So You Want a CNG Fueling Facility?

It's not easy to add CNG fueling services to an existing service station—let alone, start a new CNG fueling facility. Shell Oil's Glen Marshall discusses the ins and outs of CNG fueling system design, equipment, permitting, construction and operation.

Design, installation and operating tips
In last month's issue, Glen Marshall discussed compressed natural gas (CNG) as a motor vehicle fuel and how to plan a CNG fueling facility ("Why and How to Plan a CNG Fuel Facility," July 1998, p. 6). In this follow-up article, Glen shares his insights and provides valuable tips on CNG equipment, system design, permitting, construction and operation.

Photo 1: The Grand Opening of CNG services at a Shell gasoline station, courtesy of Shell Oil.

CNG is not pumped into a vehicle like conventional liquid fuels. CNG vehicles are equipped with special tanks and fill connections that can be joined with CNG fueling systems. The only thing that moves CNG from its ground storage system tanks into a vehicle is the differential pressure between the two. (Ground storage tanks is the term used in the trade to distinguish the CNG fueling system's storage tanks from the tanks on vehicles.)

Sounds simple enough on the surface, but designing, permitting, installing and operating an efficient, cost effective CNG fueling system involves numerous complex variables and difficult choices. Making the wrong choices can have bad consequences. For example, a system that is undersized can result in significantly increased operating and maintenance costs; an oversized system's acquisition cost is higher than warranted in the circumstances, which extends the time required to recover up-front costs, and takes more to maintain and operate than a properly-sized system. Following are some of the variables and choices that are critical to designing the right CNG system for a particular need:

• Size and type of compressor systems
• Size and type of storage tanks w
• CNG product conditioning systems (e.g., driers)
• Control systems
• Acquisition, operation and maintenance costs

The remainder of this article will deal in more detail with the above factors, as well as some other variables, and offer suggestions on how to make the right choices.

Photo 2: Compression system inside concrete block enclosure—the first CNG service station in California (Sacramento), courtesy of Shell Oil.

Size really matters

Proper compressor and ground storage tank sizing is critical. In an undersized CNG facility, the compressor system must run continuously. On the other hand, the compressor in an oversized system runs infrequently. Either way, costs can be significantly more than necessary, either in the form of maintenance and operating costs, up-front acquisition costs or both.

All fast-fill CNG equipment systems need recovery time—i.e., adequate time for the ground storage tanks to be recharged (refilled) with CNG after customer vehicles have been fueled. Such recovery time is not needed in slow-fill CNG systems, where the compressor fills the vehicle directly from the compressor with no ground storage tanks. As the names imply, slow-fill systems take much longer to fuel a vehicle than fast-fill systems (e.g., slow fill, eight to 12 hours versus fast-fill, four minutes).

In the sizing process, one must consider numerous variables, including inlet gas pressure from the gas source; typical sales patterns (e.g., continual, periodic and peak demand times); numbers of vehicles to be refueled at any given point in time; on-board storage capacity of the individual vehicles; discharge or sales pressure (2,400 psig, 3,000 psig or 3,600 psig); and average refueling time requirements (a function of piping designs for the fueling equipment and the vehicles).

Photo 3: Complete CNG compression system and ground storage tanks at Encinitas, CA station, courtesy of Shell Oil.

What will drive the compressor?

Another important variable to consider is the type of motor (natural gas, diesel or electric) that will drive the compressor. This variable is interrelated with the compressor and tank sizing factors.

Types of electrical service and electrical utility costs for the area are of paramount concern. Since electric motors require much more power to start up than to run normally, electric utilities tend to base rates on this higher current demand. These rates are known as demand charges, which are the T-Rex of operating economics when electric motors are involved. They can eat your proverbial economic lunch! Given the well-known equation V=IR (voltage equals current times resistance), the higher the voltage, the less the current required. Assume a constant given load. For 240v power, required current is roughly half that for 110v power. For 480v power, the required current is about one quarter that for 110v power.

Electrical power is paid for in units called watts, which are a function of voltage and current over time. Lower current results in lower watts and, therefore, lower electrical operating costs. Thus, for any electric motor larger than 5-10 horsepower, 480v or 240v/3-phase electrical power should be used, if available.

Unfortunately, this type of electrical power usually requires a transformer, which increases up-front costs of a CNG system. On the other hand, substituting an internal combustion engine to drive the compressor may or may not prove more economical to operate; but doing so will introduce engine exhaust emissions and noise factors that could be quite unpopular with air quality regulators and nearby neighbors.

Noise from compressor engines and other sources at a CNG facility may warrant enclosing the compression system to suppress the noise (see Photos 2 and 3). The need for an enclosure can be increased because of the weather in the area. The compression/decompression of CNG usually introduces moisture (condensation) inside the equipment, which could freeze up the equipment and the customer’s vehicle.

CNG quality is of critical concern. The more water and oil vapor entrained in the natural gas, the greater the need to add filters, separator tanks and a gas drier to condition the product before and after compression. Filtering also removes contaminating particles from the natural gas flow stream.

There are several different types of driers: inlet (low pressure); discharge (high pressure); manual- or automatic-regenerating; single column (see Photo 4) or multi-column; and others. An ill-chosen drier can substantially affect the CNG system’s efficiency and cost effectiveness.

Photo 4: Single-column CNG drier at a station in Jersey City, NJ, courtesy of Shell Oil.

A parade of options

Proper consideration of the factors discussed so far will help determine the appropriate sizes and types of essential CNG system components. However, it doesn’t end here. There are numerous other choices to be made in the types and designs of compressors, including lubed vs. non-lubed; air-cooled vs. liquid-cooled; rotary vs. reciprocating; and number of compressor stages.

Options for ground storage tanks include: Department of Transportation (DOT) bottles, American Society of Mechanical Engineers (ASME) cylinders and ASME spherical tanks.

Several options are also available for the types of controls for compressor drive motors and other systems, including mechanical, electronic, electronic with remote polling capability and more. Options also exist for the gas priority/sequencer controls (see Photo 5) for routing the gas from the compressor into the ground storage tanks and out of the storage tanks into the customer’s vehicle tank; piping systems; vent systems; island dispensers; remote dispenser readout equipment; specialty and safety equipment (e.g., emergency shutoff controls, fire extinguishers and spray arches); and site aesthetics.

Obviously, all these variables are interrelated and the resulting system must operate as a thoroughly coordinated machine. The drawing below depicts a typical CNG equipment skid layout.

So what’s the tab?

Acquisition, installation, operating and maintenance costs for a CNG facility will, of course, depend on the choices made on all of the system components. Accurately estimating these costs is a very site-sensitive and time-sensitive task which is not possible without a plan detailing the precise types, sizes and other factors related to the components. Guidelines for making ballpark estimates for planning and budgeting purposes only are presented below. The given dollar amounts represent current dollar averages and may vary depending upon final design details and local price variances. While inflation and other factors may drive costs upward over time, CNG market development, acceptance and consumption may tend to drive costs back down.

• **Fully packaged compressor system** (with electric motor drive): Roughly $750 to $1,300 per drive horsepower. This does not include the capital costs for electrical service or any electrical upgrading. Costs tend to approach the upper limit for smaller horsepower systems and systems that are not fully optimized for the compressor frame size. Internal combustion engine drives can increase these costs by about 20 percent and may or may not turn out to be more viable overall. See Photo 6.

• **Ground storage tanks** (fast-fill only): Storage tanks (ASME cylinders or spheres) should cost about $1.25 to $1.50 per standard cubic foot (scf) of storage volume. As used here, scf means the volume of gas at normal ambient temperature and atmospheric pressure, not the volume of gas after compression. DOT bottle storage, while normally less expensive, is losing favor because of disruptive regulatory testing requirements and the propensity for minor gas leaks at the piping joints. See Photo 7.

• **Dispensing equipment:** Normal costs for fast-fill dispensing systems are about $20,000 to $30,000 per hose. This includes buffer, sequencer and remote readout controls. Slow-fill systems typically use unmetered fill posts rather than fancy metering dispensers so the base costs drop to a range of $3,000 to $4,000 per hose.

• **Gas conditioning equipment:** Due to the numerous design variables, good budget guidelines are extremely difficult to provide. For pipeline quality gas (satisfying SAE J-1616 requirements), multi-column automatic regenerating systems cost between $30,000 and $150,000. The lower range limit represents smaller stations—say around 150 standard cubic feet per month (scfm), or less—while the upper limit represents facilities over 2,500 scfm. Costs can be reduced by using single column and manually regenerated designs, but this would add regenerating costs (usually done by a local service company) of about $10,000 to $25,000 per occurrence, plus some lost sales revenues during the regenerating process. The regenerating process can take from six to 10 hours.

• **Emergency control systems:** These costs are influenced by local requirements and owner preferences as to the degree of protection to be provided. Therefore, realistic budget guidelines cannot be provided herein.

• **Operating and maintenance costs:** These costs vary widely depending upon such factors as equipment selection, system design, availability of qualified local service contractors and employee knowledge. A very rough estimate is five percent to seven percent of the total capital cost for the system per year. Unlike typical gasoline stations, maintenance costs for CNG systems do not tend to vary directly with utilization levels. To the contrary, maintenance costs are often lower for stations that are used heavily and higher for those that are used infrequently.

• As a rule of thumb, 40 percent of a typical project’s cost is for equipment and 60 percent is for labor, permitting and consulting services.

Photo 5: Priority/sequencer panel with door open, courtesy of Shell Oil.

Help wanted: CNG experience a must

Given the complexity of CNG systems and the myriad regulatory and code requirements (see end of document), facility layout and system design should not be undertaken by someone untrained and inexperienced in the trade. In fact, putting a whole project together often requires using a CNG-experienced consulting engineer.

However, it may be far more practical to (1) carefully determine the anticipated operating or performance needs and (2) have an equipment packager design the equipment system and site layout. Equipment packagers are specialists that supply equipment, design systems, and often offer engineering, installation and equipment maintenance services. They can be invaluable in helping a prospective CNG operator write a comprehensive set of equipment system specifications and even to assist in identifying and evaluating the preliminary planning needs.

CNG equipment installation and maintenance also demands specialized education, training and experience. It cannot be done properly by contractors whose knowledge and experience are limited to conventional liquid fuel systems. CNG training is neither brief nor inexpensive, requiring more than a typical one- or two- day seminar. The training and experience must come from professionals experienced in gaseous fuel systems.

Photo 6: Complete CNG compression system, courtesy of Shell Oil.

Finding the good guys

Prequalifying vendors and contractors can materially reduce the complexity and confusion inherent in contract bidding, evaluation and awarding. Unqualified and poorly-performing contractors are identified and eliminated up-front. Often, vendors looking to bid on certain parts of the project, such as electrical work or pipe fitting, can be identified as having little or no prior CNG experience. They may offer lower prices by use of substandard components or substandard workmanship. Other vendors with qualifying knowledge and experience can still represent an undue financial risk.

Before trying to cut corners or costs by using substandard approaches, remember the two adages: pay me now or pay me later; and it isn't what it costs to do something, but what it might cost if you don't. Delays, damages and rework invariably cost more in the end than doing it right the first time. Doing your homework thoroughly to select the right vendors takes a little more skill and time, but it can avoid immeasurable headaches.

Proper prequalification of a potential vendor or contractor requires the following investigative work:

• Find out if the vendor or contractor has, and follows, a written "quality assurance" program. If so, audit the program's effectiveness. Inadequate quality assurance often leads to costly problems. As used here, “quality” means meeting requirements the first time around; not necessarily producing a Cadillac.

• Review the vendor’s documentation from a previous similar project. Talk to the vendor’s recent customers.

• Visit and evaluate the vendor’s facilities, equipment, spare parts or materials inventories and employees.

• Visit with the vendor’s bank or other financial source(s).

• Visit with regulatory agencies who’ve inspected the vendor’s prior projects.

• If an experienced consultant has been retained, involve that person in the above visits and evaluations.

Photo 7: Spherical CNG ground storage tanks, courtesy of Shell Oil.

Monitoring construction

It is usually impossible or impractical to be on-site to observe the entire construction process. However, frequent site visits are necessary to evaluate the progress and quality of the project. Inspecting critical construction elements and observing required testing of system components during construction are especially important. Examples could include: preparations prior to concrete placement, leak testing prior to backfilling excavations and wiring connections prior to the application of electrical power. Consultants, such as engineers and equipment packagers, may be far better qualified to perform these functions.

Construction costs should be continually documented and tracked, including extras for unforeseen problems. Such adjustments may be more than a measure of planning accuracy and job progress; they often are indicative of developing problems. Vendor and contractor payments should be progressive as a function of the degree of job completion, with a stipulated amount withheld until completion of work, verification of specification and code compliance, and of inspection approvals by regulatory agencies. Never pay fully up front.

Hazards reduced but not gone

As written earlier, natural gas is considered to be non-toxic, environmentally “friendly” and less prone to ignition than gasoline. However, there are still some safety considerations with natural gas.

Beyond the dangers inherent in high-pressure system operation, natural gas poses a simple asphyxiation hazard in concentrations exceeding about seven percent (fuel-to-air ratio). The obvious safeguard against such hazards is adequate ventilation. And, if it did not burn or explode, natural gas would not offer much as a fuel for motor vehicle engines. So fires and explosions are also a safety concern for vaporous fuels.

CNG engine combustion by-products contain very little soot (compared to diesels) and greatly reduce the formation of nitrogen oxides, carbon monoxide, sulfur dioxide and reactive hydrocarbons that add to smog problems. Aldehydes are present in CNG engine emissions, as they are in gasoline engine emissions, but these can be largely controlled by proper engine design (or conversion) and maintenance.

Carbon dioxide, the gas most associated with the greenhouse effect, is present in CNG exhaust because its formation is an unavoidable byproduct of burning any carbon based fuel. Nevertheless, the greenhouse potential of CNG emissions is between 17 percent and 21 percent lower than for gasoline exhaust. When emission components and potency are considered together, the U.S. EPA has found that exhaust from an NGV can be as much as 90 percent lower in adverse impact than those from gasoline powered vehicles.

Further, CNG equipment systems are designed to operate automatically. Such equipment should never be serviced without first shutting it down and locking it out in a positive fashion as shown bottom right. It would be very prudent to evaluate CNG equipment system operation, maintenance inspection/and test requirements against Federal, state or local OSHA requirements. You wouldn't stick your hand into a garbage disposal without first unplugging it, would you?

Be kind to your CNG customer

CNG fueling operations risk a disappointing performance if we don't consider and incorporate the educational needs of CNG customers and their employees. Dissatisfied customers, even though they may be the cause of the problems, can negatively impact chances for success. The importance of customer satisfaction and the special situations involved in fueling CNG vehicles warrant the use of User Integration Programs (UIPs). A complete UIP should include:

• A brief introduction to natural gas, including its properties, behavior, and hazards;

• Hands-on vehicle familiarization and training;

• Vehicle road performance training, including emergency and breakdown procedures for fires, traffic accidents and leaks;

• Training in vehicle refueling, including the dispensing equipment;

• Safety training;

• Simplified vehicle system trouble-shooting and diagnostics; and

• Paperwork appropriate to the jobs.

Much of the information in this and the previous article on CNG came from materials and publications from the National Gas Vehicle Institute, the Natural Gas Vehicle Coalition and the Consolidated Natural Gas Company, whose addresses were provided in the last article.

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