Facility Modification Guidelines for Maintenance and Repair of Natural Gas Vehicles

Prepared by
The Transport Project
Technology & Development Committee

March 2026

Learn more at **TransportProject.org**

THE TRANSPORT PROJECT

Disclaimer and Legal Notice

The Transport Project has made great effort to ensure the accuracy and reliability of the information contained in this document. However, this document is provided “as is,” and the reader assumes liability to ensure the information contained in this document is current and correct.

The Transport Project, its officers, employees, or agents shall not be liable for damages or losses of any kind arising out of or in connection with the use of or performance of the information provided herein, including but not limited to: damages or losses caused by reliance upon the accuracy or timeliness of any such information, or damages incurred from the viewing, distributing, or copying of those materials.

The information provided in this document is not intended as legal advice. No warranty of any kind, implied, expressed, or statutory, including but not limited to the warranties of non-infringement of third-party rights, title, merchantability, or fitness for a particular purpose, is given with respect to the contents of this document.

Questions regarding this document should be sent to: The Transport Project; 400 N. Capitol St. NW; Suite 450; Washington, D.C. 20001.

Acronyms

ACH	Air Changes per Hour
AHJ	Authority Having Jurisdiction
ASE	Automotive Service Excellence
CFD	Computational Fluid Dynamics
CFM	Cubic Feet per Minute
CNG	Compressed Natural Gas
cuft	Cubic Foot (ft^3)
DGE	Diesel Galloon Equivalent
°F	Degrees Fahrenheit
GFV	Gaseous Fueled Vehicle
IBC	International Building Code
ICC	International Code Council
IFC	International Fire Code
IMC	International Mechanical Code
LCNG	Compressed Natural Gas derived from vaporized Liquefied Natural Gas
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas and/or propane
NFPA	National Fire Protection Association
NGV	Natural Gas Vehicle
OEM	Original Equipment Manufacturer
PRD	Pressure Relief Device
PSIa	Pounds per square inch (absolute pressure)
PSIg	Pounds per square inch (gauge pressure)
QRA	Qualitative Risk Assessment
RLM	Refrigerated Liquid Methane
SDO	Standard Development Organization
sqft	Square Foot (ft^2)
TTP	The Transport Project

Table of Contents

Guideline for CNG and LNG Maintenance Facility Modifications

Background

The growth of natural gas vehicle (NGV) fleets in recent years has increased the need for additional gaseous-fuel-friendly maintenance facilities across the country. The NGV industry has largely focused its efforts on development of vehicles and fueling infrastructure, while leaving issues dealing with the design and operation of maintenance facilities to fleet owners. The fleet owners have used their internal staff and/or consultants to interpret the intent of the applicable codes to develop a facility design for liquefied natural gas (LNG) and/or compressed natural gas (CNG) applications that will be approved by the authority having jurisdiction (AHJ). This is sometimes a difficult process since the codes are "performance" documents (provide little design guidance) and use language such as, "areas subject to ignitable concentrations of gas," which requires expert evaluation of expected hazardous conditions. Guidance that provides a better understanding of the intent of the code committee when the language was drafted is needed in order to apply those requirements to the diverse (ceiling height, layout, roof construction, heating, ventilation, electrical, etc.) design of maintenance facilities.

This document provides an overview of the modifications necessary for existing maintenance facilities that service conventional liquid- or petroleum-fueled vehicles to service vehicles powered by CNG, LCNG, and LNG only, and it can be used as a guide for new facility requirements as well. The basic national codes are outlined and the rationale and/or assumptions used to develop the codes are discussed. It is important to note that an individual existing maintenance facility must be evaluated to determine any necessary modifications since the building design and activities performed in the facility can have a significant impact on the modifications required.

NOTE: *This document does not cover indoor refueling facility code requirements.*

Overview of Existing Codes

Existing National Code Requirements

National codes that cover vehicle maintenance facilities:

- International Code Council's International Fire Code (IFC 2024)
- International Mechanical Code (IMC 2024)
- International Building Code (IBC 2024)
- National Fire Protection Association's NFPA 30A (2024) Code for Motor Fuel Dispensing Facilities and Repair Garages
- NFPA 52 (2026) Vehicular Natural Gas Fuel Systems Code
- NFPA 88A (2023) Standards for Parking Structures
- NFPA 70 (2026) National Electric Code

It is important to note that the ICC code series and NFPA 30A, 52, 70, and 88A are codes that, if adopted, are adopted voluntarily by states; they usually do not adopt the latest edition; other state-specific codes may apply; and enforcement responsibility lies with the local Authority Having Jurisdiction (AHJ). The local AHJ may enforce additional requirements beyond the national codes and, therefore, they should be part of the initial evaluation discussions or at least be consulted directly before the final design of any modifications. The codes summarized in this report can be found at: https://www.nfpa.org/en/For-Professionals/Codes-and-Standards/List-of-Codes-and-Standards and https://shop.iccsafe.org/international-codes.html.

Code Development Process and Hazard Analysis

The codes discussed in this report were developed over a number of years beginning in the late 1990s. The codes are written as performance documents, not design documents, and the performance requirements are based on assumed hazards. These hazards are determined by the expert knowledge and field experience of the members of the code committees that developed the codes.

- For CNG systems, the basic hazard is the unintended release and ignition of the natural gas while the vehicle is in the repair garage. In the 1990s, some first-generation pressure relief devices (PRDs) installed on natural gas cylinders had either a design flaw or were improperly selected for the design working pressure. The result was a number of incidents where there was premature release of the cylinder contents. This full release of cylinder contents led to the assumption by the code committees that the reasonable level of hazard for CNG vehicles was a release of 150% of the largest cylinder on the vehicle, where the extra 50% was a safety factor. Since PRDs on CNG cylinders are designed to only release the fuel in the event of a fire, and not due to pressure increases in the cylinder, the PRDs were redesigned and the safety design standards were revised. Since that time, PRDs have not experienced a premature failure and have performed as expected to protect the cylinder during a fire. The potential hazard level for CNG vehicles has been quantified by Sandia National Laboratories in several research studies

available at https://energy.sandia.gov/programs/sustainable-transportation/vehicle-technologies/fueling-safety/.

- For LNG vehicles, the existing codes do not define a specific release scenario but assume two types of releases. The basic hazard for LNG systems is the possible ignition of gas released from the LNG tank relief valve due to pressure building as the contents warm over a period of time. The vacuum insulated LNG tanks are designed to have a 'hold time' of at least five (5) days before the pressure builds to the relief valve setting. Typically, the LNG pressure inside of the LNG tank builds at a rate of about 15 PSIg per day giving a 'hold time' of about seven days for a typical design (contact tank manufacturer for specific information). This is a normal operating parameter of LNG tanks. There are operating procedures that can greatly reduce the probability of an LNG tank relief valve release during planned maintenance/repair operations, such as operating the vehicle to reduce the pressure in the tank and monitoring the pressure and rate of pressure rise in the tank before entering the repair garage. The codes also have requirements that address possible liquid LNG releases in the facilities. Based on historical incident records, there has not been a reported case of a liquid LNG release in a maintenance facility.

It is important to identify all possible hazards and quantify the risks in maintenance facilities and repair garages. Specific mitigation strategies to reduce or eliminate those hazards should be considered and implemented as appropriate for each facility. Physical or engineered solutions to mitigate a specific hazard may be cost effective in eliminating it, whereas procedural mitigation techniques may only reduce the risk associated with the hazard since they are subject to the additional risk of human error.

Existing Code Requirements by Facility Activity

The codes discussed below apply to repair facilities that perform minor or major vehicle service. Both NFPA 30A and the IFC contain facility modification code requirements specific to the type of CNG or LNG vehicle service or repair, and the requirements vary depending on which code is adopted by the AHJ—and the specific edition of the code—and the fuel pressure onboard the vehicle. Exemptions exist for minor repair facilities when the vehicle's fuel tanks are empty, the vehicle has been defueled, the pressure within each of the tanks is under an established maximum value, or the total volume contained within the tanks is below a recommended maximum value.

- IFC 2311.8 (2024) exempts garages from all requirements contained in section 2311 if work is not performed on the vehicle fuel system, open flames or welding is not used, and the fuel pressure onboard the vehicle is less than 250 PSI at 70 °F.

- By definition, NFPA 30A exempts facilities from a major repair garage designation if vehicle service activity therein is limited to lubrication, tires, brakes, fluid changes and other minor or routine automotive maintenance work. However, the definition of a minor repair garage may not exempt the facility from the required modifications of a major

repair facility if the CNG fuel pressure onboard a vehicle to be serviced is above 500 PSI. This is specified in 2021 and 2024 editions of NFPA 30A.

When a maintenance facility is considering adding CNG and/or LNG vehicles to their operations, an analysis of maintenance tasks by type as a percentage of the overall activities should be done. The analysis can help determine if the facility could be divided into 'major repair' and 'minor repair' areas. With proper physical separation, the codes require only that those areas of the facility designated as 'major repair' areas are subject to the additional requirements for CNG and LNG. For detailed definitions of minor and major repair facilities, refer to the Glossary of Terms at the end of this document, and for code requirements specific to minor repair facilities, major repair facilities, and tank pressure threshold definitions, refer to NFPA 30A 7.8.4.2 and IFC 2311.

Vehicle maintenance and repair facilities may require upgrades when performing major or minor repairs on fueled vehicles. Exemptions exist for minor repair facilities when the vehicle's fuel tanks are empty, the vehicle has been defueled, the pressure within each of the tanks is under an established maximum value, or the total volume contained within the tanks is below a recommended maximum value. Additional considerations are as follows:

- Garages that do not perform engine overhauls, do not work on the vehicle fuel system, do not use open flames or welding, do not perform body, fender, or paint work, or do not perform any repairs that require defueling may not be required to perform extensive facility upgrades.

- Depending on code requirements adopted by the AHJ, the vehicle service work that may be done without any modifications to the facility includes lubrication, inspection, engine tune-ups, fluid changes, brake system repairs, tire rotation, replacement of parts not associated with the fuel system, replacement of engine components not associated with fueling, and similar routine maintenance work not associated with the fuel system.
- For jurisdictions that fall under IFC 2311 code requirements, a flammable gas detection system must be installed in the facility when fuel storage onboard the parked or serviced vehicle exceeds 250 PSI.

- For jurisdictions that fall under 2021 and 2024 editions of NFPA 30A, a flammable gas detection system must be installed in the facility regardless of the fuel storage pressure onboard the parked or serviced vehicle.

- It is important to consider discrepancies that may exist between the various code requirements and to confirm with the local AHJ which code requirements apply in your area.

<u>In general, it is industry recommended practice that fueled CNG and LNG vehicles should NOT enter an unmodified, unapproved, or unqualified facility.</u> CNG and LNG fuel systems that have been defueled or depressurized properly and sustainably per NFPA 30A 7.8.14 requirements, NFPA 52 16.3.4 requirements, OEM guidelines, and other industry best practices pose a significantly lower risk to vehicle maintenance and repair facilities. While

using a defueling strategy may meet all of the regulatory requirements for performing work on CNG and LNG vehicles inside a facility, compliance should always be confirmed with the local AHJ.

Table 1 – Code References by Facility Activity

Facility Activity	Code References
Minor vehicle service or repair	NFPA 30A (2024) 3.3.12.2, 7.8.4.2, 7.8.12.4.2, 7.8.13.4.1; IFC (2024) 2311.8
Major vehicle service or repair	NFPA 30A (2024) 3.3.12.1, 7.8.4.2, 7.8.8.2, 7.8.8.5, 7.8.8.6, 7.8.8.7, 7.8.9.2, 7.8.12.4.1

Existing Code Requirements by Category

The sections below discuss the existing national code requirements for liquid and gaseous fueled vehicle repair garages or maintenance facilities. There are seven main areas to consider when reviewing the existing codes: ventilation, pits or basement ventilation, gas detection, heating equipment (sources of ignition), electrical classification, vehicle preparation for entering repair garage and maintenance facility, and decommissioning of fuel containers. In each area, the requirement for each fuel will be shown side by side for comparison.

Table 2 – Code References by Category

Modification Category	Code References
Ventilation	IFC (2024) 2311.4.3, 2311.8.4.2, 2311.8.5, 2311.8.8, 2311.8.10; IMC (2024) Section 403; NFPA 30A (2024) 7.5, 7.8.7, 7.8.11.2, 7.8.12, 8.3 NFPA 88A (2023) 5.5.6, 5.6, 6.3, 6.6.2, 9.2.3
Ventilation in Pits	IFC (2024) 2311.4; NFPA 30A (2024) 7.4.4.4, 7.8.9
Gas Detection	IFC (2024) , 2311.8.9; NFPA 30A (2024) 7.4.6, 7.8.11; IBC (2024) 406.8.2, 916
Sources of Ignition	IFC (2024) 2311.3 NFPA 30A (2024) 7.6.6, 7.8.13, 9.2.5.1, 11.5
Electrical Classification	IFC (2024) 2311.8.10 NFPA 30A (2024) 8.2, 8.3 NFPA 70 (2026) Article 511
Preparation of Vehicles for Maintenance	IFC (2024) 2311.8.1 NFPA 30A (2024) 7.8.14
Maintenance and Decommissioning of Containers	NFPA 52 (2026) 25.3.9 (CNG), 25.4 (LNG)

NOTE: *While the various codes have similar requirements, there are a few discrepancies that should be considered. They are noted in the tables for each category.*

Ventilation - Code Requirements

The International Mechanical Code (IMC 2024) Table 403.3.1.1 requires all vehicle repair garages, regardless of fuel type or maintenance performed, to have a ventilation rate of 0.75 CFM/sqft of floor area. This information is provided for reference only as the ventilation rates required for CNG or LNG maintenance facilities are above this IMC-specific minimum threshold. Therefore, NGV facilities that meet the IFC and NFPA 30A ventilation rate requirements will meet all other general ventilation code requirements for garages and facilities as well (see ventilation requirements below in the sections for minor and major repair garages).

NFPA 88A 6.3.1 requires a ventilation rate of 1 CFM/sqft of floor area for enclosed parking garages housing conventional and gaseous-fueled vehicles. **Based on this requirement, it should be considered that the base rate for all repair garages would be at least 1 CFM/sqft since even in minor repair garages vehicles could be parked awaiting repair for an extended period of time**.

Where mechanical ventilation is required by IFC 2311.8.8.2, it must operate continuously except when it is either interlocked with a gas detection system or, for CNG applications only, electrically interlocked with the lighting circuit for CNG applications.

The codes state the ventilation rate using three different formats. Conversions for each format are shown in Table 3.

Table 3 – Ventilation Rate Conversions

Rates	CFM/sqft	CFM/12 cuft	Air changes/hour
CFM/sqft	1	1/12ft	60/room height ft
CFM/12 cuft	12ft	1	5
Air changes/hour	Room height ft/60	1/5	1

NOTE: *Any discrepancy specific to mechanical ventilation requirements in repair areas and fuel dispensing areas that may have existed between older editions of NFPA 30A and IFC 2311 has been resolved in current 2024 editions.*

Table 4 provides the code requirements for garage ventilation by fuel type.

Table 4 – Ventilation – General

Subject	Conventional Liquid Fuels	CNG	LNG
Ventilation – General	**NFPA 30A 7.3.6.7** Provides requirements for ventilation systems serving a fuel dispensing area inside a building or a repair garage. Fuel dispensing is not part of this guideline. **IFC 2311.4.3** specifies requirements where flammable vapors from class-1 liquids or LP gas could accumulate and requires minimum mechanical ventilation rate of 1.5 CFM per sqft. **IMC Table 403.1.1** Has general ventilation requirements for all repair garages of 0.75 CFM per sqft of floor area. **NFPA 88A 6.3.1** Has a ventilation requirement for enclosed parking garages during hours of operation set at 1 CFM per sqft of floor area.	**NFPA 30A 7.8.11.3, 7.8.12.1, 7.8.12.4** provide purge ventilation and minimum ventilation requirements for CNG repair garages and repair areas. **IFC 2311.8.8** requires approved mechanical ventilation systems to operate continuously for CNG repair garages at 1 CFM per 12 cuft of room volume (5 air changes per hour). There are two exceptions to these requirements: (1) mechanical exhaust ventilation systems that are interlocked with a gas detection system or electrically interlocked with the lighting circuit; and (2) Repair garages with AHJ approved natural ventilation.	**NFPA 30A 7.8.11.3, 7.8.12.1, 7.8.12.4** provide purge ventilation and minimum ventilation requirements for LNG repair garages and repair areas. **IFC 2311.8.4.2, 2311.8.5, 2311.8.8, 2311.8.10** require approved mechanical ventilation systems for LNG repair garages at 1 CFM per 12 cuft of room volume (5 air changes per hour). There are two exceptions to these requirements: (1) mechanical exhaust ventilation systems that are interlocked with a gas detection system or electrically interlocked with the lighting circuit; and (2) Repair garages with AHJ approved natural ventilation.

Ventilation in Pits – Code Requirements:

Ventilation requirements for pits, below grade and subfloor work areas are part of the basic requirements for liquid fuels where flammable vapors may accumulate. This requirement should already be met by the existing maintenance facility. However, the codes are not harmonized as to the ventilation rate. IFC requires 1.5 cfm/sqft while the NFPA 30A requirements are more complex and are specified in section 7.8.9. The local AHJ should specify the ventilation rate for each facility. Ventilation requirements differ for CNG and LNG vehicle repair garage pits because CNG and LNG behave differently if a release from their respective fuel containers were to occur. While experience has shown that there is a very low probability of a release of LNG liquid, the release of a cold vapor may initially be heavier than air and migrate to a subgrade area where it would quickly become buoyant and rise as a CNG release. The existing ventilation requirement for liquid fuels should be adequate for the addition of LNG to major repair facilities with approval of the local AHJ.

Table 5 – Ventilation of Pits

Subject	Conventional Liquid Fuels	CNG	LNG
Ventilation of Pits, Below Grade Work Areas and Subfloor Work Areas	**IFC 2311.4** and **NFPA 30A 7.4.5.4** Require ventilation rates of 1.5 and 1 CFM/sqft respectively for repair garages having a pit or basement where flammable vapors may accumulate.	**NFPA 30A 7.8.9** provides ventilation requirements **IFC** – no CNG-specific requirements	**NFPA 30A 7.8.9** provides ventilation requirements **IFC** – no LNG-specific requirements

Gas Detection – Code Requirements

Requirements for flammable gas detection in repair garages (major or minor) where CNG and LNG vehicles are maintained are specified in IFC 2311.7.2 and NFPA 30A 7.8.11 and 7.4.6. Requirements for vehicles powered by non-odorized gases are specified in NFPA 30A 7.4.6. Specific requirements under these codes for gas detection installation and operation are similar and may require the expertise of a gas detection design engineer for optimal performance.

Table 6 – Gas Detection

Subject	Conventional Liquid Fuels	CNG	LNG
Gas Detection	**IFC 2311.8.9** specifies requirements for service pits; **NFPA 30A –** No requirements	**NFPA 30A 7.8.11** provides gas detection requirements; **IFC** – no specific requirements for odorized CNG	**IFC 2311.8.9, 2311.8.9.1, and 2311.8.9.2** Requires an approved gas detection system for repair garages for LNG vehicles; **NFPA 30A 7.8.11** provides LNG gas detection requirements and **7.4.6** provides non-odorized gas detection requirements

Sources of Ignition – Code Requirements

The IFC does not have any specific requirements for CNG and LNG repair garages with respect to sources of ignition. IFC does provide requirements for liquid fuels in section 2311.3 restricting ignition sources from the space within 18 inches of the floor. This is the standard requirement in the IBC, IMC, and NFPA 70. These requirements already should be met by the existing facility.

In NFPA 30A 7.6.6 (see Note 2 below), the restrictions on heating equipment in major repair garages only apply to areas where ignitable mixtures may be present. The accepted practice at this time is to assume that there will be an ignitable mixture present in some areas of major repair garages. The identification of these areas is based on the expected volume of fuel released and its concentration in the facility. The quantification of a creditable release of both CNG and LNG should be done and representative computational fluid dynamic (CFD) modeling of those releases in various facility geometries is needed to determine if ignitable mixtures will be present. This is a time consuming and expensive process that is not usually done for individual maintenance facilities. Tools such as Sandia National Laboratories' Hydrogen Plus Other Alternative Fuels Risk Assessment Models (HyRAM+) offer valuable assessment of hazards. The software toolkit is based on significant analysis of data and models relevant to assessing the safety in the use, delivery, and storage of alternative fuels and is available at http://hyram.sandia.gov/.

Table 7 – Sources of Ignition

Subject	Conventional Liquid Fuels	CNG	LNG
Sources of Ignition – Heat Producing Appliances	**IFC 2311.3 –** Sources shall not be located within 18 inches of the floor, and appliances and equipment installed in a repair garage shall comply with the IBC, IMC, and NFPA 70A. **NFPA 30A 7.6** – Multiple requirements on heat producing appliances specified in this section; **9.2.5.1** specifies additional requirements for smoking materials and engine operation during refueling	**IFC** – No specific requirements. **NFPA 30A 7.6.6** – Where major repairs are conducted on CNG-fueled vehicles, open flame heaters or heating equipment with exposed surfaces having a temperature in excess of 750°F shall not be permitted in areas subject to ignitable concentrations of gas. **Note 1**: Minor repair garages are facilities where work is not performed on the fuel system and work is limited to exchange of parts and maintenance requiring no open flame or welding. All other garages are defined as major repair garages. **Note 2**: Determining 'areas subject to ignitable concentrations of gas' requires understanding what a credible release of CNG (the hazard) in the facility and then determining the probability of where an ignitable may be present. **7.8.13** specifies additional requirements for CNG vehicle repair areas.	**IFC –** No specific requirements. **NFPA 30A 7.6.6** – Where major repairs are conducted LNG-fueled vehicles, open flame heaters or heating equipment with exposed surfaces having a temperature in excess of 750°F shall not be permitted in areas subject to ignitable concentrations of gas. **Note 1**: Minor repair garages are facilities where work is not performed on the fuel system and work is limited to exchange of parts and maintenance requiring no open flame or welding. All other garages are defined as major repair garages. **Note 2**: Determining 'areas subject to ignitable concentrations of gas' requires understanding what a credible release of LNG or LNG vapor (the hazard) in the facility and then determining the probability of where an ignitable may be present. **7.8.13** specifies additional requirements for LNG vehicle repair areas.

Electrical Classification – Code Requirements

The IFC does not have any specific requirements for electrical classifications for CNG and LNG repair garages. NFPA 30A Chapter 8 includes requirements for electrical classification areas for liquid fuel vehicles that primarily address electrical classifications for pits and the space within 18 inches from the floor of the repair garage. NFPA 30A 8.3.9 classifies CNG and LNG vehicle repair areas as Class 1, Division 2. The exception to this classification is that, when an area below the ceiling has ventilation of at least 1 $ft^3/min/ft^2$, the area is considered unclassified. Regarding classified areas for LNG in major garages, NFPA 30A essentially has the same requirements as liquid fuels in pits and the same requirements as CNG in the 18-inch space below the ceiling.

For analyses of credible releases of CNG and LNG affecting electrical classifications in maintenance facilities of various geometries, reference studies conducted by Sandia National Laboratories (e.g. SAND2014-2342 and SAND2016-4534), which can be found at https://energy.sandia.gov/programs/sustainable-transportation/vehicle-technologies/fueling-safety/. These studies used a risk-informed process with input from a risk assessment for credible release of CNG/LNG based on experience and today's NGV technology.

Table 8 – Electrical Classifications

Subject	Conventional Liquid Fuels	CNG	LNG
Electrical Installations	**IFC Section 2311 –** No specific requirements. **NFPA 30A Chapter 8 -** Multiple electrical classifications for liquid fuel repair garages.	**IFC Section 2311 –** No specific requirements. **NFPA 30A 8.3.9** and **Table 8.3.3** specify requirements for purge ventilation electrical systems and components in CNG vehicle repair areas.	**IFC Section 2311 –** No specific requirements. **NFPA 30A 8.3.9** and **Table 8.3.3** specify requirements for purge ventilation electrical systems and components in LNG vehicle repair areas.

Preparation of Vehicle for Repair – Code Requirements

IFC 2311 addresses mitigation of the assumed hazards from releases of natural gas by isolating the CNG cylinders and LNG tanks from the balance of the fuel system by valve closures prior to maintenance. This reduces the quantity of fuel that could be released in fuel system piping and components due to damage or error during maintenance operations.

Table 9 – Preparation of Vehicles for Repair

Subject	Conventional Liquid Fuels	CNG	LNG
Preparation of vehicles for repair	**IFC and NFPA 30A -** No requirement	**IFC 2311.5** – Close fuel shut-off valve prior to repairing any portion of the vehicle fuel system. Where the fuel system has been damaged it shall be inspected and evaluated for fuel system integrity prior to being brought into the repair garage. Test the entire fuel system for leakage. **NFPA 30A 7.8.14** contains CNG defueling requirements	**IFC 2311.5** – Close fuel shut-off valve prior to repairing any portion of the vehicle fuel system. Where the fuel system has been damaged it shall be inspected and evaluated for fuel system integrity prior to being brought into the repair garage. Test the entire fuel system for leakage. **NFPA 30A 7.8.4.3** requires LNG tank pressure to be less than 65 percent of the tank maximum allowable working pressure (MAWP) and depressurization to be performed in accordance with the original equipment manufacturers' recommended procedures. **NFPA 30A 7.8.14** contains LNG defueling requirements

Maintenance and Decommissioning of Vehicle Fuel Containers

These code requirements are not found under repair garages but are part of the maintenance requirements for vehicle mounted fuel storage containers. NFPA 52, CSA/ANSI NGV 2, CGA C-6.4, and guidelines provided by the vehicle OEM, the fuel system provider, or the cylinder manufacturer should be consulted for the specific requirements regarding CNG cylinder maintenance. These requirements necessitate the development of written maintenance procedures along with certain modifications to the maintenance facility to accommodate defueling of fuel containers for fuel system maintenance and end of life decommissioning of CNG cylinders. CSA Group's SPE-2.1.1 (https://www.csagroup.org/store/product/SPE-2.1%20SERIES-18/) is a best practice document for handling end of life compressed natural gas (CNG) vehicle fuel containers that provides guidance on defueling, decommissioning, and disposal.

Table 10 – Inspection, Maintenance, Repair, and Decommissioning of Vehicle Fuel Containers

Subject	Conventional Liquid Fuels	CNG	LNG
Fuel System Inspection, Maintenance, and Repair	No specific requirements	**NFPA 52 25.3.9 –** Repair facilities should have specific written procedures for inspecting, maintaining, repairing, and decommissioning CNG cylinders. This set of requirements depends on properly trained personnel and the use of procedures as recommended by the cylinder manufacturer and/or cylinder valve manufacturer. See also **25.2**.	**NFPA 52 25.4** contains general requirements for LNG fuel system inspection, maintenance, and repair. Other codes do not provide specific requirements for maintaining LNG fuel tanks. It is recommended that the repair garage has written procedures and training material based on the LNG tank manufacturer's instructions.
Defueling and Decommissioning of Fuel Storage Containers	No specific requirements	**NFPA 30A 7.8.14** contains CNG defueling requirements for vehicles and associated facilities. **NFPA 52 25.3.4 –** Each major repair garage should install the proper defueling facility. Designs for fuel recovery systems and direct atmospheric venting systems should be approved by the AHJ as required. If the CNG cylinders have reached their end of life or are damaged, the cylinder should be purged with water or an inert gas, made unusable and scrapped according to the cylinder manufacturer's instructions.	**NFPA 30A 7.8.4.3** requires LNG tank depressurization to be performed in accordance with the original equipment manufacturers' recommended procedures. **NFPA 30A 7.8.14** contains general requirements for decommissioning LNG fuel tanks. It is recommended that the repair garage have written procedures and training material for decommissioning and defueling LNG tanks based on the LNG tank manufacturer's instructions.

Guideline for Modifications

This section will discuss steps that should be considered when determining the modifications that might be required for maintenance facilities to service CNG and/or LNG vehicles. It is important to note that each individual existing maintenance facility must be evaluated to determine any necessary modifications since the building design and activities performed in the facility can have a significant impact on the modifications required. Just as the codes are performance (not design) documents, this document does not provide specific design guidelines; but does provide the steps needed for basic decisions on the modifications required to meet code and provide for safe operations.

NOTE: *Garages designed to accommodate LNG vehicles may not require additional modifications to also accommodate CNG vehicles. However, garages designed with basic code requirements to accommodate CNG vehicles may require additional modifications to accommodate LNG vehicles.*

Plan Development and Coordination with AHJs

There are a number of basic questions that should be answered in order to begin development of the facility modification plan:

- Does the facility meet existing code requirements for liquid fuels?
  - If not, what remedial action may be required? (i.e., ventilation etc.)
- What type of NGV will the facility maintain: CNG, LNG or both?
- Will the facility provide minor repairs, major repairs, or both?
- Will the minor repair area be physically separated from the major repair area?
  - If not, the entire facility may be classified as a major repair facility.
- Will the facility procedures include the venting and decommissioning of cylinders?
- Will the facility include an indoor or outdoor refueling station?
  - Note: this document does not include guidelines for refueling stations but if a station will be installed at the same time as the facility modifications, then the overall plan should include that design and its possible interconnection with cylinder defueling.
- Will the facility include indoor parking for NGVs?

The answers to the questions above will help determine the scope of the potential facility modifications and the operating procedures for the facility. Before taking the next step in plan development, an inquiry should be made to the local AHJ(s) to determine the specific code documents that have been adopted and will be enforced. ICC's International Fire Code (IFC) has been adopted or is in use by many states and other jurisdictions throughout the U.S. In some states, the IFC may have only been adopted by some local AHJs; therefore its statewide adoption should not be assumed. Also, each state may adopt and enforce different editions of the respective code (e.g., IFC 2012 or IFC 2015, etc.). The codes are generally revised on a three-

year cycle and AHJ adoption is usually several cycles out of date. All of this information applies to NFPA code as well.

While general information on state and local adoption used to be available on ICC and NFPA websites, this is no longer the case. The local AHJ should always be consulted as the best source of information to determine the correct code and code edition that applies to a facility.

Establishing a working relationship with the local AHJ at the beginning of the project is an important step in determining the extent of the modifications that may be required including any local concerns that may not be in the national codes. When first approaching the AHJ there are several items to consider:

- Have a completed project scope for the maintenance facility that includes the fuel types, list of maintenance activities, outline operational procedures specific to the fuel types and outline of training by fuel type for all personnel.
- Meet as early as possible with the appropriate AHJ(s) to make them aware of your project plans.
    - If the AHJ is experienced with CNG/LNG installations and maintenance facility modifications, they can provide important input to the final plan development.
    - If the AHJ has no experience with NGVs, or just no experience with maintenance facility modifications for CNG/LNG, you should use this as an opportunity to provide the AHJ with the background material they will need to determine the proper code requirements to enforce.
- Provide a project timeline to the AHJ(s) and add any required inspection dates as part of the timeline.
- Set up a meeting to review the final project plan and be sure to reference proposed modifications to the specific code and/or AHJ requirement.

The final plan development should, at a minimum, consider the steps discussed in the sections below in order to meet the basic code requirements.

Analysis of Existing Maintenance Facility

When modifications are anticipated for an existing maintenance facility, a review of the facility's compliance with the existing codes may be necessary. Since the existing maintenance facility may have been built under older editions of the codes, and codes are generally not retroactive, any new modifications may require bringing the facility up to the codes now enforced for conventional liquid fuels.

Code Compliance of Maintenance Facility for Class I and Class II Fuels

The primary concerns regarding code compliance for existing facilities are:

- Ventilation rate in general garage area should be between 0.75 (IMC) and 1.0 (NFPA) CFM/sqft with inlet at least 18" above the floor.

- Ventilation rate for below grade areas (pits or basement) should be between 1.0 (NFPA) and 1.5 (IFC) CFM/sqft with exhaust air taken within 12" of the floor.
- Review the IFC and NFPA documents for requirements for sources of ignition including heating appliances since their design and placement may have a significant influence on the modifications for the CNG/LNG garage.
- When the AHJ tours the facility in the initial review process, they may determine that some remedial modifications are needed to the existing facility to come into compliance with the code editions now in place.

Minor vs. Major Repair Garages

Depending on the code and edition of code adopted by the AHJ, the requirements outlined in the sections above may not be enforceable in minor repair facilities. Both NFPA 30A and the IFC contain facility modification code requirements specific to the type of CNG or LNG vehicle service or repair, and the requirements vary depending on which code is adopted by the AHJ—and the specific edition of the code—and the fuel pressure onboard the vehicle. Exemptions exist for minor repair facilities when the vehicle's fuel containers are empty, the vehicle has been defueled, the pressure within each of the containers is under an established maximum value, or the total volume contained within the containers is below a recommended maximum value.

There may be significant savings in the cost of modifications if the maintenance facility can be divided into separate designated areas for minor and major repair activities. This can be accomplished by either having separate buildings or separate areas within one facility. The codes are not specific in how to separate major from minor repair areas but using some of the same requirements for separating indoor fueling rooms from the repair areas may be appropriate if approved by the AHJ. The codes provide some guidance for separating the minor and major repair areas within a facility, such as:

- Interior walls or partitions shall have a 1-hour fire rating and be continuous from floor to ceiling.
- For the major repair area at least one wall shall be an exterior wall and primary access shall be from the outside through the exterior wall.
- Interior access between the major and minor repair areas shall be through self-closing fire doors with the appropriate rating for the location installed as approved by the AHJ.
- The major and minor repair areas shall have separate ventilation systems as required by the codes.

If the major and minor repair areas cannot be separated, the entire maintenance garage should be modified as required to perform major repairs on CNG and/or LNG fueled vehicles as needed.

Analysis of Maintenance Activities

An analysis of existing and anticipated maintenance activities by type and quantity may be helpful in determining if the facility can be configured into separate major and minor repair areas. Table 11 provides guidance on classifying repairs by type. Consideration should also be

given to defining additional areas that may be required for inspection and preparation of vehicles prior to entering the repair facility. In addition, a designated location for defueling vehicle fuel cylinders for maintenance or decommissioning should be identified.

Table 11 – Major vs. Minor Garage Activities

Code	Minor Repair Activities	Major Repair Activities
IFC 2311.8	Work on vehicles with a fuel system that has been completely defueled, fuel container(s) that has been purged with nitrogen gas, and standard operating procedures that are approved to document and maintain the fueling status throughout the repair operations	All other repairs
	Work limited to vehicle parts exchange or maintenance with fuel pressure onboard less than 250 PSI at 70 °F	
	Work that excludes the vehicle fuel system	
	Work not requiring open flames or welding	
	Work that includes movement of a subassembly on which the motor vehicle fuel tank remains mounted to allow access to other parts of the vehicle that are not a portion of the fuel system	
NFPA 30A 3.3.12	Work including lubrication, inspection, engine tune-ups, replacement of parts, fluid changes, brake system repairs, tire rotation, and similar routine maintenance work.	Work including engine overhauls, painting, body repair, fender repair, welding, grinding, and any repairs requiring defueling

Minor Repair Garages – Requirements for CNG or LNG

It is important to evaluate individual repair area(s) within the maintenance facility and the facility as a whole to determine if the area or facility will require modifications for compliance as a major repair garage for CNG or LNG vehicles. If the repair area or facility meets the classification as minor repair garage, the extent of modifications and vehicle preparations required can be significantly less. In situations where no modifications are required to the area/facility, precautions should still be taken when servicing CNG or LNG vehicles. Such precautions and operator awareness will reduce hazards from a potential natural gas release, regardless of the area/facility classification.

Ventilation

Although the codes do not require any modifications to a continuous operation ventilation system, it is important to confirm the existing ventilation rate of at least 1 CFM/sqft. In addition, the inlet for outside air should be at least 18" above the floor of the garage for both conventional liquid and CNG/LNG fuels. Even though it is not required by the codes, consideration should be given to configuring the exhaust ports of the ventilation system to the highest points of the exterior walls or roof.

Gas Detection

In general, it is industry recommended practice that fueled CNG and LNG vehicles should not enter a minor repair facility without flammable gas detection capability. However, the code *requirements* for flammable gas detection in minor repair facilities vary, and it is important to consult the local AHJ for requirements that apply in your area.

According to 2021 and 2024 editions of NFPA 30A code, all facilities where CNG or LNG vehicles are serviced, maintained, repaired, or parked overnight shall be modified with a flammable gas detection system. 2018 and earlier editions of NFPA 30A code, however, specify a requirement based on major or minor garage classification, fuel tank storage pressure, and ceiling ventilation. IFC 2311 code requires a flammable gas detection system when fuel storage onboard the parked or serviced vehicle exceeds 250 PSI.

Table 12 – CNG Gas Detection Requirements in Minor Repair Garages

Code	Edition	Requirement
NFPA 30A	All editions prior to 2021	No requirement for flammable gas detection in minor repair facilities
	2021 and later editions	**7.8.11** – Flammable gas detection required
IFC	All	No requirement for flammable gas detection in minor repair facilities[1]

When determining the specific gas detection event sequences to ensure the safety of employees and personnel working in the building, it is important to reference code requirements such as NFPA 30A (2024) 7.8.11.2 and 7.8.11.3 for determining proper system design, operation, and failure modes. In addition to fundamental code specifications, a Gas Detection System Alarm Matrix and sequence of events recommendations are provided in Appendix B, and they should be considered when a gas detection event occurs in a "typical" natural gas compliant maintenance building with a gas detection system with auxiliary ventilation.

Depending on the code and the edition of the code adopted by the AHJ, continuous ventilation can be used as an alternative to flammable gas detection systems that are not practical or feasible in some minor facility applications. It is important to consider discrepancies that may exist between the various code requirements and to confirm with the local AHJ which code requirements apply in your area.

Major Repair Garages – Requirements for CNG

When adding CNG vehicle maintenance operations to a major repair garage, the code requirement must be evaluated to determine what types of modifications are necessary. For some code requirements, there may be more than one method to meet the requirements so an engineering analysis may be called for to determine the optimum solution. The primary difference between minor and major repair garages is a higher potential for natural gas release in major repair garages due to the nature of the vehicle service performed therein. The code requirements set performance criteria to reduce the presence of a flammable mixture and eliminate potential sources of ignition. For this set of requirements, it is assumed that only properly odorized CNG is present on the vehicles to be serviced. Un-odorized CNG is addressed in the section on LNG maintenance facilities.

[1] It is important to note that while IFC does not require [odorized] gas detection in minor repair garages servicing CNG powered vehicles, IFC 2311.8.9 does require gas detection in all garages used for repair of vehicles fueled by *non-odorized gases*, including hydrogen, LNG, and LCNG.

Ventilation

NFPA 30A (2024) specifies general ventilation requirements for all NGV repair garages. Clause 7.8.12.4.3.2 states that minimum ventilation shall not be less than 0.5 ACH, and clause 7.8.12.4.3.3 states that natural or mechanical ventilation shall extract air from within 20 in. of the ceiling.

The IFC requires a minimum of 5 ACH for continuous mechanical ventilation of CNG major repair garages. In garages where natural ventilation may be used, it must be approved by the AHJ as an exception to the stated requirements. The operation of the mechanical ventilation is required to be continuous, but there are two exceptions to this requirement: 1) ventilation system interlocked and controlled by a continuously monitoring natural gas detection system, or 2) ventilation system electrically interlocked with the lighting circuit for the garage. In addition, the IFC references IMC clauses 2311.8.8.1 and 23.8.8.2 which state that the exhaust ventilation rate shall be not less than 1 cuft per minute (0.03 m^3/min) per 12 cuft (34 m^3) of room volume.

As stated in the section on code requirements for ventilation of conventional liquid fuel vehicle repair garages, the base ventilation rate is conservatively 1 CFM per sqft or floor area. Table 2 gives the conversion from CFM/sqft to ACH as 60/room height in feet. So for a garage with a ceiling height of 12 ft, the base ventilation rate of 1 CFM/sqft equals the required 5 ACH. For a ceiling height of 24 ft, the CFM/sqft rate would have to increase to 2 CFM/sqft in order to maintain the same 5 ACH rate.

There are a number of decisions that must be made concerning ventilation when adding CNG to the existing conventional liquid fuel vehicle repair facility:

- Evaluation of existing ventilation system for code compliance.
- Separation of ventilation systems for minor repair area and major repair area if in same building.
- Ventilation rates required based on building geometry and codes.
- Operate ventilation system continuously or
    - Control ventilation system by interlocking with continuously operated natural gas detection system or
    - Control ventilation system by electrically interlocking with the lighting circuit.

Ventilation in Pits

There are no additional code requirements for major repair garages that add CNG maintenance operations. The ventilation already required for conventional liquid fuel garages for pits or below grade areas is still required for continued maintenance of conventional liquid fuel vehicles.

Gas Detection

Prior to 2021, NFPA 30A did not require natural gas detection systems in major repair garages that add CNG maintenance operations as long as the CNG is properly odorized. However, per 2021 and later editions of NFPA 30A, flammable gas detection is required in all NGV repair garages and/or the portions that serve as NGV repair areas. In general, it is industry recommended practice that CNG vehicles are fueled with odorized (i.e., pipeline quality) natural gas only, and CNG major repair should only be performed in garages with a flammable gas detection system. For any vehicles that may be fueled with non-odorized CNG from LNG (i.e., LCNG) or from non-odorized renewable natural gas (i.e., biogas) those vehicles should only be maintained in a garage designed for non-odorized natural gas as detailed in the section below on LNG major repair garages.

Natural gas detection systems in major repair garages that control the operation of the ventilation system should take the following into account:

- The natural gas detection system should be designed by an engineer with expertise in natural gas detection system design.
- The natural gas detection system should be *listed* in accordance with UL 2075 or *approved* by the AHJ**.**
- The natural gas detection system shall activate at 25% of the lower flammability limit (LFL).
- Upon activation the natural gas detection system shall:
    - Activate the mechanical ventilation system
    - Deactivate tall heating systems located in the major repair garage
    - Initiate a distinct audible and visual alarm in the garage
- The failure of the natural gas detection system shall:
    - Activate the mechanical ventilation system
    - Deactivate all heating systems located in the major repair garage
    - Initiate a trouble alarm in an *approved* location
- NFPA 72 National Fire Alarm and Signaling Code provide information on monitoring the detection systems for integrity.
- The natural gas detectors should be tested and calibrated as recommended by the manufacturer and approved by the AHJ.

Sources of Ignition

Both the IFC and NFPA 30A have a number of requirements addressing sources of ignition for liquid fuel garages. Only NFPA 30A has additional requirements for CNG vehicle major repair garages. The requirement is directed at restricting open flame heaters and any heating equipment with exposed surfaces with temperatures above 750 °F from any area subject to ignitable concentrations of natural gas.

Industry best practice is to eliminate heating equipment of these types from the major repair garage. It would take an analysis of the potential credible natural gas releases and modeling of the possible concentrations of ignitable gas within the facility in order to safely place these types of heaters in safe areas. This analysis is typically beyond normal heating design work and would be subject to approval by the AHJ on a case-by-case basis.

Electrical Classification

The codes have a number of requirements on classified locations for electrical equipment in conventional liquid fuel garages. Only NFPA 30A requires that the space within 18 inches of the ceiling of a major CNG garage be classified as a Class 1, Division 2 classified location. This means that all electrical equipment within that area must be suitable for that classification as set forth in NFPA 70, National Electrical Code. The code does provide an exception to the requirement in that it does not apply to a facility that has a ventilation rate of at least 4 ACH.

It is important to take into account the design of the ceiling support structure to determine what modifications may be necessary for the classified location. One example would be a concrete 'T' beam design that may not be easily ventilated at the required rate to eliminate the classified location, thus requiring modification of any electrical equipment in the 18-inch space below the ceiling. Conversely, an open web steel joist structure may achieve the proper 4+ ACH eliminating the classified location.

If the classified location cannot be eliminated by ventilation, then the choice may be to either modify the electrical installation to meet Class1, Division 2 requirements or move the electrical equipment below the 18-inch classified location, which in most cases would be to attach the system to the bottom of the support structure as opposed to the ceiling.

Preparation of CNG Vehicle for Maintenance

The IFC is the only code that has requirements for vehicle preparation prior to performing maintenance operations. For CNG vehicles, the procedure is to: 1) measure and record CNG vehicle fuel system pressure and the ambient temperature before vehicle enters the repair facility; 2) if measured fuel system pressure is greater than the indicated maximum pressure in Table 2311.6.2, reduce the pressure by defueling the vehicle; and 3) limit the quantity of natural gas that could be accidentally released by turning off shut-off valves of all of the fuel storage cylinders on the vehicle once it enters the repair garage. Vehicles that have cylinder-mounted solenoid valves tied to the ignition system of the vehicle will automatically close the valves when the engine is shut down. Vehicles that have manual valves on the cylinders must be closed by hand. A procedure to double-check that all valves are closed as required should be established as part of the facility's normal operations.

NOTE: industry codes and standards do not specify fuel *volume* as a qualifying attribute for CNG powered vehicles inside a facility. However, CNG volume stored onboard a vehicle should be taken into consideration as an industry best practice. For calculating the maximum fuel volume for CNG powered vehicles inside a facility, refer to Appendix C.

The IFC also requires that if there is any suspected damage to the CNG fuel system the entire system should be checked for leaks and evaluated for fuel system integrity prior to bringing the vehicle into the repair garage. While not noted in the IFC, if there is any suspected damage to the

CNG cylinder it should be inspected by a certified cylinder inspector to determine its proper disposition based on the findings of the inspection.

Maintenance and Decommissioning of Vehicle Fuel Containers

NFPA 52 requires that repair facilities have specific written procedures for inspection and decommissioning of CNG cylinders. This set of requirements depends on the existence of properly trained personnel and the use of procedures as recommended by the vehicle OEM, the fuel system provider, the cylinder manufacturer, and/or the cylinder valve manufacturer. In order to properly perform maintenance on a cylinder, the cylinder must be safely defueled.

NFPA 52 requires that each major repair garage follow proper defueling procedures with specific requirements in section 25.3.4 of the 2026 edition of the code. Designs for fuel recovery systems and direct atmospheric venting systems should be approved by the AHJ as required. If the CNG cylinders have reached their end of life or are damaged, the cylinders should be defueled, purged with an inert gas, made unusable and scrapped according to the cylinder manufacturer's instructions. For additional guidance on cylinder defueling, decommissioning, or disposal, refer to recommended practices such as those contained in the CSA SPE-2.1.1-18 technical specification document.

While not covered in this set of guidelines, a CNG refueling station may be part of the overall modifications needed by the major repair garage in order to return the vehicles to service. Consideration should be given to add a natural gas recovery system to the refueling station design in order to reduce the amount of natural gas that is released to the atmosphere.

Major Repair Garages – Requirements for LNG

To add LNG maintenance operations to a major repair garage, certain code requirements should be evaluated to determine what modifications might be necessary. For some of the modifications, there may be more than one method to meet the requirements so an engineering analysis may be called for to determine the optimum solution. The primary difference between minor and major repair garages is a higher potential for natural gas release in major repair garages due to the nature of the vehicle service performed therein. The code requirements set performance criteria to reduce the presence of a flammable mixture and eliminate potential sources of ignition. For this set of requirements, it is assumed that LNG and/or un-odorized CNG is present on the vehicles that will be serviced. LNG and un-odorized CNG major repair garages have additional requirements beyond those for odorized CNG. Proper ventilation of pits and below-grade areas is required along with a continuously operating natural gas detection system. These requirements are discussed below.

Ventilation

NFPA 30A has no specific requirements for general ventilation rates for LNG major repair garages but does require a natural gas detection system (see section below) that is interlocked

with the major repair garage's ventilation system and a system for outdoor transfer of gas that is vented from LNG vehicles parked inside for an extended period of time.

The IFC has a specific requirement for continuous mechanical ventilation of LNG major repair garages of 5 air changes per hour (ACH). In garages where natural ventilation is used, it must be approved by the AHJ as an exception to the stated requirements. The operation of the mechanical ventilation is required to be continuous but there are two exceptions to this requirement: 1) ventilation system interlocked and controlled by a continuously monitoring natural gas detection system, or 2) ventilation system electrically interlocked with the lighting circuit for the garage.

As stated in the section on code requirements for ventilation of conventional liquid fuel repair garages, the base ventilation rate is conservatively 1 CFM per sqft of floor area. Table 2 gives the conversion from CFM/sqft to ACH as 60/room height in feet. Therefore, for a garage with a ceiling height of 12 ft, the base ventilation rate of 1 CFM/sqft equals the required 5 ACH. For a ceiling height of 24 ft, the CFM/sqft rate would have to increase to 2 CFM/sqft in order to maintain the same 5 ACH rate.

With respect to ventilation, the following factors or steps should be considered when adding LNG to the existing liquid fuel repair facility:

- Evaluation of existing ventilation system for code compliance.
- Separation of ventilation systems for minor repair area and major repair area if in same building.
- Ventilation rates required based on building geometry and codes.
- Operate ventilation system continuously or
    - Control ventilation system by interlocking with continuously operated natural gas detection system or
    - Control ventilation system by electrically interlocking with the lighting circuit.

Ventilation in Pits

The ventilation already required for conventional liquid fuel garages for pits or below grade areas should be maintained and used for LNG. If it is released, LNG vapor is heavier than air at temperatures below -160 °F, but as the LNG vapor quickly warms above -160 °F it will dissipate similarly to a CNG release. Gas detection is required in repair pits of garages maintaining non-odorized CNG or LNG fueled vehicles.

Gas Detection

There are specific requirements for natural gas detection systems in repair garages that add service capability for vehicles powered by LNG or un-odorized CNG. There may be some stations that supply non-odorized CNG from LNG (i.e., LCNG) or from non-odorized renewable natural gas (i.e., biogas), but they are restricted to only fueling CNG vehicles that have on board methane detection systems. Those vehicles should only be maintained in a garage designed for non-odorized natural gas as detailed below.

The natural gas detection system design should consider inclusion of some of the following:

- The natural gas detection system should be designed by an engineer with expertise in natural gas detection system design.
- The natural gas detection system should be *listed* in accordance with UL 2075 or *approved* by the AHJ**.**
- The natural gas detection system shall activate at 25% of the lower flammability limit (LFL).
- Upon activation the natural gas detection system shall:
    - Activate the mechanical ventilation system
    - Deactivate all heating systems located in the major repair garage
    - Initiate a distinct audible and visual alarm in the garage
- The failure of the natural gas detection system shall:
    - Activate the mechanical ventilation system
    - Deactivate all heating systems located in the major repair garage
    - Initiate a trouble alarm in an *approved* location
- NFPA 72 National Fire Alarm and Signaling Code provides information on monitoring the detection systems for integrity.
- The natural gas detectors should be tested and calibrated as recommended by the manufacturer and approved by the AHJ.

Sources of Ignition

Both the IFC and NFPA 30A have a number of requirements addressing sources of ignition for conventional liquid fuel garages. Only NFPA 30A has additional requirements for major repair garages that service LNG powered vehicles. The requirement is directed at restricting open flame heaters and any heating equipment with exposed surfaces with temperatures above 750 °F from any area subject to ignitable concentrations of natural gas.

Industry best practice is to eliminate heating equipment of these types from the major repair garage. It would take an analysis of the potential credible natural gas releases and modelling of the possible concentrations of ignitable gas within the facility in order to safely place these types of heaters in safe areas. This analysis is typically beyond normal heating design work and would be subject to approval by the AHJ on a case-by-case basis.

Electrical Classification

The codes have a number of requirements on classified locations for electrical equipment in conventional liquid fuel garages. Only NFPA 30A requires that the space within 18 inches of the ceiling of a major repair garage for CNG be classified as a Class 1, Division 2 classified location. LNG is not included in this requirement, but it is expected that the AHJ would apply this requirement to a LNG facility as well. This means that all electrical equipment within that area must be suitable for that classification as set forth in NFPA 70, National Electrical Code. The code does provide an exception to the requirement in that it will not apply to a facility that has a

ventilation rate of at least 4 ACH. Since the natural gas detection sensors would most likely be placed in this classified location, the effectiveness of the ventilation system should be factored into the system design.

It is important to take into account the design of the ceiling support structure to determine what modifications may be necessary for the classified location. One example would be a concrete 'T' beam design that may not be easily ventilated at the required rate to eliminate the classified location, thus requiring modification of any electrical equipment in the 18-inch space below the ceiling. Conversely, an open web steel joist structure may achieve the proper 4+ ACH eliminating the classified location.

If the classified location cannot be addressed by ventilation, then the choice may be to either modify the electrical installation to meet Class1, Division 2 requirements or move the electrical equipment below the 18-inch classified location, which in most cases would be to attach the system to the bottom of the support structure as opposed to the ceiling.

Preparation of LNG Vehicle for Maintenance

The IFC is the only code that has requirements for vehicle preparation prior to performing maintenance operations. For LNG vehicles, the procedure is to: 1) measure and record vehicle fuel system pressure prior to entering the repair facility; 2) if the system pressure is more than 170 PSIg (1172 kPa), operate the vehicle or perform limited venting outdoors, as required, to reduce vehicle fuel system pressure and extend LNG tank 'hold-time' before the pressure relief valve would need to open; and 3) limit the quantity of natural gas that could be accidentally released by valving off all the fuel storage tanks on the vehicle once it enters the repair garage. Vehicles that have tank-mounted solenoid valves that are tied to the ignition system of the vehicle will automatically close the valves when the engine is shut down. Vehicles that have manual valves on the cylinders must be closed by hand. Operate the LNG vehicle after the valves are closed to make sure there is no liquid LNG trapped in the fuel delivery system; this also reduces the amount of natural gas that could be released unintentionally. A procedure to double-check that all valves are closed as required should be established as part of the facility's normal operations.

The IFC also requires that, if there is any suspected damage to the LNG fuel system, the entire system should be checked for leaks and evaluated for fuel system integrity prior to bringing the vehicle into the repair garage. The LNG tank manufacturer should be able to provide detailed instructions for leak testing and maintenance and repair of the LNG tank.

Maintenance and Decommissioning of Vehicle Fuel Containers

NFPA 52 requires that repair facilities have a specific written record of inspection and maintenance of LNG tanks. This set of requirements depends on the existence of properly trained personnel and the use of procedures as recommended by the vehicle OEM, the fuel system provider, and/or the LNG tank manufacturer. In order to properly perform maintenance on an LNG tank, it must be safely defueled according to written and approved procedures.

Although the codes do not require such systems, each major repair garage should install a properly engineered defueling facility. Designs for fuel recovery systems and direct atmospheric venting systems should be approved by the AHJ as required. If the LNG tanks must be serviced, they should be defueled and purged with an inert gas according to the LNG tank manufacturer's instructions.

While not covered in this set of guidelines, an LNG refueling station may be part of the overall modifications needed by the major repair garage in order to return the vehicles to service. Consideration should be given to adding a natural gas recovery system to the refueling station design in order to reduce the amount of natural gas that is released to the atmosphere.

Training

Maintenance facility modifications will be of no avail without properly trained personnel. While physical modifications to the maintenance facility will help mitigate any potential hazard from adding CNG and/or LNG vehicles to facility operations, proper training of personnel is critical to maintaining a safe work environment. The training program should, at a minimum, cover the following:

- The physical properties of CNG
- The physical properties of LNG
- Hazards associated with CNG
- Hazards associated with LNG
- Manufacturer's instructions for operation and use of handheld flammable gas detectors
- Manufacturer's instructions for maintenance, operation and calibration of natural gas detection systems installed in the maintenance facility
- OEM instructions and recommended maintenance and repair procedures for each component of the onboard fuel system and engine fueling components for both CNG and LNG vehicles
- OEM's, cylinder manufacturer's, and/or cylinder valve manufacturer's instructions for defueling and valve maintenance/removal for CNG cylinders
- OEM's and/or LNG tank manufacturer's instructions for maintaining and defueling of LNG tanks
- OEM's and/or manufacturer's instructions for maintenance and calibration of on-board LNG vehicle natural gas detection systems
- AFVi or CSA CNG/LNG fuel system inspection training for all personnel responsible for inspecting CNG/LNG on-board fuel systems
- Consider AFVi or CSA certification of all CNG fuel system inspectors

Additional Resources

Refer to the following resources for additional information on modifications that might be required for maintenance facilities to service CNG vehicles:

- NREL's CNG Vehicle Maintenance Facility Modification Handbook
- Consulting Services Offered by the Alternative Fuel Vehicle Institute
- NGV Maintenance Garage Training
- PEI RP1500-23: Recommended Practices for the Design, Installation, Operation and Maintenance of Compressed Natural Gas Vehicle Fueling Facilities
- TMC RP 542 Maintenance Facility Development Guidelines for Natural Gas Vehicles
- Section 7 of TTP's Recommended Practices for CNG Powered Refuse Trucks and the Supporting Facilities for Refueling and Maintenance

Information on the following topics is included in the above resources:

- AHJ coordination
- Existing facility analysis
- Minor vs. major repair garages
- Ceiling ventilation
- Gas detection
- Sources of ignition
- Electrical classification
- Preparation of CNG vehicle for maintenance
- Maintenance and decommissioning of vehicle fuel tanks
- Training

Acknowledgements

This publication is a product of TTP's Technology & Development Committee and the Maintenance Facility Modifications Working Group. It was previously published by Douglas B Horne, P.E. of the Clean Vehicle Education Foundation and last updated by Dan Bowerson and the NGVAmerica Technology & Development Committee in May 2017.

The purpose of TTP's Maintenance Facility Modifications Working Group, which is comprised of industry stakeholders and expert authorities within the Technology & Development Committee, is to serve the gaseous-fueled vehicle industry with the following goals and objectives:

1. Ensure the safe operation and servicing of gaseous-fueled vehicles in and around maintenance facilities.
2. Address any inconsistent or overburdensome requirements within and between relevant codes and standards.
3. Participate in code and standard development activities and collaborate with the associated development organizations to ensure that there is proper and consistent coverage for maintenance facilities involved with gaseous-fueled vehicles.
4. Develop and publish industry guidelines and best practices and review them regularly to ensure accuracy.

On behalf of the gaseous fueled vehicle industry and the network of organizations that support the safe, efficient, and sustainable operation of heavy-duty trucks powered by natural gas and hydrogen every day, The Transport Project and the Maintenance Facility Modifications Working Group would like to acknowledge the support and technical content contributions from the representatives below to develop this valuable industry resource. TTP extends our sincere gratitude to this team of knowledgeable experts for their invaluable assistance and technical expertise in the development and publication of these industry guidelines. The dedication and collaborative efforts made by all representatives below and the Maintenance Facility Modifications Working Group have been instrumental in ensuring the quality of this work.

Technical Content Contributors

Chris Culberson
Customer Care Manager
Cummins Clean Fuel Technologies

Jim Leonard
President
J.R. Leonard Construction Company

Paul Sandsted
Director of Technology and Sustainability
The Transport Project

Leo Thomason
Executive Director
Alternative Fuel Vehicle Institute (AFVi)

John Tiquet
Business Solutions Sr. Manager
WM

The GFV industry expresses our sincere gratitude for your unwavering commitment to industry safety and operational efficiency and your contributions to developing this valuable industry resource.

Appendix A

Physical Properties of CNG and LNG

Table 11 below compares some of the basic properties of typical fuels that might be found in maintenance facilities.

Table 13 – Physical Properties of Fuels

Property	Pure Methane	LNG	CNG	LPG	Diesel	Gasoline
Formula of the major chemical component(s)	CH_4	CH_4	CH_4	C_3H_8	C_3 to C_{25}	C_4 to C_{12}
Boiling Temperature, °F	-259	-259	-259	-44	370-650	80-437
Fuel Density @ 60°F [excluding RLM, LNG] (lb/gal)	1.07 (at atmospheric pressure) RLM: 3.54	3.53	1.58 (at 3500 psi)	4.22	6.7-7.4	6.0-6.5
Autoignition Temperature, °F	1202	1004	1004	850-950	600	495
Flammability Range, vol.	5% - 15%	5% - 15%	5% - 15%	2.2% - 9.5%	1% - 6%	1.4% - 7.6%
Lower Heating Value (BTU/lb)	21500	20200-21500	20200-21500	19800	18000-19000	18000-19000
Lower Heating Value (BTU/gal)	23005 RLM: 76100	72700-77400	31900-33800	84500	128400	115000
Specific Gravity @ 60°F	0.129 (at atmospheric pressure) RLM: 0.428	0.435	0.192	0.508	0.81-0.89	0.72-0.78

RLM – Refrigerated liquid methane
Source: Alternative Fuel Data Center, ALT, and Battelle

Natural Gas Properties

CNG and LNG share the same physical properties as natural gas at ambient temperatures.

- Natural gas is a mixture of hydrogen, carbon, and other gases with methane as the primary constituent.
- Natural gas is a colorless and odorless gas that has odorant added by the natural gas distribution company for safety.
- Natural gas is supplied to over 70,000,000 homes and businesses in the United States and its odor (often described as smelling like rotten eggs) is familiar to a large portion of the population.
- Natural gas is non-toxic and is a simple asphyxiant that in sufficient concentrations may displace oxygen in air.

- Natural gas is lighter than air (specific gravity 0.55 to 0.65) and quickly dissipates when released.
- Natural gas has a flammability range of 5% to 15% by volume in air.
- Natural gas has an ignition temperature of 1004 °F.

CNG Properties

- CNG in the United States has typical storage pressure of 3,600 PSIg.
- CNG is normally compressed from natural gas supplied by a distribution company and is therefore normally odorized to the appropriate level for safety.

LNG Properties

- LNG is a cryogenic liquid made by cooling natural gas to about -260 °F at atmospheric pressure.
- LNG normally has a higher percentage of methane than the natural gas it is made from since a number of constituents in natural gas are removed such as CO_2 and odorant.
- LNG is not odorized and methane detectors are used on LNG vehicles, stations, and maintenance facilities for leak detection.
- LNG vapor when released usually forms a white cloud of water vapor and becomes lighter than air at -160 °F and dissipates like CNG.

Hazards Associated with Natural Gas, CNG and LNG

Natural Gas Hazards

- Natural gas is a flammable gas that will ignite in concentrations between 5% and 15% in air.
- Natural has a higher ignition temperature (1000 °F) than most fuels but ignition sources must be controlled in areas where an ignitable may be present.
- Natural gas should not be allowed to accumulate in an enclosed space because if ignited it would cause a rapid deflagration with significant overpressure.
- Natural gas is a simple asphyxiant that can displace air (oxygen) in enclosed spaces.

CNG Hazards

- High pressure gas releases from CNG systems may cause injury from:
    - Entrained particles in the gas stream
    - Ignition by static discharge at the leak source causing a jet or torch fire
    - High intensity noise generated by the high velocity gas stream

LNG Hazards

- Cryogenic burns to exposed skin from exposure to LNG liquid spills or cold vapor releases and direct contact to piping or fittings exposed to cryogenic temperatures.
- Since the initial release of LNG vapor is heavier than air, there is a potential that the vapor could displace air (oxygen) in pits and act as an asphyxiant.

Appendix B

When determining the specific gas detection event sequences to ensure the safety of employees and personnel working in the building, it is important to reference code requirements such as those identified in the body of this document for determining proper system design, operation, and failure modes. In addition to fundamental code specifications, the sequence of events recommendations and the Gas Detection System Alarm Matrix provided below should be considered when a gas detection event occurs in a "typical" natural gas compliant maintenance facility with a gas detection system that has auxiliary ventilation.

Recommended sequence of events if facility gas detection alarm indicates 25% LEL or if system failure is detected:

- Gas Detector Horn and Strobes **ACTIVE**
- Exterior Red Beacon Light **ACTIVE**
- Auxiliary Exhaust Ventilation **ACTIVE**
- Heating System **DEACTIVATED**
- Electrical Welding Outlets **DEACTIVATED**
- **ALL OCCUPANTS MUST EVACUTE** maintenance building
- Facility manager or supervisor will take **ROLL CALL** of occupants evacuated
- Emergency response team will be **NOTIFIED** and will call the site emergency contact list
- Fire department will be **NOTIFIED** *(if required)*

Recommended sequence of events if facility gas detection alarm indicates 50% LEL:

- Emergency response team will be **NOTIFIED** of higher level and will again call the site emergency contact list
- Fire Department will be **NOTIFIED** *(if required)* and will respond to the site
- **ALL Occupants REMAIN EVACUATED**

Recommended sequence of events once the gas detection alarm levels drop below 25% LEL for 5-10 minutes:

- Exterior Red and Green Beacon Lights are **BOTH ACTIVE**
- Gas Detector Horn and Strobes **REMAIN ACTIVE**
- Auxiliary Exhaust Ventilation **DEACTIVATES**
- **Trained and designated personnel ONLY can re-enter** shop to verify system components have returned to normal, investigate cause of gas detection, and can **RESET** the system once verification of no further gas leaks is completed

Recommended sequence of events after the gas detection system has been RESET:

- personnel will reset the auto-dialer keypad or HMI display *(as equipped)*
- personnel will reset welding outlet shunt-trip breakers
- personnel will reset heating system interlock *(if required)*
- all occupants may return to the shop to resume work

NOTE: methane alarm levels at sites in Canada will be at 20% LEL and 40% LEL.

GAS DETECTION ALARM MATRIX FACTORY INSTALLED HEAVY DUTY RELAY BOARD SHALL BE PRE-PROGRAMMED BASED ON THIS ALARM MATRIX						
	1. NORMAL OPERATIONS	2. FAILURE (FAULT)	3. 25% LEL ALARM LEVEL	4. 50% LEL ALARM LEVEL	5. <25% LEL FOR 5 MINUTES	6. 25% LEL AFTER 5 MINUTES
A. EXTERIOR RED LIGHT	OFF	ON	ON	ON	ON	ON
B. EXTERIOR GREEN LIGHT	OFF	ON	OFF	OFF	ON	OFF
C. GAS DETECTOR ALARMS (HORN AND STROBE)	OFF	ON	ON	ON	ON	ON
D. EMERGENCY EXHAUST VENTILATION	OFF	ON	ON	ON	OFF	ON
E. EMERGENCY MAKE UP AIR DEVICES	OFF	ON	ON	ON	ON	ON
F. HEATING SYSTEM	OPERATIONAL	OFF	OFF	OFF	OFF	OFF
G. WELDING RECEPTACLES	OPERATIONAL	OFF	OFF	OFF	OFF	OFF
H. NOTIFY OPERATIONS PERSONNEL	NO ACTION	YES			NO ACTION	
I. NOTIFY OPERATIONS PERSONNEL	NO ACTION		YES			
J. NOTIFY OPERATIONS PERSONNEL	NO ACTION			YES		
K. NOTIFY OPERATIONS PERSONNEL	NO ACTION					YES
L. NOTIFY FIRE DEPARTMENT	NO ACTION	IF REQUIRED	IF REQUIRED	IF REQUIRED	IF REQUIRED	IF REQUIRED
M. EVACUATE OCCUPANTS	NO ACTION	EVACUATE	EVACUATE	REMAIN EVACUATED	REMAIN EVACUATED*	REMAIN EVACUATED*
* OCCUPANTS TO RE-ENTER AFTER, TRAINED PERSONNEL VERIFY SYSTEM COMPONENTS ARE RETURNED TO NORMAL OPERATION.						

Table 14 – Typical Gas Detection System Alarm Matrix example

Appendix C

Volume of Fuel as a Qualifying Attribute for CNG Powered Vehicles Inside a Facility

Section 2311.8 of the IFC states the volume of *hydrogen* within a vehicle's fuel system if brought into an unmodified shop shall not exceed 400 cuft at standard ambient conditions. However, no formula or explanation is provided on how to calculate the volume of hydrogen contained in a vehicle's fuel system based on system capacity, current pressure, or temperature compensation. While the requirement is specific to hydrogen, and there is no equivalent maximum volume limit for natural gas fuel systems, it is recommended that the same 400 cuft volume limit should apply to CNG powered vehicles in a maintenance facility as well. The guidance contained in this section should be considered as industry best practice and is recommended in the interest of utmost safety for facilities and personnel that service CNG powered vehicles.

The formulas provided in this section are for calculating the existing volume of CNG contained in a vehicle's fuel system before it enters an unmodified maintenance facility to determine if it is below the 400 cuft limit. The following parameters must be considered in order to calculate the volume:

- maximum CNG volume limit (i.e., "Allowable Vol" in formulas below)
    - 400 cuft is the limit based on 70 °F standard temperature
    - It is recommended that this value is calculated based on specific ambient conditions, fuel system capacity, existing system pressure, and gas temperature considerations below.
    - The resulting calculation adjusts for real-world ambient conditions, without assuming standard ambient conditions (14.7 PSIa, 70 °F).
- current CNG pressure (i.e., "press" in formulas below)
    - fuel system gauge(s) can provide this value
    - formulas adjust for absolute temperature in units of PSIa
    - stabilization of the pressure must be considered if the vehicle was refueled within the past [insert timeframe here] (see gas temperature consideration below)
- approximate temperature of the gas (i.e., "temp" in formulas below)
    - outside temperature reading of the chassis can be used if temperature has stabilized [insert minimum amount of time here for temperature stabilization]
    - formulas adjust for absolute temperature in units of Rankine
    - if the vehicle was recently refueled, [insert temperature compensation guidance here]
- fuel system capacity (i.e., V_T in formulas below)
    - OEM specification can be used to determine this value

Assuming 400 cuft maximum volume of CNG that can be brought into an unmodified facility per vehicle, then the following steps should be taken to determine if the existing volume of CNG contained in a vehicle's fuel system is below that maximum volume limit.

Step 1

Calculate the allowable gas volume which is based on specific ambient conditions, fuel system capacity, system pressure, and gas temperature. The resulting calculation will be at Standard Ambient Conditions, which is 14.7 PSIa and 70 °F (i.e., 529.7 Rankin).

$$Allowable\ Vol\ (ft^3) = \left[V_T\ (liters) * .0353\ \frac{ft^3}{liter}\right] * \left[\frac{press\ (PSI)+14.7\ PSI}{14.7\ PSI}\right] * \left[\frac{529.67}{temp\ (°F)+459.7}\right]$$

Step 2

Calculate the maximum system pressure allowed based on the maximum CNG volume limit calculated above, the vehicle-specific fuel system capacity variable, and the situation-specific gas temperature variable. If using 400 cuft as the maximum CNG volume constant instead of the allowable volume calculated above, then insert that value in the equation below as a constant instead of a variable.

$$Sys\ Press_{\ final} = \left(\left[\frac{Allowable\ Vol\ (ft^3)}{V_T\ (liters) * 0.0353 \frac{ft^3}{liter}}\right] * \left[\frac{Temp\ (°F)+459.7}{529.7}\right] * 14.7\right) - 14.7\ PSI$$

Step 3

The resulting calculation determines the maximum allowable system pressure corresponding to a specified ambient gas volume limit.

If the result of maximum system pressure allowed calculation in Step 2 is less than the current CNG pressure as indicated on the vehicle's fuel system gauge(s), then the vehicle can be allowed to enter the facility.

Example Calculation

If 400 cuft of natural gas is assumed as the maximum CNG volume limit, the fuel system capacity of a vehicle is 1000 liters (approximately 75 DGE), and the initial temperature of the gas is 60 ºF, then the maximum allowable system pressure would be calculated as follows:

$$Sys\ Press_{allowable} = \left(\frac{400\ ft^3}{1000 * 0.0353\frac{ft^3}{liter}}\right) * \left(\frac{60\ ^0F + 459.7}{529.7}\right) * 14.7 - 14.7$$

$$Sys\ Press_{allowable} = 148\ psi$$

NOTE: These calculations are derived from the combined ideal gas law. All pressures are expressed in absolute pressure (PSIa), and unless otherwise stated, all temperatures are expressed in absolute temperature (Rankine). Gauge pressure readings are converted to absolute pressure by adding 14.7 PSI. Fahrenheit temperatures are converted to Rankine by adding 459.7. Fuel system water volume is converted from liters to cuft by multiplying a factor of 0.0353.

Serving fleets, OEMs, servicers, suppliers, fuel producers, and fuel providers as the national voice to decarbonize North America's transportation sector through the advancement, growth, and deployment of practical, clean, and renewable gaseous fuels.

transportproject.org