JOIFF

The International Organisation for Industrial Emergency Services Management

JOIFF Guideline on Emergency Response to incidents involving vehicles powered by Alternative Fuels

(including Hybrid vehicles)

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Section 1. Foreword:

JOIFF, the International Organisation for Industrial Emergency Services Management, is a not-for-profit organisation dedicated to developing the knowledge, skills and understanding of emergency services personnel by working to improve standards of safety and of the working environment in those sectors in which its members operate.

JOIFF's prime activity is Shared Learning aimed at driving inherent safety, continuous risk reduction and safe management of residual risk in industry. JOIFF Guidelines are an important part of JOIFF's Shared Learning philosophy, to increase the JOIFF Shared Learning knowledge base in line with new developments requiring different approaches to emergency response, to assist its members to work to current levels of Good Industry Practice within their own Response Area and to ensure that emergency responders are well informed, competent and correctly equipped to deal with potential accidents/incidents to which they may be required to respond within their Area Emergency Response Plan.

This JOIFF Guideline has been developed to support those whose responsibility in their Area Emergency Response Plan includes dealing with incidents involving vehicles powered by alternative fuels. The number and types of vehicles using alternative fuels is growing rapidly leading to growth in the number of incidents, including fire, involving these vehicles. Good Industry Practice requires emergency services management which might be faced with having to provide emergency response to these incidents, to have a full understanding of the hazards and risks so that they can develop suitable Standard Operating Procedures (SOPs)/Standard Operating Guidelines (SOGs) and training materials and provide effective training for responders.

JOIFF hopes that this Guideline will provide information and background detail necessary to enable Emergency Services Management to identify the hazards, assess the risks and decide the actions necessary to take in dealing with such incidents in their Response Area.

JOIFF recommends that those who may be required to respond to incidents involving vehicles powered by alternative fuels should ascertain if any local/National rules/regulations pertaining to vehicles powered by alternative fuels are in place in the Country/Region in which they operate. These may take precedence over any comments/recommendations in this Guideline.

The Directors of JOIFF extend their thanks to the JOIFF Working Group of experts who developed this Guideline.

Section 2. Introduction:

One of the major targets towards helping combat climate change today is the reduction or elimination of the use of vehicles powered by petrol and diesel products and replacing them with vehicles referred to as "alternative fuel vehicles". Alternative fuel vehicles currently include vehicles powered by batteries (high voltage fuel cells), compressed natural gas (CNG), liquid natural gas (LNG), biofuels and hydrogen.

The use of alternative fuel vehicles of all types is a growing exponentially and includes not only passenger cars, but also light and heavy commercial vehicles, buses, coaches. fire and rescue appliances, specialist vehicles etc. The increasing number and type of these vehicles will require emergency responders to be competent in dealing with vastly different hazards than those encountered at incidents involving petrol and diesel-powered vehicles.

This Guideline provides information on some of the hazards that responders may have to identify when they have to respond to an incident involving these vehicles and discusses some important response issues and techniques. Emergency responders dealing with incidents in alternative fuel vehicles need to carry out their own Hazard Identification and Risk Assessment exercises before they begin operations at each incident and act in accordance with their own Standard Operating Procedures (SOPs)/Standard Operating Guidelines (SOGs).

Section 3. Terms and Definitions:

For the purposes of this Guideline, the following terms and definitions apply.

3.1 Alternative Fuels:
Alternative Fuels are fuels or power sources which serve, at least partly, as a substitute for fossil oil sources in the energy supply to transport and which have the potential to contribute to its decarbonisation and enhance the environmental performance of the transport sector. They include electricity, hydrogen, biofuels, natural gas compressed and liquified and liquefied petroleum gas (LPG) and their possible simultaneous and combined use by means of, for instance, dual-fuel technology systems. (From EU Directive 2014/94/EU).

3.2 Battery:
A primary battery is one that is not rechargeable, a secondary battery is one that can be re-charged.

A battery is a combination of electrochemical cells which convert chemical energy into electrical energy to provide electricity to items such as electric motors. Secondary battery cells can be as small as the standard cell used to power torches etc. but unlike this type of cell, which is usually a primary battery and cannot be recharged, secondary cells used in vehicle batteries can be re-charged many times according to manufacturer's instructions.

A battery module is a battery assembly comprising a fixed number of cells put into a frame to protect the cells from external shocks, heat and vibration. A battery pack, which is the final shape of a battery system, is composed of modules and various control/protection systems including a battery management system, a cooling system etc.

One of the currently 3most popular electric cars internationally uses a battery pack encased in protective steel comprising 4 modules containing 1000 cells each.

3.3 Electrolyte:
An electrolyte is a compound which in a solution conducts electricity and is decomposed by it. The electrolytes of all batteries, primary, secondary and whether they are alkaline, lead acid or lithium ion etc. present the hazard of being corrosive and/or toxic.

3.4 Exothermic Reaction:
An exothermic reaction is a chemical reaction that releases energy through light or heat.

3.5 Hybrid Vehicle:
A hybrid vehicle is a vehicle with more than one method of propulsion. Each method can be powered or charged by another method or can be totally independent of the other method.

If one of the methods of propulsion in a hybrid vehicle is a battery system, a similar hazard is present as in a vehicle fully propelled by batteries. Subject to a Risk Assessment, recommended emergency response actions where a hybrid is involved may be as set out in this Guideline, primarily in Section 5 Operational response for fires/incidents involving Electrically Powered Vehicles.

3.6 Stranded Energy:
Stranded energy is energy remaining in lithium ion (li-ion) cells after efforts to safely discharge the stored energy in damaged cells. Significant fire and shock hazards are presented by stranded energy as it is difficult to know when and how the batteries can be safely removed from their installation and then transported and disposed.

3.7 Thermal Runaway:
Thermal Runaway is an exothermic reaction that can occur in any battery. For the purposes of this Guideline, thermal runaway relates specifically to lithium ion (li-ion) batteries.

The anode breaks down to liberate methane and ethane gas, the electrolyte expands and evaporates, creating a vapour of flammable gases and as the temperature continues to rise, the energy stored in the battery is released, the cathode breaks down releasing oxygen and therefore provides all elements necessary for a fire.

The risk of thermal runaway begins at a temperature of around 60°C (140°F) and eventually temperatures can exceed 600°C (1112°F) as the battery becomes gaseous and a fire erupts. The time taken for a li-ion battery to go into thermal runaway is entirely dependent on the rate of heat absorption into the cell. When the increasing temperature nears 120°C (248°F), batteries may emit gas and/or rupture. If the threshold temperature near 120°C (248°F) is not crossed, the battery may smoulder and gas but may not ignite unless an external spark ignites the flammable gases emitted from it.

The exothermic reaction in a cell can drag adjacent cells into a thermal runaway and may cause li-ion cells to ignite within a battery, hours or even days after an initial fire, crash, or technical failure/production fault. The spread of thermal runaway to adjacent cells depends on a number of factors amongst which are the distance between cells, the presence of heat insulating material that may prevent spreading or the presence of means of active cooling, e.g. with a coolant etc. The amount of energy remaining in the battery when it is damaged can greatly affect the severity and duration of this reaction.

Thermal runaway can be stopped by deep cooling the battery pack or by immersing it in water – salt water is recommended (see clause 5.5.3 below). It can also be stopped by draining the battery of the energy causing the reaction, but this is a very specialist task.

Section 4. Lithium batteries.

The difference between primary lithium batteries - “non-rechargeable” or “disposable” - and secondary lithium batteries - “rechargeable” - is the form of the lithium that they contain. A primary lithium battery is a battery that has lithium metal or lithium compounds as the anode. Primary lithium batteries are also known as lithium metal batteries or “Li-Metal batteries.”

A secondary lithium battery is a battery that contains lithium ions that move from the negative electrode to the positive electrode during discharge and back again when charging. Secondary lithium batteries are also known as lithium ion batteries or “li-ion” batteries.

Li-ion batteries offer excellent power and energy density, they have a large operating temperature range and are lightweight. Low voltage li-ion batteries are widely used in portable devices such as watches, mobile phones, computers etc.

High voltage li-ion batteries are used to power electric vehicles as they are much more flexible for use than the more traditional batteries like lead acid. It is usual that all of the constituent component battery cells in an electric vehicle are sealed within a pack as inter-connected subgroups in what are called pods/modules. The exterior of each pod/module is isolated from internal components and the pod/module is then installed in a rigid metal enclosure called a battery pack. A battery pack, even in a normally discharged condition is likely to contain substantial electrical charge and can cause injury or death if mishandled. This risk increases if the outer enclosure, pod/module enclosures and/or safety circuits have been compromised or have been significantly damaged.

Li-ion batteries require a good battery management system to protect circuits to prevent thermal runaway if stressed.

Section 5 Operational response for fires/incidents involving Electrically Powered Vehicles:

Responders to a fire/incident involving a hybrid or an electrically powered vehicle should be wearing full appropriate Personal Protective Equipment (PPE) including fully charged breathing apparatus.

The following steps are recommended.

5.1 Identify the vehicle:

On arrival at the scene, the type or make of vehicle may not be immediately obvious due to the many new types and makes of vehicle now being used. This may increase the time before responders can begin the actions required to mitigate the incident.

To assist in vehicle identification, a comprehensive list of vehicles is available from the European New Car Assessment Programme (NCAP) who, in association with CTIF (International Association of Fire and Rescue Services) have produced a free app called “Euro Rescue”. This app, which can be downloaded from Google play and the Apple App Store, contains “Rescue Sheets and Emergency Response Guides” which can be installed on a mobile device.

5.2 Immobilise the vehicle:

Vehicles with electric motors as part of their propulsion, provide no audible indicators and when stationary, it may not be obvious that the engine is still running and it will move as soon as the accelerator is depressed. Electric vehicles should be chocked as soon as possible to prevent any inadvertent movement of the vehicle. Although a good preventative measure, chocking alone may not prevent movement if the drive system is engaged. If possible, setting the emergency brake and placing the vehicle in park can add additional protection against inadvertent movement.

5.3 Disable the vehicle:
The status of the vehicle can be determined by viewing the dash display, the position of the key in the ignition and/or the power button to see if the indicator light is lit. If the vehicle is "on", turn the key to the "off" position.

Some electric vehicles operate by a proximity key. If the proximity key is within range of the vehicle - usually less than 5 metres (16 feet) - the vehicle is powered "on" by a button on the dash. Turn the vehicle "off" by pressing this button. Then, place the proximity key beyond the range of the vehicle - typically greater than 5 metres (16 feet) – in a safe location in the event that it may be required to re-start the vehicle if the fire is quickly extinguished.

5.4 Extrication considerations:
When the vehicle is immobilised and disabled, vehicle extrication can commence. Always stabilise the vehicle before beginning extrication.

A damaged high voltage battery may emit corrosive, toxic, and flammable fumes so responders should use ventilation techniques to protect the occupants of the vehicle and prevent the build-up of toxic and flammable vapours in the passenger compartment. If toxic and/or flammable vapours are present in the vicinity of persons trapped, it may be considered necessary to supply them with a means of breathing protection, preferably a Self-Contained Breathing Apparatus or an external supply of air with a full face mask with a suitable filter. In this condition, responders with charged attack lines should be in close proximity to take whatever steps may be necessary to protect personnel.

Caution must be taken when using conventional extrication techniques as they may cause damage to the vehicle's battery fuel cells. Manufacturers usually route fuel pipes and high voltage cabling in electric vehicles in protected areas under the vehicle or within the vehicle panels.

Responders should constantly monitor for indications that a damaged battery may be overheating, e.g. sparking, emitting smoke, or making bubbling sounds, and deal with any fires due to these conditions.

5.5 Extinguishment considerations:
5.5.1 Li-ion batteries:
As a li-ion battery ignites, it can produce large emissions of what appears to be white smoke which will be the first sign of a thermal runaway event. The smoke is likely to be flammable and toxic and it may ignite at any time. If a fire develops and visible flames appear, a decision should be made as to whether to attempt to suppress the fire or to concentrate on protecting exposures and surrounding materials and allow the battery to burn until it self-extinguishes. If the fire is allowed to burn itself out the chemicals released will be consumed by the fire and the remains of the battery may contain considerable amounts of lithium hydroxide, a corrosive liquid.

As a fire progresses, gases venting from cells can exceed 600°C (1,110°F) and can include violent eruptions as some types of cells will hold the pressure in the casing for some time and when the outer casing fails it will vent the gases. If the gases collect in an inside space, e.g. vehicle passenger compartment, luggage hold, boat/ship, warehouse, garage, energy storage system etc. a powerful gas explosion may occur with battery debris. If there is high risk of explosion, evacuation to a safe distance may need to be necessary.

Vented electrolyte is flammable and may ignite on contact with an ignition source such as an open flame, spark, a sufficiently heated surface or contact with cells undergoing a thermal runaway reaction. Always take into account that ignition of vented electrolyte in an enclosed space may lead to an explosion.

In an explosive atmosphere, if the jet fumes are already ignited, they should be allowed to burn if it is safely possible to do so, whilst ventilating and cooling continually until the temperature of the battery cools down.

The process of failure of a li-ion battery results in some very toxic chemicals and they can mix with fire water to penetrate the ground and go into the ground water which can lead to environmental damage.

5.5.2 Extinguishment:
Extinguishing a fire in a li-ion battery can take a prolonged period. If water is the chosen medium to deal with the incident, it is likely that it will be necessary to establish a sustained water supply through a hydrant or static water source. A high voltage battery fire could require 12,000 litres (2,600 gallons) of water or more, depending on the size and location of the battery.

Because high voltage batteries are in protective cases, it is difficult to get any extinguishing agent directly onto the burning cells. Cells have limited ability to transfer heat to their nearest neighbours so if possible, the aim should be to remove heat from between the cells. The application of large volumes of water may cool the high voltage battery sufficiently to prevent the propagation of fire to adjacent cells and continuous application of water on a localised area of the battery for a prolonged period of time before moving to another section of the battery, may provide for quicker extinguishment.

To properly cool a high voltage battery pack and prevent/reduce the risk of re-ignition, continue to apply water even after visible flame is no longer present.

Lack of barriers between cells in some batteries can result in a deep seated and inaccessible fire which in practice, would require the use of more water to cool and contain the fire. The use of copious amounts of water potentially introduces the unwanted effect of shorting out other cells, thereby perpetuating the fire.

Periodically check for signs of heat using a thermal imaging camera.

5.5.3 Extinguishing media:
Water or other standard agents such as dry powder, CO_2 and Foam can be used to fight fires in electric vehicles when the batteries are not involved. When the batteries are involved, dry powder, CO_2 and Foam may extinguish the flames but they will not stop thermal runaway so water by itself or with salt and/or certain additives may be the most suitable medium for dealing with fires involving li-ion batteries.

Under certain conditions, isolating the damaged vehicle by immersing it in a container filled with water at the incident location or a spot nearby where it causes no blockage or risk may have to be considered. Immersing a battery in water only cools it down and so may stop a thermal runaway, but because the water does nothing to reduce the amount of energy in the battery, this energy may restart a thermal runaway in an unstable pack.

Applying salt water to the fire is the easiest way to support the process of draining the energy from a battery pack. Salt water does not have to be sea water, it can be water mixed with road or kitchen salt.

After applying salt water for some time, reignition can no longer take place. The energy in the battery is used for electrolysis of the salt ($NaCl$) in the water, generating chlorine and sodium hydroxide. With sufficient water being present, a sodium hypochlorite solution ($NaOCl$) in water, better known as bleach, is formed.

Notes:
At the time of writing this Guideline,
1....the Working Group could not source any information on the effectiveness of different concentrations of NaCl in salt water;
2....reports were received of ongoing testing by vehicle manufacturers on whether the use of a water/additive cutting lance will be of use in firefighting operations to permit quick access to the cell/module via the floor pan of the vehicle from the passenger compartment, in order to extinguish and prevent thermal runaway. It has been reported that during testing there has not been any electrical conductivity recorded to the user of the lance.

5.5.4 High Voltage Hazards:
During all phases of any response to incidents including during the overhaul phase, responders should avoid contact with any high voltage component until they are neutralised. Until the battery has been de-energised, responders should not attempt to cut, breach or remove the high voltage battery or any high voltage component nor drive prying tools into any area that may house or cover high voltage components as this could pose risk from severe shock/injury/electrocution.

Under normal conditions of use, high voltage batteries, cables and the electric motor do not pose an electrical hazard as reputable manufacturers incorporate safeguards to help ensure that a high voltage battery and cables are kept safe and secure during expected conditions of use. However, if the outer enclosure, pod/module enclosures and/or safety circuits of a high voltage battery and cables have been damaged, a significant risk of high voltage that can cause injury or death is likely to exist and appropriate precautions should be taken against exposure to the risk.

Responders should avoid contact with any electrical cables and components that have high voltage warning labels. Warning labels may have been burnt by the fire or been rendered illegible in other ways, so Standard Operating Procedures (SOPs)/Standard Operating Guidelines (SOGs) on this aspect should be that responders should not touch any electric drive or drive system component nor should they attempt to breach (open up) a high voltage battery or its casing for any reason.

Batteries in some electric vehicles are located relatively inaccessibly between the vehicle's under carriage and passenger compartment where it can be difficult, if not impossible, to access to apply water. Cutting holes in the vehicle floor to expose the battery can be dangerous as the fire may spread quicker, causing damage and beginning the thermal runaway process in more of the cells. Also, there is the extreme hazard of cutting into areas of the vehicle where high voltage still remains.

Many high voltage components are directly accessible from the engine compartment. Responders should not attempt to force entry into the engine compartment nor should they attempt to spike or cut the bonnet (hood) or wheel guards (fenders) with a piercing nozzle, cutting tool, or prying tool due to the risk of severe shock or electrocution. If responders are unable to gain access to the engine compartment/electric motor, fire suppression tactics should be employed until the fire is completely extinguished.

5.5.5 Using portable fire extinguishers on fires involving lithium batteries:
Lithium batteries can be primary or secondary (see Clause 3.2). Fires involving primary lithium batteries are classified as Class D Metal Fires. Portable fire extinguishers designed to deal with incipient Class D fires in primary cells contain specialist dry powders that fuse the powder to form a crust which excludes the oxygen from the surface of the molten metal. A specific agent is added to the powder to prevent it sinking into the surface of the molten metal.

Using a portable fire extinguisher on a fire involving li-ion batteries can be extremely hazardous. Li-ion batteries do not contain any metallic lithium therefore a Class D extinguishing medium will not be successful in extinguishing a fire in these batteries. Standard dry powders are not effective on fires involving li-ion batteries and foam or CO2 will have limited cooling effect, will not stop thermal runaway and may cause a chemical reaction. Some manufacturers of portable fire extinguishers recommend extinguishment by using a portable fire extinguisher with water mist mixed with certain chemical additives but applying small amounts of water on such fires can result in release of toxic and flammable gases.

If the fire is a small fire, it may be advisable to let the fire burn out by itself. The recommended method of dealing with a fire involving a small battery, is to submerge the battery in water.

Portable fire extinguishers are designed to be used primarily on incipient fires and they have limited capacity. Anyone expected to use a portable fire extinguisher on a fire involving batteries should be given suitable training as such fires can escalate very quickly and can burn at high temperatures.

If attempts to extinguish a fire involving a battery with a portable fire extinguisher have not been successful, personnel should rapidly distance themselves from the scene.

5.6 Overhaul (post fire/incident) operations:

Responders dealing with overhaul should wear full appropriate Personal Protective Equipment (PPE) including fully charged breathing apparatus due to the dangers of re-ignition and/or release of gases and particles that contain toxins and carcinogens during the overhaul process.

Following firefighting operations, responders should verify that the vehicle has been properly immobilized and disabled and if these tasks have not already been completed, the appropriate steps should be taken to do so.

Li-ion batteries involved in a fire could reignite after extinguishment anywhere from several hours to a day or more following extinguishment. Re-ignition of fire in a high voltage battery pack is typically accompanied by “whooshing” or “popping” sounds, followed by off-gassing of white smoke and/or electrical arcs/sparks which causes the re-ignition and responders should carefully observe the high voltage battery compartment to ensure it is not emitting smoke, sparking, or making bubbling sounds.

Be aware that if the battery pack contains cylindrical cells and it has been opened due to the incident, cells that will catch fire may be ejected for some distance, causing personal injury to responders and secondary fires.

Using a thermal imaging camera to assess the temperature of the battery will assist in determining if it is producing heat.

After a fire, a battery module or system may contain intact cells that still have DC voltage, meaning there is a persisting electrical hazard due to stranded energy. Responders should not try to discharge batteries – this is a specialised task and under appropriate conditions, specialists can test, handle and remove the battery's energised li-ion cells and/or drain the amount of energy trapped in the unstable battery. Contact the manufacturer’s representative for assistance in de-energising a high voltage battery and to determine the final disposition and storage of the vehicle.

5.7 Removal of a vehicle with an unstable battery pack:

When it is considered that the overhaul is completed and the vehicle is in a condition to be removed from the incident site, the vehicle should be recovered and transported to a safe location where it can be monitored until it is verified that the battery has been de-energised. Some manufacturers recommend de-energising damaged batteries by submerging them for several days in a saltwater bath until the bubbles stop, indicating that the chemical reaction inside the battery has ceased. Transporting a damaged electrically powered vehicle with an unstable battery pack immersed in water will result in an unstable recovery vehicle so it may have to remain at the scene of the incident for several days.

Removal should be on a flatbed truck and if this is not possible, it should be towed with its drive wheels off the ground – for some vehicles, towing with drive wheels on the ground poses a risk of fire in the high voltage electrical system.

If at the scene of the incident, the battery pack does not actually burn and if it is safe to do so, it may be possible to transport the container in a dry state under a fire blanket to a suitable location where the container can be filled with water and the battery pack submerged as soon as it has been unloaded.

The National Fire Protection Association (USA) recommends that vehicles containing a damaged or burned li-ion battery should not be stored in or within 15 metres (50 feet) of a structure or other vehicle until the battery can be discharged.

Section 6. Hydrogen Powered Vehicles

6.1 Hydrogen:
Hydrogen is a colourless, odourless and tasteless gas that is 14 times lighter than air, with a flammable range of 4% to 74% concentration in air and an auto ignition temperature of 585°C (1085°F). It cannot be odourised.

Gray hydrogen is made using fossil fuels like oil and coal, which emit CO_2 into the air as they combust. A cleaner version is "blue" hydrogen which is produced from natural gas and for which the carbon emissions are captured and stored or reused. The cleanest of all is "green" hydrogen, which is generated by renewable energy sources such as wind, solar or hydro without producing carbon emissions. If the electricity comes from renewable sources, then the only carbon emissions are from those embodied in the generation infrastructure.

6.2 Hydrogen Powered Vehicles:
While hydrogen powered vehicles themselves do not generate any gases that contribute to global warming, the process of making hydrogen requires energy, often from fossil fuel sources.

Hydrogen powered vehicles can be divided into two types, hydrogen to power an internal combustion engine and Fuel Cell Vehicles (FCV) - or Fuel Cell Electric Vehicles (FCEV). The chemical energy of hydrogen is converted by the power plants of such vehicles to mechanical energy by burning hydrogen in an internal combustion engine, or, more commonly, by reacting hydrogen with oxygen in a fuel cell to run electric motors. Hydrogen fuel cell vehicles utilise the same type of high voltage electrical systems found in hybrid and electric vehicles. There are no moving parts in the fuel cell, so vehicles powered by hydrogen are more efficient and reliable than a conventional combustion engine.

The battery packs of hydrogen powered electric vehicles are smaller and lighter than those of fully electrically powered vehicles and re-charging a hydrogen vehicle is much quicker than re-charging the batteries of a fully electric vehicle. This makes it very suitable for use in public transport and vehicles in businesses that cannot afford vehicle downtime.

6.3 Hydrogen cylinders/tanks:
Hydrogen cylinders in vehicles are typically found underneath a car and on the roof of buses.

Hydrogen automotive cylinders/tanks can be pressurised from 350 Bar to 700 Bar depending on tank classification - Type iii or Type iv. These high pressures, when venting or discharging, present significant safety hazards.

Hydrogen is a highly explosive gas so hydrogen cylinders/tanks in vehicles need to be strong to remain "safe" in the event of a crash, fire or other incident.

Hydrogen cylinders are equipped with temperature activated pressure relief vents. If these vents are activated, they will empty the cylinder over the course of several minutes depending on the capacity of the cylinder and how much gas is contained. On hydrogen powered cars, these vents are generally directed horizontally to the aft and/or side and on buses and trucks, they are generally vented upwards.

As pressure relief vents on hydrogen powered vehicles may be in different directions, as a priority, those attending an incident should check the available vehicle information.

6.4 Extinguishment considerations:

Responders dealing with a fire in a hydrogen powered vehicle should wear full appropriate Personal Protective Equipment (PPE) including fully charged breathing apparatus

Hydrogen fires should not be extinguished unless the flow of gas can be stopped. Hydrogen fires produce almost no radiant heat and no smoke, making it almost impossible to sense the presence of a fire unless in close proximity. At night, the flame is visible to the naked eye. Hydrogen burning with other carbon-based flames will likely give colour to the hydrogen flame.

Thermal imaging cameras should be used when dealing with a hydrogen emergency in order to determine the presence of fire.

In the event there is flame or heat impingement on a composite cylinder, it should not be cooled as this may cool the temperature activated pressure relief device and prevent it from functioning which can result in a catastrophic cylinder failure. Allow the pressure relief device to function as designed and vent the hydrogen.

High voltage electrical cells and components should be handled in the same manner as they are in an electric vehicle – see Section 5 of this Guideline.

Section 7. Gaseous Fuel Vehicles

7.1 Introduction:

7.1 Introduction:

Compressed Natural Gas is mainly composed of methane (CH4), to less than 1% of the volume it occupies at standard atmospheric pressure. It is stored and distributed in containers, usually in cylindrical or spherical shapes, at a pressure of 20–25 MPa (2,900–3,600 psi).

Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG) and Liquefied Propane Gas (LPG) are the three primary gaseous fuels used to power an internal combustion engine.

CNG is used in traditional gasoline internal combustion engine vehicles that have been modified or in vehicles specifically manufactured for CNG use, either alone with a segregated gasoline system to extend the range (dual fuel) or in conjunction with another fuel such as diesel (bi-fuel).

Although boiloff gas from LNG is heavier than air, compressed LNG is lighter than air. LNG-when released will remain at a low level until it gets warmer and then it will rise.

LPG - propane or butane - is liquefied by pressurisation at 14 MPa (200 psi) and is stored at approximately 16.5 MPa (240 psi). Propane vapours are approximately 1½ times heavier than air and will settle into low lying areas when released. Its flammable range is approximately 2%-10% in air.

Gas detection metres should be used to detect the presence of leaking gas.

7.2 Cylinder/Tank location:

Natural gas is stored on a vehicle in one of two ways, either compressed (CNG) or liquefied (LNG). The storage method plays a critical factor in its behaviour and how it is handled in an emergency.

7.2.1 Compressed Natural Gas (CNG) cylinders/tanks:

The mounting location of the cylinders/tanks varies with the type of vehicle. In passenger cars they may be located in the boot (trunk) or where the petrol (or diesel) tank would normally be located. In medium and heavy-duty vehicles, they may be mounted underneath or directly behind the cab, arranged horizontally or vertically, or in a location similar to a diesel tank. On buses and other heavy vehicles, they may be on the roof.

7.2.2 Liquid Natural Gas (LNG) cylinders/tanks:

LNG is stored at temperature down to - 163°C. LNG tanks are double walled, cold insulated and have pressure relief safety devices and emergency release connectors.

LNG is typically used on medium and heavy-duty vehicles and the tanks are most commonly found attached to the frame rails. However, in some instances they may be located behind the cab.

7.2.3 Liquid Petroleum Gas (LPG) cylinders/tanks:

In passenger vehicles, the LPG cylinder/tank is usually located in the boot (trunk), or where the petrol (or diesel) tank is usually located. In vans or trucks, they may be underneath or in between or outside the chassis rails.

In medium or heavy-duty vehicle applications, they may be located along the inside or outside of the frame rail. Due to the heavier than air nature of propane, cylinders/tanks will probably not be found mounted on the roof.

7.3 Fuel leaks in Gaseous Fuel Vehicles:

It is recommended that a combustible gas meter is used to monitor for all potential fuel leaks at a crash/extrication scene involving a gaseous fuel.

LNG leaks like a liquid and on evaporation, expands up to 600 times in volume. Leaking LNG is lighter than air and shows as a condense/steam/hot cooling water leak. There is a vent pipe for the LNG pressure relief vent and a boiloff gas pressure relief vent from the pressure built-up unit.

A small leak (dripping) of liquid phase LNG will fall onto the ground and evaporate, therefore there is no hissing of escaping gas. Some LNG tanks operate at higher pressures where a leak on liquid phase could force LNG from the tank. Here a pressurised liquid release maybe audible, depending on the size of the leak. If LNG is released from the pressure relief valve in the gas phase of the tank or associated vapour lines, then the pressure (around 16 bar) will be audible.

The flow of gas from the cylinder/tank is shut down when the vehicle ignition is turned off through the use of a low voltage solenoid. Manual shut offs may also be present to shut off the flow of gas.

7.4 Extinguishment considerations:

7.4.1 General:

Responders dealing with a fire in a Gaseous Fuel Vehicle should wear full appropriate Personal Protective Equipment (PPE) including fully charged breathing apparatus

Use standard tactics and techniques. Do not attempt to extinguish a fire fuelled by an active gas leak unless the flow of the gas can be shut down. Let it burn and protect exposures and surrounding materials until the fuel supply is exhausted.

Be aware that fire exposure may not always be apparent and if the cylinders are already involved, do not approach the vehicle. Establish a safe perimeter of at least 25 to 30 metres (80 to 100 feet) and allow it to burn while protecting any exposures.

If the fire is small and remote enough from the cylinder/tank location that there is no potential for flame or heat impingement, tactics associated with fire in conventional petrol/diesel vehicles may be used.

If the vehicle is powered by a high voltage battery that catches fire it will probably require a large, sustained volume of water. Dealing with fires in high voltage batteries is discussed in Section 5 of this Guideline.

7.4.2 Vehicles powered by Compressed Natural Gas (CNG)

CNG cylinders are equipped with a temperature activated pressure relief device. In the event there is flame or heat impingement on a composite cylinder the cylinder should not be cooled as this may cool the pressure relief device and prevent it from functioning which can result in a catastrophic cylinder failure. Allow the pressure relief devices to function as designed to vent the CNG. Contrary to venting of gas from hydrogen vehicles, CNG vehicles can vent in any direction.

7.4.3 Vehicles powered by Liquid Natural Gas (LNG)

Every effort should be made not to allow the safety valves on an LNG tank or LNG safety devices to become wet as the extremely low temperature of LNG releases will freeze the pressure relief vents."

Typically, the tanks are so well insulated that even if the vehicle becomes fully involved, there will be truly little pressure increase inside the tank. If there is an increase, the pressure relief valve should activate and bleed off the excess pressure, resetting itself when complete.

These highly temperature insulated tanks are made of cold-resistant steel and if the insulation of the tank has been compromised, which can sometimes be visible as a frozen spot on the outer wall of the tank, the pressure in the LNG tank may rise very quickly and a BLEVE (Boiling Liquid Expanding Vapour Explosion) may occur.

7.4.4 Vehicles powered by Liquid Petroleum Gas (LPG)
In the event of fire impingement on the tanks, apply copious amounts of water to keep them cool and reduce the risk of a BLEVE. This may occur if the temperature activated pressure relief device is unable to maintain a safe pressure. If a sufficient water supply is not available, evacuate to a safe distance and allow the fire to burn.

7.5 Overhaul (post fire/incident) operations:
Responders dealing with overhaul should wear full appropriate Personal Protective Equipment (PPE) including fully charged breathing apparatus due to the dangers of re-ignition and/or release of gases and particles that contain toxins and carcinogens during the overhaul process.

Always treat cylinders and tanks as pressurised, even if the pressure relief devices have activated. Gaseous fuel vehicles should be inspected to make sure the fuel system is intact and not leaking prior to removal and storage. All cylinders and tanks involved in an accident or fire must be inspected, defueled and removed from service by trained personnel.

It may be advisable to contact the manufacturer's representative for assistance in the final disposition and storage of the vehicle.

Section 8. Training, Insurance and Media

8.1 Training:

Emergency responders should be trained in dealing with response to incidents involving vehicles powered by alternative fuels, using relevant PPE and the necessary tools for mitigating such incidents. Training should be based on Standard Operating Procedures (SOPs)/Standard Operating Guidelines (SOGs) which have been developed for dealing with such incidents in the Area Emergency Response Plan. The training programme, including refresher training, should be implemented at regular intervals to continually demonstrate competence.

8.2 Insurance and Media:

Some of the actions that may be necessary in dealing with incidents involving vehicles using alternative fuels could have serious insurance implications e.g. submerging a vehicle in water, environmental damage, recycling issues, break-down services requirements etc. It may be considered advisable to engage with your Insurers on these matters prior to agreeing Standard Operating Procedures (SOPs)/ Standard Operating Guidelines (SOGs)

Incidents involving vehicles using alternative fuels, particularly major incidents, will inevitably attract media attention. To allow the media to understand and accurately report on what is happening, it may be considered advisable to engage with the media prior to any incident to explain the hazards and risks associated with such incidents and the Standard Operating Procedures (SOPs)/Standard Operating Guidelines (SOGs) that will be followed in dealing with such incidents.

Section 9 Appendix 1. Useful Sources of Information

CTIF The International Association for Fire and Rescue Services (CTIF)
https://www.ctif.org/

CTIF Rescue Sheets and Emergency Response Guides include
https://www.ctif.org/news/euro-rescue-app-now-available-download-huge-breakthrough-extrication-all-first-responders
https://www.ctif.org/sites/default/files/news_files/2020-06/RESCUE%20SHEET%20HOW%20TO%20USE%20IT.pdf
https://www.ctif.org/index.php/commissions-and-groups/ctif-iso-17840
https://etsc.eu/wp-content/uploads/5.-TOM-VAN-ESBROECK-RESCUE-SHEETS.pdf

Euro Rescue App
https://www.ctif.org/index.php/commissions-and-groups/ctif-iso-17840/news
Euro NCAP (New Car Assessment Programme):
https://www.youtube.com/watch?v=jOvn4PTLAJ0

European Union Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure

National Operational Guidance (UK) Hazard Alternative Vehicle Fuels

NFPA Alternative Fuel vehicles Safety Training Program Emergency Field Guide

NFPA Research Foundation "Best Practices for Emergency Response to Incidents Involving Electric Vehicles Battery Hazards: A Report on Full-Scale Testing Results."
https://www.nfpa.org/-/media/Files/News-and-Research/Fire-statistics-and-reports/Electrical/EV-BatteriesPart-1.ashx

NFPA Research Foundation Sprinkler Protection Guidance for Lithium-Ion Based Energy Storage Systems Final Report June 2019.

Section 10 Appendix 2: ISO 17840

ISO 17840 is an International Standard that was developed to give easily accessible information to fire fighters who deal with incidents involving vehicles. Whilst some vehicles may have similar features, not all are the same and this standard, which is supported by vehicle manufacturers, aims to make available International standardised rescue sheets for every vehicle, to identify e.g. where the batteries are, where the airbags are, where the disconnecting devices are etc.

ISO 17840 is in 4 parts and includes a system of identification for exterior marking of fuel types for buses and other heavy vehicles, including new propulsion types like electric vehicles, hybrids and various types of compressed or liquid natural gas propulsion.

ISO 17840 Series: Road vehicles Information for first and second responders

ISO 17840 PART 1 Rescue Sheet for passenger and light commercial vehicles

ISO 17840 PART 2 Road vehicles — Information for first and second responders — Rescue sheet for buses, coaches and heavy commercial vehicles

ISO 17840 PART 3 Road vehicles — Information for first and second responders — Emergency response guide template

ISO 17840 PART 4 Road vehicles — Information for first and second responders — Propulsion energy identification

ISO 17840 has established standard colours for the propulsion used in a vehicle.

- Grey is for Diesel.
- Red is for Gasoline.
- Green is for Gas.
- White is for Cryogen LNG.
- Blue is for Hydrogen.
- Orange is for high Voltage

ABOUT JOIFF

JOIFF is a not-for-profit organisation dedicated to developing the knowledge, skills, understanding and competence of emergency services personnel, primarily in high hazard industry, with the aim of improving standards of safety and of the working environment in which they operate. JOIFF's prime activity is Shared Learning to drive inherent safety, continuous risk reduction and safe management of residual risk. The 4 pillars of JOIFF's Shared Learning policy are:

- **Shared Learning – improving risk awareness amongst the members:**
  JOIFF's Shared Learning email network, its quarterly Magazine "The Catalyst" and the Members' Area of the JOIFF website provide information aimed at improving the knowledge of emergency services personnel on matters relevant to response in high hazard industry to assist them in operating to good safe industry practice. JOIFF's Shared Learning also provides a network for "Peer Assist" from members seeking information on specific matters relevant to High Hazard Industry.

- **Accredited Training –operational preparedness in emergency response and crisis management:**
  JOIFF accreditation of training is a system of quality control of the policies, protocols, procedures and courses/programmes operated by Training organisations aimed at developing competence of emergency response personnel when dealing with potential accidents/incidents to which they will be required to respond within their Area Emergency Response Plan. Key to JOIFF accredited training is accredited assessment and verification to ensure competence which should be demonstrated on an on-going basis. Successful participants in JOIFF accredited training courses/programmes receive JOIFF accredited certificates of competence issued by the JOIFF accredited Training Provider which provided the training.

- **Technical Advisory Group – improving standards of operational safety in the working environment:**
  Within the JOIFF Shared Learning knowledge base, JOIFF develops Guidelines on specific subjects to assist its Members in working to current levels of good safe industry practice and to ensure that emergency responders are well informed, competent and correctly equipped to deal with potential accidents/incidents to which they may be required to respond within their Area Emergency Response Plan. JOIFF works with Regulatory Authorities and other organisations at local, National and International level on the nature and control of safety and other issues relevant to the sectors in which its members operate.

- **Professional Affiliation – membership of a prestigious International organisation:**
  Being a member of JOIFF gives the prestige of being a member of a globally recognised organisation of emergency response and provides unique opportunities for networking and access to professionals who have similar challenges in their work through Conferences and other events.

Full Members of JOIFF are organisations which are engaged in industry and/or have nominated personnel as emergency responders/hazard management team members who provide cover to industrial organisations. Commercial members of JOIFF are organisations that supply goods and/or services to Industry, primarily High Hazard Industry.

An application for JOIFF membership can be made through the JOIFF website www.joiff.com

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