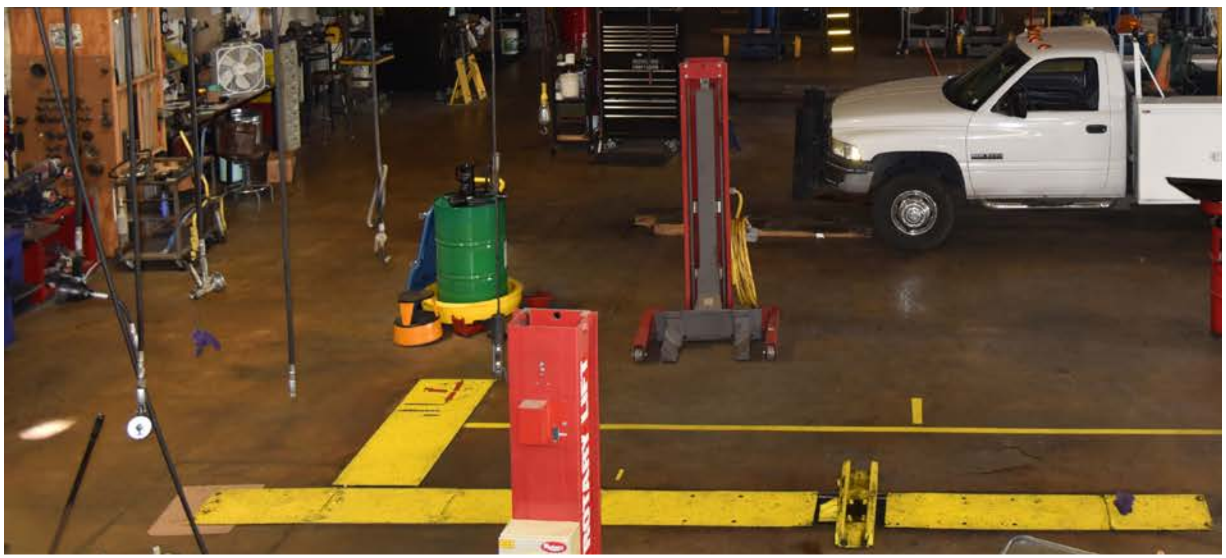
TRAINING MANUAL

September 28, 2018

PROPANE

Liquefied Petroleum Gas
(LPG, LP-Gas or Propane)

Vehicle Maintenance and Storage Garage Modifications: Requirements and Best Practices



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CleanFuelsOhio

Clean Cities
U.S. Department of Energy

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Acronyms

Term:	Definition:
ACH	Air Changes per Hour
AHJ	Authority Having Jurisdiction (the regulatory body with the authority to mandate design)
CNG	Compressed Natural Gas
CT	Current Transformer (used to monitor the current on an AC motor)
FACP	Fire Alarm Control Panel—this is the building fire panel
H_2	or GH_2-Gaseous Hydrogen
HVAC	Heating Ventilation and Air Conditioning
IFC	International Fire Code
IMC	International Mechanical Code
IR	Infrared
LEL or LFL	Lower Explosive Limit—also known as LFL or Lower Flammability Limit
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas—commonly called Propane
MAU	Make-up Air Unit—a fan and heat source for heating a building

Term:	Definition:
NEC	National Electrical Code (NFPA 70)
NFPA	National Fire Protection Association
NG	Natural Gas
NGV	Natural Gas for Vehicles or Natural Gas Vehicle (depending on context)
PM	Preventative Maintenance
PRD	Pressure Relief Device—a device mounted on vehicle CNG fuel tanks to relieve pressure inside a tank when exposed to an external fire. This device is thermally, not pressure, activated.
PSI	Pounds per Square Inch
PSIG	Pounds per Square Inch Gauge (atmospheric pressure is 0 psig)
RNG	Renewable Natural Gas—gas produced by anaerobic digestion of biomass material
SCF	Standard Cubic Feet (the volume of gas within one cubic foot at atmospheric pressure and 60°F)
TEFC	Totally Enclosed Fan Cooled electric motor
UEL or UFL	Upper Explosive Limit—also known as UFL or Upper Flammability Limit

Table of Contents

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SECTION 1

General

Care in the Application of this Document

This document is focused on the upgrades that are required and recommended with the introduction of gaseous-fueled vehicles into a conventional-fuel vehicle maintenance or storage/parking garage. This document is focused on non-residential applications. Building upgrade costs and scope are much more variable than fueling station costs and can approach the cost of fueling facilities. Upgrade costs are influenced by the type, age, condition and size of the structure, as well as the local climate and fleet operating requirements. The potential high cost and variability make it essential that Owners, Consultants, and AHJs have a thorough understanding of code requirements, best practices, and what adds safety, not unnecessary cost, to an upgrade.

There may be additional requirements not outlined herein due to the use of other fuels in the facility. The reader and fleet Owner shall note that their facility may not be fully compliant with current conventional-fuel codes and thus there may be additional upgrades not directly related to gaseous fuels that may be required to ensure a fully code-compliant facility.

Given that LPG codes require little-to-no code-mandated upgrades over and above conventional fuels, it is critical that garages receiving LPG vehicles be compliant with current conventional-fuel garage codes.

This document is not a comprehensive design specification. Rather, it is intended to provide the reader with an overview of the requirements and industry best practice typically implemented in today's gaseous-fuel vehicle garages.

The information herein describes the most common upgrades implemented in gaseous-fuel vehicle garages. Best practices often lead codes by several years, so it is advisable to follow both current codes and best practices. The upgrade requirements herein may not be exhaustive for all facilities. Some facilities may require additional or different upgrades to ensure safety. Every garage and fleet are different, so it is incumbent on the reader and the Owner of any facility to secure experienced professional assistance to determine what upgrades are required to ensure the safety of their project.

The applicable codes for garage upgrades are referenced herein and paraphrased to assist the reader in understanding their application. The reader, designer, and facility Owner are required to purchase original codes and read the full text to gain a full understanding of the code requirements and any nuance that may affect their garage upgrade project. It should also be noted that the recommendations contained herein are based on current codes; however, in some cases codes do not address all safety issues adequately. The reader shall ensure that any code updates are incorporated into their project.

The recommendations contained herein apply to the areas of the buildings that have vehicle occupancy only. This document does not include any recommendations on fueling station design or on indoor fueling and does not include facilities where indoor fueling occurs.

The Purpose of Upgrades

Why We Upgrade Facilities

Upgrades are applied to garage facilities not because gaseous fuels are less safe than conventional fuels, but because they behave differently than conventional fuels. A vapor plume from a gaseous-fuel leak may migrate to different locations in a building than a conventional liquid fuel spill, so it is important to understand these differences and manage the risks as we would with conventional fuels. Flammability requires three conditions: fuel, air, and an ignition source. The upgrades required and recommended herein are intended to reduce the possibility that these three elements occur simultaneously in the event of an accidental release of gas. It is not possible to remove the air, but it is possible to reduce the potential ignition sources and limit the amount of time and control the location that fuel is present. Upgrades are intended to provide a safe working environment while preserving the functionality of the facility.

Workarounds

Some fleet Owners propose to use workarounds rather than upgrading their facility. Proposals include:

1. The easiest and safest workaround is to contract to a maintenance provider who has already upgraded their facility. All major, and perhaps minor, repairs can be done at the third-party location, and vehicles can be parked outdoors at the fleet garage.
2. When the maintenance need is short term, or the number of gaseous-fuel vehicles is limited, some Owners manually shut off and lock out heating equipment, open all doors, and activate all fans when gaseous vehicles are in the garage. This approach may provide a safe short-term answer to this need (depending on the ventilation in the garage); however, the lockout requirement must be rigidly enforced. This approach is more practical in warm climates than cold. This is not a long-term alternative to upgrading the garage.
3. Closing the tank valves every time the vehicle enters the garage is another proposal, but it will be a tedious practice. This is an Owner recommendation when the vehicle is in the garage overnight. Note that this does not ensure that a release will not happen.
4. Defueling (also referred to as tank evacuation) is a practice that is impractical for normal maintenance operations but is required for certain repairs. Defueling should be used only when this is the only safe way to work on a vehicle

The Purpose of Upgrades

Why are Upgrades Alone Not Sufficient?

The Author of this document has extensive experience investigating the root cause of a number of gaseous vehicle, station and facility incidents that have occurred over the past three decades. It is the Author's observation that most incidents occur with three contributing factors (in random order):

1. A component manufacturing or design defect.
2. Insufficient or ineffective maintenance of equipment.
3. User error.

Training

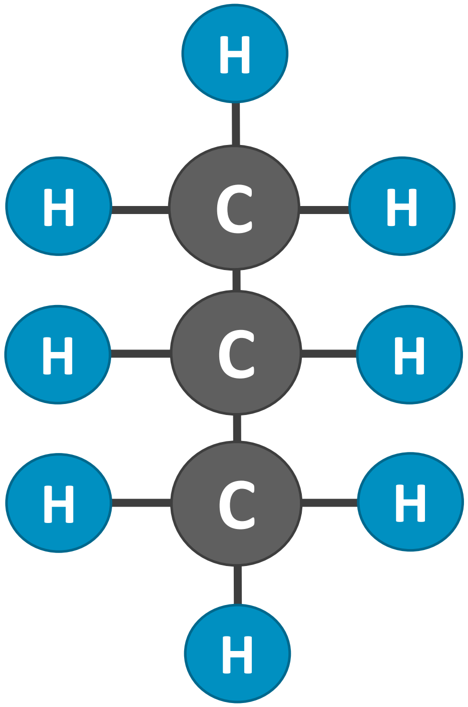
User error is often the largest single contributor to the likelihood of an incident, and in many ways, it is the easiest to control. Fleet Owners can and should ensure that personnel that interface their fleet's operations be appropriately trained then drilled to reinforce the training. Automatic and inherent safety features that are required or recommended to garage facilities will certainly enhance the safety of the facility and its users, but it is critical to understand that no level of upgrade can prevent an incident if personnel lack proper training. Employers have confidence that their staff will use common sense when working around their facility; however, common sense comes from a thorough understanding of the risks and the likely outcome of the employee's actions—training and experience provide this understanding.

Fleets must develop detailed Standard Operating Procedures (often called SOPs) which will be used as the basis for the training and drilling mentioned above. These procedures must address all credible operational risk scenarios related to the building, vehicle, fueling and defueling. The operating procedures provided later in this manual are abbreviated to a single sentence to provide a sample of the issues fleets must address—the procedures provided herein are not sufficiently detailed to meet this need. Operating Procedures must also be tailored to the specific vehicles and facility in which the fleet operates.

SECTION 2

Gas Fundamentals

Properties of Propane/Butane



Propane
C_3H_8
C = Carbon
H = Hydrogen

	Property	Value
1	Constituents	HD-5 Specification requires a minimum 90% Propane (C_3H_8) and less than 2.5% Butane (C_4H_{10}). Maximum propylene is 5%.
2	State	Gaseous at atmospheric pressure, liquid when pressurized in vehicle tank.
3	Specific Gravity (weight vs. air)	Approximately 1.5 (150 percent of weight of air at same temperature and pressure)— LPG settles in air of same temperature.
4	Flash Point (temperature where fuel vaporizes from liquid form)	Approximately -100° to -150°Fahrenheit.
5	Autoignition temperature	Approximately 850° to 950°Fahrenheit.
6	Flame color	Yellow-orange to blue.
7	Flammability range in air at atmospheric pressure	Lower Flammability Limit (LFL)~2.0 percent. Upper Flammability Limit (UFL)~9.6 percent.
8	Odor	LPG is odorless.
9	Toxicity	Non-toxic, but asphyxiant in sufficient concentration.
10	Water Content	Slightly toxic and asphyxiant in sufficient concentration. LPG will cause freeze burns if exposed to skin.
11	Source	Domestic fossil fuel that is a byproduct of oil and gas production and oil refining.

Properties of Liquefied Petroleum Gas (LPG)

	Property	Value
1	State	Liquid in the fueling station and vehicle tank. Gaseous on the vehicle downstream of the tank.
2	Nominal Pressure in Tank	312 psig tank relief valve setting but fill pressure is typically 200 to 250 psig. Approximately 270 times the density of Propane at atmospheric pressure.
3	Density	Approximately 4.24 pounds per gallon.
4	Energy Comparison to Gasoline	1 gallon of LPG=0.73 gallon of gasoline.
5	Odor	Odorless, so mercaptan odorant is added at a level that the average person can detect at 1/5th of the LFL.
6	Pump Octane Number	~105

LPG Vehicle Tank

Properties of Liquefied Petroleum Gas (LPG)

	Value	Description
Health Hazard	2	Can cause temporary incapacitation or residual injury
Flammability Hazard	4	Will vaporize and readily burn at normal temperatures
Instability Hazard	0	Stable
Special Hazard		No Special Hazard

NFPA Placard

LPG Leaks and Releases

Leak Behavior

Propane is heavier than air and will tend to find the low point of a floor space, including flowing into service pits. The description below describes general leak behavior, but a leak plume can disperse in any direction, including upward, if sufficient air turbulence and flow are present.

Slow Leak

Under a slow leak scenario, such as a fitting leak that is not audible, a liquid leak should vaporize before a liquid pool can form. A properly ventilated LPG garage should dilute and exhaust the leak without risk of incident. In fact, a very small leak will likely not be detected by a building combustible gas detection system (if one is provided). For this reason, it is good practice to check for vehicle leaks at Planned Maintenance (PM) intervals. A vehicle tank relief valve release should also fall into this category as there will be a small "burb" of gas that will reduce the pressure and the relief valve will reseal.

Fast Leak

Under a fast leak scenario, such as a serious fitting leak or component failure, the LPG will have a jet force and will release in whatever direction it is pointed. If it is a liquid leak, the liquid will fall to the floor and pool until it is fully vaporized (which happens quickly). The vaporized liquid will be heavier than the surrounding air and will tend to hang by the floor spreading into a large thin plume and find any low spots.

For this reason, combustible gas detection can be a helpful safety measure (although not a code requirement) in an LPG vehicle garage.

LPG Leaks and Releases

Leak Behavior

Propane is heavier than air and will tend to stay near the floor or find low areas to collect.

Fast Leak—Phase 1

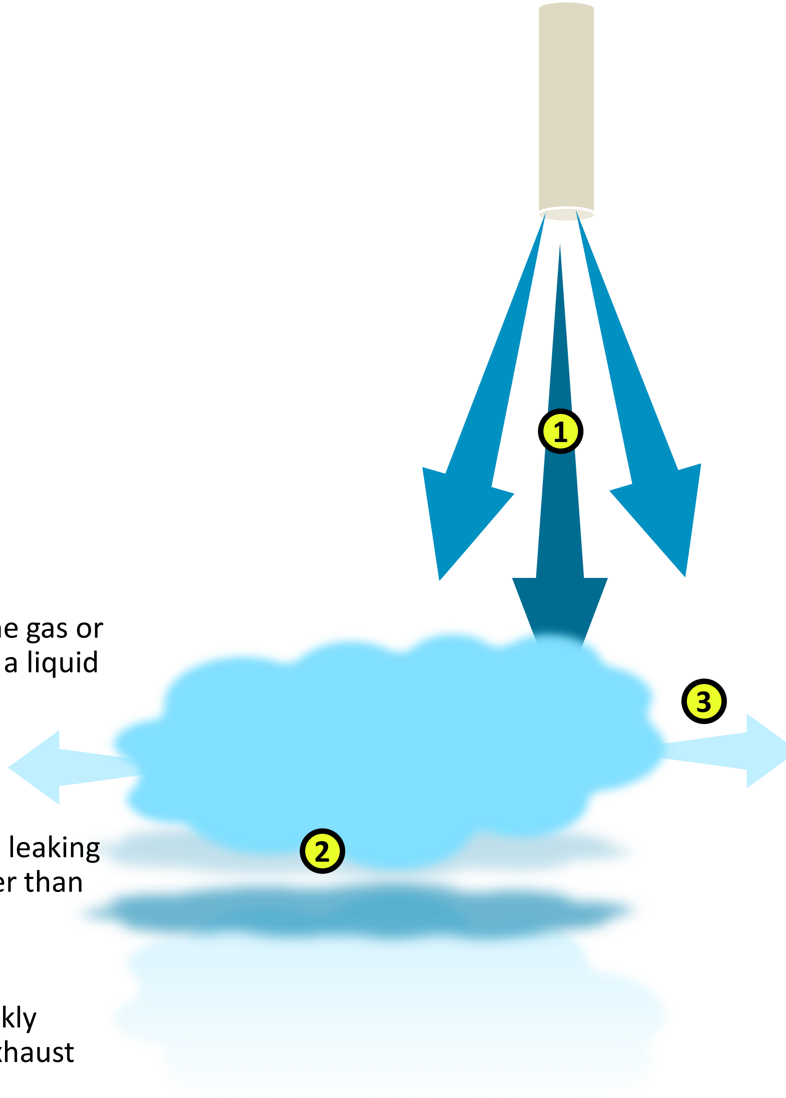
Under a fast leak scenario, such as a serious fitting leak or component failure, the gas or liquid will have a jet force and will release in whatever direction it is pointed. In a liquid leak scenario, liquid will release downward. (1).

Fast Leak—Phases 2 and 3

Liquid will pool below the leak if sufficient volume is leaked in a short time. Gas leaking from an LPG system is vaporizing from a liquid state and the vapor will be heavier than air. This cold gas plume will tend to remain at the floor (2).

As time passes it will spread and find low areas to collect (3).

For this reason, LPG garages include exhaust in pits and near the floor. This quickly vaporizes, dilutes, and pulls a gas plume to the detection (if so equipped) and exhaust systems.



LPG Leaks and Releases

Flammable Range

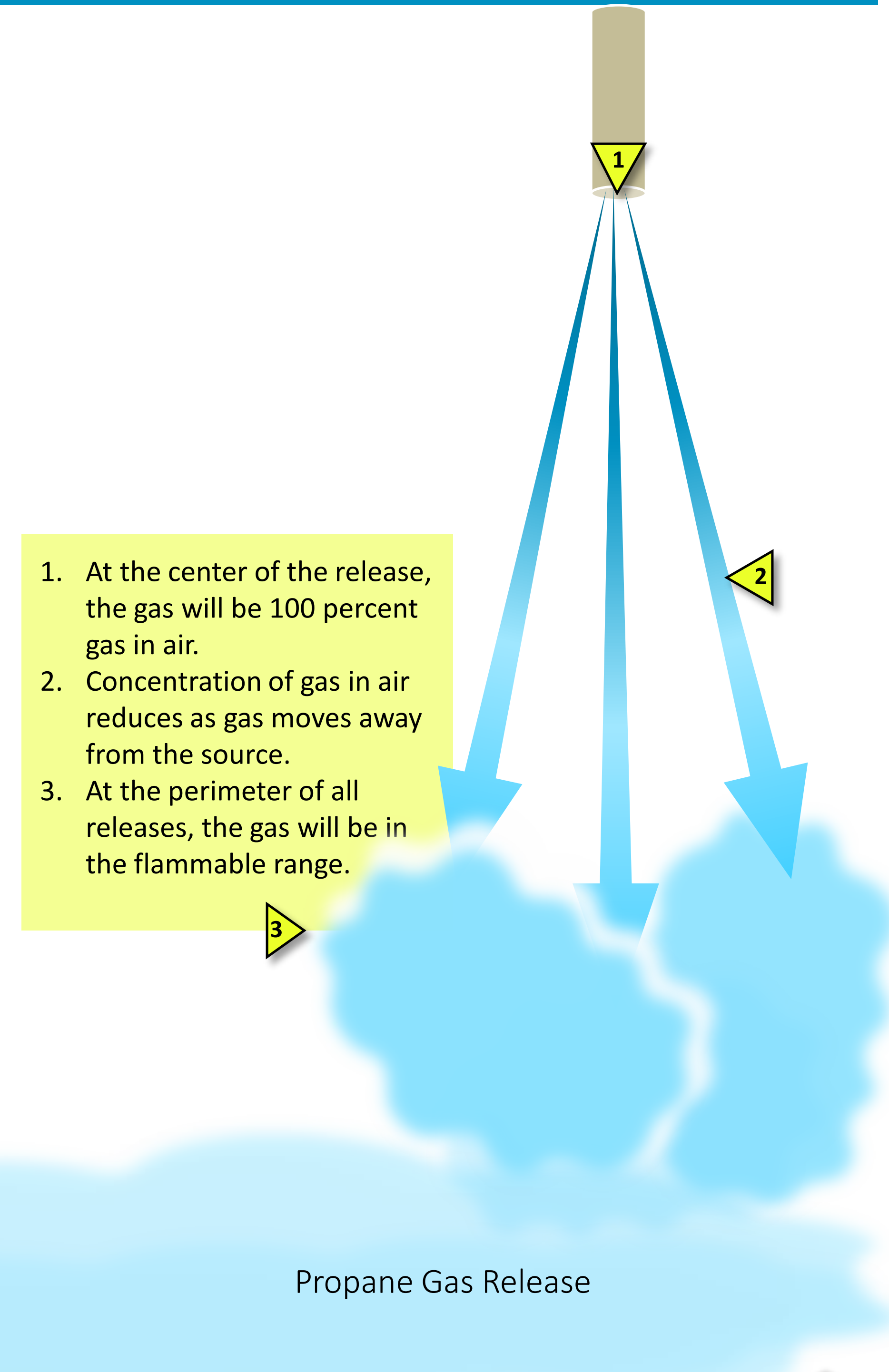
The comments below apply to vaporized gas.

It is well understood that the flammable range of propane is between 2 percent (LFL) and 10 percent (UFL) in air by volume. Below this range, the mixture is too lean to support combustion, and above this range the mixture is too rich to support combustion. This narrow range of flammability is a characteristic that greatly increases the safety related to the use of propane. There is a common misperception that if very high air changes are provided in a garage, then a gas release will be diluted and kept below the LFL.

The fallacy of this belief is that the concentration is 100 percent propane at the source and, at some point outside the leak area the concentration of gas in air is 0 percent, therefore; by definition, there is some point at which a flammable mixture exists.

Codes focus on the 18 inches at the floor for LPG and conventional liquid fuels as these fuels and their associated vapor plume will tend to stratify in this area.

Since air that is distant from the release will be at 0 percent gas in air concentration, by definition, a flammable mixture will <u>always</u> exist in the presence of a leak.



Propane Gas Release

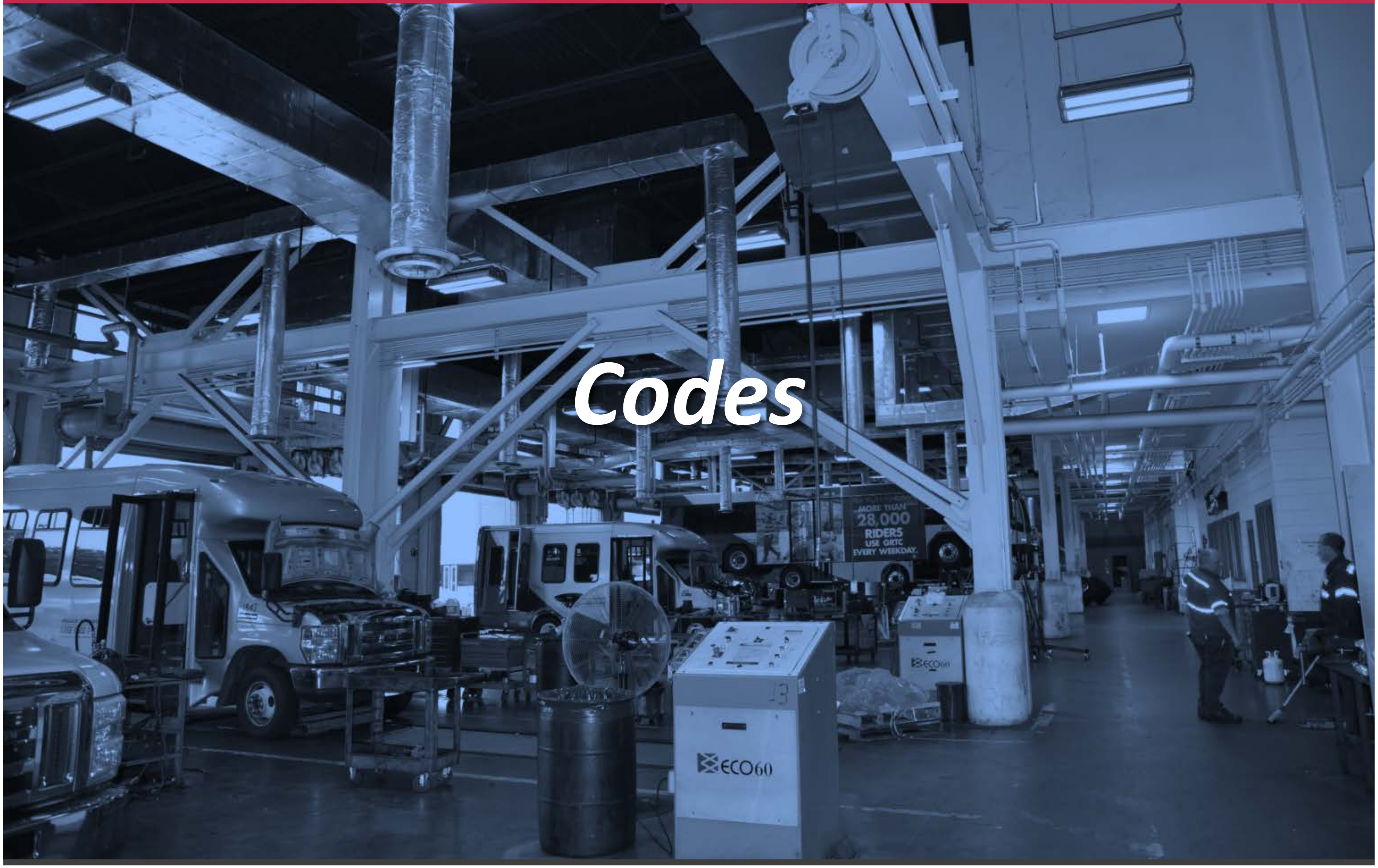
LPG Leaks and Releases

Potential Causes of a Release

Releases can be caused by a number of personnel or equipment failures. The most common releases are generally small and may result from a manufacturing defect or wear and tear resulting in a fitting that becomes loosened. A common small leak is the vehicle tank relief valve, which is designed to relieve pressure due to vaporization in the tank. Under certain circumstances, excess pressure may accumulate if the vehicle has not been driven for several days. This pressure is intentionally relieved by the relief valve, which will reseal after the excess pressure is relieved.

Fast leaks are very unusual and would result from a failure of a pressure connection, component, or from human error during repair.

SECTION 3



Codes

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Codes that Dictate the Minimum Requirements

Applicability

Users of this manual need to determine which national codes and regulations apply in their jurisdiction and whether any state or local codes and regulations will be referenced. In some cases, different codes may contradict each other or require more or less stringent requirements than other applicable codes; however, users will need to comply with the most stringent requirements of all applicable codes. While users will most likely need to comply with the most current version of the codes, some jurisdictions may be enforcing an earlier version—this needs to be determined and addressed. As previously noted, in a fleet where more than one fuel is in use, the facility must meet the code requirements for all fuels.

References in this Document

This document will reference only commonly used national codes. These references and a paraphrased summary of code requirements will be provided in the section applicable to each code section. For example, code references to heating equipment will be in the heating section of this manual, and code references to electrical requirements will be in the electrical section. Users of this manual are strongly encouraged to purchase the full versions of each of the codes referenced in this manual, and to review the full text of the document that pertains to their project. Code requirements that are duplicated between NFPA 30A, 88A and 70 will be referenced to the code most applicable.

National codes do not impose additional requirements for garages servicing LPG vehicles over those servicing conventional fuel vehicles. For this reason, it is incumbent on the designer and Owner to ensure that the garage facility is fully compliant with all current conventional-fuel garage code requirements. Unlike the other manuals in this series that focus on additional code requirements for gaseous-fuel vehicle garages, this manual will provide guidance on the design of a conventional-fuel vehicle garage, which by extension also applies to LPG-vehicle garages. This manual will also provide best practice upgrades that are unique to LPG, although not code requirements. This manual does not include the requirements for garages that service propane tanker/propane delivery vehicles, as this is an unusual and specialized application.

Codes that Dictate the Minimum Requirements

International Code Council (see state versions of these national codes)

International Building Code (IBC) (http://shop.iccsafe.org/codes/2018-international-codes-and-references/2018-international-building-code-and-references.html)

International Fire Code (IFC) (http://shop.iccsafe.org/codes/2018-international-codes-and-references/2018-international-fire-code-and-references.html) (covers requirements for HVAC, gas detection, defueling, other issues—as applicable to LPG)

International Mechanical Code (IMC) (http://shop.iccsafe.org/codes/2018-international-codes-and-references/2018-international-mechanical-code.html) (covers requirements for HVAC, gas detection—as applicable to LPG)

National Fire Protection Association (NFPA)

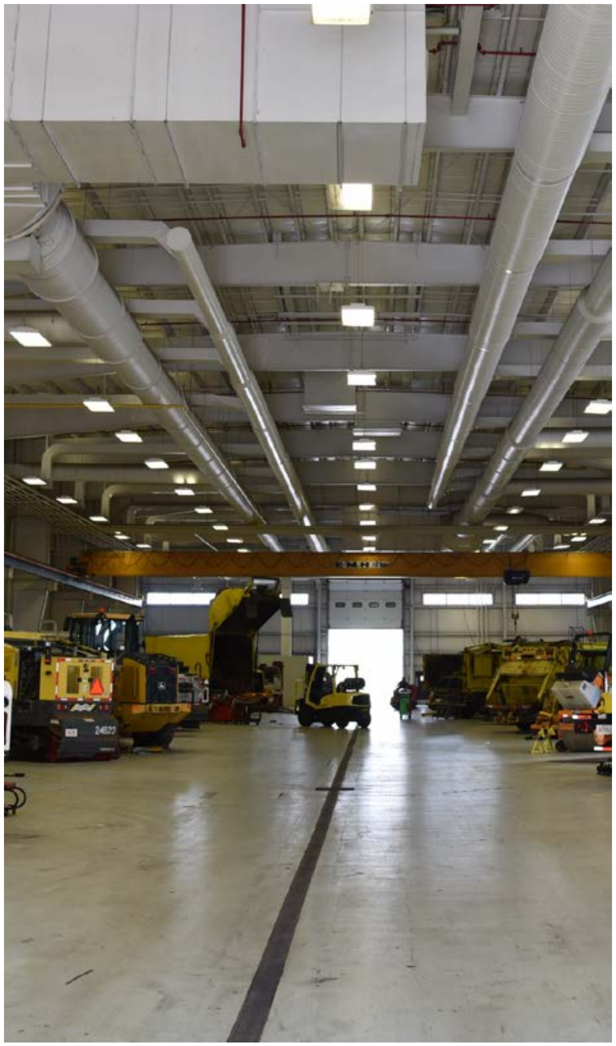
NFPA 30A: Code for Motor Fuel Dispensing Facilities and Repair Garages (https://catalog.nfpa.org/NFPA-30A-Code-for-Motor-Fuel-Dispensing-Facilities-and-Repair-Garages-C245.aspx) (covers requirements for HVAC, gas detection, electrical classification, other issues—as applicable to LPG)

NFPA 70: National Electrical Code (NEC) (https://catalog.nfpa.org/NFPA-70-National-Electrical-Code-C3315.aspx) (Covers all wiring practices including electrical requirements in hazardous locations)

NFPA 88A: Standard for Parking Structures (https://catalog.nfpa.org/NFPA-88A-Standard-for-Parking-Structures-P1213.aspx) (covers ventilation, other requirements)

NFPA 58: Liquefied Petroleum Gas Code (https://catalog.nfpa.org/NFPA-58-Liquefied-Petroleum-Gas-Code-P1187.aspx?icid=D729) (LPG Station related—does not address vehicle maintenance or storage facilities for LPG vehicles except garages that service propane tanker or delivery vehicles. This is outside of the scope of this manual.)

Codes that Dictate the Minimum Requirements



Legacy Codes and Code Migration

This manual was assembled at a time when three major codes affecting the content of the manual were released as new 2018 editions with significant changes. Notably, the IFC delegating most of the gas detection system design requirements to NFPA 30A. All three of the 2018 codes also made several minor changes and the 2018 IFC introduced some operational requirements related to service of lighter-than-air fuel vehicles.

It is likely that some jurisdictions will not yet have adopted the newest edition of these codes. To address this situation, this manual has included legacy requirements from past codes if these did not flow through to new editions. Readers are cautioned to look at the year that precedes the code references herein to ensure that the reference is applicable to their project. In some cases, such as with gas detection, there were code requirements that were dropped when code delegation occurred—these requirements are included herein as best practices. Readers are encouraged to contact code officials early in the project design phase to ascertain which codes and versions will be used in permitting the project. It is advantageous to continue this dialogue with the AHJ throughout the design phase.

Types of Garages

Defined in 2018 NFPA 30A— Code for Motor Fuel Dispensing Facilities and Repair Garages

Major Repairs: (Section 3.3.12.1)

1. Engine overhauls
2. Painting, body and fender work (and other "hot work"—cutting and grinding)
3. Repairs that require draining of the motor vehicle fuel tank (any fuel system work)

Minor Repairs: (Section 3.3.12.2)

1. Minor automotive maintenance work
2. Engine tune-ups
3. Fluid changes (e.g., oil, antifreeze, transmission fluid, brake fluid, air conditioning refrigerants, etc.)
4. Brake repairs
5. Tire rotation, repair, and replacement

The upgrade requirements of a "minor repair" garage are less extensive; however, given that most garages do some work that would be considered "major repair" it is best practice to consider the facility to be "major repair," as this gives the fleet operator more flexibility in the work performed.

Defined in NFPA 88A (2015) – Standard for Parking Structures

Scope: (Section 1.1)

1. Applies to open and enclosed parking structures.

It is best practice to apply the ventilation requirements of NFPA 88A as a minimum standard to all parking and major and minor repair maintenance garages as vehicles will be left unattended in most maintenance garages. Major repair garages have additional, higher ventilation requirements defined in NFPA 30A (in lieu of electrical upgrade) and the IMC that apply under certain conditions.

Buildings and Systems

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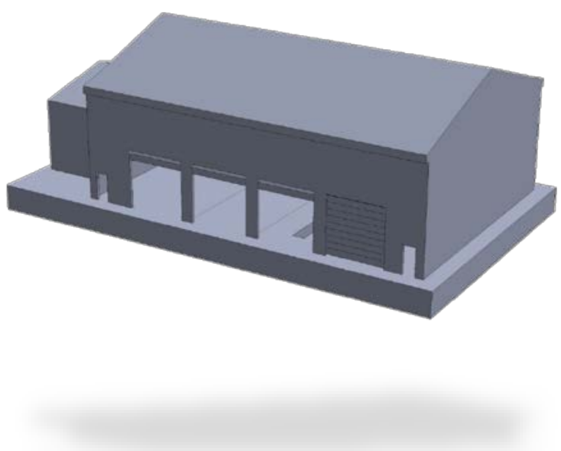
Building Geometry

Roof Structure

In lighter-than-air fuel garages, the roof structure plays a significant role in the design of upgrades and their subsequent cost. In conventional-fuel and LPG-vehicle garages, the roof plays essentially no role in the design of building upgrades and, therefore, there is little difference in upgrade cost between these building types for conventional fuels and LPG. Another issue that differs from CNG and GH_2 is that service pits are hazardous areas that require special electrical equipment and ventilation.

Gable Roof with Single or Double Pitch



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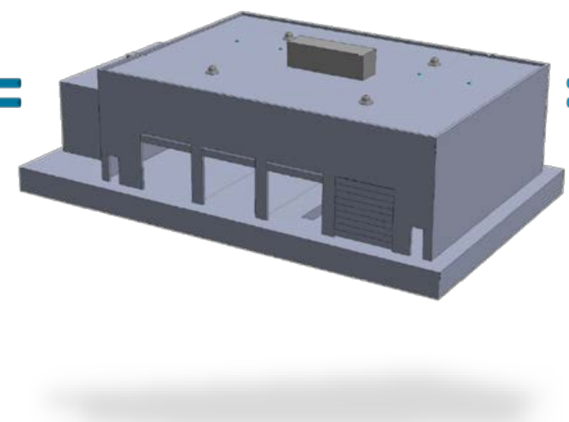
Flat Roof with Open-Web or Bar-Joist Structure



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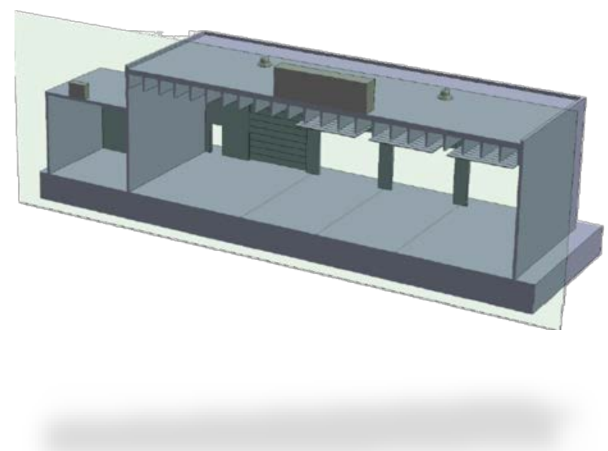
Flat Roof with Precast T-Beams



Ventilation Amount and Location

Purpose and Importance of Ventilation

Ventilation is the single most important factor in the design of upgrades for a gaseous-fuel vehicle garage, and in many cases, it is also the costliest. Properly designed and operated ventilation systems will manage the path of an accidental gas release by pushing and pulling the gas plume (cloud) quickly toward an exhaust point. Prior to exhausting the gas, the concentration of gas will be diluted by the continuous introduction of fresh air.

Many conventional-fuel garages utilize a system of exhausting at the floor and introducing fresh (make-up) air at the ceiling. This approach will also work for LPG garages, although from a comfort standpoint introduction of the warm air near the personnel and floor-level exhaust is advantageous. A well-designed ventilation system will improve indoor air quality and employee comfort.

All ventilation in a vehicle garage must be non-recirculating. This requires 100 percent fresh air to ensure that any exhausted gas/air mixture is not reintroduced into the building interior. The use of systems that intentionally recirculate a portion of the exhaust air to save on heating costs is not acceptable. In cold climates, designers should consider the use of heat exchangers to recover heat from the exhaust air.

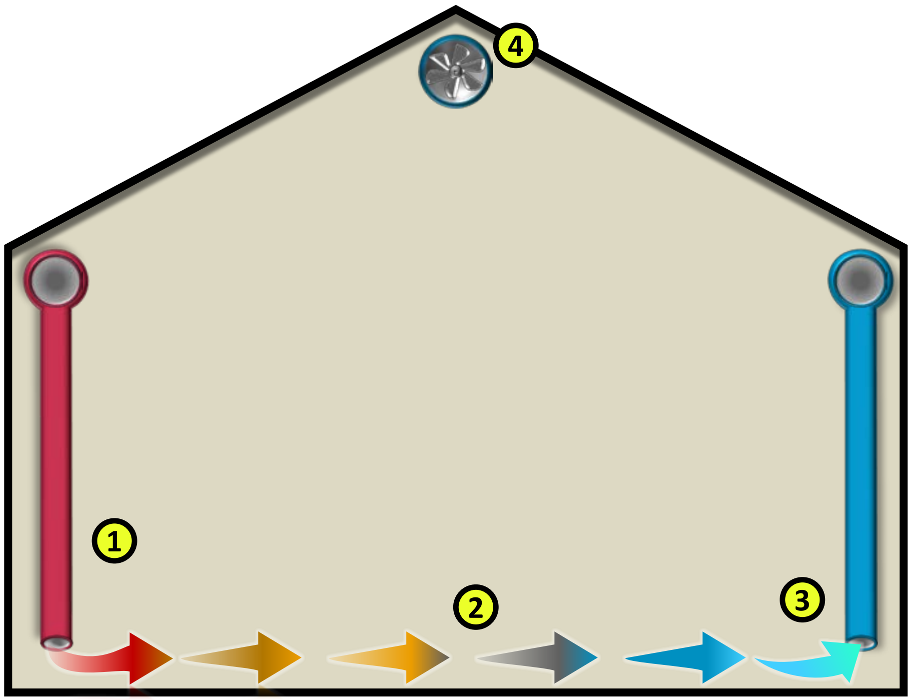
It is also good practice to exhaust at a rate that is 0.5 to 1.0 ACH more than the make-up air rate. This will create a slightly negative pressure in the garage space, ensuring that a gas release will not be “pushed” into adjacent untreated spaces.

Baseline and Emergency Ventilation

Baseline ventilation is the continuous changing of air to provide a safe and hygienic work environment. This minimum level of air change is typically as required by applicable codes and will be explained further in this document. Baseline ventilation systems can be open loop with separate heat and exhaust systems, or closed loop if a heat recovery unit is used. No recirculation of air is permitted.

Emergency ventilation systems are typically activated with a combustible gas detection system. Emergency systems may be used to provide part of the code-required air changes, or they may go beyond minimum code levels to provide even greater levels of safety. These systems are generally open loop with direct exhausting fans and automatically opening garage doors to provide make-up air.

Ventilation Amount and Location

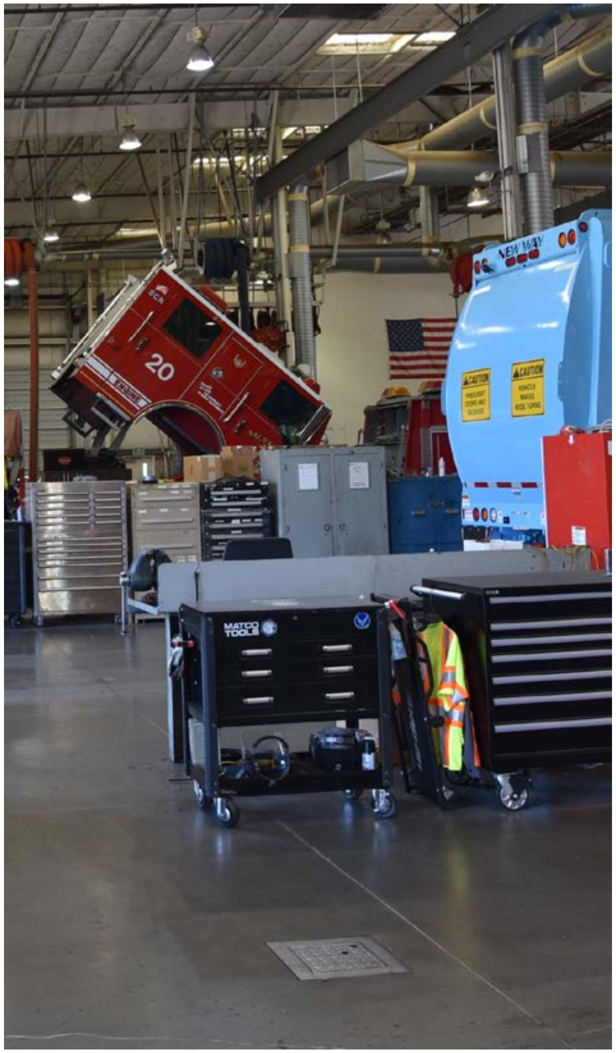


Design Philosophy for Baseline Ventilation Systems

Baseline ventilation systems operate continuously (when vehicles are in the facility) to ensure that a small or large release of gas is quickly diluted and exhausted. The IMC provides a good general description of the best (and required) configuration of baseline ventilation systems as explained below:

1. Warm air is introduced near the floor, typically on perimeter walls or between overhead doors.
2. Warm air "sweeps" the floor to provide warmth to personnel. Air is "pushed" toward the exhaust point by the continuous warm make-up air. Note that the gas detection system (if so equipped) should also be configured to be in the path of a potential leak plume.
3. Air is exhausted near the floor of the garage.
4. Exhaust ventilation is often provided at the peak of a gable roof or on the high point of a flat roof to remove excess heat in warm weather and to remove vehicle exhaust and other pollutants.
5. Conventional-fuel and LPG vehicle garage portions of the facility must not share any HVAC systems with areas not equipped for conventional-fuel or LPG vehicles (herein referred to as "untreated areas").
6. Conventional-fuel and LPG vehicle garage portions of the facility must be at negative pressure relative to untreated areas to ensure that any gas leak will not migrate to untreated areas.

Ventilation Amount and Location



Code Requirements for Major Repair Garages

2018 IMC and 2018 IFC

1. Minimum continuous exhaust rate is 0.75 cfm/ft^2 (2018 IMC Table 403.3.1.1) for repair garages (does not specify major or minor repair, so this would apply to both); however, this rate is lower than the NFPA 88A rate requirement of 1 cfm/ ft^2, which applies to parking garages but is often applied to repair garages since vehicles park there.
2. Recirculation of exhaust air is not permitted (2018 IMC Table 403.3.1.1).
3. Service pits shall include ventilation to prevent the accumulation of flammable vapor (2018 IMC 502.15). This ventilation requirement is quantified in 2018 IFC 2311.4.3 to be 1.5 cfm/ft^2.
4. Certain classes of repair garages require a sprinkler system (see 2018 IFC 903.2.9.1).

2018 NFPA 30A

1. Appendix A.7.5.1 requires manual ventilation system control switches be located near the garage entry and that the ventilation be interlocked to shut down automatically if a fire is detected.
2. This code does not explicitly have minimum mechanical ventilation requirements. Best practice is to use the 1 cfm/square foot required by 2015 NFPA 88A.

Ventilation Amount and Location

Code Requirements for Minor Repair Garages and Parking Garages

The Author has combined these two garage types since all repair garages involve the storage of vehicles so logically parking garage requirements also apply to repair garages. The codes do not provide other useful guidance on minor repair garages so many of the recommendations are best practice and not code driven.

2018 IMC and 2018 IFC

1. Minimum continuous exhaust rate is 0.75 cfm/ft^2 (2018 IMC Table 403.3.1.1 and 2018 IMC Section 404.1.1) for enclosed parking garages; however, this rate is lower than the NFPA 88A rate requirement of 1 cfm/ ft^2.
2. Recirculation of exhaust air is not permitted (2018 IMC Table 403.3.1.1).
3. If ventilation systems are operated intermittently, they shall be interlocked to operate when CO and NO_2 detectors indicate an air quality issue (2018 IMC 404.1). The minimum air flow shall be 0.05 cfm/ft^2 when the toxic gas detectors are not indicating an air quality issue (2018 IMC 404.2).
4. Non-vehicle rooms adjacent to the garage shall be pressurized to prevent airflow into them (2018 IMC 404.3).
5. Certain classes of enclosed parking garages require a sprinkler system (see 2018 IFC 903.2.10 and 903.2.10.1).

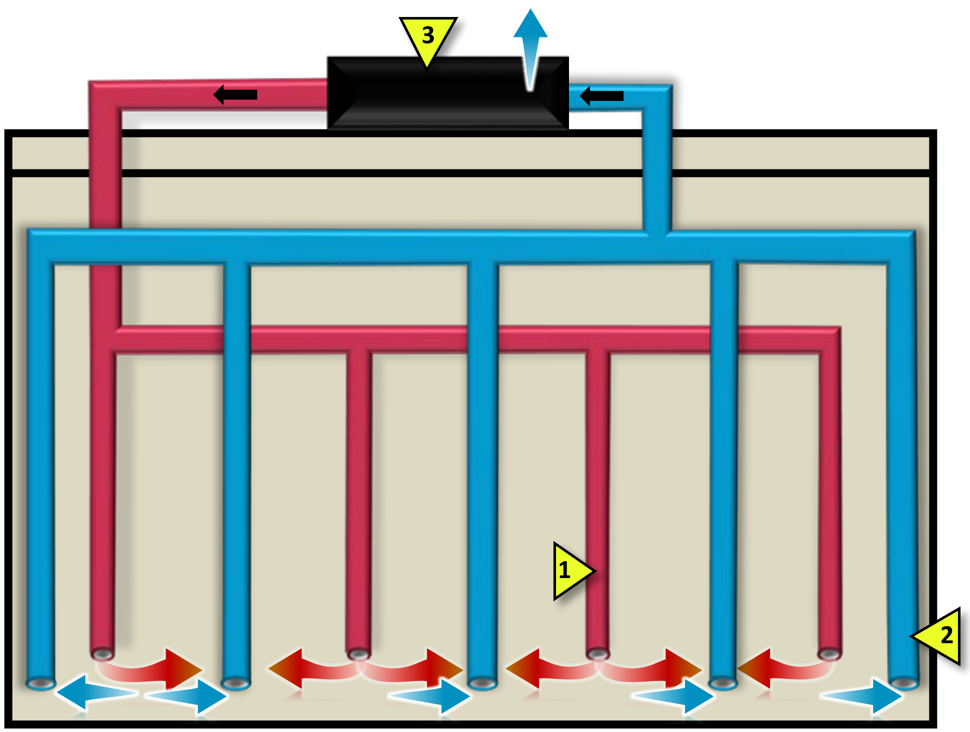
2015 NFPA 88A

1. All enclosed garages (all fuels) are required to have 1 cfm of mechanical ventilation per square foot of floor space (Section 6.3.1 and A.6.3.1). Open parking structures do not have a mechanical ventilation requirement (Section 6.3.2).

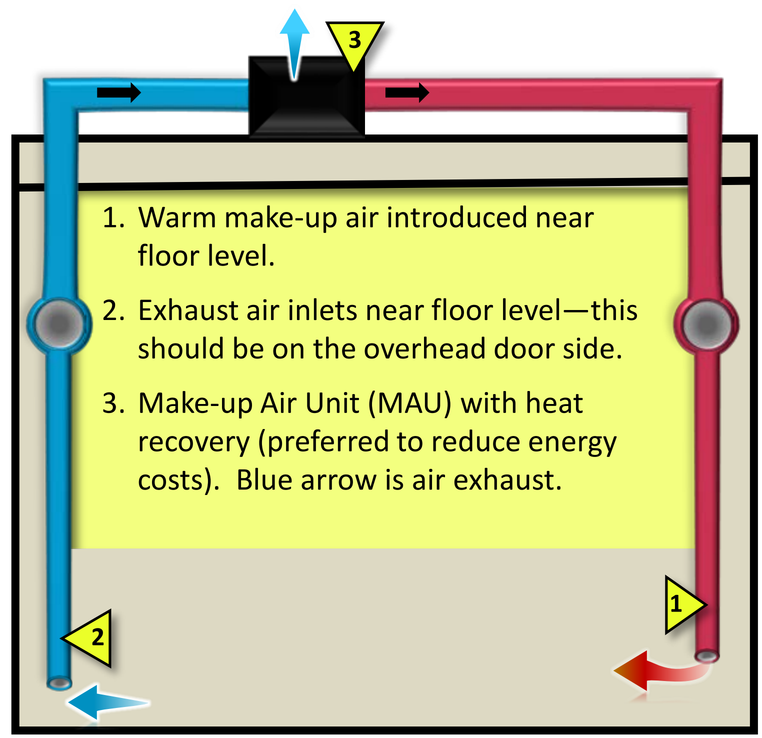
Ventilation Amount and Location

Best Practice Baseline (Continuous) Ventilation for Gable Roof with Single or Double Pitch Roof

■ Red = Warm Air | ■ Blue = Exhaust Air

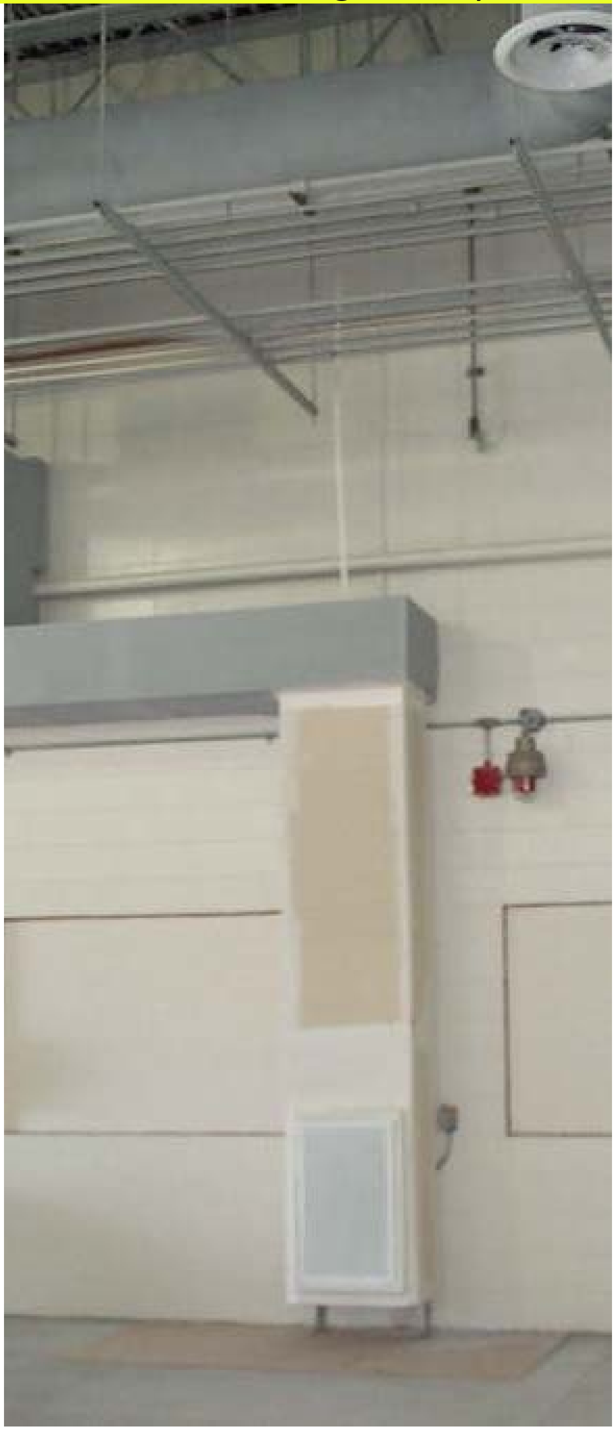


Side Elevation Section



End Elevation Section

Ventilation Amount and Location



Best Practice Baseline (Continuous) Ventilation for Floor Areas

Exhaust ventilation in conventional-fuel garages often utilize floor level inlets to sweep the floor of any heavy vapor, including vaporized LPG. This provides dilution and exhaust of heavy vapor. Depending on garage configuration, the exhaust is best located on the overhead door side of the shop. This allows the make-up air to push any vapors out the doors when doors are open.

Floor-level heating is also recommended to enhance personnel comfort and assist in pushing a vapor leak toward a floor-level exhaust duct.

Exhaust rate should be 1 cfm/ft^2 with a make-up air rate slightly lower to provide a negative pressure in the garage.

Ventilation Amount and Location

Best Practice Baseline (Continuous) Ventilation for Garages—Equipment

Rooftop heating unit (left) with energy recovery. This unit does note recirculate any air— heat is recovered through a heat exchanger.

Fan at each end of peak exhaust duct (below) provides continuous exhaust. Two fans provide redundancy.

Ventilation Amount and Location

Best Practice Baseline (Continuous) Ventilation for Service Pits

Pits must be ventilated for conventional liquid fuels and LPG (2018 IMC 502.15) at a rate of 1.5 cfm/ft^2 for LPG (per 2018 IFC 2311.4.3). Any pits shall be brought to the required standard.

Ventilation Amount and Location

View from below and above of direct-vented emergency-exhaust fan.

Best Practice Supplemental/ Emergency Ventilation

Engine exhaust capture/exhaust systems are required if vehicles are operated while stationary inside of the repair garage (2018 IMC 502.1.3).

Although not a code requirement, peak- or roof-level ventilation is also beneficial to the indoor air quality in the shop. For this reason, it is best practice to provide supplemental direct-venting (non-ducted) exhaust fans in addition to baseline ventilation.

Low wall-mounted fans could also be installed to assist in floor-level air movement and exhaust (this is most likely a warm climate approach). These fans are simple, relatively inexpensive, and provide additional safety. In warm months, these are used by some garage operators to enhance employee comfort. In case of emergency, the fans are started automatically by the combustible gas detection system (assuming one is provided) and overhead garage doors are automatically opened to provide make-up air (these steps could also be taken manually). Given that these fans will operate in a gas leak situation, the motors should be Class I, Division 1 or 2 rated, and the impellor must be non-sparking (best practice, not code requirement).

Wall-mount type fan mounted in a clerestory.

Ventilation Amount and Location

Best Practice
Ventilation Design

Designers must consider the path of the exhaust plume after it exits the building and should attempt to maximize the separation between these. Designers should also design the exhaust system so it vents vertically upward, if possible. The 2018 IMC section 601.5.1 requires a minimum of 10 feet of separation, but best practice would be much more (this clause references return air but would apply to exhaust air). It is recommended that designers provide a minimum 25 feet of separation between these openings, but more may be required due to prevailing winds and air currents around buildings (best practice).

1. The air intake on this rooftop MAU is remote from the exhaust fan, but maximizing this distance is preferred.
2. This exhaust fan is an up-blast unit, which is recommended. Equipping the unit to discharge at a higher height and further from the MAU is preferred.

Heating Systems

What are the Issues with Heating Systems?

With a propane autoignition temperature of approximately 900°Fahrenheit (F), heating systems must be installed at a height where a propane leak is unlikely to come into contact with a flame or hot surface. Heating systems should have the following characteristics:

1. Installed at code-required height or be rated for use in a hazardous location.

Workarounds

Some upgrade designers have proposed using inappropriate heating equipment with the provision that it will be switched off manually if LPG vehicles are in the shop. Unfortunately, this approach will not provide a safe environment since:

1. If the heaters are unsuitable for LPG, they are also unsuitable for gasoline vehicles.
2. Personnel may forget or be unaware that heaters need to be disabled.
3. Some heating equipment will remain above the autoignition temperature for some time.

Therefore, designers must specify the removal of all non-compliant heating equipment. It is recommended that this equipment be removed so it cannot be re-commissioned later.

See additional workarounds discussed on Page 2 of this manual.

Heating Systems

Code Requirements for Major Repair Garages

2018 NFPA 30A

1. Appliances must be of an approved type in repair garages. Solid-fuel stoves, space heaters and improvised furnaces are not permitted (Section 7.6.2).
2. Heaters must be at least 18 inches above the floor and protected from damage (Section 7.6.4).

2018 IMC

1. Ignition sources must be elevated 18 inches above the floor (304.3).
2. Appliances must be at least 8 feet above the floor, and if in the path of vehicles must be 12 inches higher than the overhead door (304.6).

Code Requirements for Minor Repair Garages and Parking Garages

The Author has combined these two garage types since all repair garages involve the storage of vehicles so logically parking garage requirements also apply to repair garages. The codes do not provide other useful guidance on minor repair garages so many of the recommendations are best practice and not code driven.

2018 NFPA 30A

Appliances must be of an approved type in repair garages. Solid-fuel stoves, space heaters and improvised furnaces are not permitted (Section 7.6.2).

2018 IMC

1. Ignition sources must be elevated 18 inches above the floor (304.3).
2. Appliances must be at least 8 feet above the floor, and if in the path of vehicles must be 12 inches higher than the overhead door (304.6).

Best Practice Tip

For safety, the code requirements for major repair garages can be applied to all vehicle spaces in the facility. This practice is frequently used in lighter-than-air gaseous-fuel vehicle garages and provides a consistent and safe approach for heavier-than-air fuel garages.

Heating Systems

Non-compliant/Unsafe Heating Equipment

Essentially any heating equipment that is less than the code required 8 feet above the floor or 12" above the overhead door height is not permitted. This includes most portable heaters, as shown below. Steam cleaning units need to be in a non-vehicle room with separate ventilation.

The open-flame/exposed element heaters on this page would ignite a gas/air mixture if a gas plume encountered the heater.

Heating Systems

Best Practice Safe Heating Equipment

There is a wide variety of safe, compliant heating equipment options. Some, such as hydronic in-floor heating, may not be a practical option for the retrofit of an existing facility. Some options offer low initial cost but higher operating costs—these will be identified in the following pages.

Long-term heating costs should be considered. With an increased air flow, it is often required that at least part of the heat should be from a warm-air system. Reliance on radiant heat alone will not be sufficient in cooler climates. Without tempering the make-up air, the garage will feel "drafty." Owners also need to consider that warm-air systems are susceptible to losing heat when large doors are frequently opened.

Paint Booths

Paint booths can be upgraded at modest cost since they are already designed as a Class I, Division 2 location; however, there are some issues to be addressed:

1. If a gas detector is to be used, it should be IR type and will need to be located in the ventilation ducting after filtration. This unit may be susceptible to "dirty lens" faults. Many Owners do not use a gas detector and instead have a practice of having minimal fuel in the vehicle tanks and running the exhaust air system whenever an LPG vehicle is in the booth.
2. It is recommended that no heat be used in the curing process for paint. The use of heat will increase the likelihood of a boil off relief valve activation from the vehicle tank. Owners may consider an outside vent line that is connected to the vehicle relief valve vent line to direct any relieved gas directly out of the booth and the building.

Heating Systems

Best Practice Safe Heating Equipment—High Initial Cost/Low Operating Cost

Hydronic heating systems use boilers (two shown to far right) along with unit heaters (two shown to near right), in-floor tubing, or hydronic coils in rooftop MAUs to provide space heating without any flame. In-floor heating is a high cost, but very effective, means of providing space heat in a maintenance shop, and it keeps the floor dry and holds heat when doors are frequently opened.

Heating Systems

Best Practice Safe Heating Equipment—High Initial Cost/Low Operating Cost

Rooftop units with energy-recovery heat exchangers are initially costlier but may recover up to 70 percent of the heat from exhaust air to preheat incoming air.

Heating Systems

Best Practice Safe Heating Equipment—Moderate Initial Cost/Low Operating Cost

Direct-fired MAUs installed outside of the vehicle space provide a safe, low-cost, high-efficiency heat source. Note that the fan must start and “prove” airflow prior to firing the burner.

The equipment shown does not include heat recovery so there is an additional operating cost due to the lost heat.

Direct-fired unit heaters can be used in the vehicle space, although sealed-combustion units provide additional safety and improved indoor air quality.

Heating Systems

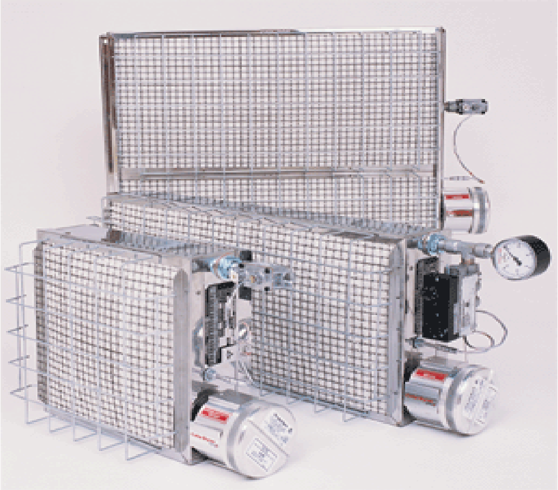
Best Practice Safe Heating Equipment—Low Initial Cost/Low Operating Cost

Waste-oil furnaces (right) are relatively inexpensive to install and very low cost to operate. Designers should ensure that all environmental regulations are met with the selected units.

A very common heating system for repair garages is the gas-fired radiant tube heater (below). These heaters are low cost to purchase and install, and the radiant heat they impart provides effective local heat in areas where large doors are frequently opened.

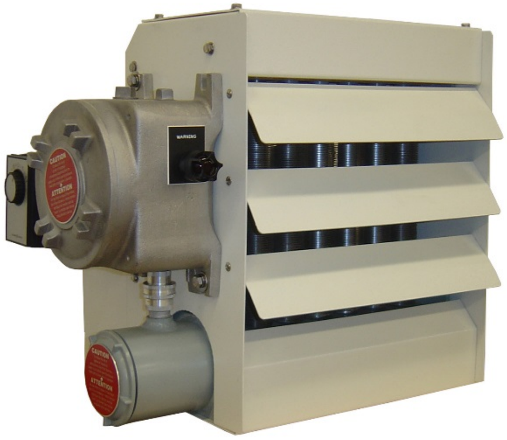
Heating Systems

Best Practice Safe Heating Equipment—Recommended Only for Supplemental Heat or Warm Climates



Class I, Division 2, Group D rated catalytic gas-fired heaters can be used in any location in a garage for supplemental heat.

Users should be aware that the output from these heaters will be insufficient for primary heating. These units are most appropriate for use in warmer climates or as supplemental heat. Units will need to be a maximum of 10 to 12 feet above the floor to be effective.



Class I, Division 2, Group D rated forced-air and convection electric heaters can be used in any location in a garage for supplemental heat.

Users should be aware that the output from these heaters will be effective in small spaces only. High equipment and energy costs make this appliance unsuitable for primary heating in large spaces.

Electrical Upgrades—Required/Recommended

Defined in 2017 NFPA 70 Article 500.5

Class I, Division 1, Group D

1. Ignitable mixtures of flammable gases or liquid-produced vapors are present under normal conditions.
2. Ignitable mixtures of flammable gases or liquid-produced vapors may be present because of repair, maintenance, or leakage.
3. Ignitable mixtures of flammable gases or liquid-produced vapors may be present because of equipment breakdown or faulty operation.

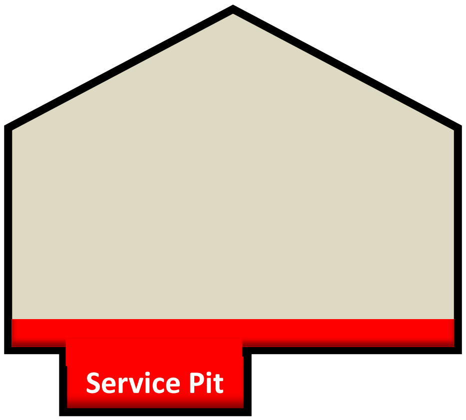
This is an area where one might frequently expect to have a flammable mixture present. NFPA 30A designates a Class I, Division 1, Group D location in unventilated service pits in a conventional-fuel and LPG garage.

Class I, Division 2, Group D

1. Ignitable mixtures of flammable gases or liquid-produced vapors are used but are contained within closed systems and escape only through accidental rupture or equipment malfunction.
2. Ignitable mixtures of flammable gases or liquid-produced vapors are prevented through positive ventilation but could become hazardous through a failure of the ventilation system.
3. An area adjacent to a Class I, Division 2, Group D location that could receive a flammable mixture from the Division 1 location, unless positive ventilation from a clean source of air is provided.

This is an area where one might infrequently expect to have a flammable mixture present due to an equipment (or personnel) failure. NFPA 30A designates a Class I, Division 2, Group D location within 18 inches of the floor in a conventional-fuel and LPG major repair garage. This requirement is waived if the garage is equipped with 1 cfm/ft^2 of continuous ventilation.

Electrical Upgrades—Required/Recommended



Purpose of Electrical Upgrades

The code-required electrical upgrades are intended to remove ignition hazards from those locations where fuel vapor might tend to accumulate—especially at the floor, since LPG could dwell there until it is fully vaporized and warmed to near ambient temperature.

Code Requirements for Major Repair Garages

2018 NFPA 30A

1. Table 8.3.2 designates a Division 1 location within a pit that is not ventilated (also see 2017 NFPA 70 Table 511.3(C)). Ventilated pits are classified as Division 2 if a minimum of 1 cfm/ft^2 of exhaust is provided at a location not more than 12" above the pit floor.
2. Table 8.3.2 designates a Division 2 location that extends 18 inches above the floor (as shown to the right). Ventilated floors are unclassified if a minimum of 1 cfm/ft^2 of exhaust is provided at a location not more than 12" above the room floor.

2017 NFPA 70

The NEC requirements in Table 511.3(C) duplicate the NFPA 30A requirements.

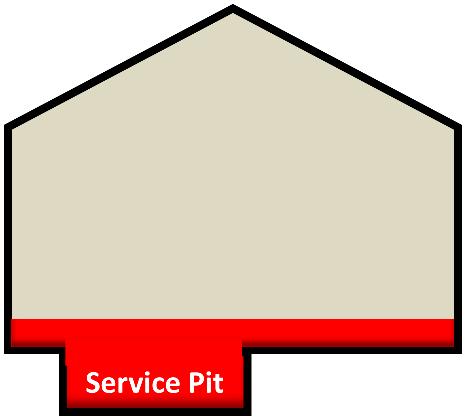
2018 IMC

Ignition sources must be elevated 18 inches above the floor (304.3).

Electrical Upgrades—Required/Recommended

Code Requirements for Minor Repair Garages and Parking Garages

The Author has combined these two garage types since all repair garages involve the storage of vehicles so logically parking garage requirements also apply to repair garages. The codes do not provide other useful guidance on minor repair garages so many of the recommendations are best practice and not code driven.



2018 NFPA 30A

Table 8.3.2 designates a Division 2 location within the pit and extending 18 inches high and 36 inches around the pit opening for pits that are not ventilated. Ventilated pits have no hazardous location designated. Generally, pits are installed in spaces where major repair also takes place, thus it is unlikely that a pit would be located in a minor repair garage—an exception may be a brake inspection or chassis wash pit.

2017 NFPA 70

The NEC requirements in Table 511.3(C) duplicate the NFPA 30A requirements.

2018 IMC

Ignition sources must be elevated 18 inches above the floor (304.3).

Best Practice for Conventional-Fuel and LPG Garages

Most repair and parking garages are designed with the 18-inch area above the floor and within pits designated as a Class I, Division 2 location, even if floor level/pit ventilation is provided. This is a relatively inexpensive safety measure to take since electrical receptacles would typically be above this level and most shop electrical equipment is also located above this level.

Electrical Upgrades—Required/Recommended

Best Practice Baseline (Continuous) Ventilation for Service Pits

For all fuels, pits must be electrically classified as Class I, Division 1 unless at least 1cfm/ft^2 of exhaust ventilation is provided within 12" of the floor of the pit, in which case the electrical classification within the pit is Class I, Division 2 (for major repair garages) (2017 NFPA 70 Table 511.3(C)).

It is critical that any pits in an LPG-vehicle garage be brought up to current standards, as it is possible for a liquid or vaporous LPG plume to linger in a pit.

Electrical Upgrades—Required/Recommended

Best Practice for Electrical Upgrades—Sample Details

There is misunderstanding of Class I, Division 2, Group D requirements. Many general-purpose components meet Division 2—for example the Division 1 rated light above is not required. The sealed fixture below meets Division 2 requirements even though there is no Division 2 label affixed to it. Designers should be familiar with the differences and opportunities to safely reduce upgrade costs.

Although not specifically called out in codes, it is best practice to provide a standby generator to power the gas detection system, fans, overhead doors, lights and other safety-related equipment.

The use of explosionproof or pneumatic power tools is not required but some garage Owners take this extra safety step.

Design of Combustible Gas Detection System

Photo credit: Sensor Electronics Corporation

Code Requirements for Major Repair Garages

There are no code requirements for a combustible gas detection system in a conventional-fuel or LPG vehicle garage. There are, however, benefits to providing a combustible gas detection system for safety in the event of a fuel release, which may occur when the facility is occupied or unoccupied.

Best Practice for the Design of Combustible Gas Detection Systems

There are a number of design variations possible, and the final design will depend greatly on the configuration of the garage. The following section describes several approaches, each with its own benefits and limitations. Although it is strongly recommended that the gas detection equipment supplier validate the design, there has been a tendency for equipment suppliers to refrain from making specific design recommendations related to the spacing and location of gas detectors. The recommendations herein represent several typical industry approaches although these would need to be adapted for a specific facility.

Design of Combustible Gas Detection System

Terminology and Technology

Catalytic

Generally regarded as older technology, catalytic units are less expensive to purchase, but the sensor requires calibration at least four times per year. The sensor will need to be changed about every three to five years. Sensors can be “poisoned” by exposure to silicones, sulphur compounds, and solvents and can be susceptible to false readings from wind. This technology is only used in point detectors.

One vendor provides an automatic calibration unit that addresses the frequent calibration concerns.

This is the only sensor technology used for H_2 sensing, and can be configured to monitor for hydrocarbons and H_2 using the same sensor. In a garage with CNG and GH_2 vehicles, this may be the best sensor type.

Infrared

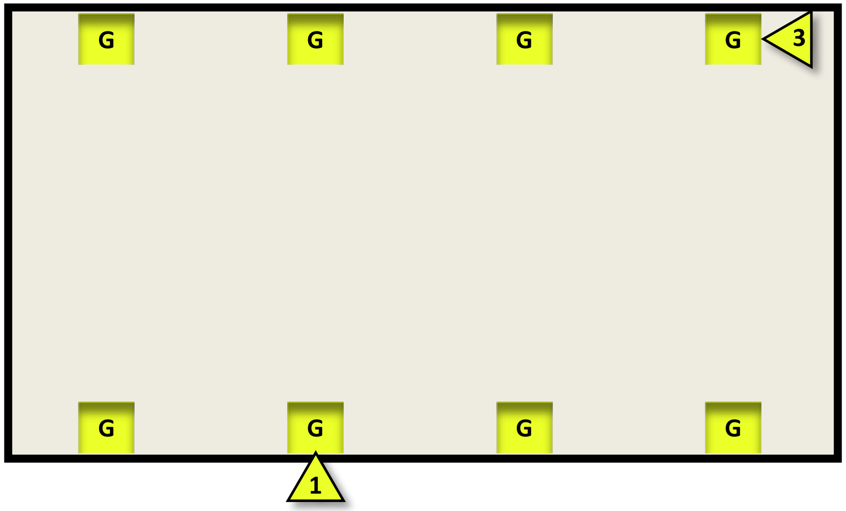
Measures gas concentration by measuring absorption of infrared light which is specific to each hydrocarbon. IR units are more expensive than catalytic, but should last 7 to 10 years, with annual calibration recommended.

Design of Combustible Gas Detection System

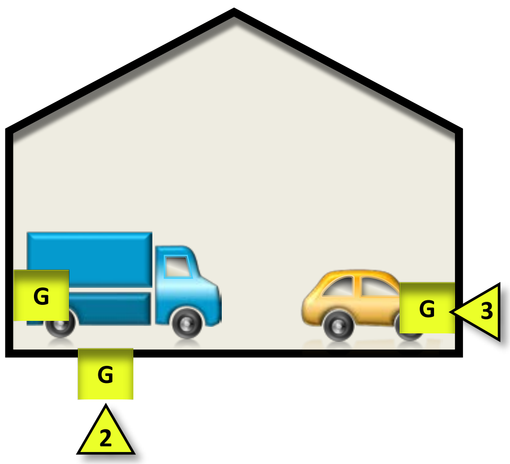
Typical Layout Using Point Detectors

1. Point detectors located on walls and columns at approximately 30' spacing.
2. Strongly recommended location: in vehicle service pits.
3. Point detectors located on walls and columns at approximately 12" above the floor.

Plan View Inverted Roof Section



End Elevation Section



Design of Combustible Gas Detection System

Additional Design Considerations (assuming code conformance with other gaseous fuels is desired—not a code requirement)

1. Systems must be fail-safe (2018 NFPA 30A 7.4.7.3 and 2018 IFC Section 2311.8.9.2), such that a failure of a system component will place the system into a response mode.
2. Assign a unique number to each detector and label it, so it is visible from the floor.
3. Gas detection circuits must be monitored for integrity as required in NFPA 72 (2018 NFPA 30A Section 7.4.7.4).
4. Gas detection controllers must be listed and labelled to UL 2017 or UL 864 and detectors to UL 2075 for Propane (2015 IFC Section 2311.7.2.1.1).
5. Gas detection systems must be provided with standby power (2018 IFC Section 916.5).

Photo credit: Sensor Electronics Corporation

Design of Combustible Gas Detection System

1. IR type combustible gas and CO/NO_2 (toxic gas) point detectors located in floor-level exhaust duct of maintenance shop areas. This is a best practice, not a code requirement, but it provides an early warning of an LPG release and an indication of noxious fumes in the garage. In both cases, additional ventilation is started.
2. Combustible gas detection in service pits in LPG vehicle garages are strongly recommended but not required by code.

Design of Combustible Gas Detection System

Best Practice Design Details

Provide highly visible status lights inside the garage and outside above overhead doors. (CNG system shown in top two photos as an exemplar.)

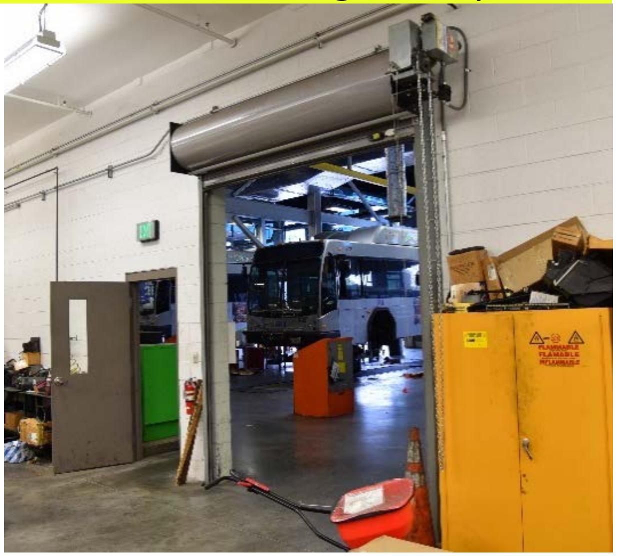
Provide manual gas detection activation buttons at man doors to allow staff to manually put the system in Level 2 response (Shown in bottom two photos).

Design of Combustible Gas Detection System

Best Practice Design Details—System Response

	Initiating Event				
Gas Detection System Response-there are no code references in this table since Combustible Gas Detection is a best practice not a code requirement.	**25% LEL (Level 1)**	**50% LEL (Level 2)**	**Manual Push Buttons**	**Trouble**	**System Failure**
Gas Detection Strobes	X	X	X	X	X
Gas Detection Horns	X	X	X		X
Fuel Valves to Building Heaters (close)	X	X	X	X	X
Open Overhead Outside Doors and Close Doors Between Shop and Adjacent Vehicle and Non-vehicle Areas.	X	X	X	X	X
Start Emergency Fans	X	X	X	X	X
Remove Power for Crane and Welding/Sparking/Noisy Equipment	X	X	X	X	X
Report and Display Fault on FACP		X	X		X
Automatic System Reset When Condition Clears (Non-latching)	X			X	
Manual System Reset When Condition Clears (Latching)		X	X		X

Architectural and Other Upgrades



General

There is no gaseous-fuel specific code guidance for architectural upgrades. There are a number of best practices. Many of these upgrades are focused on reducing the possibility of migration of a gas plume into untreated areas of the garage. These upgrades may include:

1. Walls, doors, and barriers around repair rooms are to be a minimum of one-hour fire rated and constructed in accordance with the requirements of Sections 707 and 711 of the IBC (2018 IFC 2311.8.3). Note that other code requirements related to isolating occupancy types may require a two-hour separation between garage rooms and between garages and other portions of the facility.
2. Install automatic doors to close off untreated areas such as parts rooms and machine shops (pictured top). These should close upon gas detection and fire.
3. Install self-closing man doors to close off untreated areas from the garage.
4. Seal and fire-stop the tops of walls that divide areas of the garage or garage areas and untreated areas.
5. Seal and fire-stop wall penetrations in walls that divide areas of the garage or garage areas and untreated areas (pictured center) (2018 NFPA 30A Section 7.6.3 and A.7.6.6).
6. Ignition sources, such as a hot work area (pictured bottom), should be separated from the vehicle areas by full walls or partial walls. Local pressurization of the area is also commonly used by flooding the hot work area with make-up air near floor level to repel a vapor plume

Summary of Upgrades

LPG Building Upgrade Requirements—Major Repair Garage

	Minimum Code Requirements	Typical Recommended Practice	High-End Upgrade Approach
Electrical	Class I, Division 1 within pit or upgrade continuous ventilation to 1 cfm/ft^2—reduction to Division 2 (NFPA 30A) Class I, Division 2 within 18" of floor or upgrade continuous ventilation to 1 cfm/ft^2 (NFPA 30A)—IMC requires no ignition sources 18" from floor	As per code	
Heating	No open flames or heaters < 8' above floor or 12" above door height if in traffic area (IMC)	As per code	As per code with heat recovery
Ventilation—Continuous	1 cfm/ft^2 -Same as diesel (=2.5 ACH for a 24' ceiling or 3 ACH for a 20' ceiling) and no recirculation (NFPA 88A) 1.5 cfm/ft^2 in pits (IMC)	As per code	
Ventilation—Emergency	Not required	Add additional capacity near floor level equal to baseline ventilation. Add additional ventilation near roof level for improved air quality.	
Gas Detection	Not required	IR based system on ~30' wall and column spacing—Fail-safe design	
Generator	Not required	Back-up gas detection, ventilation, overhead doors.	
Architectural	One- to two-hour fire-rated	2-hour fire rated interior walls sealed to the extent practical. Fire-rated doors between occupancy/usage areas.	

Summary of Upgrades

LPG Building Upgrade Requirements—Minor Repair or Storage Garage

	Minimum Code Requirements	Typical Recommended Practice	High-End Upgrade Approach
Electrical	Class I, Division 2 within pit or upgrade continuous ventilation to 1 cfm/ft^2—reduction to unclassified (NFPA 30A) No ignition sources within 18" of floor (IMC)	As per code	
Heating	No open flames or heaters < 8' above floor or 12" above door height if in traffic area (IMC)	As per code	As per code with heat recovery
Ventilation—Continuous (required for diesel as well)	1 cfm/ft^2 -Same as diesel (=2.5 ACH for a 24' ceiling or 3 ACH for a 20' ceiling) and no recirculation (NFPA 88A) 1.5 cfm/ft^2 in pits (IMC)	As per code	
Ventilation—Emergency	No requirements	Add additional capacity near floor equal to baseline ventilation. Add additional ventilation near roof level for improved air quality.	
Gas Detection	Not required	As per code	
Generator	Not required	Back-up gas detection, ventilation, overhead doors.	
Architectural	One- to two-hour fire-rated	2-hour fire rated interior walls sealed to the extent practical. Fire-rated doors between occupancy/usage areas.	

SECTION 5

Defueling

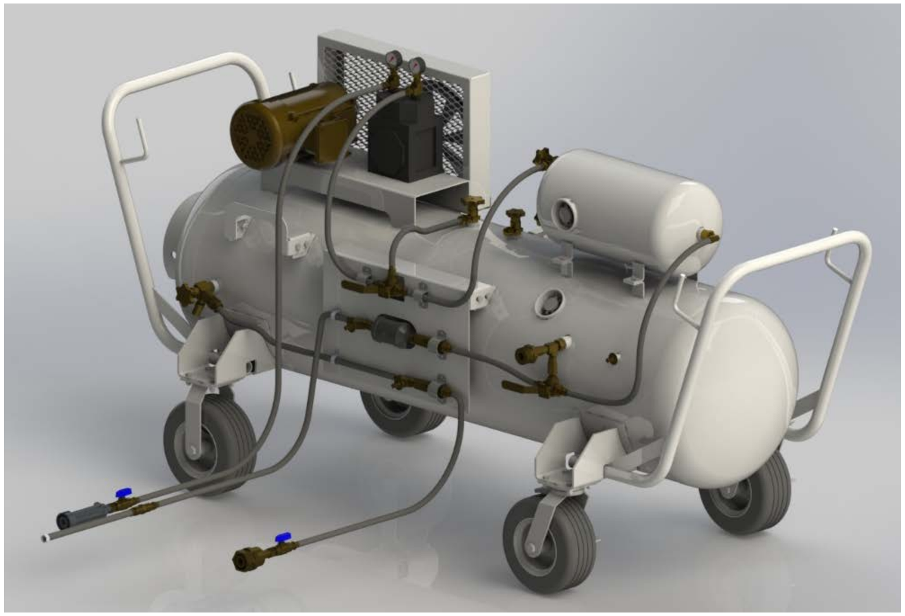
LPG Vehicle Defueling

LPG Vehicle Defueling

There is no code requirement directly requiring a defueling system (also referred to as a Propane Tank Evacuation System) or defueling capability in an LPG vehicle garage; however, there are several safety and environmental benefits:

1. Tank evacuation is required to allow repair of tank or in-tank pump.
2. The tank evacuation system safely pumps LPG from the vehicle tank and safely stores it using a closed system (as with other gaseous fuels, some residual fuel at low pressure (about 25 psig) will be vented to atmosphere). Fuel removed from a tank can then be returned to a vehicle.
3. The evacuation system is safer for personnel and the public than venting to atmosphere, which has been common industry practice. The evacuation system is also faster, so it reduces labor cost.
4. The closed evacuation system is environmentally responsible.
5. Atmospheric venting may not be legal depending on jurisdiction.

Information on this system as well as pictures and logos are provided courtesy of SLEEGERS Engineered Products Inc.



SLEEGERS


Costs

Cost

Cost of Upgrades

Since conventional-fuel vehicle garages are the baseline of this training manual series, and since there are no code-mandated upgrades required for the use of LPG vehicles in a conventional-fuel vehicle garage, the upgrade cost for an LPG-vehicle garage could be zero. This should not be assumed to be true until a thorough compliance review of the conventional-fuel vehicle garage is performed, and the garage is determined to be compliant with current conventional-fuel vehicle garage requirements.

Notwithstanding the lack of specific code requirements for LPG, there are safety improvements that should be considered, such as improved floor-level ventilation and combustible gas detection. Estimates for the cost of a gas detection system for an LPG-vehicle garage are approximately $5 per square foot.

Best Practices and Advice from Fleet Owners

marathon

Best Practice/Advice from Fleet Owners

In the process of compiling this manual, the fleet Owners interviewed were very forthcoming with advice for others. In some cases it was requested that this be kept confidential, and therefore a composite list was assembled and is presented below. Items are not listed in order of importance. In the case of differing opinions, both have been provided. Some of these recommendations come from operators of other types of gaseous fuels but are applicable to LPG. Some items are not safety related.

Code Required Operating Procedures (2018 IFC Section 2311.8.1)

1. Close vehicle fuel isolation valves before any fuel system work.
2. Any gaseous-fuel vehicle with fuel system damage must be inspected for fuel system integrity prior to bringing it in the garage.

LPG Best Practices/Lessons Learned

1. Be committed to your fuel of choice—don't "dabble" in alternate fuels.
2. If you are introducing LPG vehicles into your fleet, have an experienced design engineer check your existing garage for compliance with current codes
3. Train for in-house conversion and maintenance capability—don't rely on an installer shop. Institute a program of ongoing training for mechanics using conversion supplier training. Train vehicle technicians before the vehicles arrive.
4. Beware of personnel freezing risk.
5. Operate with overhead doors open at least 24" (warm climate).
6. Any venting is done outdoors.
7. Have hand-held gas detectors (pictured above) available to maintenance staff and use them if a leak is suspected and at regular PM intervals.
8. Locate water heaters, steam cleaners and other hot equipment outside of the vehicle space.
9. Train and "sell" employees before vehicles arrive. Everyone should have input, not just top-down.
10. Install a generator to back up the ventilation, overhead doors, lighting and gas detection in the event of a power outage.
11. Ensure that the ventilation system continuously sweeps the shop floor with air.

Best Practice/Advice from Fleet Owners

LPG SOPs

1. Train drivers in safe fueling and emergency procedures. Ensure that fuelers are not overfilling vehicles (i.e., fill level must be less than 80 percent of tank capacity (2017 NFPA 58-11.16 (2) and 12.14 (2)).
2. If you are unsure that the garage is current-code compliant, perform work outdoors. Alternatively, operate indoors with heaters turned off and exhaust fans operating continuously with overhead doors open. Do not leave vehicles indoors unattended.
3. Do not park vehicles inside the garage near heaters, water heaters, torches in use or poorly ventilated floor areas, or service pits (2017 NFPA 58-11.16 (4) and 12.14 (4)).
4. Do not fuel vehicles before bringing them in for work. If possible, ensure that vehicles are less than half full of LPG.
5. Cut battery knife switch (if so equipped) if vehicles are left in shop overnight (all fuel types).
6. During normal maintenance work, close ¼ turn valve (2017 NFPA 58-11.16 (3) and 12.14 (3) and 6.26.8.3) and run vehicle until it stalls (to empty fuel lines).
7. Turn fuel off at tank for overnight in garage.
8. Don't leave vehicles in the shop overnight (fleet does not shut off tank valve when vehicles are in the shop).
9. Turn fuel off at tank if any fuel system work is required (2015 IFC Section 2311.5).
10. Any fuel leak is an immediate "out of service"—vehicle not allowed in shop (2017 NFPA 58-11.16 (1) and 12.14 (1)).
11. Scheduled maintenance includes fuel system check.
12. 6000 miles/6-month PM inspection of fuel system (actual mileage and time interval is fleet-dependent).
13. Use a hand-held gas detector to check vehicle for leaks before working on vehicle.
14. Use safety goggles and gloves for fuel system work.
15. Do "hot work" (torches, grinders, welding, and similar work) outdoors, if possible. Use a heat induction unit where possible to avoid an open flame for hot work.

Case Studies

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AMPHITHEATER
Public Schools

Case 1: Amphitheater Public Schools, Tucson, AZ

Fuel Types in Garage

- **LPG**
- **Diesel**
- **Gasoline**

Vehicle Types

- **School Busses**
- **Light Duty**

- No upgrades performed
- 5 years of LPG operating experience with no incidents
- Most LPG maintenance garages have no upgrades as none are required by code
- Heating equipment ceiling-mounted
- No supplemental exhaust air system is required or provided
- No combustible gas detection system is required or supplied
- Use hand-held combustible gas detectors and spray bottles to check for leaks
- Work requiring fuel system breach (like a filter change) is done outdoors
- Vehicles are not defueled as they are not equipped for this

Case 1: Amphitheater Public Schools

Building Statistics

Maintenance Shop

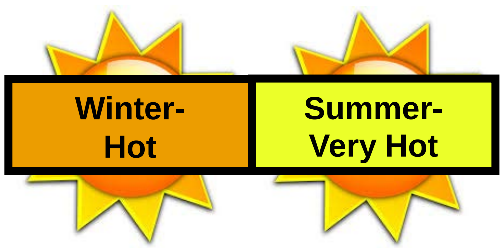
- Major repair garage
- Area: 7,900 ft^2
- Bays: 7 drive-in bays
- Shallow pitched roof with 22' peak and 20' eave.
- No service pits
- No floor drains

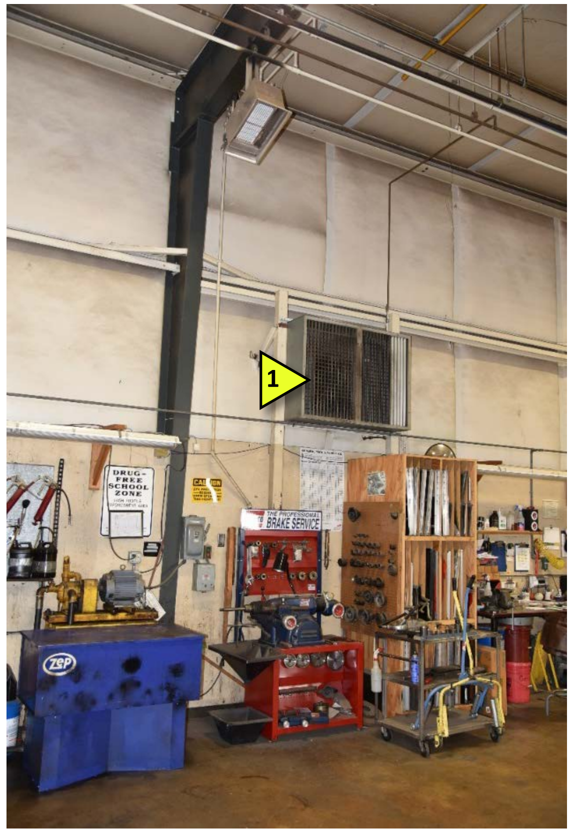
Case 1: Amphitheater Public Schools

Heating and Cooling Systems

- Unit heaters and coolers—no ducted system
- The mechanics usually open the overhead door 12" to 24"—the evaporative coolers push cool air from the opposite wall, sweep the floor and exit the building under the overhead doors. This is an effective and low-cost ventilation system for an LPG vapor release.

Climate





1. A row of 5 evaporative ("swamp") coolers on the wall opposite the overhead doors provide constant floor-level ventilation when the overhead doors are open.

16 non-explosionproof rated catalytic gas heaters provide supplemental heat.

Case 1: Amphitheater Public Schools

Exhaust Ventilation

6 roof-mounted direct-vented non-powered turbine exhaust fans

AMPHITHEATER
Public Schools

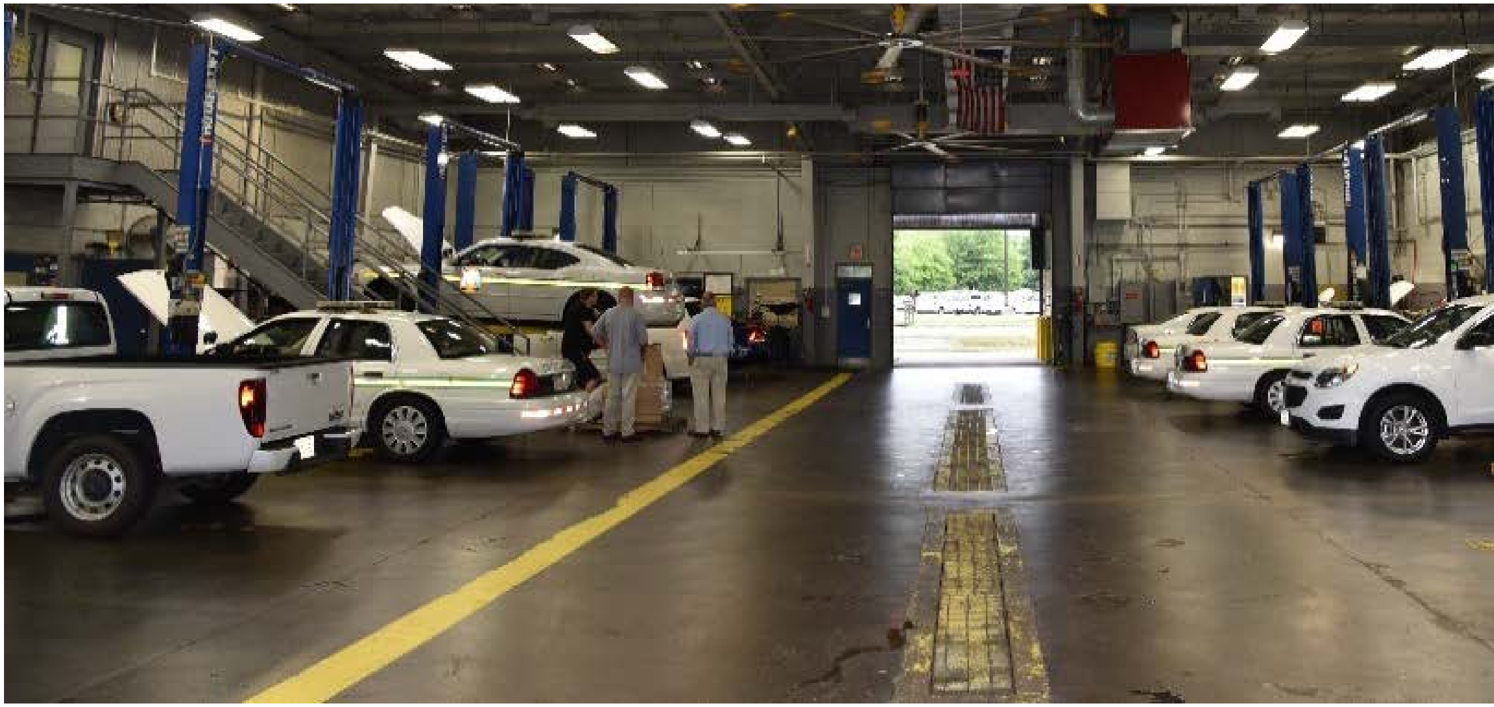
Case 1: Amphitheater Public Schools

Miscellaneous Upgrades

- Fire sprinklers over each bay
- Turn off heaters when servicing LPG buses (warm climate)

1. Gas-fired steam cleaner installed outside the shop to address the possible combustion of a floor level release of LPG.
2. Water heater mounted on the mezzanine (pictured far right) to address the possible combustion of a floor level release of LPG (2018 IMC 304.6).

Case 2: Chesterfield County, Chesterfield, VA



Fuel Types in Garage

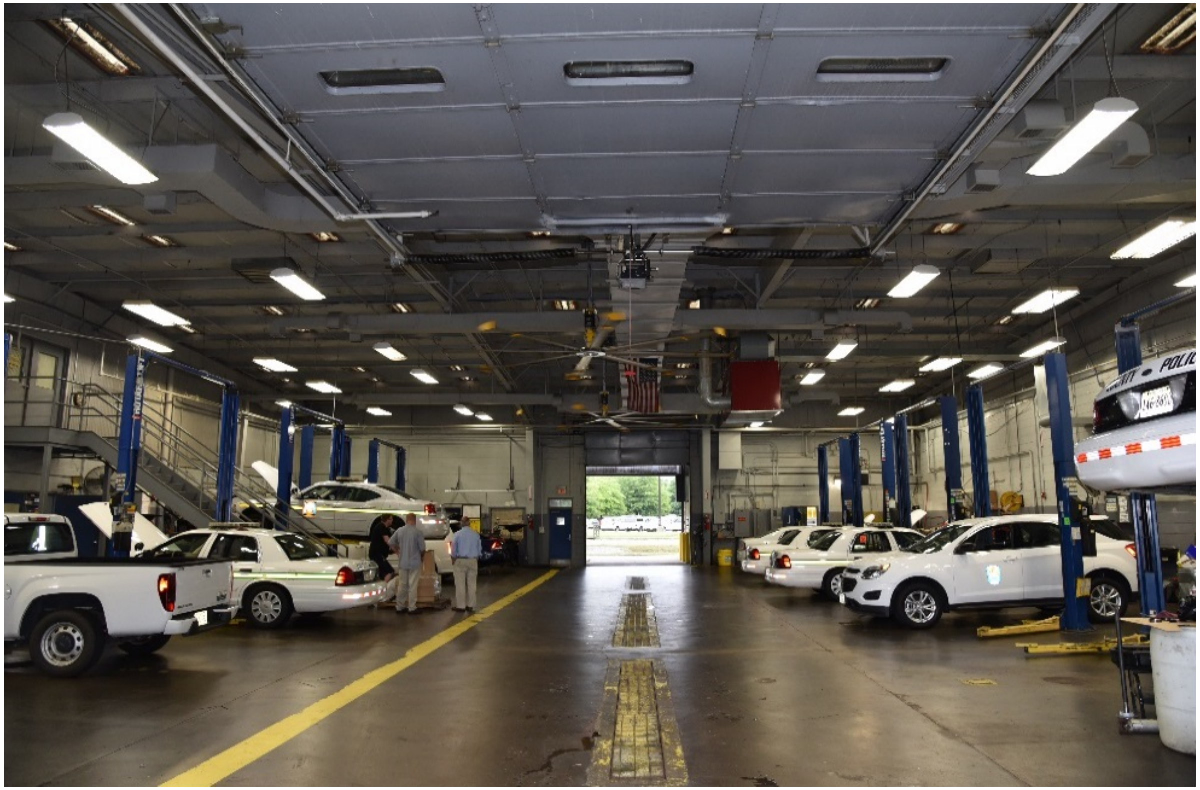
- **LPG**
- **Diesel**
- **Gasoline**

Vehicle Types

- **60 LPG vehicles—all bi-fuel LPG/Gasoline**
- **Municipal Vans, Pickups, one Forklift**
- **Police Sedans and SUVs**
- **Light and Medium Duty**

- Most LPG maintenance garages have no upgrades as none are required by code
- This garage not upgraded for LPG
- No combustible gas detection system is required or supplied. Hand-held unit is used.
- This garage typically operates with overhead doors closed
- Extensive training and operating safety procedures

Case 2: Chesterfield County, Chesterfield, VA



Building Statistics

Maintenance Shop

- Major repair garage—including “hot work”
- Area: 6,500 ft^2 in main shop
- Bays: 12 + 1
- Shallow pitched roof with 22' peak and 20' eave
- No service pits
- Central floor drain
- Not currently equipped for defueling but working on getting this capability

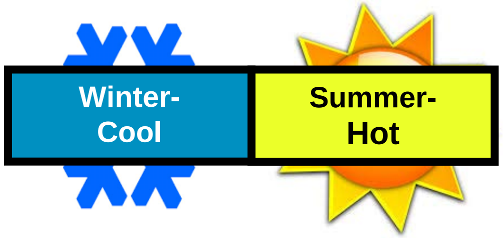
Case 2: Chesterfield County, Chesterfield, VA

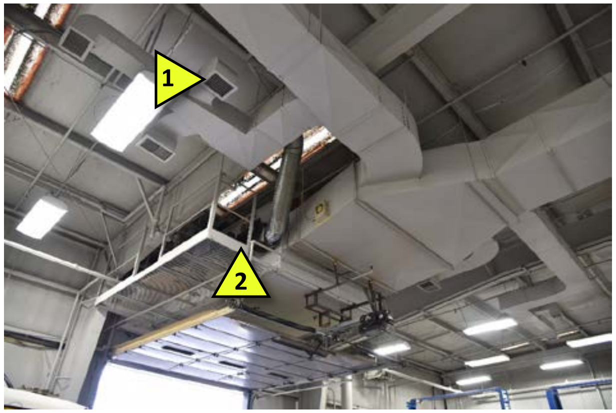
Heating Systems

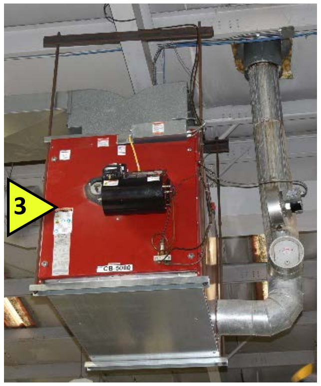
- Heating equipment ceiling-mounted
- No supplemental exhaust air system is required or provided
- Ducted direct-fired make-up air unit located inside the space at ceiling height
- Supplemental standard radiant tube heater (high-temperature) units with open un-ducted combustion

1. Central duct with heated make-up air and registers introducing air at ceiling height.
2. Direct-fired make-up air unit. Located at ceiling height inside the maintenance garage.
3. Waste-oil heater at ceiling level provides primary heat.
4. Gas unit heater at ceiling level provides supplemental heat.

Climate







Case 2: Chesterfield County, Chesterfield, VA

Exhaust Ventilation

- Roof- and wall-mounted direct-vented exhaust fans providing room exhaust
- No floor-level exhaust
- Fans are manually started
- Large ceiling fans provide circulation but not ventilation—these are for operator comfort and may help dilute a leak plume but are not for safety

Two roof-mounted exhaust fans.

One wall-mounted exhaust fan.

Case 3: City of Edmonds, Edmonds, WA

Fuel Types in Garage

- **LPG**
- **Diesel**
- **Gasoline**

Vehicle Types

- **Municipal**
- **Light and Medium Duty**
- **30 LPG vehicles-all Light Duty**
- **80 other vehicles**

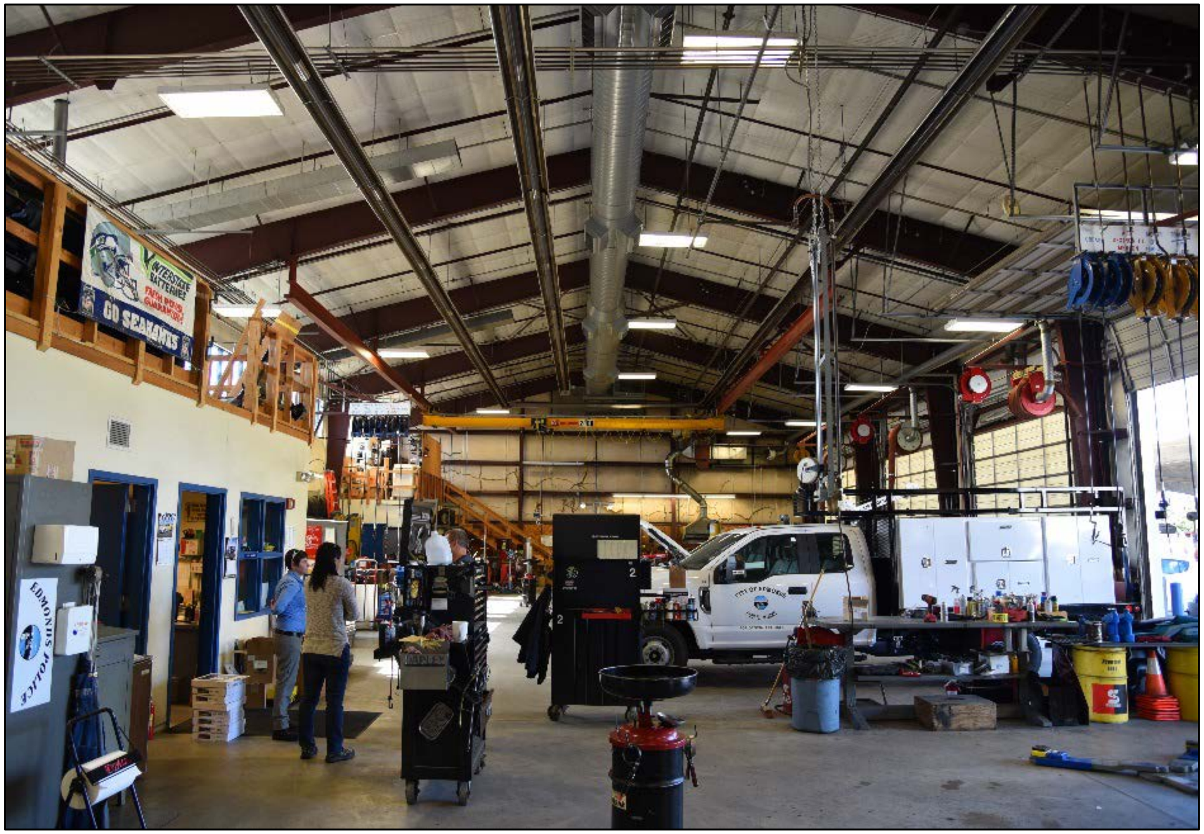
- Most LPG maintenance garages have no upgrades as none are required by code
- This garage not upgraded for LPG
- Heating equipment ceiling-mounted
- No supplemental exhaust air system is required or provided
- No combustible gas detection system is required or supplied
- Use hand-held combustible gas detectors and spray bottles to check for leaks
- Work requiring a fuel system breach (like a filter change) is done outdoors
- Vehicles are not defueled as they are not equipped for this

Case 3: City of Edmonds

Building Statistics

Maintenance Shop

- Built 1994
- Major repair garage
- Area: 7,300 ft^2
- Bays: 6, plus wash bay
- Shallow pitched roof
- No body work or paint at garage

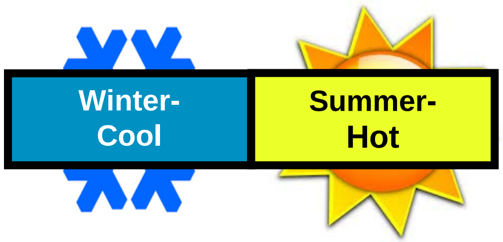


Case 3: City of Edmonds

Heating Systems

- Ducted direct-fired make-up air unit located inside the space at ceiling height
- Supplemental standard radiant tube heater (high-temperature) units with open un-ducted combustion

Climate



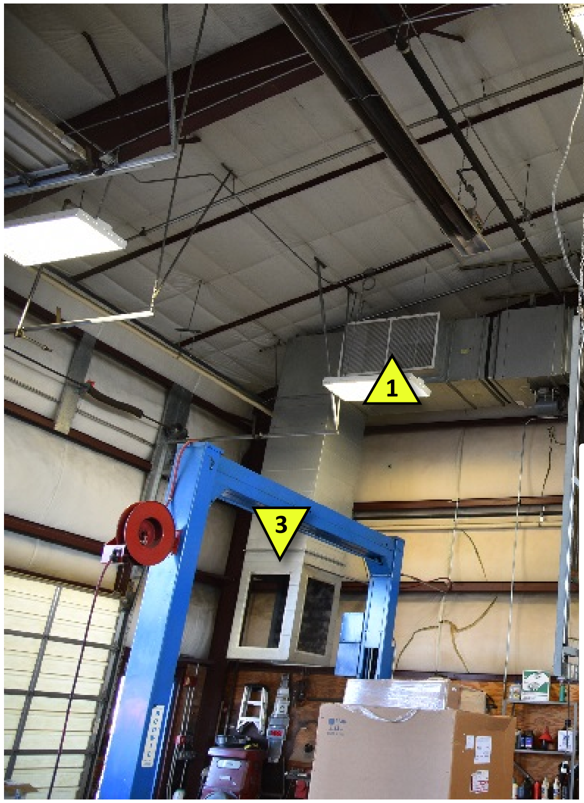
1. Direct-fired make-up air unit. Located inside the maintenance garage.

Case 3: City of Edmonds

Exhaust Ventilation

- Gable-mounted direct-vented exhaust fan providing room exhaust and fume hood exhaust above brake lathe
- Fans are manually started
- Vehicles are parked indoors unattended unless a leak is known

1. Room exhaust inlet.
2. Gable-mounted fan.
3. Fume hood.
4. Central duct with heated make-up air.
5. Heating booster ducts and fans pull warm air from ceiling and push it toward the floor.



Case 4: Franklin County Board of DD, Columbus, OH

Fuel Types in Garage

- **LPG**
- **Diesel**
- **Gasoline**

Vehicle Types

- **24 LPG vehicles**
- **School Buses**
- **Light and Medium Duty White Fleet**

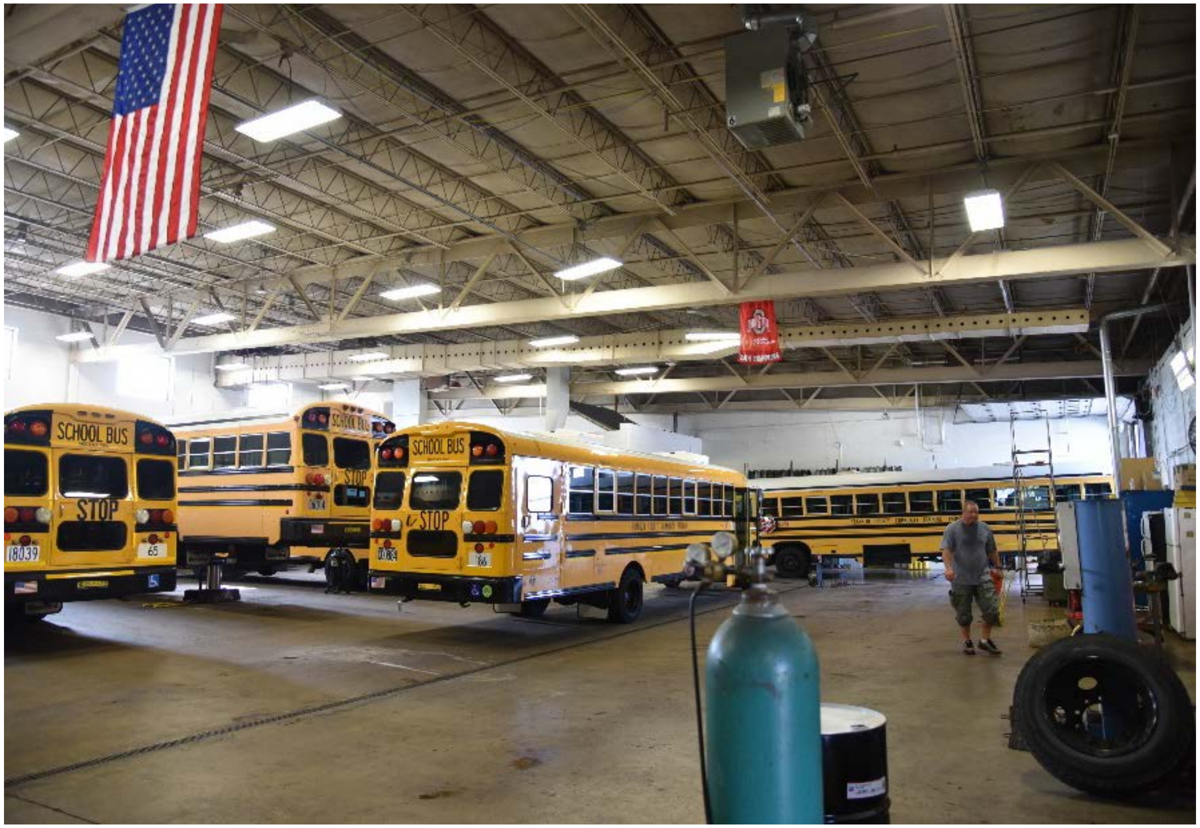
- Most LPG maintenance garages have no upgrades as none are required by code
- This garage not upgraded for LPG
- Heating equipment ceiling-mounted
- No supplemental exhaust air system is required or provided
- No combustible gas detection system is required or supplied

Case 4: Franklin County Board of Developmental Disabilities

Building Statistics

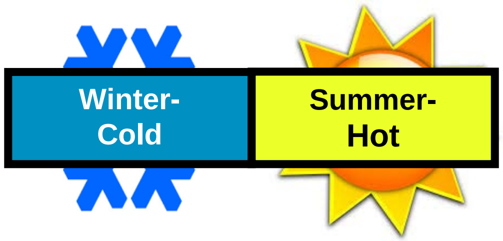
Maintenance Shop

- Constructed 1980
- Major repair garage
- Area: 17,000 ft^2
- Bays: 7 plus wash bay
- Shallow single-pitched roof with one eave at 25' and the other at 21.5'

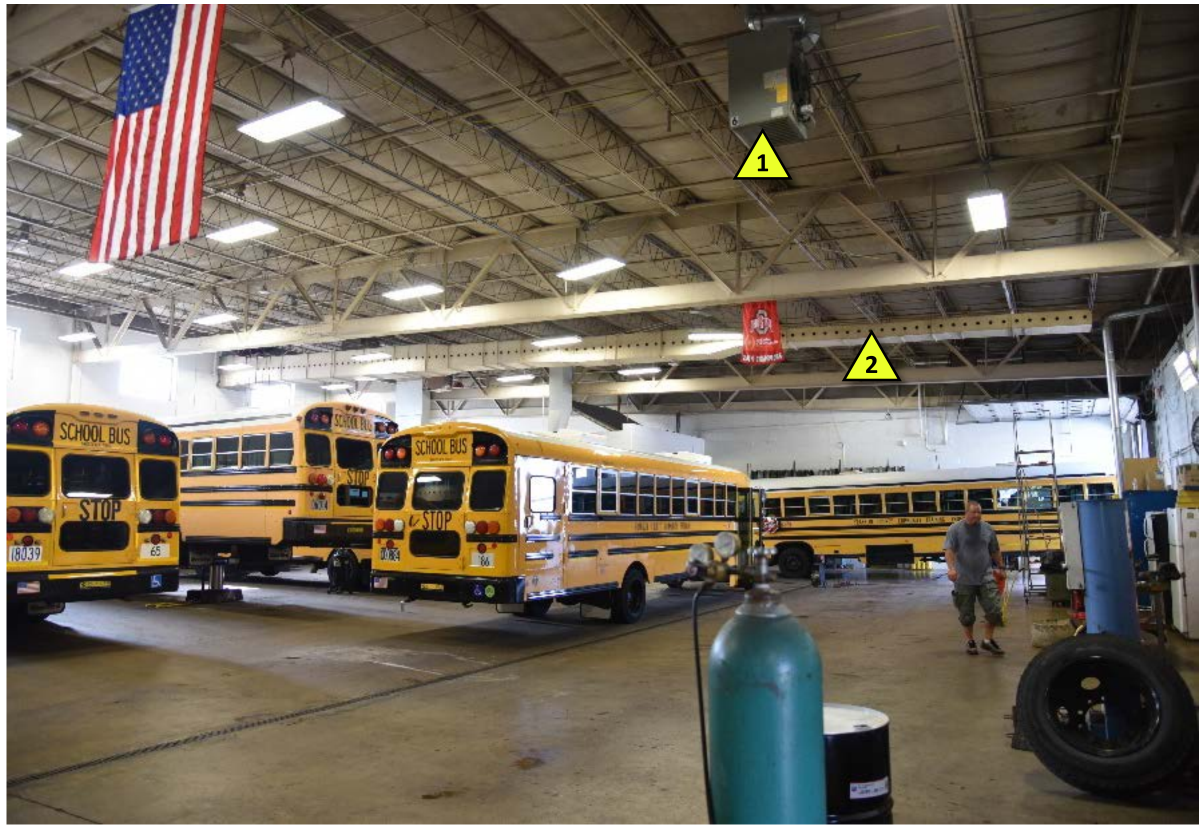


Case 4: Franklin County Board of Developmental Disabilities

Climate



1. Open-flame gas-fired unit heater at ceiling level provides primary heat.
2. Ducted exhaust at ceiling level. Intake holes along the length of the duct.



Case 4: Franklin County Board of Developmental Disabilities

Supplemental Exhaust Ventilation

- Wall-mounted direct-vented exhaust fans providing room exhaust
- Actuated dampers provide make-up air
- Fans are manually started

Wall-mounted exhaust fan.

Actuated damper opens when wall-mounted supplemental exhaust fans are operating.

Case 5: Wyandotte County, Kansas City, KS

Fuel Types in Garage

- **LPG**
- **Diesel**
- **Gasoline**

Vehicle Types

- **Municipal**
- **Light Duty**

- No incidents in garage in 17 years
- Most LPG maintenance garages have no upgrades as none are required by code
- This garage not upgraded for LPG
- Heating equipment ceiling-mounted
- No supplemental exhaust air system is required or provided
- No combustible gas detection system is required or supplied

Case 5: Wyandotte County

Building Statistics

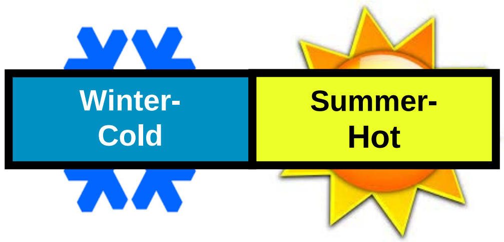
Maintenance Shop

- Opened 2001
- Major repair garage
- Area: 10,300 Fft^2
- Bays: 14
- No pits
- Shallow pitched roof with 18.75' peak and 17.5' eave

Vehicle parking in separate garage. 21,000 ft^2 of 62,000 ft^2 building allocated to LPG vehicles. No functional heat. Large wall mounted fans used for ventilation in warm weather.

Case 5: Wyandotte County

Climate



Heating Systems

- Ducted direct-fired make-up air unit located inside the space at ceiling height
- Supplemental standard radiant tube heater (high-temperature) units with open un-ducted combustion

1. Supplemental radiant tube heaters. Standard (high) temperature with open (un-ducted) combustion.
2. Direct-fired make-up air unit. Located inside the maintenance garage.
3. Central duct with heated make-up air.

Case 5: Wyandotte County

Exhaust Ventilation

- Roof-mounted direct-vented exhaust fans with make-up air provided by wall-mounted damper
- Fans are manually started

Miscellaneous Upgrades

Water heater mounted near the ceiling to address the possible combustion of a floor-level release of LPG, and to comply with the code requirement that the appliances be >8' above the floor.

Exhaust inlet for make-up air at end of shop.

Ceiling-mounted supplemental exhaust fans—manually operated.

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