Phosphorus, Inorganic & Nitrogen Flame Retardants Association

Special issue n°120 pinfa e-mobility webinars 2020

*This Newsletter summarises webinars organised by pinfa 28th October and 19th November 2020, with **nearly 450 participants** (total of the three sessions), looking at **how flame retardants can combine fire safety and sustainability in electric vehicles**.*

The events included engineering and medical experts in car safety and speakers from leading the standards organisation UL, automobile materials and equipment experts and component producers, PIN flame retardant and compound companies.

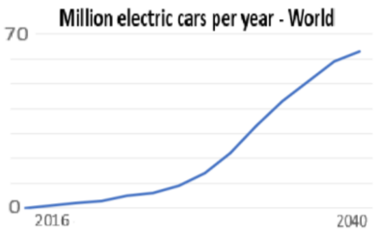
*The October pinfa webinars, targeting materials challenges for fire-safe performance plastics for e-mobility, continued the dialogue with automobile manufacturers and suppliers engaged with the **pinfa electromobility workshops already organised in China 2018 and in Japan and Europe 2019** (see pinfa Newsletter n° 103). The November webinar, organised with the European Fire Safety Alliance as part of European Fire Safety Week, engaged a wide public to discuss the importance of fire safety in the mobility energy transition to electric-powered vehicles.*

Replay the webinars here: https://www.pinfa.eu/media-events/videos/

pinfa, rue Belliard 40, B-1040 Brussels, Belgium
pinfa@cefic.be www.pinfa.org
@pinfa_eu

pinfa webinar: Materials challenges for e-mobility

CONTEXT:



Worldwide growth in electric vehicles

The global electric vehicle (EV) market was estimated at 160 US$ billion in 2019 and is expected to grow to over 800 billion US$ by 2027. Electric car sales increased 40% year-on-year in 2019, reaching around 2.6% of global car sales, and resisted better than the rest of the market to the Covid downturn in the first half of 2020 (57% EV growth in Europe despite an overall car market decline of -37%). It is estimated that **around one third of the world car market will be electric or hybrid by 2030**. Even if this proves wrong, the current low market share means that potential for growth remains huge.

Graph: million electric cars sold per year (world), 2014 – 2040. Vertical scale: 0 – 70 million/year. Based on estimates at https://www.vpsolar.com/en/electric-cars-market-statistics/

Fire risks of e-vehicles

Existing road vehicles already represent a fire risk: **over 202 000 vehicle fires, causing 560 deaths, 1 500 injuries and nearly 2 billion US$ property damage in the USA alone** (2018).

But electrical and hybrid vehicles bring **new and increased fire safety risks**:

- Specific fire risks of batteries, related to energy concentration when fully charged ("stranded energy"), to possible mechanical faults and to risk of runaway
- High amperage drive cables and connectors charging connection, move from 12V to 24V, with risks of overheating and arcing
- Proximity and interconnection of electronics (battery management), power and communications (5G)
- More cables and connectors than in traditional vehicles

Photo: https://www.shutterstock.com/fr/image-photo/san-franciscoca-782018-freeway-accident-fire-1149184103

PINFA AND FIRE SAFETY IN E-MOBILITY

pinfa's vision for sustainable fire safety

Adrian Beard, pinfa Chairperson and **Clariant**, outlined pinfa's vision, which is to improve fire safety and to reduce smoke impacts, whilst improving the environmental and health profile of flame retardants, their compatibility with recycling and their biodegradability. PIN flame retardants are the way forward.

Both voluntary or industry systems (such as ecolabels or Global Automotive Declarable Substance List GADSL) are increasingly restricting halogenated FR. Further pressure is coming on both halogenated FRs and on antimony with regulatory policies on EcoDesign, end-of-life and recycling, or with POP or other classifications. The TCO health and environment label now has a "Positive List" of accepted FRs, including a number of PIN FRs, as well as excluding halogens. pinfa companies are actively engaged in carbon footprinting and sustainability evaluation of product portfolios, and with external, independent product assessments (e.g. GreenScreen, under which several PIN FRs have obtained Benchmark 3).

PIN fire safety for e-vehicles

Electric and hybrid cars bring specific new fire safety challenges for materials. Manufacturers are at the same time looking for more sustainable materials, avoiding halogens (because of impacts of acid release on electronics), and offering mechanical performance and reliability, aesthetic quality, light weight as well as recyclability.

Pinfa facilitates **dialogue through the automobile supply chain on materials needs and FR solutions**. pinfa previously organised workshops in China 2018[1] (140 Participants) and in Japan (60 participants[2], within the ECME Conference) and Europe 2019 (100 participants). These workshops showed the interest in these questions and the need for better understanding of changes in materials specifications for e-vehicle systems, such as electrical performance, heat dissipation, durable orange colour, reduced halogenhydric acid release and challenges around batteries. A specific question identified was that of new standards. This online webinar aims to continue this dialogue.

1 = see pinfa Newsletter n°96 https://www.pinfa.eu/media-events/newsletter/

2 = pinfa Newsletter n°103 https://www.pinfa.eu/media-events/newsletter/ - and photo

3 = see pinfa 2019 Annual Report https://www.pinfa.eu/media-events/brochures-publications/

MATERIALS FIRE SAFETY CHALLENGES AND SOLUTIONS

Franz Janson, TE Connectivity

TE Connectivity has been developing and supplying connectivity and sensing products for over 75 years, including for transport systems and vehicles, industry and communications installations and equipment.

Electric vehicles imply an increased need for fire safety, especially because of high voltages, both within the car and in charging mode. This leads to increasingly demanding fire test requirements:

- UL94-V0, tending towards 0.8 mm and lower
- CTI, moving from the standard 600V to higher requirements
- GWFI for automotive interior materials
- EN 60664-1 for HV product design

At the same time, manufacturers are defining **increasingly performance and environmental specifications**:

- Halogen-Free materials, reflecting EHS and QA aspects
- Sustainability, CO_2 carbon footprint and recycling
- Orange products with heat resistance up to max. 140°C
- Resistance to humidity and water
- Dimensional stability
- Improved thermal conductivity
- Low emissions
- Flowability, to enable processing of complex product design
- Laser marking requirements

*Challenge: **Ensure that materials for HV product design secures** fire performance, mechanical and electrical properties as specified.*

"TE Connectivity is a trademark licensed by the TE Connectivity Ltd. family of companies." TE Connectivity electrical mobility
https://www.te.com/global-en/industries/hybrid-electric-mobility.html

David Qi & Antonio Nerone, RadiciGroup High Performance Polymers

RadiciGroup High Performance Polymers, a pinfa member company, formulates and supplies high performance polymer compounds, in particular polyamides. For sustainability reasons; all new developments at **RadiciGroup High Performance Polymers are non-halogenated, non-ATO materials**.

Data shows that e-vehicles contain (% weight) more polymers, especially polyamides, and less metals, than conventional vehicles. This can be explained by the push for light weight and use in the electric power chain, electronic control system and battery.

Recent developments for e-vehicles include developments of new materials combining electrical safety at high temperatures in harsh environments and high stiffness, for example to replace metals in battery housings (so reducing weight, improving corrosion resistance and avoiding electrical conductivity).

RadiciGroup High Performace Polymers sees five developing challenges for materials for e-vehicles. These are all relevant for internal combustion vehicles, but manufacturer specifications become more demanding or new standards set specific performance levels for e-vehicles.

- **Contact corrosion (galvanic)**: in use, including under temperature or elevated levels of humidity, materials must not release chemicals which can corrode metal connectors or impact electronics systems. In particular, halogenated materials or red phosphorus can generate corrosion during the vehicle life.
- **Constant colour** including after heat and ageing. This is particularly important for EV safety orange used to signal high-voltage cables, both in charging installations and within the vehicle.
- **Electrical properties**: volume resistance (the opposite of conductivity), dielectric strength (resistance to current travelling along the material surface)**.** Such properties are critical for e-mobility, for both power transmission and electronic control systems. Again, these properties must be durable after heating and ageing.

New e-vehicle standards in China

China has taken the lead in implementing specific standards for e-vehicles, for example:

- For charging stations, with **GB/T 18487** – 2001 (220V plug-in charging), **GB/T 20234** – 2015 (1000V high power charging) and **GB/T 38775** – 2020 (cordless charging), with requirements such as fire performance and electrical characteristics (antistatic / electron accumulation, electromagnetic loss), mechanical properties, water resistance.
- **GB/T 31467** – 2015, for battery packs, including fire resistance, mechanical resistance (impact, vibration, simulated crash), heat, saltwater … Fire resistance is tested with a burning gasoline tank below the battery pack, and can be achieved with PIN FR polyamide 6 and 66 grades designed for this application.

Photos: Radici – polyamides. Galvanic contact corrosion. China GB/T 31467 battery fire test.

DEVELOPMENTS IN FIRE STANDARDS FOR EMOBILITY

Thomas Wagner, UL

As Business Manager Automotive at UL (Underwriters Laboratories), Thomas Wagner outlined **new standards available or under development to ensure the fire safety of electric cars**.

Testing is component based, and most parts in e-vehicles are the same as those in combustion engine vehicles, except for fuel systems replaced by batteries and high voltage charging and drive chains. **UL94 V0** thus remains the main test for many materials, with other tests used for certain standards or certain applications, such as burning behaviour (**FMVSS 302**), **GWFI** Glow Wire Flammability Index, **CTI** comparative tracking index and **IPT** inclined plane tracking.

New developments underway include:

- **Extension of FMVSS 302** beyond interior materials to cover e.g. electronic components and multi-materials components such a display screens
- **Adaptation and extension of IPT** to assess electrical performance under high voltages (up to 7 000 V), including electrical tracking resistance (amperage, tracking path length), burning, hole formation.

It is key to remember that UL and other organisations provide tests, but requirements (level of achievement in the test) are defined by component or vehicle manufacturers, as a function of their own fire safety or other performance specifications, or of industry or regulatory standards.

Battery fire testing

In discussion, it was noted that UL 2580 (resistance of battery to simulated abuse conditions, such as impacts or accidents) includes **testing of battery resistance to an external fire**. This standard, as well as SAE J2464 and SAE J2929 also address toxic and flammable emissions.

Ruiz et al. 2018 provide a detailed assessment of testing standards and regulations for e-vehicle battery abuse testing. This includes analysis of fire tests for battery cell, pack and whole vehicle. They conclude that, given the **importance of toxic and flammable emissions**, further standards work should be developed to define testing, guidance and protocols.

"A review of international abuse testing standards and regulations for lithium ion batteries in electric and hybrid electric vehicles", V. Ruiz et al., Renewable and Sustainable Energy Reviews 81 (2018) 1427–1452, http://dx.doi.org/10.1016/j.rser.2017.05.195

Nicolas Dupont & Laurent Tribut
Schneider Electric

Electric vehicle charging poses specific fire and overheating risks, in particular fast charging stations, because of high power supply use without surveillance, especially for installations in humid atmospheres or outdoors.

A range of standards, not yet harmonised, specify electrical, design, mechanical and fire safety characteristics:

- IEC 61851, UL 2594, 2231, 2202, SAE J2293 for charging stations
- IEC 62196, UL 2251, SAE J1772 for charging plugs and sockets. These are more challenging, in particular for electrical properties.

Demanding material requirements include: electrical insulation and safety (e.g. dielectric strength, touch current, Proof Tracking Index PTI 175V), resistance to water, UV, impact, solvents (cleaning) and temperature, ageing for rubber seals and marking durability. Additionally, **for sustainability reasons, Schneider Electric requires halogen-free materials and recycled materials when they are available**.

Fire performance can be GWFI 650°C in IEC 61851, or UL94 V1, V2, FT2 to 5V, for different parts in UL 2594. UL94-V5 is a stringent rating asking for resistance to a 500W burner. In addition, UL 2202 requires flame spread rating < 200 for larger components (surface > 0.93 m^2 or one dimension > 1.83) using UL 723 Steiner Tunnel or ASTM E162 radiant panel. IEC and UL requirements are different, but each of them constitutes an “ecosystem” with installation requirements, product standards and horizontal standards which have proven to be safe.

Schneider Electric – electrical car charging https://www.se.com/ww/en/product-category/1800-electrical-car-charging/

pinfa / European Fire Safety Week webinar
Fire safety challenges for energy transition

EUROPEAN FIRE SAFETY WEEK

EUROPEAN FIRE SAFETY WEEK 2020

The European Fire Safety Week was organised for its second year in 2020 and aimed to improve awareness of fire safety for stakeholders and EU policy makers. It included seven webinars, covering vulnerable communities, reduction in escape times, data, awareness and collaboration. In total, there were **500 registrants for the seven webinars, of which 120 were participants at the pinfa webinar** on fire safety in the energy transition to electric vehicles.

Elie van Strien,
European Fire Safety Alliance

European Fire Safety Week is organised by European Fire Safety Alliance, an organisation with the mission to reduce the risk from fire in the home, led by the Dutch Burns Foundation and the Fire Service Academy (IFV), with support from industry partners including pinfa.

The pinfa webinar on fire safety in the energy transition to electric vehicles was opened by Elie van Strien, Chair of the European Fire Safety Alliance, and former fire chief in Eindhoven, Rotterdam and Amsterdam.

Fire continues to kill and injure too many people in Europe. Fire deaths in Europe are equivalent to two Grenfell fires per week.

The first European Fire Safety Week, 2019, led to a proposed EU "Fire safety action plan", with **ten actions to improve fire safety in homes**:

- Establish a European approach to improve the fire safety of the most vulnerable
- Introduce an EU fire safety standard for upholstered furniture and mattresses
- Increase application of smoke detectors
- Improve the functioning of LIP (lower ignition propensity) cigarettes
- Address fire risks of new energy systems
- Raise fire safety awareness through community fire safety projects
- Research into fire safe behaviour
- Put in place coherent EU fire data collection
- Widen the EU FIEP (Fire Information Exchange Platform)
- Improve Member States and industry cooperation on market surveillance

FIRE RISKS OF ROAD VEHICLES AND MEDICAL CONSEQUENCES

Paul Otxoterena, RiSE

Fire contributes to road accident deaths: around 5% of road fatalities in Sweden involve vehicle fires, with cause of death attributable only to fire in one third of cases. In the USA, over 30 road vehicle fires per hour are reported. Around 12% of fire deaths, 8% of civilian fire injuries and 9% of direct property damage are related to road vehicle fires.

From 2002 to 2014 the number of road vehicle accidents in Sweden decreased, but the percentage of accidents where vehicles caught fire, and the percentage of accident fatalities involving fire both increased significantly. The likelihood of fire starting increases with higher crash energy. Overall, **the survivability of vehicle crashes has improved with vehicle design and safety features, but the relative probability of fire death resulting from accidents is increasing**.

Although 80% of significant vehicle fires start in the engine compartment or drive systems, these fires only account for 40% of vehicle fire fatalities, suggesting that fire safety of other vehicle parts and interiors may be important.

Electric vehicles bring new fire risks, in particular with the risk of hydrogen fluoride (HF) emissions from batteries (toxic, irritant, corrosive), with test data showing increasing HF emissions with larger batteries.

See also ""Post-collision fires in road vehicles between 2002 and 2015", P. Otxoterena et al., Fire and Materials. 2020;1–9, https://doi.org/10.1002/fam.2862 summar ised in pinfa Newsletter n°118.

Ulf Björnstig, Senior Professor of Surgery, Umeå University

Around 20 people over ten years died in car fires in Sweden due to fire only (without fatal traumatic injuries, 2009-2018), so maybe c. 150/year in Europe (population-based extrapolation). Victims were often on the rear seat.

In over half of these fatalities in Sweden, hydrogen cyanide (HCN) was detected. This highly toxic gas is released when various nitrogen-containing materials burn, in particular polyurethanes.

In electrical vehicles, hydrogen fluoride emissions will increase fire gas toxicity. HF can be released from batteries in fire, but also from air conditioning liquids or possibly battery cooling liquids. In addition to corrosivity, HF has specific toxicity effects by reducing blood calcium and increasing potassium, so causing nervous system dysfunction and heart problems.

SPECIFIC FIRE SAFETY CHALLENGES OF ELECTRIC VEHICLES

David Qi, RadiciGroup High Performance Polymers

Laurent Tribut, Schneider Electric

Significant new fire safety challenges posed by electric vehicles:

- **High voltages,** risk of electrostatic accumulation
- **Increasing use of plastics in vehicles,** to reduce weight and because of electrical insulation requirements, as well as increasing cables and electrical insulation
- **Complex and sensitive electronic systems**
- **Specific fire risks from batteries**
- **Fire risks related to charging**, including high voltages, outside weather and humidity, risk of arcing or of overheating
- **Charging stations can result in significant fire loads** in spaces initially not designed for this, such as garages

Regulators and car manufacturers are tending to strict fire safety requirements, combined with demanding technical and electrical characteristics, durability and aesthetics. Halogen-free is increasingly required both for sustainability reasons and to avoid release of corrosive halogens which can damage electronics. PIN flame retardants are used to address these requirements.

For further technical details, see summary above of presentations at the previous webinar.

E-VEHICLES BRING NEW RISKS INTO BUILDINGS

Dieter Brants, Hulpverleningszone Oost

The fire load of electric vehicles with batteries and the heat release rate in fire are similar to that of conventional vehicles with fuel. However, the Flanders fire safety organisation (Hulpverleningszone Oost) is concerned about **new risks to fire-fighters: chemical and thermal risks from batteries (in particular hydrogen fluoride) and electrical risks** (400 – 600 V). Despite these risks, there are still today no rules on charging stations in garages in Belgium, only “guidelines”.

EV chargers are often installed in car parks not equipped with fire detection. Car parks pose specific dangers to fire-fighters: low ceiling increases smoke and toxic gas, problems for containment of contaminated extinguishing water. Low ceilings can prevent access for towing services, whereas vehicles with damaged batteries must be evacuated because of risk of reignition.

Many questions are today unanswered concerning how to deal with electric vehicle fires: How to mitigate the dangers of toxic smoke from batteries in fires? Are sprinklers effective? To what extent will fire spread from one vehicle to another? How to deal with battery fires in larger vehicles (such as buses) for which immersion in a tank of water to prevent reignition is not possible? How to identify and manage fire risks from lithium ion batteries in other appliances?

Vincente Mans, fire safety expert

Fully electric vehicles (EV) do not have conventional fuel, but batteries contain up to 400 litres (five times more volume than conventional fuel) of organic electrolyte with a comparable flash point. Today’s EV have a similar heat release rate to conventional vehicles, but this will increase as stored power increases to offer higher km ranges.

Data suggests that **today 50 - 60% of electric vehicle fires occur in garages**. Risks are increasing as garages are equipped with multiple chargers, in time one for each parking space. Current car park fire safety regulations and ventilation are designed to address smoke opacity, but toxicity becomes critical with EVs. In addition to hydrogen fluoride from batteries, an **increased use of plastics and reinforced polymers in EVs increases fire load** and can release glass or carbon fibres or nano-particles.

High voltages and currents in charging pose fire safety risks, because of possible arcing or overheating, so that fire resistant materials are important for safety, in charging installations, cables, connectors and in the EV itself. Fire safety using **PIN flame retardants avoids adding further halogenated toxic and corrosive emissions**, in case of fire, given that hydrogen fluoride is already identified as an important danger.

Lars Derek Mellert, Amstein + Walthert Progress

Large scale fire tests of EV batteries carried out for the Swiss Government, with EMPA (see pinfa Newsletter n°117) are looking at the possible **consequences of EV battery fires in enclosed structures, such as tunnels or underground car parks**.

The brand of battery is not significant, in that the chemistry is the same. A worst case of simultaneous mechanical damage to all battery cells was simulated using a steel wedge. The batteries were standard EV, new and fully charged. Fire, smoke gases and soot were assessed with and without ventilation or sprinklers.

The toxic fire gases found in conventional vehicle fires were released at similar levels, **but additionally: fluoride, cobalt, nickel, manganese and lithium** (not significant in conventional vehicle fires). These elements were present as aerosols, posing potential health dangers for fire-fighters.

Furthermore, the substances released in an EV fire imply **increased toxicity of fire extinguishing water** (fire fighting water and water needed for cooling of damaged batteries should be kept separated, if possible), and so increased decontamination costs.

More positively, the tests concluded that EV battery fires are unlikely to cause more critical damage to buildings or infrastructure than conventional vehicle fires.

Conclusions

EUROPEAN FIRE SAFETY ALLIANCE

Elie van Strien, European Fire Safety Alliance, concluded that the generalisation of electric vehicles and charging stations is inevitable, but poses important new fire safety challenges. R&D, testing and collaboration with industry is needed to find solutions to ensure the safety of vehicle users, building occupants and importantly of fire-fighters.

pinfa

Adrian Beard, pinfa President (Clariant), indicated that PIN flame retardants can reduce these risks, by avoiding fires starting (preventing ignition) and slowing their development, without increasing halogenated emissions.

Publisher information

This Newsletter is published for the interest of user industries, stakeholders and the public by pinfa (Phosphorus Inorganic and Nitrogen Flame Retardants Association), a sector group of Cefic (European Chemical Industry federation) www.pinfa.org. The content is accurate to the best of our knowledge, but is provided for information only and constitutes neither a technical recommendation nor an official position of pinfa, Cefic or pinfa member companies. For abbreviations see: www.pinfa.org