**CAA Electric Vehicle Response Guidance**

**1. Introduction**

 1.1 With the growth in environmental awareness and the move to zero emissions, the use of Electric Vehicles & Hybrid Vehicles (EVs & HEVs) and e-Ground Service Equipment (e-GSE) at aerodromes is increasing.

1.2 Voltages present in EVs & HEVs are significantly higher, up to 800 Volts direct current (DC), than those used in other vehicles (12/24 Volts DC).  Accidental contact with parts that are live at voltages above 50 Volts DC can be fatal.  For EVs & HEVs DC voltages between 60 and 1500 Volts are referred to as 'high voltage'.  The term “high voltage” is defined differently in other industry sectors.

1.3 Batteries experiencing an abnormal thermal event may produce harmful chemicals, in both vapour and liquid form. Large amounts of toxic, flammable vapour can be produced, which can give rise to deflagration (vapour cloud explosion).

1.4 Manufacturers’ EV & HEV designs differ substantially, and the related technology is evolving continually. Aerodrome Operators should consider having information specific to the make and type of EV & HEV used at their aerodrome, in the form of the Emergency Response Guide (ERG).

1.5 It is imperative that RFFS crews are aware of the risks and hazards posed by EV & HEV when responding to incidents involving such vehicles.

## **2. Types of vehicles**

### 2.1 Electric Vehicles (EVs)

2.2 Electric Vehicles use a large capacity high voltage Traction Battery and electric motor(s) to drive the vehicle.  Whilst some energy is recovered during braking (regenerative braking) the Traction Battery needs to be regularly charged from the electricity supply network when the vehicle is not in use. Charging can be Slow, Medium or Fast.

### 2.3 Hybrid Electric Vehicles (HEVs)

2.4 Hybrid Electric Vehicles have two forms of propulsion, an internal combustion engine using either diesel or petrol for fuel, and an electric drive motor powered by a high voltage battery. Hybrid Electric Vehicles will use the two sources of propulsion, switching between them automatically based on demand.  Energy recovered from the vehicle braking systems (regenerative braking) is used to charge the high voltage battery.

2.5 As well as from regenerative braking, a Plug-in Hybrid Electric Vehicle (PHEV) can also have its high voltage battery charged directly from the electrical supply network.

## **3. Risks Associated with Responding to EV & HEV Incidents**

3.1 Such risks include but are not limited to:

* Difficulty in initially identifying the vehicle as EV & HEV and obtaining the correct information, in the form of an Emergency Response Guide (ERG).
* The presence of high voltage components and cabling capable of delivering a fatal electric shock, potentially when damaged during collision or fire.
* The storage of electrical energy with the potential to cause high voltage arc or fire.
* Components that will retain a dangerous high voltage even when a vehicle is switched off or Isolated, called Stored or Stranded energy.
* The potential for the release of toxic vapours, which are flammable and potentially explosive, and also harmful liquids (acids & alkalis) if batteries are damaged and/or heated.
* When electrically driven, EVs & HEVs are silent in operation. This could cause responders to be unaware that a vehicle is moving.
* An electric vehicle may move unexpectedly, rapidly due to the high torque of the drive motor/s.

**4. EV & HEV incident hazards:**

4.1 Hazards may include but are not limited to:

* Difficulty in identifying the individual batteries or battery groups that are involved within the Traction Battery.
* Overheating due to thermal runaway - an accelerating increase in temperature caused by chemical reactions, which may lead to fire, explosion, the pressurised release of highly flammable organic electrolyte and unpredictable fire behaviour.
* Difficulty in accessing traction batteries due to their location and therefore hampering the RFFS’s ability to effectively cool affected batteries.
* The reignition of batteries, even after prolonged periods.
* If the flammable vapours are confined and reach their Lower Explosive Limit (~6-11%) the risk of vapour cloud explosion increases.
* Extinguishing flames without continuing to remove heat may move the hazard from a fire to an explosion, the vapours can auto ignite, with no warning.
* Intense, directional and sustained flames can be experienced along with the hazards posed by debris being projected as the traction battery is compromised.
* Contaminated firefighting media run-off.

**5. Operational Considerations:**

5.1 Operational considerations include but are not limited to:

* Deciding on an offensive or defensive firefighting mode depending on risk to life, property and environment. RFFS crews may be faced with 2 options – if there are no exposures then let it burn out, or to attempt to contain and suppress the fire. The option chosen may depend on the type of vehicle involved and the need to protect the surrounding area.
* Treat as a Hazmat incident, establish a ‘Hot zone’ cordon, based on any vapour cloud, the wind direction and ground slope.
* Identifying the type of Electric Vehicle - vehicle markings, vehicle responder information, discussion with driver, presence of orange cables (this colour is not standard however) and HV components.
* Assess the vehicle for both damage (following RTC) and/or abnormal thermal activity – overpressure/whistling noises, popping, off gassing of vapour and directional flames emitting from the Traction Battery (can be inside or underneath the vehicle). Use a Gas Monitor at all times – carbon monoxide is understood to be an early gas released.
* Use of Thermal Imaging Cameras (TIC) - with difficult access to and difficulty of viewing the Traction Battery, which can be shielded, the monitoring of temperatures will be less indicative – the other more obvious signs and symptoms will be evident.
* Immobilise the vehicle – without approaching in front or behind the vehicle (risk of unexpected propulsion) approach at 45 degrees and chock the wheels, place in park and apply parking brake.
* Isolate the High Voltage only by the emergency disconnects (LV) if fitted (refer to ERG) – Responders MUST NOT touch the Manual Service Disconnect (MSD) or ‘orange plug’, as this is HV and requires specific training and HV PPE.
* PPE & RPE – many chemicals may be generated during an EV & HEV abnormal thermal event and/or fire, full fire kit and Respiratory equipment (VOC filters) must be worn.
* Overpressure and vapour release noises from battery packs should be monitored. Li-On battery fires may produce between 500 - 6000 L/kWh of vapour up to 50% of which may be hydrogen, as well as other toxic and flammable gases.
* The extended time likely to be required to contain and suppress EV & HEV fires.
* Depending on tactics, the resources required to manage an EV & HEV incident.
* Current NFPA research has stated that EV & HEV fires do not require special equipment for fire suppression, however emerging good practice includes the application of vehicle fire blankets for containment of the radiated heat and reducing the vapour plume/cloud, and underchassis misting for effective cooling, absorbing radiated heat, with minimal runoff.
* Use of piercing firefighting tools causes physical damage to batteries and could make a situation worse, initiating thermal runaway in previously unaffected cells/pouches. Due to evolving Traction Battery design, with compartmentation and ‘potting’ to limit heat propagation and cascade, ‘circulating water through a battery pack’ is unlikely achievable. Water is also likely to cause short circuits in the battery pack. Using high pressure water systems to ‘disrupt’ the battery pack may remove the fuel path and stop propagation or cascade.
* Submersion is no longer favoured – manufacturers’ ERGs warn against this. Water ingress into batteries causes short circuit, hydrolysis and thermal runaway. Large volumes of contaminated water are difficult to deal with.
* The need to contain fireground runoff and consider likely ground contamination.
* An EV must not be pushed or towed as the drive motor acts as a generator, producing HV electricity that may cause issues.
* Post incident management should be conducted in liaison with responding emergency service colleagues and vehicle recovery companies, with effective Handover of information between agencies – especially regarding residual risks. The vehicle and any waste (burned batteries) are contaminated waste and will still have residual risks – stored energy, risk of reignition and hazardous chemicals (acids/alkalis). Appropriate PPE, RPE, containment, packaging & labelling must be adhered to throughout recovery, transportation and storage.
* Decontamination – treat all PPE and RPE as having ‘surface contamination’, bag at scene and arrange for cleaning, normal advanced cleaning of PPE is currently deemed sufficient for the known chemicals involved in LiB/EV fires. Use decontamination wipes for personal hygiene immediately and ‘shower within the hour’.

**6. Training**

6.1 RFFS training programmes should include but are not limited to:

* Awareness of the range of Electric Vehicles operating at their aerodrome.
* How to recognise the types of Electric Vehicles operating at their aerodrome.
* Use and interpretation of manufacturers’ Emergency Responder Guides (ERGs).
* Tactics and techniques required when responding to EV & HEV incidents.
* The use of suitable equipment to deal with EV & HEV incidents.
* Use of gas monitors to provide early detection of vapours, potentially invisible in the early stages.
* Understanding the risk of stored, stranded or residual energy (DC voltage).
* Awareness of the potential for battery re-ignition, at scene, during recovery, transport and storage.
* Use of Thermal Imaging Cameras, and their limits.
* Awareness of the resources that may be required and the time that may be needed to deal with protracted EV incidents.
* Use of appropriate PPE & RPE.
* The use of Hot zone cordons – ensure no persons are near the toxic vapour without PPE & RPE.
* Immobilising an Electric Vehicle where safe to do so.
* Awareness of high voltage systems, components and cable routing within an Electric Vehicle.
* Containing firefighting runoff and liaison with environment agencies/on-site teams.
* Access to battery packs and applying cooling or absorbing radiated heat.
* Knowledge and understanding of the risks and hazards posed by the products of thermal runway and EV fire behaviour.
* Liaison/handover with Local Authority Fire & Rescue Service colleagues and use of specialist officers (Hazmat).
* Tactics and techniques for dealing with Electric Vehicle fires where the vehicle is plugged into a charging point – isolate the charging infrastructure first.
* Liaison/handover with vehicle recovery operators – avoiding pushing or towing an EV, and the likely need for specialist recovery equipment such as Containment Units.
* Awareness of the added weight and low centre of gravity of EVs when involved in RTCs and during movement, recovery and transportation.
* Awareness of the potential for rapid fire spread, due to intense, localised directional flames and radiated heat where other vehicles, buildings or combustible materials are in close proximity.

**8. Bibliography**

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