SCR108/19-R4

Extended report on the ventilation of enclosed car parks – *Electrically Driven Vehicles*

Introduction

In our report SCR105/19 we stated that still little is known and not a great deal of meaningful research has been undertaken or published and now, to some extent, the market place has become more concerning since the report's publication in August. This extended report includes much of the previous reports content, but now covers extracts from more recent research and published data from home and abroad.

In a 2018 article, the following words were attributed to Steven Risser, a leading expert in electric vehicle fire risk and senior research leader at Battelle, an American non-profit research establishment "A battery-powered vehicle having a fire incident is newsworthy. A gasoline-powered vehicle having a fire is newsworthy only if it stops traffic."

This statement may well be true, since electrically driven vehicles currently form a small proportion of vehicles on the road and therefore such a fire will attract attention. Also, due to the relatively few electric vehicles on the road, we have very little experience of what their potential hazards are.

This ignorance is widespread due to the lack of research and published information. Such lack of information will cause concern and alarm when incidents such as a vehicle fire occur and cannot be suppressed in the way that a "conventional" car fire can be tackled.

Fighting fires on electric vehicles require different skills from our fire fighters

With legislation in place stating that all new cars from 2040 onward must be electrically driven, information is needed now to ensure that regulation and guidance is in place to cope with the actual risks.

What do we know of research undertaken?

The short answer to this question is, very little.

We are aware of a significant amount of research work being undertaken to enhance safety and increase battery life, but what of the current hazards?

In our report SCR102/19-R27 we mentioned that the BRE research in 2010 into fire spread in car parks, undertaken on behalf of Department for Housing Communities and Local Government, had specifically excluded electrically driven vehicles. Consequently no knowledge could be gleaned of the potential risks of electrically driven vehicles.

In Norway, SP Fire Research, in cooperation with Skein Fire Department, the University College of Southeast Norway and Grenland Energy have undertaken full scale tests on two electrically powered vehicles. The objective of the tests were to establish whether a battery would ignite in a road traffic collision and how much water would be needed to extinguish a battery fire when the battery had reached thermal runaway.

The results of the Norwegian tests showed that when a test vehicle dropped from a 20m height to simulate a heavy collision, a large amount of smoke was first released from the battery. Approximately 7 minutes later, the vehicle caught fire and thereafter “burned freely”.

During the second test, the battery on a test vehicle was exposed to a high temperature flame from a propane burner with the intent to cause “thermal runaway” and then test for how much water was required to extinguish such a battery fire. However, thermal runaway under these conditions did not occur.

Whilst the Norwegian tests are certainly helpful in understanding some of the risks associated with electrically driven vehicles, further research is needed to fill the knowledge gap, particularly as the electrically driven vehicles are the fastest growing sector of the car sales industry, driven by concerns over combustion engine emissions and government subsidies in the form of lower road tax charges.

The answer to the question posed at the head of this section of the report is that we know very little of any research which has been, is being or may be undertaken.

Hazards within confined spaces

The greatest risk to the public will be within confined spaces such as enclosed or underground car parks.

The most serious concern is what impact such a potential fire could have within the confined space of an enclosed or basement public car park.

In guidance recently received, Tesla advise fire fighters that when a battery catches fire, is generating heat or emitting gases, use large quantities of water to cool the battery; they state that it can take around 3000 gallons of water applied directly to the battery to extinguish the fire. The guidance warns that battery fires can take at least 24 hours to extinguish. Once the fire has been fully extinguished, at least one hour must elapse and the battery completely cooled before the vehicle is released to second responders who should be warned that there remains the risk of re-ignition (see also "Thermal runaway & Re-ignition" below).

Tesla also advise that a damaged high voltage battery can create rapid heating of the battery cells and warn that a burning or "heated" battery releases toxic vapours.

Thermal runaway & Re-ignition

New Zealand fire fighters have reported that, once a fire has been extinguished, there can be a risk of electric vehicle batteries re-igniting up to 5 days later. If damaged, short circuiting can occur, creating a chain reaction referred to as a thermal runaway and burning at temperatures of up to 1000^0C.

Lithium-ion batteries may suffer thermal runaway and cell rupture if overheated or overcharged, and in extreme cases this can lead to combustion. When handled improperly, are damaged or if manufactured defectively, some batteries can experience thermal runaway resulting in overheating. Reports have even suggested that sealed cells could explode if safety vents are overwhelmed or non-functional (such as may occur in an accident).

Concerns about the risk of re-ignition have also been expressed by in the UK by police authorities responsible for roads policing and attending vehicle collisions and then safely storing vehicles that have been involved in an accident for evidence in possible court proceedings.

The risks associated with Lithium-ion batteries with thermal runaway, extreme temperatures in the event of fire and explosion has been taken seriously in Sweden. Research has been undertaken by the RISE Research Institute of Sweden sponsored by the Swedish Energy Agency and Swedish automotive industry through the Strategic Vehicle Research and Innovation programme. Their report acknowledges that the "most severe" challenge lies in extinguishing fire inside battery packs and thereby preventing propagation of thermal runaway between battery cells.

Seven tests were carried out on lithium-ion batteries to assess how effective strategically located mist and water spray suppression systems would be in suppressing a fire and preventing thermal runaway. There was some degree of success in the tests in reducing the extreme temperatures. The seven tests were carried out on battery housings which encased a number of "dummy battery modules" as well as active ones and the removal of all other combustibles except for the live battery modules

The test report states in its conclusion that it should be borne in mind "that without cooling of the battery and without flames, there is a risk that large quantities of flammable gas are released. If these gases accumulate in an enclosed space e.g. the battery compartment, there is a risk of explosion." There was no suggestion as to how much water was needed or how or where such a storage facility could be housed.

American Approach

Authorities, engineers and researches alike in the United States are taking the development of the electrically driven vehicle market very seriously, identifying many of the potential hazards associated with them. Some of the following is referred to in the NFPA 855 document.

Requirements for example state that a "hazard mitigation analysis" (risk assessment) must always be undertaken for any technology used, this could apply to a vehicle or its storage such as a car park. Concern is expressed that a fire and/or explosion exists where there is stored chemical/electrical energy and that the hazard created can vary by technology.

Particular concern is expressed by researches in connection to the danger to first responders in the event of an accident. Specific concern exists that over pressurization of the battery housing due to overheating may cause fire or explosion. There is also the unquantified hazardous levels of electrical energy on accident damaged vehicles, the shorting from damaged parts and the risk of exposure to electrical arcing.

In order to mitigate the identified risks, a number of steps have been proposed, including:

1. Steps must be taken to ensure that toxic gases are not be released in excess of permissible levels in order to limit the exposure to them by first responders and public
2. Trained first responders must have the correct PPE when approaching a damaged vehicle
3. Evidenced based data must be provided before the maximum allowable electric vehicle numbers are permitted in a car park, based on the floor area and proximity of cars to one another within the carpark
4. More research into vehicle impact studies
5. The collection and storage of used batteries should be classed as Industrial high hazard areas.

What are the emissions?

Car park ventilation schemes are designed to control both pollution caused by routine traffic movement and to clear smoke in the event of a fire. In compliance with current building regulations, for day to day pollution control ventilation, an air change rate within the car park of 6 air changes per hour is adopted and for clearing smoke 10 air changes per hour.

It is generally accepted that the emissions from an electric vehicle will be virtually zero or significantly lower than those emitted by a petrol or diesel powered car. However, one must assume that the vehicle must emit some gases whilst moving or even parked after being driven for a significant distance. The assumption that emissions will be insignificant and harmless may be correct, but it would be wise to confirm that this assumption is true and publish the data.

In larger enclosed and underground car parks, an "engineered" solution to the day to day ventilation system can be adopted. The basis of this engineered approach is to assess the level of pollutants

emitted. This assessment is currently based on the predicted level of traffic movement and the subsequent level of CO and/or NO_x gases discharged into the atmosphere within the car park.

It is quite common nowadays to see carbon monoxide sensors mounted on the columns of larger car parks which provide a signal to the ventilation system control panel which in turn will provide the correct level of ventilation to maintain a healthy environment.

As the expected mix of internal combustion engine and electrically driven vehicles will continue to weigh heavily in favour of the internal combustion engine, for some time to come, the currently adopted design criteria may be a safe option; however, at some stage the balance will change and more accurate information will be needed in order that those responsible for all aspects of public safety can respond appropriately.

The fire hazard

The most concerning issue relates to the potential fire hazard. Engineered solutions designed to control the flow of smoke in the event of fire rather than clear it from a car park are based on design fire loads. BS7346: Part 7: 2013 publishes a table listing suggested design fire loads, 4MW for a sprinklered car park and 8MW for unsprinklered. The air velocity through a fire zone would be designed to be in the order of 1.1m/s based on an 8MW design fire load.

From information collated to date, the characteristics and intensity of an electrically driven vehicle fire could be quite different to this published guidance. The potential severity of the ignition in a battery fire is significant along with the potentially increased rapidity in fire growth rate and fire spread. Current guidance of 10 air changes per hour or designing a system based on a 4 – 8MW design fire load may be totally inadequate for this new breed of car.

The ignition of a battery fire within a car park caught on CCTV

Probably one of the greatest hazard will be from worn or damaged batteries. With the cost of replacing and recycling batteries, both costs borne by the vehicle owner, there will be a real risk of some drivers, unable to afford the cost of replacement, running cars with damaged batteries which will consequently create an enhanced risk of fire.

Recycling issues

The information available so far suggests that there are still problems with the procedures for recycling electrically driven vehicle batteries. A combined report published by the universities of Birmingham and Leicester States that Britain faces a battery mountain due to the growing number electric vehicles.

The report says that the one million vehicles sold in 2017 alone will create 250,000 tons of unprocessed battery waste when they reach the end of their 10 year lifespan. Landfill is not an option for waste lithium batteries which are flammable and could release toxic chemicals.

It is also the responsibility of the vehicle owner to replace the battery and arrange for its disposal, the cost for both also being borne by the vehicle owner. The battery life is currently quoted as being between 5 to 10 years.

The risk here is that worn, tired or even damaged batteries could still be used within a vehicle; a damaged battery can be a serious fire hazard.

MOT Testing & Vehicle servicing

There are no special provisions within the MOT testing procedures for electrically driven vehicles short of a DVLA guidance brochure entitled "*Hybrid, electric and hydrogen fuel cell systems: guidance for MOT testers"* published in September 2018. It provides a glossary of terms used for the vehicles such as:
Hybrid *– Hybrid vehicles have 2 different sources of stored energy – usually petrol and electricity*
and
Electric vehicles *– These are stored by electrical power only*

Later in the document, it goes on to say:
Carrying out MOT tests *– You can't refuse to carry out an MOT test on one of these vehicles because you are unfamiliar with it*

The document goes on to refer to ***Driving and Powering down*****,** stating that *"the biggest danger in hybrids and electric vehicles is that the vehicle may start or move off causing injury or damage***,** and then says**,** *"if you are unfamiliar with the vehicle type, ask the customer to explain"***.**

This document can be downloaded by entering *hybrid & electric vehicle MOT guidance* in Google.

During our research, one garage owner saying that, in some cases, one cannot even get to the battery to carry out an inspection if an examination was required. All they can do is check the exposed wiring. Another said that, providing he had a colleague sit in the car with his foot on the brake during the MOT checks and he didn't touch any orange wires he was OK, but there was no additional checks to be made on an electrical vehicle.

This suggests that more detailed training is required for MOT examiners as well as increasing the scope of examinations required on this type of vehicle to avoid compounding a problem that may well develop on these types of vehicle.

Fire fighting

There are also potentially different challenges faced by fire fighters when tackling a fire in an electrically driven vehicle compared to internal combustion engine car; not least if the electrically driven vehicle is under charge.

- If there is a battery fire, access to the fire source will be more difficult and is likely to be more severe than a fire within a conventional engine compartment. It is also possible that the fire fighters will be faced by two types of car fire if the fire has spread to adjacent vehicles, as is quite possible in an unsprinklered car park.
- There is a danger of electrical shock due to the extremely high voltage used in this type of vehicle, which could be as high as 600V DC
- Exposure to unknown fumes given off in the event of a battery fire. More information is need here.
- Following a battery fire being extinguished, there is a real risk of re-ignition. As explained earlier in this report, re-ignition can occur even days after the initial fire has been extinguished. Removal of the car must therefore be handled with care and the vehicle should be removed to a safe place.
- Due to the risk of re-ignition, should the car park be closed until such time that it is considered safe to remove the car to a secure location
- Is there a risk to the public or the fire service personnel associated with electrically powered vehicle fires within car parks fitted with sprinkler systems

Conclusions

It is obvious that more information is urgently needed in so many areas to enable informed decisions to be made on what risks these vehicles pose to public safety, especially in confined spaces such as enclosed or underground car parks.

Once accurate information is available, risk assessments can be undertaken and the appropriate steps taken to minimise any identified hazards.

More information is needed for architects, consulting engineers, fire engineers, fire service and regulatory authorities, including guidance on universal signage for the location of charging points and training on how to tackle a battery fire on a multiple of vehicles

Even the basics still need resolving all of which impact on safety:

- The safe disposal or recycling of batteries
- National infrastructure for charging points on motorways, service stations and car parks which can at present result in dangerous queuing
- It is essential that an accurate forecast is made on the rate of growth of electric vehicles in order to enable an adequate charging infrastructure to be constructed and adequate safety provision made within new and existing car parks and around charging points.
- Different vehicles can currently require a different charging station, standardisation is needed.
- Explanation on charging rates, DC rapid DC fast DC Standard AC 3 pin 12 Hour AC 48 hour
- Noise generation on silent electric vehicles is being addressed by car manufacturers in order to improve awareness of pedestrians, especially those who are blind or have limited sight and rely heavily on hearing. The implementation of this being a requirement and not an option is urgently needed. Increasing driver awareness that they are driving a silent car is equally important.

With electric vehicles currently representing less than 1% of vehicles on the road and around 20 new models scheduled to be launched in the not too distance future, it is reasonable to anticipate a significant increase in that proportion of electric vehicles on our roads as public confidence in them grows.

Clearly, more research is needed and more clear information must be put into the public domain. It is government policy that all new vehicles are to be electrically driven by 2040, this is only 20 years away so there is no time to waste.