Designing New Transit Bus Garages

to be Fuel Flexible

Prepared By:

Marathon Technical Services
Six Venus Crescent
P.O. Box 318
Heidelberg, Ontario, Canada N0B1Y0
Telephone: 519-699-9250

May 12, 2006

Background Information

Before discussing the building design features that are recommended for CNG and GH2 buses, it is important to understand what makes these fuels different from gasoline or diesel. The items below summarize the basic differences between the properties of gaseous and liquid fuels that influence the building design changes:

1. Natural Gas and Hydrogen are both lighter-than-air and in gaseous form at atmospheric conditions. This property allows these **fuels to quickly rise and disperse in the unlikely event of a leak**. Although lighter-than-air fuels have safety advantages, roofs and ceilings of these facilities must be designed without any unventilated "pockets" in the ceiling space that could trap gas.

   Liquid fuels such as gasoline and diesel will form a pool of liquid with a vapor layer above. Liquid fuels remain in a concentrated form after a leak, causing on-going safety and environmental concerns.

2. **Natural Gas has a very selective and narrow range of flammability**—that is, the mixture of gas in air that will support combustion (between 5% and 15% natural gas in air by volume—ratios outside of this range will not support combustion). In other words, with less than 5% Natural Gas in air the mixture is too lean and will not burn, and with greater than 15%, the mixture is too rich and will not burn. Maintenance facilities must be designed to quickly and automatically remove the risk caused by a leak, using ventilation to dilute then exhaust any leaked gas.

   As indicated in point 1, liquid fuel leaks will pool and therefore will remain in flammable or explosive mixtures until the leak is manually contained and cleaned up.

3. CNG and GH2 both have an ignition temperature of around 900 to 1200 degrees Fahrenheit (°F)—whereas Gasoline is approximately 500°F to 800°F and diesel is less than 500°F. This **relatively high ignition temperature for CNG and GH2** is an additional safety feature of these fuels. To ensure a safe environment in the maintenance garage, the surface temperature of equipment that could contact a gas leak is usually limited to 750°F.

Codes

There are several codes and standards that contain some general guidance on designing facilities for use with gaseous-fuelled vehicles, but **the majority of design decisions are left to the engineer or architect to exercise reasonable caution and to implement current industry "best practice".**

In the United States, there have been several dozen CNG bus garages constructed or retrofitted and the safety record has been very good in these facilities. This report will focus on the approach used in these facilities, which has already been accepted by the Fire Departments and Building Departments across the country.

Structural Considerations

Maintenance garages that were constructed in the 1970s often used pre-cast concrete roof structures that were either "T" shaped or "waffle" shaped. In either case, this roof construction is problematic since it creates pockets where a gas release could collect. While it is possible to adapt a garage with pre-cast concrete roof structures for safe use with gaseous fuel buses, there is a significant additional cost.

Most single story maintenance garages that are constructed today use a flat roof with "open web steel joists" in combination with I-beams to support the roof. This is a very common method of construction that one might see in a Home Depot, or other large single story commercial building. This type of construction is also well suited to gaseous fuel bus maintenance facilities, since any accidental gas release can move freely to exhaust fans without pocketing.

Another type of construction that is regaining popularity is a **gable or pitched roof** using steel roof support trusses. This type of structure is popular in the construction industry because the roof is steel with no rubber or asphalt covering or ballast required. This saves weight, cost and maintenance and it is less prone to leakage. This roof structure also helps to reduce the temperature in the summer months since the heat inside the building can more easily rise and escape. **Gable roof structures are very cost effective and are ideal for gaseous fuel buses** since there is a tendency for any leak to be naturally channeled toward the roof peak where it can be quickly and safely exhausted. An example of this type of structure would be Metropolitan Atlanta Rapid Transit Authority (MARTA) Perry Blvd. Garage, which was constructed as a new "built for CNG" garage in 1996.

In the case of either the flat roof using open web steel joists, or the gable roof structure, **there is essentially no difference in cost to make the <u>structure</u> CNG compatible.** The only structural cost difference would be to allow for additional ventilation units, which <u>might</u> be required depending on the type of Heating and Ventilating equipment selected.

Another design parameter of interest is **roof/ceiling height**. It is desirable in any transit garage to have high ceilings to assist in building ventilation—this is very evident in a diesel bus garage during roll-out. In the case of gaseous fuel garages, high ceilings provide more space for any escaped gas (in the unlikely event of a leak) to rise above potential ignition sources and move unobstructed toward the exhaust fans. High ceilings also allow for the additional height of roof mounted fuel cylinders, this is particularly important above bus lifts. This is also important in garages where there are hybrid buses with batteries or capacitors mounted on bus roofs. Most new garages would be designed with a minimum ceiling height of 20 to 24 feet (minimum of 16 feet clear under structure) in bus storage and fueling areas, and 24 to 28 feet (minimum of 22 feet clear under structure) in maintenance areas, which would be adequate for any fuel so there is **no cost difference on this issue** to provide a Fuel Flexible design.

While there is no code requirement to use **rubber roll-up doors on maintenance facilities**, we recommend this type of door, equipped with breakaway rails. Roll-up doors (like the door at the contractor pickup area at Home Depot) are typically more reliable and energy efficient than sectional doors (like a typical residential garage door). Since they open and close more quickly and reliably than conventional sectional doors, rubber roll-up doors will keep more heat in the building during periods of heavy bus entry/exit traffic. We recommend that these roll-up doors be equipped to automatically open (quickly) in the unlikely event of a gas leak, to assist in providing ventilation to the building--door openers would be equipped with provision for remote opening and closing at some future date and door motors and switches would be ordered as sealed units. High Speed roll-up doors are commonly used on maintenance garages—Marathon has reviewed this application with a high quality industrial door manufacturer and determined that the **upgrade cost applicable to a Fuel Flexible facility (to make switches safe for a gas environment) would be approximately $5000. per door.** The door itself is the same regardless of fuel type so there is no cost difference in the door.

<u>Heating Equipment</u>

It is **not acceptable to use any heater with a surface temperature greater than 750°F.** Therefore, the use of open-flame or high temperature radiant electric or gas heaters in a gaseous fuel bus garage is prohibited.

Marathon recommends that a gas fired heated makeup system be used to provide primary heat for the space. This system is further detailed below in the makeup air section. The heating units would be indirect fired and mounted outside of the building using outside combustion air.

Marathon recommends that the heating units be equipped with heat exchangers to allow heat recapture while providing 100 per cent fresh air (no re-circulation). The exhaust and intake would be physically separated and in opposite orientation to ensure that no exhaust air is re-introduced into the building.

This **heated makeup air system is required whether the garage is Fuel Flexible or just diesel and therefore there is no additional cost attributable to this system**. It should also be noted that since the air will be introduced near the floor, the **system we are proposing would provide a greater level of personnel comfort** than traditional diesel facility arrangements (where the warm air is introduced at a high level and much of the warm air does not reach the personnel).

Like diesel facilities, some additional heaters may be required for “Task Heat”. This is supplemental heat at workstations, some doorways, and other areas as determined by the designer. In a Fuel Flexible facility, this heat could be supplied using catalytic heaters that are rated safe for this application. Again **there would be no cost added for this item**.

Another heating system option is “Hydronic Floor Heat”. This system utilizes hot water from a boiler that is circulated through plastic tubes embedded in the concrete floor. Hydronic floor heat is an **energy efficient option for buildings where doors are opened and closed frequently** (regardless of fuel type) as the space reheats quickly from the heat stored in the concrete floor. Hydronic systems provide a high level of personnel comfort (people feel warm if their feet are warm), and they enhance safety since the floor will quickly dry out if water is present, (from a bus washer or snow melt off of a bus) reducing the risk of slip/fall injuries. The installed differential cost of the system (compared to other heating options) is estimated at $4 to $7 per square foot including the boilers (assuming new construction of a large system). Although the **Hydronic floor heating system is particularly well suited to Fuel Flexible garages (since there are no hot surfaces), most of the benefits apply equally to both diesel garages and to Fuel Flexible garages and therefore, we do not consider it to add cost to the Fuel Flexible garage.**

Ventilation Equipment

Many older bus garages have very poorly designed and/or poorly maintained ventilation systems and the air quality in these older facilities can be very unhealthy. Older garages are sometimes expensive to retrofit for gaseous fuels since it may be necessary to completely replace the ventilation system.

Regardless of fuel type, all new garage ventilation systems must be designed to comply with current OSHA requirements for indoor air quality. **This code requirement (which is also applicable to diesel facilities) results in a design that typically provides between 4 and 6 Air Changes per Hour (ACH) (the requirement is for 1.5 cubic feet per minute per square foot) in the bus areas of a maintenance garage. Coincidentally, gaseous-fuelled bus garages are also typically designed for a baseline ventilation rate of 5 to 6 ACH. There is no additional airflow requirement for a gaseous-fuelled bus garage and therefore no additional cost for Fuel Flexible facilities with respect to baseline ventilation.**

However, there may be a difference in where the air is introduced and exhausted between a diesel garage and a Fuel Flexible garage. In a typical diesel bus garage, makeup air (that is the fresh air supplied to replace the contaminated air that is exhausted) is often introduced at the ceiling and the exhaust openings are often near the floor. In a Fuel Flexible facility, all of the makeup air would be introduced near the floor and at least half (or in some cases all) of the exhaust will be at the ceiling. These makeup air and exhaust registers would be uniformly spaced throughout the facility to ensure thorough air mixing and exchange. Marathon typically recommends that makeup air volume be 1 ACH less than the baseline exhaust rate so that the facility has a slight “negative” pressure—this will ensure that any odors or gas leaks will not migrate into adjacent unprotected areas such as offices or parts rooms—this is good design practice for diesel or Fuel Flexible facilities. This Fuel Flexible ventilation configuration **tends to provide fresh air where the personnel are and pull smoke and other airborne contaminants up away from the people**, rather than down to them.

In short, a well-designed Fuel Flexible ventilation system will enhance indoor air quality without impacting capital or operating costs.

In new diesel bus garages there will typically be smoke extraction fans to clear the smoke after a fire. These fans would also be required in a Fuel Flexible facility, and in these facilities, they have a secondary role of supplementing the baseline exhaust system in the unlikely event of a serious gas leak from a bus. These fans would be roof mounted, non-ducted (direct exhaust) and located at various points around the facility to ensure that the entire ceiling space would be ventilated. **This system of smoke extraction/emergency exhaust fans would have a capacity of approximately 6 ACH. Since this is a requirement in diesel and Fuel Flexible facilities, it is not an additional cost item.**

Electrical Equipment

Most new **diesel garages utilize sealed lighting and other electrical fixtures that would be consistent with the equipment necessary for a Fuel Flexible facility**.

In a Fuel Flexible facility, all **likely sources of ignition above the roofline of the bus (for example switches, receptacles, motors) are either relocated** or upgraded as a precaution, but the electrical classification (the classification of risk defined in the National Electrical Code) in the area above the bus (including the area immediately below the ceiling) is in the same electrical classification (and therefore this area is considered to be no greater risk) in a Fuel Flexible facility than in a diesel bus facility, assuming the ventilation system specified herein is provided.

Electrical **equipment below the roofline of a bus in a Fuel Flexible facility is identical to that equipment which might be installed in a diesel facility**.

Standby power is typically provided in a Fuel Flexible facility to backup the ventilation system, gas detection system and overhead doors. A new diesel facility will also typically include standby power to allow it to continue operations during a power interruption.

A properly designed **Fuel Flexible facility does not have a cost premium** associated with electrical equipment, when compared to a typical new diesel facility.

Gas Detection Equipment

Marathon would recommend deferring any installation of gas detection equipment until gaseous-fuelled buses are scheduled to be deployed at a garage. There is no economy in installing this system at time of construction rather than when it is needed, and by waiting there may be improvements in performance and reliability with new technology.

Since this item is to be **deferred for later installation, there is no initial cost associated with gas detection**.

Indoor Fueling-Where Applicable

While it is most common to fuel CNG or GH2 buses outdoors, it is possible to construct indoor fueling rooms for these vehicles. It is most likely that this choice would only be made to address cold climate issues.

If a Transit Agency intends to utilize indoor fueling for CNG (there are currently no GH2 indoor fueling facilities in place), there are a number of special design considerations for the indoor fueling room. These requirements primarily come from NFPA 52-a regulation that governs the construction of CNG, LNG and GH2 stations and fueling areas. A summary is provided below of the special considerations in the fueling area of a Fuel Flexible Facility:

1. The Heating and Ventilating systems should be consistent with the other Fuel Flexible Maintenance Garage recommendations in this document, but should be independent for this room—not shared with other parts of the garage. In cold climates, Marathon would recommend that this room have primary heating supplied by hydronic in floor heat. These recommendations are true for diesel and Fuel Flexible facilities and are therefore not an added cost item.

2. The indoor fueling room must have interior fire rated, structurally reinforced walls designed to withstand 100 to 150 pounds per square foot (psf) pressure from inside the room. On new construction this can be a modest additional cost but the amount is very dependant on the design of the facility.

3. The roof and outside walls need to incorporate pressure relief panels designed to relieve at about 20 to 30 psf to prevent damage to the fuel room—this pressure would be caused by the <u>very unlikely</u> event of an un-exhausted gas leak that collects and ignites. These panels will most likely

cover the majority of the exterior walls and roof—the area and design requirements are outlined in NFPA 68-Deflagration venting. These vent panels can be purchased as pre-engineered/prefabricated or can be locally engineered and fabricated as part of the building construction contract (at a lower cost than the pre-engineered panels). In either case there is a significant cost associated with these pressure relief panels, but this cost is very difficult to estimate, as it is highly site dependent.

4. The bus entry doors should be a high-speed rubber rollup door as specified in this document, with an additional cost of approximately $5000 per door to upgrade the electrical controls to non-sparking.

5. There should also be doors at the exit to the fueling room. These doors will include a high-speed rubber rollup door, and a fire rated, pressure rated (100 to 150 psf) steel sectional door. This complete door assembly would be required at the exit to each lane with a total cost in the range of $50K to $75K per door assembly.

6. All electrical equipment in the indoor fueling room must be rated as Class 1, Division 2. While this may initially seem like a potentially burdensome cost, Marathon's experience indicates that this is actually a relatively minor additional cost.

The three main potential added costs associated with the construction of indoor fueling of gaseous-fuelled vehicles are venting panels, additional (high cost) doors, and the reinforcement of interior walls. It is possible that the **total additional cost to make an indoor fueling room Fuel Flexible could be $500K to $1M+ depending on the geographic location and the layout of the building, however, it should again be noted that most gaseous fuel dispensing is located outdoors, negating the need for this additional cost**

<u>CNG Station</u>

The local gas utility must be consulted to confirm availability and pressure of gas in the area of the site.

An example of a large transit fleet deployment of 220 buses at a proposed site would require a typical station with the following equipment (if this facility were to be CNG):

1. One twin tower fully regenerative gas dryer.
2. Four 1,200-scfm electric motor or engine driven compressors totaling 4,800 scfm. (Skid mounted/enclosed in a common building with dryer). This provides the required flow with three compressors operating, and the fourth is used to provide additional throughput capacity and redundancy in the event of a compressor breakdown.
3. 120,000 scf/5500 psig buffer
4. Four high flow transit dispensers mounted on outdoor islands.
5. De-fueling system.
6. PLC and SCADA control system. (computerized control and monitoring system)
7. Air Compressor System (how does that differ from "2" above?)
8. Pre-engineered steel Compressor/Dryer building with overhead crane, insulated and heated.

If the station is to use electric motors to drive the compressors, it would be **prudent to increase the size of the substation and electrical service at the new facility**. Depending on the available gas pressure (this affects the horsepower requirements for the compressors) this station indicated above could require an electrical service of between 2000 and 4000 Amps at 480 Volts, 3 phase.

The total footprint for the above equipment would be approximately **7,000 to 10,000 square feet**. The eventual cost of the system described above is likely to be approximately $5M to $8M in today's dollars, but it is **not recommended that the station be purchased or installed until CNG buses are scheduled for deployment at** the new Maintenance Garage.

At this time, **Marathon would simply recommend allowing for the possible future construction of a gaseous fuel station by allocating room in the layout of the site.** Using this approach, there could be little to no current cost associated with this provision.

Funding

Transit agencies should investigate available grants. For example, in New York State if the Transit Agency contracted the construction of the fueling station through an entity that pays sufficient tax in the State, this project would be eligible for a **50 per cent tax rebate on the capital cost of the station**—this would effectively reduce the cost from perhaps an estimated $8M to an estimated $4M.

Based on typical transit fuel consumption, the above CNG station would dispense approximately 2.34 Million Diesel Gallon Equivalent (DGE-a volume of CNG that has the same energy as a gallon of diesel fuel) per year. Under a current US DOE program, this station would generate **an annual subsidy of $1,170,000 from the federal government—enough to cover the capital cost of the station and the facility upgrade costs over time.**

Summary

1. Based on the above overview it is apparent **if a facility is designed from the outset to be Fuel Flexible, that the capital cost impact of constructing a garage that is Fuel Flexible can be minimal**—with much of the equipment virtually identical in performance for diesel and for gaseous fuels.

2. Conversely, several agencies have already discovered that retrofitting a facility that is designed as diesel only facility can be extremely expensive, and in several cases, **some agencies have already determined diesel garage retrofit projects of this type to be cost prohibitive.**

3. This prohibitive cost to retrofit a diesel facility can be attributed to the use of systems that are not acceptable for gaseous fuels. For example if a conventional diesel facility ventilation system were provided, it may require the complete replacement of the system including all ventilation units and ducting. This retrofit would **not only be costly, it would also be very disruptive to operations at the facility.**

4. There are a number of **personnel safety and comfort** advantages including improved air quality, and more effective heating, to a garage designed to be Fuel Flexible.

5. The prudent approach for the long term (and these facilities have 25 to 50 year lives) is to follow the example set by a large transit agency that had two functioning CNG garages and entered into a design contract for a third garage. Unsure of their future CNG strategy, **this agency hedged their bets by design and constructing the new garage with Fuel Flexible heating, ventilation, electrical and other systems. The CNG station and indoor fueling facilities were also designed but were deferred for later construction, when required.** The agency spent a little time and a very small premium now, to save a lot of time and cost later, and they kept their fuel choice options open! This agency is not alone in this approach as our company recently completed a similar Fuel Flexible design with a transit agency that has already taken delivery of hybrid buses but wishes to keep CNG as an option without incurring prohibitive retrofit costs or delays.

6. Marathon would strongly encourage any transit agency entering into the design/construction of a new transit garage to **require their design consultants to make this facility Fuel Flexible by providing a design that is consistent with the needs of gaseous fuels and liquid fuels.**

7. **The transit agency's design consultants should be encouraged to work with someone with gaseous-bus maintenance facility design experience to ensure that the equipment and approach selected are consistent with the precedents set nationally and in previous local projects.**

The information contained in this report is intended to be general in nature and representative of typical conditions and costs and is intended to reflect current industry practice at the time of writing. This document is not a design/construction specification and may not address all safety or operational requirements of a particular facility or local or state code—therefore, this document shall not be used for bidding or construction purposes. All projects involving design and construction related to the information presented in this document must be designed, reviewed and accepted, and overseen and inspected by a Professional Engineer who is experienced, qualified and licensed to provide this service—the Engineer hired by the Owner or Contractor assumes all liability related to the use of this information. Use of the information herein is solely at the risk of the user.