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TRAINING FOR COST-EFFECTIVE, CODE-COMPLIANT, MAINTENANCE FACILITIES

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PRACTICAL SOLUTIONS FOR NATURAL GAS FACILITY MODIFICATIONS

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Prepared For:
Trevelyn Hall
Program Manager
U.S. DOE/NETL

National Energy Technology Laboratory
626 Cochrans Mill Road
PO Box 10940
Pittsburgh, PA 15236
304-205-2490
Trevelyn.Hall@netl.doe.gov

GTI Technical Contact:
Tyler Manley
Principal Engineer
847-768-0697
Tyler.Manley@gastechnology.org

Gas Technology Institute
1700 S. Mount Prospect Rd.
Des Plaines, Illinois 60018
www.gastechnology.org

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Acknowledgement

Gas Technology Institute would like to emphasize that the goal of this project was to compile existing educational materials and expand upon them. In doing so, GTI would like to acknowledge that the following works have been instrumental to the development of this report:

Compressed Natural Gas Vehicle Maintenance Facility Modification Handbook. Authored by Kay Kelly and Margot Melendez, United States Department of Energy, Office of Energy Efficiency and Renewable Energy, and Co-Authored by John Gonzales and Lauren Lynch, National Renewable Energy Laboratory; Bob Coale and Jarrod Kohout, Gladstein, Neandross & Associates, 2017.

Guideline for Determining the Modifications Required for Natural Gas Vehicle Maintenance Facilities.
Prepared by Dan Bowerson, Natural Gas Vehicles for America (NGVA) Technology & Development Committee. Originally Published by Douglas B Horne, P.E. Clean Vehicle Education Foundation (2017).

Gas Technology Institute would like would also like to recognize the significant contributions of Rick Mendoza and Wally Dubno, subject matter experts in the area of natural gas vehicle maintenance facility modification at Clean Energy Fuels. In addition, Gas Technology Institute would like to recognize Sierra Monitor Corporation and Ozinga Energy for their support and contribution.

Background

As the commercial deployment of alternative fuel vehicles continues to grow and businesses begin to consider deploying significant sized fleets of natural gas vehicles, the cost of maintenance facility modifications must be considered, and can influence a company's decision to adopt alternative fueled vehicles (AFVs).

The objective of this project is to present practical solutions to Authorities Having Jurisdictions (AHJ), designers, fire officials, and other stakeholders that may someday be involved with permitting a maintenance or repair facility that is being upgraded to allow for natural gas vehicle service. This will be done by showing how codes are applied in real-world cases, as well as open discussions on how the codes are interpreted today. A secondary goal is to provide safety training to emergency response personnel involved with facilities or facilities planning.

The project will accomplish these objectives through the use of multiple outreach and training tools: on-site training seminars, facility tours, reports, and online resources. This consortium of tools will cover three fuels – natural gas, hydrogen, and propane. This report will cover applicable codes and standards for maintenance facilities that serve the natural gas industry, and will go on to present issues with these codes and best practices that a facility can implement to become code compliant. The focus of this report will be on requirements and best practices that relate specifically to natural gas.

The natural gas vehicle (NGV) industry has largely focused its efforts on development of vehicles and fueling infrastructure, while leaving issues dealing with upgrades and operations of maintenance facilities to fleet owners. Fleet owners have used their internal staff and/or consultants to interpret the intent of the applicable codes to develop facility designs for liquefied natural gas (LNG) and/or compressed natural gas (CNG) applications that will ultimately have to be approved by the local 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 design of maintenance facilities. Additionally, engineering and design firms inexperienced with alternative fuels may exacerbate the issue by providing plans that are "over-designed", which always lead to high construction costs to modify or build a maintenance facility, and some AHJs may not allow upgrades at all because of a lack of gaseous fuel education. Taking a set of codes and applying it in a practical sense to develop a set of upgrade plans can be a daunting task, yet it doesn't have to be.

Code Development Process and Hazard Analysis

Codes that govern maintenance garages are written as guidelines, not design documents, and the performance requirements are based on assumed hazards. These hazards are determined by the expert knowledge and any actual field experience of the members of the code committees that develop the codes.

Natural gas is composed of methane with slight amounts of heavier hydrocarbons. Maintenance facilities that maintain CNG vehicles indoors must be protected if a vehicle's fuel system were to leak. However, the means of ensuring safety are different from those employed for liquid fuels because of the nature of methane, which has a lower density than air. Because natural gas is lighter than air, an accidental release will rise to the ceiling of the maintenance facility and quickly dissipate across the underside of the ceiling, rather than remaining at or near floor level like liquid fuel vapors. The specific properties of methane as well as other vehicle fuels are presented in Appendix B.

Methane, the main component of natural gas, is flammable, but only within a narrow range of a mixture with air. If natural gas is present in amounts between 5%–15% by volume and encounters an ignition source, the gas may ignite.

For CNG vehicle systems, the basic hazard is the unintended release and ignition of the natural gas while the vehicle is in the repair garage. For LNG vehicles, codes assume two types of releases – liquid and gas. The facility safety systems of course are designed to detect any leak, and avoid the ignition of the gas

Although some of the means of protection for natural gas vehicle maintenance facilities are similar to those used for liquid-fueled vehicles (ventilation and elimination of ignition sources), the types and placement of protection equipment are completely different due to the lighter than air nature of natural gas. The nature of gaseous methane may also require additional safeguards that are not required in facilities servicing liquid-fuel vehicles, such as combustible gas detectors, specialized space heating, and ventilation and electrical control systems. This document goes more in depth on the equipment required for a natural gas repair shop, and shows examples of each.

Major and Minor Garages

When considering a facility upgrade, the first thing to consider is the type of work that will be performed on the natural gas vehicles. NFPA 30A and its counterpart, the IFC, are the primary documents that cover vehicle maintenance facilities. They both classify maintenance garages into two categories based on the type of work performed: major and minor. Full definitions as presented in NFPA 30A are:

1. A major repair garage is defined as:

   A building or portions of a building where major repairs, such as engine overhauls, painting, body and fender work, and repairs that require draining of the motor vehicle fuel tank, are performed on motor vehicles, including associated floor space used for offices, parking, or showrooms.

Any work that involves service on the vehicle fuel system also falls into this category.

2. A minor repair garage is defined as:

   A building or portions of a building used for lubrication, inspection, and minor automotive maintenance work, such as engine tune-ups, replacement of parts, fluid changes (e.g., oil, antifreeze, transmission fluid, brake fluid, air conditioning refrigerants, etc.), brake system repairs, tire rotation, and similar routine maintenance work, including associated floor space used for offices, parking, or showrooms.

Any work that involves service on the vehicle fuel system, or service that may lead to or cause a leak, is not permitted in a Minor Repair Garage.

When a maintenance facility is considering adding service capabilities for natural gas vehicles, an analysis of maintenance tasks by type should be evaluated. Keep in mind a maintenance facilities currently performing major repair type work on diesel vehicles will likely also be classified as a major repair facility by the local AHJ. One option to consider which may save considerable cost is to determine if a shop may be split into two sections, a ‘major repair’ area and ‘minor repair’ area. 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.

Three Pillars Of Facility Modification

There are three simple pillars of a successful solution to ensure a maintenance facility is properly protected: **Detection – Dilution – Extraction.** While there are other areas in the shop to consider, these three pillars define the basics of what is required in a maintenance facility to allow servicing of natural gas vehicles.

There are a number of codes and ordinances dealing with the design and use of a natural gas vehicle maintenance facility. The primary documents used by AHJs concerning natural gas maintenance facilities are: NFPA 30A – Code for Motor Fuel Dispensing Facilities and Repair Garages and the appropriate sections of the International Fire Code (IFC) and the International Building Code (IBC). The full list of documents are referenced in Appendix A.

Methane Detection, Control Systems, and Alarms

Current codes and regulations state that combustible gas detection systems are required for any facility that maintains vehicles that use non-odorized gaseous fuels. This means that a detection system is not required for CNG in all cases, because it is typically odorized. It is always required for LNG. The following excerpts from NFPA 30A deal with gas detection systems (**bold** added for emphasis):

> ***7.4.7*** *Gas Detection System. Repair garages* ***used for repair of vehicle engine fuel systems*** *fueled by* ***non-odorized*** *gases, such as hydrogen and non-odorized LNG/CNG, shall be provided with an approved flammable gas detection system.*
>
> ***7.4.7.1*** *System Design. The flammable gas detection system shall be calibrated to the types of fuels or gases used by vehicles to be repaired. The gas detection system shall be designed to activate when the level of flammable gas exceeds 25 percent of the lower flammable limit (LFL). Gas detection shall also be provided in lubrication or chassis repair pits of repair garages used for repairing non-odorized LNG/CNG fueled vehicles.*
>
> ***7.4.7.2*** *Operation. Activation of the gas detection system shall result in all of the following:*
>
> *(1) Initiation of distinct audible and visual alarm signals in the repair garage*
> *(2) Deactivation of all heating systems located in the repair garage*
> *(3) Activation of the mechanical ventilation system, when the system is interlocked with gas detection.*
>
> ***7.4.7.3*** *Failure of the Gas Detection System. Failure of the gas detection system shall result in the deactivation of the heating system and activation of the mechanical ventilation system and, where the ventilation system is interlocked with gas detection, shall cause a trouble signal to sound in an approved location.*

Regulations suggest, but do not categorically state, that a gas detection system is not required for facilities used to repair vehicle engine fuel systems fueled by odorized gas systems such as CNG. Industry experience has found that AHJ's will generally require a gas detection system despite the statement in NFPA 30A. The cost of the added protection provided by a gas detection and alarm system cannot be quantified in terms of personnel safety and property protection. A second item to note is that a maintenance facility's insurance underwriter is likely to require installation of a gas detection system. For these reasons, it is strongly recommended that such a system be used.

The primary functions of a combustible gas detection and alarm system are to:

- Provide warning to occupants that a methane gas release has occurred
- Eliminate potential ignition sources
- Promote quick dilution of the concentrated gas to levels well below the LFL.

Combustible gas detectors used in CNG vehicle maintenance facilities are designed and calibrated to measure methane concentrations in the air. They may be labeled as methane sensors, natural gas detectors, or hydrocarbon detectors, but they all essentially measure methane presence as a percentage of the LFL. The LFL concentration for methane in air is 5%. Methane detectors read from 0%–100% of the LFL, which means that a reading of 20% would indicate that the actual concentration of methane in the air is 1%. Using this scale, methane detectors can be used to provide alarms at any concentration.

NFPA 30A, Section 7.4.7.1 (above) states that a detection level of 25% of the LFL should be used to initiate alarms and other actions. The use of two gas detection levels rather than a single value has gained wide acceptance within the fire protection community and, with AHJ approval, should be incorporated into the operational design. By using two levels (i.e., 20% and 40% of the LFL), preliminary detection (20%) occurs earlier so that protective actions can be initiated, followed by more extreme actions if concentrations reach the second level. A two-level approach is recommended because it greatly reduces the incidence of “nuisance” alarms while still ensuring personnel and facility safety. It is important to note that a two-level detection concept must be approved by the AHJ before it can be implemented at a vehicle maintenance facility. The first level alarm will generally initiate visual indicators and ventilation only. The intent is to remove the risk while notifying staff of the issue. The second level will activate lights and horns, while also initiating all other components associated with the safety systems.

Fixed Point vs Open Path Detectors

There are two common types of combustible gas detectors: infrared and catalytic bead. Infrared detectors are available as either a point-type monitor or an open-path design. Catalytic bead detectors have the advantage of low cost, but require more frequent calibration and have a shorter life before internal components must be replaced. Of the infrared detectors open-path designs cover a larger area, but tend to be less reliable when “looking” through the atmosphere within the facility because interference from engine exhausts may result in inconsistent readings. Point-type detectors are very reliable, but protect a smaller area. A typical point-type infrared detector head is displayed in Figure 1, and an open-path type detector is illustrated in Figure 2.

Figure 1: Typical infrared combustible gas detection head.
Photo courtesy of Gladstein, Neandross & Associates, NREL

The catalytic and infrared point-type and open path detectors are available from a number of manufacturers; including, but not limited to the list below:

- Sierra Monitor Corporation
- Sensor Electronics
- RC Systems
- General Monitors (Mine Safety Appliance)
- Emerson
- Safety Systems Technology
- Det-tronics
- Pemtech
- Simark Controls

The examples below demonstrate one of the drawbacks with an open path infrared gas sensor. The measurement is taken in units of LEL per meter. The signal from the source to the detector can respond to other light-altered situations, such as diesel exhaust smoke or dust.

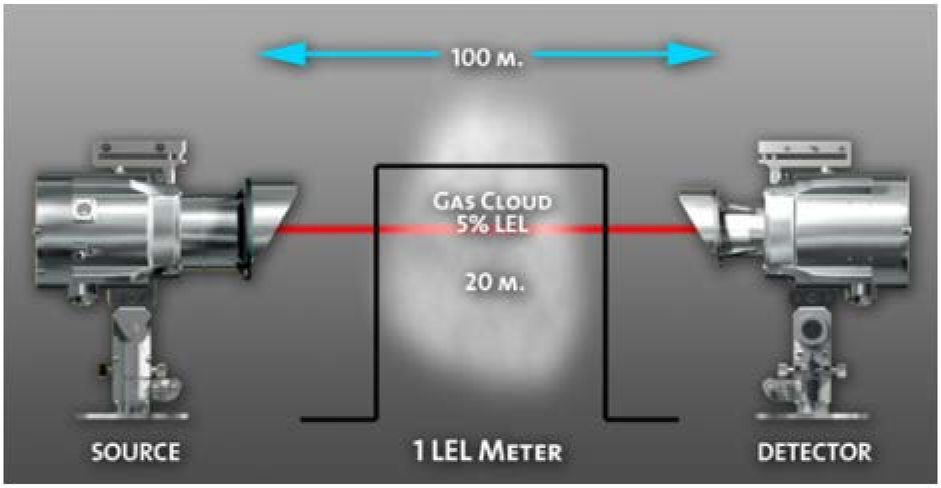

Figure 2: Open-Path Infrared Gas Detection Example 1,
Copyright © 2014 Sierra Monitor Corporation

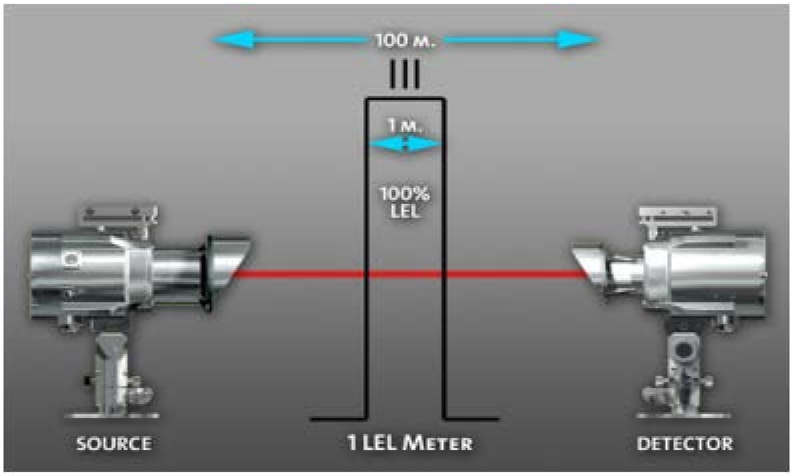

Figure 3: Open Path Infrared Gas Detection Example 2,
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Combustible gas detectors inside a vehicle maintenance facility should be located near the highest point of the structure’s ceiling. However, it is also common for gas detectors to be installed at intermediate locations to “intercept” the likely path that a vapor release would take as it rises to the high point. The location, spacing, and number of detectors must be determined by a licensed design engineer and approved by the local AHJ. Figure 4 displays a ceiling-mounted, combustible gas detection head.

Figure 4: A ceiling-mounted combustible gas detection head. Photo courtesy of Gladstein, Neandross & Associates, NREL

Because the gas detectors are located on or near the structure’s ceiling, it is important to consider detectors that are equipped with a calibration means that does not require direct access to the unit. Gas detectors are calibrated by providing a trace amount of calibration gas directly into the sensor. This is usually accomplished by connecting tubing through which calibration gases can be directed to the unit (Figure 5).

Figure 5: Gas detector calibration tubing. Photo courtesy of Gladstein, Neandross & Associates, NREL

Alarm Systems

If a two-level methane detection approach is used, the alarms connected to the detection system controls will activate first at the lower level, then again when the LEL reaches the higher level. The two levels of 20% and 40% of LEL have been widely accepted by AHJs. However, the actual values, which can be set by the user, must be approved by the AHJ. For this type of system, it is typical for a beacon to be illuminated with a specific color indicating each level, and the alarm horn to be activated. Alarm notification devices should be placed throughout the interior of the vehicle maintenance facility and any entrances so that personnel in the structure can see them regardless of parked vehicles or other equipment inside. Some AHJs and facility managers also require alarm beacon and sound panels to be located within adjacent offices and administrative areas. Common alarm status lights and horn panels are shown below in Figure 6.

Figure 6: Examples of alarm status lights and horn panels (external and internal). Photos courtesy of Gladstein, Neandross & Associates, NREL

It is recommended that the alarms for the combustible gas detection system be kept independent from the facility's fire detection alarm systems. A common recommendation is for the two systems have distinctly different colored lights and alarm sounds. This allows personnel inside the facility and any third party monitoring company to quickly determine if the risk is an occurring fire or a potential gas ignition.

Combustible gas detectors read the methane concentration in the air, and provide an output signal scaled to the concentration of the gas. Because of this, a control system is required for translating and interpreting the readings. As described previously, the three primary functions of the control system are to alert personnel of the existing conditions, activate ventilation within the structure, and eliminate possible ignition sources.

Alerting personnel is accomplished by means of the alarm beacons and sound horns. The control system can be programmed to activate the ventilation fans, open the facility doors, and/or activate any other types of secondary ventilation equipment in order to increase air flow. The control system eliminates potential ignition sources by turning off (i.e. shunt tripping) any potentially hazardous electrical circuits and heating appliances within the maintenance facility.

As part of a retrofit process, selected electrical circuits should be modified so that shunt trips are provided on all non-critical electrical circuitry. It is recommended that the shunt trips be activated only if the system detects a gas concentration of 40% LFL rather than the early-warning 20% LFL. All electric circuits within the maintenance facility should be fitted with shunt trips except the following:

- Electrical controls to the overhead doors that are selected to automatically open for the purpose of providing makeup air upon activation of the gas detection system
- Ventilation fans
- Gas detection and alarm systems and controls
- Emergency lighting
- Critical data collection or storage functions - computers, servers, etc.

Table 1: Possible Series of Actions Based on the Two Suggested Levels of Detection

	Gas Concentration Level		
Condition	**Normal**	**20% LFL**	**40% LFL**
Operation Lights – Green	On	Off	Off
Operation Lights – Amber	Off	On	Off
Operation Lights – Red	Off	Off	On
Warning Horns	Off	On – Level 1	On – Level 2
Strobe Alarms	Off	Off	On – Level 2
Supervisory Advisory	No	Yes	Yes
Fire Department Callout	No	No	Yes
Ventilation Fans	Manual	On	On
Roll-Up Doors/Louvers	Manual	Open	Open
Automatic Gas Valve	Open	Open	Closed
Shunt Trip Building Loads	No	No	Yes
Automatic Reset of System if Fault Clears	N/A	Yes	No – Manual Reset Required

A master gas detection system control panel that displays system and detector status, historical information, and other variables should be located in the maintenance supervisor’s office or other selected location. This programmable device is essentially the “brains” of the gas detection system. In addition, it is recommended that a status panel be located outside of the building. This will allow emergency response teams to ascertain the internal conditions without having to enter the structure. A typical gas detection system control panel is displayed below in Figure 7.

Figure 7: A combustible gas detection system control panel.
Photo courtesy of Gladstein, Neandross & Associates, NREL

In the unlikely event that the gas detection system fails, the codes and regulations require that similar actions be initiated that would occur in the event of a full leak that is detected. These actions include activating the ventilation system (fans and make-up air), deactivating the heating systems, closing the gas valve, and activating horns and strobes.

It is essential that the gas detection, control, and alarm system be designed by an engineer registered within the state in which the facility is located. A registered engineer will be able to select equipment to ensure compatibility of components, evaluate operating conditions, and determine required functions. Approval must be obtained by the AHJ prior to preparing final designs and ordering equipment.

The gas detection and control system is fully integrated with several functions within the maintenance facility, including shunt trips, activation of fans, opening of facility doors and other makeup air ventilation, and sounding of alarms. As an early step in the design process, a plot plan (layout) of the facility depicting the location of these functions and the hardware used to support them should be prepared for internal use and for preliminary approval by the AHJ.

It is also always recommended to install manual activation switches near the exit doors in a maintenance facility. If staff recognizes a leak, the system can then be activated manually as personnel exit the facility.

Back-up Power

Depending on procedures inside a maintenance facility during a power outage, some AHJs and/or insurance underwriters may require that back-up power be available in the event of a power failure. Back-up batteries provide power to the gas detection and alarm system. However, batteries lack the power and duration needed to operate the other critical pieces of equipment, such as exhaust fans, and provide make-up air. To ensure there is sufficient power to operate all critical equipment, a stand-by generator equipped with an automatic transfer switch is typically employed. In the event of a main power failure, the standby generator will automatically start and begin providing power to the maintenance facility. A typical emergency generator installation is shown in Figure 8.

Figure 8: A typical emergency generator installation. Photo courtesy of Gladstein, Neandross & Associates, NREL

Dilution

Once a leak has been detected, the second key part of facility modifications is the process of diluting the natural gas as it rises through the shop. Because of the nature of natural gas, it is assumed that the plume of natural gas will settle across the 18 inches of the under-side of the facility’s ceiling. A proper facility modification will introduce fresh air to mix with the plume of gas inside the building. This is typically accomplished by 3 different methods:

- Opening bay doors, either fully open or partially open
- Installing motorized vents around the facility
- Utilizing a make-air unit to provide fresh air

While each option does have advantages and disadvantages, cost is typically the deciding factor in which option to select. In facilities with bay doors that are electrically operated, this option tends to have the lowest cost. This option also raise issues of security, since a facility is always monitored 24/7 for a leak, the building is generally not occupied 24/7 by maintenance personnel. Having bay doors open in the middle of the night may pose concerns with building staff, which brings up the other two options. Installing either gravity vents or motorized louvers provides the necessary make-up air when required, but also allows for a high level of security if the building is un-occupied when fresh make up air is required.

Alternately, if a make-up air unit is installed as part of the project to provide heat into the facility, these can function very well also as a source of fresh air. Once a leak is detected, the gas supply to the makeup air unit (MAU) is isolated, halting heat production, and the unit transitions to a large blower, providing fresh air into the facility.

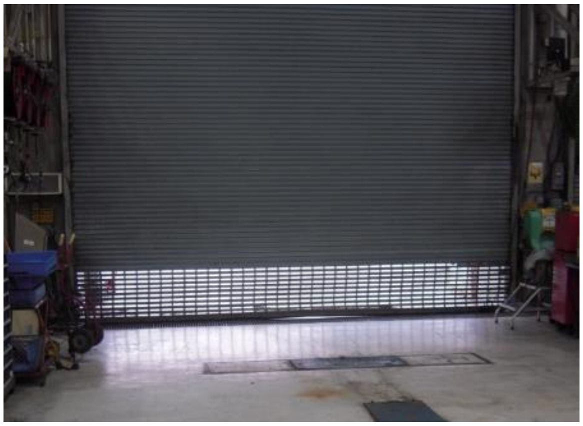

Figure 9: Security mesh in overhead doors. Photo courtesy of Gladstein, Neandross & Associates, NREL

In-wall louvers (Figure 10) can also be employed to provide a portion of the makeup air flow. Generally, they are not able to provide the sufficient makeup air volume or flow direction to meet the codes and regulations on their own. Powered side wall fans (Figure 11) may also be used to provide the requisite air flow.

Figure 10: In-wall louver that provides makeup air flow. Photo courtesy of Gladstein, Neandross & Associates, NREL

Figure 11: Powered sidewall fan that provides makeup air flow. Photo courtesy of Gladstein, Neandross & Associates, NREL

Existing maintenance facilities designed to service conventionally fueled (gasoline and diesel) vehicles should have a ventilation system that ensures vapors from liquid fuels will be evacuated from the building. Because fuel vapors are heavier than air, the ventilation system pick-up points are typically located near the floor of the facility where the vapors will accumulate. A maintenance facility that services both conventional and natural gas vehicles needs ventilation systems to address conventional fuel vapors and natural gas releases. An existing facility that is modified to service natural gas vehicles must retain the ventilation system that was designed to manage conventional fuel vapors. This will assist with the evacuation of an LNG leak. It is best practice to add additional ventilation systems to address the CNG requirements through air across the ceiling.

Rare exceptions may be granted by the AHJ to allow the existing ventilation fans to be used as long as they are compliant with natural gas use and equipped with automatic dampers to close off the flow from floor level and open the pickup points at the ceiling level. An alternative to this configuration is to automatically reverse the flow of the ventilation system for conventional fuels so that outside air is drawn into the facility and discharged at floor level in order to provide dilution makeup air for the ceiling-mounted CNG ventilation system. AHJ approval of this concept must be obtained. Automatically reversing the ventilation system for the conventional fuels is a function of the gas detection and control system.

Extraction

Ventilation of a natural gas vehicle maintenance facility is one of the key areas of concern that is addressed by both the IFC and NFPA 30A. Both codes use ventilation as a primary strategy to prevent natural gas accumulations at concentrations within the combustible range. Proper ventilation can be achieved by mechanical means (powered fans) or by convection to provide air flow. However, it is rare that convection alone can provide sufficient air flow. As briefly described in the previous section, there are several reasons for ventilating a maintenance facility. Sufficient ventilation is necessary to quickly and effectively dilute a natural gas release so that the concentration is below the combustible level. Ventilation is also necessary to provide sufficient air flow that will direct gas to the detection and alarm system that will alert occupants to safely evacuate the facility. Lastly, ventilation may aid in preventing a release from accumulating near potential ignition sources.

Unfortunately, ventilation volumes and strategies are areas where IFC and NFPA differ rather substantially. Both agree that natural ventilation may be allowed at the discretion of the AHJ. However, if the AHJ elects to require mechanical ventilation, the IFC and NFPA differ in their calculations and control strategies. Knowing which code requirements the local AHJ follows is critical to determining which control strategy should be employed for your project.

IFC Ventilation Requirements

The IFC states that facilities in which major CNG vehicle repairs are to be performed shall be ventilated at a rate of one cubic foot per minute (CFM) for each 12 cubic feet of structural volume space or, stated another way, five air changes per hour (ACH). Note that this calculation is based on the total volume of the structure, not square footage of the floor or ceiling. Furthermore, the code provides three options for operating ventilation: 1) continuously, 2) triggered upon command from the methane detection system, or 3) for CNG only, continuously while the space is occupied, via interconnection with the lighting circuit – if the lights are on, the ventilation system is operating.

The potential energy impacts of continuous operation and tempering of the entire volume of air in a facility leads many fleets, particularly those in cold climates, to elect to use methane detection as the activation mechanism. With a methane detection system strategy, the installation cost of larger ventilation systems is often comparable with the continuous ventilation strategy, but the operating cost is greatly reduced. Various approaches to ventilation system design are discussed later in this section. Proper specification, design, and installation of methane detection systems are discussed later in this document.

Ventilation Strategies

The codes do not specifically address how the ventilation is to be achieved. Some facilities rely on exhaust fans to “pull air” through the facility. In this case, make-up air is provided via natural draft through openings such as doors and louvers, or by mechanical means such as make-up air units. Other facilities are designed without rooftop exhaust fans, instead feeding make-up air into the space with interlocked, electronically actuated gravity vents in the ceiling to keep the space within proper balance. A variety of approaches are available, each with advantages or disadvantages based on factors such as 1) the AHJ's decision regarding applicable code, 2) the design and construction of the existing facility and its ability to accommodate modifications, 3) the climate in which the facility is located (i.e., warm weather versus cold weather and related air tempering energy costs), 4) ease of operation, and 5) cost.

Most AHJ's will require facilities in which major natural gas vehicle repairs will occur to meet the most stringent requirement, which requires the ventilation system to be sized for 5 ACH. However, it is essential to ensure that the building design and construction do not hinder effective air changes in the ceiling zone at the 5 ACH ventilation rate. Mechanical ventilation strategies should be reviewed in advance with the AHJ to ensure that effective ventilation is achieved in the ceiling zone.

NFPA does not specifically address operational parameters of ventilation systems in facilities where major natural gas vehicle maintenance and repair work is to be performed. Generally, fire marshals and other AHJs tend to refer to the IFC operational guidelines of 1) continuous operation, 2) continuous operations while occupied, via interlock with lighting, or 3) methane detection system-triggered. If the third operational parameter is selected, then all electrical devices in the "ceiling zone" must be removed, relocated, or replaced with devices rated Class I, Division 2.

The most common form of facility ventilation is with roof-mounted up-blast fans that exhaust to the atmosphere in a safe area (Figure 12). These exhaust fans can pull air directly from the space via the fan inlet as shown in Figure 13, or they can pull air through exhaust ductwork serving specific areas of the ceiling zone as shown in Figure 14.

Figure 12: Roof-mounted up-blast fan. Photo courtesy of Gladstein, Neandross & Associates, NREL

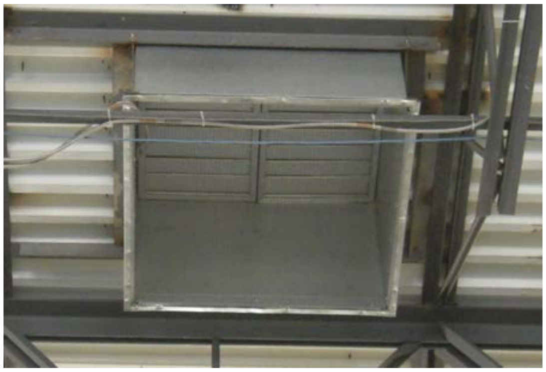

Figure 13: Ceiling-mounted direct fan intake with louvers. Photo courtesy of Gladstein, Neandross & Associates, NREL

Figure 14: Ventilation ducting used to evacuate air from specific areas. Photo courtesy of Gladstein, Neandross & Associates, NREL

Most existing maintenance facilities are equipped with roof-mounted fans, some of which may be rated for use in Class I, Division 2 areas. In some cases, existing roof-mounted fans can be used, with minimal modifications, for compliance in a natural gas maintenance facility. Roof-mounted fans require certain characteristics to be suitable for use in a natural gas vehicle maintenance facility. The fan blades and shrouds must be constructed from non-sparking materials (i.e. plastic or aluminum) to prevent the potential of igniting a release. In addition, the electric motor that drives the fan must be explosion-proof or located where a plume of natural gas does not pass over the electric motor. Figure 15 shows a non-compliant belt-driven fan.

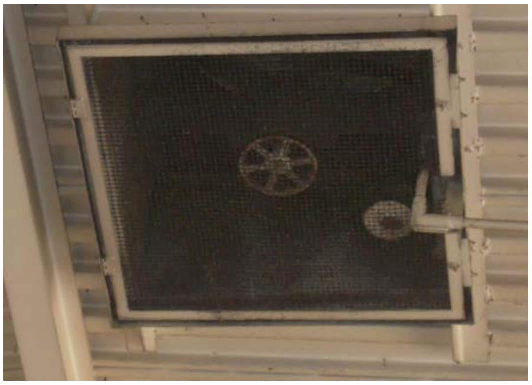

Figure 15: This fan is non-compliant due to the way intake air flows over the motor. Photo courtesy of Gladstein, Neandross & Associates, NREL

In some cases, there is insufficient space to install a fan or the structural integrity of the roof is insufficient to support the additional load of a new fan. In these cases, ground-mounted or wall-mounted fans and suitable external ducting (Figure 16) can be employed to comply with natural gas vehicle maintenance facility requirements.

Figure 16: Ground-mounted fan with external ducting. Photo courtesy of Gladstein, Neandross & Associates, NREL

Operation and control of the ventilation system depends on several factors. The exhaust fans and means for providing makeup air can 1) operate continuously, 2) be controlled automatically using a combustible-gas-detection system, or 3) be activated inter-locking the ventilation fans to the facility lighting system. A description of each method for operation and control of the ventilation system follows:

1. For ventilation systems that operate continuously, the fans are constantly running. Continuously operating ventilation systems are most commonly employed in warmer climates where ambient air does not require conditioning (heating) for worker comfort. In colder climates where the air inside the facility is heated for worker comfort, the cost of heating “once-through” air will likely be prohibitive. Continuously operating ventilation systems will require higher electrical costs and may entail increased fan maintenance costs.
2. For ventilation systems controlled using a combustible-gas-detection system, the fans are only activated when the sensors detect the presence of natural gas (manual operation is also possible). It is important to note that while a gas detection system is required for proper operation of this type of ventilation system, gas detection systems are not required for all natural gas vehicle maintenance facilities.
3. For ventilation systems activated by interconnecting with the facility lighting controls, the ventilation system is interlocked with the lighting circuit so that the fans operate whenever the facility lighting is switched on. The applicable codes and regulations assume that interior lighting will always be activated whenever a maintenance facility is occupied. Similar to the continuous ventilation system, the associated high heating costs may make this type of system cost prohibitive in colder climates.

Another design that may be considered is to employ two levels of ventilation by utilizing two-speed or variable-speed fan motors. This allows for a lower level of day-to-day ventilation, as well the higher level of ventilation once a leak is detected.

To be effective, the pickup point of the exhaust system (location where internal air is collected to be exhausted to the atmosphere) should be located at the highest point of the structure because this is the location where the release will initially accumulate. The airflow produced by the ventilation system should be designed to “sweep” across the ceiling so that it moves gas concentrations toward the pickup point and exhausts to the atmosphere. The “sweeping” effect is achieved with multiple appropriately placed fans or with ductwork accessing a number of pickup points using a single fan.

Ceiling profiles of maintenance facilities vary considerably as a result of structural roof members, varying ceiling heights, or other internal configurations. The codes and regulations do not require airflow across every square inch of ceiling; rather, the system should be designed such that the airflow eliminates accumulations of natural gas which may be subject to ignition sources. Figure 17 displays a ceiling configuration that could accumulate concentrations of natural gas, but because the "pockets" do not contain heaters, electrical wiring, or appliances, there is no ignition source. Because there is no ignition source present at these locations, it is not necessary to specifically ventilate each "pocket."

Figure 17: Ceiling configuration with "pockets". Photo courtesy of Gladstein, Neandross & Associates, NREL

Figure 18: Conventional fuel maintenance facility ventilation pickup points near the floor. Photo courtesy of Gladstein, Neandross & Associates, NREL

Regardless of the ventilation system selected, it must be designed by a registered engineer. Calculations showing the number of air changes per hour are required on the design drawings.

Ventilation in Pits

Ventilation requirements for pits, below grade and sub-floor 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/sq. ft. while NFPA requires 1.0 cfm/sq. ft. The local AHJ should specify the rate for each facility. The codes have no requirements specific to CNG or LNG. 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.

Additional Considerations for Facility Modification

For CNG facilities, applicable codes deal extensively with installation of heating and electrical devices in the 18 inches on the under-side of the ceiling. For LNG, codes look at not only the upper 18 inches (like CNG), but also the lower 18 inches just above the floor. The 18 inches above the floor is a very specific area in a maintenance facility. That area must be kept clear of all potentially spark producing equipment, not only for LNG, but also for diesel and gasoline fuels. Since this requirement also covers liquid fuels, most facilities already meet this requirement. The following sections discuss additional considerations for equipment inside a maintenance facility, especially in these areas near floors and ceilings.

Heating Systems

Maintenance facilities in most locations across the United States require some form of heating during the winter months to ensure worker comfort. Heat may be provided using a forced air central heating system that warms the air throughout the maintenance facility or utilizes an air-to-air heat exchanger. Localized space heating is another method for heating a maintenance facility. Localized space heating is typically accomplished using gas-fired infrared direct radiation or tube-type heaters, gas- (or propane-) fired devices equipped with fans, or electric infrared heating units. Most of these types of heating apparatus are mounted to either the walls of the facility or suspended from the ceiling.

All heating systems except forced-air types present specific challenges for CNG vehicle maintenance facility compliance. Codes and regulations require that specific conditions be met for both heaters and heating systems. Classification of the maintenance facility as either a major repair or minor repair category is also an important factor.

For major repair garages, NFPA 30A states that *"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."* Because it is generally not possible to delineate *"areas subject to ignitable concentrations of gas,"* for practical reasons all heating devices in a major repair garage are subject to this limitation.

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 2211.3 restricting ignition sources from the space within the 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.

With the exception of forced air central heating, each of the heaters described provides a potential ignition source in the event of a natural gas release. For flame-fired heaters it is, of course, the flame itself. For gas-fired infrared direct radiation heaters, even for those where the flame is contained within the heating elements, the surface temperature of the radiant heating elements may exceed 750°F, thereby presenting a potential ignition source. Electric heaters that employ heating coils and a fan may or may not be compliant depending upon the operating temperatures reached by the heating coils.

The figures below show various types of space heating equipment commonly found in maintenance facilities. Gas fired infrared heaters may be compliant depending on the air source, but direct heating surfaces with open flames or temperatures above 750F need to be replaced, modified, or eliminated.

Figure 19: Gas-fired infrared tube-type heater. Photo courtesy of Gladstein, Neandross & Associates, NREL

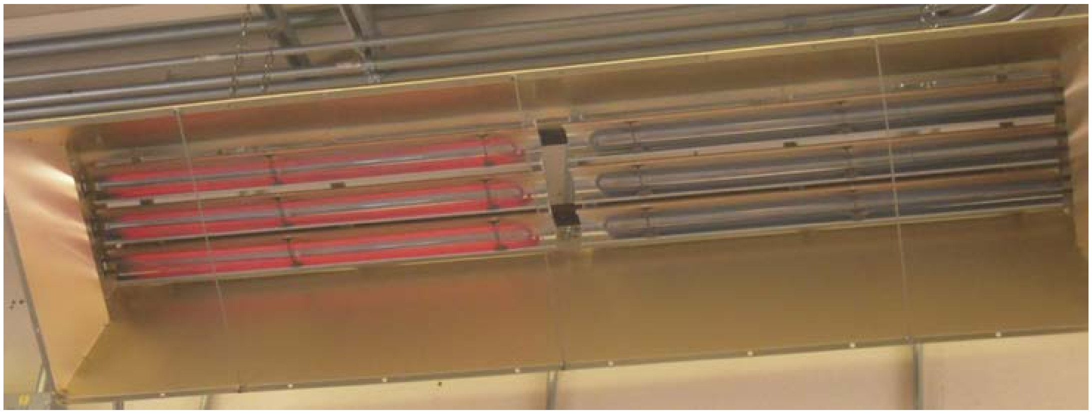

Figure 20: Electric infrared radiant heater. Note the exposed surfaces. Photo courtesy of Gladstein, Neandross & Associates, NREL

Compliance with the codes and regulations can be achieved by simply removing the non-compliant heating units and/or replacing them with units that are considered compliant. Gas-fired infrared tube-type radiant heaters (Figure 19) are commonly employed in maintenance facilities that service conventionally fueled vehicles. Manufacturers of these types of heating systems now manufacture units that have contained flames and surface elements that do not exceed 750°F. In this instance, modifying the maintenance facility's heating system to be compliant with the codes and regulation for servicing CNG vehicles would only require replacement of the heater(s). However, it is essential that the supply air and exhaust flow from gas-fired infrared tube-type radiant heater(s) be completely contained and directed to and from the outside of the maintenance facility. This can be accomplished by routing the inlet air and exhaust air through the facility wall or roof.

Figure 21: Floor-mounted portable propane heater. Note the exposed heating elements. Photo courtesy of Gladstein, Neandross & Associates, NREL

Figure 22: Ceiling-mounted gas-fired fan heater. Internal surfaces may be exposed and may present an ignition potential. Photo courtesy of Gladstein, Neandross & Associates, NREL

Portable propane heaters (Figure 21) should be prohibited from use. Gas-fired fan-type heaters (Figure 22) are not compliant because of their inherent open flames and must be replaced with units that meet the codes. This includes gas-fired fan-type heaters in which the pilot light is the only open flame.

Forced air heating systems mounted outside do not present direct hazards as potential ignition sources for combustible gas, as long as the supply air comes from outside the facility, and is not re-circulated. These types of systems become cost-effective in larger facilities that would require considerable numbers of infrared tube type heaters.

Electrical wiring and equipment

Electrical wiring, lighting, and electrical appliances all present potential ignition sources to a release of natural gas within a maintenance facility. A spark that is caused by an abnormal condition such as a short circuit within a wire conduit or junction box, or generated in normal operation of an unprotected electric motor must be addressed.

As part of a facility upgrade, special attention must be paid to the 18 inches on the underside of the ceiling. Code assumes that this is where a plume of gas will gather after a leak has developed in a vehicle. Per code, all sources of ignition in this 18 inches zone must be addressed. NFPA 30A defines this area in an natural gas repair facility as a Class I Division 2 area. This means all devices located in this area must be Class I, Division 2 certified, or must be removed from the area. A second option to address this issue is to de-classify the zone by providing at least 4 ACH across the zone. NFPA 30A states that electrical devices located in this area do not need to meet Class I, Division 2 specification if the structure has an effective continuous ventilation rate of at least 4 ACH. If the structure does not have a continuous ventilation rate of at least 4 ACH, existing electrical devices that do not meet the Class I, Division 2 specification must be re-located to below the classified zone. As an alternative to relocating the existing electrical devices, the devices may be replaced with electrical devices rated Class I, Division 2.

Additionally, unsealed conduits may also provide a means of gas migration from one portion of the facility to another. Before modifying a maintenance facility to service CNG fuel vehicles, the existing design must be taken into consideration so that each of the safety risks are mitigated. In general, it is less expensive to eliminate or relocate non-compliant electrical fixtures than to replace them with more costly explosion-proof units.

According to NFPA 30A, *"In major repair garages where CNG vehicles are repaired or stored, the area within 18 inches of the ceiling shall be designated as a Class I, Division 2 hazardous location."* In an area designated as Class I, Division 2, all electrical wiring, conduits, junction boxes, and electrical appliances must be either explosion proof or relocated so that they are not within the hazard zone. The NFPA 30A Class I, Division 2 designation does not apply for minor repair garages.

It is important to note that NFPA 30A does provide an exception to the Class I, Division 2 designation. NFPA 30A states that *"In major repair garages, where ventilation equal to or not less than four ACPH is provided, this requirement does not apply."* This exception is covered in section 3.2, Ventilation. For maintenance facilities that have determined that providing continuous ventilation is impractical, the following provides solutions for many commonly encountered conditions.

In some cases, the number of conduits or junction boxes that are located in the hazardous zone is large enough that relocating each of them is unreasonable because of the cost or complexity (Figure 23). Class I, Division 2 status can be obtained if conduits or junction boxes are provided with seal-offs, which create a physical barrier that minimizes the passage of gases from traveling freely through the conduit and will prevent the migration of methane into the conduits (see *ecmweb.com/content/sealed-fittings-why-are-they-necessary*). The use of seal-offs in lieu of relocation must be approved by the AHJ.

Figure 23: Relocating multiple conduits, such as those shown here, would be costly and complex. Photo courtesy of Gladstein, Neandross & Associates, NREL

According to NFPA 30A, low-voltage wiring and containing conduits *may* be exempt from the Class I, Division 2 requirements if they are determined to be non-sparking. Examples of potentially exempt low- voltage wiring and containing conduits include: loudspeaker and security camera wiring, wiring used for data transmission (network cables), alarm systems, and wiring used for similar applications (Figure 25). However, the AHJ must approve leaving low-voltage wiring in the Class I, Division 2 space; otherwise, it may be considered hazardous and subject to Class I, Division 2 requirements.

Figure 24: Low-voltage wiring and devices. Photo courtesy of Gladstein, Neandross & Associates, NREL

In order for lighting fixtures to comply with Class I, Division 2 requirements, they must be either classified as explosion-proof or moved to a location that is greater than 18 inches from the ceiling. All components (e.g., fixture, bulb, ballasts, transformers, etc.) must be relocated outside of the hazardous zone (Figure 25). In general, lowering the fixtures and components is the most common and cost effective approach for complying with Class I, Division 2 requirements. Also note during this process of lowering lighting, replacement or upgrades of the facilities lighting systems can occur. Options include several different styles of LED lights, which typically provide for a rapid ROI due to the future energy savings.

Figure 25: Overhead lighting fixture and ballast that are not yet lowered out of the classified zone. Photo courtesy of Gladstein, Neandross & Associates, NREL

Other electrical appliances and equipment within the hazardous zone must also be removed or relocated. Figure 26 displays a typical rotary fan with a drive motor located within the 18 inch zone. The rotary fan would be considered a potential ignition source because a rising release could encounter the fan motor before reaching the ceiling-mounted gas detectors. In some cases, the AHJ may require that all such fixtures be removed completely to avoid this hazard.

Figure 26: An overhead rotary fan that presents a potential ignition source. Photo courtesy of Gladstein, Neandross & Associates, NREL

Electric door motors, commonly found on main bay doors, are also a potential ignition source even when they are not located within the hazardous zone (Figure 27) because of the possibility of sparks generated by the electric motors. In the event that a leak is detected, the electric door motors will activate to open the doors. For this reason, some AHJs may require electric door motors to be replaced with explosion-proof equipment. Doors that are not activated during a gas detection event do not need to be replaced with explosion-proof equipment. Similarly, overhead cranes (Figure 28) should be shunt-tripped to prevent activation of their electric motors. Shunt tripping, which is further discussed in section 4.5, Gas Detection, Alarm, and Control Systems, involves an interface between the methane detection controls and the circuits within the facility electrical panel. When methane is detected, selected circuits can be instantaneously deactivated.

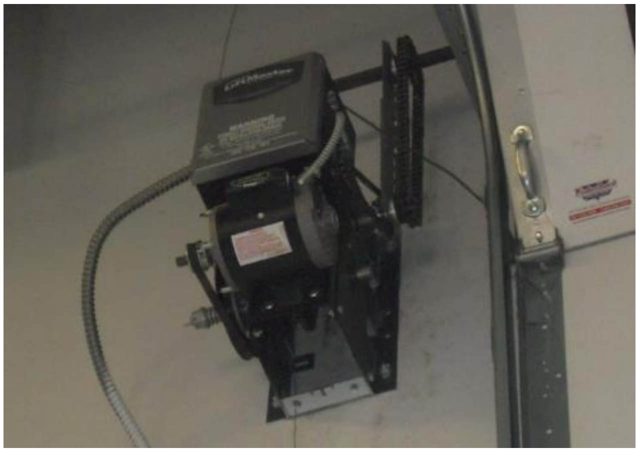

Figure 27: A typical electric door motor. Photo courtesy of Gladstein, Neandross & Associates, NREL

Figure 28: A typical overhead crane. Photo courtesy of Gladstein, Neandross & Associates, NREL

Preparation of Vehicle for Repair

IFC 2311.5 is the only code requirement that 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.

- IFC 2311.5 also requires that the fuel system on the NGV be tested for leakage by appropriate methods if there is a concern that the fuel system has experienced any damage. If damage is suspected the vehicle should be de-fueled prior to any maintenance.

Subject	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** - 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** - No requirement

Paths of Migration

Natural gas used for vehicular fuel is composed mostly of methane (CH_4) with minor amounts of other hydrocarbons. As such, it is lighter than air and will rapidly rise and dissipate if released into an open space. When this occurs indoors, the resulting release will rise to the ceiling before dispersing throughout the structure. The route natural gas travels through a structure as it dissipates is referred to as its “path of migration.” Because natural gas is normally odorless, sulfur containing compounds called mercaptans, are added as a safety feature. This gives natural gas a “rotten egg” smell. Mercaptan provides a powerful first defense in detecting a gas leak; the “rotten egg” smell can be detected in concentrations far below 1%, which provides a large safety factor to the LFL of 5%.

Natural gas concentrations at the center of a release are typically too rich to support combustion. However, as the gas disperses, concentrations are lowered to a fuel/air ratio that is capable of supporting combustion. The combustible zone for natural gas ranges from 5%–15% by volume. As dispersion continues, gas concentrations will lower to a point where the gas becomes too lean to support combustion. In order to ensure safety in the event of a release, the maintenance facility must protect against ignition as the concentration falls within the combustible zone as it rises and disperses.

Natural gas can be ignited by a spark, flame, or very hot surface. However, unlike gasoline or diesel vapors, the ignition of natural gas can only occur when concentration levels are within a narrowly defined range. To eliminate this potential safety hazard, a maintenance facility must be modified to eliminate all potential ignition sources that may come into contact with the release while gas concentrations are within the combustible zone. Additionally, a maintenance facility must be modified such that the air circulation exhausts the release as quickly as possible in order to minimize the amount of time that gas concentrations within the release are within the combustible zone.

The inadvertent release of natural gas indoors can occur in several ways. For example, a vehicle located within a facility may have a slow leak due to an improperly sealed fuel system component. Minor releases of natural gas may also occur when disconnecting fuel system components in order to perform a repair such as changing a fuel filter. Though rare, a large release of natural gas may occur in the event of a CNG tank or fitting failure that results in the entire volume of the tank emptying rapidly.

It is generally not possible for combustible concentrations of natural gas to result from minor leaks that occur over time, as these types of leaks will dissipate throughout the facility rather quickly with proper safety measures in place. While a CNG maintenance facility is designed to safely handle all types of releases, it is the large uncontrolled release that presents the greatest danger. Although this type of event is extremely rare, a maintenance facility must be prepared to protect against it.

Because natural gas is lighter than air, the release may encounter several different paths of migration as it rises. Paths of migration are also affected by air movement within the maintenance facility. For this reason, a maintenance facility must be designed to prevent the release from rising into unprotected areas that prevent or inhibit dispersion. This is accomplished by installing barriers, pressurizing adjacent areas, and sealing gaps in the structure to prevent the migration of natural gas into unprotected areas.

Examples of potential paths of migration resulting from the structural characteristics of a facility are shown below. These potential paths of migration can be eliminated by installing sealing material around the wall penetrations and at the ceiling level, as shown in Figure 29.

Figure 29: Unsealed conduit or pipes passing through walls or ceilings present a potential path of migration. Photo courtesy of Gladstein, Neandross & Associates, NREL

Figure 30: Structural members passing through a wall present a potential path of migration. Photo courtesy of Gladstein, Neandross & Associates, NREL

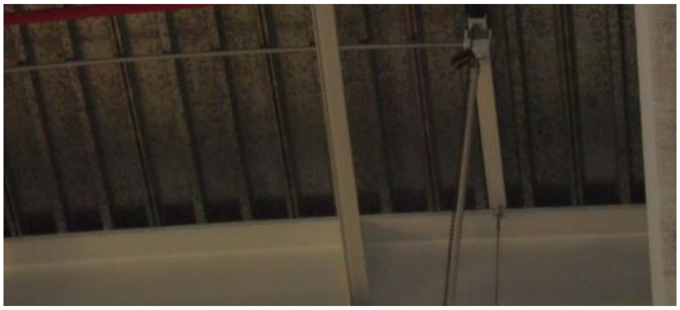

Figure 31: Gaps between walls and the ceiling present a potential path of migration. Photo courtesy of Gladstein, Neandross & Associates, NREL

Figure 32: Wall penetrations properly sealed to prevent migration. Photo courtesy of Gladstein, Neandross & Associates, NREL

Figure 33 shows an open passageway to an adjacent non-maintenance area through which gas migration could occur. The maintenance area must be isolated from other areas in a facility by using a complete seal.

Figure 33: A potential path of migration created by an open passageway. Photo courtesy of Gladstein, Neandross & Associates, NREL

Stairways accessing an upper level could accentuate the upward gas flow. In these cases, the potential path of migration should be contained by installing a door that would prevent upward gas flow. The door must be fitted with a self-closing mechanism to keep it closed except when in use. Operating protocols and signage should also be used to ensure that the door is not propped open. Doors should not be fitted with louvers.

Figure 34: Stairways to upper levels are a potential path of migration. Photo courtesy of Gladstein, Neandross & Associates, NREL

Figure 34 shows a storage area for vehicle parts adjacent to a workshop that is serviced with a pass-through window. Open windows present a potential path of migration for the transmission of natural gas to an unprotected area. This condition can be eliminated to the satisfaction of the AHJ by installing an air dam above the opening that only activates when a leak is detected, or installing a pressurizing fan in the parts room to prevent the inward flow of gas from the maintenance area. It is important to understand the functions of an opening as a solution is developed for upgrading a facility.

Figure 35: A pass-through window presents a potential path of migration. Photo courtesy of Gladstein, Neandross & Associates, NREL

Best Practices

Getting Started

The cost to upgrade a maintenance facility should be considered in order to properly evaluate moving a fleet to natural gas. The recommended first step is developing a cost-effective upgrade plan with a qualified design firm to determine what the costs will be. Major factors that will be considered at this point include whether your facility is leased or owned, the facility's age, and the overall condition of the facility. Additional upgrades outside of natural gas requirements may be considered at this time, including LED lighting, efficient heating, fire suppression, etc.

Contacting a local engineering firm with general experience is an option, however selecting a firm with limited natural gas vehicle experience typically leads to increased expense and overdesign. Very high facility upgrade costs tend to delay the decision to move to natural gas, or and may cancel the plans altogether. Consultation with industry leaders, Natural Gas Vehicles for America (NGVA), or experienced natural gas firms should always be considered.

Utilizing a firm with experience in natural gas upgrades will not only lead to a cost-effective upgrade plan, but these firms also assist with financial evaluations, identification of grant funding, natural gas fueling station construction, and natural gas vehicle procurement aspects that must considered during a transition to a natural gas fleet.

Cost Considerations

The cost of natural gas vehicle maintenance facility upgrades is highly variable, and unique features in each garage can significantly increase or decrease the cost of modification. An initial consultation is a great way to find out whether your garage has any of these unique features. A design firm with the proper experience will be able to help a garage owner understand the unique aspects of any particular garage, and can develop a plan that will address code compliance with a strategy that includes detection, dilution, and extraction. Before any unique challenges or cost saving opportunities are taken into account, many garage owners find that cost to bring a bay into compliance can range from $50,000-125,000. [1]

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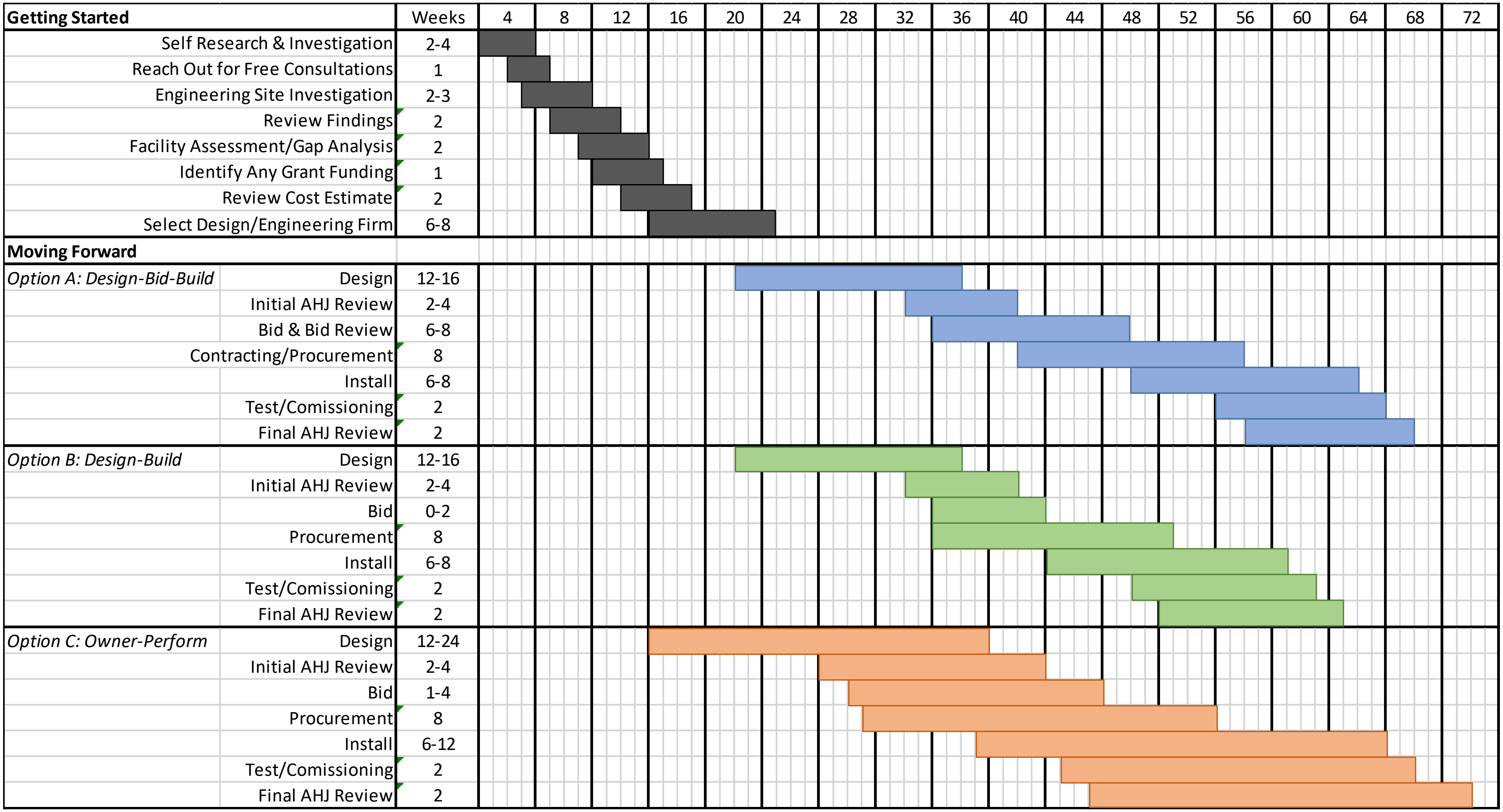
[1] Kelly, K., & Melendez, M. (2017). *Compressed Natural Gas Vehicle Maintenance FacilityModification Handbook.* U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy.

Typical Schedule

The figure below shows a range of schedules for a maintenance garage upgrade. All three of the scenarios involve common first steps: basic research, reaching out for initial and often free consultations, site reviews, and selection of the path forward after review of cost estimates. The Design-Bid-Build option includes separate steps of working with a design firm, bidding jobs and equipment, and procuring and installing equipment. A design-build firm is able to accelerate certain steps of the modification. If an owner chooses to undertake the design and modification, there is much more variability in the schedule, and much higher likelihood of unforeseen schedule impacts.



Getting Started		Weeks
	Self Research & Investigation	2-4
	Reach Out for Free Consultations	1
	Engineering Site Investigation	2-3
	Review Findings	2
	Facility Assessment/Gap Analysis	2
	Identify Any Grant Funding	1
	Review Cost Estimate	2
	Select Design/Engineering Firm	6-8
Moving Forward		
Option A: Design-Bid-Build	Design	12-16
	Initial AHJ Review	2-4
	Bid & Bid Review	6-8
	Contracting/Procurement	8
	Install	6-8
	Test/Comissioning	2
	Final AHJ Review	2
Option B: Design-Build	Design	12-16
	Initial AHJ Review	2-4
	Bid	0-2
	Procurement	8
	Install	6-8
	Test/Comissioning	2
	Final AHJ Review	2
Option C: Owner-Perform	Design	12-24
	Initial AHJ Review	2-4
	Bid	1-4
	Procurement	8
	Install	6-12
	Test/Comissioning	2
	Final AHJ Review	2

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:

- Is the facility currently permitted for vehicle service operations (even liquid fuels)?
- Does it 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 include a fueling station?
  - Note: this document does not include guidelines for fueling stations but if a station will be installed at the same times 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. Also, each state may adopt and enforce different editions of the respective code (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. General information on state and local adoption can be found at the ICC web site http://www.iccsafe.org/gr/pages/adoptions.aspx .

To be sure that the correct code and code edition is used the local AHJ is the best source of information.

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.

Ventilation

When lighter than air gaseous fuels such as natural gas and hydrogen are accidentally released from a vehicle, they tend to rise towards the ceiling of a facility, and their migration is strongly affected by the air movement within a facility. To monitor for this situation in a typical garage, the protection strategy is to detect a leak, dilute it if possible, and then extract the hazardous plume of gas.

Photo courtesy of Gladstein, Neandross & Associates, NREL

Detection is carried out with hydrocarbon gas detectors mounted near the ceiling. The ventilation system should be designed to, upon detection of gas, introduce fresh air supply to dilute and turn on exhaust fans to extract the plume. Ventilation systems can be active or passive systems. Active systems are typically integrated with mechanical ventilation systems, while passive systems utilize gravity vents with either mechanical or gravity extraction to allow fresh air to be introduced into the facility.

The International Fire Code states that facilities performing major repairs on natural gas vehicles must have an emergency ventilation rate of one cubic foot per minute (cfm) for each 12 cubic feet of shop space or, stated another way, five air changes per hour (ACH). Furthermore, the code provides three options for providing ventilation: 1) continuously (i.e. fans are always running), 2) on standby, activated by continuous monitoring methane detection system, or 3) for CNG facilities only (i.e. no LNG repairs), ventilation may operate continuously while personnel are present, , via interconnection with the lighting circuit.

Continuous Ventilation

Continuous ventilation typically has the lowest up-front installation costs, as it avoids requiring any lowering of electrical equipment from the classified zone. Over the long term, this type of modification tends to have the highest operational costs, especially in cold weather climates, due to the fact that heated air is removed from the facility at a continuous rate. Though detection is non-essential in this strategy, dilution and extraction are still key. Make-up air for dilution must come from the outdoors and should be introduced as low as possible. Exhaust intakes should be located as high as possible, and care should be taken to eliminate any areas within the ceiling geometry, that could potentially trap hazardous gas. Facilities must have approval from the local AHJ to employ continuous ventilation, so early coordination is critical. Ventilation rates should be five air changes per hour or one cubic feet per minute (CFM) per square foot of floor space.

The ventilation system runs continuously, which will add to electricity bills. A continuous ventilation system constantly pulls makeup air from outside the facility, which means that this air must constantly be conditioned. In moderate climates, where heating or cooling is not necessary for most of the year, continuous ventilation is often a good option. In cooler climates, garages that only intermittently service alternative fuel vehicles, or fleets that are trialing these vehicles might consider continuous ventilation.

Standby Ventilation

The second two strategies must meet the flow requirements listed above, but only on demand (controlled by the methane detection system). The first strategy is to have the ventilation system activate when gas detectors sense hazardous conditions. The second strategy is to have the ventilation system interlocked with the lighting circuit, so that any time the lights are on, the ventilation system is operational.

As with continuous ventilation, consideration must be given to ongoing heating and electrical costs. Detection is often used in colder climates because the up-front cost of the detection system is minor compared to the cost of continuously removing the conditioned (i.e. heated) air.

Natural Ventilation

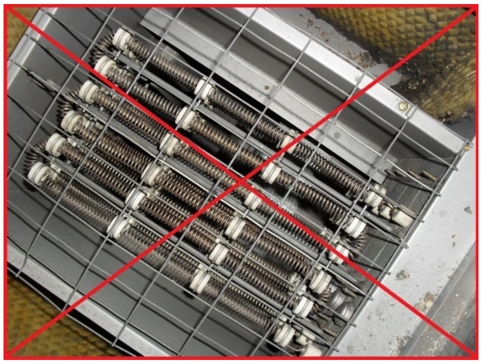
One form of continuous ventilation is natural ventilation. Some garages may have sufficient natural ventilation to meet these ventilation rates with little or no modifications to the design of the facility. Dilution and extraction are still important factors in the design, and the same concepts apply; fresh air must enter the facility as low as possible, and must leave through high points. These types of facilities typically have no doors, or have the sides of the facility open to the surrounding environment. Consideration still needs to be given to areas that may trap gas as it rises.

There are a number of ceiling vents that allow passive natural ventilation. Gravity vents rely on the fact that hot air rises. These vents simply provide a path for air to exit a facility as it rises while preventing wind from reversing flow through the vent. Gravity vents are typically equipped with features that block rain or snow from falling into the facility. Ridge vents are a special type of gravity vent that is particularly useful in buildings with ridged or high roof lines.

Heating Appliances

Maintenance facilities in most locations across the United States require some form of heating during the winter months to ensure worker comfort. Heat may be provided using a forced air central heating system that warms the air throughout the maintenance facility or utilizes an air-to-air heat exchanger. Localized space heating is another method for heating a maintenance facility. Localized space heating is typically accomplished using open flame gas-fired, infrared, direct radiation, tube-type heaters fueled by natural gas or propane, or electric infrared heating units. Most of these types of heating apparatus are mounted to either the wall or roof of the facility or suspended from the ceiling.

All heating systems present specific challenges for CNG vehicle maintenance facility compliance. Codes and regulations require that specific conditions be met for both heaters and heating systems. For major repair garages, NFPA 30A gives the guidance that heaters with surfaces above 750°F shouldn’t be permitted in areas where gas may be. The IFC does not have any specific requirements for CNG and LNG repair garages with respect to sources of ignition.



Each of the following heaters provides a potential ignition source in the event of a natural gas release. For flame-fired heaters it is, of course, the flame itself. For gas-fired infrared direct radiation heaters, even for those where the flame is contained within the heating elements, the surface temperature of the radiant heating elements may exceed 750°F, thereby presenting a potential ignition source. Electric heaters that employ heating coils and a fan may or may not be compliant depending upon the operating temperatures reached by the heating coils.

Portable propane heaters should be prohibited from use. Gas-fired fan-type heaters are not compliant because of their inherent open flames and must be replaced with units that meet the codes. This includes gas-fired fan-type heaters in which the pilot light is the only open flame.

Forced air heating systems present a hazard if gas is mixed with makeup air to the unit. Forced air heating must use makeup air from outside the areas of the facility that may experience a gas leak.

Compliance with the codes and regulations can be achieved by simply removing the non-compliant heating units and/or replacing them with units that are compliant. Gas-fired infrared tube-type radiant heaters are commonly employed in maintenance facilities that service conventionally fueled vehicles. Manufacturers of these types of heating systems now manufacture units that have contained flames and surface elements that do not exceed 750°F and sealed combustion chambers.

Note that the heaters above have ducting (see arrows) to draw fresh air from the ceiling of the facility. Supply air and exhaust flow from gas-fired infrared tube-type radiant heater(s) must be completely contained and directed to and from the outside of the maintenance facility. This can be accomplished by routing the inlet air and exhaust air through the facility wall or roof.

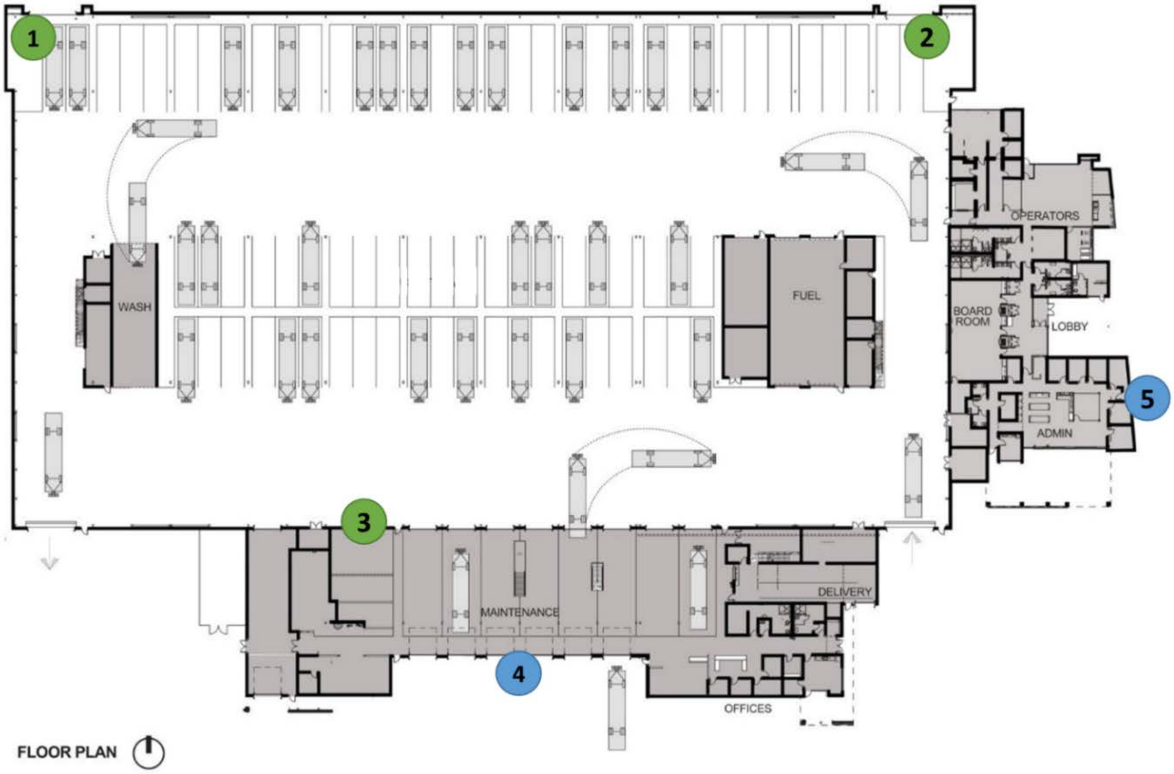
Portable propane heaters should be prohibited from use. Gas-fired fan-type heaters are not compliant because of their inherent open flames and must be replaced with units that meet the codes. This includes gas-fired fan-type heaters in which the pilot light is the only open flame.

Forced air heating systems mounted outside do not present direct hazards as potential ignition sources for combustible gas, as long as the supply air comes from outside the facility, and is not re-circulated. These types of systems become cost-effective in larger facilities that would require considerable numbers of infrared tube type heaters.

Alarm Systems

When a gas detection system is required, it will be installed with an alarm system to alert facility personnel of any hazardous situations. This alarm panel and its visual and audible indicators should be visible and audibly heard from all parts of the building. The example below shows the floor plan of a large bus depot where it is not necessary to place alarming indicators at each corner. Three indicators are sufficient to alert anyone in the large bus storage area. Indicator #3 can be located in an area that will alert both the storage area and the maintenance area (in grey, below the storage area).

In addition to alerting personnel inside the facility, indicators should also be located outdoors, near entrances so that first responders and facility personnel arriving to site can easily determine the situation when they arrive. Consider placing these indicators near the fire department lock box and near any main entrances through which emergency services will likely enter. Outdoor indicator 4 in the diagram below is near the bus entrance to the facility, and indicator 5 is near the lobby entrance.



Visual signals should be unique, for each prescribed action, and for each emergency scenario; signals for actual fires should be different than signals for gas presence. It is also necessary to have instructions near any alarm panel that clearly indicates which action should be carried out for each visual signal; Visitors to the facility also need to know what actions to take during an emergency.

The table below lists a typical sequence of operations used to configure a methane detection system. In this case, the alarm system is integrated with a gas detection system, and has three states – normal, gas detected at 20% of the Lower Flammability Limit (LFL), and gas detected at 40% of the LFL. The table shows the different indication and preventive actions taken during each state of the gas detection system.

Condition	**Gas Concentration Level**		
	Normal	**20% LFL**	**40% LFL**
Operation Lights – Green	On	Off	Off
Operation Lights – Amber	Off	On	Off
Operation Lights – Red	Off	Off	On
Warning Horns	Off	On – Level 1	On – Level 2
Strobe Alarms	Off	Off	On – Level 2
Supervisory Advisory	No	Yes	Yes
Fire Department Callout	No	No	Yes
Ventilation Fans	Manual	On	On
Roll-Up Doors/Louvers	Manual	Open	Open
Automatic Gas Valve	Open	Open	Closed
Shunt Trip Building Loads	No	No	Yes
Automatic Reset of System if Fault Clears	N/A	Yes	No – Manual Reset Required

Gas Detector Placement

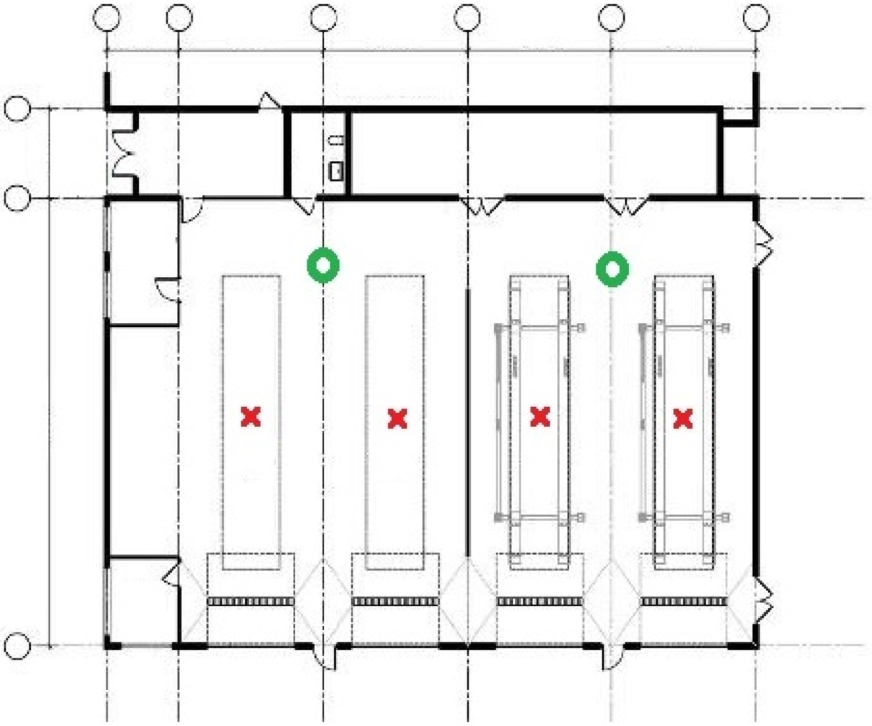
Natural gas and hydrogen garages may be required to install gas detection systems to protect the facility and monitor for a gas releases or leaks. Garages that carry out major repair services (i.e. engine or fuel cell work, painting, body and fender work, welding, and repairs that require draining of the motor vehicle fuel tank) are typically required by code to have a gas detection and alarm system that will alert occupants of the garage with audio and visual signals.

Both natural gas and hydrogen tend to rise to the highest point in ceiling, even if disturbed by air currents or other obstacles. Gas sensors should be placed near the high point of the ceiling, above a service bay where gaseous fueled vehicles are serviced, in a location that is in the line of ventilation or air flow to optimize detection. They should be placed away from corners or walls, so that gas can easily be sampled. A review of the manufacturer's recommended detection area of influence, combined with considering the ceiling, will optimize placement.

The up-front cost of such a system will rely in part on the number of gas detectors, and on-going maintenance costs should be considered. Careful consideration during the specification of the location of individual gas detectors will keep these costs to a minimum. Neither NFPA 30A, NFPA 2, nor IFC specify exactly where gas detectors should be located within a facility.

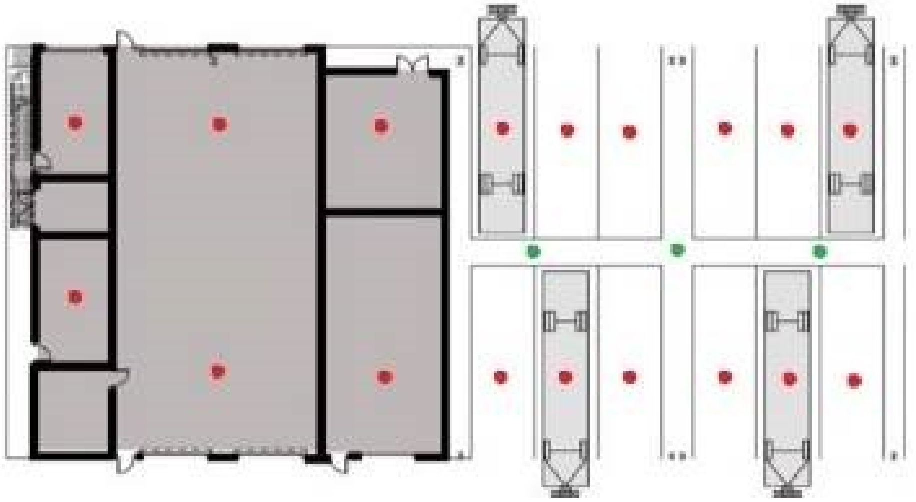
In Between Bays

It is wise to place detectors above but in between individual vehicle service areas, or in between rows of service areas in larger garages. This will Avoid placement next to walls or in corners, but still places sensors approximately above the vehicles while they are in the service area, right in the potential path of migration.



In the Aisle

Placing detectors in between individual service areas allows one detector to protect two service areas, reducing the number of detectors by half, and therefore reducing cost. Placing one detector in the aisle between four individual service areas reduces the number of detectors by four.



This placement also allows for continued cost savings on reduced maintenance. With this configuration, the sensors can be maintained and calibrated without moving or interrupting vehicle service because ladders, scissor lifts, and other means of access can fit in between service areas without relocating vehicles. In addition, the number of gas detectors may be further reduced in adjacent office areas if properly sealing doors are installed, or if positive pressure is used to ensure no gas can enter the area.

When developing a facility that includes methane detectors, the OEM design recommendations should always be reviewed with the OEM technical staff.

Electrical Devices

Electrical wiring, lighting, and electrical appliances all present potential ignition sources in the event of a natural gas release within a maintenance facility. A spark could be a result of an abnormal condition such as a short circuit within a wire conduit or junction box or generated in normal operation of an unprotected electric motor. Either case can be a cause for ignition and must be addressed.

Classified Areas

The area within 18 inches of the underside of the ceiling is of special interest for electrical devices. The applicable codes assume that a plume of gas will gather in this location after a leak has developed from a vehicle. All sources of ignition in this 18 inches zone must be addressed. NFPA 30A defines this area in a natural gas repair facility as a Class I, Division 2 zone. This means all devices located in this area must be Class I, Division 2 certified, or must be removed from the area. In general, it is less expensive to eliminate or relocate non-compliant electrical fixtures than to replace them with more costly certified material.

Figure 36: This conduit is within 18 inches of the ceiling. This is acceptable if the conduit is sealed against gas migration, but may need to be moved if it is a path of gas migration.

Additionally, unsealed electrical conduit may provide a means of gas migration from one portion of the facility to another. Before modifying a maintenance facility to service CNG fuel vehicles, the existing design must be taken into consideration so that gas migration patterns are taken into account.

An alternative option to address this issue is to de-classify the zone by providing ventilation at a rate of at least four air changes per hour across the zone. Continuous air circulation will prevent gas from accumulating in ignitable concentrations. This may be a less expensive option in temperate climates where heating isn't needed.

Shunt Trips

As part of a retrofit process, selected electrical circuits should be modified so that shunt trips are provided on all non-critical electrical circuitry. The control system minimizes potential ignition sources by turning off (i.e. shunt tripping) any potentially spark producing operations (i.e. welding plugs) or equipment and heating appliances within the maintenance facility. It is recommended that the shunt trips be activated only if the system detects a gas concentration of 40% LFL rather than the early-warning 20% LFL. Electric circuits that include the equipment listed below should not be shunt-tripped due to their function during an emergency scenario.

- Ventilation fans
- Emergency lighting
- Gas detection and alarm systems and controls
- Critical data collection or storage functions - computers, servers, etc.
- Any critical load which would cause damage or injury if electrical power was interrupted
- Electrical controls to the overhead doors that automatically open for the purpose of providing makeup air upon activation of the gas detection system

Figure 37: Examples of spark-producing equipment.

Bay Partitioning

Maintenance facilities are often not purpose-built for vehicle service, and if they are, they are likely designed with considerations primarily for petrol fuels - gasoline and diesel. Retrofitting certain garages can be relatively straightforward, while others present unique challenges. Existing facilities may have ceiling geometries or space layouts that would make designing a cost-effective gas detection system difficult. A garage may have numerous paths of migration that would allow natural gas to flow in to adjacent spaces, pits, or to upper floors. A garage may simply be very large and the expense of upgrades would require a considerably long ROI (return on investment).

One potential solution is to partition a part of the maintenance facility - one or more bays - rather than upgrade an entire maintenance facility. Partitioning a section of a garage will reduce the number of gas detectors required, reduce the number of non-explosion proof electrical devices that need to be relocated, and reduce the amount of ventilation required in the modified area.

One solution that exists today is a vapor-tight methane barrier that can be used to isolate the bays that need to be upgraded. Clean Energy's Facility Modification division has developed the NGV Easy Bay™. Custom fabricated panels are scalable to accommodate a single bay isolation project or can be used to divide a large building into multiple bays for servicing or storing vehicles. There is a retractable option for convenient storage, and the panels can be relocated to expand an existing NGV service area. Once installed, the area can still service gasoline and diesel vehicles, in addition to natural gas vehicles.

Training

Facility modifications to improve safety in alternative fuel garages require considerable effort, and this effort will be wasted if the personnel who work in the facility are not generally aware of their role in safety. Physical modifications to the maintenance facility will help mitigate any potential hazard from adding CNG and LNG vehicles to facility operations, but proper training of personnel is critical to maintaining a safe work environment.

Employees, contractors, and visitors to the facility each need specific guidance on how to respond to emergencies. For new employees, gas properties, risk mitigation basics, and specific aspects of any installed alarm systems should be covered. For permanent employees, consider holding ongoing training as often as gas detection systems are calibrated – this is typically every six months. This training should serve as a refresher, and doesn't need to include every aspect.

Consider having contractors and visitors go through an abbreviated training as part of an orientation program or a welcome presentation. This should at minimum cover evacuation procedures and guide them against doing anything that actively works against safety procedures. Consider teaming visitors with a trusted employee that can guide them in case of emergency.

Recommended training topics include:

- The physical properties of compressed or liquefied natural gas, propane, or hydrogen
- Hazards associated with compressed or liquefied natural gas, propane, or hydrogen
- Review gas detection alarm scenarios and what actions should be taken in each case
- Procedure if natural gas odorant is smelled and the alarm system hasn't activated
- Why it is important to follow safety procedures and not circumvent safety equipment
- Building evacuation drills or training in conjunction with alarm scenario.
- First responder interaction training
- Procedures for after an emergency situation
- Training for maintenance of gas detection system equipment
- General OEM guidelines for the onboard fuel storage system and engine fueling components for alternative fuel vehicles

You may also consider:

- CNG cylinder inspection certification of at least one maintenance technician
- ASE certification of CNG vehicle technicians (F1 Test)
- OEM-provided or OEM-certified instruction for maintenance procedures for the onboard fuel storage system and engine fueling components for alternative fuel vehicles

Multiple Fuels

Many garages that service gasoline, diesel, or propane vehicles may be considering an expansion or modification of their facilities to include natural gas vehicles as well. Those upgrading a garage for natural gas may want to plan ahead to be able to meet requirements for gasoline, diesel, propane, or hydrogen. In either situation, multiple requirements must be met.

Because natural gas and hydrogen will rise, while propane and liquid fuel vapors fall, both the area near the ceiling and the area near the floor may be subject to Class I Division 2 electrical classification. Additionally, ventilation intakes should not be located within 18 inches of the ceiling or the floor. Code compliant heating appliances will be necessary in both areas, and a gas detection system may be deemed necessary per the local code officials.

For more details on how to comply with code requirements for propane or natural gas, please see the information available at AltFuelGarage.org.

References

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Natural Gas Vehicles For America (NGVA). (2017). *Guideline for Determining the Modifications Required for Natural Gas Vehicle Maintenance Facilities.*

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Appendix A: Additional Codes

Primary Codes include:

- International Building Code
- International Electrical Code
- International Mechanical Code
- National Building Code
- National Electrical Code
- National Fire Code
- National Mechanical Code
- NFPA 30A – Code for Motor Fuel Dispensing Facilities and Repair Garages
- NFPA 52 – Vehicular Gaseous Fuel Systems Code
- NFPA 88A – Standard for Parking Structures

These documents contain similar (or in many cases identical) language. In addition to the documents listed above, many states and local authorities have their own codes. It is essential to recognize that all of these documents provide valid and safe methods for facility design, but it is the AHJ that has the final say in which are used. The codes summarized in this report can be found at:

http://www.nfpa.org/aboutthecodes/list_of_codes_and_standards.asp?cookie%5Ftest=1 and http://shop.iccsafe.org/codes/2015-international-codes-and-references.html

Modification Category	Code References
Ventilation	IMC (2015) Table 403.3.1.1; IFC (2015) 2311.7.1, 2311.1.1, 2311.7.1.2; NFPA 30A (2015) 7.5.1, 7.5.2,7.5.3, 7.5.4, 7.4.7.2,7.4.7.3
Ventilation in Pits	IFC (2015) 2311.4; NFPA 30A (2015) 7.4.5.4
Gas Detection	IFC (2015) 2311.7.2,2311.7.2.1, 2311.7.2.2, 2311.7.2.3; NFPA 30A (2015) 7.4.7,7.4.7.1, 7.4.7.2, 7.4.7.3, 7.4.7.4
Sources of Ignition	NFPA 30A (2015) 7.6.6
Electrical Classification	NFPA 30A (2015) 8.2.1
Preparation of vehicles for Maintenance	IFC (2015) 2311.5

Table 2: Properties of Alternative Fuels

Compound	**Formula**	**Density (lb/ft^3) Gases @ STP**	**Auto-Ignition Temperature (°F)**	**Lower Flammability Limit (LFL) %**	**Upper Flammability Limit (UFL) %**
CNG (Methane)	CH_4 (majority)	0.0447	1,004	5.3	15.0
Propane	C_3H_8	0.1175	850-950	2.2	9.5
Gasoline	C_8H_{18}	0.287	495	1.4	7.6
Diesel	-	>0.3825	600	1.0	6.0
Hydrogen	H_2	0.0056	1,050-1,080	4.1	74.00
Air	-	0.0806	-	-	-

Appendix B: 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 gasses with the primary constituent being methane.
- 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 º 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 -260ºF 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 a 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 º F and dissipates like compressed natural gas.

Appendix C: Review of codes for Methane Detection

Subject	**Liquid Fuels**	**CNG**	**LNG**
Gas Detection	**IFC and NFPA 30A –**No requirements	**IFC and NFPA 30A –** Have no requirements for gas detection for odorized CNG or odorized LCNG.	**IFC 2311.7.2, 2311.7.2.1, 2311.7.2.2, and 2311.7.2.3** Require an approved gas detection system for major repair garages for LNG vehicles where (work is done on the fuel system and the work may require use open flames or welding) **NFPA 30A 7.4.7,7.4.7.1, 7.4.7.2, 7.4.7.3 and 7.7.4.4** The requirements are essentially the same in NFPA except that it is limited to facilities where "repair of vehicle engine fuel systems" takes place

Appendix D: Review of Codes for Heating Systems

Subject	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 – please see document	**IFC** – No specific requirements **NFPA30A 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.	**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 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.

Appendix E: Review of Codes for Ventilation

Subject	Liquid Fuels	CNG	LNG
Ventilation – General	**NFPA 30A 7.5.1, 7.5.2, 7.5.3 and 7.5.4** Provides for ventilation systems serving a fuel dispensing area inside a building or a repair garage. Fuel dispensing is not part of this guideline. **IFC –** No specific requirements for liquid fuels but does reference the IBC for general ventilation requirements. **IMC 2012 Table 403.1.1** Has general ventilation requirements for all repair garages of 0.75 cfm per sqft of floor area. **NFPA 88A 5.3.2** Has a ventilation requirement for enclosed parking garages during hours of operation set at 1cfm per sqft of floor area. 2	**NFPA 30A – No specific requirements for CNG** **IFC- 2311.7.1, 2311.7.1.1 and 2311.7.1.2** – Require approved mechanical ventilation systems 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) Work is not performed on the fuel system and is limited to exchange of parts and maintenance requiring no open flame or welding. (2) Repair garages with AHJ approved natural ventilation.[2]	**NFPA 30A – 7.4.7.2 & 7.4.7.3** the operation and failure of gas detection systems be interlocked with an existing mechanical ventilation system for garages repairing LNG engine fuel systems. **IFC- 2311.7.1, 2311.7.1.1 and 2311.7.1.2** –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) Work is not performed on the fuel system and is limited to exchange of parts and maintenance requiring no open flame or welding. (2) Repair garages with AHJ approved natural ventilation.[2]

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[2] There seems to be a discrepancy between NFPA 30A and IFC in that: NFPA 30A 7.5.1 – 7.5.4 only requires ventilation for fuel dispensing areas within the maintenance facility, where IFC 2211.7.1 – 2211.7.1.2 uses similar language for CNG repair facilities assuming that indoor fueling will always be part of the repair facility even to the point of requiring the **"system shall shut down the fueling system"** if the ventilation fails.

Subject	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 to 1 cfm/sqft respectively for repair garages having a pit or basement where flammable vapors may accumulate.	**IFC and NFPA 30A –** No requirements specific to CNG	**IFC and NFPA 30A –** No requirements specific to LNG

Appendix F: Review of Codes for Electrical Installations

Subject	**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 8.2.1*** In major repair garages where CNG vehicles are repaired or stored, the area within 18 in. of the ceiling shall be designated a Class I, Division 2 hazardous location. Exception: This requirement shall not apply where the ventilation rate is not less than 4 air changes per hour. **Note** 3 The assumption made by the code committee, as stated in Annex A.8.2.1, was that the release of CNG in the facility would be equal to 150% of the largest CNG cylinder. Since the assumption defines the hazard expected, any change in this assumption may result in future code changes.	**IFC Section 2311 –** No specific requirements. **NFPA 30A 8.2.1*** Only covers CNG but would expect the AHJ to extend the requirement to LNG as well. See note in CNG column on assumption made for extent of hazard.