California State Fire Marshal
Flammability Standards for Building Insulation Materials

July 24, 2014 Draft

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~~<To be added later>~~

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CSFM Flammability Standards for Building Insulation Materials Working Group Analysis and Recommendations

FOREWORD

(KR) The Office of the State Fire Marshal convened a working group (see Appendix A) for the review of flammability standards for building insulation materials that was brought through AB 127 of 2013 by Assembly member Skinner that addressed Fire safety, fire retardants in building insulation. The intent of the working group is to review published data and technical information, examine peer reviewed scientific studies and information, and determine recommendations, that may include alternatives to current methodologies, to the SFM to identify what conditions flame retardant chemicals may be omitted from building insulations without compromising and or reducing fire safety of the building, building occupants and firefighters.

The working group was requested to focus their efforts on the following areas, which are consistent with new requirements in Health and Safety Code §13108.1:

1. Review the California flammability standards for building insulation materials, including whether the flammability standards for some insulation materials can only be met with the addition of chemical flame retardants.
2. Determine if updated insulation flammability standards should be adopted that maintain overall building fire safety and ensure that there is adequate protection from fires that travel between walls and into confined areas, including crawl spaces and attics, for occupants of the building and any firefighters who may be in the building during a fire.

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SOURCES OF DATA

The working group was asked to review current research, testing, published reports, codes, standards and regulations to form a basis for the observations, conclusions and recommendations. These documents had to include data and observations that are applicable to modern technologies, concerns and building construction practices. Anecdotal data would be considered by the committee, but not given as much weight as the technical data described above.
The referenced documents that the working group selected to use as a basis for their work are included in Appendix B. In many cases data and findings cited in this report include footnotes references to the source document.

ISSUES AND ANALYSIS

Fire performance in California Building Standards Codes. The International Building Code and International Residential Code, which form the basis for the California building and residential codes are developed by a government consensus process. Among other objectives, the purpose of these codes is to establish requirements to safeguard life and property from fire and other hazards attributed to the built environment and to provide safety to fire fighters and emergency responders during emergency operations. (R1)

(MF/LR) add California Fire Tests (LR Doc) consider adding Table as an appendix.

Fire test standards. These codes require specific levels of fire safety based on risks associated with the specific occupancy and building type. In many cases this is done by requiring building materials and assemblies to comply with specific fire test standards that are adopted by reference in the code. Examples of such fire test standards are NFPA 286, ASTM E84, and UL 790. In general these fire test standards consist of specific performance standards that evaluate the fire performance of the materials and assemblies being tested, and their ability to resist unacceptable fire growth. These standards do not include requirements that specify that materials (such as flame retardants) must be used in products to achieve a specific fire ~~performance~~ test response characteristic or a fire resistance rating ~~classifications or fire ratings~~. The addition of flame retardants is strictly at the discretion of the manufacturer of the product, who may use it to achieve a specific fire rating.

Building code requirements for insulation - <Short summary based on LR presentation, with a reference to Appendix C for text of current California requirements?> (LR to provide)

Building envelope – The working group's scope is insulating materials used for thermal or acoustic insulation within the building envelope. This includes insulation used in the following locations and applications:
1) On the building exterior, including but not limited to insulation in Structural Insulated (or Insulating) Panels (SIP), Exterior Insulation and Finish Systems (EIFS), External Wall Insulation System (or EWIS) and similar systems (typically continuous insulation).
2) Inside the building's interior and exterior wall cavities
3) Between floors (i.e. in the ceiling cavity of the floor/ceiling assembly)
4) Between ceiling membranes and attic spaces
5) That is part of a roof or deck structure (e.g. between joists or rafters, or insulation applied as part of the outer layers of the roof covering system)
6) In crawl spaces and doors
7) As part of a cold room/freeze room.
8) As part of below grade insulation and related thermal breaks.

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The working group intentionally excluded from consideration insulation used for mechanical equipment, ductwork, piping, appliances and other installed equipment.

< HH comment – this section was moved from later in the report>
Flame retardants used in insulation. Some of the many materials used as building insulation other than foam plastic include cellulose, fiberglass, mineral wool, cotton and cementitious foam. (TC) Cellulose insulation relies upon flame retardants such as ammonium sulfate, boric acid, borate and borax. TC) Mineral ~~w~~ool, glass fiber and cementitious foam insulations typically do not include flame retardants.

Comment [KR1]: verify

One of the building insulation products discussed at length by the working group relative to the use of fire retardant chemicals is expanded polystyrene (EPS) foam. EPS presently uses primarily hexabromocycledodecane (HBCD) at a concentration of approximately 0.7% to meet fire performance standards. The EPS industry is transitioning to a new polymeric flame retardant, butadiene styrene brominated copolymer, which has been assessed by the U.S. EPA as having "low hazard designations for all human health endpoints due to its high molecular weight and limited potential for absorption." (R-2)

Comment [KR2]: This entire sections needs to be reviewed and readdressed!

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~~Is this section applicable?~~
Toxicity and building materials. Building and residential codes, and fire test standards do not include requirements that restrict the use of toxic materials in building materials. Toxicity is a concern in today's built environment, but bans against using specific chemicals and formulations in California are handled through the legislative process, in conjunction with CAL EPA. (KR pt 12 12-1563 (Warren Alquest Act) verify applicability (HH – Believe the reference should be to Chapter 10.5 of the Act, but is this applicable?)

Firefighter toxicity considerations. During and after firefighting operations firefighters are exposed to toxic gases and byproducts of combustion. Products of combustion from the burning of natural or synthetic materials are likely to contain carbon dioxide, carbon monoxide, hydrogen cyanide, halogen acids, organic irritants and other gases and aerosols, in various concentrations, as well as polynuclear aromatic hydrocarbons (PAHs). Firefighter exposure to dioxins can occur in the course of their work, and exposure to brominated dioxins is of particular concern. (R-3) [MH] In fact, the toxicity (and carcinogenicity) of fire atmospheres is primarily associated with exposure to PAHs (and, in particular, to benzo(a) pyrene, or BAP, the most toxic and carcinogenic of them).

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It is unknown how HBCD-generated dioxins contribute to the total dioxin toxicity experienced by firefighters, but given the high rates of dioxin-associated cancers in this population, reduction of dioxin exposures is desirable where feasible.

Studies (reference??) show that firefighters have higher rates of cancers associated with dioxin exposure, including multiple myeloma, non-Hodgkin's lymphoma, prostate and testicular cancers. [MH] In fact, there is abundant evidence that the firefighter cancer is associated primarily with the emission of polycyclic aromatic hydrocarbons (PAHs, particularly benzo-a-pyrene, BAP), which are the result of all fires, irrespective of what materials are burning.

[MH] On the other hand, the concentrations of the polybrominated dioxins and furans that are the result of emissions resulting from brominated flame retardants are dwarfed by those of the PAHs. Also, the carcinogenicity of the PAHs (especially BAP) is so much higher than that of the polybrominated dioxins and furans that the toxicological effect of polybrominated dioxins and furans is negligible in terms of its effect on firefighter health or public health.

[MH] Troitzsch investigated the role of acutely toxic components in fire gases and that of other pollutants formed in fires. The study focused particularly on the measurements made during some large German fires, including the infamous Düsseldorf airport fire of 1996. The study found that PAHs (polycyclic aromatic hydrocarbons) are found in high amounts in all fires and contain strong carcinogens. On the other hand, polyhalogenated dioxins and furans (PHDD/Fs) are generated from organic or inorganic compounds in fires (including flame retardants) usually at amounts that are three orders of magnitude lower. The work concluded that decomposition products from flame retardants, including particularly dioxins and furans do not play a significant role in the acute toxicity of fire gases, since that is dominated by carbon monoxide. He then looked at the chronic toxicity of pollutants, in these well documented fires. The work found that the cancer risk from polycyclic aromatic hydrocarbons is up to 500 times higher than that of polyhalogenated dioxins and furans formed from the halogenated flame retardants. The author concludes that the hazard from these polyhalogenated dioxins and furans in fires is being highly overestimated. He finds that the chronic toxicity of polybrominated dioxins and furans resulting from the flame retardants involved in such fires is negligible. In other words, the work showed that impact of the PAHs resulting from all fires is much larger than that of PHDD/Fs and that the contribution of flame retarded plastics to cancer risk is negligible. (Fire Gas Toxicity and Pollutants in Fire: The Role of Flame Retardants, by J. Troitzsch, in "Flame Retardants 2000, February 8-9, 2000, London, pp. 177-184, Interscience Communications, London, UK, 2000).

[MH] Thus, there is no evidence that firefighter cancers, which are a serious issue, are associated with dioxins and furans but there is evidence that firefighters sufer enhanced rates of cancer compared to the rest of the population.

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However, other studies have examined the combustion by-products of polystyrene polymers and concluded that their decomposition products were not

unusually toxic when compared to the toxicity of other natural and synthetic materials and that the addition of flame retardants did not significantly alter combustion by-product toxicity. (R-4) Walter and Veena to work together on this as there is difference of ops.

JB to revise

History of foam plastics in building codes - - The A presentation was provided to the working group detailing the history relating to the regulations for foam plastic insulation in the Building Codes in the United States and a summary of the current Code requirements in the CBC. The presentation described the early issues with describing the flammability of foam plastics, the resultant Federal Trade Commission Consent Cease and Desist Order, and the Industries' research to develop new tests that are applicable to the application and assembly to be used in construction as well as the introduction of Code requirements into the Code for the regulation of foam plastics. The presentation then provided an overview describing the various test requirements and their applications in the current CBC which form the basis for the appropriate use of foam plastic insulation in construction. The presentation is located HERE.

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- ~~Material test methods versus assembly test methods~~(Are assembly test adequate to determine fire safety without the added materials test)
- Are the current test methods the right test methods to provide the correct level of fire safety? Is there a link between the required test results and the actual need in the codes?

- Is it possible to use thermal barriers in lieu of insulation materials with FR chemicals?

Flame retardant~~s~~ chemicals were not addressed individually for the purpose of this working group.

~~Risk Assessments have been performed on HBCD and the conclusions are summarized as follows:~~

~~Canada "HBCD [is] not entering the environment in a quantity or concentration or under conditions that constitute or may constitute a danger in~~

~~Canada to human life or health." Screening Assessment Report on Hexabromocyclododecane, at p. 50.~~

~~Australia "... release of [HBCD] to the environment over the product's [polystyrene insulation panels] life is expected to be very small ..." Priority Existing Chemical Assessment Report No. 34, Hexabromocyclododecane at p.75~~

~~European Union "... the exposure from [polystyrene construction boards] is considered insignificant and therefore not brought forward to the risk characterization." Risk Assessment, Hexabromocyclododecane, at p. 381~~

<HH Suggestion – Move references in the following to Appendix B, possibly include these points under the above E 84 heading, or other new headings>

(PW) What data rebuts the following assertions and/or the supporting information?

Assertion 1: The ASTM E84 test does not accurately predict the performance of foam ~~polymer~~ plastic insulation under real-world fire conditions. [MH] However there is abundant evidence that materials that perform badly in the ASTM E84 test will have poor fire performance.

Assertion 2: Assembly tests are necessary to certify foam plastic insulation for many applications, as cited in http://osfm.fire.ca.gov/codedevelopment/pdf/wgfsbim/CaBldgCodeInsulFireTests20140225.pdf and the related discussion the 25 February 2014 meeting. [MH] The code requires a combination of assembly testing (via NFPA 275) for thermal barriers and material testing where the material testing ensures that an "entry level" of fire performance of the insulation is available before it is submitted to assembly tests.

[MH] In fact, NFPA 275 (thermal barrier test) requires the thermal barrier to be tested together with the insulation in the NFPA 286 test and to control flashover, heat release and smoke release for 15 min. In 1928, Simon Ingberg of the National Bureau of Standards, published a paper on the severity of fire in which he equated the gross combustible fuel load (combustible content in mass per unit area) to the potential fire exposure in terms of duration of exposure to a fire following the standard (ASTM E119) fire curve. This means that Ingberg demonstrated that the standard ASTM E119 fire curve was representative of the typical severity of the fires associated with combustible contents present in buildings in the 1920's (i.e. their fire load) [Tests of the Severity of Building Fires by SH Ingberg, NFPA Quarterly, Vol. 22, pp. 43-61, 1928]. Studies by UL [Impact

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of Ventilation on Fire Behavior in Legacy and Contemporary Residential Construction,, by Stephen Kerber, Thomas Fabian and Pravinray Gandhi (UL), 2008] where full scale experiments were conducted to examine the changes in fire development in modern room's contents versus that that may have been found in a house in the mid-20th century. The modern rooms utilized synthetic contents that were readily available new at various retail outlets, and the legacy rooms utilized contents that were purchased used from a number of second hand outlets. The rooms measured 12 by 12 ft, with an 8 ft ceiling and had an 8 ft wide by 7 ft tall opening on the front wall. Both rooms contained similar types and amounts of like furnishings. Both rooms were ignited by placing a lit candle on the right side of the sofa and allowed to go to flashover and maintain flashover for a period of time before being extinguished. The fire in the modern room transitioned to flashover in 3 minutes and 30 seconds while the fire in the legacy room did the same (with a slightly lower peak temperature) after 29 minutes and 30 seconds. It is clear that modern rooms result in hotter fires that go to flashover faster, so that the time temperature curve of the ASTM E119 fire test (which is based on the fire growth in legacy rooms) is less likely to be representative of the actual fire hazard. Therefore protection required in the 21st century must be at least as high as that required in the 1970s.

Assertion 3: [MH] Thermal barriers (NFPA 275) are necessary ~~and sufficient~~ to prevent the foam from contributing to the development of a large fire ~~ignition~~ until after flashover conditions occur~~, regardless of whether the foam has flame retardant added or not~~. Absent a thermal barrier, all combustible materials, including both flame retarded ~~retardant~~ foams and non-flame retarded foams will ignite upon flashover, ~~if not~~and probably before. However, thermal barriers are required by code (since the 1970s) to separate foam plastic insulation from the habitable environment. (For example see the corner test comparing various insulating materials at https://www.youtube.com/watch?v=snlhECzj1E8&noredirect=1)
(TC) Thermal barriers are sufficient to prevent flaming ignition. They do not necessarily prevent smoldering ignition. [MH] Smoldering ignition is not an issue of concern usually, until there is transition from smoldering to flaming.
Point of further discussion

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Assertion 4: Because the flame retardants in the commercial products do not prevent the foam insulation from burning, fire safety requires that insulating foams in occupied areas must be in an assembly protected by thermal barriers.
(TC) Thermal barriers are not always required for foamed plastics. Ignition barriers are often required in lieu if thermal barriers in certain occupancies (e.g.R occupancies) See http://www.icc-es.org/News/Articles/AY126ThermalBarriersSPF2011-51811.pdf). The following is extracted from the above document for information:

"Ignition barriers do not afford as high a degree of protection from fire as thermal barriers but are considered acceptable for attic and crawl spaces where entry is limited. Building code authorities may accept alternative ignition barrier materials and/or alternative assemblies based on large-scale tests such as outlined in ICC -ES Acceptance Criteria 377, Appendix X."

Assertion 5: Since all foam insulations must be protected from ignition by a thermal barrier or ignition barrier in the assembly, the appropriate fire safety test must be based on the performance of the assembly, not on E84. In fact, E84 test results showing a low FSI for foams might mislead users as to the foam's actual fire risks.

(TC) There is no data to confirm that foam plastics without flame retardants can successfully meet the requirements of our existing thermal barrier fire tests, or that they would be adequately protected by current ignition barriers, which are generic and do not require testing. If flame retardants were removed, the majority of~~all~~ existing systems would be invalidated.
[MH] The most widely used commercial foam plastic insulation materials require the addition of flame retardants in order to meet the ASTM E84 requirements in codes. On the other hand some specialized foam plastic insulations exist that can meet the code requirements based on the NFPA 286 room-corner test and be used without thermal barriers, in some cases without using flame retardants.

Assertion 6: Since ASTM E84 does not provide meaningful data for insulating foams, this test should not be required as a certification test for insulating foams.

(TC) ASTM E84 is one of the tools used and needed to determine system performance. ~~Foamed plastics with unknown or very high flame spread ratings (e.g. no flame retardants) are not typically tested for these applications. There is no data to confirm that foam plastics without flame retardants can successfully meet the requirements of our existing thermal barrier fire tests, or that they would be adequately protected by current ignition barriers, which are generic and do not require any testing.~~ [MH] All foam plastic insulation materials are required by their listings and, often also by their specifications (such as ASTM C578 for polystyrene), to meet a fire test (such as ASTM E84 and, in some cases also ASTM D2863 or the oxygen index) before they can be placed on the market. As discussed in terms of assertion 5, some specialized foam plastic insulation materials can meet the code requirements of NFPA 286 and do not need the thermal barrier. All foam plastic insulation materials must have been tested to ASTM E84, irrespective of whether they need the thermal barrier or not. Undoubtedly the protection afforded by ignition barriers is much less than that afforded by thermal barriers and that is why they are permitted only in attics and crawl spaces where entry is limited.

Support for the assertions is found in:

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1) The 2012 paper by Vytenis Babrauskas et al
(http://dx.doi.org/10.1080/09613218.2012.744533)
What evidence rebuts the points (below) made in this paper?

a) The Steiner Tunnel Test results for Fire Spread Index (FSI) do not correlate well with other fire test results, such as corner tests (plots and references on p. 742.) Low FSI (< 25) samples can show very short times (<2 min) to flashover. Conversely, some high FSI (> 60) samples appear to have flashover times as long as 15 minutes. As such, E84 tests of polymer foams do not accurately predict expected fire performance. [MH] See responses to assertions above. It is correct that some low flame spread index results can be associated with poor fire performance but high flame spread index results are always associated with poor fire performance.

b) Commercial FR foam insulation contributes significantly to the fire when there is no thermal barrier. [MH] Foam plastic insulation is not permitted to be used without a listed thermal barrier in the habitable environment.

c) Standard fire resistant gypsum board or other NFPA 275-compliant thermal barrier is necessary and sufficient to prevent foam from igniting in the event of a room fire until well after flashover has occurred. Since unprotected commercial FR foams will lead to room flashover if uncovered, and the thermal barrier keeps FR-free foam from igniting, it is unclear that added FR improves fire safety.

(TC) It is not known whether or not standard fire resistant gypsum board or other NFPA 275 compliant thermal barriers are sufficient to prevent foam from igniting in the event of a room fire until well after flashover has occurred. [MH] All listings of foam plastic insulation and of thermal barriers are based on tests conducted with foam plastic materials that comply with the code requirements for ASTM E84 testing. Furthermore, the primary issue is not preventing ignition of the insulation but ensuring that the fire does not spread into other compartments.

d) Fire propagation in the wall cavity is primarily a function of cavity geometry and size - and that FSI does not play a significant role (p.741) [MH] Fire propagation is affected to a very large degree by the heat release rate of the combustible materials and flame retardants decrease heat release rate.

If no evidence rebuts these points, then why require ASTM E-84 testing for insulation foams? [MH] Abundant evidence, as shown above, rebuts all the points.

2) Reports on facade structure fires show that ~~flame retarded~~ polystyrene foams are a significant fuel source for fast spreading fires. All cases studied where there have been façade fires involving foam plastic insulation with fast flame spread have been shown to be cases where the type of fire protection required by US

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codes was absent. Two recent studies have looked at such fires, both in the US [D.H. Evans and M.M. Hirschler, "Foam Plastics in Building Construction", Session T44, NFPA Annual Meeting June 2014, Las Vegas, NV] and internationally [N. White, "Fire Hazards of Exterior Wall Assemblies Containing Combustible Components", Session W22, NFPA Annual Meeting, June 2014, Las Vegas, NV].

References accessed 14 March 2014:

http://magazine.sfpe.org/fire-investigation/monte-carlo-exterior-facade-fire

http://www.fireengineering.com/articles/2010/05/modern-building-materials-are-factors-in-atlantic-city-fires.html

Do these reports support the hypothesis that using a FR in the polymer is insufficient on its own, and so the thermal or ignition barrier is a critical component of the sub-assembly or building system? [MH] The issue is not whether foam plastic insulation with flame retardants affords sufficient fire safety since that use is not permitted by code: a thermal barrier (when separated from the habitable environment) or an ignition barrier (in attics and crawl spaces where entry is limited) is always required.

(TC) Thermal Barriers are required for interior protection. Tests of exterior facades do not require "thermal barriers" as defined here. There are other test methods for evaluating performance of facades under exterior fire exposure conditions (e.g. NFPA 285, NFPA 259). Consequently, the impact of removing flame retardants from foamed plastics installed on the exterior surface of exterior wall assemblies is unknown.

Do these reports support the hypothesis that once a fire is intense enough to breach the thermal barrier controls, the FR does not significantly reduce the fire growth or spread? [MH] Clearly data shown below (under 3) indicate that flame retardants decrease the heat released by polymers and, thus, increase fire safety, as long as the proper combination of polymers and flame retardants is used.

Does ASTM E84 testing predict real world performance, or is assembly testing necessary to assess actual fire performance?

(TC) No. [MH] Assembly testing is always necessary but it must also be accompanied by material testing.

3) [MH] Papers submitted by Marcelo Hirschler ["Flame retardants and heat release: review of traditional studies on products and on groups of polymers", by M.M. Hirschler (Article published online, Fire and Materials, 03/11/2014, DOI: 10.1002/fam.2243) and "Flame retardants and heat release: review of data on individual polymers", by M.M. Hirschler (Article published online, Fire and Materials, 03/11/2014, DOI: 10.1002/fam.2242)] show that Heat Release Rate (HRR) can be reduced, and Time to Ignition (TTI) increased, if sufficient levels of the appropriate

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systems of flame retardants are added. However, a significant part ~~most~~ of these data appear to be from experiments using ~~high levels of flame retardants, and often~~ mixtures of different flame retardants because combinations may be necessary to get the appropriate improvement in fire performance for each system. QUESTION: Do the standard commercial insulation products have HRR and TTI values that are substantially and meaningfully different than the flame retardant free materials?

[MH] Data obtained for heat release of rigid polyurethane foam and polyisocyanurate foam in the cone calorimeter heat release test demonstrate very significant levels of improvement on heat release rate. In the case of rigid polyurethane foam the improvement in heat release rate (shown in Appendix E as Table 1) is 40%, while it is 46% for polyisocyanurate foam (shown in Appendix E as Table 2). Data on heat release of solid polystyrene in the cone calorimeter also show high improvements in the range of 40-60% in heat release rates depending on the system, using a variety of different flame retardant additive systems (shown in Appendix E asTables 3-8). Data on heat release in small scale tests (like the cone calorimeter) is very difficult to obtain for polystyrene foam because of its physical properties (the way it melts and shrinks). However, limited data, showing some 20% improvement can be found in foamed EPS (shown in Appendix E as Table 9).

[MH] More important, the positive effect of flame retardants on the fire performance of polystyrene foam is demonstrated by the fact that improvements are found by using different tests, including both ASTM E84 (in the US) and the Single Burning Item test (EN 13823) and the small burner test (ISO 11925-1) in the European Union [Compilation of International Building Regulations (Fire) Relevant for EPS/XPS, by Per Blomqvist, Margaret Simonson McNamee and Per Thureson, in SP Technical Note 10 (2010)]. Similar results are found with other foam plastic insulations (polyurethane and polyisocyanurate). In all cases the fire performance of the flame retarded insulation is better than that of the non flame retarded one.

~~Please provide data.~~

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(TC) Please see Table below, extracted from, **NIST NCSTAR 2: Vol. I, Report of the Technical Investigation of The Station Nightclub Fire,** William Grosshandler, Nelson Bryner, Daniel Madrzykowski, *Fire Research Division Building and Fire Research Laboratory, National Institute of Standards and Technology, and* Kenneth Kuntz, *Federal Emergency Management Agency U.S. Department of Homeland Security,* June 2005, page 74.

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Table 4.2 Peak HRR, time to sustained Ignition, and time to Peak HRR

polyurethane foam sample ID	External Radiant Flux, kW/m^2	Time to Sustained Ignition, Average,* seconds	Time to Peak Heat Release, Average,* seconds	Peak Heat Release Rate, Average,* kW/m^2
NIST				
PUF-FR	35	13	36	453
PUF-NFR-A	35	7	30	605
PUF-NFR-B	20	14	45	450
	35	6	30	586
	40	4	29	820
	60	3	24	1154
	70	3	21	970
ATF [24]				
Polyether PUF	20	9	37	260
Polyether PUF	40	3	31	297
Polyether PUF	60	1	26	415

* Average values include all individual test runs at each specific external thermal flux. Data from individual test runs are provided in Appendix A.

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Full Report available at http://www.fire.nist.gov/bfrlpubs/fire05/PDF/f05032.pdf

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3a) HRR appears to show some relationship to ignition source energy flux (e.g. http://osfm.fire.ca.gov/codedevelopment/pdf/wgfsbim/HirschlerFAM2242FlameRetardantsHeatRelease2FireMaterials2014.pdf, table 3, or table 16. Table 16 suggests that higher ignition energy flux results in increased HRR. What is the energy flux range (kW/m2) expected at flashover? At flashover conditions does the FR create a meaningful difference? Again, what data supports the answer?

[MH] It is well known that heat release rate increases with incident heat flux; this has been demonstrated for all materials (e.g. see "Heat release from plastic materials", M.M. Hirschler, Chapter 12 a, in "Heat Release in Fires", Elsevier, London, UK, Eds. V. Babrauskas and S.J. Grayson, 1992. pp. 375-422.). The key fire safety interest is in preventing flashover and/or delaying high heat release in rooms away from the room of origin after flashover, because once flashover has occurred survival in that room is impossible. Data described above shows that flame retardants decrease heat release.

4) A series of reports indicate that improperly applied Spray Foam Insulation can spontaneously ignite during the exothermic curing process, or during spraying if an ignition source is present. References accessed 14 March 2014:
http://www.greenbuildingadvisor.com/blogs/dept/green-building-news/three-massachusetts-home-fires-linked-spray-foam-installation

http://www.capecodonline.com/apps/pbcs.dll/article?AID=/20110211/NEWS/102110323 (last paragraph)

http://www.greenbuildingadvisor.com/blogs/dept/green-building-news/nze-project-tragic-fire-and-will-rebuild

These reports raise the following questions regarding industry claims that the flame retardant protects during transport and construction. [MH] The newspaper stories referenced talk about fires that occurred in which spray foam insulation contributed to the fire, probably following improper installation that did not follow the manufacturers' installation instructions or the instructions from the Spray Polyurethane Foam Industry and ICC ES (http://www.icc-es.org/News/Articles/AY126ThermalBarriersSPF2011-51811.pdf). Spray polyurethane foam is a combustible material.

a) What studies, if any, have been conducted on the flammability of the two SFI components?

b) What do these studies tell us about the comparative safety of the FR and non-FR versions during transport and construction? [MH] Spray polyurethane foam is not transported as such but the two components (an isocyanate and a polyol) are combined on site during application. Thus transport of the foam is not relevant.

(Note - as has been pointed out, the fire code does not address transport and construction phases, but since the industry claims this benefit it would be useful to see the actual data supporting the assertion.)

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- What is the criteria used to determine/measure that the level of fire safety is maintained? Match the intent of the bill?
- Way to judge economic impact? Is this needed? (may be addressed during drafting of recommendations)
- Impact on sprinklered versus non-sprinklered buildings?
- Will insulation products burn or ignite "greater" without compliance to ASTM E84? (Placeholder PW to revise question) (TC) Yes
- Is there an alternative to ASTM E84 to create compliant insulation products?
- Are there situations that ASTM E84 does not provide meaningful data regarding the suitability of material application/use assembly…?

- What are the fire safety impacts on existing building undergoing construction.
- What insulation materials need to be addressed in this review?

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CURRENT STATE REGULATIONS AND LOCAL ORDINANCES

California regulations covering insulation are included in Health and Safety Code, Sections _____. (KR)

- List of fire tests in the California codes (provide reference to (LR presentation doc unless this is included as Appendix C)

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RECOMMENDATIONS

The working group was tasked with providing the State Fire Marshal with recommendations on the two following areas, as described in the Foreword.

<HH comment – If full consensus is not reached, do we wish to provide a minority opinion for each of the following items. If so how do we capture these opinions?>

ITEM FOR DISCUSSION…

One- and two-family dwellings type V-B construction
Wall construction proposal:

- One layer of 5/8 type X Gypsum (wallboard/sheathing) both sides of wall, joints of exterior on framing or blocking;
- 2x4 (16 in on center), 2x6 (24 in on center) wood stud wall construction.
  - Potential for Simpson Strong Wall- *Lorraine to reasearch*
- Solid fill of stud wall cavity with non FR insulation. (Need to specify what,which insul - Look at UL for data)

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- Maximum 1" air space. (CEC Part 6 requires any airgap to be on the nonconditioned side except for spray foam applications). [test to be run with 1" air space and without airspace]
- Firestopping ASTM E814 for all penetrations, notched, bored holes, DWV other plumbing, electrical, mechanical ducting, fire sprinklers.
- Electrical installations rated boxes
- Labeling by listing agency and identification by mfg. of non FR insulation (enforcement issue).

- Testing criteria for wall comparison:

  ASTM E119 test (UL 263) Run test for standard wall with FR insulation to determine where failure is accomplished, establish baseline, run test on non FR insulation.

  NFPA 286 run test for, room corner test (run to failure) with interior finish code criteria (CBC/CRC)

  Standard wall for testing purpose:
  ½" Gypsum interior side
  3/8" OSB exterior sheathing or 7/16 struct sheathing
  Solid fill of stud wall cavity with FR insulation. (Need to specify what/which insulation - Look at UL for data).

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- 5/8 type X both sides of wall;
- 2x4, 2x6 or 2x8 wood stud including staggered stud wall construction.
- Solid fill of stud wall cavity with non FR insulation meeting???
- Need list standards that need to be modified or exempted:
  ASTM E84, ASTM D2863, C578, C1029, C1289, C591...
- Maximum 1" air space.
- Firestopping ASTM E814 (not just typical fire blocking) for all penetrations, notched, bored holes, DWV other plumbing, electrical, mechanical ducting, fire sprinklers.
- Electrical considerations conduit, rated boxes? Look at studies (UL) NFIRS, CAIRS for electrical fires.
- Labeling and identification of non FR insulation (enforcement issue).

One- and two-family dwellings type V-B construction
Floor/Ceiling construction proposal:

- 3/4 plywood (floor side) with leveling compound- Check with UL
- 2x10 wood joists
- Two layers of 5/8 type X Gypsum (wallboard/sheathing) ceiling side

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- Solid fill of stud floor/ceiling cavity with non FR insulation.
- Maximum 1" air space. [Test to be run with no airspace and 1" airspace]-
  - Further research to see if both test are needed
  - Further research to see if 1" is the correct size. ½" or 1.5" or 3" more appropriate?
  - Potential for larger gap may exist, as compared to to wall assembly
- Firestopping ASTM E814 for all penetrations including penetrations of thermal barriers, notched, bored holes, DWV other plumbing, electrical, mechanical ducting, fire sprinklers.
- How to- or need to-address ducting? What type of if any ducting is used?
- Electrical installations, including lighting – -rated boxes
- Exceptions for thermal barriers (R316.5.13/2603.4.1.14) shall not be accepted.
- Labeling by listing agency and identification by mfg. of non FR insulation (enforcement issue).

One- and two-family dwellings type V-B construction
Crawlspace construction proposal:

- 3/4 plywood (floor side)
- 2 x 10 floor joists
- 3/4 plywood (crawlspace side) - need more data or use flr/clg assembly above
- Exceptions for thermal barriers (R316.5.4/2603.4.1.6) shall not be accepted (need further discussion/information).
- Solid fill of stud floor/ceiling cavity with non FR insulation.
- Maximum 1" air space. [Test to be run with no airspace and 1" airspace]-
  - Further research to see if both test are needed
  - Further research to see if 1" is the correct size. ½" or 1.5" or 3" more appropriate?
  - Potential for larger gap may exist, as compared to to wall assembly

  ~~Maximum 1" air space.~~
- Firestopping ASTM E814 for all penetrations including penetrations of thermal barriers, notched, bored holes, DWV other plumbing, electrical, mechanical ducting, fire sprinklers.
- Electrical installations rated boxes
- Labeling by listing agency and identification by mfg. of non FR insulation (enforcement issue).

One- and two-family dwellings type V-B construction
Attic construction proposal:

- 3/4 plywood (exterior side)
- Roof rafter or truss (top chord)
- ~~One~~Two layer of 5/8 type X Gypsum (wallboard/sheathing) (attic side) is this enough?

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- Solid fill of ~~stud floor/ceiling~~ cavity with non FR insulation.
- Maximum 1" air space. [Test to be run with no airspace and 1" airspace]-
    - Further research to see if both test are needed
    - Further research to see if 1" is the correct size. ½" or 1.5" or 3" more appropriate?
    - Potential for larger gap may exist, as compared to to wall assembly

~~Maximum 1" air space.~~
- Insulation must be enclosed in above mentioned assembly..
- Firestopping ASTM E814 for all penetrations, notched, bored holes, DWV other plumbing, electrical, mechanical ducting, fire sprinklers.
- Exceptions for thermal barriers (R316.5.3/2603.4.1.6) shall not be accepted (need further discussion/information).
- Electrical installations rated boxes
- Labeling by listing agency and identification by mfg. of non FR insulation (enforcement issue).

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For all assemblies need baseline heatrelease to determine max heatrelease for non FR insulation. Need data! NFPA 286

What foam or any insulation materials need to be addressed or excluded? Federal standards that may require FR

Does this type of assembly provide equivalent to a typical wall constructed with a thermal barrier FR foam for occupant to safely exit the building and firefighter safety?
Unknown without testing (ASTM E119 for baselin and comparison? Including hose stream)

What if any test is necessary?

Sprinkler substitutions/considerations?

What about required rated walls.

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CBC
2603.3 Surface-burning characteristics.
Unless otherwise indicated in this section, foam plastic insulation and foam

plastic cores of manufactured assemblies shall have a flame spread index of not more than 75 and a smoke-developed index of not more than 450 where tested in the maximum thickness intended for use in accordance with ASTM E 84 or UL 723. Loose fill-type foam plastic insulation shall be tested as board stock for the flame spread and smoke-developed indexes.

Exceptions:

1. Smoke-developed index for interior trim as provided for in Section 2604.2.
2. In cold storage buildings, ice plants, food plants, food processing rooms and similar areas, foam plastic insulation where tested in a thickness of 4 inches (102 mm) shall be permitted in a thickness up to 10 inches (254 mm) where the building is equipped throughout with an automatic fire sprinkler system in accordance with Section 903.3.1.1. The approved automatic sprinkler system shall be provided in both the room and that part of the building in which the room is located.
3. Foam plastic insulation that is a part of a Class A, B or C roof-covering assembly provided the assembly with the foam plastic insulation satisfactorily passes FM 4450 or UL 1256. The smoke-developed index shall not be limited for roof applications.
4. Foam plastic insulation greater than 4 inches (102 mm) in thickness shall have a maximum flame spread index of 75 and a smoke-developed index of 450 where tested at a minimum thickness of 4 inches (102 mm), provided the end use is approved in accordance with Section 2603.10 using the thickness and density intended for use.
5. Flame spread and smoke-developed indexes for foam plastic interior signs in covered and open mall buildings provided the signs comply with Section 402.6.4

- Flame spread index and smoke-developed index shall not be ~~restricted~~ required for sub-grade foam plastic insulation located 6” below finish grade and separated from the interior by a minimum of 4-inch ~~(25 mm)~~ thickness of masonry or concrete. ~~Unrestricted~~ ~~exterior~~ Exterior sub-grade insulation may extend a maximum of 12” above grade where it is covered with an exterior material that protects against ignition: ~~1/4 inch thick (6.4 mm) wood structural panel; 1/4~~1/2-inch-thick ~~(6.4 mm)~~ cement board ~~or~~ other eq non combustible materials ~~; corrosion-resistant sheet metal having a base metal thickness of 0.016 inch (0.4 mm) or other approved UV-resistant material~~ installed in such a manner that the foam plastic insulation is not exposed. Unrestricted insulation shall be separated from combustible concealed spaces by fireblocking materials as listed in 718.2.1. Labeling by listing agency and identification by mfg. of non FR insulation (enforcement issue).

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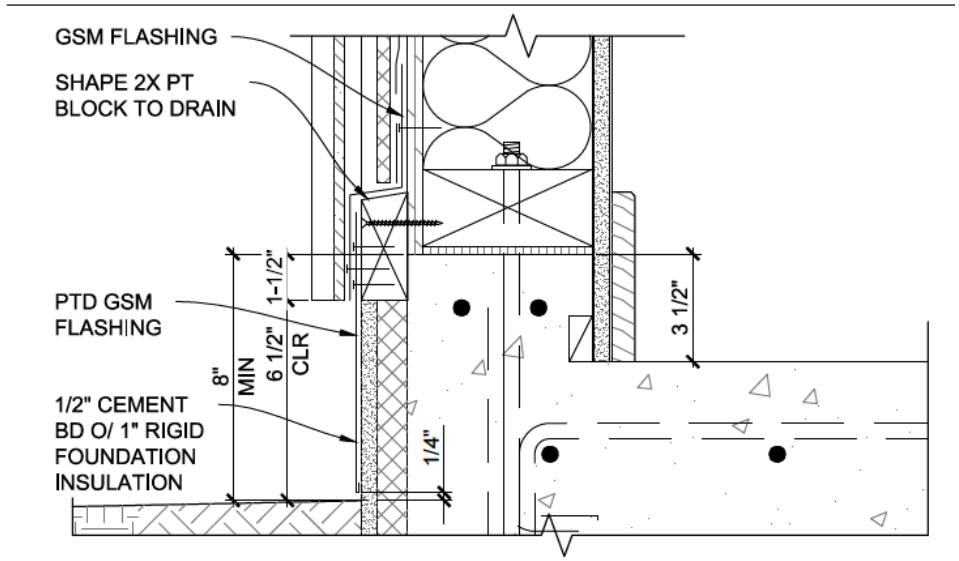

12 A1-8.7 CONC CURB @ GRADE, TYP

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SEE DETAIL 3/A1-8.2 FOR TYP NOTES

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APPENDIX A – WORKING GROUP MEMBERS

CSFM FLAMMABILITY STANDARDS FOR BUILDING INSULATION MATERIALS WORKING GROUP

~~This information was added using best available information and needs a review~~

- Kevin Reinertson - Chair CAL FIRE – Office of the State Fire Marshal

Working Group Members

- Eric Banks - BASF Corp., representing the Spray Foam Coalition of the Center for the Polyurethanes Industry (CPI)
- Jesse Beitel - Hughes Associates, representing the American Chemistry
- Council (ACC)
- Tonya Blood - Bureau of Electronic and Appliance Repair, Home Furnishings and Thermal Insulation (BEARHFTI)
- George Combs- Bayer Material Science LLC
- Gordon Damant - Damant & Associates
- Barb Fabian- Owens Corning
- Michael D. Fischer - Kellen Company, representing the Polyisocyanurate Insulation Manufacturers Association (PIMA)
- Gene Gantt - California State Firefighters Association
- Andrew Henning - CAL FIRE – Office of the State Fire Marshal
- ~~Dr.~~ Marcelo M. Hirschler - GBH International, representing the North American Flame Retardant Alliance (NAFRA)
- Howard Hopper - UL LLC
- Avery Lindeman - Green Science Policy Institute
- Donald Lucas - Environmental Energy Technologies Division - Lawrence
- Berkeley National Laboratory
- Jim McGowan - California Building Standards Commission
- Robert Raymer - California Building Industry Association (CBIA)
- Walter Reiter - Expanded Polystrene (EPS) Industry Alliance
- Lorraine A. Ross - Intech Consulting Inc., representing the Extruded Polystyrene Insulation Manufacturers Association (XPSA)
- Veena Singla - Natural Resources Defense Council
- Adria Smith - Fountain Valley Fire Department, representing Cal Chiefs /
- SoCal Fire Prevention Officers Association
- Joel Tenney - ICl-IP America Inc., representing Israeli Chemicals
- Paul Wermer, Paul Wermer Sustainability Consulting, representing the U.S. Green Building Council of California
- Kevin White - California Professional Firefighters
- Mike Wilson - California Department of Industrial Relations, representing California Labor & Workforce Development Agency (LWDA)

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Working Group Alternates

- James Carver – City of El Segundo, representing CalChiefs, Southern California Fire Prevention Officers
- Carrie Cathalifaud - Bureau of Electronic and Appliance Repair, Home Furnishings and Thermal Insulation (BEARHFTI)
- Tim Earl - GBH International, representing the North American Flame Retardant Alliance (NAFRA)
- John Ferraro- Extruded Polystrene Foam Association (XPSA)
- Steve Fischer - Bureau of Electronic and Appliance Repair, Home Furnishings and Thermal Insulation (BEARHFTI)
- Justin Malan - ECO Consult, representing the U.S. Green Building Council
- of California
- Jerry Phelan- Bayer Material Science
- Greg Pruden, Department of Consumer Affairs
- Steve Risotto - American Chemistry Council
- Tim Shestek - American Chemistry Council
- Jeff Sickenger - KP Public Affairs, representing the American Chemistry Council
- Don Wheat- ?
- John Woestman- Extruded Polystyrene Foam Association

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APPENDIX B - REFERENCED DOCUMENTS

The ~~referenced documents that the working group selected to use as a basis for their work are included below. These are limited current research, testing,~~ published reports, studies, codes, ~~standards~~ and regulations ~~. These documents are limited to current applicable subjects that are directly related to U.S. codes, standards and research.~~ that support information included in the body of this report are referenced below, with cross reference (R-X) numbers for correlation.

R1 – Based on IBC Section 101.3.

R-2 - Flame Retardant Alternatives for Hexabromocyclododecane, EPA Design for the Environment, 2013, EPA Pollution Prevention and Toxics, ChemView Database

R-3 - Bates 2007; IARC 2010; LeMasters et al. 2006 <HH - Is this properly referenced in the body?>

R-4 - Indrek S. Wichman, Progress in Energy and Combustion Science 29 (2003) 247-299. See also Mario Rossi, Polymer Degradation and Stability 74 (2001) at 508.

<HH - What do we wish to do with these?>

R1VS
Bates, Michael N. 2007. "Registry-Based Case – Control Study of Cancer in California Firefighters." American Journal of Industrial Medicine 344: 339–44. doi:10.1002/ajim.20446.
Desmet, Koen, Marc Schelfaut, and Pat Sandra. 2005. "Determination of Bromophenols as Dioxin Precursors in Combustion Gases of Fire Retarded Extruded Polystyrene by Sorptive Sampling-Capillary Gas Chromatography–mass Spectrometry." Journal of Chromatography A 1071 (1-2): 125–29. doi:10.1016/j.chroma.2004.12.019.
Ebert, J, and M Bahadir. 2003. "Formation of PBDD/F from Flame-Retarded Plastic Materials under Thermal Stress." Environment International 29 (6): 711–16. doi:10.1016/S0160-4120(03)00117-X.
IARC. 2010. "IARC Monographs on the Evaluation of Carcinogenic Risks to Humans: FIREFIGHTING". Lyon: International Agency for Research on Cancer.
LeMasters, Grace K, Ash M Genaidy, Paul Succop, James Deddens, Tarek Sobeih, Heriberto Barriera-Viruet, Kari Dunning, and James Lockey. 2006. "Cancer Risk among Firefighters: A Review and Meta-Analysis of 32 Studies." Journal of Occupational and Environmental Medicine / American College of Occupational and Environmental Medicine 48 (11): 1189–1202.
Shaw, Susan D, Michelle L Berger, Jennifer H Harris, Se Hun Yun, Qian Wu, Chunyang Liao, Arlene Blum, Anthony Stefani, and Kurunthachalam Kannan. 2013. "Persistent Organic Pollutants Including Polychlorinated and Polybrominated Dibenzo-P-Dioxins and Dibenzofurans in Firefighters from

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Northern California." Chemosphere 91 (10): 1386–94. doi:10.1016/j.chemosphere.2012.12.070.
Weber, Roland, and Bertram Kuch. 2003. "Relevance of BFRs and Thermal Conditions on the Formation Pathways of Brominated and Brominated-Chlorinated Dibenzodioxins and Dibenzofurans." Environment International 29 (6): 699–710. doi:10.1016/S0160-4120(03)00118-1.

DL (summaries and references)
Babrauskas, V. et al. (2012) Flame retardants in building insulation: a case for re-evaluating building codes, Building Research and Information, 40:6, 738 – 755
Note: This review paper asks questions that directly respond to AB 127. The questions were answered by a thorough scientific review of the literature, with over 100 papers cited. A brief summary of this paper is given below, along with summaries from the most relevant papers cited. Note that this summary is not a proper literature review, and the results from these studies need to be examined in detail.
The Steiner Tunnel test is invalid for plastic foams. In the unusual case of a cavity constructed in violation of codes without proper firestopping, the Steiner Tunnel test rating for insulation materials does not influence fire propagation. If buildings
are constructed in violation of code with exposed insulation, meeting the Steiner Tunnel test requirements still does not provide for acceptable behavior of these materials. Furthermore, research does not support the view that the change should
be to replace the Steiner Tunnel with a more accurate test. If this were done, all economically viable foams would end up being precluded from use. Such a step is
not necessary, as the code provisions for thermal barriers alone provide adequate
fire safety benefits, i.e. the thermal barrier provides a 15-min finish rating, effectively protecting insulation from fire. (743)
US Building Codes do not regulate materials usage during construction or demolition, and all requirements refer only to the condition as found after completion of construction. (740)
Babrauskas, V. (2003): Ignition Handbook, Fire Science Publ. and Society of Fire Science
Engineers, Issaquah, WA.
The auto-ignition temperatures of polyurethane and polystyrene are greater than 400ºC.
National Fire Protection Association (NFPA) (2009): Standard method of fire tests for the
evaluation of thermal barriers (NFPA 275), NFPA, Quincy, MA.
This test ensures that barriers which pass the test will protect underlying foams

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for at least 15 minutes after flashover, as simulated by the standard fire resistance
test. After 15 minutes, the temperature at the interface of the thermal barrier and the foam cannot be greater than 121ºC (on average), and the maximum allowable
temperature at any one thermocouple is 163ºC. The values are greatly below the ignition temperatures of insulation foams and thus provide a safety factor, not just a bare minimum.

Zicherman, J.B. and Eliahu, A. (1998): Finish ratings of gypsum wallboards. Fire Technology,
34, 356-362.

The authors tested half-inch gypsum wallboard from a number of manufacturers and found that they provided 15- to 20-minute finish ratings; at the end of the test period, all samples tested had retained structural integrity. Foam would not have been ignited behind these materials.

D'Sousa, M.V. et al (1981): Performance of protective linings for polystyrene insulation in a
corner wall test. Fire Technology, 17(2), 85-97

In a full-scale room-corner test, a 0.5-inch gypsum barrier protected expanded polystyrene (EPS) foam insulation for 30 minutes.

Mehaffey, J.R. et al (1994): A Model for predicting heat transfer through gypsum-board/woodstud
walls exposed to fire. Fire and Materials, 18(5), 297-305.

Gypsum wall board samples were tested using the criteria in NFPA275. All samples achieved finish ratings of 16 – 24 minutes.

Babrauskas, V. et al (1997): Testing for surface spread of flame: new tests to come into use.
Building Standards, 66(2), 13-18

The Steiner Tunnel test (ASTM E84) is unreliable for evaluating fire hazard of plastic foams.

Factory Mutual (1974): Foamed Polystyrene for Construction (Data Sheet 1-58), Factory
Mutual, Norwood, MA.

Factory Mutual (1978): Foamed Polystyrene for Construction (Data Sheet 1-58), Revision,
Factory Mutual, Norwood, MA.

"Flame spread ratings by ASTM E84 tunnel test should be disregarded for foamed
plastics."

Note: According to Vyto Babrauskas, PhD, "This was the conclusion by one of the nation's most respected fire research establishments. Nothing has changed in
the procedures of ASTM E84 testing that would justify changing that conclusion." (personal communication, March 13, 2014)

ASTM (2012): Standard Test Method for Surface Burning Characteristics of Building Materials

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(ASTM E84 – 12a), ASTM International, West Conshohocken, PA.
"Testing of materials that melt, drip, or delaminate to such a degree that the continuity of the flame front is destroyed, results in low flame spread indices that do not relate directly to indices obtained by testing materials that remain in place." (Section 1.4)
Rose, A. (1971): Flammability of lining and insulating materials (Canadian Building Digest
DBD-141), National Research Council of Canada, Ottawa, ON.
Some foams tested could not be evaluated using ASTM E84 because of excessive
smoke production which made observation of the flame front impossible.
Rose, A. (1975): Fire testing of rigid cellular plastics (IR-422), National Research Council of
Canada, Ottawa, ON.
Some foams tested intumesced to such a degree that air flow in the Steiner Tunnel
is no longer reflective of the prescribed test conditions.
In corner tests of exposed foams, insulation materials with code-allowed FSI values between 18 and 65 led to room flashover in as little as 0.5 minutes.
Choi, K.K. and Taylor, W. (1984): Combustibility of insulation in cavity walls. Journal of Fire
Sciences, 2(3), 179-188:
Fire propagated rapidly when a gap of 1 inch or larger was present between insulation and the interior face of the wall. Smaller gaps did not display rapid propagation of flames.
"The flame spread rating of materials used in the tests was not a significant factor [of fire propagation in the wall cavity]." (185)
Williamson, R.B. and Baron, F.M. (1973): A corner fire test to simulate residential fires. Journal
of Fire and Flammability, 4, 99-105.
Low flame spread index rigid polyurethane foams can undergo extremely rapid fire development if used uncovered. The materials tested had FSI values < 25.
Castino, T.G. et al (1975): Flammability Studies of Cellular Plastics and Other Building
Materials Used for Interior Finishes. Subject No. 723, Underwriters Laboratories, Northbrook,
IL.
There is no correlation between Flame Spread Index and fire safety: low FSI does
not imply a long time to flashover, nor does it imply a small amount of specimen destroyed in a fire.
Lee, B.T. (1985): Standard room fire test development at the National Bureau of Standards, in
Fire Safety: Science and Engineering (ASTM STP 882), ASTM, Philadelphia, PA, pp. 29-44.
In full-scale room fire tests, uncovered polyisocyanurate and polystyrene foams

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with FSI < 25 resulted in very rapid times to flashover.
Dillon, S.E. (1998): Analysis of the ISO 9705 Room/Corner Test: Simulations, Correlations and
Heat Flux Measurements (NIST-GCR-98-756), National Institute of Standards and Technology,
Gaithersburg, MD.
Exposed, flame retardant-treated foams were studied in large-scale burn tests. Extruded polystyrene (XPS) produced flashover in only 1.5 minutes, and expanded polystyrene (EPS) produced flashover in only 1.4 to 1.8 minutes.
Babrauskas, V. (1996): Wall insulation products: full-scale tests versus evaluation from benchscale
toxic potency data, in Interflam 1996, Interscience Communications, London, pp. 257-274.
Foam plastic insulation materials meeting the current flammability standards for foam insulation (Steiner Tunnel test) do not perform acceptably in ISO 9705, considered to be a reliable test for assessing the fire hazard of exposed wall/ceiling surfaces.
Ahrens, M. (2011): Home Structure Fires, National Fire Protection Association, Quincy, MA.
Insulation within a structural area was the primary item contributing to flame spread in only 2% of US home structure fires. Foam insulation very rarely presents a fire safety issue when it is properly protected behind a thermal barrier. This amounted to zero deaths and only 40 injuries (1% of fire injuries for the entire US).
Posner, S. et al (2010): Exploration of Management Options for HBCD, Swerea IVF, Mölndal,
Sweden.
“Using thermal barriers it is possible to fulfill fire safety requirements in most of the uses in constructions and buildings with EPS and XPS without a fame retardant.” (40)
“The national fire safety requirements are achieved by the building codes specifying the different uses of insulation products in buildings and construction, through the use of thermal barriers. In Scandinavian countries like Norway and Sweden buildings are constructed to prevent the spread of fire and additionally the
buildings should not pose and health and/or environmental hazard to residents and
the local environment.” (46)
Molyneux, S. et al.(2013) The effect of gas phase flame retardants on fire effluent toxicity.
Polymer Degradation and Stability:
The presence of halogenated flame retardants may increase toxicity of fire effluents under certain combustion conditions.
Ebert, J. and Bahadir, M. (2003): Formation of PBDD/F from flame-retarded plastic materials
under thermal stress. Environment International, 29(6), 711-716.

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Formation of dioxins has been observed during incorporation of brominated flame
retardants and processing (e.g. extrusion cycles) of plastic foam insulation. Dioxin
byproducts from manufacturing processes can be found in the commercial insulation product and in workplace air. Dioxins can be produced when halogenated flame retardants burn either in accidental fires or during intentional incineration.
Polystyrene containing HBCD can produce brominated dioxins when burned. The amount produced will depend on the conditions of combustion.
Weber, R. and Kuch, B. (2003): Relevance of BFRs and thermal conditions on the formation
pathways of brominated and brominated-chlorinated dibenzodioxins and dibenzofurans.
Environment International, 29(6), 699-710.
Brominated and brominated-chlorinated dibenzodioxins and dibenzofurans are produced during thermal processing of products containing brominated flame retardants, including during accidental fires of intentional incineration.
World Health Organization (WHO) (1998): Polybrominated Dibenzo-p-dioxins and
Dibenzofurans (EHC 205), WHO, Geneva.
Human exposure to chlorinated dioxins has been associated with adverse health effects including some types of cancer, liver problems, impairment of immune, endocrine, or reproductive function, and disruption of nervous system development.
"PBDDs/PBDFs are contaminants that are more or less similar to PCDDs/PCDFs in their persistence and toxicity. Therefore, humans and the environment should be protected from them… Brominated flame retardants and their precursors appear to be a main source of PBDDs/PBDFs."
"Owing to the accumulating and toxic potential of some PBDDs/PBDFs, every effort should be made to prevent exposure of humans to, and pollution of the environment by, these compounds. Brominated flame retardants should not be used where suitable replacements are available, and future efforts should encourage the development of further substitutes."
Van den Berg, M. et al. (2006) The 2005 World Health Organization reevaluation of human and
mammalian toxic equivalency factors for dioxins and dioxin-like compounds. Toxicological
Sciences, 93(2), 223-241.
Development of human exposure guidelines for brominated dioxins has been identified as a high priority by the World Health Organization.
Birnbaum, l. S. et al. (2003): Health effects of polybrominated dibenzo-p-dioxins (PBDDs) and
dibenzofurans (PBDFs). Environment International, 29(6) 855-860.
Brominated dioxins can have similar effects to those associated with chlorinated dioxins. Brominated dioxins could be contributing to the total dioxin toxicity

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experienced by humans.
“Essentially all of the classic effects demonstrated for TCDD and the other chlorinated dioxins and furans…have been observed in the limited studies with PBDDs and PBDFs.” (857)
Desmet, K. et al (2005): Determination of bromophenols as dioxin precursors in combustion
gases of fire retarded extruded polystyrene by sorptive sampling-capillary gas chromatographymass
spectrometry. Journal of Chromatography A, 1071(1-2), 125-129.
Polystyrene containing HBCD can produce brominated dioxins when burned. The amount produced will depend on the conditions of combustion.
Hsu, J.F. et al (2011): An occupational exposure assessment of polychlorinated dibenzo-p-dioxin
and dibenzofurans in firefighters. Chemosphere, 83(10), 1353-1359.
Serum samples from fire service professionals showed higher polychlorinated dibenzo-p-dioxin and dibenzofuran (PCDD/F) exposure than the general population, suggesting occupational exposure to these chemicals.
Bates, M.N. (2007): Registry-based case-control study of cancer in California firefighters.
American Journal of Industrial Medicine, 344, 339-344.
In a statistical analysis of cancers registered in California, firefighting was associated with increased rates of testicular cancer, melanoma, brain cancer, esophageal cancer, and prostate cancer.
LeMasters, G.K. et al (2006): Cancer risk among firefighters: a review and meta-analysis of 32
studies. Journal of Occupational and Environmental Medicine/American College of
Occupational and Environmental Medicine, 48(11), 1189-1202.
A meta-analysis of 26 studies on cancer occurrence in firefighters reveled that firefighters are at higher risk for multiple myeloma, non-Hodgkin lymphoma, prostate, and testicular cancer.

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APPENDIX C – AB 127 Bill Text

The people of the State of California do enact as follows:

SECTION 1. The Legislature finds and declares that for some insulation materials, current insulation flammability standards can only be met using chemical flame retardants and that new standards proposed pursuant to this act may provide manufacturers with flexibility in meeting the flammability standards, with or without the addition of chemical flame retardants, and would be consistent with maintaining overall building fire safety.

SEC. 2. Section 13108.1 is added to the Health and Safety Code, to read:

13108.1. The State Fire Marshal, in consultation with the Bureau of Electronic and Appliance Repair, Home Furnishings, and Thermal Insulation, shall review the flammability standards for building insulation materials, including whether the flammability standards for some insulation materials can only be met with the addition of chemical flame retardants. Based on this review, and if the State Fire Marshal deems it appropriate, he or she shall, by July 1, 2015, propose for consideration by the California Building Standards Commission, to be adopted at the sole discretion of the commission, updated insulation flammability standards that accomplish both of the following:
(a) Maintain overall building fire safety.
(b) Ensure that there is adequate protection from fires that travel between walls and into confined areas, including crawl spaces and attics, for occupants of the building and any firefighters who may be in the building during a fire.

Consider adding April 14, 2014 letter from Assemly member Skinner

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APPENDIX D – RELATED CALIFORNIA LAWS & REGULATIONS

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Appendix E – Tables on Heat Release and Flame Retardants (from "Flame retardants and heat release: review of data on individual polymers", by M.M. Hirschler (Article published online, Fire and Materials, 03/11/2014, DOI: 10.1002/fam.2242)

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Table 1 – Effectiveness of Flame Retardants on Heat Release of a Rigid Polyurethane Foam

Cone @ 25 kW/m^2	TTI (s)	Pk HRR	Improvement	FPI
Rigid PU foam	s	(kW/m^2)	%	(m^{2}skW^{-1})
Control	26	890	0	0.03
with alkyl aryl phosphate	41	548	38	0.07
with Fyrol RDP	65	910	2	0.07
with Fyrol RDP + Zn	33	720	19	0.05
with Zn stannate & Zn stearate			46	0.02
with Zinc stannate	31	424	52	0.07
with Zn hydroxystannate	36	471	47	0.08

Notes: TTI: time to ignition in cone calorimeter test; Pk HRR: peak heat release rate in cone calorimeter test; FPI: fire performance index (ratio of time to ignition and peak heat release rate, in cone calorimeter test). Improvement %: percentage improvement in Pk HRR based on the untreated material.

Table 2 – Effectiveness of Flame Retardants on Heat Release of a Polyisocyanurate Foam

Cone @ 40 kW/m^2	TTI	Pk HRR	FPI	Av HRR	THR
Polyisocyanurate foam	s	kW/m^2	(m^{2}skW^{-1})	kW/m^2	MJ/m^2
40 kW/m2	-	-	-	-	-
Untreated	4.3	161	0.03	69	11
Plus TCPP	4.6	87	0.05	19	5
Improvement%	7	46	98	72	55

Notes: TTI: time to ignition in cone calorimeter test; Pk HRR: peak heat release rate in cone calorimeter test; Avg HRR: average heat release rate during test in cone calorimeter test; THR: total heat released during test in cone calorimeter test; FPI: fire performance index (ratio of time to ignition and peak heat release rate, in cone calorimeter test). Improvement %: percentage improvement in relevant property based on the untreated material. TCPP: Tris (1-chloro-2-propyl) phosphate.

Table 3 – Effectiveness of Halogen-containing Nanocomposites and Antimony Oxide as Flame Retardants on Heat and Ignitability Properties of Polystyrene Materials

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Cone calorimeter	TTI	Pk HRR	FPI	THR
35 kW/m^2	s	kW/m^2	(m^{2}skW^{-1})	MJ/m^2
Polystyrene				
Untreated	59	1242	0.05	100
Plus FR1	43	1065	0.04	77
Improvement %	-27	14	-15	23
Plus FR1 + ATO	41	590	0.07	50
Improvement %	-31	52	46	50
Plus FR2	33	707	0.05	62
Improvement %	-44	43	-2	38
Plus FR2 + ATO	42	541	0.08	45
Improvement %	-29	56	63	55
Plus FR3	34	967	0.04	71
Improvement %	-42	22	-26	29
Plus FR3 + ATO	43	813	0.05	51
Improvement %	-27	35	11	49
Plus FR4	34	813	0.04	75
Improvement %	-42	35	-12	25
Plus FR4 + ATO	44	875	0.05	61
Improvement %	-25	30	6	39

Notes: TTI: time to ignition in cone calorimeter test; Pk HRR: peak heat release rate in cone calorimeter test; THR: total heat released during test in cone calorimeter test; FPI: fire performance index (ratio of time to ignition and peak heat release rate, in cone calorimeter test). FR1: butyric acid pentabromobenzyl ester; FR2: pentabromobenzyl ester polyacrylate; FR3: methacrylate acid pentabromobenzyl ester; FR4: and acrylic acid pentabromobenzyl ester; ATO antimony oxide. Improvement %: percentage improvement in relevant property based on the untreated material.

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Table 4 – Effectiveness of Brominated Additives (with and without antimony oxide) as Flame Retardants on Heat and Ignitability Properties of High Impact Polystyrene

Cone @ 40 kW/m^2	TTI	Pk HRR	Av HRR 3 min	Eff. Ht Comb	FPI
	s	kW/m^2	kW/m^2	MJ/kg	(m^{2}skW^{-1})
HIPS	60	968	621	30.7	0.06
HIPS + SbO	62	910	580	28.6	0.07
HIPS + Deca	55	708	470	17.0	0.08
HIPS + Deca + SbO	72	360	255	10.1	0.20
HIPS + DBE	54	782	487	18.6	0.07
HIPS + DBE + SBO	78	393	302	10.8	0.20
HIPS + BT93	54	768	509	19.6	0.07
HIPS + BT93 + SbO	88	423	293	12.2	0.21
HIPS + HBCD	72	885	710	23.2	0.08
HIPS + HBCD + SbO	80	766	423	13.2	0.10
Improvement % SbO	3	6	7	7	10
Improvement % Deca	-8	27	24	45	25

Improvement % Deca + SbO	20	63	59	67	223
Improvement % DBE	-10	19	22	39	11
Improvement % DBE + SbO	30	59	51	65	220
Improvement % BT93	-10	21	18	36	13
Improvement % BT93 + SbO	47	56	53	60	236
Improvement % HBCD	20	9	-14	24	31
Improvement % HBCD + SbO	33	21	32	57	68
Brominated additives at 12%; antimony oxide at 4%					
Sb: antimony oxide					
Deca: decabromodiphenyl oxide					
DBE: Decabromodiphenyl Ethane					
BT93: Ethylenebis(tetrabromophthalimide)					
HBCDE: hexabromocyclododecane					

Notes: TTI: time to ignition in cone calorimeter test; Pk HRR: peak heat release rate in cone calorimeter test; Avg HRR 3 min: average heat release rate during the 3 minutes following ignition in cone calorimeter test; Eff. Ht Comb: effective heat of combustion in cone calorimeter test; FPI: fire performance index (ratio of time to ignition and peak heat release rate, in cone calorimeter test).

Table 5 – Effectiveness of Synthetic Micas as Flame Retardants on Heat and Ignitability Properties of Polystyrene Materials

Cone @ 50 kW/m^2	TTI	Pk HRR	FPI	Ht Comb	THR
Synthetic Micas	s	kW/m^2	(m^{2}skW^{-1})	MJ/kg	MJ/m^2
Polystyrene	65	1294	0.05	30.6	111
PS + 1 (18.6 wt% Mica O)	51	513	0.10	27.9	94
PS + 2 (9.3 wt% Mica O)	49	428	0.11	27.1	98
PS + 3 (1.9 wt% Mica O)	63	911	0.07	29.4	111
PS + 4 (10 wt% Mica N)	41	995	0.04	30.8	113
PS + 5 (5 wt% Mica N)	43	1146	0.04	31.7	117
PS + 6 (1 wt% Mica N)	52	1201	0.04	31.9	117
Mica O: dimethyl, di(hydrogenated tallow) ammonium treated sodium fluorinated synthetic mica					
Mica N: Sodium fluorinated synthetic mica					
Improvement % 1	-22	60	98	9	15
Improvement % 2	-25	67	128	11	12
Improvement % 3	-3	30	38	4	0
Improvement % 4	-37	23	-18	-1	-2
Improvement % 5	-34	11	-25	-4	-5
Improvement % 6	-20	7	-14	-4	-5

Notes: TTI: time to ignition in cone calorimeter test; Pk HRR: peak heat release rate in cone calorimeter test; THR: total heat released during test in cone calorimeter test; Ht Comb: effective heat of combustion in cone calorimeter test; FPI: fire performance index (ratio of time to ignition and peak heat release rate, in cone calorimeter test). Improvement %: percentage improvement in relevant property based on the untreated material.

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Table 6 – Effectiveness of Sodium Montmorillonites as Flame Retardants on Heat and Ignitability Properties of Polystyrene Materials					
Cone @ 50 kW/m^2	TTI	Pk HRR	FPI	Ht Comb	THR
Sodium montmorillonite	s	kW/m^2	(m^{2}skW^{-1})	MJ/kg	MJ/m^2
Polystyrene	65	1294	0.05	30.6	111
PS + 1 (16.2 wt% MMT O)	52	446	0.12	26.9	97
PS + 2 (8.1 wt% MMT O)	58	555	0.10	26.6	98
PS + 3 (1.6 wt% MMT O)	66	1080	0.06	29.9	111
PS + 4 (10 wt% MMT N)	40	792	0.05	29.2	106
PS + 5 (5 wt% MMT N)	41	993	0.04	29.5	111
PS + 6 (1 wt% MMT N)	57	1106	0.05	29.8	110
MMT O: dimethyl, di(hydrogenated tallow) ammonium treated montmorillonite (Cloisite 15A)					
MMT N: sodium montmorillonite (Cloisite Na+)					
Improvement % 1	-20	66	132	12	13
Improvement % 2	-11	57	108	13	12
Improvement % 3	2	17	22	2	0
Improvement % 4	-38	39	1	5	5
Improvement % 5	-37	23	-18	4	0
Improvement % 6	-12	15	3	3	1

Notes: TTI: time to ignition in cone calorimeter test; Pk HRR: peak heat release rate in cone calorimeter test; THR: total heat released during test in cone calorimeter test; Ht Comb: effective heat of combustion in cone calorimeter test; FPI: fire performance index (ratio of time to ignition and peak heat release rate, in cone calorimeter test). Improvement %: percentage improvement in relevant property based on the untreated material.

Table 7 – Effectiveness of Phosphonium Synthetic Micas as Flame Retardants on Heat and Ignitability Properties of Polystyrene and Associated Materials					
Cone @ 50 kW/m^2	TTI	Pk HRR	FPI	Ht Comb	THR
Phosphonium treated synthetic micas	s	kW/m^2	(m^{2}skW^{-1})	MJ/kg	MJ/m^2
Polystyrene	65	1294	0.05	30.6	30.6
PS + 1 (styrene/maleic anhydride)	64	1280	0.05	30.8	30.8
PS + 2 (PS + 1 + 8.3 wt% Mica P)	65	557	0.12	26.5	26.5
PS + 3 (8.3 wt% Mica P)	64	586	0.11	26.6	26.6
Mica P: Triphenyl, n-hexadecyl phosphonium treated sodium fluorinated synthetic mica					
System 1: Addition of styrene/maleic anhydride					
Improvement % 1	-2	1	0	-1	-1
Improvement % 2	0	57	132	13	13
Improvement % 3	-2	55	117	13	13

Notes: TTI: time to ignition in cone calorimeter test; Pk HRR: peak heat release rate in cone calorimeter test; THR: total heat released during test in cone calorimeter test; Ht Comb: effective heat of combustion in cone calorimeter test; FPI: fire performance index (ratio of time to ignition and peak heat release rate, in cone calorimeter test). Improvement %: percentage improvement in relevant property based on the untreated material.

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Table 8 – Effectiveness of Layered Double Hydroxides as Flame Retardants on Heat and Ignitability Properties of Polystyrene				
Cone @ 35 kW/m^2	TTI	Pk HRR	FPI	THR
-	s	kW/m^2	(m^{2}skW^{-1})	MJ/m^2
Polystyrene	88	813	0.11	138
PS + 5 wt% LDH-DBP	72	616	0.12	133
Improvement %	-18	24	8	4
PS + 5 wt%5 LDH - SMM 30 min DBP	65	517	0.13	133
Improvement %	-26	36	16	4
PS + 5 wt% LDH - SMM 60 min DBP	66	621	0.11	131
Improvement %	-25	24	-2	5
PS + 5 wt% LDH-syntal DBP	59	627	0.09	129
Improvement %	-33	23	-13	7
PS + 10 wt% LDH-DBP	74	444	0.17	127
Improvement %	-16	45	54	8
PS + 15 wt% LDH-DBP	95	402	0.24	125
Improvement %	8	51	118	9
-	-	-	-	-
DBP: 3,4-dihydroxybenzophenone				
LDH: layered double hydroxides				
SMM: surface modification				
LDH syntal: commercial material				

Notes: TTI: time to ignition in cone calorimeter test; Pk HRR: peak heat release rate in cone calorimeter test; THR: total heat released during test in cone calorimeter test; Hf Comb: effective heat of combustion in cone calorimeter test; FPI: fire performance index (ratio of time to ignition and peak heat release rate, in cone calorimeter test). Improvement %: percentage improvement in relevant property based on the untreated material.

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Table 9 – Effectiveness of Flame Retardant Systems on Heat and Ignitability Properties of Foamed Expanded Polystyrene (EPS)			
Foamed EPS	TTI	Pk HRR	FPI
35 kW/m^2	s	kW/m^2	MJ/m^2
EPS	77.7	310.5	0.25
EPS Plus Commercial FR	81	230.6	0.35
Improvement % FR	4	26	40
-			
Foamed EPS	TTI	Pk HRR	FPI
30 kW/m^2	s	kW/m^2	MJ/m^2
EPS	73	299	0.24
EPS Plus Commercial FR	77	238	0.32

Improvement % FR	5	20	33
Foamed EPS	TTI	Pk HRR	FPI
40 kW/m^2	s	kW/m^2	MJ/m^2
EPS	28	394	0.07
EPS Plus Commercial FR	40	321	0.12
Improvement % FR	43	19	75
Foamed EPS	TTI	Pk HRR	FPI
50 kW/m^2	s	kW/m^2	MJ/m^2
EPS	18	407	0.04
EPS Plus Commercial FR	24	379	0.06
Improvement % FR	33	7	43
Note: Data at 35 kW/m^2 was determined by the authors, while data at 30, 40 and 50 kW/m^2 was obtained by comparison of published data from other authors			

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~~**Code considerations related to ASTM E84** – Several code sections require insulation in the building envelop to comply with flame and smoke developed indexes that are established by E 84 Steiner tunnel testing. Considerations related to these testing requirements are as follows:~~

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