Risk Control Guide

ELECTRIC VEHICLE CHARGING AND ENCLOSED CAR PARKS

Contents

Scope

This document is intended to provide initial guidance on electric vehicle charging and car parks. It is not a comprehensive loss prevention guide for which other documents such as NFPA 88A (Standard for Parking Structures) and Approved Document B: Fire Safety Volume 2: Buildings other than dwellings (Section 11) or local equivalents should be referred.

This guidance does not cover open, single level, car parks, where typical arrangements are considered lower risk provided chargers are located away from buildings, important equipment, hazardous areas, etc.

Introduction

Electric Vehicles and Charging

The emerging risk and increased use of electric vehicles and associated charging equipment has led to a need for guidance on management of the associated risks, but clear guidance, regulations and legislation are not currently available.

There are concerns over potential increases in fire severity, duration and frequency associated with the increased use of electric cars and vehicle charging equipment within car parking facilities. However, it remains uncertain whether the increase in electric vehicles and charging equipment will notably increase the fire risk and/or frequency.

Electric vehicles do present a new hazard due the presence of Li-ion batteries in these vehicles. These batteries can be subject to thermal breakdown (thermal runaway), for which there is no effective extinguishing method, given the energy and oxygen for the event are present within the battery. Whilst the peak in the heat release rate of ICE (Internal Combustion Engine) vehicle fires is likely due to the involvement of fuel (diesel/petrol), an electric car battery thermal event can last for many hours or until the energy in the battery is used up. However, note that the total heat of combustion for electric vehicles remains similar to that of ICE vehicles.

There is a potential further hazard associated with electric vehicles, as a battery thermal runaway event may release toxic gases from the battery, plus there is the potential for additional electrical hazards compared with petrol/diesel vehicles.

Car Park Fire Loading (Electric and Petrol/Diesel Vehicles)

There is evidence that modern vehicles present an increased fire hazard than vehicles on which the existing fire standards for car parks are based, due to an increased fire loading. This has been driven by several factors such as:

- A desire for lighter, cheaper and less corrosion prone materials, such as the use of plastic materials for bumpers and bodywork.
- An increase in the use of softer and padded materials for interior crash protection, comfort, and noise reduction, such as plastic and foam interior materials.
- An increase in electronics and associated equipment, which increases the fire load and potentially increases the chance of an electrical ignition source.

The increase in plastic content means that vehicles are now (2019) estimated to contain around 50% plastics. This plastic content continues to increase with one estimate stating an average car will have 350kg of plastic in 2020 compared with 200kg in 2014.

There is some evidence that this increase in fire load is having an impact in vehicle fire hazard. One study in 2015 looked at parking garage fires between 1995 and 1997 and between 2010 and 2014. This study showed that 2% of the fires in the earlier period involved more than 3 vehicles, whereas 8% of the fires in the later period involved more than 7 vehicles. Additionally the time to extinguish fires increased, with 95% of fire extinguished in less than 60-mins in 1997 compared with 40% between 2010 and 2014, and less than 1% of fires taking longer than 2-hrs to extinguish in 1997 compared with 30% between 2010 and 2014.

There have been incidents of large fires in car parks that have caused severe damage to the buildings and parked vehicles, such as (**Note these were not caused by Li-Ion Batteries**):

- The Kings Dock Car Park fire in Liverpool on 31st December 2017 where a fire in (non-electric) vehicle spread to approximately 1,150 vehicles and destroyed the car park structure.
- Grezenbach, Switzerland on 27th November 2004 when the concrete ceiling or a parking garage collapsed trapping seven firefighters who were killed in the incident.
- Douglas shopping Village Shopping Centre in Cork, Ireland when a vehicle fire spread to around 60 cars despite early identification of the fire.

Some fire protection sprinkler standards for car parking have been revised with increased recommended discharge densities in recent years.

Furthermore, recent car park fires (such as the multi-storey car park fire in Kings Dock, Liverpool, in 2017) suggest that previous assumptions regarding the low likelihood of fire spread between car park floors may now be incorrect. Increased vehicle fire loads and changes in car park design, such as lower ceiling heights, and floors laid to manage rainwater increasing the risk of burning fuel flow, may be factors affecting fire performance.

Guidance

Vehicle Charging Location

Locate electric vehicle charging points where the chances of effective manual firefighting are maximised, and the chances of fire spread and damage minimised. Ideally chargers should not be in underground car parks, and if this is unavoidable then provide adequate sprinkler protection and/or effective fire separation to reduce the potential for fire spread between vehicles.

Locations of vehicle charging are listed below in order of preference. As an example, locate charging equipment on unenclosed roof areas in preference to lower enclosed floors, and with 100% underground car parks place close to building entrances if installation of chargers cannot be avoided.

Locations of vehicle chargers in order of preference:

1. External charging points away from buildings and equipment, such as within secure, outdoor, open, areas.
2. Detached, low value, buildings.
3. Unenclosed roof levels of multi-story car parks (within hose stream reach or accessible to fire tenders).
4. Aboveground sprinklered carparks.
5. Aboveground levels of open sided car parks where firefighting hose streams can reach (typically within 15-m of external ground floor level).
6. Ground floor levels of enclosed car parks within access of firefighting hose streams from building entrances. (i.e. external firefighting is possible).
7. Aboveground level of enclosed car parks within access of firefighting hose streams from safe access points
8. Belowground level areas with adequate automatic sprinkler protection.
9. Belowground level areas with 120-min fire separation from other areas, including automatically closing fire shutters or doors at access points to the charging areas (including vehicle access points) and minimum 120-mins structural integrity
10. Belowground level area with no fire separation or sprinkler protection but with minimum 120-min fire integrity (this offers no fire control and is undesirable).

Charging equipment should be located on a raised island (minimum 100-mm) and should be protected against impact damage by kerbs, bollards, or metal barriers.

Vehicle Charging Separation

Maximise the separation distance between vehicle charging bays, with 5-m minimum separation distance ideal. When 5-m is impractical, then provide a minimum addition of 1-m separation above standard vehicle parking bays sizes for vehicle charging bays.

Preferably provide fire rated separation from and between charging bays. If possible, provide 120-min fire separation (e.g. concrete or brick wall). A 60min fire wall (e.g. twin-skin plasterboard wall) would be beneficial if it can be sufficiently robust or protected from impact. Provide the fire separation on three sides of the vehicle bay, it is recognised that a fire door or shutter at the vehicle access/egress side is unlikely to be practical but would be preferred.

Ensure that combustible or flammable materials, such as storage, waste materials, etc., are not kept near (within 10-m) of chargers and vehicles on charge.

Fire Separation (Electric and Standard Vehicles)

Provide minimum 120-min fire separation from car parks to areas of differing occupancy. For larger car parks, separate into smaller areas with 120-min fire separation.

Provide below grade areas (without adequate sprinkler protection) with 120-min fire separation between groups of vehicles (both electric and standard), with the maximum group size minimised, plus minimum 120-min fire integrity to structural elements. Provide the separation on three sides of each group with only the vehicle access route unprotected. Evaluate the maximum group size on a case by case basis. Note unsprinklered below grade areas are the least desirable situation for car parks and may not be an acceptable arrangement.

Floor Slopes

Ensure floor slopes are arranged to prevent burning fuel spills compromising the fire separation, flowing past walls or allowing rapid fire to spread between vehicles and/or floor levels (for hybrid electric vehicles or standard vehicles exposed by the original fire). Adequately sized and arranged drainage is an alternative to floor slopes to control the flow of liquids.

Building Structure Fire Resistance

Provide minimum 120-min fire resistance integrity for all car parks, including structural members, floors, ceilings, and side walls.

Fire Protection

Vehicle car fires will spread between cars when sprinkler protection is not provided, therefore prioritise the provision of sprinkler protection to prevent an uncontrolled fire. This applies to below-grade, enclosed and open-sided car parks.

There may be potential for manual control of a fire, but only if rapid and effective response from the fire department occurs and they have safe access for firefighting and adequate water supplies. Effective firefighting is less likely to be possible in enclosed and below grade car parks, so sprinkler protection is considered an even higher priority in these locations. Below grade areas are especially challenging for manual firefighting.

Sprinkler standards design densities for carparks may be inadequate for preventing fire spread between modern vehicles under some conditions, due to increases in vehicle fire loads since they were originally developed. Note that some fire protection agencies have increased their recommended sprinkler densities in recent years and the NFPA are considering increased densities. Existing specifications include:

- LPC: Ordinary Hazard 2 – 5-mm/min over 144-m^2 (180-m^2 dry systems)
- NFPA: Ordinary Hazard 1 – 4.1-mm/min over 370-m^2 (480-m^2 dry systems) to 6.1-mm/min over 260-m^2 (338-m^2 dry systems).
- FM: Hazard Category 2: 8-mm/min over 230-m^2 (300-m^2 dry systems).

Use the following design densities for new installations and review existing protection systems for potential upgrades. The following are considered more likely to be adequate for preventing a controlled fire involving modern vehicles:

- LPC: High Hazard Process 1 (HHP1): 7.5-mm/min over 260-m^2 (350-m^2 dry systems).
- NFPA: Extra Hazard Group 1 (EH1): 8.2-mm/min over 465-m^2 (605-m^2 dry systems) to 12.2-mm/min over 230-m^2 (300-m^2 dry systems). *Note this is more onerous than the LPC and FM designs chosen but the next occupancy protection level down (OH2) is considered potentially insufficient.*
- FM: Hazard Category 2: 8-mm/min over 230-m^2 (300-m^2 dry systems).

Fire Detection – General

Install fire detection per BS 5839-1, or local equivalent, unless an automatic sprinkler protection system is installed. Point detection using multi-sensor heads should be provided. A P1 system to BS5839 or equivalent should be provided. Include smoke detection and ensure the type and settings avoid false alarms from standard vehicle exhaust fumes, multi-sensors are likely to be most appropriate.

Manual call points should also be provided ensure that the fire alarm can be activated manually.

Link the fire alarm to a permanently attended location from where a response can be arranged, and the fire department called.

Fire Detection - Charging Areas

Provide fire detection in charging areas regardless of the presence of fire protection sprinklers, to aid in the early identification of smouldering faults or vehicle fires. Include smoke detection and ensure the type and settings avoid false alarms from standard vehicle exhaust fumes, multi-sensors are likely to be most appropriate.

Provide flame detection for unenclosed roof area charging locations where there is potential for fire spread between vehicles.

Link the detection to isolate the power to vehicle chargers and to a constantly attended location from where a rapid response can be raised, and the fire department called.

Fire Brigade Response and Access

Complete pre-planning with the local fire department at annually.

Develop site plans for the fire department and ensure they are provided to the fire department prior to attending any incident. Include the following in the plan:

- Access routes for firefighters.
- Locations of electrical shut-off switches and other electrical isolation points.
- Locations of the nearest hydrants, and wet/dry riser connections.
- Layouts for each floor.
- Details of fire protection systems.

Ensure safe access for manual firefighting, if this is not available then provide sprinkler protection (always provide sprinkler protection when cost justified or required for local regulations regardless of safe access).

Water supplies for manual firefighting

Ensure hydrants or an alternative water source for reliable fire brigade pump suction is provided. Ensure sufficient water is provided for taking suction at a minimum of 1,900-l/min at 1.5-bar, within 90-m of all areas or closer if required by local regulations or the local fire department.

Ensure water supplies are sufficient for prolonged cooling of the vehicle battery, as batteries can burn for a prolonged period. 24-hrs water supply for battery cooling should be provided.

Manual Firefighting Equipment

Focus on sprinkler protection, rapid fire identification, fire department call out and response.

Vehicle fire blankets are beneficial for suppressing vehicle fires, consider their provision for charging locations by competent people. They will not extinguish a battery thermal event, which can continue without oxygen but can suppress a vehicle fires under some circumstance and therefore stop or delay fire spread between vehicles. Competent / trained people should be trained in the use of the blankets.

Where fire extinguishers are provided, then CO_2 or dry powder extinguishes are appropriate, but will not extinguisher a battery thermal event.

Smoke Control / Ventilation Systems

Ensure ventilation systems comply with BS7346: Part 7: 2013 (Design of car park ventilation systems for a fire condition) and Approved Document B, or local equivalent and are agreed with the local fire department as part of a strategy for fighting fires manually.

Li-ion batteries do not discharge gas under normal conditions, but nonetheless adequate ventilation is needed to ensure batteries are kept cool during charging and fumes/gases released during battery thermal runaway conditions are removed sufficiently to assist with manual firefighting. Ventilation may need to be mechanical, especially for removal of gases discharged by thermal runaway of batteries in enclosed or below grade areas.

Provide mechanical ventilation for enclosed car parks designed to provide at least 10 air changes per hour during a fire (additional ventilation rates may be needed), linked to activate on fire detection. Ensure the system has an independent power supply. Provide outlets that are split between high and low level (circa 50% high and 50% low).

If the car park is defined as ‘open’ per local legislation, then still consider mechanical ventilation for Li-Ion battery thermal events, to ensure sufficient ventilation is provided to remove vent gases etc.

Any ventilation system must not affect the adequacy of sprinkler system due to delated activation of fire protection. Refer to the appropriate sprinkler system for guidance.

Vehicle Charging Installation and Safety Devices

Ensure charging equipment is installed by a competent person, for example those recognised by National Inspection Council for Electrical Installation Contracting (NICEIC) or local equivalent.

Ensure electrical supplies for charging are suitable for the purpose and electrical load and are dedicated for the chargers.

Provide emergency isolation switches for vehicle charging in a location where they can be accessed in an emergency, such as manned locations or building entrances.

Ensure activation of the fire alarm and sprinkler systems isolates electrical supplies to chargers.

Ensure charging installations are installed and used in compliance with manufacturers recommendations and local legislation. Ensure charging units limit charging to 80% of full-battery charge and do not operate if vehicle battery management systems have indicated a fault condition.

Locate power cables feeding charging units in metal trunking, steel conduit or underground ducting.

Provide RCD protection and ensure it will activate for AC and DC fault currents.

Provide clear notices at charging points that indicate which vehicles can be charged. Ensure rapid chargers are clearly differentiated by signage from conventional chargers.

Refer to the IET Code of Practice on electric vehicle charging equipment installation for further details of charging point installation requirements.

Provide protection against deliberate damage, such as enhanced security (e.g. CCTV) where appropriate.

Maintenance

Ensure the chargers and charging equipment are maintained in accordance with manufacturers guidance.

Complete the following inspections on chargers and associated equipment and keep records to allow auditing:

- Weekly visual inspection noting damaged cables, chargers, etc. Remove damaged equipment from use until repairs are made and ensure equipment is isolated (e.g. isolation/lock-out procedure) where needed.
- Annual electrical inspections, or more frequent inspections if deemed necessary by risk assessment.
- Annual infra-red inspections. Ensure this is done after equipment has been performing charge operations for a continuous period of at least 60-mins.
- 3-yrly fixed wiring inspection, or local equivalent.

Provide physical steps to ensure vehicle charging leads are maintained in good condition.

Ensure fire protection and detection systems are maintained in line with local standards.

Any portable electrical equipment should be periodically inspected at a period in line with a risk assessment.

Staff Training

Train car park staff and local personnel such as building management and maintenance personnel to ensure they are aware of actions that should be taken in the event of a fire, including ensuring that charging shut-down has occurred.

Fire Risk Assessments

Complete fire risk assessments and include consideration of the passive, active and procedural items included in this document and any other mitigation measures that might be needed.

Technical Information / Glossary of Terms.

Thermal Runaway

Batteries can fail in an uncontrolled manner leading to thermal runaway. Thermal runaway is rapid self-heating caused by exothermic reactions between battery components, normally following short circuiting between electrodes. The cause is usually due to manufacturing defects or abuse rather than poor cell design. Typical causes include:

- Thermal abuse, such as exposure to fire.
- Mechanical abuse, such as impact damage.
- Electrical abuse such as overcharging, external short circuit or over discharge.
- Internal cell faults such as presence of foreign metallic particles or poor electrode alignment.
- Failure of battery management systems.

The high energy density of battery cells and presence of combustible electrolyte mean a thermal runaway event can be a very energetic event. The severity will be greatest when the cell is fully charged (or over charged) but even fully discharged Li-ion cells contain the combustible electrolyte. Cells with higher charge levels do present a significant higher energy content and risk of thermal runaway.

Thermal runaway leads to an increase in internal cell temperature and pressure that can lead to the cell venting, and ignition of vented gases that can propagate to adjacent cells. Cell contents can be ejected if sufficient venting is not provided (e.g. vents do not open properly or are obstructed) but vehicle battery design means this is unlikely given the cells are located in protective cases.

Gases vented from the cell will vary with cell chemistry but will likely be flammable and toxic (such as hydrogen fluoride (HF)).

Commodity Classification

There are currently no publically available large-scale fire test data for vehicle Li-ion electric batteries and commodity classifications are currently not defined in fire protection sprinkler standards.

Charging Types:

- Slow charging (3kW): Most suited to home or office locations where charging times can be extended (e.g. overnight or all day) or where topping up charge. A vehicle charge from flat to fully charged would typically take around 8-hrs.
- Fast charging (7-22kW): Typically, public charging stations. A vehicle charge from flat to fully charged would typically take around 3-hrs to 4-hrs.
- Rapid charging (43-50kW): Less typical and many electric vehicles are not compatible, allow charging to 80%. A vehicle charge from flat to 80% would typically take around 30-mins.
- Super charging (150kW): There are reports these are being launched at some filing stations. A vehicle charge from flat to 80% would reportedly take around 10-mins.

Batteries and Cells

A Li-ion cell is an electrochemical unit that contains electrodes, separator, and electrolyte. There are alternating layers of anode and cathode materials separated by a porous film (separators) within the cell.

A Li-ion battery or battery pack is a collection of cells or cell assemblies, with housing, electrical connections, and possibly electronics for control and protection.

Chemistry

Chemistry of the Li-ion batteries varies, and development continues.

Lithium nickel magnesium cobalt oxide (LiNiMnCo02 or NMC) and derivatives are widely used as the positive electrode for electric vehicle li-ion batteries.

Graphite is commonly used as a negative electrode.

The electrolyte is typically a mixture of organic carbonates (such as ethylene carbonate) and complexes of lithium ions.

The Li-ion cell works by electrochemical reactions in the materials of the anode and cathode. During discharge oxidation occurs at the anode to produce positively charged lithium ions and negatively charge electrons, the ions travel through the electrolyte and electrons through an external circuit. They then recombine at the cathode (together with cathode material) in a reduction reaction. During charging the reactions and flow of charge is in the opposition direction.

Electric Vehicle Types:

Hybrid Electric Vehicle (HEV): A vehicle that combines an electric propulsion system with an internal combustible engine. Typically, there is a form of capturing the vehicle's kinetic energy, for example via a braking system, and storing that energy in a battery before using it in a n electric drive system to compliment the combustion engine propulsion.

Plug-in Hybrid Electric Vehicle (PHEV): A hybrid electric vehicle whose battery can be charged by plugging into an external power source.

Purely Electric Vehicle (EV): A vehicle that uses an electric propulsion system powered mostly commonly from Li-ion batteries.

Lithium-ion battery (or Li-ion battery)

A type of rechargeable battery commonly used for electric and hybrid electric vehicles. Lithium ions move from the negative electrode through an electrolyte to a positive electrode during discharge, and back during charging. The electrolyte can be combustible and if the cell is damaged or incorrectly charged thermal runaway can occur that can lead to fires.

Open car park

A car park with natural airflow for ventilation via open sides, so the space is similar to outdoors. A percentage of openings in walls is used to define the change to an enclosed car park. For example (varying depending on local legislation) an aboveground car park with open sides with aggregate vent area not less than 1/20th of the level's floor area, of which at least 50% (1/40th) must be equally provided by two opposite walls.

Further Information

References

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