Promat

PRESERVE & PROTECT

FIRE PROTECTION SOLUTIONS FOR EV CHARGING ZONES IN CAR PARKS

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INTRODUCTION

Cars are not what they used to be, and neither are car fires. Fires in car parks involving large numbers of cars appear on the news frequently, in some cases even involving many hundreds of cars as well as structural collapse[1]. Safety regulations do not keep up with changing fire hazards such as larger and more combustible cars, new energy carriers such as lithium batteries and the technical requirements for effective extinguishing systems to control such fires.

With the increasing share of electric vehicles, chargers are being installed in more and more car parks. In most cases these will be existing car parks, with limited design freedom. Electric vehicle fires are more likely to occur during charging[2] and the fire development in case of thermal runaway of a lithium battery is very different from internal combustion engine vehicle fires. Instead of vertical flames in a traditional car fire, thermal runaway of a lithium battery may lead to horizontal jet flames, very fast temperature development and pressure waves.

It will often be wise to adopt fire safety measures to mitigate the risks associated with charging of electric vehicles. Where some countries now have standards for the quantity, power supply and safety requirements of chargers, regulations for how to fire protect these areas are only just starting to develop.

Although the development of EV fires in car parks is not yet fully understood and is the subject of various research programmes, first indications are that EV battery fires, compared to fires of internal combustion engine vehicles:

- → Develop more rapidly
- → Produce jet-like flames, often horizontally
- → Are extremely difficult to extinguish
- → Emit toxic smoke containing Hydrogen Flouride

1 Examples of car park fires involving hundreds of cars or more: Liverpool Echo Arena, UK (2018), Stavanger Airport, Norway (2020), Märsta, Sweden (2021), Luton Airport, UK (2023), Prior Velho, Portugal (2024), each with extensive online information available.

2 Statistics can be found on www.evfiresafe.com

Fire Curve

Regulations usually adopt the standard (ISO-834 / EN 1363-1) fire curve for fire design of structures. With the strong increase in the weight of cars and the use of plastics, car fires are more severe, develop rapidly and are more likely to involve multiple cars in a short period of time. Over the past years, several big car park fires have occurred involving large numbers of cars and leading to partial collapse of the structure.

In the case of EV batteries, the fire moreover develops very fast with horizontal jet-like flames, further increasing the speed of spreading of the fire to adjacent cars.

For car park protection, Promat recommends the use of solutions that have been successfully tested against the hydrocarbon fire curve (EN 1363-2), to guarantee that the product will not fail in case of fast developing fires and combining the heat release of many cars burning simultaneously

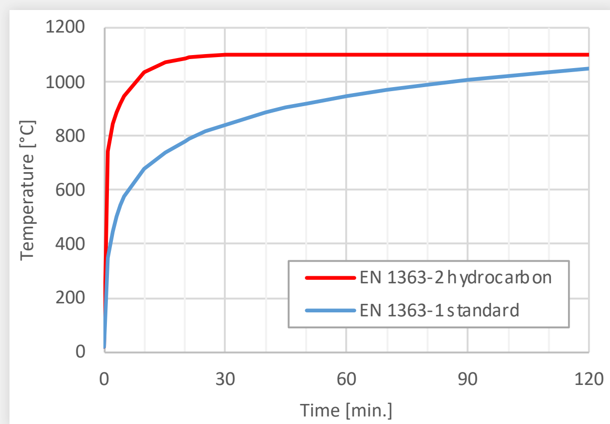
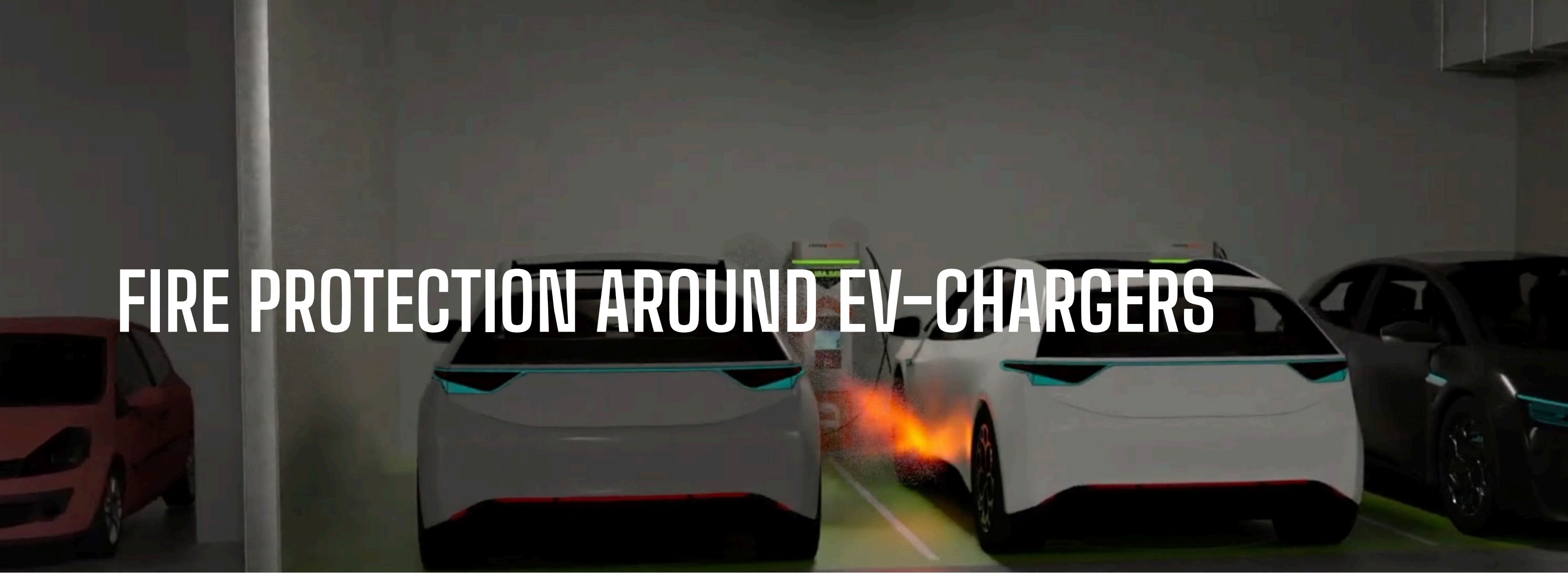


Figure: hydrocarbon vs. standard fire curves

Promat is on the forefront of developing new fire protection solutions to reduce fire damages and ensure continuity of operation. In this dynamic and developing landscape, Promat focuses on solutions for protection of the structure against severe fires, solutions for limiting the spread of the fire, including jet flames and pressure waves, and solutions for control of the smoke with the aim of reducing damage and enabling effective and safe fire brigade intervention.

With many decades of experience in harsh environments such as tunnels and petrochemical facilities, Promat offers solutions to withstand very fast fire development, extremely high temperatures, blast pressure waves and highly corrosive smoke. As each car park is different, Promat offers these solutions as building blocks and will be happy to support you when designing a fire safe car park.



FIRE PROTECTION AROUND EV-CHARGERS

Battery fires in electric vehicles: a new risk but solutions are available

With the gradual transition towards battery electric vehicles, fire risks change. Electric vehicle fires are different than internal combustion engine vehicle fires: thermal runaway of a battery array will cause a very fast fire development[3], with horizontal jet-like flames[4] and possibly pressure peaks. Battery fires emit specific toxic[5] and highly corrosive smoke, are extremely difficult to extinguish and may re-ignite even after many hours or days. The rate of fire development, toxicity of the smoke and potential for accumulation of explosive gases depend strongly on the state of charge of the battery, which is one of the unpredictable factors in battery fires.

Battery casings are designed to protect the battery and resist external influences such as water. Therefore, suppression agents are not able directly cool the fire inside the battery. Also, the cooling effect of water will cause mixing of smoke with fresh air, often reducing visibility and possibility of effectively extract the smoke.

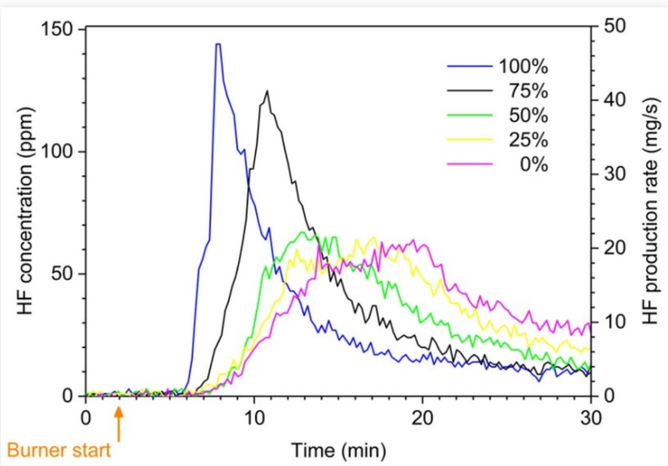


Figure: an example of toxic fluoride gas production in small scale battery experiments, as a function of the state of charge of the battery[8]

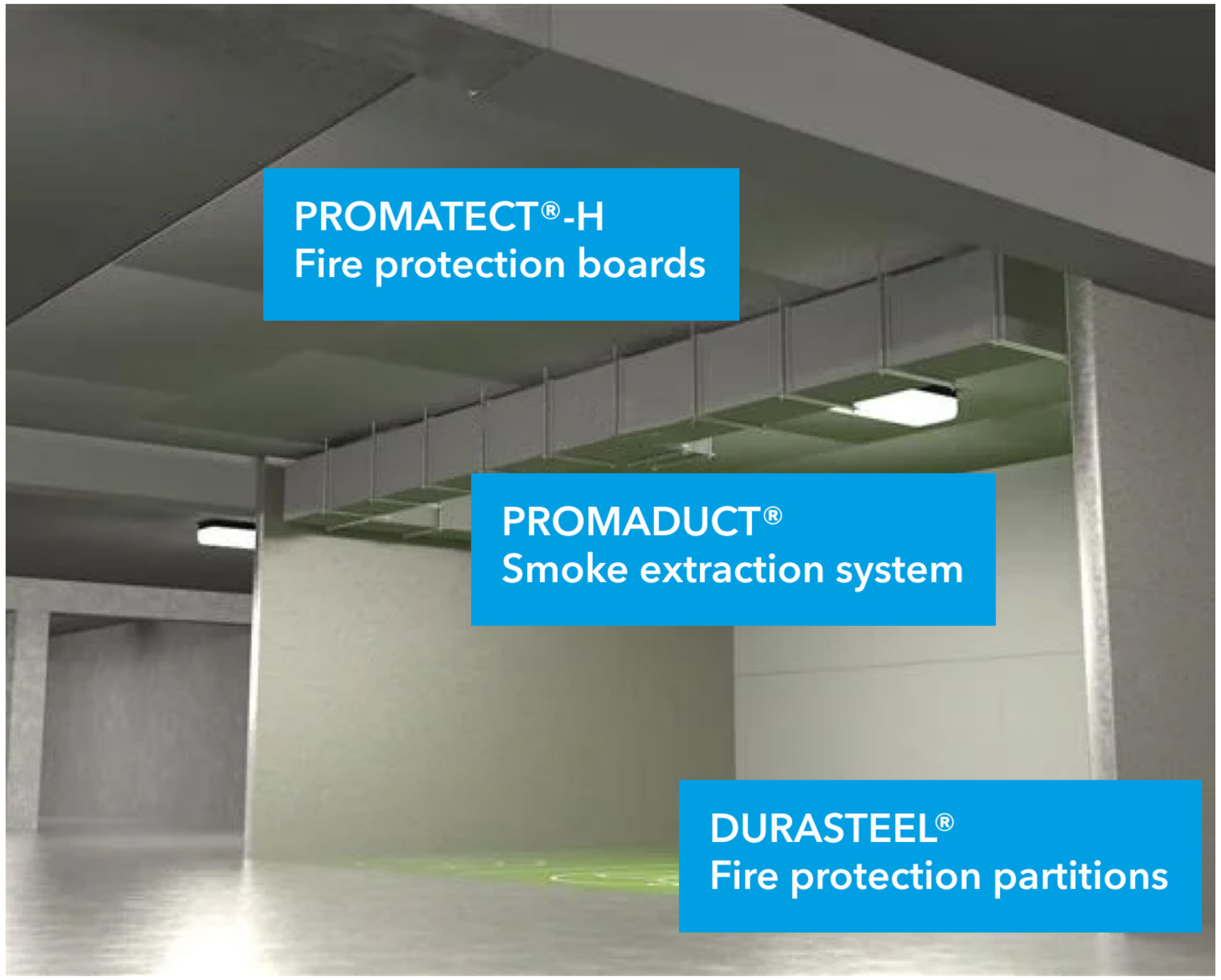
As battery fires are almost impossible to extinguish[6,7], there are 2 scenarios for the fire brigade:

- Drag the burning car outside and lift it into a special water container, immersing the vehicle in water for one or more days until the battery has fully cooled down, or
- Keep the burning car where it is, let it burn and avoid spreading of the fire.

Although statistics are limited, there are indications that the probability of an EV catching fire is relatively high when charging. For this reason, Promat offers a specific set of solutions for charging zones in car parks.

[3] D. Brzezinska, P. Bryant, Performance-Based Analysis in Evaluation of Safety in Car Parks under Electric Vehicle Fire Conditions, Energies 15 (2022) 649.
[4] Z. Zhou, X. Zhou, D. Wang, M. Li, B. Wang, L. Yang, B. Cao, Experimental analysis of lengthwise/transversal thermal characteristics and jet flow of large-format prismatic lithium-ion battery, Appl. Therm. Eng. 195 (2021) 117244.
[5] F. Larsson, P. Andersson, P. Blomqvist, B.-E. Mellander, Toxic fluoride gas emissions from lithium-ion battery fires, Sci Rep 7, www.nature.com (2017), https://doi.org/10.1038/s41598-017-09784-z
[6] P. Sun, R. Bisschop, H. Niu, X. Huang, A Review of Battery Fires in Electric Vehicles, Fire Technol. 56 (2020) 1361-1410.
[7] L. Kong, C. Li, J. Jiang, M.G. Pecht, Li-ion battery fire hazards and safety strategies, Energies 11 (2018) 2191

Fire protection solutions for the electric vehicle charging zone



The great advantage of knowing the most likely location of fire ignition is that the safety can be improved efficiently by applying preventive fire safety measures at the charging zones. Promat recommends combining 3 strategies:

- Structural protection: protection of all loadbearing elements such as concrete or steel beams and columns, floors, and loadbearing walls. Avoiding instability of the structure is the basic condition for saving human lives, limiting damage and effective fire brigade intervention. For battery fires the rate of temperature increase, maximum temperatures and fire duration may be different from the standard fire curve. Therefore, Promat recommends the use of fire protection materials such as **PROMATECT®-T** and **PROMATECT®-H**, which are resistant against severe fire curves such as petrochemical fires and tunnel fires.
- Avoid spreading of the fire: by physically separating the charging zones from the remainder of the car park, spreading of the fire can be limited. Promat recommends **DURASTEEL®** fire barriers because of their resistance against severe fires and explosions. Despite their slim footprint, **DURASTEEL®** fire barriers are robust in day-to-day operation of the car park.
- Smoke extraction: by creating a partial compartment with fire barriers, smoke will be more confined and smoke extraction ducts above the charging zone can efficiently extract the smoke. By controlling the spread of the fire and the smoke, visibility and accessibility of the fire is facilitated for safe and effective evacuation and fire brigade intervention.

Design recommendations

As EV battery fires are fundamentally different from fires of internal combustion engine vehicles, traditional design assumptions, models and criteria for the fire protection design of car parks are not validated for areas in car parks that are equipped with EV-chargers. The development and spread of heat and smoke in case of EV battery fires is the subject of research. By absence of validated design guidance, Promat provides the following practical recommendations:

Fire rating: For determination of the fire resistance requirement in minutes it must be considered that a battery fire is very difficult or even impossible to extinguish, multiple cars may be involved in the fire and high temperatures may occur with intervals for a long time. By lack of a clear understanding of the duration of the fire and to provide time for the fire brigade to intervene (e.g. preparing to drag the burning car out of the car park), a fire rating of 120 minutes can be assumed which is common for fire protection of tunnels and petrochemical facilities. For car park protection, Promat recommends the use of the hydrocarbon fire curve.

Partition walls resistant to a hydrocarbon fire curve are to be placed at least at the following locations:

- Between groups of three[8] parking spaces equipped with EV-chargers
- Between emergency exits and parking spaces equipped with EV-chargers

Passive fire protection resistant to a hydrocarbon fire curve is to be applied on all **concrete and steel columns and beams** within a distance of 20m from any parking space equipped with an EV-charger. Indicative thermal radiation calculations based on a maximum of 3 cars burning show that at this distance, heat radiation levels are low enough to avoid major structural damage.

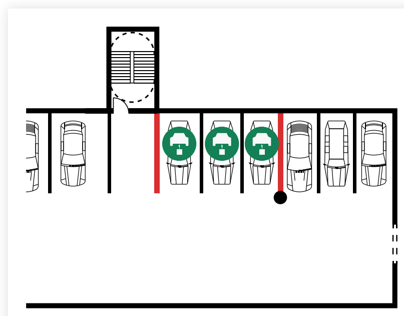
Passive fire protection resistant to a hydrocarbon fire curve is also to be applied to the **ceiling** directly above and any **structural walls** directly behind the parking space equipped with an EV-charger, to protect those elements from flame impingement.

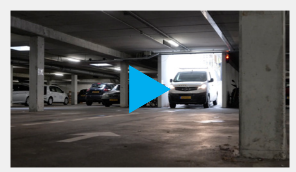
Smoke extraction ducts above parking spaces equipped with EV-chargers should have at least one extraction point for every group of three parking spaces. To place the smoke extraction duct at the location of dense smoke rather than direct flames, it is recommended to position the duct above the edge of the parking space and the roadway, while the other 3 sides are closed by the car park walls or **DURASTEEL®** barriers to avoid uncontrolled spreading of the smoke.

Separating groups of parking spots with EV-chargers by fire barrier walls has multiple advantages:

- No spread of fire to cars on the other side of the barriers, containing the fire to a small location, ensuring it remains controllable
- By not involving other cars, the heat radiation levels to the adjacent areas are limited
- Concentrating the smoke at the location of the burning EV(s) ensures maximum effectiveness of the smoke extraction system

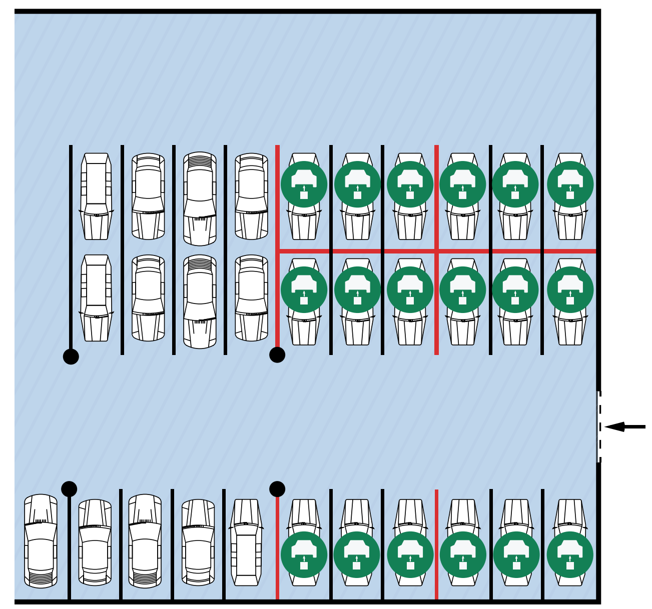
Place a fire barrier wall between EV Charging area and emergency exits.





Watch the video

Create charging zones of 3 EV cars.



8 The proposal for three parking space to be separated by partitions follows from the Hungarian regulations (TvMI 1.6:2024.02.01 - Technical Directive on Fire Protection - Annex P). In principle, a different number can follow from a risk analysis, taking into account the fact that the number of cars involved in the fire directly impacts the heat radiation levels, fire duration and smoke production.

01 PROTECT THE LOAD-BEARING STRUCTURE

Concrete and steel structures need fire protection

In many recent large scale car park fires the effects on the loadbearing structure have drawn attention. News articles frequently show that floors, columns and beams collapsed, causing the falling of cars into the fire and spreading of the fire to the next floor level. This can happen with both steel and concrete structures.

Concrete structures can spall when exposed to a sudden temperature increase, due to the moisture trapped in the pores of the concrete and due to stresses caused by thermal expansion. Spalling is a progressive process of layers of concrete violently breaking off the surface, which can quickly leave the steel reinforcement inside the concrete directly exposed to the fire, jeopardizing the loadbearing capacity of the structure.

Steel structures without fire protection will heat up quickly during fire because steel conducts heat well and steel elements usually have a large exposed surface compared to the steel volume. Without fire protection, within 10 to 20 minutes a steel element reaches a temperature of ca. 500-700°C, which will in most cases lead to structural failure of the element

Car fires typically cause a relatively fast temperature rise which can cause failure of unprotected concrete and steel elements. In the past, car park fires were seen as slowly travelling fires, where the fire spreads from one vehicle to the next one, and while a next vehicle starts to burn, the first vehicle has burnt out completely and will cool down.

However, with modern cars, the fire is so intense and propagation to a next car occurs so quickly that large numbers of cars may burn simultaneously, leading to a situation that cannot be controlled by the fire brigade.

Fire protection solutions to resist the real fire

Various car park fires[1] in recent years included many cars burning simultaneously and partial collapse of concrete and steel structures, designed for the standard (ISO-834) fire curve. With modern cars, the temperature development may be significantly more severe than the standard fire curve used in fire tests. To avoid consequences as in those major car park fires, it is important to apply products that are resistant to more severe fires such as the hydrocarbon fire curve.

PROMATECT®-H for protection of concrete[2] and steel[3] elements can withstand the hydrocarbon fire curve, which quickly reaches 1100°C. By using hydrocarbon fire tested solutions, you will not only be prepared for the fires of today but also those of the future.

Benefits

- → 40+ years of experience in fire protection of tunnels, petrochemical facilities and commercial buildings
- → Technical support to design against severe fire exposures
- → For standard fire exposures use our free online Structural Protection Calculator, for hydrocarbon fire exposure ask our technical experts!

PROMATECT®-H is a high density calcium silicate board which has been extensively tested for fire protection of concrete and steel elements against hydrocarbon fire. **PROMATECT®-H** boards have a track record of more than 40 years providing fire safety.

[1] A relatively well documented case involving 1400 cars and structural collapse is the fire of the Liverpool Echo Arena multi-storey car park. More information about this fire can be found on www.cross-safety.org
[2] 40 mm of **PROMATECT®-H** will limit the temperatures of columns and beams to <300°C and slabs and walls to <200°C after 120 minutes exposure to the hydrocarbon fire curve
[3] Depending on the section factor of the steel, 30 to 50 mm of **PROMATECT®-H** will limit the steel temperature to <500°C after 120 minutes exposure to the hydrocarbon fire curve

02 AVOID SPREADING OF THE FIRE

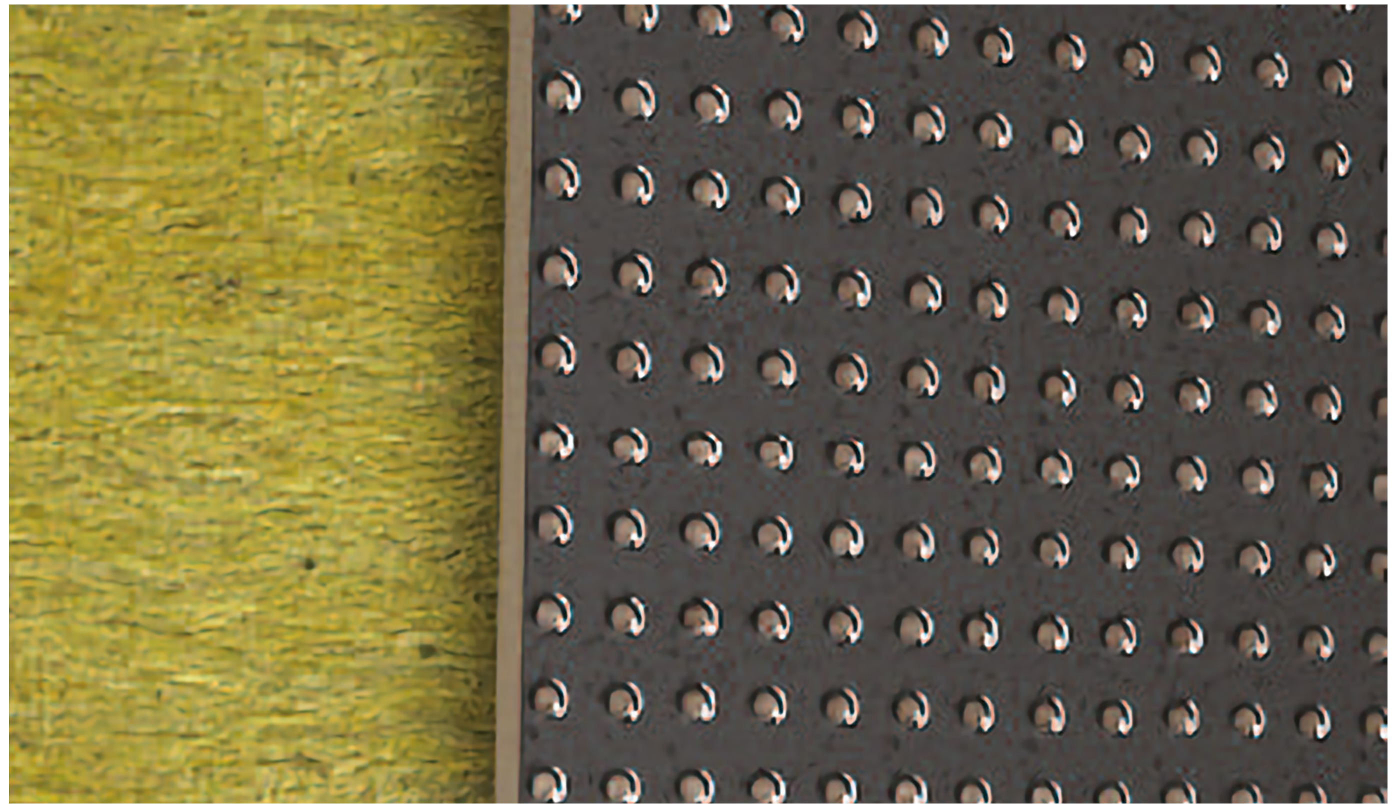
Compartmention keeps fire under control

In the traditional sense of building regulations, compartmentation means to fully enclose the fire inside an area. Inside car parks this is rarely possible because the use as a car park requires open and connected spaces. Nevertheless, avoiding a “travelling fire” is key to stay in control and prevent major damage and interruption of business continuity.

Compartmentation solutions such as partition walls in car parks offer clear fire safety benefits, especially around emergency exits, EV-charging zones and ramps. A careful design of the car park’s floor plan including partition walls can serve to:

- limit and control the spread of fire and smoke,
- resist jet-like flames and pressure waves,
- enable smoke control systems to function more effectively.

In this way, partition walls such as **DURASTEEL®** barriers help to avoid large and uncontrollable fires and enable the fire brigade to intervene in a safe and effective way.



Fire protection solutions

Promat offers **DURASTEEL®** partition walls to resist severe conditions such as hydrocarbon fires and blast pressures. **DURASTEEL®** panels consist of a calcium silicate core and external perforated steel sheets, and have been used extensively in demanding applications such as the energy and petrochemical sectors for hydrocarbon fire and blast protection.

DURASTEEL® partitions consist of a metal frame with **DURASTEEL®** panels screw-fixed to it, with adjustable fire resistance performance by using backer strips behind the panel joints and mineral wool insulation inside the cavity, and adjustable blast resistance by selecting the correct frame sections based on blast calculations.

DURASTEEL® barriers are commonly used for fire and blast protection in petrochemical installations, energy networks, industrial buildings and infrastructure.

With over 90 years of track record, **DURASTEEL®** barriers have been tested to resist blast pressures as well as hydrocarbon fires, and even an explosion followed by a hydrocarbon fire.

Benefits

- No need to worry about fire temperatures exceeding the standard fire curve, nor about pressure waves caused by jet flames in case of thermal runaway of batteries.
- Effectively stopping flames from reaching and igniting the next car.
- Can be used in combination with a Promat smoke extraction duct system. In car parks of complex geometry, **DURASTEEL®** barriers can limit and guide the spread of smoke, to ensure optimum control and extraction.
- An additional advantage is that **DURASTEEL®** barriers are durable and robust, limiting as much as possible the need for maintenance and repair.
- Slim footprint, only circa 200mm width for a **DURASTEEL®** barrier to maximise the number of parking spaces, without compromising the fire safety.
- **DURASTEEL®** has been tested in accordance with EN, UL and ASTM standards. Included in those tests was impact testing pre, and post exposure to fire, to ensure that fire performance is not compromised, as well as hose stream testing after fire exposure.

Controlling the smoke enables the fire brigade to act

Car fires cause dense and often hot smoke, which if not controlled can cause widespread damage to cars and other inventory and limit the fire brigade's ability to intervene due to lack of visibility. In the case of battery fires of electric vehicles, the smoke is especially corrosive and toxic, emitting hydrogen fluoride (HF) as well as specific metals such as nickel, cobalt, lithium, and manganese, depending on the battery chemistry.

Moreover, if the car park is located under a building, failure to control the smoke may lead to smoke entering the building, posing a direct threat to human lives and property.

Adequate smoke control systems are therefore crucial for the fire safety of car parks, to ensure effective fire brigade intervention, reducing damage and ensuring continuity of operation.

Especially for closed car parks with complex geometries, smoke extraction requires an elaborate design of flow, obstacles and inlet and extraction points.
EV batteries are designed to strongly resist external influences including water ingress. For this reason, water-based firefighting systems are normally not able to extinguish the battery fire. Moreover, extinguishing the flames of a battery in thermal runaway creates the risk of accumulation of explosive gases.

Water-based firefighting systems may reduce the heat release of the fire, but smoke production continues. Especially with the low ceiling height in car parks relative to the floor area, cooling the smoke causes the end of stratification, strongly reducing tenability conditions and visibility. Also, as battery fires are hard to control, the required quantity of water is much higher than for internal combustion engine car fires, requiring special sprinkler systems and matching water supply and extraction of large volumes of potentially polluted water.

Fire protection solutions

Promat offers smoke extraction duct systems fully tested in accordance with EN 1366-8, built-up of calcium silicate boards such as **PROMATECT®-L500**, **PROMATECT®-LT** or **PROMATECT®-LS**. These boards are resistant against high fire temperatures without losing integrity or large deformations as would typically occur in the case of a steel duct.

Depending on the complexity of the floor plan and obstacles for the flow of smoke such as deep beams, the smoke control can be helped by partition walls to avoid propagation of the smoke but rather concentrate it around exhaust points of the smoke extraction duct.

Also, the vertical smoke extraction towards the extraction fan and out of the car park can be built as a Promat smoke extraction duct system, tested in accordance with EN 1366-8 in vertical orientation.

[4] NBN S 21-208-2 (2014) Fire protection in buildings – Design of smoke and heat extraction systems of closed car park structures
[5] S. Kang, M. Kwon, J.Y. Choi, S. Choi, Full-scale fire testing of battery electric vehicles, Applied Energy Vol. 332 (2023), 120497

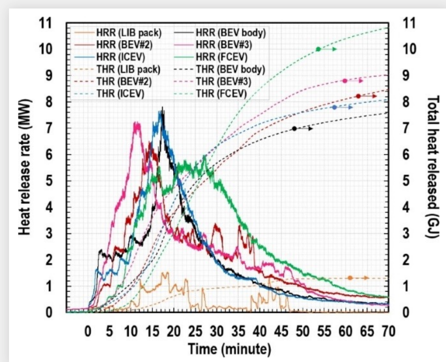
Benefits

- Fully fire tested smoke extraction duct solutions, proven in practice
- **COMBI-PROMADUCT®**: the option to combine comfort ventilation with smoke extraction in the same duct
- BIM software available for efficient design of Promat smoke extraction duct systems

PROMAT smoke extraction ducts can serve a dual purpose for ventilation in daily operation. For more information about the **COMBI-PROMADUCT®** solution, contact Promat.

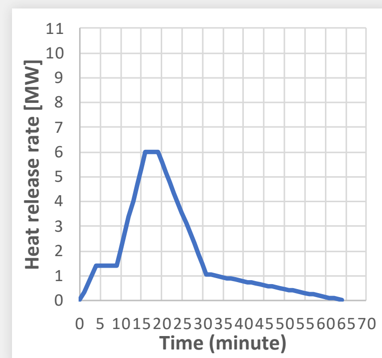
Some regulations give guidance on input for CFD modelling to support the design of smoke control systems. One set of regulations that is used in various countries is the Belgian standard NBN S 21-208-2 (2014)[4]. This standard provides guidance on heat release curves for fires involving one car and two cars.

Although various fire experiments on cars have been published, in many cases the information on the cars is limited. Some very well-documented experiments on modern cars are reported by S. Kang et.al.[5]



Heat release rates from full-scale tests[5] on lithium battery vehicles (BEV#2, BEV#3), an internal combustion engine vehicle (ICEV) and a fuel-cell electric vehicle (FCEV)

Comparing the test results to the guidelines for a single car fire in the Belgian design standard as shown in the table below, it is clear that fires in both internal combustion engine vehicles and electric vehicles of modern design exceed the design recommendation for a single burning car, in terms of peak heat release rate as well as total heat release. For this reason, engineers nowadays often assume more severe heat release curves, for example with a peak heat release rates of 8 MW and faster initial increase rates.



Heat release rate for a single car fire in accordance with Belgian regulations[4] for smoke extraction of closed car parks

	PEAK HEAT RELEASE RATE [MW]	TOTAL HEAT RELEASE [GJ]
NBN S 21-208-2 (single car)	6.00	6.84
Test result BEV#2	6.51	8.45
Test result BEV#3	7.25	9.03
Test result ICEV	7.66	8.08
Test result FCEV	5.99	10.82

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