NRC/UBC Fueling Station With Intelligent Compression

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ABSTRACT

BOC Canada Ltd. will design, integrate and construct the second fueling station on the Hydrogen Highway™. This station will be located at the National Research Council's Institute for Fuel Cell Innovation on the campus of the University of British Columbia. BOC's design will bring together an existing alkaline electrolyser, new compression, storage and dispensing.

The station will be designed to serve fuel cell passenger vehicles using 350-bar storage. However, the flexible design concept will allow for many other user needs including the potential for servicing larger vehicles, as well as filling portable storage systems for use at satellite stations. The novel station design also offers the potential to fuel from multiple hydrogen sources.

Together with NRC, this fueling station will be used to increase public, consumer and investor awareness of hydrogen technologies. Design and construction of this facility will assist in the development of industry codes & standards and familiarize authorities having jurisdiction with hydrogen fueling. The system concept offers the utmost attention to safety, novelty and flexibility.

Keywords: Hydrogen fueling station, hydrogen codes and standards, hydrogen quality assurance.

Background

A vehicle fueling station is under development by BOC Canada Ltd. and the National Research Council Canada (NRC). This station is located at NRC's Institute for Fuel Cell Innovation on the campus of the University of British Columbia (UBC). It is is part of the Hydrogen Highway™ with the Canadian Transportation Fuel Cell Alliance also a participant in this station.

The station is designed for hydrogen fueled passenger vehicles such as cars and light trucks. The first users of the station will be the Vancouver Fuel Cell Vehicle Program (VFCVP). The VFCVP is managed by Fuel Cells Canada (FCC) and consists of a three-year evaluation of a fleet of four fuel cell powered Ford Focus under real world conditions. Other potential users are hydrogen internal combustion engine (H_2ICE) vehicles, fuel cell powered commercial work vehicles, lift trucks and satellite stations for fueling vehicles at alternative sites.

Introduction

BOC has assumed the lead role in system integration of the new fueling station. Major components of the station are a Stuart Energy IMET-20 electrolyzer owned by NRC, 450-bar storage and dispensing equipment supplied by General Hydrogen through a separate CTFCA project agreement, and compression and storage supplied by BOC as part of this fueling station project. In addition to compression and storage, BOC will supply engineering, construction and commissioning services. NRC will provide intelligent station controls, data acquisition, supervisory controls, facilities integration and remote monitoring of the system.

As this is one of the first Canadian sites to generate, store and dispense hydrogen adjacent to a institutional property, special consideration is required in the development and application of appropriate process safety standards and codes. To date, most hydrogen fueling stations have been built by partnerships for use by trained technicians in the evaluation of hydrogen or fuel cell technology products. This is the first station designed for use by employees of the fleet vehicles users.

In addition to safety considerations, hydrogen quality assurance (QA) is also a major consideration. Many fueling stations are supplied with liquid hydrogen and almost all impurities must be removed from the hydrogen prior to liquefaction. Methodologies to certify the quality of hydrogen produced onsite, as well as dispensed to the vehicles, must be developed as part of this project.

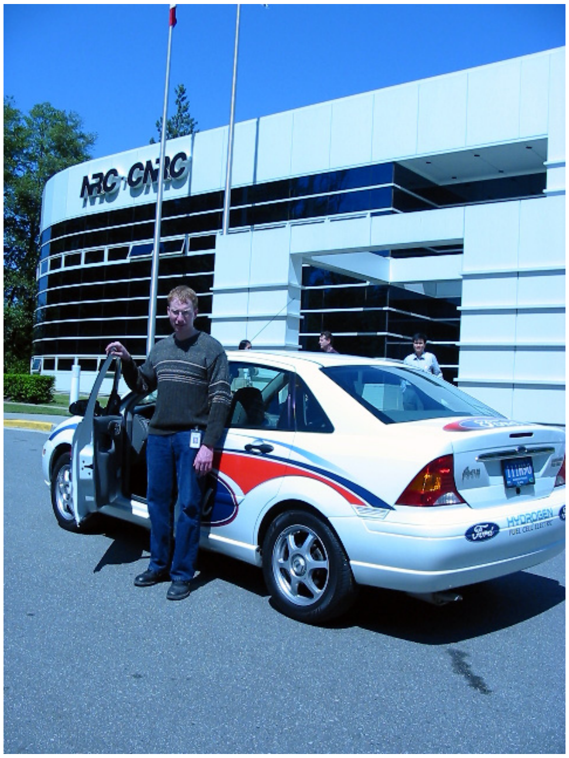

Figure 1: Ford Fuel Cell Vehicle at NRC

Equipment Description

Electrolyzer

The existing NRC owned Stuart Energy IMET-20 has a rated capacity of 29 kg/day at a maximum of 10-bar. NRC is in the process of verifying output and hydrogen quality. Since this electrolyzer uses an alkaline electrolyte, methods must be developed to verify that there is no potassium hydroxide carry-over in the hydrogen stream.

The electrolyzer is housed in an outdoor enclosure approximately 2.4 m high by 2.4 m wide and 6.1 m long. It is located adjacent to the NRC-IFCI maintenance bay area and serviced with a 600 VAC electrical feed and deionized water. Peak electrical consumption is estimated at 70 kW and peak water consumption is estimated to be 17 litres / hour.

Figure 2: IMET-20 Electrolyzer at NRC

Compression & Storage

BOC will supply a compression and storage system to increase the hydrogen from electrolyzer output pressure to 250-bar for intermediate storage and ultimately to 450-bar required for vehicle dispenser storage. The compression system consists of two diaphragm compressors. The first stage compressor is matched to the electrolyzer output capacity and under normal operation, will compress 29 kg / day of hydrogen to approximately 90-bar, which is the operating pressure of the first bank of storage.

When the electrolyser and first stage compressor are running, the second stage compressor will boost the pressure from the first bank (at 90-bar) up to 250-bar which is the operating pressure of the second and third banks of storage (46 kg combined). After either the second or third bank is up to operating pressure, the second stage compressor is used to further increase the hydrogen pressure to 450-bar at up to 8 kg/h, which is the pressure required for supply to the vehicle dispenser.

The two compressors and cooling system will be housed in a frame approximately 3.2 m high by 2.4 m wide and 7.3 m long. The three banks of compressed hydrogen storage consist of ten composite tubes, which will be supported on top of the frame.

The compressors and storage will be placed on an existing hydrogen tube trailer storage pad to minimze cost of installation and ensure that all siting requirements with respect to proximity to building, other fuels, oxidants and property line are met.

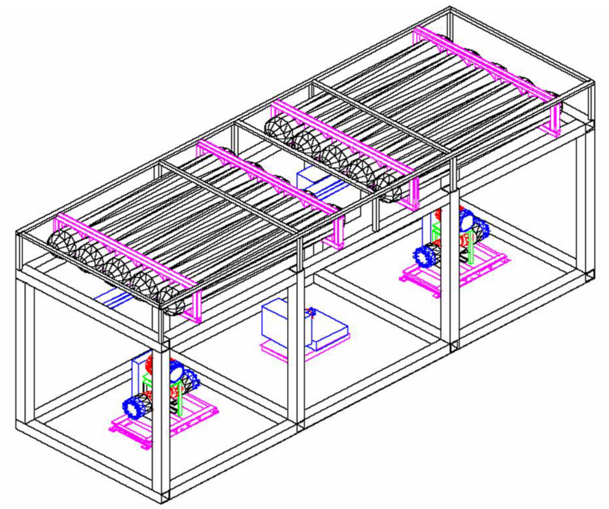

Figure 3: Compressors & 250-bar storage layout.

High-Pressure Storage & Dispensing

The dispenser and associated storage are supplied by General Hydrogen under a separate CTFCA project and integrated into the fueling station by BOC. The dispenser is designed to supply up to 4 kg per minute with target fill times for the Ford vehicles of 2 to 3 minutes.

Sixty-seven kilograms of hydrogen are stored at 450-bar in an enclosure with a footprint of 1.8 m by 2.4 m. The storage tower and dispenser are located in NRC-IFCI's demonstration area in the general proximity of the compressors.

Figure 4: Hydrogen dispenser

Design Considerations

Station Design Requirements

At start-up, system load is expected to be significantly lower than rated capacity of the station. Each Ford Focus tank holds a maximum of 5 kg of hydrogen with an estimated range of 260 to 320 km. The target vehicle mileage is 12,000 to 15,000 km per year per vehicle. Thus each car is expected to consume 250 kg H_2 / year and fuel 50 to 80 times per year.

Accordingly, the compression and storage system must be designed to offer flexibility in the following situations:

- Frequent cycling since the station will not be required to operate continuously.
- High turndown ratio since it may be advantageous to run the electrolyzer at part-load to minimize electrical demand charge[1].
- Ability to accept hydrogen sources at varying pressure as hydrogen tube trailers will be used to back up the electrolyzer, plus alternative hydrogen generators may be added to the fueling station in the future.
- Ability to rapidly refill the dispenser storage from intermediate pressure storage to ensure multiple vehicles can fill in quick succession and larger vehicles may be filled.
- Ability to fill multi-cylinder packs and satellite stations for use off-site.

In response to these system requirements, BOC developed the system as shown in Figure 5 and described in the following section.

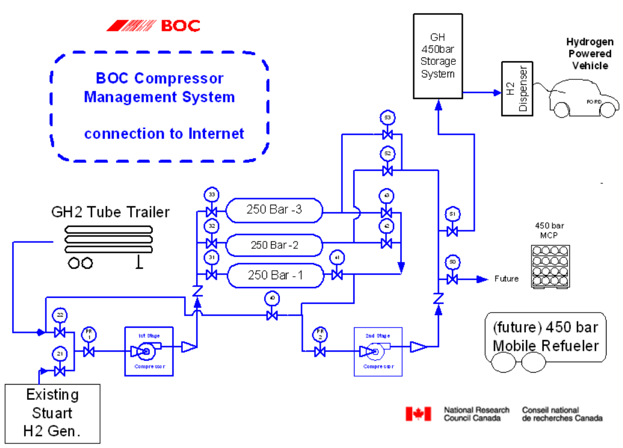

Figure 5: Station Process Flow Diagram

System Design & Control

This compression system uses two stages of compression and three banks of storage at two operating pressures. This allows the requirements described in the previous section to be managed in the following ways:

- The dual compressor design reduces cycling of each individual unit. The first stage compressor will operate continuously within the constraints of the supervisory control.[2] The second stage compressor will operate intermittently to transfer stored hydrogen to the high-pressure storage and optimise the hydrogen storage in the low-pressure banks. The second stage compressor will operate independently from the first stage compressor, and with the low pressure storage (250-bar), allows for filling of the dispenser storage without starting the first-stage compressor.
- A high turndown ratio is required to ensure part-load operation can be achieved. Part-load operation may be desirable to minimize electrical demand charge during peak hours, or deal with temporary system bottlenecks due to maintenance or other factors. The diaphragm compressors are positive displacement devices. However, since volumetric flow must remain relatively constant, turndown is achieved as system pressure and flow adjust according to the characteristics of the compressor.
- Hydrogen from tube trailers at approximately 160-bar will be used for commissioning and may be required as backup or supplement for the electrolyser. In addition, alternate hydrogen generation technologies may be added to this system in the future. Again, the system has the ability to manage these variations, as the flow through the compressor will increase up to 8 kg/h at a suction pressure of 160 bar.
- Hydrogen is dispensed from 450-bar storage to the 350-bar vehicle storage. Since hydrogen storage tube temperature rises as they are being filled, the vehicle tank pressure must exceed 350-bar by approximately 20% in order to achieve a 5 kg fill. This overpressure requirement determines the number of complete fills that can be achieved before the dispenser storage must be replenished. A two-stage compression system allows for more rapid refilling of the dispenser storage system.

[1] Electrical demand charge is directly related to peak power consumption during a calendar month. At full load, the system will consume approximately 100 kW. By operating the electrolyzer and compressor at part load, electrical demand charge can be decreased.

[2] Examples of supervisory control are restricting operation to off-peak hours to minimize electrical demand charge OR to daytime to reduce noise during evening and early morning hours.

- The use of two-stage compressors will allow for rapid filling of multi-cylinder packs and satellite stations that will eventually be used for fueling at alternate sites. The design offers the potential for compression above 450-bar with appropriate tubing and valve design.

Process Safety Considerations

Due to the hazards posed by the handling of compressed and flammable gas, in addition to the industrial hazards associated with operating complex machinery, this design will undergo a thorough safety review process led by Hydrogen Safety LLC. In addition, the individual sub-systems will be reviewed thoroughly by their respective equipment design and supply teams.

Two equally important safety considerations are the station's location, which occupies a common site with a combined use research centre and office building housing 200 occupants and the station user group, which will consist of trained vehicle drivers rather than trained research technicians.

During the safety review process, the project team will work with local authorities having jurisdiction (AHJs) to familiarize them with the station safety features to maintain approval for fueling station siting. In addition, the project team will work with codes and standards committees to ensure the development of appropriate regulations for fueling stations.

An area closely linked to safety is the insurance industry. BOC is sharing their knowledge of hydrogen equipment and safety systems with representatives from this field to enable insurers to assign an appropriate and not overly burdensome risk assessment to this project.

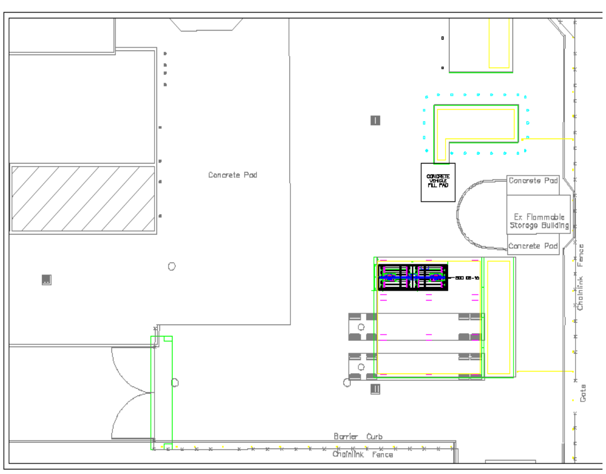

Figure 6: Station Layout at NRC

Quality Assurance

Ensuring adequate hydrogen quality for fueling of PEM fuel cell vehicles is an important factor in station design. Some fueling stations are designed for H_2 ICEs and therefore do not have the strict hydrogen purity requirements of PEMFC systems. Other stations are supplied with liquid hydrogen, which offers extremely low levels of contaminants.

The station uses diaphragm compressors, which are oil-free and thus eliminate the risk of oil contamination. In addition, the hydrogen will be generated by alkaline electrolysis, which eliminates the risk of sulphur, ammonia and CO contamination. However, water and oxygen content must be monitored, as well as ensuring that there is no KOH carryover from the electrolyte.

Therefore, a comprehensive QA program will be developed. The program will include the following:

- Identification of contaminants to be monitored.
- Analytical methods, minimum detection limits and maximum contaminant levels.
- Sampling procedures and equipment.
- Monitoring frequency for each contaminant.
- Acceptable analytical laboratories.

This program is necessary to verify the suitability of the components included within this station design as well as ensure a controlled evaluation of the vehicles fueling at the station.

Controls & Information System Scope

BOC and NRC will jointly work to provide a system to control and monitor the station safely and efficiently. Data acquisition, storage and access is an important factor since this station will be used to evaluate station as well as vehicle design and operation.

BOC will design the master control for the entire station function including integration of non-BOC supplied sub-systems such as electrolyser, dispenser and storage. This master control system will ensure that the station is interlocked to start-up, operate and shutdown safely.

NRC shall provide alarm management, data acquisition and storage, supervisory control and data access to partners. Supervisory control is used to enhance the station operation based on logistics such as predicted vehicle fuelling schedules, electrical cost schedules, noise by-laws and equipment maintenance schedules. NRC will also provide the "Plug & Produce" function as described in the following section.

Plug & Produce

One of NRC's longer-term objectives is to work with the industry to develop Plug & Produce capability for energy devices. The hydrogen fuelling station could be considered an energy node, which is made up of a variety of energy devices: electrolyser, low & high-pressure hydrogen storage, compressor and dispenser.

Initially, the station is expected to fuel the four Ford fuel cell cars a couple of times a week. However, the demand for hydrogen will increase as traffic increases over a period of time. This may require adding more capacity for generating, storing, compressing or dispensing hydrogen. Typically every time the configuration of the station is changed, it requires reconfiguration of its centralized supervisory control and data acquisition system.

NRC proposes a "Plug & Produce" approach. Each energy device would be equipped with its own control. When a new device, such as a compressor is added, its controller will announce its availability and the service it can provide. From that point on, whenever compressed hydrogen is needed, the added compressor is available to provide the service. Selection between compressors is accomplished by using what is known as "contract-net protocol based negotiations" employed in modern distributed agent-based control systems.

This technique has been researched and used by well-known companies such as Rockwell Automation, Daimler Chrysler, Toshiba and Fanuc for distributed control of factories and supply chains. They have verified that these systems are efficient, scalable, robust and economical. NRC's intention is to utilize this technology for scalable hydrogen infrastructure design that will allow increased throughput without continual re-engineering of controls.

Public Interest, AHJs and Other Parties

One of the goals for this station, and the entire Hydrogen Highway is to promote awareness and acceptance of hydrogen and fuel cell technologies among the public, authorities having jurisdiction, insurance providers and investors.

NRC and BOC will achieve this goal in conjunction with CTFCA, through a number of channels. AHJs will be familiarized with the station during the design and commissioning stages. Results of the safety analysis will be provided for AHJ review and insurance industry discussion. Tours of the station will be offered through trade organizations.

Finally, public and investor education will be available through NRC, CTFCA and BOC's outreach and media programs.

Summary

In conclusion, the new NRC/UBC Fueling Station will provide hydrogen for the evaluation of fuel cell and ICE passenger vehicles. The station design and build will also offer opportunities in the field of code development.

The flexible station design uses a novel two-stage compression and storage system that allows for high turndown, varying compression ratios, rapid refilling of dispenser storage, addition of alternative hydrogen supplies, and fueling of satellite stations.

A thorough safety review will be conducted and safe operation is ensured through the control system. Data will be managed for review and evaluation of station reliability and operation. Supervisory control strategies and Plug & Produce concepts will also be assessed.

A quality assurance program will be developed and implemented for this station. And the project participants will develop a comprehensive awareness and outreach program for this site.

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