California Fuel Cell Partnership

Emergency Response Guide

Fuel Cell Vehicles and Hydrogen Fueling Stations

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disclaimer

Emergency Response Guide For Fuel Cell Vehicles

The California Fuel Cell Partnership is a collaboration in which several companies and government entities are independent participants. It is not a joint venture, legal partnership, or unincorporated association.
More information about the CaFCP can be found on the website: http://www.cafcp.org.

DISCLAIMER – IMPORTANT INFORMATION

This *Emergency Response Guide* is intended for use by emergency response personnel who have extensive training in responding to emergencies. Members of the public should not attempt to respond to an emergency involving a fuel cell vehicle but instead should contact emergency response personnel.

The California Fuel Cell Partnership provides the attached *Emergency Response Guide For Fuel Cell Vehicles* document for the purpose of sharing information about responding to emergency situations involving fuel cell-powered light-duty vehicles and transit buses, and hydrogen fueling stations. This document is made available on an "as is" basis for "informational purposes" only. The information contained herein may change without notice.

The CaFCP and its individual members, collectively and individually, disclaim any liability for injuries resulting from actions expressed or implied in this document.

This guide provides general background information and should not be used as a substitute for any detailed information that may be available from the manufacturer with respect to each vehicle's design and safety features. The *Emergency Response Guide For Fuel Cell Vehicles* is not intended to replace or supercede the *Emergency Response Guidebook* prepared by the United States Department of Transportation.

Updates to this document will be made available online at **http://www.cafcp.org**.
Questions pertaining to the information within this document should be directed to: **info@cafcp.org**.

overview

preface

Background

Since the advent of the automobile in the late 1800s, steady progress has been achieved in automotive technology. These advancements—from engine performance to power-to-weight ratio—have made the internal combustion (IC) engine a reliable source of power for this means of transportation. In addition to these advances, a great deal of safety engineering has been developed for protecting vehicle passengers. Emergency response personnel have established proven ways of safely extracting a passenger from these vehicles in the event of an accident.

Today, new and cleaner vehicle technologies are gaining attention as a means of reducing or eliminating air pollution from the automobile. These include electric, battery-powered vehicles, which produce no direct emissions. While battery-powered electric vehicles still face significant challenges to consumer acceptance, emergency response and safety methods have been developed in recent years. Illustrated comparisons for emergency response between today's cars and electric vehicles were developed for a publication from the California State Fire Marshall: "Emergency Response to Electric Vehicles" (see Bibliography).

New technologies also include the fuel cell, an electrochemical device that generates electricity by combining hydrogen and oxygen. When using hydrogen as a fuel, its only emission is water vapor. In the 1960s, NASA significantly advanced the fuel cell (first invented in 1839) as a source of power and water generation onboard spaceships. Since the 1990s, automobile manufacturers have been experimenting with this power source. In addition to producing zero or near-zero emissions, fuel cell vehicles (FCVs) could potentially provide significant public and personal benefits, including greater fuel efficiency, reduced noise due to its quiet operation, and additional onboard power for consumer use.

Safety First

Many of these FCVs are currently being tested on public roads at the California Fuel Cell Partnership (CaFCP) in West Sacramento, California, as well as in selected fleets throughout the state. Vehicle manufacturers, energy providers, fuel cell technology companies, the state of California, and the federal government have teamed up to demonstrate the technology and its fuels, and to explore commercialization challenges.

Today, these prototype and limited production vehicles have many built-in safeguards, which make them equal to or safer than IC vehicles today (reference DOE/CE/50389-502). But, since these vehicles use a new kind of fuel (most use compressed hydrogen carried onboard), it is important to educate both ER personnel and the public about how these vehicles react in an accident and how to safely extract passengers.

The safe use and operation of FCVs and hydrogen refueling is one of the most important goals set by the CaFCP. Emergency response training is a key stepping-stone to achieving this goal. The **Emergency Response Guide** is intended to be a supplement for established emergency response guides, and to educate ER personnel on the important safety characteristics of this new and promising technology.

Acknowledgements
The Safety Team at CaFCP originally created a Light Duty Fuel Cell Vehicle Emergency Response Guide under the leadership of Jesse M. Schneider, Senior Mechanical Engineer, DaimlerChrysler RTNA. The team obtained approval for its publication from the CaFCP Steering Team. Collaborators also include the Office of the California State Fire Marshall as well as the West Sacramento and Richmond Fire Departments. A Heavy Duty Fuel Cell Vehicle Guide was later created by the CaFCP Bus Team, following the example set by the light duty guide and in close coordination with the Safety Team. Ken Koyama and Jennifer Allen of the California Energy Commission played particularly important roles in leading the efforts of a team of experts ranging from the California transit agencies who will be operating fuel cell buses (FCB) in California, to state and federal government employees in communication with other international FCB programs. Many thanks go out to all those who were involved.

Guide Overview
The **Emergency Response Guide** is one source of information for the Emergency Responder, now incorporating both of the aforementioned resources. It is designed to provide the emergency response community, as well as transit and fleet operators, with a safety handbook that includes the following:

- Introductory information about the CaFCP, and the fuel cell and fueling technology it supports;
- Detailed information about hydrogen properties as a gas and as a cryogenic liquid (relevant to both light duty vehicles and buses);
- Information specific to light duty fuel cell vehicles currently being demonstrated on California roads;
- Information specific to hydrogen fuel cell buses, both currently and soon to be, in use by California transit agencies; and
- Detailed cut sheet diagrams of current fuel cell light duty vehicles and transit buses.

Since these vehicles are not yet in volume production, and changes are likely, the CaFCP will update this Guide to reflect the changes of value to the emergency responder. Plans for future editions of this Guide include the incorporation of emergency response materials for hydrogen fueling stations. When finalized, these materials will be made available to all recipients of the ER Guide.

Any comments or questions concerning this document can be directed to the CaFCP Safety Specialist at info@cafcp.org.

about CaFCP

Introduction

The California Fuel Cell Partnership (CaFCP) is a collaboration of automotive companies, fuel providers, fuel cell technology companies, and government agencies that are placing fuel cell vehicles (FCVs) on the road in California. This path-breaking venture began in April 1999.

The CaFCP includes auto manufacturers (DaimlerChrysler, Ford, General Motors, Honda, Hyundai, Nissan, Toyota and Volkswagen); energy providers (Air Products, BP, ChevronTexaco, ExxonMobil, Methanex, Pacific Gas and Electric, Praxair, Proton Energy Systems, Shell Hydrogen, Stuart Energy, and Ztek); technology companies (Ballard Power Systems and UTC Fuel Cells); government agencies (California Air Resources Board, California Energy Commission, South Coast AQMD, US Department of Energy, US Department of Transportation and US Environmental Protection Agency); and bus transit agencies (AC Transit, Santa Clara Valley Transportation Authority, and SunLine Transit Agency).

The CaFCP is a voluntary effort to advance a new vehicle technology that could move the world toward practical and affordable environmental solutions. Since its formation in 1999, members have focused on four main goals:

- Demonstrate fuel cell vehicle technology by operating and testing the vehicles under real-world conditions in California;
- Demonstrate the viability of alternative fuel infrastructure technology, including hydrogen and methanol stations;
- Explore the path to commercialization, from identifying potential problems to developing solutions; and
- Increase public awareness and enhance opinion about fuel cell electric vehicles, preparing the market for commercialization.

As of July 2004, 56 FCVs have participated in CaFCP demonstrations, including three fuel cell buses (FCBs). CaFCP members have been demonstrating these vehicles in California under day-to-day driving conditions. The facility headquarters in West Sacramento, California, houses vehicle maintenance bays, a hydrogen fueling station and a methanol fueling station. Through 2007, the 30 members will work to facilitate the placement of up to 300 fuel cell vehicles in independent, fleet demonstration projects within the state, focused in the greater Los Angeles region and the San Francisco-Sacramento corridor.

Fuel cell buses will operate in regular, daily route operations in at least three California transit districts -- AC Transit and Santa Clara VTA in the northern and southern Bay

Area regions, respectively, and SunLine Transit agency in Palm Springs. Although fuel cell buses are still in the prototype stage and their long-term commercial acceptability is not known, the use of fuel cells in buses is one of the most commercially advanced of all the fuel cell vehicles applications to date. They offer a large platform for system components and fuel storage, and they can be fueled at a central fueling station with trained personnel to regularly maintain them.

Hydrogen stations will demonstrate early applications of hydrogen fueling technology while supporting the fleet projects. As of July 2004, 13 hydrogen fueling stations exist in California, with many more planned for development within the next few years. It is anticipated that, by closely coordinating operational procedures, prototype fuel cell vehicles in fleet use would be able to utilize this growing network of fuel stations.

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 fuel cell vehicles and hydrogen fueling stations, and to help prepare local communities for the vehicles and fueling by training 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.

Further information can be found on the CaFCP website: www.cafcp.org.

section 1
essential information

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Section 1 – Essential Information

1. How Fuel Cells Work

What is a fuel cell?

A fuel cell is an electrochemical device in which the energy of a chemical reaction is converted directly into electricity. Unlike an electric cell or battery, a fuel cell does not run down or require recharging; it operates as long as the fuel and an oxidizer are supplied continuously from outside the cell. A fuel cell converts the chemical energy of the fuel directly into electricity without any intermediate thermal or mechanical processes. The electrical energy can be used to do useful work directly while the heat is either wasted or used for other purposes.

History

The invention of the fuel cell is credited to Sir William R. Grove in 1839. His fuel cell used a dilute sulfuric acid as the electrolyte, oxygen as the oxidizing agent, and hydrogen as the fuel. Until recently, their use has been confined to the laboratory and to exotic applications such as space travel. Phosphoric Acid fuel cells were used for the Apollo program and are being used on the space shuttle.

More recently, fuel cells have captured worldwide attention as a clean power source for electric vehicles (EVs). EVs powered by fuel cells are being developed by numerous auto manufacturers, and have generated interest and enthusiasm among industry, environmentalists, and consumers.

Proton Exchange Membrane (PEM) Fuel Cells

The type of fuel cell most commonly used in passenger FCVs today is a Proton Exchange Membrane, primarily due to its relatively low operating temperature, efficiency, and relatively high energy density compared to other fuel cell technologies. PEM fuel cells generate electricity from a catalyst-facilitated chemical reaction between hydrogen and oxygen ions, from the air, in a cell. Several cells combined make up a fuel cell stack.

How a PEM Fuel Cell Works

An individual fuel cell consists of two electrodes, one positively charged (cathode) and one negatively charged (anode), with a substance that conducts electricity (electrolyte) sandwiched between them. Oxygen from the air passes over the cathode and hydrogen over the anode, generating electricity and water. Using a catalyst on the membrane (usually platinum) optimizes this electrical process.

Fueling the PEM with Hydrogen

The hydrogen fuel for a fuel cell EV can be supplied in several ways. Some vehicles carry a pressurized tank of pure gaseous hydrogen, and some vehicles carry liquefied hydrogen. Others could be equipped with a “fuel reformer” that converts hydrocarbon fuels—such as methanol, natural gas, or gasoline into a hydrogen-rich gas.

Fuel Cell Vehicular Systems

Individual fuel cells must be combined into groups called fuel cell stacks in order to achieve the necessary power required for motor vehicle applications. These stacks are combined with control and safety systems to make a reliable and safe vehicle. Once operating, the output power generated by the fuel cells must be conditioned and absorbed by a load. Suitable alarms may shut down the process (fuel supply/ high voltage electricity) if unsafe operating conditions occur and a cell voltage monitoring system must monitor fuel cell stack performance.

A fuel cell stack requires fuel, oxidant and coolant in order to operate. The gases must be humidified and the coolant must be controlled. To achieve this, the fuel cell stack must be surrounded by a fuel system, fuel delivery system, air system, stack cooling system and humidification system.

Benefits of Fuel Cell Vehicles

Since the hydrogen fuel (combined with oxygen from air) is converted directly into electricity electrochemically, instead of using a combustion process, a fuel cell can operate at much higher efficiencies than internal combustion engines, extracting more energy from the same amount of equivalent fuel. Fuel cell systems have relatively few moving parts — although there are sometimes moving parts external to the fuel cell in the system— and the only byproducts are water and heat when pure hydrogen is used as the fuel, making it a quiet, reliable, and clean source of power for transportation.

A fuel cell EV, powered by an electric motor, promises the air quality benefits of a battery-powered EV, combined with the driving range and convenience of a conventional gasoline engine. Compared to conventional vehicles, fuel cell EVs can offer:

- Zero or near-zero smog-forming emissions
- Reduced water pollution from oil leaks
- Lower greenhouse gas emissions (CO_2)
- Higher fuel economy
- Greater engine efficiency
- Much quieter and smoother operation

If renewable forms of energy are used as a source for hydrogen, fuel cell EVs will have truly zero emissions from “well to wheel.”

Today, there are also many FCV “hybrids” with electrical storage onboard. Similar to IC “hybrids,” these vehicles optimize the power range of the fuel cell system and recover energy during braking, when the electric motor is converted into a generator, thereby charging the onboard battery/ ultra capacitor. This increases overall efficiency of the vehicle.

Particular Concerns for FCVs

In a FCV, there are two major systems that an emergency responder should be aware of: (1) hydrogen high (and low) pressure systems and (2) high (and low) voltage systems.

Sections 2 and 3 explain how these systems operate under normal conditions and under impact/ and fire situations.

2. Hydrogen Information

All fuels are hazardous. Hydrogen is not more dangerous than other fuels, but its properties are unique and it must be handled appropriately. Hydrogen's hazards are usually more easily managed than those of hydrocarbon fuels due to hydrogen's tendency to rise away from the vehicle instead of pooling.

The molecular symbol for hydrogen is H_2. Hydrogen is a colorless, odorless, tasteless, non-corrosive, and flammable gas. It is also the lightest-weight gas. Since hydrogen is lighter than air, it rises and does not "pool" on the ground like gasoline, diesel, or propane fuel vapors. Gaseous hydrogen (GH_2) and liquid hydrogen (LH_2) diffuse rapidly in air.

Hydrogen Characteristics

Hydrogen gas is nontoxic but may induce suffocation (asphyxiation) if the oxygen is displaced in a confined space (similar to nitrogen or helium). Additional health hazard data are given in the hydrogen Material Safety Data Sheets (MSDS). Another reference is the Sourcebook for Hydrogen applications by the DOE/ NREL.

Figure 1 relates the ignition energy required to ignite a fuel mixture to the upper and lower flammability limits (UFL and LFL, respectively) of hydrogen, gasoline, and methane (CH4). For hydrogen to ignite, the percentage of fuel in the air needs to be both within the UFL and LFL. Additionally, an ignition source with enough energy must be present (i.e., the energy level should be on or above the curve for each gas). In a confined space, a hydrogen-air concentration within this flammable range can be explosive. It should also be noted that H_2 burns with an invisible or near invisible flame.

As depicted in Figure 1, the LFL for Hydrogen (4%) is actually higher than Gasoline (1%). This means, it requires a greater percentage of H_2 in the air than gasoline to ignite. However, hydrogen has a wider flammability range (% in air) than Methane (CH_4) or Gasoline (also see Table 1 below). One can also see from the figure that a variety of ignition sources can ignite a hydrogen-air mixture, sometimes as low as common static if it occurs in the proper mixture percentage. Note that the LFL for methanol (not shown) is 6%, which is higher than hydrogen.

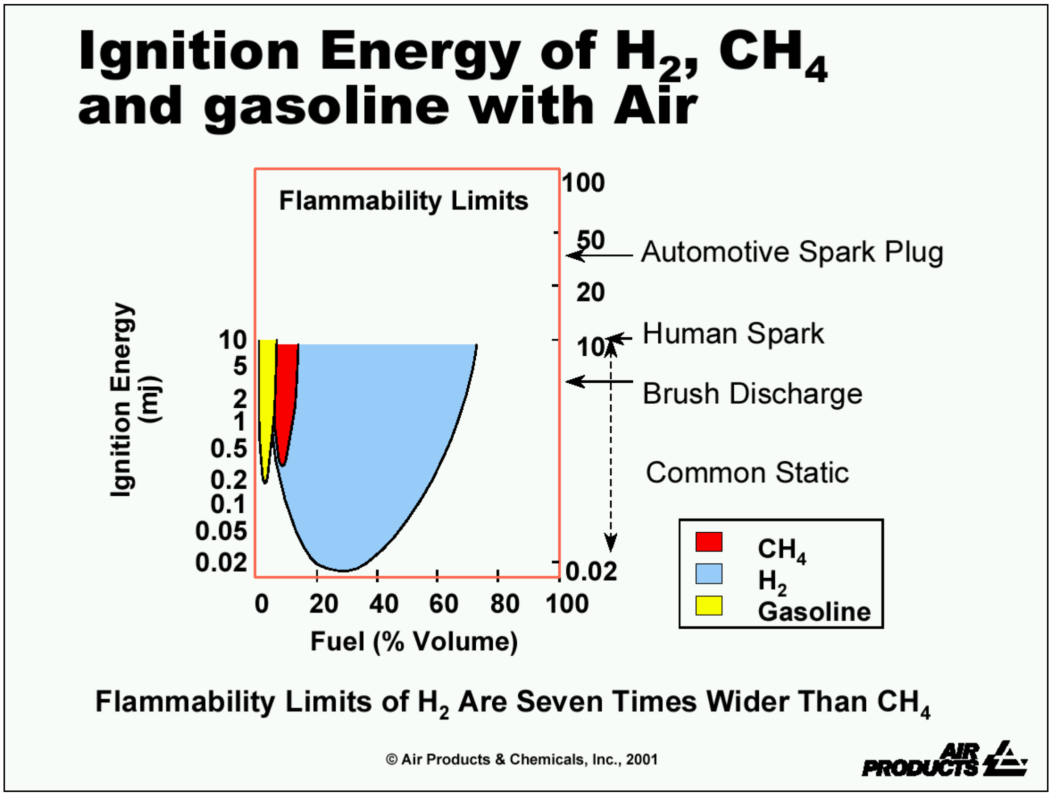

Figure 1: Flammability Limits vs. Ignition Energy of H_2, CH_4, and Gasoline in Air

Property	Hydrogen	Propane	Gasoline
Ignition energy in MJ/g	20	250	250
Lower flammability limit in air at room temperature and one atmosphere (%)	4%	2%	1%
Upper flammability limit in air at room temperature and one atmosphere (%)	75%	10%	8%

Table 1: From "Evaluation of Vehicle Fuel Safety Regulations and Test Methods for New Fuels and Technologies" (see Bibliography, Section 5).

This wide range presents an increased probability of ignition. However, hydrogen's high buoyancy and high diffusivity in air tend to reduce the duration over which the hydrogen gas-air mixture is in the flammable concentration range.

Noted Hydrogen Hazards

Leaks form the basis of all gaseous hydrogen hazards. The properties of hydrogen that contribute to its leak hazard are:

- it has the lowest molecular weight and is the smallest molecule of any element
- it has the lowest density and the highest buoyancy of any element
- it can cause brittleness in some materials, including metals (but materials chosen for hydrogen applications are not susceptible to brittleness)

- it is colorless, odorless, and tasteless
- it burns invisibly and without smoke
- it can generate electrostatic charges and sparks through flow or agitation
- it has the lowest ignition energy of any fuel (less than one-tenth that of other fuels)
- it has a wide flammability concentration range of 4% to 75%

Liquid (Cryogenic) Hydrogen (LH_2)

Hydrogen may also be stored as a liquid, at fueling stations and onboard vehicles (see ER Diagrams, Section 6, to note liquid hydrogen-carrying vehicles). In order for hydrogen to exist as a liquid, it must be kept at cryogenic temperatures. The boiling point for hydrogen is –423°F (-253°C), and hydrogen evaporation occurs in a 1:848 expansion ratio (for further details, see Liquid Hydrogen MSDS in Section 5 – References). Due to hydrogen's extremely low boiling point (the lowest of any matter other than helium) in combination with such a high expansion ratio, hydrogen storage tanks typically employ a vent stack to safely release gasified hydrogen and prevent tank overpressurization (see Section 2 – Light Duty FCVs for more information on specific applications for LH_2 storage).

Venting or leaking liquid hydrogen may be indicated by a white cloud, formed by condensed water vapor in the ambient air. These clouds may—because of the higher density of cold gases—move horizontally or even downwards and contain some cold hydrogen gas. The extent of the H_2 cloud may reach beyond the visible portion of the cloud. However this hydrogen will warm up within seconds and quickly disperse upwards. It is recommended to stay "upwind" of such clouds and remove ignition sources. Although ignition sources may not be present at the leak or spill location, fire could occur if the flammable mixture comes into contact with an ignition source.

WARNING for LH_2 Storage Devices!

Never spray water on an **LH_2** vent stack. It may freeze and hinder the pressure relief. Excessive pressure may then rupture the cryogenic storage tank and release hydrogen.

Additional Hazards for Liquid Hydrogen

LH_2 poses a frostbite hazard (cryogenic burns) if it comes in contact with skin [refer to DOT emergency response guide]. Additionally, in case of emergency release super-cooled components, such as PRDs, pipes, valves, can 'burn' the skin with contact. The cryogenic temperature of released liquid hydrogen can liquefy ambient air, which can cause the same frostbite hazard as the liquid hydrogen. It is more likely to get in contact with condensed (liquid) air than it is with liquid hydrogen. Always wear eye protection and gloves made of appropriate protective material to protect your skin against frostbite hazard caused by LH_2 or spilling liquefied air. Please refer to the MSDS Sheets and the DOT Emergency Response manual when dealing with liquid hydrogen.

WARNING!

The extremely low temperature of liquid hydrogen can precipitate the liquification of oxygen when hydrogen is exposed to or poorly insulated from ambient air. Liquefied air must not be allowed to drip on combustible materials such as tar and asphalt. In this case an explosive mixture can be created because of the high oxygen content of condensed air (up to 50%). Even a very small energy amount may ignite such a mixture.

Ignition Sources

In the case of a release, care should be taken to eliminate sources of ignition. Ignition sources can include open flames, mechanical sparks, electrostatic discharges, sparks from electrical equipment, and welding and cutting operations. Care should also be taken not to have any of these sources of ignition near the hydrogen vent stack (see Section 6 – ER Diagram for individual vent stack/PRD location). However, if hydrogen is released – such as during a vehicle PRD event – then all of the fuel will be evacuated in a short amount of time. (For more information, see Section 2 – Light Duty Fuel Cell Vehicles).

Additional Resources for Hydrogen

Further information may be found at the following websites:

- www.airproducts.com/Products/LiquidBulkGases/HydrogenEnergyFuelCells/
- www.praxair.com/Praxair.nsf/AllContent/hydrogen/
- www.hydrogensafety.info/

3. How to Identify a Fuel Cell Vehicle

Fuel Cell Vehicles can be identified by two methods:

A. Vehicle graphics – Current fuel cell vehicles display graphics or lettering on various body panels indicating that the vehicles are powered by fuel cells (reference graphics in the vehicle diagrams)

B. Blue diamond identification symbols – These symbols identify the type of fuel stored in the fuel tank and are applied to the exterior of the vehicle (typically on the rear of the vehicle) to warn emergency responders of the unique fuel hazards associated with hydrogen-fueled vehicles (fuel cell or internal combustion engine). The diamond should be blue with white lettering.[1]

Notes:

- CNG vehicles on the road today display a blue diamond with "CNG" in the diamond.
- Blue diamonds are a recommended practice by The Society of Automotive Engineers (SAE)

Below are two examples of labels a first responder could use in identifying a hydrogen-fueled vehicle:

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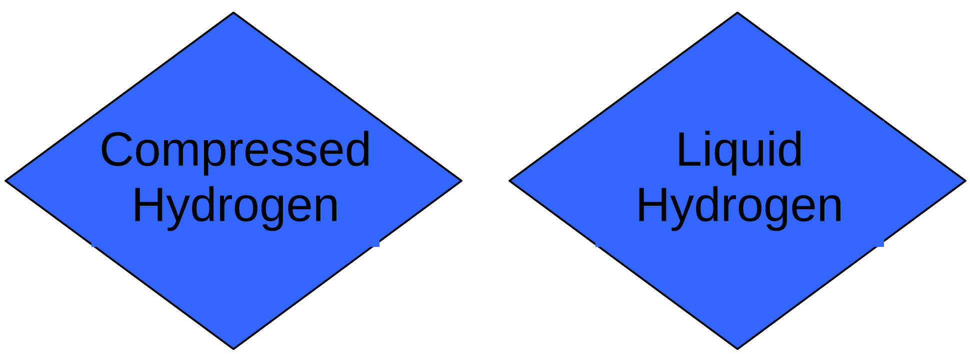

[1] The Society of Automotive Engineers, *J2578 - Surface Vehicle Recommended Practice*, page 19, section 4.7

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light duty
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Section 2 – Light Duty Fuel Cell Vehicles

1. Light Duty Fuel Cell Vehicles in California

As of July 2004, 56 fuel cell vehicles have participated in CaFCP demonstrations, including three fuel cell buses (FCBs). CaFCP members have been demonstrating these vehicles in California under day-to-day driving conditions. The facility headquarters in West Sacramento, California, houses vehicle maintenance bays, a hydrogen fueling station and a methanol fueling station. Through 2007, the members will work to facilitate the placement of up to 300 fuel cell vehicles in independent, fleet demonstration projects within the state, focused in the greater Los Angeles region and the San Francisco-Sacramento corridor.

2. Low and High Voltage System Information

12V/ High Voltage Delivery and Storage Systems

In a FCV there is a standard 12V battery as well as a secondary high voltage system. The conventional 12V battery is used primarily in startup and running accessories.

The high voltage delivery system, which originates from the fuel cell, is between 200–400V. This system powers the electric motor, cooling system, etc. and can be identified by orange cables. In some vehicles there is an additional high voltage storage device in the form of batteries or ultra capacitors that is used to store electrical energy (improve the efficiency of the vehicle). Reference the ER FCV Diagram for each vehicle manufacturer for locations of the high voltage delivery systems.

When a vehicle is turned off, the High Voltage delivery system is deactivated, although it may take up to a few minutes for the electric motor to completely discharge (see individual ER diagram). During this time, only the high voltage storage system (shown as Orange WITH cross-hatch) retains an electric charge.

3. Onboard Vehicular Hydrogen Storage Systems for Light-Duty Vehicles

Compressed Hydrogen

Compressed Hydrogen (CH_2) is generally stored in Type 3 or Type 4 pressure vessels or tanks, which are stronger than conventional gasoline tanks. 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 pressure level depends on the tank system/ vehicle type and is currently at 3600 or 5000 psi (250 or 350 bar) and in the near future may be up to 10,000 psi (700 Bar). These tanks have been extensively tested for structural integrity in order to not leak hydrogen in the event of an impact.

In the unlikely event of a tank system failure, the hydrogen will be released, usually within a few minutes, by a pressure release device (PRD/TRD) or Temperature Release device through the vent stack (see ER Diagram for individual vent stack/PRD location).

In this case a loud hissing sound usually indicates the pressure release (reference H_2 release indicators). Remain clear of the release area if there are indicators present. This is especially important if the vehicle is in or near a fire (refer to Table 1 for a summary).

Table 1: Compressed Hydrogen

Tank Type	carbon wrapped exterior Type 3 aluminum-lined or Type 4 polymer-lined
Pressure	3600 to 10,000 PSI (250 bar – 700 bar)
Temperature	Ambient (after settle down)
Pressure Release Devices	If tank temperature or pressure exceeds limits, hydrogen is released, usually within a few minutes by a pressure release device (PRD) through the vent stack. An increase in hydrogen gas temperature, resulting in an increase in pressure, will also cause the PRD to release. Tank release indicators: • Loud hissing sound with PRD release Concentrated flame stream (may be invisible or nearly invisible depending on environment)

⚠ WARNING!

A controlled pressure release through a PRD can ignite into a <u>concentrated</u> invisible or nearly invisible flame for a short period (reference text). Care should be taken to avoid spraying water on PRDs or gas vents to avoid extinguishing any flame and potential explosive reignition. Remove any potential ignition sources from the area. Allow flame to burn out. Protect exposures.

Emergency response personnel should keep a designated distance away from the immediate area [refer to DOT emergency response guide regarding this distance], and protect surrounding exposures with hose streams until the gas completely vents to the atmosphere.

Liquid (Cryogenic) Hydrogen

Liquid Hydrogen (LH_2) is stored at –423°F (-253°C). The fuel storage cylinders are typically made of stainless steel and stronger than gasoline tanks. Cryogenic LH_2 cylinders have a tank within a tank to form a thermos-like insulating protection to reduce the rate of the boil-off of the LH_2. The space between the inner and outer tank is vacuum-sealed.

Ice frost or ice crystals on the outside of the cylinder could indicate an unlikely inner cylinder failure. In this case the LH_2 would begin to boil off into a vapor and the pressure relief valve would expel excess hydrogen gas through a vent stack to the atmosphere (see ER Diagram for individual vent stack location). Emergency response personnel should evacuate the immediate area [refer to DOT emergency response guide regarding the distance for evacuation area], and protect surrounding exposures with hose streams until the gas completely vents to the atmosphere.

⚠ WARNING for LH_2 Vehicles!

Never spray water on the LH_2 vent stack. It may freeze and hinder the pressure relief. Excessive pressure may then rupture the tank and release hydrogen (See ER Diagram for each individual vehicle).

Venting liquid hydrogen may be indicated by a white cloud, formed by condensed water vapor in the ambient air. These clouds may—because of the higher density of cold gases—move horizontally or even downwards and contain some cold hydrogen gas. The extent of the H_2 cloud may reach beyond the visible portion of the cloud. However this hydrogen will warm up within seconds and quickly disperse upwards. It is recommended to stay "upwind" of such clouds and remove ignition sources.

Although ignition sources may not be present at the leak or spill location, fire could occur if the flammable mixture comes into contact with an ignition source.

WARNING!

Liquefied air must not be allowed to drip on combustible materials such as tar and asphalt. In this case an explosive mixture can be created because of the high oxygen content of condensed air (up to 50%). Even a very small energy amount may ignite such a mixture.

Low Pressure Hydrogen System

A fuel cell system operates at a much lower pressure than the hydrogen storage tanks. High pressure hydrogen is generally reduced with a pressure regulator to below 70 Psi (5 Bar). This lower pressure hydrogen is fed into the fuel cell through hydrogen fuel lines. The hydrogen fuel lines (tubes) are generally made of stainless steel and are routed between the hydrogen tanks and fuel cell "stack." Depending on the specific FCV, there may be both high and low pressure lines located in the vehicle. Reference each manufacturer's Diagram for locations of the hydrogen tank and lines.

When the vehicle is turned off, the high-pressure hydrogen system is isolated (illustrated as Pink with cross-hatch in ER diagram) and cannot flow. There may be a small amount of low-pressure hydrogen left in the fuel lines.

Note—Some vehicles have an external (outside of tank) pressure regulator—see individual ER diagram for location.

4. Vehicle Safety Systems

In the event of an accident/hydrogen detection:

There are many safety systems in the prototype hydrogen FCVs. These systems work independently and in conjunction to ensure the safety of the occupant and their surroundings. The sensors disable (isolate) both the high voltage and hydrogen storage systems in the event of an impact, or hydrogen detection. Here is a summary of these systems:

- **Hydrogen Sensor(s)—**These sensors detect hydrogen leakage. If a hydrogen leak is detected, the hydrogen storage system and electrical systems will be isolated.

- **Impact Sensors**—These inertia-based sensors detect a vehicle impact. In the event of an impact the hydrogen storage and electrical system will be isolated.

- **Pressure (or Thermal) Release Device**—If there is a fire near the vehicle's hydrogen storage system, this device is designed to release the hydrogen (in a controlled manner) in the tank to the atmosphere through a special vent (see individual ER diagrams for vent locations). The purpose of this device is to prevent a hydrogen tank explosion due to extreme pressure build-up. This device will activate (open) if there is a significant pressure or temperature build-up near the tank, which can occur when the tank is exposed to significant heat (i.e., a fire). This device in effect functions as a fusible plug, which opens a valve at a rated temperature/ pressure. This event is characterized by a "hissing" sound, which is the sound of the hydrogen rapidly venting from the PRD vent orifice. At this time, stay well away from the vent area. This jet stream of hydrogen gas could ignite. Refer to the Indicators Section.

  Note: a PRD and TRD have the same function and achieve the same goal, however the PRD detects a pressure rise, while the TRD detects temperature rise.

- **Emergency Shutoff Button—**Some prototype FCVs have a manual shutoff switch in vehicle which gives the passenger/driver an additional way to shut down the vehicle and isolate the hydrogen storage and electrical storage systems. Reference the individual shut-down procedure.

5. Passenger Rescue/ Extrication

Before attempting to rescue occupants from a disabled or damaged Fuel Cell Vehicle or trying to move a damaged vehicle, it is important to make sure that the system is no longer running and that there are no indicators of a PRD/TRD release. Refer also to the Section below: PRD/TRD Indicators. In addition, refer to the "Manual Shut-down" procedure in the following pages for directions on how to manually "turn off" each L.D. FCV at the CaFCP.

If extrication of a passenger is necessary, standard procedure is to be followed, but additional care is to be taken into consideration for the hydrogen and electrical systems. If there is a need to cut into the vehicle to remove an occupant, make sure of the following:

- Manual shut-down procedure is followed
- If any cutting into a FCV is required, (with a Hurst Tool, etc.) caution should be taken to avoid critical components of the fuel cell system. Critical Components are defined as the hydrogen storage system and high voltage electrical storage. Any "Cross-hatched area" in the diagram should not be cut under any circumstances (i.e., vent stack, etc.). Details of each vehicle are to be found in the ER Vehicle Diagrams.
- In the case of an impact and/or a vehicle fire, approach a FCV **away** from the location of the PRD/TRD vent as indicated in the FCV diagrams. Do not stand near or in the stream of a PRD/TRD event. This is especially important if the vehicle is on fire.

WARNING:

The high voltage storage (Orange with crosshatch) should **not** be cut for any reason. After following the manual shutdown procedure, if necessary, the high voltage delivery system (Orange WITHOUT crosshatch) can be cut only if necessary. Please refer to the individual ER Diagram before making such decision, as it may be necessary to wait a few minutes for the system to discharge. If this procedure is not followed, electric shock can result.

WARNING:

The hydrogen storage tanks (Pink with crosshatch) should never be cut into in the event of an emergency. After following the manual shutdown procedure, if necessary, some of the low pressure Hydrogen lines (PINK without crosshatch) can be cut with caution. Please reference the individual Fuel Cell Vehicle diagrams. If this procedure is not followed, a hydrogen release is possible.

Location/Environment

As in all vehicle emergencies, position responding apparatus uphill, upwind, and away from the H_2 vent direction of a fuel cell vehicle accident whenever possible. Staying uphill from the accident is recommended for hybrid or Methanol FCV in order to keep emergency response personnel and equipment away in the case of from spilled electrolyte and/or methanol. With vehicle fires, staying upwind and away from H_2 vent will keep personnel from operating in toxic smoke and fumes and to avoid being in the path of PRD release. Follow the standard vehicle approach method (45 degree approach angle) taking into account the direction of the vehicle's PRD or TRD. Reference individual ER Diagram for location of vent.

6. Responding to Accidents

Non-Injury Accidents

For these emergencies, protective clothing is recommended (i.e., out pants, jacket, boots, gloves, and helmet with face shield). Reference "Equipment Recommendations for FCV Hazards." This provides the firefighting personnel with the essential protection necessary when responding to all vehicle accidents. Do not wear jewelry, rings, necklaces, or watches, as all of these items are highly conductive. Hydrogen leak detectors, if available, should be used to check for system leaks.

Catastrophic Accidents and Vehicle Fires

For these emergencies full protective clothing is recommended (IE turnout pants, jacket, boots, helmet, and SCBA). Personnel working directly with the vehicle should also be equipped with high voltage rubber gloves and use static dissipative equipment. These recommendations provide firefighting personnel with the essential protection necessary from the potential of electric shock, flammable/explosive gas, and hazardous fumes encountered during rescue. UV detectors, if available, should be used to scan for invisible hydrogen flames. If no flames are present the vehicle should be scanned with a hydrogen leak detector, if available.

Accidents Involving Different Fuel Sources

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 there is a gasoline or diesel fuel spill near a fuel cell vehicle, spray the spilled fuel with foam to render the fuel inert if safe to do so.

7. Vehicle Identification

Fuel Cell Vehicles can be identified by two methods:

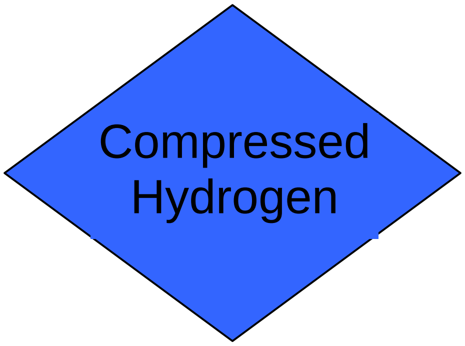
A. Vehicle graphics – Current fuel cell vehicles display graphics or lettering on various body panels indicating that the vehicles are powered by fuel cells (reference graphics in the vehicle diagrams)

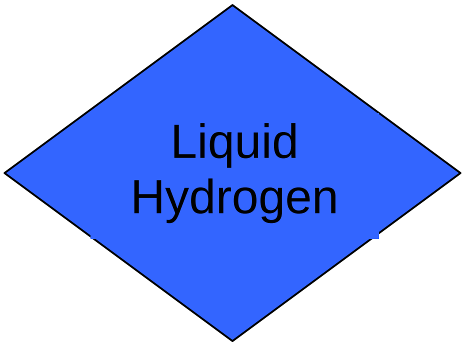
B. Blue diamond identification symbols – These symbols identify the type of fuel stored in the fuel tank and are applied to the exterior of the vehicle (typically on the rear of the vehicle) to warn emergency responders of the unique fuel hazards associated with hydrogen-fueled vehicles (fuel cell or internal combustion engine). The diamond should be blue with white lettering.[1]

Notes:

- CNG vehicles on the road today display a blue diamond with "CNG" in the diamond.
- Blue diamonds are a recommended practice by The Society of Automotive Engineers (SAE)

Below are two examples of labels a first responder could use in identifying a hydrogen-fueled vehicle:





[1] The Society of Automotive Engineers, *J2578 - Surface Vehicle Recommended Practice*, page 19, section 4.7

8. Hydrogen Release Indicators

As mentioned previously, a FCV is designed to be as safe or safer than conventional vehicles. In the event of an impact, the high voltage and high pressure hydrogen systems are deactivated through an impact sensor similar to those used in an airbag. But, as an added measure it is recommended that the “manual shut-down” procedure be carried out.

Extra care should be taken if there is a vehicle fire or an audible hissing sound coming from the vehicle, as there exists the possibility that the hydrogen will be released through a controlled PRD/ TRD event (for a short amount of time).

Below is a list of hydrogen release indicators:

Compressed Hydrogen PRD/TRD Release

- A loud hissing sound usually indicates a PRD/TRD release.
- An invisible pressurized gas jet will emanate from the vent stack in the event of a PRD release.
- This release can ignite into a concentrated flame stream. Hydrogen burns with a flame that may be invisible depending on the environmental conditions.

Liquid Hydrogen Leak

- Fog or cloud formed around the (cryogenic) hydrogen storage tank. Please note that the actual Hydrogen vapors may extend outside the visible cloud area.
- Ice Crystals formed around the storage Tank.

Note—sometimes frost can be apparent around the fuel lines with no leak being present.

9. Equipment Recommendations for FCV Accident

Standard Equipment Recommendations

- Turnout Pants
- Turnout Jacket
- High Voltage Boots
- High Voltage Gloves
- Helmet and Face Shield
- Self-Contained Breathing Apparatus (SCBA)
- Insulated Hand Tools

Special Equipment Recommendations

The following equipment can be helpful in fuel cell vehicle emergencies but are not required:

Static dissipative clothing and equipment are recommended.

Garments should meet or exceed the following standards:

- NFPA 70E
- NFPA 1975
- ASTM F1506-98
- OSHA Final Rule 1910.269
- Typically constructed of Nomex IIIA

To detect hydrogen fires:

UV Optical Sensor
(IR sensors typically are better suited for hydrocarbon fires)

If the above is not available:

Long Handle Broom
(The bristles should be made of a material that is easily ignited but does not release toxic fumes when burning, for example corn straw brooms.)

Hold the broom in front of you as you slowly approach the vehicle. It will ignite when passed through a hydrogen fire.

To detect hydrogen leaks (prioritized starting with the most effective sensor):

Thermal Conductivity Sensor
(Functions well in stable air environments with minimal temperature variations)

Or

Catalytic Combustion Sensor
(typically used by HAZMAT teams)
(Functions well for detecting 0 to 4 % H_2 in air, but not hydrogen specific)

Or

Electrochemical Sensor
(Exposure to cryogenic or time varying temperatures can make sensor unreliable)

For additional Information:

Reference the aforementioned documents/ DOT Emergency Response Guidebook and Emergency Response to Electric Vehicles.

section 3
fuel cell
transit buses

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Section 3 – Fuel Cell Transit Buses

1. Hydrogen Fuel Cell Buses in California

Fuel cell buses are being tested at 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.

Buses will be in operation between 2004 and 2005. In addition, buses are being tested at Sacramento Municipal Utility District and the University of California at Davis.

General Configurations
A fuel cell bus typically weighs about 5000 pounds more than a diesel bus and 2200 pounds more than a compressed natural gas bus. A fuel cell bus is taller than a diesel bus due to the hydrogen tanks located on the roof of the bus. A fuel cell bus drives and operates much like its internal combustion engine (ICE) counterpart.

Currently, fuel cell buses, such as these built with fuel cells from Ballard Power Systems, are identified with the use of logos and designs, and may also have an SAE diamond "compressed hydrogen" sticker on the rear of the bus.

A fuel cell bus normally contains an emergency shutdown device (ESD) switch on the control panel near the driver. An external shutdown switch, normally used for maintenance, will be accessible from the exterior of the bus, either in the rear or the side of the bus. Refer to the specific bus diagrams for the location of these ESD switches. These switches enable the engine to be shut down from more than one location and may allow restart from the exterior of the bus.

ThunderPower fuel cell bus fueling up with hydrogen at SunLine facility in Thousand Palms, CA.

WARNING:

You may not know that the bus is on because there is little or no noise such as you would hear with an ICE bus. If the bus is running, you may or may not hear the motor compressor or blower humming.

2. Low and High Voltage System

Cabling and Disconnects

High voltage systems are clearly marked “high voltage” by the color of the cable. On fuel cell buses, high voltage cables are insulated in bright orange,. High voltage cables are isolated from low voltage wiring. High voltage systems may include watertight, anti-abrasive, flexible conduit and bulkhead connectors and National Electrical Manufacturers Association (NEMA) rated electrical boxes, and are securely bonded. Refer to the bus diagrams for the location of the high voltage wiring.

Depressing any ESD switch shuts down the low voltage system and disconnects the hydrogen. ESD switches are located by the driver. If an electrical problem with the high voltage system occurs, some buses may automatically shut down after several seconds. The bus may have a manual override switch on the instrumentation panel next to the driver to allow the driver to override any automatic shut down procedure long enough to move the bus to a safe location.

In addition to the ESD switch, the bus will have at least one externally located shutdown device switch, usually in the back of the bus with the high voltage components. These switches are normally used for maintenance shutdown but may also be accessed by emergency responders. For clarity and simplicity, the bus diagrams will refer to all shutdown device switches as ESD switches.

Even with all safety precautions, it is impossible to be sure the high voltage system is off.

WARNING:

Never cut into the high voltage source (see Section 6 – Vehicle Diagrams, for the specific bus). Residual voltage may exist with some buses. Assume high voltage is present and do not water down electrical components.

Even with all safety precautions, high voltage is still present in the batteries and associated cables.

Batteries and Ultracapacitors

Although batteries and ultracapacitors are difficult to burn, if exposed to extreme heat or fire, the plastic casing, cabling, and other flammable materials will burn.

If electrolyte is spilled and exposed to fire, the fumes and gases resulting can be extremely toxic.

Battery and Ultracapacitor Fires

Wear full protective clothing and self-contained breathing apparatus. Depending on the type of batteries or ultracapacitors, fumes from electrolytes and plastics should not be inhaled or allowed to come into contact with clothing or skin. Refer to the specific bus diagram.

Battery Type	Characteristics	Extinguishing Fires	Spills
Lead Acid	Sulfuric acid electrolyte	• Wear full protective clothing and self-contained breathing apparatus. • Use CO_2 or dry chemical fire extinguishers.	• Remove combustible materials and sources of ignition. • Stop flow with duct tape over crack in case.
Nickel Metal Hydride (NiMH)	• Electrolyte is 30% (by weight) potassium hydroxide in water. • The electrolyte is a base, not an acid as in lead-acid batteries. • Like nickel-cadmium batteries, NiMH batteries use an aqueous alkaline electrolyte and a nickel hydroxide cathode. • The metal hydride anodes on a NiMH battery are nontoxic. • The electrolyte will react with zinc, aluminum, tin, and other materials, releasing flammable hydrogen gas.	• Wear full protective clothing and self-contained breathing apparatus. • Extinguish fires with Class D metal fire extinguisher.	• If possible (see cautions and warnings regarding use of water in other sections of this guide), flush spill with water and neutralize with vinegar or other dilute acid. **CALL HAZMAT.** • Dike spill with sand or vermiculite. • Do not allow electrolyte material to flow into storm drains. • Prevent contact with any part of the body. The electrolyte is extremely corrosive. • Use caution – the electrolyte reacts violently with many organic chemicals.

Nickel Cadmium (NiCd)	• The electrolyte is a mixture of distilled or demineralized water and potassium hydroxide, and may also contain sodium and lithium hydroxides. • High ambient air temperatures can impact NiCd batteries – they require some type of thermal management system to regulate the electrolyte temperatures.	• Wear full protective clothing and self-contained breathing apparatus. • A fully engulfed battery could allow cadmium vapors, which are toxic and carcinogenic, to escape in the smoke. • Use a dry chemical fire extinguisher.	• **CALL HAZMAT**. Dike to control runoff.
Sodium Nickel Chloride ($NaNiCl_2$)	• $NaNiCl_2$ batteries operate from 260 to 350 degrees Celsius, but are contained in a thermos-like flask to insulate them and protect anyone coming in contact with the battery.	• Let the batteries burn! • Nickel chloride is not considered to be a fire hazard or particularly reactive, but sodium metal is highly reactive, flammable, corrosive, and exothermically reactive with water. A sodium fire will burn violently and may be accompanied by explosions that splatter molten metal. • If possible, batteries should be allowed to burn. Do not use water. • If absolutely necessary, battery fires should be suppressed with dry soda ash, salt, dry sand, or an extinguishing agent designed for combustible metals.	• The contents of each cell are self-neutralizing if the solid electrolyte breaks. • Nickel chloride can cause skin, eye, and respiratory irritation.

Ultracapacitors	• Ultracapacitors contain very small amounts of electrolyte and have no free liquid. Various organic electrolytes are used in ultracapacitors. • Ultracapacitors are constructed as a rugged, hermetically sealed container to house the electrode and electrolyte. • Ultracapacitors can withstand more physical abuse than batteries, have a longer useful life than batteries, and require no maintenance over their entire lifetime.	• Wear full protective clothing and self-contained breathing apparatus on positive pressure. • In the event of burning ultracapacitors, if possible move to an open area to avoid breathing vapors released during burning. • If the fire must be contained do not use water. Water should never be used to extinguish flame in the presence of high voltage electricity. Use fire extinguishing methods appropriate to surrounding media. There are no special requirements to extinguish an ultracapacitor fire. • Ultracapacitors, as sealed containers, will build pressure in the presence of heat. When sufficient pressure has built up, the cell will open along a seam in the casing, releasing electrolyte vapors.	• If an ultracapacitor is opened, there will be no free liquid released, only vapors. Adequately ventilate any enclosed area where there may be open capacitors before entering the area. • Avoid contact with organic salts that will remain after electrolyte evaporation. Organic salts are a skin and eye irritant. Use gloves to handle any part that shows evidence of organic salt contamination.

3. On-Board Vehicular Hydrogen Storage Systems for Fuel Cell Buses

Compressed Hydrogen

Compressed Hydrogen (CH_2) is generally stored in Type 3 or Type 4 pressure vessels or tanks, which are stronger than conventional gasoline tanks. 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 type of vessels.

The pressure level depends on the tank system/ vehicle type and is currently at 3600 or 5000 psi (250 or 350 bar) and in the near future may be up to 10,000 psi (700 Bar). These tanks have been extensively tested for structural integrity in order to not leak hydrogen in the event of an impact.

In the unlikely event of a tank system failure, the hydrogen will be released, usually within a few minutes, by a pressure release device (PRD/TRD) or Temperature Release device through the vent stack (see ER Diagram for individual vent stack/PRD location). In this case a loud hissing sound usually indicates the pressure release (reference H_2 release indicators). Remain clear of the release area if there are indicators present. This is especially important if the vehicle is in or near a fire (refer to Table 1 for a summary).

Table 1: Compressed Hydrogen

Tank Type	carbon wrapped exterior Type 3 aluminum-lined or Type 4 polymer-lined
Pressure	3600 to 10,000 PSI (250 bar – 700 bar)
Temperature	Ambient (after settle down)
Pressure Release Devices	If tank temperature or pressure exceeds limits, hydrogen is released, usually within a few minutes by a pressure release device (TRD/PRD, see Chapter 3 of this section for more information) through the vent stack. An increase in hydrogen gas temperature, resulting in an increase in pressure, will also cause the TRD/PRD to release. Tank release indicators: • Loud hissing sound with PRD release • Concentrated flame stream (may be invisible or nearly invisible depending on environment)

WARNING!

A controlled pressure release through a PRD can ignite into a concentrated, invisible or nearly invisible, flame for a short period (reference text). Care should be taken to avoid spraying water on PRDs or gas vents to avoid extinguishing any flame and potential explosive reignition. Remove any potential ignition sources from the area. Allow flame to burn out. Protect exposures.

Emergency response personnel should keep a designated distance away from the immediate area [refer to DOT emergency response guide regarding this distance], and protect surrounding exposures with hose streams until the gas completely vents to the atmosphere.

4. Bus Safety System

On-board Hydrogen Leak Detection

Although the potential for hydrogen leaks is minimized through design and materials used, the presence of hydrogen on-board a bus requires additional equipment to ensure passenger safety. A leak detection system detects escaped hydrogen. In most cases, the on-board leak detection system is only active when the bus is on.

A leak detection system consists of a series of sensors that are linked to the vehicle's control system. The sensors are located at strategic locations around the vehicle (such as beneath the roof canopies and in the engine compartment). The sensors are typically calibrated to trigger a warning at concentrations below the lower flammability limit (LFL) of hydrogen. Since the LFL of hydrogen is 4% hydrogen in air, these warnings are typically set to occur at hydrogen concentrations of 0.2%, 0.6%, and 1% in air. Thus, the leak detection system will sound an alarm before gas concentrations reach a dangerous level.

When a sensor trigger occurs, the control system alerts the driver by way of dashboard lights, a message display center, or other means and shuts down the engine if an alarm concentration occurs. Measured percentage of hydrogen concentrations may be concurrently displayed on dedicated leak indicators.

Once leaked, hydrogen mixes with air and is flammable over a wide range (4% to 75% in air) of concentrations. This flammable mixture is very easy to ignite, and, once ignited, burns intensely. The flame is invisible or nearly invisible in daylight. If hydrogen leaks into an enclosed environment, the risk of combustion and explosion is increased. If hydrogen leaks into an open environment, it rises quickly and is rapidly diffused, reducing the risk of fire.

To some extent, the potential for fire is reduced through design. Materials of construction are fire-resistant and are thoroughly bonded to the conductive metal chassis to prevent static charge accumulation. Fuel lines never pass through the passenger compartment, eliminating the potential for hydrogen to leak into the vehicle.

Hydrogen Fuel Tanks

In a transit bus application, hydrogen is stored on the roof in a series of high pressure cylinders. Placing the fuel storage cylinders on the roof takes advantage of hydrogen's high buoyancy — any leaked gas dissipates quickly and tends to mix and migrate vertically to the atmosphere. These storage cylinders contain the vast majority of hydrogen on the vehicle. The amount of hydrogen present in the fuel cell is very small when operating, and none while shut down.

(Review National Fire Protection Association code section 497 for dangers with hydrogen release.)

WARNING:

Never apply mechanical force to cylinders. Fuel tanks are made of composite materials, and abrasion to a cylinder may cause a rupture.

Hydrogen can pose an asphyxiation hazard if a significant amount of hydrogen leaks into an enclosed and unvented area. Outdoors, the hydrogen tends to rise rapidly and the risk of asphyxiation at human level is usually negligible. However, the invisible hydrogen cloud may diffuse in all directions, including downward.

WARNING:

Do not cut fuel lines. If a fuel line is broken or displaced, a hissing noise may be heard. Leaking gas may be hot and pose burn and high-pressure hazards. Do not walk near a potentially broken or displaced line, or vent valves. Refer to the specific bus diagrams.

Emergency Venting

The tanks pressure release device or PRD will release pressure when the tank pressure increases beyond its rated capacity. The PRD must be vented to the outside of the vehicle. If the fuel cell tanks must be vented, locate the bus away from any source of ignition and overhead obstructions, such as operating electrical equipment, overhead power lines, overhead roofs, canopies, or bridges. A PRD release will produce an audible hissing sound.

Mixtures of hydrogen and air are potentially flammable and explosive, and can be easily ignited by a spark or hot surface.

⚠ WARNING:

Hydrogen's flammability limits are very broad (4% to 75% concentration in air). Even minor static discharge can ignite a flammable concentration. Take special care to keep ignition sources away from any escaping hydrogen.

Conditions Unique to Hydrogen Fuel Emergencies

1. Flammability

Hydrogen flames are invisible or nearly invisible in daylight. High-pressure fuel storage cylinders include PRDs that are designed to release the cylinder contents when the contents reach a rated temperature/pressure through fire/extreme overpressure, thus preventing explosive pressure buildup within the cylinders. The PRD discharge is routed to vents that protrude to the top surface of the bus canopy, allowing unimpeded access to the atmosphere.

⚠ WARNING:

Static electricity may cause ignition. Ignition with a pressure release through a PRD produces a concentrated flame for a short period of time (the heat of combustion of hydrogen is more than double that of gasoline, per unit mass).

Some transit bus applications include a fire suppression system in order to detect and extinguish fires. The fire suppression system consists of a series of sensors that are linked to the vehicle's control system. The sensors are located at strategic locations around the vehicle (such as the beneath the roof canopies and in the engine compartment) and are designed to trigger an alarm in the event of fire. Some types of sensors also can detect high heat. Fuel cell applications may include thermal wire wound around the fuel cell stacks that are designed to short when melted, signaling the control system.

When a sensor trigger occurs, 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).

The invisibility or near invisibility of hydrogen fires makes them hard to detect and a serious hazard to personnel. Hydrogen fires may be large or small. The intensity of a fire is directly related to the level of pressure behind the underlying leak. Fires may manifest themselves through the presence of flames, smoke from adjacent equipment engulfed in the flames, heat waves, a burning smell, explosion, component damage, or trigger of the fire suppression system. Very small fires may not be noticeable through any of these means.

⚠ WARNING:

The function of the PRD is to allow the hydrogen gas to escape if the temperature or the pressure in the system reaches a critical state. In the event of a PRD release it will not be possible to shut off the fuel source.

If a PRD release does not occur, the protocol for fighting a hydrogen fire is similar to fighting any fire fueled by a gas. Eliminate the fuel source by shutting off the flow of hydrogen gas (refer to specific bus diagrams for location of shutoff valves). If this is not an option, allow the fuel to burn out.

As with any fire, evacuate all personnel except those fighting the fire, contact local fire authorities if needed, and fight the fire from as great a distance up wind as possible. The object is to minimize the risks of injury and danger to people, and risk of damage to equipment in the surrounding area.

If a fire occurs on board a hydrogen fuel cell bus, shut it down as soon as it is safe to do so. This closes the solenoid valves for each fuel cylinder and the high-pressure solenoid, effectively isolating the fuel in the fuel storage system. An alarm shutdown by the fire suppression system should automatically discharge retardants within the fire area. If the fire continues, use standard fire fighting techniques as described above.

The hydrogen fuel flows into and out of each cylinder through a system that includes an integral solenoid valve, check valve, excess flow valve and shutoff valve assembly (or "manual lockdown assembly"). The solenoid valve automatically closes and isolates the cylinder whenever the bus is off. The excess flow valve interrupts the fuel flow out of the cylinder whenever the flow rate is excessive (such as if a pipe bursts or during vigorous venting). When closed, the excess flow valve permits a small amount of leakage so that the outlet and cylinder pressures equalize over a period of time, thereby restoring normal valve function.

An external hand valve is typically installed in the inlet pipe associated with each cylinder. This valve provides an additional level of safety to the integral solenoid valve.

PRDs are at one or both ends of each cylinder and protect against explosion in the event of a fire. Each pressure relief device is in contact with the internal gas pressure and contains a eutectic compound that acts as a plug. When exposed to fire, the eutectic compound melts and the internal gas escapes through a vent line that passes through the roof canopy. Refer to the specific bus diagram.

2. Asphyxiation Hazards

Hydrogen displaces air, so any release in an enclosed space could cause asphyxiation. Because hydrogen is colorless, odorless, and tasteless, its presence cannot be detected easily. It is the lightest gas, being only 0.07times the density of air and having a rate of diffusion 3.8 times faster than air. These properties allow it to fill a confined space rapidly. (Refer to NFPA 50A, Standard for Gaseous Hydrogen Systems at Consumer Sites.) Individuals experiencing dizziness, drowsiness, nausea, or loss of consciousness should be moved to an open area. DO NOT ENTER THE AREA. Hydrogen reaches its flammability level before it reaches asphyxiation levels so keep all ignition sources away from the area.

5. Vehicle Identification

Fuel Cell Vehicles can be identified by two methods:

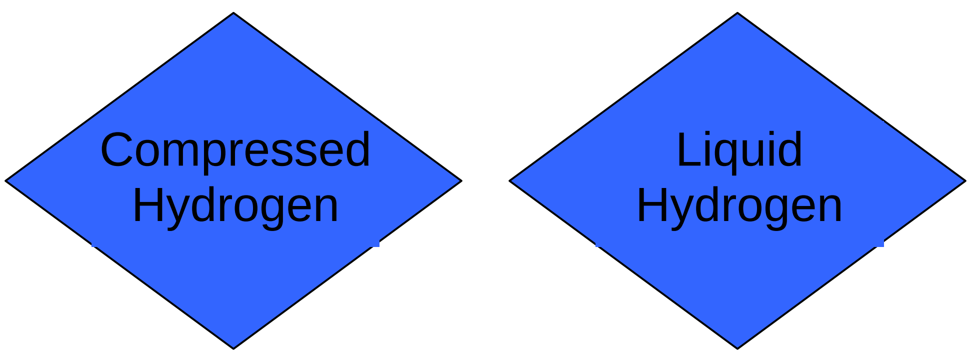
A. Vehicle graphics – Current fuel cell vehicles display graphics or lettering on various body panels indicating that the vehicles are powered by fuel cells (reference graphics in Section 6 – Vehicle Diagrams).

B. Blue diamond identification symbols – These symbols identify the type of fuel stored in the fuel tank and are applied to the exterior of the vehicle (typically on the rear of the vehicle) to warn emergency responders of the unique fuel hazards associated with hydrogen-fueled vehicles (fuel cell or internal combustion engine). The diamond should be blue with white lettering.[1]

Notes:

- CNG vehicles on the road today display a blue diamond with "CNG" in the diamond.
- Blue diamonds are a recommended practice by The Society of Automotive Engineers (SAE)

Below are two examples of labels a first responder could use in identifying a hydrogen-fueled vehicle:



[1] The Society of Automotive Engineers, *J2578 - Surface Vehicle Recommended Practice*, page 19, section 4.7

6. Responding To Fuel Cell Bus Incidents

In the event of a fuel cell bus incident, the driver of the bus, if possible, will follow recommended shut down procedures provided by the individual transit agencies. Passengers should exit through the bus doors and emergency exits, as appropriate and when it is determined safe to do so. Passengers should be moved to a safe location upwind and away from the bus.

Emergency response personnel should be notified they are responding to an incident involving a fuel cell bus. Emergency response vehicles should be maneuvered up wind of the disabled bus. Approach the vehicle away from the PRD vent location. The venting location is shown in the attached emergency response (ER) diagrams.

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 there is a gasoline or diesel fuel spill near a fuel cell vehicle, spray the spilled fuel with foam will render the fuel inert if safe to do so.

Hydrogen Fires

Hydrogen fires do not have a visible flame and generate little smoke. However, there will be visible flame or smoke if the hydrogen fire has other combustible material burning with it. A UV optical sensor provides the best detection of a hydrogen fire, but if it is not available and a hydrogen fire is suspected, use a long handled broom with bristles made of a non-toxic, easily ignited material. Hold the broom in front of you as you slowly as you approach the bus. The broom will ignite if passed through a hydrogen fire.

Fires should not be extinguished unless the hydrogen leak can be stopped. Allow the gas to burn out. Protect exposures.

WARNING:

It is important to identify the location of the relief valve vents (PRDs and TRDs) before beginning any operation around the bus. Approach the bus at 45 degrees. Isolate the area around the ends of the tanks. Do not approach the PRD and TRD areas of the tanks if the bus is on its side. Withdraw immediately in the event of any audible hissing or rising sound from a PRD or TRD.

High Voltage Considerations

High voltage electrical components are typically labeled "high voltage" – cables may be identified by their bright orange, red, or yellow loom or weave.

WARNING:

Do not cut into anything labeled "high voltage" or color coded as being high voltage. Refer to the attached specific bus diagram.

7. Recommended Equipment

The following equipment is recommended in responding to a hydrogen fuel cell bus incident.

Standard Equipment	1. Turnout Pants 2. Turnout Jacket/Coat 3. High Voltage Boots 4. High Voltage Gloves 5. Helmet and Face Shield 6. Self-contained Breathing Apparatus (SCBA) 7. Electrically-Insulated Hand Tools 8. Foaming Agents (interior and non-hydrogen fuel related fires)
Special Equipment (helpful but not required)	1. Static dissipative clothing and equipment that meet or exceed the following standards: a. NFPA 70E b. NFPA 1975 c. ASTM F1506 d. OSHA Final Rule 1910.269 e. Nomex IIIA construction
Fire Detection Equipment	1. UV Optical Sensor (best) or 2. Long handled corn straw broom or equivalent non-toxic easily ignited material
Hydrogen Leaks Equipment	1. Thermal Conductivity Sensor or 2. Catalytic Combustion Sensor or 3. Electrochemical Sensor

section 4
hydrogen fueling stations

As of August 2004, this section is under development by CaFCP.

section 5
reference documents

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Section 5 – References

1. Bibliography

Balon, T., Chernicoff, W. and Raj, P. *Design Guidelines for Bus Transit Systems Using Electric and Hybrid Electric Propulsion as an Alternative Fuel*. U.S. Department of Transportation, Federal Transit Administration, Office of Research, Demonstration, and Innovation. DOT-FTA-MA-26-7071-03-1. March 2003

Clean Air Program: *Design Guidelines for Bus Transit Systems Using Hydrogen as an Alternative Fuel*. U.S. Department of Energy, Federal Transit Administration, Office of Research, Demonstration, and Innovation. DOT-FTA-MA-26-7021-98-1. October 1998

Chang, E., Rawson, M., and Slaughter, R. *Emergency Response to Electric Vehicles*. California Department of Forestry and Fire Protection, Office of the State Fire Marshal. September 1997

Direct Hydrogen-Fueled Proton-Exchange-Membrane Fuel Cell System for Transportation Applications: Hydrogen Vehicle Safety Report, prepared for the U.S. Department of Energy by Ford Motor Company and Directed Technologies, Inc., Report No. DOE/CE/50389-502, May 1997.

Emergency Response Guide for Light Duty Fuel Cell Vehicles, California Fuel Cell Partnership. December 2002

Evaluation of Vehicle Fuel Safety Regulations and Test Methods for New Fuels and Technologies. Transportation Development Centre Transport Canada. June 2002

Hydrogen Fuel Cell Engines and Related Technologies. Curriculum for training courses at College of the Desert, Energy Technology Training Center. December 2001

Knapp, J. and R. Slaughter. *Emergency Response to Electric Vehicles, The Electric and Hybrid-Electric Bus Addendum*. Electric Power Research Institute and the U.S. Department of Energy. April 2001

Ordin, P. et al. Safety Standards for Hydrogen and Hydrogen Systems, Guidelines for Hydrogen System Design, Materials Selection, Operations, Storage, and Transportation. National Aeronautics and Space Administration. NSS 1740.16. February 1997

Slaughter, Rodney, *Emergency Response to Natural Gas Vehicles,* California Office of Traffic Safety, California Energy Commission, California Natural Gas Vehicle Coalition, January 2003

Society of Automotive Engineers International, *Surface Vehicle Recommended Practice*, SAE J2578, Issued December 2002.

2000 Emergency Response Guidebook, developed jointly by Transport Canada, the U.S. Department of Transportation, and the Secretariat of Transport and Communications of Mexico, 2000

2. Fuel Cell Vehicle Technical Terminology

ACTIVATION

Chemical. Treatment of a substance by heat, radiation, or other activating reagent to produce a more complete or rapid chemical or physical change.

Electrical. The process of treating a cathode to increase its rate of reduction.

ANODE

The negative electrode at which oxidation occurs.

AUXILIARY POWER

Power from an independent source that functions as required to augment/support various performance criteria established for the prime power source.

BIPOLAR PLATES

Conductive plate in a fuel cell stack, which acts as an anode for one cell and a cathode for the adjacent cell. The plate may be made of metal or a conductive polymer (which may be a carbon-filled composite). The plate usually incorporates flow channels for the fluid feeds and may also contain conduits for heat transfer.

BLOWDOWN

The difference between the opening and closing pressures of a relief/safety valve.

BLOWER

A fan used to force air and/or gas under pressure.

BOOST REGULATOR

Voltage conversion device used to raise the voltage in a DC system.

CH or CH_2

Abbreviation for Compressed Hydrogen ($\mathbf{H_2}$)

CATALYST

A chemical substance that increases the rate of a reaction without being consumed; after the reaction it can potentially be recovered from the reaction mixture chemically unchanged. The catalyst lowers the activation energy required, allowing the reaction to proceed with more quickly or at a lower temperature.

CATHODE

The positive electrode at which reduction occurs.

CIRCUIT, SAFETY-CONTROL
A circuit or portion thereof involving one or more safety controls in which failure due to grounding, opening or shorting of any part of the circuit can cause unsafe operation of the controlled equipment.

COMPRESSOR
A device used for increasing the pressure and density of gas.

CONTROLS
Devices designed to regulate the gas, air, water or electrical supplies to the controlled equipment. These may be manual, semi-automatic, or automatic.

Limit: A control, which automatically responds to, changes in temperature, pressure, flow, or level for limiting the operation of the controlled equipment. This device is not considered an operating control.

Operating: A control, other than a safety control or interlock, to start or regulate equipment operation according to load demand and to stop or regulate equipment operation on satisfaction of demand or upon reaching normal temperature or pressure in the equipment being operated. An operating control also may actuate auxiliary equipment.

Safety: Automatic controls and interlocks (including relays, switches, and other auxiliary equipment used in conjunction therewith to form a safety-control system) which are intended to prevent unsafe operation of the controlled equipment.

CRYOGENIC LIQUID
A refrigerated liquefied gas having a boiling point colder than –90°C (-130°F) at 101kPa (14.7 psia) absolute (source DOT 49 CFR 173.115). Hydrogen is liquid at –253°C (-423°F) at atmospheric pressure.

DIFFUSION
Movement of a species under the influence of a gradient of chemical potential (i.e., a concentration gradient).

DRIVETRAIN
The elements of a propulsion system, such as the motor, transmission, axle and wheels that produce and transmit mechanical power to the drive wheels of a vehicle.

ELECTRODE
An electric conductor through which an electric current enters or leaves a medium, whether it be an electrolytic solution, solid, molten mass, gas, or vacuum.

ELECTROLYTE
A non-metallic electrical conductor in which current is carried by the movement of ions.

EXTRICATION
The act of releasing or removing by untangling or unsnarling someone from an accident vehicle.

FCV
The acronym for “Fuel Cell Vehicle”.

FLAMMABLE (EXPLOSIVE) LIMITS
For gases or vapors, which form flammable mixtures with air or oxygen, there is a minimum concentration of vapor in air or oxygen below which propagation of flame does not occur on contact with a source of ignition. There is also a maximum concentration of vapor or gas in air above which propagation of flame does not occur. These boundary-line mixtures of vapor or gas with air, which if ignited will just propagate flame, are known as the "lower and upper flammable limits" (LFL and UFL) or the "lower and upper explosive limits" (LEL and UEL), and are usually expressed in terms of percentage by volume of gas or vapor in air. LEL and LFL are different terms for the same concept and can be used interchangeably. A mixture below the lower flammable limit is too "lean" to burn or explode and a mixture above the upper flammable limit too "rich" to burn or explode.

FUEL CELL
An electrochemical device, which can continuously convert the chemical energy of a fuel and an oxidant to electrical energy. The fuel and oxidant are typically stored outside of the cell and transferred into the cell as the reactants are consumed.

FUSIBLE PLUG
A device which opens and keeps open a relief vent by the melting or softening of a fusible plug or cartridge at a predetermined temperature.

GH_2 or GH_2 or GHY
Abbreviation for gaseous hydrogen.

GROSS POWER
The fundamental power output of an energy source prior to any conditioning and losses associated with the production of power suitable for the connected load.

GROSS VEHICLE WEIGHT (GVW)
A manufacturer’s rating for maximum vehicle operating weight.

HEAT EXCHANGER
A vessel in which heat is transferred from one medium to another.

IDLE POWER
The system rate of doing work when only the minimum work rate is employed by the system.
IDLE TIME
The time when a system is capable of but not producing power; startup time.

INTERLOCK
A control to prove the physical state of a required condition and to furnish that proof to the safety shutoff device circuit.

LH_2 or LHY or LH_2
Abbreviation for Liquid or Cryogenic Hydrogen (**H_2**).

LOAD-FOLLOWING
A mode of operation where fuel cell power plant is generating variable power depending on the ac load demand.

LOCATION, HAZARDOUS (CLASSIFIED)
Any area or space where combustible dust, ignitable fibers, or flammable, volatile liquids, gases, vapors or mixtures are or may be present in the air in quantities sufficient to produce explosive or ignitable mixtures.

LOWER EXPLOSIVE LIMIT (LEL)
The lowest concentration of a flammable gas/vapor in air in which flame is propagated if ignited.

MEMBRANE
The separating layer in a fuel cell, which acts as electrolyte (a cation-exchanger) as well as a barrier film separating the gases in the anode and cathode compartments of the fuel cell.

MEMBRANE ELECTRODE ASSEMBLY (MEA)
Structure consisting of a proton-exchange membrane with surfaces coated with catalyst/carbon/binder layers and sandwiched by two microporous conductive layers (which function as the gas diffusion layers and current collectors).

OPEN CIRCUIT VOLTAGE
The voltage at device terminals when no appreciable current is flowing. Also known as no load voltage.

OPERATING PRESSURE
The variable pressure at which a system operates in response to changes in various operating conditions.

OPERATING PRESSURE, MAXIMUM
The steady-state gauge pressure at which a part or system normally operates. It shall not exceed the allowable working pressure, and it is usually kept at a suitable level below the setting of pressure-limiting/relieving devices to prevent their frequent functioning.

ORIFICE
The opening in an orifice cap, orifice spud or other device whereby the flow of gas is limited and through which the gas is discharged.

PASSIVE STATE
A state for the fuel cell internal components normally entered when the power plant is purged with steam, air or nitrogen, or per the manufacturer's instructions when the power plant is turned off or prior to when the power plant is turned on (initialization).

PRD
The acronym for "Pressure Relief Device". (Also see VALVE, RELIEF)

PRESSURE
The force exerted against an opposing body or the thrust distributed over a surface, expressed in weight per unit of area.

Absolute: The pressure above zero pressure, the sum of the atmospheric and gauge pressures.
Atmospheric (Standard): The pressure of the weight of air and water vapor on the surface of the earth at sea level, namely 29.92 inches (760 mm) mercury column or 14.69 pounds per square inch (101.3 kPa).
Barometric: The atmospheric pressure as determined by a barometer, usually expressed in inches (mm) of mercury.
Gauge: The pressure above atmospheric pressure.
Vacuum: Any pressure less than that exerted by the atmosphere.

PROTON EXCHANGE MEMBRANE (PEM)
A membrane with the ability to transport protons (H+) from the anode to the cathode in a fuel cell.

PURGE
To free a gas conduit of air, gas or a mixture of air and gas.

RATED POWER
The value stated on the generator nameplate. It is the power available at the output terminals of a component or piece of equipment that is operated in compliance with the manufacturer's performance specifications.

REFORMER
A vessel within which fuel gas and other gaseous recycle stream(s) (if present) are reacted with water vapor and heat, usually in the presence of a catalyst, to produce hydrogen rich gas for use within the fuel cell power plant.

REFORMATE GAS
The fluid which exits the fuel reformer and acts as feed to the fuel cell stack.

REGENERATIVE BRAKING
The recovery of some fraction of the energy normally dissipated in braking into energy that can be used or stored.

REGULATOR, PRESSURE
A device placed in a gas line for reducing, controlling and maintaining the pressure in that portion of the piping system downstream of the device.

SHUTDOWN, SAFETY
The action of shutting off all fuel and ignition energy to the gas utilization equipment by means of a safety control or controls such that restart cannot be accomplished without manual reset.

SPECIFIC GRAVITY
The ratio of the weight or mass of a given volume of a substance to that of an equal volume of another substance (air for gases, water for liquids and solids) used as a standard, both measured under the same conditions.

STANDARD ATMOSPHERE
A standard unit of atmospheric pressure, defined as that pressure exerted by a 760-millimeter column of mercury at standard gravity (980.665 centimeters per second per second) at temperature 0 degrees C.

THERMAL EFFICIENCY
Efficiency with which a power source transforms the potential heat of its fuel into work or output, expressed as the ratio of the useful work done by the power source in a given time interval to the total heat energy contained in the fuel burned during the same time interval, both work and heat being expressed in the same units.

TRD
The acronym which stands for “Temperature Relief Device”. (Also see FUSIBLE PLUG)

VALVE, RELIEF
A safety valve designed to forestall the development of a dangerous condition by relieving either pressure, temperature or vacuum.

Pressure: A valve which automatically opens and closes a relief vent, depending on whether the pressure is above or below a predetermined value.
Temperature: A valve that automatically opens and closes a relief vent, depending on whether the temperature is above or below a predetermined value.

VENTILATION
The natural or mechanical process of supplying conditioned or unconditioned air to, or removing such air from any space.

VENTILATION, PROPER
In general, the dilution of a flammable gas/vapor with air to a point safely below its lower explosive limit (LEL). As applied to this standard, a sufficient or adequate supply of fresh air and proper exhaust to outdoors or to a safe location with a sufficiently-vigorous and properly distributed air circulation to ensure that the flammable gas/vapor concentration in all parts of the enclosure will be below 25 percent of the LEL at all times.

3. Release Notes – CaFCP Emergency Response Guide

Version:	2.0
Released:	August, 2004
Note:	Controlled Document. Remove and destroy obsolete parts of the document.

CHANGE RECORD

Version	Date	Section Affected	Reason/Initiation/Documents/Remarks
1.0	Dec. 2002	All	First release
2.0	August 2004	All	What was known as the “Emergency Response Guide for Light Duty Vehicles” is now included as section 2 into the new “Emergency Response Guide” that contains fuel cell buses and (soon to include) hydrogen fueling stations, in addition to light-duty vehicles. For purposes of this Change Record the sections of the document are as follows: • Overview • Section 1 – Essential Information • Section 2 – Light Duty Fuel Cell Vehicles (based on version 1) • Section 3 – Fuel Cell Transit Buses • Section 4 – Hydrogen Fueling Stations • Section 5 – References • Section 6 – Vehicle Diagrams References to the "Emergency Response Guide for Light Duty Vehicles" version 1.0 will be abbreviated as "LD ERG"
		Overview	Added: Disclaimer, LD ERG section 1 (Preface) and 2 (California Fuel Cell Partnership) with text modifications
		Section 1	Added: LD ERG section 3 (Fuel Cell Definition) and 4 (Hydrogen Information for Fuel Cell Vehicles) with text modifications and Vehicle Identification text
		Section 2	Removed: LD ERG sections 1 (Preface), 2 (The California Fuel Cell Partnership), 3 (Fuel Cell Definition), Hydrogen Information for Fuel Cell Vehicles, 5 (Methanol), 12 (Fuel Cell Vehicle Technical Terminology), 13 (Appendix), 14 (Bibliography) and 15 (Reference Documents) Added: Vehicle Identification text

		Section 3	Added: "Fuel Cell Transit Bus ERG" and Vehicle Identification text
		Section 4	Text to be added at a later date
		Section 5	Added: LD ERG 7 (Fuel Cell Vehicle Technical Terminology), 14 (Bibliography) with added text from "Fuel Cell Transit Bus ERG" & SAE reference and 15 (Reference Documents)
		Section 6	Added: the following shutdown procedures/diagrams: DaimlerChrysler F-Cell & F-Cell Sprinter, Ford FCV, Honda FCX, Toyota FCHV, GM HydroGen3, Gillig/Ballard Fuel Cell Bus, ThunderPower Updated: The following shutdown procedures/diagrams: Nissan Xterra FCV Removed: The following shutdown procedures/ diagrams: DaimlerChrysler NECAR 4 & 5, Ford FCV 264/Focus/ P2000, Honda FCXV3/V4

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section 6
vehicle diagrams

table of contents

Section 6 – Vehicle Diagrams

1. Common ER Diagram Format

Color Key

High Voltage Wires/Components—**Orange**

- Cross-hatch (vertical) high voltage storage system (i.e., high voltage battery, super capacitor)

Low and High Pressure Hydrogen storage, lines, components—**Pink**

- Cross-hatch (45 degrees) hydrogen high pressure system (i.e., hydrogen tanks, external regulators)

Emergency Electrical/ H2 Shutoff/ 12V Battery—**Red**

Items Included in Diagram

- Vent locations and flow direction
- Hydrogen Tanks
- Hydrogen lines (low and high pressure)
- Hydrogen Regulators (if external)
- H_2 Shutoff Valve (if applicable)
- All high voltage lines
- Electric Motor
- DC-DC Converter
- Fuel Cell Stack Location

12V Battery (location of a safe place to cut 12V Lines)

- Super capacitor/ High Voltage Battery locations
- H_2 Filling neck/ lines
- Key Shut off and Master Turn off Switch Location
- PRD (Pressure Release Device) Release Location
- Identify Front and Rear Vehicle Locations
- MSDS reference of High Voltage Storage
- Methanol/Gasoline/ Sodium Borohydride Tank & Fuel Line Location

All diagrams include a picture of vehicle's actual component diagrams or representative diagrams to scale**.** A common key format is located on upper left hand portion of each diagram. Each diagram shows ***side*** view and ***top*** view.

- *Please note, the LH_2 and CH_2 MSDS Sheets are included in the References section of this document. Please reference external MSDS sheets if required.*

CaFCP ER Guide Disclaimer:

DAIMLERCHRYSLER ⇒

NECAR4A – F-CELL – F-CELL SPRINTER

FORD ⇒

FOCUS

GM ⇒

HYDROGEN3

HONDA ⇒

FCX

HYUNDAI ⇒

SANTA FE FCEV

NISSAN ⇒

XTERRA

TOYOTA ⇒

FCHV-4 – FCHV

VW ⇒

BORA HYMOTION

GILLIG/BALLARD FCB ⇒

THUNDERPOWER FCB ⇒