BSEF
The International Bromine Council

Flame retardants

PREVENTING FIRES AND PROTECTING PEOPLE

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Introduction

Welcome to the new guide to flame retardants for 2021

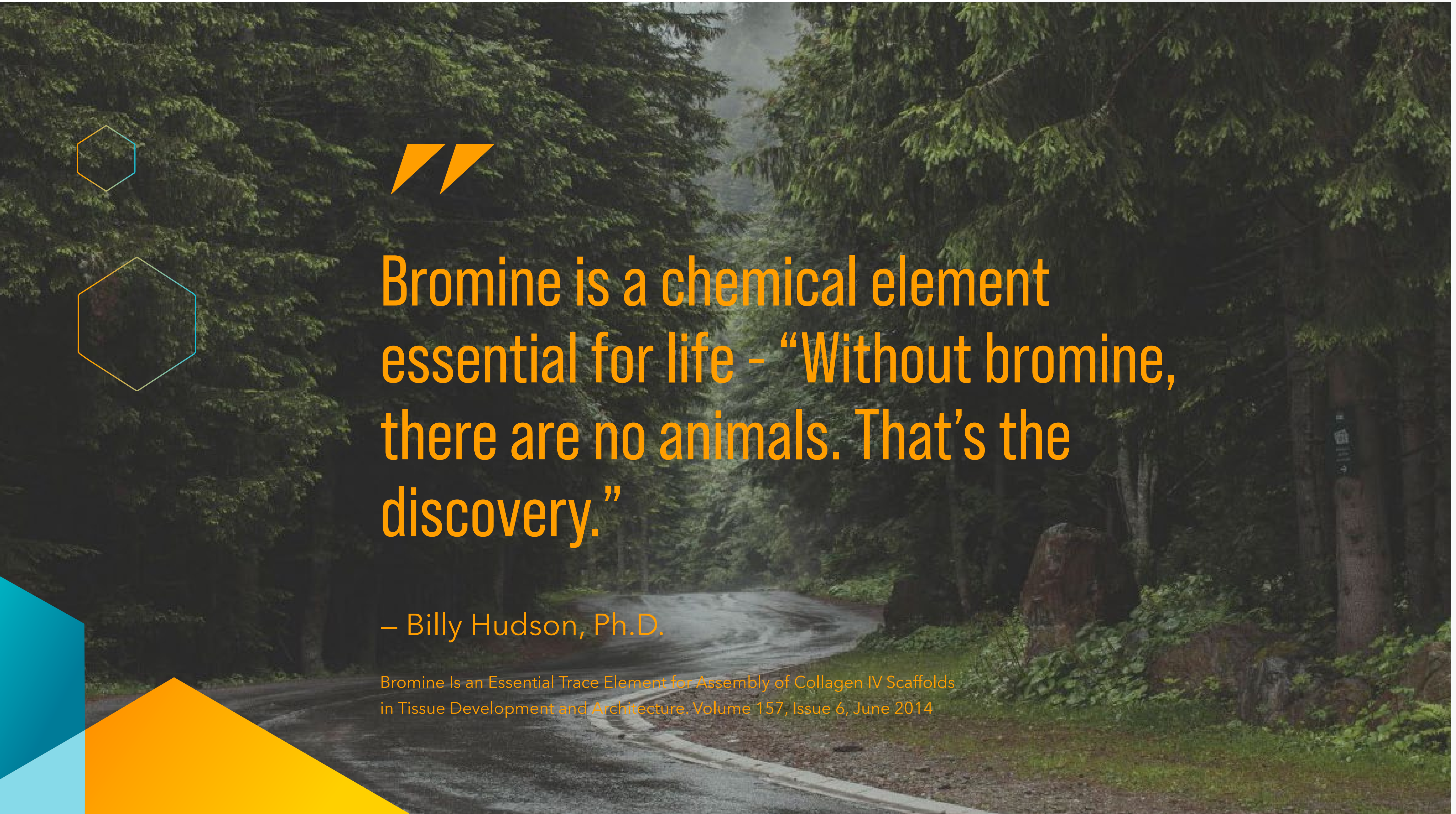
It is my pleasure to introduce this brochure to you. Let me begin by sharing some thoughts based on my personal experience. Prior to entering the world of flame retardants, I worked at a petrochemical plant heading up the Environmental, Health and Safety department. Here we had to manage a whole spectrum of what were termed "major accident hazards" - explosives, corrosives, toxics and ecotoxics, exothermic substances and last but not the least, flammables. Which brings me to the topic of fire. Can fire be "managed" ? Well yes it can - up to a certain point. It is at the early or incipient stages, before a fire gets totally out of control, where the risk is best managed. And this early stage control is the domain of flame retardants. They perform their magic at the molecular level, either to prevent ignition altogether or to retard the developing fire.

Now a brief history - the use of flame retardants can be traced back to the ancient Romans and Greeks, but it was not until the advent of plastics and synthetic textiles in the '50s and '60s that the industry really took off. More and more flammable materials and ignition sources entered our living spaces and our transportation systems; it was soon realised that fire safety standards were essential to reduce their risk. Such standards were developed for electrical and electronic appliances, furniture, thermal insulation and many other products, providing the life blood for the growth of the FR industry. And these standards in turn led to rapid advances in flame retardant and polymer chemistry, a trend that continues to the present day, giving rise to flame retardant industry, which is valued at an estimated $7 bn globally.
A final thought to conclude : in the specialty chemicals arena, there are very few substances that can lay claim to such a societal benefit as life safety. We in BSEF can therefore take pride in our industry's contributions in this field.
I hope you enjoy reading the brochure. "

> In the specialty chemicals arena, there are very few substances that can lay claim to such a societal benefit as life safety.

Kasturirangan Kannah

Chair of the Board of Directors at BSEF,
The International Bromine Council



> Bromine is a chemical element essential for life - "Without bromine, there are no animals. That's the discovery."
>
> – Billy Hudson, Ph.D.

Bromine Is an Essential Trace Element for Assembly of Collagen IV Scaffolds in Tissue Development and Architecture. Volume 157, Issue 6, June 2014

About BSEF

BSEF the International Bromine Council, was founded in 1997. Since then, we have been working to improve and increase knowledge on the uses and benefits of bromine-based technologies in a wide range of applications and industry sectors.

We strongly believe in science and innovation. Through investments in research and development BSEF members create robust bromine-based technologies meeting the needs of society.

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- We work with a variety of national, regional and international networks of downstream user associations to develop, promote and support the use of bromine in its different applications;
- We support the many benefits of bromine and bromine-based technologies and support the technological advancement of the industry;
- We actively initiate and fund scientific research programmes to examine the role of bromine and bromine-based chemicals in human health and the environment;
- We share our knowledge freely, and we do not undertake any kind of commercial or trading operations;
- We promote the long-term use of bromine as a vital and intrinsic contributor to a sustainable future for mankind;
- We promote the safe use and handling of bromine and support the Responsible Care approach of the global chemical industry.

Flame retardants

WHAT ARE THEY, WHY DO WE NEED THEM AND HOW DO THEY WORK?

fire – mankind's friend and foe

Man's ability to harness fire has arguably provided the basis for human civilisation. It brought mankind light, heat and the capacity to cook. However, natural disasters and accidents unfortunately mean it has also brought about destruction and even death. Even today, fire still demands respect and preventative actions to minimise its destructive potential.

Unexpected or uncontained fire can cause large-scale destruction, injury and loss of life. It is therefore vital that everything practical is done to minimise the risk of fire and, in the event that fire does happen, to help minimise and contain its spread as much as possible.

Fire retardancy is an essential component of modern building and product safety.

By helping to prevent fires or reducing their rate of spread, effective flame retardants can extend the time available for action and intervention. This makes flame retardants an essential layer of fire safety strategies.

Fire retardancy – a technique that dates back more than 3000 years

There is evidence - dating as far back as the Ancient Egyptian civilisation, some 3000 years ago - of mankind using treatments and coatings to reduce the flammability. They were known to have soaked the reeds and grass they used for building in seawater, impregnating them with mineral salts to provide fire retardancy qualities. The Chinese and Romans civilisations also regularly soaked wood used for construction in an alum solution to improve its resistance to fire.

Fire retardancy – still a priority today

Fire retardancy remains vitally important today – indeed it covers many aspects of our lives. We work, we travel, we carry electronic devices, and we rightly expect the setting and the equipment to be a safe as possible.
In addition, we take it for granted that we can routinely use a wide range of electronic devices within these settings. Yet without adequate flame retardancy, all of these could pose a potential fire risk. The same applies to the furniture and furnishings that surround us.

"While the needs of consumers are becoming increasingly complex, there is a growing need to ensure safety and security. Flame retardants, which prevent deadly fires, have been used in various economic activities and commodities to protect our lives and property from fire risks, contributing a great deal to ensuring safety and security."

"However, as a safe and secure society has become normal, we, including those engaged in economic activities, tend to forget about technologies and techniques required for safety and security control and the benefits they provide. The same can be said about the role of flame retardants and the safety and security they ensure."

Hiroshi Watanabe

Director General, Japan Chemical Industry Association

Therefore appropriate fire retardancy must be deployed in a greater range of settings; in the buildings where we live and work, in the transport we rely on – aeroplanes, trains, cars – and in the furniture and equipment we use within these settings.

The need for such widespread safety measures make the use of flame retardants an essential consideration in an ever-increasing number of aspects of modern life.

As advances in material sciences continue, to address the challenges of a green economy, the science of flame retardants must continue to advance in parallel.

"

By making our goods non-flammable and flame-retarding, and with the help of many sectors and scientific disciplines we will minimise the number of precious lives and property lost in fires and the terrible social impact associated with this.

Masaru Kitano

Professor at Shukutoku University in Japan, and author of "Introduction to Flame Retardancy, Protect your life and property from fire".

Fire Safety – a complex and continuously evolving science

Although we have made immense progress in our ability to reduce the risk posed by fire, we can and do continue to learn and apply the lessons from those fires that do occur.

It is important to recognise that flame retardants – invaluable as they are – are only one component in fighting the threat of fire. Reducing fire's capacity for damage and injury demands a combination of applied science and effective regulation.

Major incidents such as blazes are routinely the subject of inquests, not only to discover the cause of the fire but also to discover what could have been done to improve the safety and protection of people and property. Post-accident investigations, such as those into the crash of Swissair Flight 111 or the fire at the Harrow Court tower block in Stevenage in the UK, directly led to changes in regulation related to the fire resistance in the materials used.

However, the recommendations from such inquests are not restricted to flame retardation alone. They recognise that fire safety requires a multidisciplinary approach. For example, the inquest into the fire on a British Airtours aircraft in 1985 led to industry-wide changes in aircraft design. It proposed revisions that included not simply greater use of flame retardants but also changes to the seating layout near emergency exits, floor lighting, fire-resistant wall and ceiling panels, more fire extinguishers and clearer evacuation rules.

It will never be possible to prevent fire completely. Our aim, therefore, should be to minimise the risk of fire occurring wherever possible

It will never be possible to prevent fire completely. Our aim, therefore, should be to minimise the risk of fire occurring wherever possible and to take measures to reduce the likelihood of injury to people and damage to property when it does.

In addition, we must maximise protection for the most vulnerable and at risk – the young, the elderly and those with disabilities. This is why fire safety regulations are not universal, but they reflect the situation where they are used. Where evacuation is likely to take longer, for example where people have reduced mobility, the regulations that apply will reflect this; in design, materials used and even clothing.

The science of fire prevention will continue to evolve, as we learn from each incident and refine our approach. While we can never eliminate the threat from fire completely, we can continue to reduce the risk through all available approaches.

[1] https://www.britannica.com/event/aSwissair-flight-111
[2] https://www.independent.co.uk/news/uk/this-britain/mother-and-two-firefighters-killed-in-tower-block-blaze-484887.html

"Fire science is the scientific branch to discover knowledge on how fires behave, how they ignite, how they spread, how they emit smoke and how they can be suppressed. This scientific knowledge is then given to engineers and authorities, who can then use that knowledge to create new technologies, combine it with previous things that they know work or to create new things. And little by little, by combining knowledge and engineering we can create a safer world."

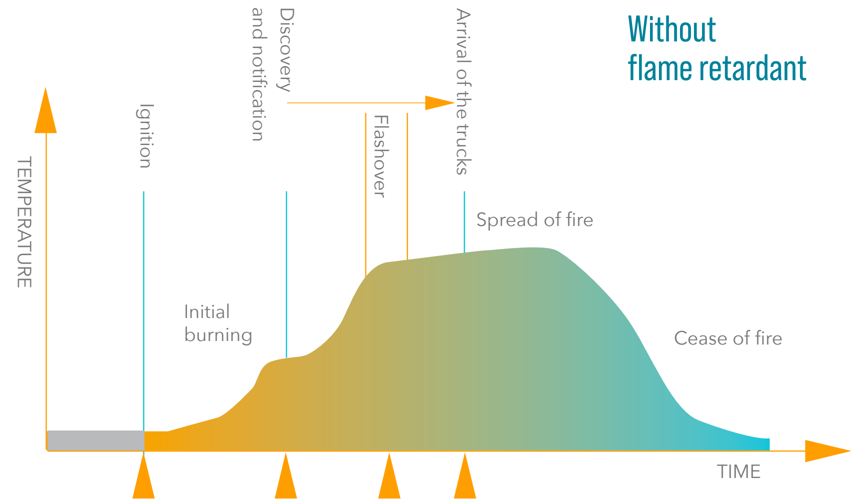
Guillermo Rein

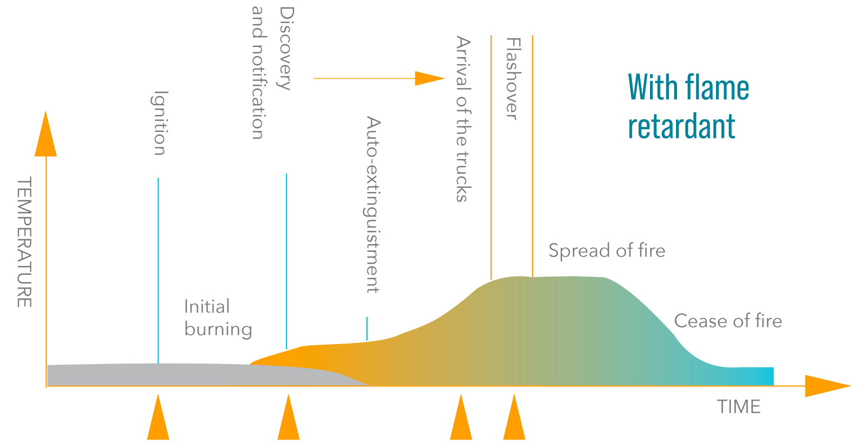
Professor of Fire Science at the Department of Mechanical Engineering of Imperial College, London.

The modern history of fire retardancy

The birth of the modern fire retardancy techniques

Although there has been a long history of fireproofing treatments, the modern scientific principles of fire retardancy were first established in the early 19th century by French chemist and physicist Joseph Louis Gay-Lussac . He defined a number of methods for improving the fire resistance of textiles, particularly cottons; indeed, some of the methods he defined are still applicable today.





Flashover:
Flashover is a phenomenon that can occur when temperatures achieve a certain critical temperature. This occurs when the flammable gases in a room reach their ignition points virtually simultaneously, meaning fire then spreads rapidly. Flame retardants lower initial burning rates and delay the onset of flashover. This increases the time available for evacuation and prevents the spread of fire and smoke before emergency services arrive.

Fire retardancy approaches

Although many of these earlier techniques still retain valid applications, the science of fire retardancy is continuously advancing. This is both desirable and inevitable, as the way that we live and work is constantly evolving.

Our home and work environments are unrecognisable from even a few years ago. There are new materials for building and construction; new types of furniture and furnishings being used within them and a new range of new devices and appliances in use. All of these advances have to be made safe from the risk of fire.

As discussed, such safety measures are not achieved solely through increased use of retarding agents; there is a wider methodological approach. Fire safety – and thus minimising the risk to people and property from those fires that do occur – is planned and built in from the outsets.

So-called 'fire engineering' is an approach that maximises protection to a building and its occupants – as well as the surrounding community in the event of a fire. This will examine a wide range of aspects such as design and layout, placement of emergency exits and proposed materials. It also ensures full compliance with national and local fire regulations.

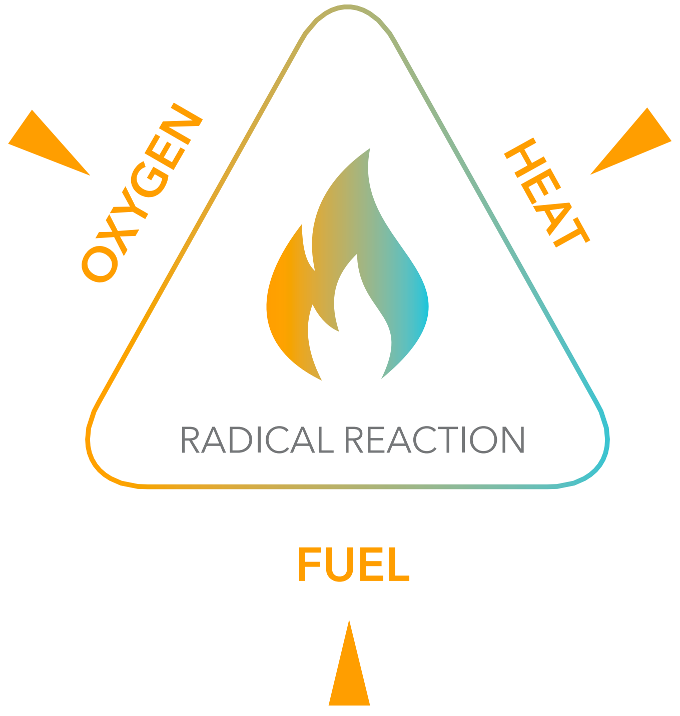
In buildings, the role of flame retardants is to supplement the efforts of fire engineers. By helping to prevent and slow the spread of flames, they maximise both the time for intervention and – where necessary – the time to escape.

Flame retardants act in one or several key ways to stop the burning process.

They act to:

- Disrupt the exothermic radical chain reactions of combustion (capture the H and OH high-energy free radicals)
- Physically insulate the fuel from the heat source (by production of a fire-resisting "char" or glassy layer on surface, thereby limiting the process of pyrolysis)
- Dilute the flammable gases and concentration of oxygen in the flame formation zone (by emitting water, nitrogen or other inert gases)

FIRE TETRAHEDRON



Flame retardants – at the core of fire safety

Responding to the needs of society

A key driver behind the science of fire retardancy is changing societal demands. Peoples' expectations of comfort, convenience, cost-effectiveness and reliability – be it in their home, their office, their car – are constantly increasing.

To address this, manufacturers are taking advantage of advances in material science. Traditional construction resources - such as wood, metal and animal hair or hides - are now being augmented or even replaced by new, synthetic materials. These new materials are increasingly based on plastics, composites, foams and fibre-based fillings.

Although such materials offer significant advantages – they are often lighter, stronger and less costly to produce – the fact that they rely on synthetics pose their own challenges for fire retardation. If not suitably treated, these materials may be more flammable than those they replace. Therefore, all materials need to meet the highest modern safety standards.

If not suitably treated, these materials may be more flammable than those they replace

In addition to this changing environment, people routinely surround themselves with modern electronic equipment, much of it portable. They also make use of textiles and materials in ways that would not have been recognised by previous generations. These applications pose their own risk of fire; electronic devices are inevitably sources of heat generation.

These changes to how we live and what we use will continue to evolve. The ongoing green revolution – particularly the drive to reduce energy consumption – is already seeing the emergence of new materials that are strong, lightweight, and fully recyclable. These in turn need to be properly treated to ensure that they are fully flame retarded.

This will effect increase in importance as enhancements to mobile networks roll out. The introduction of 5G has huge promise for increasing transmission speeds. However, the lower impedance and better dissipation demands much higher voltages and generates more heat; and will therefore require appropriate flame retardants to address these needs.

The drive for greater safety is continuous; manufacturers of flame retardants therefore will work to ensure that the demands driven by societal change are fully met.

Helping deliver on safety legislation requirements

The public rightly expect the buildings that they live and work in, and the products that they use, meet minimum safety standards. These safety standards are determined by legislation, are increasingly set out at international and European level, and will include requirements for flame retardancy. This means flame retardancy science plays a vital role in meeting the demands posed by safety legislation.

Such requirements are not static; they undergo continuous refinement as knowledge increases and improves as the science develops. Industry is constantly developing new methods and technologies to meet demands for improved flame retardant materials. Professionals in fire retardancy science proactively work to assess and address potential fire risks before they pose a danger.

In addition, formal reviews of fire-related incidents and disasters – in buildings, transport, homes or in devices - often reveal previously unforeseen risks that could be avoided, with improvements in the materials used and in the design chosen.

Industry is constantly developing new science and technologies to meet demands for improved flame retardant materials

In order to prevent future occurrences, legislators may make increased demands on manufacturers to use materials with improved flame retardancy. These may need to:

- Have a higher ignition temperature
- Burn more slowly
- Offer greater insulation against fire

Brazil has experienced several serious fire accidents in public spaces. In 2013, a fire in a nightclub in Santa Maria, Rio Grande do Sul, saw 245 casualties. The high death toll was in part due to poor compliance with fire regulations; however, it was also attributed to the use of unsuitable flammable material as soundproofing. The Brazilian Flame Retardants Association, ABICHAMA, was created to raise awareness on the importance of fire safety and help define fire safety standards.

Flame retardants – key uses and applications

While flame retardants cover an immense range of applications, there are certain core areas where their use dominates. These are electronic and electrical equipment, furniture and furnishings, building materials and transport.

Electronics and Electrical Equipment

Electronic devices have become omnipresent in our lives. Nowadays, we take our portable personal devices, flat screen televisions and monitors and wireless audio and video connectivity for granted. Yet most of these technologies would have seemed like science fiction only a generation ago.

Televisions – from wooden cabinets to flat screens

The television provides a case study for the importance and influence of flame retardants on modern design. Gone are televisions in substantial wooden cases, video and tape recorders with piano key-sized controls and telephones fixed to the wall (and used only for talking). Now in electronic devices, portability and high functionality are a given.

1960s

TELEVISION EXTERNAL CASINGS heavily treated wood which requires oils and polishes to protect the finish

UPHOLSTERED FURNITURE FILLING uncomfortable and expensive straw, feathers or cotton

INSULATION Porous stone and wood construction with hardly any insulation at all

Present

UPHOLSTERED FURNITURE FILLINGS: safer, low allergenic foams and fibres

TELEVISIONS EXTERNAL CASINGS: lightweight, affordable plastic materials that are cleaned with the wipe of a cloth

INSULATION: modern energy-efficient buildings with plastic foams and cellulosic materials with high thermal insulation power

Televisions were the first ‘modern’ electrical appliances to be found in virtually every home. Initially, these were large, bulky, and immobile, relying on traditional materials such as wood and metal in their construction.

However, as consumer demand increased exponentially (colour television sets started to become commonplace in the 1960s) so did the demand for more user-friendly design. What emerged reflected the revolutionary developments in design and technology of the late 1960s and 1970s. The key was the steady replacement of wood and metal with plastics. Initially, plastic use in TVs was restricted to ‘non-visible’ components - back panels and a few internal components. However, this in itself was a revolution; previously, plastics had been viewed as an indication that goods were cheap and low-quality. Ultimately, however, they became the main constituent.

The use of plastics offered numerous advantages; it could be injection-moulded into relatively complex, sophisticated shapes. However, before this could happen, there was important consideration - fire safety. Older televisions, which used cathode ray tubes rather than modern LCD or LED displays, consumed a great deal of energy and created a considerable amount of heat. For this reason, it was important that the plastics used in these televisions were fire-resistant.

> Although the plastic in the average LCD TV has the same potential to generate the heat as six litres of petrol, the inclusion of modern flame retardants renders them much safer

A modern LCD TV is constructed almost entirely of plastics in order to make them lighter and more resource efficiency.

Despite the amount of plastic components used they pose virtually no fire risk to consumers. Flame retardants are blended into the polymers used to make the plastic casings, meaning that they are unlikely to burn. If they do, the rate of burning will be greatly slowed, allowing longer to deal with any issues. The same applies to internal components, which are also protected by flame retardants incorporated within the Printed Circuit Boards (PCBs) and wiring. Therefore, although the plastic in the average LCD TV can be highly flammable, the inclusion of modern flame retardants renders them much safer.

Consumer demand has seen computers, tablets and mobile phones become ever smaller and more portable. These smaller sizes mean that the heat-producing elements – such as the battery and the CPU –need to be positioned closer together in a smaller, more-confined space. In the event of damage or malfunction, the use of flameretardant plastics means that there is suitable protection for users.

TELEVISION

1950s

1970s

AN LCD TV CONTAINS AN AVERAGE OF 8.4 KG OF PLASTICS, WHICH, WITHOUT THE APPLICATION OF FLAME RETARDANTS, WOULD BE EQUIVALENT TO ROUGHLY 6 LITRES OF GASOLINE IN TERMS OF POTENTIAL HEAT RELEASE

Let´s Talk Bromine

Read the full article:
lets-talk-bromine.bsef.com

Making electric & electronic equipment safe

Plastics are versatile, diverse, mouldable and lightweight, which is why this material is very popular to use in the production of electrical equipment and electronic appliances.

The high volume of plastics in this kind of equipment poses a fire risk. Most E&E devices contain 1 to 9kg of plastic materials; often used in thin sheets and relatively easy to ignite when in contact with internal and external electrical current and heat sources.

Incorporating brominated flame retardants (BFRs) into polymers components gives flame retardant properties. BFRs can either be added to polymer materials during production or can be reacted with materials such as epoxy used in the manufacture of printed circuit boards.

Consumers have the right to expect products which are efficient, reliable and safe. For that reason the Flame retardant industry has been committed to developed innovative products that meet the most stringent fire safety requirements. National governments are also attentive to the products that may not meet the fire safety requirements.

Domestic appliances - increasing convenience

Another area that has benefited from the increasingly widespread use of flame-retardant plastics is the manufacture and design of our major domestic appliances. The ability to safely introduce electronic controls into many of these devices has significantly improved their performance and convenience.

An everyday device like a washing machine has evolved from simply being a labour saving device to become the complex, intelligent appliances we see now. The introduction of electronically controlled systems mean that modern machines are not only better at cleaning, they use less water, less energy and less detergent in each cycle. Their size has decreased, and their convenience increased, as a result.

Clearly, bringing together heat and electricity in the vicinity of a printed circuit board (PCB) - in a potentially damp or humid environment – poses a potential fire hazard. Therefore flame retardants are an essential element in the manufacturing of those electronic circuit boards used in washing machines. It is these properties that ensure the safety of the complex, electronically controlled operation of these appliances.

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Consumer safety is a key priority for the home appliance industry. Promoting the use of brominated flame retardants, and working with all the actors in the value chain, can help ensure circularity and consumer safety."

Paolo Falcioni

Director General of APPLiA (Home Appliance Europe),

Fire safety at home and work

Furniture and furnishings

The furniture with which we fill our homes and offices, the carpets, curtains and wallcoverings that we use to personalise our space, all rely on completely different materials from those that previous generations used.

The majority of lethal domestic fires have been shown to start in sofas, armchairs and beds

Foams are far more practical, more cost effective and offer numerous other advantages. The fillings are light, hard-wearing and suitable for moulding into virtually any shape desired. Unlike fibres, they retain their shape – and comfort - throughout their lifecycle, without sagging or the need to be re-stuffed. Nor do these foams provoke allergic reactions.

Furnishing

From impractical to functional

However, for furniture - and bedding - that rely on these foams, the risk of fire is a major consideration. With both traditional and contemporary materials, there is a potentially combustible mix of air and flammable material.

Fortunately, flexible polyurethane foams lend themselves to treatment with modern flame retardants. They work well with additive compounds, which can be incorporated at the point of manufacture; these help increase the ignition temperature of the foam and reduce the rate at which flame spread.

1800s
Horsehair and wool filling

1950s
Wool filling

Present
Foam filling

Research

An overview and experimental analysis of furniture fire safety regulations in Europe by Eric Guillaume (Efectis France, Espace Technologique, Saint- Aubin Cedex, France) ; Rene de Feijter; Laurens van Gelderen (Efectis Nederland, Bleiswijk, The Netherlands), 3 March 2020.

An overview and experimental analysis of furniture fire safety regulations in Europe

The study analyses the fire performance of upholstered furniture across countries and demonstrates wide differences in performances. Released in March 2020 and conducted by Eric Guillaume, Rene de Feijter, Laurens van Gelderen from the fire research laboratory 'Efectis' in France and the Netherlands, the study individually tested real sofas purchased around Europe.

The study concluded that furniture fires are significant events and safety regulations should be robust for public protection. The data showed British standard BS5852 designed products, that use flame retardants, significantly outperformed products from other countries in both ignition resistance and time to peak heat release.

Without ignition, there is no fire. When there is a fire it longer to peak heat release what is importantly correlated with greater escape times for occupants.

Sleeping easy – modern bedding materials

For mattresses and bed pillows, the advantages of modern materials over traditional ones are similar; polyurethane foams offer considerable improvements, often when used in combination with natural materials.

Indeed, the advantages of polyurethane foams in beds extends beyond the home. As they are more comfortable, practical and hygienic, they also offer potential benefits in healthcare settings. For those forced to spend extended periods in bed - for example due to injury or disability, whether at home or in hospital - the advantages are easily apparent. Foam mattresses allow for light, adjustable beds that help avoid problems with pressure sores, improving quality of life for patients and make life easier for carers.

As with sofas and armchairs, the foams used in bedding are treated at the point of manufacture to ensure the required level of flame-retardant quality.

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Flame-retardant chemicals are effective. There's no doubt about it. The impact of adding flame retardant to the covering material and urethane foams adds defense in depth to the furnishing that may save lives.

Dr Matthew S. Blais

Director of Fire Technology, Southwest Research Institute

Fabrics and furnishings

Another area that has seen a revolution in materials used in recent years is in the use of soft furnishings such as carpets and curtains. Traditionally, these were based on wools, silks and cottons; they were often expensive, difficult to clean and maintain, and as were susceptible to insect damage and mould.

In addition, as we seek more energy-efficient homes and working spaces, with better insulation and more natural light, there is a growing demand for lighter, more-flexible fabric solutions. The use of these synthetic fibres has hugely increased to meet this consumer choice and demand. It is no surprise that synthetic fibres, such as nylon polyamide, polyester and olefin were quick to take hold in this market.

The most common approach for textiles is to combine synthetic and natural fibres; while polyester and cotton blends are the most commonly used in home furnishings. However, virtually all fabrics – natural, synthetic or blended– will burn if not treated. In addition, curtains and other wall hangings present a highly specific fire risk. The fact that they hang vertically means that fire can travel much more quickly upwards though the materials. Therefore, flame retardation remains a vital consideration in their manufacture.

The key is to introduce flameretardants – most commonly bromine-based - at each stage of manufacture. These can be incorporated into the material at the time of manufacturing, introduced as an additive during the colouring or finishing process or used to treat the finished product.

Research

Blais, Matthew S., Karen Carpenter, and Kyle Fernandez. "Comparative Room Burn Study of Furnished Rooms from the United Kingdom, France and the United States." Fire Technology (2019).

Comparative Room Burn Study of Furnished Rooms from the United Kingdom, France and the United States

Researchers from Southwest Research Institute, an independent, non-profit research organisation, set out to explore questions frequently encountered in discussions about fire safety standards, fire performance and the efficacy of flame retardants. The study was conducted to evaluate differences in fire performance of identically configured rooms, based on the furniture fire safety standards of three countries: France, United Kingdom and U.S.

Differences among country-specific fire codes in real-world scenarios can dramatically affect overall fire conditions, including ignition development, smoke generation, escape time, and time available for emergency personnel response.

Country fire codes for upholstered furniture and home furnishings affect performance in fires.

- The time to flashover (the time for a room to be completely engulfed in fire) of furnishings from the U.K. was delayed more than 13-17 minutes in comparison to countries with less protective standards.
- Likewise, escape time significantly increased in the U.K. room burns, adding 13-15 minutes of escape time.

Smoke is not more acutely toxic from furniture containing fire retardants.

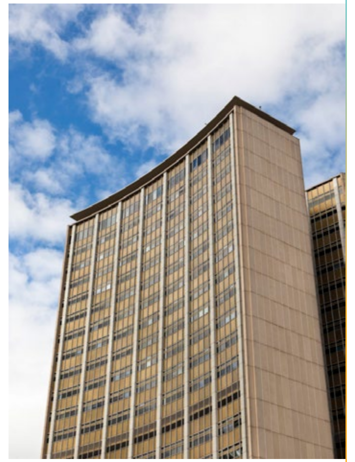
- The chemical composition of the smoke generated in the room featuring the highest level fire retardant standards (i.e., U.K.) was less acutely toxic.

Comparison of the heat release data shows the UK room configuration – the country with the most stringent fire ignition standards – are significantly less flammable than either the French or US room configurations. In all cases, furniture represented the largest room fuel load, and its fire performance heavily influenced the testing outcomes.

Building & construction

Advances in techniques and technologies – along with increasing environmental awareness and the need to address climate change – have radically changed modern approaches to building. Modern buildings routinely seek to allow more natural light and better insulation, in order to reduce their day-to-day running costs and their environmental footprint.

1960s



present

Structural elements

In the pursuit of greener buildings, wood appears an ideal construction material; it is light, easy to work with and highly versatile. It is also a renewable resource and offers excellent insulation properties – all of which are valuable properties for a lower energy economy.

Fortunately, treatment with modern flame retardants makes the safety of wood as a building material a reality, ensuring it is compliant with stringent modern fire safety regulations. This has seen a resurgence of timber use in house building, for construction, panelling and flooring.

A whole range of factors, including socio-economic developments, technological innovation, new style and design requirements and a growing emphasis on environmental concerns, have contributed to an ongoing evolution into the way our buildings are constructed.

Protecting structural integrity

Another structural role for flame-retardant plastics is in protecting steelwork. In the event of intense fires, structural steel can lose its integrity and even collapse if it surpasses a critical temperature.
To prevent this, the steel can be coated with a special plastic coating which, when exposed to flame, expands to become a non-flammable foam. This helps insulate the metal and reduce the risk of collapse of steel-framed buildings.

Insulation

The environmental agenda is influencing the way we build as it is the desire to make houses and offices more efficient. In order to reduce energy consumption, a key step is to reduce heat loss from the building. The advent of new materials is what is making this revolution possible. The current state-of-the-art insulating materials include expanded and extruded polystyrene foams, rigid polyurethane foams, glass or rock wool and natural and synthetic cellulose fibres.
Insulation materials find other applications in modern buildings, such as for soundproofing. As we look to increase housing density and to encourage urban living, such measures are essential, to help reduce the noise from neighbours and local businesses. Expanded and extruded polystyrene foam board– usually in the form of large sheets - can be inserted into internal walls and in basements, providing insulation. These boards are routinely treated with flame retardants before final installation.

Flame retardant materials are also essential for other roles in buildings. For example, modern houses have a far higher concentration of electrical and communication cables running through the walls. Frequently, these are bunched together and often running vertically – a known vector for fire transmission. Therefore, in modern buildings, all cables are routinely treated with plastic insulation coated with flame retardants. This helps minimise the risk of any unwanted spark or flame using the cables as a conduit to spread fire. The surrounding insulating materials should further reduce any risk.

Innovation

To read more visit:
www.bsef.com/fire-safety

A new generation of brominated flame retardants: Butadiene Styrene Co-polymer.

An innovative brominated polymeric flame retardant has been developed as an alternative to Hexabromocyclododecane (HBCD) to provide effective flame retardant performance in polystyrene foams such as Expanded Polystyrene (EPS) and Extruded Polystyrene (XPS). These foams, commonly used in building and construction, ensure that homes, offices and public buildings are energy efficient and comfortable, whilst meeting fire safety requirements.

High molecular weight brominated polymer: the efficient, non-hazardous solution. This flame retardant exhibits a superior environmental profile to that of HBCD – being stable, with a high molecular weight. It is also classified as a non-hazardous polymer and as a Polymer of Low Concern(PLC) with officially recognised environment, health & safety characteristics.

Polymeric flame retardants, generally speaking, are inherently sustainable substances. Their high molecular weight makes them unlikely to penetrate through the cell membranes of living tissues. They are therefore not likely to be bioavailable and to bioaccumulate in the food chain.

> Polymeric FRs such as butadiene styrene brominated copolymer demonstrate that the chemical industry is able to continuously innovate in response to societal concerns, whilst at the same time ensuring functional flame retardancy of polymers. This is important, as it enables flame-retarded materials to continue to perform a vital and valuable role as part of fire safety strategies for protecting lives and property

Research

Comparative Room Burn Study of Furnished Rooms from the United Kingdom, France and the United States
Matthew S. Blais, Karen Carpenter & Kyle Fernandez
Fire Technology volume 56, pages489-514(2020)

Transport

Our world seems to have shrunk dramatically in the last few years. The public has embraced the opportunities offered by cheap travel. The tremendous expansion of low-cost airlines has been seen in every corner of the globe. Meanwhile, the cost of trains and car hire have dropped to compete.

A driving force behind this rapid expansion in travel has been the growth in developing and using new, strong materials, such as carbon composites, plastics and metal alloys. These lightweight material do not compromise on strength and safety.

At the same time, many of these new materials - particularly plastics – are simpler and cheaper to form and mould. This has the overall impact of lowering the building costs of vehicles – be they aeroplanes, trains or cars. It also fits well with the growing 'green agenda' of lower fuel and energy consumption.

However, with the deployment of new materials comes the challenge of ensuring their safety – including 'fire safety'.

Plastics- the key to more climate-friendly air travel

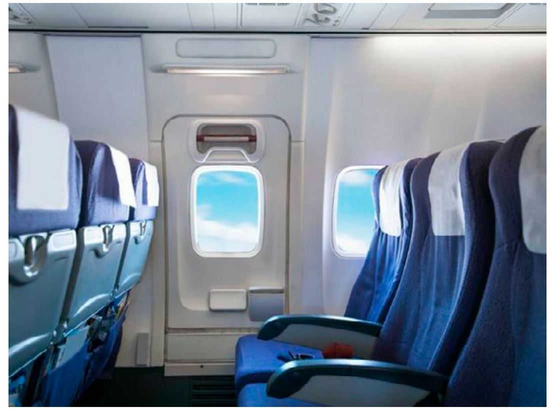
In all modern aircraft, plastics are used for a vast range of internal parts, including sidewalls, bulkheads and overhead luggage bins. There are also synthetics used in seat padding and for carpets. Their use helps dramatically reduce the overall weight of the aircraft and thus improves its fuel economy.

In an aircraft, any fire poses a huge threat to safety; clearly these new materials must be safe and fireproof. Fortunately, the use of modern flame retardants means that regulators around the world are happy to certify these novel materials as ignition resistant and safe for use in this most demanding of environments.

Plastics and synthetics are also no longer restricted to internal use. They are replacing traditional metals such as aluminium and titanium. One of the latest Airbus models, the A350XWB, uses carbon-fibre reinforced plastic extensively in its wing structures and fuselage; the Boeing 787 is 50% composites (but 80% volume).

In addition to their use in structural materials, plastics play other important roles. For example, an Airbus A380 requires an immense 500km of electrical cabling, required to control every aspect of the aircraft. All of this must be carefully insulated – indeed, a number of aircraft accidents have been attributed to faulty insulation.

Aircraft manufacturers are increasingly able to use plastics, polymers and composites in aircraft fittings, equipment and structures because these materials can be made ignition resistant.



2008 Airbus a380 20% composite materials

present A350 and b787 50% composite materials

High-speed trains – making overland journeys greener

The desire for faster, non-polluting trains have led manufacturers to take advantage of similarly strong yet lightweight plastics throughout the carriages. Indeed, as concerns over global warming continue to increase, more journeys will shift from aircraft to electric-powered trains. At the same time, there will be pressure to use lightweight materials – such as plastics - that can be easily and extensively recycled.
However, the threat posed by fire on a train is as real as on an aeroplane. The Channel Tunnel fire of 2008 – which fortunately took place on a freight train and did not lead to any deaths - caused extensive damage and led to a number of injuries. Fortunately, once again, modern flame retardants can be included in the new materials used to build these trains.

Cheaper, lighter and safer cars

For many people, personal transport will always mean a car. Here, plastics were once viewed as the 'cheap' option - wood and leather were the mark of quality. Nowadays, however, even the most upmarket cars now sport by feature high-quality synthetic materials in their structure, external panels and internal components. Meanwhile, ultrahigh-performance sports cars look to plastics and composites to save weight and maximise their aerodynamic qualities.

On a more day-to-day level, plastics and composites are increasingly important in mainstream cars. These are often used in out-of-sight locations, such as close to the engine or the rear of the dashboard, areas subject to high levels of heat from the engine or from onboard electronics. Nowadays, the average car contains 105 kg of plastics (9.3 percent of materials used), a level that will only increase in future. These applications are made feasible due to the presence of flame retardants within these plastics.

In future, plastics used in cars will need to adapt further, as new demands emerge. Cars are no longer exclusively powered by internal combustion engines alone – there are now electric vehicles – often relying on lithium ion batteries - and, in future, those powered by hydrogen fuel cells.

Practical aspects of using flame retardants

While the benefits of using flame retardants appear self-evident, it is important to ensure that the retardants themselves are safe.

There are two main aspects to consider:
1. Are the materials the correct ones for the situation and conditions of use?
2. Are the flame-retardant materials themselves safe?

Flame retardants consist primarily of halogens (brominated or chlorinated), phosphorus and inorganic types. While their applications vary depending on the types of plastics, parts, finished products and desired functions, they can be broadly categorised as shown in Figure X, based on their composition and usage.

Types of Flame Retardants

Classification by composition

Inorganic flame retardants	Organic flame retardants
Metal hydroxide-based	Halogen-based
Antimony-based	Phosphorus-based
Other (red phosphorus-based, etc.)	Other (composite, etc.)

Classification by usage

Additive flame retardants	Reactive flame retardants
Organic	Vinyl group-containing
Inorganic	Epoxy group-containing
	Hydroxyl group-containing
	Carboxylic acid-containing
	Other

There are two main approaches to flame retarding. The first is to use flame retardants. These are incorporated into plastics and rubber products during manufacturing, or are applied as a treatment to the surface of fibres and paper. These do not render materials totally non-combustible; rather, they will burn (ignite) for a short time when heated by fire, but the flame will not spread. The material extinguishes when separated from the flame source (self-extinguishing).

The second approach uses flame retardant promoters. This relies on chemical substances that are not flame retardant in their own right, but can enhance the effectiveness of other flame retardants such as halogen compounds.

Ensuring the materials used to manufacture flame retardants are safe

While the importance of flame retardants in improving product safety is clear, it is equally important that the materials themselves are safe and non-toxic.
The term ‘flame retardant’ is a description of the function of a chemical, rather than a substance itself. In reality, there are a wide range of substances used – more than 200 - to provide this function, sometimes alone on their own, but often in combination. However, there are only a small number of substances that dominate use; bromine, phosphorous, nitrogen, and chlorine along with a several mineral-based substances.

Using the correct flame retardants

The decision on which materials are the correct ones for each situation is governed by the fire safety standards. Fire safety standards have seen flame retardation become an integral part of a huge range of products. These standards are constantly under review and subject to continuous improvement, as regulators learn from experience.

The application of these regulations has proved highly effective. For example, the introduction of a European fire safety standard for audio, video and similar electronic apparatus - standard EN 60065 – stipulates that these devices now have to be designed in such a way that avoids the risk of spontaneous ignition and minimises the spread of fire wherever possible. The use of flame retardants has allowed manufacturers to replace older, potentially more flammable materials with lightweight and inexpensive plastics with improved fire resistance. Given the increasing numbers of electronic devices in all settings, this represents a considerable contribution to safety in the home, office and transport. Similar advances have been seen in making foam-filled furniture and textiles.

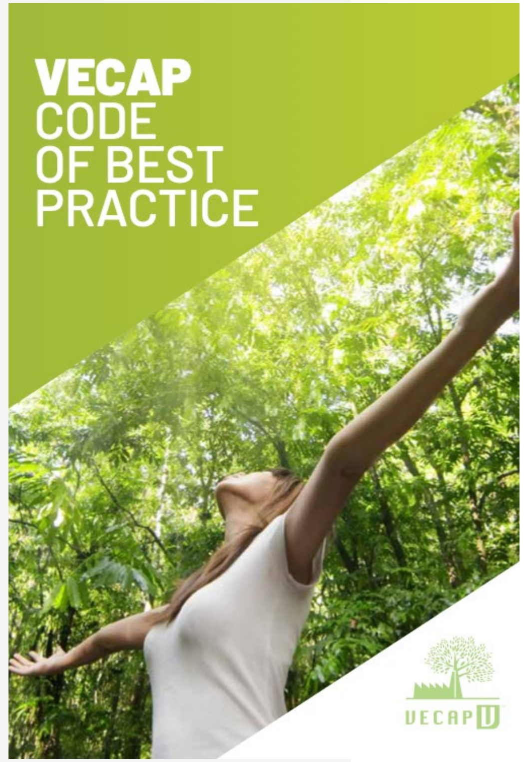
Many manufacturers pursue standards that are above and beyond those required for compliance with existing fire safety standards and deploy them in areas where their use is not yet prescribed. In addition, innovation to improve the effectiveness – and the safety – of flame retardants continues.

The Voluntary Emission Control Action Program (VECAP)

The Voluntary Emission Control Action Program (VECAP) is a product stewardship scheme for the management of chemicals throughout the value chain, which goes beyond regulatory and legislative requirements. It was launched in 2004 by the International Bromine Council (BSEF) and the UK Textile Finishers Association to reduce emissions of the brominated flame retardant Deca-BDE. In 2015, it was expanded to include all powder brominated flame retardants (BFRs) produced by VECAP member companies.

VECAP’s original concept – as a tool to control emissions during handling and use of BFRs – has evolved into a comprehensive system of chemicals management, which can be applied to a much wider range of processes and raw materials.

Through VECAP, the industry reiterates its voluntary commitment to take responsibility for the environmentally sound management of chemicals within the context of a European Framework for Corporate Social Responsibility (CSR). The programme adds to the industry’s call for a solid CSR strategy as per the latest European public consultation on the Commission’s work in the area of CSR. The brominated flame retardants industry seeks to reduce the environmental footprint of its value chain and ensures resources are used as efficiently and sustainably as possible.



To read more visit:
bsef.com/sustainability/vecap

The science behind flame retardation

In order to understand how flame retardants work, it is helpful to understand how materials catch fire and burn. For solid materials such as modern plastic polymers to catch fire, it is rarely enough for them to simply be exposed to a naked flame; they are generally quite stable.

First, the material needs to be broken down by the heat of the flame; this produces (potentially) flammable gases. When these are mixed with oxygen, they can start a series of exothermic radical chain reactions that release further flammable gases. Where this becomes self-sustaining, then there is fire. However, without this process and the absence of these conditions, there will be no fire; the material will smoulder or even self-extinguish.

The role of flame retardants in preventing fires

Interrupting the process and reducing emission of flammable gases is an effective way of preventing fire taking hold; this is the role of flame retardants. This can happen through several mechanisms:

- Radical quenching: this involves capturing the high-energy free radicals in the gases, slowing down the process and help prevent it becoming a self-sustaining chain reaction.
- Thermal shielding: this sees the creation of a glassy, fire-resistant layer on the outside of the material, preventing the fuel from reaching the reaction.
- Gas phase dilution: by diluting the level of the components that feed the fire by releasing inert gases or water.
- Endothermic decomposition: this uses materials that absorb energy as their temperature rises, thus cooling the area and reducing the intensity of any fire.

Types of flame retardant

Bromine

Bromine is a member of the halogen group of elements. It is found widely in nature, both as a salt and in organo-bromine compounds such as bromomethane, a gas emitted by marine organisms. Although rarer than other halogens such as chlorine and fluorine, bromine is abundant in salt lakes and brine wells; Israel (particularly the Dead Sea) and the US are the largest producers.

Bromine is widely used as the basis for organic flame retardants in plastics used in electrical and electronic equipment, including large and small domestic appliances such as refrigerators and washing machines, as well as in televisions and computers. It is also deployed in plastics used for transport applications - cars, trains and aeroplanes - and can be applied to the foams used in furniture and other soft fittings. Due to its unique interaction with the combustion process, bromine is an extremely efficient flame-retardant technology. This means that a relatively small amount is required to achieve the required flame resistance.

To read more visit:
bsef.org

> Bromine Found to be Essential to Human Life. Bromine – an element with atomic number 35 and the chemical symbol Br – is the 28th chemical element essential for tissue development in humans and all other animals, says a team of researchers led by Prof Billy Hudson of Vanderbilt University School of Medicine.

Research

Billy G. Hudson et al. 2014. Bromine Is an Essential Trace Element for Assembly of Collagen IV Scaffolds in Tissue Development and Architecture. Cell, vol. 157, no. 6, pp. 1380–1392; doi: 10.1016/j.cell.2014.05.009

Chlorine

Like bromine, chlorine is also a member of the halogen group of elements. It is widely found in nature, most commonly as sodium chloride – better known as table salt. Sodium chloride is mined underground or extracted from seawater; almost 2 percent of the mass of sea water is chlorine.
Although more commonly thought of as a disinfectant, chlorine has a range of important applications in flame retardation. Chlorinated paraffins and chlorinated phosphates are used as fire retardants in leathers, paints and coatings and rubbers. It is also used in textiles and foam fillings for furniture, where the polymer polyvinylchloride (PVC), which contains chlorine atoms, also shows some intrinsic fire-resistant properties.

Nitrogen

Nitrogen is one of the most common elements on Earth, making up almost 80 percent of the atmosphere. It is an essential nutrient for plants; indeed, nitrogen is found in every living organism. As a flame retardant, it has a limited number of applications – in nylon polyamides, certain hard plastics, polyurethane foams and coatings for textiles and wall coverings.
In addition, because nitrogen is inert, some flame retardants rely on emitting nitrogen to dilute the level of flammable gases, helping to dampen any fire present.

Phosphorous

Phosphorus is an element commonly found in the earth's crust – usually as a phosphate. It is an essential element for life and a component of DNA. Phosphorus for commercial use is usually mined, with large deposits in China, Morocco and Russia.

In flame retardant applications, it is used to produce liquid and solid organic or inorganic flame retardants. These are used extensively to make fire-resistant polyurethane foams for soft furnishings such as chairs and mattresses as well as thermal insulation. Phosphorus-based agents are also used in several electrical applications; flexible PVC commonly used in insulation for electric cables, electronics and high-temperature polymers (plastics) used for manufacturing switches and connectors.

Other inorganic and mineral materials

As well as these widely used materials, there is a range of other inorganic and mineral compounds used either directly as flame retardants, or in combination with bromine, phosphorus or nitrogen as elements of flame-retardant systems.

Common examples include melamine compounds (based on nitrogen), graphite (a form of carbon, similar form to the one in pencils), silica (as in glass and sand) and inorganic phosphates (ammonium phosphate and polyphosphate). Common mineral compounds include certain phosphates, metal oxides, hydroxides, and other metal products (aluminium, zinc, magnesium, molybdenum, boron, antimony).

Some inorganic and mineral compounds are used as components in flame retardant systems, in combination with other substances. This is common for achieving fire safety in plastics, foams, textiles (both natural and man-made), wood and timber products.

Gas Phase – combustion quenching

In the gas phase, halogenated flame retardants work by substituting the high-energy radicals with low-energy counterparts– the so-called 'quenching' effect. This will work to slow down the reaction and prevent it from becoming an established fire. Although found in many halogens, the ability of bromine to provide this quenching effect is particularly pronounced, as is released active bromine atoms into the gas phase before the material reaches its ignition temperature. This is why, of the different halogens, bromine-based fire retardants are the most common. They offer high effectiveness for common plastics in a range of applications and can be incorporated into the raw material for the polymer without any major impact on its properties.

Thermal shielding – solid phase

When heated, phosphorus-containing flame retardants release an acid, which causes the material to form a glassy layer – a so-called 'char'. This creates a barrier that prevents potential fuel from reaching the flame and the heat from reaching the material. There are a wide range of phosphorus-based flame-retardants available. Phosphorus-based compounds can be chemically bound to the plastic molecules during the polymerisation process.

Gas Phase – dilution

At the simplest level, gas dilution works by releasing inert gases – principally nitrogen – into the area of combustion. By diluting the flammable gas / oxygen mix, it prevents the initiation of a chain reaction. In addition, the nitrogen is believed to encourage the formation of crosslinked molecular structures that promote 'char' formation.

Most nitrogen-based flame retardants use melamine, which is usually found in polyurethane foams and nylon polyamides.

Endothermic decomposition

There are a range of inorganic flame retardants, of which the most common are metal hydrates, principally aluminium hydroxide and magnesium hydroxide. These operate by a process known as endothermic decomposition, meaning that as they reach high temperatures, they absorb energy, cooling the surrounding area and slowing the pyrolytic process. They also release inert gases – usually water vapour – inhibiting combustion.
Although effective, these materials need to be present in large quantities or be used in combination with other types of flame retardants, such as bromine or nitrogen.

Chemical Safety

Chemical safety in products is the domain of chemical regulators, not fire safety standards. The purpose of domestic fire safety standards is to ensure that people are safe in their homes. However, all chemicals produced in Europe in quantities of over 1 tonne per annum undergo extensive research and testing to ensure their safety in use. This is mandated by the EU's Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) Regulation.

Registration under REACH is a pre-requisite to placing a new chemical FR on the market. The registration includes a detailed Chemical Safety Report (CSR) which enables the authorities to assess the safety of the chemicals for their intended uses. This assessment is done by the ECHA as well as member state competent authorities (e.g. HSA in Ireland).

The registration phase is not the end game of REACH. The law stipulates that companies should regularly update their registration dossiers to ensure that the data on safety of chemicals is complete and up-to-date. New chemicals must be fully registered too.

The chemicals registered under REACH are regularly prioritised and reviewed. On the basis of the scientific evidence from such reviews, actions are taken to manage their potential risk. Where a concern is highlighted, a full evaluation is undertaken, which may - in some cases – lead to their restriction in particular applications. It may even lead to their total phase out, if it is proven that they are Substances of Very High Concern (SVHC).

The mere presence of flame retardants (or other chemicals) does not mean that exposure will result in harm. This was confirmed by a recent EPA-funded study and is supported by the European Chemical Agency's (ECHA) own website, which states that "The fact that an article contains a SVHC does not necessarily mean that consumers are exposed to it or that there is a risk for consumers."
Given this, EU chemicals legislation is considered the most ambitious chemicals legislation in the world and has formed the basis of chemicals frameworks including in Korea, China, Taiwan, Turkey and Russia.

Consumer safety is a core tenet for all flame retardant producers, both when it comes to fire safety and chemical safety. Managing and reducing risk is key to meeting societal demands. Notwithstanding the strict regulatory requirements, industry is constantly innovating in order to respond to consumers' demands in developing new flame retardants.

BSEF

BSEF – the International Bromine Council, represents the major global bromine producers. Since 1997, the organisation has been working to foster knowledge on the uses and benefits of bromine-based solutions. BSEF strongly believes in science and innovation.

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Through investments in research and development BSEF members create robust bromine-based technologies meeting the needs of society.

www.bsef.org

OUR MEMBERS

BSEF champions bromine's many benefits around the world. Bromine- based solutions are essential to many of the most important advancements in science and technology.
The members of BSEF are Albermarle Corporation, ICL Industrial Products, Lanxess and Tosoh Corporation.

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