Vehicle maintenance facility design for the servicing of commercial fleet CNG/LNG vehicles

Guideline for fleet operators in British Columbia

FORTIS BC™
Energy at work

October 2019

Table of contents

1.0 Introduction

This guideline is intended to inform the fleet operator on the design requirements for new and existing facilities for maintaining compressed natural gas (CNG) and/or liquefied natural gas (LNG) vehicles and obtaining a CNG/LNG maintenance facility operating permit in accordance with the regulatory requirements of Technical Safety BC (TSBC).

Shop modifications are part of the company's Risk Mitigation Plan for the service or repair of CNG and/or LNG vehicles. The type of modifications should match the type of work to be performed, and should encompass, overall, the company's Site Safe Work Plans.

Furthermore, this guideline provides information related to the project management of facility construction and operation. This document is not exhaustive and it is recommended that the fleet operator employ the services of an experienced professional engineering firm in the execution of a facility upgrade or new construction project.

1.1 Definition of terms

The following acronyms and terms are used in the guideline:

- AC – air conditioning
- ACH – air changes per hour
- CB – catalytic bead
- CNG – compressed natural gas
- CSA – Canadian Standards Association
- ERP – emergency response plan
- GWP – global warning potential
- HVAC – heating ventilation and air conditioning
- IR – infrared
- LNG – liquefied natural gas
- NGV – natural gas vehicle
- OEM – original equipment manufacturer
- PIC – person-in-charge
- PPE – personal protective equipment
- PRV – pressure relief valve
- RPT – rapid phase transition
- TSBC – Technical Safety British Columbia

1.2 Scope

This document is applicable to facilities used to service NGVs operating on natural gas in the form of CNG and LNG. These vehicles include on-road and off-road vehicles such as passenger cars, light duty pick-up trucks, refuse trucks, transit buses, mine haul vehicles and other on and off-road vehicles. The scope of this guideline is limited to the NGV maintenance facility only and is not applicable to indoor fuelling facilities, testing facilities, or facilities to maintain non-NGV vehicles operating on other alternative gaseous fuels including hydrogen and propane.

1.3 Disclaimer

This guideline is provided for information purposes only and should not be used to replace independent verification and review of applicable laws and regulations. This guideline should also not be used as a substitute reference for the CSA B401 code and other relevant codes and standards.

Information contained in this guideline may not be current, exact, accurate or complete and may include application of undisclosed assumptions and extrapolations and should not be relied upon to any greater extent than is appropriate having regard to independent analysis, review, verifications, investigations and judgments performed by the reader and its professionals and other experts.

FortisBC does not make any warranties or representations of any kind, implied, expressed, or statutory, including but not limited to the warranties of non-infringement of third party rights, title, merchantability, or fitness for a particular purpose, regarding any information contained in this guideline. FortisBC shall not be responsible for reliance by any person on the contents of this guideline nor be liable for any of the information contained herein, including its interpretation, accuracy or completeness.

2.0 Background

2.1 Codes and standards

Until recently there have been no Canadian codes and standards that are applicable to the design of NGV maintenance facilities. Experienced Canadian engineering firms have applied NFPA 30A to provide design guidance until now. In 2018, the CSA will be publishing a new standard entitled the CSA B401 *NGV Maintenance Facilities Code*. The guidelines provided in this document are based on the final DRAFT version of this code. It is fully expected that the TSBC will recognize this code as a valid standard for design of NGV maintenance facilities.

Other codes, standards and regulations that are relevant to facility upgrade design and their applications are shown in Table 2.1.

Table 2.1 – Reference codes and standards

Code/Standard	Title	Application
BCGSR Section 16/28	*British Columbia Gas Safety Regulations*	requirements for facility operating permits; requirements for personnel qualifications, training and certification
CSA B401	*NGV Maintenance Facility Code*	overall standard for the design of NGV maintenance facilities for CNG and LNG vehicles
CSA C22.1	*Canadian Electrical Code*	installation of electrical equipment in nonhazardous and hazardous locations
CSA B149.1	*Natural Gas and Propane Installation Code*	natural gas and propane fired heating appliances
BCBC	*British Columbia Building Code*	structural tie-in for HVAC equipment; general facility ventilation requirements
BCFC	*British Columbia Fire Code*	fire safety provisions
ASHRAE 62.1	*Ventilation For Acceptable Indoor Air Quality*	minimum ventilation for maintaining indoor air quality

2.2 Natural gas properties

Natural gas has unique chemical properties resulting in special design requirements for facilities that handle this alternative fuel. The properties of CNG and LNG have some significant differences as shown in Table 2.2.

Table 2.2 – Natural Gas Properties

	CNG	LNG
temperature (typical)	15 °C	-150 to -161 °C
colour	invisible	clear and water-like
odour	rotten egg smell due to addition of mercaptan	odourless
density (specific gravity)	0.58 – 0.65	≥ 1.0 below -140°C
flammable concentration range	5 – 15 mol% in air	5 – 15 mol% in air once vaporized
composition	primarily methane (CH_4)	primarily methane (CH_4)

Natural Gas Safety Data Sheets are available at https://www.cdn.fortisbc.com/libraries/docs/default-source/about-us-documents/safetydatasheet_naturalgas_pipelinequality.pdf?sfvrsn=9bb4c8e7_2

When CNG is leaked, the natural gas will quickly rise in open air to the ceiling space of a maintenance facility. When LNG is leaked it will initially flow downward to floor level after which it will quickly warm and then begin to rise to the ceiling space similar to leaked CNG. The design of an NGV maintenance facility for LNG fuelled vehicles has some additional requirements to those of CNG.

2.3 Safety hazards

Natural gas in the form of CNG and LNG is very safe provided certain basic safety precautions are followed at all times. Awareness of the risks and hazards associated with these forms of the fuel is very important so that proper facility design and handling procedures are followed.

CNG and LNG are highly flammable when leaked at atmospheric pressure, vaporized (as with LNG) and mixed with air. CNG and LNG can also cause asphyxiation when leaked in a confined space when little or no air is present. Most hazards between CNG and LNG are similar but there are also differences. These are explained below.

2.3.1 CNG hazards

The main CNG safety hazard inside a maintenance facility is leakage from faulty valves and fittings. The risk of leaks can be decreased by reducing the fuel container gas pressure and by isolating fuel container contents at its container valve during maintenance work. Other risks include damage during major repairs and hot work. To minimize the risk of damage during these operations, cylinders should be reduced in pressure or emptied and purged with nitrogen.

Safety hazards can be reduced with:

- continuous ventilation
- interlocking ventilation with a gas detection system
- removal of ignition sources
- approved work procedures

2.3.2 LNG hazards

LNG safety hazards inside a maintenance facility are typically due to leakage from valves and fittings and discharging relief valves. LNG will build up pressure as it heats up in the LNG fuel container. Pressure inside the fuel container can increase at a rate as high as 15 psig per day. Proper planning and development of WorkSafe BC procedures can reduce gas release events. Risk of leaks can be reduced by isolating the fuel supply at the fuel container valve; however, this will not prevent pressure rise inside the LNG fuel container

Safety hazards can be reduced with:

- continuous ventilation
- interlocking ventilation with a gas detection system
- reducing fuel container pressure before entering the facility
- connecting a captive vent to the fuel container pressure relief valve
- removal of ignition sources
- approved work procedures
- local portable gas detection (odourless gas)

- personal gas detection monitors

2.4 Sources of ignition

Awareness and control of sources of ignition inside an NGV maintenance facility are essential for the operation of a safe facility. A typical maintenance facility will have a variety of ignition sources, some being less important than others. Upon breach of containment CNG and LNG will leak into the atmosphere, vaporize (in the case of LNG) and mix with surrounding air. Once the leaked natural gas dilutes with air to a volume mixture less than 15 mol % of fuel in air (15 parts natural gas to 85 parts air), a flammable gas cloud is formed. This cloud will drift from the leak source and if it encounters an ignition source, it may ignite resulting in a fire. If the ignition is in a confined space, it will heat up the air very rapidly, causing a pressure rise and possible explosion. In open and unconfined spaces, natural gas will not explode, unlike other fuels such as propane.

Ignition sources present in a typical vehicle maintenance facility include, but are not limited to:

- open flame unit heaters
- open radiant tube heaters
- gas fired make-up air units
- gas fired pressure washers
- gas fired water heaters
- hot work operations including welding, grinding and flame cutting
- high temperature sealed combustion tube heaters
- electrical contact closure switches and motor contactors
- brushed motors used in hand tools
- hot surfaces above 400 ^{o}C
- trouble lights that are not explosion-proof
- steel on steel blade to shroud fans and blowers
- lighting with hot surfaces
- portable stereos and radios
- mobile phones

Each of the above ignition sources has a differing level of risk or probability of causing an ignition when a flammable gas cloud is present. An open flame has a high probability of ignition when a flammable gas cloud is present at near 100%. A mobile phone has a very low risk of ignition. Sources of ignition can be rated from “certain” to “negligible” and are tabulated in Table 2.3.

Table 2.3 - Strength of ignition sources

Category (Strength of source)	**Examples of ignition source**	**Ignition potential (quantitative)**	**Risk (qualitative)**
Certain	pilot light, open flame or flare	1	very high risk
Strong	electric motor (sparking open-drop type), hot work	>0.5	high risk
Medium	vehicles, faulty wiring, motor contactor	<0.5, >0.05	medium risk
Weak	electrical appliances, mechanical sparks, mobile phones	<0.05	low risk
Negligible	intrinsically safe equipment, radio frequency sources	0	very low/no risk

2.5 Hazardous area classification

Area classification is used to define the risk or probability of the presence of a flammable gas mixture in a particular area. Area classification is used in the CSA B401 Code to define requirements for electrical equipment including wiring, cabling, junction boxes and other connection methods within those areas. The Canadian Electrical Code defines the rules for the design of electrical equipment within those areas. Hazardous areas are classified by zones 0, 1 and 2. If there is no risk for the presence of a flammable gas mixture, then the area is defined as “non-hazardous”.

Table 2.4 - Definition of zones

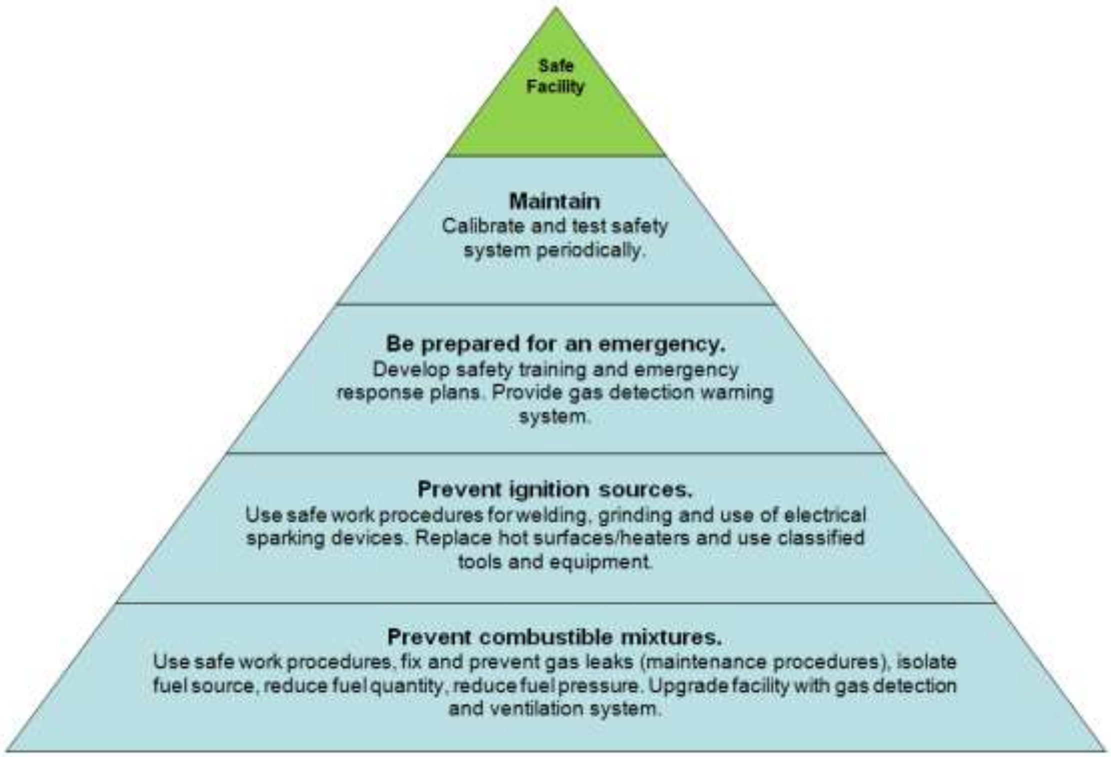
Zone	Definition
0	Area where a flammable gas-air mixture is present continuously or frequently, i.e. more than 1,000 hours per annum or more than 10% of the time.
1	Area where a flammable gas-air mixture is likely to occur under normal operation occasionally, i.e. between 10 – 1,000 hours per annum or 0.1% - 10% of the time.
2	Area where a flammable gas-air mixture is unlikely to occur in normal operation but if it does occur will persist for only a short period of time, i.e. less than 10 hours per annum or less than 0.1% of the time.

There are various areas within a maintenance facility that are designated with a hazardous area classification by the CSA B401 Code. Special provisions for electrical design are required in these areas.

3.0 Facility design overview

3.1 Elements of a safe facility design

Upgrading a facility for CNG and LNG safety requires gas safety system equipment; however, safety system safety equipment alone does not make a safe facility. There are four preventative measures that need to be practiced in the facility to ensure CNG or LNG safety. The key elements of facility safety are presented in the following diagram.



This diagram presents a hierarchy with the prevention of combustible mixtures in the facility as a foundational goal. The items above the foundation are additional safeguards to be put in place using technology and facility management.

3.2 Major gas safety system requirements

The major requirements of a gas safety system include:

- a minimum rate of continuous ventilation
- standby purge or continuous ventilation and make-up air provisions
- gas sensors spaced throughout the facility
- gas safety system controls to monitor the gas sensors, initiate standby purge ventilation, annunciate the condition through audible and visual alarms and to notify supervisory personnel and first responders
- automatic and procedural isolation of potential ignition sources
- elimination of strong and certain ignition sources (see table 2.3) including certain heating appliances or replacement with alternate heating appliances

- de-fuelling system
- LNG tank relief vent system
- fire extinguishers
- personnel training
- safe work procedures (specific to CNG and LNG)
- emergency response plan

There are some important differences in the above requirements depending on the definition of the facility operational requirements as discussed in Section 3.3.

3.3 Definition of facility design requirements

3.3.1 Major vs. minor repair

The requirements for facility design are dependent on the type of maintenance operations performed within the facility. In the CSA B401 code, operations are differentiated as either "major repair" or "minor repair" and are defined as follows.

Major repair - *activities carried out on vehicles that need extensive work such as engine overhaul, painting, body work, welding and/or grinding work, and fuel system repairs.*

Minor repair *- activities carried out on vehicles including lubrication, inspection, and minor maintenance such as engine tune-ups; parts replacement; replacement or addition of oil, brake fluid, antifreeze, transmission fluid, and air-conditioning refrigerants; brake system repairs; tire rotation, repair, or replacement; and other similar routine maintenance.*

In addition, a *major repair facility* is a facility in which major and minor repair operations may occur. A *minor repair facility* is a facility in which minor repair operations may occur only. Under some special conditions there can be an exception to this and this is explained in Section 3.3.2.

For major repair facilities, the requirements for facility gas safety systems are more extensive and also costlier than for minor repairs. When considering the investment in a gas safety system, it is recommended that careful consideration be made to the type of operations that will be performed within the facility.

3.3.2 Special provision for major repair inside a minor repair facility

The CSA B401 code does have some special provisions that allow major repair operations within a minor repair facility. If a vehicle is de-fuelled to less than 500 psig, the vehicle may enter into a minor repair facility and undergo major repair operations. The pressure to which a vehicle is de-fuelled should be in accordance with an approved company operating procedure and will be dependent on the type of work to be performed. For example, if the work being performed is on the fuel container then a complete de-fuelling may be required including purging with inert gas (i.e. nitrogen).

The client is duly warned against a quick decision in applying this provision without careful consideration to its implications for operations. There are some limitations and pitfalls to the use of this provision.

- To de-fuel a vehicle requires additional equipment on or close to the premises. If a client has a CNG station on the premises a de-fuelling system can be installed to draw down the pressure in the fuel container and recycle it back into the CNG station.
- If the above is not available, the operator can deplete the fuel container to a low pressure level through use. This takes coordination and time. The remaining fuel must then be vented through a vent stack.
    - *Warning – Natural gas is a greenhouse gas with GWP relative to carbon dioxide of 28 – 36 over 100 years. Any venting of natural gas is discouraged. If necessary, the volumes of natural gas vented should be kept to an absolute minimum. In addition, any venting of natural gas exceeding 10 kg per event must be reported to Environment Canada by law.*
- In the event that a vehicle has an unexpected breakdown, the opportunity to de-fuel the vehicle is much more challenging and may impact the schedule to repair. The vehicle must be de-fuelled below 500 psig before entering the maintenance facility.
- Dedicated fuel vehicles (i.e. vehicles that can only operate on natural gas), may have very limited range to travel to a fuelling station once the repair is completed. In addition, if the engine requires operation during the repair, the fuel pressure will deplete further and may not provide enough operating time. Furthermore, the ability of the vehicle to pull out of the facility to travel to a fuelling station may be impeded.
- Some engines require greater fuel container pressure than 500 psig to maintain full operation. Some engines will have automatic engine power limiting controls that do not allow them to operate at full power for engine testing below 500 psig.
- Transferring fuel to a NGV inside a minor or major repair facility is prohibited. If a vehicle cannot be driven out of a facility it will have to be towed out and to a fuelling facility. An alternative is a vehicle to vehicle fuel transfer outside of the facility in accordance with an approved operating procedure and with special equipment.

3.4 Cost considerations

3.4.1 Upgrade of existing facilities

Most maintenance facilities are legacy buildings that are not designed for NGV maintenance operations and may require numerous upgrades. The existing ventilation systems will likely not have the necessary capacity or electrical equipment hazardous location ratings, requiring replacement. For major repair facilities, heaters may be open flame or closed combustion with high temperature surfaces and require demolition and replacement. Electrical systems and sub-panel feeders may not be well separated making automatic power isolation for ignition control difficult. The architecture of the building may not provide sufficient separation between maintenance spaces and adjacent offices, requiring building modification.

Upgrades for minor repair are substantially less costly than for major repair. LNG repair facilities will cost slightly more than CNG facilities. Approximate costs for facility upgrading are provided in Table 3.1. Table 3.1 should be considered as a rough guide only. Cost can vary considerably depending on the nature of the modifications required.

Table 3.1 – Facility upgrade cost

	Installed cost range	
No. of bays	Major repair	Minor repair
1	\$100K - \$150K	\$40K - \$60K
6	\$200K - \$300K	\$100K - \$150K
12	\$300K - \$400K	\$150K - \$200K

Note that the incremental cost increase to upgrade larger facilities is relatively small. This is due to various fixed costs that do not change with facility size and economy of scale for equipment.

3.4.2 New construction

The cost to construct a new maintenance facility to allow NGV minor or major repair is substantially lower than the upgrading of existing facilities. For example, the incremental cost increase for the specification of fans and heaters with the required features (i.e. spark resistance, explosion-proof, higher capacity, low temperature heaters, etc.) is relatively small in comparison with demolition and replacement. In addition, facilities can incorporate architecture to facilitate rooftop ventilation and make-up air features that may require a building modification if upgrading an existing facility. The additional construction cost to up-fit a new maintenance facility with a gas safety system may be 30-60% of the cost of an existing facility upgrade.

3.5 Hazardous area classification

The CSA B401 code designates various areas with an area classification. These are important to understand and require electrical equipment to be selected and installed appropriately.

3.5.1 Minor repair

For CNG minor repair facilities all spaces are unclassified if minimum normal continuous ventilation is provided (see section 5.1).

For LNG minor repair facilities all spaces are unclassified if minimum normal continuous ventilation is provided (see section 5.1) with the exception of pits. Pits having continuous ventilation are unclassified but pits having standby ventilation have an area classification of Class 1 Zone 2 Group IIA.

If minimum normal continuous ventilation is not provided, then the area 500 mm below the ceiling and 4,500 mm in all directions from the purge fan outlet are designated a Class 1 Zone 2 Group IIA area.

3.5.2 Major repair

For CNG major repair facilities all spaces are unclassified if minimum normal continuous ventilation is provided (see section 5.1); however, ventilation fans, disconnects and gas sensors must still be rated and wired for Class 1 Zone 2 Group IIA within 500 mm of the ceiling and 4500 mm in all directions from a purge fan outlet despite this being an unclassified area.

Note: This provision can seem confusing in that even though the area is unclassified, Zone 2 equipment and wiring is still required within the distances specified. This is an additional precaution in the event of a catastrophic leak which has a very low probability but may result in a major consequence if ignition were to occur.

If minimum normal continuous ventilation is not provided, then the area 500 mm below the ceiling and 4500 mm in all directions from the purge fan outlet are designated a Class 1 Zone 2 Group IIA area.

For LNG major repair facilities, the above is also applicable with an exception that the area from floor to 500 mm elevation above the floor is a Class 1 Zone 2 Group IIA area. Furthermore, the entire pit that has continuous ventilation is designated Class 1 Zone 2 Group IIA. If the pit has standby ventilation, it is designated as Class 1 Zone 1 Group IIA.

4.0 Building architecture considerations

4.1 Separation

A maintenance facility must have a distinct separation between the minor and major repair areas and adjacent occupancies such as offices, lunch room, washroom, parts inventory room, foyer, etc. This separation should be by way of a fire wall extending from floor to ceiling. The separation must be gas tight. Any penetrations and gaps through the wall from water pipes, electrical conduits or other items, should be sealed to prevent gas migration to adjacent spaces. In addition, there must be a complete separation of HVAC systems between the minor or major repair areas and adjacent spaces so that in the event of a gas leak, the leak is not propagated to areas not equipped accordingly. Air conditioners (AC) that draw air from the maintenance area into adjacent offices or offices within the repair area (see Figure 4.1) must be demolished or replaced with alternate equipment such as ductless split type AC units.

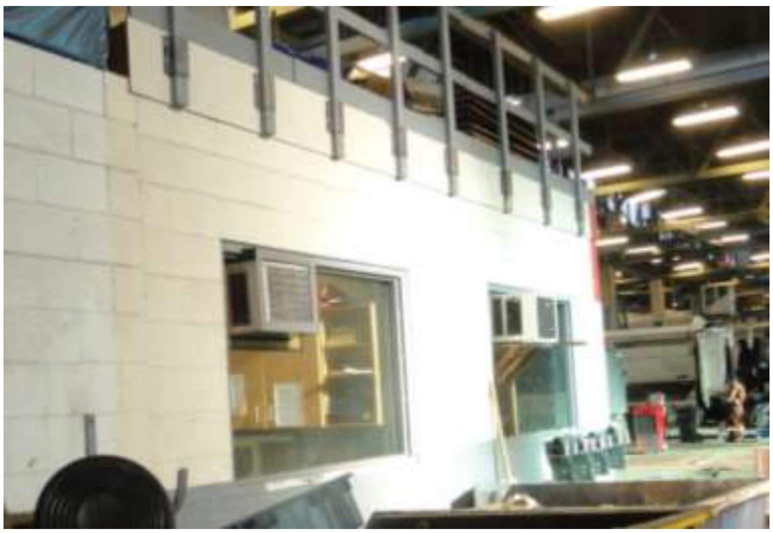


Figure 4.1 – air conditioner cross ventilation

4.2 Closures

Openings in the separation wall between the minor or major repair area and adjacent spaces may include man-doors, roll-up doors and sliding windows. Man-doors should be fire rated and equipped with self-closing mechanisms to maintain the door in a normally closed position. Through signage, operational procedures, policies and training, propping open of doors should be prohibited.

Roll-up doors are also often used for access to storage rooms and parts inventories. These doors are to remain closed when not in use. It is recommended that signage, warning light and audible alarm be interlocked with the door to assure that it is closed when not in use.

Windows that are installed in separation walls should be self-closing or non-opening.

Figure 4.2 – automatic door closures

4.3 Gas entrapment areas

Gas entrapment areas are places where gas may accumulate or may be impeded from moving toward a gas sensor. This can result in gas build-up without any warning and response. Gas entrapment features may include overhanging mezzanines, open stairwells, pocketed ceilings, ceiling beams, sky lights, hallways, side rooms with doorless entrances and other features. A professional opinion on whether or not a specific feature warrants the introduction of risk mitigation measures is recommended to avoid unnecessary expenses.

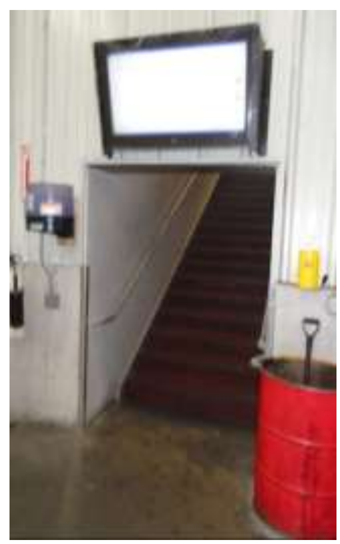


Figure 4.3 – overhang mezzanine with pocketed ceiling

Figure 4.4 – doorless staircase

Methods to deal with these areas include the following:

- installation of through-vents in mezzanine floors and skylights
- installation of forced ventilation in the ceilings of side rooms
- installation of doors on open stairwells
- installation of gas sensors in ceiling pockets
- drilling through-holes in beams (subject to approval by a structural engineer)

4.4 Floor drains

In major repair maintenance facilities that service LNG fuelled vehicles, attention must be paid to the location of floor drains. A major leak of LNG could flood a drain resulting in a rapid phase transition (RPT) from liquid to vapor inside a drain pipe or holding tank. Drains and connected in-ground holding tanks may not be sufficiently vented resulting in excessive pressure build-up as the LNG rapidly evaporates leading to explosion.

Figure 4.5 – floor drains and holding tank

It is recommended that a professional opinion be obtained to assess whether or not risk mitigation is necessary. This may include installation of additional vents or open grate covers on holding tanks.

5.0 Ventilation systems

Adequate ventilation is a key requirement for both minor and major repair facilities. A minimum level of normal ventilation provides dilution to flammable and noxious gases to prevent accumulation. Normal ventilation is continuous and is provided to maintain air quality and prevent accumulation of flammable gas from small leaks. In addition, various levels of purge ventilation capacity are required depending on facility type and size. Existing or new HVAC systems can also be integrated to provide normal, continuous and purge ventilation capacity.

5.1 Normal ventilation

Normal ventilation of a minimum of 0.5 ACH must be provided for both minor and major repair facilities for the facility ceiling area to remain unclassified. This ventilation must be a continuous and reliable. Normal ventilation may be provided by passive or forced ventilation. Additional and higher rates of ventilation may be required by building code for maintaining air quality from other noxious gases including carbon monoxide (CO) and nitrous oxides (NOx).

5.1.1 Passive ventilation

Passive ventilation may be natural draft ventilation drawing air upward through some form of ceiling ventilation opening(s). Some challenges with dependence on passive ventilation are that the ventilation rate may be affected by weather conditions; ventilation up through the ceiling may not be available with existing construction; and passive ventilation rates are difficult to estimate. Professional help should be retained to determine if existing draft ventilation is adequate.

5.1.2 Forced ventilation

Forced ventilation is usually provided by an electric motor driven fan or blower. Purge ventilation fans may also be used to provide normal ventilation by operating at low speed while on standby, using a variable speed drive. Fans without ducts can be installed directly in the facility ceiling or ducted such that air is drawn from within 0.5 meters of the ceiling height and exhausted outdoors.

5.1.3 Noxious gas ventilation

Ventilation to deal with noxious gases from vehicle emissions may be required by building code to meet occupancy air quality requirements and may be up to 2 ACH or more. Such ventilation systems can be used to meet and exceed normal ventilation requirements for NGV maintenance facilities; however, for major repair facilities any purge fans must meet have a Class 1 Zone 2 Group IIA hazardous area classification rating (see Section 5.3). Another aspect to be aware of is that noxious gas ventilation systems often operate only when the facility is occupied. For natural gas maintenance facilities, normal ventilation of 0.5 ACH must be available continuously if a natural gas vehicle is located within the facility.

5.2 Ventilation system design

The normal and purge ventilation system is a key aspect of the gas safety system design. The ventilation system must effectively remove accumulated gas from anywhere in the facility ceiling. The location of fans and make-up air locations is important to assure adequate purging of the entire facility volume. Consideration must also be given to potential gas hold-up areas resulting from beams, mezzanines and other architectural features. It is recommended that ventilation design be executed by an experienced professional.

5.2.1 Ventilation fan selection

The most common location for the installation of purge ventilation fans is the facility roof top. Side wall mounting may also be used; however, ducting to the fan is likely required to meet the requirement to pull intake air from within 500 mm of the ceiling. Roof top fans may also be ducted in the event that the fan mounting location is limited and does not align with the desired location to extract air.

Down-blast centrifugal fans are often used for roof top application. These units are weather resistant and will not allow snow accumulation unlike an up-blast fan. Other fan types including mixed flow and axial fans may also be used depending on the location. It is also required that fans be of spark resistant construction of a minimum of AMCA Spark C.

Figure 5.1 – rooftop down-blast fan

Fans outfitted with backdraft dampers are important for building heat retention when not operating. The designer should also consult building codes to determine the quality of backdraft damper required to meet applicable energy efficiency standards.

Backdraft dampers can be either gravity or motorized. Gravity type backdraft dampers are less reliable than motorized units and certainly less energy efficient. If motorized backdraft dampers are used in the ceiling area of major repair facilities, they must meet a Class 1 Zone 2 Group IIA hazardous area classification.

Fan motors and disconnects must also be selected with the appropriate hazardous area classification (see Section 5.3).

5.3 Purge ventilation

Purge ventilation must be available as a mitigation measure in the event of a major gas leak.

5.3.1 Purge ventilation rates

For minor repair facilities a minimum purge ventilation rate of 2 ACH is required. For major repair facilities, the ventilation rate is dependent on the volume of the facility in accordance with Table 5.1.

Table 5.1 – Purge ventilation schedule for major repair facilities

Minimum air changes per hour (ACH)	Major repair area volume V (m^3)
10.0	V< 400
8.5	400≤V<800
7.0	800≤V<1,600
6.0	1,600≤V<3,200
5.0	3,200≤V<6,400
4.5	6,400≤V<12,800
4.0	V≥12,800

Large facilities require less ACH than small facilities. The reason for this is that large facilities have greater total ventilation capacity and also more space for flammable gas dilution with air through convective mixing.

5.3.2 Continuous ventilation

For minor and major repair facilities purge ventilation may be provided on a continuous basis. The advantage of this is that no gas sensors and related controls are required, reducing capital cost. The disadvantage is that in northern climates, maintaining comfort is challenging and high rates of heat loss can incur a major operating expense. For this reason, continuous ventilation is not normally recommended for minor or major repair facilities located in Canada.

5.3.3 Standby ventilation

Standby purge ventilation is commonly provided for minor and major repair facilities to reduce heat loss. Purge ventilation is activated upon the detection of a flammable gas concentration. A manual activation switch must also be provided; however, the manual switch must not be able to defeat the automatic initiation of purge ventilation.

5.3.4 Make-up air options

When purge ventilation is activated, a high volume of air must be exhausted from the facility. To replace this air, an equal volume of fresh make-up air must be drawn into the facility from outdoors. The designer must be sure to have adequate provision for this make-up air.

Make-up air is often provided by automatically rolling up one or more entrance doors at least 600 mm to allow a gap below the door for air flow. The number of doors rolled up and their location should be selected to distribute adequate fresh intake air to purge the entire facility volume.

An alternate means of make-up air provision is to provide louvers near ground level. The opening of these louvers must be reliable. Gravity louvers are not very reliable therefore motorized louvers are recommended. Location and number of louvers should be selected to allow for adequate fresh intake air distribution to purge the entire facility volume.

5.4 Other HVAC systems and integration

5.4.1 Make-up air units

Make-up air units (MAU) are often provided in maintenance facilities to replace heated air exhausted by the normal ventilation system to maintain air quality. MAUs are usually gas-fired and present a potential ignition source. For major repair facilities, these units must be located outdoors with make-up air discharged into the facility through a duct. MAUs must be air balanced with separate exhaust fans such that the pressure inside the maintenance facility is at a slightly negative pressure relative to adjacent spaces. In addition, the MAU must be outfitted with a high quality backdraft damper (i.e. AMCA 511 Pressure Class 1 minimum) to prevent potential back flow of gas back to the MAU burner. This damper must also be outfitted with a position switch to prove open and closed positions. Failure of the damper to open fully or close fully upon activation must initiate a trouble condition.

The exhaust fans that are balanced with the MAU may also be used as purge ventilation capacity. A variable speed purge fan may operate at low capacity balanced with the MAU and then when called on for purge ventilation may ramp up in speed to provide purge ventilation capacity. Additional make-up air provisions must then also be employed as per section 5.3.4 when operating in purge mode.

An alternative is to operate additional exhaust fans to the MAU exhaust fans to provide the full purge ventilation capacity if single speed fans are used.

5.4.2 Heat and energy recovery ventilators

Heat and energy recovery ventilators can also be present in maintenance facilities. If coupled with a fired heating system, similar provisions as with MAUs are required (see section 5.4.1). These units will also be balanced with exhaust fans and can be integrated as part of a purge ventilation system strategy.

5.5 Pit ventilation

Where pits are employed in LNG minor and major repair facilities, either continuous ventilation or standby ventilation must be employed. The ventilation rate should be a minimum of 0.3 $m^3/min/m^2$ (1 $ft^3/min/ft^2$) based on floor area. Exhaust inlets must be located within 300 mm (12 in) of floor level. For CNG minor and major repair, no additional ventilation is required for pits unless additional ventilation is required to deal with the presence of other noxious gases as per building code.

5.5.1 Continuous ventilation

Continuous ventilation may always be present or may be activated manually when the pit is in use. When using continuous ventilation in a major repair pit, the entire pit has a hazardous area classification of Class 1 Zone 2 Group IIA. In addition, the same hazardous zone extends 4.5 meters in all directions from the blower exhaust outlet to outdoors. Blower motors and any electrical wiring and equipment must be compliant with the hazardous zone. For minor repair pits, the area is unclassified if continuous ventilation is used.

5.5.2 Standby ventilation

Pits may use standby ventilation if the standby ventilation is initiated by the gas sensors located in the pit. When using standby ventilation in a major repair pit, the entire pit has a hazardous area classification of Class 1 Zone 1 Group IIA. In addition, the same hazardous zone extends 4.5 meters in all directions from the blower exhaust outlet to outdoors. Blower motors and any electrical wiring and equipment must be compliant with the hazardous zone. For minor repair pits, the same applies except that the hazardous area classification is Class 1 Zone 2 Group IIA.

If using standby ventilation, a manual switch should also be available and readily accessible to initiate ventilation. The manual switch should not ever be capable of defeating the standby operation of the ventilation system.

6.0 Heating systems

6.1 General requirements

All heating equipment must be approved for installation. Improvised or modified heating equipment cannot be used. Other than the former, for minor repair facilities, there are few restrictions on the type and use of heating equipment other than that the elevation of air inlets are a minimum of 500 mm above floor level and minimum of 1,000 mm below the ceiling.

6.2 Temperature limitations

For major repair facilities, ignition sources related to heating equipment are of critical concern. Heaters employing open flames are not permitted. Furthermore, sealed combustion heaters, such as radiant tube heaters, even though they are not open flame, can have very high surface temperatures and are not permitted unless meeting specific temperature limitations. This also applies to some catalytic heaters. The maximum surface temperature threshold for compliance for use in a major repair facility is 400 ^{o}C (752 ^{o}F). It is recommended to use only heaters that are certified by the manufacturer to have surface temperatures that are in compliance with the maximum threshold.

6.3 Radiant heating

6.3.1 Discrete tubular radiant heating units

One of the most common methods of maintenance facility heating is the use of discrete radiant tube heaters operating on natural gas. Radiant heat warms surfaces rather than air, which is important when doors are often opened or remain open during operation in cold weather. Most legacy tubular heating units have high surface temperatures that are not in compliance for major repair facilities. Low intensity tubular heaters are available that are in compliance with the maximum surface temperature threshold and can be used as replacements for existing heaters. The disadvantage of low intensity heaters is that additional heaters will need to be installed to make up an equivalent heating load. In addition, these heaters do not provide the same intensity of warmth and may result in complaints from personnel coming out of the cold and wanting to warm up quickly by standing beneath one.

Figure 6.1 – low intensity discrete radiant tube heater

6.3.2 Multiple tubular radiant heating system

A variation on the discrete radiant tube heater is a multiple tubular radiant heating system. This type of heating system is custom engineered to the facility and provides space economy, reduced number of roof or side wall penetrations and increased efficiency. Greater efficiency is obtained through less heat rejection to outside air. Instead of a single burner and tube, multiple burners are integrated into a system of tubes with the hot air pulled through the tubes with one or more vacuum pumps. These systems provide enhanced heat distribution and are available as surface temperature compliant low intensity heaters.

Figure 6.2 – multiple tubular radiant heating system

6.3.3 Catalytic heaters

Catalytic heaters are acceptable for use in a major repair facility if surface temperature compliant. Catalytic heaters have greater flexibility in terms of where they can be mounted and do not require air intake and exhaust ducting.

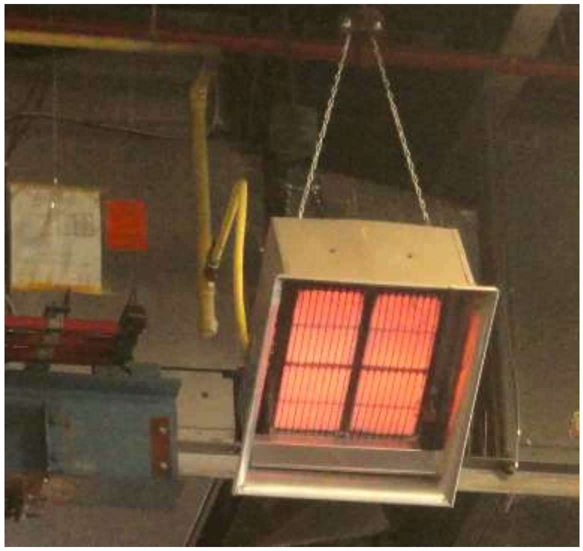


Figure 6.3 – natural gas catalytic heater

6.4 Fired unit heaters

Fired unit heaters use open flames and are not compliant for use in a major repair facility. These units must be demolished and replaced with alternate compliant heating.

Figure 6.4 – Fired Unit Heater

6.5 Hydronic heating

Hydronic of hot water heating is a satisfactory solution for major repair facilities and should be considered for new construction of NGV major repair facilities. Hydronic heating can be provided through in floor heat and/or through radiators. If a boiler is used to supply the hot water, it must be located outside of the major repair facility.

6.6 Electric heating appliances

Electric heating is acceptable in major repair facilities as long as surface temperatures do not exceed 400°C (752°F).

6.7 Other heating equipment

Open flame portable heaters are non-compliant in major repair facilities. Fired water heaters are non-compliant and must be replaced with electrical water heaters or relocated from the major repair facility. Pressure washers that include fired heating are non-compliant and must be relocated.

7.0 Gas detection controls and alarms

The gas sensing, controls and alarms are key elements of the gas safety system required for both minor and major repair facilities and provide mitigating response in the event of a major gas leak.

7.1 Gas detection

7.1.1 Catalytic bead

Catalytic bead (CB) gas is one of two main types of gas sensing technologies that are in use. CB technology uses a catalyst in the sensor to burn gas molecules when present. The burning of gas results in a temperature rise which is detected electronically. As such, CB technology is a fixed point sensor technology able to detect gas only in a specific location.

CB type sensors are susceptible to damage from chemical vapors such as silicone and sulfur vapors which may be present in a shop environment. CB type sensors are not fail-safe and may not respond if gas is present due to the poisoning of the catalyst resulting in a coating that is resistant to the presence of flammable gases. Calibration intervals should not exceed –three to six months or the manufacturer's recommendation whichever is less.

CB sensors are available as industrial grade and commercial grade sensors. Industrial grade sensors typically have a Class 1 Zone 1 Group IIA hazardous area classification suitable for major repair facility application. Commercial grade sensors are unclassified and can only be used for minor repair facility application. Commercial grade sensors are much less expensive than industrial grade units but may be less reliable and require more frequent calibration.

7.1.2 Infrared

Infrared (IR) sensors are more expensive than CB but have the advantage of far greater reliability and are nearly fail safe. IR sensors work on the principle of detecting gas through absorption using an infrared light source along with a measurement and reference detector. IR sensors are typically of industrial quality only and have a hazardous area classification of Class 1 Zone 1 Group IIA. Calibration intervals should not exceed 1 year or the manufacturer's recommended internal, whichever is less. IR sensing technology is highly recommended as the lowest risk technology for major and minor repair facilities.

7.1.2.1 Fixed point gas sensors

Infrared gas sensors are available as fixed point or open path. Fixed point IR sensors use non-dispersive infrared technology. These sensors depend on the gas migrating toward the sensor at a single point location. Fixed point sensors are most commonly used for NGV maintenance facility application.

Figure 7.1 – fixed point gas sensor

7.1.2.2 Open path

Open path IR sensors are able to detect gas along an IR beam that can be up to a few hundred meters in length. Open path sensors require an IR transmitter and a receiver at the opposite end of the beam. Alternatively, transmitter and receiver can be combined by providing a retroreflector at the far end of the beam. Open path sensors can provide excellent coverage by detecting gas anywhere along the length of the beam. They provide rapid response to leaks due to the increased coverage.
Open path sensors are more expensive than fixed point gas sensors but can provide greater coverage with fewer sensors for large facilities resulting in significant cost savings. One of the main challenges with open path sensors is assuring IR beam clearance in the ceiling spaces that are often taken up by structural beams, trusses, cables and other items.

Figure 7.2 – open path IR gas sensor

7.1.3 Gas sensor installation design

Due to the lighter than air density of natural gas, gas accumulation will occur in the ceiling spaces of the facility. As the gas rises to the ceiling it may be diluted, but over time it will concentrate in the ceiling. Gas sensors are required to be located with their sensing point or beam within 500 mm of the ceiling.

In addition, the spacing of the sensors must be such that coverage is adequate for the area. It is recommended that a professional be employed to design the gas sensor layout to assure adequate coverage for the facility.

For LNG major repair facilities, gas sensors must also be provided within maintenance pits. In these locations, fixed point sensors should be located within 500 mm of the lowest floor elevation. Gas sensors must also be provided within 500 mm of the main floor level.

7.1.4 Gas sensor calibration

Gas sensors require periodic calibration on an interval dependent on the technology and the manufacturer's recommendation. To facilitate calibration, gas sensors that are not readily accessible (i.e. in the ceiling) should be provided with calibration tubing extending from the gas sensor down to floor level and located next to the transmitter. This will allow a technician to easily apply a calibration gas to test the sensor while having the sensor transmitter display readily visible.

Figure 7.3 – gas sensor calibration tubing

7.2 Control system

The gas safety control system is the heart of the gas safety system which will process gas sensor data, initiate purge ventilation and annunciation and activate various other responses.

7.2.1 Minor repair

For minor repair facilities, unless continuous purge ventilation is used, the control system must interlock the gas sensors with a purge fan start control at a maximum of 20% LEL. The starting of the purge fans must initiate an audible and visual alarm. At the same time any open flame heating equipment should be automatically extinguished. This may be done using a lighting contactor or shunt trip.

The purge ventilation system must also have means for manual activation. When the purge ventilation system is activated automatically or manually, a building evacuation should occur.

A control system may be designed using a small PLC or relays. Any failure of the control system and components including fan motor failure, gas sensor, PLC and relays should be detectible a visual and audible alarm and should initiate the purge ventilation system. The purge ventilation should continue operating until acknowledged manually at the gas safety control panel.

The control system must be secure from tampering or programming changes without authorization. It is recommended that an alarm acknowledge function be included in the gas safety control panel to allow a qualified person to reset the controls and extinguish the alarms.

For maintenance facilities that use continuous ventilation, the failure of the ventilation system must be annunciated with a visual and audible alarm.

7.2.2 Major repair

For major repair facilities, the gas safety control panel must be a fire-rated life safety panel listed in accordance with CAN/ULC-S527. Gas safety system circuits should be monitored for integrity including those for gas sensors, call buttons, signalling lines and means of notification.

The gas safety system should activate the purge ventilation system (unless operating continuously) upon the detection of a maximum flammable gas concentration of 20% LEL (Warning Level) and send a notification to supervisory personnel. At this threshold, visual and audible annunciators should be activated and building evacuation should occur. If the flammable gas concentration continues to rise to 40% LEL (Danger Level), then all low intensity heating equipment should be automatically extinguished and all unclassified electrical equipment within 500 mm of the ceiling and any circuits providing power for hot work equipment should be automatically isolated. At 40% LEL emergency responders should be automatically notified.

Figure 7.4 – gas safety control system

If lighting is isolated, then emergency lighting should be provided where required.

Call buttons should also be available to activate the purge ventilation system. The response should be the same as if 20% LEL is detected.

It is recommended that an alarm acknowledge function be included in the gas safety control panel to allow a qualified person to reset the controls and extinguish the alarms.

The gas safety system controls must be capable of system failure detection including fan motor start failure, monitored circuit failure and gas sensor failure. Upon detection the failure should be annunciated visually and audibly and an automatic notification of supervisory personnel should occur. The trouble alarm must also initiate gas shut-off to heating equipment and start the purge ventilation system which should remain operating until qualified personnel acknowledge the trouble alarm.

7.3 Alarm annunciation and initiation

7.3.1 Minor repair

For minor repair facilities, an alarm must be annunciated visually and audibly in at least one location within the facility where it is audible and visible to all occupants. A single red annunciation light is suitable as a visual indicator. Audible alarms should have a sound power of a minimum of 10 dBA above background noise and, but not less than, 65 dBA or greater than 110 dBA.

7.3.2 Major repair

For major repair facilities at least one visual and audible alarm must be provided within the major repair facility. The visual alarm should be at least a two color light set to annunciate a Warning and Danger level. It is recommended that amber and red be used for Warning and Danger levels respectively. An optional green light is also often provided to annunciate the normal and all clear condition.

Figure 7.5 – indoor tri-color annunciation and horn

Figure 7.6 - outdoor tri-color annunciation and horn

Furthermore, it is recommended that at least one set of annunciation lights and horn be located outdoors to indicate status of the facility from outside. These indicators are very useful for monitoring of facility status in the event of an emergency by the evacuees and first responders.

In addition to the annunciators in the facility and outdoors, additional annunciators are required to be provided in occupied spaces immediately adjacent to the major repair space which may include service counters, offices, lunch room, parts inventory and other spaces. The annunciators may be simple amber light units with a built-in horn to indicate the warning level for evacuation response.

7.4 Manual activation

Provision of manual activation of the purge ventilation system by manually activating a call button is required. Activating the purge ventilation system must provide a response similar to automatic activation at the 20% LEL warning level.

For minor repair facilities, at least one call button must be readily accessible to manually initiate the purge ventilation fans. For large minor repair facilities multiple call buttons at all exits and alarm annunciators are recommended to assure ready accessibility and effective notification. For small facilities, the call button and alarm annunciators may be mounted directly on the gas safety system control panel.

For major repair facilities, a call button is required at all emergency exits.

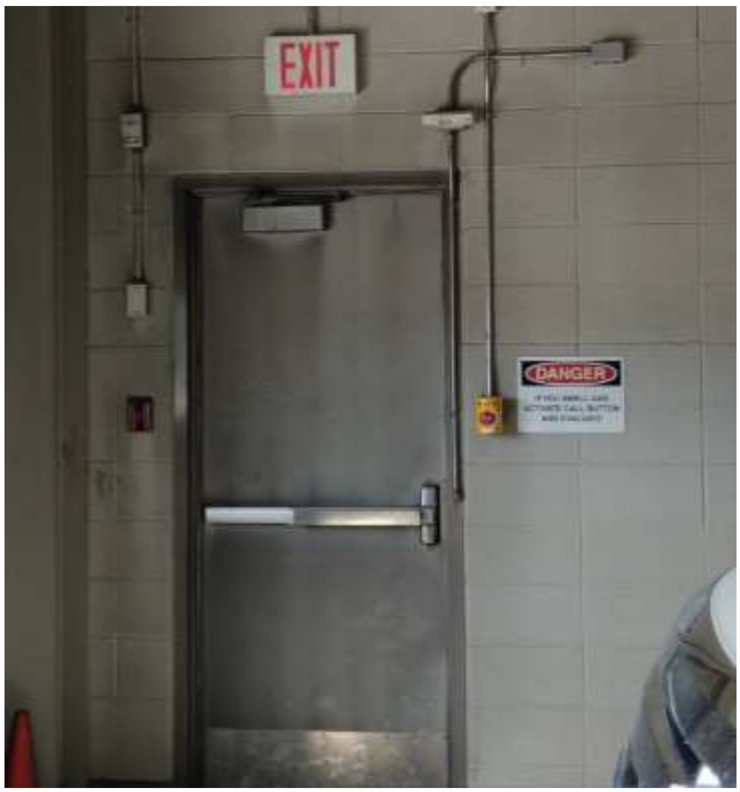


Figure 7.7 – Call button (yellow) for purge ventilation system activation

7.5 Back-up power

For major repair facilities the control system must have an uninterruptible power supply (UPS) to maintain power to the gas sensors and controls for a minimum of 4 hours. The UPS need not be able to power the purge ventilation fans.

8.0 Signage

Signs are an important part of the gas safety system providing direction on policy and emergency response. Signs to be provided should include, but are not limited to, those for:

- maintaining separation wall doors and windows closed at all times
- identification and use of call buttons
- limitations for welding and hot work
- no smoking, no open flames and no sparks
- instructions for evacuation at beacon lights and horns

Some examples of signs are provided in the following figures.

Figure 9.1 – call button and door closure signs

Figure 9.2 – sign for limitation on welding

Figure 9.3 – instructions for emergency response

9.0 Defuelling systems and vents

For some maintenance operations the de-pressurizing of fuel containers is required. If a major repair is to take place inside a minor repair facility, the fuel container of a CNG fuelled vehicle must be depressurized to 500 psig or less. If major repair is to take place in a minor facility, an LNG fuelled vehicle must be completely emptied and purged with an inert gas. If hot work is required on a vehicle with the potential for damage to the fuelling system, then the fuelling system should be depressurized and purged with inert gas. CNG and LNG require differing equipment for depressurization and emptying.

9.1 CNG

9.1.1 Defuelling and gas recovery systems

If a vehicle has more than 10 kg of natural gas within it fuel system, the de-fuelling must occur at a facility where the natural gas can be recovered and used. Natural gas is a potent greenhouse gas with venting of more than 10 kg of natural gas reportable to Environment Canada. The most convenient location to de-fuel a vehicle is at a CNG fuelling station which has the appropriate equipment. Not all CNG fuelling stations have de-fuelling equipment.

A de-fuelling system at a CNG station may allow the vehicle to vent some of its fuel contents into stationary storage for temporary storage and/or into the suction line of a compressor. The operational procedures for de-fuel systems vary depending on design. Some systems can only defuel when there is demand at the CNG dispenser and compressors are operating. Others can temporarily store the gas that is de-fuelled by operating a compressor to draw down the de-fuelling vehicle and recompress the de-fuel gas into storage vessels independent of CNG dispenser demand.

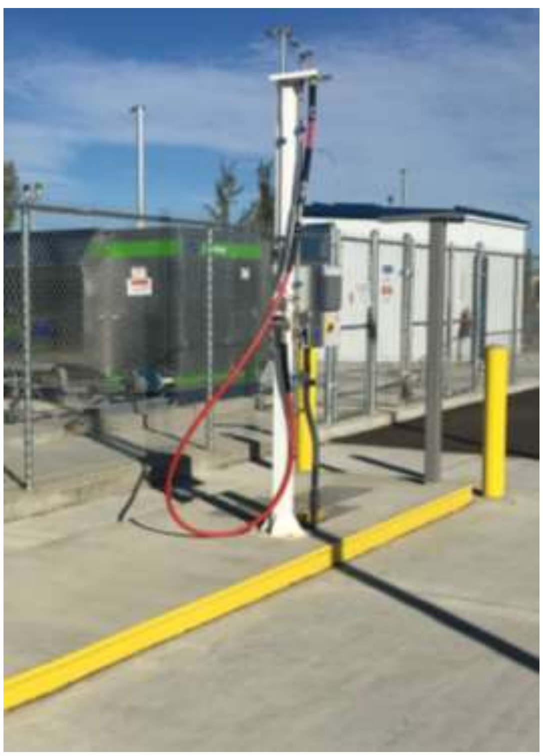


Figure 9.1 – De-fuel post

Figure 9.2 – De-fuel panel and post

9.1.2 Vehicle to vehicle transfer

An alternative to de-fuelling is vehicle-to-vehicle fuel transfer. A fuel transfer can occur if the receiving vehicles fuel container is at a much lower pressure than the vehicle to be de-fuelled. A special hose is used to make the connection between the two vehicles. This procedure must only be executed outdoors and by qualified personnel in accordance with an approved procedure. Grounding of the two vehicles is also a requirement.

9.1.3 De-fuelling vent systems

A de-fuelling vent can be used to vent a small amount of gas remaining in the CNG fuel container to atmosphere (i.e. < 10 kg). A typical large CNG container (i.e. used on transit buses) may have a volume of 276 litres. To comply with the 10 kg vent limitation, the container would need to be at a pressure below 600 psig at the start of the vent procedure, if it is desired to vent the fuel container completely.

Note: Any venting of natural gas to atmosphere is discouraged. Natural gas is a potent greenhouse gas. If venting is required, release volumes should be as low as reasonably practical.

De-fuel vent systems are relatively inexpensive and can easily be installed just outside a maintenance facility. A de-fuel vent typically includes a flexible hose, nozzle, grounding connection, grounding rod, vent stack, vehicle crash protection and a nitrogen purge connection.

Figure 9.3 – de-fuel vent systems – no hose shown

Figure 9.4 – de-fuel vent stack

9.2 LNG

9.2.1 LNG vehicle to vehicle transfer

LNG may be transferred from one vehicle to another. If the LNG tank has a liquid drain valve and connection, this can be used to connect a transfer hose from one tank to another. To make a transfer, the receiving tank must be at lower pressure than the donor tank. This procedure should only be executed by personnel who are trained in accordance with an OEM procedure using OEM provided equipment.

9.2.2 LNG vehicle to station transfer

If an LNG station is located conveniently, LNG may be transferred from the vehicle to the station. If the LNG tank has a liquid drain valve and connection, this can be used to connect a transfer hose from the vehicle to the liquid return line of the LNG station. To make such a transfer, the donor tank must be at a higher pressure than the liquid return line and connected tank. This procedure should only be executed by personnel who are trained in accordance with an OEM procedure using OEM provided equipment.

9.2.3 Venting of LNG to a flare

LNG can be drained from a LNG container by venting to a flare. The equipment required is a vaporizer and a flare with controls. The LNG tank is connected to the vaporizer using the liquid drain connection. The LNG flows through the vaporizer and then to the flare for combustion. This system can be used to completely drain the LNG liquid leaving only the remaining vapor at atmospheric pressure. The remaining vapor can then be purged using nitrogen. Purging the fuel container may require repeated pressurization and de-pressurization through the drain valve to reduce the partial pressure of natural gas to well below the lower flammability limit. Installing an LNG vent flare system must be done in accordance with applicable regulations. Venting of the fuel container to a flare must be executed only by trained personnel in accordance with an OEM procedure using OEM connectors, adapters and transfer hoses.

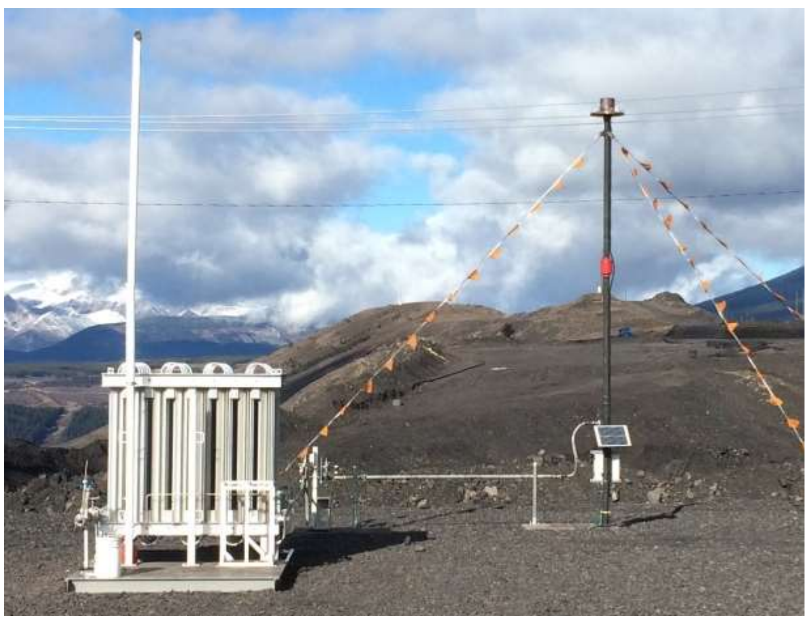


Figure 9.5 – LNG container de-fuel vaporizer and flare

9.2.4 Pressure relief vent

When an LNG vehicle is parked or stored and no fuel is being used, the pressure inside the fuel container will rise as heat is transferred to the fuel causing the fuel to evaporate. LNG fuel containers may increase in pressure as much a 15 psi per day when no fuel is being consumed. This creates an issue for LNG vehicles that are parked inside a maintenance facility for a prolonged period of time. To address this issue, it is recommended that LNG maintenance facilities have pressure relief valve (PRV) vent systems installed within the facility. An LNG PRV vent system consists of a cryogenic hose connected to a rigid piping vent stack that directs the vent gas to atmosphere at a safe outdoor location, usually above roof level. The cryogenic hose is often stored on a special hose reel and has either a mechanical connection to connect directly to the PRV port or a gas collector to cover the outlet port. When the vehicle is in the maintenance facility, this hose is connected to the vehicle PRV as part of an operating procedure.

10.0 Safety system management

10.1 Management responsibility and corporate policy

Management is ultimately responsible to maintain the operational integrity of the gas safety system. It is recommended that management delegate one individual as person-in-charge (PIC) to take day-to-day responsibility for the gas safety system and adherence to related operational policies and procedures. The PIC should report directly to management. Responsibilities should be documented and well defined. Responsibilities should include:

- maintaining safety system operation and maintenance log book;
- maintenance of the gas safety system and calibration of gas sensors;
- development, training and implementation of an emergency response plan (ERP) as required by WorkSafe BC and Canadian occupational health and safety regulations;
- development and implementation of NGV safe work instructions and procedures and train personnel as required by WorkSafe BC;
- assure that maintenance staff are trained, qualified and have the necessary certificates and endorsement credentials for working on natural gas vehicles;
- assurance that established work procedures, policies and protocols are followed; and,
- maintenance of the facility operating permit

Equipment inspections and calibration of gas sensors should follow, at a minimum, the equipment manufacturers' recommendations.

10.2 TSBC operating permit and endorsement

To operate a NGV maintenance facility, the owner must have an operating permit from Technical Safety British Columbia (TSBC). To obtain a permit TSBC requires that:

- Personnel working on NGVs be certified by TSBC. Pre-requisites are that personnel be a minimum third year apprentice mechanic or have a trade qualification as an automotive, commercial transport or heavy duty mechanic. Such personnel must be trained and then must pass a TSBC certification examination. In addition, they will need to be trained and certificated by the OEM. The OEM certificate will also be required to obtain an endorsement and a conversion certificate of qualification from TSBC; and,

- The facility must have a gas safety system installed that meets the requirements of CSA B401. TSBC can be expected to make an inspection of the facility and review the safety plan. An operations and maintenance manual and an emergency response plan (ERP) are usually sufficient as the safety plan.

10.3 Commercial vehicle inspection program (CVIP)

Commercial vehicles operating on natural gas (CNG or LNG) will need additional or modified inspection procedures to include the inspection of the natural gas fuel system. The requirements for these inspections can be found at cvse.ca

10.4 Safe work procedures

Safe work procedures are required for personnel working on CNG and LNG vehicles to ensure work is conducted in a consistent and safe manner. Accidents can happen when proper work instructions are not followed. Safe work procedures in the form of checklists are valuable tools to ensure that the key safety checks and procedures are executed. CSA B401 provides three Annexes with information to help guide the development of safe work procedures. It is also essential that OEM manuals be referenced for vehicle specific procedures and information. The following is a minimum list of safe work procedures: (Note: this list may not be exhaustive.)

- personnel safety protection, tools and required use
- vehicle preparation for before bringing into the facility including how to
  - check fuel pressure and fuel quantity
  - check gas system for leaks
  - de-fuel a vehicle and when required
  - purge the tank and fuel system with nitrogen
- vehicle preparation when in the facility including how to
  - isolate the fuel in the tank
  - prepare the vehicle for extended duration repairs
- fuel filter replacement
- fuel components replacement
- tank inspection and replacement
- inspection of tanks and fuel system for gas leaks after repairs or parts replacement
- vehicle accident damage inspections
- hot work requirements
- requirements for and use of portable heating equipment
- use of portable PPE equipment
- use of classified trouble lights and when required

10.5 Hot work procedure

Hot work including welding, grinding and flame cutting can be executed in a major repair facility but in accordance with approved hot work procedures. NFPA 51B is a good reference when developing procedures. Minimum requirements include establishment of a fire safe perimeter and minimum distance setbacks from other vehicles. Hot work procedures must include requirements for fuel system draining, purging, isolation and protection, depending on the vicinity of the hot work to a vehicle fuel system. It is also recommended that an internal hot work permit system be established. Procedures for the cessation of hot work activities in the event of an emergency should also be established.

10.6 Emergency response plan

An emergency response plan (ERP) is part of the safety plan that will be required to obtain an operating permit from TSBC. Every maintenance facility, regardless of the fuel, should have an ERP. Emergency situations will arise and preparedness in the handling of various scenarios will prevent escalation, serious injury and property loss. The Canada Health and Safety Act and WorkSafe BC have requirements for ERPs. CSA B401 Annex C also provides information regarding the ERP. Usually the safety officer owns the ERP; however, outside resources may be used to prepare the plan and provide training. As a minimum the plan should include the following elements:

- emergency contact list
- policy statement, purpose and scope
- emergency response providers and responsibilities
- site particulars
- hazard identification
- emergency procedures and equipment
- general response to an emergency
  - minor emergency
  - serious emergency
  - critical emergency

- other potential emergencies
- implementation
  - ERP and general CNG and LNG safety training
  - ERP updates and approval

All personnel must be trained to understand the operation of the safety system, their operational responsibilities and how to respond in accordance with the ERP.

10.7 Safety systems maintenance and testing

The maintenance of the safety system is critical to continued safe operations of the maintenance facility. This includes monitoring that operational activities comply with safety system requirements and personnel are trained to understand safety system procedures.

Regular maintenance items include, but are not limited to, calibration of gas sensors in accordance with the manufacturer's recommended schedule, ventilation fan maintenance (i.e. bearing lubrication, belt tensioning, belt replacement, etc.), safety signage integrity, monitoring of facility renovations or changes that may impact safety systems, ventilation fan flow testing, verification of control system UPS operation and integrity of emergency lighting.

A complete safety system test should be conducted annually to assure that all controls, ventilation, safety devices (call buttons, audible alarms, visual alarms, etc.), shunt trips, heater controls, etc. are functioning properly.

All operations and maintenance requirements should be documented in an operations and maintenance (O&M) manual dedicated to the gas safety system.

An option for facility operators is to establish a maintenance contract with an outside organization to undertake routine maintenance of the safety system in accordance with the O&M manual maintenance schedule.

10.8 Safety system log book

A safety system log book should be maintained by the PIC and should document all activities related to the gas safety system including, but not limited to, maintenance, equipment change outs, control changes, equipment failures, facility modifications, upgrades, procedure revisions and incidents and their resolution.

10.9 Facility insurance

It is recommended that the Owner contact facility insurers of the change in operations to assure that adequate insurance coverage is maintained with the addition of CNG/LNG major repair operations.

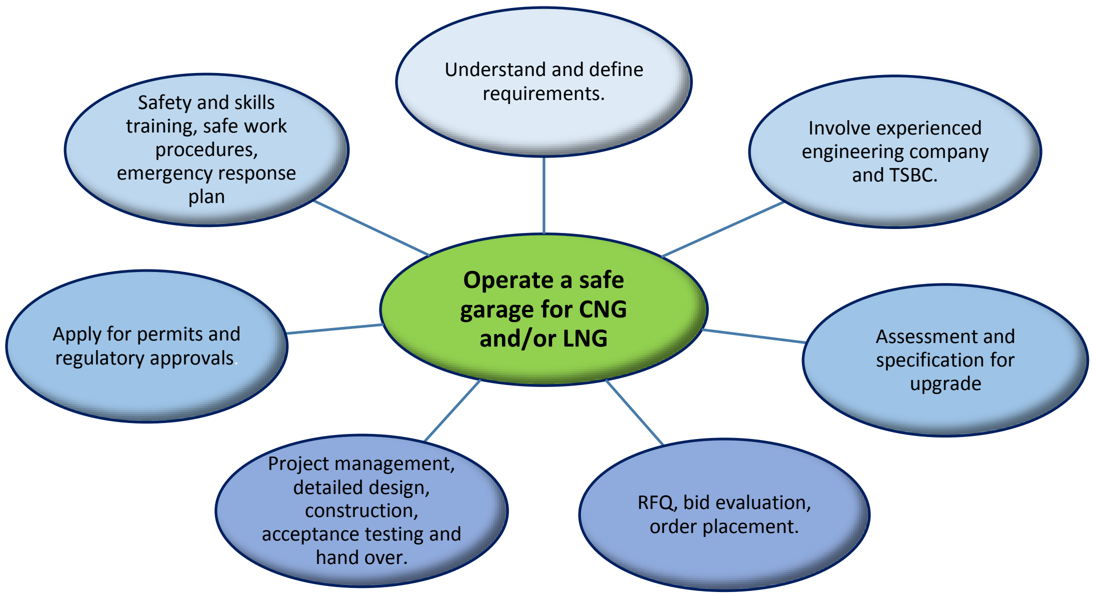
10.10 Annual inspections

The operating permit must be renewed annually. TSBC may decide to inspect the facility at any time for compliance with the Gas Standards Safety Act and review procedures and records of maintenance and testing of the system in the Safety Systems Log Book.

11.0 Project management

11.1 Elements of a successful project

The following diagram presents the important elements of a successful project. The objective is to achieve a cost effective, timely and safe CNG and/or LNG maintenance facility.



Responsibility for each of the elements can be assigned to different parties. Some activities require specific expertise and experience such as the facility assessment, system design specifications and detailed engineering.

11.2 Feasibility assessment

A facility assessment is the first step in defining the anticipated use of a maintenance facility and requirements for new facilities or existing facility upgrades. A proper assessment can reduce the extent of a facility upgrade or new facility costs. Involvement of an experienced engineering firm is therefore recommended at an early stage to determine the specific upgrades required, develop a design specification and determine a capital upgrade budget. The owner can then make an informed decision on project go-ahead.

11.3 Engineering firm involvement

Once the owner makes a decision to proceed with the project, it is recommended that an experienced engineering firm be engaged to do the detailed engineering and building permitting. Professional input will also streamline the TSBC permitting process.

It is also recommended that TSBC be informed at an early stage of the project and be provided with a safety plan for the new construction or upgrade. The feasibility assessment report can be used as the initial safety plan. A design registration with TSBC is not required. Design registration is only required for pressurized piping systems used for CNG tank de-fuelling or venting.

11.4 Project schedule

A typical project schedule for the upgrade of an existing eight bay maintenance facility is shown in Figure 11-1.

Table 11-1 – typical project schedule

Month	1	2	3	4	5	6	7
Project definition (Feasibility assessment, system specification, budget, go no-go decision)							
Detailed engineering (Detailed engineering, permitting, contractor bid process)							
Project execution (Construction, operating permits, training, Safe work procedures, ERP)							
Handover (Inspections, testing, training, handover)							

An overall project timeline can be reduced by using an experienced engineering firm and contractors. Design-build contracts may also reduce overall schedule duration.

Careful scheduling of installation construction of the safety upgrade is important to minimize interference with day-to-day operations and loss of productivity.

Annex A

Maintenance facility upgrade case study

This Annex provides a case study of a maintenance facility upgrade to assist the reader in understanding the process from conception to operation. The following case study is based on an actual project. For the purposes of this study, the client will be called "ABC Waste and Recycling Collection Services" hereinafter referred to as "ABC".

A.1 Client description

ABC has been in business for more than 50 years and operates waste and recycling collection services throughout Canada. One of their many sites is located in the lower mainland of British Columbia. At this site, ABC operates 30 refuse haul trucks that are dedicated CNG fuelled vehicles. ABC also has a time fill CNG fuelling station on the same site. Prior to investing in CNG fuelled vehicles, ABC operated diesel fuelled trucks and did all their own servicing in their own maintenance facility.

A.2 Facility and operational description

A description of the facility and its use prior to undergoing an upgrade for maintaining CNG fuelled vehicles is summarized in the following table.

Table A-1 maintenance facility description

Parameter	Data	Units
Shop length	55	metres
Shop width	28	metres
Ceiling height above floor	8.5	metres
Total floor area	1540	sq. metres
Service bay dimensions	6 x 14	metres
Number of service bays	18	
Space heating	high intensity radiant tube heaters	
Ventilation system	six manually operated vent fans (roof mounted)	
Operational activities within the Shop	- hot work (welding, grinding, cutting, body work) taking up 6 service bays - part department/inventory within shop taking up 1.5 service bays - storage taking up 1.5 service bays - major and minor repair operations in 9 service bays	

A.3 Maintenance facility upgrade feasibility assessment

Before making a decision on proceeding with the facility upgrade, the client desired to understand the total capital cost. In addition, the client wanted to know what the upgrade entailed and how it might impact its operational activities. To answer these questions, an experienced engineering consultant was retained to do a site assessment and deliver a report. As part of the assessment report development, the following activities were undertaken:

1. The client was interviewed to understand the facility's operational requirements including, but not limited to, type of natural gas vehicle (LNG/CNG), repair activities (major/minor repair), other operations (hot work, body work, painting) and requirements for de-fuelling, etc.

2. A site inspection was executed to obtain important data on the existing facility including, building dimensions, electrical service specifications, floor layout, heating system, ventilation systems, building access doors, facility architecture (i.e. fire walls and separation), mezzanines, gas entrapment features, operational activities and their locations, etc.
3. The engineering consultant then analyzed the site data and developed a preliminary safety system concept design. The final report included a concept floor plan drawing showing the location of safety system equipment including fans, heaters, gas sensors, annunciation devices, make-up air provisions, life safety control panel, motor starters and architectural upgrades. The report included information on existing heater and fan demolition and preliminary sizing of new ventilation equipment and heaters. In addition, various operational changes were recommended and detailed in the report.
4. The final report was delivered to the client and provided sufficient design detail and narrative for the client to fully understand what the building upgrade entailed. In addition, a capital budget of $325,000 was estimated at an accuracy of +/- 25%, based on the preliminary concept design.
5. With this report, the client was equipped to make an informed go or no-go decision on procession to construction. ABC decided to proceed with construction.

The total facility assessment phase had a duration of four weeks from kick-off to delivery of the final report.

A.3 Maintenance facility engineering and construction

ABC retained the same engineering consultant to undertake detailed engineering, permitting, project management and construction management. On this project, the client acted as the general contractor, with the engineering firm providing the coordination of the subcontractors. This may have saved some costs by avoiding general contractor fees. On the other hand, additional cost risk was transferred to the client and the coordination services of the engineering consultant had to be paid for.

<u>A.3.1 detailed engineering</u>

After project kick-off, the engineering firm developed detailed design drawings for construction. These included architectural, mechanical, structural, electrical and controls drawings and specifications. The ABC facility had some unique features that had to be addressed in the upgrade design and these included the following:

1. A parts department/room was located within the shop area with large double doors directly adjacent to a service bay. A potential risk of gas leakage into the parts room was identified and had to be addressed. This solution was to install automatic door closures on the double doors to maintain door closure. To provide further risk mitigation, passive roof vents were installed in the ceiling of the parts room to allow gas migration out of the room and into to the shop space.
2. A lunch room on the opposite side of the wall separating the maintenance space from the office space had a wall air conditioner that drew air into the lunch room from the maintenance area. This cross ventilation presented a risk of drawing in leaked gas from the shop. The air conditioner was replaced with a ductless split type air conditioner to maintain the integrity of the wall separation.

The design drawings were reviewed with the client at the 30% and 90% completion stages to assure alignment with client expectations.

A.3.2 Construction

A set of permit drawings was delivered to the local building department for building permit.

In parallel, the engineering firm coordinated a bid process for subcontractors including heating, ventilation, electrical and controls and architectural.

The duration to obtain the building permit was four weeks. By the time the building permit was obtained, the subcontractors were selected and construction was able to proceed with the ordering of equipment.

The total construction period was four months.

A.3.3 Testing commissioning and training

After completion of construction, the gas safety system was tested and commissioned. The testing was coordinated by the engineering consultant. The ventilation system was flow tested by a third party consultant. The heating system was tested by the installation contractor. The gas sensors were calibrated and the entire integrated gas safety control system was tested by the electrical contractor to assure the initiation and response of all equipment. The duration of the testing and commissioning was two days.

A general safety and system operational training was provided by the engineering consultant for the client and his personnel. This included a one-hour classroom session and then a hands-on system operation training. The engineering consultant prepared and delivered a comprehensive manual to be used by the client for reference to system operation, maintenance procedures, preventative maintenance schedule and trouble shooting. The engineering consultant also prepared an emergency response plan (ERP) specific to operation of a natural gas vehicle maintenance facility. The engineering consultant provided the client with an orientation on the plan and the client integrated the plan into the overall facility plan and provided personnel training.

A.3.4 Operations and permit

ABC appointed one person responsible to assure that the gas safety system is maintained, personnel are adequately trained, that associated company operational procedures are adhered to and that the gas safety system logbook is kept up-to-date. ABC decided to contract the maintenance, gas sensor calibration and annual testing of the gas safety system to an outside firm specializing in the testing of safety systems.

Upon completion of commissioning, a local safety officer from Technical Safety British Columbia (TSBC), was notified to conduct an inspection of the facility. The inspection passed and an operating permit was issued by TSBC.

Total construction duration including engineering, testing and commissioning was six months. The total cost of the construction was $340,000.