

NGVAMERICA

Natural Gas Vehicles for America



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SOLID WASTE ASSOCIATION
of North America

Natural Gas »»
A Clean, Safe and Smart Choice
for the Waste and
Recycling Industry



Natural gas as a vehicle fuel is an increasingly common choice of refuse companies and local governments.

Because of the lower operating costs and reduced environmental impact of natural gas vehicles, more than 50% of new refuse trucks placed into service are fueled by natural gas. The Solid Waste Association of North America (SWANA) and NGVAmerica have developed the following document to provide basic knowledge about natural gas vehicles, highlight some of the safety parameters that the natural gas systems and components must endure, and make recommendations for proper maintenance and operation of these vehicles. This paper will provide broad information, while more detailed information is available via the links at the end of the document.

Natural Gas for Use in Transportation

Compared to diesel, natural gas has 27% lower carbon dioxide emissions, 13% – 17% lower greenhouse gas emissions on a well-to-wheel basis (100% renewable natural gas increases that benefit to over 80%), and 95% lower NOx emissions with new natural gas engines on the market. Not only does natural gas provide a proven technology to lower emission impacts, it provides energy security, fuel diversity and lower long-term costs when used as a transportation fuel. The U.S. is the largest natural gas producer in the world, and thanks to the shale gas revolution, there will be decades of affordable reserves. Natural gas provides fuel diversification for fleets, and because of the historically stable price of natural gas, allows fleets to more accurately estimate fuel costs in the future. Natural gas also eliminates the need for costly emission control systems as are required on diesel vehicles.

Natural gas typically consists of over 95% methane with smaller amounts of ethane, propane, butane, carbon dioxide and other trace gases. The high methane content gives natural gas its high octane rating (120 – 130) and clean-burning characteristics, allowing high engine efficiency and low emissions.

Natural gas is used as a motor fuel in approximately 150,000 vehicles in the United States, and 20 million worldwide. As with all vehicle fuels, natural gas can be used safely if simple, common sense procedures are followed. In fact, natural gas has safety advantages compared to gasoline and diesel: it is non-toxic and has no potential for ground or water contamination in the event of a fuel release. Natural gas is lighter than air and dissipates rapidly when released. An odorant is added to provide a distinctive and intentionally disagreeable smell that is easy to recognize. The odor is typically detectable at one-fifth of the gas' lower flammability limit.

Natural gas vehicles have an excellent safety record for two primary reasons: the properties of the fuel itself and the integrity of the natural gas vehicle and its fuel delivery system (i.e., storage containers, fuel lines, valves, and pressure relief devices). Compressed natural gas cylinders must pass extreme test requirements as detailed in Federal Motor Vehicle Safety Standard (FMVSS) 304 and CSA ANSI NGV2 in the U.S., and Canadian Motor Vehicle Safety Standard (CMVSS) 301.2 and CSA B109 in Canada, before they can be certified and installed on a vehicle:

- ▶ **Bonfire Test** — cylinders, with 100% and 25% service pressure, are placed 18 inches over a flame and required to vent the entire contents to atmosphere, reducing the pressure inside the cylinders
- ▶ **Penetration Test** — 30 caliber armor piercing bullet is fired at a cylinder. The acceptance criteria is that the bullet penetrate the cylinder without causing shrapnel
- ▶ **Pressure Cycling** — 10% to 125% service pressure for 4,000 cycles at 185°F and 10% to 80% service pressure for 4,000 cycles at -40°F
- ▶ **Burst Pressure** — cylinder pressure must exceed 2.25 times service pressure (8,100 psi for a 3,600 psi cylinder) without rupture
- ▶ **Chemical Exposure Tests** — cylinders are exposed to sulfuric acid, sodium hydroxide, methanol/gasoline, ammonium nitrate, windshield washer fluid, etc.

Natural gas has a very limited range of flammability—it will not burn in concentrations below about 5% or above about 15% when mixed with air. Gasoline and diesel burn at much lower concentrations and ignite at lower temperatures. Although it takes very little energy to ignite a flammable mixture of air and natural gas, gasoline, or diesel; natural gas burns at a higher temperature.

CNG fuel systems store natural gas at levels of 3,000 – 4,500 pounds per square inch (psi). Although the use of high pressure vessels poses different concerns than liquid fuels, the compression, storage and fueling of natural gas vehicles meet stringent industry and government safety standards. The use of high pressure systems is also not unique to natural gas vehicles. High-pressure gases are used safely every day in industrial and medical applications. Hydrogen fueled vehicles, although currently not in widespread use, store hydrogen at pressures of 5,000 – 10,000 psi.

All vehicles pose a level of risk, and natural gas vehicles are no different. If natural gas vehicles are maintained and operated within their recommended service conditions, the vehicles are as safe as a gasoline or diesel vehicle.

Operation

All motor vehicle fuels present certain hazards if not handled properly. Fuels contain energy, which must be released by burning. Gasoline is a potentially dangerous fuel, but over time, we have learned to use it safely. The same is true of natural gas. Natural gas safely generates our electricity, heats our homes and cooks our meals. But, like gasoline, natural gas must be understood and respected in order to be used safely.

Natural gas powered vehicles are designed and built to be safe in normal and abnormal conditions, i.e. vehicle impact. Natural gas fuel containers are required to meet rigorous test requirements. These assessments are part of industry standards to test the CNG containers far beyond normal environmental and service damage risks.

There are two main types of filling available for compressed natural gas vehicles—time fill and fast fill. Time fill is typically used for fleets which return to a “home base” for a period of time, such as refuse trucks, and there is enough time for the vehicle to fill over a number of hours. Fast fill stations are much more similar to a gasoline or diesel retail experience. Fast fill stations are typical for users that are not necessarily returning to the same location, or where the vehicle is not able to be down for hours during a filling event.

CNG vehicles store the natural gas at a service pressure of 3,600 psi (some older systems use a service pressure of 3,000 psi). CNG remains in a gaseous state throughout the system. Along the way, the natural gas typically will flow through a coalescing filter, which will remove any moisture and/or compressor oils, and a pressure regulator, which reduces the pressure from 3,600 psi down to the required pressure at the fuel rail (typically around 85 psi). Figure 1 shows a typical compressed natural gas system.

Vehicles powered by natural gas will often have defueling devices. These devices provide a means to remove the natural gas from the vehicle prior to service or maintenance. It is important to contact the fuel system provider to understand the specific defueling process, as different types of fuel systems require different defueling processes.

Typical Agility CNG System P&ID



1. CNG Cylinders
2. Manual Tank Valve
3. Pressure Relief Device (PRD)
4. Ball Valve (Emergency Shutoff Valve)
5. Manifold
6. Pressure Transducer
7. Bleed Valve
8. Defuel Control Valve
9. Defuel Port
10. Check Valve
11. Fill Manifold
12. Fill Receptacle
13. Fill Receptacle
14. Low Pressure Gauge
15. High Pressure Gauge
16. Filter
17. Solenoid
18. Regulator
19. Regulator PRV Vent
20. Tubing
21. Pressure Relief Device

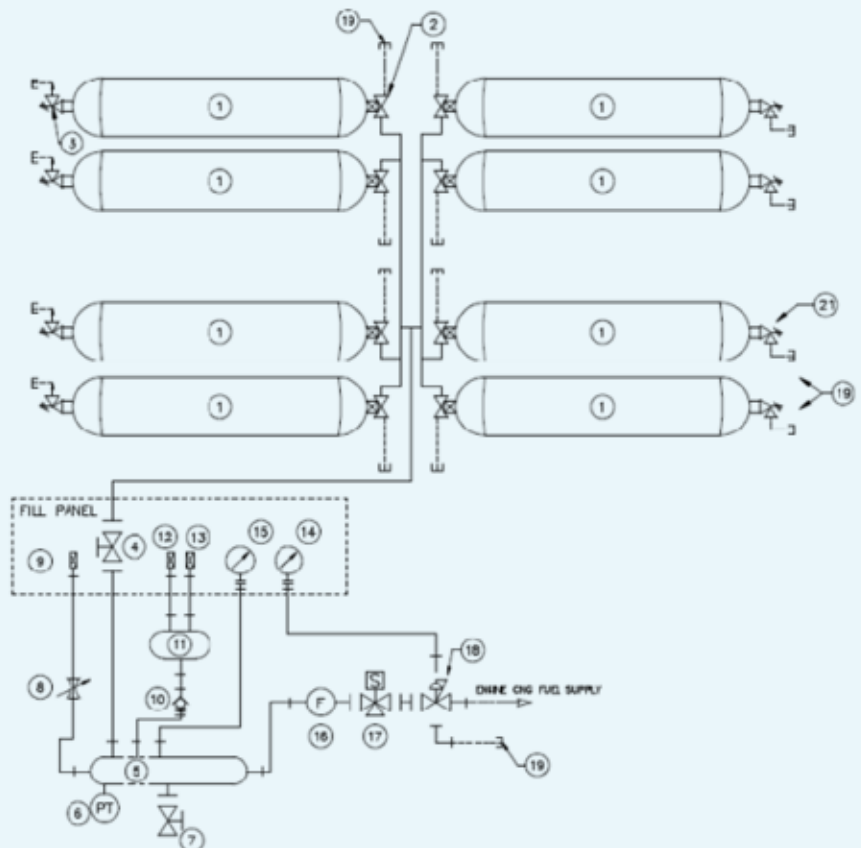


Figure 1

Maintenance

All vehicle fuel systems and fueling stations require regular monitoring and maintenance. CNG fuel systems and stations require regular inspections to ensure that the safety of the vehicle and station is not compromised. Inspections should always be conducted by qualified or certified personnel.

CNG cylinders have a limited service life, typically 15, 20 or 25 years. The “expiration date” is labeled on the cylinders and cylinders should NOT be used after the date listed. The cylinders are designed for a specific service life, and failure to comply with the manufacturer stated expiration date may result in harm to personnel and/or property. For recommendations on what vehicle owners should do with expired cylinders, visit <http://goo.gl/cuiv8>.

Vehicle Inspection

Similar to other vehicle components, compressed natural gas cylinders require inspection and maintenance at specified intervals. Below is a summary of the current standard and regulation requirements:

Code or Standard	Section	Requirement
FMVSS 304	7.4 Labeling	Each fuel container shall have a label that states: <i>“This container should be visually inspected after a motor vehicle accident or fire and at least every 36 months or 36,000 miles; whichever comes first, for damage and deterioration”</i>
CSA ANSI NGV 2-2007 (R2012)	2.1.3 Periodic In-Service Inspections	Each container shall be visually inspected at least every 36 months, or at the time of any re-installation, for external damage and deterioration.

FMVSS 304 was originally intended to be used by light-duty vehicle manufacturers and the 36 month or 36,000 mile recommendation was tied to warranty timeframes. NGVAmerica is working with the US Department of Transportation (DOT) to update FMVSS 304 to be more applicable with all vehicle segments.

It is recommended that the fleet owner/operator follow the cylinder manufacturer or CNG system installer’s recommendations for service and inspection. If instructions are not available from the cylinder manufacturer or CNG system installer, fleets may choose to implement the following three levels of visual inspection:

1. cursory Visual Inspection

Observe CNG system shielding and enclosures for damage including dents, gouges, scrapes, cuts, abrasions, discoloration, heat damage, etc, and any readily accessible system components for signs of damage or leakage. During this level of inspection, shielding, enclosures, coverings and system access panels should not be opened. The cursory visual inspection should be performed as part of every pre-trip and post-trip and can be conducted by the driver.

2. General Visual Inspection

A close examination of all system shielding and readily accessible system components. Shields and enclosures of the CNG fuel system should be inspected for any damage including dents, gouges, scrapes, cuts, abrasions, discoloration, heat damage, etc, and any readily accessible system components for signs of wear, damage, or leakage. During this level of inspection, access panels should be opened, but shielding and enclosures should not be removed. The general visual inspection can be completed by a technician that is knowledgeable of CNG fuel system components, including the types of enclosures and shielding. It is recommended that a general visual inspection be performed during preventative maintenance activities.

3. Detailed Visual Inspection

A thorough inspection of the complete high pressure CNG fuel system. The inspector should inspect the complete high pressure CNG system including all of the cylinders, which likely requires shielding, coverings and enclosures to be removed; however, mirrors and cameras may be used. The detailed visual inspection should be conducted by an inspector that is either certified by an outside entity or qualified by the fleet owner.



CNG Fueling Facility Maintenance

CNG fueling facilities require regular inspections to ensure that the safety of the facility and operation of the vehicles are not compromised. Fuel facility inspections should always be conducted by qualified or certified personnel.

The CNG fuel station builder should provide maintenance recommendations. Figure 2 provides a list of routine maintenance recommendations:

Typical CNG Fueling Facility Maintenance Requirements					ANGI
Item	Service Item	Daily	Monthly	Every 2000 Hours of Operation or Annually	Every 4000 Hours of Operation
Compressor — Based on a 4 Stage ANGI-Ariel Package					
1	Monitor & Record Working Pressures and Temperatures	▼			
2	Check Compressor Piping and Tubing for Obvious Leaks, Loose Connections or Loose Clamps	▼			
3	Check for Rough or Unusual Noises	▼			
4	Check Compressor Oil Level	▼			
5	Drain Receiver Tank		▼		
6	Drain Condensate Pot		▼		
7	Change Compressor Oil & Filter and Clean Strainer			▼	
8	Clean Interstage Filter Elements and Replace Inlet & Final Discharge Filter Elements			▼	
9	Inspect Safety Relief Valves			▼	
10	Inspect Compressor Valves			▼	
11	Check/Calibrate Gas Detector			▼	
12	Inspect Compressor Rings and Seals				▼
13	Verify Driver / Compressor Alignment				▼
14	Inspect Compressor Crankshaft Main & Rod Bearings				▼
15	Inspect Compressor Lube Drive Chain				▼
16	Drain & Clean Heat Exchanger Cores				▼
Dryer					
17	Check Dryer Piping and Tubing for Obvious Leaks, Loose Connections or Loose Clamps	▼			
18	Check & Record Dew Point Monitor		▼		
19	Replace Inlet & Discharge Filter Elements			▼	
20	Inspect Safety Relief Valves			▼	
Valve Panels					
21	Check Panel Tubing for Obvious Leaks, Loose Connections or Loose Clamps	▼			
22	Inspect Safety Relief Valves (If Installed)			▼	
ASME Storage Vessels					
23	Check Valve Connections and Tubing for Obvious Leaks, Loose Connections or Loose Clamps	▼			
24	Inspect Safety Relief Valves			▼	
25	Drain Vessels If Required			▼	
Dispensers / Hose Posts					
26	Check Tubing for Obvious Leaks, Loose Connections or Loose Clamps	▼			
27	Visually Check Hose Assemblies for Cracks, Wear, Damage and Leakage	▼			
28	Check Hose Conductivity			▼	
29	Replace Filter Elements			▼	
30	Inspect Safety Relief Valves			▼	
General					
31	Check Operation of ESD System		▼		
32	Check/Drain System Relief Valve Vent Stacks		▼		

Figure 2 NOTES: The above maintenance operations and intervals are for reference only. Operators should check with their specific equipment suppliers to confirm actual maintenance intervals. In addition to the above, all code required checks and tests (e.g. 3-year relief valve test, fire extinguisher check etc.) should be carried out.

Maintenance Facilities

Because compressed natural gas is lighter than air, and will not collect on the ground as diesel or gasoline would, care should be taken before servicing a natural gas vehicle. Liquefied natural gas is stored at cryogenic temperatures, and as such, at the point of release from a container the natural gas is heavier than air. However, as the temperature rises immediately, natural gas rises. Local authorities having jurisdiction (AHJs) make the final determination as to what requirements are needed in a facility which will be servicing natural gas vehicles, but typically the AHJ will adopt either the International Fire Code (IFC) or NFPA 30A.

Current guidance is somewhat vague, and there has been some confusion within the design, vendor and code enforcement community. The guidance should be based on assessing the risk and modifying a particular facility accordingly. Modifications typically are only required if “major repairs” are to be performed. Some areas covered in the IFC and NFPA 30A are ventilation levels, elimination of hot surfaces (above 750°F), and the modification of electrical components if within 18” of the ceiling if the minimum air changes per hour (ACH) is not achieved. For more detailed information for maintenance facility requirements, please visit <http://goo.gl/FOM6bg>

First Responders

As the use of natural gas in waste and recycling collection vehicles has increased, the industries have experienced two incidents in which there has been a compressed natural gas (CNG) cylinder rupture – Indianapolis, IN in January 2015 and Hamilton, NJ in January 2016. The waste and natural gas vehicle industry continues to investigate the root cause of the ruptures to ensure that there is appropriate coverage in codes and standards.

All vehicle fuels pose a risk if involved in an accident or a fire. It is important that first responders have appropriate training to deal with alternative fueled vehicles, such as those powered by natural gas. CNG vehicles are equipped with a thermally activated pressure relief device(s). These devices usually have a eutectic material, which melts at 219°F, allowing the gas to be released to atmosphere through a vent tube. If a natural gas vehicle is involved in a fire, it is important that first responders do not spray water

on the CNG tanks. Water may in fact cool the pressure relief devices, not allowing the fuel to be released and causing pressure to build in the tanks. The National Fire Protection Association (NFPA) has developed free online training for first responders, <http://goo.gl/WKPUrk>

CNG system installers and manufacturers may also offer manuals for first responders. If fleets will be running refuse trucks on natural gas, it is recommended to share these materials with local fire departments. For example, Agility Fuel Systems has a first responder training guide available, <http://goo.gl/wtL9C3>

Training

Training is essential when implementing new technology. While technicians and vehicle operators will have the most “hands on” experiences with the natural gas fuel system, all personnel that are directly or indirectly affected by natural gas vehicles and fueling stations need to have safety and awareness training.

A basic natural gas safety and awareness training should employ the following learning objectives:

- ▶ Describe natural gas origin, supply, and distribution techniques
- ▶ Understand the properties and hazards of compressed/liquefied natural gas
- ▶ Identify the differences as compared to liquid fuels
- ▶ Describe emissions from natural gas vehicles compared to liquid fueled internal combustion vehicles
- ▶ Describe the advantages and disadvantages of natural gas as a motor fuel
- ▶ Understand an overview of the components and operation of the fuel system on board natural gas powered vehicles

- ▶ Understand an overview of the equipment and operation of a natural gas fueling station
- ▶ Understand site specific emergency action plans

Operator/Driver training should include the following learning objectives in addition to the basic natural gas safety and awareness training:

- ▶ Identify and employ safety precautions and techniques when driving natural gas powered vehicles, including job required personal protective equipment (PPE) and hazardous energy control program (HECP) requirements for natural gas powered vehicles
- ▶ Describe fuel consumption and range of natural gas vehicles
- ▶ Understand how to fuel natural gas powered vehicles
- ▶ Identify and employ required personal protective equipment for LNG refueling
- ▶ Understand vehicle specific emergency action plans, including vehicle accidents, engine fires, and load fires

- ▶ Understand and employ the procedures required to perform daily vehicle inspections

Technician training should include the following additional learning objectives in addition to the Operator/Driver training and basic natural gas safety and awareness training:

- ▶ Identify natural gas vehicle maintenance facility related safety requirements
- ▶ Understand how to take appropriate actions for any unsafe condition
- ▶ Identify and employ safety precautions and techniques when working on natural gas vehicles, including job specific personal protective equipment (PPE) and hazardous energy control program (HECP) requirements for natural gas fuel system maintenance
- ▶ Understand and employ routine maintenance procedures and hazard mitigation for natural gas vehicles including fuel system maintenance and hot work procedures

- ▶ Identify the major fuel system components and understand their operation, safety precautions, and maintenance requirements
- ▶ Identify the types of CNG cylinders, potential hazards, types of damage, and fuel system inspection requirements
- ▶ Understand the basic principles and potential safety hazards of defueling

Many CNG cylinder and natural gas fuel system component manufacturers offer training to fleets. There are also companies that offer training and certification for natural gas vehicles and fueling stations.

Conclusion & Recommendations

Natural gas powered refuse trucks are a growing component of the fleet in the United States and Canada, due to their environmental, energy security, and economic benefits. Natural gas refuse trucks are helping lead the way in the transition away from diesel and gasoline fuels. While natural gas vehicles are as safe as diesel or gasoline powered vehicles, proper training and maintenance of the vehicles, including all fuel system components and fueling facilities, is required.

For further information or questions, please contact:

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Industry Links

- ▶ **NGVAmerica**—
ngvamerica.org
- ▶ **Solid Waste Association of North America (SWANA)**—
swana.org/
- ▶ **NFPA Alternative Fuel Vehicles Training Program for Emergency Responders Online Training**—
<http://goo.gl/eanlui>
- ▶ **McNeilus Street Smart Parts Documents**—
<https://goo.gl/RpQdf1>
- ▶ **Agility Fuel Systems' First Responder Guide: CNG and LNG Vehicle Fuel Systems**—
<http://goo.gl/wtL9C3>
- ▶ **CSA Group First Edition of Exp2.1, Best Practice for Defueling, Decommissioning, and Disposal of Natural Gas Vehicle Fuel Containers**
<http://goo.gl/cuiiv8>



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