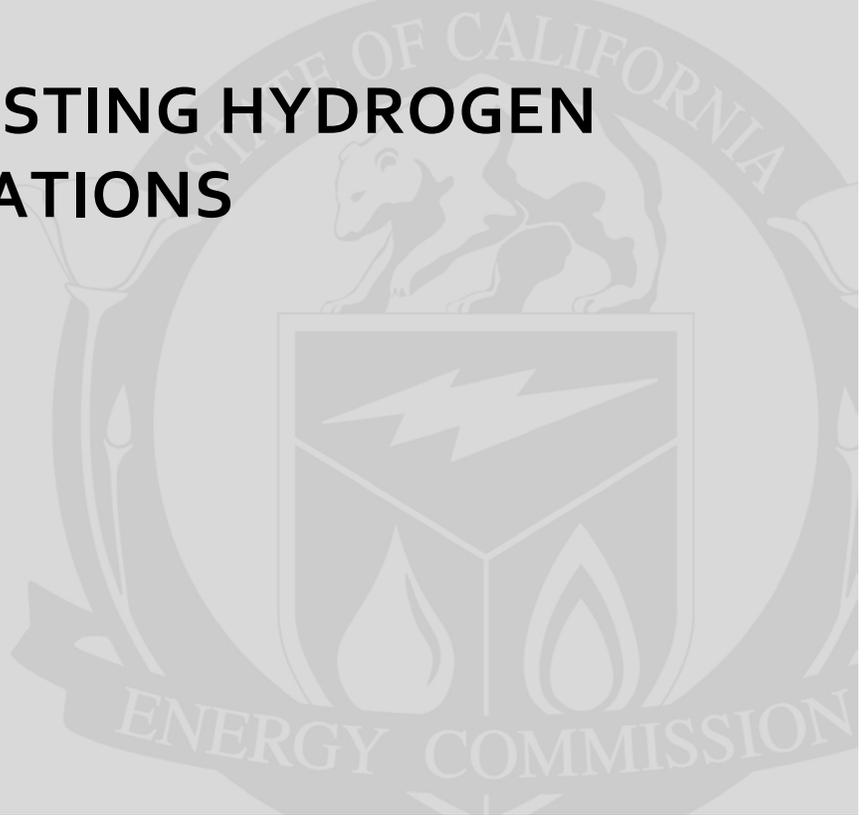


Alternative and Renewable Fuel and Vehicle Technology Program

PROJECT REPORT

STATUS OF EXISTING HYDROGEN REFUELING STATIONS



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PREFACE

Assembly Bill 118 (Núñez, Chapter 750, Statutes of 2007), created the Alternative and Renewable Fuel and Vehicle Technology (ARFVT) Program. The statute, subsequently amended by Assembly Bill 109 (Núñez, Chapter 313, Statutes of 2008), Assembly Bill 1314 (Wieckowski, Chapter 487, Statutes of 2011), and Assembly Bill 8 (Perea, Chapter 401, Statutes of 2013), authorizes the California Energy Commission (Energy Commission) to develop and deploy alternative and renewable fuels and advanced transportation technologies to help attain the state's climate change policies.

The *2013-2014 Investment Plan Update* recognized, "To prepare for the early commercial launch of fuel cell vehicles in California, the Energy Commission is committed to funding sufficient hydrogen refueling stations in key areas. Without a guarantee of sufficient infrastructure, automakers will be unable to commit significant resources to the production of FCEVs. Given the high upfront cost of hydrogen refueling infrastructure, public funding for these stations is necessary until FCEVs can support their growth and continued operation."

The California Air Resources Board issued its *Annual Evaluation of Fuel Cell Electric Vehicle Deployment and Hydrogen Fuel Station Network Development* report in June 2014, indicating the number of hydrogen-fueled vehicles in California will increase to roughly 6,650 in 2017 and 18,465 in 2020. Adequate refueling infrastructure must be available for these vehicles to launch successfully into the market and contribute to the state's long-term GHG emission reduction targets. Overcoming this barrier is one of the central actions identified in the Governor's *2012 ZEV Action Plan*.

The Energy Commission understands that existing hydrogen station upgrades/refurbishments are needed for the existing hydrogen refueling infrastructure, and these existing stations are suitably zoned and permitted, which increases a station operator's ability to successfully complete upgrade projects within a short time frame.

ABSTRACT

The California Energy Commission awarded a contract to the South Coast Air Quality Management District to develop, release, and manage a competitive request for proposals; develop agreements; and fund companies that refurbish and upgrade existing, publicly accessible hydrogen refueling stations. This report assessed the current state of selected hydrogen refueling stations that may be candidates for upgrades, including increased capacity to address projected fuel cell vehicle growth, higher pressure 700 bar (10,000 pounds per square inch [psi]) vs. 350 bar (5,000 psi) onboard vehicle storage systems, point-of-sale systems, and other related equipment. Interviews and site visits were conducted with the owners, operators, and technology suppliers of existing hydrogen refueling stations to gather information and document the design, equipment, operating and maintenance experience, and potential for upgrades for each station. The existing hydrogen refueling stations that were included in this study are listed in the executive summary. The California Energy Commission and the South Coast Air Quality Management District will draw on this report in evaluating competitive bids submitted for refurbishment and upgrades to existing, publicly accessible hydrogen refueling stations.

Keywords: California Energy Commission, fuel cell vehicles, fuel dispensers, hydrogen, hydrogen refueling stations, hydrogen refueling infrastructure, public access, upgrades

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EXECUTIVE SUMMARY

Overview

The California Energy Commission, through a contract with the South Coast Air Quality Management District, intends to provide funds for refurbishing and upgrading existing, publicly accessible hydrogen refueling stations. When the upgrades are completed in 2015, these stations will contribute significantly to the hydrogen refueling infrastructure network in locations supported by the Energy Commission.

This report summarizes the current state of existing hydrogen refueling stations within California. A brief history, average amount of hydrogen dispensed, and the condition and specifications of existing equipment are addressed for each station. The existing hydrogen refueling stations that were included in this study are listed in Table 1.

Table 1: Existing Hydrogen Refueling Stations

Host Site	City
AC Transit	Emeryville
Chevron - Harbor City	Harbor City/Long Beach
City of Burbank	Burbank
City of Riverside	Riverside
City of Santa Ana	Santa Ana
City of Santa Monica	Santa Monica
CSULA	Los Angeles
LAX	Los Angeles
Orange County Sanitation District	Fountain Valley
SCAQMD	Diamond Bar
Shell - Newport Beach	Newport Beach
Shell - Santa Monica Blvd	Los Angeles
Shell - Torrance Pipeline	Torrance
SunLine Transit	Thousand Palms
UC Irvine	Irvine

Method

The following method was used for this study:

- Existing hydrogen refueling stations were identified by the South Coast Air Quality Management District, the California Air Resources Board, and the California Energy Commission. TechCompass visited the sites, acting on behalf of the State of California, through a subcontract with South Coast Air Quality Management District, to document the state of these stations and identify the need for potential upgrades.

- TechCompass interviewed owners, operators, and/or technology providers responsible for the various hydrogen refueling stations. The interviews focused on past operating experience of the hydrogen refueling stations and identified the potential need for any equipment upgrades.
- Equipment needs were identified for the potential upgrades of each site to guide the South Coast Air Quality Management District in managing the request for proposals. The competitive request for proposals included applications with detailed specifications and costs for proposed station upgrades.
- TechCompass prepared a concise report summarizing the findings of the hydrogen refueling site assessments, including public accessibility.

Findings

Some general observations are offered based on the interviews, site visits, and follow-up research that were conducted.

- Regarding the 14 Southern California hydrogen stations visited, no two had identical designs and installations. Only the stations in Riverside and Santa Monica were similar.
- Most of the existing stations represent early generation design and technology. The operation of these stations has provided valuable lessons to technology developers, owners/operators, automakers, fuel cell vehicle drivers, first responders, code enforcement officials, and the public. These early generation designs and technologies are not easily upgraded; however, the lessons learned from them over the last few years have resulted in significant technical evolution.
- During the study, several hydrogen stations were down and not available for refueling vehicles. The problems ranged from computer “glitches” that were easily rectified in a matter of hours to equipment failures that necessitated extended shutdown times (several weeks for one station).
- A common theme for all of the owner/operators was their need for a “Weights and Measures” certified, point-of-sale hydrogen dispenser. There are strong interest and demand by the owner/operators for such a system so that they can begin selling the hydrogen they provide to users and start recovering some of their costs. Reportedly, without such a dispenser, it is difficult to create a viable business model.
- The site assessment also included a review of signage. The assessment determined that simple street signs would help guide drivers to hydrogen refueling stations, as well as help educate the public about the growing

availability and use of hydrogen as a transportation fuel. A good example of effective signage included Riverside's signs that direct drivers to an alternative fuel station.

The following sections provide a detailed assessment of the current state of selected hydrogen refueling stations that may be candidates for upgrades.

CHAPTER 1:

Introduction

The California Energy Commission provided a \$6,690,828 contract to South Coast Air Quality Management District (SCAQMD) to assess the needs at existing hydrogen refueling stations, seek competitive bids for upgrade and refurbishment of existing dispensing equipment, and test and evaluate the completed upgrades. The Energy Commission believes upgrades are needed to bring existing hydrogen refueling stations up to minimum standards needed to dispense hydrogen by the kilogram and to ensure a reliable supply of hydrogen fuel in areas of planned fuel cell electric vehicle (FCEV) deployment.

In accordance with the contract scope, SCAQMD released Request for Proposals (RFP) #P2014-09 and received nine proposals totaling \$15,942,433.05. Proposals were received from station developers to upgrade existing hydrogen refueling stations at Los Angeles International Airport (LAX); Torrance; Fountain Valley; California State University, Los Angeles, campus; Thousand Palms (two proposals); Harbor City; and Burbank. The ninth proposal received was for a mobile refueler.

Staff members from the Energy Commission, Air Resources Board, and SCAQMD met in January 2014 to analyze and score the proposals. SCAQMD staff applied an iterative negotiation process with applicants that substantially reduced the bid prices. Based on the high scores for the evaluation criteria, the team recommended funding the following five proposed projects:

1. **The Shell Torrance station** (2051 West 190th St., Torrance) – This station has been open to the public since May 2011 and is capable of refueling any FCEV at 350 bar or 700 bar. It is supplied by pipeline-fed hydrogen from the adjacent Air Products hydrogen production facility. The current capacity of the station is about 50 kg/day and would increase to 100-200 kg/day after upgrades.
2. **The LAX station** (10400 Aviation Blvd., Los Angeles) – This station was built in January 2009 to refuel General Motors' (GM) FCEVs. The current capacity of the station is roughly 30 kg/day and would increase to 200kg/day, be open to the public, and be able to refuel any type of FCEV after upgrades. Note: Subsequent to this project report, this station will be moved to a nearby address.
3. **The Burbank station** (145 West Verdugo Ave., Burbank) – This station was built in 2008 and refuels primarily Daimler and GM FCEVs under contractual agreements. The current capacity of the station is about 100 kg/day and would remain at 100kg/day, be open to the public, and be able to refuel any type of FCEV after upgrades.

4. **The Harbor City station** (25800 South Western Ave., Los Angeles) – This station opened for public use in April 2013 but needs a larger compressor and a newer technology point-of-sale dispenser to dispense hydrogen by the kilogram and to ensure a reliable supply of hydrogen fuel. The current capacity of the station is nearly 100 kg/day and would remain at 100 kg/day after upgrades.

5. **The SunLine Transit station** (32-505 Harry Oliver Trail, Thousand Palms) – This station opened in April 2000 and is still fully operational, but is used primarily to refuel two fuel cell buses. Upgrades would allow FCEVs to refuel at the higher 700 bar pressure, giving them the range needed to travel to other hydrogen stations in the network. The current capacity of the station is about 50 kg/day and would increase to 200 kg/day after upgrades.

CHAPTER 2:

AC Transit – Emeryville

Location

1172 45th Street
Emeryville, CA 94608

Station Overview

AC Transit operates a fleet of 12 fuel cell buses out of its Emeryville site. Its first fuel cell bus began operation in August 2010, with all 12 in service by October 2011. The fleet has accumulated about 500,000 miles.

The Emeryville hydrogen refueling station was installed by Linde, LLC. Liquid hydrogen is delivered weekly, with 9,000 gallons stored on site to support the fuel cell buses. The cryogenic liquid hydrogen is vaporized and compressed for use by two Linde Ionic Compressors (IC50). The Emeryville site stores 360 kg of hydrogen as a gas at 480 bar in high-pressure cylinders. This compressed hydrogen is dispensed to the fuel cell buses through two 350 bar dispensers.

In addition, the site has an electrolyzer that produces up to 65 kg/day of hydrogen. The electricity used by the electrolyzer is offset by renewable electricity produced from solar panels located at the station.

Since April 2012, the Emeryville site has had a publicly accessible street-side dispenser to support light-duty hydrogen fuel cell vehicles with both 350 bar and 700 bar hoses. For the street-side dispenser, 28 kg of hydrogen is compressed and stored at 900 bar using two Linde mechanical compressors (MF90). A -40° C chiller is used to enable fast filling to 700 bar.

Operating Experience

AC Transit has an operation and maintenance service contract with Linde. The Emeryville station refuels 12 fuel cell buses per day and up to 20 light-duty vehicles per day. Refueling time to fill is 8-20 minutes per bus, depending on storage pressure at the time the fill is initiated for buses. Light-duty vehicle fill times are 4-8 minutes.

The AC Transit-Emeryville hydrogen station had a valve failure on May 4, 2012. The valve that failed was a pressure relief device on the compressed hydrogen storage system. The failure caused the release of 300 kg of hydrogen, which ignited at the exit of the vent pipe and burned for 2.5 hours, resulting in an evacuation of the surrounding area. The Emeryville Fire Department eventually allowed technicians to enter the station and stop the flow of gas, ending the event. Following a comprehensive review

completed in February 2013, the cause identified was that materials incompatible with hydrogen were used in the construction of the valve.

AC Transit conducted a comprehensive review of all the system components and trained AC Transit staff, as well as local first responders regarding hydrogen safety and the design of the station. In addition, AC Transit conducted comprehensive public education and outreach to address concerns and perceptions that may have resulted from the valve failure. The Emeryville hydrogen station has been recommissioned, and all refueling operations restarted in May 2013.

Potential Future Upgrades

Since the Emeryville station has been recently recommissioned, the only upgrade that may be warranted would be an increase in hydrogen storage capacity to accommodate additional demand.

Figure 1: AC Transit – Emeryville Station



Photo Credit: Energy Commission Staff

Liquid hydrogen storage



Photo Credit: Energy Commission Staff

Dispenser island and canopy

CHAPTER 3:

Chevron – Harbor City

Location

25800 S. Western Avenue
Harbor City, CA 90710

Station Overview

The Chevron – Harbor City station was designed and built and is maintained by Air Products and Chemicals, Inc. (Air Products). The hydrogen refueling system was installed and opened for public use in April 2013.

Gaseous hydrogen is supplied to the station in high-pressure trailers from Air Products. The trailers store 230 kg of hydrogen at 517 bar, and a booster compressor is used to fill permanently mounted tanks that can store 64 kg of hydrogen at 965 bar. The station is equipped with a dispenser with two nozzles, one for 350 bar and one for 700 bar refueling. The dispenser is installed on one of the fuel islands adjacent to gasoline dispensers. The supply capacity is 100 kg/day.

Operating Experience

Refueling agreements are in place with Honda, Daimler, and Vision Motor Corp., and users are given a personal identification number (PIN) that is required to use the hydrogen refueling station. Based on California Air Resources Board (ARB) reports, other fuel cell vehicle manufacturers are working on refueling agreements. Also, 33 fills were reported by ARB for April 2013, or an average of 1 fill per day. Should the site be selected for upgrades, it will be made publicly accessible.

Potential Future Upgrades

Future upgrades may be warranted for the cooling system and dispenser. Air Products reports that the lessons from the Chevron-Harbor City design/build effort have been used and integrated into a robust product approach for future hydrogen refueling stations.

Figure 2: Chevron – Harbor City Station



Photo Credit: TechCompass

Dispenser



Photo Credit: TechCompass

Storage trailer



Photo Credit: TechCompass

Equipment layout



Photo Credit: TechCompass

Station layout

CHAPTER 4:

City of Burbank

Location

145 W. Verdugo Avenue
Burbank, CA 91510

Station Overview

The city of Burbank Station was built by British Petroleum (BP) in 2008 as one of the most advanced hydrogen stations to date. It has a self-contained natural gas reformer system with a 108 kg-per-day steam-reforming capacity and 224 kg of high-pressure storage at 435 bar. The station can dispense at 350 bar using the high-pressure storage and 700 bar using a hydraulic booster compressor. BP eventually decided to stop operating the station in 2009, and the current owner and operator of the station is Hydrogen Frontier. With cost-sharing support from the South Coast Air Quality Management District (SCAQMD), Hydrogen Frontier maintains the reformer, and the station has been dispensing hydrogen.

The H2GEN HGM2000 natural gas reformer produces 99.99 percent pure hydrogen from 60 psi pipeline natural gas after purification through a 200 psi pressure swing adsorption system. The hydrogen is compressed for storage to 435 bar using two 2.1 kg/hr. PDC Machines, Inc. diaphragm compressors. If a vehicle using the 350 bar pump pulls into the station, the hydrogen from the storage tanks is dispensed directly into the vehicle. When there is a vehicle requiring 700 bar, the hydrogen from the storage tanks is sent to the Air Products S700 hydraulic booster compressor that can discharge pressure up to 875 bar. The booster compressor capacity is 50 kg per hr., or 0.8 kg per minute.

After leaving the compressor, the hydrogen for 700 bar refueling enters a closed-loop cooling system to chill the hydrogen to -20° C before it is dispensed into the vehicle. With the chiller, the fill rate is 1.75 kg per minute, while without the chiller it is 0.25 kg per minute. The hydrogen is dispensed through one of two nozzles on the dispenser.

Operating Experience

With Hydrogen Frontier operating the Burbank station, the reformer is operational, and the station refuels primarily Daimler and GM fuel cell vehicles under contractual agreements. To minimize thermal stresses and to avoid the long startup time to achieve operating temperatures, the reformer operates continuously at about 55 percent load, regardless of refueling demand. Hydrogen Frontier monitors the operation of the station continuously and provides on-call technical support that minimizes station down time.

This level of reformer operation and station maintenance is conducted with funding support from the SCAQMD.

Hydrogen Frontier reports that, on average over the last 13 months, the Burbank station refueled 41 fuel cell vehicles per month (350 and 700 bar combined) delivering 120 kg hydrogen per month. During that time, the peak month had 76 fills (350 and 700 bar combined) delivering 220 kg of hydrogen.

Potential Future Upgrades

The Burbank station, with its 5+ year-old reformer system, requires substantial operating and maintenance support. Hydrogen Frontier is discussing continued funding support with the SCAQMD.

In addition, the aging station could benefit from equipment upgrades, including:

- Precooling system (for Class A fills).
- Dispenser 70 & 35 Mpa (POS capable).
- PDC compressor repair.
- Fire alarm system replacement (new).
- Hydropac upgrade control system.
- Uninterruptable power supply.
- New power meters (data collection).
- New cameras and recording system (security).
- Awning over dispenser.
- Fencing improvements.

Figure 3: City of Burbank Station



Photo Credit: TechCompass

Dispenser



Photo Credit: TechCompass

Chiller for dispenser



Photo Credit: TechCompass

Reformer



Photo Credit: TechCompass

Diaphragm compressor



Photo Credit: TechCompass

Water treatment



Photo Credit: TechCompass

Booster compressor



Photo Credit: TechCompass

Hydrogen storage

CHAPTER 5:

City of Riverside

Location

8095 Lincoln Avenue
Riverside, CA 92504

Station Overview

The City of Riverside was part of the SCAQMD's Five Cities Program – Demonstrating Hydrogen Vehicles and Infrastructure. The SCAQMD awarded contracts to Air Products to install and demonstrate hydrogen refueling stations in Burbank, Ontario, Riverside, Santa Ana, and Santa Monica. The hydrogen vehicles funded by the Five Cities Program were 30 Toyota Priuses, which were converted, tested, certified, and maintained by Quantum Fuel Systems Technologies Worldwide, Inc. This station opened in January 2006.

The Riverside hydrogen refueling station is open to public use and is an integral part of an alternative fueling station that includes dispensers for compressed natural gas (CNG) and liquefied propane gas (LPG). The main restriction set by Riverside is that a user needs to attend hydrogen refueling safety and operational training before operating the dispenser. After users complete the training, they are supplied with a PIN, which the user must enter to operate the hydrogen dispenser.

The city of Riverside operates and manages the station with equipment and maintenance provided by Air Products.

The Riverside station has on-site hydrogen generation by a Proton Energy Systems HOGEN (R) 200 electrolyzer with a production capacity of 12 kg/day. The HOGEN 200 system includes a water cooling system and control panel. A reverse osmosis water treatment system is used to prevent formation of minerals on the surface of the proton membranes. An Air Products Series 200 diaphragm compressor compresses the hydrogen for storage in three storage tanks that have a combined storage capacity of 60 kg at 536 bar. The hydrogen is dispensed through an Air Products dispenser at a fill pressure of 350 bar.

Operating Experience

The Riverside station experiences limited use following the completion of the Five Cities Program. Infrequently, Riverside provides fuel to hydrogen fuel cell buses during transport. The electrolyzer, compressors, storage, and dispensers are all operational; however, two of the three stacks in the proton electrolyzer need to be replaced.

Furthermore, the LED user display of the flame detector system needs to be replaced due to damage from sun overexposure.

Potential Future Upgrades

Riverside is interested in upgrading its hydrogen refueling capabilities, and the site is well-located near the Riverside Freeway (State Highway 91). Since this station uses early generation (7+ year old) technology, upgrading may necessitate complete replacement of the equipment. It is limited to 350 bar refueling and needs upgrading to the 700 bar standard. Little, if any, of the existing equipment can be reused. Riverside has space to accommodate these upgrades and is willing to continue operating the facility. The city would also like to incorporate an alternative fuel information center and install a canopy over the alternative fuel island, ideally with solar panels to run the equipment.

Upgrading with the latest hydrogen refueling technology would include a small boost compressor, high-pressure ground storage for cascade fueling, a cooling and dispensing system to meet the requirements of SAE TIR-J2601, and a California Department of Food and Agriculture, Division of Measurement Standards-approved POS dispenser.

Figure 4: City of Riverside Station



Photo Credit: TechCompass

Hydrogen storage dispenser



Photo Credit: TechCompass

Hydrogen storage compressor, storage, electrolyzer layout



Photo Credit: TechCompass

Controls and water treatment



Photo Credit: TechCompass

Compressor



Photo Credit: TechCompass

Storage

CHAPTER 6:

City of Santa Ana

Location

215 S. Center Street
Santa Ana, CA 92703

Station Overview

The City of Santa Ana was part of the SCAQMD's Five Cities Program – Demonstrating Hydrogen Vehicles and Infrastructure.

For Santa Ana, Air Products provided its hydrogen fueling services. The basis for these services is Air Products' mobile hydrogen refueler, which integrates a compressed hydrogen supply with a self-contained dispenser into a trailer. The mobile refueler used in Santa Ana is about 26 ft. long and 8 ft. wide, which based on Air Products information, stores up to 150 kg of compressed hydrogen at 480 bar. The system dispenses to 350 bar using a programmable logic controller to accurately manage vehicle refueling. The vehicle interface is SAE J2600-compliant.

The mobile refueler is remotely monitored by Air Products using wireless telemetry. This allows Air Products to monitor the fuel level and exchange the "empty" mobile refueler with a "full" unit when needed. Air Products also maintains the mobile refueler and ancillary equipment.

Operating Experience

Santa Ana city officials reported no issues with the Air Products system and appreciated the ease of the hydrogen mobile refueler operation and the no-fuss swapping of empty refuelers. Santa Ana has only two of the original five hydrogen Priuses still in use. The limited range of the vehicles, reportedly fewer than 40 miles, limited the use of the Priuses in the city fleet. The two remaining vehicles are used primarily as "station cars" for city employees that commute by train and then use the hydrogen Priuses for travel between the train station and city facilities.

Potential Future Upgrades

The City of Santa Ana has an interest in alternative fuel vehicles, including hydrogen. It would consider procuring hydrogen vehicles when they become available at a reasonable cost. The location of the mobile refueler is behind the entrance gate to the city yard and, although the City of Santa Ana welcomes the public to use the hydrogen refueler, it is not a freely accessible site. Santa Ana plans to install a publicly accessible

LPG dispenser and would consider a similar arrangement for hydrogen dispensing, if a solution with a compact footprint could be identified.

Figure 5: City of Santa Ana Station



Photo Credit: TechCompass

Mobile refueler adjacent to CNG



Photo Credit: TechCompass

Integrated dispenser



Photo Credit: TechCompass

Mobile refueler (front)



Photo Credit: TechCompass

Mobile refueler (back)

CHAPTER 7:

City of Santa Monica

Location

2500 Michigan Avenue
Santa Monica, CA 90404

Station Overview

The City of Santa Monica was part of the SCAQMD's Five Cities Program – Demonstrating Hydrogen Vehicles and Infrastructure. The Santa Monica station became operational in June 2006. The hydrogen station usually dispenses hydrogen during business hours when the Priuses are refueled for city use.

The City of Santa Monica hydrogen station is located in a city yard, with the dispenser adjacent to a CNG dispenser on the same refueling island. The Santa Monica station features on-site hydrogen generation using a Proton Energy Systems HOGEN (R) 200 electrolyzer. The HOGEN 200 system has a hydrogen production capacity of 12 kg/day. The HOGEN 200 system includes a water cooling system and control panel. A reverse osmosis water treatment system is used to prevent mineral formation on the surface of the proton membranes. An Air Products Series 200 diaphragm compressor compresses the hydrogen to 480 bar for storage in three storage tanks that have a combined storage capacity of 52.5 kg. The hydrogen is dispensed through an Air Products dispenser at a filling pressure of 350 bar.

Operating Experience

This facility is not open to the public. The hydrogen dispenser requires a key code to be entered before refueling.

The electrolyzer, compressor, storage, and dispenser are all operational and about 7 years old. Air Products conducts periodic maintenance visits to test and confirm the operating conditions of the facility equipment. Should the site be selected for upgrades, it would be made publicly accessible.

Potential Future Upgrades

The City of Santa Monica is still interested in continuing the use of hydrogen fuel but has no hydrogen vehicles. The city's five hydrogen Priuses were removed from service at the completion of the Five Cities Program; however, Santa Monica officials have indicated that they would procure and use new hydrogen vehicles when they become available. They would like to maintain the availability of a hydrogen refueling station; however, Santa Monica plans to relocate its hydrogen dispenser and CNG dispensers to another part of the city yard. If funding is provided to upgrade this hydrogen station facility, the city is willing to maintain the station. Since the station is in good working

order, it does not require any new equipment except for an upgraded hydrogen fuel dispenser and associated infrastructure to fuel newer hydrogen vehicles at 700 bar. Should the station be selected for upgrades, paid for with public funding, it would be made publicly accessible.

The ARCO station at 1819 Cloverfield Blvd., around the corner from the Santa Monica City yard, is scheduled to have a retail hydrogen station added by Air Products as part of the Energy Commission's program. When that publicly accessible retail station becomes operational, it will greatly reduce the utility of the City of Santa Monica station as part of the hydrogen refueling network.

Figure 6: City of Santa Monica Station



Photo Credit: TechCompass

Dispenser



Photo Credit: TechCompass

Compressed Hydrogen Storage



Photo Credit: TechCompass

Compressor



Photo Credit: TechCompass

Controls and water treatment systems



Photo Credit: TechCompass

Electrolyzer

CHAPTER 8:

California State University, Los Angeles

Location

5151 State University Drive
Los Angeles, CA 90032

Station Overview

The CSULA hydrogen refueling station has been in the conceptual and construction phases for nearly 10 years and is finally nearing operational status. Delays have been encountered in the commissioning of the station, due to design issues. The station is constructed to supply both 350 bar and 700 bar Type B filling capabilities, but lack of a buffer tank produces an unacceptable hydrogen pulsation during fills. There is general consensus that incorporation of a buffer tank(s) between the station compressors and dispenser unit will rectify this concern.

The facility is composed of the following major components:

- Electrolyzer hydrogen generator manufactured by Hydrogenics rated at 60 kg/day
- Hydrogen compressors
 - PDC diaphragm, rated at 25 Nm³/hr. and 6,000 psig max (350 bar side)
 - 2 Hydro-Pac Intensifiers, rated at 230 sf³/min (combined) and 12,000 psig max.
- Three hydrogen storage tanks manufactured by CPI providing up to 60 kg total storage at 350 bar (7000 psig safety reliefs)
- Hydrogen chiller manufactured by Quantum Fuel Systems Technologies Worldwide, Inc. (-20° C to enable Class B fills)
- Hydrogen fuel dispenser, including card reader, manufactured by Quantum Fuel Systems Technologies Worldwide, Inc.
- Utility support equipment that includes a process cooling water system for removing waste heat from the compressors, an instrument air compressor to provide air for air-actuated valves, and a water treatment system to produce deionized water as electrolyzer water feedstock.

Operating Experience

Progress on the pulsation control buffer tank(s) has been stalled due to a contract dispute between the university and the design-builder over responsibility for the buffer tank and other matters. During this period, the 350 and 700 bar sides of the system have not been fully operational. Work is underway to recommission the station by performing essential repairs and preventative maintenance on the station compressors,

dispenser and other systems. The goal is to restore 350 bar filling capabilities and then install the buffer tank(s) during the next several months. Engineering and procurement of the buffer tank(s) have not yet been completed, and the costs are, therefore, undetermined.

Commissioning of the CSULA station is in progress. Initial fills of a hydrogen Prius to 350 bar were successfully completed during the week of September 9, 2013.

Potential Future Upgrades

Material support in the following areas may have the greatest effect on station availability and performance:

- Pulsation buffer tank(s) design and installation. Although the exact cost has yet to be determined, this improvement will have a significant effect on station performance, particularly during 700-bar fills. It is uncertain whether this may provide an opportunity for expanding station storage capability in a “two-for-one” opportunity.
- Additional storage volume. Additional 350 and/or 700 bar storage volumes to advance the station toward future Type A capabilities.
- Upgraded hydrogen chiller capability (from -20° C to -40° C or greater) to advance the station toward Type A fill capabilities.
- Upgraded dispenser capability to advance toward Type A capabilities.
- Operations and maintenance assistance could improve station reliability and availability. Possible areas could include:
 - Parts inventory supply (for example, high-pressure fittings, filters, check and safety valves, part refurbishment/overhaul kits, calibration equipment and supplies, and lubricant stocks).
 - Weights and measures assistance.
 - Technical training for personnel.

Figure 7: California State University, Los Angeles, Station



Photo Credit: TechCompass

CSULA Station



Photo Credit: TechCompass

Booster compressors



Photo Credit: TechCompass

Dispenser



Photo Credit: TechCompass

Electrolyzer



Photo Credit: TechCompass

Fuel island



Photo Credit: TechCompass

Diaphragm compressor

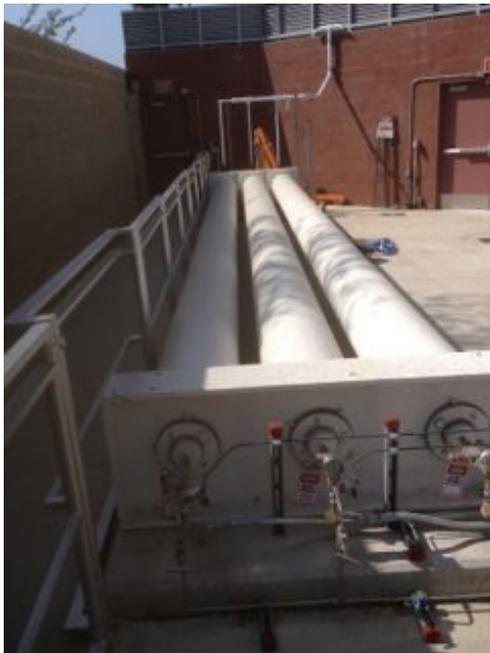


Photo Credit: TechCompass

Hydrogen storage



Photo Credit: TechCompass

Hydrogen chiller

CHAPTER 9:

Los Angeles International Airport (LAX)

Location

10400 Aviation Blvd.
Los Angeles, CA 90045

Station Overview

The LAX station operates 24 hours a day, 7 days a week, and is one of the stations dispensing to GM hydrogen vehicles in Southern California. The station has hydrogen delivered by tube trailer and is dispensed at 700 bar. The station is collocated with a Clean Energy natural gas refueling station at the corner of Aviation Blvd and 104th Street. The station is restricted to GM vehicles and, as of 2012, Daimler fuel cell vehicles.

The station began operations in January 2009. Hydrogen is supplied by Praxair in tube trailers, with the storage capacity dependent on the size of the tube trailer delivered to the site. The station also has medium- and high-pressure storage arranged as a cascade for refueling. The medium-pressure storage has a capacity of 32 kg at 420 bar, and the high-pressure vessels have a capacity of 10 kg at 950 bar. The hydrogen from the tube trailers is compressed using three Maximator DLE 75-2 pneumatic booster compressors to either the medium- or high-pressure storage.

A Sullair 3000 40 hp air compressor supplies the compressed air to drive the pneumatic compressors. Liquid nitrogen, which is normally used in the chiller to precool the hydrogen before dispensing, can be used as a backup if the air compressor goes down. In that event, nitrogen would be vaporized in an ambient air vaporizer to supply the pressurized gas necessary to operate the pneumatic boosters. The three booster compressors refill and pressurize the vessels and can operate as refueling occurs in other banks. The hydrogen is precooled to -35° C using the liquid nitrogen chiller to enable faster refueling. The hydrogen is dispensed through an Air Liquide 700 bar hydrogen fast-fill dispenser using a TK-17 WEH nozzle with infrared communication. The dispenser fill rate with the chiller is about 0.75 to 0.9 kg per minute, with a protocol optimized for GM fuel cell vehicles.

Operating Experience

The station is owned and operated by GM, which prepared the location, managed the permitting, and paid for the equipment. Air Liquide supplied the equipment and designed the station. In the near term, GM intends to turn over ownership and operation of the station to Air Liquide.

Potential Future Upgrades

The existing station design is unique, purpose-built, and optimized to refuel GM fuel cell vehicles. Although it is operational for 700 bar refueling, the design is considered to be obsolete but has yielded many lessons learned on station design and hydrogen refueling. Air Liquide is developing a plan to upgrade the station with the latest state-of-the-art features in a modular, scalable package. Should the station be selected for upgrades, paid for with public funding, it would be made publicly accessible.

Figure 8: Los Angeles International Airport (LAX) Station



Photo Credit: TechCompass

Dispenser



Photo Credit: TechCompass

Medium- and high-pressure storage



Photo Credit: TechCompass

Hydrogen tube trailer



Photo Credit: TechCompass

Compressors



Photo Credit: TechCompass

Liquid nitrogen storage

CHAPTER 10:

Orange County Sanitation District

Location

10844 Ellis Avenue
Fountain Valley, CA 92708

Station Overview

Fountain Valley is the demonstration site for the world's first trigeneration station, which is a combined heat and power system that produces hydrogen in addition to heat and electricity. The system runs on natural gas and biogas generated by the Orange County Sanitation District's (OCSD) wastewater treatment facility. Hydrogen produced by the system is sent to a refueling station that is designed to support 25 to 50 fuel cell electric vehicles. A stationary fuel cell system also produces 250 kilowatts of electricity to power the wastewater treatment facility. The project was developed as a partnership among the U.S. Department of Energy, ARB, South Coast Air Quality Management District (SCAQMD), OCSD, Southern California Gas Company, and private industry. The project is managed by Air Products, and additional partners include FuelCell Energy and UC Irvine's (UCI) National Fuel Cell Research Center. As a demonstration, the station is contracted to continue operation until mid-2015 under sponsorship of the ARB and SCAQMD.

The demonstration is based on a special-purpose trigeneration, high-temperature molten carbonate fuel cell, supplied by FuelCell Energy and powered by anaerobic digester gas. The hydrogen production rate is 100 kg per day, which is compressed locally to 455 bar. Hydrogen gas is conveyed via 2,000 feet of pipeline from the fuel cell trigeneration site to the publicly accessible hydrogen dispensing station. Additional compression is provided at the dispensing site. Ancillary equipment for the energy station includes an anaerobic digester gas cleanup skid, hydrogen separation, and purification.

A PDC Machines, Inc. diaphragm compressor, rated at 100 kg/day and 540 bar, compresses the hydrogen gas for transfer through the pipeline to storage tanks at the dispensing location. The storage capacity at the dispensing site is 150 kg of hydrogen gas at 540 bar. A reciprocating piston booster compressor, rated at 800 bar delivery pressure, supplies the 700 bar dispenser. The SAE TIR-J2601-compliant hydrogen dispenser is collocated with a CNG fuel dispenser and is equipped with two nozzles: one for 350 bar and one for 700 bar refueling. A mechanical chiller is used to precool the hydrogen to -40° C at the dispenser for fast fills. Fill rates of 3.8 minutes per kg were achieved during the second quarter of 2013.

Operating Experience

This station requires two refueling contracts: one with Air Products and one with UCI. Three automakers executed access agreements and payment agreements with UCI in December 2011. The station is designed to deliver 100 kg/day of hydrogen and support 28 vehicles per day. The average usage in April 2013 was about 1.5 vehicles per day. Should the site be selected for upgrades, it would be made publicly accessible.

Potential Future Upgrades

As noted above, this station is a technology demonstration contracted to continue operation until May 31, 2014, under sponsorship of the ARB and SCAQMD. ARB and SCAQMD are discussing plans for this station with the equipment suppliers and the host site.

Figure 9: Orange County Sanitation District Station



Photo Credit: TechCompass

Hydrogen dispenser on fuel island



Photo Credit: TechCompass

Dispenser adjacent to freeway access



Photo Credit: TechCompass

FuelCell Energy fuel cell



Photo Credit: TechCompass

Diaphragm compressor



Photo Credit: TechCompass

Digester gas clean-up system



Photo Credit: TechCompass

Hydrogen clean-up system

CHAPTER 11:

South Coast Air Quality Management District

Location

21865 E. Copley Drive
Diamond Bar, CA 91765

Station Overview

The SCAQMD hydrogen refueling station is located behind a security gate in the parking lot of the main office in Diamond Bar, California. Hydrogen refueling is available to a SCAQMD-owned fleet of vehicles and to the public during SCAQMD normal business hours, Tuesday through Friday from 7:30 a.m. to 5:30 p.m. SCAQMD staff is available for refueling during business hours, and the dispenser requires a key code to be entered before refueling. All hydrogen refueling must be documented into a fuel log to keep record of all hydrogen dispensed.

The SCAQMD station uses a Stuart Energy CF-400 Community Fueler to produce up to 24 kg of hydrogen a day. A reverse osmosis water treatment with a bed deionizing system is used before water enters the hydrogen generation process. The hydrogen is compressed with a reciprocating compressor to 393 bar and stored in three tanks with a combined capacity of 60 kg and a maximum pressure of 460 bar. The hydrogen is dispensed through one FTI International Group Inc. dispenser at a filling pressure of 350 bar.

Operating Experience

SCAQMD has owned and operated the station since it opened in 2005. The typical usage rate is 20 kg/month.

The initial supplier was Stuart Energy, which was acquired by Hydrogenics in 2005. Hydrogenics has a service contract to support the SCAQMD station at an annual cost of \$84,000 and conducts preventive maintenance visits to test and confirm the operating conditions of the equipment. In addition, Hydrogenics reports about 10 unscheduled visits per year to repair equipment as needed as part of the service contract.

Potential Future Upgrades

The SCAQMD station is being upgraded with new equipment, including 700 bar fast-fill capabilities through a California Energy Commission grant awarded to Air Products.

Figure 10: South Coast Air Quality Management District Station



Photo Credit: TechCompass

Dispenser



Photo Credit: TechCompass

Electrolyzer



Photo Credit: TechCompass

Compressed hydrogen storage

CHAPTER 12:

Shell – Newport Beach

Location

1600 Jamboree Road
Newport Beach, CA 92660

Station Overview

The Newport Beach station is located at 1600 Jamboree Road near the Fashion Island shopping mall and Newport Center business district. The hydrogen refueling system was integrated into a modern, large retail gasoline station. Equipment construction and installation were performed by PowerTech Labs, and Hydrogenics provides the operation and maintenance services. The hydrogen station opened to the public in July 2012.

The station uses an onsite steam methane reformer to generate hydrogen from natural gas. The reformer produces up to 100 kg of hydrogen per day at 15 bar. Two hydraulic compressors fill high-pressure storage tanks, one compressing hydrogen up to 482 bar and the other boosting that pressure up to 965 bar. Two banks of hydrogen storage tanks store the compressed hydrogen, with 72 kg at 413 bar and 108 kg at 827 bar. A dedicated hydrogen refueling island is equipped with two Gilbarco dispensers. Each dispenser has two nozzles, one for 350 bar fills and the second for 700 bar fills. A mechanical chiller cools the hydrogen to -20° C to enable fast fills. The refueling capacity is 25 vehicles with the reformer output of 100 kg/day. Refueling times are less than 8 minutes per vehicle.

Operating Experience

The Newport Beach station averages 150 fills/month, ranging from 108 to 192 fills per month. The hydrogen dispensed averages 324 kg per month, with a range of 281 to 421 kg per month. Based on this history, the station is underused for the reformer capacity, thus resulting in the routine venting of unused hydrogen.

Despite inspections three times per week and monthly maintenance by Hydrogenics, this site suffers from false emergency stop alarms and computer glitches that result in about 10 unscheduled service events per month.

Potential Future Upgrades

Although this is a relatively new station, some upgrades may be warranted. Specifically upgrading the dispensers with certified POS systems and possibly replacing the aging reformer.

Figure 11: Shell – Newport Beach Station



Photo Credit: TechCompass

Fuel island



Photo Credit: TechCompass

Fuel island



Photo Credit: TechCompass

Dispenser



Photo Credit: TechCompass

Reformer



Photo Credit: TechCompass

Booster compressors



Photo Credit: TechCompass

700 bar storage



Photo Credit: TechCompass

350 bar storage



Photo Credit: TechCompass

Cooling system

CHAPTER 13:

Shell – Santa Monica Blvd.

Location

11576 Santa Monica Blvd.
West Los Angeles, CA 90025

Station Overview

This station is located on the corner of Santa Monica Boulevard and Federal Avenue, less than one-half mile west of the I-405 freeway. This one-of-a-kind station has the hydrogen generation, compression, and storage equipment installed on top of a specially designed and built canopy over the refueling island of an existing retail gasoline station. The footprint of the entire refueling station is nearly 19,000 sq. ft., while the footprint of the canopy with the hydrogen equipment is about 1,245 sq. ft.

The Hydrogenics electrolyzer produces up to 30 kg per day of hydrogen at 10 bar. The tap water used in the electrolyzer is filtered and deionized by an ELGA Purelab Prima Purifier using a deionizer and carbon filters. All residual water from the electrolyzer process is treated by a Siemens H₂O Technology Chem Feed wastewater system before the water is released into the sewer system. The water purification and wastewater systems are located at ground level behind the gas station, near the entrance to the car wash.

The hydrogen produced by the electrolyzer is compressed to 448 bar using a 30 kg/hr. 2-stage diaphragm compressor. The three hydrogen storage vessels can store up to 40 kg at 448 bar. When a vehicle is refueling, the hydrogen is dispensed by a Hydrogenics Model 350/6.1/1 dispenser at 350 bar through a WEH TK-16 nozzle. This nozzle has an interface for data transfer between vehicle and fueling station that is coded for pressure and fuel type, which will not allow connection to natural gas vehicles or other pressure ranges. The hydrogen is dispensed at a rate of 0.25 to 0.55 kg per minute.

Operating Experience

The station has been owned and operated by Shell since it was completed in 2008. Hydrogenics is contracted by Shell to provide operation and maintenance services, including weekly inspections and monthly preventive maintenance. In 2013, there was an average of two unscheduled service events per month. The most common cause was inadvertent emergency stop activations and simple resets due to power outages.

Since the station provides only 350 bar fills, the primary customer is Honda. Over the past year, the station has averaged 80 fuel cell vehicle refuelings per month, ranging

from 61 to 112 vehicle refuelings. The hydrogen dispensed over the past year averaged 170 kg/month, ranging from 121 to 227 kg/month.

Potential Future Upgrades

All equipment is operational and in good condition. Although the site is space-constrained, it is in a heavily trafficked area and close to a major freeway. The upgrades for equipment and installation that would increase the utility of the station include:

- 700 bar upgrade (compression, storage, chilling, dispensing).
- POS-capable dispenser.

Figure 12: Shell – Santa Monica Boulevard Station



Photo Credit: TechCompass

Fuel island



Photo Credit: TechCompass

Dispenser



Photo Credit: TechCompass

Hydrogen information center



Photo Credit: TechCompass

Electrolyzer



Photo Credit: TechCompass

Compressed hydrogen storage



Photo Credit: TechCompass

Compressor



Photo Credit: TechCompass

Electrical panels and controls

CHAPTER 14:

Shell – Torrance Pipeline

Location

2051 W. 190th Street
Torrance, CA 90501

Station Overview

This is a dedicated hydrogen-only refueling station that was opened to the public in May 2011 and is owned and operated by Shell. It is located adjacent to Interstate 405 at Western Avenue. The station uses pipeline-fed hydrogen from the Air Products Wilmington and Carson hydrogen production facilities. Air Products designed, built, and maintains this station.

The Air Products pipeline supplies the station with hydrogen at 60 bar, which contains carbon monoxide, carbon dioxide, and methane levels up to 15 parts per million. These contaminants are removed using membrane purifiers upstream of the compressors. A 50 kg/day PDC Machines diaphragm compressor increases the hydrogen pressure to 448 bar, and a Hydropac hydraulic booster compressor further raises the pressure to 1,000 bar. Hydrogen is stored in two banks, with 120 kg at 448 bar and 32 kg at 1,000 bar. There are two dispensers, each equipped with two nozzles; one nozzle for 350 bar and the other for 700 bar fills. A mechanical chiller pre-cools the hydrogen to -20° C at the dispenser to enable fast fills. With a capacity of 50 kg/day, the station can fill 10 to 12 vehicles per day. A refueling agreement is required to refuel at this site and is equipped with a hydrogen vehicle authorization system, which is a wireless vehicle recognition system that allows station-to-vehicle recognition for quick refueling. In addition, the station has a community learning center onsite for users to learn about hydrogen and fuel cell vehicles.

Operating Experience

The Torrance station averages 368 fills/month, ranging from 256 to 426 fills/month. The average amount of hydrogen dispensed is 1,000 kg/month, ranging from 688 to 1,293 kg/month.

Preventive, scheduled maintenance includes twice weekly inspections and monthly maintenance. The site averages four unscheduled service events per month, with compressors being the primary source of the unscheduled events.

At the time of this report, this station suffered an extended shutdown as a result of the failure of membrane purifiers required to scrub the pipeline hydrogen to meet fuel cell vehicle requirements.

Potential Future Upgrades

Although this is relatively new station, some upgrades may be warranted, specifically upgrading the dispensers with a certified POS system and increasing the capacity of the station with a new compressor. Should the station be selected for upgrades, paid for with public funding, it would be made publicly accessible.

Figure 13: Shell – Torrance Pipeline Station



Photo Credit: TechCompass

Hydrogen information center



Photo Credit: TechCompass

Dispensers



Photo Credit: TechCompass

Fuel island



Photo Credit: TechCompass

Cooling system



Photo Credit: TechCompass

Hydrogen storage banks



Photo Credit: TechCompass

Diaphragm compressor



Photo Credit: TechCompass

Booster compressor



Photo Credit: TechCompass

Hydrogen clean-up skid

CHAPTER 15:

SunLine Transit

Location

32505 Harry Oliver Trail
Thousand Palms, CA 92276

Station Overview

SunLine Transit owns and operates this alternative fuel station, which provides CNG and hydrogen. It opened in April 2000 and is still fully operational. The station was originally equipped with an electrolyzer, using power generated from solar panels to produce hydrogen. In 2003, the electrolyzer system was replaced with a natural gas steam reformer to generate hydrogen onsite.

There are two operating diaphragm compressors on site, including a high-pressure compressor at 414 bar used for filling the American Society of Mechanical Engineers-certified storage tubes for cascade dispensing via gas from tube trailers and a low-pressure process compressor at 207 bar used for filling the tube trailer from the reformer. The reformer is a HYRADIX natural gas reformer, which is fed with water treated by reverse osmosis using a GE Osmonics water purification system. The reformer also has an ArctiChill cooling tower, and the cooling water has a reverse osmosis purification system to reduce algal growth. The hydrogen production rate is 9 kg/hr., but SunLine reports that it typically averages 50 kg/day to meet its current demand. The reformer can be operated by a computer from a nearby office building.

The storage capacity of the station is 345 kg of hydrogen. There are two sets of three tubes manufactured by FIBA Technologies, Inc. with a storage pressure of 414 bar that provide 240 kg of storage. A trailer holds 16 tubes with a storage pressure of 207 bar and 105 kg of storage.

The hydrogen produced at the station is 99 percent pure hydrogen and can be dispensed at 250 bar or 350 bar through two FTI International Group, Inc. dispensers. Hydrogen passes through an obsolete inline Rosemount hydrogen purity analyzer, which SunLine is looking into replacing once funding is available for a new unit. The 350-bar dispenser can provide a fast or slow fill, depending on the vehicle. SunLine typically fills its buses in 20-30 minutes, delivering 2-3 kg/minute.

Operating Experience

The SunLine hydrogen station is open and available to the public but is used primarily by SunLine to refuel its two fuel cell buses. Honda and Toyota occasionally refuel their fuel cell vehicles at SunLine as well. A user is required to watch a video about operating

the dispensers and associated safety precautions before refueling at the station. The pedestal that houses the audio and video for the operational and safety training video is next to the dispenser. After watching the video, the user is assigned a PIN that the user needs to operate the dispenser. Along with the PIN, the user is required to pay a \$50 service fee to use the station for each use. Users can pay with cash, credit card, or prepaid SunLine card by contacting the station ahead of time.

Potential Future Upgrades

SunLine is expecting the delivery of two more fuel cell buses, which could still be fueled from the capacity of the current reformer system; however, the reformer has about four more years of life remaining. At that point, in about 2016, SunLine will either look at a new reformer system or consider moving to a liquid hydrogen delivery system, which SunLine believes may be more cost-effective if its fuel cell bus fleet increases to five or more.

While SunLine would entertain adding 700 bar refueling for light-duty vehicles, its priority is to support its fuel bus operations, which require only 350 bar. A modular, 700 bar refueler that could be separate from the main refueling island may be of interest to SunLine.

Figure 14: SunLine Transit Station



Photo Credit: TechCompass

Dispenser



Photo Credit: TechCompass

High-pressure storage



Photo Credit: TechCompass

Trailer storage



Photo Credit: TechCompass

Compressor for reformer



Photo Credit: TechCompass

Storage compressor



Photo Credit: TechCompass

Cooling tower



Photo Credit: TechCompass

Reformer



Photo Credit: TechCompass

Process water treatment

CHAPTER 16:

University of California, Irvine

Location

19172 Jamboree Road
Irvine, CA 92616

Station Overview

The UCI hydrogen refueling station usually dispenses compressed hydrogen only during the day. The station stores liquefied hydrogen delivered by a liquid tank truck and dispenses compressed hydrogen to refuel vehicles, as needed.

Air Products, through a subcontract agreement with the National Fuel Cell Research Center (NFCRC), owns, operates, and maintains all onsite mechanical equipment, including the liquid hydrogen tank, compressed hydrogen tanks, dispensers, evaporators, and compressors. Air Products supplies the liquefied hydrogen using a delivery tank truck and continuously monitors the performance of the refueling station remotely through a telemetry system. The data are accessible to the NFCRC and Air Products staffs through a Web tool.

The storage capacity of the refueling station is 52 kg of compressed hydrogen gas at 540 bar and 385 kg of liquid hydrogen. The station uses two compressors. The first compresses the vaporized liquid hydrogen at a rate of 25 kg/day from 7 to 14 bar up to 500 bar for storage. A reciprocating piston booster compressor is then used to deliver 700 bar to the dispenser. A mechanical chiller precools the hydrogen to -20° C to enable fast fills.

Operating Experience

The UCI refueling station is restricted to authorized fuel cell vehicles owned by entities that hold agreements with NFCRC. These entities include Toyota, Honda, Daimler, General Motors, Nissan, Mazda, the U.S. Postal Service, and UCI.

UCI reports that, in 2012, Air Products delivery frequency of liquid hydrogen was roughly every two weeks, averaging 668.7 kg of hydrogen per month. From July 2012 to June 2013, about 7 vehicles per day refueled at the station with a recorded one-day maximum of 20 vehicle refuelings. The station was designed for 25 kg/day, but 59 kg/day was recorded as the maximum achieved. The refueling times averaged 2.2 minutes per kg.

Potential Future Upgrades

The UCI station is being upgraded with new equipment, including 700-bar fast-fill capabilities through a California Energy Commission grant awarded to Air Products. In addition, UCI is considering the addition of a dispenser for fuel cell buses.

Figure 15: University of California, Irvine Station



Photo Credit: TechCompass

Dispenser

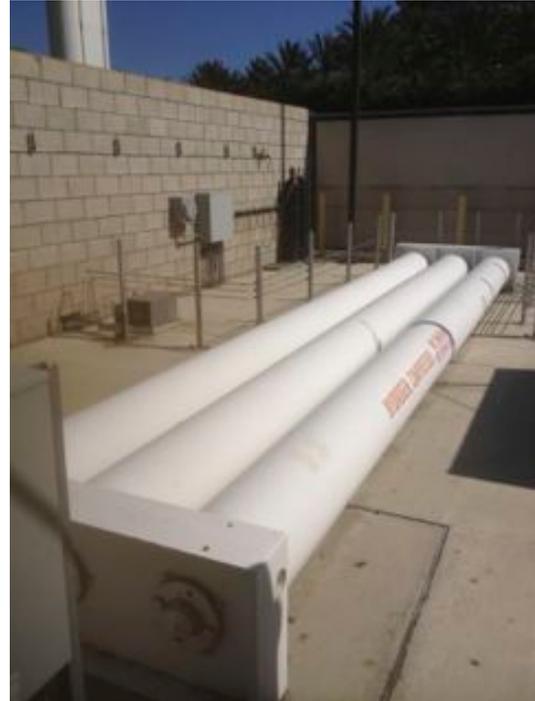


Photo Credit: TechCompass

Compressed hydrogen storage



Photo Credit: TechCompass

Compressors – booster and main



Photo Credit: TechCompass

Liquid hydrogen storage



Photo Credit: TechCompass

Main compressor



Photo Credit: TechCompass

Liquid hydrogen vaporizers

Acronyms

Alternative and Renewable Fuels and Vehicle Technology (ARFVT)

British Petroleum (BP)

California Air Resources Board (ARB)

California State University, Los Angeles (CSULA)

Compressed natural gas (CNG)

Fuel cell electric vehicle (FCEV)

Liquefied propane gas (LPG)

Los Angeles International Airport (LAX)

National Fuel Cell Research Center (NFCRC)

Orange County Sanitation District (OCSD)

Personal identification number (PIN)

Point of sale (POS)

South Coast Air Quality Management District (SCAQMD)

University of California, Irvine (UCI)