HONDA SOLAR HYDROGEN REFUELING STATION

1. PROJECT GOALS

Honda is working towards making the hydrogen-powered society of the future a reality by studying the entire process of hydrogen production, storage and supply, including investigation of technologies that will reduce the level of carbon dioxide that is emitted in the hydrogen production process. Like other automotive companies, Honda Motor Company is conducting a significant hydrogen fuel cell research and development program. In fact, Honda delivered the first commercial fuel cell vehicle (FCV) to the City of Los Angeles, California on 2 December 2002, and four additional vehicles will be delivered in early 2003. Honda also launched the FCV fleet program in Japan on the same day. Honda’s FCX vehicle is the first FCV in the world to be certified by the California Air Resources Board (CARB) and by the Environmental Protection Agency (EPA).

A significant milestone in this program was achieved in July 2001, when Honda became the first automobile manufacturer to open a solar-powered hydrogen production and fueling station. The station is located at Honda's research and development center in Torrance, CA. It is being used to:

- Conduct studies on hydrogen production, storage and fueling using renewable energy sources
- Support the company's ongoing fuel cell-powered vehicle development program

Also, Honda is operating the station to help verify more efficient methods for producing hydrogen using renewable energy while, at the same time, gaining insight into the challenges involved in developing hydrogen production and fueling stations for the future.

2. PROJECT DESCRIPTION

In July 2001, Honda R&D Company, Ltd. and U.S.-based Honda R&D Americas, Inc. opened its first solar powered hydrogen production and fueling station. The station uses an array of photovoltaic (PV) cells to extract hydrogen from water via electrolysis. When power from the PV array is unavailable or insufficient (e.g., due to cloud cover, etc.), electricity from the grid is used for the electrolysis process. The station is shown in Figure 1.

The only other similar facility in the United States that uses solar energy to produce hydrogen for FCVs is the facility at SunLine Transit Agency in Thousand Palms, CA, where hydrogen is generated for fuel cell-powered city buses and small urban vehicles such as golf carts.

Honda’s 2003 model year FCV builds on the company’s FCX-V3 and V4 experimental cars, which were extensively demonstrated, showcased and evaluated in the United States and Japan. Using its FCX-V3 and V4 vehicles, Honda has been participating in the California Fuel Cell Partnership based in Sacramento, CA.

Figure 1: Honda's hydrogen production, storage and fueling station in Torrance, CA

3. DESCRIPTION OF COMPONENTS

3.1 Hydrogen Fueling Station

The hydrogen refueling station is located at Honda's research and development center in Torrance, CA. It consists of:

- 8 kW array of photovoltaic (PV) cells
- Electrolysis system that uses electricity to extract hydrogen from water
- Control system for using solar-generated electricity with maximum efficiency
- Compressor for compressing the hydrogen to 350 bar (5000 psi) for storage
- Compressed hydrogen storage tank with a capacity of 400 liters at 350 bar

When solar power from the PV array is unavailable or insufficient (e.g., due to cloud cover, etc.), electricity from the grid is use for the electrolysis process. A schematic diagram of the total system is shown in Figure 2.

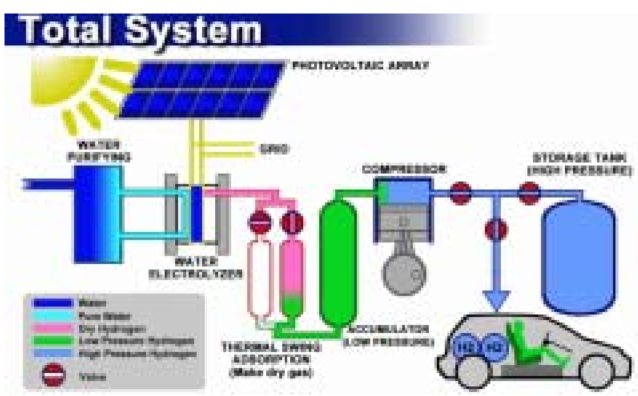

Figure 2: Schematic of Honda's hydrogen fueling station

The system, when running exclusively on solar energy, can produce about 5,700 liters (at 350 bar) of gaseous hydrogen per year. This is enough to fuel one car for a year. By using both solar power and electricity from the grid, the station's production capability is 26,000 liters per year. The capacities of the station are summarized in Table 1. Cars can be fueled at the rate of 20 liters per minute. Hydrogen is dispensed to the vehicle using a unique fast-fill and multi-bank cascade system. A mass flow sensor records the amount of fuel delivered.

Table 1: Capacities of the hydrogen production and fueling station (at 350 bar)

Hydrogen production	liters/year	26,000 (solar and electric power) 5,700 (solar power)
Hydrogen storage	liters	200
Hydrogen filling	liters/min	20

Several new technologies were developed for the station. An innovative pure water recirculation system keeps water losses in the electrolyser at a minimum. The control system maximizes hydrogen production efficiency by regulating fluctuations in electric power production caused by changes in sunlight intensity. Consequently, Honda is able to minimize energy losses associated with producing hydrogen using solar energy.

One of the unique features of this advanced hydrogen station is its nearly silent operation and its visual impact; it promotes a “customer-friendly” image with its graceful canopy design and its compact and easy-to-operate features. All hardware systems are hidden from the user, so the station is not at all “intimidating”. Instead, it conveys a positive sense of the future of energy, including renewable options and safe operation.

3.2 Honda Fuel Cell Vehicle FCX

Honda’s 2003 model year FCV, the FCX, is a two-door, four-passenger hatchback sedan. Electricity for the electric motor is generated by a fuel cell that runs on compressed hydrogen gas and oxygen from air. The hydrogen is stored at 350 bar in two fuel tanks, located under the floor of the rear passenger seats, with a total capacity of 156 liters. The car has a top speed of 150 km/h and a cruising range of up to 355 km. The power train consists of a Ballard proton exchange membrane (PEM) fuel cell and an AC synchronous electric motor.

The FCX utilizes Honda's own independently developed high-efficiency, high-output ultra-capacitor energy storage system to achieve regenerative braking and powerful, responsive driving performance. The layout of the power train's structural components has also been optimized to provide a spacious interior with room for four adults in a compact body that maintains a high level of collision safety performance no matter what the crash direction.

This latest version of the Honda FCV achieves 15 percent more maximum drive motor torque than previous models and also provides improvements in mid-to-high range power output characteristics and acceleration. It also has an increased driving range of 355 km, about 40 km more than the previous model. The system outline is shown in Figure 3, and the specifications of the vehicle and of the power train are given in Table 2. A photograph is shown in Figure 4.

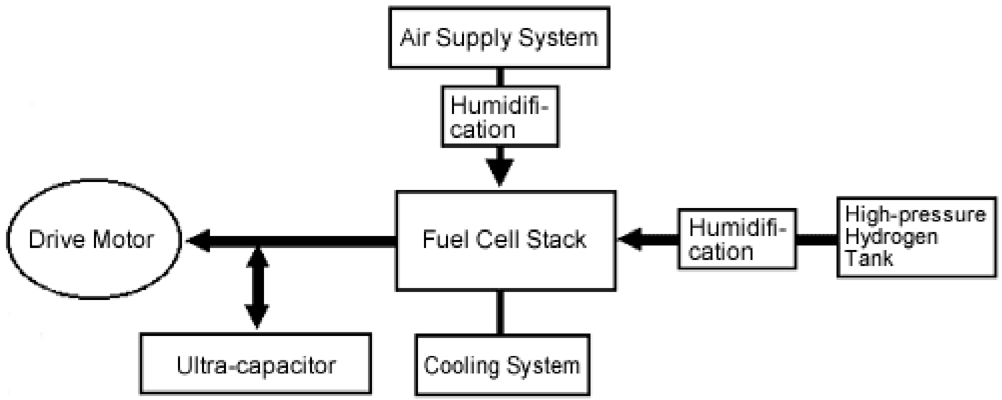

Figure 3: System outline diagram

Table 2: Honda FCX specifications

Vehicle	Length	4165 mm
	Width	1760 mm
	Height	1645 mm
	Maximum Speed	150 km/h (93 mph)
	Cruising Range	355 km (220 miles)
	Seating Capacity	4 adults
Motor	Maximum Power Output	60 kW (80 hp)
	Maximum Drive Torque	272 Nm (201 lb-ft)
	Motor Type	AC synchronous
Fuel Cell Stack	Stack Type	PEFC (proton exchange membrane - Ballard)
	Power Output	78 kW
Power storage	Honda Ultra Capacitor	
Fuel	Type	Compressed gaseous hydrogen
	Storage Method	High-pressure hydrogen storage tank (350 bar)
	Fuel Capacity	156.6 liter

4. HYDROGEN FUELING OPERATIONS

Only Honda staff that have undergone special training and have been given a password are allowed to perform fueling of vehicles and operation of the hydrogen dispenser. Fueling operations are conducted using the interface screen of the station. The station has two filling modes:

- "Fast Fill" mode: FCVs are fueled directly from the high-pressure hydrogen tank in a short period
- "Slow Fill" mode: FCVs are fueled by the hydrogen compressor in a comparatively long period

Figure 4: Photograph of the Honda FCX hydrogen fuel cell-powered car

After the vehicle is properly positioned at the station, the fueling process involves the following steps:

(1) The Driver/Operator touches the "Fuel Vehicle" button on the interface screen to start the fueling process.

(2) When the operator sees the message ***"Please enter your ID"*** on the screen, he/she enters his/her ID and password.

(3) With the correct ID and password accepted by the station, the screen displays the message "***CAUTION! We are ready to charge hydrogen into your car. Confirm that shift lever is in the PARKING position."*** The operator is required to confirm his/her preparation for fueling. If the operator is ready, he/she touches the "OK" button.

(4) The screen then displays ***"Connect electrical connector".*** The operator then connects the electrical coupler, which means that the FCV is grounded. Then, he/she touches the "OK" button.

(5) Next, the screen displays ***"Connect fuel nozzle".*** The operator then lifts up the fuel nozzle and puts it into the vehicle. He/she then touches the "OK" button. Now, all requirements for dispensing hydrogen into the vehicle have been met.

(6) The screen then displays: ***"Hydrogen Refueling"****.* The operator selects the mode, "Fast Fill" or "Slow Fill". Fueling now starts.

(7) When fueling is completed, the operator sees the following message on the screen: ***"Fast (Slow) Fill Finished".*** The operator touches the "OK" button.

(8) The screen then shows the message: ***"Please Disconnect the fuel nozzle".*** The operator disconnects the fuel nozzle, returns it to its receptacle and presses the "OK" button.

(9) The screen then displays ***"Please disconnect the electrical connector".*** When electrical disconnection is completed the operator presses the "OK" button.

(10) Finally, the screen displays ***"Thank you for your cooperation. Have a nice drive!"*** The operator then touches the "OK" button. The system is now disabled.

5. ENVIRONMENTAL ASPECTS AND SAFETY ISSUES

Safety was a top priority in the development of the station. Honda engineers worked closely with City of Torrance officials during planning, design and construction. The station was built to standards for hydrogen systems developed by the National Fire Protection Association. In addition, an infrared camera is used to monitor operations at all times. The system is designed to immediately shut down in the event of an earthquake.

The Honda fueling station achieves vehicle refueling without special clothing requirements, in contrast to Ford and the Chicago Transit Authority, which require their fueling operators to wear special fire resistant clothing (i.e., Nomex suits) leather gloves and eye protection. Honda designed the station, including hardware and refueling procedures, with maximum safety requirements so that hydrogen fuel may be accepted by society. The refueling operation is easy enough for everyone to use because the station requires the user to go through specific refueling steps, communicated through the touch screen interface panel.

Once hydrogen begins flowing into the vehicle, Honda has no special safety rule regarding where the operator should position himself. For example, Chicago requires the operator to leave the area until fueling was completed. At Honda, the operator usually stands by and watches the fueling process.

The only weather/environmental condition that Honda has identified during which fueling is not to be done is an actual or expected thunder and/or lightning storm. Since the facility is outdoors, in general, fueling is not done when it is raining.

6. REGULATORY ASPECTS AND LICENSING PROCEDURES

6.1 Construction and operation permits

Honda worked with the City of Torrance, CA to obtain the required permits for the station. The codes and standards referenced in the permitting process were as follows (NFPA refers to the National Fire Protection Association, ASME to the American Society of Mechanical Engineers):

- NFPA 50A: Standard for Gaseous Hydrogen Systems at Consumer Sites
- NFPA 70: National Electric Code
- NFPA 496: Standard for Purged and Pressurized Enclosures for Electrical Equipment
- NFPA 497A: Recommended Practice for Classification of Class I Hazardous Locations for Electrical Installations in Chemical Process Areas
- NFPA 30: Flammable and Combustible Liquids Code
- NFPA 88: Standard for Fire Doors and Fire Windows
- CFC Article 52: Motor Vehicle Fuel-Dispensing Stations (California Fire Code)
- ASME Boiler and Pressure Vessel Code, Sect. VIII, Div. 1 (storage container)
- ASME Boiler and Pressure Vessel Code, Sect. VIII, Div. 2 (relief devices)
- ASME B31.3: Chemical Plant and Petroleum Refinery Piping Code (same as ANSI)

Before the City of Torrance issued construction and operating permits, Honda conducted thorough FMEA (Failure Mode and Effects Analysis) and HAZOP (Hazard and Operability Study) studies. The FMEA was conducted internally at Honda. The HAZOP was conducted with a hazards expert from the City of Torrance Fire Department present.

Permitting a hydrogen fueling station was a new process for the City of Torrance, as well as Honda. Since there was no "How to Permit a Hydrogen Fueling Station" process or a guidebook regarding the codes and standards that should be referenced in permitting a station, Honda and the City worked together to ensure that all applicable codes and standards were met. The City of Torrance was very knowledgeable and helpful in permitting the hydrogen station, and both Honda and the City learned a lot through the experience.

6.2 Emergency response plan

Honda also developed and documented an emergency response plan. In the case of an emergency, three colored lights, mounted in a visible location near the hydrogen station, indicate the emergency level. The three steps are displayed in Table 3.

Table 3: Stages of emergency response

Signal	Indication	Action
Yellow Flashing Light	Equipment trouble	No danger
Blue Flashing Light with audible pulsating siren	Hydrogen leak	Security is notified
Red Flashing Light with audible steady siren	A fire has been detected by the infrared camera	Security is notified and fire department is called immediately

The plan also documents who is to be contacted at each emergency level (see Figure 5).

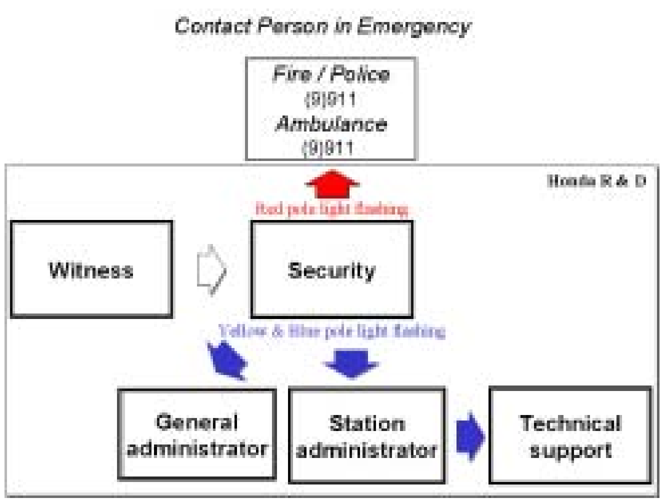

Figure 5: Contact person in emergency

With respect to compliance measures (e.g., annual inspections, record keeping, etc.), the City of Torrance Fire Department requires an annual inspection of the hydrogen station.

6.3 Vehicle certification

The hydrogen-powered Honda FCX is the first FCV in the world to receive government certification, paving the way for the commercial use of FCVs. In July 2002, it was certified by the California Air Resources Board (CARB) as a Zero Emission Vehicle (ZEV) and by the U.S. Environmental Protection Agency (EPA) as a Tier-2 Bin 1, National Low Emission Vehicle (NLEV), the lowest national emission rating. The FCX will also meet applicable U.S. safety and occupant protection standards.

Certification allows Honda to place fuel cell vehicles in commercial operation, to evaluate them in real-world applications and to study the development of an appropriate refueling infrastructure. However, it is important to remember that significant cost, technology and infrastructure issues remain prior to the mass marketing of fuel cell vehicles.

7. FURTHER PLANS

On 2 December 2002, the first Honda FCX was formally delivered to the City of Los Angeles in a ceremony attended by Mayor Jim Hahn and Hiroyuki Yoshino, President and Chief Executive Officer of Honda Motor Co., Ltd. Under the two-year lease agreement, the City will pay $500 a month to lease the first of five Honda FCX models with the other four vehicles being delivered in 2003. In addition, Honda has contracted with Air Products and Chemicals, Inc., based in Allentown, PA with local operations in El Segundo, to provide the hydrogen fuel and refueling infrastructure. Los Angeles City employees will use these FCVs on a day-to-day basis for commuting and regular business activities, generating a range of information to be used in further developing the fuel cell vehicle for practical use in everyday life.

In a parallel ceremony on the same day, a FCX vehicle was delivered to the City of Tokyo.

With these two vehicles, Honda has started a lease program for a limited number of FCXs in the U.S and Japan. During the first two-to-three-year period, Honda will lease about 30 fuel cell vehicles in California and the Tokyo metropolitan area, two locations with access to a hydrogen fuel supply infrastructure. The company currently has no plans, however, for mass-market sales of fuel cell vehicles or sales to individuals.