

**Recommended Practices for CNG Powered Medium and Heavy-Duty Trucks**

**Foreword**—This SAE Recommended Practice is intended as a guide for standard practice and is subject to change in order to keep pace with experience and technical advances. Its purpose is to promote safety and efficiency by making available to sellers and buyers of commercial compressed natural gas (CNG) powered medium and heavy-duty trucks (TRUCKS) a recommended practice for construction, operation, and maintenance of such TRUCKS. (TRUCKS defined as vehicles with a gross vehicle weight (gvw) of greater than 6350 kg (14 001 USA pounds.)) The intent of this document is to cover TRUCKS only and specifically excludes passenger vehicles such as: buses, recreational vehicles, motor homes or vehicles which may incorporate a TRUCK chassis in their construction.

This document was developed by the SAE J2406 Committee, which was organized in 1998 to guide the trucking and NGV industries in their efforts associated with the use of CNG as an alternate fuel for use in medium and heavy-duty trucks. Prior to the first meeting, preparatory work for this recommended practice was built upon the strong foundation established by the Truck Engine - Chassis Manufacturer's LNG Technical Subcommittee of the ATA Foundation's Alternative Fuels Task Force in developing SAE J2343 – Recommended Practices for LNG Powered Heavy Duty Trucks.

The first steps of the SAE J2406 Subcommittee's work included (1) Review of the Modes and Effects Analysis (FMEA) - SAE J2343, (2) detailed review of existing codes, standards, recommended practices, and regulations pertinent to trucks and CNG in force or in preparation. It is the intent of the SAE J2406 Recommended Practices to reference and follow the path of the SAE J2343 Recommended Practices whenever and as closely as possible. The content and format for SAE J2406 will utilize the content, FMEA and practices from the SAE J2343 document as it applies to compressed natural gas applications for TRUCKS.

Although a separate FMEA was not conducted for this document, the committee did make use of the applicable sections from the original SAE J2343 FMEA documentation. The SAE J2343 committee's original work began with a FMEA for LNG onboard fuel systems, facilitated by Failure Analysis Associates. This study identified Failure Scenarios and Failure Mechanisms, which could potentially lead to the identified Failure Scenarios. The committee also recognizes that there are FMEA's that have been performed for automobiles and small trucks that remain within the domain of the owners and were not available to the committee for review.

It is the intent of this document to insure the safety and utilization of components for CNG onboard fuel system applications whenever possible, i.e., to avoid the potential failure mechanisms that could be identified, where possible, and to devise and recommend means of construction, operation, and maintenance which would warn of an impending fault or failure, and/or mitigate the outcome should a failure occur. In all cases the CNG onboard fuel system should be consistent and in conformance with applicable federal, state and local requirements.

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This publication necessarily deals to some extent in generalities, because it is not possible to anticipate and address every individual set of conditions that might be found in constructing, operating, and maintaining CNG powered TRUCKS. It is intended to be a practical guide illustrating rather than dictating the application of these Recommended Practices. The correct application of these practices in any field situation must rely on sound judgment and experience. Whether or not to institute this voluntary document is up to each individual company, and members of the Subcommittee have not reached any agreement to use it or to require its use.

This document does not address the choice of compressed natural gas (CNG) tank(s) or the method of mounting, as this is application specific. In all cases, the choice and mounting of the CNG tanks shall be in accordance with the chassis manufacturer's recommendations. (In conjunction with a CNG tank supplier's recommendations for the specific application).

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**1. Scope**—This SAE Recommended Practice provides guidance for the construction, operation, and maintenance of CNG powered medium and heavy-duty trucks. The intent of this document is to cover TRUCKS (6350 kg (14 001 gvw pounds) and above) and specifically excludes passenger vehicles such as: buses, recreational vehicles, motor homes and/or passenger vehicles which may incorporate a truck chassis in their construction.

**1.1 Purpose**—The purpose of this document is to establish a uniform practice for construction, operation, and maintenance of CNG powered TRUCKS and is subject to change to keep pace with experience and technical advances.

## 2. References

**2.1 Applicable Publications**—The following publications form a part of this specification to the extent specified herein. Unless otherwise indicated, the latest issue of each publication shall apply. Specific documents pertaining to a scope of work are referenced at the end of this document (6.5).

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001. (724-776-4790 ([www.sae.org/products](http://www.sae.org/products)))

SAE J1703—Fuel Systems - Trucks and Truck Tractors  
SAE J1616—Recommended Practice for Compressed Natural Gas Vehicle Fuel  
SAE J2343—Recommended Practice for LNG Powered Heavy - Duty Vehicles

2.1.2 ANSI/IAS PUBLICATIONS—Available from CSA 8501 East Pleasant Valley Rd., Cleveland, Ohio 44131. ([www.csa.ca](http://www.csa.ca)) 800-463-6727 or Natural Gas Vehicle Coalition, 1100 Wilson Blvd. STE. 850, Arlington, VA 22209 703-527-3022 ([kbatte@ngvc.org](mailto:kbatte@ngvc.org)).

ANSI/AGA NGV2—Basic Requirements for Compressed Natural Gas Vehicle (NGV) Fuel Containers  
ANSI/AGA PRD1—Pressure Relief Devices for Natural Gas Vehicle (NGV) Fuel Containers  
ANSI/AGA NGV1—Standard for Compressed Natural Gas Vehicles - Refueling Connection Devices  
ANSI/FCI 70-2—Control valve seat Leakage

2.1.3 FEDERAL MOTOR VEHICLE SAFETY STANDARDS (CODE OF FEDERAL REGULATIONS PUBLICATION)—Available from Superintendent of Documents, U.S. Gov. Printing Office, Wash D.C. 20402 ([www.access/gpo.gov](http://www.access/gpo.gov)).

FMVSS 301 (49CFR571.301)—Fuel System integrity  
FMVSS 303 (49CFR571.303)—Fuel System integrity of compressed natural gas vehicles  
FMVSS 304 (49 CFR571.304)—Compressed Natural Gas Fuel Container Integrity

2.1.4 CALIFORNIA CODE OF REGULATIONS—Available from Barclays Law Publishers, Attn.: Client Services, P.O. Box 3066, South San Francisco, and CA 94083. (<http://ccr.oal.ca.gov>).

California Title 08 - CNG & LNG vehicle regulations

2.1.5 COMPRESSED GAS ASSOCIATION PUBLICATIONS—Available from Compressed Gas Association, Inc., 1725 Jefferson Davis Highway, Suite 1004, Arlington, VA 22202-4102. 703-412-0900 ([www.cganet.com](http://www.cganet.com)).

CGA -Pressure Relief Standards S1.1 Part 1 — Cylinders for Compressed Gases  
CGA C- 6.1 Methods for External Visual Inspection of NGV Fuel Containers and their installation  
CGA S1.2 Part 2 — Cargo and portable tanks for compressed gases  
CGA C -6.4 Methods of external visual inspection of natural gas vehicle fuel containers and their installation.  
CGA Pressure Relief Standards S1.3 Part 3 — Compressed Gases Storage Containers

2.1.6 NFPA PUBLICATIONS—Available from National Fire Protection Agency, 1 Batterymarch Park, P.O. Box 9101, Quincy, MA 02269-9101.800-344-3555 (<http://catalog.nfpa.org>).

NFPA 52—Compressed Natural Gas (CNG) Vehicular Fuel Systems  
NFPA 70—National Electrical Code

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2.1.7 DEPARTMENT OF CALIFORNIA HIGHWAY PATROL - TITLE 13 REGULATIONS—PO BOX 942898 Sacramento, CA 94298

CCR Title 13 - Section 934, Compressed Natural Gas  
CCR Title 13 - Section 936, Installation  
CCR Title 13 - Section 935, LNG fuel systems

**2.2 Related Publications**—The following publications are provided for information purposes only and are not a required part of this specification.

2.2.1 FEDERAL MOTOR CARRIER SAFETY ADMINISTRATION—Publications Available from Superintendent of Documents, U.S. Government Printing Office, Washington, DC 20402. ([www.access.gpo.gov](http://www.access.gpo.gov)).

2.2.2 TEXAS RAILROAD COMMISSION PUBLICATION—Texas administrative code Available from Railroad Commission of Texas, Capitol Station P.O. Box 12967, Austin, Texas 78711-2967 ([http://infor.sos.state.tx.us:80/pum/plsql/readtac\\$ext.ViewTAC](http://infor.sos.state.tx.us:80/pum/plsql/readtac$ext.ViewTAC))

2.2.3 CANADIAN STANDARDS ASSOCIATION—Available from Standards Department, 178 Rexdale Boulevard, Rexdale (Toronto) Ontario, Canada M9W 1R3 800-463-6727 ([www.csa.ca](http://www.csa.ca)).

2.2.4 CANADIAN GAS ASSOCIATION—Available from Canadian Gas Association, 55 Scarsdale Road, Don Mills (Toronto), Ontario, Canada M3B 2R3.

2.2.5 GTI PUBLICATIONS—Available from Gas Technology Institute, 1700 South Mount Prospect Road, Des Plaines, IL 60018 ([www.GTI.org](http://www.GTI.org)).

2.2.6 ASME PUBLICATIONS—Available from American Society of Mechanical Engineers, United Engineering Center, 345 East 47th Street, New York, NY 10017

2.2.7 DEPARTMENT OF INDUSTRIAL RELATIONS—Division of Occupational Safety and Health - Pressure Vessel Unit 1515 Clay Street, Suite 1302 - Oakland, CA 94612

2.2.8 CCPS PUBLICATION—Available from the Center for Chemical Process Safety of the American Institute of Chemical Engineers - 345 East 47th St., New York, NY10017

**3. Fuel System Components and Definitions**—The following definitions were derived in assembling this document.

**3.1 Maximum Allowable Working Pressure (MAWP)**—The highest pressure which should be allowed downstream of the high-pressure regulator.

**3.2 Pressure Regulator**—Any device used to reduce pressure (independent of flow) exclusive of engine control devices. Pressure regulators should be incorporated into the fuel system in accordance with the engine manufacturer's recommendation.

**3.3 Service Pressure**—The settled pressure at a uniform gas temperature of 21 °C and 70 °F and full gas content. For this document it is defined as the pressure for which the equipment has been constructed for use under normal operating conditions. The maximum system pressure shall not exceed 125% of the nominal service pressure. The individual tank manufacturer defines the service pressure of the CNG tanks.

**3.4 Pressure Relief Valve(s)**—The fuel system should be equipped with pressure relief valves, or pressure control valves, of which are generally located downstream of the high pressure regulator. Relief valve set pressures should follow the engine manufacturer's recommendations. Relief valve outlets should be protected from fouling by dirt, debris, snow, ice, and/or water.

- 3.5 Fuel Quantity Indicator**—Each system should be provided with a fuel quantity indicator, which can be read from inside the cab of the TRUCK. The minimum accuracy of plus or minus one-eighth of the volume of the fuel system is required. Plumbing CNG gas into the cab is absolutely forbidden.
- 3.6 Pressure Indicator**—Each fuel system should be provided with a gauge or other means of determining the system's pressure. Methods of determining fuel system pressure shall be included to allow safe servicing of the system, and mounted in such a fashion as to be protected from damage during operation and maintenance – assembly and disassembly.
- 3.7 Shutoff Valves**—Shutoff valves should be provided for each line, which supplies fuel to the engine. Shutoff valves should be located at or near the fuel tank and should be permanently labeled.
- 3.8 Excess Flow Device**—A method to prevent excess flow should be provided for each line, which supplies fuel to the engine. Excess flow devices should be oriented so as to minimize the effect of road vibration on the valve actuation.
- 3.9 Fuel Tank Supports**—Fuel tanks shall be oriented and mounted on the vehicle in accordance with the TRUCK chassis and CNG tank manufacturer's recommendation for the specific application.
- 3.10 Automatic Shutoff Valve(s)**—Automatic shutoff valves should be included in the system and fail closed on loss of actuating power regardless of orientation (i.e., mounted at any angle) or available pressure differential. The automatic shutoff valve should close on loss of ignition or loss of engine operation. Automatic shutoff valves should be rated at the MAWP (maximum allowable working pressure) of the fuel tank gas supply.

#### **4. Fuel System General Design — Construction Considerations**

- 4.1 General**—All materials used in valves, components, and devices which could be exposed to CNG during normal operation should be rated for exposure to gas temperatures ranging from  $-87^{\circ}\text{C}$  to  $+121^{\circ}\text{C}$  ( $-125^{\circ}\text{F}$  to  $+250^{\circ}\text{F}$ ) CNG service environments. Fuel system components should be designed to meet the conditions for which it will be exposed, as it relates to minimum/maximum temperatures and pressures. Environmental factors, which the vehicle is likely to encounter during its useful service lifetime, should also be considered. All components should be suitable for the intended service and shall be included in the vibration, durability and corrosion testing of the chassis OEM. All components should be adequately supported and suitable for the intended service. Upon assembly or reassembly, the complete fuel system should be leak tested with a suitable medium or device.
- 4.1.1 FUEL SYSTEM CLEANLINESS**—After assembly or reassembly of the fuel system, the components between the container and the engine should be free of dust and debris before the system is put into service. Great care should be taken to prevent the introduction of any combustible mixtures within the fuel system during reassembly.
- 4.1.2 GAS DETECTION**—CNG is normally an odorized gas. Therefore, methane detection is at the option of the final stage manufacturer and/or the OEM chassis manufacture. Unodorized methane may be available for this CNG application. If the CNG is not odorized, methane detection is required as per SAE J2343. If no odorant is used, placement of the devices shall conform to the final stage and/or OEM chassis manufacturer's recommendations.
- 4.1.3 ELECTRICAL REQUIREMENTS**—The electrical system should conform to the original equipment engine and chassis manufacturer's recommendations for electrical system safety and performance.
- 4.1.4 GAS FILTRATION**—The filters should remove particles, moisture and oil in accordance with the recommendations of the engine manufacturer. In addition, the number and specifications of the fuel filters should be specified by the engine manufacture. All fuel system components must be sized for the maximum fuel flow of the engine in accordance with the engine manufacturer's specifications.

4.1.5 DEFUELING REQUIREMENTS—Each vehicle should be provided with components suitable for defueling the onboard fuel tanks. Adequate documentation should be provided describing a safe method of defueling the system.

## 5. Operation

5.1 **General**—The final stage manufacturer will have the responsibility for the integration of the engine and the fuel system on to the truck chassis. Therefore, the final stage manufacturer is responsible for obtaining the approval of the CNG fuel system installation from the: Truck, Engine and Fuel System original equipment manufacturer. Due to the large degree of variation possible in CNG fuel system configurations and component specifications, information regarding the CNG fuel system content i.e., OEM chassis, engine, fuel container supplier, methane detection, etc. should be provided for by the final stage manufacturer within an operating manual. The content described should be presented in sufficient depth and clarity so as to provide a basic understanding of systems unique to CNG powered TRUCKS. Furthermore, the final stage vehicle manufacturer has the responsibility for collection and consolidation of the CNG related component, operating and maintenance manuals.

5.2 **Fuel System Overview**—The following topics should be covered in the operating manual.

5.2.1 FUEL TANK SYSTEM—The basic construction, operation and safety features i.e., relief valves, manual shutoff valves, excess flow devices, shall be discussed in sufficient detail so as to provide a basic understanding of the fuel system that is unique to CNG powered TRUCKS. CNG fuel tanks should be inspected as required by the tank manufacturer's cylinder label.

5.2.2 PRESSURE RELIEF VALVES—The basic construction and operation should be discussed in sufficient detail to provide an understanding of the relief valve operation.

5.2.3 AUTOMATIC AND MANUAL SHUTOFF VALVES—The basic construction and operation should be discussed in sufficient detail to provide an understanding of the shutoff valve operation.

5.2.4 VENT SYSTEM—The basic construction and operation should be discussed in sufficient detail to provide an understanding of the vent operation.

5.3 **Operational Safety**—At a minimum, the following topics should be covered in the operating manual when addressing Operational Safety:

5.3.1 LEAK DETECTION DEVICES—The operating manual should explain how to properly detect CNG leaks with suitable references to appropriate leak detection devices.

5.3.2 METHANE LEAK DETECTION—The function, maintenance and remedial action necessary, if one is supplied, should be adequately explained in the operating manual.

5.4 **Fueling Safety**—The following topics should be covered in the operating manual when addressing CNG Safety.

5.4.1 GROUNDING FOR ELECTROSTATIC DISCHARGE—Grounding is accomplished through the refueling hose specifications and design. This is incorporated in the hose design in order to eliminate the possibility of electrostatic discharge.

5.4.2 DEFUELING—A proper means of defueling the vehicle should be addressed in the operator's manual.

- 5.5 Fuel Quality**—This topic should be covered in the operating manual when addressing fuel quality and should be specific to the engine manufacturers' requirements for the year and type of engine.
- 5.5.1 **FUEL SPECIFICATION**—The engine manufacturer should specify the minimum CNG methane concentration, and the (void model) maximum allowable concentrations of: inert gas, heavy hydrocarbons and other potential contaminant concentrations that are acceptable for delivery to the engine. Appropriate CNG fuel may not be available in all areas and the vehicle owner should check with the fuel provider and the engine manufacturer to ensure that the fuel is acceptable for his application.
- 5.5.2 **FUEL CONTAMINATION**—Fuel can be contaminated by the CNG refueling station, and the operating manual should address this potential problem. A recommendation for onboard filter(s) service interval should be provided in the text of the engine-operating manual.
- 6. Maintenance—General**—Due to the large degree of variation possible in fuel system configuration and component specifics, this source of information/content should be covered by the final CNG stage manufacturer's maintenance manual. The document should provide technicians with sufficient understanding to work on CNG powered TRUCKS safely, and should contain a caution against substitution of components that do not conform to the OEM 's specifications.
- 6.1 Final Stage Manufacture**—The following topics should be covered in the maintenance manual as supplied by the final stage manufacturer when addressing CNG safety.
- 6.1.1 **SAFETY HAZARDS**—The following safety hazards should be explained in the maintenance manual: cold metal contact, asphyxiation, over pressurization, high pressure gas system hazards, and fire hazards associated with the use of CNG as a vehicle fuel. Gas releases into the atmosphere should also be discussed.
- 6.1.2 **PROTECTIVE EQUIPMENT**—The use of appropriate protective equipment during fuel system maintenance and defueling should be discussed.
- 6.1.3 **FUEL SYSTEM LEAKS**—The maintenance manual should explain the necessity for repairing fuel system leaks. Included within this text should be the proper method and tools necessary.
- 6.2 Facility and Vehicle Safety during Maintenance**—The following topics should be covered in the maintenance manual when addressing maintenance facility safety along with a discussion of risks associated with each:
- 6.2.1 **FUEL SYSTEM BLEED DOWN**—Appropriate cautions regarding all pressurized fuel lines, components and appropriate methods for de-pressurizing the fuel system for maintenance work should be included.
- 6.2.2 **LEAK TESTING**—The maintenance manual should provide a procedure for leak testing the fuel system if any maintenance is performed on the fuel system.
- 6.2.3 **PROTECTION FROM IGNITION SOURCES**—The maintenance manual should explain the proper procedure for protecting the fuel system from ignition sources such as: welding, flame cutting, etc., which may be performed on the vehicle. The potential hazards, which could arise from weld splatter, arc strikes, cutting of a live fuel line, etc. should be explained.
- 6.3 Fuel System Maintenance Overview**—The maintenance manual should contain a caution against modifying the CNG fuel system from its original configuration. The basic construction, operation, inspection, maintenance, and safety features i.e., relief valves, manual shutoff valves, excess flow devices, etc.) should be discussed in sufficient detail to familiarize the service technician with the proper maintenance procedures for the CNG onboard fuel system. Special emphasis should be placed on the explanation of the high-pressure segment of the CNG system.

**6.4 System Components**—The maintenance manual should discuss all fuel system replacement parts and give the replacement part specifications, appropriate installation and servicing procedures. The manual should also cover all items that are unique elements relating to the CNG fuel system and any items that are not covered in this text.

**6.5 Document Related Source Information**—The construction of a TRUCK is an integrated process. The original equipment chassis and engine manufacture should always be consulted for each application. The following publications form a part of this body of work to the extent specified herein. The publications are provided for resource or information purposes only and are not a required part of this document. Unless otherwise indicated, the latest issue of a publication shall apply.

SAE J1703—Fuel Systems - Trucks and Truck Tractors

SAE J1616—Recommended Practice for Compressed Natural Gas Vehicle Fuel

SAE J2343—Recommended Practice for LNG Powered Heavy - Duty Vehicles

ANSI/AGA NGV2—Basic Requirements for Compressed Natural Gas Vehicle (NGV) Fuel Containers

ANSI/AGA PRD1—Pressure Relief Devices for Natural Gas Vehicle (NGV) Fuel Containers

ANSI/AGA NGV1—Standard for Compressed Natural Gas Vehicles -Refueling Connection Devices

ANSI/FCI 70-2—Control valve seat Leakage

California Title 08 - CNG & LNG vehicle regulations

FMVSS 301 (49CFR571.301)—Fuel System integrity

FMVSS 303 (49CFR571.303)—Fuel System integrity of compressed natural gas vehicles

FMVSS 304 (49 CFR571.304)—Compressed Natural Gas Fuel Container Integrity

CGA -Pressure Relief Standards S1.1 Part 1 — Cylinders for Compressed Gases

CGA C- 6.1 Methods for External Visual Inspection of NGV Fuel Containers and their installation

CGA S1.2 Part 2 — Cargo and portable tanks for compressed gases

CGA C - 6.4 Methods of external visual inspection of natural gas vehicle fuel containers and their installation.

CGA Pressure Relief Standards S1.3 Part 3 — Compressed Gases Storage Containers

NFPA 52—Compressed Natural Gas (CNG) Vehicular Fuel Systems

NFPA 70—National Electrical Code

CCR Title 13 - Section 934, Compressed Natural Gas

CCR Title 13 - Section 936, Installation

CCR Title 13 - Section 935, LNG fuel systems

**7. Generic SAE J2406 CNG Fuel System Schematic for TRUCKS**—See Figure 1.