III.C.3 Forecourt Storage and Compression Options

William E. Liss (Primary Contact),
Louis A. Lautman
Gas Technology Institute
1700 S. Mount Prospect Road
Des Plaines, IL 60018
Phone: (847) 768-0753; Fax: (847) 768-0501
E-mail: william.liss@gastechnology.org

DOE Technology Development Manager:
Mark Paster
Phone: (202) 586-2821; Fax: (202) 586-9811
E-mail: Mark.Paster@ee.doe.gov

DOE Project Officer: Jesse Adams
Phone: (303) 275-4954; Fax: (303) 275-4753
E-mail: Jesse.Adams@go.doe.gov

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Objectives

- Examine technical feasibility and cost implications of an array of forecourt compression and storage configurations.
- Define approaches to reduce the cost and footprint of onsite hydrogen storage.
- Develop an effective tool for hydrogen fueling station performance and cost scenario analyses.

Technical Barriers

This project addresses the following technical barriers from the Delivery section (3.2.4.2) of the Hydrogen, Fuel Cells and Infrastructure Technologies Program Multi-Year Research, Development and Demonstration Plan:

(B) Reliability and Costs of Hydrogen Compression

(F) Hydrogen Delivery Infrastructure Storage Costs

Technical Targets

	2005 Status	2010 Target
Compression: At Refueling Stations		
Cost Contribution ($/gge of hydrogen)	$0.60	$0.40
Hydrogen Energy Efficiency (%)	94%	95%
Storage		
Refueling Site Storage Cost Contribution ($/gge of hydrogen)	$0.70	$0.30

The combination of onsite hydrogen compression and storage contributes approximately $1.3/gge (1 gge = 1 kg of hydrogen) to the delivered cost of hydrogen. The target is to reduce this to a level of $0.7/gge by 2010. Optimization of the sizing of onsite compression and storage can reduce capital costs and increase compressor uptime – leading to reduced operating and maintenance expenditures. In achieving minimization of capital, operating, and maintenance costs, however, it is important that peak hydrogen fueling system delivery performance not be compromised.

Accomplishments

- Developed information regarding representative daily vehicle demand profiles based on analyses of gasoline and compressed natural gas fueling station data. The normalized demand profiles differ from those previously used in H2A analyses. Based on our analyses, the current H2A demand profile overstates the variance between on-peak and off-peak demand during normal business hours. The implications from the new demand profiles should translate into lower system capital costs (due to a more muted range between peak and off-peak demand) and reduced costs for delivered hydrogen.
- Enhancements were made to the Gas Technology Institute (GTI) CASCADE H_2 software model to include new features related to compressor energy consumption, expansion of storage configurations, increase in the number of station hydrogen dispensers, profile of vehicles (demand), integrated economic analyzer, and other features.

Introduction

The focus of this project is development of analytical tools and insights for design and operation of onsite hydrogen fueling stations. There are a variety of system topologies and operating strategies that can be used to deliver compressed hydrogen to a compressed gas hydrogen vehicle. In particular, this project is focused on trade-off analysis of hydrogen compression, storage, and dispensing capacity and subsystem configuration. Key system optimization parameters include: capital cost (including investment in compression, storage, and dispensing), operating and maintenance cost, and delivery performance – in particular, the system's ability to perform at peak demand while satisfying customer expectations regarding fill time.

Approach

The approach of this project initially focused on enhancing analytical software encompassed in GTI's CASCADE H_2 program. A new version, called CASCADE H_2 Pro, is being used to incorporate features that allow a more expanded techno-economic assessment of hydrogen fueling station configurations. Updated size, performance, and cost parameters will be obtained based on review of various hydrogen compression, storage, and dispensing products. Using this software tool and other analytical evaluations, a number of system configurations and operating scenarios are to be evaluated.

A key requirement when assessing the sizing and performance of a compressed gas fueling station is establishment of the station demand requirements – i.e., the demand profile. In this effort, we will gather and analyze data from gasoline station operation as well as compressed natural gas vehicles. From this, a daily fuel demand profile (by hour) will be developed for stations of varying size.

Results

Data were gathered and analyzed to define suitable daily hydrogen fueling station demand profiles. Two key sources of information were used:

- Data on three different high-volume gasoline stations (courtesy of ConocoPhillips)
  - Hourly bin data showing daily demand ranging from 5,000 to 15,000 gge per day
- Fleet-oriented, public access compressed natural gas fueling stations
  - Hourly bin data ranging from 500 to 1,000 gge per day

These databases were analyzed for hourly demand profile and scaled to develop an hourly load profile equivalent to daily hydrogen demand of 1,200 kg. Figure 1 shows a comparison of hourly bin demand data for a gasoline fueling station located in a residential setting, a compressed natural gas fleet-oriented fueling station, and the H2A demand profile.

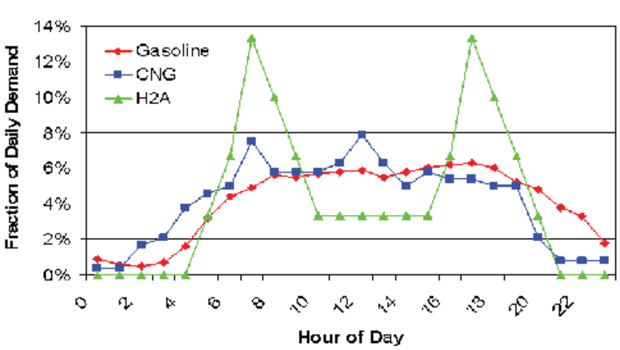

FIGURE 1. Comparative Daily-Hourly Fuel Demand

The shape of this type of load profile can have a strong influence on the design and capital cost of a compressed gas fueling station. The H2A model appears to have a more severe profile in terms of the variability between the on-peak and off-peak demand during normal business hours. This may require a revisiting of the H2A model due to the potential for the current demand profile to require an over-investment in capital equipment.

GTI has a compressed gas fueling station sizing program. This was modified for hydrogen applications in 2002 and released as CASCADE H_2 (along with interim reversions). Enhancements were made to expand the technical and economic features of this program during the first phase of this project. The following is a summary of some of the analytical tool enhancements:

- Improved system flow representation
- Multiple, simultaneous vehicle fueling
- User selectable maximum dispenser flow rate
- Multiple vehicle types and flexible scheduling
- User definable compressor characteristics
- Power consumption, volumetric efficiency
- Compressor electric power and demand calculation
- Time of day and seasonal rates
- Station life cycle cost analysis
- Improved charting and reporting features

Figure 2 shows example data input screenshots for the station sizing and configuration as well as the economic analyses parameters. A revised version of the CASCADE software is planned (called CASCADE H_2 Pro) that will be distributed through our partnership, InterEnergy Software (interenergysoftware.com).

Figure 3 shows a couple of graphs representing the change in onsite hydrogen storage pressure with vehicle refueling demand as well as compressor power demand over this period. These data are being used to assess the station fill performance (e.g., time of fill) and cost.

A feature being incorporated into the model is analysis of system fill performance. The most important parameter is the required time to fill vehicles, which is influenced by factors such as the amount of hydrogen in storage and the pressure level of the storage gas. One analysis looked at a scenario of 1,200 kg/day station with storage levels ranging from 30 to 120 ft^3 of water capacity. As shown in Figure 4 and Table 1, increasing storage led to an improvement in average fill time and a reduction in variation in fill performance. These data provide essential performance along with cost.

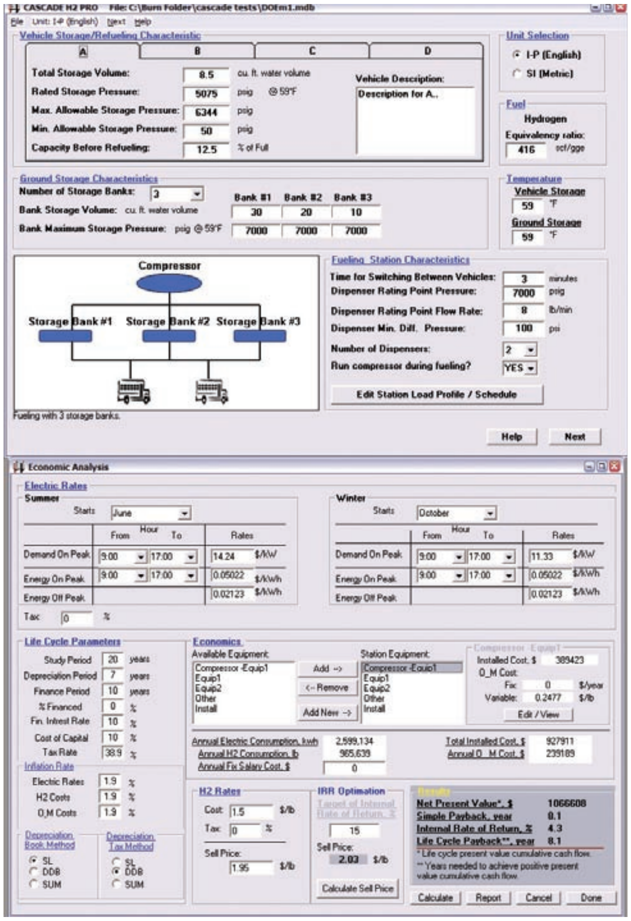

FIGURE 2. Example CASCADE Program Screens

Conclusions and Future Directions

The project is resulting in beneficial insights on the cost and performance trade-offs when sizing hydrogen fueling stations. Preliminary analyses indicate the current H2A demand profile may be overly demanding in terms of the on-peak and off-peak fuel demand at typical fueling stations (based on review of gasoline and compressed natural gas stations). Modifications to the H2A fuel demand profile is likely to result concomitant reductions in station capital and operating costs.

An improved hydrogen station sizing tool is being developed and will be made available for use by interested parties. This will help integrate technical and economic parameters – allowing users to analyze various station sizing scenarios.

Future efforts will examine a range of system configurations or topologies, resulting in an assessment of the cost and performance trade-offs.

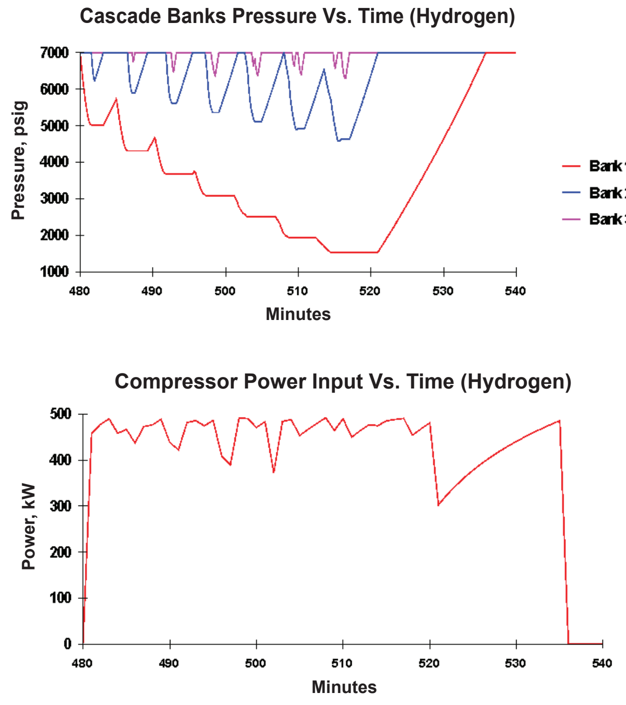

FIGURE 3. Example CASCADE Output Graphs

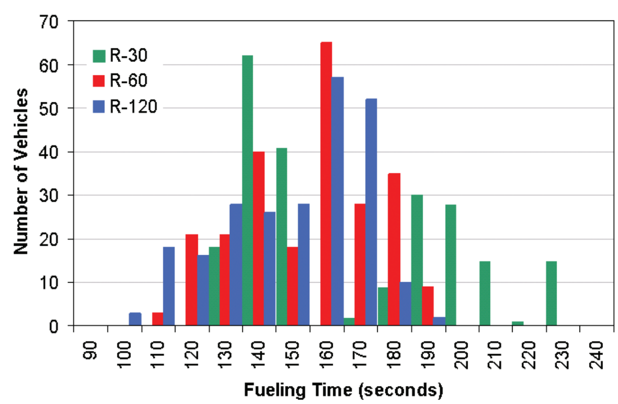

FIGURE 4. Vehicle Fill Times – Effect of Storage

TABLE 1. Influence of Onsite Storage On Fill Performance

	R-30	R-60	R-120
Average Fill Time (seconds)	173	149	145
Standard Deviation	42	19	20