Incidents Involving Electric Vehicles

Fire Service College National Challenge 2015

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Operational Guidance - Incidents involving Electric Vehicles

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**Incidents Involving Electric Vehicles**

**Scope**

This operational guidance provides a generic overview to the hazards, risks and related control measures associated with incidents involving electrical vehicles.

An electric vehicle (EV) can be described as;
- Electric Vehicles (EV)
- Range-extended Electric Vehicles (REEV)
- Range-extended (plug-in) Hybrid Electric Vehicles (REHEV/PHEV)

For simplicity, this document uses ‘EV’ to refer to all the vehicle types above.

The Fire and Rescue Service (FRS) attends many incidents involving road vehicles and the potential for these to involve EVs is rapidly increasing. The incidents can vary greatly but the majority include vehicles involved in road traffic collisions (RTCs), vehicles involved in fire, or vehicles submerged in water.

FRSs will recognise that other hazards will exist when dealing with any of these categories of incident and this document should be read alongside other relevant operational guidance.

**Significant Hazards and Risks**

The significant hazards that FRS personnel face when attending incidents involving EVs fall into a number of categories:
- Limited experience
- Electric shock
- Ancillary equipment hazards
- Hazardous substances
- Fire
- Struck by moving vehicles
- Sharps
- Additional ignition sources
- Community impact

**Limited Experience**

Incidents involving EVs are relatively new to the FRS and, as such, there is limited operational experience amongst FRS personnel. The technology involved is constantly developing and all major motor manufacturers are now developing a range of EV.
This includes vehicles other than cars, such as public service vehicles (PSVs) and, as a result, there is a rapidly increasing potential of FRS personnel attending incidents involving EV’s.

**Electric Shock**

The introduction of high-voltage electrical components in EV’s lead to extra safety hazards compared with conventional vehicles and each EV component technology presents electrical hazards.

FRS’s personnel when attending incidents involving EV’s are at risk from electric shock due to the EV’s technology and systems components. These will include:

- Batteries/Super-capacitors
- High voltage (HV) Cables, Motors, Generators
- Power electronics
- Charging station coupling/connection

EV’s contain a wide variety of technologies; however, all are manufactured following strict standards for safety in design. High-voltage components are required to be insulated from the body of the vehicle to a very high degree but there is no guarantee that the high-voltage system will not become a hazard when the EV is involved in an emergency incident.

High-voltage battery packs power the high-voltage electrical systems and can range from 60V to 800V. These are comprised of many cells of lower voltages, connected in series. All high-voltage wiring used in EV’s is coloured orange and these wires should be considered to contain enough voltage to be a lethal hazard. The high-voltage wires run in protective sheathing under the vehicle from the battery pack to the engine compartment. In normal circumstances, HV cables do not run inside the passenger compartment and should not be encountered during most extrication procedures.

EV’s also contain conventional 12V low-voltage systems and the 12V battery is used to power all accessory systems including windows, SRS, central locking, etc.

In most cases, the 12V system closes the relays that connect the high-voltage battery to the rest of the system.

Solar Ventilation Systems are available on some EV’s, these comprise of a solar panel which is built into the roof and which operates a fan contained within the air-conditioning system. This allows ventilation of the vehicle interior when the vehicle is parked in direct sunlight. The power output from the solar panel is not connected to the 12V auxiliary battery and will not feed back into the SRS circuits. However, these are capable of producing electricity and exposing FRS personnel to electric shock during extrication/cutting techniques.
Ancillary Equipment Hazards

FRSs could be called to attend an incident involving EV ancillary equipment. This could be an incident involving an EV and a recharging station; or one where a non-EV vehicle collides with a recharging station.

At such incidents, in addition to the risk of fire and/or explosion, there is also the potential for electric shock and/or physical injury to the driver and any passengers, to other road users/members of the public, and to emergency services personnel.

Potential scenarios for consideration include:

- **EV is driven away with charging still underway** – The cable from the charging station may be broken, connectors and other equipment may be damaged. Any damaged equipment or exposed cable ends present an electric shock risk. The cable ‘stub’ trailing from the moving EV presents a mechanical impact risk to anyone within the vicinity as does the cable ‘stub’ left attached to the recharging station as this may recoil when the tension is suddenly released. When the current in the cable is suddenly broken (by the cable snapping or pulling out of the connectors) this may draw an arc. This causes noise, may initiate a fire and may expose persons nearby to arc flash (burns due to radiant energy). The potential for initiating a fire and/or explosion are enhanced if the recharging station is associated with a filling station dispensing LPG, CNG and/or petrol. **Note:** similar hazards would occur if the cable is vandalised while in use or if an EV that is being recharged is involved in a collision.

- **User connecting or disconnecting the EV** – The user will be making or breaking connections between the connectors on the cable and those on the recharging point and vehicle. Although these connectors are designed to prevent accidental contact with live conductors, such protection can fail if there is mechanical damage to the connector housing. When connecting and disconnecting the EV, the user will be making or breaking large currents. Systems are designed to enable these currents to be made or broken in a controlled manner but, if the system malfunctions an arc could be drawn with the same potential hazards as those described previously.

- **EV Charging Equipment involved in a Collision** – As mentioned previously, a vehicle that collides with a recharging station may not necessarily be an EV. Damage to the vehicle (sustained during the collision) may result in the release of flammable fuel, damage to the recharging station may result in sparking, and this has the potential to result in fire and/or explosion. If the recharging station is associated with a filling station dispensing LPG, CNG and/or petrol, a flammable or explosive atmosphere may exist without any leakage of fuel from the vehicle involved in the collision. Common practice within the UK is to design roadside electrical equipment so that any impact dislodges the equipment from its mountings, causing a plug to pull out and disconnect the supply. However, this is not recommended for EV recharging...
stations as it is important to break the current in a controlled manner before a plug is withdrawn. Due to the high currents associated with EV recharging, a plug that pulls out on impact has the potential to create a source of ignition.

**Hazardous Substances**

In addition to the common automotive fluids encountered in conventional vehicles, i.e. brake fluids, incidents involving EV’s may expose FRS personnel to other hazardous substances.

High voltage batteries contain an electrolyte that is likely to be a flammable and/or corrosive material which could also react with water to produce harmful gases. This has the potential to be hazardous not only to FRS personnel, but also to the environment.

The exact chemical constitution of electrolyte contained within an EV battery may vary dependent upon the manufacturer.

**Fire**

With the exception of a liquid fuel/LPG fire (unless the incident also involves a conventional fuelled vehicle) the same hazards are present if an EV is involved in a fire as those that are associated with a conventional vehicle. These hazards will include:

- Heat, flames and hot surfaces
- Collapse of load or vehicle
- Smoke and products of combustion, some of which can be very toxic.

Although EV’s may not carry conventional fuels, they will have a quantity of flammable liquid contained within the high-voltage battery.

**Struck by moving vehicle**

EV’s create less exterior noise than conventional vehicles and, when stationary, can be silent. Although some manufacturers are fitting EV’s with artificial noise generation systems to reproduce the familiar sound of a combustion engine it can never be assumed that an EV is shut off simply because it is silent.

**Sharps**

In addition to the sharps hazards associated with conventional vehicles, some EV’s may have solar panels which are built into the roof. These are an additional sharps hazard when attending incidents involving EV’s.

**Additional ignition sources**

Some EVs are provided with High Intensity Discharge (HID) lighting. These run off the 12V circuit and use a step-up transformer to create an electrical arc within the quartz tube of the headlight bulb. The operating voltage of this system is approximately 25,000V.
This arc heats up the gas within the tube to create a very bright light source. This high-voltage/low amperage system does not create a lethal amount of voltage; however, the arc is hazardous in that it is an ignition source and can cause an electric shock. EVs fitted with HID lighting that are damaged in a frontal collision do have the potential to arc.

**Community Impact**

Any incident occurring on a road has the potential to cause a local or more wide-spread impact on the community. This can adversely affect public, leisure and business communities.

Although, relatively scarce at the moment and as the supporting infrastructure grows any incident involving EV ancillary equipment, such as public charging facilities, is likely to impact on the users of EV’s as the next nearest charging facility may be some considerable distance away.

Incident Commanders should be mindful of the impact that incidents involving EV’s can have over the wider community.

**Key Control Measures**

**Pre-Planning**

An essential element of the management of risk is pre-planning. The Integrated Risk Management Plan (IRMP) will identify Fire & Rescue Service’s (FRS) response standards in terms of equipment and operational personnel required for safe systems of work to be employed.

FRS should have standard operating procedures and risk assessments in place for the full range of incidents they may attend, including arrangements with other FRS and partner agencies.

Particular attention must be paid in the pre-planning to the control of other road users and other emergency service personnel to ensure that safe systems of work can be employed.

FRS should collate information on risks in their area and make site specific risk information available to all relevant personnel prior to and upon arrival at such incidents. This information should include an awareness of the expanding infrastructure to support EV’s, such as the location of EV recharging stations.

It is important that procedures are in place to ensure that all PPE, appliance and equipment are appropriate for the use to which they are put and are properly tested and maintained.
Command and Control

Adherence to incident command procedures is vital in ensuring the safety of personnel on the incident ground. The Incident Commander should follow the principles of the current National Incident Command System.

Prior to committing any resources into the hazard area, the Incident Commander must take account of all known factors before selecting and implementing a safe system of work. A thorough safety brief prior to deploying personnel into the hazard area must be carried out.

An ongoing review of the systems of work should be undertaken to identify any change in risk and to ensure the implementation of suitable control measures for the chosen system of work. This should include the appropriate use of cordons and ensuring spans of control are maintained within recognised ranges to provide suitable levels of supervision.

Incidents involving EV’s are likely to be attended by more than one emergency service and early liaison with other agencies must be undertaken to ensure a co-ordinated and safe response to these incidents.

Some EV’s have a ‘Smart Key System,’ this is also known by other terms, such as ‘intelligent key’. These systems consist of a key transmitter/receiver that enables the EV to recognise the key when it is in proximity to the vehicle. Once recognised, the smart key will allow the user to lock and unlock doors without pushing any buttons and to start the EV without inserting the key into an ignition switch. It is important to ensure that when smart keys are removed from EVs, they must be kept at a suitable safe distance of at least 5 metres away (this figure is a guide and may vary with each vehicle) from the EV.

Personal Protective Equipment

FRS must ensure that any PPE is fit for purpose and meets all necessary safety standards. PPE should also take account of the need for FRS personnel to be visible against the operational background and ensure that the Incident Commander and other managerial and functional roles (as defined in the National Incident Command System) are distinguishable.

All personnel must use the appropriate levels of service provided PPE and respiratory protective equipment as determined by the safe systems of work.

Safe Systems of Work

All of the above control measures will contribute to the creation of a safe system of work. In addition to these, there are, however, a number of other factors to be considered.

This guidance should be read in conjunction with other national documents.
Incidents involving EVs will often involve joint agency working. Safe systems of work need to ensure the safety of other agencies on the scene, particularly if their presence is required within the inner cordon.

Considerations for specific incident types will include;

**EV’s involved in Road Traffic Collisions**

In most circumstances, disconnecting the 12V battery will render the high-voltage system safe, thus preventing the vehicle from restarting. This procedure can be seen as vehicle specific, with varied battery technology being adopted from manufacturer to manufacturer.

EV’s will only be considered safe from an electrical current following a full ‘service disconnect’ and isolation of the 12V battery.

All EV’s have a high-voltage battery service disconnect (which is often referred to as the ‘orange plug’) of some kind. The location of these varies according to the vehicle type and, whilst some are easily accessible, others are not. Any attempt to remove this ‘plug’ should only be attempted with extreme caution, utilising appropriate PPE and with strict adherence to the manufacturer’s instructions.

Additionally, EV’s have a system of G-force sensors that operate in a similar manner to those that activate SRS systems. These will automatically isolate the high voltage supply from the rear battery compartment to the front electric motors in the event of a serious frontal collision.

This high-voltage link will also shut down if there is any interruption to the power supply e.g. severing of the high voltage cable, water submersion or any damage to the vehicle causing a “short circuit” within any of the high-voltage components.

The high-voltage system may remain powered for up to ten minutes after the vehicle is shut off or disabled. FRS personnel should avoid touching, cutting or breaching any orange high-voltage power cable or high-voltage component.

An EV must never be assumed to have the high-voltage system shut off just because it is silent. If still powered, any accidental depression of the accelerator pedal, by either casualty or rescuer, can cause the vehicle to move. Wherever possible, the instrument panel should be observed for any visual indication relating to the status of the EV. Any indication on the instrument panel such as ‘READY’ or ‘DRIVE’ will signify that the high-voltage system is still powered. The EV will be shut off when there is no such visual indicator and instrument panel lights are out.

It is important that during the early stages of an RTC involving an EV that the wheels are chocked to prevent movement, that the parking brake is applied and that the high-voltage system is shut off. The mechanism for applying the parking brake and switching off the high-voltage system will vary dependant upon the type of EV.
As previously described, some EVs may have solar panels which are built into the roof. Due to the difficulty of breaking or cutting solar panels, this procedure is not advised. If it is necessary to cut the solar panel, at least one module of panel must be covered by a thick material, such as a canvas sheet, that will block sunlight and prevent the panel generating electricity, prior to the cutting operations.

Although there could be many different types of RTC’s involving EV’s, these can be considered in three categories:

- **EV in a light collision, SRS not activated** – As the SRS has not activated, it should also be assumed that the high-voltage disconnect has not operated and the high-voltage system should be considered to be live. The incident commander should ensure the following:
  
  o That all personnel are aware that the EV is possibly in “ready” mode  
  o Chock wheels and stabilise the vehicle  
  o Identify that the SRS has not activated  
  o Establish EV ignition mode, gear lever position, parking brake mode and location of ignition keys. Where possible shut off the EV, engage the parking brake and remove the ignition keys.  
  o Identify if access can be gained to the EV 12v battery for system isolation  
  o Check the vehicle damage to assess whether high-voltage wiring or components have been damaged.  
  o Where it can be confirmed that there is no such damage to high-voltage wiring or components, standard rescue operations can be commenced.

- **EV in a medium collision, SRS activated** – As the SRS has activated, the high-voltage disconnect should also have activated and the high-voltage system should be shut off. This will need to be confirmed by checking the instrument panel as previously described. The incident commander will then need to ensure the same sequence of actions is followed, as detailed above, before rescue operations are commenced.

- **EV in a severe collision and heavily traumatised** – Where an EV has become heavily traumatised there is the potential for exposure to high-voltage due to damage to high-voltage components or the exposure of high-voltage wiring. In addition to the previous actions the Incident Commander should:
  
  - Ensure that wherever possible, high-voltage components are identified and checked for damage and that any high-voltage cables are checked for exposure  
  - Establish the high-voltage battery condition and check for leaks  
  - Ensure that all personnel on the scene are made aware of the potential hazards  
  - Consider additional PPE (electrical gloves, eye protection).
• **EV’s involved in Fire**

If an EV is involved in fire, standard operating procedures for vehicle fires should be adopted. Water has been proven to be a suitable extinguishing agent and copious amounts of water should be applied from a safe distance. It is worth noting that small amounts of water can react with the high-voltage battery electrolyte to produce toxic gases and appropriate PPE must be worn.

The use of copious amounts of water will effectively control a fire, even if the fire is within the high-voltage battery pack. It will achieve this by cooling adjacent battery modules to a point below their ignition temperature. Any remaining battery modules that are on fire will quickly burn themselves out. The high-voltage battery pack cover must never be breached, or removed, in order to extinguish the fire. It is recommended that, if it is directly involved in fire, the Incident Commander should allow the high-voltage battery pack to burn itself out.

• **EV’s Submerged in Water**

As the high voltage circuit of an EV is insulated from the vehicle body, an EV that is submerged in water but not physically damaged does not have the potential for a high voltage on the metal vehicle body and, as such, is safe to touch. Where this situation can be confirmed, normal access to casualties and extrication procedures can be performed. In this situation, high voltage orange colour coded power cables and high voltage components should never be touched, cut or breached and if the EV has not automatically been disabled the power switch must be turned off prior to operations.

If, however, the EV has been subject to heavy trauma, or where the condition of the EV cannot be determined, there is the potential for FRS personnel, and any other rescuers/emergency services personnel to be exposed to an electric shock. In this situation, specialist manufacturers advice/guidance should sought before attempting any rescue.

**Safety Officers**

The early appointment of one or more Safety Officer(s) will help ensure that risks are either eliminated or reduced to an acceptable level. The Safety Officers must be briefed regarding the nature of the incident, the allocated task and prevailing hazards and risks. The Incident Commander should confirm that the Safety Officer understands:

- Their role and area of responsibility
- Allocated tasks
- Lines of communication.

Those undertaking the Safety Officer role should:

- Be competent to perform the role
• Ensure personnel are wearing appropriate personal protective equipment
• Ensure any equipment used is set up in a safe manner and is appropriate for the task and environment
• Ensure safe working practices are adopted and implemented
• Monitor the physical condition of personnel and/or general or specific safety conditions at the incident, in accordance with their brief
• Take any urgent corrective action required to ensure safety of personnel
• Update the Incident Commander or senior safety officer regarding any change in circumstances
• Not be engaged in any other aspect of operations, unless this is required to deal with a risk critical situation.

• Ensure emergency procedures are initiated

An evacuation signal must be agreed and understood by all persons actively engaged in operations (including non-fire service personnel). Under normal circumstances the standard fire and rescue service signal will suffice (repeated short sharp blasts on an Acme Thunderer type whistle).

To avoid fatigue and loss of concentration the safety officer should be relieved at frequent intervals. When relieved a thorough briefing must take place before the role of safety Officer is exchanged.

The role of a Safety Officer can be carried out by any of the fire service roles, but the complexity of the task, size of the incident and scope of responsibility should be considered by the Incident Commander when determining the supervisory level required.

Post Incident

The following measures, as appropriate to the nature and scale of the incident, should be considered to eliminate or reduce risks after the incident:

• Any safety events; personal injuries, exposure to hazardous substances, near-misses should be recorded, investigated and reported in line with legislative and local requirements.
• Conduct a debrief to identify and record any lessons learnt from the incident. Debrief types will vary in proportion to the incident and in line with the FRS protocols.
• Consider the need for any changes to standard operating procedures, appliances, equipment or training in light of lessons learnt from de-briefs and/or safety events.
• Consider the need to refer to other agencies any issues or concerns that are identified either at the incident or through de-briefs/safety events.

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