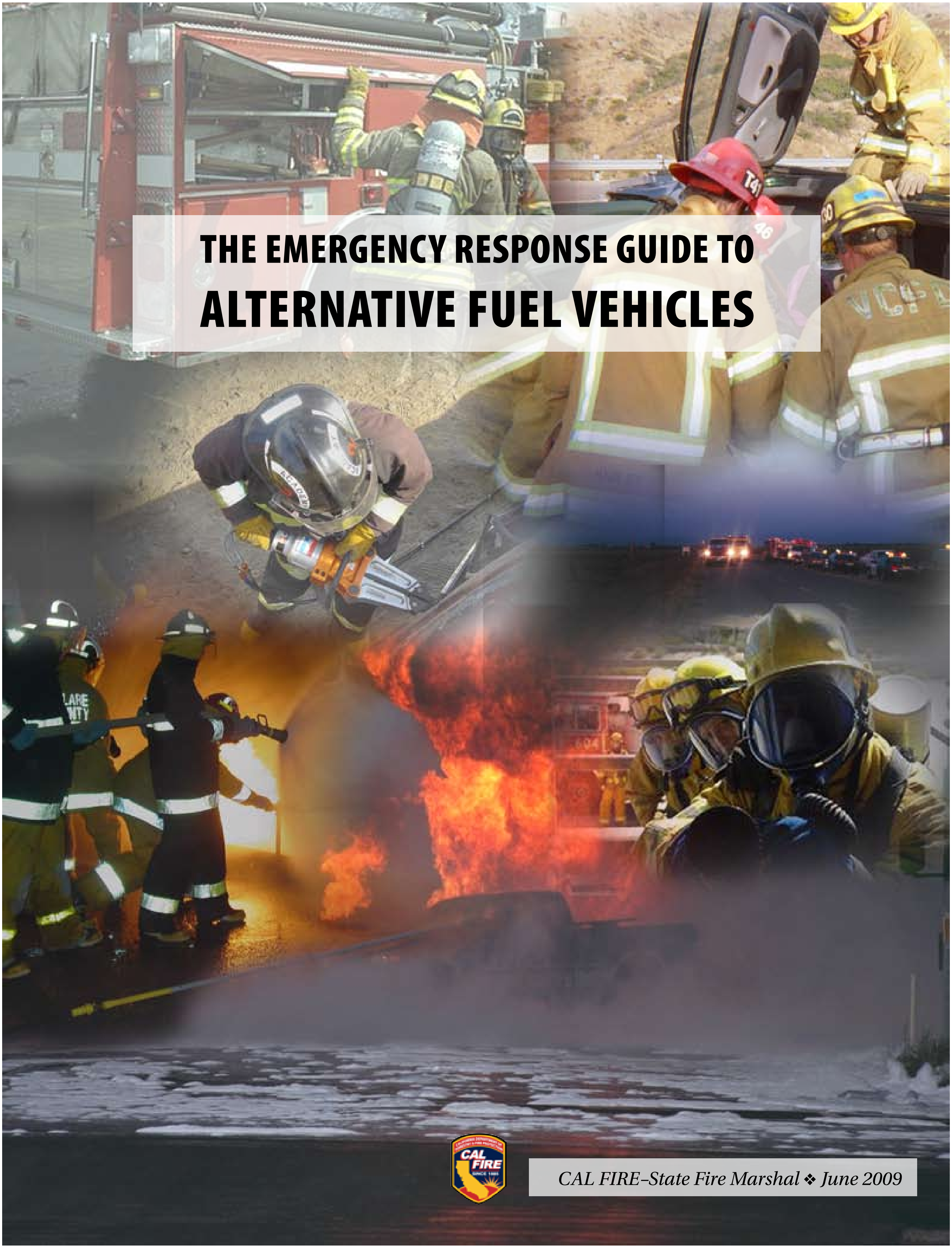
# THE EMERGENCY RESPONSE GUIDE TO
# ALTERNATIVE FUEL VEHICLES



*CAL FIRE–State Fire Marshal ❖ June 2009*

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## Disclaimer

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# Chapter I.

## INTRODUCTION

### I. INTRODUCTION

The text you hold in your hand has been 15 years in the making. This book combines the training programs that have been produced to address a variety of alternative fuel vehicle programs as they have "come of age" over the years. These projects span from electric vehicles, the vehicle of choice in the mid 1990's to Fuel Cell Vehicles, the vehicle of choice for tomorrow. In between we have also seen propane, natural gas, hybrid electric, and bio-fuels as other alternative fuel choices.

This training manual is designed to prepare emergency medical, law enforcement, and fire service personnel for an emergency response involving a wide range of alternative fuel vehicles. Funding for this program was provided by the California Air Quality Control Board. This text explores and provides an overview of the basic operation of alternative fuel vehicles, their component parts, infrastructure, and importantly, how this technology affects the standard operating procedures for emergency response personnel.

This requires a great deal of guess-work in that, in the context of the millions of vehicles on the road today, only a small percentage alternative fuel vehicles compete with gasoline or diesel vehicles, and even fewer alternative fuel vehicles have been involved in accidents.

But, any discussion of alternative fuel vehicles must begin with an understanding of how and why this technology has suddenly come to our attention. Four areas of influence include: environmental concerns, government regulation, energy diversity and homeland security, and the innovation of the auto industry have all converged to make these vehicles today's reality.

*Vehicular traffic contributes significantly to air quality concerns and it's relationship to global warming.*

#### Environmental Concerns

Alternative fuels and energy vehicles are viewed as a mechanism to reduce the environmental impact of automotive vehicles in terms of air quality, water pollution, and global warming.

Air quality concerns and the formation of Photochemical smog has been associated, and the brunt of many jokes, with California and specifically with Los Angeles for several decades. The inland valleys of California have the perfect conditions for the development of photochemical smog. The necessary ingredients are: 1) the type of pollutants put out by automobiles, and 2) sunlight. The primary pollutants involved are a mixture of oxides of nitrogen and hydrocarbons, both emitted by the millions of automobiles on our freeways and roads.

In the presence of sunlight, reactions take place that form a new set of chemicals, including ozone, which is a corrosive substance, harmful to the health of humans. Since California has lots of cars and lots of sunshine, we also have lots of smog. Things get worse when you add in thermal inversions, typical of many parts of California's inland valleys, which trap the air with its pollutants, and lead to a concentration of pollutants in the atmosphere. This phenomenon is recognized by leading scientist as a contributing factor in global warming.

Reduced emission vehicles, or vehicles that burn a cleaner fuel such as ethanol, biodiesel, natural gas or propane along with zero-emission vehicles like electric and fuel cell vehicles, have proven effective in reducing vehicle emissions and clearing the atmosphere.

Water pollution is also an area where clean energy technologies can be used effectively. Internal combustion vehicles have been targeted by government agencies as a "non-point" pollution source. These sources are varied and sometimes hard to identify. But examples include storm runoff from city streets, which include huge amounts of motor oil, spilled fuel and anything else that has been dumped on the street, accounting for a majority of water pollution. In this case, electric vehicles, which require no motor oil, can help minimize non-point sources of water pollution.

## Government Regulations

To reduce these environmental issues, California, in 1990, established a zero emission mandate for vehicle manufacturers. The focus of this mandate was to meet federal clean air requirements. Then, as now, electric vehicles are the only vehicle propulsion system that can meet this mandate. All of the major original equipment manufacturers scrambled to develop a vehicle that would achieve the states mandate that is acceptable to the consumer. The Federal Government soon followed suit with a version of fuel reduction policies that focus on energy diversity.

In 1992, Congress approved, and the President signed, the National Energy Policy Act. The National Energy Policy Act establishes a national goal to reduce petroleum consumption by 10 percent by 2000 and 30 percent by 2010.

The Act had many requirements for developing alternatives to petroleum use in the transportation sector. These requirements applied primarily to government and private fleets and to encourage the purchase and use of all types of alternatives to petroleum, including a tax credit for refueling facilities. Specific to alternative fuel vehicles, the Act provides tax credits for their purchase. The goal of this Act is to decrease America's reliance on foreign oil by developing alternative domestic energy sources.

*The key to America's homeland security is in the development of sustainable alternative fuel sources.*

## Energy Diversity & Homeland Security

It has been recognized since the first oil embargo in the 1970's that America needs to reduce its reliance on imported fuel stocks from countries who aim to use the profit from our purchase to undermine the security of our nation. Global warming and our use of fossil fuels are also cited as a motivating factor in finding sustainable alternatives to gasoline and diesel fuels. In a key note speech, Matt Bettenhausen, the Director of California Emergency Management Agency (CAL EMA), noted that "alternative energy is a homeland security issue."

The most obvious target for fuel diversification and air quality is the millions of vehicles on American roads. Mobile sources are the largest source of air pollution. Cars and trucks are the main source of smog forming pollutants and carbon monoxide. Cars and trucks are not the whole story, heavy-duty diesel trucks and off-road sources such as locomotives, ships, and utility engines also contribute to the air pollution problem.

Even though technological advances mean that new internal combustion vehicles produce about 80 percent less pollution than vehicles from the 1970s, increases in population, number of vehicles, and miles driven continue to offset the benefits of these cleaner cars. This gave rise to the concept of Zero emission vehicles, or "ZEVs." These vehicles were required to have no tailpipe emissions under any and all modes of operation for the life of the vehicle.

Today, the only vehicles that can meet this standard are electric and fuel cell powered vehicles. Although, fuels like natural gas, propane and hydrogen also offer very low emissions and provide a transition to meet the intention of government mandates.

## Industry Innovation

*1912 Detroit Electric Car at BC Hydro's Stave Falls visitor center in Mission British Columbia.*

*—Courtesy of Detroit Electric*

While the concept of alternative fuel vehicles may conjure images of the technological future, you must realize that many of the technologies we are going to explore have actually competed for a market share along with steam and internal combustion engines over 100 years ago.

Solutions to modern problems like air pollution and energy diversity are riding on the successful reintroduction of alternatives to fossil fuel vehicles. Along with this re-emerging technology comes the uncertainty of how new vehicle technology fits within the context of our day-to-day lives. It is a context that often includes: daily commutes, rush hour traffic, traffic jams, servicing, automotive repairs, occasional tows, and yes, vehicle incidents, accidents and collisions.

To this cause, billions of dollars are spent in research and development by the automotive industry to provide better air quality, and greater diversity of transportation energy sources. Long before Federal and State Governments began mandating energy diversity and air quality standards, original equipment manufacturers (OEMs), electric utilities, independent companies, and the academic community began researching, testing, and developing vehicles powered by a range of fuel/energy options. Clearly, the automotive industry perceived a unique niche in the market and its members have been racing one another ever since to fill the void.

The fact is our dependence on fossil fuels and the environmental impact of using them have driven many vehicle manufacturers to find solutions to moving people from point A to point B and to do it economically and in an environmentally safe manner. Today the alternative vehicle

*Alternative fuel vehicles: Top L-R Mercedes c300 Flex Fuel, Toyota Prius Hybrid, Bottom L-R Honda Civic CNG, Ford Roush F150 Propane* choices offered by original equipment manufacturers (OEMs) include; neighborhood electric vehicles, hybrid electric vehicles and ethanol powered vehicles. Hydrogen and fuel cell vehicles are coming-up in the not too distant future.

Fleet vehicles and mass transit systems run the range of all electric, hybrid electric, natural gas and propane, to fuel cell technologies. Even though as a consumer you are limited in choices that include primarily ethanol and hybrid electric vehicles—this training program will prepare you for the wider range of fleet and future alternative fuel options that are just around the corner.

## Program Focus

The solution to our environmental concerns and our dependence on fossil fuels appears to be not just one alternative fuel/energy source but a plethora of choices in a variety of vehicle make and models that we normally associate with internal combustion technology (ICE).

*—Courtesy of Ventura County Fire Department*

Realize that vehicles, no mater how the vehicles are fueled, may eventually end-up in a collision or become involved in fire which will, in-turn, impact you as the emergency responder. The fuel/energy available today requires emergency responders to have an understanding and appreciation of the situations they may already be facing or will be facing in the very near future.

*"Realize that vehicles, no mater how the vehicles are fueled, may eventually end-up in a collision..."*

It is important to note, that this text deals exclusively with vehicles built by original equipment manufacturers (OEM's). After market vehicle conversions are not within the scope of this program. The focus of this training program is also limited to road worthy vehicles such as passenger cars, light trucks, vans, sport utility vehicles, heavy duty vehicles, as well as transit vehicles like school, tour, and municipal busses. Off road vehicles, motorcycles, golf carts, and forklifts are not the focus of this program. However, the alternative fuel/energy technologies discussed in this program may also be extrapolated and applied to vehicle conversions and off-road vehicles as well.

Please note that emergency response guidelines (ERG's) for specific make and models of vehicles are not included in this text. New vehicles and their specific configurations change from model-to-model and year-from-year. This text presents a generic configuration of the fuel/

energy technologies. It is important to consult the emergency response guidelines published by original equipment manufacturer for vehicle specific emergency response information.

## Program Goal

This training program will provide fire, emergency medical, and law enforcement personnel information for each of the alternative fuel technologies available so that they can make informed decisions at the scene of a vehicle emergency.

## Objectives

The objectives to meet this goal include:

- ❖ Insure safety for emergency response personnel by providing reference and training material for all the alternative fuel/energy technologies available.
- ❖ Spotlight hazards associated with each fuel/energy source
- ❖ Review the infrastructure that supplies the fuel/energy to alternative vehicles
- ❖ Demonstrate that Standard Operating Guidelines (SOG's) are applicable to the new fuel/energy technologies.

This training program is divided into three sections: Internal Combustion Vehicle Technologies, Electric Vehicle Technologies and Response to Vehicle Emergencies. The training materials have been modularized so that they can be taught as each technology becomes prevalent in your jurisdiction and/or taught in conjunction with auto extrication training. The modular format is appropriate for tailboard training or can be taught in its totality as an instructor lead training program.

Like all training programs we start with the known and work towards the unknown. In this case with internal combustion vehicles, and the alternative fuels that support them, and then move on to electric vehicle technologies and the infrastructure that support those. All of this technical information will be tied together in the "Response to Vehicle Emergencies" section.

# Chapter II.

## INTERNAL COMBUSTION

### A. Introduction

There is no one in emergency service today that didn't grow up behind the steering wheel of an internal combustion engine (ICE). We are as familiar with this technology and the associated hazards as we are with breathing. As we've gotten older and wiser, we have watched as the automotive industry has grown as well.

In response to the rising numbers of deaths and injuries due to vehicle impacts to other vehicles or inanimate objects—the industry has developed standards for occupant safety. Many of these safety features like, air bags, pretensioned seatbelts, and pneumatic bumpers, continues to have a profound effect on emergency responders.

Similarly, as the cost of fuel has risen, the automotive industry has responded by offering a plethora of alternative fuel and energy technologies. Alternative fuel vehicles challenge emergency responders to redefine our standard operating procedures to manage these new technologies and fuels.

The key word here is "fuels." We should be aware and recognize that all fuels burn and pose fire and explosion risks if their combustion is not controlled. So safety is always an issue with fuels used in ICEs.

Most people use hydrocarbon fuels such as gasoline, propane, and natural gas often times without thinking about it. Tens of millions of people pump gasoline into their cars every day. It is commonplace for us to turn on the tap to get hot water, to light our stoves, or to heat our homes. We usually do not think about the use of the fuels that supply these conveniences, but when we do it is more often than not when the utility bill comes in every month. Other than cost, we readily accept the risks associated with the use of these fuels because systems that use them achieve sufficient levels of safety.


*Rising fuel costs will continue to draw people towards alternative fuel vehicle options.*

The challenge for emergency responders is to properly identify the fuel system and take action according to the hazards they present. The fuels that are most often associated with fleet vehicles include natural gas and propane. But bio-fuels like ethanol and biodiesel are appearing not only in fleet but in consumer vehicles as well. With the push towards hydrogen in fuel cell vehicles, OEM's are researching the use of hydrogen as a viable fuel in ICE vehicles—knowing that the infrastructure that supports the delivery of hydrogen to the consumer is only around the corner.

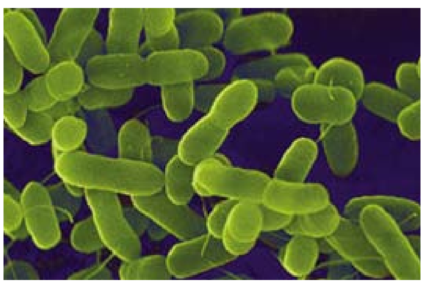
*The challenge for emergency responders is to properly identify the fuel system and take action according to the hazards they present.*

This section explores the benefits, hazards, and infrastructures that support each of these alternative fuel types including fuels like ethanol and biodiesel, natural gas, propane and hydrogen.

## B. Ethanol

Worldwide pressure on petroleum producers and consumers has driven the demand for cleaner burning and more economical fuel sources. Pure ethanol and ethanol blended fuel is receiving international attention as the revolutionary solution to meet this new market demand and stricter environmental regulations.

So much so that, today, there are over 110 bio-refineries in the United States and Canada alone. It estimated that soon there will be over 180 bio-refineries with production exceeding 12 billion gallons per year in North America.



*E.Coli Bacteria*

In Brazil, sugarcane is used exclusively as a feedstock in the manufacture of ethanol. In North America, however, corn is the primary source of ethanol fuel with some controversy regarding the diversion of a food source to a fuel source. Researchers are also exploring other biotic material such as algae and e-coli bacteria as a potential sustainable feedstock. Researchers are also investigating the use cellulosic ethanol by doubling the efficiencies of enzymes that are used to breakdown any plant matter into ethanol. The result of this research would allow a wider range of plant material to be used as feedstock in the production of ethanol in the future.

Ethanol fuels pose unique hazards and risk not typically associated with conventional petroleum products. Unlike gasoline and diesel, ethanol fuels are water soluble, conductive to electricity, have a wider flammable range, and react less effectively to standard firefighting foam. Firefighters and emergency personnel must address these and other concerns before responding to fires and spills. Ethanol fuels must also be stored, transported, and generally handled differently than other hydrocarbons.

*A select number of fueling stations offer the option of using E-85 or Biodiesel in California.*

### Ethanol Properties

Alcohol fuels offer both advantages and disadvantages to vehicle performance. Ethanol falls short of BTU energy content compared to gasoline. This translates to an estimated 27% to 30% loss of vehicle miles-per-gallon traveled compared to the same volume of gasoline. On the positive side, with ethanol's higher octane ratings, vehicle operators are impressed with improved torque and horsepower over much of the engine speed and range.


*Ethanol is a colorless liquid with a gasoline odor.*

Ethanol is a colorless liquid with a gasoline odor. The flammability range of ethanol is 3% to 19% with an auto ignition temperature of 793° F. Like gasoline, released vapors are heavier than air and can pool in low laying areas or travel a distance, ignite and flash back. Ethanol may react vigorously with heat and oxidizing materials such as; nitrates, peroxides and acids. It is advisable to isolate ethanol fumes from heat, sparks, and hot metal surfaces. While ethanol is a low emission fuel, combustion may produce carbon monoxide, carbon dioxide, aldehydes and ketones.

The health effects of ethanol when inhaled or ingested may produce central nervous system depression characterized by headaches, nausea, dizziness, loss of balance and coordination, and stupor. Vapors or spray mists may be irritating to nasal and respiratory tract. This product may be irritating to skin and eyes resulting in redness, itching or burning. Aspiration of ethanol can induce chemical pneumonia.

*The yellow gas cap is an indication that this vehicle can be using gasoline or E-85.*

## Vehicle Identification

Many blended gasoline/alcohol fuels are being dispensed across California and the country as E-85. E-85 is an 85% alcohol and 15% gasoline blend. Special badging or insignia can be found on the right rear and right rear quarter panel of the vehicle identifying it as a Flex-fuel vehicle. Some manufacturers also used yellow gas caps to help identify that the vehicle uses both gas and ethanol. Driver/operators have the option to use either all gasoline or a blend of gasoline and ethanol when filling their tanks.

## Vehicle Operation

Ethanol vehicle operation is the same as any other internal combustion vehicle that you are already familiar with. Shut-off the engine using the ignition key. Set the parking break and chock the wheels when working around ICE vehicles.

*Many fleet vehicles offer the driver the flex-fuel option; using regular gasoline or E-85*

## Ethanol Vehicle Refueling

Ethanol is delivered by tanker truck to service stations and stored in underground tanks. Consumers use standard gasoline service pumps to fill their vehicles. The standard service station safety features apply-breakaway hoses, an emergency shut-down switch, and protection of the pump island from vehicle collisions.

*A Jello shot made from pure grain alcohol demonstrates the characteristic blue flame that would be barely visible in the daylight.*

*—Courtesy of myscienceproject.com*

### Emergency Response Considerations

When alcohol burns it produces a very pale light. In the daytime, burning alcohol fuel can hardly been seen other than a shimmer in the air as minimal smoke is produced with the burning of other hydrocarbons present in the fuel and air. Use a thermal image camera to verify an alcohol fuel fire.

Alcohol fuels do not react to standard firefighting extinguishment methods. Water dilutes the alcohol increasing the size of a running fuel fire. The best firefighting agent for alcohol fires is Alcohol Resistant Aqueous Film Forming Foam (AR-AFFF). The International Association of Fire Chiefs and the Ethanol Emergency Response Coalition tested a range of firefighting foams at the Ansul Fire Technology Center, in Marinette, Wisconsin in February 2007. AR-AFFF was determined to be the most effective fire extinguishing agent over standard AFFF, Class A foam, emulsifiers, conventional flouro-protein foam, and Alcohol-resistant film-forming flouro-protein (AR-FFFP) foam when tested against E-10 and E-85/95 fuels using the UL162 test methodology.

To stay current on this fuel technology, it is recommended that you visit the “Ethanol Emergency Response Coalition” web-site for new or updated information on this fuel technology *http://www.ethanolresponse.com/*


*Biodiesel is yellow in color with a slight cooking oil scent.*

## C. BIODIESEL

Pure biodiesel is referred to as B100 Biodiesel, which is a non-toxic, biodegradable, renewable, carbon-neutral, sulfur-free, domestically “grown” biofuel. B100 Biodiesel is refined from many American-grown fuel/energy crops such as soybeans, canola, rape-seed and even palm trees.

Biodiesel is yellow in color with a slight cooking oil scent. Not surprising when you consider that biodiesel is made primarily from soybeans or recycled vegetable oils and fats. It can be made from any triglyceride oil, including the vegetable oil used in kitchens, in a process called transesterification. Transesterification is a catalytic process where vegetable oils or animal fats react with an acid (methanol or ethanol) to produce biodiesel.

It can be blended with regular diesel or can be the sole fuel source. Biodiesel is an effective alternative fuel for diesel engines. Older diesel engines may require fuel system modifications since biodiesel could cause rubber seals to deteriorate. The biodiesel market is expected to grow to over 40 million gallons this year. Presently there are over 100 major fleets that use biodiesel; many are federal government agencies like NASA, the National Park Service, and the military.

Municipalities using biodiesel realize the additional benefit as an inexpensive way to meet their EPA clean air mandates. A case in point can be found in the partnership developed in Arizona between the Rio Rico Fire District and the University of Arizona. Together this partnership is collecting waste oil from local restaurants and converting it, at two fire stations, into biodiesel to run about 20 vehicles including fire engines and ambulances. This partnership is being funded by the EPA with a $90,000 grant.

*This Engine is powered with biodiesel made on site at the Rio Rico Fire Station in Arizona.*

*—Courtesy of Rio Rico Fire Deparment*

A 2006 study conducted by the U.S. Department of Energy's National Renewable Energy Laboratory found that for large vehicles, burning a mixture of 20 percent biodiesel to 80 percent petroleum diesel, known as B-20, reduced emissions of particulate by 16.4 percent, carbon monoxide by 17.1 percent and total hydrocarbons by 11.6 percent.

## Biodiesel Properties

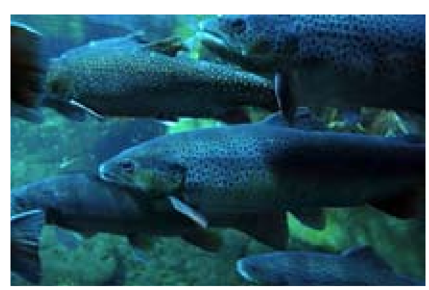
The good news is that biodiesel is nontoxic. The acute oral lethal dose is greater than 17.4 g/Kg body weight. By comparison, table salt (NaCL) is nearly 10 times more toxic. A 24-hr. human patch test with undiluted biodiesel produced a very mild irritation. The irritation was less than the result produced by 4 percent soap and water solution.

*Biodiesel is non-toxic. Nevertheless, protect the aquatic environment by preventing fuel from entering storm drains and waterways*

Additional environmental concerns shows that a 96-hr. lethal concentration for bluegill of biodiesel grade methyl esters was greater than 1000 mg/L. Lethal concentrations at these levels are generally deemed "insignificant" according to NIOSH (National Institute for Occupational Safety and Health) guidelines in its Registry of the Toxic Effects of Chemical Substances.

Biodiesel degrades four times faster than petroleum diesel. Within 28 days, pure biodiesel degrades 85 to 88 percent in water. Dextrose (a test sugar used as the positive control when testing biodegradability) degraded at the same rate.

Blending biodiesel with diesel fuel accelerates the diesel fuels biodegradability. For example, blends of 20 percent biodiesel and 80 percent diesel fuel degrade twice as fast as #2 diesel alone.



The flash point of a fuel is defined as the lowest temperature at which the vapor above a combustible liquid can be made to ignite in air. The flashpoint of biodiesel is 266° Fahrenheit, well above petroleum based diesel fuel's flash point of around 125° Fahrenheit. Testing has shown the flash point of biodiesel blends increases as the percentage of biodiesel increases. Therefore, biodiesel and blends of biodiesel with petroleum diesel are safer to store, handle, and use than conventional diesel fuel.

To mitigate a release or spill, emergency responders should isolate the fuel from potential ignition sources such as; flares, smoking or flames in the hazard area. Stop the leak if you can do it without risk. Keep unnecessary people away; isolate hazard area and deny entry. Isolate for half mile in all directions if tank truck or storage tank is involved in fire. Water spray may reduce vapor but may not prevent ignition in closed spaces.

*Any diesel vehicle can be fueled with biodiesel including these long haul trucks.*

Although this product is not considered to be a water pollutant, releases of this product should be prevented from contaminating soil and water, and from entering drainage and sewer systems. Contain liquid to prevent further contamination of soil, surface water or groundwater. Soak up small spills using absorbent material such as paper, rags, or sawdust and place into containers for later disposal.

### Vehicle Identification

Most diesel vehicles can switch to biodiesel without any changes to the vehicle. There are no standards that require vehicle owners to provide badging or signage for the fuel that they have on board.

### Vehicle Operation

Biodiesel vehicle operation is the same as any other internal combustion vehicle that you are already familiar with. Shut-off the engine using the ignition key. Set the parking break and chock the wheels when working around ICE vehicles.

### Biodiesel Vehicle Refueling

Biodiesel is delivered by tanker truck to service stations and stored in underground tanks. Consumers use standard service pumps to fill their vehicles. The standard service station safety features apply, breakaway hoses, an emergency shut-down switch, and protection of the pump island from vehicle collisions.

### Emergency Response Considerations

Combustion of biodiesel fuel produces carbon monoxide, carbon dioxide along with thick smoke. It is recommended that dry chemical, foam, CO2, or water spray (fog) is used for extinguishment. Caution must be exercised as a water stream may splash the burning liquid and spread the fire. Water spray should be used to cool drums of biodiesel exposed to fire.

A characteristic of biodiesel is that, like linseed oil, biodiesel soaked rags or spill absorbents can cause spontaneous combustion. Biodiesel soaked rags or spill absorbents should be stored in approved safety containers and disposed of properly. Oil soaked rags may be washed with soap and water and allowed to dry in well ventilated area. Firefighters should use self-contained breathing apparatus to avoid exposure to smoke and vapor.

In an accidental spill, remove sources of ignition, contain spill to smallest area and if possible stop the leak. You can pick up small spills with absorbent materials and dispose of these materials properly to avoid spontaneous combustion. It maybe good to know the Specific Gravity of biodiesel is 0.88 or slightly lighter than water. Which means that biodiesel can float on the surface of the water and can quickly get into storm drains and natural waterways.

*"In an accidental spill, remove sources of ignition, contain spill to smallest area and if possible stop the leak."*

To recover large spills for salvage or disposal, wash hard surfaces with safety solvent or detergent to remove remaining oil film. The greasy nature of the oily film will result in an unsafe slippery surface.

To stay current on this fuel technology, it is recommended that you visit the "National Biodiesel Board" web-site for new or updated information on this fuel technology. *http://www.biodiesel.org*

## D. NATURAL GAS (CNG & LNG)

Natural gas is the fuel many people use to heat their homes and cook their food. But natural gas also has a proven safety record as a vehicle fuel. Unlike gasoline, natural gas is nontoxic, non-corrosive, and contains almost no smog-forming hydrocarbons. With its high ignition temperature and narrow explosive range, natural gas is much less likely than gasoline to ignite accidentally.

Natural gas vehicles, or NGVs, offer another solution to the pressing problems of air pollution, ocean and ground water contamination, and questionable global oil supply. NGVs meet low emission standards well ahead of state mandated phase-in schedules. Natural gas has a reputation as a reliable domestic fuel. With vast reserves still avail-


*CNG distribution centers in California.*


able in the continental U.S., natural gas is well positioned to serve our transportation energy needs for years to come.

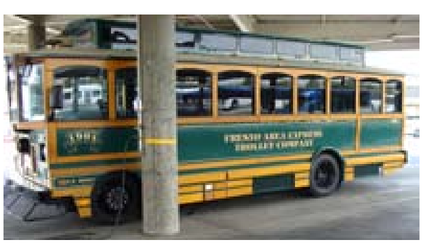
NGVs are powered by a clean and reliable domestic fuel that is available through a rapidly expanding retail infrastructure. With over 80,000 miles of distribution pipeline within California alone, natural gas is already available in most communities. The number of compressed natural gas (CNG) fueling stations has grown in California from a mere handful in 1990 to several hundred today. Across the country there are more than 1,300 fueling stations, with more stations being built each week.

Over 40 different manufacturers have at one point produced light, medium and heavy duty vehicles and engines. There are over 109,000 NGVs on U.S. roads and over one and a half million worldwide. New vehicles are available mostly to fleet vehicle operators. Fleet vehicles include: state and local government, transit, taxi, school, refuse trucks, street sweepers, postal, and freight delivery vehicles.

The driving cost and range of NGVs compares well to gasoline and diesel vehicles, with fuel efficiency for light duty vehicles of 25 to 30 miles per gallon. Fleets that have switched to NGVs have found their overall operating costs comparable to or lower than conventional vehicles.

Natural gas burns cleaner than other fuels, reducing routine maintenance costs and has lower emissions. The use of natural gas can help eliminate U.S. dependence on foreign oil, increasing national security and lowering the foreign trade deficit.

Natural gas is an abundant, domestically available product. Natural gas is primarily methane (CH4). It originates through conversion of organic material by micro-organisms (biogenesis), thermal decomposition of buried organic matter (thermogenesis), or deep crustal processes (abiogenesis). When formed by thermogenesis or abiogenesis, buoyant methane migrates upward through rock pores and fractures, then, either accumulates under impermeable layers or eventually reaches the surface and dissipates into the atmosphere.



*Natural gas mass transit vehicles are easy to identify with their characteristic hump on the roof, where the CNG cylinders are stored.*

Because natural gas is lighter than air, it doesn't pool on the ground as do gasoline, diesel, ethanol and propane fuels. The fuel storage cylinders for natural gas are stronger than gasoline tanks and can withstand crash, bonfire, and gun-shot tests.

There are two distinct fuel storage techniques for NGVs: Compressed Natural Gas (CNG) and Liquefied Natural Gas" (LNG). Even though natural gas is a safe and reliable fuel, the two fuel storage techniques warrant different safety precautions and awareness by emergency response personnel.

## Natural Gas Properties

Natural gas is compressed so that it can be used as a practical and portable fuel supply. CNG is comprised mostly of methane with 5 to 20 percent of other vapors such as ethane, propane, and butane. A methane molecule is comprised of four hydrogen and one carbon atom and is considered a "simple" hydrocarbon (CH4). Comparatively, gasoline and diesel are considered "complex" hydrocarbons.

## Compressed Natural Gas

CNG is naturally colorless and odorless. To aid in detection of gas leaks, producers add an odorant, mercaptan, which smells like sulfur or rotten eggs. This smell can be detected before the gas reaches its lower flammability limits. Natural gas is non-toxic and presents no exposure hazard. However, natural gas can displace the atmosphere and can pose an asphyxiation hazard in enclosed spaces. Fortunately, natural gas can be ventilated to the outside and dispersed into the atmosphere.

*Card-lock facilities like this one in Chico, California service the area's CNG fleet vehicles.*

CNG is stored under high pressure, and its storage cylinders are thicker than other types of fuel tanks. If a high-pressure fuel system component fails, gas can be released suddenly and forcefully. CNG systems are commonly pressurized up to 3600 psi—almost 30 times the pressure in an air-brake system. This is similar to the pressure of a self-contained breathing apparatus (SCBA).

> ***"When ignited, CNG produces a flame that is visible under most conditions."***

Natural gas is lighter than air and will rise if released into the atmosphere. Vapors from gasoline, diesel, ethanol, or propane, on the other hand, are heavier than air and tend to settle in low lying areas. The buoyancy of natural gas provides emergency responders with the option of allowing the gas to release itself to the atmosphere without harm to the environment, or of allowing a gas-fueled fire to burn itself out.

All fuels are flammable when vaporized and mixed with air. When CNG is released to the atmosphere, it is already in vapor form. When ignited, CNG produces a flame that is visible under most conditions. Under certain conditions, as in an unventilated confined area, CNG can also explode.

To be a fire or explosion hazard the air/fuel vapor ratio must be within the flammable range. For natural gas, the flammable range occurs when the fuel/air mixture is between 5 and 15 percent. Below 5 percent, the fuel/air mixture is too lean to burn; above 15 percent the fuel/air mixture is too rich to burn.

As a safety measure, many CNG installations have combustible gas detectors located on the ceiling—in some cases in the fuel compartment of the vehicle—to detect gas rising from a leak. These detectors sound an alarm when the mixture reaches one-fifth of the lower flammability limit.

*Commercial LNG facilities, like this one, refuel a variety of LNG fleet vehicles.*

## Liquefied Natural Gas

The characteristics of LNG are similar to those of CNG. The difference is that LNG is stored as a liquid under pressure at low temperature in a cryogenic storage tank. Unlike CNG, odorant is not added to LNG. Therefore you cannot rely on the characteristic smell ("rotten eggs") of natural gas to detect a leak.

As a cryogenic liquid, LNG will burn or cause frostbite on exposed skin. Just as natural gas is lighter than air, LNG is lighter than water. LNG will form ice crystals on water and float on the surface.

LNG vapors are lighter than air— but only after it warms to above –160 degrees (F). At –160 degrees (F) the vapor is the same weight as air. From –260 to –160 degrees (F) the vapor cloud is heavier than air.

Any gas when cooled or sufficiently compressed becomes a liquid. Steam, for example, turns to water below 212 degrees (F) under standard pressure. Methane, on the other hand, turns to liquid at –258 degrees (F).

**The advantages of storing natural gas as a liquid include:**

- ❖ Lower level of impurities, which in turn provides a more consistent and controlled mixture of gas to air in the engine.
- ❖ Lower storage pressure. LNG tanks are stored at 230 psi, rather than the 3,600 psi used for compressed natural gas.
- ❖ Greater storage density. LNG holds 2-3 times more than CNG.


LNG is stored in a double walled, stainless steel tank, much like a thermos. It is possible to store at least three times as much natural gas in the same volume of space as compressed gas. LNG cylinders have been subjected to the same rigorous safety tests that CNG cylinders undergo, including burn, crash, and gunshot tests and perform as well. LNG cylinders are built to DOT4L specifications according to NFPA 57.

Should a failure occur in both walls of a LNG tank, so that LNG flows out, it will pool as a liquid and form a vapor cloud that will dissipate into the atmosphere. A small leak or dribble from a refueling operation gives the liquefied natural gas a liquid mercury like character with silver beads of natural gas dancing around the pavement until they quickly dissipate into the atmosphere.

Because of the physical differences between LNG and liquefied petroleum gas (Propane or LPG), along with the differences in storage techniques, Boiling Liquid Expanding Vapor Explosion (BLEVEs) is less of a concern for LNG storage cylinders. There have been no recorded cases of catastrophic failure, or of BLEVE's associated with liquefied natural gas.

Water should not be sprayed on a liquefied natural gas spill. The reaction of water to the cryogenic liquid could cause the liquid to splatter violently over a wide area. When water is applied, it warms the liquid, increasing the amount of vapor production.

When water is applied to a LNG fire the increase in vapor volume increases the intensity of the fire. If the fuel cannot be allowed to safely burn itself off then a high flow Purple K fire extinguisher should be used. High expansion foam can be used to cover the surface of a 2 dimensional LNG fire to reduce the intensity of the fire.

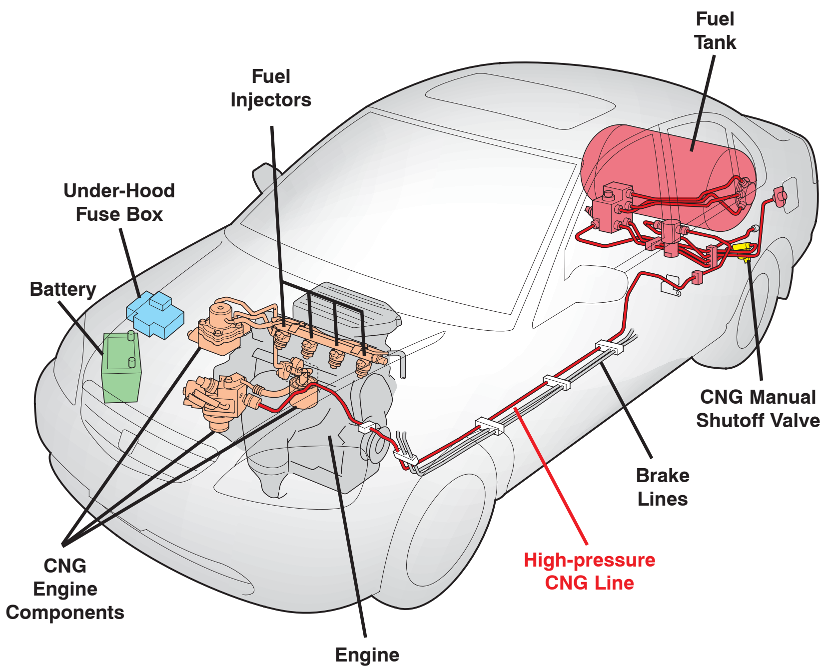
Every effort should be made to insure that the cryogenic liquid is not allowed to flow into storm or sewer drains. You can contain the liquid with an earth or sand dike.

## Vehicle Identification

Emergency responders can expect to encounter a wide range of vehicle types that use natural gas as their primary or secondary fuel source; passenger vehicles, mass transit vehicles, refuse disposal vehicles, and freight vehicles.

In the transition from gasoline or diesel fuel, many of these vehicles may contain both gasoline tanks and natural gas cylinders that can be easily switched at the discretion of the vehicle operator. In either case—bi-fuel or all natural gas—the emergency responder must first identify the vehicles fuel system before committing to a specific fire or rescue operation.

Many production NGVs are modifications of the same make and model (gasoline or diesel) vehicles that you see on the road every day. So how do you distinguish NGVs involved in an incident from their standard fuel counterparts? When an NGV is delivered to the customer, it comes equipped with a distinctive diamond shaped insignia with "CNG" or "LNG" printed in the middle. These decals are typically located on the




rear or side/rear of the vehicle and on exposed cylinders.

These natural gas industry approved symbols were designed to aid emergency response personnel by identifying the type of fuel being used. However, you should recognize that there is no guarantee the customer will keep the insignia on the vehicle or that the insignia will be easily identified after a vehicle collision or fire.

## Vehicle Operation & Shutdown

Natural gas vehicles, both CNG and LNG, operate much as their gasoline and diesel fuel counterparts. Some vehicles use both gasoline and CNG as a Flex-Fuel or Bi-Fuel vehicle. In either case, an ignition key is used to turn on the engine and allow the fuel to flow from the CNG cylinder or LNG container to the fuel regulator and on to the combustion engine. The fuel regulator reduces the fuel pressure on CNG vehicles from 3,600 psi to a range of 60 to 120 psi, depending on make and model of the vehicle. For LNG vehicles, the fuel is regulated from 230 psi to a range of 75 to 120 psi.

The fuel regulator regulates the pressure delivered to the engine. The fuel regulator can be located close to the CNG cylinder or LNG container, or it can be located within the engine compartment. If the regulator is near the fuel tank, downstream natural gas will be at relatively low pressures. If the regulator is near the engine, pressures from the tank to the regulator will be relatively high. The fuel flows from the cylinder or container to the regulator — then to the engine compartment and engine. Fuel is routed from the cylinder through stainless steel tubing and high-pressure fittings either under or through the vehicle chassis. There is no circumstance where the stainless steel fuel lines transverse the posts, roof or passenger compartment of the vehicle. Realizing that high-pressure fuel lines are present, caution should be exercised during extrication emergencies to ensure that the fuel lines are not inadvertently severed.

To shut down an NGV, you turn the ignition key to the “off” position, which simultaneously turns off the engine and stops the flow of fuel from the cylinder. NGVs have a manual shutoff valve at the cylinder or container. To insure that a CNG or LNG cylinder or container is no longer flowing fuel, or to stop a fuel leak, locate the cylinder or container shut-off valve under the vehicle chassis or close to the fuel cylinder. The shut-off valve requires a quarter turn to shut off the flow of fuel from the cylinder. The location of the fuel shut-off valve can vary from make and model of vehicle. Typically, it is near and under the cylinder itself.

## Fuel Cylinders

Fuel cylinder construction is the same for all gaseous fuels, natural gas, propane, and hydrogen. CNG cylinders are similar in design and construction to the air tanks used in Self Contained Breathing Apparatus (SBA's). However, instead of pressurized air, CNG cylinders contain pressurized natural gas. The high-pressure gas exerts forces on the walls of the cylinders. To withstand these forces, cylinders are made of thick-walled, high strength materials such as steel, aluminum, or composites.

*Cylinders come in a variety of construction materials; steel, aluminum, and fiber wrapped.*

Cylinders are made to withstand much higher pressures than the normal service pressure. For example, a cylinder rated for service at 3,600 psi is designed to withstand pressures in excess of 8,100 psi. Regardless of this design potential, cylinders should never be pressurized above their maximum fill pressure (generally, 1.25 times the service pressure).

The typical CNG cylinder has a cylindrical shaped sidewall with hemispherical domes on the ends. The cylinder ends typically contain a metal port that can be used for inserting a valve, end plug, or other part. The expected life span of a cylinder is normally 15-20 years.

***Cylinders used for natural gas, propane or hydrogen, are all made to withstand 1.25 times the service pressure.***

**The four types of CNG cylinders are:**

***Type 1:*** An all metal cylinder made of steel or aluminum.

***Type 2:*** A cylinder with a metal liner made of steel or aluminum and a hoop-wrapped fiber overwrap.

***Type 3:*** A cylinder with a thin metal liner and fully wound-fiber overwrap.

***Type 4:*** A cylinder with a plastic liner and a fully wound-fiber overwrap.

In composite-wrapped cylinders, the composite fiber overwrap plays a key role in resisting the high gas pressure forces pushing against the cylinder liner wall. As gas pressure increases, it produces tension on the fibers and causes them to stretch slightly. Fibers can easily handle normal gas pressure. However, going beyond the maximum fill pressure may put too much stress on the fibers leading to fiber breakage and possible cylinder failure.

For safety, the CNG cylinders are equipped with pressure relief devises (PRD). The devise is set at a predetermined temperature which will vent the CNG before any chance of explosion.

*A vehicle fire and inoperative pressure relief device (PRD), allowed this cylinder to fail.*

*–Courtesy of Seattle F.D. Washington*

On most vehicles a vent tube is attached to the PRD which will vent pressurized gas to the outside of the vehicle. When a cylinder is involved in a vehicle fire the compressed gas will expand and will open the PRD and allow the cylinder to vent. The cylinder will continue to vent until all of the gas is expelled. For LNG containers, the PRD will vent-off excess pressure then the PRD will re-seat itself. It is important to not fill the LNG vent tube with water as the escaping gas will freeze, blocking the vent tube.

The pressure relief device releases gas when the cylinder is exposed to a fire, to insure that the cylinder will not explode. It can also release pressure when the tank pressure increases beyond its rated capacity. The vent tube can be located at the rear or the side (rear) of the vehicle, depending on manufacturer. It is important for emergency response personnel to identify the location of the relief device vent before they begin any operation around the vehicle. When PRDs operate they vent the entire contents of the cylinder(s) they are protecting. When a PRD operates you may hear a loud, high-pitched whistle.

*This Hydrogen cylinder is undergoing the bonfire test.*

A number of standards have been developed for natural gas cylinders, including NGV2 Standard, (ANSI/CSA NGV2 "Basic Requirements for Compressed Natural Gas Vehicle Fuel Containers"). This is a voluntary industry standard which contains ten design qualification tests, including pressure cycle, environmental pressure, burst, impact, bonfire, and gunshot.

The FMVSS 304 standard (49 CFR 571.304 – "Compressed Natural Gas Fuel Container Integrity") is a mandatory Federal (NHTSA/ DOT) Motor Vehicle Safety Standard applicable to all CNG cylinders sold for motor vehicles in the US. FMVSS is similar to an older version of NGV2 but has fewer design qualification tests. Transport Canada and the International Organization for Standardization (ISO) have cylinder standards similar to NGV2.

For the fire service, NFPA 52 "Compressed Natural Gas CNG Vehicular Fuel Systems," along with FMVSS 303, ensure that pressurized CNG fuel tanks are shielded from damage by road hazards and mounted to minimize damage from a collision. To this end, fuel tanks cannot be mounted in front of the front axle or behind the rear axle. The tanks must be securely fastened to the vehicle and shielded from direct heat generated by the vehicle exhaust system. Pressure relief devices (PRD) must be vented to the outside of the vehicle.

Depending the on the make, model, and vehicle manufacturer, natural gas containers may be found in the rear, trunk, pick-up bed, as side tanks, or on top of the vehicle. In passenger vehicles and small trucks, the CNG cylinders are typically found in the rear of the vehicle, mounted in the pickup bed, the vehicle trunk, or under the rear of the vehicle where a gasoline tank had previously been mounted. Large heavy duty vehicles may replace their saddle-mount diesel tanks with LNG containers, while buses may have LNG containers under the passenger compartment or CNG cylinders on top of the vehicle.

## CNG Vehicle Refueling

Natural gas is delivered to the refueling site from an intricate network of transmission and distribution pipelines that crisscross the country. Typically, distribution or feeder lines deliver product to site at, or below, 60 psi. Pressure in the transmission pipeline runs 60 psi or greater.

*From the pipeline natural gas is scrubbed, dried, and compressed before it is pumped to the customers vehicle.*

Natural gas is then run through several stages before it is delivered to the customer. From the feeder line the gas is sent through a dryer to remove moisture and then through a filter to remove particulate matter. The natural gas is then compressed to 3,600 psi and stored in above ground storage tanks. The storage tanks can hold 10,000 cubic feet or 300 gallons of product.

The refueling customer typically has a plastic card that unlocks and provides access to the natural gas dispenser. The customer then attaches the hose to the vehicle and begins the refueling operation. Once fuel has been transferred the dispenser automatically stops the flow of fuel.


*Emergency response plans of any refueling station should include the locations of emergency shut-down switches.*

**The NFPA Standards for natural gas fuel systems include:**

- ❖ NFPA 52, "Compressed Natural Gas (CNG) Vehicular Fuel Systems Code"
- ❖ NFPA 57, "Liquefied Natural Gas (LNG) Vehicular Fuel Systems Code"

**Each of these standards specifies that refueling stations have manual and automatic shut-off valves. A number of methods are designed to shut off the flow of natural gas:**

1. *A manual shut-off switch is located at the main CNG dispensing location. Customers are trained to shut down the dispenser if they feel a problem or hazard exists. If the dispenser detects a problem it will automatically shut down.*
2. *Breakaway protection is provided in the event of a vehicle pulling away from the refueling station while the fueling hose is still connected to the vehicle. The breakaway device stops the flow of natural gas to the dispenser.*
3. *A manual emergency shut-down switch is located at a remote location from the dispenser. The location is clearly marked with a red sign and white lettering. The emergency switch will stop the flow of fuel to the dispenser.*
4. *For emergency response personnel, a curbside shut-off valve is provided. The emergency shut-off valve will turn off the gas supply to the dispenser.*

*It is important that emergency response personnel identify and locate the curbside valve before responding to an emergency at the facility.*

5. *Another emergency shut-off switch is located on the compressor control panel. Typically a trained gas company employee would use this switch and any of the valves located in the compressor and storage area while performing maintenance. The switch shuts down power and the flow of gas to the compressor.*

When pre-planning a natural gas fueling station, be sure to review the gas company's EPA mandated MSDS sheets (See Appendix A) and emergency action plan. These documents specify the locations of the main electrical power as well as emergency shutoff valves and switches. Preplans of the fueling facility should include the location of fuel storage areas, compressors, along with manual, curbside and emergency shut-off valves and switches.

"Preplans of the fueling facility should include the location of fuel storage areas, compressors, along with manual, curbside and emergency shut-off valves and switches."

Emergency response to refueling stations must include the use of full structural firefighting clothing and SCBAs. You can protect and extinguish a fire involving a vehicle or threatening exposures using water and foam. If the venting CNG is on fire and it doesn't threaten lives or exposures you can let the fire continue to burn until a gas company employee arrives to lend assistance. With LNG facility fires you could also allow the fuel to burn off. You should not put water on a LNG fuel leak. If the area around above ground fueling containers, are involved in a fire, and if there is no liquefied natural gas, carefully approach the tanks and use water to cool the tanks and/or to protect surrounding exposures.

*Residential refueling offers flexibility to CNG vehicle operators.*

## CNG Residential Refueling

Though not yet common, several companies are marketing compressors that take the natural gas piped to a residential site and compress it to refuel a CNG vehicle. The residential fueling facility (RFF or vehicle refueling appliance—VRA) is an assembly used for compression and delivery of natural gas into vehicles. The RFF includes all associated equipment such as hoses and couplings. Similar to commercial refueling stations, RFF systems have manual and automatic safeguards that shutoff both the flow of fuel and electrical power as mandated by NFPA 52.

All related equipment for an RFF is designed to minimize the possibility of physical damage and vandalism. The systems can be allowed either indoors or outdoors, but outdoor installation is preferable. With indoor installations, a gas detector set to alarm at one fifth the flammable limit is required, and the compression unit must be located to allow venting to the outdoors.

The ability for homeowners to fuel their vehicles in their own driveways suggests that emergency responders should be prepared to deal with natural gas emergencies not only on the highway, but at commercial refueling stations and in residential settings. To find out if you have residential refueling in your jurisdiction, contact the local building department and ask for any codes or ordinances that allow such devices. Also, inquire about recently issued permits and the location of residences that have installed RFF systems.

## LNG Refueling

LNG relies on tanker trucks to get the fuel to the refueling station. A tanker truck has the capacity of delivering up to 10,000 gallons per load. It is estimated that at least 200,000,000 gallons of LNG are trucked into California every day. And, every year this capacity keeps increasing.

*LNG re-fueling is handled by skilled professionals. Note the Protective gear, rubber apron, gloves, and face shield to protect the operator from cryogenic burns.*

The delivery truck transfers the LNG to an on-site storage tank or vehicle for mobile refueling operations. Refueling operators wear rubber aprons, work boots, leather welding gloves, safety glasses and face shields to protect themselves from the cryogenic liquid. Fuel is transferred from the storage tank to the vehicle through a vapor shielded dispenser. An emergency shut-off switch is located in the dispenser panel and at a safe remote location between 30 and 75 feet away.

*Ice crystals around the LNG tank valves during re-fueling is normal.*

Cryogenic LNG containers, consists of two nested tanks that form a thermos-like insulating vessel to keep the liquid from reaching its boiling point at the designed storage pressure. The space between the inner and outer tank is vacuum sealed and filled with an insulating material to keep the liquid below its boiling point. After LNG flows from the tank, it is heated by a heat exchanger to form vapor, which is then regulated to the proper pressure before it enters the engine.

*Ice crystals on the exterior of the tank indicate a tank failure.*

Large vehicles with sidesaddle tanks can hold up to 170 to 180 gallons of LNG. If opened to the atmosphere this volume of LNG would quickly dissipate into the atmosphere often times before emergency response personnel can get to the scene. It is common to see ice, frost or ice crystals on the outside of the container valve and hoses. Ice or frost on the container, however, would indicate a container failure. A slight loss in vacuum pressure would be indicated by sweat forming on the exterior of the tank. In either case, the LNG vapor would begin to boil off and the pressure relief valve would expel excess natural gas to the atmosphere.

It is important to note that LNG pressure relief devices will re-seat after pressure is sufficiently lowered. Importantly, vapor clouds around an LNG vehicle, does not always indicate a leak or a problem. When dealing with a cryogenic liquid, it should be recognized that one cannot see natural gas vapors. The vapors that are visible will be the moisture in the air as it is cooled by the cryogenic fluid or metal cylinders, valves, and lines that contain liquefied natural gas.

In an emergency involving LNG fuel leaks the immediate area should be evacuated and the surrounding exposures should be protected with hose streams until the gas completely vents to the atmosphere. You can use hose streams to direct the dispersal of the vapors away from exposures. If the vapor catches on fire protect exposures with hose streams and let the vapors burn off. If it is necessary to extinguish the fire, do not use water! Instead use a high flow Purple K extinguishing agent.

## Emergency Response Considerations

As a flammable gas, CNG leaks and fires can occur during fueling, maintenance, repair or as a result of traffic collisions. Open flames will cause CNG to ignite, which disallows smoking, welding, grinding or any other open flame operations around CNG facilities or vehicles. CNG also can be ignited by sparks from electrical equipment, static electricity, and contact with hot surfaces. CNG fires can be fought using foam or water. However, water should not be used when fighting LNG fires.

*Live-fire training on the rim of the Grand Canyon, demonstrates the characteristics of an LNG fire.*

One recommended strategy when dealing with NGV emergencies is to allow the gas vapors to dissipate into the atmosphere or to burn off all the fuel when no lives or exposures are threatened.

A leak from the high-pressure side of a CNG fuel system could produce a high-velocity cold gas jet. As the jet travels, the concentration of the gas drops as it mixes with ambient air. A release could cause injury from flying debris, the high jet momentum, or exposure to the extremely cold gas near the release point. The high velocity jet can create high intensity noise alerting emergency response personnel to a gas leak problem and/or its location.

If the gas jet comes in contact with a spark, a jet fire or “torch fire” at very high temperatures can cause serious burns and structural damage. Remember, however, that the gas-to-air mixture has to be within the 5 to 15 percent range for ignition to take place. The ideal response to a natural gas leak is to isolate potential sources of ignition from coming into contact with the gas plume until it is safely dissipated into the atmosphere. With a torch fire protect surrounding exposures from radiant heat or direct flame impingement with fog streams allowing the torch fire to burn itself out.

The greatest danger for natural gas is in enclosed spaces. Natural gas can displace oxygen in the atmosphere making it a potential asphyxiant hazard. In enclosed spaces, and in the proper flammable range, natural gas can explode when in contact with an ignition source.

**Emergency response to CNG and LNG can be pre-planned with the following actions:**

1. *Use gas detectors to determine a leak in the fuel system.*
2. *Isolate the fuel from potential sources. This can be accomplished by shutting-off the fuel valves on the vehicle or at the refueling station, or by directing the vapor cloud away from buildings and other potential sources of ignition with a fog stream.*
3. *If the fuel is on fire, protect surrounding exposures with hose streams and allow the fuel to burn it self off.*
4. *Use foam or water to extinguish a CNG fire if necessary.*
5. *Use a high volume of Purple K to extinguish a LNG fire, being careful of flashback after the fire has been extinguished.*
6. *Use high expansion foam on the surface of a LNG fire to reduce the fire's intensity.*
7. *Avoid contact with the high velocity jet in a CNG Leak*
8. *Avoid contact with LNG liquid.*
9. *Use sand or dirt to create a berm around a LNG fuel leak making sure that the fuel does not flow into sewer or storm drains.*

LNG will cause first degree burns or frostbite if not treated immediately. If a person has LNG on their clothes, defrost the fabric with water before trying to remove the clothing. Otherwise, frozen fabric will adhere to the skin—increasing the damage to the injured area.

*"LNG will cause first degree burns or frostbite if not treated immediately."*


*Consult original equipment manufacturer for the location of the fuel shut-off valve.*

## Coalition Interest

This section was originally funded by the California Office of Traffic Safety and the California Energy Commission with assistance by the California Natural Gas Coalition and Pacific Gas and Electric (PG&E). To stay current on this fuel technology, it is recommended that you visit the "California Natural Gas Vehicle Coalition" web-site for new or updated information on this fuel technology *http://www.cngvc.org.* It is highly recommended that you go to the original equipment manufacturer for specific emergency response guidelines for specific makes and models of vehicles.

## E. PROPANE

Propane gas and liquefied petroleum gas (LPG), is the nation's third most common vehicular fuel, after gasoline and diesel. There are over 270,000 on-road vehicles in the United States and more than 10 million worldwide that operate on propane. A large number of these are used in fleets that include light-to heavy-duty trucks, buses, taxicabs, police cars, and rental and delivery vehicles.


*Unlike CNG fueling stations, LPG fueling stations require a trained to technician to transfer fuel to the vehicle.*

Propane is safer (slower burning, higher ignition temperature) than gasoline, and because of its relatively simple chemical makeup it is potentially cleaner burning. Oil & filter changes can be extended when engines are run exclusively on propane. Likewise, longer engine life (often 180,000-200,000 miles) is expected.

Winter start-ups are easier with gaseous propane, but during hot weather, propane displaces already thin intake air which leads to a hot start and a potential loss of power. Propane lacks lubricity, so some OEMs use hardened valves/seats and guides; nor does propane provide for intake cooling, as do vaporizing liquid fuels.

In many ways propane and liquefied petroleum gas is somewhat similar in use to CNG and LNG. Vehicle operation and shut-down procedures are the same. The differences lay in the characteristics of these two fuel types along with their differences in storage techniques that emergency responders must be aware of.

### Propane Properties

LPG contains about 90% propane, with small concentrations of ethane, butane, propylene, and other gases. Propane and butane are both a


*Most propane vehicles are used in fleet operations, and are available from vehicle manufacturers as an option.*

derivative of crude oil extraction processes and are classified as liquefied petroleum gasses (LPG). Thirty percent of the propane produced today is extracted from crude oil and 70 percent is processed from natural gas. Like CNG, LPG is colorless and odorless in its natural state. Mercaptan, an odorant, is added to LPG to aid in leak detection.

At atmospheric pressure, propane remains a vapor down to –44° F. Under moderate pressure (typically well below 200 psi at 70° F) propane shrinks to a liquid 270 times more dense than when gaseous, making it ideal for compact on-board vehicle storage. If vented, propane boils off as a gas.

LPG is stored under pressure as a liquid. Because its boiling point is -44°F, liquid LPG expands rapidly into a vapor under normal outdoor temperatures and without containment. Liquid propane leaks are generally more dangerous than propane gas leaks because a small volume of spilled liquid propane can boil off into a large volume of propane vapor. LP gas expands 1.5 times for every 10 degree rise in temperature. In a closed container this increases the volume of liquid gas and increases container pressure. A pressurized tank or cylinder exposed to fire creates the potential for a BLEVE (Boiling Liquid Expanding Vapor Explosion).

*"A pressurized tank or cylinder exposed to fire creates the potential for a BLEVE (Boiling Liquid Expanding Vapor Explosion)."*

Unlike CNG, LPG is 1.5 times heavier than air. If a leak in the fuel system occurs the gas readily dissipates. However, under the right conditions, propane gas can settle in low unventilated areas and become concentrated when there is no air movement.

The flammable limit for LPG is between 2.15 percent and 9.6 percent — slightly less than the percentage for CNG. The ideal combustion ratio for propane is 24 parts of air to one part propane.


### Vehicle Identification

Similar to CNG and LNG, propane is marked in a blue diamond and the decal is affixed to the rear bumper of the vehicle.

### Vehicle Operation

Propane vehicle operation is the same as any other internal combustion vehicle that you are already familiar with. Shut-off the engine using the ignition key. Set the parking break and chock the wheels when working around ICE vehicles.

### Vehicle Refueling

Propane is distributed by rail and truck to local retailers. Modern propane dispensing equipment is designed for refueling at a rate of about


*Refueling stations that offer propane are easily identified with above ground storage tanks.*

12-18 gallons/minute. Propane refueling sites are found at public fill stations and truck stops, at equipment rental outlets, and at RV dealers and some campgrounds. Prices vary widely. Some bulk suppliers of propane offer direct retailing. LPG for rural domestic and farm use is normally trucked in and stored on site.

Liquid propane is pumped to the vehicle under pressure by a trained technician and is stored in steel tanks at 200 psi. Propane's "storage ratio" to gasoline is roughly 1.1 to 1, thus a bi-fuel propane vehicle tank doesn't take up as much cargo space as tanks for CNG. Propane tanks are filled to 80% to allow for expansion. If exposed to summer heat and sunshine, propane tank temperatures and pressures can rise radically. These conditions are handled by the tank's 20% expansion volume, pressure relief valves and the vehicle's fuel pressure regulator(s).

*Isolate fuel from potential ignition sources by shutting off fuel valves or by directing the vapor away from exposures using a fog stream.*

While the actual content of propane can vary, LPG intended as a vehicle fuel should be of the highest quality (>88% propane minimum) with little sulfur, paraffin, or olefin content. There is, as of yet, no national distribution system for propane as a vehicle fuel.

### LPG Emergency Response

When responding to an LPG vehicle incident, wear full structural firefighting clothing, approach the vehicle and tanks from the side, and direct hose streams to the top of LPG tanks to keep the vapor space cool. Whenever possible, avoid approaching the pressurized tanks from their ends in case of a tank BLEVE. The configuration of LPG fuel tanks varies by manufacturer. On the 22-foot shuttle buses, they are typically mounted horizontally, side-by-side underneath the floor, behind the batteries.

**Emergency response to LPG emergencies can be pre-planned with the following actions:**

1. *Use gas detectors to determine a leak in the fuel system.*
2. *Isolate the fuel from potential sources. This can be accomplished by shutting-off the fuel valves on the vehicle or at the refueling station, or by directing the vapor cloud away from buildings and other potential sources of ignition with a fog stream.*
3. *If the fuel is on fire, protect surrounding exposures with hose streams and allow the fuel to burn it self off.*
4. *Use foam or water to extinguish a LPG fire if necessary.*
5. *Avoid contact with the high velocity jet in a LPG Leak.*
8. *In confined space, allow LPG to ventilate before entering the space.*


*From a emergency responders perspective what can go wrong, will go wrong, as evidenced by this truck driving over a propane tank.*

### Information updates

To stay current on this fuel technology, it is recommended that you visit the "Propane Education and Research Council" web-site for new or updated information on this fuel technology, *http://www.propanesafety.com.* It is highly recommended that you go to the original equipment manufacturer for specific emergency response guidelines for specific makes and models of vehicles.

## F. HYDROGEN


*BMW has designed an internal combustion engine that uses hydrogen for the fuel.*

Hydrogen was first recognized as a distinct element in 1766 by the English chemist, Henry Cavendish, who called it inflammable air. His new discovery was found to form water on combustion with air, which led to it being named hydrogen, which means 'water former.' Hydrogen was little used until early in the nineteenth century when 'town gas,' a mixture of hydrogen, methane, carbon dioxide, and carbon monoxide made from coal was used for cooking and lighting.

Today, hydrogen is an important chemical commodity. In the U.S. alone, more than eight million tons are produced annually, mostly by steam reforming natural gas. Hydrogen has been transported safely both as a cryogenic liquid and as a compressed gas by rail, barge, truck, and pipeline for use in the aerospace, food, petrochemical, and semiconductor industries. These industries have an excellent safety record with hydrogen because they understand the risk and how to manage it.

Hydrogen is not only used in internal combustions engines, but also in fuel cell processes to generate electricity. BMW's Hydrogen 7 is one of several hydrogen fueled prototype passenger vehicles that can be ready for distribution.

Hydrogen vehicles, and fuel cell vehicles that rely on hydrogen, are stymied by the "chicken and the egg" syndrome. Vehicle manufacturers cannot mass produce vehicles to make them affordable without a reliable fuel supply. On the other hand, the refueling infrastructures are not being built, because there is no vehicle demand for the fuel. The only solution to this "which will come first" problem is for the Federal government to muster the resources and build the infrastructure necessary for the growth and acceptance of this technology.

Nevertheless, hydrogen as a fuel is as promising as any of the other alternative fuel choices. There are over 200 vehicles that rely on gaseous hydrogen, with 22 that utilize liquid hydrogen, on California roadways today—enough vehicles for emergency responders in major metropolitan areas like Los Angels, San Diego, San Francisco and Sacramento to become familiar with this technology.

## Hydrogen Properties

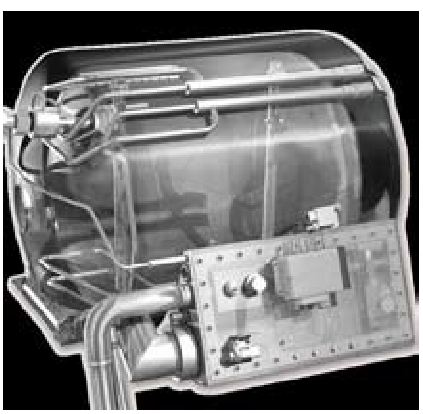
Hydrogen is most commonly used as a gas compressed to 2,400 psi or as a cryogenic liquid at below -253 degrees Celsius (20 degrees above absolute zero).

When volume is a consideration, hydrogen may be stored as a liquid. One and a half million cubic feet of hydrogen as a liquid can be stored in the same space it takes to store 100,000 cubic feet of hydrogen as a gas. Typically you would find hydrogen storage at electronic plants, NASA, and food processing facilities.

*"Hydrogen is most commonly used as a gas compressed to 2,400 psi or as a cryogenic liquid at below -253 degrees Celsius."*

**The properties of hydrogen make it an acceptable fuel choice:**

- ❖ Hydrogen has no color, no odor (and cannot be odorized), no taste or flavor.
- ❖ Hydrogen is less flammable than gasoline. The self-ignition temperature of hydrogen is 550 degrees Celsius. Gasoline varies from 228-501 degrees Celsius, depending on the grade.
- ❖ Hydrogen disperses quickly. Being the lightest element (fifteen times lighter than air), hydrogen rises and spreads out quickly in the atmosphere. When a leak occurs, hydrogen gas quickly becomes so sparse that it cannot burn. Even when ignited, hydrogen burns upward, and is quickly consumed. By contrast, materials such as gasoline, diesel, ethanol and propane vapors are heavier than air, and will not disperse as quickly, remaining a flammable threat for much longer.
- ❖ Hydrogen is a non-toxic, naturally-occurring element in the atmosphere. By comparison, gasoline and diesel is poisonous to humans. Hydrogen can, like any other gas, displace oxygen in confined areas making it an asphyxiant hazard.
- ❖ Hydrogen combustion produces water vapor and heat. When pure hydrogen is burned in pure oxygen, only pure water is produced. A scenario, which only occurs in laboratories and the space shuttle. In any case, when a hydrogen engine burns, it actually cleans the



*BMW H2 Tank*

ambient air, by completing combustion of the unburned hydrocarbons that surround us. Compared with the toxic compounds (carbon monoxide, nitrogen oxides, and hydrogen sulfide) produced by petroleum fuels, the products of burning hydrogen is obviously much safer.

- ❖ Hydrogen can be stored safely. Cylinders currently in use for storage of compressed hydrogen (similar to compressed natural gas tanks) undergo and have survived intact through testing including; shot test with six rounds from a .357 magnum, detonation test with a stick of dynamite next to the cylinder, and subjecting them to fire at 1500 degrees F. It is not likely that a typical gasoline tank wouldn't survive any of these tests.
- ❖ Hydrogen has three times the energy content per pound as gasoline or diesel fuel, and has 71% less greenhouse gas emissions per energy unit over the whole fuel production cycle relative to gasoline.

As an asphyxiant, it should be noted that before suffocation could occur, the lower flammability limit of hydrogen in air would be exceeded possibly causing both an oxygen-deficient and explosive atmosphere. Exposure to moderate concentrations may cause dizziness, headache, nausea and unconsciousness.

Exposure to atmospheres containing 8-10% or less oxygen will quickly bring about unconsciousness without warning leaving individuals unable to protect themselves. Lack of sufficient oxygen may cause serious injury or death.

## Hydrogen Vehicle Identification

The BMW Hydrogen 7 vehicle will undoubtedly set the industry standard when hydrogen ICE vehicle become more prevalent as the first commercially available ICE hydrogen vehicle. The BMW Hydrogen 7, like all alternative vehicles, is clearly labeled and/or badged. BMW utilizes both gasoline and hydrogen fuel capabilities in their internal combustion engine (ICE). When one or the other fuel runs out, the vehicle automatically switches over to the other. This vehicle has a range of 310 miles on gasoline and an extra 125 miles on Hydrogen.

## Hydrogen Vehicle Operation

Hydrogen vehicle operation is the same as any other internal combustion vehicle that you are already familiar with. Shut-off the engine using the ignition key or power button. Set the parking break and chock the wheels when working around ICE vehicles.

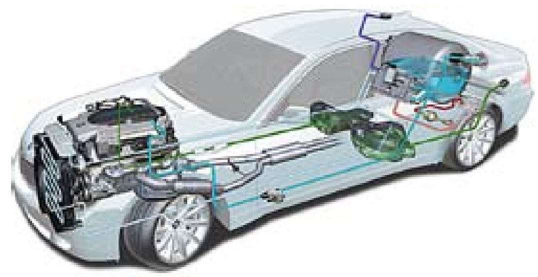
BMW's Hydrogen 7 uses an insulated cryogenic tank to hold 18 lbs of liquid hydrogen. The design of this tank is equal to 57 feet of normal



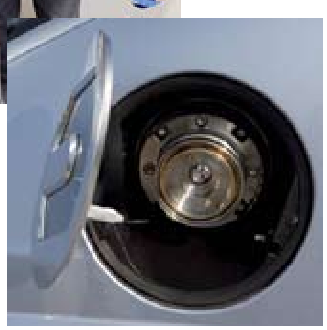
*H2 warning systems are standard in BMW.*

insulation material. Hydrogen in the storage tank will boil off over time. The boil off management system will burn excessive hydrogen gas in a catalytic converter. It takes only nine days for 1/3 of the liquid hydrogen in the tank to become a water vapor.

Due to the risk of hydrogen vapors, parking the BMW Hydrogen 7 in an enclosed space is not an option. BMW has a number of safety features built in to their hydrogen vehicle including: driver warning systems in the case of a hydrogen system malfunction, gas detectors, and pressure relief vent openings on the roof of the vehicle. In the event of an overturned vehicle, hydrogen will also be relived from the underside of the vehicle. The hydrogen system is further monitored through a GPS signal.



The vent tubes run through the rear C support on both sides of the vehicle. BMW points out that during extrication the A and B pillars can be severed and the roof folded back without cutting the C pillars. For the rescue team this means a roof flap is the only available extrication option as roof removal is not recommended. Fuel lines to the engine compartment do not run through the passenger compartment, but within the undercarriage of the vehicle.



There are three batteries in the trunk. Two support the hydrogen boil-off, leak detection and warning systems. These batteries should never be controlled by firefighters. There is however, a single 12 volt battery that supports normal electrical functions of the vehicle. This battery can and should be controlled during extrication operations. BMW has placed labels on all three batteries with safety instructions.

The door lock pins on the interior door panel flash red in the event of a hydrogen release inside the vehicle cab. Proper actions include removing side window glass and placing a power blower for hydrogen gas removal.

You can expect to see additional improvements being made by BMW in hydrogen boil-off management and fuel tank efficiency in the future.

## Hydrogen Refueling

Hydrogen fuel stations are in the planning and development process in key metropolitan areas of California with a focus on

San Francisco Bay Area, Sacramento, Los Angeles and Orange County. Hydrogen stations are not a "one-size-fits-all" technology. Some stations can make hydrogen fuel on site by reforming natural gas or electrolyzing water. Other stations dispense hydrogen made at a central production facility which is then trucked to the on-site storage tank. Some stations will only dispense hydrogen fuel while others will dispense it along side other fuels. For larger applications like fleet vehicles, an on-site stationary fuel cell system can make electricity and heat for buildings, as well as hydrogen for fleet vehicles.

## Hydrogen Emergency Response

The protocols for fighting a hydrogen fire are similar to the basic rules for fighting any fire fueled by a flammable gas. The first thing to do is to eliminate the ignition source and/or isolate the fuel. If this is not an option, the fuel source is generally allowed to burn itself out while protecting exposures to minimize the risks of injury and danger to the surrounding area.

Hydrogen fires have a pale blue to invisible flame and generate little smoke. However, combustible material in or near the hydrogen flame, and particles in the air will likely render a visible flame and give off smoke. Use ultra-violet and/or infra red (IR) detectors, if available, to scan for invisible hydrogen flames. If no flames are present, scan the vehicle with a hydrogen leak detector (combustible gas detector rated for hydrogen), if available. Hydrogen is easily ignited with low-ignition energy such as static electricity. Pressure in containers can build-up and may rupture. Do not extinguish hydrogen fires unless the leak feeding the flame can be stopped. If safe to do so, allow the gas to burn out and protect exposures.

*Because the hydrogen is vented through the BMW's "C" pillars the manufacturer recommends a roof fold to extricate occupants.*

To stay current on this fuel technology, it is recommended that you visit the "Hydrogen 2000" web-site for new or updated information on this fuel technology. *http://www.hydrogen2000.com.* It is highly recommended that you go to the original equipment manufacturer for specific emergency response guidelines for specific makes and models of vehicles.

# Chapter III.

## ELECTRIC VEHICLES

### A. Introduction

The other alternative to powering our vehicles comes in the form of electricity and electric drive trains. This is, once again, a familiar energy source that most of us are aware and familiar with. While many people consider vehicles that run on electricity as being exotic, the reality is that electric vehicles have been around as long as internal combustion vehicles over 100 years ago.

This section explores the benefits, hazards, and infrastructures that support each of these electric vehicle types including zero emission vehicles (ZEV's or all electric vehicles), hybrid electric vehicles, hybrid electric buses and fuel cell technologies.

Electric vehicles provide many air quality benefits in that; they have no tailpipe emissions, no emission control equipment, like catalytic converters, PCV (positive crankcase ventilation), valves or oxygen sensors. There is no equipment to fail or deteriorate in use. This means that vehicles will always have zero emissions.

*A young women at the turn of the century demonstrates the ease of charging the electric vehicle.*

Electrical power plants that generate electricity used to charge electric vehicles do have air emissions. But these power plants must also meet stringent emission standards that are easier to monitor than millions of vehicles on the road. Analysis has shown that when considering the increased power plant emissions attributable to electric vehicles. Electric vehicles are still more than 90 percent cleaner than the cleanest petroleum technologies that are now becoming commercially available.

*The safety of charging an electric vehicle is demonstrated with a little girl on a rainy day charging the families EV-1.*

To imagine this technology in the context of our daily lives, we must first understand the technology itself. How do electric vehicles operate? What are their safety considerations? What do you need to know about electricity, its storage, and charging systems? Can you imagine yourself, confronted with an electric vehicle emergency and being able to deal with it effectively and safely? We will address questions like these in this section.

In 1990, when California initiated the zero emission mandate there was an expectation that thousands of all electric vehicles would populate American roadways. Original equipment manufacturers, like General Motors and Toyota, lead the way to an all electric vehicle future in their

EV-1 and RAV-4 vehicles. These vehicles were taken out of production when California extended the Zero emission mandate several years later.


*Neighborhood electric vehicles fill a niche in our choice of transportation*

Once the ZEV mandate had been pushed back electric vehicles had been relegated to neighborhood electric vehicles that get up to 35 miles at a top speed of 30 miles per hour. Improvements to battery technology, has brought about a re-birth of electric vehicles. The electric vehicle technology that was developed a decade ago is the same high voltage system that is in use with the neighborhood electric, ZEV's, hybrid electric vehicles and the fuel cell vehicles we see today. The information is transferable to all types of electric vehicle power-trains. This section forms the foundation of information for other electric vehicle discussions that will follow.

## B. ELECTRIC VEHICLE TECHNOLOGY

In many ways, electric vehicles are very similar to internal combustion vehicles. Some of the electric vehicles, like the Chevy Volt, are being developed and designed from the ground up, using special materials and design practices to reduce vehicle weight and increase the vehicles aerodynamics. Other electric vehicles are adaptations of an internal combustion vehicle style with the power train replaced with an electric power-train.

*Ready for delivery, the Phoenix truck, Phoenix SUV , and the Tesla roadster. Are each all electric vehicles or ZEV's.*

So what are the similarities and differences between an internal combustion vehicle and an electric vehicle? Many of the safety features are the same such as air bags, power steering and antilock braking systems. Many materials like paints, coatings, glasses, plastics, upholstery, metals, wiring, insulation, rubber, and others are the same as those on internal combustion vehicles. But that is where the similarity ends.

The primary differences between the two vehicle types include a battery pack instead of a fuel tank, an electric motor instead of a internal combustion engine, high and low voltage systems instead of just low voltage, and an electronic control module instead of an ignition system to name a few. What we need to know; is how an electric vehicle operates, how each of the components inter-relate, and how all of this effects our emergency response.

### Battery Properties

A battery consists of five major components: electrodes, separator, terminals, electrolyte, and a case or enclosure. There are two terminals per battery, one negative and one positive. The electrolyte can be a liquid, gel, or solid material. Traditional batteries such as lead acid (Pb Acid), Nickel Cadmium (NiCd), and others have used a liquid electrolyte. The electrolyte may be either acidic or alkaline depending on the type of battery. In the Advanced Sealed Lead Acid and Nickel Metal Hydride batteries the electrolyte can also be in the form of a gel and/or suspended in a glass mat.

In the most basic terms, the battery is an electrochemical cell in which an electric potential (voltage) is generated at the battery terminals by a difference in potential between the positive and negative electrodes. When an electrical load such as a motor is connected to the battery terminals, an electric circuit is completed and current is passed through the motor generating the torque.

Outside the battery, current flows from the positive terminal through the motor, and returns to the negative terminal. As the process continues, the battery delivers its stored energy from a charged to a discharged state.

If the electrical load is replaced by an external power source that reverses the flow of the current through the battery, a battery can be recharged. This process is used to reform the electrodes to their original chemical state or full charge.


*Lead acid batteries are fairly easy to maintain in fleet operations, like school and other mass transit vehicles.*

## Lead Acid Batteries

The lead acid battery is the most common choice for powering the initial fleet of electric vehicles. It is a mature technology that predates the development of the automobile and is universally used in internal combustion vehicles. In addition to maturity, other attractive features of the lead acid battery include a large manufacturing, distribution, service, and recycling infrastructure; low cost; compatibility with rapid charge; reliability; and, reduction of environmental problems. In its advanced, recombinant, valve-regulated configuration the electrolyte is immobilized, the container sealed, and the issues of electrolyte spillage and hydrogen and oxygen gas emissions during normal operation are eliminated.

The electrode of an electrochemical cell where oxidation, or the loss of electrons, takes place is defined as the anode (Pb). The electrode where reduction, or the gain of electrons, takes place is defined as the cathode (PbO2). In the lead acid battery, oxidation and reduction occur respectively at the positive and negative electrodes when charging, and at the negative and positive electrodes respectively when discharging. For simplicity, we will reference the anodes and cathodes as positive and negative electrodes.

The positive electrode of a lead acid battery consists of a lead grid that is covered with lead oxide. The negative electrode is essentially lead with an inert expander that causes the surface to be porous. These electrodes are interspersed and electrically insulated from one another with an inert separator. The electrolyte is sulfuric acid (H2SO4) which may be a liquid solution in flooded cell designs, or immobilized in an absorptive glass mat, or suspended in a gel in valve regulated designs.

The electrical potential between the positive and negative electrode is about 2 volts. This varies with temperature, the state of the charge, and whether or not the cell is being charged or discharged. During discharge, the voltage decreases as the state of charge decreases. As the battery approaches a state of full discharge, the exchange of electrons from the positive and negative electrodes continues until both are covered with lead sulphate and are at equal electrical potential. This is referred to as a discharged cell. Typically, when the cell voltage reaches approximately 1.5 volts, the cell should be recharged.

During the charging process, the reactions occur in the opposite direction to reform both electrodes back to lead and lead oxide respectively. As reformation proceeds, the electrical potential of the cell is returned to its original value of approximately 2 volts. During charging, the battery can enter a state of overcharge where the electrodes will give off-gasses in the form of oxygen from the positive electrode and hydrogen from the negative electrode. In conventional, free flowing electrolyte batteries, the gasses bubble through the electrolyte to the surface and out of the battery. This results in the electrolyte level in the battery dropping, necessitating water being added to maintain the operability of the battery.

*Sealed" or "Valve regulated" lead acid batteries are becoming in the norm in most vehicles on the road today.*

Over the last couple of decades, significant advances have been made to lead acid batteries. Development of advanced, recombinant valve regulated lead acid batteries has eliminated off-gassing and electrolyte level changing. The electrolyte is absorbed in a glass mat between the electrodes. Because of this, gasses generated during overcharge are prevented from bubbling away. This allows sufficient time for the gasses to recombine into water and sulfuric acid.

These types of lead acid batteries, however, still have a regulated valve in the event there is some type of abnormal condition such as charger run away where an excessive overcharge of the battery may occur. In a scenario where uncontrolled amounts of hydrogen and oxygen gas are generated inside the battery, venting is allowed.

Technological advances in lead acid battery technology, has resulted in greater cycle life and higher available energy. New charging systems monitor the cell voltage and stop the charging in order to prevent the cell voltage from reaching the levels where gas liberation occurs. Ventilation systems for charging rooms will no longer be needed.

These advanced lead acid batteries will be common in light duty cars, vans, and pickups. Unfortunately, due to cost constraints associated with large numbers of advanced batteries, heavy duty busses may still rely on conventional lead acid batteries. Consequently, for heavy-duty vehicle charging stations, ventilation will be required.

Vehicle manufacturers have tested vehicles submerged in water with some interesting results. They report off-gasses of hydrogen and oxygen create "mini-burst" that are restricted to the battery compartment. The phenomenon sounds like a crackling noise. These tests show that there is no immediate threat to emergency personnel operating around submerged electric vehicles. In these tests, no lethal voltages were reported around the vehicle, vehicle frame, or to the test dummies in the driver and passenger seats."

*General Motors tested the EV-1 in a submerged tank to demonstrate that electricity will not escape and harm occupants or emergency responders while working n the water.*

## Lead Acid Battery Fires

With lead acid battery fires personnel should wear full protective clothing and self-contained breathing apparatus on positive pressure. Extinguish lead acid battery fires with CO2, Foam, or Dry Chemical. Copious amounts of water and/or foam can be used on electric vehicle fires with no danger to response personnel of electrical shock. If the batteries are on the charger, turn off electric power at the building supply source. Do not use water on the charger unit to extinguish due to potential shock hazard.

For a number of reasons, flooded lead acid batteries may still be used in mass transit vehicles such as school, tour, and municipal busses. In the case of an electric transit vehicle turnover, electrolyte could spill out in sufficient quantities to necessitate a hazardous materials response and cleanup. Passenger vehicles on the other hand, will more than likely use advanced sealed lead acid batteries, where the potential for leakage is minimal. Advanced lead-acid batteries can be crushed to 60 percent of their original volume before any electrolyte is spilled. Should this occur, you may expect to see about a cup of electrolyte on the ground. The potential for a hazardous materials response for all passenger vehicle battery types, only occur in catastrophic accidents such as an electric vehicle being hit by a train where the hazardous material is spread out over a large area.

Cleanup for released or spilled Sulfuric Acid includes; removing all combustible Material and sources of ignition, and stop the flow of material (use duct tape over cracks in the battery case) and contain spill by diking with soda ash (Sodium Carbonate) or quick-lime (Calcium Oxide). Small electrolyte leaks can be flushed with water and neutralized with dilute acid (vinegar). Large spills must be contained, do not allow material to flow into storm drains.

*The Sanyo Nickel Metal Hydride Battery is currently used in all Ford vehicles*

## Nickel Metal Hydride

Nickel Metal Hydride (NMiH) batteries have been available for consumer products for several years. NMiH batteries have higher performance (life cycle, specific energy, and energy density) than advanced lead acid. Because of this, NMiH batteries had been the next type of battery developed and commercialized for electric vehicle applications.

The electrolyte in NMiH batteries is 30 percent by weight potassium hydroxide in water. Therefore, the electrolyte is a base compared to the acid electrolyte of lead acid batteries. In many ways, NMiH batteries are similar to NiCd. Specifically, NMH and NiCd both use an aqueous alkaline electrolyte and a nickel hydroxide cathode. Unlike NiCd, NMH batteries do not use toxic cadmium for the anode. NMH uses a metal alloy capable of storing hydrogen formed at the anode during charging, and releasing the hydrogen during discharge. These metal alloys eliminate the potential health hazard associated with cadmium. Also, these alloys have higher energy storage capacities than cadmium.

NMH batteries operate at ambient temperatures and are also sealed like the advanced lead acid and valve regulated batteries. The nominal cell voltage for NMH batteries is 1.2 volts. The hydrogen is absorbed and stored in the metal hydride in a solid hydride phase as opposed to a gas.

During a discharge/charge cycle, there is no net change in electrolyte quantity or concentration in NMH. The constant concentration maintained in the NMH battery electrolyte results in better battery performance compared to NiCd batteries where the electrolyte concentration varies. Better performance is indicative of lack of off-gassing during normal operation, high and low temperature operations, and a longer life cycle of the battery.

NMH batteries are also more tolerant of overcharge and over discharge than many other types of batteries. During overcharging, the nickel hydroxide cathode becomes fully charged and begins generating oxygen. This oxygen recombines with hydrogen at the anode to form water and heat. At low charge rates, the battery can keep up with the oxygen generation and recombination cycle. However, at high charge rates, oxygen can be produced faster than the anode can recombine it resulting in internal cell pressure buildup. Once the pressure reaches a certain value, the valves will open and vent the oxygen to the outside of the battery. The advanced charging systems developed for electric vehicle applications monitor the battery voltage to prevent the generation of gasses during charging.

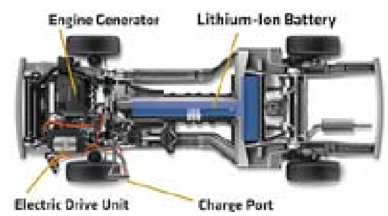
## Nickel Metal Hydride Battery Fires

Extinguish Nickel Metal Hydride battery fires with Class D extinguisher (Metal-X or similar). If batteries are on the charger, turn off electric power at the building supply source. Copious amounts of water and/or foam can be used on electric vehicle fires with no danger to response personnel of electrical shock. Electrolyte solution is extremely corrosive to all human tissue and reacts violently with many organic chemicals, especially nitro-carbons and chloro-carbons. The electrolyte also reacts with zinc, aluminum, tin, and other active ingredients releasing flammable hydrogen gas.

### Lithium Ion

The third battery type likely to be commercialized for electric vehicle applications is lithium-ion. Early pres releases suggest that the Chevy Volt will be using Lithium-ion batteries. Because lithium is the metal with the highest negative potential and lowest atomic weight, batteries using lithium have the greatest potential for attaining the technological breakthrough which will allow electric vehicles the greatest performance characteristics in terms of acceleration and range.

Lithium metal itself is highly reactive with air and most liquid electrolytes. Lithium powder can even ignite spontaneously in air. Solid lithium metal ignites at temperatures above 180ºC (356ºF), and can have explosive or violent reactions with compounds containing sulfur, metal oxides, titanium trioxide, and vanadium pentoxide. To avoid these problems associated with metal lithium, lithium intercalated graphitic carbons (LiXC) are being investigated and show high potential for good performance while retaining cell safety.




*Lithium Ion Batteries are stored beneath the passenger compartment in a "T" pattern, note the orange cables identifying the high voltage cabling.*

During discharge, lithium ions (Li+) are released from the anode and travel through an organic electrolyte toward the cathode. Organic electrolytes (i.e., nonaqueous) that are stable against reduction by lithium and oxidation at the cathode are required since lithium would react chemically with the water of aqueous electrolytes. When the lithium ions reach the cathode, they are incorporated into the cathode material quickly. This process is easily reversible. Because of the quick reversibility of the lithium ions, compared to lead acid or NMH technology, lithium-ion batteries can charge and discharge faster. Lithium-ion batteries produce about the same amount of energy as nickel metal hydride cells, but they are typically 40 percent smaller and weigh half as much. This allows for twice as many batteries to be utilized thus doubling the amount of energy storage thus increasing the range of the vehicle.


*The Hitachi Lithium Ion battery has reached a breakthrough in battery technology with a power density of 4,500 W/kg or 1.7 times the output of other lithium ion batteries.*

There are various types of materials being evaluated for use in lithium-ion batteries. Generally, the anode material being looked at is various forms of carbon with focus on graphitic and hydrogen-containing carbon materials. There are three types of oxides of transition being evaluated for the cathode: cobalt, nickel, and manganese. Initial battery development appears to be using cobalt oxide which is technically preferred to either nickel or manganese oxides. However, the cobalt oxide is the costliest of the three, with nickel substantially less, and manganese being the least expensive.

In the construction of lithium-ion batteries, where cobalt oxide cathodes are used, the cathode is manufactured from an aluminum foil with a cobalt-oxide coating. The anode is manufactured from a thin copper sheet coated with carbon materials. The sheets are layered with a plastic separator, then rolled up like a jellyroll and put inside a steel container that is filled with a liquid electrolyte containing lithium hexofluorophosphate. This battery has an open circuit voltage of roughly 4.1 volts at full charge.

*Neighborhood elecetric vehicles like the GEM e-4 and all electric ATV's like the Bad Boy Buggy pictured here, can reach speeds up to 30 miles an hour with a range of 30-35 miles on a single charge.*

In addition to their potential for high specific energy, lithium-ion batteries also have an outstanding potential for long life. Under normal operation, there are few structural changes of the anode and cathode by the intercalation and removal of the smaller lithium ion. Additionally, the high voltage and conventional design of lithium-ion batteries hold promise for low battery cost, especially when cobalt is replaced by manganese.

Overcharge of lithium-ion batteries as with NMH and lead acid batteries, must be carefully controlled to prevent damage to the battery in the form of electrode or electrolyte decomposition. Because the electrolyte in a lithium-ion battery is non-aqueous, the gassing issue associated with the dissolution of water has been eliminated. Development of advanced battery management systems are key to ensure the batteries operate safely during normal operation and in the event of vehicle accidents. As previously mentioned for NMH and lead acid batteries, charging systems must be capable of working with the battery management systems to ensure overcharging does not occur.

## Lithium Ion Battery Fires

Do not use water or foam to extinguish lithium-ion battery fires. Extinguish lithium-ion battery fires with dry sand, sodium chloride powder, graphite powder, or copper powder. Copious amounts of water and/or foam can be used on electric vehicle fires with no danger to response personnel of electrical shock. Cleanup lithium-ion electrolyte spills with dry sand or other noncombustible material and place into container for disposal.

## Vehicle Identification

Electric vehicles produced in the mid nineties were required to have badging and insignia on the sides and rear of the vehicle identifying the vehicle as an electric vehicle or "E.V." Neighborhood electric vehicles are small in size and their appearance is easily identifiable form other vehicles on the road today. The next generation of all electric vehicles will not only have a distinctive aerodynamic design but will also carry identifying badging and insignia.

## Vehicle Operation

The operation of an electric vehicle is analogous to an internal combustion vehicle. An "ignition" key or electronic key is used to power up the vehicle instrumentation panels and electronic control module. A gearshift placed in "Drive" or "Reverse" engages the vehicle. When the brake pedal is released, the vehicle may "creep" similar to internal combustion vehicles. When the driver pushes on the accelerator pedal, a signal is sent to the electronic control module which in turn applies a current and voltage from the battery system to the motor that is proportional to how much the accelerator is depressed. The motor then applies torque to the wheels.

*The manufactures of electric vehicles incorporate familiar controls to simulate driving an ICE vehicle.*

Because torque/power curves for electric motors are broader than for internal combustion engines, acceleration in electric vehicles can be quicker. When the accelerator pedal is released, many electric vehicles have a built-in drag feature that mimics the engine compression of an internal combustion vehicle. This drag feature gently slows the vehicle.

Electric vehicles are equipped with a regenerative braking system. When the brake pedal is depressed to slow the vehicle, or if the vehicle is allowed to coast, the electronic control module changes the motor to a generator. The kinetic energy of the moving vehicle is then converted back to electricity as the vehicle slows down. This creates a sensation similar to downshifting to slow down an internal combustion vehicle.

*Regenerative brakes capture the kinetic energy, that is usually lost in slowing down or stopping, back into electrical energy.*

An appealing quality of the electric vehicle is that they operate noiselessly. For the most part, the handling and operation of many electric vehicles are comparable in operation and safety to their internal combustion counterparts. Emergency response personnel may not be able to determine if the vehicle is on or off by sound alone. Personnel should inspect the instrument panel for information regarding vehicle status. The 12-volt battery must be in operation for the instrument panel indicators to appear, so it is best to check the vehicle status before disengaging the 12 volt battery.


*The electronic control module is the most prominent feature you see when you look under the hood of this ford hybrid.*

The major components of the electric vehicle are; motor and electronic control module, battery and battery management system, charger, cabling system, braking system.

The electric vehicle is propelled by an electric motor and an electronic control module. In an electric propulsion system, it is the electronic control module that regulates the amount of current and voltage that

*Orange colored cabling identifies, for emergency responders, the high voltage cables running beneath the vehicle udercarriage.*

***Major manufacturers employ a variety of safety features to isolate the high voltage system from the rest of the vehicle including: pilot circuits, inertia switches, and manual disconnects,***

the electric motor receives. The controller takes a signal from the accelerator pedal in the vehicle, and controls the electric energy provided to the motor, causing the torque to turn the wheels.

The motor and motor control unit, are both high voltage components and should not be tampered with. Care should be exercised when working around the engine compartment of any electric vehicle. High voltage wiring can be identified by orange wires and cabling.  Most automobile manufacturers are also putting high voltage labels on high voltage components. Many familiar vehicle components are not present in electric vehicles. You will not find an air filter, carburetor, distributor, or spark plugs. In emergency response, look for the physical differences of the vehicle for a positive identification.

It is important for optimal performance of any battery type that a battery management system to monitor the operating condition of the battery pack is installed. Many electric vehicles incorporate battery management systems that are capable of monitoring the performance of each cell within the battery modules. Parameters such as cell voltage, current, and temperature are monitored to closely control the charge/discharge cycles, as well as temperature to preserve cycle life of the battery.

Electric vehicles have two different wiring systems: high and low voltage. The high voltage system is primarily for providing energy to the motor to propel the vehicle. However, some vehicle manufacturers have used high voltages to power heating/cooling systems, power steering pumps, and some sensors. The Society of Automotive Engineers (SAE), have developed a standard color code (orange) for high voltage wiring in electric vehicles.

A separate 12-volt auxiliary battery is typically used for accessories such as instrumentation, lights, stereo, etc. The separate 12 volt battery is kept charged by a DC to DC converter that “steps down” the voltage from the high voltage traction batteries.

In their electric vehicles, major automobile manufacturers use isolated electric busses for both the positive and negative sides of the battery. This is an important safety feature. In the event the positive electric bus loses isolation from the vehicle frame or chassis, no electrical current will pass through the frame or the chassis. The implication of this design feature is that vehicle drivers or emergency responders will not be shocked by the accidental loss of isolation between the positive or negative electric busses and the vehicle frame or chassis. This differs from internal combustion electrical systems because the 12 volt DC systems rely on the vehicle frame and chassis as the negative electric bus. However this is acceptable because 12 volt systems are not dealing with lethal voltages as is the case with the high voltage systems of electric vehicles.

All of the manufactured electric vehicles have special manual disconnects that uncouple the high voltage wiring system from the battery pack. The location of these disconnects are vehicle specific and are intended to be used by service personnel doing maintenance on the vehicles. All of the production vehicles also have an automatic high voltage system disconnect as a primary safety feature. These disconnects are based either on ground fault monitoring, an inertia switch or a pilot circuit.

*The Pinifarina Electric Vehicle is a collaboration between French and Italian auto manufacturers. Note that the battery pack is installed under the passenger compartment.*

In the case of the ground fault monitoring disconnects, they operate on the same concept as the ground fault monitoring devices used in households. These devices monitor the ground system in the vehicle for current that may leak from the high voltage system. If a fault in terms of current leakage is detected, the devices automatically disconnect the high voltage system from the battery system. The location of the ground fault monitoring system is vehicle specific, but is typically found in the vicinity of the battery pack.

In the case of vehicles that use the inertia switch disconnect, the end result is the same but the method is slightly different. The inertia switch senses high deceleration rates, as may be encountered in a vehicle accident. If a rapid deceleration occurs, the inertia switch is automatically tripped and the high voltage system is disconnected from the battery system. The inertia switch is set for a low impact.  Inertia switches are also common to internal combustion engines to de-energize electric fuel pumps in the event of an accident. In most cases, the inertia switch on electric vehicles can be reset by pressing the button on the device itself. Though, the location of these switches may vary from among vehicle designs, many are located in the motor compartment.

Other vehicles use pilot circuit disconnects, again the end result is the same but the method is entirely different. Throughout the motor compartment, high voltage cables are routed between the battery pack, electronic control module, motor, charging port, and other high voltage components. Running parallel to these high voltage cables is a pilot circuit that acts as a simple continuity loop. The pilot circuit is attached to the high voltage cable so that it is impossible to disconnect, sever, or rupture the high voltage cable without doing the same to the pilot. If an accident occurs resulting in the high voltage cable becoming disconnected, and hence the pilot cable, the pilot circuit will record that electrical continuity has been lost and automatically disconnect the high voltage cabling from the battery pack. The location of the pilot circuit disconnect system is also vehicle specific, but is typically found in the vicinity of the battery pack.

*This photovoltic enhanced recharging station creates electricity to assist in recharging these early electric vehicle models. Electric vehicle charging stations were established in the mid-1990's in major metropolitan parking areas; airports, shopping malls, along with government and fleet facilities*

Some vehicle manufacturers are employing a combination of two disconnect systems for both redundancy and safety. Whether a ground monitor, inertia switch, or pilot circuit is used, it is important to know that these devices only isolate the rest of the vehicle from the batteries voltage. Lethal levels of electricity may still be present in the battery pack. An electric vehicle battery pack should be treated with the same caution and respect as a fuel tank or cylinder found in internal combustion vehicles.

## EV Recharging

With electric vehicles comes electric vehicle recharging infrastructure, both public and private. The infrastructure includes recharging units, ventilation, and electrical safety features for indoor and outdoor charging stations. To ensure the equipment is installed safely, changes have been made to Building and Electrical Codes.

During electric recharging, the charger transforms utility supplied electricity into energy that is compatible with the electric vehicle's battery pack. According to a definition by the Society of Automotive Engineers (SAE), the full "electric vehicle charging system" consists of the equipment required to condition and transfer energy from the constant frequency, constant voltage supply network to the direct current, for the purpose of charging the battery and/or operating vehicle electrical systems while connected (e.g., vehicle interior pre-conditioning, battery thermal management, on-board vehicle computer, etc.). The charger communicates with the battery management system which dictates how much voltage and current is delivered from the building wiring system to the battery system.

*The EV-1 used the inductive charging method, transferring energy magnetically to the vehicle battery pack.*

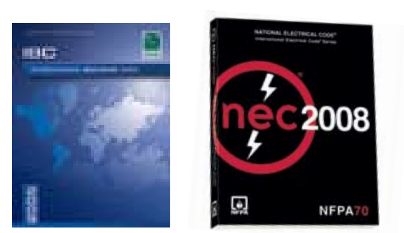
Charging is accomplished by passing an electrical current through the battery to reform its active materials to their high-energy charge state. The charging process is basically a reverse of the discharging process, in that current is forced to flow back through the battery, driving the chemical reaction in the opposite direction. The methodology by which this is done is different for each battery type due to the variations in chemical components.

The electric vehicle will be connected to some type of "Electric Vehicle Supply Equipment (EVSE)" that is, in turn, connected to the building wiring. This equipment is defined by the National Electrical Code (NEC) as "the conductors, including the ungrounded, grounded, and equipment grounding conductors, the electric vehicle connectors, attachment plugs, and all other fittings, devices, power outlets, or apparatuses installed specifically for the purpose of delivering energy from the premise wiring to the electric vehicle."

For residential and most public charging locations, there are two power levels that will be used. "Level 1", or convenience charging would take place while connected to a 120-volt, 15-amp branch circuit and would result in a complete recharging cycle taking anywhere from 10-15 hours. This type of charging system uses the common grounded electrical outlets and would most often be used when Level 2 charging is unavailable. "Level 2" charging will take place while connected to a 240-volt, 40-amp circuit, dedicated for usage only by an electric vehicle. At this voltage and current level, a full recharge is typically 3 to 6 hours, depending on battery type. EVSE for this power level is required to be hard-wired to the premises wiring.

"Level 3" is any EVSE with a power rating larger than "Level 2". The majority of the "charging system" is moved off of the vehicle platform. This type of charging would be the electric vehicle equivalent of a commercial gasoline service station where an electric vehicle can be charged in a matter of a few minutes. To accomplish this goal, it is probable that this equipment may be rated at power levels between 75-150 kilowatts, necessitating that the supply circuit to the equipment be rated at 480-volt, 3-phase, and between 90 and 250 amps. Supply circuits may even be larger. This Level 3 equipment would only be handled by specially trained personnel.

All EVSE equipment, at all power levels, will be required to be manufactured and installed in accordance with published standards documents such as: NFPA (NEC Article 625), SAE (J-1772, J-1773, J-2293, others), UL (2202, 2231, 2251, others), IEEE/IEC, FCC (Title 47 - Part 15), and several others.




*Check the currently adopted code in your jurisdiction for specific recharging system requirements.*

There are currently two prime methods of transferring power to the electric vehicle; conductive and inductive. The connection process must be safe and convenient to use by everyone.

With the conductive coupling method, connectors use a physical metallic contact to pass electrical energy when joined together. Specific electric vehicle coupling systems (connectors paired with inlets) have been designed that provide a non-energized interface to the charger operator. Not only is voltage prevented from being present before the connection is completed, but the metallic contacts are completely covered and inaccessible to the operator.

The inductive connection is developed primarily for electric vehicle application (though it has seen some application with other small appliances). With this system, the coupling system acts as a transformer. Alternating current power is transferred magnetically or "induced," between a primary winding (on the supply side) to a secondary winding (on the vehicle side). This system uses EVSE that converts standard power-line frequency (60 Hz) to high frequency (80,000 - 300,000 Hz) reducing the size of the transformer equipment.

*Buses parked in enclosed areas for maintenance or service should have adequate ventilation per code.*

To ensure safe charging equipment to support electric vehicles, the National Electric Vehicle Infrastructure Working Council (IWC) was formed to address electric vehicle infrastructure. The IWC is a consortium of representatives from across the nation and around the world, representing industries such as electric utilities, automotive engineers, electrical manufacturers, code consultants, electric vehicle industry organizations, regulatory agencies, and independent testing laboratories such as Underwriters Laboratory.

The IWC developed recommended code language that address the electrical requirements for electric vehicle charging equipment and, along with the Society of Automotive Engineers (SAE), submitted code language proposals for inclusion in the 1996 National Electrical Code (NEC). After minor revision, the National Fire Protection Agency adopted Article 625, Electric Vehicle Charging System Equipment into the (NEC) which addresses electric vehicle charging equipment and systems. The IWC has also proposed codes for the Uniform Building Code. These codes cover issues associated with the location of charging equipment and the installation of ventilation systems when appropriate. There are several issues associated with electric vehicle charging equipment that these codes address. Primarily, the issues can be classified as pertaining to electrical safety devices required in the equipment or ventilation of the location where the charging system is installed.

Regarding electrical safety for example, the electric vehicle connector must be polarized and be configured so that it is non-interchangeable with other electrical devices such as electric dryers. The method by which the electric vehicle charging equipment couples to the electric vehicle can be either conductive or inductive, but must be designed so as to prevent against unintentional disconnection. Additionally, the new electrical codes require that electric vehicle charging loads be considered continuous and therefore the premise wiring for the electric vehicle charging equipment must be rated at 125 percent of the maximum load of the charging equipment.

All electric vehicles charging equipment must have ground-fault circuit interrupter devices for personnel protection and rain-proofing for outdoor compatible equipment. An interlock to de-energize the equipment in the event of connector or cable damage must be incorporated.

Furthermore, a connection interlock is required to ensure there is a non-energized interface between the electric vehicle charging equipment and the electric vehicle until the connector has been fastened to the electric vehicle. A ventilation interlock is also required in the electric vehicle charging equipment.

The ventilation interlock enables the electric vehicle charging equipment to determine if a vehicle requires ventilation and whether ventilation is available. If ventilation is included in the system, the ventilation interlock will allow any vehicle to charge. However, if ventilation is not included in the system, the mechanical ventilation interlock will allow non-gassing battery equipped vehicles to charge, but not gassing battery equipped vehicles.

Title 24, California Code of regulations addresses location and ventilation issues associated with electric vehicle charging. Specifically, these codes address where electric vehicle charging equipment can be installed. If a ventilated charging system is to be installed, the codes specify how much mechanical ventilation must be provided to ensure any hydrogen off gassed during charging is maintained at a safe level in the charging area.

The ventilation rates called out in the building codes are calculated to comply with the requirements of the National Fire Protection Association published in standard NFPA 69, Explosion Prevention Systems. This standard establishes requirements to ensure safety with flammable mixtures. Section 3-3, Design and Operating Requirements, requires that combustible gas concentrations be restricted to 25 percent of the Lower Flammability Limits.

This design criteria provides a safety margin when working with atmospheres containing hydrogen. Hydrogen is combustible in air at levels as low as 4 percent by volume of air. Therefore, for the charging station to not be classified as ‘hazardous,” the hydrogen concentration must not exceed 10,000 parts per million, which equates to 1 percent hydrogen by volume of air.

*Though redundant safety features should disconnect the high voltage system, emergency responders should always approach an electric vehicle as if it presents an electrical shock hazard.*

*When involved in a front end collision, this state owned electric car performed as it was designed to shut-down the high voltage system on impact.*

*Note the size and consider the weight of the batteries on an electric bus.*

*Buses and mass transit vehicles present the potential for mass casualties along with the need to potentially mitigate spilled electrolyte.*

## Electric Vehicle Emergency Response

Electric vehicles are safe to operate around under normal operating conditions. When involved in a collision, the redundant safety features of the vehicle are designed to protect the vehicle occupants as well as the emergency responders from electric shock.

When an electric vehicle is involved in an accident the inertia switch will automatically disconnect the traction batteries from the rest of the vehicle. If the vehicle is severely damaged, to the point where high voltage components and wiring have been severed, the pilot circuit disconnect will also isolate the power to the traction batteries rendering the vehicle safe for emergency responders to work around.

Emergency responders should still approach the damaged vehicle as if it could pose an electrical shock hazard by wearing full protective clothing boots, and gloves.

## Electrical Safety

- ❖ Under no circumstance should the battery pack be cut into! While high voltage systems may be disconnected from the battery pack, the batteries themselves still have potential as an electric shock hazard.
- ❖ Emergency response personnel should avoid wearing; rings, necklaces, watches or any other jewelry when operating around an electric vehicle.
- ❖ Additional safety gear should be used including high voltage rated nonconductive boots and gloves for hands on personnel coming into physical contact with the vehicle.
- ❖ All hand tools, such as screw drivers, pry bars, and pliers, should be equipped with insulated handles rated for 1,000 volts.
- ❖ Do not cut high voltage wiring due to the potential for electric shock. High voltage cables and components can be identified by orange coloring or labeling.
- ❖ Manual disconnects are typically located at a point that is readily accessible to emergency response personnel to disconnect the battery pack from the rest of the vehicle.
- ❖ Do not cut through the high voltage wiring from the charging unit to the vehicle or the premise wiring. Power can be disconnected by removing the EVSE coupler from the vehicle, or turning off the power at the charging unit, the sub-panel or the buildings main electrical panel.

Other considerations when working with electric vehicles include battery location and weight. It is important to note the location and shape of the battery pack for all vehicles. Typically, the battery case is under the vehicle and/or between the vehicle's rear wheels. The battery case should not be opened, punctured, or cut into under any circumstance by emergency response personnel. If the battery is punctured by a conductive object, assume the object has electrical potential.

The weight of the battery pack, especially in busses and transit vehicles maybe another consideration for the rescue and recovery of accident victims. The collective weight of the batteries can range between; 1,600 pounds for step vans, 5,000 pounds for busses, and in passenger vehicles from 1,000 to 1,500 pounds.

The curb weight of electric vehicles is essentially the same as their internal combustion counterparts. The weight of heavier engines and fuel tanks is replaced by the weight of the battery pack. Because the batteries are located low and in the center of the vehicle such as in transit buses, vehicle rollover should be rare. If a rollover should occur, the vehicle may need shoring up to keep the weight of the battery pack from potentially crushing the passenger compartment or shifting during rescue efforts.

### Electric Vehicle Fires

Vehicle fires that involve the interior of contents of the vehicle, and have not reached the battery storage area, can be safely extinguished with water. Vehicles in a structure that is involved in a fire can also be safely extinguished with water once the electrical utilities have been disconnected. Protecting the vehicle from additional fire damage would keep the fire from extending to the battery pack.

As a rule batteries do not burn, or rather, they burn with great difficulty. If batteries are exposed to fire, however, the fumes and gasses generated are considered extremely corrosive. Spilled electrolyte could react and produce toxic fumes and release flammable and explosive gasses when it comes in contact with other metals.

Due to the potential of explosive gasses, personnel should prevent and/or eliminate all open flames and avoid creating sparks. The population imbalance between electric and internal combustion vehicles is rather large and would suggest that should an electric vehicle become involved in an accident it would more than likely occur with an internal combustion vehicle. Circumstances should dictate whether or not the vehicles can be safely separated from one another to reduce the presence of fuel vapors in the vicinity of electrical sparks. Always assume that toxic and explosive gasses are present at the scene of the emergency.

*Nickel Metal Hydride Battery modules burn rapidly and can be quickly reduced to ashes leaving only the metal alloy plates.*

## C. HYBRID ELECTRIC VEHICLES

The first generation of the all electric vehicles in the mid 1990’s provided several proven technologies that are now employed in hybrid electric

*Hybrid technology is showing-up in a wide range of vehicles including this FOSS Hybrid Tug Boat now being tested in the Long Beach Harbor.*

vehicles. The high-voltage system that was pioneered in all electric vehicles such as the motor and electronic control module, battery and battery management system, charger, cabling system, and regenerative braking system are all included in hybrid electric vehicles. Hybrid electric vehicles (HEV's) are vehicles that combine a small fuel efficient internal combustion engine with an electric power train.

Hybrid technology is not limited to passenger vehicles. The Port of Long Beach is experimenting with a hybrid tug boat. Mass transit vehicles also employ hybrid technology, so much so that mass transit hybrids will be treated as a separate module.

Then there are vehicles like the soon to be released Chevy Volt that are not technically hybrids. By definition a hybrid is a vehicle that uses two fuel/energy systems to directly power the drive train. The Chevy Volt for example is an electric vehicle. The Chevy Volt also uses an internal combustion engine, not to power the drive train, but to generate electricity for the electric drive train. The Volt, with both an internal combustion engine and electric motor on board, should also be included in this discussion for hybrid vehicles.

Honda and Toyota are the first auto manufacturers to offer hybrid electric vehicles to the general public. Other major auto manufacturers are following suit by also offering hybrid vehicle options. Similar to all-electric vehicles previously described, emergency response to hybrid electric vehicles should follow the same basic safety protocols and precautions.

## Electrical Power

HEV's can take advantage of existing vehicle infrastructure and services. The HEV battery pack is recharged while the vehicle is moving-- eliminating the need for external recharging. However, there is a strong movement for Plug-In Hybrids or PHEV's. Plug-in hybrid electric vehicles will have an additional battery pack to increase mileage and range of the vehicle. At this point plug-in hybrids are an after market

*General Motors has embraced Hybrid Electric technology and now offers this as an option in a wide range of vehicle models* addition to the hybrid vehicle, although manufacturers are researching the addition of plug-in options.

The size of the nickel metal hydride battery pack varies according to vehicle manufacture. The Toyota's, Prius, contains a 288 volt battery pack, while Honda's, Insight, contains a 144 volt battery pack.

Photovoltaic or solar generated electricity is also being experimented with. While solar powered cars are not a practical application today, due to the lack of surface area needed to generate enough electricity to power the vehicle, CNN news reports that Toyota is considering adding a photovoltaic module to the roof of the Toyota Prius to generate enough electricity to power the air conditioning system. One after market manufacturer has developed a Photovoltaic module designed to fit specific models of hybrid vehicles and claims that the module can add 20 to 30 extra miles to the vehicles range. This will be an added consideration for emergency responders in the near future.


*After market installation of solar panels on the Toyota Prius could potentially increase vehicle range 20 to 30 miles.*

A photovoltaic cell operates much as a battery does by using sunlight to react with chemical solids to produce electricity. Unlike a battery, the energy must be used directly or stored in a battery for future use. Importantly, the photovoltaic electrical system will only operate when the sun is shining. The wiring may be run through the "C" pillar to the battery pack. The voltage and amperage of a small photovoltaic system will not be enough to harm emergency personnel, but may produce a mild shock.

*Toyota Future Solar*

Otherwise, emergency responders should always assume that high voltage components; cables, electronic control module, battery management system and motor, are energized when operating around the vehicle. A high voltage cable will run underneath the vehicle from the power supply in the rear of the vehicle to the electric motor under the hood. For quick identification, all high voltages cables will be orange. A single, or in some cases multiple, 12-volt auxiliary battery provides service to the interior lights, radio, and air conditioner.

## Fuel Tank

The Honda's Insight utilizes a 10.6 gallon plastic resign gas tank instead of steel to help reduce the vehicles overall weight. The gas tank in Toyota's Prius, uses a collapsible internal bladder to reduce fuel vapors. In both vehicles the tank is located in the rear of the vehicle and under the battery pack. Hybrid vehicles currently use regular gasoline to power the internal combustion engine. Fleet vehicles, such as buses may use other fuel types.

*The Pinifarina utilizes solar electricity to recharge the battery and extend vehicles mileage.*

*The anatomy of a hybrid electric vehicle includes an electric motor and gas fueled engine with a battery pack to store electrical energy. All Hybrid electric vehicles have badging and insignia identifying it as a hybrid electric vehicle.*

## Vehicle Identification

Auto manufacturers provide insignia, badges, or logos on the exterior to distinguish the HEV from other vehicle types. High voltage warning labels will be found around high voltage components in the engine compartment.

On the interior, the instrument panel is the most distinguishing characteristic of the HEV. The instrument panel will contain information regarding vehicle operation in digital and/or analog displays for fuel levels and the energy levels in the battery pack.

## Vehicle Operation

Similar to internal combustion and all electric vehicle operation, the HEV driver will turn an ignition key to power-up the vehicle. Some vehicles manufacturers use a smart key system in which a power button replaces the ignition key. When the vehicles ready light is "on" and the shift selector is placed in "drive" the vehicle engages either/or both the internal combustion engine and the electric motor.

With all HEV's, pushing on the accelerator pedal the internal combustion engine and the electric motor will assist one another until the vehicle is at cruise speed. At cruise speeds either the electric drive train or ICE will maintain the cruise speed. The electric motor or internal combustion engine will engage once again if the vehicle is under a load as in acceleration or driving up an incline.

In both vehicles, while coasting or braking, the electric motor reverses and becomes an electric generator which recharges the battery pack. When idling, the engine will temporarily shut-down allowing for additional fuel/energy savings. When the engine is stopped, the vehicle operates silently.

HEV's are made from essentially the same materials as other automobiles on the road. Small high performance engines made from light weight materials also help reduce vehicle weight. You will find light weight magnesium oil pans and a plastic gas tanks instead of steel constructed components. The HEV battery pack and electronic control module is smaller and more compact than their all-electric counterparts.

*Response to vehicle emergencies occur every day throughout California.*

*–photo courtesy of VenturaCounty F.D.*

*Fires that involve the vehicle rear or trunk of a hybrid vehicle must be approached with greater caution due to Hybrid Battery pack or pressurized fuel cylinder location.*

## Hybrid Vehicle Emergency Response

Firefighters should follow their department standard operating guidelines, many of which have been developed with the standards recommended in NFPA and IFSTA. Water is the recommended extinguishing agent and the attack line selected should be placed between any exposures and be in a uphill, upwind, and up-scene direction whenever possible. The attack line selected is recommended to be 1.5 inch or greater. Approach to the vehicle should be at a 45 degree angle to avoid explosions from tires, and other pneumatic and hydraulic devices in the vehicle.

Engine compartment fires should be approached from a safe direction and generally require the hood to be opened or displaced to knockdown and extinguish the fire. The gas-electric hybrid vehicle will contain both an electric and gasoline motor, with various other engine components that are found on a standard vehicle.

Passenger compartment fires should be approached from a safe direction and may be extinguished with a properly selected fire stream that provides protection to the firefighter and will provide the required cooling and extinguishing effect. Standard and hybrid vehicles may now have one or more 12 volt batteries within the passenger compartment, in a wheel well and/or rear passenger seats.

Fires that involve the vehicle rear or trunk of a hybrid vehicle must be approached with greater caution due to Hybrid Battery pack or pressurized fuel cylinder location. Fires located here in the battery pack may be attacked from a safe distance to the rear of the vehicle. It then can be extinguished with a properly selected fire stream that provides reach and protection to the firefighter and will also provide the required cooling and extinguishing effect. Copious amounts of water and/or foam can be used on electric vehicle fires with no danger to response personnel of electrical shock.

All hybrid high voltage battery systems are designed with fuses that will trip and restrict any high voltage from being released into a fire stream and pose a threat to responders. There will be no energized vehicle body parts after a fire. If any exposure of high voltage cables or engine parts occurs after a fire, do not handle, cut, or pry. Treat all high voltage components as if they were charged or were to become reenergized.

## D. HYBRID-ELECTRIC BUS TECHNOLOGY

Like electric buses, hybrid-electric buses range in size from small 22-foot shuttles and medium size buses to full-size transit buses. Many of the same cities operating electric shuttles are also purchasing new hybrid-electric buses. Several hybrid transit bus demonstrations are underway in Southern California and other areas of the country.

The typical 22-foot hybrid-electric shuttle buses operate in many of the same settings as their pure electric counterparts but are able to handle longer routes due to their increased range. The full-size hybrid transit buses operate on the same duty cycle as conventional buses. Hybrid-electric buses differ from pure electric and internal combustion buses because they use a battery pack as well as a fuel tank, and have a conventional internal combustion engine or turbine in addition to an electric motor.

### Hybrid-Electric Bus Batteries

The battery packs on hybrid-electric buses are smaller and store less energy than those on pure electric buses because the buses do not rely solely on the batteries for motive power. Like pure electric buses, hybrid buses plug in to the utility grid. Although some models depend on the grid for regular charging, many, especially the large transit buses, plug in only to "equalize" batteries to preserve the battery chemistry. Each manufacturer recommends different charging regimens.

As with batteries on pure electric buses, do not attempt to cut into or open the battery pack. With an operating voltage range of 200-700 volts, batteries pose potential electric shock hazards. The battery packs on hybrid-electric buses vary in size and configuration. Batteries on the shuttle-size hybrids are located under the floor, along the sides of the bus, directly in front of the rear wheels. Instead of three or four battery boxes, however, a fuel tank replaces at least one set of batteries. The same design elements seen on pure electric shuttles such as exterior access doors and metal structures to separate the batteries and fuel tanks are designed into these buses.

The full-size hybrid buses typically store their batteries in two long, flat tubs on the vehicles' roofs. Their dimensions are approximately 9 feet by 3 feet by 1 foot. The weight of these batteries varies by manufacturer, but a typical hybrid bus battery pack weighs an average 1,600-2,200 pounds.

As stated previously, batteries burn only with great difficulty. If batteries are exposed to fire, typically the plastic casing, cabling and other flammable materials will burn; the insides of the batteries rarely burn. If, however, a battery's electrolyte is spilled and exposed to fire, fumes and gases can be extremely toxic. Spilled electrolyte can cause short-circuiting of batteries and electrical circuits. Likewise, spilled electrolyte can react with other materials and produce toxic fumes. In addition, the presence of liquid and gaseous fuels in hybrid buses presents potential complications in the event of a battery fire.

Almost all hybrid-electric shuttle buses currently on the road in the U.S. use lead-acid batteries. Some manufacturers are testing nickel-metal hydride and nickel-cadmium batteries. The previous discussion on electric bus and electric car technology discusses the properties of these batteries and appropriate emergency response.

### Liquid and Gaseous Fuels

Another challenge for emergency response personnel is to quickly identify the type of fuel being used on the hybrid vehicle and to assess the potential hazards. While full-size transit bus hybrid engines typically run on diesel, small shuttle-size hybrids with micro-turbines (and the full-size buses that are using larger micro-turbines) can operate on liquid or compressed natural gas, propane, or diesel fuel.

*"Another challenge for emergency response personnel is to quickly identify the type of fuel being used on the hybrid vehicle and to assess the potential hazards."*

### Diesel

Most of the full-size transit hybrids use diesel fuel instead of CNG or LPG. For most emergency response agencies this is a familiar fuel and standard-operating guidelines apply to emergency response if the fuel is spilled or involved in a fire.

Diesel fuel is stored and transported as a liquid. The flammable limits for diesel are a low 0.6-7.5 percent and the auto-ignition temperature for diesel is 230°C. Comparatively, the auto-ignition temperature for CNG and LPG is 450°C and the auto-ignition temperature for gasoline is about 300°C. Similar to propane, diesel fumes are four to six times heavier than air and can pool in low-lying areas.

Diesel fuel leaks in the tank or fuel lines should be stopped using plugs and/or stoppers designed for this purpose. Prevent leaking diesel fuel from entering storm drains and other waterways. Clean up spilled diesel fuel with an absorbent material. Use foam to extinguish diesel fuel fires. As with all operations involving fuels and fires, use full structural fire-fighting gear and SCBA.

The fuel tank on hybrid shuttles usually occupies the space used by a battery compartment in a pure electric shuttle. Typically, it is put in place of the forward-most battery on the street side. The size of the tank varies depending on the fuel, but is typically, 50-75 gallons for diesel, propane or LNG fuel.

CNG tanks are typically smaller, and are mounted on the roof — the most common placement of CNG tanks in today's CNG-fueled transit buses. The diesel tank in the full-size transit hybrid typically is located under the curbside passenger seats.

The Natural Gas or Propane fuel cylinders on all hybrid buses must meet applicable standards for safety, strength, secure attachment, and ventilation. For example, NFPA 52 and FMVSS 303 ensure that pressurized CNG fuel cylinders are shielded from damage by road hazards and mounted to minimize damage from a collision. To this end, fuel cylinders cannot be mounted before the front axle or after the rear axle. The cylinders must be securely fastened to the frame of the vehicle and shielded from direct heat generated by the vehicle's exhaust system. Pressure relief valves must be vented to the outside of the vehicle.

*There are many hybrid electric buses on the road today that use a range of fuels to power the internal combustion engine.*

Manufacturers have designed their vehicles to ensure that no electrical sparks from high voltage systems come in contact with fuel tanks. Propane and LNG tanks used on the shuttle buses are approximately one-quarter inch thick steel and are separated from the battery compartments by structural members and sheet metal. The larger transit buses, with their fuel tanks underneath the floor and battery packs on the roof, have separation built in to their vehicle designs.

### Vehicle Identification

Like their electric bus counterparts, many, but not all, hybrid-electric buses display large lettering indicating that they are hybrids. Each fuel has its own industry-approved symbol. Most hybrid-electric bus manufacturers have incorporated the industry symbols for LPG, CNG or LNG, into their designs to aid emergency response personnel in identifying the type of fuel used on board. Although some buses do not prominently display their hybrid status, the fuel symbols will be present on the rear bumper and in the appropriate compartment, such as on the fuel tank compartment door or fuel-fill cover.

*The operating voltage for full-sized hybrid electric bus is between 500 to 700 volts.*

### Vehicle Operation

A hybrid-electric bus operates much like any other bus: the driver turns the key or pushes a button to start the vehicle and shifts a gear to begin movement. Acceleration is fast and smooth, as on an electric bus, but this is where the similarity ends.

The components on a hybrid-electric bus include: drive system, controller, electric motor, and turbine or conventional internal combustion engine; fuel storage, including battery and battery management system, and fuel tanks and piping; cabling and wiring; brakes; body and frame. All hybrid buses use regenerative braking systems.

As with electric cars and buses, you may not be able to immediately identify that a hybrid bus is “on” because it may be quiet. When some hybrid buses, such as the small shuttles, are stopped, the engines or turbines turn off so there is no engine rattle or vibration typical of a conventional bus. The engines on the full-size transit buses typically do not shut down when they are stopped. Check the vehicle’s instrument panel for indication lights to determine whether or not the bus is on. Even if the bus appears to be turned off, always assume high voltage is present due to the possibility of component or indicator failure.

Some large transit buses are designed to perform battery optimization after they are turned off, which means some components beside the batteries may still be energized with high voltage. In general, always assume high voltage is present between the batteries and associated cabling.


Many of the shuttle and medium-size hybrids can start their duty cycle in all-electric mode if the driver chooses. When the driver steps on the accelerator in a hybrid-electric shuttle, it sends an electrical signal to the controller/power converter unit, which controls the energy flow to the electric motor. The motor then drives the wheels. Electric motors in shuttles typically are AC induction, while motors in mid-size 35-foot hybrid buses are AC or DC directly driving the axle, depending on the configuration. When the batteries have been discharged, at a predetermined level, the system’s micro-turbine turns on automatically. This allows the batteries to recharge while the vehicle is operating. The controller directs current flow primarily from the batteries, but as power requirements dictate, supplements with current generated by the fuel driven turbine.

Based on the same technology as a jet engine, a micro-turbine generates electricity through rotating components mounted on a single shaft and supported by air bearings. An axial compressor feeds high-pressure air to a combustion chamber where fuel is injected and burned, producing an exhaust stream that spins a turbine at up to 96,000 RPM. A permanent-magnet generator mounted on the shaft produces electric current, generating 30 kW. The micro-turbines in use with the small- and medium-size hybrid shuttles run on compressed or liquefied natural gas, diesel, or propane.

The operating voltage of a typical small or medium-sized hybrid-electric shuttle using a micro-turbine is 200-700 volts. Full-size hybrid-electric buses operate at 500-700 volts. Do not tamper with these high voltage systems. The electrical components are typically labeled "high voltage." You can identify high voltage cables by the color of their orange insulation. As with any internal combustion engine, do not expose yourself or others to an engine running in an enclosed space; asphyxiation or carbon monoxide poisoning can occur.

Some of the full-size transit buses have an onboard sensor that automatically shuts down the engine in the event of fire. Likewise, some of the hybrid shuttles feature an automatic sprinkler/fire suppression system that engages when heat sensors in the battery and micro-turbine compartments sense abnormally high temperatures. This system automatically shuts down the vehicle and all high-voltage systems and discharges chemical or foam fire suppressants into these compartments.

The high voltage system is located in the same place on hybrid buses as on pure electric shuttle buses — at the back of the vehicle. It is clearly marked "high voltage" inside the external door, and all high voltage cabling is insulated with a bright orange loom, the color recommended by the Society of Automotive Engineers (SAE), and isolated from low voltage wiring.

These buses have the same safety features to turn off the high voltage system as their electric counterparts. They are: ignition key or master switch, manual shutoff switch accessible from the driver's seat, emergency cut-off switch located in the back of the bus with the high voltage components, inertia switch in some models, and automatic fire extinguishing systems in others.

On Full-Size Buses, the high voltage propulsion control system is typically located on the roof toward the back of the bus. The electric motor resides directly behind the rear wheels, and the generator is located behind the motor, accessible from the rear access door. As with other hybrid and electric buses, the areas are clearly labeled high voltage and all high voltage cabling is wrapped in red and white tape weave. Some manufacturers use orange or yellow tape.

A high voltage master disconnect switch is located in the vehicle battery compartment on the rear curb side of the bus. Other switches disconnect both 12-volt and 24-volt power isolator switches. All three switches should be turned off in the event of an accident or emergency. Remember, while the configuration varies by manufacturer, it is reasonable to assume that similar systems for disconnecting high voltage and low voltage exist on large hybrid transit buses.

Even with all of the safety precautions in place, there is still high voltage present in the batteries and associated cables. Do not cut high voltage wiring because of the potential for electrical shock. Use caution when working around or near the traction battery system. Remember that high voltage wiring is marked in orange.

### Hybrid-Electric Bus Refueling/Recharging

Electrical infrastructure requirements for hybrid buses are similar to those for electric buses, although the charging requirements for the different hybrid vehicle designs are quite different. While smaller shuttle buses typically charge every night as do their electric bus counterparts, the full-size transit buses charge less frequently – and then only for battery equalization, which is a routine maintenance requirement.

The charging process, use of conductive couplers and Level 2 and 3 charging, basic design recommendations such as distance between the bus and the charger, and temperature control are comparable for electric and hybrid-electric buses.

Building codes dictate where electric vehicle charging equipment can be installed. As with electric cars, ventilation in areas where electric buses are charged must comply with requirements in NFPA Standard NFPA 69, Explosion Prevention Systems. Article 625 of the National Electrical Code (NEC®) also addresses ventilation requirements for enclosed spaces used for EV charging.

*"Preplans of the facility should include the location of fuel tanks and manual shut-off valves."*

Refueling facilities for the various liquid and gaseous fuels used in hybrid buses must follow all applicable standards for the fuels used. Operators must take care to ensure that high voltage charging, for example, does not occur in close proximity to CNG refueling. Typically, separate buildings and refueling stations exist to ensure separate infrastructures.

The Standard for CNG Fuel Systems, NFPA 52, ensures that refueling stations have manual shut-off valves. One shut-off valve is located at the tank. An emergency shut-off valve, which terminates the power supply and gas supply to the compressor and dispenser, is located at a distance from the refueling area.

Breakaway protection is also provided in the event of a vehicle pulling away from the refueling station while the hose is still connected to the vehicle. The breakaway device stops the flow of natural gas.

Emergency response to refueling stations must include the use of full structural firefighting clothing and SCBAs. Preplans of the facility should include the location of fuel tanks and manual shut-off valves. If a vehicle is on fire at the refueling location, manually shut down the refueling operation at the tank or from the remote location. Disconnecting the main power source to the facility will also shut down the flow of fuel. You can then put out the fire using water and foam. If the tanks are involved in a fire, approach the tanks from the side and use water to cool the tanks and other exposures.

## Hybrid Bus Emergency Response

Emergency response to fires in hybrid buses depends upon the different fuels in use. Generally speaking, the use of water and foam will mitigate a majority of incidents. Even if no fire is present, responders should deploy hose lines to protect exposures (nearby property) and passengers exiting the bus in the form of a rescue path.

*Bus fires occur fairly regularly. Response personnel should preplan for this type of emergency.*

*—billbennettphoto.com*

Remember, as with pure electric buses, the first priority after passenger evacuation is eliminating the potential for fire on the bus to spread to the batteries or fuel compartments. It is good policy to separate internal combustion vehicles from electric and hybrid electric buses to minimize gasoline fuel vapors in the vicinity of electrical sparks. Use water or foam to extinguish flames. Follow standard fire response procedures for each fuel and battery type.

When performing extrication, avoid cutting in the high voltage areas around the batteries, the high voltage components or cabling. In addition, do not cut fuel lines; escaping liquid or gaseous fuels may have flammable or explosive properties upon release into the atmosphere.

Extinguish hybrid-electric bus fires with water or foam. Remember that the basic body and shell of the bus contains the same materials as any other bus. These materials can be toxic if fully engulfed in flames. Use full structural firefighting gear and SCBA.

Do not cut through the high voltage charging wire extending from the bus's charge port to the charging unit. To disconnect the power, turn off the charging unit, turn off the sub-panel or flip the breaker in the building's main panel. After the power is off, you can safely disconnect the charging connector from the bus. Take note that there may be separate electrical meters and power supply boxes for the hybrid-electric buses and for the rest of the building.

In the event of a hybrid-electric bus fire during charging, first disconnect the power to the charger, either at the charger itself or at the building's circuit breaker as described above. Extinguish the fire using standard procedures, water and/or foam. If the fire has engulfed the battery pack, follow the procedures for that specific battery type. Similarly use appropriate extinguishing agent for the type of fuel on-board.

Emergency response to hybrid electric vehicle collisions and emergencies should follow the same protocols for all-electric vehicles. Emergency response personnel should:

- ❖ Wear full protective clothing when working around electric vehicles including turnout coats, pants, helmets, gloves, and boots.
- ❖ Avoid wearing rings, watches, or any other jewelry when working around any type of electric vehicle to guard against potential shock hazards.
- ❖ Use additional safety gear including; high voltage rated non-conductive boots & gloves.
- ❖ Use hand tools, such as screw-drivers, pry bars, and pliers equipped with insulated handles.
- ❖ Wear self-contained breathing apparatus in the vicinity of any and all vehicle fires.
- ❖ Avoid cutting or puncturing the battery pack or high voltage cables.

## E. HYDROGEN FUEL CELL

It was in the late 1800s when the first automobiles came on the scene. These early cars used a variety of fuels and engines, including steam engines and electric motors. Over time, internal combustion engines using gasoline and diesel became most common and are the majority of the vehicles on the road today.

*Fuel Cell buses are seen in and around major metropolitan areas of the State.*

Automakers have always pursued other types of vehicles and fuels. Today, many of these vehicle technologies are gaining attention as the world looks for cleaner vehicles and non-petroleum fuels. Many automakers are exploring electric drive technology with gasoline-electric vehicles, all electric vehicles and fuel cell electric vehicles.

California has more fuel cell vehicles (FCVs) and hydrogen fuel stations than in any other region of the world. Average Californians drive and fuel many of these vehicles that are part of demonstration fleets at government and municipal agencies, parcel delivery companies, transit agencies, utility providers, universities and even as private vehicles.


*This Nissan demonstration vehicle reveals the drive system underneath the passenger compartment.*

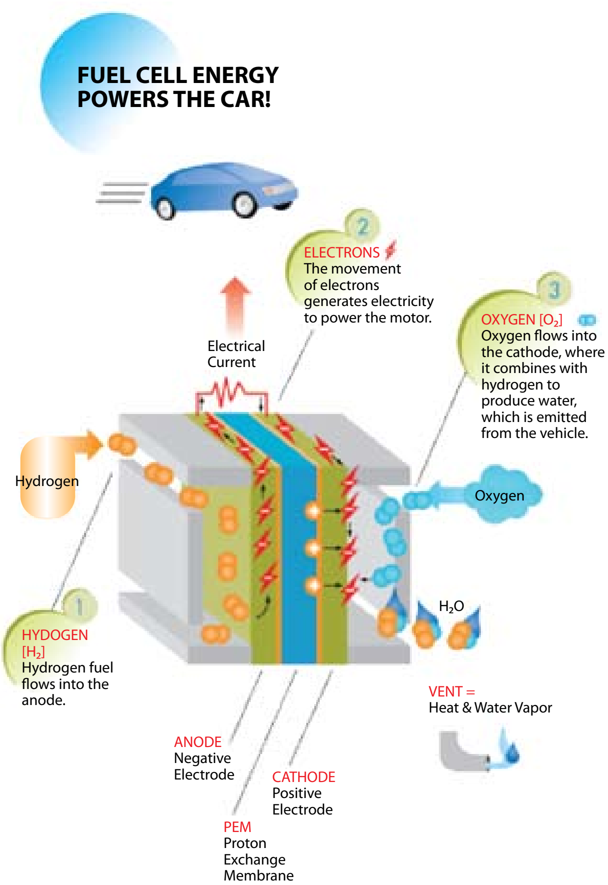
As of January, 2007 the California Fuel Cell Partnership (CaFCP) members have placed 158 FCVs and nine buses on California's roads in demonstration programs. Many of these vehicles are on the road every day in the greater Los Angeles area, San Diego, Palm Springs, Sacramento, and the San Francisco Bay Area. The vehicles fuel at 23 regional hydrogen stations, with many more planned in the very near future.

Fuel cell vehicles on the road in California today incorporate extensive safety systems similar to and, in many cases, more advanced than those incorporated in conventional gasoline vehicles. In fact, many automobile and energy industry experts point out that FCVs have potential safety benefits over conventional vehicles.

The safe use and operation of FCVs is a priority for CaFCP members. Educating emergency responders about the unique characteristics of FCVs is vital to promote safety. “The Hydrogen Fuel Cell Vehicle Emergency Response Safety Handbook” reproduced in part here, covers the fundamentals of this promising technology and is intended to supplement established emergency response training materials.

An FCV, powered by an electric motor, provides an environmentally friendly solution for air quality, and has great acceleration and torque. Compared to conventional vehicles, FCVs offer:

- Zero tailpipe emissions – a hydrogen-powered fuel cell vehicle has no polluting exhaust. The only tailpipe emission is water vapor.
- Quiet operation – FCVs can reduce noise pollution in urban areas.
- Energy efficiency – Fuel cell vehicles are 2-3 times more efficient than conventional vehicles.
- Energy diversity – hydrogen can be obtained from many sources, including renewables presenting the opportunity to develop a more diverse and sustainable energy supply portfolio.




A fuel cell is an electrochemical device that produces electricity efficiently, silently and without combustion. Unlike a battery, a fuel cell does not require recharging. It will produce electricity as long as hydrogen fuel is supplied. Fuel cells have been a reliable power source for many years. Fuel cells are currently used to power vehicles, buildings, laptop computers and video cameras.

## Fuel Cell and Hydrogen Properties

Automakers use a type of fuel cell called a Proton Exchange Membrane, or PEM, fuel cell. The PEM fuel cell uses an electrochemical reaction between hydrogen and oxygen to generate electricity. Like a conventional battery, a PEM fuel cell consists of two electrodes, the anode and the cathode, separated by a polymer electrolyte membrane coated on either side by a catalyst.

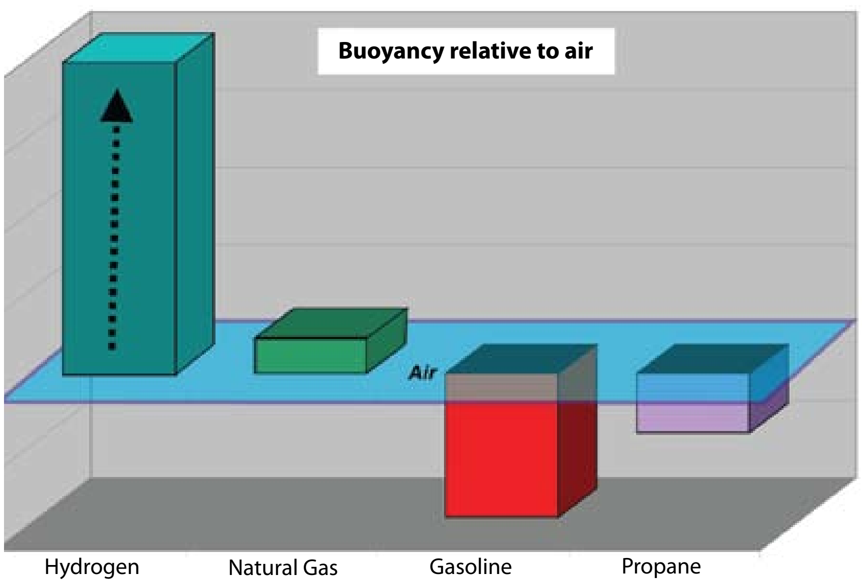
Hydrogen flows into the anode, where in the presence of the catalyst, the hydrogen molecules dissociate into electrons and protons. The hydrogen protons are able to pass through the membrane into the cathode. The electrons flow through an external circuit which produces electricity to power the vehicle. The electrons rejoin the protons in the cathode, and combine with oxygen to form water and heat.

Individual fuel cells are combined into a fuel cell stack that resembles a loaf of bread. The number of fuel cells combined into a fuel cell stack determines the amount of power it can supply. Today's FCVs use between 65 and 90-kilowatt fuel cell systems. Many FCVs also use a high-voltage battery similar those in gasoline-electric hybrids to supplement the fuel cell and recover energy during braking.

In an FCV, hydrogen is stored in tanks on-board the vehicle as a compressed gas. A few vehicles, however, store the hydrogen as a liquid.

When handled properly, hydrogen is as safe as or safer than other fuels. Its properties are unique and must be well-understood to be handled appropriately. Unique properties, such as buoyancy and diffusivity, can often times make it more manageable than hydrocarbon fuels.

As discussed earlier in the internal combustion section, hydrogen is the simplest of all elements, containing one proton and one electron. In nature, it's never found by itself, but always combined with something

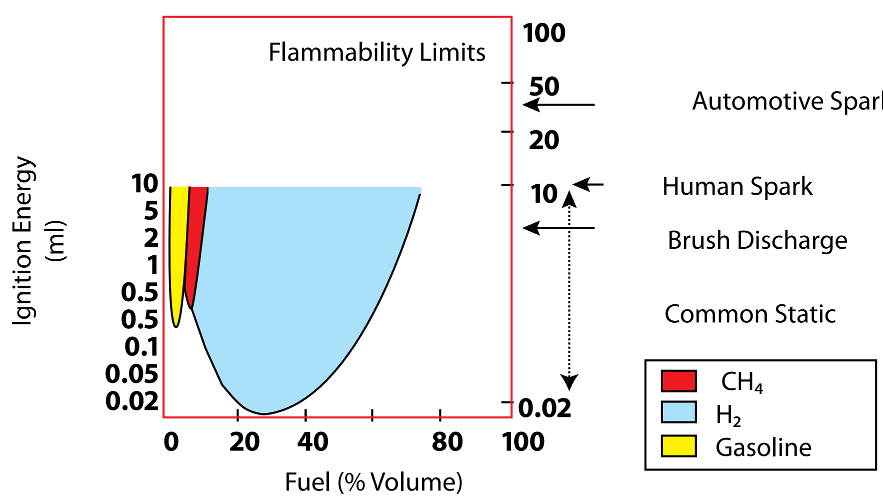



else. You'll often see hydrogen referred to as "H2" to denote its molecular structure—always two atoms bound together. Hydrogen has a very low boiling point (-423oF) and is predominantly used in its gaseous form in fuel cell vehicles.

Gaseous (GH2) hydrogen is the lightest of all gases. Because hydrogen's density is 0.07 times the density of air, it rises and diffuses rapidly. Compared to natural gas, GH2 rises eight times faster and diffuses approximately four times more rapidly. Gaseous hydrogen is flammable, but does not “pool” on the ground like gasoline, diesel or propane fuel vapors.

Hydrogen gas is nontoxic, non-corrosive and benign to the environment. It can, however, rapidly fill a confined space and, like any gas that displaces oxygen, it can induce suffocation (asphyxiation). Asphyxiation warning signs and symptoms include dizziness, drowsiness, nausea and/or loss of consciousness. (Please see the hydrogen Material Safety Data Sheets (MSDS) or Sourcebook for Hydrogen Applications published by the US Department of Energy for additional information about health hazards.)

Hydrogen, like all fuels, is flammable. Because it is a small, active and light molecule, it can be more difficult to confine than other fuels. When hydrogen does ignite, it burns with an invisible or near-invisible flame. The graph and table on the next page relate the ignition energy required to ignite a fuel mixture at the upper and lower flammability limits (UFL and LFL, respectively) of hydrogen, gasoline, and methane (CH4).




Flammability Limits of $H_2$ Are Seven Times Wider Than $CH_4$



| Property | Hydrogen | Propane | Gasoline | Natural Gas |
|---|---|---|---|---|
| Ignition energy in MJ/g | 20 | 250 | 250 | 300 |
| Lower flammability limit in air at room temperature and one atmosphere | 4% | 2% | 1% | 5% |
| Upper flammability limit in air at room temperature and one atmosphere | 75% | 10% | 8% | 15% |

The ignition source must have enough energy to ignite the fuel (i.e., the energy level should be on or above the curve for each gas). A variety of ignition sources can ignite gasoline, natural gas and hydrogen-air mixtures, sometimes as low as common static if it occurs in the proper mixture percentage.

Explosive hydrogen-air mixtures are difficult to create, requiring high hydrogen concentrations in air from 18.3% to 59%, conditions typically only possible in special, confined spaces. Furthermore, the concentration of fuel to air mixture for hydrogen is 29%, significantly greater than that of gasoline vapor or natural gas (2% and 9%, respectively).

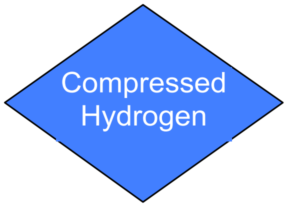
The lower flammable limits (LFL) for hydrogen (4%) is higher than gasoline (1%). This means it requires a greater percentage of hydrogen in the air than gasoline to ignite. Hydrogen does, however, have a wider flammability range (up to 75% in air) than methane or gasoline. This wide range of flammability presents an increased probability of ignition. Hydrogen's dispersion characteristics tend to reduce the likelihood that a flammable mixture will form in air.

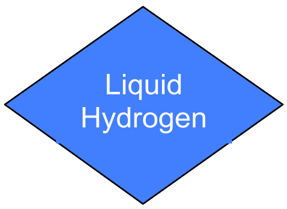

For hydrogen to exist as a liquid, it must be kept at cryogenic temperatures in pressurized and thermally insulated containers. The boiling point for hydrogen is -423°F (-253°C), and evaporation occurs in a 1:848 expansion ratio (see Appendix A). Most of the liquid hydrogen used for FCVs is in storage containers at hydrogen fuel stations. Some vehicles, however, store LH2 rather than GH2.

Liquid hydrogen poses a frostbite hazard (cryogenic burns) if it comes in contact with skin. Additionally, in the case of emergency release, super-cooled components such as pressure release devices, pipes and valves, can "burn" the skin upon contact. Please refer to the MSDS Sheets and the DOT Emergency Response manual when dealing with liquid hydrogen.

Due to hydrogen's extremely low boiling point (the lowest of any matter other than helium) and its high expansion ratio, LH2 storage tanks typically use a vent stack to safely release GH2 and prevent tank over-pressurization (see the Hydrogen Station Emergency Response Safety Handbook for more information on specific applications for LH2 storage).

A white cloud formed by condensed water vapor (and sometimes liquid oxygen) may indicate venting or leaking LH2. These clouds may—because of the higher density of cold gases—move horizontally or even downwards and contain cold GH2. The hydrogen cloud may extend beyond the visible portion of a vapor cloud. This hydrogen will, however, warm up within seconds and quickly disperse upwards.



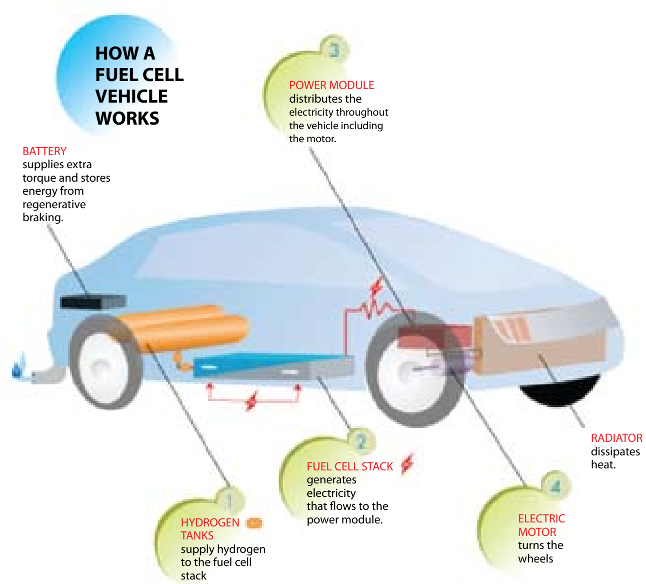




The cryogenic temperature of released LH2 can liquefy ambient air, which can cause the same frostbite hazard as the LH2 itself. For this reason, LH2 storage tanks are typically installed on concrete pads. Liquefied air has a high oxygen content (up to 50%) that can react with surfaces containing tar and asphalt. The result can be an explosive mixture with low ignition energy.

In the case of an LH2 or GH2 release, eliminate ignition sources, including open flames, mechanical sparks, electrostatic discharges, sparks from electrical equipment, and welding and cutting operations. When building or permitting a station, make sure none of these ignition sources are near the hydrogen vent stack.

## Fuel Cell Vehicle Identification

In most cases FCV are built from existing makes and models of vehicles you see on the road every day. You can identify a fuel cell vehicle by:




*Since 2000, nine fuel cell buses have been placed into service in California by SunLine Transit in Thousand Palms, Alameda-Contra Costa Transit (AC Transit) in the San Francisco Bay area and Santa Clara Valley Transportation Authority (Santa Clara VTA) in the Silicon Valley.*

- ❖ Vehicle graphics – Most fuel cell vehicles display graphics or lettering on various body panels indicating that the vehicles are powered by fuel cells.
- ❖ Blue diamond identification symbols – Usually applied to the rear of the vehicles, the blue diamond identifies the type of fuel stored in the fuel tank. The diamond is usually blue with white lettering.

## Fuel Cell Vehicle Operation

Fuel cell vehicles are electric vehicles that use hydrogen stored in tanks on board and a fuel cell stack to create electricity instead of requiring a rechargeable battery. The electricity from the fuel cell stack flows into a power module, which distributes the electricity to the electric motor that turns the wheels of the car. In many models, a high-voltage battery, similar to those in gasoline hybrids, provides extra torque when accelerating or climbing a hill, and helps improve fuel economy. An FCV's components include low and high voltage systems, a fuel system and vehicle safety systems.

*The elevated roof on the Ballard Hydrogen Bus stores the hydrogen cylinders that power the vehicles fuel cell.*

Most light duty fuel cell vehicles are built on existing vehicle platforms of each auto manufacturer and drives like its internal combustion counterpart. All fuel cell vehicles have the same basic components (electric motor, fuel cell stack, cooling system, etc.). Component placement varies somewhat in different makes and models, just like conventional vehicles. Light duty fuel cell vehicles are heavier than their conventional counterparts, (anywhere from 700 to 1,000 lbs.) primarily because of on-board hydrogen storage and the weight of the fuel cell stack.

Similarly, a fuel cell bus (FCB) drives much like its internal combustion engine counterpart. Because its fuel tanks are on the roof, a FCB is taller than a diesel bus, but about the same height as a CNG bus. The FCB is about 5,000 pounds heavier than a diesel bus and 2,200 pounds heavier than a compressed natural gas bus.

Fuel cell vehicles have both low voltage and high voltage electrical systems. The low voltage system is powered by a 12-volt battery similar to those found in conventional vehicles and runs the 12-volt accessories. As with conventional vehicles, disconnecting a 12-volt battery cable shuts down the vehicle and isolates sources of electrical energy. The high voltage system powers components that propel the vehicle.

The high voltage system includes the fuel cell, propulsion motor, high voltage cables and other power electronics components. Some vehicles also have a high voltage storage device (batteries or ultra capacitors). The high voltage systems in FCVs range from 200 to 450 volts. High voltage cables are orange, as SAE recommends (Figure 6). For specific information about the location of these cables, please refer to the ER FCV Diagram for each vehicle model or to manufacturer-issued documentation.

When a vehicle shuts down, the high voltage delivery system is designed to deactivate in seconds. Depending on the amount of hydrogen still in the fuel cell, it may take up to a few minutes for the electric motor and fuel cell stack to completely discharge. Only the high voltage batteries or ultra capacitors retain an electric charge after vehicle shut down.

Compressed gaseous hydrogen (GH2) is generally stored in Type 3 or Type 4 pressurized vessels or tanks (Figure 7). These tanks are stronger than conventional gasoline tanks and built to Canadian Standards Association (CSA) International standards. A Type 3 tank is an aluminum-lined tank with carbon fiber wrapped on the outside. The Type 4 tank has a polymer lining (typically polyethylene) with a carbon fiber wrap. The carbon fiber provides additional strength for these types of vessels.

The maximum pressure level used on a given vehicle type depends on the fuel tanks installed. Currently, storage tanks on the vehicles hold hydrogen at either 5,000 psi (350 Bar) or 10,000 psi (700 Bar) when completely full. The actual pressure depends on the amount of hydrogen in the tank and the allowable working pressure, which can be as low as a few hundred psi or as high as 10,000 psi. Vehicles and tanks are extensively tested and are designed to maintain their integrity in the event of an impact.

In the event of a fire impinging on the hydrogen storage tank, a temperature-activated pressure-release device (PRD/TRD) will open to rapidly release hydrogen, usually within a few minutes. The PRD/TRD is integrated into one end of the tank assembly and is sometimes routed through a vent stack. In vehicles with multiple tanks, each tank has its own PRD/TRD. If a PRD/TRD activates, you will usually hear a “bang” followed by a loud hissing sound, similar to the sound of a high pressure air hose. The tank will empty in 2-3 minutes.

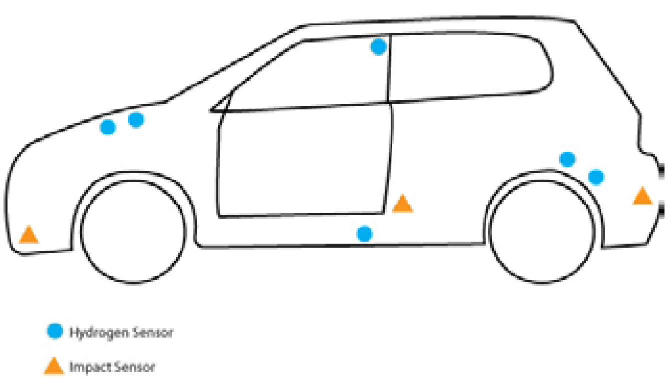



*Diagram shows a sample of hydrogen sensors and impact sensors that will shut off hydrogen fuel supply if the vehicle is damaged.*

A controlled pressure release can ignite into a concentrated invisible or nearly invisible flame. Typically, particles in the air and/or combustible materials in the vent area will render a visible flame. Hydrogen flames radiate one-tenth the heat of gasoline flames, so the sensation of heat is not a strong indicator of a flame. (Other sections of this handbook cover this in more detail.)

A fuel cell system operates at a much lower pressure than the GH2 storage tanks. High pressure hydrogen is generally regulated below 70 psi (5 Bar) just outside of the storage tanks, reducing the amount of high pressure piping. This lower pressure hydrogen is fed into the fuel cell through fuel lines. These lines are stainless steel tubes routed between the fuel tanks and fuel cell stack. Some FCVs have high and low pressure lines located in the vehicle.

When the vehicle is turned off, solenoids that default to a closed position securely isolate the high-pressure hydrogen inside the fuel tanks. A small amount of low-pressure hydrogen may remain in the fuel lines, but the equivalent in energy is no more than a tablespoon of gasoline.

Liquid hydrogen, stored cryogenically at –423ºF (-253ºC), is more common at hydrogen fuel stations than on board FCVs. Vehicle storage tanks for LH2 are typically made of stainless steel and are stronger than gasoline tanks. Cryogenic LH2 cylinders have a tank within a tank with a vacuum seal between the inner and outer tanks. This forms a thermos-like insulating protection to reduce the rate of boil-off of the cryogenic hydrogen. If not operated for a week or so, some models of LH2 vehicles will safely vent hydrogen gas from time to time to prevent pressure build up in the cryogenic storage tanks.

Ice frost or ice crystals on the outside of the fuel tank may indicate a leak or tank failure. If a serious accident caused the inner tank to fail, the pressure relief valve will expel excess GH2 through a vent stack to the atmosphere.


*Hydrogen Sensor used in hydrogen powered vehicles.*

## Vehicle Safety Systems

Pre-commercial light duty FCVs and fuel cell buses have many safety systems that work independently and together to protect the safety of the occupants and their surroundings. In the event of an impact, fuel leak or operation outside of normal parameters, sensors isolate the high voltage and hydrogen storage systems. The following is a summary of these systems (L= Light Duty Fuel Cell Vehicle and B=Fuel Cell Bus):

1. *Hydrogen sensors (L,B)—Sensors located throughout the vehicle (including the passenger cabin) detect the presence of hydrogen. If a sensor detects a leak, the solenoids that default to a closed position in the hydrogen tank close locking high pressure hydrogen in the tanks. At the same time, relays that default to an open position in the electrical system open to isolate high voltage sources.(Figure 8)*

2 *Sensors on fuel cell buses are placed beneath roof canopies and in engine compartments, and are linked to an on-board alarm system that sounds at concentrations as low as 0.2% in air. Upon triggering a sensor, the control system can alert the driver by way of dashboard lights, a message display center or other means. Dedicated leak indicators may concurrently display the measured percentage of hydrogen concentrations. See individual bus diagrams for exact information.*

3. *Impact sensors (L,B)—FCVs use inertia-based sensors, similar to air bag sensors, to detect a vehicle impact. In the event of an impact, the high pressure hydrogen storage and electrical systems will be isolated.*

4. *Thermally Activated Pressure Relief Device (L,B)—In case of a fire near a vehicle's hydrogen tanks, a device integrated into the assembly*

*of each fuel tank is designed to release the hydrogen (in a controlled manner) from the tank into the atmosphere through a vent. This prevents a tank rupture due to overpressure (over-temperature). This device activates (opens) when a significant temperature build-up near or around the tank, melting a fusible metal plug and opening the device, allowing the tank to vent rapidly. If a PRD/TRD activates, you will usually hear a "bang" followed by a loud hissing sound. The tank will empty in 2-3 minutes.*

5. *Fire suppression system (B)—Some transit buses include a fire suppression system that will detect and extinguish fires. When the sensor is triggered, the control system alerts the driver by way of dashboard lights, a message display center or other means and shuts down the engine. After the vehicle is shut off, single-shot fire retardants may be released into one or more zones associated with the triggered sensor. Fire retardants do not discharge into the vehicle passenger compartment. A very loud sound accompanies a retardant discharge.*

   *A cloud of dry chemical retardant dust may exit the vehicle from the discharge areas. Avoid breathing the dry chemical dust as it will irritate throat and lungs. In most cases, the fire suppression system is active at all times unless the vehicle battery knife switches are open (disconnected). Some types of sensors can also detect high heat. Fuel cell buses may include thermal wire wound around the fuel cell stacks that are designed to short when melted, signaling the control system.*

6. *Emergency shutoff button or emergency shutdown device (L,B)—Early prototype light duty FCVs may have a manual shutoff switch in the vehicle to give the passenger/driver an additional method to shut down the vehicle and isolate the high pressure hydrogen storage and high voltage sources. A fuel cell bus normally contains an emergency shutdown device (ESD) switch on the control panel near the driver and at least one externally located shutdown device switch, usually in the back of the bus with the electrical components. These switches enable the engine to be shut down from more than one location and may allow restart from the exterior of the bus. Depressing any ESD switch shuts down the low voltage system and disconnects the high pressure hydrogen. If an electrical problem with the high voltage system occurs, some buses may automatically shut down after several seconds. For clarity and simplicity, the bus emergency response diagrams refer to all shutdown device switches as ESD switches.*



*The futuristic Protera Fuel Cell Bus is being test marketed in major metropolitan areas.*

7. *12 -Volt battery cable & key-off (L,B)—As with conventional vehicles, disconnecting a 12-volt battery cable and turning the key to the 'off' position shuts down the vehicle and, in the case of FCVs, isolates the high pressure hydrogen and high voltage sources.*

Vehicle safety systems are configured in fail-safe designs, meaning that the default (un-powered) position for valves controlling hydrogen flow from the storage systems is "closed," and the default position of voltage relays is "open." All system operations monitors must be within normal ranges to close voltage relays and open the valves to allow hydrogen to flow from the fuel tanks.

## Hydrogen Refueling

As mentioned in a previous section, hydrogen fuel stations are in the planning and development process in key metropolitan areas of California with a focus on San Francisco Bay Area, Sacramento, Los Angeles and Orange County. Hydrogen stations are not a "one-size-fits-all" technology. Some stations can make hydrogen fuel on site by reforming natural gas or electrolyzing water. Other stations dispense hydrogen made at a central production facility which is the trucked to the on-site storage tank. Some stations will only dispense hydrogen fuel while others will dispense it along side other fuels. For larger applications like fleet vehicles, an on-site stationary fuel cell system can make electricity and heat for buildings, as well as hydrogen for fleet vehicles.

Commercial refueling stations will have the same safety features, remote emergency shut-off, breakaway protection, and pump protection, as conventional fuel stations.

*Hydrogen fuel stations can generate hydrogen on-site or be trucked in to the refueling facility.*

## Fuel Cell Vehicles Emergency Response

Approach a fuel cell vehicle the way you approach a conventional vehicle. If possible, position the responding apparatus up hill, upwind, and away from the vehicle. Follow the standard vehicle approach method (45 degree approach angle) taking into account the direction of the vehicle's PRD. Reference individual manufacturer emergency response Diagrams for location and direction of vent. The standard operating procedures should also include:

- ❖ Listen for leaking hydrogen (loud hissing)
- ❖ Identify vehicle type (note blue diamond sticker)
- ❖ Confirm vehicle is off (key off, cut 12V negative cable)
- ❖ Remove fuel spills, conventional vehicles and ignition sources from FCV
- ❖ If safe, let any hydrogen fires burn; protect exposures
- ❖ Avoid using spreaders for rocker panel purchase point; if needed, use a cradle for the ram
- ❖ Do not cut high voltage or hydrogen lines

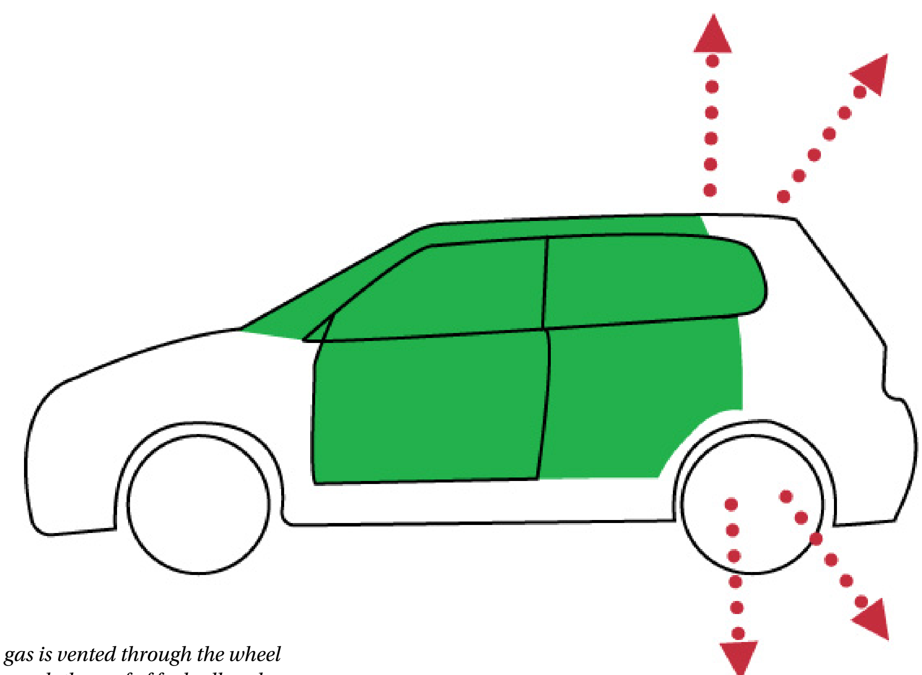
## Non-Injury Accidents

Wear full protective clothing as required for any vehicle emergency. If available, use combustible gas detectors to check for system leaks. Maneuver emergency response vehicles upwind of the disabled vehicle and approach the vehicle away from the PRD vent location. Please see model-specific diagrams for information on vehicles in your area.

## FCV Fires

Wear full protective clothing including self contained breathing apparatus (SCBA). If working directly with the vehicle use high-voltage rubber gloves and use static dissipative equipment. This equipment provides the essential protection for handling electrical components, flammable gas and hazardous fumes.

Hydrogen fires do not have a visible flame and generate little smoke. However, combustible material in or near the hydrogen flame, and particles in the air will likely render a visible flame and give off smoke. Use ultra-violet and/or infra red (IR) detectors, if available, to scan for invisible hydrogen flames. If no flames are present, scan the vehicle with a hydrogen leak detector (combustible gas detector rated for hydrogen), if available. Do not extinguish hydrogen fires unless the leak feeding the flame can be stopped. If safe to do so, allow the gas to burn out and protect exposures.



*Hydrogen gas is vented through the wheel wells or through the roof of fuel cell and hydrogen fueled vehicles.*

## Multi-Vehicle Accidents

If a fuel cell vehicle and an internal combustion engine vehicle are involved in a collision, move the internal combustion engine vehicle away from the fuel cell vehicle when it is safe to do so. If gasoline or diesel fuel spills near a fuel cell vehicle, spray the spilled fuel with foam to render the fuel inert.

## Fuel Cell Bus Accidents

In the event of a fuel cell bus incident, the bus driver will, if possible, follow shut down procedures provided by the transit agency. Passengers will exit through the bus doors and emergency exits, as appropriate and when it is determined safe. Move passengers to a safe location upwind and away from the bus.

## Rescue/ Extrication

Before attempting to rescue occupants (patients) from an FCV or moving a damaged vehicle, check the following:

- ❖ The vehicle is turned off or no longer running
- ❖ Look for a white cloud near the vehicle, an indication of a liquid hydrogen release
- ❖ You do not hear a loud hissing, similar to a fire extinguisher or high pressure air hose, an indication of a gaseous hydrogen release

If you need to extricate a patient, follow standard procedures with additional consideration for the hydrogen and electrical systems. If you need to cut into an FCV (with a Hurst Tool, etc.) do not cut crucial components of the fuel cell system that include the hydrogen storage system and high voltage electrical storage (batteries or ultra capacitors). These components are usually under the flooring or in the front compartment (“under the hood”) of the vehicles.

In the case of an impact and/or a vehicle fire, approach an FCV away from the location of the PRD/TRD vent. Do not stand near or in the stream of a controlled release. This is especially important if the vehicle is on fire.

## Hydrogen Gas Releases

A FCV is designed to be as safe as or safer than conventional vehicles. In the event of an impact, impact sensors similar to those used in an airbag system deactivate the high voltage and high pressure hydrogen systems.

Take extra care if a vehicle is on fire or you hear a loud hissing sound from the vehicle. If a vehicle leaks hydrogen or the PRD/TRD activates, the vehicle's fuel tank will empty in 2-3 minutes and the hydrogen will rapidly dissipate in the atmosphere.

When the PRD/TRD releases you will hear a "bang" followed by a loud hissing sound (lasting only 2-3 minutes), similar to the sound of a discharging fire extinguisher. If you hear an audible hissing sound from a location other then the PRD/TRD then hydrogen is escaping from another component of the vehicle.

If released hydrogen Ignites, an extended, near invisible flame accompanied by a loud hissing sound can be observed and detected with positive readouts from combustible gas detectors capable of measuring hydrogen. Hydrogen flames are visible to UV/IR detection equipment.

### The California Fuel Cell Partnership

The material contained in this section was provided by the California Fuel Cell Partnership. The California Fuel Cell Partnership is a collaboration of 31 member organizations working towards the commercialization of FCVs.

California FUEL CELL PARTNERSHIP
DRIVING FOR THE FUTURE

Through a "learn by doing" approach to vehicle and infrastructure demonstration, CaFCP members will continue to promote the development of practical codes and standards for FCVs and hydrogen fuel stations, and to help prepare local communities for the vehicles and fuel by educating local officials, including emergency response personnel. Members will also continue to expand public awareness through education and outreach activities, consistent with the pace of technology development.

To find more information about the California Fuel Cell Partnership and its members visit *www.cafcp.org.*

# Chapter IV.

## EMERGENCY RESPONSE

### A. INTRODUCTION

In today's emergency response environment you can no longer assume that all vehicles are built and powered like one another. Some alternative vehicles have a distinctive design while others are incorporated into well known and existing ICE vehicle bodies. New vehicle construction techniques and new fuels and energy sources on the vehicles of today, and tomorrow, require that emergency responders maintain an extra measure of vigilance when approaching the scene of an emergency.

### B. ALT-FUEL VEHICLE EMERGENCIES

Emergency response personnel along with incident commanders must recognize the special hazards involved during incidents with Alt-Fuel Vehicles. NFPA 1670 outlines the steps needed for departments to prepare for safe and effective operations at incidents involving vehicles of all types. For emergency responders to make appropriate decisions regarding fire control and extrication operations, standard operating guidelines must include steps to identify the vehicle type and energy source early in the incident.

This would include identifying the alternative fuel vehicle type using the vehicles stickers, placards, emblems, badging along with the vehicle style. Positive vehicle identification will provide incident commanders with the critical information on the potential hazards of the emergency. Hybrid vehicle identification reveals that an internal combustion engine is used in combination with an electric motor and high voltage battery pack. Dual fuel, bi-fuel, or flex fuel vehicles reveal that your crew will need to mitigate a combination of gasoline/natural gas or diesel/propane or any combination of fuels. Electric, suggests that you have the potential for mitigating electric/hydrogen and potentially photovoltaic energy.

*Formal Training in all facets of vehicle response, that also include information regarding alternative fuels, will insure scene, victim, and personnel safety.*

Hybrid vehicle identification, for example reveals that an internal combustion engine is used in combination with an electric motor and high voltage battery pack. Dual fuel, bi-fuel, or flex fuel vehicles reveal that your crew will need to mitigate a combination of gasoline/natural gas or diesel/propane or any combination of fuels. Electric, suggests that you have the potential for mitigating electric/hydrogen and potentially photovoltaic energy.

Will you need to mitigate liquid fuels such as gasoline, ethanol, diesel or bio diesel? Chances are the only change to current operations regarding liquid fuels is the use of AR-AFFF on ethanol blended fuels. Protocol for controlling, containing and cleaning or recovering these fuels will remain unchanged.

Or, will you be mitigating a gaseous fuel such as Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG), Propane (LPG) or Hydrogen or Liquid Hydrogen? In each case inertia switches should have isolated the fuel to the cylinder. If the pressure in the storage cylinder expands, the pressure relief valve will release its contents to the atmosphere. The question for emergency responders is whether or not all potential ignition sources can be removed from the area to avoid the released gases from igniting. If the gases have ignited, then protecting exposures and allowing the fuel to burn off is the best tactic when safe to do so.

When all this information is collected and processed then you have the basis for making decisions regarding the fuel systems in terms of what you know:

- ❖ All Alt-Fuel Vehicles have one or more fuel/energy storage containers onboard.
- ❖ Common locations are within the trunk, bed of a pick-up, inside a van, or below the undercarriage.
- ❖ Pressures vary from 2,500 psi and may be up to 10,000 psi.
- ❖ Container may be plastic, steel, aluminum, carbon wrap, fiberglass wrap or other composite material.
- ❖ Pressurized tanks have pressure-relief valves which from past experience have been known to fail.
- ❖ Fuel shutoff valves are provided on high-pressure systems in the form of a manual screw valve or ¼ turn Hoke Valve. They are usually on or close to the storage container.

With all this information and data the next priority is to mitigate a fuel leak or compromised battery using once again the standard operating guidelines. All of these operations are considered as high-risk operations in which all appropriate PPE shall be used:

- ❖ In the event the shutoff valve cannot be reached a hose line can be used to disperse vapors away from the patient(s).
- ❖ Liquid tanks may be plugged or the fluid may be captured
- ❖ Pressure tanks need to be turned off or have a line pinched to control a leak
- ❖ Recognize Battery Pack Hazards

  a) 12 volts systems—corrosive acid present

b) 24 volt systems—corrosive acid/base present

c) High Voltage—May exceed 300 volts & 10 amps

d) HAZMAT—exotic battery chemistries and off gassing of toxic fumes

## C. ALT-FUEL VEHICLE FIRES

In most cases fires in alternative-fuel vehicles can be dealt with using conventional vehicle firefighting tactics. However, emergency responders must recognize that vehicle fires, regardless of fuel type, produce substantial amounts of toxic products in a very small space. They also present multiple other threats including:

*Like ICE vehicles, emergencies involving alternative fuel vehicles can take place in areas where they are stored, fueled, and maintained.*

- ❖ Pressurized Tanks—BLEVE (Boiling Liquid Expanding Vapor Explosion)
- ❖ Liquid Fuel Leaks—Fuel may build on ground around responders then ignite
- ❖ Gaseous Fuel Leaks—May add to fire intensity
- ❖ Electric Vehicles—High voltage hazards
- ❖ Air bags and other Supplemental Restraint System components—Air bags, particularly those mounted in steering wheels and dashboards, have been known to explode during vehicle fires and propel debris and flaming material great distances from the vehicle
- ❖ Compression bumpers—Compression struts on bumpers can explode sending the bumper several feet away from the vehicle
- ❖ Hood & Tailgate Struts—Gas struts, commonly used to hold open hoods and tailgates, can explode and launch the strut a great distance
- ❖ Standard transmission vehicles-shorting of wiring may cause vehicle starter to engage. If vehicle is in gear it may roll forward or back as engine turns over.
- ❖ Drivelines—Vehicle driveline may overheat, explode, and launch shrapnel like a pipe bomb
- ❖ Brake pots—Brake pots on commercial vehicles may melt releasing the coil brake spring. The spring may be propelled great distances, typically to the rear of the vehicle.

*Consider that many of the fuels are delivered in tanker trucks and trains. It is not uncommon for these tanker vehicles to be involved in an emergency.*

*—Courtesy of Mike Waldron*

- ❖ Falling loads—Tie down straps on loads may melt and suddenly release the load.
- ❖ Unknown Cargo—Trunks, Trailers and Storage areas may contain hazardous cargo

When approaching fires in alt-fuel vehicles, responders should use their conventional response guidelines. Some of the updated guidelines that pertain to both conventional vehicles as well as alt-fuel vehicles should include the following:

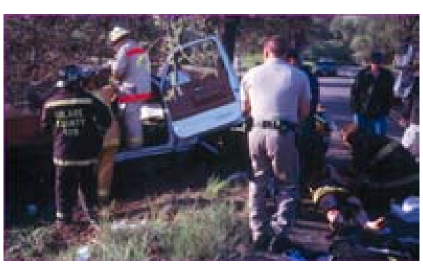
- ❖ Park apparatus approximately 100 feet away from fire
- ❖ Approach from Upwind & Uphill
- ❖ 1 ¾ inch lines should be used as the minimum size attack line
- ❖ Approach all vehicles at a 45 degree angle to the vehicle
- ❖ Do not approach the vehicle until the hose line is fully charged
- ❖ Use a sweeping motion from bumper to bumper to cool fuel tanks and other explosion hazards
- ❖ For unvented heavy interior fires, do not open doors until one or more windows are removed (use pike pole, etc.) and fire is knocked down
- ❖ Complete fire extinguishment with the least amount of firefighters so as not to expose more than necessary

## D. EXTRICATION SAFETY AND ORGANIZATION

Beyond the recognized challenges presented by alternative vehicles, the vehicle itself is like most others on the road today. That is not to say that the vehicles on the road today do not already present their own unique hazards and challenges—they certainly do! This section provides a review of such considerations and the management practices that should be employed at all vehicle emergencies for effective scene management and scene safety.

*"Due to intensive training by the Department of Homeland Security, law enforcement is fully participating within the Incident Management System."*

The State Highway Patrol or local law enforcement have jurisdiction with regards to vehicle emergencies on the roadway. Due to intensive training by the Department of Homeland Security, law enforcement is fully participating within the Incident Management System. Fire Department or EMS agencies may be in charge of the emergency if they arrive first to the scene of the emergency, but the scene is turned over to law enforcement upon their arrival. Fire and EMS agencies then fall into the Operations Section of the Incident Management System.



*Vehicle emergencies involve the collaboration of law enforcement, fire and EMS.*

The command structure can include law enforcement, investigation, traffic control, coroner, EMS, triage, treatment, transport, fire, fire control, rescue, HazMat, plus other duties not taken on by law enforcement. For communication purposes it is important to use appropriate ICS titles for your positions, where law enforcement is Incident Command and fire and EMS is relegated to Operations or Branch ICS levels. It is important before the emergency to get involved in what the local emergency response plans are for your community. Most jurisdictions have written plans, interagency agreements and mass casualty protocols that affect highway incident management in their area. Get familiar with these issues as part of your local orientation and training.

## The Extrication Team

Unlike Wildland or Structural fires, fire departments typically send a very limited number of resources on the first alarm to vehicle collision incidents. When a collision involves entrapment or a "pin-in", resources can become depleted very rapidly.

The strength of successful extrication operations is dependent on having sufficient resources to fill a minimum of ten "Extrication Team" positions as described below. Multiple "pin-ins", particularly if in multiple vehicles, may require multiple teams. For this reason it is important to conduct an effective scene assessment and order additional resources as necessary to fill these Extrication Team positions:

## Team Leader

In early stages of the incident may also perform as Operations Section Chief, Fire/Rescue Branch Director or even the Incident Commander and will perform other team roles until all other positions are staffed.

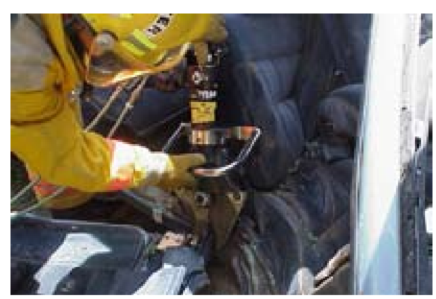
*A charged line and nozzle person stand ready 25 ft. from the rescue operation.*

## Safety Officer

In the early stages of the rescue may also be Team Leader, or positions discussed above. This individual should separate from Incident Command/Team Leader as soon as possible. The Team Leader may perform as Safety Officer until the position is staffed.

## Nozzle Person

The Nozzle Person position is critical to the incident. Nozzle Persons must remain at the nozzle and NOT be assigned other tasks, including the overall role of Safety Officer. They must fill only this position. On larger incidents multiple hose lines and Nozzle Persons may need to be deployed. To avoid injuring rescuers with hose streams, to avoid forcing burning flammable liquids to spread under or around vehicles and to allow for the best overall scene coverage, it is imperative that all nozzles be positioned well away from where rescuers are working. Rescuers can be best protected if nozzles are positioned at least 25 ft. away.



*The most experienced tool operator should be used for live rescues.*

*The operator back-up doesn't watch the tool, but the victim and the tool operator.*

*The Tool Staging Manager keeps tools and equipment organized and accessible to the rescue operation*

*Team Assistants are valuable assets for fetching tools and equipment assisting EMS personnel or the rescue team when required.*

In the event that fire erupts, the first priority of the Nozzle Person is to immediately apply water in a fog pattern over the rescue site to allow rescuers to escape, similar to the way airport firefighters apply water over the aircraft as they make their initial approach. Once rescuers have retreated to safety, the Nozzle Persons may then safely switch to a direct attack mode and move in to quell the fire without fear of pushing the fire onto rescuers or injuring them with hose streams.

## Tool Operator

The Team Leader should use the most experienced tool operator for live rescues. Allow less experienced persons to run tools or work on body recoveries. This is a high stress and physically demanding position. Rotation should be allowed between Operator and the Back-up Operator frequently.

## Operator-Back-up person

The Operator-Backup person may be the Team Leader or Safety Officer in the early stages of the emergency. They serve as the immediate safety back-up for tool operator and victim(s) watching the victim and remainder of vehicle for reaction, while operator focuses on tool contact. Importantly, the Operator Back-up person does not watch the tool itself!

## Personnel/Tool Staging Manager

In early stages of the emergency the Tool Staging Manager can be performed as a dual role for Team Leader or Safety Officer. The Tool Staging Manager keeps the tools and equipment organized, often times using tarps for the tool staging area. This team member oversees tool set-up and ensures tools and people return to the staging area.

## Team Assistants—"Go-fers" and Tool Set-Up Person

Whenever possible it is best to strive for at least four persons to assist with tool set-up, cribbing, and traffic control. The Go-fers are an invaluable asset to any team operation in that they can assist EMS or fetch tools and equipment for the Tool Operator.

Successful extrication requires teamwork, and no member of the team is more important than another. Though a rookie firefighter may be assigned the seemingly mundane task of directing traffic at an incident, that role is critical and provides for the safety of the seasoned veteran using the JAWS to extricate a victim. Regardless of their roles, everyone on the team contributes to the team's overall success!

Again, don't underestimate your resource needs! Major incidents may require multiple extrication teams, and will tap resources rapidly. Order tools, equipment and personnel early and order enough.

## Personal Protective Equipment & Safety

You and your team are your first priority! It is important in the emergency decision making process to keep your priorities straight beginning with the first priority—yourself, followed by your crew, the community, and the victim(s). It is imperative that you do not put priority number four, the victim, before yourself or your crew. This means that your response vehicle should be properly positioned, initial traffic controls measures started, and protective hose lines put in place, as needed, before you begin operations to treat and free victims. Past experience has shown that when you do you risk the entire operation. Your responsibility is to send your crew home to their families at the end of the shift alive and uninjured!

Taking care of your self should go without saying, but it is always important to review your own personal safety requirements. Always wear full protective clothing: Turnout pants, coat, helmet, eye protection, and leather gloves along with SCBA. If you see or smell fuel in flammable or toxic areas (as in many vehicle accidents), then do not hesitate to don your SCBA. If you haven't heard of these requirements enough in the course of your career—you can say that you've heard it once again here! Beyond personal protective equipment the following recommendations are suggested for you and your team safety:

- ❖ Dust masks and face shields are appropriate for vehicle emergencies
- ❖ Use a Personnel Accountability System
- ❖ Establish Personnel and Tool staging areas
- ❖ Rescuers must "check-in" upon arrival
- ❖ Rescuers stay in staging until assigned, return to staging when tasks are completed
- ❖ Stage out of the "Danger Zone" and clear of oncoming traffic

## E. OPERATIONAL SAFETY

Remember that your second priority is to protect other emergency responders. On the initial size-up of the emergency, other hazards should be noted and communicated to other individuals and agencies on scene. They may not recognize the hazards, or have


*Vehicle placement is critical to the safety of the rescue operation.*

appropriate personal protective equipment and may need to back-out and away from the scene of the emergency until the situation is stabilized. In cases such as this you should use firm but polite warnings to get people to safety. These hazards could involve:

*Angle your emergency vehicle to oncoming traffic to allow "bank shot away" from the work area.*

### Protection from Traffic

Each year many emergency workers are killed or injured when struck by on-coming traffic at the scene of a roadway emergency. While working on the roadway is always dangerous, such factors as hills, curves, darkness, heavy rain, and fog all add to the hazard. Poor visibility and other conditions can increase the danger dramatically. You must take steps to protect yourself, your crew, and other rescuers. This can be accomplished by getting traffic control assistance, using traffic control devices like road flares, cones, signs, and flag persons.

You can use your emergency vehicle as a barrier by parking emergency vehicles at a slight angle to the traffic lane. An emergency vehicle may travel less when struck at angle and offending vehicles tend to "bank shot" away from the work area. Parking at angle also makes the emergency vehicle's stripes and lighting more visible. If using an engine as a barrier always park with pump panel facing away from oncoming traffic. Other recommendations include:

- ❖ Establish a 50 foot Danger Zone (100 feet for alternative fuel vehicles)
- ❖ The "Danger Zone" is not a parking lot! Keep it clear of Emergency Vehicles!
- ❖ Create adequate workspace – move debris/tripping hazards
- ❖ Reduce threat from fire by removing ignition sources
- ❖ Be ready for fire:
  - Pull, charge and staff one 1-3/4 inch or equivalent hose line
  - Large incidents may require multiple lines
  - Consider pulling hose lines when no "pin-in"
  - Position nozzles at least 25 ft. away
  - If fire erupts, protect people with water first
  - Apply fog streams overhead, don't use straight streams
  - Consider having specialized fire extinguishers ready

## Eliminating Ignition Sources

This text recommends in several sections to eliminate ignition sources. This is an extremely important aspect of scene management when working with all vehicles and highly recommended when working with alternative fuel vehicles as well.

Consider disconnecting battery first by weighing the fire hazard risk against the necessity you might need battery power further in the emergency. Do not cut battery cables. If you need to reconnect the battery for any reason—you cannot reconnect cut battery cables.

- ❖ Use caution when placing power units and portable generators
- ❖ Use caution when placing road flares
- ❖ Crack flare over knee before lighting to prevent rolling
- ❖ Do not spot apparatus in fuel spill areas
- ❖ Stop traffic if necessary

## Stabilize Involved Vehicles

The amount of stabilization needed, if any, will be dictated by the amount of damage to the vehicle(s), ground conditions, and other factors.

*Stabilizing the vehicle is essential to safe rescue operations.*

- ❖ Chock at least two wheels
- ❖ Turn off ignition switch
- ❖ Put vehicle in park
- ❖ Crib body, frame, or bumper - to ground
- ❖ Simply deflating the tires, DOES NOT make the vehicle stable!
- ❖ If using "Step Cribs" insert under the vehicle at a 45 degree angle
- ❖ Use ropes, other devices as needed
- ❖ Cribbing may loosen as victims or vehicle parts are removed.

## Downed Power Lines

When conducting a scene assessment look-up and around for electrical power lines. If power lines are down do not approach until power is confirmed to be shut-off.
Caution and common sense are the watch words when working or parking around damaged lines or poles. Realize that damage at one location may drop lines in another location out of immediate view. Downed power lines across fences may become energized and pose an even greater shock hazard. Always provide barriers to prevent contact. Rely on electrical professionals for moving downed lines safely. If not already

Realize that a damaged power line or pole may drop power lines at another location out of immediate view.

incorporated into your Standard Operating Guidelines add these policies:

*1. Immediately notify Dispatcher! Do not just say "Lines Down", give specific location: "East side of the building, laying across driveway," or "On north shoulder of roadway, 100 ft. west of Engine 21," and "In tree, at southeast corner of the garage." Provide the name of utility company when possible. Dispatch will sound alert tones, broadcast warning and all units at, or responding to, the scene must acknowledge.*

*2. Provide a safety person and a visible barrier such as Black and Yellow flagging a minimum of 25 ft. from wires/ hazard area. Do not allow anyone to lift flagging or enter area and maintain the exclusion zone until power is confirmed off by utility company. Note: It is recommended that - in lieu of common "Fireline –Do Not Cross" flagging—every Fire Department adopt and use some form of special "Life Hazard Warning" flagging for situations such as downed power lines.*

## Additional Hazards

Like power lines, working in, on or around railroad tracks is another potential hazard at the scene of an emergency. If you are operating on, or close to, rail road tracks your list of priorities has just been expanded. If you are not able to IMMEDIATELY move victims off of the tracks you should:

*1. Immediately get a flare or fusee onto the tracks at least one mile in each direction. Leave a person near the tracks at the flare/fusee to serve as a lookout and be seen by the train engineer.*

*2. Notify dispatch to call the railroad to inform them of the emergency.*

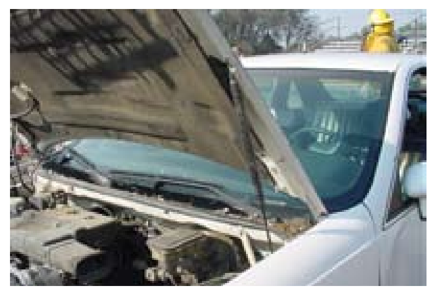
Remember a train may already be too close for railroad dispatch to warn in time and it takes a while to slow or stop a train, so getting someone with a flare or fusee down the tracks a mile is a priority.

Hazardous materials pose another potential hazard. Scene size-up should also include identifying placards, insignia, badging, and other identifying markings. With the growing number of alternative vehicles on the road consider the vehicle type. Look around the vehicle for liquid, powder, solids or gas releases. Listen for the sound of gas releasing into the atmosphere. If you smell rotten eggs, the suspect vapor cloud could either be natural gas or propane. Do you observe people running away from the emergency? It is important to isolate the scene, identify the suspect substances and deny entry!

## F. SPECIAL THREATS IN NEWER VEHICLES

Late model vehicles, regardless of fuel type, contain special hazards that all emergency responders should be aware of. Many of the new innovations designed to protect vehicle occupants in a collision, make it more difficult, and more hazardous for emergency responders to conduct rescue work following a collision. Some of the more common hazards are outlined below, but it is critical that emergency responders recognize that these hazards are changing and growing all the time, and they must take steps to stay informed about "what's new".

There are numerous emergency services related websites, magazines and other sources that provide regular updates on changes to vehicle technology. Regular visits to automotive dealer showrooms or vehicle manufacturing facilities also provide great opportunities for emergency responders to see the latest technologies, ask questions and become better prepared to respond to emergencies involving newer vehicles.



*Even small hood struts like the one shown can violently and unexpectedly explode during a fire sending an arrow like projectile through the air.*

Here is some general information about several hazards that are common to many newer vehicles:

- ❖ Compression Bumpers
  Late model vehicles frequently have bumpers that are made of lightweight materials that melt or burn away when subjected to substantial fire. These bumpers are mounted to large gas or liquid filled struts that compress in a very low speed collision and minimize vehicle damage. When subjected to fire, and particularly after the bumper has melted or burned away, these struts can explode and rocket large pieces of the strut, and any remaining portion of the bumper for a great distance away from the front or rear of the vehicle. These have caused suffered serious injuries to emergency responders. To reduce risk of injury when heavy fire involves the front or rear of the vehicle always apply large volumes of water, wear full PPE and approach the vehicle from the side.
- ❖ 12 Volt Battery
  You can never assume you'll find the battery under the hood of the

vehicle! The 12 volt battery maybe relocated to another location like the wheel well, under the rear seat, in the trunk, or under the rear cargo area floor. Several late model vehicles also have two or more 12 volt batteries, mounted in different locations. If available, the vehicle "Owners Manual" can assist in identifying battery locations.

- Suspension Systems
  The air cushion common on buses and truck trailers is also a potential hazard and can fail. You can find hydraulic/air suspension systems on upscale passenger vehicles or modified show vehicles. Personnel should never get underneath a vehicle unless the vehicle has been cribbed and stabilized as it may drop suddenly and without warning. These components also react explosively during a fire.

*Personnel must be aware if all hydraulic and pneumatic systems on all types of vehicles including the hydraulics used in mass transit vehicles that "kneel" to allow access for handicapped customers.*

- Passive Roll Bar System
  Optional on newer convertibles, passive roll bar systems deploy when a vehicle rolls-over and/or when airbags deploy. There are several types of mechanisms; Hydraulic System, Mechanical System and Pyrotechnic System. Some of these can be raised while driving through a switch on the dashboard. The roll-bar is mounted immediately behind front and/or rear seats. The potential risk is that some models can deploy suddenly during a rescue. Rescue personnel should always avoid the deployment zones of the roll bar system.
- Supplemental Restraint Systems
  When developing passenger safety systems for vehicle occupants, the Supplemental Restraint Systems (SRS) technologies have proven a challenge and a hazard for emergency personnel who are not prepared to mitigate them. SRS include seat belt pretensioners and airbags:
- Seat Belt Pretensioners
  Seat belt pretensioners activate in a collision to tighten seat belts of front and/or rear seat occupants to keep proper airbag distance, and/or keep the occupants head in vehicle. These generally activate with the front airbags. The pretension devices can be found on seat belt buckle or incorporated into retractor at the pillar or inside seat. Depending on vehicle make and model, the sensor that activates the device may be in A, B or C pillar, door or elsewhere in the vehicle. The caution here is that some use a pyrotechnic device and some are mechanical. Importantly, like airbags they could be deployed after the accident.
- Airbags
  Airbags can explode during fire sending pieces rocketing through windows or the roof. It is advisable to cool the interior of the vehicle before approaching. Typical airbag activation components include the deceleration and impact sensors along with the SRS control module.

Most airbags are constructed of heavy nylon and inflate by an explosion of Sodium Azide that fills bag with nitrogen gas. Many newer systems use compressed gas cylinders and various inert gases. The bags are packed in talcum powder to act as a lubricant. When a bag deploys it may appear to look like a HAZ-MAT emergency in progress. These airbags are often hidden in the steering wheel, dashboard, upholstery, and can deploy from the roof or pillars of the vehicle.

The chemical propellant used in most airbags is Sodium Azide. This chemical is more toxic than Cyanide and if a few grams are ingested it can be fatal. Obviously this poses an inhalation hazard, and the chemical can also be easily absorbed through skin. When it is wet or heated it can ignite violently! When water is applied the combination can create a very explosive acid. Damaging airbag components should be avoided at all costs. An Internet search for "Sodium Azide" will provide numerous links to some interesting and important information about this chemical.

When an airbag deploys only trace amounts of Sodium Azide should remain. It is advisable to ventilate the vehicle upon arrival. The gas can cause respiratory distress in some people and the talcum powder residue found in the vehicle can be irritating to the skin and respiratory system. Dust masks and eye protection should be part of your own personal protective equipment.

*Air bags are hidden in the steering wheel, dashboard, upholstery, and can deploy from the roof or pillars of the vehicle.*

Be aware that crushing or damaging the SRS Control Modules may result in activation of all SRS devices in the vehicle simultaneously. It is advisable to check for and avoid control modules which can be located under seats, in the console, or kick panels.

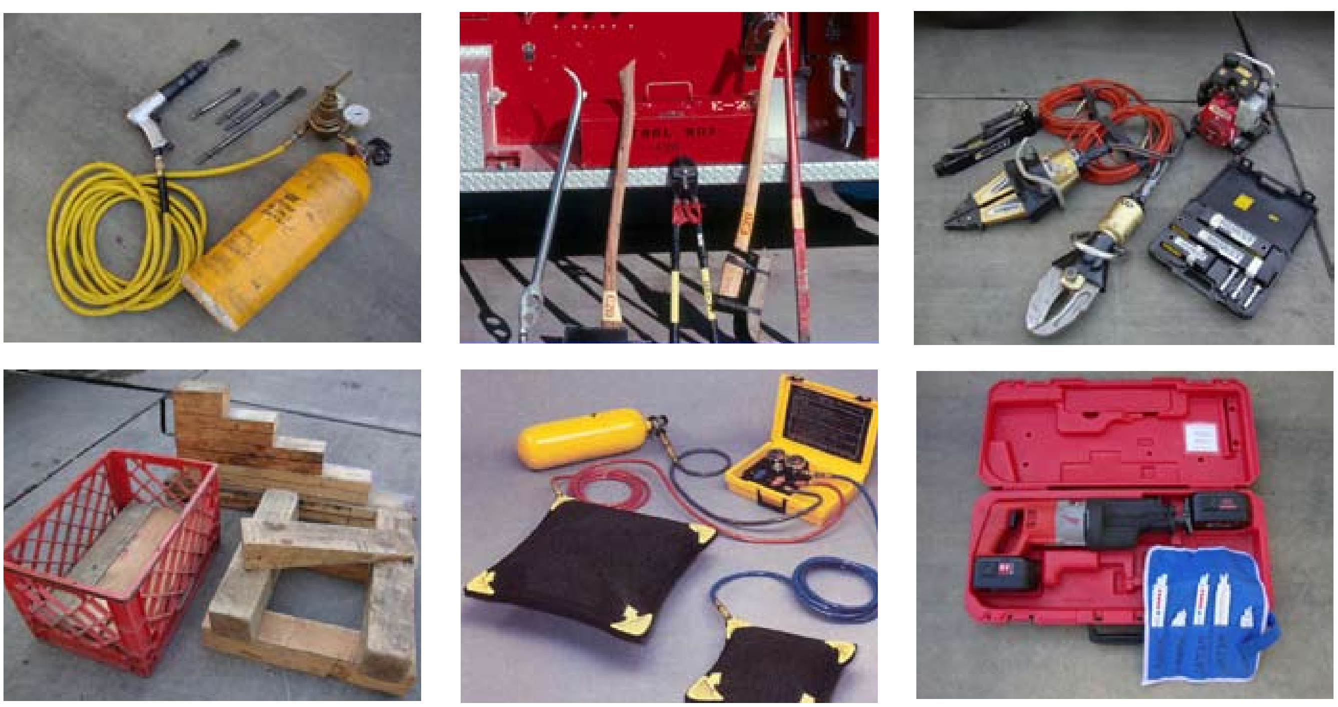
Other airbag systems include:

- ❖ Head Protection System (HPS) also known as Inflatable Tubular Structure (ITS)
- ❖ Inflatable Curtain Systems
- ❖ Knee/Leg bolster systems
- ❖ Some are located across bottom of dash or under steering column
- ❖ Some built into front edge of seat
- ❖ And under carpet systems to lift feet off floor and protect knees from dashboard
- ❖ The near future might include Exterior "Pedestrian Protection Bags"
- ❖ Newer steering wheel/dashboard airbags may be designed to deploy twice.

All of these airbags may be left un-deployed even after severe collisions. The newer systems select which airbags to deploy based on many factors like:

- ❖ Weight on seat
- ❖ Seatbelt buckled
- ❖ Distance from Airbag
- ❖ Child Safety Switch
- ❖ Force of Collision
- ❖ Angle of Collision

Rescuers cannot completely disable airbags or pretensioners. There is no standardization of SRS wiring, although SRS wiring and connectors in newer vehicles are typically yellow in color. It is important to recognize that it may not be possible to access and disconnect a vehicles 12 volt battery system. As such extreme caution must be used when rescue efforts commence. It is also worth remembering that even if the 12 volt battery is disconnected, there may be another someplace in the vehicle, and there may also be devices in the vehicle that have small lithium type batteries for storing device settings and so forth. There is always a potential that when cutting wiring or performing other recue work that wires can become crossed and power from other sources may find its way to a SRS component. Cutting, pushing, pulling, friction and static may all result in SRS deployment.  It is essential that rescuers make



*Tools common to the auto-extrication experts include (l-r) air chisel, a variety of hand tools, jaws kit, cribbing materials, high pressure and low pressure air bags, and sawzall.*

every effort to avoid performing these tasks until all rescuers are clear of potential SRS deployment zones. If at all possible, rescuers, including ambulance personnel, should get out of the vehicle and away from SRS components while work is being done on the vehicle.

The use of airbag restraint devices is not recommended by NFPA and others. The best protection is to avoid accidental activation by being cautious of cutting or displacing areas that may contain Airbag components:

- Steering wheels and columns
- Dashboards
- Cushions on seat backs
- Interior door panels
- Under seats and in consoles
- Lower middle and back corner of doors
- Above base of "A" & "B" pillars: Common location for SRS modules, pretensioners, etc.

This list appears to be all the areas that you would hope that you could use to cut, pull or pry. Which is, again, why you should not cut, push or pull until all rescuers and EMS personnel are clear of the airbag deployment areas. Rescue personnel should not be in the vehicle during active cutting, pushing, and pulling.

Accident victims can be protected by tilting the steering wheel up, moving the seat backwards, reclining the seat, all while rescuers are aware of hidden airbag locations and expecting a sudden airbag deployment. Applying the 10 and 18 rule, by staying 10 inches away from any undeployed steering wheel, door or seat mounted airbag and 18 inches away from any undeployed dashboard or roof rail mounted airbag will provide a measure of safety for rescue personnel.

Rescue personnel have developed the "peel and peek" protocol to expose what is underneath the pillars. By peeling back the decorative finish on the vehicles interior of the pillars and roof edges, you can expose the hidden dangers inherent in airbags, seatbelt pretentioners, and other seat belt components and avoid cutting through them. But before you cut a pillar it is advisable to consider whether the intact pillar will be needed as an anchor point for pushing or pulling at some other phase of your operation.

*"Applying the 10 and 18 rule, by staying 10 inches away from any undeployed steering wheel, door or seat mounted airbag and 18 inches away from any undeployed dashboard or roof rail mounted airbag will provide a measure of safety for rescue personnel."*

## CONCLUSION

What will we be using as transportation 20 to 30 years from now and what fuel/energy source will emerge as the dominant choice is unpredictable. There should be no doubt that the next decade will bring about significant changes to the vehicles we see on the road today. The expressed purpose of this text is to prepare you for this uncertain future by providing you with the wide range of available information regarding these new vehicle technologies.

The fact that the public is provided with a range of alternative fuel/energy vehicles will certainly impact each individual vehicle emergency. But the strength of our Standard Operating Guidelines is that they are written in a way that takes into account changes to the emergency response environment. When you analyze the variety of fuels, ethanol, biodiesel, natural gas, propane and hydrogen along with the voltages in electric, hybrid electric and fuel cell vehicles you discover that there is really nothing new here for emergency responders, just new applications of the hazards that we've grown accustomed to mitigating throughout our careers. Knowing the potential hazards in these and all vehicles will keep you and your crew safe from harm.

*A team meeting at the start of an auto-extrication class ensures a safe training environment and an understanding of assigend roles.*

**EMERGENCY RESPONSE GUIDEBOOK 2008 QUICK REFERENCE**

**(This a quick guide for Alt- Fuel Vehicle emergencies refer to the ERG 2008 guide for more detailed information)**

| ID Number | Guide Number | Material | Potential Hazards | Public Safety | Emergency Response |
|---|---|---|---|---|---|
| 1203 | Guide 128 | **Gasoline** | **FIRE OR EXPLOSION**<br>**HIGHLY FLAMMABLE: Will be easily ignited by heat, sparks or flames.**<br>Vapors may form explosive mixtures with air.<br>Vapors may travel to source of ignition and flash back.<br>Most vapors are heavier than air. They will spread along ground and collect in low or confined areas (sewers, basements, tanks).<br>Vapor explosion hazard indoors, outdoors or in sewers.<br>Runoff to sewer may create fire or explosion hazard.<br>Containers may explode when heated.<br>Many liquids are lighter than water. | As an immediate precautionary measure, isolate spill or leak area for at least 50 meters (150 feet) in all directions.<br>Keep unauthorized personnel away.<br>Stay upwind.<br>Keep out of low areas.<br>Ventilate closed spaces before entering. | **FIRE**<br>**CAUTION: All these products have a very low flash point: Use of water spray when fighting fire may be inefficient.**<br>**CAUTION: For mixtures containing alcohol alcohol-resistant foam may be more effective.**<br>**Small Fire**<br>Dry chemical, $CO_2$, water spray or regular foam.<br>**SPILL OR LEAK**<br>**ELIMINATE** all ignition sources (no smoking, flares, sparks or flames in immediate area).<br>All equipment used when handling the product must be grounded.<br>Do not touch or walk through spilled material.<br>Stop leak if you can do it without risk.<br>Prevent entry into waterways, sewers, basements or confined areas.<br>A vapor suppressing foam may be used to reduce vapors.<br>Absorb or cover with dry earth, sand or other non-combustible material and transfer to containers.<br>Use clean non-sparking tools to collect absorbed material. |

**EMERGENCY RESPONSE GUIDEBOOK 2008 QUICK REFERENCE**

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| ID Number | Guide Number | Material | Potential Hazards | Public Safety | Emergency Response |
|---|---|---|---|---|---|
| 3475 | 127 | **Ethanol**<br><br>**Ethanol & Gasoline mixture with more than 10% Ethanol** | **FIRE OR EXPLOSION**<br><br>**HIGHLY FLAMMABLE: Will be easily ignited by heat, sparks or flames.**<br><br>Vapors may form explosive mixtures with air.<br><br>Vapors may travel to source of ignition and flash back.<br><br>Most vapors are heavier than air. They will spread along ground and collect in low or confined areas (sewers, basements, tanks).<br><br>Vapor explosion hazard indoors, outdoors or in sewers.<br><br>Runoff to sewer may create fire or explosion hazard.<br><br>Containers may explode when heated.<br><br>Many liquids are lighter than water. | As an immediate precautionary measure, isolate spill or leak area for at least 50 meters (150 feet) in all directions.<br><br>Keep unauthorized personnel away.<br><br>Stay upwind.<br><br>Keep out of low areas.<br><br>Ventilate closed spaces before entering. | **FIRE**<br><br>**CAUTION: All these products have a very low flash point: Use of water spray when fighting fire may be inefficient.**<br><br>**Small Fire**<br><br>Dry chemical, CO2, water spray or alcohol-resistant foam.<br><br>**SPILL OR LEAK**<br><br>**ELIMINATE** all ignition sources (no smoking, flares, sparks or flames in immediate area).<br><br>All equipment used when handling the product must be grounded.<br><br>Do not touch or walk through spilled material.<br><br>Stop leak if you can do it without risk.<br><br>Prevent entry into waterways, sewers, basements or confined areas.<br><br>A vapor suppressing foam may be used to reduce vapors.<br><br>Absorb or cover with dry earth, sand or other non-combustible material and transfer to containers.<br><br>Use clean non-sparking tools to collect absorbed material. |

**EMERGENCY RESPONSE GUIDEBOOK 2008 QUICK REFERENCE**

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| ID Number | Guide Number | Material | Potential Hazards | Public Safety | Emergency Response |
|---|---|---|---|---|---|
| 1202<br><br>1993 | 128 | **Diesel** | **FIRE OR EXPLOSION**<br><br>**HIGHLY FLAMMABLE: Will be easily ignited by heat, sparks or flames.**<br><br>Vapors may form explosive mixtures with air.<br><br>Vapors may travel to source of ignition and flash back.<br><br>Most vapors are heavier than air. They will spread along ground and collect in low or confined areas (sewers, basements, tanks).<br><br>Vapor explosion hazard indoors, outdoors or in sewers.<br><br>Runoff to sewer may create fire or explosion hazard.<br><br>Containers may explode when heated.<br><br>Many liquids are lighter than water. | As an immediate precautionary measure, isolate spill or leak area for at least 50 meters (150 feet) in all directions.<br><br>Keep unauthorized personnel away.<br><br>Stay upwind.<br><br>Keep out of low areas.<br><br>Ventilate closed spaces before entering. | **FIRE**<br><br>**CAUTION: All these products have a very low flash point: Use of water spray when fighting fire may be inefficient.**<br><br>**CAUTION: For mixtures containing alcohol or polar solvent, alcohol-resistant foam may be more effective.**<br><br>Small Fire<br><br>Dry chemical, CO2, water spray or regular foam.<br><br>**SPILL OR LEAK**<br><br>**ELIMINATE** all ignition sources (no smoking, flares, sparks or flames in immediate area).<br><br>All equipment used when handling the product must be grounded.<br><br>Do not touch or walk through spilled material.<br><br>Stop leak if you can do it without risk.<br><br>Prevent entry into waterways, sewers, basements or confined areas.<br><br>A vapor suppressing foam may be used to reduce vapors.<br><br>Absorb or cover with dry earth, sand or other non-combustible material and transfer to containers.<br><br>Use clean non-sparking tools to collect absorbed material. |

**EMERGENCY RESPONSE GUIDEBOOK 2008 QUICK REFERENCE**
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| ID Number | Guide Number | Material | Potential Hazards | Public Safety | Emergency Response |
|---|---|---|---|---|---|
| 1971<br>1972<br>1075<br>1049 | 115<br><br>115<br><br>115 | **NATURAL GAS**<br><br>**PROPANE**<br><br>**HYDROGEN**<br>Compressed and Liquified | **EXTREMELY FLAMMABLE.**<br>Will be easily ignited by heat, sparks or flames.<br>Will form explosive mixtures with air.<br>Vapors from liquefied gas are initially heavier than air and spread along ground.<br>**CAUTION: Hydrogen (UN1049), Hydrogen, refrigerated liquid (UN1966) and Methane (UN1971) are lighter than air and will rise. Hydrogen fires are difficult to detect since they burn with an invisible flame. Use a thermal image camera.**<br>Vapors may travel to source of ignition and flash back.<br>Cylinders exposed to fire may vent and release flammable gas through pressure relief devices.<br>Containers may explode when heated.<br>Ruptured cylinders may rocket. | As an immediate precautionary measure, isolate spill or leak area for at least 100 meters (330 feet) in all directions.<br>Keep unauthorized personnel away.<br>Stay upwind.<br>Many gases are heavier than air and will spread along ground and collect in low or confined areas (sewers, basements, tanks).<br>Keep out of low areas. | **FIRE**<br>**DO NOT EXTINGUISH A LEAKING GAS FIRE UNLESS LEAK CAN BE STOPPED.**<br>**CAUTION: Hydrogen (UN1049), and Hydrogen, refrigerated liquid (UN1966) burn with an invisible flame. Hydrogen and Methane mixture, compressed (UN2034) may burn with an invisible flame.**<br>**Small Fire**<br>Dry chemical or CO2.<br>**Fire involving Tanks**<br>Fight fire from maximum distance or use unmanned hose holders or monitor nozzles.<br>Cool containers with flooding quantities of water until well after fire is out.<br>Do not direct water at source of leak or safety devices; icing may occur.<br>Withdraw immediately in case of rising sound from venting safety devices or discoloration of tank.<br>ALWAYS stay away from tanks engulfed in fire.<br>For massive fire, use unmanned hose holders or monitor nozzles; if this is impossible, withdraw from area and let fire burn. |

**EMERGENCY RESPONSE GUIDEBOOK 2008 QUICK REFERENCE**
**(This a quick guide for Alt- Fuel Vehicle emergencies refer to the ERG 2008 guide for more detailed information)**

| ID Number | Guide Number | Material | Potential Hazards | Public Safety | Emergency Response |
|---|---|---|---|---|---|
| | | | | | **SPILL OR LEAK**<br>ELIMINATE all ignition sources (no smoking, flares, sparks or flames in immediate area).<br>All equipment used when handling the product must be grounded.<br>Do not touch or walk through spilled material.<br>Stop leak if you can do it without risk.<br>If possible, turn leaking containers so that gas escapes rather than liquid.<br>Use water spray to reduce vapors or divert vapor cloud drift. Avoid allowing water runoff to contact spilled material.<br>Do not direct water at spill or source of leak.<br>Prevent spreading of vapors through sewers, ventilation systems and confined areas.<br>Isolate area until gas has dispersed.<br>**CAUTION: When in contact with refrigerated/ cryogenic liquids, many materials become brittle and are likely to break without warning.** |

**EMERGENCY RESPONSE GUIDEBOOK 2008 QUICK REFERENCE**

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| ID Number | Guide Number | Material | Potential Hazards | Public Safety | Emergency Response |
|---|---|---|---|---|---|
| 1830 | 137 | **Sulfuric Acid (Electrolyte used in Lead Acid Batteries)** | **HEALTH**<br>CORROSIVE and/or TOXIC; inhalation, ingestion or contact (skin, eyes) with vapors, dusts or substance may cause severe injury, burns or death.<br>Fire will produce irritating, corrosive and/or toxic gases.<br>Reaction with water may generate much heat that will increase the concentration of fumes in the air.<br>Contact with molten substance may cause severe burns to skin and eyes.<br>Runoff from fire control or dilution water may cause pollution.<br>**FIRE or EXPLOSION**<br>**EXCEPT FOR ACETIC ANHYDRIDE (UN1715), THAT IS FLAMMABLE**, some of these materials may burn, but none ignite readily.<br>May ignite combustibles (wood, paper, oil, clothing, etc.). | As an immediate precautionary measure, isolate spill or leak area in all directions for at least 50 meters (150 feet) for liquids and at least 25 meters (75 feet) for solids.<br>Keep unauthorized personnel away.<br>Stay upwind.<br>Keep out of low areas.<br>Ventilate enclosed areas. | **FIRE**<br>When material is not involved in fire, do not use water on material itself.<br>**Small Fire**<br>Dry chemical or $CO_2$.<br>Move containers from fire area if you can do it without risk.<br>**SPILLS OR LEAKS**<br>Fully encapsulating, vapor protective clothing should be worn for spills and leaks with no fire.<br>Do not touch damaged containers or spilled material unless wearing appropriate protective clothing.<br>Stop leak if you can do it without risk.<br>Use water spray to reduce vapors; do not put water directly on leak, spill area or inside container.<br>Keep combustibles (wood, paper, oil, etc.) away from spilled material.<br>**Small Spill**<br>Cover with DRY earth, DRY sand or other non-combustible material followed with plastic sheet to minimize spreading or contact with rain. |

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| ID Number | Guide Number | Material | Potential Hazards | Public Safety | Emergency Response |
|---|---|---|---|---|---|
| | | | Substance will react with water (some violently), releasing corrosive and/or toxic gases and runoff.<br><br>Flammable/toxic gases may accumulate in confined areas (basement, tanks, hopper/tank cars, etc.).<br><br>Contact with metals may evolve flammable hydrogen gas.<br><br>Containers may explode when heated or if contaminated with water.<br><br>Substance may be transported in a molten form. | | Use clean non-sparking tools to collect material and place it into loosely covered plastic containers for later disposal.<br><br>Prevent entry into waterways, sewers, basements or confined areas. |

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| ID Number | Guide Number | Material | Potential Hazards | Public Safety | Emergency Response |
|---|---|---|---|---|---|
| 1824 | 154 | Sodium Hydroxide<br>Solution<br>(Electrolyte used in Nickel Metal Hydride Batteries) | HEALTH<br>TOXIC; inhalation, ingestion or skin contact with material may cause severe injury or death.<br>Contact with molten substance may cause severe burns to skin and eyes.<br>Avoid any skin contact.<br>Effects of contact or inhalation may be delayed.<br>Fire may produce irritating, corrosive and/or toxic gases.<br>Runoff from fire control or dilution water may be corrosive and/or toxic and cause pollution.<br>**FIRE**<br>Non-combustible, substance itself does not burn but may decompose upon heating to produce corrosive and/or toxic fumes.<br>Some are oxidizers and may ignite combustibles (wood, paper, oil, clothing, etc.).<br>Contact with metals may evolve flammable hydrogen gas.<br>Containers may explode when heated. | As an immediate precautionary measure, isolate spill or leak area in all directions for at least 50 meters (150 feet) for liquids and at least 25 meters (75 feet) for solids.<br>Keep unauthorized personnel away.<br>Stay upwind.<br>Keep out of low areas.<br>Ventilate enclosed areas. | FIRE<br>**Small Fire**<br>Dry chemical, $CO_2$ or water spray.<br>**Large Fire**<br>Dry chemical, $CO_2$, alcohol-resistant foam or water spray.<br>Move containers from fire area if you can do it without risk.<br>Dike fire-control water for later disposal; do not scatter the material.<br>**SPILLS**<br>ELIMINATE all ignition sources (no smoking, flares, sparks or flames in immediate area).<br>Do not touch damaged containers or spilled material unless wearing appropriate protective clothing.<br>Stop leak if you can do it without risk.<br>Prevent entry into waterways, sewers, basements or confined areas.<br>Absorb or cover with dry earth, sand or other non-combustible material and transfer to containers.<br>**DO NOT GET WATER INSIDE CONTAINERS.** |

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| ID Number | Guide Number | Material | Potential Hazards | Public Safety | Emergency Response |
|---|---|---|---|---|---|
| 3480<br>3481 | 147 | **Lithium Ion** | **HEALTH**<br>Contact with battery electrolyte may be irritating to skin, eyes and mucous membranes.<br>Fire will produce irritating, corrosive and/or toxic gases.<br>Burning batteries may produce toxic hydrogen fluoride gas (see GUIDE 125).<br>Fumes may cause dizziness or suffocation.<br>**FIRE**<br>Lithium ion batteries contain flammable liquid electrolyte that may vent, ignite and produce sparks when subjected to high temperatures (> 150 °C (302 °F)), when damaged or abused (e.g., mechanical damage or electrical overcharging).<br>May burn rapidly with flare-burning effect.<br>May ignite other batteries in close proximity. | As an immediate precautionary measure, isolate spill or leak area for at least 25 meters (75 feet) in all directions.<br>Keep unauthorized personnel away.<br>Stay upwind.<br>Keep out of low areas.<br>Ventilate closed spaces before entering. | FIRE<br>**Small Fire**<br>Dry chemical, CO2, water spray or regular foam.<br>**Large Fire**<br>Water spray, fog or regular foam.<br>Move containers from fire area if you can do it without risk.<br>**SPILL OR LEAK**<br>**ELIMINATE** all ignition sources (no smoking, flares, sparks or flames in immediate area).<br>Do not touch or walk through spilled material.<br>Absorb with earth, sand or other non-combustible material.<br>Leaking batteries and contaminated absorbent material should be placed in metal containers. |

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