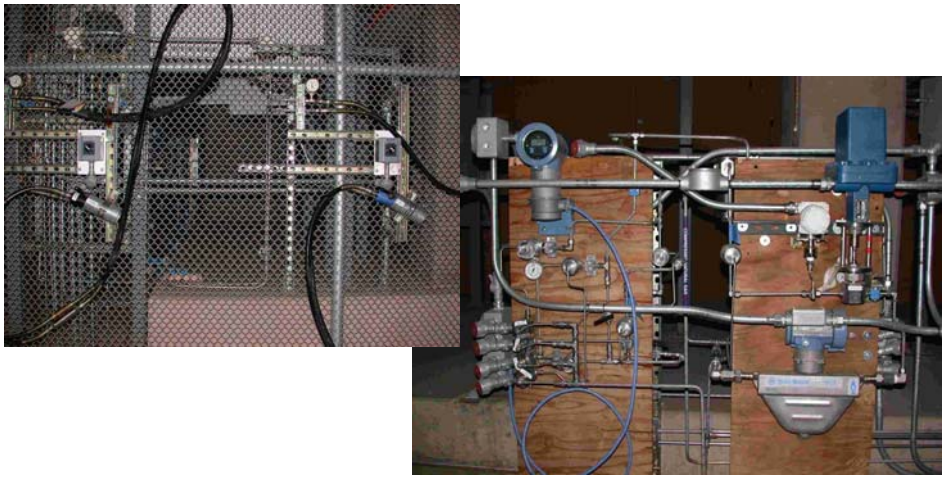
U.S. Department of Energy
Energy Efficiency and Renewable Energy

INL/EXT-05-00006

U.S. Department of Energy
FreedomCAR & Vehicle Technologies Program
Advanced Vehicle Testing Activity

Hydrogen, CNG, and HCNG Dispenser System – Prototype Report



TECHNICAL REPORT

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February 2005

Idaho National Laboratory
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Prepared for the
U.S. Department of Energy
Assistant Secretary for Energy Efficiency and Renewable Energy
Under DOE Idaho Operations Office
Contract DE-AC07-05ID14517

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Introduction

The U.S. Department of Energy's Advanced Vehicle Testing Activity is currently testing a prototype gaseous fuel dispenser developed by the Electric Transportation Engineering Corporation (ETEC). The dispenser (Figure 1) delivers three types of fuels: 100% hydrogen, 100% compressed natural gas (CNG), and blends of hydrogen and CNG (HCNG) using two independent single nozzles (Figure 2). The nozzle for the 100% hydrogen dispensing is rated at 5,000 psig and used solely for 100% hydrogen fuel. The second nozzle is rated at 3,600 psig and is used for both CNG and HCNG fuels. This nozzle connects to both a CNG supply line and a hydrogen supply line and blends the hydrogen and CNG to supply HCNG levels of 15, 20, 30, and 50% (by volume).

The dispenser incorporates proportional flow control valves for both the hydrogen and CNG gas streams to control gas flow rates from 100 to 40,000 scfh. These flow rates support fast fueling times—less than 5 minutes for typical light- and medium-duty vehicles. The control valves are trimmed by a digital dispenser controller using mass flow signals provided by coriolis mass flow transducers in each of the hydrogen and CNG gas streams. The dispenser controller adjusts the control valves to provide real-time ratio control of blended fuels.

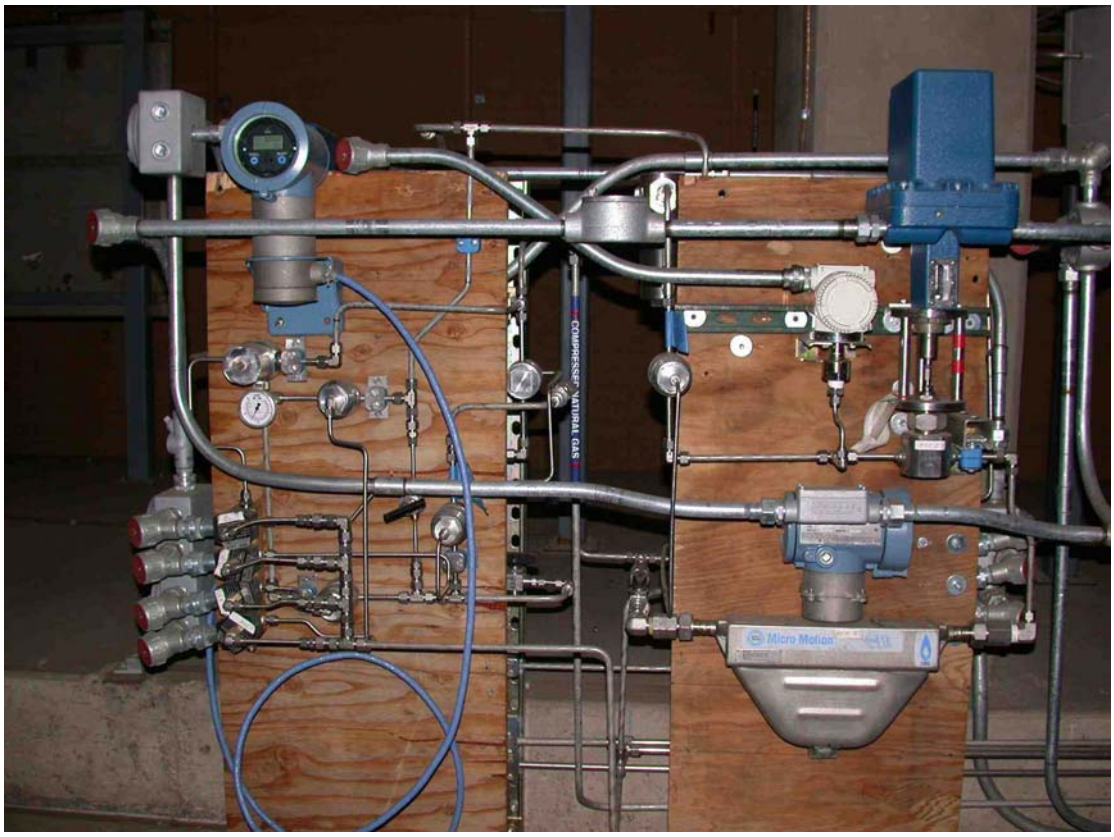

Figure 1. 100% hydrogen, CNG, and 15, 20, 30, and 50% blended HCNG (by volume) prototype dispenser brassboard design.

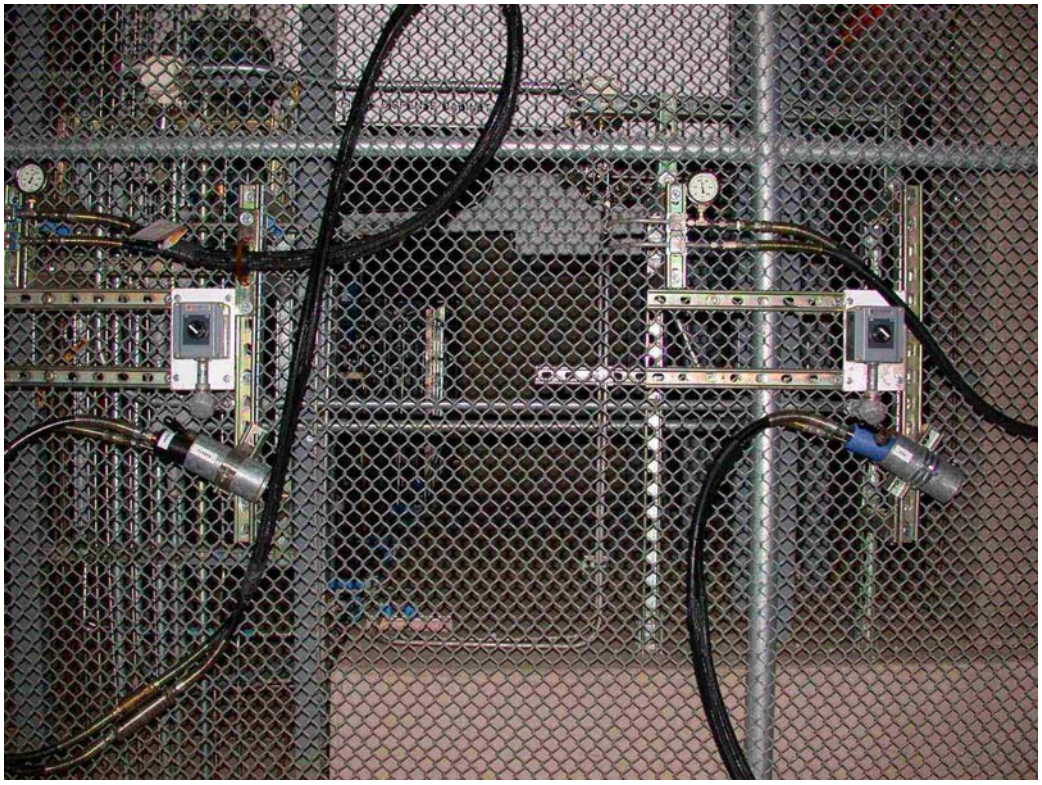

Figure 2. The 100% CNG and HCNG nozzle is on the left; the 100% hydrogen nozzle is on the right. The nozzles are being used to fuel vehicles to test the prototype dispenser operations.

Hose Integrity

The dispenser periodically monitors the integrity of the hose between the dispenser and the vehicle. Using signals from pressure transmitters, mass flow meters, and temperature sensors, the dispenser controller monitors for excessive fuel flow, excessive fill time, and low hose pressure during the initial phase of fueling and during the time between supply pressure zone changes. It terminates fueling if any of these parameters exceeds a programmable limit.

Card Reader and Display

The dispenser includes an interactive display screen and card reader/authorization feature. The dispenser controller interfaces with standard card reader/authorization systems to accurately monitor the amount of fuel dispensed and report such data to the system in a compatible format. Typically, pulses proportional to the volume of fuel dispensed (in gasoline gallon equivalents [gge]) are sent to the card reader. The card reader then calculates the sale cost and bills the customer according to the card used for system access.

A display screen is the human-to-machine interface; it prompts the customer through actions to dispense fuel, and includes the following features:

- Allows selection of the fuel type, including the percent blend of HCNG fuel
- Displays price per gge
- Provides dispensing real-time status
- Displays total amount of fuel dispensed and the dollar amount of the transaction.

Other Dispenser Interfaces

The dispenser controller incorporates an RS232 port compatible with a PDA to obtain diagnostic information and to support programming. The controller also incorporates an RS485 port for real-time access to operational parameters. A contact closure interface is also installed for emergency shutdown from local and remote emergency shutdown switch locations.

Controlled Starts and Stops

Typical dispensing at high pressures inherently creates a "gas hammer" of the process gas within the system, which can impact the dispensing hose and other fueling components. The proportional control valves in the ETEC dispenser smooth out the start and stop of fuel flow to prevent gas hammer. The dispenser controller is programmed to regulate startup and shutdown pressure ramps by controlling the flow through these valves.

Hazard Operations Analysis

The effects of worst-case hydrogen release scenarios have been modeled. These analyses concentrate on:

- The potential release rate of hydrogen from the high-pressure piping
- The accumulation and mixing of hydrogen and air in the dispenser
- The venting of hydrogen from the dispenser.

Based on these analyses, design features have been incorporated into the system to mitigate the effects of worst-case hydrogen release scenarios.

Safety Features

An emergency shutdown interface is provided to react to a contact closure from local or remote emergency shutdown switches. Other fueling shutdown input signals include:

- Over-pressure
- Excessive flow
- Leak
- Drive-off
- Over-temperature (including large temperature differential).

And safety interlocks are installed to address:

- Vehicle check valve failure
- Fuel supply initiated alarms/trips
- Flame scanners
- Combustible gas sensors
- Excess fuel flow rate
- Excess fill time
- Minimum flow
- High supply pressure
- Fuel supply pressure failure
- Loss of control power.

Dispensing System Operation

In addition to the safety checks, operating the dispensing system includes the following steps and processes:

- The dispenser controller receives enable signals from the point of sale (credit card reader) system and initiates fueling.
- The controller receives an enable signal from the dispenser hand switch.
- The controller relieves pressure stored in the output header by opening a high-pressure vent.
- Before dispensing fuel, a small puff of gas is delivered to verify vehicle tank pressure.
- Using the above pressure measurement and an ambient temperature measurement, the controller calculates the initial fill pressure and the temperature-compensated final fill pressure, allowing the dispenser to deliver the maximum amount of fuel possible.
- To dispense fuel, the controller sends a "fill request" to the fuel supply plant controller (via ModBus).
- Filling commences when the Alternative Fuel (Hydrogen) Pilot Plant opens the valve(s) for the appropriate gas. For additional information on the Alternative Fuel (Hydrogen) Pilot Plant see: Arizona Public Service – Alternative Fuel (Hydrogen) Pilot Plant Design Report (INEEL/EXT-03-00976) at http://avt.inel.gov/h2station.html
- During the fill, the dispenser modulates the flow control valves to produce smooth and efficient fuel delivery and to deliver the proper ratio of hydrogen and CNG, when applicable.
- If the flow of gas drops below a programmable set point for initial flow rate, the dispenser will request the fuel supply plant controller to provide flow from the next higher pressure zone. During this request period, the dispenser will modulate the flow control valves for increased input pressure to maintain the proper flow rate during transition to the higher-pressure zone. If a higher-pressure zone is not available, the dispenser controller will allow flow to continue until a programmable minimum flow is reached or the temperature-compensated fill pressure has been met.
- During the connection and fill process, the dispenser monitors for fault conditions. The fill is considered complete when the tank pressure reaches the maximum temperature-compensated fill pressure. Once the fill is complete, a message is sent to the fuel supply plant to close the appropriate valves, and final data are transmitted to the card reader.
- The emergency shutdown mode will quickly close all gas supply valves in the event of an emergency. The emergency shutdown mode may be entered through either hardware interrupt (emergency shutdown switch) or through logic in the dispenser controller.

Testing

The dispenser system is currently providing fuel for a small AVTA test fleet of 100% hydrogen and blended HCNG fuel vehicles operated by the Arizona Public Service Company. Data being collected includes pressure, flow, and temperature versus time for various fills and fill rates. When the testing is complete, the dispenser will be repackaged into a commercial design.