The risks of Lithium ion electric vehicles and considerations for the parking industry

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This article takes a brief look at various risk factors that may be considered when planning and operating the parking of Electric Vehicles (EV) with charging bays within MSCP and surface car parks.

My ongoing research is to seek to understand the elements involved with EV, to prepare for the requirements and precautions needed to attempt to evaluate the risks of fire, then to use this information to seek to provide workable solutions for prevention of fire, detection systems, provision of equipment and training programmes, selection of effective methods of containment, prevention of fire spread and ultimately extinguishing fires in car parking situations. To achieve this a fundamental understanding of the functionality of EV batteries, charging methods and rates, and moreover how to deal with malfunctions and accidents which can lead to a fire, all need to be compiled and evaluated. This study will evolve as new ideas, inventions and data are made available.

This discussion raises many questions; in 1972 Johnny Nash sang 'There are more questions than answers'. Just as true today as it was then, therefore we must choose our questions carefully.

Is it reasonable to charge EV with up to 750kw in carpark situation, where at present it is forbidden to fill a petrol tank?

Should information about every type of EV battery system be available on an internet data base for providers of parking and charging services, and their local fire brigade so relevant techniques can be employed in case of emergency?

Should there be a coded number or symbol placed on the EV registration plate similar to those used by commercial heavy goods transport?

Is there need for changes in MSCP design to accommodate the different added fire risks?

Should parking bay arrangements be organised to avoid or reduce the possibility of impact accidents within a car park?

Should more sophisticated, intelligent detection and alarm systems be employed where EV are parked in large numbers?

Because a fire in an EV may take up to 24 hours to be fully sure it is safe to move the vehicle, perhaps the parking bays in MSCP should be capable of being isolated so the car park does not have to close?

Worldwide, wildly differing estimates suggest there are well over 1 billion cars in use. Of these approximately 3 million are Electric or hybrid vehicles. Estimates of the availability of carbon fossil fuels suggest there is less than sixty years of oil and gas reserves, and, depending on which statistics we read there will be between 200 and 3,000 years of coal. These figures demonstrate several things. Firstly, all the statistics need careful scrutiny and interpretation, secondly, whatever figures we work with, they all lead to the fact that one day fossil fuels will not be available. Thirdly, the use of carbon fossil fuels may come to an end before the resources are fully used up; it has been said that the Stone Age did not come to an end because of a lack of stone.

These figures and consequent projections are used to promote the movement towards renewable energy, taxation on our 'carbon footprint' and the building of solar panel farms and wind powered generators, which at present show no possibility of providing the energy we presently consume. Whenever the oil and gas does run out we will have to rely on nuclear reactors or revert to coal, unless the renewable energy systems are vastly improved and become capable of producing all the power we currently need plus the extra load to make EV become truly viable. An eight hour charge for 1 billion cars requiring between 350kw and 750kw each will demand more generating capacity than we presently have.

Despite these difficulties more EV are appearing on the roads and the parking industry will need to catch up with the realities of charging these vehicles within their carparks, requiring not only large infrastructure changes but an awareness of the changing risks involved with the new systems and new EV energy technologies. http://www.ev-volumes.com has an article showing we are in an exponential curve which suggests by 2027 half the world's new car sales will be EV. The UK government has set goals to eliminate Internal Combustion Engines (ICE) by 2040, and governments around the world are proactively encouraging the use of EV, which, like a game of hide and seek, are coming, ready or not.

No matter what the growth rate of EV (Tesla alone are planning for half a million per year by 2020) the reality is car parks need to accommodate them, even though the fire risks are not fully known or understood. Statistics are unreliable or at worst manipulated to a point they are unusable. One example of this was a statement in a YouTube video (I round the figures here as an example) that 1 in 1,500 ICE cars are destroyed by fire compared to only 1 in 22,000 EV's. However, the ICE figures were arrived at including arson (depending on which country, this can be up to 60% of all car fires) and vehicles of all ages, over a period since records began, whereas the figures for EV's included a much lower percentage of arson (new cars are not usually burnt for insurance claims) and concerned much younger, higher end quality cars; the figures did not include the last three years which means the EV cars were all around 5 years old. The conclusion was forthrightly stated that EV are less likely to catch fire than ICE vehicles, which cannot be shown using data from entirely different types of vehicles and ages, even if EV are safer.

With great caution I have looked at the technical research available for the causes of fire in Lithium ion batteries, EV and possible ways to control any resulting fire in the environment of a car park. It is not possible for me here to enter into a full discussion of all the aspects of the science, legislation, economics and politics involved and can only present this overview which I hope will help to inform car park owners of the complexity of accommodating EV in carparks. An excellent article on the matters discussed here can be found at Sciencedirect.com volume 81. Part 1. January 2018. Pages 1427 – 1458.

An EV faces the biggest risk of fire from its batteries. Battery technology is improving all the time, with safety systems being added as fast as legislation is brought in to cover the new technologies, and vice versa. Charging controls and battery management systems are becoming more intelligent, the use of better fire calming chemicals within the battery compartments, including external intumescent barriers designed to resist thermal runaway and isolate the batteries from each other. Battery cooling systems have been installed to attempt to limit the chances of spontaneous ignition of the batteries, which in some cases can occur as low as 66.5°c.

Vehicle compartments are required to protect passengers from toxic corrosive fumes from the batteries which are vented into the atmosphere. Research is ongoing to find less flammable and toxic electrolytes, better anodes and cathode materials, improved battery venting systems and more efficient chemical screen barriers within the batteries which allow more efficient movement of the charged ions back and forth through the charging and discharging cycles, whist having a higher flash point temperature. Battery components are being designed to hold larger charges, yet the designs need to accommodate expansion of the battery. These advances clearly are reducing the risk of thermal runaway in batteries, and other advances in charging technology and car design are further reducing the risk of fire; but no technology will ever be perfect, and we have much to learn about the risks, which as yet are not fully understood or quantified. EV manufacturers promote their cars saying there are thousands of moving parts in ICE vehicles but only hundreds in EV; this is only true if you do not count the thousands of batteries that expand and contract with every charge cycle.

ICE vehicles have had 192 years of development (the first ICE was produced on the 1st April 1826) and much is understood about the fire risks they present. Methods of extinguishing ICE fires are well advanced and are still advancing, with new ideas about firefighting techniques and methodologies constantly being developed. Despite this, serious fire events continue to occur in car parks with devastating results, although these are rare. The unknown risks presented by EV are to be added into the methodology of risk assessments which must consider we have very little accurate data and even less information about how to deal with an EV fire event.

An example of the lack of general information is exemplified in the way we hear about the causes of thermal runaway, the composition of the batteries and the safety issues they raise. It was not easy to uncover a little-known fact that in some batteries the chemical composition can produce its own oxygen (not to be confused with Lithium Oxygen batteries) as the chain reaction within the battery proceeds once overheating and burning begins. This will contribute greatly to the problems of extinguishing such fires in battery systems using these chemical combinations, because they cannot be starved of oxygen, which is the main method of extinguishing a fire. This scenario may lead damaged batteries to reignite or continue to burn when there is little oxygen available. Thermal runaway causing batteries near to each other to reach critical ignition temperatures do not need to be punctured, because, as the flash point temperature is achieved the electrolytes will ignite which in turn can burn with the oxygen they produce within the battery. If an EV is damaged by impact, the control systems and intelligent battery management may be compromised and may lead to short circuits within undamaged batteries leading to a fire occurring long after the initial damage has occurred.

Other main causes of fire in EV occur during the charging process. Differing battery configurations require different charging rates. Each manufacturer installs systems best suited to their vehicle, all of which require different charging rates and power supply. Battery management is designed to prevent over charging, and some charging points will only allow an 80% charge. If any of these systems fail the battery pack is at risk of igniting. Unlike the batteries in our laptops and mobile phones, the batteries for EV should not be rapidly charged too often (only 10% of charges should be rapid), they should not be allowed to be fully discharged and will function longer if not charged to 100% frequently. If these guide lines are not followed, batteries become compromised, and as in ICE vehicles if the maintenance schedules are not followed the car becomes a higher risk.

With this bewildering array of facts, figures, science and commercial interests it is difficult to accurately evaluate the risk of fire in an EV, or more poignantly an EV being charged in a carpark. The conclusion must be that, whatever the chances are, we must expect there will be an EV fire event in our car parks and we must be prepared to deal with it when, not if, it happens.

At present many fire brigades are not fully equipped to deal with a fire resulting in thermal runaway, as was demonstrated at the scene of a fatal accident where the vehicle was left to burn out over a period of six hours, only to reignite on the recovery vehicle and then again 24 hours later (https://youtu.be/T3RNISfwa4E). The fire chief commented he was reluctant to pump the recommended 3,000 US gallons (11,370 Litres) or 11.37 tons of water into the car as he had concerns about possible dangerous pollution from battery chemicals being washed into the environment. Tesla cars have stickers inside the rear boot with instructions showing the main power delivery should be cut with a disc cutter in case of a battery fire. Firefighters either need to consult this information located inside a locked boot during a fire or have prior knowledge of how to deal with a fire in that particular vehicle.

Lithium is a metal which spontaneously ignites and burns fiercely when immersed in water, although few batteries now contain pure lithium. Experiments in extinguishing lap top fires by the Federal Aviation Administration (fire tests were simulated for commercial flights) show inert gas extinguishers are most effective if followed with an external dowsing of water to cool the appliance. Covering the lap top with a pile of ice causes reignition, thermal runaway and explosions. The FAA recommend any liquids from the drinks tray can be used except those containing alcohol. Carbon dioxide gas also can react unfavourably with various electrolytes; therefore, it is more effective and safer to use inert gases such as argon.

Following the loss of several aircraft, parcel delivery companies, who regularly use air transport for batteries are researching the use of an expanding mousse containing argon to smother battery fires, and along with the computer industry, the use argon gas extinguisher systems to protect against fires in computer centres where the equipment is highly sensitive and would be damaged by other fire extinguishing systems. These systems work by entirely displacing air (argon is roughly one third denser than air and naturally exists in our atmosphere) in a defined and sealed compartment; such as the hold in an aircraft. Whole rooms may be flooded with the gas, which raises concerns for staff safety as the gas, although not poisonous, does not support life and will kill a person rapidly by suffocation as it replaces available oxygen. For this reason, it is used in the poultry industry as it is not toxic and does not physically damage the birds, nor render them inedible.

The tragic loss of pilot's lives came about because the effects of thermal run-away risks were not understood; the resulting fires were in aircraft that had no efficient way to extinguish the fires causing the aircraft to crash. One example was UPS Airlines flight 6 cargo flight, 3rd September 2010, with the loss of two pilots. The head long pre-emptive rush into installing new technology does not always bode well. Legislation and certification always follow as technology progresses, testing can only simulate known possible scenarios, and the methodology of the tests can be directed by commercial interests. These sad lessons are there for us to learn from and serve to warn us of the possible foolishness of taking on board a new technology that is not yet tried and tested in the environment of MSCP as have been ICE vehicles, which have also devastated buildings and surface car parks.

As the car industry continues to seek ever more efficient EV, the technology will change rapidly. As with many past technologies, just as they are perfected something else totally unforeseen replaced them. With the discovery of metal, Stone Age spear makers lost their jobs, the VHS versus Beta Max debate was all in vain when digital storage, and now the internet is changing everything.

The parking community will eventually provide mass parking for EV and possibly be required to install charging posts without the technology being fully developed or its risks fully understood. I have not researched the cost of these installations and therefore have not made any consideration as to who will pay for what, but the costs of installation and upgrading power supply to carparks will also be a continuing issue for the carparking companies and owners.

There is much that is unknown and much to learn about the evolving EV technology and how to deal with the new challenges they bring for the parking industry, particularly in emergency situations; we need to inform and educate ourselves to answer the questions outlined above and develop solutions for fire containment and extinction of EV batteries. However, should someone find a way to split the water molecule cheaply, battery cars, along with fossil fuel cars, will be a thing of the past, not the future.

Notes (and some useful references) consulted for this article

NASA Safety Centre
Ventura Aerospace… First, Cargo Foam being an argon-generated foam is completely inert. Argon does not react chemically like other gases such as Nitrogen or CO2. This inerting http://venturaaerospace.com/how-fire-suppression-works/ Video – fire suppression test

NASA Lithium Prevent tm test
(Journal of The Electrochemical Society, 162 (9) A1905-A1915 (2015) A1905 Experimental Analysis of Thermal Runaway and Propagation in Lithium-Ion Battery Modules Carlos F. Lopez, a Judith A. Jeevarajan,b,∗,c,z and Partha P. Mukherjeea,∗,z))

Latest 2018 International Building Code requires Energy Storage Systems to have Thermal Runaway Containment
As renewable energy becomes more common, it is apparent that lithium battery powered energy storage systems present a significant fire threat. In response, the 2018 International Building Code requires an energy storage system to be able to contain a runaway lithium battery cascading event.

Several energy storage companies are UL tested and certified in accordance with UL 9540, but do not have a runaway containment certification.
Just recently, UL modified UL 9540 to include runaway containment, noted as UL 9540a. Energy storage manufacturers can now test in accordance with UL 9540a to be certified for runaway containment and achieve 2018 building code compliance.
Beyond this, it is widely anticipated UL 2580 and UL 1973 will also include UL 9540a, to test electric vehicles and repurposed batteries for use in energy storage systems. It is also expected that NFPA 855 will also include UL 9540a. To round out safety certification testing requirements, lithium battery packs should also exhibit resistance to an external fire, such as presented by a Class A fire. PyroPhobic System's Lithium Prevent™ offers a passive, intumescent composite module that has been proven to contain a runaway event to a single point and will protect lithium batteries from an external fire.

Timothy Riley provides PyroPhobic System's International Business Development since 2008. To learn more about Lithium Prevent please contact triley@pyrophobic.com.

Protec fire detection PC
EN/BS5839-1 recommendation.