EUROPEAN FIRE SPRINKLER NETWORK

Position paper on sprinkler systems in car parks containing electric vehicles

November 2023

Contents

Introduction

Electric vehicles (EVs) are much more common than just three years ago, and we are all aware that battery fires are a significant technical challenge to fire services. Many fire safety experts, including regulators, are asking questions about what fire protection measures should be taken in car parks as they hold increasing numbers of EVs, some of which are being charged. Some jurisdictions already require sprinklers in large, enclosed car parks, but are questioning whether those sprinkler systems can deal with EVs, while other jurisdictions that do not require sprinklers are discussing whether they now should.

This position paper is intended to gather what we know about the fire risks posed by EVs, to what extent they can be mitigated by sprinklers and whether any changes should be made to the current design guidance for sprinkler systems in car parks. At the time of writing we do not have all the information we would like to address these questions. This paper will be periodically revised as more information becomes available.

Background

According to the European Commission[1], road transport accounts for 18% of all CO_2 emissions in the European Union. Voters are pressing their politicians to act to reduce these emissions and on 29 June 2022 all climate ministers of the Member States of the European Union agreed to ban the sale of new internal combustion engine vehicles by 2035[2]. A number of Member States wanted to go faster and elsewhere in Europe Norway will ban them from 2025[3]. Against that, the UK recently relaxed its ban to 2035 from 2030. Meanwhile governments and city authorities have introduced incentives for EVs, such as reduced sales taxes on new cars, reduced annual road taxes and charges. In March 2022 EVs comprised 86% of new sales in Norway[4], with hybrids a further 6%. Almost a quarter of cars on Norwegian roads are plug-in (EV or plug-in hybrid). Other European countries are behind but EV sales are growing rapidly, with plug-ins early in 2022 accounting for 21% of French[5], 26% of German[6], 32% of Dutch[7] and 40% of Belgian[8] new car sales. The trend is that in a few years the majority of new car sales will be electric and some years after that the majority of cars on the road will also be electric. It is therefore time to assess how sprinkler systems can contribute to protection from fires in EVs, and whether there is any need to change sprinkler system designs to protect against this changing risk.

[1] https://ec.europa.eu/clima/eu-action/transport-emissions_en
[2] https://www.euractiv.com/section/transport/news/eu-countries-approve-end-to-combustion-engine-sales-by-2035/
[3] https://roadmapsforenergy.eu/norway-fossilfuel-car-ban/
[4] https://insideevs.com/news/578743/norway-electric-car-sales-march2022/
[5] https://insideevs.com/news/592228/france-plugin-car-sales-may2022/
[6] https://cleantechnica.com/tag/germany-ev-sales/
[7] https://insideevs.com/news/592213/netherlands-plugin-car-sales-may2022/
[8] https://www.brusselstimes.com/belgium/217095/electric-car-sales-boom-but-need-for-charging-points-becomes-acute

Internal combustion engine vehicle (ICEV) fires in car parks

There used to be a misperception among some fire safety experts that car fires did not spread from one car to another. To correct this, the EFSN collected accounts of incidents where large numbers of cars were destroyed, finding several every month. We made our point and it is now more widely accepted that fire can spread. Some have claimed this is new and due to the changes in car design. While car park fires involving dozens of cars occurred 20 years ago[9,10,11], new cars are now 12 cm wider yet the standard width of a parking space is unchanged so that cars are closer together and fire can more easily spread[12].

Today cars also present a higher fuel load, being not only larger but containing many more plastics, particularly externally. The fuel tank is now also plastic and more prone to rupture in a fire, spreading fuel and creating a pool fire which more rapidly spreads fire to other vehicles. All these factors combine to mean that car parks are today more vulnerable to large fires, even without considering the presence of EVs. NFPA conducted a literature survey in 2020 which established that cars in the US present a higher fuel load and are larger than in the past.[13] In recent years there have been some huge fires in unsprinklered car parks, causing structural collapse, such as in Luton[14], Liverpool[15], Cork[16] and Stavanger airport[17]. None of these fires was started by EVs, nor did subsequent investigations indicate that EVs were a factor in them becoming so large. Firefighters were unable to prevent the development of these fires, even though at Stavanger airport an aircraft crash tender was used. When a car park fire is below a building in which people sleep, any fire spread to the rest of the building would present a severe risk to life, particularly if the building structure is weakened. In 2006 a fire in a car park below a care home in Bristol[18] in the UK spread up the outside of the building, entering at several levels and causing the death of one resident seated near a window, who was unable to move. The building was sprinklered, except for the car park. All the cars were destroyed but the fire did not penetrate past the first sprinkler on the residential floors. It was particularly disappointing that this car park was not sprinklered given that the rest of the building was protected. The cost saving in the sprinkler system was reportedly just £10,000.

There is already a strong case for fitting sprinklers in large car parks, before considering EVs.

Electric vehicle fires

While EVs reduce CO_2 emissions there are concerns about their behaviour in fire. Battery fires are very difficult to extinguish, with reports of reignitions 24 hours or more after the fire was thought to

[9] https://www.aria.developpement-durable.gouv.fr/accident/26176/
[10] https://www.ladepeche.fr/article/2004/07/15/257666-200-voitures-brulees-dans-un-feu-de-parking.html
[11] https://www.ditzingen.de/iframeFeuerwehr/ditzingenEinsaetze/ditzingen.de/dcm/admin/basic/content-management/document2d0d.html?document_id=A333637555621061
[12] https://www.sueddeutsche.de/wirtschaft/autos-wagen-werden-immer-breiter-1.3970552
[13] https://www.nfpa.org/News-and-Research/Data-research-and-tools/Building-and-Life-Safety/Modern-Vehicle-Hazards-in-Parking-Garages-Vehicle-Carriers
[14] https://www.bbc.co.uk/news/uk-england-beds-bucks-herts-67313813
[15] https://www.bbc.co.uk/news/uk-england-merseyside-46290095
[16] https://www.irishtimes.com/news/ireland/irish-news/up-to-60-cars-scorched-in-accidental-cork-car-park-blaze-1.4004015
[17] https://www.youtube.com/watch?v=-6juEM8UTsc
[18] https://www.ife.org.uk/Firefighter-Safety-Incidents/2006-monica-wills-house/41922

be extinguished[19,20]. Experts are asking questions about the peak heat release rate and fire growth rate of electric vehicle fires, as well as the probability of such fires occurring as they try to assess the risk these vehicles pose. RISE of Sweden reviewed available test data and found no difference in peak heat release rate or total heat released between ICEVs and EVs[21]. It also conducted its own series of fire tests, which confirmed this finding.[22] Other variables are the probability of a fire occurring and fire growth rate. Anecdotal evidence of ICEV fires unsurprisingly indicates that they are more likely in older vehicles. There are very few old EVs in circulation, so we do not yet know whether a 10-year-old EV is more likely to catch fire than an ICEV of the same age. Some claim that EVs are more likely to catch fire when under charge but RISE did not find evidence for that view[23].

While a fire in an electric bus in Paris in April 2022[24] was spectacular, developing extremely rapidly to engulf the entire bus and in an enclosed space would very likely have led to spread to other vehicles, there are plenty of incidents where fires in ICE buses or trucks in enclosed spaces also led to most or all the vehicles in the space becoming involved[25]. Until and unless an EV fire involves the battery, it will develop similarly to a fire in an ICEV, since similar material is burning (tyres, seats, bumpers, etc.).

By contrast tests and real incidents such as above have shown that battery fires can develop very rapidly[26] and so would generate sufficient heat to ignite another vehicle more quickly than a fire that starts in an ICEV, given that it takes some time before a plastic fuel tank fails. In testing the plastic tank must survive two minutes of direct fire exposure but in practice it takes some time before a fire in an ICEV grows large enough to attack the fuel tank.[27,28] Once the fuel tank ruptures for the first ICEV the resulting pool fire then can quickly involve other cars.

Considering that an EV fire involving the battery is likely to grow much faster than a fire in an ICEV and spread to other vehicles before firefighters arrive, the probability of EV car park fires becoming large may be higher than for ICEV fires.

When a car park fire spreads to multiple vehicles it can generate so much heat and such high temperatures that firefighters cannot get close enough to fight the fire. There is also a risk to firefighters of concrete spalling above them. Added to these risks to firefighters, EV fires can generate hydrogen fluoride and other corrosive gases when the batteries burn[29,30] and can release hydrogen and carbon monoxide which can explode[31,32].

---

[19] https://www.nfpa.org/News-and-Research/Data-research-and-tools/Building-and-Life-Safety/Modern-Vehicle-Hazards-in-Parking-Garages-Vehicle-Carriers
[20] https://patch.com/new-hampshire/nashua/tesla-vehicle-bursts-flames-second-time-week-nashua
[21] http://ri.diva-portal.org/smash/get/diva2:1522149/FULLTEXT01.pdf
[22] Drencher system tests – Comparing gasoline-fuelled and battery electric vehicles, M. Arvisdon, RISE, Fire Sprinkler International 2023, Amsterdam, June 2023
[23] https://risefr.no/media/publikasjoner/upload/2020/report-2020-30-charging-of-electric-cars-in-parking-garages.pdf
[24] https://www.ratp.fr/groupe-ratp/newsroom/bus/incendie-sur-un-bus-electrique-ce-matin-la-ratp-retire-temporairement-de
[25] http://news.bbc.co.uk/1/hi/england/gloucestershire/8560304.stm
[26] https://lithiumionsafety.co.uk/
[27] https://www.fireengineering.com/firefighter-training/vehicle-fires-plastic-fuel-tanks/#gref
[28] https://www.ri.se/en/what-we-do/services/fire-testing-of-plastic-fuel-tanks
[29] https://www.nature.com/articles/s41598-017-09784-z
[30] http://ri.diva-portal.org/smash/get/diva2:1522149/FULLTEXT01.pdf
[31] https://www.osti.gov/servlets/purl/1574807
[32] https://www.evfiresafe.com/post/electric-car-explosions

Sprinkler systems in car parks

Sprinkler systems are fitted in car parks to prevent spread of fire from the first vehicle to others. They also cool the first vehicle and limit the heat release rate from it. Sprinklers always complement the work of firefighters, and in a car park they enable firefighters to get sufficiently close to the fire to complete extinguishment. Occasionally sprinklers extinguish the fire but this is unlikely when cars are designed to prevent ingress of rainwater. Sprinklers cannot extinguish a fire in the battery of an EV, nor in the engine of an ICEV but they can slow development to external combustible parts of the vehicle, cool the gases released in the fire and wet adjacent vehicles to prevent fire spread to them.

Hydrogen fluoride is highly soluble so some experts have wondered to what extent the water from a sprinkler system could not only prevent fire spread but also wash out HF and other soluble, corrosive gases from EV fires. RISE of Sweden conducted tests but they were inconclusive on this point. Acidic gases hinder the approach of the fire brigade to complete extinguishment and remove the EV in which the fire began, although RISE has already shown from testing and simulations that maximum concentrations are 'relatively low'[33].

As discussed above, EV fires that involve the battery are likely to spread faster than ICEV fires. In the presence of a sprinkler system the faster a fire develops, the earlier the first sprinkler will operate. With the low ceiling height in a car park heat will quickly reach the sprinklers and they will operate well before the fire can spread to other vehicles.

Electric vehicle fires in sprinklered car parks

We only have a small number of anecdotal examples of EV fires in sprinklered car parks. Some of these fires did not involve the battery so may not be worst cases[34]. One that did involve the battery occurred in Germany in November 2021[35], where an EV was under charge and caught fire. The sprinkler system operated but was unable to prevent significant damage to three other vehicles. The EV where the fire began burnt out completely. Temperatures above that EV were high enough to cause minor spalling of the concrete ceiling. Yet the fire brigade was able to approach the fire to prevent further spread, and the car park did not suffer structural collapse as in the unsprinklered car parks of Liverpool, Cork and Stavanger when the fire started in an ICEV. The sprinkler system installed in this car park would have been designed in accordance with VdS CEA 4001, which applies the same OH2 criteria as EN 12845, i.e. an application density of 5 mm/min over 144 m^2 for wet systems. In Germany sprinklers are required in underground car parks and the fire brigade has stated that it sees underground car parks with EVs as no more dangerous than those with ICEVs[36].

[33] http://ri.diva-portal.org/smash/get/diva2:1522149/FULLTEXT01.pdf
[34] https://sprinkler.nl/sprinklers-controleren-brand-parkeergarage-epe/
[35] https://auto.oe24.at/thema/elektro-suv-vw-id-4-in-tiefgarage-ausgebrannt-370-000-euro-schaden/501045155
[36] https://www.feuerwehrverband.de/keine-erhoehte-brandgefahr-durch-in-tiefgaragen-abgestellte-elektrofahrzeuge/

Sprinkler system design for maritime vehicle carriers

There have been some high profile fires on maritime vehicle carriers, leading to major losses, including of the vessel itself. The European Union sponsored the Lashfire research project, which among its work packages looked at fire protection systems. RISE of Sweden conducted fire testing with EVs and trucks, showing that a conventional deluge system, such as has been installed for decades on vessels, could prevent fire spread between EVs.[37]

Sprinkler system design for electric vehicle protection in car parks

EV fires can reignite more than 24 hours after they appear to be extinguished. It may therefore be a good idea for a sprinkler system in a car park to have a fire brigade inlet connection, so that it can be supplied indefinitely with water.

We are unaware of any incident where a sprinkler system designed to OH2 for EN 12845 was unable to control a fire in an EV or an ICEV. There are many examples of such designs successfully controlling or even extinguishing ICEV fires in car parks[38,39]. Research by the Fire Protection Research Foundation identified higher fuel loads in modern vehicles but did not recommend changes to sprinkler system design[40]. No fire tests were conducted yet NFPA 13 subsequently cited the research as justification to increase the hazard category for car parks to its OH2, which is different from OH2 for EN 12845, increasing the typical application density from 6.1 mm/min to 8.1 mm/min. This change was not connected with the increasing presence of EVs in car parks.

While vehicle trends in the US and Europe are similar, vehicles remain larger in the US. State building codes also mandate sprinklers in car parks and mains water supplies typically have far greater capacity than in most European countries, being dimensioned for fire service needs. As a result a decision to increase the water demand by a third has relatively little impact on sprinkler system cost in the US, it still being possible to supply the system from the water main. However, in Europe a proposal to increase the hydraulic demand by almost five times to 12.5 mm/min over 260 m^2 would mean that far fewer systems could be supplied by the mains. A tank and pump not only significantly increase the system cost but take up valuable parking spaces. National fire safety regulators are aware of these issues, which increase their resistance to proposing that sprinklers be required in car parks. Several have even introduced requirements to fit sprinklers in enclosed car parks but reduced the hazard category for smaller car parks. Belgium is the latest country to do so[41], where EN 12845 OH1 or NFPA 13 LH and a 30 minute water supply are specified for car parks with compartments smaller than 1,250 m^2. Meanwhile there is anecdotal evidence that sprinkler systems designed to EN 12845 OH2 of CEA 4001 OH2 control fire spread from EVs.

In the absence of evidence that the current EN 12845/CEA 4001 hazard category of OH2 for car park sprinkler systems for EVs is inadequate, and with the peak heat release rate and fire load being similar for EVs and ICEVs, the EFSN recommends OH2 continue to be applied.

---

[37] Drencher system tests – Comparing gasoline-fuelled and battery electric vehicles, M. Arvisdon, RISE, Fire Sprinkler International 2023, Amsterdam, June 2023

[38] https://sprinkler.nl/sprinklers-controleren-brand-parkeergarage-in-eindhoven/

[39] https://sprinkler.nl/sprinklerinstallatie-controleert-parkeergaragebrand-arnhem/

[40] https://www.nfpa.org//-/media/Files/News-and-Research/Fire-statistics-and-reports/Building-and-life-safety/RFModernVehicleHazards-in-ParkingGarages.pdf

[41] https://www.ejustice.just.fgov.be/eli/arrete/2022/05/20/2022032282/moniteur

RISE of Sweden tested drencher systems on EV fires, simulating the situation on a maritime vehicle carrier. It found that drencher systems prevented fire spread between EVs just as well as between ICEVs.[42] Meanwhile in the US the Fire Protection Research Foundation began a project in 2021 that will also conduct fire tests with EVs under sprinklers[43]. The results from these and other projects will inform future reviews of this position paper.

Water mist system design for car parks

For many years VdS has offered VdS 3883-4 *Fire Test Protocol for Water Mist Systems Part 4: Protection of car garages*. The scope covers '*non-stacking garages, fully enclosed garages and underground garages' and 'is applicable for horizontal, flat ceilings with heights of 2m and above.*' As cars can vary, the VdS protocol requires a set of sprinkler reference tests for each water mist approval. Both systems are tested in a full-scale set-up above three cars. The central car is ignited and the water mist system passes when:

- *'The total averaged damage of the water mist test series is less than or equal to the total averaged damage of the sprinkler test series.*
- *The windscreens and windows of the two passenger cars are not damaged.*
- *The fire did not spread to other cars.*
- *The total average ceiling gas temperature of the water mist test series is less than or equal to the total average ceiling gas temperature of the sprinkler test series.'*

There is also a table with the maximum numbers of nozzles that can activate.

VdS 3883-4[44], is the basis for a future European standard, EN 14972-5, which is now being drafted.

None of the testing standards specifically reference EVs but as highlighted above, the intensity of an EV fire has not yet been shown to be more significant than an ICEV fire.

Conclusion

Sprinkler systems can prevent fire spread from the first to other vehicles in a car park. This applies both to ICEVs and to EVs. The fire brigade can then approach to complete extinguishment.

In the absence of evidence that the current EN 12845 hazard category of OH2 for fire protection of car parks fails to deliver adequate fire protection, and evidence that it does control fire spread in real fires, the EFSN position is that the design hazard category should remain OH2 under EN 12845.

For water mist systems, specifications should refer to VdS 3883-4 or EN 14972-5.

[42] Drencher system tests – Comparing gasoline-fuelled and battery electric vehicles, M. Arvisdon, RISE, Fire Sprinkler International 2023, Amsterdam, June 2023
[43] https://www.nfpa.org/-/media/Files/News-and-Research/Resources/Research-Foundation/Current-projects/ProjectSummaryEVParkingGarages.ashx
[44] https://shop.vds.de/publikation/vds-3883-4en