Designing a CNG FUELING

You've made the decision to transition to compressed natural gas (CNG) for your vehicle fleet — here's your next step. **BY ROB ADAMS**

Project use and need before constructing a CNG fueling station in order to size correctly. Pictured is the City of Columbus, Ohio, CNG fueling station, a project in which Adams served as consultant.

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Compressed natural gas (CNG) is considered one of the cleanest, safest, and lowest-cost vehicle fuels, and it's produced in North America. However, it isn't as simple to handle as conventional fuels such as gasoline and diesel. Not only are there added vehicle costs, the decision to construct a CNG fueling station is a major factor in switching a fleet. CNG stations are a significant capital and operating commitment that should be given full consideration before purchasing decisions are made.

Make a Plan for Transition

Develop a plan for CNG transition early, as it is necessary to think ahead about facility design. It is possible to oversize a facility, but it is more common to under-size equipment, particularly the compressor. Small compressors can lead to slow or incomplete fueling.

First, assemble current fueling records:

- Gallons of fuel consumed per day by vehicles that will operate on CNG. Average fuel consumption for the fleet should be used, not the maximum or the tank capacity.
- Number of vehicles to be fueled per day, noting that CNG vehicles often carry less fuel than liquid-fueled vehicles and therefore may require more frequent fueling.
- Fueling patterns at the site. For example, do vehicles return to the yard for several hours a day or come only for fueling?
- Will vehicles be bi-fuel CNG/gasoline or dedicated CNG? This will impact the level of redundancy required in the CNG station.

Some vehicles may not be immediate candidates for CNG. These include older vehicles scheduled for disposal in the near term and low-use vehicles. Diesel vehicles are often difficult to satisfactorily convert to CNG, so it may be advisable to wait until the next trading cycle and replace them with OEM-dedicated CNG engines on new vehicles.

(At a glance)

Plan ahead when constructing a CNG fueling station. Consider:

- Will the station be a fast-fill or time-fill?
- How many vehicles need to fuel there, when, and how much fuel?
- How large does the station need to be?
- What types of station components do you need to purchase?

Determine Station Type

There are two styles of CNG stations in wide use today. These are time-fill (also called slow-fill) and cascaded fast-fill. A third style, buffer fast fill, is mostly used for transit applications and will not be discussed here.

1. Time-Fill Station

In a time-fill station, gas is first dried to reduce the moisture. Then, after compression, CNG is dispensed through a manifold to all vehicles simultaneously. This system is simple and can be the most cost-effective method because the compressor is often smaller than required for fast-fill, and there is no storage or cascading required. There may be manpower savings as drivers connect to the manifold and walk away, with no time lost in fueling. See Figure 1 on page 27.

Time-fill has several limitations. It is applicable only when fleet vehicles return to a common facility for several hours, preferably overnight. Also, while it is possible to accurately measure fuel dispensed to each vehicle, it is generally cost prohibitive and complicated.

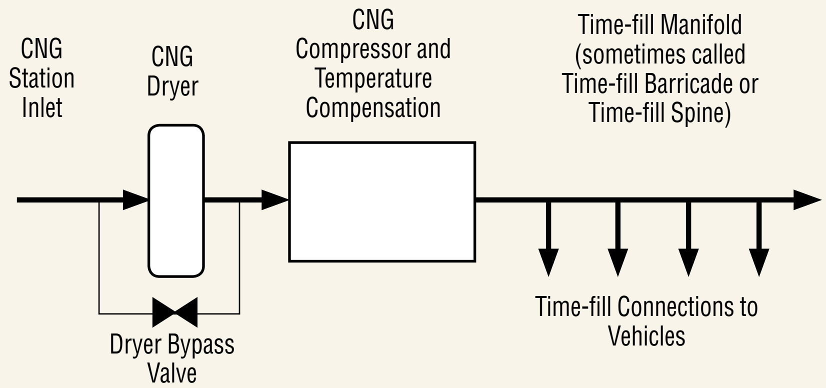
2. Fast-Fill Station

One answer to the problems of a time-fill station is a cascaded fast-fill station. See Figure 2 on page 27.

The primary difference between time-fill and fast-fill is the use of a group of high-pressure vessels divided into banks (usually

STATION

Figure 1: Time-Fill Station Schematic



In a time-fill station, CNG gas is dispensed through a manifold to all vehicles simultaneously.

three) which are automatically "sequenced" or "cascaded" to fill a vehicle.

The cascade fast-fill provides higher flows than the compressor alone, so vehicles fuel in a similar time to liquid-fueled vehicles. Individual metering is easy, and fast-fill accommodates fleets that do not stay in a yard.

Capital cost can be a deterrent from using fast-fill. Note that as storage is depleted (below 60-70% of stored volume), fill times increase, particularly with marginal or undersized compressors.

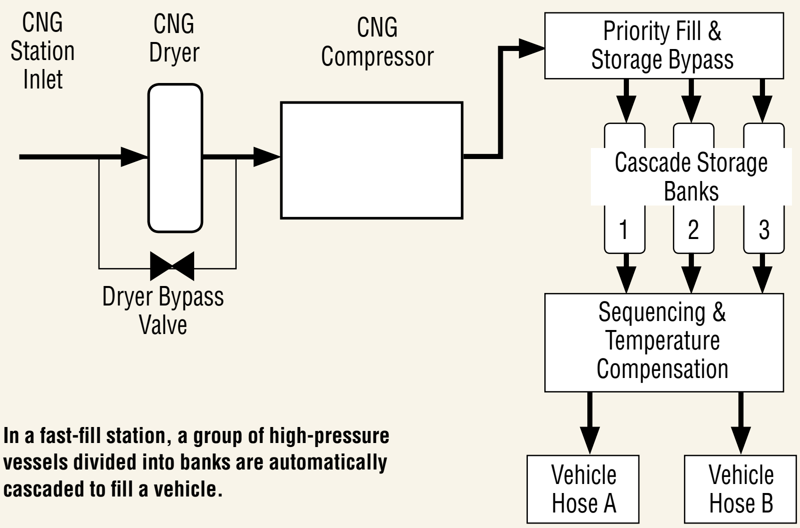
Understand Station Components

The following is a brief overview of station equipment:

1. Gas dryers

Gas dryers are needed to reduce the

Figure 2: Cascade Fast-Fill Station Schematic



In a fast-fill station, a group of high-pressure vessels divided into banks are automatically cascaded to fill a vehicle.

Pictured is a typical Marathon Corporation-designed time-fill barricade.

moisture content of the gas.

Usually, station inlet drying is preferred over high-pressure drying. Inlet dryers have various advantages over outlet dryers, including a lower capital cost and lower operating and maintenance costs. They are also safer because drying is done at low pressures.

To reduce capital and maintenance costs, a single tower dryer with a manual regeneration system can be used in many small- to medium-sized CNG stations.

2. Gas compressors

Compressors are the heart of the station. Many styles and manufacturers exist, but all are reciprocating compressors — that is, they contain pistons that run in cylinders. Variations are due to differences in the heritage of the machine.

The "package" (equipment on the skid supporting the compressor) can be more critical than the compressor block design. Some block manufacturers have several "packagers" with varying quality and capabilities. Don't assume that one compressor package is equal to the next if they share a common block manufacturer.

In machines with 50 hp or less, the lowest-cost compressors tend to be converted air compressors. This usually limits suction pressure to 5-15 lbs. per square inch gauge (PSIG) and most are lubricated design.

Above 50 hp, industrial and gas patch adaptations become more cost effective. These machines are more complex than air compressors but tend to be more rugged.

At least one compressor manufacturer markets a "non-lubricated" compressor, meaning that the cylinders receive no lubrication. This can simplify the machine and possibly eliminate oil carryover to the vehicle. However, there are drawbacks to non-lube compressors, including potentially lower life of internal wear items in the compressor including rings and piston rod seals and a need to run compressors slower and cooler. Purchasers should check to ensure the machines have been used successfully on CNG applications for several years.

If you are using a lubricated compressor, it should utilize synthetic oil that will not vaporize. This oil can be effectively removed from the gas stream using a properly designed filter system. The compressor supplier must ensure that the synthetic oil is compatible with any equipment or oil that might be in the system.

Air-cooled compressors have proven their durability and are the industry standard.

Horizontally opposed designs are proving popular above 50 hp with their inherent balance (low vibration) and ease of service, and they can be used at very high horsepower applications. Other configurations for compressors less than 300 hp include V and W cylinder arrangements.

A CNG compressor generates 90 to 100 dBA noise at three feet, so it may be necessary to provide an acoustical enclosure. A properly engineered enclosure is costly, but it is the most effective noise control on the site and facilitates installation of equipment near property lines or buildings. In climates where temperatures drop below 20°F, enclosures can be equipped with space heaters.

Higher utility gas service pressure will reduce the compressor size, cost, and horsepower. See if this is offered by the local gas utility. The higher the inlet pressure, the fewer stages and the lower horsepower is required to produce the same standard cubic feet per minute (scfm) of flow. For example, based on 100 scfm and 4,500 PSIG discharge pressure, 5 PSIG suction requires 5 stages at 60 hp; 100 PSIG suction requires 4 stages at 36 hp; and 300 psig suction requires 3 stages at 26 hp.

The U.S. CNG industry has standardized on 3,600 PSIG vehicle pressure, which implies dispensed pressures of up to 4,500 PSIG. Compressors should be rated for continuous operation with a discharge pressure of 4,500 PSIG.

Pictured is a single tower dryer with on-skid regeneration. Dryers reduce the moisture content of the gas.

Most new CNG stations use electric motors to power the compressor rather than the natural gas engines sometimes used in the past. Electric motors are simple, compact, create no on-site emissions, and are very reliable.

3. Gas storage

Gas storage is used on fast-fill stations

◀Pictured is a 200 hp non-lubricated CNG compressor package with acoustical enclosure.

Pictured is a 35,000 scf, 5,500 PSIG tube type storage.

only. Several configurations (small tubes, large tubes, and spheres) are available. Fleets can use cost as the main selection criterion.

For cascade stations, storage should be set up in three banks. Storage vessels should have a minimum design pressure of 5,500 PSIG (the most common current storage design pressure) and should be equipped with condensate drains. Generously sized storage will improve station performance and reliability.

4. Gas dispensers

Gas dispensers vary widely depending on application; however, the following are general guidelines:

▶ ***Time-fill***

- NGV1 time-fill type connectors
- 3/4-inch conductive CNG hose rated at 5,000 PSIG (the most common current rating) with hose retractors and in-line breakaways
- Coalescing filters for each manifold.

▶ ***Fast-fill Cascade***

The following typical design will provide maximum reliability and performance for light- and medium-duty vehicle applications:

- NGV1 fast-fill type connectors
- 3/8-inch or 3/4-inch conductive CNG hose rated at 5,000 PSIG with hose retractors and in-line breakaways
- Coalescing filters for each line
- Mass flow meter and electronic display compatible with fuel management systems for each hose
- Electronically controlled priority fill (to control gas flow from compressor to storage) and sequencing (gas flow control from storage to vehicle)
- Electronic temperature compensation adjusts vehicle fill pressures to compensate for ambient temperature changes and "heat of compression," the temperature rise in the vehicle tank during a fast-fill operation. The system should be designed for a reference pressure of 3,600 PSIG.
- Station electronic controls should be integrated to maximize safety and performance. Remote network monitoring should be provided to reduce downtime and repair costs.

Natural Gas Benefits Can Outweigh Costs

Design and selection of a CNG fueling station is more involved

Station Sizing Examples:

1. Time-Fill

- 50 dedicated CNG garbage trucks previously using 25 gallons of diesel per day
- Vehicles return to yard 16 hours/day

CNG required per day = 50 vehicles x 25 gallons diesel x 137 scf NG/gallon diesel ÷ 0.88 CNG to diesel efficiency factor (diesel engines are more fuel efficient than CNG engines) = 194,602 scf/day.

Assume 12 hours of compressor operation per day:

$$\frac{194{,}602 \text{ scf}}{12 \text{hrs/day} \times 60 \text{ mins/hr}} = 270 \text{ scfm}$$

Since this is not a bi-fuel vehicle operation, we will assume 100% redundancy requirements:

$$\frac{270 \text{ scfm} \times 2.0 \text{ redundancy factor}}{2 \text{ compressors}} = 270 \text{ scfm per compressor}$$

2. Cascade Fast-Fill

- 100 dedicated CNG pickup trucks previously using 6 gallons of gasoline per day
- Vehicles do not park overnight in yard

CNG per day = 100 vehicles x 6 gallons gasoline x 120 scf NG/gallon gasoline = 72,000 scf/day.

If one third of the fleet fuels 7-8 a.m., then we would size as follows, assuming an average fill time of 6 minutes, or 10 vehicles/hose/hour:

$$\frac{33 \text{ vehicles/peak hr}}{10 \text{ vehicles/hose/hour}} = 3.3 \text{ hoses, hence two 2-hose dispensers are needed}$$

It is assumed that the storage is 35,000 scf (typical) and that 40% of storage is utilized (requires electronic priority fill and sequencing). The CNG from storage is 40% of 35,000 scf = 14,000 scf

Thus, the compressor(s) must produce:

$$\frac{(72{,}000 \text{ scf/day} \times 1/3 \text{ of the fleet per peak hour}) - 14{,}000 \text{ scf storage}}{50 \text{ minutes of compressor operation per peak hour}} = 200 \text{ scfm}$$

(Compressor does not start immediately so 50 minutes of operation are used.)

Assume 50% redundancy since the vehicles are dedicated CNG:

$$\frac{200 \text{ scfm} \times 1.5 \text{ redundancy factor}}{2 \text{ compressors}} = 150 \text{ scfm per customer}$$

than gasoline or diesel fueling stations. A properly sized and designed station will reliably serve a fleet for many years, allowing the fleet to comply with federal and local clean air mandates while enjoying the benefits of a relatively inexpensive domestic vehicle fuel. ✪

About the Author

Rob Adams is a professional engineer with more than 30 years and nearly 200 CNG station projects in the CNG market. He is the founder and principal of Marathon Corporation. He can be reached at radams@marathontech.ca.