GBH International
2 Friars Lane
Mill Valley, CA 94941
Tel: (415) 388-8278 – FAX: (415) 388-5546
mmh@gbhint.com

# Benefits of Flame Retardants – Marcelo M. Hirschler - January 2016

Some of the benefits of flame retardants can be seen from the following facts.

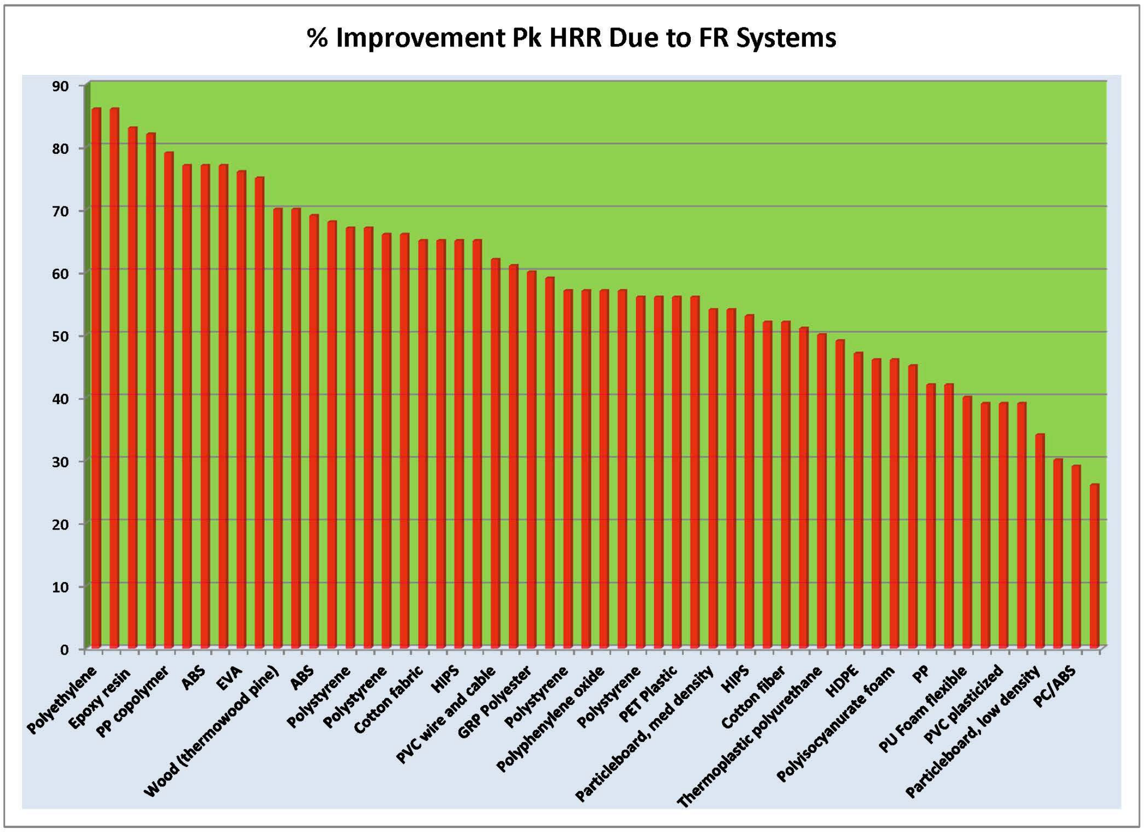
1. The use of flame retardants in combustible materials leads to a decrease in the heat released in fires.
2. The use of the correct type and amount of flame retardants improves the fire performance of the associated materials.
3. Fires with properly flame retarded products result in much fewer toxic products than fires with the same products without flame retardants.
4. Fires with properly flame retarded products result in much less destruction than fires with the same products without flame retardants.
5. Fires with properly flame retarded products result in much less flame spread to nearby products than fires with the same products without flame retardants.
6. Fires with consumer products have decreased significantly over the last 30 years or so, partially because of the increased use of flame retardants.

## 1. Flame retardants and heat release.

Flame retardants can be used to significantly decrease heat release rate of polymers, and the effectiveness of such systems can be extremely high. A set of studies [1-3] of the effects of flame retardants on the heat release of natural and synthetic combustible materials showed the effectiveness of flame retardants on heat release. The figure below [1] shows a large number of systems (a total of 56 systems) and the percentage improvement in peak heat release rate due to the addition of various flame retardant systems. The improvement can be higher than 80%.
Another study investigated the fire performance of 5 non-flame-retarded products and compared it with that of properly flame retarded alternate products [4]. The full sets of non-flame-retarded and flame retarded products were ignited in a room-corridor arrangement and the heat released by the non-flame-retarded products was 4-5 times higher than that released by the flame retarded products (1,640 kW vs. 345 kW).

The emphasis on heat release is presented because it has been demonstrated that the peak heat release rate is the key property governing the intensity of a fire [5]. Heat release rate is critical because as the heat release rate becomes greater more materials will ignite and burn and will propagate the fire. On the other hand, if heat release rate remains small, it is possible (or even likely) that the next product will not ignite and that the fire will be confined to the area (or even the object) of origin. Thus, a higher heat release rate will promote faster flame spread. On the other hand, neither increased smoke obscuration nor increased smoke toxicity will cause a fire to become bigger. It is essential to understand the concept that heat release rate if the most important fire safety property because a distinction needs to be made between: (a) the reason a fire becomes big and results in large losses (including fire fatalities, fire injuries and significant property loss) and (b) the actual "cause of death" for a fire fatality. The two are different.

GBH International
2 Friars Lane
Mill Valley, CA 94941
Tel: (415) 388-8278 – FAX: (415) 388-5546
mmh@gbhint.com




## 2. Flame retardants and improved fire performance.

As discussed above, the most important means to describe fire performance is based on heat release. However, it is also clear that fire growth and flame spread are predicted by heat release rate. Two extensive research programs dealing with fire growth on combustible wall lining materials tested several wall lining materials in bench-scale and large-scale fire tests and both showed that fire growth (for example measured as flame spread) was much lower for materials that generated lower heat release [6, 7]. This led to the development of models predicting whether full room involvement (also known as flashover) results as a function of the heat released by the materials. Therefore, since flame retardants decrease heat release they also improve fire performance. including fire fatalities, fire injuries and significant property loss) and (b) the actual "cause of death" for a fire fatality. The two are different.

It is essential to note, a flame retardant system must be tailored to the substrate (or polymer) that it is used with. It is an essential requirement for an adequate flame retarded polymeric system to exhibit adequate fire performance that the flame retardant additive system appropriately improves the heat release rate of the substrate. This often requires extensive research to ensure that the right system is used for each substrate. Typically, flame retardants that are effective with a specific substrate are ineffective with alternate substrates (even if they are similar in chemical composition).

### 3. Flame retardants and toxic product release.

In order to understand this it is important to review the concept of flashover, which is that stage in the development of a contained fire in which all exposed surfaces reach ignition temperature more or less simultaneously and fire spreads rapidly throughout the space. In practice fire statistics classify any fire that goes beyond the room of origin as a "flashover fire" [8], because typically additional details are not available and because a fire that has gone beyond the room of origin has clearly been a very large fire. Thus, any discussion of "flashover fires" includes all fires that are either known to have gone to flashover or known to have gone beyond the room of origin, without distinction. In the US the vast majority of fire fatalities occur away from the room of fire origin (i.e. have been classified as flashover fires because they extended beyond the room of origin [8]). At the moment when fires go to flashover the concentration of combustion products (i.e. toxic gases) accelerates significantly, so that there is both a quantitative and a qualitative difference in the toxicity of the atmosphere as soon as the fire becomes a flashover fire. That is one of the key reasons why fire atmospheres are much more toxic after flashover [8].

On the other hand, the "cause of death" (in the US) is usually listed as "the effects of smoke inhalation". This means that the listed "cause of death" is, more often than not, the direct result of insult by smoke and toxic gases, while the actual cause of death is that the fire became large (typically a flashover fire) because the heat release rate was large. It is important to note that it is now consensus in the fire safety community that the smoke toxicity of virtually all common products, whether they contain flame retardants or not and irrespective of the combustible substrate involved, have very similar smoke toxic potencies [9, 10, 11].

In the study comparing flame retarded and non-flame retarded products discussed above [4] the results showed that none of the test specimens produced smoke of extreme toxicity. The smoke from both sets of products was similar in potency and comparable to the potency of the smoke produced by materials commonly found in buildings. However, in terms of the total quantities of toxic gases produced in the room fire tests, expressed in 'CO equivalents,' the quantities produced by the flame retarded products were one third of the amounts of toxic products produced by the non-flame-retarded products. With regard to the overall fire hazard the study indicated that the impact of flame retardant materials on the survivability of the building occupants was also assessed by comparing the time to untenability in the burn room, which is applicable to the occupants of the burn room. The results showed that the average available escape time was more than 15-fold greater for the flame retarded products than for the non-flame-retarded products.

### 4. Flame retardants and total amounts burnt.

Multiple studies have shown that when properly flame retarded products are involved in a fire, the fire is much less likely to spread to other products and much more likely to remain small. This means that the amount of products burnt will be much smaller. In the study discussed above [4] it was found that three of the five flame retarded products assessed would not ignite (and thus would not burn) when exposed to the same fire source that caused any one of the non-flame-retarded products to burn and be destroyed completely. Thus, the only way that the five flame retarded products could be made to burn is by using an auxiliary burner to avoid finding no flame propagation at all. The study found that the amount of material consumed in the fire tests for the flame retarded products (in spite of the additional burner) was less than half the amount lost in the tests for the non-flame-retarded products.

GBH International
2 Friars Lane
Mill Valley, CA 94941
Tel: (415) 388-8278 – FAX: (415) 388-5546
mmh@gbhint.com

Interestingly, when products produce significantly lower heat release (and thus much less material destroyed or burnt) there is also usually lower smoke released, leading to better visibility for victims trying to escape or first responders trying to initiate rescue from a fire. In the study above, the amount of smoke generated from both tests was not significantly different but in 90% of studies of room-corner fire tests (where flame propagation, heat release and smoke release are assessed) the products with lower heat release also had lower smoke release [12].

5. **Lower flame spread for properly flame retarded products.**

This has been explained earlier. The lower heat release resulting from properly flame retarding products has as a consequence, lower flame spread [6, 7]. For example, building interior finishes, principally wall and ceiling coverings, can have a major impact on both fire growth and ultimate fire size [13]. Wall and ceiling coverings may act like a "fuse," spreading flames away from fire origin to involve other objects, causing the fire to grow to large size. Interior finishes may also provide a large, unbroken surface over which flame spreads. As the wall or ceiling covering exhibits higher heat release rate, the flame spreads faster to involve greater surface area and the fire size increases. If the interior finish exhibits poor fire performance, the flames from the interior finish may release sufficient energy to cause the formation of a hot gas layer. If the wall or ceiling covering is well flame retarded the fire will stop spreading and cease being a problem. NFPA fire loss statistics show that interior wall coverings are responsible for being the item first ignited in homes in many fires and for an even larger proportion of civilian fire fatalities. The most recent statistics on home structure fires were published in 2015 [14].

6. **Fire statistics show that fewer fires are starting at consumer products now.**

Fires associated with a variety of consumer products have decreased significantly over the last 30 years or so, as shown in the following list (based on NFPA statistical data in various reports). One of the reasons for this decrease (but, of course not the only one) is the use of flame retardants improving the fire performance of consumer products.

| **Fires starting in various consumer products** | | | | |
|---|---|---|---|---|
| | **1980** | **2010-2011** | **Decrease (%)** | **Reference** |
| Heating Equipment | 230,300 | 53,600 | 77 | 15 |
| Electrical | 75,000 | 47,700 | 36 | 16 |
| Washers & dryers | 25,000 | 16,800 | 33 | 17 |
| Refrigerators, freezers, ice makers | 3,040 | 1,680 | 45 | 18 |
| Electronic equipment rooms | 1,600 | 190 | 88 | 19 |
| Office equipment (non-home) | 1,720 | 600 | 65 | 20 |
| Office equipment (home) * | 540 | 640 | -19 | 20 |
| * Note that the use of office equipment (computers) in homes has increased from less than 2% in 1980 to more than 75% in 2010, meaning that the proportion of fires to computers in homes has decreased | | | | |

GBH International
2 Friars Lane
Mill Valley, CA 94941
Tel: (415) 388-8278 – FAX: (415) 388-5546
mmh@gbhint.com

**References:**

1. "Effect of flame retardants on polymer heat release rate", M.M. Hirschler, in Fire and Materials Conf., San Francisco, CA, Feb. 2-4, 2015, pp. 484-498, Interscience Communications, London, UK.
2. "Flame Retardants and Heat Release: Review of Traditional Studies on Products and on Groups of Polymers", M.M. Hirschler, Fire and Materials (Article published online, Fire and Materials, 03/11/2014, DOI: 10.1002/fam.2243), 2014.
3. "Flame Retardants and Heat Release: Review of Data on Individual Polymers", M.M. Hirschler, Fire and Materials (Article published online, Fire and Materials, 03/11/2014, DOI: 10.1002/fam.2242), 2014.
4. "Fire Hazard Comparison of Fire-Retarded and Non-Fire-Retarded Products," NBS Special Publ. 749, V. Babrauskas, R.H. Harris, R.G. Gann, B.C. Levin, B.T. Lee, R.D. Peacock, M. Paabo, W. Twilley, M.F. Yoklavich and H.M. Clark, National Bureau of Standards, Gaithersburg, MD, 1988.
5. "Heat Release Rate: The Single Most Important Variable in Fire Hazard", V. Babrauskas and R.D. Peacock, Fire Safety Journal, 18, 255-272 (1992).
6. "Proceedings of Eurefic [European Reaction to Fire Classification] Seminar", D. Bluhme, P.J. Hovde, M. Kokkala, B. Sundstrom and U. Wickstrom (Programme Manager), 11-12 Sept. 1991, Copenhagen, Denmark, Interscience Communications, London, UK.
7. "Models for calculating flame spread on wall lining materials and the resulting heat release rate in a room", B. Karlsson, Fire Safety Journal, 23, 365-386 (1994).
8. "Fire Conditions for Smoke Toxicity Measurement", R.G. Gann, V. Babrauskas, R.D. Peacock and J.R. Hall, Jr., Fire and Materials, 18, 193-99 (1994).
9. "The Role of Bench-Scale Data in Assessing Real-Scale Fire Toxicity", NIST Tech. Note # 1284, V. Babrauskas, R.H. Harris, E. Braun, B.C. Levin, M. Paabo and R.G. Gann, National Inst. Standards Technology, Gaithersburg, MD, 1991.
10. "Fire Retardance, Smoke Toxicity and Fire Hazard", M.M. Hirschler, in Proc. Flame Retardants '94, British Plastics Federation Editor, Interscience Communications, London, UK, Jan. 26-27, 1994, pp. 225-37 (1994).
11. "Fire Safety, Smoke Toxicity and Acidity", M.M. Hirschler, Flame Retardants 2006, February 14-15, 2006, London, pp. 47-58, Interscience Communications, London, UK, 2006.
12. "Heat Release Testing of Consumer Products", M.M. Hirschler, Journal ASTM International (JAI), 6(5) DOI: 10.1520/JAI102258, May 2009, Amer. Soc. Testing & Materials, West Conshohocken, PA.
13. "Interior Finish", M.M. Hirschler, Chapter 18.2 in "NFPA Fire Protection Handbook, 20th Edn", Editor-in-chief: Arthur Cote, pp. 18/23-18/42, NFPA, Quincy, MA, 2008.
14. "Home Structure Fires", M. Ahrens, NFPA, Quincy, MA, September 2015.
15. "Home Fires Involving Heating Equipment", J.R. Hall, Quincy, MA, October 2013.
16. "Electrical Fires", J.R. Hall, Quincy, MA, April 2013.
17. "Home Fires Involving Clothes Dryers and Washing Machines", J.R. Hall, Quincy, MA, September 2012.
18. "Home Structure Fires Involving Kitchen Equipment Other Than Cooking Equipment", J.R. Hall, Quincy, MA, November 2012.
19. "Computer Rooms and Other Electronic Equipment Areas", J.R. Hall, Quincy, MA, March 2012.
20. "Home and Non-Home Fires Involving Office Equipment", J.R. Hall, Quincy, MA, September 2013.