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UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
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Memorandum

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THROUGH: Hugh McLaurin, Associate Executive Director
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SUBJECT : Technical Rationale for the Standard for the Flammability (Open-Flame) of Mattress Sets and Responses to Related Public Comments

Mattress and bedding fires continue to be one of the major contributors to residential fire deaths. Based on national fire loss estimates for the years 1999-2002, ignition of mattresses and bedding resulted in an estimated 15,300 residential structure fires, 350 deaths, 1,750 injuries, and $295.0 million in property loss annually (Smith & Miller, 2005).

A significant portion of these deaths and injuries is caused by ignition from open-flame sources. The most common open-flame ignition sources in mattress and bedding fires are lighters, matches, and candles. Other small open-flame heat sources include sparks and embers escaping from fueled equipment, arcs and sparks from operating equipment, torches, and fireworks.

Mattresses/Foundations Rulemaking

In October 2001, the U.S. Consumer Product Safety Commission (CPSC) voted to issue an advance notice of proposed rulemaking (ANPR)[1] to develop a mandatory open-flame standard for mattresses. Support for issuing the ANPR was provided in a staff briefing package, dated August 16, 2001, that summarized staff studies and industry sponsored research relating to defining the hazards associated with open-flame ignition of mattresses. The package also

[1] Mattresses/foundations would be regulated under the Flammable Fabrics Act (FFA), 15 USC 1191-1204. Pursuant to the requirements specified in the FFA, CPSC follows a three-step rulemaking process, beginning with an advance notice of proposed rulemaking (ANPR), followed by a notice of proposed rulemaking (NPR), both of which include specified time periods for soliciting public comments. Publishing a final rule, which includes an effective date for compliance with the mandatory requirements, is the third and final step.

evaluated several petitions received in 2000 from the Children's Coalition for Fire-Safe Mattresses (CCFSM) requesting open-flame standards for mattresses. The ANPR was published in the *Federal Register* on October 11, 2001 (66 FR 51886) and invited comments concerning the risk of injury associated with the regulatory alternatives being considered, and other possible options.

CPSC staff analyzed public comments received on the ANPR and prepared a package for the Commission with a draft notice of proposed rulemaking (NPR) including a draft proposed mattress flammability standard.[2] On December 22, 2004, the Commission voted to publish the NPR for mattresses, including the proposed mattress standard.

The NPR for mattresses was published in the *Federal Register* on January 13, 2005 (70 FR 2470) and invited comments for a 75-day period that ended March 29, 2005. During the comment period, the Commission received 543 comments from individuals, businesses, associations, and interested parties representing various segments of the mattress industry. This memorandum provides background, technical rationale, and supporting justification for the staff's draft final mattress standard, *Standard for the Flammability (Open-Flame) of Mattress Sets,*[3] *16 CFR Part 1633,* and responds to comments raising specific issues related to the test method and performance criteria received on the NPR and proposed mattress standard.

Background and Supporting Justification

Several years of research on mattress fires conducted by the National Institute of Standards and Technology (NIST) for the industry and CPSC provide the basis for the staff's draft final standard and test criteria (and the basis for California Technical Bulletin 603 requirements, the State of California's mandatory mattress flammability standard). The comprehensive, scientifically-based research projects were designed to address the open-flame ignition of mattresses and bedclothes under controlled conditions closely resembling those of actual fire scenarios.[4] The program focused on understanding the characteristics of fires involving mattress and bedclothing assemblies and on developing an appropriate and technologically practicable methodology to measure (or characterize) and effectively address the hazard.

A burning mattress is generally the primary energy contributor in a typical bedroom fire. These fires typically include simultaneous burning of bedclothes. The burning bedclothes create a large open-flame ignition source for the mattress. Once the mattress is ignited and involved, the fire develops rapidly, creating dangerous flashover conditions. The rapid and intense burning of the mattress, along with burning bedclothes, is likely to quickly ignite and involve other

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[2] The Briefing Package—*Notice of Proposed Rulemaking for the Flammability (Open-Flame) of Mattresses and Foundations and Options for Addressing Bedclothes Involvement in Mattresses/Bedding Fires*, submitted to the Commission on November 1, 2004, is available from the U.S. CPSC Office of the Secretary or at (www.cpsc.gov/library/foia/foia05/brief/briefing.html). The package also included a draft ANPR to address flammability standards for bedclothes. The Commission voted to publish the ANPR for bedclothes; the ANPR for bedclothes was published in the *Federal Register* on January 13, 2005 (70 FR 2514).

[3] *Mattress Set*, as defined in the *staff's draft final standard*, means mattresses intended to be sold with a foundation and includes mattresses intended to be sold alone. The title incorporates this definition and reflects a change from the title of the proposed standard included in the NPR.

[4] Complete reports are available from National Institute of Standards and Technology (NIST), Gaithersburg Maryland (www.fire.nist.gov/bfrlpubs).

objects in the room. These fires tend to grow rapidly, reach untenable room conditions (threatening life safety and preventing escape from the fire), and exceed flashover conditions within a few minutes. This typical fire scenario provides insufficient time for escape from the fire source, room of origin, and other rooms under certain conditions.

Early in the fire, the hazard is contained to the room. The fire forces relatively small amounts of dilute smoke from the room. As the room fire grows, the layer of accumulating hot gases and smoke thickens downward from the ceiling. Eventually, the layer can descend from the ceiling to reach the floor level. The smoke interface heights are dependent on the door opening; the interface height is pushed further downward as the bedroom door is more and more closed.[5] Fire modeling and available fire test data show that the interface descends to about five feet for relatively small fires (with heat release rates of approximately 300kW). For fires exceeding 600kW, the interface descends to less than three feet. Heat release rates exceeding 500kW are generally considered to pose a serious threat as a dangerous pre-flashover situation is approaching, and the threat of igniting nearby items is high. The threat of incapacitation to occupants in the room of origin is also likely.

Flashover is the point at which the entire contents of a room are ignited simultaneously by radiant heat from the hot gases and smoke accumulating in the upper portions of the room. As the layer of hot gases accumulates and smoke at the ceiling thickens, the heat release rate of the burning bed and the temperature in the room increase. Room temperatures typically exceed 600-800°C (approximately 1100-1470°F) at flashover. The high heat release rates and room temperatures lead to the rapid production of carbon monoxide and depletion of oxygen in the room environment. Flaming combustion of unburned volatiles outside of the room of origin begins. Heat, hot toxic gases, and smoke being pushed from the room of origin pose a serious threat to those outside the room in which the fire originated.

Flashover occurs when the heat release rate reaches a critical value. The critical heat release value depends on several factors, predominately room size and ventilation. The ability of a person to escape a fire depends on fire growth and intensity, smoke density, and threat from heat and toxic gases. The rapid and intense burning of traditional mattresses in typical fire scenarios provides insufficient time for escape from the fire source, room of origin, and other rooms under certain conditions. Discovery and escape from the fire must take place before the fire grows to the critical heat release rate for the specific room.

NIST estimates of critical heat release rates were based on relationships between heat release and estimated hazard. A critical heat release rate for an ordinary sized room is estimated to be about 1000kW (1.0MW). This estimate is based on a collective contribution from any items possibly involved. Staying below this value could be accomplished by reducing the heat release from the bed and by reducing the likelihood of involving other objects in the same room (Ohlemiller & Gann, 2002; Ohlemiller et al., 2000).

About two-thirds of all mattress fatalities are attributed to mattress fires that lead to flashover. This accounts for nearly all the fatalities that occur outside the room of fire origin and about half of the fatalities that occur within the room of origin (Ohlemiller & Gann, 2002; Hiser,

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[5] A somewhat different situation may result if the door is closed completely and the fire gets starved for oxygen.

2001). Tests on traditional twin size mattress constructions (16 CFR Part 1632 compliant) without bedclothes measured peak heat release rates that exceeded 2000kW (2.0MW) in less than 300 seconds (5 minutes). Peak heat release rates of king size mattresses approached a factor of two times greater than tests of twin size mattresses (Ohlemiller & Gann, 2002).

Draft Final Standard

The *Standard for the Flammability (Open-Flame) of Mattress Sets, 16 CFR Part 1633,* referred to as *draft final standard* in this memorandum, establishes flammability requirements that all mattress sets must meet before sale or introduction into commerce.[6]

The performance criteria specified in the *draft final standard* are intended to effectively and feasibly reduce the risks associated with mattress fires (Tenney, 2004). These hazards are closely associated with a mattress' peak rate of heat release and total energy. A mattress with a limited contribution to the fire, especially early in the fire, will substantially increase the available time for occupants to discover the fire and escape, and, therefore, substantially reduce the current risks associated with mattress fires.

The *draft final standard* includes a full-scale test method using a pair of T-shaped gas burners designed to represent burning bedclothes to determine the flammability of mattress sets. The burners test an area of the mattress, assumed to be representative of the entire assembly, for resistance to flame penetration. A specified local heat flux is imposed by the burners simultaneously to the top and side of the mattress and foundation set for a specified duration. The top burner duration is 70 seconds and the side burner duration is 50 seconds. The *draft final standard* limits the peak heat release rate to 200 kilowatts (kW) for a mattress set, not to be exceeded at any time during a 30 minute test, and limits the total heat release to 15 megajoules (MJ) for the first 10 minutes of the test.[7]

Peak rate of heat release Limiting the peak rate of heat release of the mattress to 200kW (during the 30 minute test) ensures a less flammable design and will have the most impact on available escape time. It represents a significant improvement in performance compared to traditional mattress designs. The peak rate of heat release limit accounts for the contribution of bedclothes and other room contents to the fire hazard, ensures that the mattress does not cause flashover on its own, is technically feasible, and considers many factors related to the fire scenario (such as room effects). It also ensures the benefits and estimated effectiveness identified in the hazard analysis by CPSC staff are achieved (Smith & Miller, 2005).

Test duration The test duration of 30 minutes is related to, but not equivalent to, the estimated time required to permit discovery of the fire and allow escape under typical fire scenarios. A 30 minute test is based on an analysis of the hazard and the technological feasibility of producing complying mattresses. It is intended to provide a substantial increase in time for an

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[6] The *draft final standard* is a separate document found in the Briefing Package and is available from the U.S. CPSC. The current version reflects changes recommended by the CPSC staff based on comments received on the NPR and *proposed standard* and test data.

[7] In fire testing, the fire size is expressed as the heat release rate (HRR) in kilowatts (kW). Joule is a unit of energy; one Watt is equal to one Joule per second (1W= 1J/s).

occupant to discover and escape the fire. The number of failures, test variability, performance unreliability, and associated costs increase significantly with a longer test period. Under certain conditions,[8] staying at or below the proposed 200kW limit for a 30 minute test is estimated to provide an adequate time for fire discovery and escape by occupants in the bed or otherwise in the room of fire origin. Much of the effectiveness is based on a timely escape from the hazardous conditions.

Early limit of total heat release The effectiveness of the standard depends on the need for early discovery and escape from the fire without delay. Limiting the early contribution of the mattress will have the greatest impact on reducing the risk as the mattress will have little involvement in the fire for the specified period of time. The early limit of 15 MJ for the first 10 minutes of the test partially compensates for burning bedclothes and ticking by preventing early involvement of the mattress as the bedclothes burn and compensates for other items that might be involved early in a fire.[9] The total heat release limit for the first 10 minutes of the test is a practical and simple measure that provides a substantial increase in escape time by slowing the rate of fire growth and severity while still permitting a range of technically feasible, practicable, and cost effective mattress design options.

The *draft final standard* allows the test to be conducted in either an open calorimeter or test room configuration. The *draft final standard* requires a minimum of three specimens to be tested (each yielding passing results) for each qualified prototype design. The *draft final standard's* definition of "prototype" excludes differences in ticking, allowing the substitution of ticking materials without additional prototype qualification, unless the ticking itself provides the fire performance properties to meet the requirements.[10]

Inter-Laboratory Study

To evaluate the *draft final standard* and test method, an inter-laboratory study or precision and bias (P&B) study was conducted to explore the sensitivity, repeatability, and reproducibility of the NIST test protocol specified in the *draft final standard*. The study was designed to evaluate the robustness and validity of the test protocol (*a test of the test*), rather than the performance of the specific mattress designs.

Sensitivities were explored by varying a range of possible test facility and operator errors primarily associated with test set-up measurements. The selected factors could reasonably be expected to occur with some frequency when commercial laboratories are conducting routine

[8] The assumed conditions are that the bedclothes do not contribute to the mattress fire to the extent that the combined fire rapidly poses a hazardous condition, preventing escape, or threatens ignition of other objects in the room, accelerating further fire growth. It is further assumed that occupants of the room are capable of reacting to a fire in a timely manner.

[9] NIST research, supported by fire modeling and early fire research, suggests untenable fire conditions occur at 10 minutes and 25MJ. This represents a total contribution from all possible items involved in the fire. It suggests that any single item must be lower than 25MJ.

[10] If the ticking itself provides the fire performance properties to meet the requirements in the *draft final standard*, ticking changes cannot be made during production without a new prototype qualification or showing to the satisfaction of the Commission staff, through tests and/or technical evaluation, that a change would not negatively influence the specified fire performance test criteria.

testing. Repeatability was evaluated with multiple tests of the same mattress designs at a single laboratory. Another part of the study was designed to explore possible differences in performance when tests were conducted in different laboratories with different test room configurations (open calorimeter or test room). All of the participating laboratories conducted multiple tests of eight different mattress designs that had been constructed so as to minimize possible variations in manufacturing. This test series used eight mattress designs that varied critical elements (barrier [sheet or high-loft], type of mattress [single or double sided], and the style of mattress [tight or pillow top]). The data were analyzed for sensitivity, repeatability, and reproducibility in order to confirm the precision of the NIST test protocol or reveal which, if any, test parameters need to be revised.

A detailed statistical analysis of the test data does not suggest either unreasonable sensitivities or practical limitations of the NIST test protocol (Damant/Inter-City Testing & SPSC, 2005). The results were not affected by the varying range of parameters selected for the sensitivity study. The specified ignition source is severe enough and the test duration long enough to allow a valid/realistic evaluation of mattress set performance. The test method is able to identify relative mattress performance and is capable of measuring differences between good and bad mattress designs. Thus, mattresses either pass or fail the proposed test criteria, showing that the inconsistencies in the test results do not suggest either unreasonable sensitivities or practical limitations in the test protocol. These findings support previous test experiences that showed the test to be a robust, valid test method.

Despite the validity of the test method, the data shows some significant differences in the test results reported by the laboratories. Some variability was expected due to the inherent variability of full-scale fire tests compared to other types of tests. However, a variety of reasons may provide some explanation for the reported data differences in this study. These reasons may be identified as non-randomization of samples, lab procedural issues, differences in instrumentation calibration, and data analysis, or material and construction inconsistencies. Differences in laboratory practice due to laboratory infrastructure, equipment, maintenance procedures, and familiarity with the test protocol, could have influenced the test results. Not randomizing the samples or tracking what production went to what laboratories could have also been a contributing factor. It is not known how much these differences influenced the measurements of the laboratories.

The reported differences in performance appear to be driven substantially by the performance of the two selected barriers. Prior test experience shows that some mattress designs exhibit more consistent fire performance than other designs suggesting that mattress design (e.g., tight-top, pillow-top) is a major factor in performance differences. In the study, however, the differences caused by the selected barriers were more prominent. The particular sheet style that was selected for the study proved to be unexpectedly fragile. As a result, the selected sheet style barrier either broke open (causing failure of the mattress design) or remained intact but revealed localized construction problems (causing data differences). If the selected sheet style barrier had performed more consistently, mattress design may have been shown to be a more prominent factor. Although it may have at one time, the selected mattress design does not appear to be representative of the current residential mattress market.

The differences in the reported results could have also been influenced by material and construction inconsistencies. Evaluations of the samples revealed construction deficiencies, but it is not known how these deficiencies affected the results. This emphasizes the importance of controlling components, materials, and methods of assembly. Quality assurance procedures, standardized testing, written records, and visual inspections are all possible options for assuring, verifying, and controlling consistency of production.

Despite the number of factors that may have contributed to the significant differences in the reported test results, the P & B study provides support for the requirements specified in the *draft final standard.* The reported differences suggest that, when the test procedures are correctly followed, compliance with the specified requirements is dependent on the combined characteristics and resulting behavior of selected mattress components, mattress design, and consistent manufacturing processes.

NPR Comments

During the comment period following publication of the NPR, approximately 550 comments were received. Several of the received comments were considered to be of a technical nature, relating to the need for specific component requirements, changes to the proposed test protocol, test apparatus, proposed requirements, and smoke alarm detection. A detailed discussion of the received technical comments and responses is provided in Appendix A. A few of the comments raised technical issues requiring additional test work. For example, there were several comments requesting a change in the specified burner hole size. Several commenters requested revised, more detailed temperature and relative humidity requirements. Other commenters questioned the flammability behavior of certain mattress designs.

Additional Test Work

Additional test work was conducted to explore the technical issues raised in the received comments and provide technical support for finalizing the *draft final standard* test protocol and requirements. CPSC contracted with NIST to conduct a series of tests to evaluate the heat flux of different burner hole sizes, effects of temperature and relative humidity conditions, flammability behavior of one-sided mattresses, and the effects of flame retardant durability on the fire performance of selected flame resistant barriers.

Heat flux of burner hole size NIST developed a pair of propane gas burners to consistently simulate the typical heat impact imposed on a mattress by bedding items to be incorporated into a full-scale fire test for mattresses. The burners were designed based on test data collected from an earlier study that characterized bedclothes (Ohlemiller et al., 2000). Since two different burning conditions were exhibited on the side and top of the mattress, two different gas burners were developed. One burner simulated the heat impact observed on the top of the mattress and the other on the side of the mattress. The burners serve as the ignition source in California Technical Bulletin 603 and the CPSC's NPR and proposed standard. Both standards include NIST's burner specifications for propane gas flow rates to each burner, the spacing of the burner from the test surface, and the size of the holes to be drilled in the burner heads.

A commercial version of the NIST burner apparatus was manufactured by a commercial supplier to the mattress industry. The commercial version, which has been supplied to various test laboratories to conduct full-scale mattress testing in accordance with TB 603 and CPSC's proposed regulation, incorporated several refinements; inadvertently, the commercial version incorporated larger diameter holes in both of the burner heads (1.50 mm vs. 1.17 mm). The holes incorporated in the commercial version are 65% larger in area than the original NIST burners. The difference in hole size implies differing emerging gas flow velocities, distances of the gas jets reaching out from the burner, and heat fluxes between the two burners.

To determine the effects of the larger diameter burner holes on peak burner heat flux, NIST made heat flux scans on four different propane gas burners. The four burners represented two different burner designs, each with a burner for the top of the mattress and a burner for the side of the mattress. Data was obtained from scanning locations relative to the centerline of the burner in regions where the flame jets came closest to the surface of the mattress. The goal was to measure and compare the peak flux of the burners relative to the specified peak fluxes seen in the earlier NIST study that characterized bedclothes and supported the burner development (Ohlemiller, 2000/NISTIR 6497).

The NIST heat flux scanning apparatus used to compare the two burner holes allows fine movement and the measurement of narrow flux peaks that exist opposite the burner. This apparatus was not available at the time when the burner was developed. Comparing the heat flux scans (obtained by the more recently available scanning apparatus) of the two different burner designs provides support for continuing the use of the commercial version of the NIST burner apparatus that incorporates larger diameter holes in both of the burner heads. As reported by NIST, the results of the study show that the burners with the larger holes do a better job of meeting the target peak flux levels of bedclothes than do the original burners with the smaller holes (Ohlemiller, 2005d).

<u>*Temperature and humidity effects*</u> The *draft final standard* requires all test samples to be conditioned in a controlled temperature and relative humidity environment for a specific time period prior to testing. The samples are to be removed from the controlled storage conditions and tested. However, the laboratory test area conditions may be significantly different from the sample storage conditions. The test area conditions and time the sample is exposed to these conditions may impact the flammability behavior and test results of mattresses. NIST explored the effects of laboratory relative humidity on mattress performance when tested in accordance with the *draft final standard* requirements.

Likely consequences of changes in ambient humidity and temperature on mattress flammability were estimated based on the moisture regain properties of common mattress component materials over time. The study focused on the impact of humidity on hydrophilic materials. Since water has a high heat capacity, the ability of certain materials to absorb significant amounts of moisture has the potential to significantly impact flammability behavior. The flammability behavior of hydrophobic materials would not be influenced by changes in humidity.

NIST concluded that temperatures approaching 30°C (86°F) and relative humidity levels above about 75 percent are likely to impact heat release rate measurements as a function of time for some mattress designs, especially those containing hydrophilic materials. The time the sample is exposed to such conditions was found to be a contributing factor and should be minimized, preferably to no more than 20 minutes (Ohlemiller, 2005b).

Since exposure to certain environmental conditions is likely to have an impact on test results, it is reasonable to specify test area environmental conditions and require a maximum time allowed for exposure of a mattress sample to the fire test room conditions in the *draft final standard.* Based on NIST's findings, the test area conditions should be maintained at a temperature greater than 15°C (59°F) and less than 27°C (80.6°F) and a relative humidity less than 75 percent. Initiation of flammability testing of mattress samples is required to begin within 20 minutes after removal of the mattress sample from environmentally controlled storage conditions (Ohlemiller, 2005b). The storage conditions should be greater than 18°C (65°F) and less than 25°C (77°F) and a relative humidity less than 55 percent.

Flammability behavior of single-sided mattresses In the past few years, single-sided mattresses have become an increasingly larger and more significant portion of the residential market. By design, a single-sided mattress has only one side intended to be a sleeping surface. The other side is not intended to be a sleeping surface and is typically covered with a minimal barrier material. When the mattress is aligned on its matching foundation, the bottom (non-sleeping) surface is not exposed to the burner ignition source specified in the *draft final standard.* In addition, there is essentially no gap between the foundation and bottom surface of the mattress into which flames could penetrate, either during or after the burner exposure.

The staff had some concerns regarding the minimal protective covering of the bottom surface when used in real world situations. In actual usage, it would seem likely that the mattress may not remain perfectly aligned with its matching foundation. Bedclothes used with the mattress are likely to be folded or tucked between the mattress and foundation. This could create a gap between the mattress and foundation, allowing a possible exposure of the bottom surface to burning bedclothes. In addition, it is possible that the mattress could be used with a foundation that is non-fire resistant. Sales data suggest that a portion of mattresses are not sold with a foundation.

To evaluate the potential vulnerabilities associated with the actual usage of single-sided mattresses, NIST examined a single-sided mattress design, considered to be a reasonably representative construction, with various foundation conditions. The design's compliance with CPSC's *draft final standard* was confirmed later during this study. The conditions included testing the mattress aligned on top of its intended foundation (baseline tests), on top of a misaligned foundation, and on top of a completely unprotected foundation. All tests were intended to be conducted using bedclothes as the first item ignited.

As intended, two baseline tests of the mattress aligned on its intended foundation were conducted with bedclothes. The design proved to be vulnerable to the burning bedclothes, although the behavior had no relation to the structure of the bottom surface. Instead, the resulting fire was caused by a splitting of the side panel barrier in the area of the folded-over bedclothes. The fire grew to a significant size (exceeding 200kW; occurring after the peak heat release rate resulting from the burning bedclothes) within about 11 minutes (660 seconds) of the test and continued to grow until it penetrated the top of the foundation. The combined mattress/foundation fire led to the reported peak heat release rate (exceeding 700kW), between 18-20 minutes (1080-1200 seconds). The peak fire size would be sufficient to ignite other objects in the room (room effects generally start to happen at heat release rates of about 300kW to 400kW; heat release rates exceeding 500kW are generally considered to pose a serious threat as dangerous pre-flashover conditions are approaching and the threat of igniting nearby items is high) and ultimately lead to flashover (Ohlemiller, 2005c).

To check the design's compliance with the *draft final standard* and compare behavior observed in that test with behavior using bedclothes, two additional tests of the mattress aligned on its intended foundation were conducted using the gas burners. Both tests easily met the criteria in the *draft final standard.* In one of the tests, a small split developed in the crevice of the pillowtop section of the mattress, but there are no consequences from such a split after exposure to the burners. Exposure to burning bedclothes, on the other hand, greatly increases the probability that flames will get into any split that might develop. NIST suggests that any tendency for the barrier to split appears to signal a potential problem in real world conditions (Ohlemiller, 2005c).

The gas burners represent the local heat flux imposed on a mattress by burning bedclothes and impose a maximum thermal load which is comparable in severity to that of burning bedclothes to a representative section of the mattress. Burning bedclothes have a progressive burn pattern that typically ignites a larger area of the specimen than the stationary burners within a specified time. Bedclothes are a highly variable ignition source, even under controlled conditions, making them inappropriate to use as a standard ignition source in a mattress performance test. Although the stationary burners do not emulate the moving fire of burning bedclothes, the burners are representative of local heat fluxes imposed by burning bedclothes. Tests with bedclothes result in a rapid exposure of all vulnerable mattress surfaces and are, therefore, in this aspect, more severe and representative of real world conditions (Ohlemiller, 2000).

Continuing with the intended test plan, tests of the mattress when misaligned on top of its foundation, as well as tests with an unprotected foundation, resulted in similar fire behavior when tested with bedclothes; the mattress side panel barrier split open in the area of the folded over bedclothes, resulting in fire in the interior of the mattress that would eventually ignite the foundation, becoming a significant fire. This behavior led to fire growth conditions that interfered with an evaluation of the potential vulnerabilities associated with the actual usage of single-sided mattresses. Although a significant fire was developing in the mattress interior, crevice flames initiated by the burning bedclothes persisted at various locations of the mattress set. For tests with the misaligned foundation, it is possible that the persistent crevice flames could have contributed to a growing overall fire. However, the failing of the barrier in the side panel did not allow any noticeable behavior, caused by the misalignment, to be observed (Ohlemiller, 2005c).

Tests with the unprotected foundation also resulted in a combined fire involving the mattress and foundation. Involvement of the foundation did not appear to be strongly dependent on the mattress interior fire, but was caused by persisting crevice flames that involved the top of the wooden foundation frame. This suggests that an unprotected foundation could affect the overall fire performance of such a mattress and foundation system. Although the use of a single-sided mattress on an unprotected foundation appears to pose an increased hazard, the behavior of the barrier and resulting fire made such a determination nearly impossible (Ohlemiller, 2005c).

The vulnerability of the design to the burning bedclothes did not have any relation to the structure of the bottom surface. Instead the observed fire behavior of the tested design seemed to be caused by the characteristics of the barrier used on the top/side of the mattress. NIST concluded char shrinkage was the likely reason for the differing behavior between tests with burning bedclothes and gas burners. Char shrinkage, if the charring barrier shrinks under exposure to heat, places additional tensile stresses in the protective char. The total shrinkage (not percent) is proportional to the length (and width) of the area exposed; bedclothes expose a much larger area than the burners. Char shrinkage and the potential for char splitting also depend on the specific geometry of the mattress design and initial level of stress in the mattress surfaces. Once the barrier (and its char) exceeds its stretch capabilities, it can be expected to split and break. This is more likely to occur when a larger area is exposed to heat, but it may not require the whole area to be exposed to the highest heat fluxes. This behavior is dependent on the characteristics of the barrier and may become more prominent as manufacturers seek to optimize their mattress designs.

The potential consequences associated with this behavior and the actual usage of single-sided mattresses emphasizes the importance of limiting the early contribution of the mattress to allow for a timely discovery and escape from the fire conditions (Ohlemiller, 2005c). The potential consequences associated with a mattress design that would behave in this manner have been accounted for in the effectiveness estimates (Smith & Miller, 2005). In such cases, the *draft final standard's* limit on the early contribution of the mattress to the fire (15 MJ in the first 10 minutes) is especially critical to maintaining tenable conditions early in the fire and allowing for timely discovery and escape from growing fire conditions. A mattress with a limited contribution to the fire, especially early in the fire, will substantially increase the available time for occupants to discover the fire and escape, and, therefore, substantially reduce the current risks associated with mattress fires.

Flammability performance (durability) of selected flame retardant barriers The need for materials that are flame resistant and exhibit improved flammability performance to meet the proposed standard has spurred improvements in manufacturing, innovations in technologies, and the development of new products. In some cases existing products have found new uses while in other cases new products have been created. The range of technologically feasible and viable solutions and design choices for improving flammability performance and meeting the proposed test criteria are considerable.

Improved flammability performance may be obtained by the use of a variety of fire retardant materials. Some fibers are inherently flame resistant because of their polymeric nature or modified production techniques. Fire retardant chemicals may be applied to finished component products, possibly as backcoating, used as topical fiber surface treatments, or incorporated into manufactured fibers at the time of formation to produce flame resistant fibers.

Mattress components, such as barrier materials, may be constructed using treated fibers, inherently flame resistant fibers, or combinations or blends of these fibers and other traditional fibers. The components are available in various textile forms such as woven fabrics, knits, various non-wovens (e.g., wet-laid, spunlaced, needlepunched), battings, and loose fill. Depending on the mattress/foundation design, either one component or several components used in various combinations may be incorporated. The components may be added into the design or may be used to replace an existing component (drop-in).

Some components and barrier materials being used by major mattress manufacturers to meet the *proposed standard* incorporate water-soluble fire retardants. To explore concerns about possible health effects associated with the exposure to fire retardant chemicals (discussed separately in this package) and concerns about fire retardant chemicals remaining effective (flammability performance) after exposure to water or other liquids, NIST and CPSC staff conducted some studies.

NIST and CPSC staff examined two mattress designs that incorporated barrier materials/systems utilizing different inorganic compounds that are both somewhat water soluble. The inorganic compounds include boric acid/borax combinations and ammonium polyphosphate. Both designs were tested in accordance with the *proposed standard* before and after being subjected to ten repeated cycles of localized wetting and drying by CPSC staff (Laboratory Sciences). The cycles were representative of a bed-wetting scenario, anticipated to be a likely and compromising moisture exposure to a mattress.

The repeated wetting and drying cycles were conducted by the CPSC staff. Samples of both designs were also dissected for evaluations of fire retardant chemical content by the CPSC laboratory. A complete summary of the procedures used for wetting and drying and results of the chemical content analysis is provided in Appendix B.

In this limited evaluation, the effects of repeated wetting and drying cycles did not change the overall flammability performance. Both designs showed localized, persistent smoldering in the exposed areas. For the design containing a borate treated system, despite the smoldering, the repeated wetting exposures had no significant consequences on overall fire growth. The same appears to be valid for the design using an ammonium polyphosphate treated system. However, the smoldering was more pronounced and transitioned into flaming in two cases of the design containing the ammonium polyphosphate system. The limited testing of this design suggests that this behavior could be significant in certain circumstances (Ohlemiller, 2005a).

A producer of ammonium polyphosphate barrier products provided additional information based on their own independent test data. Mattress designs containing ammonium polyphosphate barrier systems were tested before exposure to moisture (control mattresses) and after being exposed to treatments simulating a repeated bed-wetting scenario. To simulate a bed-wetting scenario, synthetic urine was applied to a localized area of each mattress. A sheet and weight were placed on top of the wetted area for eight hours; the weight and sheet were removed, the mattresses were allowed to dry for 16 hours. This cycle was repeated for three, six, or nine cycles. Each sample was tested in accordance with the *proposed standard.* The control and exposed mattresses were reported as yielding passing results for peak heat release rate and total heat release. According to the presented findings of this limited evaluation, mattresses tested after exposure to wetting showed equivalent burn performance at 30 minutes to the control mattresses that were not exposed to the simulated bed-wetting treatment. Detailed test data and observations made during the testing were not provided by the producer. It should be noted that the exposure methodology used for this evaluation was different from the methodology in the NIST/CPSC staff evaluation[11], discussed above and in Appendix B.

Independent of the possible significance of pronounced smoldering, all of the tested samples passed the early total heat release requirements of the *proposed standard.* The exposure to water was localized, and even if the exposed area had decreased fire resistance, the remainder of the mattress should retain its resistance and thus retain improved flammability performance, especially the performance expected early in the fire (Ohlemiller, 2005a). Since localized wetting is anticipated to be the most likely, and perhaps most severe, exposure of a mattress to deeply penetrating water in real-world applications, limited available data do not suggest it is necessary to modify the requirements to include a test for durability in the *draft final standard.*

<u>Technical support for test method</u> Additional technical support for finalizing the *draft final standard* test protocol and requirements was provided by a series of tests conducted by CPSC staff at the Federal Bureau of Alcohol, Tobacco, Firearms and Explosives (ATF) Fire Test Laboratory. Some of the mattress designs tested at ATF were also tested by NIST for validation and correlation purposes. A complete explanation of the test series is available in Appendix C. This test work supported refinements of the *draft final standard* test protocol. Included in these are refinements of the required test frame and test set-up protocol for mattresses tested alone, without a foundation.

<u>Draft Final Standard for Mattresses</u>

Support for the *draft final standard* is provided by the findings from the P & B study, an assessment of engineering related comments received after publication of the NPR, and additional research and test work.

The test method was developed after years of research and test data including studies of residential fire scenarios, characterizing mattress flammability behavior, cost estimates, technical feasibility, egress, and effectiveness. The technical rationale for limiting the peak heat release rate to 200kW for a mattress set, not to be exceeded at any time during the 30 minute test, and limiting the total heat release to 15MJ for the first 10 minutes, is well supported. The criteria specified in the *draft final standard* ensure a less flammable mattress design that is expected to substantially reduce the current risks (deaths and injuries) associated with mattress fires (Tenney, 2004).

[11] Differences in the methodology include the volume of applied synthetic urine, method of application, and burner exposure relative to the wetted area.

Reducing the overall and early fire contribution of the mattress is technologically feasible, practicable, cost effective. The *draft final standard* allows a range of mattress design options while ensuring estimated effectiveness by increasing the time before flashover occurs or minimizing the possibility of flashover. Increasing available time to discover the fire and escape is critical since much of the estimated effectiveness emphasizes the need for early discovery and escape from the fire without delay. Taking these factors into account, the CPSC staff recommends that the *draft final standard* is the best approach to addressing hazards associated with mattress fires.

Appendices

Appendix A: *Summary of Comments Related to Test Method and Criteria and Responses*

Appendix B: Cobb, D. Chemist, Division of Chemistry (2006). *Durability of Flame Retardant Chemicals in Mattress Barriers After Repeated Insults with Synthetic Urine.* Memorandum to Allyson Tenney, Directorate for Engineering Sciences, Washington, DC: Directorate for Laboratory Sciences, U.S. Consumer Product Safety Commission.

Appendix C: Porter, D. Electrical Engineer, Division of Electrical Engineering and Flammability Engineering (2006). *Mattress Flammability –Suggested Revisions to Proposed 16 CFR Part 1633 Standard for the Flammability (Open Flame) of Mattresses and Mattress/ Foundation.* Memorandum to Allyson Tenney, Directorate for Engineering Sciences, Washington, DC: Directorate for Laboratory Sciences, U.S. Consumer Product Safety Commission.

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Tohamy, S. (2005). *Final Regulatory Analysis of Staff's Draft Standard to Address Open-Flame Ignitions of Mattresses.* Washington, DC: Directorate for Economic Analysis, U.S. Consumer Product Safety Commission.

Appendix A: Summary of Comments Related to Test Method and Criteria and Responses

The NPR for mattresses was published in the *Federal Register* on January 13, 2005 (70 FR 2470) and invited comments for a 75-day period that ended March 29, 2005. During the comment period, the Commission received 543 comments from individuals, businesses, associations, and interested parties representing various segments of the mattress industry. Comments raising specific issues related to the test method and performance criteria are included in this document.

Comments on *proposed standard* test protocol

i. *Require an open calorimeter configuration; do not allow tests to be conducted in a test room* (CF05-1-531 Sealy Mattress Company); ***Allow the use of alternative room dimensions*** (CF05-1-516 GBH International).

The *draft final standard* allows the test to be conducted in either an open calorimeter or test room (10 feet by 12 feet by 8 feet) configuration. Either configuration is considered acceptable since appreciable differences in test measurements (based on the *draft final standard* requirement that limits the peak heat release values to 200kW) are not expected between the two specified test configurations. Validation was provided by the inter-laboratory study data generated by laboratories using one of the two specified test configurations. The open calorimeter configuration is more conducive to close visual observations of the test progression and subtle failure mechanisms than the test room configuration.

A third test configuration, a smaller test room (8 feet by 12 feet by 8 feet), is included in California TB 603. CPSC staff does not feel this is an acceptable configuration because of operator safety concerns caused by the awkwardness of using the test burners in the smaller room. The smaller test room configuration was not utilized for the inter-laboratory study and no data has been submitted to CPSC staff supporting its use.

ii. *Increase room dimensions to accommodate mattresses larger than twin size* (CF05-1-516 GBH International).

Tests of mattresses larger than twin size are anticipated to be conducted in an open calorimeter. However, if the test room is the selected test configuration, the test specimen should be placed on an angle in the test room (§1633.7(a)(2)(ii)) so that the interaction of flames on the side surfaces of the test specimen and heat reflection from the walls are minimized.

iii. *Do not restrict to twin size tests* (CF05-1-516 GBH International).

This *draft final standard* does not restrict tests to twin size mattresses. The *draft final standard* specifies that *all tests must be conducted on specimens that are no smaller than a twin size (twin size means any mattresses with dimensions 38 inches x 74.5 inches, all dimensions may vary by ½ inch), unless the largest size mattress set produced is smaller than a twin size, in which case the largest size must be tested* (§1633.4(b)(3)(c)).

iv. *Change specified burner hole size to #53 drill size (1.50 mm) used on production burners* (CF05-1-519 Serta International; CF05-1-523 International Sleep Products Association).

NIST developed a pair of propane gas burners to consistently simulate the typical heat impact imposed on a mattress by bedding items to be incorporated into a full-scale fire test for mattresses. A commercial version of the NIST burner apparatus was manufactured by a commercial supplier to the mattress industry. The commercial version, which has been supplied to various test laboratories to conduct full-scale mattress testing in accordance with CPSC's *proposed standard* (and California Technical Bulletin 603), incorporated several refinements; inadvertently, the commercial version incorporated larger diameter holes in both of the burner heads (1.50 mm vs. 1.17 mm).

Recent work conducted by NIST evaluated peak heat fluxes from the two versions of gas burner designs (burner hole sizes of 1.50mm, #53 drill size and 1.17mm, #56 drill size). The study showed that the burners with the larger holes do a better job of meeting the target peak flux levels of bedclothes than do the original burners with the smaller holes. The *draft final standard* specifies a nominal burner hole size of 1.50 mm, which corresponds to Grade 10 machining practice with a well formed #53 drill bit (§1633.7(a)(5)(ii); §1633.7(a)(5)(iii)). This maintains the integrity of all supporting research and manufacturer testing to date and provides support for continuing the use of the commercial version of the NIST burner apparatus that incorporates larger diameter holes in both of the burner heads.

v. *The use of screens should be optional* (CF05-1-519 Serta International).

If there is any visual evidence that the burner flames are disturbed by draft during the burner exposure durations, the burner regions must be enclosed on two or more sides by at least a triple layer of screen wire (§1633.7(c)(1)). Drafts during the burner exposure are known to influence fire test results; this parameter is well controlled in typical fire test standards. CPSC staff does not agree that the screens should be optional in such cases.

vi. *The wrapping of copper tubing should be optional* (CF05-1-519 Serta International).

The copper tubing should be protected with insulation, but it is not required. This provision protects the financial investment in the equipment and helps to assure continued testing without interruption to replace damaged equipment. This is clarified in §1633.7(a)(5)(iv) of the *draft final standard.*

vii. *Tighten sample conditioning and test area requirements; limit time between removal of sample from conditioning to start of test* (CF05-1-529 Underwriters Laboratories, Inc.; CF05-1-531 Sealy Mattress Company).

The sample conditioning requirements in §1633.7(b) of the *draft final standard* have been revised to specify a temperature range greater than 18°C (65°F) and less than 25°C (77°F).

CPSC staff agrees that exposure of a mattress sample to the fire test room conditions could likely have an impact on test results. Some laboratories have observed seasonal variations in test performance. It is reasonable to require that testing of a specific conditioned sample should begin within a certain amount of time after removal from the conditioning room. Based on NIST's evaluation of the effects of laboratory humidity in fire test performance, the *draft final standard,* §1633.7(c)(2), requires that testing must begin within 20 minutes after removal from the conditioning room. Test area conditions must also be maintained at a temperature greater than 15°C (59°F) and less than 27°C (80.6°F) and a relative humidity less than 75 percent. These specifications will minimize environmental influences on test results.

viii. *Clarify burner placement for mattresses with seamless edges* (CF05-1-523 International Sleep Products Association).

The *draft final standard* has been clarified to include mattresses with seamless edges with revisions of terms and sections pertaining to such mattresses.

ix. *Allow tests of the mattress alone to have a test frame with a material under it instead of an open frame* (CF05-1-523 International Sleep Products Association).

Available test data does not provide evidence that a frame, other than the bed frame specified in §1633.7(a)(4) of the *draft final standard,* is necessary for mattresses tested alone. Consumers may use mattresses on an open frame rather than a solid frame that would be expected to be more protective. Therefore, CPSC staff believes that an open frame is more appropriate to ensure improved flammability performance.

x. *Several comments requested the use of slightly modified test equipment. For example, one commenter requested to use a modified technique to obtain the required burner offset from the specimen instead of the specified foot. Another comment pertained to using an alternate method of measuring the gas flow, rather than using a rotameter type of flowmeter* (CF05-1-531 Sealy Mattress Company).

To address such equipment issues that would not be expected to influence the test, the draft final standard includes a provision for the use of alternate apparatus in §1633.7(k): *Mattress sets may be tested using test apparatus that differs from that described in this section if the manufacturer obtains and provides to the Commission data demonstrating that tests using the alternate apparatus during the procedures specified in this section yield failing results as often as, or more often than, tests using the apparatus specified in the standard. The manufacturer shall provide the supporting data to the Office of Compliance. Staff will review the data and determine whether the alternate apparatus may be used.*

<u>Comments on test criteria</u>

xi. *Reduce number of test replicates (require one test) for mattresses that do not exceed a peak heat release of 50kW during the 30 minute test* (CF-1-510 Wm. T. Burnett and Co.).

The *draft final standard* requires a minimum of three specimens to be tested, each yielding passing results, for each prototype design. Three replicates per design has been the general practice of the industry as they researched options for meeting California TB 603 requirements and for the other numerous research studies conducted to develop the *draft final standard*. The inter-laboratory study was conducted using three replicates per design for the test series and was shown to identify mattress set performance, relative to the proposed criteria, for an individual laboratory. CPSC staff continues to maintain that testing of three replicates of each prototype design is needed in order to obtain a meaningful measure of mattress fire performance.

xii. ***Consider changes to test criteria: limit the peak rate of heat release to 100kW; require that the test duration be continued until one of the following happens, (1) there are no visible signs of any type of burning, (2) flashover appears inevitable, (3) one hour has elapsed*** (CF05-1-516 GBH International).

The technical rationale for limiting the peak heat release rate to 200kW for a mattress set, not to be exceeded at any time during the 30 minute test, and limiting the total heat release to 15MJ for the first 10 minutes, is well supported by research, test data, and regulatory analysis.[12] The criteria specified in the *draft final standard* ensure a less flammable mattress design that will substantially reduce the current risks (deaths and injuries) associated with mattress fires.

Reducing the overall and early contribution of the mattress is technologically feasible, practicable, cost effective, and allows a range of mattress design options while ensuring estimated effectiveness by increasing the time before flashover occurs or minimizing the possibility of flashover. Increasing available time to discover the fire and escape is critical since much of the effectiveness depends on early discovery and escape from the fire without delay.

xiii. ***Adopt alternate test methods: increase the burner duration to at least 120 seconds; include the option to test any location on the side of the mattress*** (CF05-1-516 GBH International).

The *draft final standard* includes a full-scale test method using a pair of T-shaped gas burners designed to represent burning bedclothes to determine the flammability of mattress sets. The test method was developed after years of research and test data including studies of residential fire scenarios, characterizing mattress flammability behavior, cost estimates, technical feasibility, egress, and effectiveness. Taking these factors into account, the CPSC staff recommends that the *draft final standard* is the best approach to addressing hazards associated with mattress fires.

<u>Comments asking for additional test requirements</u>

xiv. ***Require separate test for foam and padding, such as adopting the February 2002 draft of California Technical Bulletin 117, to limit the heat release possible in the bedroom should the foam or padding be exposed (e.g. children playing)*** (CF05-1-516 GBH International).

The *draft final standard* includes a full-scale test method to determine the flammability of mattress sets. A full-scale test is generally considered the most reliable and definitive method

[12] The Briefing Package—*Notice of Proposed Rulemaking for the Flammability (Open-Flame) of Mattresses and Foundations and Options for Addressing Bedclothes Involvement in Mattresses/Bedding Fires*, submitted to the Commission on November 1, 2004, is available from the U.S. CPSC Office of the Secretary or at (www.cpsc.gov/library/foia/foia05/brief/briefing.html).

for measuring performance of a product that contains many materials in a complex construction, such as a mattress. The fire performance of individual mattress or foundation components does not necessarily reveal the likely fire performance of the complete mattress or foundation. Polyurethane foam is just one of many components used to construct a mattress.

xv. *Require tests for barrier durability after exposure to moisture* (February 22, 2005 Hearing, The Felters Group; CF05-1-504 National Association of State Fire Marshals; CF05-1-510 Wm. T. Burnett and Co.; CF05-1-518 DuPont Advanced Fibers Systems).

Data provided by commenters was either irrelevant (tests using smoldering cigarettes) or represented severe exposure to barrier materials, apart from the mattress, before testing. New test data supplied by manufacturers of barrier products and obtained through a limited evaluation of effects of moisture on flammability behavior by CPSC staff and NIST staff, do not support requiring specific durability tests for barrier components. CPSC/NIST staff tests of mattress designs that incorporated barrier materials/systems utilizing different inorganic compounds, that are considered to be at least somewhat water soluble, were conducted after ten localized, wetting and drying cycles. The effects of the wetting exposures did not change the overall flammability performance. The CPSC/NIST staff tests suggest that, even if exposed areas have somewhat decreased fire resistance, the remainder of the mattress should retain its resistance and thus retain improved flammability performance, especially the performance expected early in the fire. Since localized wetting, as in bedwetting, is anticipated to be the most likely exposure of a mattress to moisture in real-world applications, it would not appear to be necessary to modify the requirements in the *draft final standard* to account for mattress designs that incorporate barrier systems that use water-soluble compounds as flame retardants.

xvi. *Ensure adherence with quality assurance programs (no specific suggestions or requirements were provided by the commenter)* (CF05-1-518 DuPont Advanced Fibers Systems).

While a variety of components is available to improve the flammability performance of mattresses and meet the proposed mattress flammability standard, their effectiveness must be determined by the performance of the entire mattress/foundation system. The selected component is dependent on the mattress design and materials needing protection. Once the component is shown to improve the flammability performance of a particular design, the consistency of the quality of that component as well as the manufacturing process are critical for ensuring effectiveness and overall performance of the mattress. The requirements in the *draft final standard*, §1633.11(d), adequately describe the need for component quality consistency and allow manufacturers to use programs closely suited to their distinctive needs.

xvii. *Concern if mattresses constructed to meet the requirements of the draft final standard will result in no smoke alarm going off during a mattress fire* (Commissioner Moore).

Fire modeling is a useful analytical tool for exploring theories and providing insight to a predicted fire scenario. Modeling is often used to estimate smoke alarm response times in particular fires. Using actual test data, CFAST, the Consolidated Model of Fire Growth and Smoke Transport, calculations were used by NIST to predict smoke optical density. CFAST is a zone or finite element fire model in which each room is divided into zones assumed to be internally uniform.

CFAST smoke optical density predictions were calculated by NIST using a hypothetical mattress fire with a steady heat release rate of 42kw which continues at this rate for 10 minutes, representing a modest mattress fire. Figure 1 shows smoke optical density versus time in all of the rooms (based on a single floor ranch house and "bedroom 4" is really the rest of the house beyond the bedrooms). All room doors are assumed to be open. All three bedrooms branch off of a single hallway. According to NIST, there are differing values for the range of smoke optical densities that will trigger typical ionization and photoelectric smoke alarms. The range shown corresponds to the less sensitive set of numbers (more conservative estimates). The CFAST predictions show that the smoke alarms will sound in all of the rooms by 400 seconds (between 6-7 minutes) at the latest. If there were a smoke alarm in the hallway, the alarm would have gone off between the times for Bedroom 1 and Bedrooms 2 and 3.

The time it takes for the smoke alarm to sound is a function of the size of the fire and the location of the smoke alarm. NIST expects the time for the smoke alarm to sound (approximately 1-2 minutes) would be the same from fires involving traditional and complying mattresses if the smoke alarm is in the bedroom (room of origin). If the smoke alarm is outside of the bedroom (or room of origin), the smoke alarm would likely sound sooner (the fire would be larger quicker) from fires involving traditional mattresses compared to a complying mattress, but there would be significantly less time to escape from the fire conditions. Earlier NIST tests on traditional twin size mattress constructions (16 CFR Part 1632 compliant) without bedclothes measured peak heat release rates that exceeded 2000kW (2.0MW) in less than 300 seconds (5 minutes). A critical heat release rate (flashover occurs) for an ordinary sized room is estimated to be about 1000kW (1.0MW). Complying mattresses (those that meet the criteria in the *proposed standard*) represent a significant improvement in performance compared to traditional mattress designs and will substantially increase the available time for occupants to discover the fire and escape.

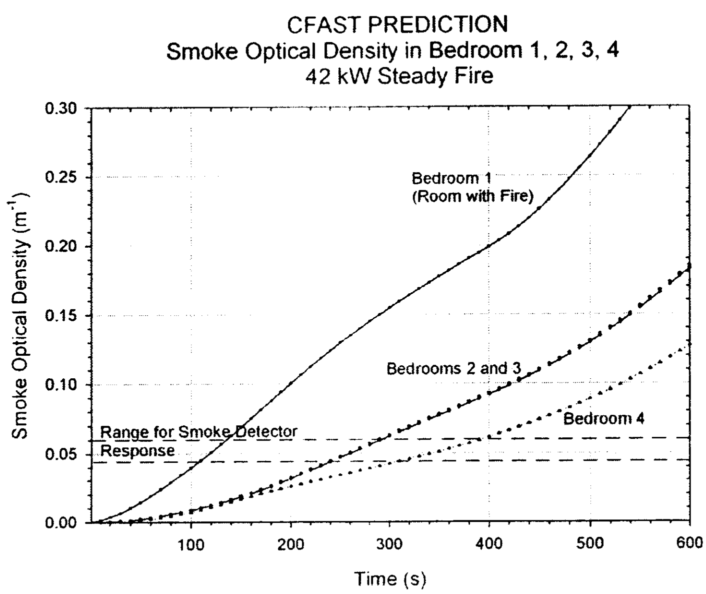

Figure 1. Time (s) and Smoke optical density (m^{-1}) (Ohlemiller, 2005; NIST)

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

MEMORANDUM

Appendix B **DATE:** December 12, 2005

TO : Allyson Tenney, Division of Combustion and Fire Science

THROUGH: Andrew G. Stadnik, P.E., Associate Executive Director, Directorate for Laboratory Sciences (LS)
Joel R. Recht, Ph.D., Director, Division of Chemistry (LSC)

FROM : David Cobb, Chemist, Division of Chemistry

SUBJECT : Durability of Flame Retardant Chemicals in Mattress Barriers After Repeated Insults with Synthetic Urine

SUMMARY:

Two types of mattresses that contained barriers treated with flame retardant chemicals (FRC) were subjected to repeated insults with synthetic urine poured each time in the same location to determine the amount of FRC removal from the barrier and effects on flammability through open flame testing. One set of mattresses contained a barrier that was treated with boric acid (H_3BO_3), the other set contained a barrier that was treated with ammonium polyphosphates (APP). Over a 10 day period, 200 milliliters (ml) of synthetic urine was poured daily onto each mattress. The liquid was poured through a 2" hole in the center of an 11" diameter 25 lb barbell weight which sat atop of a layer of cotton knit fabric above a layer of cotton sheeting on top of the mattress. The weight and the 2 layers of cotton were kept in place for 8 hours followed by 16 hours of uncovered drying between each wetting cycle[1]. After the final wetting, the mattresses were allowed 5 days in an air-conditioned laboratory to fully dry and condition before open flame testing at the National Institute of Standards and Technology (NIST). Additional mattresses were wetted similarly, but in multiple locations, and dissected for laboratory evaluation of FRC content and smoldering ignition testing. Fire tests of the control mattresses and the mattresses which had been wetted were conducted and are discussed separately in this package.

1. H_3BO_3 is very water soluble, and >80% of H_3BO_3 was removed from the treated cotton batting (barrier) in the local area of insult with synthetic urine. The construction of the H_3BO_3 mattresses included H_3BO_3 both in the barrier (just below the ticking) and in the "shoddy pad" (below multiple layers of other foam and padding materials). The shoddy pad did not suffer significant H_3BO_3 loss due to little or no liquid penetration that far into the mattress.

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[1] The rationale for the wetting protocol was reached as a staff consensus via internal meetings and other communications with staff representing Compliance, Economics, Epidemiology, Fire Sciences, Health Sciences, Human Factors and Laboratory Sciences. The rationale was based on a scenario of once per year bedwetting for 10 consecutive years.

2. APP is also very water soluble. The synthetic urine contains phosphate, which resulted in high levels of phosphate residue in the sheeting materials after drying. Thus, the migration of APP from the barrier to the sheet and fabric could not be determined after exposure. A significant decrease in phosphate in the mattress components in the area below the wetting was measured, though these results are somewhat confounded by the phosphate in the simulated urine.

BACKGROUND:

LSC reported[2] on the migration of H_3BO_3 from mattress barriers following exposure to synthetic urine and synthetic perspiration. The relatively large amount of H_3BO_3 released from the barrier following exposure to aqueous solvents, along with public comments received prompted the staff to investigate the durability of mattresses with water soluble FRCs in their construction considering normal consumer use and the impact any loss of FRC would have on flammability.

Two types of mattresses with water soluble FRCs were chosen for durability testing. One mattress type had a barrier treated with H_3BO_3, the other mattress type had a barrier treated with APP.

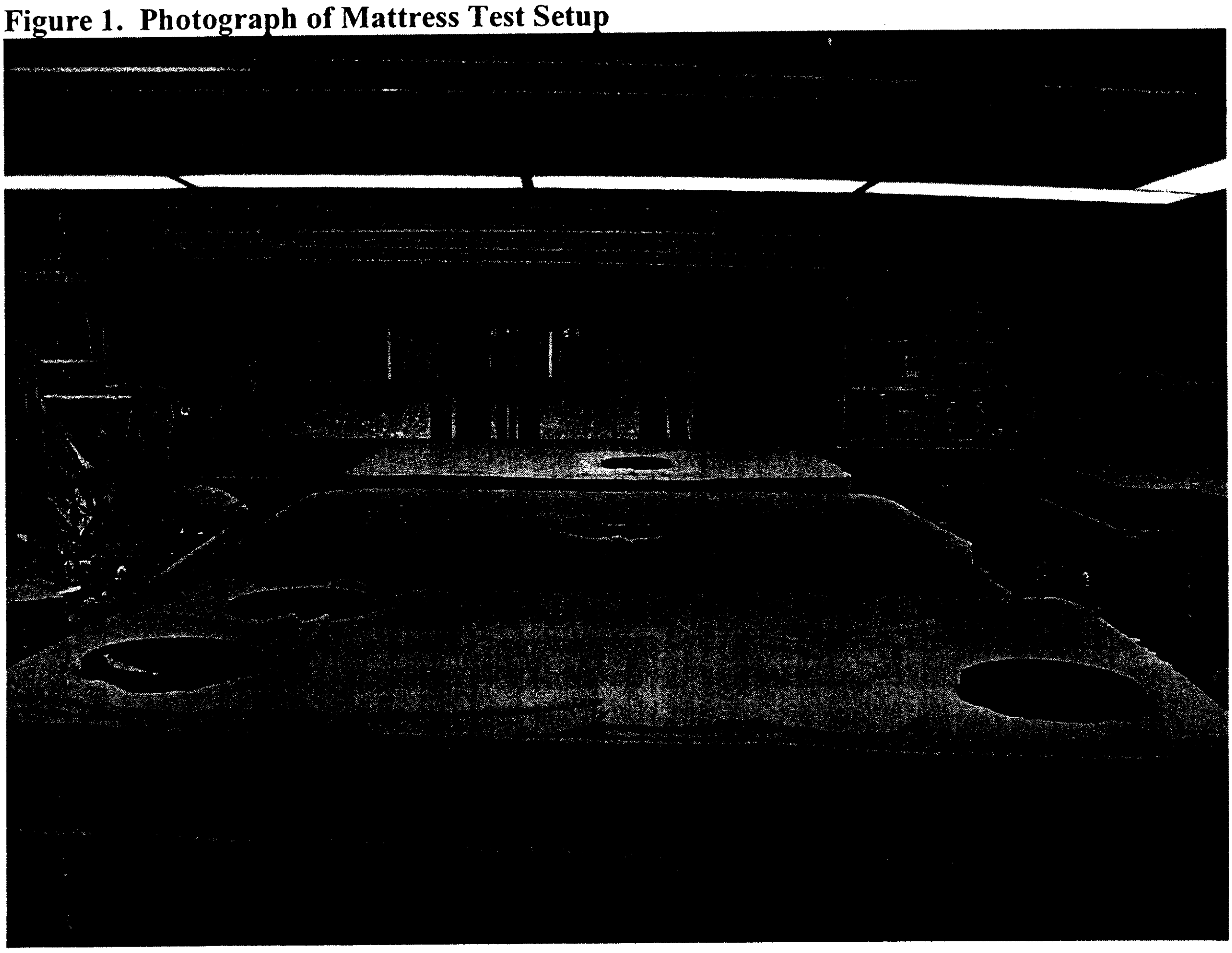
SYNTHETIC URINE INSULT

Four mattresses of each type were subjected to exposure to synthetic urine. Three of the mattresses of each type were exposed in only one area, and later burn tested at NIST. The 3 mattresses treated with H_3BO_3 that were later burn tested at NIST were designated JJC1, JJC2, and JJC3. One mattress from each type was divided into 8 sections, with 6 of the sections subjected to urine exposure. Two of the sections were not subjected to urine exposure and served as controls. The sections of this mattress were later subjected to chemical testing or cigarette smoldering tests. The mattress treated with H_3BO_3 that was subjected to chemical and smoldering tests was designated JJC4. A photograph of the mattress test set up is contained in figure 1.

The recipe for the synthetic urine was obtained from the National Association of Biology Teachers (NABT) archives. The synthetic urine contained the following amounts of chemicals per liter of deionized water; 18.2 grams (g) of urea, 7.5 g of sodium chloride, 4.5 g of potassium chloride, 4.8 g of sodium phosphate. The pH was checked to ensure it was in the 5-7 pH range of normal urine, and specific gravity was checked to ensure it was within the 1.015 to 1.025 g/ml range. 2.0 g of creatinine and 50 milligrams (mg) of albumin powder were added to each liter of synthetic urine and dissolved prior to use.

[2]CPSC Memo from David Cobb (July 2005)

Figure 1. Photograph of Mattress Test Setup



The procedure for the synthetic urine insult was as follows:

1. An 18"x18" standard knit sheet material was placed on each section of mattress to be subjected to urine exposure.
2. An 18"x18" standard cotton fabric was placed on top of each standard sheet.
3. A 25 lb weight was placed on top of the fabric and sheet near the middle, but in an area where a quilting-seam would be under the center hole of the weight.
4. 200 ml of synthetic urine was poured through the center hole of the weight. The pour rate was as fast as could be done without overflowing the center hole of the weight. It typically took between 20-60 seconds to pour all 200 ml of synthetic urine. A photograph of the synthetic urine pour is contained in figure 2.
5. After 8 hours, the weights were removed. The sheets and fabrics were collected for chemical analysis. The mattresses were allowed to dry overnight. The only exception was for 3 sections of the mattresses designated for chemical and cigarette smoldering tests, for which the 25 lb weights were removed once all the synthetic urine had penetrated into the mattress section.
6. Steps 1-5 were repeated daily over a 10 day period so that a total of 2000 ml of synthetic urine was added to each exposure section.

Figure 2 Photograph of Synthetic Urine Exposure

After the last synthetic urine exposure, the mattresses were allowed to dry/condition at room temperature and humidity conditions for a total of 5 days before testing. Sections of the mattresses designated for chemical testing were cut and removed from mattress springs. Each individual component material was chemically analyzed for boron (B) and phosphorus (P).

CHEMICAL ANALYSIS

The sheet and fabric materials collected from the mattress treated with H_3BO_3 were analyzed for B using inductively coupled plasma atomic emission spectroscopy (ICP-AES). The results of the analysis are contained in tables 1a and 1b. Three aliquots were obtained from each sheet and fabric material collected. Each aliquot was a circle with a diameter of 10.4 centimeters (cm). The aliquots obtained from the center where the synthetic urine was poured were designated with a "1" location number. Aliquots obtained from the corner, about 12" from center were designated with a "3" location number. Aliquots obtained between the two, about 6" from the center, were designated with a "2" location number. The aliquots were placed in test tubes, and 10 ml of 7% nitric acid was added to each test tube. The test tubes were placed on a hot plate for 2-3 hours. The tubes were vortexed and centrifuged prior to analysis.

Three aliquots from each mattress component from the mattress treated with H_3BO_3 were collected in a manner similar to that employed with the standard sheet and fabric. The aliquots were extracted with 10 ml of 10% hydrochloric acid instead of nitric acid, and were analyzed for B, P and antimony (Sb). Sb was found in similar barrier materials in previous studies[2], but only trace levels (<0.003%) were detected in even the control aliquots from this particular mattress. P analysis was conducted to determine the extent of synthetic urine penetration into the mattress components. The P results are contained in table 2. B analysis was conducted to determine which components were treated, and the extent of B migration due to the synthetic urine insult. The B results are contained in table 3.

The phosphorus content of the synthetic urine interfered with measuring the amount of APP transferred to the sheets and fabrics from the APP treated mattresses. The mattress components were analyzed to determine potential P losses in the barrier. The results of this analysis are contained in table 4.

Table 1a. Boron concentration in sheet and fabric after simulated bedwetting for Mattresses JJ1-JJ4, with 25 lb weight over wetted area for 8 hours.

			Boron μg/cm^2										
Mattress #		**Distance From Pour Point**	**Day 1**	**Day 2**	**Day 3**	**Day 4**	**Day 5**	**Day 6**	**Day 7**	**Day 8**	**Day 9**	**Day 10**	**Total**
JJ1	Sheet	0-2"	7.38	4.58	2.23	1.51	0.84	3.13	0.31	0.56	1.23	0.07	21.83
		4-8"	11.15	5.68	3.95	2.83	2.65	4.25	1.55	0.84	1.68	0.6	35.17
		10-14"	18.01	6.24	5.06	4.42	4.32	4.29	3.59	2.28	1.84	2.01	52.04
	Fabric	0-2"	21.84	9.7	6.01	4.31	1.52	5.87	0.63	0.89	2.91	0.17	53.84
		4-8"	28.24	13.51	9.82	7.72	5.25	7.01	4.54	2.96	4.34	1.22	84.62
		10-14"	35.96	13.51	7.29	9.94	6.21	5.27	6.57	5.87	4.56	3.57	98.75
JJ2	Sheet	0-2"	10.07	7.84	2.68	2.5	0.4	2.06	0.71	0.2	0.39	0.09	26.94
		4-8"	15.81	16.46	4.78	2.9	3.17	2.42	1.72	1.08	2.09	0.65	51.1
		10-14"	20.74	19.25	3.15	5.64	4.94	3.12	1.85	2.08	2.05	3.43	66.26
	Fabric	0-2"	25.13	19.82	7.32	6.59	0.69	6.03	2.43	0.21	0.76	0.17	69.16
		4-8"	32.02	37.41	14.14	13.75	7.73	5.87	5.91	1.01	3.42	3.53	124.78
		10-14"	28.8	41.47	6.79	9.71	10.49	5.45	4.85	3.73	4.68	2.53	118.51
JJ3	Sheet	0-2"	10.59	5.51	2.43	1.6	1.27	2.09	0.94	0.18	0.24	0.15	25.01
		4-8"	16.16	6.62	3.79	4.88	2.46	2.36	1.26	0.37	1.35	1.49	40.75
		10-14"	18.02	7.22	4.3	3.73	4.94	4.02	2.39	2.44	2.1	2.58	51.73
	Fabric	0-2"	24.56	10.3	6.36	3.7	3.32	5.4	2.41	0.26	0.43	0.96	57.69
		4-8"	45.19	9.87	8.83	11.5	7.34	7.9	3.3	1.02	3.45	1.03	99.44
		10-14"	47.76	9.57	7.68	13.11	10.43	6.32	6.05	4.68	6.02	3.66	115.28
JJ4	Sheet	0-2"	10.2	2.07	2.77	0.74	1.65	0.95	0.31	0.26	0.67	0.24	19.86
		4-8"	14.47	4.64	3.59	3.6	3.6	1.76	1.42	0.64	0.84	0.28	34.85
		10-14"	13.81	4.86	4.16	16.31	6.85	2.91	1.89	2.53	3.51	0.85	57.68
	Fabric	0-2"	21	5.49	6.92	1.35	2.58	2.07	0.75	0.43	1.05	0.24	41.89
		4-8"	34.41	10.65	10.57	5.76	5.59	7.64	2.47	0.73	1.69	0.9	80.39
		10-14"	31.71	8.91	9.76	7.29	8.65	9.92	3.92	2.8	6.97	3.61	93.55
Average	**Sheet**	**0-2"**	**9.56**	**5.00**	**2.53**	**1.59**	**1.04**	**2.06**	**0.57**	**0.30**	**0.63**	**0.14**	**23.41**
		4-8"	**14.40**	**8.35**	**4.03**	**3.55**	**2.97**	**2.70**	**1.49**	**0.73**	**1.49**	**0.76**	**40.47**
		10-14"	**17.65**	**9.39**	**4.17**	**7.53**	**5.26**	**3.59**	**2.43**	**2.33**	**2.38**	**2.22**	**56.93**
	Fabric	**0-2"**	**23.13**	**11.33**	**6.65**	**3.99**	**2.03**	**4.84**	**1.56**	**0.45**	**1.29**	**0.39**	**55.65**
		4-8"	**34.97**	**17.86**	**10.84**	**9.68**	**6.48**	**7.11**	**4.06**	**1.43**	**3.23**	**1.67**	**97.31**
		10-14"	**36.06**	**18.37**	**7.88**	**10.01**	**8.95**	**6.74**	**5.35**	**4.27**	**5.56**	**3.34**	**106.52**

Table 1b. Boron concentration in sheet and fabric after simulated bedwetting for Mattress JJ4, with 25 lb weight removed immediately after wetting.

JJ4	Sheet	0-2"	4.64	4.59	2.3	0.88	0.52	0.46	0.17	0.12	0.21	0.14	14.05
		4-8"	4.92	7.72	3.95	3.19	0.86	0.93	1.74	1.14	0.81	0.2	25.45
		10-14"	6.52	5.83	4.69	3.38	3.22	2.84	1.74	4.42	3.17	1.01	36.82
	Fabric	0-2"	9.14	12.51	6.31	2.93	0.51	0.38	0.4	0.42	0.29	0.15	33.02
		4-8"	13.37	14.17	8.93	8.38	2.04	2.74	1.37	0.5	1.64	0.84	53.98
		10-14"	12.49	9.69	7.84	9.9	6.77	7.09	5.95	1.79	5.46	1.66	68.64

Table 2. Phosphorus Results of Mattress Components

Condition	Material	Location	%P
Control	Interwoven	Avg of 3	0.001
Weighted	Interwoven	0-2" from pour point	0.000
Weighted	Interwoven	4-8" from pour point	0.008
Weighted	Interwoven	10-14" from pour point	0.016
Unweighted	Interwoven	0-2" from pour point	0.090
Unweighted	Interwoven	4-8" from pour point	0.001
Unweighted	Interwoven	10-14" from pour point	0.006
Control	ticking	Avg of 3	0.101
Weighted	ticking	0-2" from pour point	0.424
Weighted	ticking	4-8" from pour point	0.340
Weighted	ticking	10-14" from pour point	0.330
Unweighted	ticking	0-2" from pour point	0.210
Unweighted	ticking	4-8" from pour point	0.238
Unweighted	ticking	10-14" from pour point	0.327
Control	Bottom foam	Avg of 3	0.000
Weighted	Bottom foam	0-2" from pour point	0.060
Weighted	Bottom foam	4-8" from pour point	0.001
Weighted	Bottom foam	10-14" from pour point	0.001
Unweighted	Bottom foam	0-2" from pour point	0.028
Unweighted	Bottom foam	4-8" from pour point	0.001
Unweighted	Bottom foam	10-14" from pour point	0.001
Control	Top foam	Avg of 3	0.000
Weighted	Top foam	0-2" from pour point	0.060
Weighted	Top foam	4-8" from pour point	0.001
Weighted	Top foam	10-14" from pour point	0.001
Unweighted	Top foam	0-2" from pour point	0.028
Unweighted	Top foam	4-8" from pour point	0.001
Unweighted	Top foam	10-14" from pour point	0.001
Control	Shoddy Pad	Avg of 3	0.039
Weighted	Shoddy Pad	0-2" from pour point	0.040
Weighted	Shoddy Pad	4-8" from pour point	0.040
Weighted	Shoddy Pad	10-14" from pour point	0.040
Unweighted	Shoddy Pad	0-2" from pour point	0.040
Unweighted	Shoddy Pad	4-8" from pour point	0.038
Unweighted	Shoddy Pad	10-14" from pour point	0.040
Control	Barrier	Avg of 3	0.023
Weighted	Barrier	0-2" from pour point	0.431
Weighted	Barrier	4-8" from pour point	0.150
Weighted	Barrier	10-14" from pour point	0.261
Unweighted	Barrier	0-2" from pour point	0.317
Unweighted	Barrier	4-8" from pour point	0.069
Unweighted	Barrier	10-14" from pour point	0.046

Table 3. Boron Results of Mattress Components

Condition	Material	Location	% B	B µg/cm2	Percent Change
Control	Interwoven	Avg of 3	0.012	0.53	NA
Weighted	Interwoven	0-2" from pour point	0.016	0.93	32
Weighted	Interwoven	4-8" from pour point	0.006	0.25	-46
Weighted	Interwoven	10-14" from pour point	0.019	0.82	60
Unweighted	Interwoven	0-2" from pour point	0.013	0.72	6
Unweighted	Interwoven	4-8" from pour point	0.008	0.33	-29
Unweighted	Interwoven	10-14" from pour point	0.026	1.39	117
Control	ticking	Avg of 3	0.017	3.13	NA
Weighted	ticking	0-2" from pour point	0.085	17.61	394
Weighted	ticking	4-8" from pour point	0.155	29.88	805
Weighted	ticking	10-14" from pour point	0.219	48.34	60
Unweighted	ticking	0-2" from pour point	0.053	9.62	210
Unweighted	ticking	4-8" from pour point	0.163	29.44	849
Unweighted	ticking	10-14" from pour point	0.236	42.67	1276
Control	Bottom foam	Avg of 3	0.096	25.35	NA
Weighted	Bottom foam	0-2" from pour point	0.054	14.32	-44
Weighted	Bottom foam	4-8" from pour point	0.106	27.84	10
Weighted	Bottom foam	10-14" from pour point	0.082	21.66	-14
Unweighted	Bottom foam	0-2" from pour point	0.063	17.16	-34
Unweighted	Bottom foam	4-8" from pour point	0.069	17.38	-28
Unweighted	Bottom foam	10-14" from pour point	0.078	19.94	-18
Control	Top foam	Avg of 3	0.122	56.34	NA
Weighted	Top foam	0-2" from pour point	0.010	5.10	-92
Weighted	Top foam	4-8" from pour point	0.048	21.56	-60
Weighted	Top foam	10-14" from pour point	0.110	50.87	-10
Unweighted	Top foam	0-2" from pour point	0.010	5.01	-92
Unweighted	Top foam	4-8" from pour point	0.106	43.72	-13
Unweighted	Top foam	10-14" from pour point	0.154	65.14	27
Control	Shoddy Pad	Avg of 3	1.468	757.95	NA
Weighted	Shoddy Pad	0-2" from pour point	1.691	859.51	15
Weighted	Shoddy Pad	4-8" from pour point	1.389	728.02	-5
Weighted	Shoddy Pad	10-14" from pour point	1.333	715.32	-9
Unweighted	Shoddy Pad	0-2" from pour point	1.670	860.89	14
Unweighted	Shoddy Pad	4-8" from pour point	1.595	795.41	9
Unweighted	Shoddy Pad	10-14" from pour point	1.603	738.65	9
Control	Barrier	Avg of 3	1.618	689.94	NA
Weighted	Barrier	0-2" from pour point	0.202	77.53	-87
Weighted	Barrier	4-8" from pour point	0.256	92.24	-84
Weighted	Barrier	10-14" from pour point	1.054	352.40	-35
Unweighted	Barrier	0-2" from pour point	0.173	67.96	-89
Unweighted	Barrier	4-8" from pour point	1.183	568.26	-27
Unweighted	Barrier	10-14" from pour point	1.731	997.12	7

Table 4 Phosphorus Results for the APP Mattress Components

Condition	Material	% P
Contol	Top Foam	0.000
Weighted	Top Foam	0.089
Contol	Middle Foam	0.000
Weighted	Middle Foam	0.045
Contol	Bottom Foam	0.000
Weighted	Bottom Foam	0.000
Contol	Interwoven	0.000
Weighted	Interwoven	0.060
Contol	Ticking	0.002
Weighted	Ticking	0.138
Contol	Polyester Fiber Pad	0.000
Weighted	Polyester Fiber Pad	0.000
Contol	Barrier	1.327
Weighted	Barrier	0.260
% P loss in barrier = 80.4		

DISCUSSION

The following was noted from the chemical analysis results:

1. Figures 3a and 3b show that the highest B results were found on the sheet and fabric samples obtained after the 1st day of the urine insult. The B levels decreased over time, but B levels greater than 1 $\mu g/cm^2$ were still detected in samples collected after 10 days.

Figure 3a.

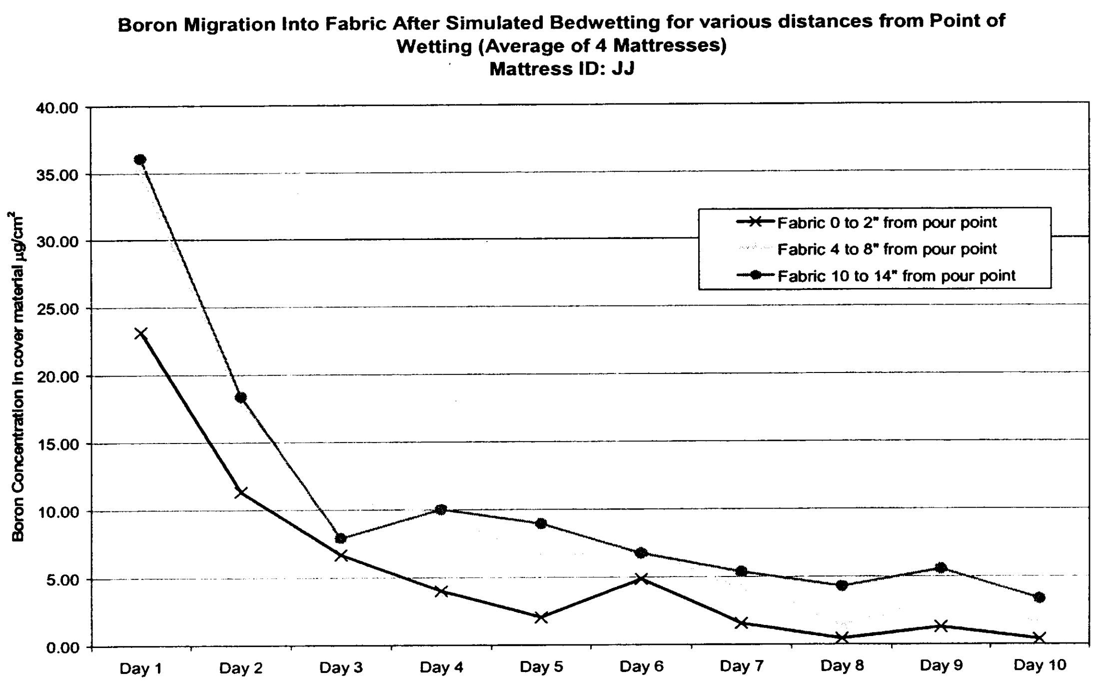
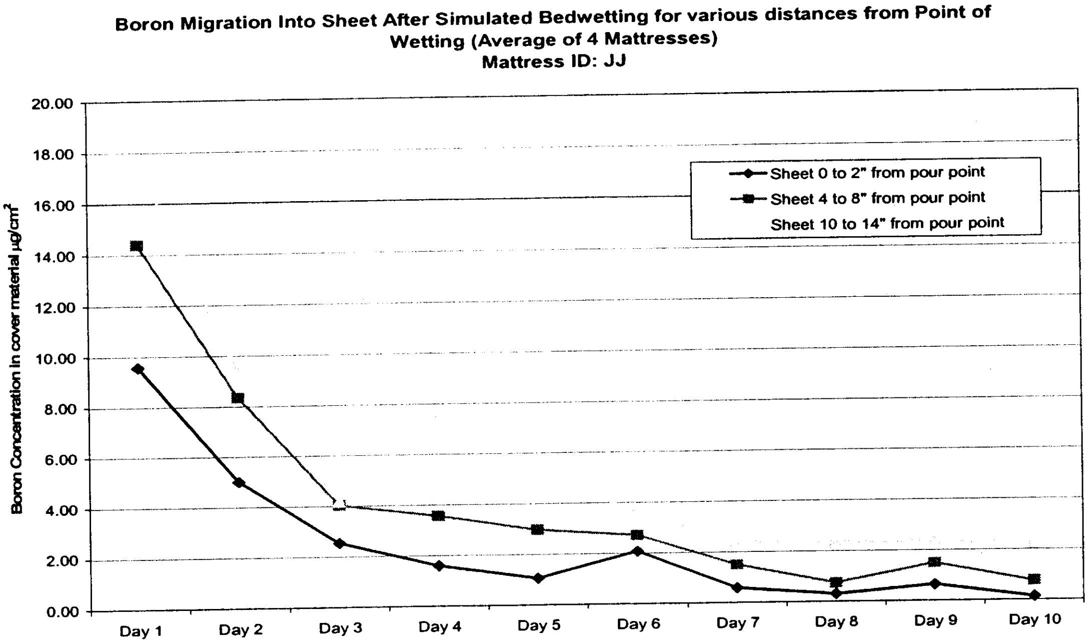


Figure 3b



2. Table 2 on phosphorus results shows the depth of penetration of the synthetic urine into the mattress components of the H_3BO_3 mattress. Based on P results it appears that the synthetic urine penetrated through the 2 foam layers at least close to the pour zones, but did not penetrate as much further away. The synthetic urine may have reached the interwoven, but probably did not reach the shoddy pad which was between the interwoven and the springs.
3. Table 3 shows that the shoddy pad was treated with chemicals containing B. The shoddy pad had B levels similar to that found in the barrier, about 1.5% of which corresponds to 8.6% H_3BO_3. Only trace amounts (<0.1%) of B was found in other components.
4. Based on the P results found and noted in table 4, it appears that the synthetic urine penetrated down to the interwoven layer, but did not reach the bottom foam and the polyester fill pad which were just above the springs. It appears that at least 80% of the APP was removed from the barrier near the pour zone. The actual loss is probably higher due the fact that some of the P found in the barrier after the exposure test is likely due to residual synthetic urine phosphate rather than APP.
5. The fabric picked up more B than the sheet, and samples obtained further away from the pour zone at location 3 had higher B amounts. Table 5 shows the total B results for the sheet and fabric at the various locations. It appears that the B deposited more in areas where the liquid wicked away from the pour zone and evaporated.

Table 5. Comparison of B on Sheets and Fabric

Matress ID	Location ID	Total Days µg/cm² B Sheet	Total Days µg/cm² B Fabric
JJC1	1	21.83	53.84
	2	35.17	84.62
	3	52.04	98.75
JJC2	1	26.94	69.16
	2	51.10	124.78
	3	66.26	118.51
JJC3	1	25.01	57.69
	2	40.75	99.44
	3	51.73	115.28
JJC4P5	1	19.86	41.89
	2	34.85	80.39
	3	57.68	93.55
JJC4P6	1	14.05	33.02
	2	25.45	53.98
	3	36.82	68.64

6. The average B level found in the control sections of mattress JJC4 which were not exposed to synthetic urine was 1.6% or 690µg/cm².
7. Table 6 shows that more B was lost from the barrier when the weight was left in place for the 8 hour exposure.

Table 6. Effect of 25 lb Weight on B Migration

JJC4 Weight(W)/ No Weight (U)	Location	%B Loss
W	1	87.5
	2	84.2
	3	34.9
U	1	89.3
	2	26.9
	3	-7.0

8. Table 7 shows the B migration results to the ticking, sheet, and fabric for both the weighted and unweighted sections of mattress JJC4. The total B found in these 3 components does not account for the total loss of B in the barrier. Some B must have migrated to other mattress components such as the foam, or to other sections of the barrier.

Table 7. Boron Migration to Sheet, Fabric, and Ticking

JJC4 Mattress Weighted (W)/ Not Weighted (U)	Site Location	Sheet	Fabric	Ticking	Total	%B loss to 3 components
W	1	19.86	41.89	17.61	79.36	11.5
	2	34.85	80.39	29.88	145.12	21.0
	3	57.68	93.55	48.34	199.57	28.9
U	1	14.05	33.02	9.62	56.70	8.2
	2	25.45	53.98	29.44	108.87	15.8
	3	36.82	68.64	42.67	148.13	21.5

Appendix C:

UNITED STATES
CONSUMER PRODUCT SAFETY COMMISSION
WASHINGTON, DC 20207

Memorandum

January 6, 2006

TO : Allyson Tenney, Division of Fire Sciences

THROUGH: Andrew Stadnik, Associate Executive Director Laboratory Sciences

for Edward Krawiec, Director Division of Electrical and Flammability Engineering

FROM : Diane Porter, Electrical Engineer
Division of Electrical Engineering and Flammability Engineering

SUBJECT : Mattress Flammability –Suggested Revisions to Proposed 16 CFR Part 1633 Standard for the Flammability (Open Flame) of Mattresses and Mattress/Foundation Sets

Introduction

The U.S. Consumer Product Safety Commission (CPSC) is developing a regulation that addresses the flammability of mattresses ignited by open flames. CPSC staff has recently conducted tests on various non-standard size and/or non-foundation type mattresses to assess whether changes should be made to the test procedures specified in the proposed 16 CFR 1633 standard.

Examination

Three replicates of the following non-foundation type mattresses were tested to determine if revisions to the proposed regulation were needed:

1. Organic Cotton Futon
2. Foam Core Futon
3. Crib Mattress (conventional)
4. Crib Mattress (CFR 1632 and TB 603)
5. Visco- Solid Core Foam
6. Latex – Solid Core Foam
7. Sofa Bed Mattress
8. Air Mattress (ticking and upholstery type)
9. Flip Chair
10. Bunk Bed Mattress

During testing, several observations were noted that may affect the performance of the test specimen. These observations are listed below:

- Construction Features (e.g., handles, zippers, air vents)
    - If the test specimen has a unique construction feature that is located within the zone of the specified placement of the burners, the burners should be located such that the ignition flame impinges on the construction feature.

- Sleep Surface
    - If the intended sleep surface of the test specimen (e.g., flip chair) is not obvious, it may be necessary to repeat the tests on both sides using additional test specimens.

- Folded or Segmented Sections
    - If the test specimen is folded when not used as an intended sleep surface (e.g., flip chair, mattresses used in furniture), it may present surface irregularities when unfolded to be used as a sleep surface. If bowing exists, additional effort may be necessary during test setup to ensure the test specimen is as flat as possible.

- Gaps
    - Gaps may exist between segments of the test specimen. It will be important to eliminate all gaps as much as possible before testing.

- Inflation of Air Mattresses
    - The manufacturer's instructions for assembly and inflation need to be followed during test setup. The air pressure in the air bladder may modify the performance of the test specimen. The test specimen should be inflated to the maximum capacity recommended in the manufacturer's instructions. If no instructions are provided, the maximum pressure permitted by the supplied pump and any relief valves (if provided) should be used.

Suggestions

All of the full-scale test work conducted by CPSC staff during the development of the staff's draft standard involved standard size twin mattress on matching foundations. The primary objective of this series of tests was to explore the need for revisions or additions to the draft final standard to ensure appropriate test procedures and fixtures are used to determine conformance of non-standard size and/or non-foundation supported mattresses. The most immediate need was to modify the test frames to accommodate the dimensions and shapes of non-standard mattresses. The frames used by CPSC staff were redesigned to allow for changes in the width and length. Changes in height were needed to allow for the bottom of the vertical burner to have at least a one inch clearance from the support surface for any given test specimen. Horizontal support beams were also constructed to provide support on all four sides of a sample if its dimensions were smaller than the standard twin size mattress and/or to provide additional support to minimize sagging of a highly conformal mattress (e.g., a futon) below the bottom of the test frame. In testing the types of non-foundation mattresses described above, setup time varied depending on the width, length and rigidity of the test specimen. On average, setup time was approximately 20 minutes. Most of the setup time was required in order to adjust the frame and provide proper placement of the test specimen on the frame. In order to minimize time a sample is out of the conditioning environment to 20 minutes or less, one sample may be needed to make adjustments and then returned to the conditioning room while other like samples are tested. Consideration should be given to revising the proposed standard to accommodate the following:

- The thickness of the test specimen can affect the vertical burner setup. Some adjustments to the height of the test frame may be necessary to maintain a minimum one inch distance between top of vertical burner and mattress, and one inch clearance between the bottom of the vertical burner and the supporting surface.

- Lack of rigidity and variable perimeter dimensions of some mattresses will require additional supports or modified frame dimensions. The added supports minimize sagging, and the proper frame size provides support on all sides of the test specimen.

- Some type of non-combustible filler may be needed at the corners of the frame to eliminate air gaps between the test specimen and the frame supports.

- A modified platen may be needed to accommodate different dimensions of non-standard mattresses while maintaining the function of the platen. It is intended to ensure that the burners are parallel to the mattress surfaces.