Alternative-Fuel Technology – Natural Gas

Editor's note: In previous issues of TechNews, we discussed Alternate Fuel Technology goals, provided an AFV market overview, and discussed alcohol fueled vehicles. This issue deals with natural gas and NGVs (natural gas vehicles). For more information, please contact Bob Rodriguez at NATEF. Phone: 703-713-3086.

If you're a technician and haven't yet seen a natural gas powered vehicle (or NGV), you soon will... especially if you work in a fleet environment. Being familiar with NGVs—what they look like, and how they work—*before* they show up at your shop, could make a difference in whether you confidently and successfully service them, or turn them away. Here we'll explain the basics of natural gas (NG) and NGVs to help you feel confident enough to look under a few hoods and attend some classes. Having done so, you're sure to appreciate the safety and clean performance of natural gas motorfuel over liquid gasoline.

Overview

Natural gas vehicles have filled a "niche" in the marketplace for many years; until recently, most NGVs were converted from dedicated-gasoline to bi-fuel vehicles so the driver could select either fuel. Conversion system suppliers still sell quality products to the marketplace, but with tighter EPA standards and OBD-II, the buying trend has shifted towards OE designed and built NGVs.

Vehicle Applications

According to the DOE, there are an estimated 102,000 compressed natural gas (CNG) vehicles in the U.S. Common on-road applications include taxicabs, vans, school buses, coaches, refuse & delivery trucks, police & municipal vehicles. Non-road applications include material and baggage handling vehicles. The obvious reason: fleet vehicles can be centrally NG refueled at lower cost, there's reduced fuel pilferage, and extended vehicle range is not a requirement.

Why Switch?

Admittedly, EPACT mandates that federal, state and municipal (and certain private) fleets use alternative fuel vehicles. Yet, financial incentives do help make AFV purchases attractive, with natural gas vehicles (NGVs) being one such option. The fuel is generally less expensive and considered by many as safer than gasoline. It burns clean, is domestically sourced, abundant, and often locally available.

Fuel Definitions and Characteristics

In the utility industry, natural gas is sold in standard cubic feet, or SCF. In the automotive industry, gaseous CNG is sold in gasoline-gallon-equivalents, or GGE. The DOE states that "The GGE of CNG is 123 CF …(based on 929 Btu/CF of CNG and 114,264 Btu/Gallon of gasoline)." By mass, a GGE of NG has been defined as 5.66 pounds.

Pipeline NG is typically 95-96% methane (>88% is required for motorfuel); LNG (see below) is about 99% methane. NG's simple chemical makeup (CH_4) is easily broken down during combustion, thus it's very clean burning for domestic or vehicle use. While NG is piped into the home at <1 psi, the same gas is either compressed to 3000-3600 psi for on-board storage, or chilled to *minus 260 degrees Fahrenheit* to become a clear cryogenic liquid (LNG) at 1/600th its gaseous volume. While LNG saves space, it requires double-walled insulated tanks to keep it cryogenic; if not, it boils off. LNG is considered impractical for passenger cars because of tank size, but an attractive alternative for truck and bus use.

Compared to gasoline, NG contains considerably less thermal energy. At 29,000 Btu per gallon; a bi-fueled vehicle running on CNG has somewhat limited range. A dedicated NGV with cranked up compression ratios, however, can take advantage of NG's 120–130 (R+M)/2 octane rating for a considerable improvement. Natural gas is not visible, so suppliers add Mercaptan (with its familiar rotten-egg scent) to NG so it can be detected; building codes may require methane detectors if NGVs are to be stored indoors.

Infrastructure

Stationary and mobile vehicle "fast-fill" compressor stations can be set up wherever NG is available. These tend to be expensive, but overnight "timed-filling" offers a less expensive option. Only a small compressor is required for timed-filling; "at-home" filling is not uncommon. Because natural gas temperature and pressure are inter-related, fast-filling raises tank temperature and pressure, thus affecting fill capacity. By contrast, timed-filling keeps tank temperatures down so more NG can be compressed and stored for greater vehicle range. For refueling of line-haul trucks and buses, both CNG and LNG fill-sites are being established at strategic locations on certain interstate highways forming a system of "Clean Corridors."

Want to Learn More about NGVs?

For in-depth information, search the Web [www.afdc.doe.gov], visit a dealer selling NGVs, or attend an NGV or Clean Cities Conference- you'll quickly learn about NGVs and perhaps drive a few during a "ride 'n' drive." Ask lots of questions to learn about natural gas vehicles: you'll be better prepared for them when they show up in your service bay… if they're not there already!

ASE F-1 Compressed Natural Gas Vehicle Exam

ASE's "F-1" Light Vehicle Compressed Natural Gas technician exam is crafted by NGV industry experts. The exam focuses on knowledge of NGV conversions; engine performance, diagnosis and repair; and NGV safety (see test specs below). Those interested in taking the F-1 exam may obtain more test information from ASE's Official ASE Preparation Guide available at www.asecert.org or call 703-713-3800.

Subject matter expertise can be obtained from many sources, including the National Alternative Fuel Training Consortium [www.nrcce.wvu.edu], 1-304-293-7882; and the National Fire Protection Assn [www.nfpa.org], 1-800-344-3555 (ask for publication *NFPA-52*).

ASE "F-1" (CNG Technician) Test Specifications

Content Area	No. of Q's	% of test
a. Vehicle Conversion Compatibility Analysis	4	7%
b. Conversion Parts Fabrication	3	5%
c. Conversion Equipment Installation	9	16%
d. Leak Testing and Repairs	7	13%
e. Conversion Initial Adjustments and Performance Verification	8	15%
f. In-service system Diagnosis and Repair	17	31%
g. Cylinder Safety	7	13%
Total	55[1]	100%

[1]Does not include up to 10 questions used for statistical research.

Whether converted or OE, dedicated or bi-fuel, NGVs serve a variety of needs in the marketplace. The AFDC website (www.afdc.doe.gov/advanced_cgi.shtml) lists NGV models from manufacturers like Honda, DaimlerChrysler, Ford, GM, and Toyota.

The Nuts and Bolts of CNG Vehicles

The outstanding difference between a dedicated gasoline auto and an NGV is the pressure at which CNG is stored on board—typically 3000 to 3600 psi. The robust cylindrical tanks required to contain such pressures take up space, add weight, and affect handling. The two or more tanks needed for gasoline-comparable range may be located between the frame rails and/or behind the rear axle. Light-duty CNG vehicles often have tanks behind the back seat or in the trunk/pickup bed. Some low-ride buses have CNG tanks on the roof.

CNG tanks may be constructed of steel or aluminum and/or composite materials. Tanks are manifolded together and safety valves, regulators and other unique components ensure safety and reliable operation of the NG fuel system. On bi-fuel vehicles, the NG components parallel the normal gasoline delivery system. If the vehicle is aftermarket converted to natural gas, NFPA-52 regulations determine how, and often where, CNG components are to be installed.

A Word on Tank Safety

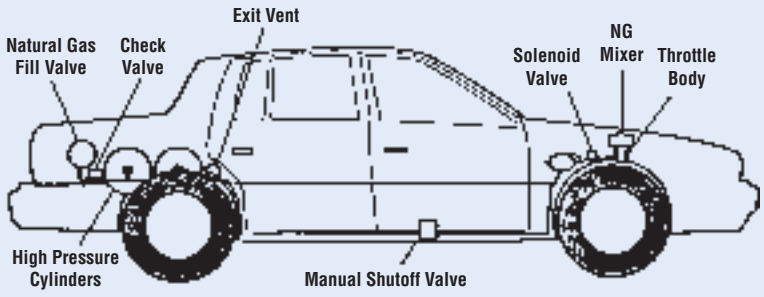
Some people have anxieties over servicing (or driving) an NGV, usually over possible tank rupture and fire. These fears are understandable, but extensive tests show NGV fuel systems to be safer than gasoline systems. Very few tank-related incidents have occurred. Just like SCUBA tanks, however, CNG tanks must be handled properly and be periodically inspected, tested and replaced. Tanks are robust and are rated well above working pressures, are equipped with pressure relief devices (PRDs), and are vented to the outside.

The NG Fuel System

On-board CNG tanks are filled from a fast-fill, or a time-fill compressor station. A standardized quick-connect fill-valve (with breakaway provision) is located at the normal gasoline cap location (or possibly in the grill or under the hood), and feeds CNG to the on-board tanks. Each tank has its own pressure relief device and shutoff valve. From the tanks, CNG is routed through hefty stainless steel lines to an externally accessible quarter-turn manual shutoff valve, then to the engine compartment.

All NGVs use pressure-reducing regulators to drop and stabilize fuel pressure to workable levels (typically ~100 psi). A primary or multi-stage regulator, located along the frame rail and/or under the hood, is usually warmed with engine "coolant" to prevent freeze-up. On naturally aspirated NGVs, a secondary regulator drops pressure to near atmospheric. A vacuum or ignition controlled valve serves as a fuel "lock-off" to shutoff the fuel supply to the engine.

Fuel is delivered to the intake system via either a fuel mixer, a "throttle body" injector assembly, or port injectors. Naturally aspirated bi-fuel vehicles often feed NG into the intake system via a variable venturi "mixer," which sits above the gasoline system's throttle body or carburetor. Sometimes gaseous fuel is released to the intake air stream using a fixed venturi "spray bar" or a "fuel ring," which resembles a stove-top burner.



Electronically controlled systems may use a bank of EFI gaseous injectors (similar to gasoline port-injectors) for metering the fuel to the intake. Some engine families use port NG injection systems. Because NG is gaseous, it displaces incoming air. Thus, bi-fuel vehicles tend to lose power (~10%) on NG because of lost volumetric efficiency. Only dedicated NGVs can make up for this loss with raised compression ratios. Dedicated NGVs may also use a unique catalytic converter, but no EGR or knock sensor.

Combustion and Emissions

Ignition demands are higher for NG: it's harder to ignite, and the timing curve must be adapted (advanced) for the slower and longer burn-time. NG's higher stoichiometric ratio (17.2:1) requires closed-loop bi-fuel adaptation via added electronics for HO2S, knock sensor, and EGR functions. OBD-II systems must remain intact, and engines must be certified under EPA regulations. Natural gas vehicle (NGV) pre-cat HC and CO emissions are inherently low. Dedicated NGV tailpipes easily pass a "white glove" inspection; in fact, Honda calls their dedicated Civic GX the "cleanest on earth."

From the exterior, most CNG and LNG vehicles look similar to gasoline or diesel vehicles, minus the pollution and the noise. All can be identified by a diamond-shaped label on the rear of the vehicle.