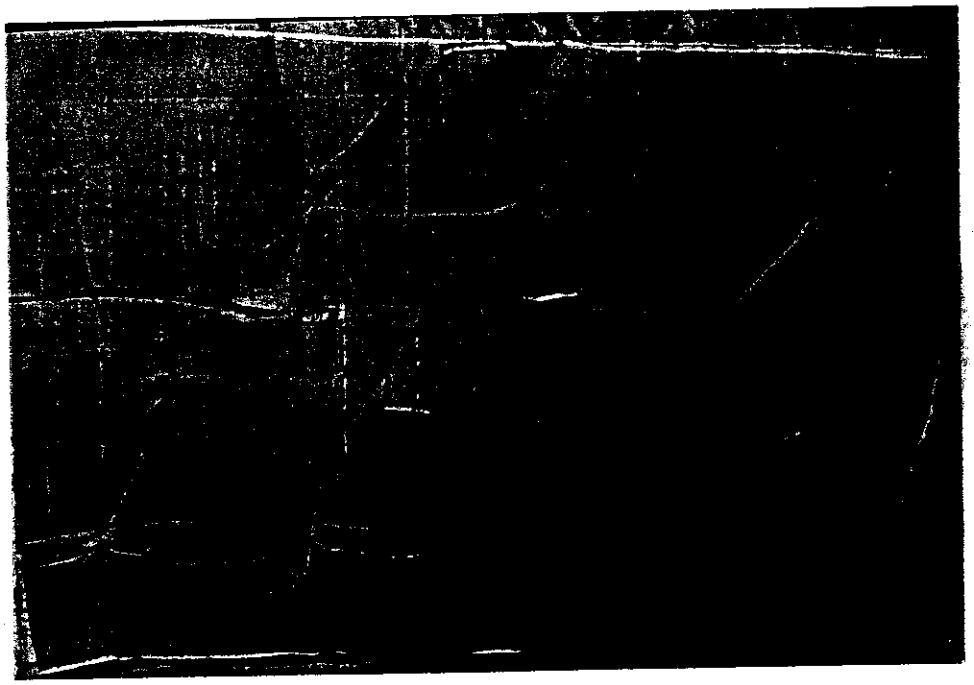
PERM-A-LATOR MATTRESS TESTING MACHINE



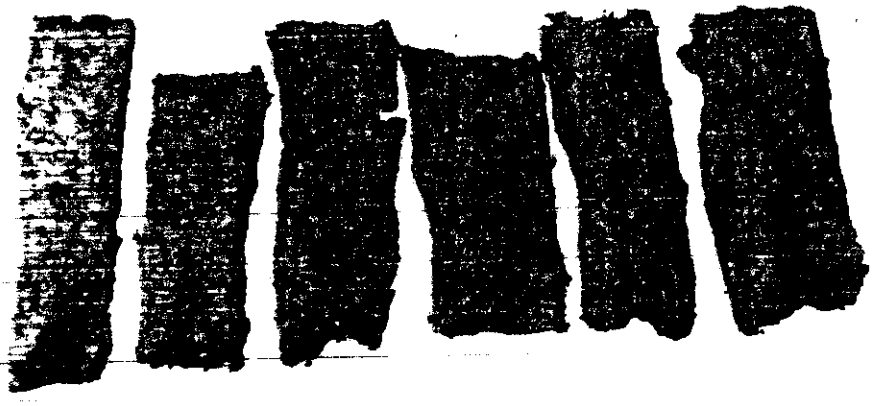
CUT AWAY VIEW OF MATTRESS AFTER 135,000 CYCLES ON PERM-A-LATOR MATTRESS TESTING MACHINE.



CIGARETTE TEST - FEDERAL STANDARD FF 4-72

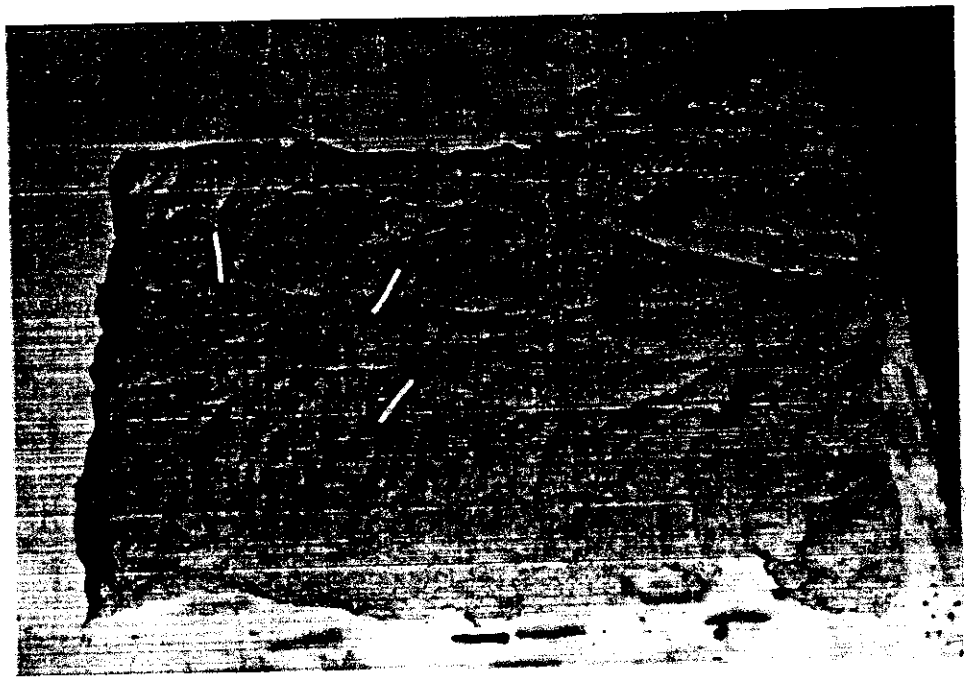


OPEN FLAME TEST - CALIFORNIA BULLETIN 117



CIGARETTE TEST - CALIFORNIA BULLETIN 117

CIGARETTE TEST - CALIFORNIA BULLETIN 117



HOGAN AND ASSOCIATES, INC.
P.O. Box 13212 Riverside Station
Memphis, Tennessee 38113
Telephone (901) 948-4469

ARKANSAS DEPARTMENT OF CORRECTIONS FR-MATTRESS

Actual prison use - 3 1/2 years

Test results from four different laboratories

No appreciable difference between the boric acid content of the top and bottom samples of FR cottnn batting.

No indication of leaching or migration of boric acid within the mattress.

A. L. [illegible]
[illegible]

[illegible] WHITE
[illegible]

March 15, 1983

Mr. Bob James
Regan and Associates, Inc.
1151 Channel Avenue
Memphis, Tennessee 38113

Dear Bob:

Thank you for your company's interest and participation in the recent meeting of the South Central Regional Correctional Industry Association. Your hospitality room was enjoyable and informative to everyone present.

Also, the closest we can come to aging the test mattress is 3½ years old, and it has been in continuous use.

Again, thank you and if I can be of any assistance to you, please don't hesitate to contact me.

Sincerely,

Bob Fletcher
Administrator
Correctional Industries

BF:blb

cc: File

HOGAN AND ASSOCIATES, INC.
P.O. Box 13212 Riverside Station
Memphis, Tennessee 38113
Telephone (901) 948-4469

April 1, 1982

Test results for boric acid content on State of Arkansas mattress.

These are the results from 4 sources.

Date:	Source	(1 side)	(Top)	(Random)
3-3-82	Hogan & Assoc.	9.6%	10.1%	9.4%
3-5-82	Barrow-Agee Lab.	8.9%		
3-23-82	U.S.D.A. (New Orleans)	9.1%	9.3%	
3-29-82	Guilford Lab.	12.0%	10.0%	11.5%
	Average	9.9%	9.8%	10.4%
	Overall Average	10.0%		

HOGAN AND ASSOCIATES, INC.
P.O. Box 13212 Riverside Station
Memphis, Tennessee 38113
Telephone (901) 948-4469 March 3, 1982

Chemical titration test on State of Arkansas prison mattress in use 4½ years.

Grade FR-55 Cotton Batting Felt:

Three tests were conducted on 3 samples of felt from this mattress.

Test #1. Sample from one side of mattress = 9.6% Boric Acid.

Test #2. Sample from other side of mattress=10.1% Boric Acid.

Test #3. Random sample from mattress = 9.4% Boric Acid.

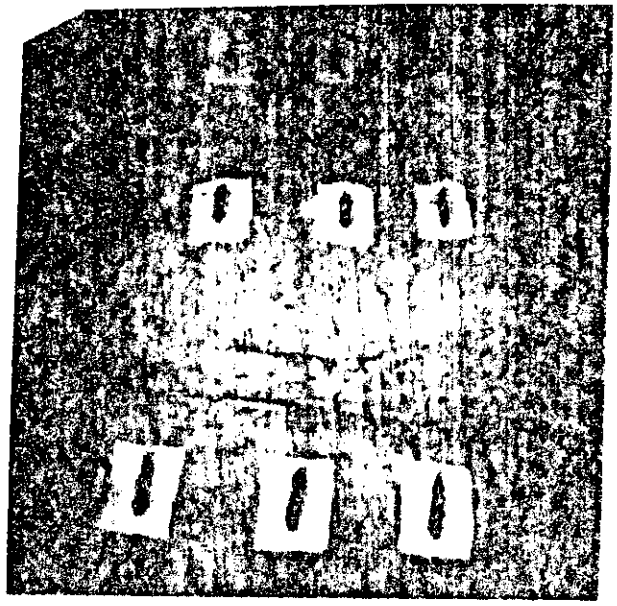
Average boric acid content from the 3 tests = 9.7%

Note: Visual observation upon opening this mattress indicated no boric acid laying within the ticking inside the mattress between the cotton batting and the ticking.

From the chemical titration tests conducted on th is mattress,which had been in use for 4½ years, there was no indication of leaching or migration of the boric acid within the mattress.

A cigarette burn test was also conducted on this mattress by laying 9 lit cigarettes covered with cotton sheeting on representative samples of cotton batting from this mattress and there were no failures in 9 cigarettes.

(Photo attached)



HOGAN AND ASSOCIATES, INC.
P.O. Box 13212 Riverside Station
Memphis, Tennessee 38113
Telephone (901) 948-4469

March 3, 1982

U.F.A.C. test conducted on cotton batting from State of Arkansas prison mattress which is reported to have been in use 4 years.

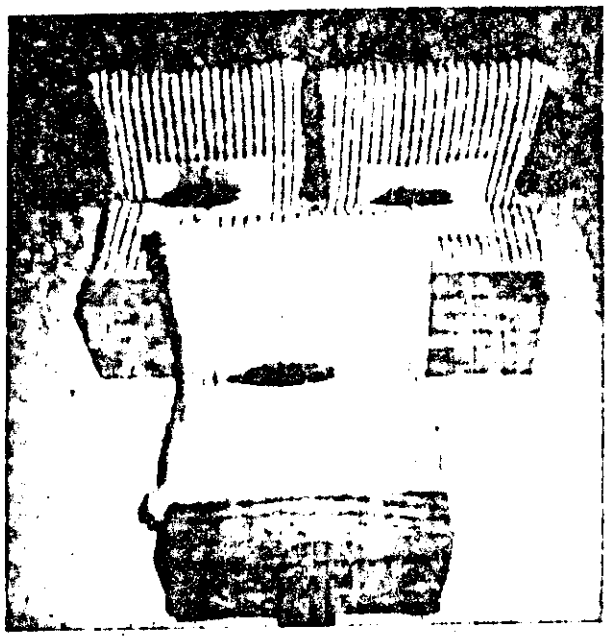
Three prototypes were tested in accordance with U.F.A.C. method for testing cotton batting felt in upholstered furniture.

The three samples tested had a vertical char of 1/2".
The criteria for the U.F.A.C. test states if any vertical char of 1.5 inches or greater is obtained in any one of the samples the filling/padding material fails the test.

Of the three samples tested each test obtained a vertical char not exceeding 1/2" which is well within the limits for the U.F.A.C. test.

Note: Even though the U.F.A.C. test is not a required test for mattress filling materials, we have found through experience in testing, it is a more stringent test than either the open flame test or the cigarette test which are standard test methods for mattress filling materials,namely cotton batting felt.

(Photo attached)



UNITED STATES DEPARTMENT OF AGRICULTURE
SCIENCE AND EDUCATION ADMINISTRATION

AGRICULTURAL RESEARCH
SOUTHERN REGION
SOUTHERN REGIONAL RESEARCH CENTER
1100 ROBERT E. LEE BOULEVARD
P.O. BOX 19687
NEW ORLEANS, LOUISIANA 70179

March 23, 1982

Mr. James Hogan
Hogan and Associates, Inc.
P. O. Box 13212 Riverside Station
Memphis, Tennessee 38113

Dear Mr. Hogan:

I received the sample of boric acid treated cotton batting that was taken from a mattress in use for over four years in the State of Arkansas penal institution. I appreciate the opportunity to evaluate these materials as we at the Research Center have been investigating flame/smolder resistant cotton batting for several years.

Our laboratory analysis is as follows:

boric acid content (top)	9.7%	9.2%	9.4%	9.1%
boric acid content (bottom)	8.7%	9.0%	9.5%	9.2%
UFAC filling/padding component cigarette test	Sample passed all criteria			
Open flame test	All flame and smolder self-extinguished once the flame was removed. Exposure time was one minute			

There is no appreciable difference between the boric acid content of the top and bottom samples. The top averaged 9.3% and the bottom averaged 9.1%. I should also comment that there was no noticeable boric acid powder in the packing box used in shipping these materials to us. However, this was not unexpected as I recall my visit to your plant a few years ago. I remember being quite impressed at that time how free your plant was of boric acid dusting, and how it was virtually impossible to shake the boric acid out of the treated batting. Apparently your method of mixing the boric acid powder and water insoluble organic spray lubricant is quite effective in physically adhering the boric acid and fibers together. In doing so, the boric acid is then "in the right place" during exposure to the ignition source, whether it be a cigarette or an open flame. As the temperature of the batting rises above 200°F the boric acid begins to decompose to water and boric oxide (boric acid is 43% water). The loss of water continues to approximately 340°F. Above 340°F only boric oxide remains. The boric oxide melts and flows freely like molted glass to coat the fibers at temperatures of about 800-1000°F. It is thought that this coating provides a barrier to retard the movement of oxygen and heat to the coated fibers. It is also believed that chemical bonding takes place between the boron and carbon atoms so as to alter the mechanism of oxidation of the charred fibers.

Temperatures inside the butt end of a burning cigarette have been measured as high as 1650°F. Such extreme ignition temperatures are easily resisted by boric acid treated cotton batting. The temperatures of open flames can vary considerably, depending upon the extent of combustion of the burning materials. For example, bunsen burner flame temperatures that have been measured at 1300°F, can theoretically produce a flame temperature of over 3000°F. When boric acid treated cotton batting materials are exposed to open flames the exposed areas will char, releasing smoke. However, once the flame is removed the material will self-extinguish, and the char will have only penetrated a small distance into the batting. (This behavior is likened to the ablative heat shields used in early space capsules during re-entry).

It is very important that consideration be given to both the flame and smolder resistance in regard to institutional mattresses. We should not forget that the Federal Flammability Standard for Mattresses permits untreated polyurethane core mattresses in the consumer market. These mattresses, although highly smolder resistant to cigarette ignition, burn like "gasoline fires" when exposed to open flames. It is obvious that penal institutions must protect against open flames - however protection against smoldering combustion must also be assured, as either combustion can be just as deadly as the other.

Sincerely,

Julius Neumeyer

JULIUS NEUMEYER
Chemical Engineer
Textile Chemical Engineering Research
Engineering and Development Laboratory

RROW-AGEE Laboratorie

E • P. O. BOX 156 • MEMPHIS, TENNESSEE 38101 • TELEPHONE 18
PA, NSPA, Memphis Board of Trade
merican Oil Chemists' Society

BARROW-AGEE Laboratories

8 SATURN DRIVE • P. O. BOX 156 • MEMPHIS, TENNESSEE 38101 • TELEPHONE (901) 332-1590
Official Chemists: NCPA, NSPA, Memphis Board of Trade
Referee Chemists: American Oil Chemists' Society

GAN & ASSOCIATES, INC.
MPHIS,
NNESSEE

HOGAN & ASSOCIATES, INC. 057057
MEMPHIS,
TENNESSLE

TTON BATTING FELT

TOP

TE OF ARKANSAS MATTRESS

1/2 YRS. OLD

Sample of COTTON BATTING FELT

Marked TOP

STATE OF ARKANSAS MATTRESS

4-1/2 YRS. OLD

C.C.

RON AS BORIC ACID 8.97%
(H_3BO_3)

BORON AS BORIC ACID 7.89%
(H_3BO_3)

Laboratory No.

552

...n of Official Agricultural Chemists and Official *Methods of Association of Official Agricultural Chemists and Official Methods of American C... Chemists Society Employed in This Analysis.*

GUILFORD LABORATORIES, INC.
P.O. Box 9735/Plaza Station/Greensboro, N.C. 27408

March 29, 1982

REPORT OF ANALYSIS

Job #: H&A20309

Customer: Hogan & Associates, Inc.

Samples: #3510; Sample #1, Top FR-55 St. Ark.
#3511; " #2, Bottom FR-55 St. Ark.
#3512; " #3, Random FR-55 St. Ark.

Request: Flammability analysis & % Boric Acid determination

RESULTS: UFAC Padding/Filling:

	vertical char (in.)		
Tests:	1	2	3
Sample #3	0.3	0.4	0.3

Sample #3 complies with the criteria of the UFAC Padding/Filling Test. There was not enough batting for Samples 1 & 2 to be tested.

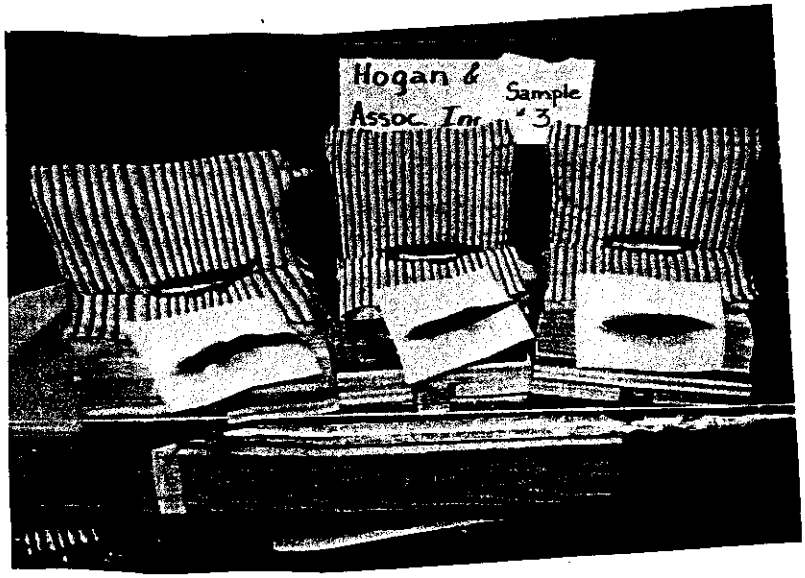
Boric Acid Determination: H3H-1

	% Boric Acid
Sample #1	10.0
#2	12.0
#3	11.5

If there should be any questions, please do not hesitate to contact us.

D LABORATORIES, INC./Sansia D. Hall

Sansia D. Hall



MATTRESSES AS REQUIRED BY U.F.A.C. AND STATE OF CALIFORNIA TECHNICAL BULLETIN 117.

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1. FLAME RETARDANT: (OPEN FLAME) CALIFORNIA BULLETIN 117

   A. SPECIMENS TESTED: A MINIMUM OF 5 SPECIMENS, EACH SPECIMEN 12" x 3", MAXIMUM THICKNESS OF 1" SHALL BE TESTED.

   B. CHAR LENGTH: MAXIMUM CHAR LENGTH OF EACH SPECIMEN TESTED SHALL NOT EXCEED 8 INCHES, AVERAGE NOT OVER 6 INCHES.

   C. AFTER FLAME: MAXIMUM AFTER FLAME SHALL NOT EXCEED 10 SECONDS, AVERAGE NOT OVER 5 SECONDS.

   D. AFTER GLOW: AVERAGE FOR THE 5 SPECIMENS SHALL NOT EXCEED 15 SECONDS.

---

2. CIGARETTE RESISTANT: CALIFORNIA BULLETIN 117

   A. SPECIMENS TESTED: A MINIMUM OF 3 SPECIMENS SHALL BE TESTED, LAYING A LIGHTED CIGARETTE ON EACH SPECIMEN COVERING THE CIGARETTE WITH A LAYER OF COTTON SHEETING. THE SPECIMENS SHALL BE 12" x 12" IN THICKNESS OF USE.

   B. CHAR LENGTH: MAXIMUM CHAR LENGTH SHALL NOT EXCEED 2 INCHES IN ANY DIRECTION OF CIGARETTE.

---

3. FILLING/PADDING COMPONENT TEST METHOD AS SET FORTH IN U.F.A.C. TEST PROCEDURES FOR NON MAN MADE FILLING MATERIALS USED IN UPHOLSTERED FURNITURE.

   A. TEST PROCEDURE WILL CONSIST OF TESTING 3 PROTYPES AS ILLUSTRATED IN FIGURES 1 AND 2 OF U.F.A.C. FILLING/PADDING TEST METHOD INSTRUCTION.

   B. IF ONE OR MORE IGNITIONS OF THE FILLING/PADDING MATERIAL AND COVER FABRIC OCCURS, THE MATERIAL FAILS THE TEST.

   C. IF ANY VERTICAL CHAR OF 1.5 INCHES OR GREATER IS OBTAINED, THE FILLING/PADDING MATERIAL FAILS THE TEST.

TEST RESULTS

STATE OF ARIZONA — 4 YR. OLD (MATTRESS)

DATE 3/3/82 CUSTOMER _____ BALE TAG # _____ SIZE _____

CIGARETTE RESISTANT

CHAR LENGTH

½"	½"	½"
1"	½"	½"
2"	½"	½"
½"	½"	½"

U.F.A.C. TEST

IGNITION	VERTICAL CHAR
0	½"
0	½"
0	½"

FLAME RETARDANT

CHAR LENGTH	AFTER FLAME	AFTER GLOW
½"	0 Sec.	8 Sec.
	Total	Sec.
		Average

Matthews 527

NCBI Comments on 16CFR 1633
Filed with the Consumer Product Safety Commission
March 29, 2005

The raw materials used in cotton batting consist of cotton gin motes (also referred to as "regins"), cotton linters, and sometimes raw cotton (100 percent cotton and cotton byproducts) and cotton textile mill byproducts (that usually contains some polyester). "Shoddy," reconstituted fiber from fabric cuttings and other textile mill yarn 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 can be further processed to remove cotton plants parts. Linters are fuzz fibers, less than 0.5 inch 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 byproducts, 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 waste fiber byproducts and this trend leads to fewer varieties of textile mill wastes. Textile mill byproducts 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 or/and needle punched product that is made flame resistance and smolder resistant either by using boric acid as the fire retardant or by blending with inherently flame resistant fibers (e.g., modacrylic and Basofil®). It is an improved product that can be used as a drop in component fire barrier in mainstream soft furnishings (i.e., mattresses/bedding and upholstered furniture).

FR-cotton battings can be used as surface or interior products. In the mattress industries, smolder and flame resistant cotton batting is used directly under cover fabrics as well as in inner padding layers as insulators, cushioning padding and for filling. 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. In filled bedclothes (mattresses pads, comforters, quilts, etc.) cotton batting can serve as the filling alone or in combination with other materials. In all of these applications, cotton batting can be helpful in meeting the various flammability requirements.

HEALTH EFFECTS OF BORIC ACID

Some have questioned the toxicity of borates and in particular boric acid. Toxicological research on boric acid that addresses human health and environmental effects of boric acid and borates has been conducted by Rio Tinto Borax for over 30 years. This research has shown that boric acid and borates are safe in consumer products such as futon, mattresses and upholstered furniture, since they have low intrinsic toxicity and the exposure to borates in these products is limited (i.e., toxic

doses to humans are unattainable from use of boric acid in mattresses, futons, bedclothes, and upholstered furniture).

The main source of boron for most humans is through the consumption of a normal healthy diet. Fruits, vegetables, and nuts are rich in boron. The U.S. national average intake of boron from diet is 1 to 2 mg/day. Boron, in the form of boric acid, is an essential micronutrient for plants and an integral part of a plant's life cycle. While it has not been proven that Boron is needed for humans to live, evidence is mounting in the scientific community, including the World Health Organization that boron is nutritionally important to maintain optimal human health and may be essential for humans.

In August 2004, the National Center for Environmental Assessment raised the allowable daily dose of human consumption of boron. The NCEA is the division of the Environmental Protection Agency charged with assessing health risks associated with substances found in the environment.

The increase from 6.3 milligrams to 14 milligrams was the result of a multi-year assessment of more than 200 studies on boron's health effects.

To be toxic boric acid must be internalized via ingestion, dermal absorption, and inhalation.

• **Ingestion (oral exposure)** – If boric acid is ingested, it will be excreted rapidly by the kidney. The half-life of boric acid is < 24 hours, and borates are not retained in fatty tissues. The lowest NOAEL (No Observable Adverse Effect Level, which is the highest dose used in laboratory studies in which exposed animals show no adverse effects) for borates was observed in studies of pregnant rats receiving boric acid. Rats that received 54.8 mg boric acid/kg/d showed no effects, whereas rats that received 76 mg boric acid/kg/day exhibited offspring with reduced birthweight. Thus, 54.8 mg boric acid/kg/d is the NOAEL. For a 60 kg woman to be exposed to the equivalent of this dose would require ingestion of around 3.3 grams of boric acid every day. A NOEAL from a separate study is used to determine the possibility of effects to male reproduction; however, this NOAEL is well above 54.8 mg boric acid/kg/d, and so the most conservative and relevant threshold value for humans is 3.3 g boric acid/day. This level of exposure is unachievable from the use of boric acid in sleep products or other soft furnishings.

• **Dermal absorption** – Exposure to boric acid could occur from a ripped or otherwise damaged mattress. However, health effects are unlikely to occur because boric acid has only negligible absorption across intact skin.

• **Inhalation** – For boric acid to be toxic by inhalation it would necessitate a concentration of suspended boric acid in the air of 493 mg/m3, which is 50 times higher than the concentrations observed in boric acid processing plants. This would be unattainable from the use of boric acid in sleep products and other soft furnishings.

The NCBI currently is testing to determine the exposure levels of boric acid that might be released from mattresses and futons containing cotton batting. The testing of TB603 compliant mattresses is being conducted under the simulated harsh condition of a child bouncing on the bed/futon. Test protocol includes the positioning of a filtered air pump above the surface of the bed to test the air for boric acid before, during, and after the test function. The surface of the mattress will be tested before and during the test by means of a wipe to determine the amount of borate that might come through the mattress fabric.

(NOTE: The testing was to be completed before the March 29 deadline for these comments. However, the laboratory conducting the tests experienced equipment failure, delaying completion of the project. The NCBI will submit results to the Consumer Product Safety Commission upon the completion of the testing.)

• Toxicity of Boric Acid

-Acute Toxicity: Oral LD50 2660 - 4100 mg B/kg (obtained from rat studies) - Chronic Toxicity: Reproductive and Developmental Effects Controlled toxicity tests performed on laboratory animals at high doses have resulted in effects on reproduction in males and developmental effects on the fetus in females. However, humans could not be exposed to sufficient boric acid to cause a reproductive effect from soft furnishings. Only serious abuse or by deliberate ingestion by humans could equivalent does that cause effects in animals be reached; effects such as vomiting and diarrhea at these and lower does (e.g., 2g/day) would prevent both continual and single intake of high oral does by humans.

□ Reproductive Effects:

-No observable adverse effects (NOAEL) observed at concentrations > 100 mg BA/kg/day

-Equivalent dose for 70 kg man: 7.0 g BA/day

□ Developmental Effects:

-No effects observed at concentrations > 54.8 mg BA/kg/day

-Equivalent dose for 60 kg woman: 3.3 g BA/day

□ Cancer: Borates are non-carcinogenic.

In summary, boric acid and borates are safe in consumer products such as futons, mattresses and upholstered furniture, since they have low intrinsic toxicity and the exposure to borates in these products is limited (i.e., toxic doses to humans are unattainable from use of boric acid in mattresses, futons and upholstered furniture).

UL/NCBI THIRD-PARTY CERTIFICATION PROGRAM

Introduction/History

Suppliers to the mattress industry were mandated by the Federal government [DOC/CPSC Mattress Standard 16 CFR 1632] (17) in 1972 to make their products cigarette (smolder) resistant and in 1974 cigarette and open flame resistant requirements were mandated by California for Upholstered Furniture (TB117). The National Cotton Batting Institute (NCBI) member-companies responded by working with the U.S. Department of Agriculture (USDA), ARS, SRRC in developing a protective product: boric acid-treated cotton batting. There were basically three flammability test protocols to comply with: the CPSC Federal Standard FF4-72 (now 16 CFR 1632), California TB117-vertical flame test for batting, and UFAC Padding and Filling test.

In the early 1980s, because there were indications that unacceptable cotton batting was being sold and that cotton batting was being considered a "bad actor" in the fire safety arena, NCBI developed a voluntary quality assurance program called SAF'R'BATT. This allowed a way for members to show that they were complying with the required flammability tests. However, the problem of non-compliance in the industry still continued to exist. The SAF'R'BATT program was discontinued by the late 1980s because NCBI members realized little or no benefit in the marketplace and there was continued apathy on the part of customers.

In 1989-92, NCBI developed a "quick" test method that was actually harsher than the required flammability tests. This test is ASTM D 5238-98 – the cotton batting sandwich test. This provides a fast and effective procedure to check the performance of the cotton batting and can be used by manufacturers for quality control during manufacturing and by customers to show that the product they are buying meets the required flammability tests.

In the mid 1990s, NCBI instituted a monitoring program where the customers are the enforcement agents. This is the NCBI/UFAC Quality Assurance Program. As part of this program, an instruction manual and video were provided to customers in order that they could help make sure the products they received were manufactured properly and passed the UFAC Padding and Filling test by using ASTM 5238.

However, again people were apathetic and the "good players" saw no real benefit from the program. It had become obvious that NCBI could not police the entire cotton batting industry nor could its customers. Therefore, NCBI members felt that it was imperative to have an independent third party to monitor compliance in efforts to prevent non-compliance. Underwriters Laboratories (UL) was selected by NCBI as the best program. In September 1998 NCBI members voted to make compliance with UL certification mandatory for membership in NCBI. The program was instituted in March 1999 and has been very positive.

Elements of the UL Independent Third-Party Certification Program:

- Unannounced inspections at least quarterly
- Testing (CA TB117, UFAC)

□ Cigarette (smolder) and open flame resistance (TB 117)

□ UFAC Padding and Filling Test [Cigarette (smolder) resistance ignition]

NCBI Quality Assurance Element of the Program:

- During the manufacturing of FR-cotton batting, NCBI certified members have to test no less than every two hours using ASTM 5238 and keep records of testing results which UL reviews.
- Monthly reports have to be prepared
- Quarterly UFAC tests and analysis of chemical content are required

This independent third-party certification program validates cotton-based batting as a way to meet the regulatory concerns of flammability confronting manufactures of mattresses/foundations, futons, filled bedding products, and upholstered furniture.

In summary, mattress, futon, bedclothes and upholstered furniture manufactures who want to purchase and use FR-cotton batting now have sources to purchase smolder and flame resistant cotton batting that is certified as appropriate for use in meeting flammability standards.

PREPARATION OF FR-COTTON BATTING: CIGARETTE (SMOLDER) AND OPEN FLAME RESISTANT

Boric Acid Treatment

In the early 1970s the USDA, developed the process of adding boric acid to cotton to produce smolder and flame resistant cotton batting. The application process has been improved in recent years so that boric acid no longer dusts-out or leaches-out of the batting. (See Appendix A, results of testing for loss of boric acid in mattresses with a history of use.)

Boric acid (about 10 percent) is added to the raw materials in the willow or mixing machine prior to garnetting along with a lightweight oil and 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 the boric acid evenly distributed and there is little or no dust-out or leach-out of the boric acid. (See Appendix A, results of testing for loss of boric acid in mattresses with a history of use.)

To produce a thermal bonded batting about 10-20 percent 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.

Fiber Blend Products

To make the batting smolder and flame resistant as well as durable to wet treatments inherently flame resistant fiber such as modacrylic and Basofil® can be added and blended with the "cotton" fibers with or without a low-melt polyester. In this way the various batting products can be produced for use as fire blocking barriers or as filling material.

Properly prepared FR-cotton batting passes the harshest of smolder resistant as well as open flame tests.

RESULTS OF FR-TESTING:
BURNING PROPERTIES OF COTTON BATTING

Untreated Cotton

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

Test method: ASTM D5238-98 ("sandwich batt" test) 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 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.

Open Flame Ignition

Properly prepared 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: Cotton batting was tested using a modified TB 117 vertical open flame test -- the ignition source was modified from a 1.5-inch high flame to a 4-inch high flame and the burn time was extended from 12 seconds to 10 minutes.

Results: The piece of cotton batting tested only charred, and flaming ceased when the ignition source was stopped.

Test method: Cotton batting was also tested using a modified version of the draft proposed revised TB 117 test method 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 seconds to 10 minutes.

Results: The cotton batting only charred and did not burn through.

Test method and results: Mattresses made with FR-cotton batting as the primary barrier material have passed • TB 129 and TB 603.

SUMMARY

In summary, engineered cotton batting properly treated with boric acid or blended with inherently flame resistant fibers (e.g., modacrylic or Basofil®) 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 barrier in mainstream soft furnishings (i.e., mattresses/bedding and upholstered furniture). It should be helpful in meeting the various cigarette resistance and open flame resistance regulations for mattresses, futons, and upholstered furniture.

Appendix A

Results of Testing for Loss of Boric Acid-treated Cotton Batting In Mattresses with a History of Use

UNITED STATES DEPARTMENT OF AGRICULTURE
SCIENCE AND EDUCATION ADMINISTRATION

AGRICULTURAL RESEARCH
SOUTHERN REGION
SOUTHERN REGIONAL RESEARCH CENTER
1100 ROBERT E. LEE BOULEVARD
P.O. BOX 19687
NEW ORLEANS, LOUISIANA 70179

March 23, 1982

Mr. James Hogan
Hogan and Associates, Inc.
P. O. Box 13212 Riverside Station
Memphis, Tennessee 38113

Dear Mr. Hogan:

I received the sample of boric acid treated cotton batting that was taken from a mattress in use for over four years in the State of Arkansas penal institution. I appreciate the opportunity to evaluate these materials as we at the Research Center have been investigating flame/smolder resistant cotton batting for several years.

Our laboratory analysis is as follows:

boric acid content (top)	9.7%	9.2%	9.4%	9.1%
boric acid content (bottom)	8.7%	9.0%	9.5%	9.2%
UFAC filling/padding component cigarette test	Sample passed all criteria			
Open flame test	All flame and smolder self-extinguished once the flame was removed. Exposure time was one minute			

There is no appreciable difference between the boric acid content of the top and bottom samples. The top averaged 9.3% and the bottom averaged 9.1%. I should also comment that there was no noticeable boric acid powder in the packing box used in shipping these materials to us. However, this was not unexpected as I recall my visit to your plant a few years ago. I remember being quite impressed at that time how free your plant was of boric acid dusting, and how it was virtually impossible to shake the boric acid out of the treated batting. Apparently your method of mixing the boric acid powder and water insoluble organic spray lubricant is quite effective in physically adhering the boric acid and fibers together. In doing so, the boric acid is then "in the right place" during exposure to the ignition source, whether it be a cigarette or an open flame. As the temperature of the batting rises above 200°F the boric acid begins to decompose to water and boric oxide (boric acid is 43% water). The loss of water continues to approximately 340°F. Above 340°F only boric oxide remains. The boric oxide melts and flows freely like molted glass to coat the fibers at temperatures of about 800-1000°F. It is thought that this coating provides a barrier to retard the movement of oxygen and heat to the coated fibers. It is also believed that chemical bonding takes place between the boron and carbon atoms so as to alter the mechanism of oxidation of the charred fibers.

Temperatures inside the butt end of a burning cigarette have been measured as high as 1650°F. Such extreme ignition temperatures are easily resisted by boric acid treated cotton batting. The temperatures of open flames can vary considerably, depending upon the extent of combustion of t burning materials. For example, bunsen burner flame temperatures that hav been measured at 1300°F, can theoretically produce a flame temperature of over 3000°F. When boric acid treated cotton batting materials are expose to open flames the exposed areas will char, releasing smoke. However, on the flame is removed the material will self-extinguish, and the char will have only penetrated a small distance into the batting. (This behavior is likened to the ablative heat shields used in early space capsules during re-entry).

It is very important that consideration be given to both the flame and smolder resistance in regard to institutional mattresses. We should not fo that the Federal Flammability Standard for Mattresses permits untreated po urethane core mattresses in the consumer market. These mattresses, althoug highly smolder resistant to cigarette ignition, burn like "gasoline fires" when exposed to open flames. It is obvious that penal institutions must protect against open flames - however protection against smoldering combus must also be assured, as either combustion can be just as deadly as the ot

Sincerely,

JULIUS NEUMEYER
Chemical Engineer
Textile Chemical Engineering Research
Engineering and Development Laboratory

RAMCON INCORPORATED

RAMCON BUILDING 223 SCOTT STREET MEMPHIS, TENNESSEE 38112 TELEPHONE 901 / 458-7000 TELEX 53-806

SPECIAL MATTRESS TESTING REPORT

On March 10, 1982 we received from Mr. James N. Hogan of Hogan & Associates, Inc. of Memphis, Tennessee a mattress on which we conducted a number of tests.

It is our understanding that the mattress supplied by Mr. Hogan had been in use in a penal institution for more than three years prior to our receiving it for test. It is also our understanding that the filling material in the mattress is smoulder-resistant cotton batting made from a boric acid-treated cotton manufactured by Hogan & Associates formerly Kroehler Manufacturing Company.

The mattress is a slab or solid core type (no innerspring) approximately three inches thick and containing approximately 25 pounds of the treated cotton batting. The covering is "Staff Check" coated fabric ticking.

The boric acid content of the cotton batting in the mattress was measured by Dr. Gareth Barnard of our laboratory. In the mattress as received by us, samples were drawn from three levels of the batting which were designated as "top", middle, and "bottom". The "as received" boric acid content at each level was 9.2% for the top, 9.5% for the middle, and 8.8% for the bottom.

After these measurements were made, the mattress was placed on a test stand and subjected to accelerated wear testing under a 250 pound hexagonal wooden roller. This roller was operated for 135,000 cycles, which is a wear test sufficiently long in most cases to destroy even the spring of an innerspring mattress. Although the number of cycles cannot be accurately related to years of actual use, our accelerated wear test is probably equivalent to the normal wear life of a mattress.

After subjecting the mattress to the 135,000 cycles of accelerated wear, the boric acid levels from the "top", "middle", and "bottom" thirds of the cotton filling material were again measured. The concentrations were 8.1% in the "top", 7.9% in the middle, and 7.6% in the "bottom" levels of the batt.

From this test we conclude that the mechanical working of a mattress containing boric acid-treated cotton applied by the method of Hogan & Associates will have a relatively minor effect on boric acid levels during the normal service life of such a mattress.

To determine the effect, if any, on the smoulder-resistant and fire-resistant properties of the batting and mattress, we conducted the following tests:

I. Open Flame Test - California Bulletin 117

Sample No.	After Flame (secs.)	After Glow (secs.)	Char Length
1	-0-	-0-	< 1/4"
2	-0-	-0-	< 1/4"
3	-0-	-0-	< 1/4"
4	-0-	4	< 1/4"
5	-0-	-0-	< 1/4"

II. Cigarette Test: California Bulletin 117

#1 plain surface without sheets	1/4"	#1 surface with sheets	1/4"
#2 plain surface without sheets	1/4"	#2 surface with sheets	1/4"
#3 plain surface without sheets	1/4"	#3 surface with sheets	1/4"

All Passed

III. FF 4-72 Test Results:

SMOOTH	QUILTED	TAPED
Passed	Passed	Passed
Passed	Passed	Passed
Passed	Passed	Passed

Without Sheets

SMOOTH	QUILTED	TAPED
Passed	Passed	Passed
Passed	Passed	Passed
Passed	Passed	Passed

IV. UFAC TEST:

Prototype #1 sustained smouldering. Number 2 vertical char, less than 1/2". Number three sustained smouldering.

V. Thickness of mattress prior to test was approximately three inches and after 135,000 cycles of accelerated wear was still three inches, within the limits of measurement.

Summary

The accelerated wear testing and subsequent flammability evaluation made on the mattress submitted by Hogan and Associates indicated that mechanical action of wear during use will have a relatively minor effect on the boric acid concentration in the cotton batting of slab or solid core mattresses made by the process employed by Hogan and Associates.

Even after three years of actual use the 135,000 cycles of accelerated testing, the Hogan and Associates mattress easily passed the open flame vertical test specified by California Bulletin 117.

After three years of actual use and 135,000 cycles of accelerated wear the treated cotton batting in the Hogan and Associates mattress met the cigarette resistant requirements of California Bulletin 117.

After three years of actual use and 135,000 cycles of accelerated wear the Hogan and Associates mattress easily passed the cigarette resistant requirements of FF 4-72, the Federal mattress flammability standard.

After three years of wear and 135,000 cycles of accelerated wear the treated cotton batting in the Hogan and Associates mattress did not meet the requirements of the UFAC prototype furniture test, using standard mattress ticking. It is possible that the initial boric acid levels were not high enough to meet this severe test, and that with higher initial boric acid levels the mattress filling material would meet the requirements of the UFAC even after the type of wear to which this test mattress was subjected.

George S. Buck, Jr.
President

GSBjr:jj

OFFICIAL CERTIFIED TEST RESULTS

SHELBY COUNTY SHERIFFS DEPARTMENT MATTRESS

3 YEARS 2 MONTHS OF ACTUAL USE IN SHELBY COUNTY JAIL

SPECIAL MATTRESS TESTS BY RAMCON INC.

Mattress subjected to accelerated wear testing on Perm-A-Lator mattress testing machine for 135,000 cycles after being in actual use for 3 years and 2 months.

(Mattress manufacturers state this represents a minimum of 10 years usage.)

TEST RESULTS BY RAMCON INC.

From this test we conclude that the mechanical working of a mattress containing boric acid-treated cotton applied by the method of Hogan & Associates will have a relatively minor effect on boric acid levels during the normal service life of such a mattre-s.

FR Cotton passed California Bulletin 117 test

Mattress passed FF 4-72 Federal Standard

Thickness of mattress prior to testing - 3"

Thickness of mattress after testing - 3"

CONCLUSIONS

Original FR Cotton produced by Hogan & Associates on 11-28-78 passed all smolder and fire resistant tests

The same mattresses and FR Cotton passed all smolder and fire resistance under an actual malicious aggravated arson attempt at Shelby County Sheriffs Department Prison on Feb. 3, 1981

FR Cotton taken from the same group of mattresses passed all smolder and fire resistant tests on March 10, 1981

FR Cotton taken from the same group of mattresses passed all smolder and fire resistant tests on March 12, 1982

A mattress taken from the same group passed the Special Mattress Test by Ramcon Inc., as stated above, on April 28, 1982. This test simulates a minimum of 13 years usage

January 17, 2003

Mr. John McCormack
Bureau of Home Furnishings
And Thermal Insulation
3485 Orange Grove Avenue
North Highlands, CA 95660-5595

Dear Mr. McCormack,

It has come to my attention that there has been some discussion about the possibility of cotton batting/pads treated with boric acid having a problem with leaching when subjected to water. While it is true that boric acid is an inorganic borate that is water-soluble I cannot imagine a "real" situation that would render the product in a mattress or upholstered furniture unsafe without ruining the entire unit. In order to "wash" the boric acid out of the fiber it would have to become totally saturated and flushed. I submit to you that any filling material that would have the opportunity to be subjected to such harsh circumstances would be ruined and lose its value as a filling material.

Under normal and even excessive use there are numbers of documented cases where cotton batting treated with boric acid remained very effective after being taken out of service. I cite the following as a partial listing of these examples:

1. Louisiana State Penitentiary – Angola, LA 1982. A fire consumed everything inside the mattress manufacturing area of the prison with the exceptions of concrete, steel and cotton mattresses. In the housing area piles of mattresses were found to be extinguished and smoldering but the cotton inside had not burned away. Pursuant to this event the LSU Fireman Training Center pulled mattresses from the Cammeron Parish Jail in Louisiana. These mattresses had been in use for approximately 2 years. They were subjected to a fire test with the ignition source being a rolled newspaper placed into the mattress also in a rolled configuration. The mattress charred and smoldered but did not burn away. The LSU Fire Training Center stated that they were "very pleased with the performance of the boric acid treated cotton after being in the field for some time".
2. Shelby County Jail – Shelby County, TN 1981. Inmates stacked several mattresses and tried to ignite them. "The mattresses," said arson officials, "did not burn well." The mattresses were recovered and the cotton was extracted and tested for compliance to TB 117and UFAC. They passed both with ease. The cotton was then

analyzed for boric acid content. The boric acid level in the cotton batting ranged from 9.4% to 10.1 %. These mattresses had been wetted as a result of the fire departments efforts to contain the fire (really only smoke).

3. State of Arkansas Corrections 1982. Several mattresses were taken out of service after fours years of use in the Arkansas State Prison. The mattresses were sent USDA in New Orleans for testing and evaluation. The boric acid treated cotton batting inside these mattresses was tested for compliance to Cal TB 117 and UFAC. All specimens passed and self extinguished. The samples were then analyzed for boric acid content. The boric acid in the cotton batting ranged from 8.7% t0 9.7%. This was done after these mattresses had been subjected to over four years of harsh use.

I cannot reason that any test procedure in which padding or filling components would be subjected to submersion and flushing by water could remotely correlate with the harshest of conditions in actual use.

I respectfully submit this information for your consideration.

Yours truly,

Kenneth R. Oliver
President
Jones Fiber Products, Inc.
Memphis, TN 38113

NESTOR B. KNOEPFLER, JOHN P. MADACSI AND JULIUS P. NEUMEYER

Southern Regional Research Center *
New Orleans, Louisiana 70179

PERMANENCE OF BORON CONTAINING TREATMENTS FOR COTTON BATTING PRODUCTS THAT MEET THE MATTRESS FLAMMABILITY STANDARD FF 4-72**

(Received February 5, 1975)

ABSTRACT: Mattresses manufactured after December 22, 1973, are required to comply with FF 4-72 by passing a cigarette test. The standard requires protection against smoldering combustion, which involves a degree of resistance not encountered in flame retardance for fabrics. The borates are the only chemical systems found to yield cotton batting for mattresses that pass the standard. Of concern in the use of the borate is their lack of durability. Storage tests on cotton batting treated with various boric oxide donors showed that the greatest loss of boric oxide occurs during the first 60 days after manufacture. The rate of loss was related to the amount of boric oxide donor that was surface deposited and also to the solvent employed in the treatment. When the boric oxide content was maintained at 4.1% in samples treated using aqueous systems and at 2.4% in samples treated from alcohol solvent systems, the mattresses passed FF 4-72 after prolonged storage.

INTRODUCTION

COTTON BATTING CAN be rendered flame retardant by the application of urea phosphates, borated amido polyphosphates, or ammonium phosphates, alone or in combination with thermoplastic or thermosetting resins [1, 2, 3, 4]. Such products pass the AATCC vertical flame test [5] and the modification of that test developed at SRRC for batting products thicker than ½ inch [6]. The products can readily meet the requirements of Motor Vehicle Standard 302 [7]. The treated products exhibit "after-glow" values of less than five seconds when tested by either the AATCC or the MVSS 302 procedures. However, when these treated cotton batting products are assembled in mattresses and the composite structure evaluated

*One of the facilities of the Southern Region, Agricultural Research Service, U.S. Department of Agriculture.

**Presented at the 1974 AATCC National Technical Conference, Braniff Place, New Orleans, Louisiana, October 9–12, 1974.

This work is being carried out under a Cooperative Agreement between the U.S. Department of Agriculture and the National Cotton Batting Institute and under a Memorandum of Understanding with the Textile Fibers and ByProducts Association and the National Cottonseed Products Association.

The Mattress Flammability Standard does not in any way indicate or demand performance after storage or use for extended periods of time. However, the wording of PL 90-189 of December 14, 1967, which amended the Flammable Fabrics Act of 1953 to include mattresses, is such that manufacturers may be liable for failure even after their product has been in service for many years. This paper will report storage tests of treated cotton batting with particular emphasis on the loss of boric oxide under steady state elevated temperatures at 65% relative humidity.

EXPERIMENTAL AND RESULTS

The rawstock for this work consisted of a blend of 60% Delta first cut linters and 40% textile waste fibers from the Piedmont area. The first cut linters and the textile waste fibers were individually cleaned in conventional textile mill equipment. After cleaning the textile waste fibers were formed into picker laps. The linters needed to achieve the 60%–40% ratio were spread by hand on the laps, and the mixture repassed through the picker to form laps. These laps, which were quite uniform in fiber content, served as feed for subsequent operations.

One- to two-gallon batches of the aqueous treating formulations were prepared in the laboratory. The concentration of the formulation was adjusted to achieve the desired add-on with approximately 100% wet pick-up. When solutions were limited by saturation values, the wet pick-up was controlled to yield the desired add-on after drying. Similar batches of formulations were used for the treatments that included the alcohols. For these, however, the alcohol-water ratios were varied to obtain the desired concentration of boric acid to yield dry add-ons sufficient to pass FF 4-72 when the wet pick-ups were about 100% by weight of the cotton being treated.

Samples of the lap were weighed dry, then fed to a laboratory padder. The wet impregnated lap was reweighed to determine the wet pick-up. To obtain a preselected wet pick-up, the pressure on the padder squeeze rolls was adjusted and the wet lap was repassed through the padder and then reweighed. The treated rawstock was dried in a laboratory circulating air oven at approximately 220°F. After equilibration for 24 hours the treated rawstock was sampled for chemical analysis and then garnetted to yield batts 3/4 inch thick with a nominal density of 2.0 pounds/ft^3.

The treated batts were equilibrated overnight and again sampled for chemical analysis before being assembled into miniature (mini-) mattresses as shown in Figure 1. A control grey and white pin stripe ticking weighing 8 oz. yd was used for all tests. The ticking was not treated for flame retardance. The sewn ticking was pulled down over the mock-up structure so that the valley formed at the roll edge was 1½ inch above the base plate, and the crown of the mini-mattress was 2¼ inch above the asbestos sheeting. The ticking was held in place by six ¾-inch binder clips. The ends of the mini-mattress were then sealed with 2-inch wide masking tape.

by the cigarette test of the Mattress Flammability Standard FF 4-72 [8], smoldering combustion ensues and the mattresses fail to pass the standard [9, 10]. Phosphorus compounds, although considered to be efficient inhibitors of both flaming and glowing in cellulosic fabrics, are not effective for the prevention of smoldering combustion in mattress structures [9, 10, 11, 12].

Boric oxide donors such as ammonium pentaborate and boric acid are effective in conferring smolder resistance to cotton batting. The action of these salts in forming boric oxide glasses at about 325°C and the softening and flow of the glasses at about 500°C coat the fibers during the combustion reactions. The boric oxide glasses are thermally stable at temperatures greater than 750°C [12, 13].

Thermoanalytical data [12] has shown that borax-boric acid treatments for cotton batting are less effective than boric acid alone in inhibiting smoldering combustion. The decreased effectiveness can be attributed to the catalytic effect of the Na^+ ion on the oxidation of the carbonaceous char remaining after pyrolysis [12] especially under the high temperatures (above 400°C) existing in mattresses undergoing smoldering combustion. Alkali metals are known to catalyze carbon oxidation [14].

The limited solubility of boric acid in water at room temperature (20–25°C) creates problems in treating cotton batting. To obtain the desired 8–10% dry add-on of boric acid from a 100% wet pick-up during processing the water must be heated to about 70°C. This introduces another problem. When hot water is used, boric acid is deposited on the surface of the fibers as they cool.

Many alcohol type solvents dissolve boric acid in higher concentrations than water does. Among these are methanol, ethanol, and glycerol. 2-propanol, also included in this study, does not have a very high solvating action on boric acid, but it has the unusual characteristic of being a solvent for boric acid that is intolerant of water. Water added to 2-propanol solutions of boric acid immediately precipitates crystalline boric acid. Previous research at SRRC has also shown that the solubility of boric acid in ambient temperature water can be improved by the presence of 2 to 4% ammonium carbonate by weight of the total mixture [15]. Similarly, many of the borax-boric acid mixtures that were evaluated were chosen because they improve the solubility of the boric acid at room temperature.

Of concern in the use of the borate salts or boric acid for preventing smoldering combustion is their instability when exposed to elevated temperatures and high relative humidity. It is well known that boric acid is volatile, exhibiting significant vapor pressure in its solid state as well as in water solutions [16, 17, 18, 19, 20, 21, 22, 23, 24]. Fabrics treated with borax-boric acid and then exposed to 88% relative humidity and 120°F for two weeks show increasing afterglow when tested as the storage proceeds [25]. The loss of glow resistance in fabrics exposed to saturated air at 65°C for 24 hours is attributed to losses of boric acid from the fabric [25, 26, 27]. Researchers have pointed out that borax-boric acid treatments are not durable and should not be used when service for more than one year is required [25, 26, 28].

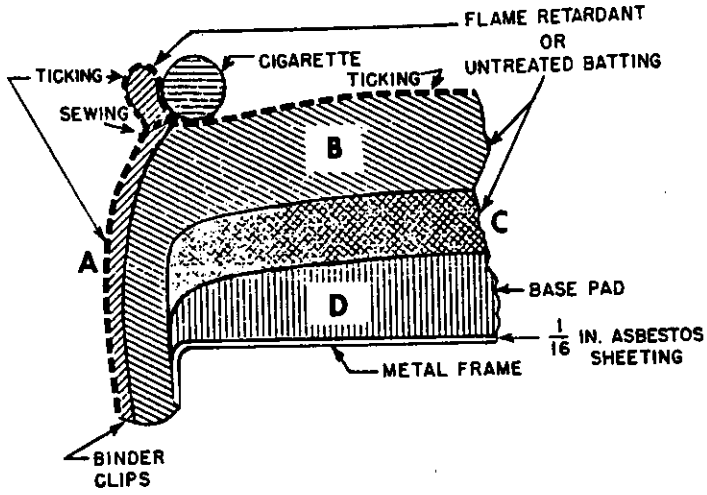

Figure 1. Typical mini mattress construction.

Laboratory evaluations have shown that the most vulnerable place for cigarette ignition is the tape or roll edge [10]. Subsequent testing of the mini-mattresses was therefore carried out by placing a lighted cigarette in the valley formed by the roll edge and the flat surface of the bare mini-mattress. Three tests were used. A lighted cigarette was placed on the bare surface next to the roll edge. If ignition did not occur during this test, a lighted cigarette was placed between two sheets with the lower sheet being depressed into the valley between the tape (roll) edge and the flat surface. Mini-mattresses passing these two tests would meet the requirements of FF 4-72. Samples that passed the two-sheet test were subjected to a more severe test where two lit cigarettes were placed side by side on the tape edge. Samples that passed all three of the above procedures were considered to exceed the requirements of FF 4-72 sufficiently that a manufacturer could be reasonably sure that his products would consistently comply with the standard.

Stability Studies

Samples of cotton batting treated with ammonium pentaborate, sodium borate ($Na_2O/B_2O_3 = 0.25$), a 1:1 ratio borax:boric acid ($Na_2O/B_2O_3 = 0.18$), boric acid alone, and boric acid-ammonium carbonate were evaluated for their durability to various temperatures at 65% relative humidity.

Table 1 shows the ignition data obtained on these samples installed in mini-mattresses and tested within 72 hours after treatment of the fibers. Mini-mattresses constructed with cotton batting having an add-on of 4.3% ammonium pentaborate

Table 1. Performance Data on Cotton Batting Treated with Various Smolder Resist Formulations and Tested Within 72 Hours of Manufacture in a Mini-Mattress Structure.

	Aqueous System % Add-On	One Cigarette		Two Cigarettes
		Bare Mattress	Between 2 Sheets	Bare Mattress
Ammonium Pentaborate	4.3	N	N	I
	4.6	N	N	I
	7.0	N	N	I
	7.5	N	N	I
	9.1	N	N	N
	10.0	N	N	I
	14.6	N	N	N
	15.3	N	N	I
Sodium Borate (Na_2O/B_2O_3=0.25)	4.0	N	N	I
	4.5	N	I	-
	9.1	N	N	I
	10.9	N	N	N
	15.8	N	N	N
	17.0	N	N	N
Boric Acid	9.3	N	N	N
Boric Acid	11.4	N	N	I
Boric Acid[1/]	8.9	N	N	I
Boric Acid[1/]	10.0	N	N	N
Borax:Boric Acid (Na_2O/B_2O_3=0.18)	8.3	N	I	I
	8.9	N	N	I
	Alcohol System % Add-On			
5.7% Boric Acid in:				
2-Propanol	3.87	N	N	I
20% Methanol	4.17	N	N	I
20% Ethanol	3.87	N	N	I
10% Glycerol	4.49	N	N	I

1/ 2% Ammonium carbonate added to improve solubility of boric acid.
N = No ignition
I = Ignition

passed the cigarette test requirements of FF 4-72. An add-on of at least 9.1% sodium borate ($Na_2O/B_2O_3 = 0.25$) was needed to consistently pass FF 4-72. This add-on level also yields products that pass the two-cigarette test.

Where boric acid is used, an add-on of about 10% yields products that satisfy the requirements of FF 4-72. However, to achieve this add-on of boric acid it was necessary either to employ a wet pick-up of about 166% to compensate for the limited solubility of boric acid in water at room temperature or to increase the water temperature to about 160°F. Neither of these alternatives are commercially attractive because of the high costs of drying or of maintaining the treating bath at 160°F.

During the course of this research, it was determined that small amounts of ammonium carbonate effectively increased the solubility of boric acid in water at room temperature. The sample treated with 10% boric acid – 2% ammonium carbonate passed FF 4-72.

to 225 days and at 110°F and 70% relative humidity for 100 days. At seven-day intervals, portions of the stored samples were analyzed for boric oxide content. Figures 2, 3, and 4 illustrate graphically the loss of B_2O_3 for the respective products plotted from the least squares fit of the data for each temperature. Initial boric oxide content was considered as 100%. Similar data for sodium borate (0.25 Na_2O/ B_2O_3) at 105 and 160°F and approximately 65% relative humidity are shown in Figure 5.

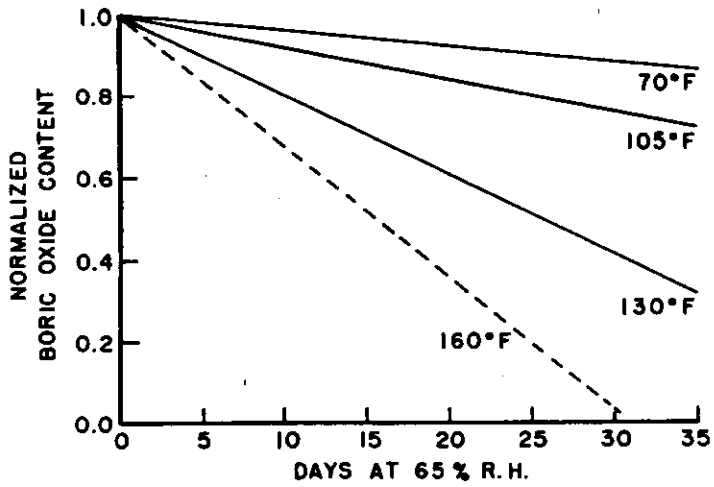

Figure 2. Loss of boric oxide from cotton batting treated with ammonium pentaborate and stored at various isotherms.

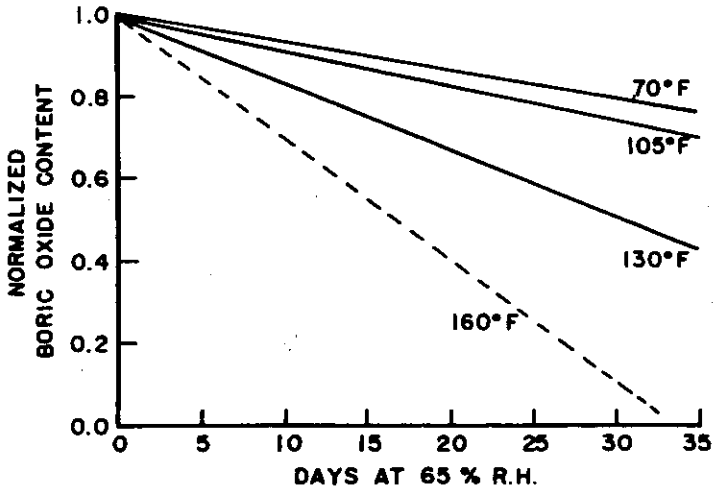

Figure 3. Loss of boric oxide from cotton batting treated with boric acid and stored at various isotherms.

Various alcohols were also used as solvents for boric acid as shown in Table 1. Products from all of the systems consistently passed FF 4-72 and, in contrast with the aqueous systems, required substantially less boric oxide add-on. As little as 2.18% boric oxide in cotton batting deposited from the 20% ethanol and the 2-propanol systems passed the test of one lighted cigarette between two sheets. This is equivalent to an add-on of 3.87% boric acid.

Samples of all the materials reported in Table 1 were tested by a modified vertical flame test [6]. Those with sodium oxide present demonstrated the greatest resistance to flaming.

Table 2. Initial B_2O_3 Content of Experimental Samples Prepared for Stability Studies Using Aqueous Systems for Treatment.

B_2O_3 Donor	Na_2O:B_2O_3 Ratio	Add-On %	B_2O_3 %	1 Cigarette		2 Cigarettes
				Bare Mattress	Two Sheets	Bare Mattress
Ammonium Pentaborate	-	4.3	2.51	N	N	I
Ammonium Pentaborate	-	4.6	3.03	N	N	I
Sodium Borate	0.25	4.0	3.23	N	N	I
Sodium Borate	0.25	4.5	3.35	N	I	-
Boric Acid	-	11.4	3.39	N	N	I
Ammonium Pentaborate	-	7.0	3.48	N	N	I
Borax:Boric Acid (1:1)	0.18	8.9	3.63	N	N	I
Boric Acid	-	10.0	3.87	N	N	N
Borax:Boric Acid (1:1)	0.18	8.3	4.00	N	I	I
Ammonium Pentaborate	-	7.5	4.11	N	N	N
Boric Acid	-	8.9	4.43	N	N	I
Boric Acid	-	9.3	4.68	N	N	N
Ammonium Pentaborate	-	9.1	4.73	N	N	N
Ammonium Pentaborate	-	10.0	4.82	N	N	I
Ammonium Pentaborate	-	15.3	5.09	N	N	I
Ammonium Pentaborate	-	14.6	5.36	N	N	N
Sodium Borate	0.28	9.1	5.63	N	N	I
Sodium Borate	0.28	10.9	5.81	N	N	N
Sodium Borate	0.28	15.8	8.48	N	N	N
Sodium Borate	0.28	17.0	8.84	N	N	N

N = No ignition
I = Ignition

Table 2 shows the B_2O_3 content of the samples prepared for storage stability. The two samples that failed the two-sheet test both contained sodium oxide (Na_2O). These findings again reinforce the belief that Na^+ ions have an adverse effect upon smolder resistance. The data show that all samples having a B_2O_3 content of 4.11% or higher passed all of the requirements of FF 4-72. The source of the B_2O_3, i.e., ammonium pentaborate, sodium borate, borax:boric acid, or boric acid, had an effect upon the ability to confer sufficient smolder resistance to pass the two-cigarette test.

Samples of the various products shown in Table 2 were stores at temperatures of 70, 105, 130, and 160°F at approximately 65% relative humidity for periods of up

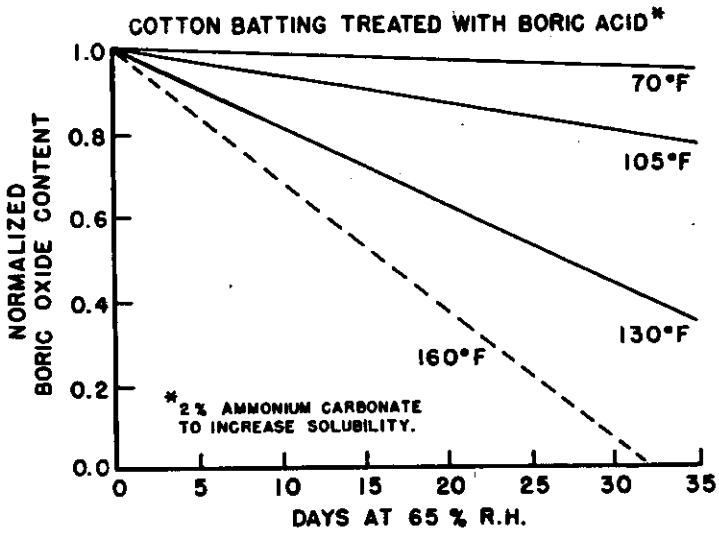

Figure 4. Loss of boric oxide from cotton batting treated with boric acid plus 2% ammonium carbonate stored at various isotherms.

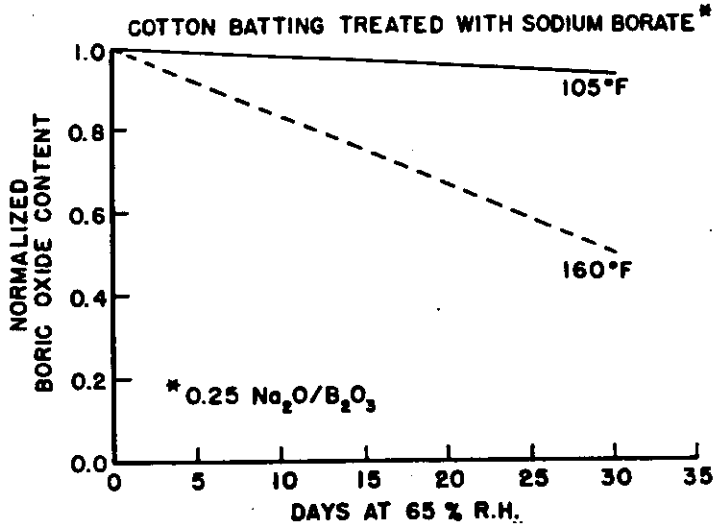

Figure 5. Loss of boric oxide from cotton batting treated with sodium borate stored at various isotherms.

Stability studies were also conducted on cotton batting employing different solvent systems. As shown in Table 3 boric acid was the B_2O_3 donor in each case. Of importance is the fact that all treated samples passed FF 4-72, and a treatment which employed from 50 to 100% methanol passed the more severe two-cigarette test. For comparison a control treated via a water system is also shown in Table 3.

Table 3. FF 4-72 and Two Cigarette Performance (Boric Acid Solvent Systems).

Solvent	Add-On %	B_2O_3 %	1 Cigarette Bare Mattress	1 Cigarette Two Sheets	2 Cigarettes Bare Mattress
Water	8.54	4.82	N	N	N
100% Methanol	10.40	5.87	N	N	N
80% Methanol	9.04	5.10	N	N	N
50% Methanol	6.40	3.61	N	N	N
40% Methanol	4.66	2.63	N	N	I
2-Propanol	4.21	2.18	N	N	I

N = No Ignition
I = Ignition

When the data from Figures 2, 3, 4, and 5 for the different treatments are plotted for isotherms as shown in Figures 6 and 7, it becomes apparent that the cotton battings treated with different donors were losing B_2O_3 at different rates over the first 30 to 35 days after treatment. There is reason, however, to believe that at some point in time a steady state will prevail, and further losses of B_2O_3

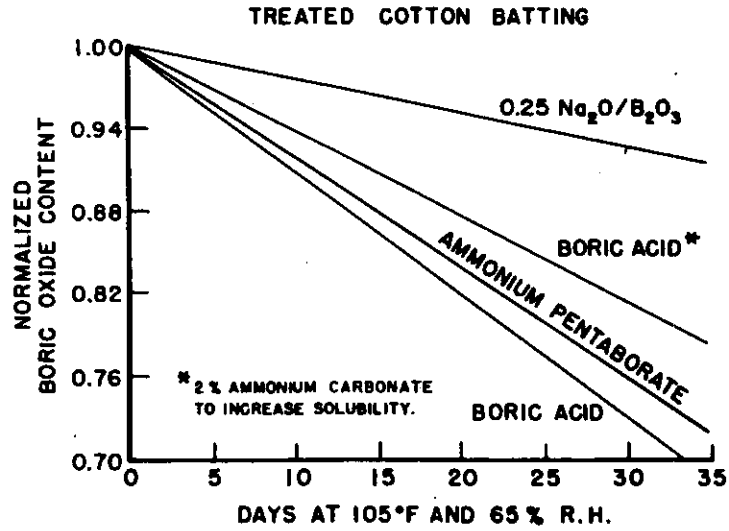

Figure 6. Effect of treatment on loss of boric oxide from cotton batting stored at 105° F and 65% relative humidity.

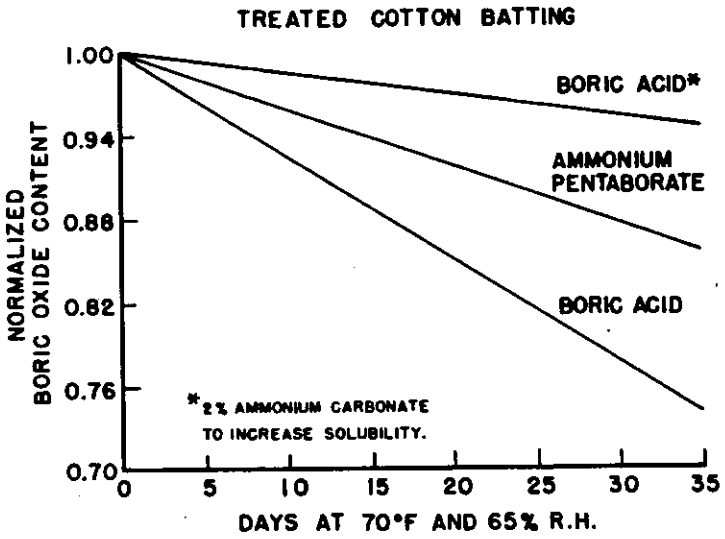

Figure 7. Effect of treatment on loss of boric oxide from cotton batting stored at 70° F and 65% relative humidity.

will be at a much slower rate than was observed for the first 30 to 35 days. There are indications that the high initial rate shown by some of the samples is probably due to loss of the boric oxide donor deposited on the surface of the fibers. Once this surface deposition is lost, diffusion and further loss will be at a much slower rate. From Figure 6 it can be seen that samples treated with sodium borate ($Na_2O/B_2O_3 = 0.25$) lost boric oxide at a significantly slower rate than did samples treated with boric acid or ammonium pentaborate stored at 105°F and 65% relative humidity.

From both Figures 6 and 7 it is apparent that the boric acid: ammonium carbonate system lost B_2O_3 at a slower rate than either boric acid alone, or ammonium pentaborate.

Figures 8 through 11 show the results obtained when the storage stability tests at 70°F and 65% relative humidity were extended for 225 days. The curves are the least squares fit to the data assuming a first order irreversible reaction for the loss of boric oxide.

From Figure 8, it can be seen that regardless of the initial add-on of ammonium pentaborate, up to 5.2% B_2O_3 content, essentially all of the B_2O_3 loss occurred in the first 60 days. As shown in Table 2 an add-on as low as 2.51% derived from ammonium pentaborate provides sufficient smolder resistance to pass FF 4-72. All of the stored products of Figure 7 can thus be expected to pass FF 4-72.

From Figure 9 it is apparent that for the sodium borate systems the greatest loss of reagent also took place within the first 60 days of storage and that further loss of B_2O_3 with continued storage at 70°F and 65% relative humidity was minimal.

Figure 10 shows the pattern of boric oxide loss on extended storage of cotton batting products treated with boric acid, and the reduction of loss where ammo-

Table 1. Performance Data on Cotton Batting Treated with Various Smolder Resist Formulations and Tested Within 72 Hours of Manufacture in a Mini-Mattress Structure.

	Aqueous System % Add-On	One Cigarette		Two Cigarettes
		Bare Mattress	Between 2 Sheets	Bare Mattress
Ammonium Pentaborate	4.3	N	N	I
	4.6	N	N	I
	7.0	N	N	I
	7.5	N	N	I
	9.1	N	N	N
	10.0	N	N	I
	14.6	N	N	N
	15.3	N	N	I
Sodium Borate (Na_2O/B_2O_3=0.25)	4.0	N	N	I
	4.5	N	I	-
	9.1	N	N	I
	10.9	N	N	N
	15.8	N	N	N
	17.0	N	N	N
Boric Acid	9.3	N	N	N
Boric Acid	11.4	N	N	I
Boric Acid[1/]	8.9	N	N	I
Boric Acid[1/]	10.0	N	N	N
Borax:Boric Acid (Na_2O/B_2O_3=0.18)	8.3	N	I	I
	8.9	N	N	I
5.7% Boric Acid in:	Alcohol System % Add-On			
2-Propanol	3.87	N	N	I
20% Methanol	4.17	N	N	I
20% Ethanol	3.87	N	N	I
10% Glycerol	4.49	N	N	I

1/ 2% Ammonium carbonate added to improve solubility of boric acid.
N = No ignition
I = Ignition

passed the cigarette test requirements of FF 4-72. An add-on of at least 9.1% sodium borate ($Na_2O/B_2O_3 = 0.25$) was needed to consistently pass FF 4-72. This add-on level also yields products that pass the two-cigarette test.

Where boric acid is used, an add-on of about 10% yields products that satisfy the requirements of FF 4-72. However, to achieve this add-on of boric acid it was necessary either to employ a wet pick-up of about 166% to compensate for the limited solubility of boric acid in water at room temperature or to increase the water temperature to about 160°F. Neither of these alternatives are commercially attractive because of the high costs of drying or of maintaining the treating bath at 160°F.

During the course of this research, it was determined that small amounts of ammonium carbonate effectively increased the solubility of boric acid in water at room temperature. The sample treated with 10% boric acid – 2% ammonium carbonate passed FF 4-72.

nium carbonate is present. These data also confirm that essentially all of the significant losses are sustained in the first 60 days of storage.

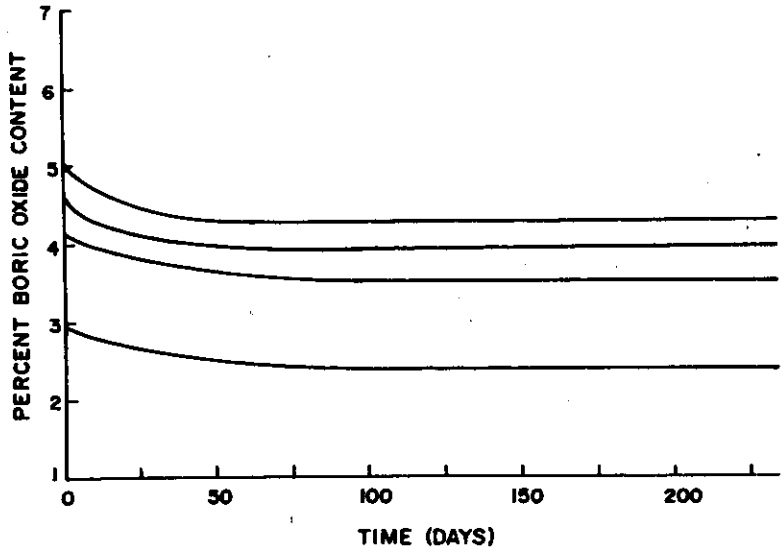

Figure 8. Loss of boric oxide from cotton batting treated with ammonium pentaborate and stored at 70° F and 65% relative humidity.

The data in Figures 8 through 10 can be interpreted as showing that the hypothesis attributing the early losses of B_2O_3 to surface deposited material is a reasonable explanation of the observed phenomena. Correlating the residual B_2O_3 contents of these samples shown in Figures 8, 9, and 10 with the B_2O_3 content needed to pass cigarette testing (Table 1) indicates that most of these samples could be expected to pass FF 4-72 after extended storage periods.

Figure 11 compares the data from Figures 8 through 10 for different B_2O_3 donors based upon initial B_2O_3 content as 100%. These data indicate that is it possible to determine and predict the eventual residual B_2O_3 content of cotton batting products treated with any of a number of chemical systems containing the borates when these products are stored for extended periods of time at 70°F and 65% relative humidity. Approximately 10% of the sodium borate treatment was lost, compared to 17–20% of the boric acid or ammonium pentaborate treatments.

The ratio of borax to boric acid in the treating formulation has an effect upon the rate of loss of boric oxide during storage. The data shown in Figure 12 were obtained on samples stored at 110°F and 70% relative humidity for up to 100 days. The data in Figure 12 can be interpreted as meaning that Na_2O stabilizes the boric acid since the rate of loss of boric oxide decreases with increasing Na_2O content.

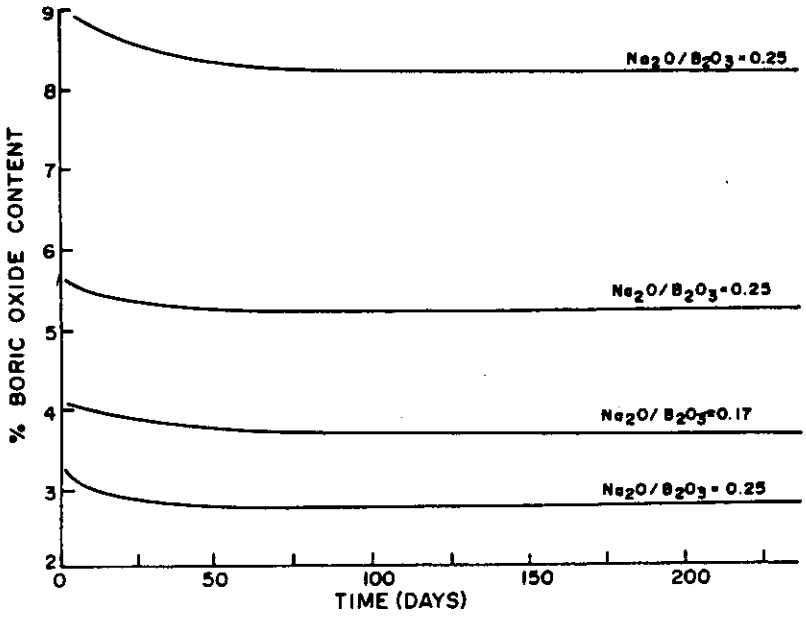

Figure 9. Loss of boric oxide from cotton batting treated with sodium borate-boric acid and stored at 70° F and 65% relative humidity.

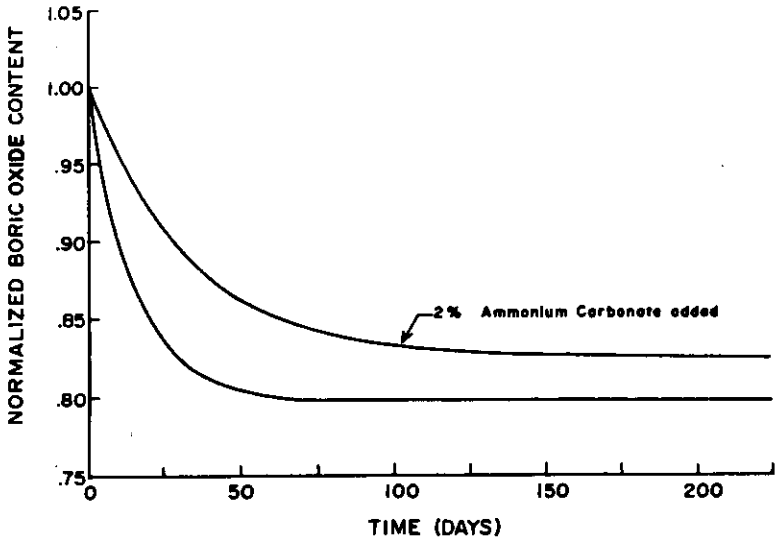

Figure 10. Loss of boric oxide from cotton batting treated with boric acid upon storage at 70° F and 65% relative humidity initial add-on = 100%.

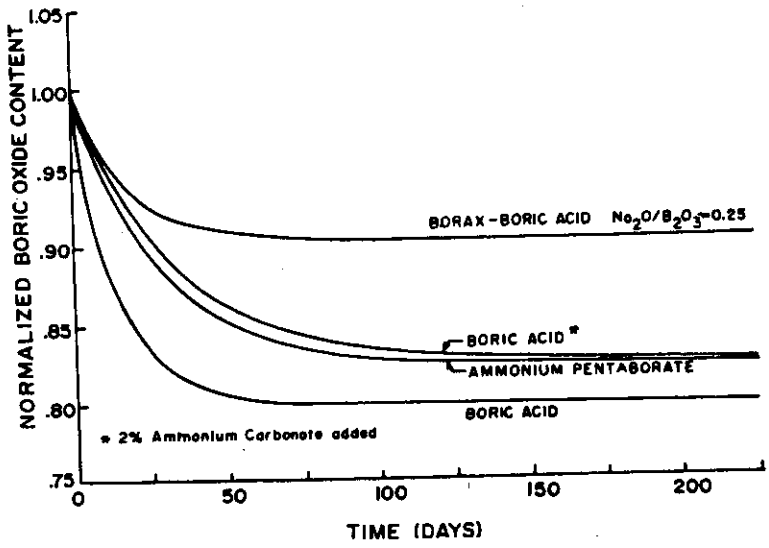

Figure 11. Loss of boric oxide from cotton batting stored at 70° F and 65% relative humidity for different B_2O_3 donors. Initial add-on = 100%.

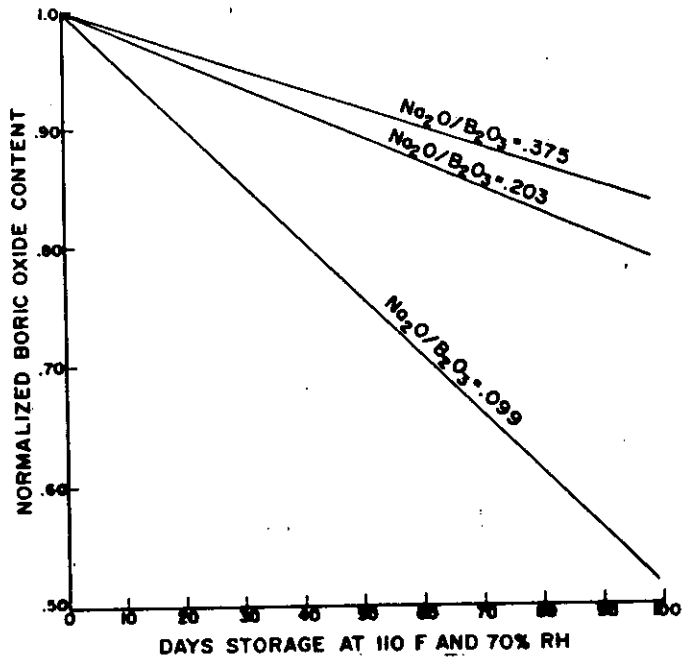

Figure 12. The effect of Na_2O/B_2O_3 ratio upon the loss of boric oxide from cotton batting treated with borax-boric acid upon storage at 110° F and 70% relative humidity.

The method of application of the boric acid to the cotton fibers also has an effect upon the stability of the products to extended storage. Figure 13 shows the rate of loss of boric oxide from samples of cotton batting that had been impregnated by immersion, by spraying according to a commercially recommended procedure, or by treatment according to a commercial process that involves dusting of finely divided boric acid powder onto the fibers after garnetting. The most rapid loss of boric oxide occurred when the dry powder system was used, and the slowest rate when the fibers had been impregnated by immersion. These findings again confirm that the boric acid donor deposited upon the surface of the fibers is lost more rapidly than the boric oxide deposited within the fibers.

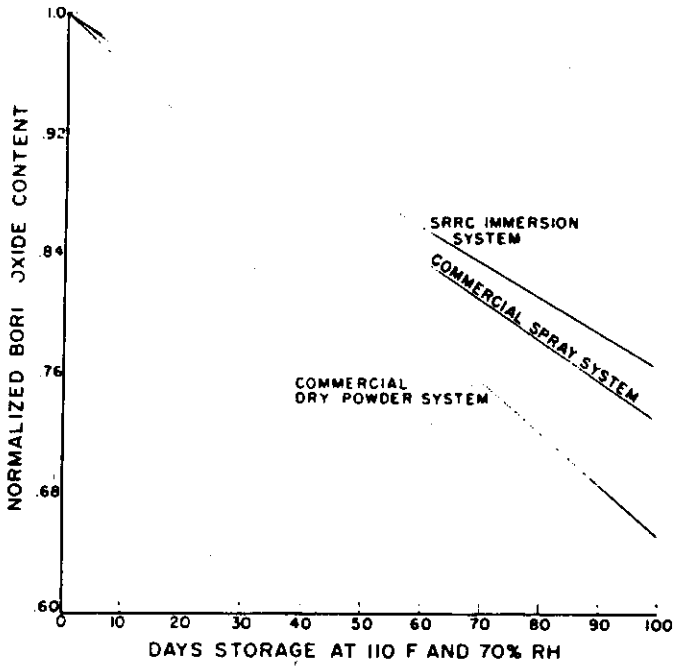

Figure 13. Effect of treatment method upon the loss of boric oxide upon storage where boric acid is the donor.

Figure 14 shows the rate of loss of boric oxide for products that had been treated using water, methanol or 2-propanol as the solvent for the boric acid.

The initial boric oxide values for these three materials before storage were 4.58, 4.57, and 1.77 respectively. The rate of weight loss for the products treated in alcohol systems were greater than for the materials treated in an aqueous system. The alcohol systems resulted in the deposition of a higher concentration of the

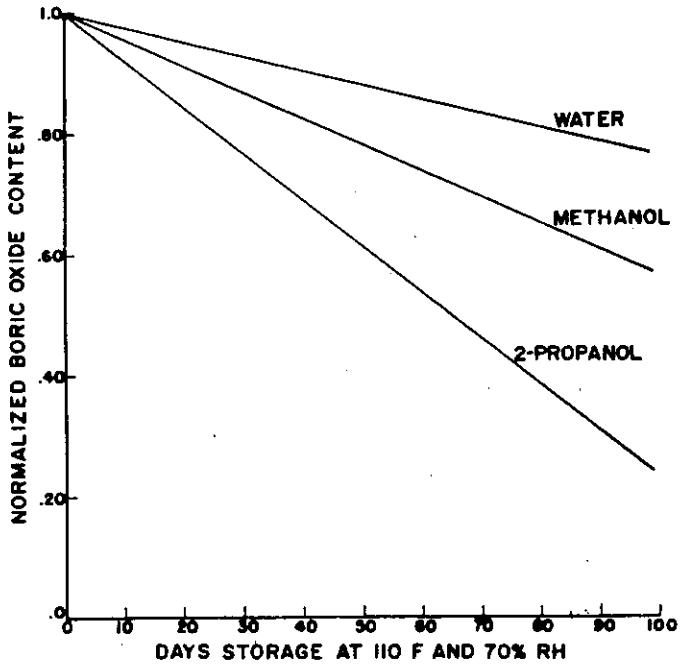

Figure 14. Loss of boric oxide from cotton batting treated with boric acid dissolved in various solvent systems.

boric acid on the surface of the cotton fibers during the treatment of the rawstock than did the aqueous system. This has been observed when the treated batts were dried, equilibrated at ambient conditions for 24 hours, and garnetted. The losses of boric oxide content of the water, methanol, and 2-propanol systems were 9.8%, 37.2%, and 34.2%, respectively. As a general observation, the losses of boric oxide that accompany garnetting result from the mechanical removal of material deposited upon the surface of the fibers. The curves in Figure 14 show the loss of treatment that remains after garnetting.

Based on the amount of treatment lost, the 2-propanol treatment appears to have the highest surface deposition. Its isotherm demonstrates a loss of about 76% boric oxide after 100 days. On the premise that the concentration of the alcohol might influence how boric acid is deposited, thereby affecting the stability of the treated cotton product, a study was conducted in which methanol content was varied from 100% to 40% of the total solvent system. When the treating formulation contained 80% methanol – 20% water, the loss of boric oxide took place at the slowest rate, as seen in Figure 15. The next slowest rate of loss of boric acid occurred from the sample treated from 100% methanol solvent. With 50% and 40% methanol – water solvent systems, the rates of loss of oxide were considerably

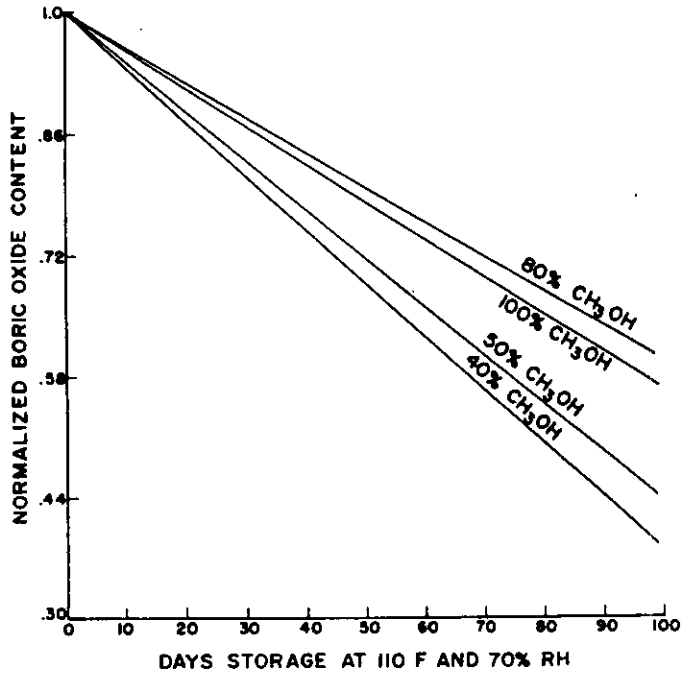

Figure 15. Loss of boric oxide from cotton batting treated with saturated solutions of boric acid in methanol.

faster. As shown previously in Figure 14, when the aqueous system was applied, more boric oxide appeared to have remained with the cotton during the 100 days of storage than occurred with the alcohol systems. In contrast, Figure 15 indicates that as the water ratio of the methanol system is increased, the boric oxide content in the treated batting decreased. These findings indicate more surface deposition on the fiber. It would be expected that a decrease in boric acid deposited on the surface of the fibers would be found as the water ratio increased. One possible explanation of this phenomenon can be attributed to the formation of methyl esters of boric acid at ambient temperature. In the presence of water, the esters react and decompose, probably to the boric acid form. Thus water-methanol ratios have a direct influence on the deposition of boric acid onto the surface or within cotton fibers. Trimethyl borate is readily formed at ambient temperature in the absence of water. The ester has a high vapor pressure. The ester may be decomposed by moisture before it reaches the fibers or subsequently after deposition. Both situations would affect the add-on.

SUMMARY AND CONCLUSION

The cigarette ignition data presented herein confirm that it is possible to comply with the requirements of the Mattress Flammability Standard FF 4-72 by treating cotton batting with a number of chemical systems containing boric oxide donors. A boric oxide content in excess of 2.51% by weight of the cotton in an aqueous system was needed to resist the initiation of smoldering by a single cigarette on the bare mattress surface. Maintaining the boric oxide content above 4.1% in an aqueous system or 2.18% in a solvent system makes possible passage of the more severe two-sheet test.

There are noticeable losses of the treating compound during the initial period after treatment. The rate of this initial loss varies with the particular boric oxide donor, the solvent used, the method of application and with the temperature and humidity of the storage conditions. The losses are essentially complete after 60 days storage at 70°F and 65% relative humidity. These data tend to confirm the hypothesis that the early loss of boric oxide results from the volatilization of the boric oxide donors deposited on the surface of the fibers. The results obtained in this study should be compared with the performance of treated products stored under fluctuating conditions of temperature and relative humidity.

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Stevenson, Todd A.

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From: David Bright [DBright@sleepproducts.org]
Sent: Tuesday, March 29, 2005 11:12 AM
To: Stevenson, Todd A.
Subject: Mattress NPR

ISPA-SPSC 1633 Comments (final...

Please find the attached comments from the International Sleep Products Association and Sleep Products Safety Council regarding the Mattress NPR; Standard for the Flammability (Open Flame) of Mattresses and Mattress/Foundation Sets; Proposed Rules, 70 Fed. Reg. 2470 (Jan. 13, 2005).

Please contact me if you have any difficulty in opening this document. Thank you.

David Bright
Government Relations Associate
International Sleep Products Association
ph (703) 683-8371
fax (703) 683-6967
www.sleepproducts.org

Matthews

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Underwriters Laboratories Inc.®

Northbrook Division
333 Pfingsten Road
Northbrook, IL 60062-2096 USA
www.ul.com
tel: 1 847 272 8800

March 29, 2005

Office of the Secretary
U. S. Consumer Product Safety Commission
Room 502, 4330 East – West Highway
Bethesda, MD

Subject: Notice of Proposed Rulemaking – Standard for the Flammability (Open Flame) of Mattresses and Mattress / Foundation Sets – Federal Register Vol. 70, No. 9, January 13, 2005, Draft 1633 Standard.

Dear Chairman Stratton and Commissioner Moore:

This letter supplements our previous communications dated November 23, 2003 and March 10, 2005, on the proposed subject. In those letters we expressed support of CPSC's efforts toward incrementally improving the flammability of mattresses available to the general public.

Underwriters Laboratories (UL) fully encourages efforts to increase public safety, particularly in the area of fire protection. We believe that collective body of work undertaken by the Consumer Product Safety Commission (CPSC), the California Bureau of Home Furnishings and Thermal Insulations (CBHFTI), the Sleep Products Safety Council (SPSC) and the mattress industry as a whole represents a tremendous improvement in the reduction in flammability of mattresses. This example of the cooperation of Federal and State governments with the private efforts of the mattress industry could be a model for future safety initiatives.

UL has previously communicated our support of the mattress flammability test protocol and performance criteria in a previous letter to the CPSC dated November 23, 2003.

In addition to the November 23, 2003 letter and in the spirit of support of CPSC's activity, we offer the following comments for the Commission's consideration.

Testing Methodology and Laboratory Accreditation

Sample Conditioning - Consideration should be given to revising the sample pre-test conditioning environment. Currently the proposed test protocol specifies the temperature shall be greater than 65 °F and less than 55 % RH. We recommend these requirements be tightened with a defined range. Many existing fire test protocols (ASTM E84 for instance) require samples of similar if not larger size to be conditioned at a temperature of 73.4 +/- 5°F and at a relative humidity of 50 +/- 5%. The ASTM E 84 test method applies to a wide range of building products and has been successfully implemented by numerous testing laboratories for decades. We recommend following these conditioning procedures for the mattress flammability standard. These tighter specifications should help to minimize potential seasonal that may arise due to varying product moisture retention behavior.

Prototype Size - Consideration should be given to demonstrating compliance of larger sized (full, queen, king) to the requirements if warranted. Initial testing of twin size mattress that result in close to noncompliant HRR peak (175 kW for example) and fire extension to the extremities of the twin mattress would be justification to conduct tests on larger sized mattresses as HRR is a function of the available fuel. This is a practical solution to scaling effects. We recommend that if the twin sized sample demonstrates burn damage to the extremities, then the largest sized mattresses should also be tested.

Laboratory Accreditation – We recommend to the Commission that that test results to demonstrate compliance with the proposed rule be obtained by an independent accredited laboratory. This recommendation is based upon UL's extensive experience in electrical safety testing of consumer products where fire-related incidents are rare. The general public has confidence in this system and we believe this new rule requires the same level of credibility. In addition, independent laboratories providing this service should be accredited by an independent agency to ensure that uniform implementation of the standard and that acceptable laboratory practices are in place (sample conditioning, combustion make-up air, data recording, calibration, maintenance, environmental controls, etc.). Consumers, product manufacturers and suppliers will realize the benefits of this increased oversight with increased confidence and assurance that this new ruling will be enforced in a uniform manner.

Elimination of 16 CFR 1632

Consideration should be given to withdrawing the current cigarette requirement and protocol of 16 C.F.R. Part 1632. The proposed test protocol represents a more sophisticated quantitative approach of which the basis of the test (oxygen consumption calorimetery) is widely accepted in the fire protection engineering community.

Refurbished and Rebuilt Mattress Products

It is understood that the proposed flammability requirements (Subpart C, "Interpretation and Policies", Section 1633.14) will be mandated for all mattresses sold within the United States. We strongly recommend that this should apply irrespective to initial manufacturing location (US or overseas – see below) and should also include retrofitted and rebuilt mattresses. The regulation would be applicable throughout the country and would preclude State and local jurisdictions.

Imported Products

We also recognize that mattress supply and manufacture is part of the global economy. The source and supply of mattress components and products will likely change over time in accordance with factors such as labor costs and raw materials availability, transportation efficiencies and energy costs. To ensure the uniform implementation of this standard, we support the monitoring of imported goods from importers, agents and/or foreign mattress manufacturers. We also make this recommendation based upon our experience in the testing and Certification of over 18,000 product categories that are designed, sourced and manufactured throughout the world.

We appreciate the opportunity to provide comment. If you wish to discuss further, please feel free to contact me at your convenience.

Sincerely:

J. Thomas Chapin

J. Thomas Chapin, PhD.
General Manager, Fire Safety SBU
Underwriters Laboratories, Inc.
847-343-4918
j.thomas.chapin@us.ul.com

Bureau of Home Furnishings and Thermal Insulation
3485 Orange Grove Avenue
North Highlands, California 95660
(916) 574-2041, Fax (916) 574-2043

March 29, 2005

U.S Consumer Product Safety Commission
Office of the Secretary
Washington, DC 20207-0001

Subject: Comments on "Mattress NPR"

The California Bureau of Home Furnishings and Thermal Insulation (Bureau) supports the adoption of a federal standard for mattresses, mattress sets, and futons that addresses an open-flame hazard. Further, the Bureau recommends that the final federal standard closely resembles California's Technical Bulletin 603[1] (TB 603).

The Bureau adopted TB 603 through Assembly Bill 603, which mandated the Bureau to adopt a standard for the open-flame resistance of mattresses, mattress sets, and futons[2]. TB 603 limits fire growth in mattresses, mattress/box spring sets, and futons when exposed to a large open flame for 30 minutes.

The Bureau began enforcing the requirements of TB 603 on January 1, 2005. Although too early to assess in California, this higher level of fire resistance should decrease fire deaths, injuries, and property loss over the long term.

The adoption of a national standard will level the playing field for the mattress market in the United States. All domestic and overseas mattress manufactures would be required to comply with the same federal standard. Enforcing a national standard would allow for closer cooperation between the states and increase consumer protection.

This open flame hazard associated with a bedroom fire is well established through fire statistics, field studies, and anecdotal evidence. The majority of bedroom fires not caused by smoldering cigarettes involve a match, candle, lighter, or an electrical malfunction that ignites an article of filled bedclothing. While the fire begins with the bedclothing, it grows to eventually involve the mattress. The combination of the burning bedclothes, a burning mattress, and other combustibles in the room often leads to a life-threatening condition within three minutes. Mattresses designed to meet TB 603 or a similar standard will be less likely to lead to a bedroom flashover fire than a mattress which is only cigarette-resistant. Significant fire-safety improvements can be achieved by slowing down the rate of growth of a fire and prevent or delay flashover.

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[1] California Technical Bulletin # 603, "Requirements and Test Procedure for Resistance of a Mattress/Box Spring Set to a Large Open-Flame", January 2004 (enforced January 2005).
[2] California Assembly Bill 603 (Dutra), Chaptered August 2001.

The Bureau and the National Institute of Standards and Technology (NIST) assessed the flaming insult typically seen by a mattress from burning bedclothes[3] and the development of a test methodology to determine the amount of fire contribution from a mattress[4]. NIST also conducted research to determine how modifications in the flammability of bedclothing products might improve the fire safety environment of a bedroom[5]. NIST compared the effect of the gas burners used in the test protocol to actual burning bedclothes[6] and found a reasonable correlation between the two methods of ignition for worst case prototypes. These conclusions support a national standard that addresses the risk associated with the flaming ignition of a mattress ignited directly or by secondary ignition from other burning materials.

TB 603 is identical to that proposed in the federal Notice of Proposed Rulemaking except CPSC proposes a more stringent criteria for total heat release: 15 megajoules in the first 10 minutes rather than 25 megajoules for TB 603. NIST validated that lowering the total heat release from a product in the first ten minutes of a fire to 25 megajoules decreases the probability that the fire will spread and contribute to flashover. Also, most mattresses will exhibit low total heat releases if the peak heat release values stay well below 200 kilowatts. Thus, the Bureau supports the change to a 15 megajoule total heat release in the first 10 minutes. This stricter criterion will provide added safety for smaller mattress products, which alone may not produce a peak heat release of 200 kilowatts but may contribute to the ignition of other combustibles in the bedroom if a 25 megajoule heat output is allowed.

Enforcement of the TB 603 standard for mattress products entering the California market has demonstrated that manufacturers can comply with TB 603 requirements without causing major supply chain and cost disruptions. The Bureau is not aware of massive disruptions in the sale of mattresses in California as a result of material and construction changes necessitated by this standard. Since the beginning of the year, the Bureau has tested mattress products from approximately 68 different manufacturers and reports an 80.8 % pass rate. The failures either did not contain fire-resistant barrier protection or the barrier-contained design, material, or construction defects, which could reasonably be corrected with improved quality controls. This indicates that mattresses may be routinely made to comply with this standard if the manufacturer is intentional about compliance and due diligence is undertaken.

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[3] "Flammability Assessment Methodology for Mattresses", Ohlemiller, T. J.; Shields, J. R.; McLane, R. A.; Gann, R. G., NISTIR 6497; 94 p. June 2000

[4] "Estimating Reduced Fire Risk Resulting From An Improved Mattress Flammability Standard", Ohlemiller, T. J.; Gann, R. G., NIST TN 1446; 80 p., August 2002

[5] "Effect of Bed Clothes Modifications on Fire Performance of Bed Assemblies", Ohlemiller, T. J., Gann, R. G., NIST TN 1449, 37 p. February 2003.

[6] "Flammability Tests of Full-Scale Mattresses: Gas Burners versus Burning Bedclothes", Ohlemiller, T.J., 26 p., NISTIR 7006, July 2003.

With regards to labeling, the Bureau recommends the adoption of a mandatory flammability label on all mattress products meeting a future open-flame standard. The label should contain a positive statement that the product meets the federal flame-resistance standard. This statement could be combined with the existing voluntary statement regarding cigarette resistance assuming that law remained in effect or could be worded as appropriate to warn the consumer of smoldering hazards. The label would act as a guarantee of compliance for wholesalers and retailers and would assist regulators in screening compliant from non-compliant products. It would also serve as an educational tool for consumers to alert them to the existence of the improved standard.

The Bureau also endorses the continuance of the issuance of written guaranties from manufacturers to retailers for mattress products in compliance with the new open flame standard. Similarly, this guaranty form could be reworded to include compliance with both the flaming and smoldering standards, assuming both would remain in effect.

While the Bureau reserves comment on the possible need for mandatory prototype testing, we encourage manufacturers to establish thorough quality control, employee training, and product testing programs. Manufacturers should recognize that the standard being proposed is a finished product standard, and the test outcome is affected by many factors. Material, design, and construction changes can have a significant impact on the test outcome. In the absence of mandatory prototype testing, proactive, periodic testing of finished sleep products should be performed routinely by manufacturers to ensure that no changes occur in material components or construction processes that would cause failure of the standard.

Finally, the Bureau appreciates the close collaboration with the Consumer Product Safety Commission's technical staff and the industry to develop this draft standard.

Respectfully submitted,

Brian J. Stiger
Chief

STATE OF CALIFORNIA
DEPARTMENT OF CONSUMER AFFAIRS
BUREAU OF HOME FURNISHINGS AND
THERMAL INSULATION
3485 ORANGE GROVE AVENUE
NORTH HIGHLANDS, CALIFORNIA 95660-5595

TECHNICAL BULLETIN 603

REQUIREMENTS AND TEST PROCEDURE FOR RESISTANCE OF A MATTRESS/BOX SPRING SET TO A LARGE OPEN-FLAME

January 2004

Requirements and Test Procedure for Resistance of a Mattress/Box Spring Set to a Large Open-Flame[1]

1. Scope

This protocol provides a means of determining the burning behavior of mattress/foundation sets intended for any use by measuring specific fire test responses when the test specimen, a mattress plus foundation, is subjected to a specified flaming ignition source under well-ventilated conditions.

This is a test protocol for mattresses placed on top of their intended foundations. This test also applies to mattresses that will not be used with a foundation. As a practical matter, the size of the test specimen is limited to twin size since larger mattresses are difficult to test in available room enclosures (and they may pose an excessive fire risk to the test facility).

Test data are obtained which describe the burning behavior, during and subsequent to the application of a specific pair of gas burners, from ignition until all burning has ceased, a period of 30 minutes has elapsed, or flashover of the test room appears inevitable.

This protocol does not provide information on fire performance of mattresses under conditions other than those specified in this test protocol. In particular, this protocol does not apply to smoldering ignition by cigarettes. See *Limitations* below for further restrictions.

The rate of heat release from a burning test specimen is measured by oxygen consumption calorimetry. See *Limitations* below for further restrictions.

The burning behavior is documented by video recording.

Use SI units in reporting results. Other units are for information only.

This protocol is used to measure and describe the response of materials, products or assemblies to heat and flame under controlled conditions, but does not by itself incorporate all factors required for fire hazard or fire risk assessment of the materials, products or assemblies under actual fire conditions.

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[1] This enforceable standard is based on the National Institute of Standards and Technology Publication titled "Protocol for Testing Mattress/Foundation Sets Using a Pair of Gas Burners", dated February 2003.

Certain trade names and company products are mentioned in the text or identified in an illustration in order to specify adequately the experimental procedure and equipment used. In no case, does such identification imply recommendation or endorsement by the Bureau of Home Furnishings and Thermal Insulation, nor does it imply that the products are necessarily the best available for the purpose.

Fire testing of products and materials is inherently hazardous and adequate safeguards for personnel and property shall be employed in conducting these tests. This test protocol may involve hazardous materials, operations and equipment.

This protocol does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this protocol to establish appropriate safety and health practices and to determine the applicability of regulatory limitations prior to use. In particular, the user should be aware of the possibility of fires as large as 3 MW from some mattress/foundation combinations. This can greatly exceed the capacity of the normal hood system used and the user may have to suppress the fire well before such a peak.

2. Referenced Documents.

2002 ASTM Standards, Volume 04.07

E 1590 Standard Test Method for Fire Testing of Mattresses
E 176 Standard Terminology of Fire Standards

3. Terminology

Definitions – For definitions used in this test method and associated with fire issues, refer to the terminology contained in Terminology E 176.

Definitions of terms specific to this standard:

Product – a mattress manufactured to be used without a foundation, a mattress/box spring set or a futon, for which the fire-test-response characteristics are to be measured.

Specimen – the manufactured sample of the product or a representative prototype of the product.

4. Summary of the Test Protocol

This fire-test-response protocol utilizes a pair of propane burners, designed to mimic the heat flux levels and durations imposed on a mattress and foundation by burning bedclothes. These burners impose differing fluxes for differing times on the mattress top and on the sides of the mattress/foundation. During and subsequent to this exposure, measurements are made of the time-dependent heat release rate from the specimen. Carbon monoxide emissions are measured as a necessary part of the heat release rate measurement. Carbon monoxide yield may be reported optionally.

An all test configurations, the specimen is placed on top of a short bed frame that sits on a catch surface.

In Test Configuration A, the above assembly is placed under an open hood which captures the entire smoke plume and is instrumented for heat release rate measurements.

In Test Configurations B and C, the above assembly is placed within a burn room. All smoke exiting from the room is caught by a hood system instrumented for heat release rate measurements. The room layout and size differ for Test Configurations B and C.

5. Significance and Use

This fire test method provides a means of measuring the important fire-test-response characteristics of a burning mattress/foundation specimen or a mattress specimen alone. After ignition by a pair of propane burners, the test specimen is allowed to burn freely under well-ventilated conditions. The most important fire-test-response characteristic measured in this test method is the rate of heat release, which quantifies the energy generated by the fire.

The rate of heat release is measured by means of oxygen consumption calorimetry. A full discussion of the underlying principles, the limitations and the requisite instrumentation of this method are found in ASTM E1590.

The test method also provides a measure of the emissions of the carbon oxides (CO_2 and CO) from the test specimen. These are important to accurate measurement of the heat release rate. They are also significant toxicants in a fire. The user of this protocol may optionally analyze the fire plume gases for other toxicants.

The dual propane burner, flaming ignition source used here has been shown to mimic the local thermal insult (heat flux and duration) imposed on a mattress/foundation by burning bedclothes. It has been shown that flaming ignition of bedclothes is the cause of a significant fraction of residential bed fires in the United States. A localized, match-size, bedclothes ignition is magnified strongly when flames spread on the bedclothes and this can result in the burning of the mattress/foundation.

One of the following three configurations is to be used in this protocol:

Test Configuration A – An open calorimeter (or furniture calorimeter). It should be noted that this open configuration is much more suited to close observation of specimen behavior than the next two configurations which involve testing within a room context. Subtle failure mechanisms, such as limited seam openings on a blackened specimen, cannot be discerned from the observer distances implicit in the two room configurations below.

Test Configuration B – A test room having the following dimensions: 3.66 m by 2.44 m by 2.44 m (12 ft by 8 ft by 8 ft) high. A room configuration (such as Configuration B or C) provides test conditions closer to the end use of the product. There is some indication in the literature that some designs will exhibit a higher peak heat release rate in a room, if

that peak is at least 200 kW. More typically, room effects require higher peak heat release rates.

Test Configuration C – A test room having the following dimensions: 3.66 m by 3.05 m by 2.44 m (12 ft by 10 ft by 8 ft) high.

Rooms having other dimensions are acceptable, provided test data are available to establish that results equivalent to those obtained as above are obtained.

Measurements are available to show that room effects are negligible below a heat release rate of 200 kW. Above this heat release rate, room effects (heat release rate enhancement) are noticeable for mattresses, such as those composed entirely of polyurethane foam or a comparably melting material, that burn as an upwardly exposed, "pool" fire. They are less noticeable for mattresses whose flames are predominantly internal to the mattress/foundation structure with minimal exposure to hot smoke layer radiation.

Limitations:

While in principle the procedures laid out here could be used to test specimens up to king size, the rooms available in most testing laboratories cannot accommodate bed sizes larger that twin. Furthermore, the potential peak fire size could double with a king size bed, readily overwhelming the flow capacity of typical exhaust systems.

This test protocol is not applicable to ignition by cigarettes or by any other smoldering source.

The ignition source used here is designed to mimic the local heat flux imposed on a mattress/foundation by burning bedclothes. This source has been shown to be capable of providing a distinction between mattress/foundations of differing design and to provide results that, in many cases, correlate directly with the results obtained with burning bedclothes. This source does not replicate the moving nature of the heat flux pattern imposed on a mattress/foundation by burning bedclothes, nor the fact that burning bedclothes can, potentially, ignite a much larger area of the specimen at a given time. Also, this ignition source has not been shown to replicate an internal deflagration phenomenon sometimes exhibited by mattress designs based on an external barrier when subjected to burning bedclothes. The internal over-pressurization that this deflagration causes can rupture the mattress barrier or seams and lead to a fire that is larger than that seen with the burner ignition source used here.

The dual burner ignition source was designed on the basis of a limited survey of the thermal insult from burning bedclothes. It is not known what fraction of the real world bedclothes are represented by this survey.

It is not known whether the results of this test protocol will be equally valid if a mattress/foundation is burned under conditions different than those specified here. In

particular, the effects of varying the heat flux intensities of the two burners or their durations have not been examined in detail.

6. Apparatus

Test Configurations:

Open Calorimeter Layout. (Test Configuration A). In this configuration, the mattress/foundation to be tested is placed under the center of an open furniture calorimeter. Figure 1 shows the test assembly atop a bed frame and catch surface.

The area surrounding the test specimen in an open calorimeter layout shall be sufficiently large that there are no heat re-radiation effects from any nearby materials or objects. The air flow to the test specimen should be symmetrical from all sides. The air flow to the calorimeter hood shall be sufficient to assure that the entire fire plume is captured, even at peak burning. Skirts may be placed on the hood periphery to help assure this plume capture, if necessary, though they must not be of such an excessive length as to cause the incoming flow to disturb the burning process. Skirts must also not heat up to the point that they contribute significant re-radiation to the test specimen. The air supply to the hood shall be sufficient that the fire is not in any way limited or affected by the available air supply. The fire plume should not enter the hood exhaust duct[2].

Test Room Layout. (Test Configuration B). The test room shall have dimensions 2.44 m ± 25 mm by 3.66 m ± 25 mm by 2.44 m ± 25 mm (8 ft by 12 ft by 8 ft) high. The room shall have no openings permitting air infiltration other than a doorway opening 0.76 m ± 6.4 mm by 2.03 m ± 6.4 mm (30 in by 80 in) located as indicated in Fig. 2 and other small openings as necessary to make measurements. Construct the test room of wood or metal studs and line it with Class A fire-rated wallboard or calcium silicate board. Position an exhaust hood, as outlined in ASTM E 1590, outside of the doorway so as to collect all of the combustion gases. There shall be no obstructions in the air supply to the set-up.

Test Room Layout. (Test Configuration C). The test room shall have dimensions 3.05 m ± 25 mm by 3.66 m ± 25 mm by 2.44 m ± 25 mm (10 ft by 12 ft by 8 ft) high. The room shall have no openings permitting air infiltration other than a doorway opening 0.97 m ± 6.4 mm by 2.03 m ± 6.4 mm (38 in by 80 in) located as indicated in Fig. 3 and other small openings as necessary to make measurements. Construct the test room of wood or metal studs and line it with fire-rated wallboard or calcium silicate board. Position an exhaust hood, as outlined in ASTM E 1590, outside of the doorway so as to collect all of the combustion gases. There shall be no obstructions in the air supply to the set-up.

The test rooms shall contain no other furnishings or combustible materials except for the test specimen.

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[2] Brief (seconds) flickers of flame that occupy only a minor fraction of the hood exhaust duct inlet cross-section are not a problem since they do not signify appreciable suppression of flames.

The locations of the test specimen are shown in their respective room layouts (Figs. 2 and 3). In both cases, the angled placement is intended to minimize the interaction of flames on the side surfaces of the test specimen with the room walls. Note that one corner of the test specimen is to be 13 cm to 17 cm (5 to 6.7 in.) from the wall and the other corner 25 cm to 30 cm (10 to 12 in.) from the wall. This maintains consistency between the two configurations.

Ignition Source:

The ignition source consists of two T-shaped burners as shown in Figs. 4 and 5. One burner impinges flames on the top surface of the mattress; the second burner impinges flames on the side of the mattress and on the side of the foundation. Each burner incorporates a stand-off foot to set its distance from the test specimen surface (Fig. 6). Both burners are mounted with a mechanical pivot point but the side burner is locked in place to prevent movement about this pivot in normal usage. The top burner, however, is free to rotate about its pivot during a burner exposure and is lightly weighted so as to exert a downward force on the mattress top through its stand-off foot. Thus the burner, will follow a receding top surface on the test specimen (Fig. 7).[3]

The combination of burner stand-off distance and propane gas flow rate to the burners determines the heat flux they impose on the surface of the test specimen so that both of these parameters are tightly controlled.

Each of the burners in Figs. 4 and 5 is constructed from stainless steel tubing (12.7 mm dia with 0.89 ± 0.5 mm wall thickness; 0.50 in dia with 0.035 ± 0.002 in wall). The T head of the top surface burner (horizontal burner, Fig. 4) is 305 ± 2 mm (12 ± 0.08 in) long with gas tight plugs in each end. Each side of the T contains 17 holes equally spaced over a 135 mm length (8.5 mm ± 0.1 mm apart; 0.333 ± 0.005 in). Note that the holes on each side begin 8.5 mm (0.33 in) from the centerline of the burner head. The holes are drilled with a #56 drill and are to be 1.17 mm to 1.22 mm (0.046 in to 0.048 in) in diameter. Note also that the holes are pointed 5° out of the plane of the Figure. This broadens the width of the heat flux profile imposed on the surface of the test specimen.

The T head of the side surface burner (vertical burner) is constructed similarly, as shown in Fig. 5, except that its overall length is 254 ± 2 mm (10 ± 0.08 in). Each side of the burner head contains 14 holes spaced evenly over a 110 mm length (8.5 mm ± 0.1 mm apart; 0&333 ± 0.005 in). The holes are drilled with a #56 drill and are to be 1.17 mm to 1.22 mm (0.046 in to 0.048 in) in diameter. Note that here also the holes are pointed 5° out of the plane of the Figure.

When the two burners are set up to impinge on the test specimen, their gas jets should point toward each other with this 5° angle of deflection.

[3] In contrast to the sloped feed tube for the side burner shown in Figure 7, that tube will be horizontal when the side burner pivot is locked in place, as is usual during a test exposure.

Figure 6 shows the details of the burner stand-off, found on each burner. This consists of a collar fixed by a set screw onto the inlet tube of the burner head. The collar holds a 3 mm dia stainless steel rod having a 12.7 mm by 51 mm by (2 - 2.5 mm) thick (0.5 in by 2 in by (0.08 – 0.10) in thick) stainless steel pad welded on its end with its face (and long axis) parallel to the T head of the burner. Note that the foot pad is displaced ca. 10 mm to 12 mm from the longitudinal centerline of the burner head so that it does not rest on the test specimen in an area of peak heat flux.

A short section (9.5 mm OD, ca. 80 mm long; 3/8 in OD, ca. 3.2 in long) of copper tubing is placed in the inlet gas line just before the burner to facilitate making the burner nominally parallel to the test specimen surface (by a procedure described below). The copper tube on the top surface burner must be protected from excessive heat and surface oxidation by wrapping it with a suitable layer of high temperature insulation. Both copper tubes are to be bent by hand in the burner alignment process. They must be replaced if they become work-hardened or crimped in any way.

The gas inlet lines (12.7 mm OD stainless steel tubing; 0.50 in) serve as arms leading back to the pivot points and beyond, as shown in Fig. 7. The length to the pivot for the top burner, approximately 1000 mm (40 in), is chosen to lessen the angle through which the burner head will rotate when it follows a receding test specimen surface. This lessens the variability of the heat flux imposed on the burner surface during such movement. The top burner arm has a pair of moveable cylindrical counterweights that are used, as described below, to adjust the downward force on the stand-off foot.

Figure 7 shows the frame that holds the burners and their pivots, which are adjustable vertically in height. All adjustments (burner height, burner arm length from the pivot point, counterweight positions along the burner arm) are facilitated by the use of knobs or thumbscrews as the set screws. The three point footprint of the burner frame, with the two forward points on wheels, facilitates burner movement and burner stability when stationary.

The metal arms attached to the burners are themselves attached to a separate gas control console by flexible, reinforced plastic tubing[4]. The gas control console is mounted separately so as to facilitate its safe placement outside of the test room throughout the test procedure. The propane gas lines running between the console and the burner assembly must be anchored on the assembly before running to the burner inlet arms. A 1.5 m ± 0.025 m (58 in ± 1 in) length of flexible, reinforced tubing between the anchor point and the end of each burner inlet allows free movement of the top burner about its pivot point.

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[4] Because the tubing puts a load on the rear end of the top burner arm, its length (from burner arm to anchor point) is specified. The stiffness of the tubing is also a factor in this and so the type of tubing makes some difference in ease of setting the downward force of the top burner. Fiber-reinforced plastic tubing (6 mm ID by 9.5 mm OD; ¼ in ID by 3/8 in OD) made of PVC has been found to be satisfactory. The fiber reinforcement is desirable as a safety measure since this thermoplastic tubing is being used in a hot environment.

Note that the flexible tubing is vulnerable to heat damage in a room test and so the burner assembly should be withdrawn from the room immediately after the burner exposure ends.

Each burner head has a separate pilot light consisting of a 3 mm OD (1/8 in OD) copper tube with an independently-controlled supply of propane gas. The tube terminates within 10 mm of the center of the burner head. Care must be taken to set the pilot flame size small enough so as not to heat the test specimen before the timed burner exposure is begun.

Each burner has a flow control system of the type shown in Fig. 8. Propane gas from a source such as a bottle is reduced in pressure between 35 to 70 kPa (10 to 20 psig) and fed to the system shown in Fig. 8. The gas flow to the burner is delivered in a square-wave manner (constant flow with rapid onset and termination) by means of the solenoid valve upstream of the flowmeter. An interval timer (accurate to ± 0.2 s) determines the burner flame duration. The pilot light assures that the burner will ignite when the solenoid valve opens[5]. The gas flow is set using a rotameter type of flowmeter, with a 150 mm scale, calibrated for propane. Note that the flow resistance of the burner holes causes a finite pressure increase in the flowmeter above ambient; this must be taken into account when the flowmeter is calibrated. (If a calibration at one atmosphere is provided by the manufacturer, the flowmeter reading, at the internal pressure existing in the meter, required to get the flow rates listed below must be corrected, typically by the square root of the absolute pressure ratio. This calls for measuring the actual pressure in the flow meters when set near the correct flow values. A value roughly in the range of 1 kPa to 3 kPa – 5 in to 15 in of water – can be expected.)

Generally, the flowmeter manufacturer may provide only a one point calibration and so it will be necessary to do separate calibrations of the two meters for the conditions used in the test. This requires putting a high accuracy, volume displacement, flow measurement device such as a diaphragm test meter into the line between the flowmeter and the burner (the propane flowing from the burner during calibration is burned). Again, it is necessary to measure the actual pressure in the test meter during calibration. Calibrate at three or more points in a flow range that surrounds the target values (below). Fit a line to the points to determine the location of the flowmeter setting necessary to obtain the desired propane flow rates for mattress flammability testing. Appendix B gives more details of gas flow calibration.

Use propane gas with a known net heat of combustion of 46.5 ± 0.5 MJ/kg (nominally 99 % to 100 % propane). Each burner has a specific propane gas flow rate set with its respective, calibrated flowmeter. The gas flow rate to the top burner is 12.9 L/min ± 0.1 L/min at a pressure of 101 ± 5 kPa (standard atmospheric pressure) and a temperature of 22 ± 3 °C (72 ± 5 °F). The gas flow rate to the side burner is 6.6 ± 0.05 L/min at a pressure of 101 ± 5 kPa (standard atmospheric pressure) and a temperature of 22 ± 3 °C

[5] If the side burner, or more commonly one half of the side burner, fails to ignite quickly, adjust the position of the igniter, bearing in mind that propane is heavier than air. The best burner behavior test assessment is done against an inert surface (to spread the gas as it would during an actual test).

(72 ± 5 °F). For the flowmeters supplied with the burner assembly, the black float setting for the top burner is expected to be in the 85 mm to 95 mm range. For the side burner, the expected range for the black float is 115 mm to 125 mm. The total heat release rate of the two burners is 29 kW. The top burner produces 19 kW and the side burner produces 10 kW.

Location of the Gas Burners. Place the burner heads so that they are within 300 mm (1 ft) of the mid-length of the mattress. The general layout for the room configurations is shown in Figs. 2 and 3.

For a quilted mattress top, the stand-off foot pad must alight on a high, flat area between dimples or quilting thread runs. The same is to be true for the side burner if that surface is quilted. If a specimen design presents a conflict in placement such that both burners cannot be placed between local depressions in the surface, the top burner takes precedence.

Burner Set-Up and Alignment. Since the heat flux levels seen by the test specimen surfaces depend on burner spacing, as well as gas flow rate, care must be taken with the set-up process. The goal is to place the burners in relation to the mattress and foundation surfaces in the manner shown in Fig. 9, i.e., at the nominal spacings shown there and with the burner tubes nominally parallel[6] to the mattress surfaces on which they impinge.

The following sequence has been found to be satisfactory. Other procedures are acceptable only if they result in proper burner set-up as described below.

- Just prior to moving the burner adjacent to the test specimen, briefly ignite each burner, one at a time, and check that the propane flow to that burner is set at the appropriate level on its flowmeter to provide the flows listed above. Check that the timers for the burner exposures are set to 70 s for the top burner and 50 s for the side burner. For a new burner assembly, check the accuracy of the gas flow timers against a stop watch at these standard time settings

Burner Alignment Procedure:

Complete the following before starting:

- For the mattress top burner, the pivot point and the two metal plates around it must be clean and well-lubricated so as to allow smooth, free movement.

- The two burners must be set such that the 5° out-of-plane angling of the flame jets makes the jets on the two burners point slightly toward each other.

[6] The top burner will tend to be tangential to the mattress surface at the burner mid-length; this orientation will not necessarily be parallel to the overall average mattress surface orientation nor will it necessarily be horizontal. This is a result of the shape of the mattress top surface.

- Since the burner stand-off feet are protrusive and somewhat vulnerable, they must be checked periodically for straightness and perpendicularity between foot pad and support rod. The stand-off feet should be clean of residue from a previous test.

- Have at hand the following items to assist in burner set-up: the jig, shown in Fig. 10, for setting the stand-off feet at their proper distances from the front of the burner tube; a 3 mm (1/8 in.) thick piece of flat stock (any material) to assist in checking the parallelness of the burners to the mattress surfaces; a sheet metal platen (24 gage stainless steel has proven satisfactory) that is 300 mm (12 in) wide, 610 mm (24 in) long and has a sharp, precise 90° bend 355 mm (14 in) from one 300 mm wide end.

1) Place the sheet metal platen on the mattress with the shorter side on top. As noted above, the location is to be within 30 cm (1 ft) of the longitudinal center of the mattress and the intended location of the stand-off foot of the top burner is not be in a dimple or crease caused by the quilting of the mattress top. Press the platen laterally inward from the edge of the mattress so that its side makes contact with the either the top and bottom tape edge or the vertical side of the mattress.[7] Use a 20 cm (8 in) strip of duct tape (platen to mattress top) to hold the platen firmly inward in this position.

2) With both burner arms horizontal (pinned in this position), fully retract the stand-off feet of both burners and, if necessary, the pilot tubes as well[8]. (Neither is to protrude past the front face of the burner tubes at this point.) Move the burner assembly forward (perpendicular to the mattress) until the vertical burner lightly contacts the sheet metal platen. Adjust the height of the vertical burner on its vertical support column so as to center the tube on the crevice between the mattress and the foundation.[9] (This holds also for pillow top mattress tops, i.e., ignore the crevice between the pillow top and the main body of the mattress.) Adjust the height of the horizontal burner until it sits lightly on top of the sheet metal platen. Its burner arm should then be horizontal.

3) Move the horizontal burner in/out (loosen the thumb screw near the pivot point) until the outer end of the burner tube is 13 mm to 19 mm (1/2 in to 3/4 in) from the corner bend in the platen (this is facilitated by putting a pair of lines on the top

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[7] Mattresses having a convex side are treated separately since the platen cannot be placed in the above manner. Use the platen only to set the top burner parallelness. Set the in/out distance of the top burner to the specification in step 3 above. Set the side burner so that it is approximately (visually) parallel to the flat side surface of the foundation below the mattress/foundation crevice once its foot is in contact with the materials in the crevice area. The burner will not be vertical in this case. If the foundation side is also non-flat, set the side burner vertical (± 3 mm, as above) using a bubble level as a reference. The side surface convexities will then bring the bowed out sections of the specimen closer to the burner tube than the stand-off foot.

[8] The pilot tubes can normally be left with their ends just behind the plane of the front of the burner tube. This way they will not interfere with positioning of the tube but their flame will readily ignite the burner tubes.

[9] For tests of the mattress alone, set the side burner mid-height equal to the lower ~~tape~~ edge of the mattress.

of the platen 13 mm and 19 mm from the bend and parallel to it). Tighten the thumb screw.

4) Make the horizontal burner parallel to the top of the platen (within 3 mm, 1/8 in over the burner tube length) by bending the copper tube section appropriately. Note: After the platen is removed (Step 7 below), the burner tube may not be horizontal; this is normal. For mattress/foundation combinations having nominally flat, vertical sides, the similar adjustment for the vertical burner is intended to make that burner parallel to the sides and vertical. Variations in the shape of mattresses and foundations can cause the platen section on the side to be non-flat and/or non-vertical. If the platen is flat and vertical, make the vertical burner parallel to the side of the platen (± 3 mm) by bending its copper tube section as needed. If not, make the side burner parallel to the mattress/foundation sides by the best visual estimate after the platen has been removed.

5) Move the burner assembly perpendicularly back away from the mattress about 30 cm (1 ft). Set the two stand-off feet to their respective distances using the jig designed for this purpose. Install the jig fully onto the burner tube (on the same side of the tube as the stand-off foot), with its side edges parallel to the burner feed arm, at about the position where one end of the foot will be. Loosen the set screw and slide the foot out to the point where it is flush with the bottom end of the jig. Tighten the set screw. Make sure the long axis of the foot is parallel to the burner tube. IT IS ESSENTIAL TO USE THE CORRECT SIDE OF THE SPACER JIG WITH EACH BURNER. DOUBLE CHECK THIS. THE JIG MUST BE CLEARLY MARKED.

6) Set the downward force of the horizontal burner. Remove the retainer pin near the pivot. While holding the burner feed arm horizontal using a spring scale[10] hooked onto the thumbscrew holding the stand-off foot, move the small and/or large weights on the feed tube appropriately so that the spring scale reads 170 g to 225 g (6 oz to 8 oz).

7) Remove the sheet metal platen (and tape holding it).

8) Hold the horizontal burner up while sliding the burner assembly forward until its

[10] An acceptable spring scale has a calibrated spring mounted within a holder and hooks on each end. Ohaus Scale Corp (Florham Park, NJ) makes a very inexpensive spring scale with a 58 mm (2 ¼ in) range of movement in response to a 250 g (9 oz) weight that is adequate for this purpose.

stand-off foot just touches the mattress and/or the foundation[11], then release the horizontal burner. The outer end of the burner tube should extend at least 6 mm to 12 mm (1/4 in. to ½ in.) out beyond the uppermost corner/edge of the mattress so that the burner flames will hit the tape edge. (For a pillow top mattress, this means the outer edge of the pillow top portion and the distance may then be greater than 6 mm to 12 mm (¼ in. to ½ in.)) If this is not the case, move the burner assembly (perpendicular to the mattress side) – not the horizontal burner alone - until it is. Finally, move the vertical burner tube until its stand-off foot just touches the side of the mattress and/or the foundation. (Use the set screw near the vertical burner pivot.)

9) Make sure all thumbscrews are adequately tightened.

10) If there is <u>any</u> indication of flow disturbances in the test facility which cause the burner flames or pilot flames to move around, place screens around the burners so as to minimize these disturbances[12]. These screens (and any holders) must be far enough away from the burners (ca. 30 cm (12 in.) or more for the top, less for the side) so that they do not interact with the flames growing on the mattress/foundation surfaces. For the top surface burner, a triple layer of window screen approximately 30 cm (12 in.) high sitting vertically on the mattress top (Fig. 9) has proved satisfactory. For the side burner a triple layer of screen approximately 15 cm (6 in.) wide, formed into a square-bottom U-shape and held from below the burner has proved satisfactory. Individual laboratories will have to experiment with the best arrangement for suppressing flow disturbances in their facility.

11) Proceed with the test (see Test Procedure below and Appendix A).

Support Structure. See Fig. 1; the arrangement shown there applies to all test configurations. The mattress is centered on top of the foundation (except as noted below). The mattress/foundation assembly is placed on top of a short welded bed frame (1.90 m by 0.99 m by 115 mm high; 75 in by 39 in by 4.5 in high) made from 25 mm (1 in) steel angle. The frame is to be completely open under the foundation except for two crosspieces, 25 mm wide (1 in) at the 1/3 length points. The bed frame feet rest on a surface of either calcium silicate board or fiber cement board of the type used as underlay for tile flooring, 13 mm (0.5 in) thick, 2.11 m by 1.19 m (83 in by 47 in). This surface must

[11] The foot should depress the surface it first contacts by no more than 1 mm to 2 mm. This is best seen up close, not from the rear of the burner assembly. However, if a protruding tape edge is the first item contacted, compress it until the foot is in the plane of the mattress/foundation vertical sides. The intent here is that the burner be spaced a fixed distance from the vertical mattress/foundation sides, not from an incidental protrusion. Similarly, if there is a wide crevice in this area which would allow the foot to move inward and thereby place the burners too close to the vertical mattress/foundation sides, it will be necessary to use the spacer jig (rather than the stand-off foot) above or below this crevice to set the proper burner spacing. Compress the mattress/foundation surface 1 mm to 2 mm when using the jig for this purpose.

[12] The goal here is to keep the burner flames impinging on a fixed area of the specimen surface rather than wandering back and forth over a larger area.

be cleaned between tests to avoid build-up of combustible residues. Lining this surface with aluminum foil to facilitate cleaning is not recommended since this might increase fire intensity via reflected radiation. The board serves as a catch surface for any flaming melt/drip material falling from the bed assembly and may be the location of a pool fire that consumes such materials. The low bed frame height is chosen to allow interaction between such a pool fire and the bed assembly. The bed frame and bed are centered on this catch surface. The catch surface is optionally raised above the floor of the test facility by 25 cm (10 in) by placing it on top of a steel framework capable of supporting the weight of the bed assembly. The added height is not believed to affect system performance; it may ease the set-up process for the test operator.

Heat Release Rate Measurement. Heat release rate measurements in all three configurations shall follow the procedures and instrumentation recommendations described in detail in ASTM E 1590. The only change is in the calibration levels of the system from 40 and 160 kW to 75 and 200 kW.

Video Recording. Place a video camera so as to have (when the lens is zoomed out) just slightly more than a full-length view of the side of the test specimen being ignited, including a view of the flame impingement area while the burner assembly is present. The view must also include the catch pan so that it is clear whether any melt pool fire in this pan participates significantly in the growth of fire on the test specimen. The camera is to include a measure of elapsed time to the nearest 1 s within its recorded field of view (preferably built-in to the camera). For the room-based configurations, the required full-length view of the sample may require an appropriately placed window, sealed with heat resistant glass, in one of the room walls. Place the camera at a height just sufficient to give a view of the top of the specimen while remaining under any smoke layer that may develop in the room. The specimen is to be brightly lighted so that the videotape does not lose detail to over-exposed flames. This will require a pair or more of 1 kW photo flood lights illuminating the viewed side of the specimen. The lights may need to shine into the room from the outside via sealed windows.

It is useful, in testing prototype designs, to have an observer narrate fire and/or specimen behavior to the videotape, using a remote microphone since fine details are typically more visible to an observer than to the camera. Key issues to note are penetration (if any) of barrier materials or seams in the mattress and/or the foundation, appearance of flames in the interior of the mattress and/or foundation and any occurrence of an abrupt over-pressurization in the mattress (very briefly swelling the mattress and possibly opening barrier seams). Crackling sounds, indicating fire involvement of the wood in the base of the foundation, are also important markers of fire progression in the foundation interior.

Test Procedure

Initial Conditions:

The ambient temperature shall be above 12 °C (54 °F) and the relative humidity must be below 70%. Test specimens are to have been conditioned for at least 24 hours within these limits prior to testing.

Horizontal air flow at a distance of 0.5 m (20 in) on all sides of the test specimen at the mattress top height shall be ≤ 0.5 m/s (1.6 ft/s). If there is any visual evidence that the burner flames are being shifted around during their exposure durations, the burner regions must be enclosed on two or more sides by a quadruple layer of screen wire. The screen(s) for the top burner sits on the mattress top but must be far enough away typically 30 cm (12 in.) or more so as not to interfere or interact with flame spread during the burner exposure. The screen for the side burner will require a separate support from below. All screens are to be removed at the end of the 70 s exposure interval.

Remove the test specimen from the conditioning room immediately before it is to be tested. Be sure the bed frame is approximately centered on the catch surface. Place the mattress and foundation on the bed frame. Carefully center them on the bed frame and on each other[13].

Place the burner assembly adjacent to the test specimen and align/space the burner heads as described above. Be sure the alignment platen is removed from the test specimen. Care must be taken, once this set-up is achieved, to avoid bumping the burner assembly or disturbing the flexible lines that bring propane to it.

Charge the hose line to be used for fire suppression with water.

Ignite the pilot lights on both burners and make sure they are small enough as to not heat the test specimen surfaces significantly.

With the calorimetry system fully operational, after instrument zeroes and spans, start the video lights and video camera and data logging systems at least one minute before burner ignition.

Start the burner exposure by activating power to the burner timers.

When the burners go out (after 70 s for the longer exposure), carefully lift the top burner tube away from the specimen surface, producing as little as possible disturbance to the specimen. Remove the burner assembly from the specimen area to facilitate the video camera view of the full side of the specimen. In the case of the room-based configurations, remove the burner assembly from the room to protect it. Remove all screens.

Record the heat release rate and video view until one the following has occurred:

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[13] If the mattress is 1 cm to 2 cm (0.5 in. to 1 in.) narrower than the foundation and can be plausibly shifted so that the side to be exposed is in the same plane as the foundation, do so. This keeps the heat flux exposure the same for the sides of the two components.

- All signs of burning have ceased (smoldering, as indicated by continued smoke emission, may transition into flaming; it is considered here to be a form of burning)
- 30 minutes has elapsed since the start of the burner exposure. (The test ends at 30 minutes. For informational purposes in assessing a new design, it may be useful to continue longer if the heat release rate is at least 50 kW and is increasing.)
- Development of a fire of such size as to require suppression for the safety of the facility

Note the time and nature of any unusual behavior that is not fully within the view of the video camera. This is most easily done by narration to a camcorder.

Run the heat release rate system and datalogger until the fire has been fully out for several minutes to allow the system zero to be recorded. If the test ends at 30 minutes with some residual combustion and it is not to be followed further, suppress it to permit this zero recovery.

Test Criteria

A mattress, a futon or a mattress/box spring set fails to meet the requirements of this test procedure if any of the following criteria are exceeded:

- A peak rate of heat release of 200 kW.

- A total heat release of 25 MJ in the first 10 minutes of the test.

Report

The test report includes the identity of the testing laboratory, the identification and any available compositional details of the test specimen, the test date and the conditions of both pre-conditioning (relative humidity and temperature) and testing (relative humidity and temperature). Also include any notes (with timing) on unusual behavior of the specimen during the test that may not have been captured on the video. The body of the report contains graphs of heat release rate versus time from two minutes before the start of ignition all the way through the zero recovery period, along with a tabulation of the measured data that goes into the heat release rate calculation. If requested, calculate gas yields in accord with the procedure given in ASTM 1590. Include the videotape with any narration of the test.

Appendix A: Burner Operation Sequence

(Applies to L&P Version of the Burner Assembly)

Starting point:

> AC power on (red knob out); propane pressure set between 10 to 20 psig at bottle; timers set to 70 s (top burner) & 50 s (side burner); flowmeters pre-set to values that give the requisite propane gas flow rates to each burner. Pilot tubes set just behind front surface of burners; pilot flow valves set for ca. 1 cm (1/2 in.) flames.

Position burner on test specimen and remove sheet metal platen.

Place screens around both burners.

Open pilot ball valves one at a time and ignite pilots with hand-held flame; adjust flame size if necessary being very careful to avoid a jet flame that could prematurely ignite the test specimen (Beware: after a long interval between tests the low pilot flow rate will require a long time to displace air in the line and achieve the steady-state flame size.)

Open both burner ball valves.

Start test exposure by simultaneously turning on power to both timers (timers will turn off burners at appropriate times.)

Check/adjust propane flow rates (DO THIS ESSENTIAL TASK IMMEDIATELY). Experience shows the flow will not remain the same from test-to-test in spite of fixed valve positions so adjustment is essential.)

After burners are out:

> Lift top burner and back assembly away from specimen
> Turn off power to both timers
> Remove screens (if used)
> Turn off pilots at their ball valves