CALIFORNIA FUEL CELL PARTNERSHIP
CaFCP
Adam Gromis, CaFCP
Thomas H. Schucan, IEA Hydrogen Program

1. PROJECT GOALS

In January 1999, two state government agencies joined with six private sector companies to form the California Fuel Cell Partnership (CaFCP). The CaFCP is working in California to demonstrate and promote the potential for fuel cell-powered electric vehicles as a clean, safe, and practical alternative to vehicles powered by internal combustion engines. When Governor Gray Davis formally announced the CaFCP on April 20, 1999 at the State Capitol in Sacramento, California, he said, "California has teamed with some of the best automotive manufacturers and energy providers in the world, to develop an exciting new technology that is both environmentally safe and commercially viable". The CaFCP is a pioneering government-industry collaborative, cost-shared project having the goals of:

- demonstrating fuel cell technology by operating and testing vehicles on California’s roads
- demonstrating alternative fuel infrastructure technology
- exploring the path to commercialization
- increasing public awareness through a coordinated outreach plan.

More members have joined the CaFCP in the subsequent years, and at the present it includes 8 automotive companies, 4 energy providers, 2 fuel cell technology developers and 6 government agencies. In addition, eleven associate members assist in specific areas of expertise to help meet the CaFCP’s goals. The government agencies and companies participating in the CaFCP work together under a voluntary, non-binding agreement.

2. GENERAL DESCRIPTION OF PROJECT

The CaFCP is demonstrating fuel cell electric vehicles in California, along with the fueling infrastructure to serve them, under real-world conditions. A headquarters facility in West Sacramento, California, houses vehicle maintenance bays, a hydrogen fueling station and a methanol fueling station. Additional satellite fueling stations will be installed and operated in various locations in the state.

The CaFCP is exploring the path to commercializing fuel cell electric vehicles by examining such issues as fuel infrastructure requirements, vehicle and fuel safety, market incentives, and consumer acceptance. The CaFCP is increasing public awareness of fuel cell vehicle technology and the benefits it can offer through a number of outreach approaches, including exhibits, hands-on vehicle demonstrations, and presentations to schools, conferences, and community stakeholders.

Currently, the CaFCP is implementing its on-road operations program, including deployment of fueling infrastructure and the operation of 58 (as of July 2004) fuel cell vehicles on California roads over the last four years. A jointly supported, comprehensive study "Bringing Fuel Cell Vehicles to Market: Scenarios and Challenges with Fuel Alternatives" was completed in 2001 to investigate fuel cell vehicle fueling options. The CaFCP has also included methanol refueling in its history of vehicle-station interface experience.
Table 1: Full Members of the California Fuel Cell Partnership

| Fuel Cell Technology Partners | Ballard Power Systems  
|                             | UTC Fuel Cells  
| Automotive Partners         | DaimlerChrysler  
|                             | Ford Motor Company  
|                             | General Motors  
|                             | Honda  
|                             | Hyundai  
|                             | Nissan  
|                             | Toyota  
|                             | Volkswagen  
| Energy Partners             | BP  
|                             | ExxonMobil  
|                             | Shell Hydrogen  
|                             | ChevronTexaco  
| Government Partners         | California Air Resources Board  
|                             | California Energy Commission  
|                             | South Coast Air Quality Management District  
|                             | U.S. Department of Energy  
|                             | U.S. Department of Transportation  
|                             | U.S. Environmental Protection Agency  

Table 2: Associate members

| Hydrogen fuel providers | Air Products and Chemicals  
|                         | Praxair  
| Hydrogen fuel generators| Pacific Gas and Electric Company  
|                         | Proton Energy Systems  
|                         | Stuart Energy  
|                         | Ztek Corporation  
| Methanol provider       | Methanex  
| Bus transit agencies    | AC Transit (San Francisco Bay area)  
|                         | SunLine Transit Agency (Palm Springs area)  
|                         | Santa Clara Valley Transportation Authority (San Jose)  
| Academic institutions   | Institute of Transportation Studies (ITS), University of California, Davis (UC Davis)  

The present full members are listed in Table 1. They include twenty companies and organizations from around the world.

Additionally, there are eleven associate members who assist in specific areas of expertise to help meet the CaFCP’s goals, in particular with respect to hydrogen fuel infrastructure needs.
and to the CaFCP’s West Sacramento hydrogen refueling facility. A list of these associate members is given in Table 2.

All these members are voluntarily working together to achieve a common vision—preparing to commercialize the vehicle technology of the 21st Century. The CaFCP is directed by a Steering Team composed of one executive member from each of the full partners. The Steering Team meets quarterly, and provides policies and direction for the organization. An Executive Director leads the CaFCP programs through a Working Group, a team which is comprised of smaller teams focusing on vehicle operations, fuel infrastructure, interoperability issues between cars and stations, the bus program, safety, joint studies and communications. The work of the members is supported by an administrative staff on-site at the West Sacramento headquarters facility.

3. DESCRIPTION OF MAIN FACILITIES

The CaFCP has constructed a one-of-a-kind headquarters office in West Sacramento, which includes hydrogen accommodating maintenance bays for fuel cell electric vehicles, a hydrogen refueling station that can be utilized by all eight automotive members, and a large gallery space for public visitation and member gatherings and meetings.

The facility serves as an operations base for executing the CaFCP’s goals of demonstrating fuel cell vehicle technology and an alternative fuel infrastructure. The 5,000 m² (55,000 sqft), state-of-the-art facility opened in November 2000. It is shown in Figure 1.

![Figure 1: Headquarters of California Fuel Cell Partnership](image)

Eight indoor garage "bays" have been designed to house vehicles for routine servicing, repairs, and diagnostic purposes. Each of these is occupied by one of the automotive partners.

Energy members BP, ExxonMobil, Shell Hydrogen and ChevronTexaco along with associate members Air Products and Chemicals, Inc. and Praxair jointly designed and built a hydrogen fueling facility, which dispenses compressed hydrogen fuel for the vehicles.

A 7,600 l (2,000 gal.) Methanol Fueling Station was constructed and commissioned in April 2002 by the Methanol Fuel Cell Alliance of DaimlerChrysler, Ballard, BP, Statoil, BASF and Methanex.

Ballard Power Systems leases space at the facility for administrative and technical purposes.
In addition to being the operations center for executing the CaFCP's technical goals, the facility features a public gallery with exhibits, models and literature. In addition, CaFCP conducts tours that introduce visitors to fuel cell technology; an open public tour is held every fourth Friday of the month from 1:00 to 3:00 in the afternoon.

### 3.1 Vehicle Maintenance Bays

The facility is divided into 10 separate sections. There are no interior doors connecting adjacent sections. The automotive members are using eight of the sections. Each of these areas is approximately 560 m² (6000 sq ft) in size. The spaces occupied by the automotive members are being used for servicing, maintaining and testing prototype FCVs. The automotive member sections of the facility are each divided into general office space at the front and work bay/laboratory space behind the offices (approximately 400 m² or 4200 sq ft). The work bay areas have 7 m (22 ft) ceilings and are specially designed and ventilated to enable servicing of vehicles with on-board compressed or liquid hydrogen fuel tanks. Each automotive bay is equipped with 5 hydrogen sensors designed to enunciate early warnings to all occupants at detection levels of 10%, 20%, and 40% of the lower flammability limit (LFL) of hydrogen (approximately 4%, by volume, in air). At any detection level, all unnecessary electrical and heating in the bay is deactivated and the airflow increases three-fold. Although the CaFCP recognizes that these systems do not necessarily represent the extent of likely requirements that future fuel cell service facilities will be subject to, safety remains the number one priority of the CaFCP. Over the course of its four year operation, the few small hydrogen releases that have occurred were appropriately detected by the system, none of which resulted in hydrogen fires or harmful situations.

### 3.2 Hydrogen Fueling Station

The fueling station shown in Figure 2, which services all of the FCVs, is located at the back end of and detached from the operating building. It was jointly designed and constructed by six companies – Air Products, Praxair, BP, Shell, ChevronTexaco and ExxonMobil. Because of the nature of the partnership, the fueling station is co-owned by the six companies listed above, rather than being owned by the CaFCP.

![Figure 2: West Sacramento hydrogen fueling station](image)

In accordance with California regulation and existing codes for industrial hydrogen installations (namely the National Fire Protection Agency’s standards 50A and 50B), it was sited at least 23 m (75 ft) from the main building and any neighboring buildings. The CaFCP along with Air Products, coordinates the collective training of all new staff people, on proper hydrogen handling procedures and practices, and trains OEM technicians in hydrogen refueling operations for the West Sacramento station. The facility consists of a liquid hydrogen storage tank, an ambient air vaporizer, compression and high pressure gaseous hydrogen storage system; and hydrogen dispensing systems.

#### 3.2.1 Liquid Hydrogen, Vaporization, Compression and Gaseous Storage System

While the FCVs use compressed hydrogen gas as the fuel for their fuel cells, hydrogen is delivered to the CaFCP by tanker trucks as a cryogenic liquid at a temperature of about -253
°C (-423 F). The liquid hydrogen, vaporization, compression and gaseous storage system (LHVCSS) consists of the following major components:

- One 17,000 l (4500 gal.) liquid hydrogen storage tank
- Vaporizer to convert the liquid hydrogen to gaseous hydrogen
- Compressor to raise the hydrogen gas pressure to 43 MPa (6250 psi)
- Three compressed hydrogen gas storage units for storing gas pressurized to 6250 psi. They are rated at 50 MPa (7255 psi).

The liquid hydrogen storage tank is a double wall construction tank designed to contain a pressure of 1 MPa (150 psi) and tested to 1.5 MPa (225 psi). The actual working pressure of the tank is in the range of 50 psi. The station is equipped with an 8 m-(25 ft)high vent stack for the release of boil-off hydrogen from the cryogenic storage tank to prevent overpressurization.

The storage tubes store compressed hydrogen gas at 43 MPa. These tubes were designed to ASME standards (Boiler and Pressure Vessel Code) with a design pressure of 50 MPa, and tested to 1.5 times that level. As with the storage tank, the tubes contain pressure relief valves to safely release any overpressure.

### 3.2.2 Hydrogen Dispensing System

The fueling station provides three hydrogen dispensing modes:

- cryogenic liquid,
- 25 MPa (3600 psi), and or 35 MPa (5000 psi) gas.

The liquid dispensing line siphons directly off of the liquid hydrogen storage tank. The liquid line hose is completely vacuum jacketed to ensure the hydrogen stays cold and to provide optimum safety for the refueling operator. During fueling, as soon as the hydrogen in the line is cold enough to allow liquid flow, the liquid dispenser delivers hydrogen at a few liquid gallons per minute.

For dispensing gaseous hydrogen, liquid hydrogen is vaporized and compressed to 43 MPa (6250 psi) for intermediate storage in high-pressure gas cylinders. During fueling, either of two special hydrogen dispensers transfer the pressurized hydrogen to the FCV on-board storage tanks at either 25 MPa (3600 psi) or 35 MPa (5000 psi), depending upon vehicle design. The dispensers are similar to those used for compressed natural gas, except they operate at a higher pressure and are designed specifically for handling hydrogen. They utilize remote shutoff capability, vapor return lines, back-flow prevention valves, leak detection, and breakaway hoses (i.e., in case the car is driven away while the fill hose is attached, the hose and nozzle will break off and stop the flow of hydrogen). Also, the nozzles are non-interchangeable nozzles (i.e., to prevent inadvertent use of a 35 MPa dispenser with a car designed with a 25 MPa tank).

### 3.3 Methanol Fueling Station

Methanol is one of four main candidates to provide the hydrogen needed to power the FCVs of the future. Although automakers seem to be concentrating on direct hydrogen-fueled FCVs today, methanol may play a role in later years of development. GM, Ford, DaimlerChrysler, Toyota, Honda and Nissan have all demonstrated methanol-powered FCVs. In view of this significance, a methanol fueling station was constructed at the CaFCP Headquarters Facility. It is shown in Figure 3.
Trucks transported the fuel to the CaFCP, where it was transferred to an aboveground storage tank. The presence of methanol allowed the resident methanol FCVs to refuel on-site. As a result, the CaFCP and its members were able to gain experience using methanol as well as further their understanding of its viability as a future fuel source for FCVs. The station is shown in Figure 3. Its purpose has been satisfied, and it has been decommissioned as of 2004.

Methanex and the other Energy Members supplied both the hardware and the methanol for the station.

The refueling mechanism employed at the CaFCP fueling station was developed by the Swedish company IDENTIC AB. The nozzle has two key features:

- a dry break coupling connection which eliminates the possibility of exposure or the possibility of fueling anything other than a methanol fuel cell vehicle; this feature also eliminates siphoning or ignition access to the vehicle tank;
- a fiber optic level sensing mechanism, which eliminates the possibility of overfilling the vehicle.

An overview of the fueling stations installed by members of CaFCP by 2002 is shown in Table 3. Many more have been installed since then (see updated information on www.cafcp.org).

Table 3: Fuel stations installed by CaFCP members by 2002 (g=gaseous)

<table>
<thead>
<tr>
<th>Location</th>
<th>Generation/storage</th>
<th>Dispensing</th>
<th>Design capacity</th>
<th>opened</th>
</tr>
</thead>
<tbody>
<tr>
<td>West Sacramento</td>
<td>liquid hydrogen delivered/to site</td>
<td>Cryogenic liquid, 25/35 MPa (g)</td>
<td>100 kg/day</td>
<td>11/01/2000</td>
</tr>
<tr>
<td>CaFCP HQ</td>
<td>17,000 l (4,500 gal.) cryogenically stored</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>West Sacramento</td>
<td>liquid methanol delivered/to site</td>
<td>Identical no-spill, anti-siphon nozzle</td>
<td>7,600 l (2,000 gal. storage)</td>
<td>04/25/2002</td>
</tr>
<tr>
<td>CaFCP HQ</td>
<td>above ground, double/wall/storage vessel</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Richmond AC/Transit</td>
<td>Hydrogen energy station (HES)</td>
<td>25/35 MPa (g)</td>
<td>24 kg/day</td>
<td>10/30/2002</td>
</tr>
<tr>
<td></td>
<td>24 kg hydrogen generated on site</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thousand Palms Sunline Transit</td>
<td>Stuart Energy HES</td>
<td>20/25/35 MPa (g)</td>
<td>24 kg/day</td>
<td>04/01/2000</td>
</tr>
<tr>
<td></td>
<td>425 kg H2 stored</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hyrafix AT natural gas reformer</td>
<td>205 kg/day, generated on site</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
3.4 Vehicles

In the first four years of the partnership (2000-2003), 58 fuel cell passenger vehicles and 2 fuel cell buses have been in operation in California, and the members have accumulated over 306,000 km (190,000 miles) on those vehicles (all numbers as of July 2004). A line-up of hydrogen fuel cell vehicles in front of the California Fuel Cell CaFCP's hydrogen fueling station is shown in Figure 4. They are, from right to left: Honda FCXV3, Hyundai Santa Fe FCEV, DaimlerChrysler NECAR 4, Toyota FCHV-4, General Motors HydroGen 3. Short descriptions of all these vehicles are given in CaFCP's website (http://www.cafcp.com/fuel-vehl_cars.html), but a listing of all the technical specifications would exceed the scope of this case study. As an example we present more information on one of the two fuel cell buses.

An overview of the locations in development for or hosting the demonstration of hydrogen infrastructure is shown in Figure 5.
3.4.1 ThunderPower fuel cell bus

The 30-foot hybrid fuel cell bus shown in Figure 6 was developed by ThunderPower LLC, a joint venture by Thor Industries and ISE Research. It is powered by a compact but powerful 60 kW fuel cell power plant manufactured by Thor/ElDorado National; the bus chassis uses a drive system by ISE-TVI Thunderbolt™ and includes hybrid propulsion components of Siemens' ELFA™ propulsion system. The propulsion system is efficient, quiet, and reliable and can triple the fuel economy of a conventional bus. The only emissions the system produces are water and air, making the bus a zero emissions vehicle. Some of the main characteristics of the bus are summarized in Table 4.

<table>
<thead>
<tr>
<th>Table 4: ThunderPower Bus Facts</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bus Chassis</strong></td>
</tr>
<tr>
<td><strong>Model Year</strong></td>
</tr>
<tr>
<td><strong>Length/Width/Height</strong></td>
</tr>
<tr>
<td><strong>GVWR/Curb Weight</strong></td>
</tr>
<tr>
<td><strong>Seats</strong></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td><strong>Wheel Base</strong></td>
</tr>
<tr>
<td><strong>Drive System</strong></td>
</tr>
<tr>
<td><strong>Engine</strong></td>
</tr>
<tr>
<td><strong>Batteries</strong></td>
</tr>
<tr>
<td><strong>Transmission</strong></td>
</tr>
<tr>
<td><strong>Vehicle Controls</strong></td>
</tr>
<tr>
<td><strong>Brakes</strong></td>
</tr>
<tr>
<td><strong>Hydrogen Storage</strong></td>
</tr>
<tr>
<td><strong>Propulsion</strong></td>
</tr>
<tr>
<td><strong>Drive System</strong></td>
</tr>
<tr>
<td><strong>Nominal Output</strong></td>
</tr>
<tr>
<td><strong>Peak Output</strong></td>
</tr>
<tr>
<td><strong>Rated Speed</strong></td>
</tr>
<tr>
<td><strong>Storage Device</strong></td>
</tr>
<tr>
<td><strong>Battery Pack</strong></td>
</tr>
<tr>
<td><strong>Fuel</strong></td>
</tr>
</tbody>
</table>
4. INTEROPERABILITY

One of the key goals of the CaFCP is working towards vehicle and station interoperability. Since the CaFCP’s inception, engineers from various members have been working to establish informal guidelines for hydrogen dispensing, and vehicle to station connection safety which can be utilized and agreed upon by all of the FCV developers and station owners. The members see interoperability as a key to future commercialization, something which we take for granted today. When modern customers pull up to a gasoline service station, the thinking has already been done for them. Regardless of the make or model of vehicle they use, the fueling nozzle fits in to their vehicle fill port. Drivers today can even make a good number of mistakes while fueling their car, while the process remains relatively safe and the fuel, in the end, is delivered to their vehicle. With little guidance from national or international standards, the CaFCP saw early on that the vehicle-fueling interface would be a key area where collaborative work could provide great benefit to the whole industry. Member engineering work has evolved to focus on three primary aspects of interoperability: fueling protocol, station review, and hydrogen fuel quality.

One of the primary pieces of the fueling interface is the procedure by which the fuel is dispensed into the vehicle. Such a procedure would need to specify the various roles, responsibilities, and assumptions that the vehicle operator, fuel dispenser at the station, and vehicle itself must take on. In order for the fueling to be relatively ergonomic, fast, effective, and safe such a procedure must carefully balance the roles of these three players. To this end, a CaFCP Interface Guideline document was generated by member collaboration and has been in continual revision for the last four years. Working with real vehicles and real stations is one of the unique components of the CaFCP. Through the operation of actual vehicles between actual stations, all participants continue to learn and better understand the interface procedure and move closer to better functioning interoperability practices.

In addition to the fueling procedure, member engineers have been working on evaluation criteria for hydrogen fueling station performance and minimum level of safety validation. Was a commissioned station put through all of the appropriate rigors to ensure a relatively safe and sure operation? How does the dispenser perform and work with the vehicle it is fueling? How often should the performance and other aspects of the station be reviewed to ensure good
operation through its useful life? These questions and others have become very important to the CaFCP Station Review sub-team working to develop protocols that both station owners and vehicle operators can agree upon. CaFCP members hope that consensus creation of such protocols will eventually work towards a future where any FCV can drive up to any station and receive a well performed fueling under relatively safe conditions.

Finally, the CaFCP member engineers have been investigating the quality of the fuel coming through the dispenser. Fuel cells are not unlike our lungs, and prefer to take in relatively clean fuel. Fuel cell robustness may improve in the future, but for today, very high purity hydrogen is required. Certain species such as sulfur and hydrocarbons tend to degrade the platinum membranes in the systems while other possible contaminants such as nitrogen work to dilute the hydrogen fuel stream and cut fuel cell stack performance. Other issues come into play when considering the various methods in which hydrogen can be produced. Some stations may supply hydrogen which was once liquefied, others might produce it on-site through natural gas reformation or water electrolysis – each of these methods can introduce different contaminants to the fuel stream. CaFCP automotive and fuel members have been working hand in hand to balance all of these issues to arrive at consensus guidelines which can ensure acceptable use by all FCVs and fueling stations.

While the CaFCP is not a standards development organization (SDO), the valuable work being conducted here is often recognized as having a wider relevancy – thus some of the work has been incorporated into the language of standards drafted by the SDO community. The CaFCP is ultimately very interested in sharing its lesson’s learned and experiences with other organizations, once that work has proven valuable internally. Outside of the technical community the CaFCP is also interested in sharing lessons learned with other similar organizations and demonstration programs world-wide in order that key information on safety and interoperability best practice can become better understood on a global level.

5. PERFORMANCE AND OPERATIONAL EXPERIENCE

5.1 Hydrogen Fueling Operations

Fueling is performed only by staff of the members that have received training in proper hydrogen handling procedures and practices. Access to the fueling station’s compressed hydrogen dispensers is limited to authorized persons that have undergone special training and issued a Personal Identification Number.

Fueling the FCVs is a very quick and automated process, allowing a safe fill of the vehicle tank in about 4 minutes -- comparable to existing car fill-up times. The driver, or other authorized personnel, connects an electrical cable used for grounding and/or communication between the vehicle and the station. If the vehicle utilizes communication, the connection will allow the station to know the vehicle tank volume, temperature and pressure.

CaFCP conducts four types of fueling operations, depending upon the hydrogen pressure required by the vehicle and whether or not the vehicle is instrumented for temperature and pressure monitoring. Detailed sequences have been elaborated for the fueling of vehicles:

1. with pressure and temperature signals to 25 MPa or 35 MPa (3600 or 5075 psi)
2. without pressure and temperature signals to 35 MPa (5075 psi)
3. without pressure and temperature signals to 25 MPa (3600 psi)
4. and liquid fueling.

Filling with a gaseous fuel is very different from filling with a liquid fuel. The issue of greatest importance here is the safe operation of the refueling. When a gas is pushed into a volume, and becomes pressurized, the gas temperature rises within that volume. Because of material design and safety limits required by the manufacturers, the tank must not be allowed to ever heat up to levels determined unsafe. Furthermore, the outside air temperature will contribute to the overall temperature of the tank. Therefore, at the very least, the temperature of the ambient air must be taken into consideration, along with the speed at which hydrogen is pushed into the vehicle tank. When all appropriate variables are considered, refilling with hydrogen becomes a fast and safe process. The CaFCP Interface Guideline, although it is a work in
progress, seeks to coordinate all of these issues, balancing safety, performance and ease of use, for the total refueling process.

5.2 Fuel Cell Bus Program

One of the main goals of the California Fuel Cell CaFCP is to show that the technology of fuel cell-powered electric vehicles promises practical, affordable, and environmentally friendly transportation solutions for California and the world. The project includes demonstrating fuel cell electric buses under real-world operating conditions at three California transit agencies. The CaFCP Bus Team has worked to establish contracts, through the CaFCP transit agency associate members, for 7 fuel cell buses to be delivered throughout 2004 and 2005. Transit buses using fuel cell technology can potentially reduce emissions and petroleum use, while operating more quietly than a conventional diesel bus and providing excellent public exposure to the technology.

The California Air Resources Board (CARB) designated diesel emissions a toxic air contaminant in 1998. As such, transit buses will be required to further reduce tailpipe emissions. As part of this effort, CARB adopted a Transit Bus Fleet Rule and new bus emissions standards in February 2000, which includes a zero emission bus component. While the regulations do not specify the technology, some of the transit districts covered under this rule will meet these requirements utilizing hydrogen fuel cell technology. As a result, California’s transit properties are in a unique environment as a first application of fuel cell vehicle technology in the heavy-duty sector.

5.2.1 Test Sites

Three transit agencies have joined as Associate Members — AC Transit (in the San Francisco Bay Area), SunLine Transit Agency (in the Palm Springs area), and Santa Clara Valley Transportation Authority (in the South Bay Area) — to serve as initial test sites for the Bus Program. The CaFCP will demonstrate seven fuel cell electric buses in regular transit service at these three locations beginning in 2004.

- AC Transit has contracted for four Van Hool buses powered by UTC Fuel Cells and integrated by ISE Research.
- Santa Clara VTA has contracted for three Gillig buses powered by Ballard fuel cells and integrated into the chassis by Ballard Power Systems.
- SunLine will acquire, for demonstration, one of the buses contracted for by AC Transit.

The buses will operate for two years in regular transit service, carrying fare-paying customers over normal routes. From 2004-2006, the transit operators will collect and evaluate the following data from the fuel cell bus demonstration project:

- Operating and maintenance costs
- Range and fuel consumption
- Reliability of the fuel cell stack
- Service availability (hours in operation)
- Implementation/training experience
- Fleet/consumer/public acceptance
- Performance expectations
- Safety

The CaFCP seeks to collaborate with other bus demonstration programs in the United States, Europe and Japan to maximize information exchange and lessons learned.

5.2.2 Demonstrations of the ThunderPower fuel cell bus in real conditions

The ThunderPower bus was delivered to SunLine Transit Agency on August 20, 2002. Due to its exceptional performance during an initial simulated operation phase, the bus was placed into revenue service on November 6, 2002, two weeks earlier than originally planned. From November 2002 to February 2003, the prototype advanced technology bus served Palm Desert, California, which is not far from SunLine’s hometown of Thousand Palms. This is the first fuel cell bus to enter revenue service in the state of California.
Vehicle data, such as mileage, fuel consumption, ambient temperature, average speed, and driver and passenger comments have been collected since the bus started its first demonstration at SunLine Transit, followed by two further demonstrations at Los Angeles County Metropolitan Transportation Authority (LAMTA), and at Alameda-Contra Costa Transit (AC Transit), the third-largest public bus system in California, serving 13 cities in the San Francisco bay area. In all three locations, fare paying passengers have been carried on regular transit routes, and the fuel economy has been determined in comparison to parallel runs with regular buses (CNG at SunLine and LAMTA, Diesel buses at AC Transit) of the same size, running along the same routes.

All three operators collaborated with the U.S. Department of Energy's (DOE) Hydrogen, Fuel Cells & Infrastructure Technologies (HFC&IT) Program on the evaluation of the performance data gathered during this demonstration. Their aim was to help fleets make informed purchasing decisions and help researchers assess whether fuel cell vehicles can meet commercialization requirements. In Table 5 the reports of the actual test data collected in the field test at SunLine are represented in comparison with the data obtained for a conventional Diesel bus.

**Table 5: Performance data of the ThunderPower fuel cell bus in the SunLine test period**

<table>
<thead>
<tr>
<th>Parameter</th>
<th>value</th>
<th>units</th>
<th>Fuel Cell Bus</th>
<th>Diesel Bus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceleration</td>
<td>(0-30) sec</td>
<td>17</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0-50) sec</td>
<td>54</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>Top Speed</td>
<td>km/h (mph)</td>
<td>89 (55)</td>
<td>105 (65)</td>
<td></td>
</tr>
<tr>
<td>Weight</td>
<td>kg (lbs)</td>
<td>11,445 (25,180)</td>
<td>10,989 (24,175)</td>
<td></td>
</tr>
<tr>
<td>Interior Noise</td>
<td>(stopped) db(A)</td>
<td>57</td>
<td>71</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(35 mph) db(A)</td>
<td>65</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(55mph) db(A)</td>
<td>75.9</td>
<td>77</td>
<td></td>
</tr>
<tr>
<td>Mileage (gasoline equivalent)</td>
<td>l/100 km (mpg)</td>
<td>24.5 (9.6)</td>
<td>58.8 (4)</td>
<td></td>
</tr>
</tbody>
</table>

A graphical summary of the fuel cell bus operations over the AC Transit operation period is shown in Figure 7. A line graph indicates the total miles achieved by the bus since its delivery to AC Transit. The days highlighted in light red indicate incidents the bus was not available to AC Transit due to maintenance. The incidents in the light green color are incidents not counted against the total reliability such as a demonstration or attendance at a conference. During the revenue service period at AC Transit, the fuel cell bus encountered three issues that prevented it from continuing service. These issues included a failed electrical contactor, a failed hydrogen regulator, and a failed communication transceiver. Minor component failure was the cause of the downtime while the major components such as the fuel cell stack, the battery pack, cooling systems, and the drive system continued to perform. Similar conclusions have also been obtained in the other two revenue service demonstrations.
Figure 7: Fuel cell bus operational data obtained in revenue service at AC Transit

A summary of the three demonstrations is shown in Table 6. In addition to these results, the very low noise levels were found to be attractive to the driver as well as the riders. Although all three operators were pleased overall with the bus and considered the demonstration a success, they indicated a need to learn more about the reliability and durability of this type of propulsion system when used in transit buses. A longer-term demonstration would yield a better understanding of how close this technology is to commercialization. Maintenance costs were particularly identified as a significant challenge. A more detailed report “ThunderPower Fuel Cell Bus Evaluation at SunLine Transit Agency” has been published in November 2003 (see http://www.eere.energy.gov/cleancities/progs/afdc/vwbs2.cgi?8020). Details are featured on the buses’ performance during its six months of operation at SunLine, including its three months of revenue service.

Table 6: Summary of bus operation

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Units</th>
<th>SunLine</th>
<th>LAMTA</th>
<th>AC Transit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Duration</td>
<td>months</td>
<td>6</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Bus availability</td>
<td>%</td>
<td>71</td>
<td>96</td>
<td>82.5</td>
</tr>
<tr>
<td>Local specifics</td>
<td></td>
<td>summer environment high temperatures up to 45°C</td>
<td>intensive inner-city Los Angeles drive cycles</td>
<td>intensive grades in Richmond and Berkeley hills</td>
</tr>
<tr>
<td>Consumption (gasoline equiv.)</td>
<td>l/100km (mpg)</td>
<td>24 (9.6)</td>
<td>31 (7.6)</td>
<td>32 (7.3)</td>
</tr>
<tr>
<td>Consumption (relative to CNG)</td>
<td>%</td>
<td>240</td>
<td>180</td>
<td>231*</td>
</tr>
<tr>
<td>Total mileage</td>
<td>km (mi)</td>
<td>14,500 (9,000)</td>
<td>2,400 (1,500)</td>
<td>3,900 (2,430)</td>
</tr>
</tbody>
</table>

5.2.3 Funding

The government members are seeking both state and federal funds to supplement the bus demonstration program. Overall, approximately $27 million will be sought to provide assistance for buses, infrastructure and operating costs.
The California Air Resources Board has secured $5 million in state funds over two years to assist transit agencies that will purchase the buses.

The California Energy Commission has secured $1 million in state funds for infrastructure costs. AC Transit has secured $8 million in state funds from the California Transportation bill.

The U.S. Department of Energy and the Bay Area Air Quality Management District have each committed $300,000. Requests for additional funds are being pursued from the US Department of Transportation through Congressional earmarks and through fuel cell bus development programs.

6. ENVIRONMENTAL ASPECTS AND SAFETY ISSUES

As with all fuels, hydrogen has energy and must be treated with respect. The CaFCP and its members are committed to the safe and responsible use of hydrogen as a vehicle fuel. The CaFCP headquarters facility is designed and constructed with specialized safety features that will accommodate vehicles fueled with hydrogen. For example, ventilation systems prevent any possible build-up of hydrogen inside the work bays, and hydrogen detection systems notify occupants and the local fire department in the unlikely event that hydrogen reaches unsafe levels. Electrical systems are specially designed to use explosion-proof features where necessary. Two-hour firewalls separate the work bays from the office areas, and the roof is constructed of non-combustible materials. It should be noted that many of these measures are early extra precautions, and have a potential to be relaxed in the future while still providing an appropriate level of safety.

6.1 Vehicle Maintenance Bays

Since the facility was designed to accommodate indoor servicing in the eight work bays of FC vehicles with hydrogen in their on-board storage tanks, it is equipped with specialized hydrogen detection and alarm systems, in addition to the standard fire safety systems.

Hydrogen is allowed in the work bays only when it is in a vehicle driven into the bay to be serviced or stored. Otherwise, hydrogen cylinders are not permitted indoors. No FCV fueling of any kind is permitted in the work bays.

Each automotive work bay has five hydrogen detectors to provide comprehensive and redundant coverage, and a strip chart and LED screen displaying real-time hydrogen concentration at each of the five sensors. In addition, there is a master panel located in the main electrical room where the status of each bay can be monitored, plus a parallel alarm display in the main office of the facility.

In addition to the hydrogen detection system, the work bays are designed and equipped with other safety measures. These include:

- Class I, Division 2 rated electrical fixtures and equipment within 18 inches of the ceiling and from the floor
- Two-hour rated fire walls separating the work bays from the offices and adjacent work bays
- The ventilation system will continuously exhaust a minimum of 2.5 l/s per m2 of floor space (0.5 cub.ft./min/sq.ft.). This amounts to approximately .9 m3/s (1900 cub.ft./min). This is the equivalent of a complete air exchange every 50-60 minutes.
- An HVAC system that is separate from the ventilation system
- Work bay floors include grounding bars and are painted with a conductive epoxy coating to minimize static electricity
- The underside of the roof of each bay is painted with static-resistant paint to minimize a static charge, and a slight grade is implemented in the design to allow buoyant gas flow towards the back wall of the bay where it is allowed to escape into the outside air.

6.2 Hydrogen Fueling Station

The hydrogen fueling station is designed and constructed with similar attention to safety. Hydrogen detection systems notify personnel in the unlikely event of a leak, and fire suppression systems are located nearby. The aim was not only to meet or exceed all industry
standards, but also to help establish new standards for meeting the requirements of fuel cell vehicles.

The storage tank is a double wall construction, designed as an ASME-coded vessel, the world’s highest design standard for storage tanks. The inner wall is a 1.3 cm (1/2 inch) thick stainless steel plate designed to contain a pressure of 1 MPa (150 psig) and tested to 1.5 MPa (225 psig). The actual pressure of the tank is in the range of .7 MPa (100 psig). In the unlikely event that the tank pressure exceeds the normal working pressure, multiple redundant relief valves will automatically open and release the hydrogen safely through the vent stack. Hydrogen, which is much lighter than air, will quickly dissipate into the atmosphere causing no environmental or safety hazards.

The fuel dispensing system was designed using Failure Mode and Effect Analysis (FMEA) procedures and Process Hazard Analysis procedures established for the hydrogen industry. Specialists from each of the participating auto companies worked with CaFCP to develop this fuel dispensing station.

The station is monitored by an Ultra Violet/Infra Red (UV/IR) detector and equipped with alarms to detect and alert staff in the unlikely event of a hydrogen fire. The fueling station is also monitored remotely via telemetry by Air Products. If a fire is detected, a building wide alarm will sound requiring safe tenant evacuation. All staff have been trained in fuel station operation, emergency response procedures, and procedures for the safe handling of hydrogen.

7. CODES AND STANDARDS APPLICATION

Codes, standards and regulations that guided design and construction of the CaFCP hydrogen fueling station included the following:

- NFPA 50A: Standard for Gaseous Hydrogen Systems at Consumer Sites
- NFPA 50B: Standard for Liquefied Hydrogen Systems at Consumer Sites
- ASME: Boiler and Pressure Vessel Code
- NFPA 70: National Electric Code

The station is used to fill vehicles with gaseous hydrogen. The hydrogen is stored cryogenically at a temperature of -253 °C (-423 F). This system is safely and commonly used in over 1,000 industrial installations across the United States, although this is one of the first designed and utilized to fill fuel cell vehicles. Each of these facilities meets or exceeds safety standards set by the National Fire Protection Association (NFPA), the American Society of Mechanical Engineers (ASME) and other technical guidelines. The design standards can be found in the hydrogen industry website: www.HydrogenUS.com. The "Hydrogen Codes and Standards Matrix" contained in this website is a living document. It includes changes and editions from standards development organizations. More information on codes and standards is listed in the website of the US Department of energy. Some of the relevant links are:

http://www.eere.energy.gov/hydrogenandfuelcells/technical_info.html#tech_pubs_scs

7.1 Implementation of the CaFCP Hydrogen Station

From start to finish the West Sacramento hydrogen station took a little longer than a year to complete, a process largely handled in parallel with the development of the CaFCP headquarters facility. Key CaFCP members worked closely with members of the West Sacramento fire department, particularly the hazardous materials section, to work through the learning curve often associated with the implementation of such new technology. The local Air Quality Management District (or AQMD) was also notified and brought into the process; fortunately the periodic release of very small amounts of hydrogen was of little concern since hydrogen is known to have benign environmental affect. Through the course of the project, the local Hazardous Materials chief was kept well aware of progress and changes to the station and eventually signed off on the building permit and the fuel dispensing permit. Additionally, as per regulations by the state of California, the station owners were required to fill out a
Hazardous Materials Business Plan and follow guidelines to report on the status of the station on an annual basis.

7.2 Lessons learned on station implementation

Through the development of the West Sacramento station and other stations that CaFCP members have worked to implement in California, much has become understood to benefit future projects. The following key points summarize some of what has been learned:

Application of existing codes to new uses

Historically, hydrogen has been used as an industrial gas. Until new codes are developed for hydrogen as a transportation fuel, existing industrial codes must be used to establish commercial fueling stations. In certain areas, however, existing codes will not address new project needs. In this early stage of development, a lot of communication and coordination will be required between project implementers and local officials whose job it is to approve the project. Education and as much available information as can be managed, and as early as it can be delivered, will move projects forward.

Codes and standards development

In the codes and standards community, a lot of coordination and participation from government and industry together will be required across all of the appropriate codes and standards development organizations to expedite appropriate and efficient hydrogen and fuel cell codes for the future. The complex linkage between international and national codes and standards, state adoption and regulation promulgation, and local application must be balanced and understood in order for future success in the move towards appropriate guidance for officials and developers.

Public engagement

The surrounding neighborhoods and communities who call the area selected for a future hydrogen station their home are key stakeholders who may decide the fate of a given project. It is important to engage with the general public early, aiming to educate and empower communities with correct and up-to-date information about hydrogen, hydrogen fueling stations, and fuel cell vehicles. Such efforts can quickly diffuse uninformed fears and misconceptions that can otherwise thwart project success.

8. PUBLIC ACCEPTANCE

One of the major goals of the CaFCP is to increase the public awareness through a coordinated outreach plan. In addition to receiving numerous visitors, including many elected officials, at the headquarters, an important part of this plan is the organization of showcase events. As an example we include an account of the "Rally thru the Valley" 2003. We show the positive effect of events like this on the public opinion by summarizing the results of a public survey conducted in 2002.

8.1 Public survey of opinion 2002

A growing number of Californians look with favor on the development of fuel cell vehicles, according to a recent survey conducted for CaFCP. Notably, the public by a wide margin approves of government support for pre-commercial demonstration of fuel cell technology and the development of alternative fueling stations.

In a telephone survey of 600 California adults, 56% of those polled gave high marks for the continued development of fuel cell vehicles. Respondents said they expect that fuel cell vehicles will be safe, environmentally friendly, and fuel-efficient. A majority of those polled are optimistic that fuel cell cars will be available for purchase in the next five years.

"We are encouraged by the favorable response from Californians to the development of this new technology that can deliver cleaner, more efficient cars, buses and trucks worldwide," said Don Huberts, former CaFCP chairman and CEO of Shell Hydrogen.

The survey found general awareness of fuel cells had increased from less than one in four a few years ago, to about one in three Californians today. "We’re making progress, but we still
have a long way to go," said Huberts, who cautioned that expectations for market availability should be tempered by the realization that major technical, fuel and regulatory issues still must be addressed.

A majority of those contacted (55%) in the poll also said it is important for the government to support the precommercial development and demonstration of fuel cell vehicles, while only 14% said government involvement is not important.

Other findings included:

- Nearly one-third of Californians say development of new power sources such as fuel cells is the most important environmental improvement needed for automobiles, followed by the development of cleaner fuels;
- When respondents were repolled about fuel cell vehicles after the technology was described, the overall favorability jumped to 72 percent;
- No single definition of fuel cells dominates perceptions, so a “clean slate" exists for the CaFCP and other proponents.

A similar public survey has been conducted in 2003. It has shown that 4 in 10 Californians have now heard of fuel cells or hydrogen, up from 2 of 10 in the previous survey.

8.2 Rally thru the Valley

After a very successful "Rally thru the Valley 2002" the California Fuel Cell CaFCP has organized similar events in 2003 and 2004. After a checkered flag start at the California Fuel Cell CaFCP’s West Sacramento headquarters, the 2003 Road Rally traveled from the State’s Capitol to Southern California, making stops in air quality hot spots including Fresno and Bakersfield. In addition to public test drives, the fuel cell vehicles made refueling stops and held public vehicle displays in the cities of Stockton, Ripon, Merced, Tulare and Valencia. In each city, the Road Rally was greeted by public officials and scores of citizens eager to test drive the alternative fueled vehicles.

In Los Angeles, Mayor James Hahn shared his support for the Road Rally and fuel cell vehicles and Deputy Mayor Brian Williams greeted the Road Rally at the Los Angeles Zoo in Griffith Park. "Los Angeles has entered a new era of transportation by signing a two-year lease to put hydrogen-powered fuel cells into practical use," said Mayor Hahn. "Our city is playing a lead role in showing the world our commitment in addressing environmental affairs." A picture of some of the vehicles crossing the finish line in Los Angeles is shown in Figure 8.

![Figure 8: Picture of Rally thru the Valley 2003](image_url)
technology is being developed," said Firoz Rasul, chairman emeritus of Ballard Power Systems and 2004 chairman of the California Fuel Cell Partnership.

Added Catherine Dunwoody, CaFCP executive director, "More vehicles and more public rides than ever before, that is what puts this road rally into the record books." At public events in three counties, more than 800 individuals and families signed up, often to try out at least two or three of the vehicles, keeping the auto company vehicle teams busy providing several thousand test rides in the state-of-the-art hydrogen-powered cars.

The road rally kicked off at California’s newest hydrogen fuel station at the Diamond Bar headquarters of the South Coast Air Quality Management District. CaFCP also brought a mobile hydrogen fueling station to support the caravan of vehicles during the rest of the trip. In coming years, fuel cell vehicles will be able to fill up with hydrogen at designated fueling stations throughout the state. California Governor Arnold Schwarzenegger has launched the California Hydrogen Highway Network to promote broad availability of hydrogen fuel stations by 2010.

On September 17, 2004, test rides were given in the fuel cell vehicles at the Long Beach Convention Center in conjunction with the League of California Cities annual convention, and the following day public rides were given at the Orange County Fair Grounds in Costa Mesa. From there, the California Highway Patrol escorted the fuel cell cars down Pacific Coast Highway for an overnight stop at the U.S. Marine Corp’s Camp Pendleton. On Sunday, September 19, the finale was held as the vehicles arrived at noon for the final public ride and drive event.

San Diego County supervisor Ron Roberts greeted the fuel cell caravan at the finish line with the checkered flag. "Government and industry working together can make this exciting technology a reality," Roberts said, and he called on fellow San Diegans to "take advantage of this chance to drive a part of the future!"

Dr. Alan Lloyd, chairman of the California Air Resources Board and CaFCP steering team member, and Joe Kellijian, Solana Beach council member and representative of the San Diego Association of Governments, joined Roberts in kicking off the public event by taking the first fuel cell tests rides along the waterfront. Hundreds of San Diego residents and families followed their lead, lining up throughout the afternoon festivities to go for a spin in the fuel cell cars.


The path to commercializing fuel cells for transportation may be long and challenging, but the California Fuel Cell CaFCP has made a significant start in the nation's most populous state. In the first four years (1999-2003), the CaFCP has made great strides toward each of the four main project goals. Specific accomplishments include:

- Automotive members placed 55 fuel cell vehicles on California roads and highways through 2003.
- Transit agency members have placed orders for seven fuel cell buses to be delivered and begin regular transit service in 2004-2005.
- Energy members installed and operated two hydrogen-fueling stations and one methanol fueling station in California, with nine other hydrogen stations installed and operated independently by individual partners. Members are expected to install additional hydrogen-fueling stations through 2004. A key objective is to promote fuel station interoperability among all of these stations.
- CaFCP members constructed a state-of-the-art testing and demonstration facility in West Sacramento, California.
- CaFCP members jointly commissioned and completed a fuel scenarios study through an independent consultant. This study was completed in October 2001 and examined the benefits and challenges of four different fuels for fuel cell vehicles - hydrogen, methanol, gasoline and ethanol. CaFCP automotive members confirmed their first fuel cell vehicles will operate on compressed hydrogen.
- The CaFCP hosted two technology forums that helped build relationships between CaFCP members and companies that develop and market advanced technology used in fuel cell vehicles and fueling infrastructure.
• CaFCP members initiated a hydrogen vehicle facilities study to examine practical facility design for housing and maintaining hydrogen fuel cell vehicles. This study is expected to be completed in 2004.
• CaFCP members jointly developed an emergency response guide for fuel cell vehicles. This guide is used to train local fire departments and other first responders in the areas of California where fuel cell vehicles are operated. Seven emergency response agencies have been trained through October 2003.
• CaFCP members have coordinated with key stakeholder groups (e.g. environmental, academic and political leaders) and other fuel cell vehicle projects underway worldwide. Members hosted a world-wide fuel cell vehicle project forum in October 2002.
• In 2002, CaFCP members organized and participated in a 300-mile road rally that took fuel cell vehicles to local communities along California's Central Coast. In 2003, a 400-mile road rally rolled through California's Central Valley (Sacramento to Los Angeles) over three days, reaching more than 100,000 people.
• Together the CaFCP has reached over 500,000 people with information regarding fuel cell vehicle and fueling technology and the benefits it can provide. Over 12,000 people have been able to drive in a fuel cell vehicle.
• As part of its outreach program, the CaFCP distributed 2,000 fuel cell learning kits to California teachers and brought over 4,000 visitors to the headquarters facility in West Sacramento, California.
• CaFCP surveys show that awareness of fuel cell technology has increased from less than 25% of Californians knowing about fuel cells in 2000 to about four in ten Californians having heard about the technology in 2003.

Along with these specific accomplishments, the CaFCP has proven its value as a forum where the challenges of fuel cell vehicle commercialization are tackled by a diverse group of industry and government representatives with one common goal - to maximize the potential for fuel cell vehicles and fueling technology to help California and the world achieve a cleaner, more sustainable future.

10. FUTURE PLANS 2004-2007

The California Fuel Cell CaFCP members will continue working together through 2007 to promote further progress towards fuel cell vehicle commercialization. The organization will work together to move fuel cell technology for transportation to the next level – placing vehicles and fueling infrastructure into the hands of real-world users such as fleets and working closely with communities to facilitate the introduction of this new technology. The CaFCP will continue as a collaborative industry-government forum where the challenges of fuel cell vehicle commercialization can be addressed by a diverse group of representatives working toward a common goal.

As an organization the CaFCP plans to coordinate, facilitate and integrate activities that will accomplish the following goals:

Conduct Fleet Demonstrations

The CaFCP will facilitate members' placement of up to 300 fuel cell cars and buses in independent, fleet demonstration projects within the state during this phase. CaFCP members plan to focus these vehicles primarily in two main areas – the greater Los Angeles region, and the Sacramento-San Francisco area.

Conduct Fuel Demonstrations

The CaFCP members plan to construct fuel stations to support the independent demonstration projects. By concentrating vehicles and supporting refueling stations in defined regions the members will be able to focus resources more effectively in these early deployments. Fuel station interoperability – “common fit” fueling protocols – will allow all vehicles to utilize a growing network of fuel stations.
Facilitate the Path to Commercialization

The CaFCP and its members plan to work together to help prepare local communities for fuel cell vehicles and fueling by training local officials, facilitating permit processes and sharing lessons learned. The CaFCP and its members also plan to promote the development of practical codes and standards for FCVs and fueling stations, and help to obtain financial and other support where needed.

Enhance Public Awareness, Education and Support

The CaFCP plans to continue working together to raise public awareness through general outreach to public and media, consistent with pace of technology development. Increased focus will be placed on coordination with stakeholders and other fuel cell vehicle programs worldwide, sharing resource documents and lessons learned to further progress toward commercialization.

Over the four years 2004 through 2007 the CaFCP members will demonstrate that a diverse group of companies and individuals can succeed with one common goal – to maximize the potential for fuel cell vehicles and fueling technology to help California and the world achieve a cleaner, more sustainable future.

11. CONTACT INFORMATION

California Fuel Cell CaFCP
3300 Industrial Blvd., #3300
West Sacramento, CA 95691
Telephone: 001 916 371-2870
Fax: 001 916 375-2008
Email: info@cafcp.org

Many links to additional information can be found starting from the CaFCP Website (http://www.cafcp.org).