Application & Installation Guide

Gaseous Fuel Systems

Liquid Cooled Generator
(20 kW to 450 kW)

LEBE0053-02

Foreword

READ THIS MANUAL THOROUGHLY. This manual has been prepared to familiarize personnel involved with the installation of generator sets with the manufacturer's installation requirements. Information and instructions contained herein are not intended to replace or supersede, local, state, or national safety, electrical, and building codes pertaining to such installations. Applicable laws, codes, and standards must always take precedence over the recommendations contained herein. Always check with the local Authority Having Jurisdiction (AHJ) for the codes or standards that apply.

Only authorized dealers or qualified, competent installation contractors or electricians thoroughly familiar with applicable codes, standards, and regulations should install this standby electric power system. The installation must be in strict compliance with all codes, standards, and regulations. Start-up procedures must be performed by an authorized dealer.

It is not intended that this manual be used by any unqualified person for the purpose of installing a generator set. Installation, inspection, and testing of the system must be attempted only by competent, qualified electricians or installation contractors who are familiar with the equipment and with all installation codes and requirements.

It would be impossible to provide details for every installation configuration. For this reason, much of the information in this manual is general in nature. Illustrations of typical installations are not intended to serve as specific installation plans, but may be used in the planning and design process when considering the selection and purchase of a generator set for standby power applications. Always have the unit specific drawings and manuals on hand before beginning any installation.

Sources of Information

Installation information and recommendations contained herein are derived from the following sources:

- Knowledgeable engineers, service technicians, and service representatives
- The National Electric Code (NEC)
- National Fire Protection Association (NFPA) codes and standards
- Other sources as listed in Subsection 1.7
- Various manufacturing standards and best practices

If an open bottom is used, the engine-generator is to be installed over non-combustible materials and should be located such that combustible materials are not capable of accumulating under the generator set.

After the system has been installed, do nothing that might render the installation in noncompliance with such codes, standards, and regulations.

Every effort was made to ensure that the information in this manual was both accurate and complete at the time it was released. However, the manufacturer reserves the right to change, alter, or otherwise improve this product at any time without notice.

Warning: California Proposition 65. This product contains or emits chemicals known to the state of California to cause cancer, birth defects, and other reproductive harm.

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1.0 Safety

1.1 Introduction

Read this manual thoroughly. If any portion is not understood, contact the nearest authorized dealer for clarification. The manufacturer also requires that the dealers oversee the installation of the standby generator set. These individuals are trained/qualified service technicians familiar with the control systems and available options, and also have full access to drawings, publications, and other information required for a successful installation.

1.2 Safety Rules

Throughout this publication, and on tags and decals affixed to the generator, DANGER, WARNING, CAUTION, and NOTE boxes are used to alert personnel to special instructions about a particular operation that may be hazardous if performed incorrectly or carelessly. Observe them carefully. They indicate:

- A hazardous situation or action that, if not avoided, will result in death or serious injury.
- A hazardous situation or action that, if not avoided, could result in death or serious injury.
- A hazardous situation or action that, if not avoided, could result in minor or moderate injury.

Note: Notes provide additional information important to a procedure or component.

These safety warnings cannot eliminate the hazards they indicate. Observing safety precautions and strict compliance with the special instructions while performing the action or service are essential to preventing accidents.

Four commonly used safety symbols accompany DANGER, WARNING, and CAUTION boxes and the type of information each indicates:

- This symbol points out important safety information that, if not followed, could endanger personnel and/or property.
- This symbol represents the potential for an Explosion Hazard.
- This symbol represents the potential for a Fire Hazard.
- This symbol represents the potential for an Electrical Shock Hazard.

SAVE THESE INSTRUCTIONS. This manual contains important instructions that should be followed during installation of the generator set and batteries. The manufacturer suggests that these safety rules be copied and posted in potential hazard areas. Safety should be stressed to all installers, operators, potential operators, and service and repair technicians for this equipment.

1.3 General Hazards

- For safety reasons, the manufacturer recommends that this equipment be installed, serviced, and repaired by an Authorized Service Dealer or other competent, qualified electrician or installation technician who is familiar with all applicable codes, standards, and regulations.
- Ensure that the generator is installed, operated, and serviced in accordance with the manufacturer's instructions and recommendations. Following installation, do nothing that might render the unit unsafe or in noncompliance.
- The engine exhaust fumes contain carbon monoxide, which can be DEADLY. If breathed in sufficient concentrations, carbon monoxide can cause unconsciousness or even death. For this reason, adequate ventilation must be provided. Exhaust gases must be piped safely away from any building or enclosure that houses the generator to an area where people, animals, etc. will not be harmed.

- Keep hands, feet, clothing, etc. away from drive belts, fans, and other moving or hot parts. Never remove any drive belt or fan guard while the unit is operating. Ensure that all guards, covers, and protective devices removed during maintenance or service are reinstalled.
- Adequate, unobstructed flow of cooling and ventilating air is critical in any room or building housing the generator to prevent buildup of explosive gases and to ensure correct generator operation. Do not alter the installation or permit even partial blockage of ventilation provisions, as this can affect safe operation of the generator.
- Keep the area around the generator clean and uncluttered. Remove any materials that could become hazardous.
- When working on this equipment, remain alert at all times. Never work on the equipment when physically or mentally fatigued.
- Inspect the generator regularly, and promptly repair or replace any worn or damaged components using only factory-approved parts and procedures.
- Before performing any maintenance on the generator, always disconnect the battery cables to prevent accidental startup. Disconnect the cable from the battery post indicated by a NEGATIVE, NEG, or (-) first, then remove the POSITIVE, POS, or (+) cable. When reconnecting the cables, connect the POSITIVE cable first, the NEGATIVE cable last.
- Never use the generator or any of its parts as a step. Stepping on the unit can stress and break parts, and may result in exhaust, fuel, oil, or coolant leaks.

1.4 Electrical Hazards

- All generators produce dangerous electrical voltages and can cause fatal electrical shock. Utility power delivers extremely high and dangerous voltages to the transfer switch as well as the generator when it is in operation. Avoid contact with bare wires, terminals, and other connections. Ensure all covers, guards, and barriers are in place, and that they are properly secured and/or locked before operation. If work must be done around an operating unit, stand on an insulated, dry surface to reduce potential shock hazard.
- Do not handle any kind of electrical device while standing in water, while barefoot, or while hands or feet are wet. DANGEROUS ELECTRICAL SHOCK MAY RESULT.
- If it is necessary to stand on metal or concrete while installing, operating, servicing, or repairing this equipment, lay down a dry wooden platform and cover with insulated mats before beginning.
- Verify that the generator is properly grounded.
- Wire gauge sizes of electrical wiring, cables, and cord sets must be adequate to handle the maximum electrical current (ampacity) to which it will be subjected.
- Before installing or servicing equipment, verify that all power voltage supplies are positively turned off at their sources. Failure to do so can result in hazardous and possibly fatal electrical shock.
- Connecting this unit to an electrical system normally supplied by an electric utility is by means of a transfer switch so as to isolate the generator electric system from the electric utility distribution system when the generator is operating. Failure to isolate the two electric system power sources from each other by such means will result in damage to the generator and may also result in injury or death to utility power workers due to backfeed of electrical energy.

- Generators installed with an automatic transfer switch will crank and start automatically when NORMAL (UTILITY) source voltage is removed or is below an acceptable preset level. To prevent automatic startup and possible injury, disable the automatic start circuit (battery cables, etc.) before working on or around the unit. Place a "DO NOT OPERATE" tag on the generator control panel and on the transfer switch.
- In case of accident caused by electric shock, immediately shut down the source of electrical power. If this is not possible, attempt to free the victim from the live conductor. AVOID DIRECT CONTACT WITH THE VICTIM. Use a nonconducting implement, such as a dry rope or board, to free the victim from the live conductor. If the victim is unconscious, apply first aid and get immediate medical help.
- Do not wear jewelry when working on this equipment. Jewelry can conduct electricity resulting in electric shock, or may get caught in moving parts resulting in injury.

1.5 Fire Hazards

- Keep a fire extinguisher near the generator at all times. Keep the extinguisher properly charged and be familiar with its use. Direct any questions to the local fire department.

Note: DO NOT use any carbon tetra-chloride type fire extinguishers. These fire extinguishers emit toxic fumes and the liquid can damage wiring insulation.

1.6 Explosion Hazards

- Properly ventilate the room or building housing the generator to prevent buildup of explosive gas.
- Do not smoke around the generator. Immediately wipe up any fuel or oil spills. Ensure that no combustible materials are left in the generator compartment, or on or near the generator, as FIRE or EXPLOSION may result. Keep the area surrounding the generator clean and free of debris.
- All types of fuels are potentially FLAMMABLE and/or EXPLOSIVE and must be handled with care. Inspect the fuel system frequently and correct any leaks immediately. Be sure fuel supply lines are properly installed, purged, and leak tested before placing the generator set into service.

1.7 Standards Index

Be sure the generator set is in strict compliance with all applicable local, state, and federal laws, codes, and regulations pertaining to such installations. Always use the current version or edition of the applicable law, code, and regulation as it applies to the local jurisdiction. In the absence of pertinent local laws and standards, use the following published materials as a guide.

- National Fire Protection Association (NFPA) 70: The National Electric Code (NEC)*
- NFPA10: Standard for Portable Fire Extinguishers*
- NFPA 30: Flammable and Combustible Liquids Code*
- NFPA 37: Standard for Stationary Combustion Engines and Gas Turbines*
- NFPA 54: National Fuel Gas Code*
- NFPA 58: Standard for Storage and Handling of Liquefied Petroleum Gases*
- NFPA 68: Standard on Explosion Protection by Deflagration Venting*
- NFPA 70E: Standard for Electrical Safety in the Workplace*
- NFPA 99: Health Care Facilities Code*

- NFPA 101: Life Safety Code*
- NFPA 110: Standard for Emergency and Standby Power Systems*
- NFPA 211: Standard for Chimneys, Fireplaces, Vents, and Solid Fuel Burning Appliances*
- NFPA 220: Standard on Types of Building Construction*
- NFPA 5000: Building Code*
- International Building Code**
- Agricultural Wiring Handbook***
- ASAE EP-364.2 Installation and Maintenance of Farm Standby Electric Power****

This list is not all inclusive. Check with the AHJ for any local codes or standards which may be applicable to the jurisdiction where the generator is installed. The above listed standards are available from the following internet sources:

*www.nfpa.org

**www.iccsafe.org

***www.rerc.org Rural Electricity Resource Council; P.O. Box 309; Wilmington, OH 45177-0309

****www.asabe.org American Society of Agricultural & Biological Engineers; 2950 Niles Road; St. Joseph, MI 49085

1.8 Generator Location

Locate the generator set so that it is readily accessible for maintenance, repair, and firefighting purposes. For outdoor and rooftop installations, comply with code requirements for minimum distance from combustible walls and building openings. For indoor installations, adhere to requirements for fuel supply, ventilation, exhaust ducting, proximity to combustible materials, etc.

1.8.1 General Location Guidelines

Consider the following:

- The supporting structure must be adequate for the generator set and its accessories.
- For roof-mounted applications, consideration should be given to the support strength of the structure and the need for vibration isolation. Consult a structural engineer for recommendations.
- Be sure the site is clean, dry, not subject to flooding, and provided with adequate drainage in the event of heavy rains.
- Be sure the location permits noise and vibration to be effectively isolated.
- Verify that the site provides easy access to the generator set for maintenance, repair, and firefighting purposes.
- Keep a minimum of five feet of clearance around each side of the generator set to facilitate the repair or replacement of major components.
- Be sure the location permits engine exhaust gases to be piped safely away from inhabited or occupied areas. Consider the direction of prevailing winds to prevent exhaust gases from being carried back to the engine area or to the fresh air intake vents of nearby buildings.

- The site must allow for the provision of an adequate fuel supply. Consider the length and diameter of pipe required to provide adequate fuel volume and pressure for the unit to run at its full load capacity.
- Be sure the location permits sufficient air flow for cooling and ventilation. For indoor applications, keep supply air and radiator outlet air ducting to a minimum. For outdoor applications, consider the proximity of any walls, fences, or other noise abatement or security barriers. For outdoor units with enclosures, do NOT face the radiator discharge end of the enclosure into the prevailing wind.
- In cold weather locations, consider heating of the enclosure (which may be required by application). For indoor units with supply air ventilation, consider a means to control ambient air temperature in extreme cold conditions.
- Verify that the unit is securely fastened to the mounting pad to prevent movement caused by vibration.
- Verify that all fuel, coolant, exhaust, and electrical connections have flexible sections to isolate vibration. Exhaust systems must also allow for thermal expansion and contraction. Cracks and fractures, with the resulting leakage, can develop rapidly without proper vibration isolation.

1.8.2 Weather Considerations

Consider local weather conditions during installation. There are various accessories available to ensure fast, reliable starting and operation regardless of local climatic conditions. Enclosed unit heaters, engine jacket water heaters, lube oil heaters, and battery warmers make starting of the engine more dependable and reliable. Strip heaters for the alternator and control cabinets eliminate condensation by maintaining the temperature above the dew-point.

1.9 Emissions Compliance

1.9.1 Closed Units

The exhaust system is installed at the factory on units with enclosures. If safe operation requires that the exhaust be extended, consult an authorized service dealer for the recommended pipe size for the length of the run required. Extending the exhaust piping can cause excessive backpressure leading to loss of power and engine and/or exhaust system overheating.

1.9.2 Open Units

Open units are intended for indoor installation in a suitably designed structure. Open units are shipped with the catalytic converter (if used) loose for on site installation. For units with an exhaust catalyst, use the unit specific installation drawing to properly locate the oxygen (O_2) sensor for the emissions monitoring system. If the O_2 sensor and catalyst are not correctly installed, the emissions system will not work properly and the unit will not be in compliance with its EPA certification, conditions which may lead to engine damage.

Open units not requiring an exhaust catalyst may be ordered with a ship-loose silencer. Consult the installation drawings for length of piping from the engine connection to the silencer, size of engine exhaust outlet, and any other unit specific requirements.

Use of the factory provided Catalytic Converter/Catalyst is mandatory at all times in order to maintain EPA Emissions Compliancy.

2.0 Gaseous Fuel

Gaseous fuels, such as Liquid Petroleum Gas (LPG) and Natural Gas (NG), are highly volatile and their vapors are explosive. LPG is heavier than air and will settle in low areas. NG is lighter than air and will settle in high areas. Even the slightest spark can ignite these fuels and cause an explosion.

2.1 General

Consult a local gas distributor or licensed plumber/installer when installing a gaseous fuel supply system or refer to information published by various federal agencies. For a list of some of these publications, see Standards Index.

2.1.1 Fuel System Conversion

Industrial units come from the factory configured and EPA certified with the fuel system ordered. Any one of the following gaseous fuel systems may be installed:

- NG
- LPG-V Withdrawal

To determine if a generator set is eligible for a field fuel conversion, contact your local authorized Cat® service dealer.

2.2 Gaseous Fuel Properties

2.2.1 Natural Gas (NG)

NG is lighter than air. It is found in the gaseous state at normal ambient temperatures and pressures. It is highly explosive and can be ignited by the slightest spark. For this reason, fuel lines must be free of leaks and adequate ventilation is absolutely essential. Local fuel/gas codes dictate the maximum pressure under which natural gas can be delivered to a site or structure. The supply pressure from the utility meter/regulator is usually not the same as that required by the generator set, so a separate primary regulator providing the correct pressure and volume of fuel to the generator set is required. If the local utility source pressure is less than that required by the generator, it is up to the local utility to provide the volume of gas at the required pressure.

2.2.2 Liquid Propane Gas – Vapor (LPG-V) and Liquid Propane Gas – Liquid (LPG-L)

LPG is heavier than air. The gas vapors are explosive and can be ignited by the slightest spark. LPG-V is supplied by liquid propane stored in tanks. Propane exists in its liquid form at or below its boiling point (-44° F) as well as when it is stored under pressure. LPG tank pressure is dependent on the ambient temperature and the liquid volume in the tank, and can be over 200 psi. For LPG-V withdrawal, the gas is withdrawn from the top of the tank, above the liquid level. A first-stage regulator at the tank reduces the gas pressure to a lower line pressure value. This line pressure is then reduced to the correct operating pressure and volume for the generator set through the use of a second-stage regulator. For units which use propane in its liquid form (LPG-L), the tank uses a special fitting to allow for withdrawal of the liquid propane.

2.3 Gaseous Fuel Systems

Consult a local gas distributor or licensed plumber/installer when installing a gaseous fuel supply system or refer to information published by various federal agencies. For a list of some of these publications, see Standards Index.

2.3.1 Natural Gas (NG) System

The local utility will usually provide the piping (meter and pressure regulator) from the main distribution line to the generator site. The local utility is also responsible for providing gas at sufficient volume and pressure to operate the primary regulator, so that the regulator can provide the correct volume of gas at the required pressure to the generator.

From the primary regulator, gas flows to the generator connection point, which is the end of the manufacturer supplied flexible fuel line. The flexible fuel line can be connected directly to the generator connection point (perpendicular to the frame rail), or by an elbow and short nipple to the frame rail itself (to run parallel to the frame rail). The nipple and elbow used must be the same pipe size as the flexible fuel line and generator connection point. Install a flexible fuel line between the rigid supply piping and the gas connection at the generator, and must be installed straight without bends or kinks. The primary regulator outlet and the generator connection point must be sized correctly to provide the generator with the required volume and pressure when it is operating at 100% of its rated load.

On the generator the unit mounted regulator (it may be either a demand regulator or a pressure regulator) and its associated shutoff valves control the flow and pressure to the unit for proper operation. The fuel pressure required for the generator to operate is always measured at the inlet of the unit mounted regulator. For the location of the pressure test connection, see Gas Pressure Test Port Location. The supply pressure and volume must meet the requirements described in the unit specification sheet. If specifications are not met, the generator will not operate properly and will probably display symptoms, such as hard starting, rough running, inability to carry load, and erratic operation.

The piping system between the primary actuator pressure regulator and the generator must be properly sized to provide the fuel volume required at 100% load while also staying within the pressure range noted on the unit specification sheet. Allow a minimum of 10 feet between the primary regulator and generator.

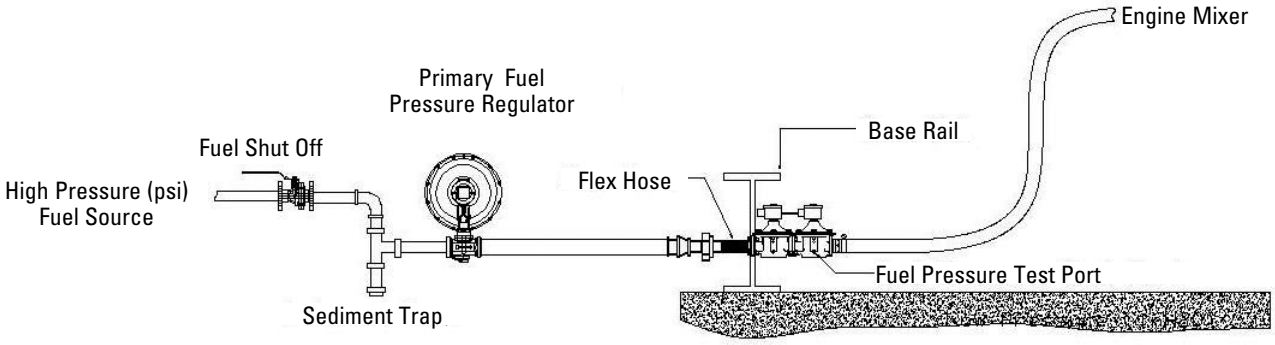


Figure 2.1 – Typical NG Fuel System

2.3.2 Liquid Propane Gas – Vapor (LPG-V) Withdrawal System

This type of system uses the vapors formed above the liquid fuel in the supply tank. The maximum tank fill capacity is 80% and a minimum of approximately 20% of the tank capacity is needed for fuel expansion from the liquid to vapor state. Gas pressure and volume requirements for an LPG-V system at the connection point of the generator are listed on the unit specification sheet.

Pressure regulation for vapor withdrawal systems is typically a two-step process. First, by reducing the high tank pressure to a lower line pressure with a first-stage regulator, then reducing the line pressure to the pressure required by the unit with a second-stage regulator. Both regulators and the associated system piping and valves need to be sized correctly to provide the generator with the required volume and pressure of fuel at the generator connection point.

The piping system connecting the outlet of the first stage regulator to the connection point on the second stage regulator must be properly sized to provide the fuel volume required by the unit at 100% load.

The piping system between the outlet of the second stage regulator and the generator connection point must be sized to provide the fuel volume required by the generator at 100% load while also staying within the pressure range noted on the unit specification sheet.

Allow a minimum of 10 feet between the primary regulator and generator.

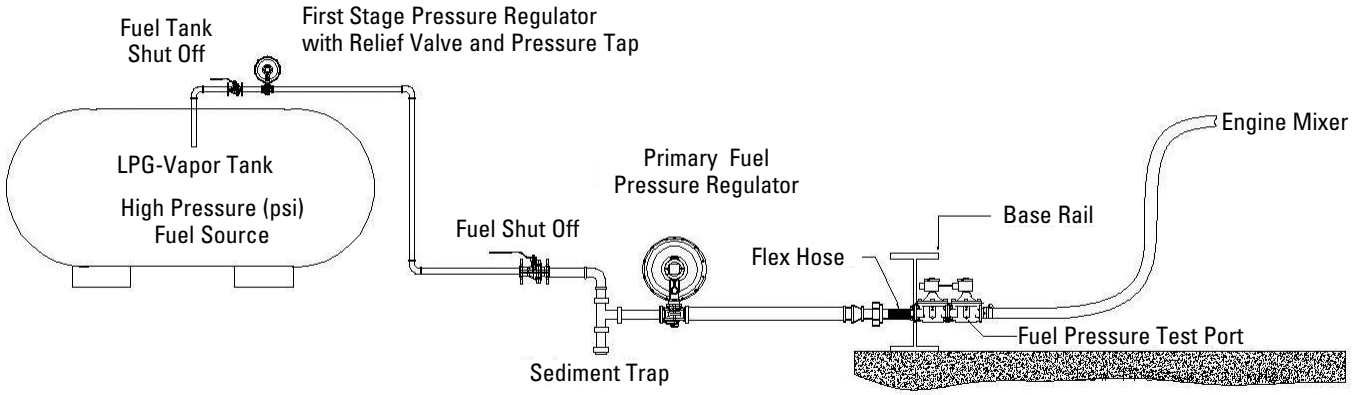


Figure 2.2 – Typical LPG-V Withdrawal Fuel System

2.3.3 Liquid Propane Gas – Liquid (LPG-L) Withdrawal System

This system delivers LPG-L to the connection point on the generator set. For the prime mover to use the LPG-L fuel, the fuel must be vaporized prior to being delivered to the fuel mixer (carburetor). LPG-L will vaporize at a temperature of (-44°F/-42.2°C). The generator set LPG-L fuel system delivery pressure shall have a operating range of 58-180 psi (400-1242 kPa) (liquid line pressure), depending on the ambient temperature and liquid level in the storage tank. The fuel tank delivery pressure shall not fall below the minimum specified working pressure rating of the vaporizer.

LPG-L enters the vaporizer and passes into a “flash” chamber. The pressure drop in this chamber vaporizes the liquid tank pressure to approximately 11-14 in H_2O (2.9-3.5 kPa).

Heated engine coolant from a properly working jacket water heater is necessary to heat the flash chamber of the vaporizer and to prevent the vaporizer from icing.

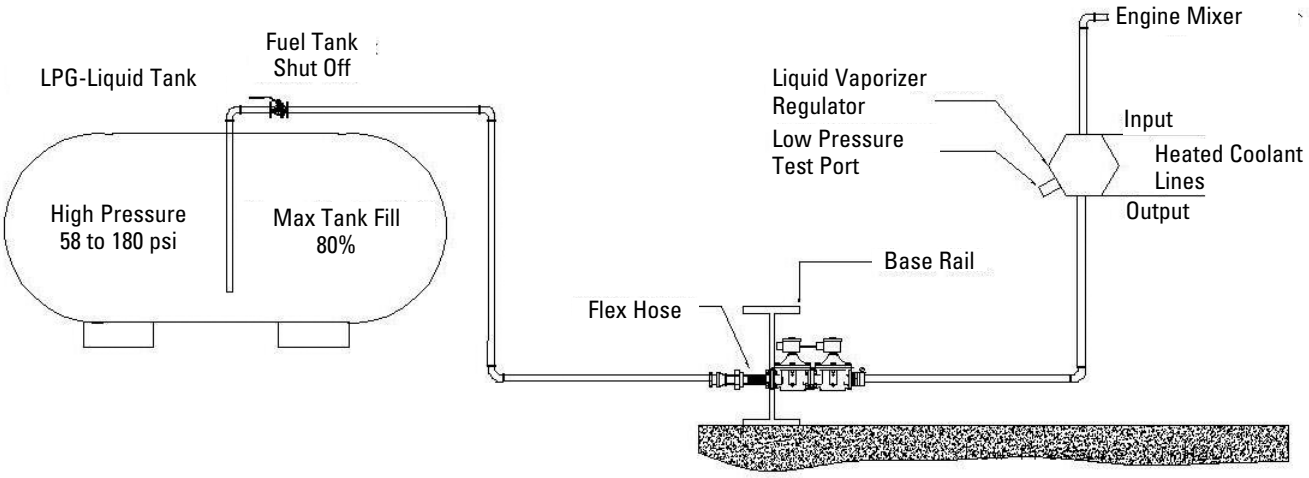


Figure 2.3 – LPG-L Withdrawal Fuel System

2.3.4 Dual Fuel Natural Gas-Liquid Propane Gas (NG-LPG) System

Some applications use a dual fuel system where the primary source may not be available during a power outage. Dual fuel systems use NG as the primary fuel and LPG-V or LPG-L withdrawal as the secondary fuel. For dual fuel units, the specific fuel pressure, volume, and pipe sizing requirements for each fuel type must be observed. See Figure 2.4.

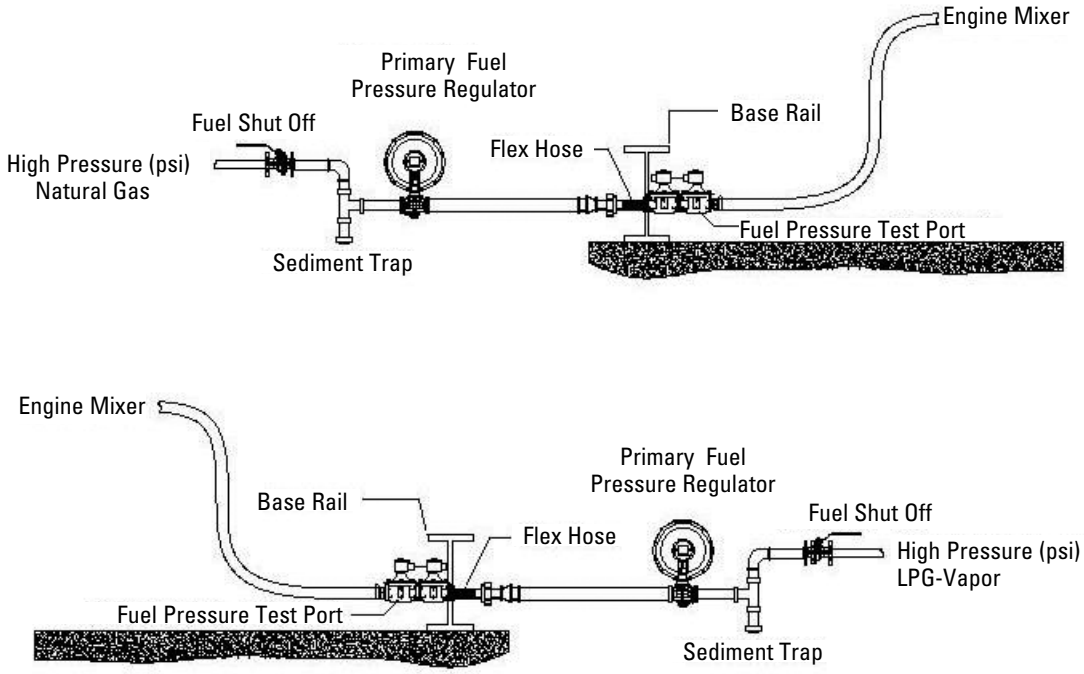


Figure 2.4 – Dual Fuel System

2.3.5 Drip Leg

Drip legs should be installed at the bottom of a vertical run of pipe in the line before the primary regulator. Their purpose is to allow sediment, debris, and condensation to collect in the bottom of the pipe where it will not be picked up and carried by gas flow. A properly installed Drip Leg/Sediment Trap shall be constructed to change the direction of gas flow by 90º. The vertical wall of pipe above the drip leg allows gravity to work on condensation and force it to fall to the bottom of the drip leg piece of pipe. It protects the items downstream from getting clogged or otherwise affected by debris in the gas line.

2.4 Gaseous Fuel System Piping

2.4.1 General Information

One of the most common causes of a generator set not operating properly is improper sizing and installation of the gaseous fuel supply system between the meter (utility source) and the generator connection. The fuel supply system consists of a primary regulator to regulate the flow and volume from the source (utility supply) to the generator, and all of the associated piping, fittings, and shutoff valves, both upstream (feeding the main meter/regulator) and downstream (between the meter and primary regulator), which connect the fuel source to the connection point on the generator. The fuel supply system must be capable of supplying the correct volume of fuel within the correct pressure range to the connection point on the generator. The volume of fuel required and the operating pressure required are listed in the technical specifications for the applicable generator. Fuel pressure at the unit must remain within the specified operating range and not drop below the minimum pressure specified.

2.4.2 Definitions

The following definitions are provided for use in this manual.

Term	Description
Allowable Pressure Drop	The design pressure loss in the system under maximum probable flow conditions, from the point of delivery to the inlet connection of the generator set, shall be such that the supply pressure at the generator is greater than or equal to the minimum pressure required by the generator at its full load capacity.
Authority Having Jurisdiction (AHJ) (NFPA-54)	An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.
Cubic Foot (ft^3) of Gas (NFPA-54)	The amount of gas that would occupy 1 ft^3 when at a temperature of 600ºF saturated with water vapor and under a pressure equivalent to 30 in. w.c.
Generator Connection Point	The connection point for the fuel supply system to the generator set is the end of the manufacturer-supplied flexible hose fitting which connects to the fitting on the base frame of the generator. See Subsection 2.3.1 for more detailed information.
psi & psig	Measure of pressure in pounds per square inch and pounds per square inch gauge.
Inches of Water Column (in. w.c.)	Measure of pressure in inches of water column (in. w.c.). 14 in. w.c. = approximately 0.5 psi.

Term	Description
Primary Regulator	A pressure regulator installed between the service regulator (NG) or first-stage regulator (LPG-V) sized to provide the pressure and volume required by the generator at its full rated load capacity.
Regulator (for LPG-V) (NFPA-58)	
First-Stage Regulator	A pressure regulator for LPG-V service designed to reduce pressure from a container to 10.0 psig or less.
High-Pressure Regulator	A pressure regulator for LPG-L or vapor service designed to reduce pressure from the container to a lower pressure in excess of 1.0 psig.
Second-Stage Regulator	A pressure regulator for LPG-V service designed to reduce first-stage regulator outlet pressure to 14 in. w.c. or less. For generator set purposes, this is also referred to as the Primary Regulator.
Regulator (for NG fuel) (NFPA-54)	
Pressure Regulator	Equipment placed in a gas line for reducing, controlling, and maintaining the pressure in that portion of the piping system downstream of the equipment.
Service Regulator	A pressure regulator installed by the servicing gas supplier to reduce and limit the service line gas pressure to delivery pressure.

Table 2.1 – Definitions

2.5 Final Operating Test

A properly configured and sized fuel system provides the fuel volume and fuel pressure required for the generator set to operate correctly in all modes of operation. To confirm proper fuel system operation, a series of tests must be performed as further described below.

2.5.1 Gas Pressure Test Port Location

Using a suitable pressure gauge or water manometer, measure the gas pressure to the generator at the test port located either before the fuel solenoid shutoff valve(s) or located on the fuel solenoid shutoff valve. Reference Figure 2.5.

The factory-installed fuel pressure test port is typically provided with a special test port plug. This test port plug is installed using a pipe tee. When fitted, the low fuel pressure switch is located in the opposite end of the test port plug tee.

The test port plug allows fuel pressure test readings to be taken quickly without leaving costly gauges installed in the fuel line.

Use the “Pete’s Plug” as follows:

1. Clean and lubricate gauge adapter probe with a small amount of petroleum jelly or silicone grease.

2. Assemble gauge adapter.

3. Using the appropriate sealant, screw barbed fitting into gauge adapter.
4. Install fuel hose of the proper pressure gauge onto barbed fitting.
5. Slowly unscrew protective cap from the test port plug.

   Note: Quickly tighten the cap if escaping gas or liquid is heard or felt. Replace the plug if defective.
6. Insert gauge adapter into test port plug and secure.

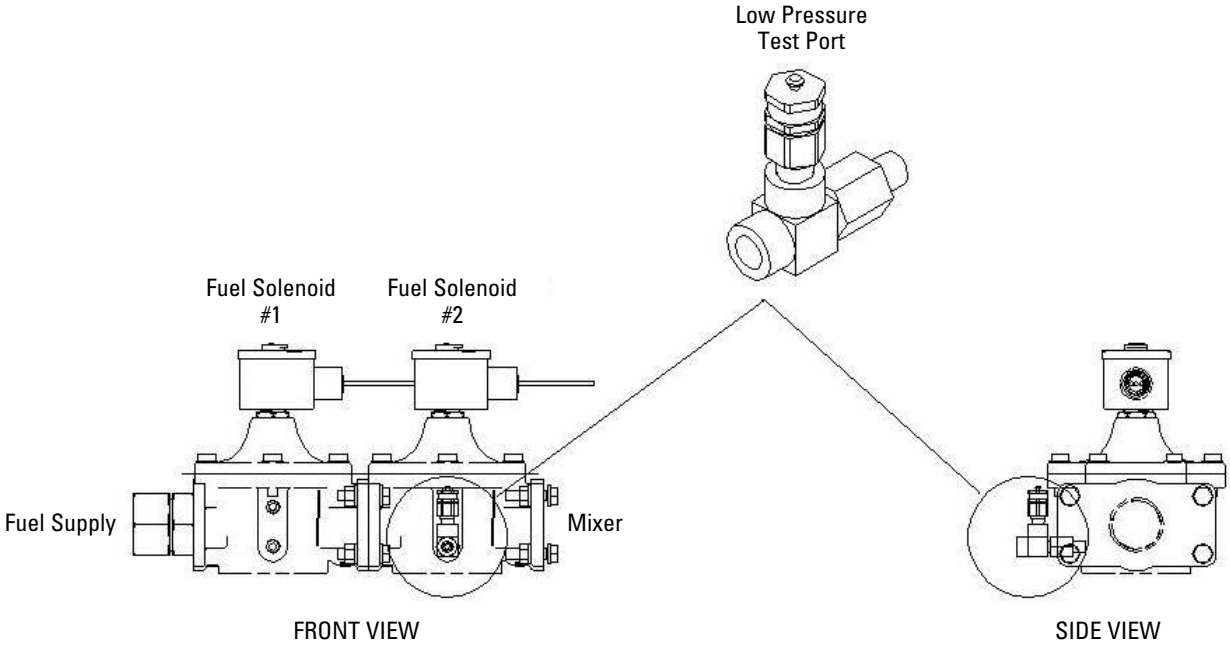


Figure 2.5 – Fuel Pressure Test Point and Low Fuel Pressure Switch

7. Once the fuel pressure reading is obtained, remove gauge adapter probe and screw protective cap onto fuel pressure test port plug.

   Note: Take necessary readings as quickly as possible. Severe deformation of the valves may occur if gauge adapter probe is left in the test port plug for a period of hours or days.

   Note: Below 45ºF the neoprene core of the plug does not recover its original shape as rapidly as it would at higher temperatures. Therefore, upon removal of the gauge adapter probe, the valves may not close fully and immediately, or they may remain slightly open until the operating temperature is above 45º F. Lower pressures and the length of time the gauge adapter probe is inserted also can affect the valve closing rate. The protective cap is provided to eliminate the small amount of leakage that might occur following removal of the gauge adapter probe.
8. Tighten protective cap to prevent tampering.

2.5.2 Final Test Procedure

This procedure must be performed during the startup or commissioning procedure. It requires a resistive load bank connected to the unit, or a combination of load bank and system load, to bring the unit to its full rated kW load capacity. This test must be performed and documented to validate the operation of the fuel system.

Measure the fuel supply pressure under each of the following conditions:

Static Pressure. The pressure when the unit is not running. This pressure must not exceed the maximum pressure for the unit as listed in the specification sheet.

Cranking Pressure. The pressure when the unit is cranking. If the pressure drops excessively (equal to or greater than 2 in. w.c. below static, or below the specified minimum required pressure) during cranking, it is an indication that the fuel system is incorrectly sized or installed. It could also indicate that the primary regulator is improperly sized or mounted too close to the unit's connection point. If this condition exists the unit may experience hard starting and will not perform as expected at full load or during load transients.

Running No-load Pressure. The pressure when the unit is running at rated frequency and voltage with no load. This pressure should be at or slightly below the maximum pressure listed for the unit in the specification sheet. The typical No Load fuel pressure drop is 1.0 in. H_2O or less.

Running Full-load Pressure. The pressure while the unit is running at full rated load (kW). The measured fuel pressure shall never fall below the specified minimum value nor, shall the Fuel Pressure Drop be equal to or greater than 2.0 in H_2O.

Best Practices Piping Requirements

These are the manufacturer best practices for configuring and sizing low pressure fuel supply piping to generators. These best practices have been developed specifically for the manufacturer's product and may not represent conventional gaseous fuel system sizing methods, particularly those used frequently with low volume appliance installations. Compliance with these best practices will ensure the generator set engine will operate properly under dynamic conditions.

- The primary fuel pressure regulator outlet to the generator connection point must not be less than six feet of properly sized pipe. Do not connect a primary regulator directly to the connection point (flexible fuel line) on the generator. The fuel system piping between the primary regulator and the connection point on the generator acts as a mechanical "capacitor" (accumulator) which stores gas and, therefore, can minimize or maximize the changes in delivery pressure that the generator sees during cranking and load changes.
- The required fuel pressure to the unit is measured at the factory provided generator set Test Port. (See Gas Pressure Test Port Location.)
- Seasonal utility supply pressure changes can occur. The fuel delivery pressure to the primary regulator can have adverse effects on the proper operation of the generator. The fuel supply pressure to the unit must remain within the specified operating parameters for the unit as stated in the generator specification sheet and the dynamic fuel pressure drops previously stated must not be confirmed. Contact the local utility to find out what can be done to correct such seasonal changes. The low fuel pressure system piping and primary fuel demand regulator must be sized based upon the minimum utility fuel delivery pressure that the generator set will be exposed to.
- The use of a Drip Line/Sediment Trap is required for all NG and LPG-V installations. The Drip Line/ Sediment Trap is to be installed on the High Pressure side of the Primary Fuel pressure regulator between the Shut off valve and the inlet connector to the Primary Fuel Pressure regulator. The Drip Line/Sediment Trap shall be constructed in such a manner to change the direction of gas flow by 90º. Check local codes in your jurisdiction regarding requirements.

- The generator set must have its own dedicated fuel supply. There must not be any other loads connected to the outlet of the primary regulator for the generator.

For LPG-V Systems. Due to the nature of the conversion process from LPG-L to LPG-V, consider the following:

- The vaporization rate of a given LPG tank is dependent on the liquid level in the tank (wetted surface area), the ambient temperature around the tank, and relative humidity.
- When ambient temperatures are low (below 40ºF) and engine fuel consumption is high, and sufficient humidity is present, condensation can occur resulting in frosting of the tank at the liquid level. This can lead to a reduced rate of vaporization. See the LPG tank sizing section for more information.

2.5.3 Operating Fuel Pressure Requirements

The unit specification sheet lists the "Operating Fuel Pressure" range for the generator as well as the 100% load fuel consumption rate. The range gives the maximum and minimum acceptable pressures for proper operation of the unit. The maximum allowable fuel system pressure drop, measured at the unit mounted test port, from a static condition to a full-load condition, shall not be equal to or greater than 2 in. w.c. Additionally, the observed fuel pressure drop shall not be sufficient to result in exceeding the minimum specified fuel pressure limit of the Operating Fuel Pressure range. For example, if a unit has an operating fuel pressure range of 11 in. H_2O to 14 in. H_2O and the primary fuel pressure regulator has an output pressure set point of 12 in. H_2O the maximum allowable pressure drop for this system would be 1 in. H_2O. As the fuel pressure drop cannot be sufficient to exceed the minimum specified fuel pressure limit.

2.5.4 Engine Fuel Consumption

The volume of gaseous fuel the unit consumes at various load values is listed in the applicable generator specification sheet. NG and LPG-V values are provided in Cubic Feet per Hour (CFH or ft^3/hour). LPG-L values are provided in Gallons Per Hour (GPH). International units are also provided in the specification sheets.

It may be necessary to convert CFH to BTUs per Hour. The following conversion formulas are provided to do so:

- For NG, multiply CFH by 1000 to get BTU per hour.
- For LPG-V, multiply CFH by 2500 to get BTU per hour.

2.5.5 Primary Pressure Regulators

Pressure regulators are designed to automatically adjust flow to meet downstream demand at a required pressure. The typical regulator installed as the primary regulator for a generator set is of the direct acting, internally registered design. Direct acting means that the pressure sensing element acts directly to open the valve and control the flow to the load while maintaining the desired pressure. The pressure sensing element is typically a diaphragm which is opposed by a combination of spring pressure and atmospheric pressure. The valve is the restricting element and consists of some type of variable restriction (cone, poppet, disc) which closes against a fixed seat. Internal registration means that the pressure used for sensing comes from within the valve body, usually through a passage from the secondary side (outlet) to the sensing diaphragm.

The primary regulator must be sized properly to provide the required fuel volume flow at a given pressure within the specified operating range when the generator is cranking or operating at its full load capacity. The generator fuel consumption values and required operating pressures are listed in the applicable specification sheet for the generator.

The generator set manufacturer requires that the primary pressure regulator be sized for a fuel delivery rate at least 150% of the generators required fuel consumption (at 100% load), and that the regulator provide no more than a 2 in. w.c. pressure drop from minimum flow to full flow (regulator droop).

Various regulator manufacturers provide sizing tables, flow capacity, pressure drop tables, and distributors who will help size a regulator correctly to a system.

2.5.6 Primary Pressure Regulator Sizing and Installation Requirements

The following are the requirements from the generator set manufacturer in regard to specifying, sizing, and installing a Primary Fuel Pressure Regulator.

1. All primary fuel pressure regulators should be installed and used in accordance with federal, state, and local codes and regulations.
2. The Primary Fuel Pressure Regulator for a NG or LPG-V fuel types, shall be installed at the generator set radiator exhaust end of the installation pad on the same side as the flex hose connection. The outlet of the Primary Fuel Pressure Regulator shall be spaced 6 ft. min. to 10 ft. max. from the connection point between the steel pipe and the flex hose.
3. The primary fuel pressure regulator must possess the following qualifications:
   - Be sized to have a fuel flow delivery rating (CFH) at least 50% greater than the generator 100% rated kW fuel consumption requirement. The recommended selection for orifice diameters is to use the smallest practical orifice that will still provide a CFH fuel flow rate at least 1.5 times greater than the required full load CFH rating of the generator set.
   - Be approved for a mechanized engine application. A standard HVAC type regulator or standard appliance regulator is prohibited.
   - Have an accuracy rating of 1% or less and/or have a maximum allowable pressure droop rate of not more than 2.0 in. w.c. droop is the reduction of outlet pressure experienced by pressure-reducing regulators as the flow rate increases. It is stated as a percent, in inches of water column, or in pounds per square inch and indicates the difference between the outlet pressure at low flow rates and the outlet pressure at the published maximum flow rate. Droop is also called offset or proportional band. A maximum allowable pressure droop of 2 in. w.c. droop, from minimum flow to full flow, for proper generator operation.
4. The generator must have a dedicated fuel supply and shall not be shared with any other appliances (furnace, water heaters, ranges, etc.).
5. The regulator shall have 2.0 in. connectors. When a regulator appears unable to pass the published flow rate, be sure to check the inlet pressure measured at the regulator body inlet connection. The inlet pressure range for the primary fuel pressure regulator is as follows:
   Gensets less than 300kW - Absolute minimum 2.0 PSI, Optimum 5.0 PSI, Maximum 15.0 PSI.
   Gensets greater than 300kW - Absolute minimum 5.0 PSI, Optimum 10.0 PSI, Maximum 15.0 PSI.
   Supply piping up to regulators can cause significant flowing pressure losses.
6. When adjusting the pressure set-point, the regulator should be flowing at least 5% of the normal operating flow. The generator set manufacturer recommends an outlet pressure set point of 13.0 in. H_2O.
7. For every 15 psid (differential) across the regulator, expect approximately a one degree drop in gas temperature due to the natural refrigeration effect. Freezing is often a problem when the ambient temperature is between 30º and 45ºF (-1º and 7ºC), particularly with LPG-V systems.
8. Vents should be pointed down to help avoid the accumulation of water condensation or other materials in the spring case.

9. Keep vents open. Do not use small diameter, long vent lines. Use the rule-of-thumb of the next nominal pipe size for every ten feet of vent line and three feet of vent line for every elbow in the line.
10. For a generator set, the connection point on the generator is considered to be end of the flex hose. The flex hose is the same size as the connection point on the generator frame rail (see installation drawings).
11. The primary fuel pressure regulator shall be installed with the diaphragm case positioned in a vertical plane.

2.6 Sizing the Gaseous Fuel Supply System Piping

Local fuel gas codes may vary widely. For this reason, the sizing of the Low Pressure Fuel pipe is the responsibility of the Cat dealership. For additional information regarding the steps to properly size piping for NG or LPG systems, consult the applicable NFPA bulletins (NFPA-54: National Fuel Gas Code, and NFPA-58: Liquefied Petroleum Gas Code).

When using a local gas distributor or installer make sure they have documentation that supports the specifications and requirements stated within this document. The fuel system requirements and best practices conveyed in this manual must be provided to the representative responsible for sizing the fuel system. The final acceptance test of the system will be measuring the fuel pressure as required in Gas Pressure Test Port Location. If the pressure requirements are not met, the fuel supply system is not correct.

Note: The following information is to provide assistance in planning gaseous fuel supply installations for generators. In NO WAY should this information be interpreted to conflict with any applicable fuel gas codes or local requirements/regulations. Contact the local AHJ if questions arise. It is recommended that a local gas distributor or licensed installer be consulted when sizing and installing any gaseous fuel supply systems.

2.6.1 Low Pressure Gas Piping General Rules

The following general rules apply to piping used in gaseous fuel systems:

- Black Iron piping is used for NG and LPG-V fuels. When installing LPG-L, the industry standard is Copper Pipe.
- A stainless steel braid flexible hose (Flex Hose) between the generator connection point and the rigid black iron supply piping is required. The flex hose shall be directly connected to the fuel connection inlet at the generator rail without any pipe fittings installed between the flex hose connector end and the generator connection point. The flex hose shall be installed in a straight line perpendicular to the generator set rail with no kinks or bends.

  A modified length flex hose can be used to maintain this requirement and still accommodate unique installation pad sizing/spacing. The flex hose diameter shall be equal to the diameter of the connector fitting at the generator connection point at the rail.

  The supplied flexible hose is not to be installed underground or in contact with ground. It must be connected between the rigid supply piping and the connection fitting on the base of the generator set. The flexible hose is for in-line installation only. Bends, kinks, or off-center in-line installation of the flexible hose is NOT allowed.
- The black iron piping must be of the correct diameter to maintain the required supply pressure and fuel flow volume when the prime mover is subjected to varying load conditions.
- The low fuel pressure system must be properly purged and leak-tested in accordance with the applicable codes and standards.
- The use of applicable code and regulation approved pipe sealant or joint compound on all threaded fittings to reduce the possibility of leakage is acceptable.

- A sediment trap and fuel shut off valve shall be installed on the high pressure side of the primary fuel pressure regulator. The sediment trap shall be constructed to change the direction of fuel flow by 90º.

Note: In the absence of local purging and leak test standards, NFPA-54 (National Fuel Gas Code) may be used as a guide.

2.6.2 Minimum Low Pressure Fuel System Spacing

The low pressure fuel pipe run begins at the output of the primary fuel pressure regulator and extends to the connection point of the flex hose. The primary fuel pressure regulator for each fuel type, shall be installed at the generator set radiator exhaust end of the installation pad on the same side as the flex hose connection. The outlet of the primary fuel pressure regulator shall be spaced 6 ft. min. to 10 ft. max. from the connection point between the steel pipe and the flex hose. The volume of piping between the primary pressure regulator and the flex hose is a mechanical "capacitor or ballast" which is used to maintain proper engine performance during transient conditions.

2.6.3 Calculating Method for Low Pressure Fuel (Black Iron) Pipe Size

The generator set manufacturer uses the "Equivalent Length" method to calculate the required pipe diameter size needed for a specific generator. The equivalent length method converts pressure losses inherent to pipe fittings into a "length of pipe" value which is added to the overall linear run of estimated pipe length to be used in the fuel supply system.

The total linear pipe run length is measured from the output of the primary fuel pressure regulator to the fuel inlet connection point at the generator. The planned pipe system should be broken up into straight pipe runs and connectors. The total length of straight pipe and the equivalent length of the connectors will be added to determine the overall length of the black iron pipe run.

All pipe fittings (elbows, tees, couplings, unions, etc.) create a pressure loss due to the inherent resistance coefficient of the fitting, and must be accounted for. There are various tables available which provide the equivalent length of straight pipe for particular fittings. Table 2.4 is the Equivalent Length Table that the generator set manufacturer uses. The table was compiled using information from NFPA 54 and other resources. The information in the tables provided in this section was derived from NFPA 54 as well as other sources.

For all low pressure fuel pipe size calculation purposes, the absolute minimum linear pipe run length will always be 10 ft.

2.6.4 Natural Gas (NG) and Liquid Propane Gas – Vapor (LPG-V) Pipe Sizing

To properly calculate the pipe size needed for a specific generator set operating on either NG fuel or LPG-V fuel, use the following process:

1. Obtain the CFH rating (fuel consumption) of the generator set when operating at 100% rated kW from the generator set specification sheet. Multiply this value by 1.50. This is the flow volume (150%) you will use to size the regulator and piping system. For LPG-V units, the table values are in thousands of BTUs per hour. To convert the LPG-V fuel consumption from CFH to BTU/hour, multiply the CFH value by 2500.
2. Obtain the fuel pressure operating range of the generator set from the generator set specification sheet. The preferred static pressure set-point is the maximum value listed for the unit (typically 13.0 in. w.c.). Remember that the final test is to have a system that provides the maximum flow volume required by the unit (100% load) with no more than a 2 in. w.c. pressure drop, from no-load to full load, when measured at the unit test point.

3. Determine or verify that the Primary Regulator (or second stage regulator for LPG-V) being used will provide the flow volume required at the pressure required by the unit, with no more than a 2 in. w.c. pressure drop from no flow to full flow. The regulator should be sized to 150% of the units full load fuel consumption volume.
4. Record the actual linear distance (feet of pipe) from the primary fuel pressure regulator to the fuel inlet connection at the generator set.
5. Record the total number of all pipe fittings, and size, between the primary fuel pressure regulator and the fuel inlet connection at the generator. Because the equivalent length of fittings is determined by the fitting size, start with a pipe size at least equal to the body size of the regulator selected. For example, if the regulator selected has a body size of 2-inch pipe, start with pipe and fittings of 2-inch size.

   Note: List each fitting individually.
6. Convert each pipe fitting into its "Equivalent Length" value (see Table 2.4 for the most common fittings). This information can be obtained from the pipe manufacturer or from the tables in NFPA 54. For valves, most valve manufacturers provide either CV values for this purpose, or an equivalent pipe length. Also note the difference in equivalent length for tee fittings when the flow is straight through versus through the branch – it is significant. The minimum Equivalent Length of any fitting or valve shall be equal to 1 ft.
7. Add up all the equivalent lengths for the pipe fittings being used in the system. This is the equivalent length of pipe represented by all of the fittings.
8. Add the linear distance measured in Step 4 to the calculated equivalent length value for all the fittings derived in Step 7. This is the "Total Calculated Pipe Length" for the fuel supply system.
9. Use Table 2.2 for NG Fuel or Table 2.3 for LPG-V Fuel to determine the appropriate Specific Gravity value and Multiplier.
10. From the left side column of the appropriate table, locate the value of pipe length that most closely represents the actual length derived in Step 8. Always "round up" to the next longer pipe length value provided in the table (e.g., if the calculated length is 41 ft., select a pipe length of 45 ft. from the table).

    Note: The pipe run length used in calculating the proper pipe size will never be less than 10 feet.
11. Using the pipe length value found in Step 10, move across the table within the same row until you find a CFH rating (or BTU/hour rating for LPG-V in Table 2.3) greater than the value identified in Step 1.
12. As a minimum, a specific gravity of 0.65 for NG fuel and a specific gravity of 1.6 for LPG-V must be used when calculating the maximum fuel flow volume of the pipe size selected. From Table 2.5, select the corresponding correction factor. Multiply the CFH rating from Step 11 by the appropriate specific gravity correction factor.
13. Confirm that the maximum CFH/BTU value for the pipe size used is greater than the rating identified in Step 1.
14. If the table value for the pipe size and length used for calculations is less than the CFH/BTU rating identified in Step 1, redo the calculations using the next larger pipe size.
15. If the table value is greater than, or equal to, the volume rating identified in Step 1, move to the top of the column in the table and record the pipe size diameter.

    Note: The installed low pressure fuel system must comply with Gas Pressure Test Port Location. The final test of the system (Final Operating Test) is the final approval of any system installed. If the requirements are not met for full load volume at no less than the minimum required pressure, the unit will not pass.

NG Specific Gravity: 0.60 (consult local supplier for Specific Gravity of local supply).

Inlet Pressure (at beginning of pipe run) less than 1.5 psi. For generator applications this will be not greater than the maximum pressure allowed for the unit (typically 14 in. w.c. (0.5 psi) – see unit specification sheet for correct range.

Nominal Pressure Drop 0.3 in. w.c. (measured at end of pipe run) Pipe Size (in.). Schedule 80 pipe.

Iron Pipe Sizing for Natural Gas (NG)

Nominal:	3/4	1	1-1/4	1-1/2	2	2-1/2	3	4
Actual ID	0.824	1.049	1.38	1.61	2.067	2.469	3.068	4.026
Pipe Length (ft.)	Flow Capacity in Cubic Feet per Hour (NG values shown)							
10	273	514	1060	1580	3050	4860	8580	17500
15	219	413	848	1270	2446	3899	6893	14060
20	188	353	726	1087	2094	3337	5900	12034
25	166	313	643	964	1856	2958	5229	10665
30	151	284	583	873	1681	2680	4738	9663
35	139	261	536	803	1547	2466	4359	8890
40	129	243	499	747	1439	2294	4055	8271
45	121	228	468	701	1350	2152	3805	7760
50	114	215	442	662	1280	2030	3590	7330
60	104	195	400	600	1160	1840	3260	6640
70	95	179	368	552	1060	1690	3000	6110
80	89	167	343	514	989	1580	2790	5680
90	83	157	322	482	928	1480	2610	5330
100	79	148	304	455	877	1400	2470	5040

Table 2.2

Table 2.2 shows the flow capacity, in cubic feet per hour, of NG, with a specific gravity of 0.60, through standard schedule 80 pipe at a pressure drop, from one end of the pipe run to the other, of 0.3 in. w.c. This information comes from the tables in NFPA-54 (National Fuel Gas Code). For pipe length and diameters. For flow rates not shown, consult with either NFPA-54 or a local gas supplier or installer. For gases with specific gravity other than 0.60, apply the corresponding correction factor (Table 2.5).

Iron Pipe Sizing Table for Undiluted Propane (vapor) (Schedule 80 pipe).

LPG-V Specific Gravity: 1.50 (consult local supplier for specific gravity of local supply).

Inlet Pressure less than 11 in. w.c. For generator applications this will be not greater than the maximum pressure allowed for the unit (typically 14 in. w.c. – see unit specification sheet for correct range).

Nominal Pressure Drop 0.5 in. w.c. (measured at end of pipe run).
Intended use for piping between Second-Stage regulator and generator connection point.

Iron Pipe Sizing for Undiluted LPG-V

Nominal:	3/4	1	1-1/4	1-1/2	2	2-1/2	3	4
Actual ID	0.824	1.049	1.38	1.61	2.067	2.469	3.068	4.026
Pipe Length (ft.)	Flow Capacity CFH							
10	241	456	933	1397	2694	4286	7579	15,476
20	166	312	643	960	1849	2948	5198	10,635
30	133	251	516	770	1488	2369	4206	8532
40	114	215	440	659	1274	2028	3583	7302
50	101	190	391	587	1127	1806	3175	6468

Table 2.3

Table 2.3 shows the flow capacity, in thousands of BTU/hour, of undiluted LPG-V, with a specific gravity of 1.50, through standard Schedule 80 pipe with an inlet pressure of 11 in. w.c. at a nominal pressure drop from one end to the other of 0.5 in. w.c. This information is a condensed version of the information found in the tables in NFPA-54 (National Fuel Gas Code). For pipe length and diameters, or flow rates, not shown in the table please consult NFPA-54, NFPA-58, or a local gas supplier or installer.

The values in the table are in thousands of BTU/hour, so multiply the values shown by 1000 to get the actual value.

To convert cubic feet/hour (CFH) to BTU/hour multiply by 2500.

To convert BTU/hour to cubic feet/hour divide by 2500.

Standard Screw Fittings

Pipe Size (inches)	I.D. Inches	90° Elbow	45° Elbow	90° Tee, Flow Through Run	90° Tee, Flow Through Branch
3/4	0.824	2.1	0.97	1.4	4.1
1	1.049	2.6	1.23	1.8	5.3
1-1/4	1.380	3.5	1.6	2.3	6.9
1-1/2	1.610	4.0	1.9	2.7	8.0
2	2.067	5.2	2.4	3.5	10.4
2-1/2	2.469	6.2	2.9	4.1	12.4
3	3.068	7.7	3.6	5.1	15.3
4	4.026	10.1	5.4	6.7	20.1
6	6.065	15.2	8.1	10.1	30.3

Table 2.4

This table shows the typical equivalent length in feet of pipe for standard screwed fittings used with schedule 40 pipe. For fittings other than those shown, consult a local gas supplier/installer.

Specific Gravity Multipliers

Specific Gravity (1)	Multiplier	Specific Gravity (1)	Multiplier
0.35	1.31	1.00	0.78
0.40	1.23	1.10	0.74
0.45	1.16	1.20	0.71
0.50	1.10	1.30	0.68
0.55	1.04	1.40	0.66
0.60	1.00	1.50	0.63
0.65 = Calculating NG Pipe Size	0.96	1.60 = Calculating LPGV Pipe Size	0.61
0.70	0.93	1.70	0.59
0.75	0.90	1.80	0.58
0.80	0.87	1.90	0.56
0.85	0.84	2.0..	0.55
0.90	0.82	2.10	0.54

Table 2.5

Note: Table 2.5 shows the multipliers to be used for gases with different specific gravity values than those used in Table 2.2 and Table 2.3. The information for this table came from NFPA-54 (National Fuel Gas Code). To use the table, obtain the specific gravity of the gas being used from the supplier. Find that SG value in the table, and use the multiplier provided in the column to the right. Apply the multiplier found to the flow rate, for the pipe size and length, found in either Table 2.2 or Table 2.3. Note that Table 2.2 is for NG flow rates in CFH, and Table 2.3 is for LPG-V flow rates in thousand of BTU/hour.

The generator set manufacturer recommends that a minimum Specific Gravity of 0.65 for NG and 1.60 for LPG-V be used when sizing the low fuel pressure system and piping.

2.6.5 Liquid Propane Gas – Liquid (LPG-L) Pipe Sizing

Sizing pipe for LPG-L withdrawal is slightly simpler than for vapor withdrawal. The liquid fuel will be supplied from the source (tank) at a pressure between 50 and 180 psi. When selecting pipe remember that schedule 40 is only rated for a maximum rating of 150 psi. Schedule 80 black iron pipe is rated to a maximum of 300 psi. Due to the high pressure delivery rate of the LPG-L fuel, acceptable fuel line piping for LPG-L withdrawal shall be at minimum either Schedule 80 Black Iron Pipe or Copper Tubing (Schedule L or ACR). Confirm the local code requirement with the AHJ to determine which type of piping is acceptable for the site installation.

To properly calculate the pipe size needed for a specific generator set operating on either LPG-L fuel, use the following process:

1. Obtain the Gallon Per Hour (GPH) rating (fuel consumption) of the generator set when operating at 100% rated kW from the generator set specification sheet.
2. Measure the total pipe run distance from the source (tank) to the connection point on the generator set. The connection between the rigid supply pipe and the generator must be made through a suitable flexible hose at the generator set.
3. List any fittings and their equivalent pipe length. Add up the total equivalent pipe length for all fittings in the system. It is recommended to start with the pipe size of the connection on the generator set. Reference tables for Iron Pipe and for Copper Pipe.

4. Add the total pipe run and the total equivalent length of pipe fittings together. This is the total calculated pipe length of the supply line.
5. Using the GPH value identified in Step 1 and the total equivalent pipe length calculated in Step 4, use the table below for Iron Pipe and Table for Copper Pipe, identify the appropriate pipe size diameter that will support the required GPH (at 100% load) over the total pipe run distance.
6. If the value found in the table is greater than the calculated pipe length, move up the column to find the appropriate size pipe. If the recommended pipe size differs from the size used to estimate the equivalent length of the fittings used, recalculate the total pipe length using the new recommended size pipe.

LPG-L Pipe Sizing

Liquid Gas Flow (CFH)	Liquid Gas Flow (GPH)	Maximum Pipe Length in Feet (standard sch 80 pipe)			
		1/4 inch sch 80	3/8 inch sch 80	1/2 inch sch 80	3/4 inch sch 80
360	10	729			
540	15	324			
720	20	182	825		
1440	40	46	205	745	
2160	60	20	92	331	
2880	80	11	51	187	735
3600	100	7	33	119	470

Table 2.6

LPG-L Pipe Sizing

Rated Internal Working Pressure for Type L*

	Annealed							Drawn**						
Nominal Size, in.	S= 6000 psi 100° F	S= 5100 psi 150° F	S= 4800 psi 200° F	S= 4800 psi 250° F	S= 4700 psi 300° F	S= 4000 psi 350° F	S= 3000 psi 400° F	S= 6000 psi 100° F	S= 5100 psi 150° F	S= 4800 psi 200° F	S= 4800 psi 250° F	S= 4700 psi 300° F	S= 4000 psi 350° F	S= 3000 psi 400° F
1/4	912	775	745	729	714	608	456	1569	1569	1569	1569	1524	1478	1432
3/8	779	662	636	623	610	519	389	1341	1341	1341	1341	1302	1263	1224
1/2	722	613	589	577	565	481	361	1242	1242	1242	1242	1206	1169	1133
5/8	631	537	516	505	495	421	316	1086	1086	1086	1086	1055	1023	991
3/4	582	495	475	466	456	388	291	1002	1002	1002	1002	972	943	914
1	494	420	404	395	387	330	247	850	850	850	850	825	801	776
1-1/4	439	373	358	351	344	293	219	755	755	755	755	733	711	689
1-1/2	408	347	334	327	320	272	204	702	702	702	702	682	661	641
2	364	309	297	291	285	242	182	625	625	625	625	607	589	570
2-1/2	336	285	274	269	263	224	168	577	577	577	577	560	544	527
3	317	270	259	254	248	211	159	545	545	545	545	529	513	497
3-1/2	304	258	248	243	238	202	152	522	522	522	522	506	491	476
4	293	249	240	235	230	196	147	504	504	504	504	489	474	460
5	269	229	220	215	211	179	135	462	462	462	462	449	435	422
6	251	213	205	201	196	167	125	431	431	431	431	418	406	393
8	270	230	221	216	212	180	135	464	464	464	464	451	437	424
10	271	231	222	217	212	181	136	466	466	466	466	452	439	425
12	253	215	207	203	199	169	127	435	435	435	435	423	410	397

Table 2.7

*Based on maximum allowable stress in tension (psi) for the indicated temperatures (°F).

LPG-L Pipe Sizing

Pressure Loss in Fittings and Valves Expressed as Equivalent Lengths of Tube, feet

Nominal or Standard Size, in.	Fittings					Valves			
	Standard Ell		90° Tee						
	90°	45°	Side Branch	Straight Run	Coupling	Ball	Gate	Btfly	Check
3/8	0.5	–	1.5	–	–	–	–	–	1.5
1/2	1	0.5	2	–	–	–	–	–	2
5/8	1.5	0.5	2	–	–	–	–	–	2.5
3/4	2	0.5	3	–	–	–	–	–	3
1	2.5	1	4.5	–	–	0.5	–	–	4.5
1-1/4	3	1	5.5	0.5	0.5	0.5	–	–	5.5
1-1/2	4	1.5	7	0.5	0.5	0.5	–	–	6.5
2	5.5	2	9	0.5	0.5	0.5	0.5	7.5	9
2-1/2	7	2.5	12	0.5	0.5	–	1	10	11.5
3	9	3.5	15	1	1	–	1.5	15.5	14.5
3-1/2	9	3.5	14	1	1	–	2	–	12.5
4	12.5	5	21	1	1	–	2	16	18.5
5	16	6	27	1.5	1.5	–	3	11.5	23.5
6	19	7	34	2	2	–	3.5	13.5	26.5
8	29	11	50	3	3	–	5	12.5	39

Table 2.8

Note: Allowances are for streamlined soldered fittings and recessed threaded fittings. For threaded fittings, double the allowance shown on the table.

The equivalent lengths presented above are based upon a C factor of 150 in the Hazen-Williams friction loss formula. The lengths shown are rounded to the nearest half foot.

2.6.6 Sizing Liquid Propane Gas (LPG) Tanks for Vapor Withdrawal

The manufacturer recommends that the installer consult with a reputable LPG supplier when sizing LPG storage tanks and their associated pressure regulators and piping systems. The installer and/or Cat dealer shall communicate the information specified herein with the LPG fuel supplier to ensure that the fuel system is properly sized to meet the generator set manufacturers requirements.

The operation of an LPG-V system depends on the vaporization of the liquid stored in the tanks. As the vapor above the liquid level is withdrawn the pressure in the tank decreases. This change in pressure causes the liquid to “boil” in order to restore the pressure equilibrium. The liquid in the tank uses the temperature difference between its boiling point (-44ºF for Propane, and 15ºF for Butane) and the outside temperature to extract enough heat to enable vaporization (boiling). Only the liquid in contact with the tank wall absorbs heat from the outside. The area of the tank where the liquid is in contact with the tank wall is referred to as the “wetted surface area.” Cold weather results in a reduced tank vaporization capacity because there is less heat energy available to boil off the liquid into vapor. The wetted surface area of the tank must be large enough to sustain the vaporization rate required by the generator. Depending on the relative humidity and the ambient temperature, frosting can occur on the outside of the tank when it is in use; this will further inhibit the heat transfer required to sustain vaporization.

Several factors affect the rate of vaporization for LPG tanks:

- The size of the tank (wetted surface area). As the wetted surface area decreases the rate of vaporization decreases.
- The lowest liquid level the tank will be allowed to reach relates directly to the wetted surface area. The typical maximum fill level for LPG tanks is 80%, and the lowest recommended operating level is 20%. This provides a volume equivalent to 60% of the tank capacity to be used to calculate run time. Most tank sizing tables provide the vaporization rate of the tank at the lowest allowable level (20%); any tank level above this point will have a higher vaporization rate.
- The mean relative humidity.

To size an LPG tank for a desired run time the following information is required:

- The maximum vapor consumption of the generator (in BTU/hour) at 100% load. The specification sheet for the generator will list the fuel consumption rate, usually in cubic feet/hour. To convert CFH to BTU/hour, multiply by 2500.
- The fuel consumption rate of the generator, at 100% load, in gallons/hour. To convert CFH (propane vapor) to GPH divide by 36.38; to convert BTU/hour to GPH divide by 91502.
- The desired run time.
- The minimum operating temperature expected.

The most important information to consider when sizing LPG tanks for vapor withdrawal is the vaporization rate of the tank at the minimum temperature expected, and at the minimum fuel level the tank will be allowed to reach. The vaporization rates shown in the table below are based on the tank at 20% of its fill capacity.

- Multiply the gallons/hour fuel consumption of the generator (at 100% load) by the longest run time expected/desired.
- Determine the fuel consumption in BTU/hour of the generator (at 100% load).
- Determine the lowest expected operating temperature.
- Look at Table 2.9. Using both the Minimum Operating Temperature column and the Tank Vaporization Capacity column, find the BTU/hour vaporization rate of the generator (at 100% load) that corresponds to the lowest expected operating temperature.
- Look to the 2nd column (on the left) and see what the Available Tank Capacity is. If it is greater than the total run time fuel consumption, look to column 1; this is the correct size tank required. If it is less than the total run time fuel consumption, then you will need to go to the next larger tank size. Recheck the lowest operating temperature and the tank vaporization capacity.

Note: Recommended tank size is 250 gallons, minimum, or larger.

Tank Vaporization Capacities

Tank Capacity Total (gal)	Available Tank Capacity (gal) See NOTE 1	Minimum Operating Temperature (° F)	Tank Vaporization Capacity (BTU/hr) See NOTE 2	Length (Inches)	Diameter (Inches)
		40	507,600		
250	150	20	338,400	94	30
		0	169,200		
		40	642,600		
325	195	20	428,400	119	30
		0	214,200		
		40	792,540		
500	300	20	528,360	119	37
		0	264,180		
		40	1,217,700		
850	510	20	811,800	165	41
		0	405,900		
		40	1,416,960		
1000	600	20	944,640	192	41
		0	472,620		

Table 2.9

Note 1: The available tank capacity is approximately 60% of the total fill capacity. This is based on a maximum fill level of 80% and a minimum operating level of 20% (80%-20% = 60%).

Note 2: The vaporization capacity shown in this table is based on a tank level of 20%. This represents the smallest allowable wetted surface area of the liquid in the tank. As the liquid level goes up the wetted surface area increases and the vaporization rate increases.

Note: The installed low pressure fuel system must comply with Gas Pressure Test Port Location. The final test of the system (Final Operating Test) is the final approval of any system installed. If the requirements are not met for full load volume at no less than the minimum required pressure, the unit will not pass.

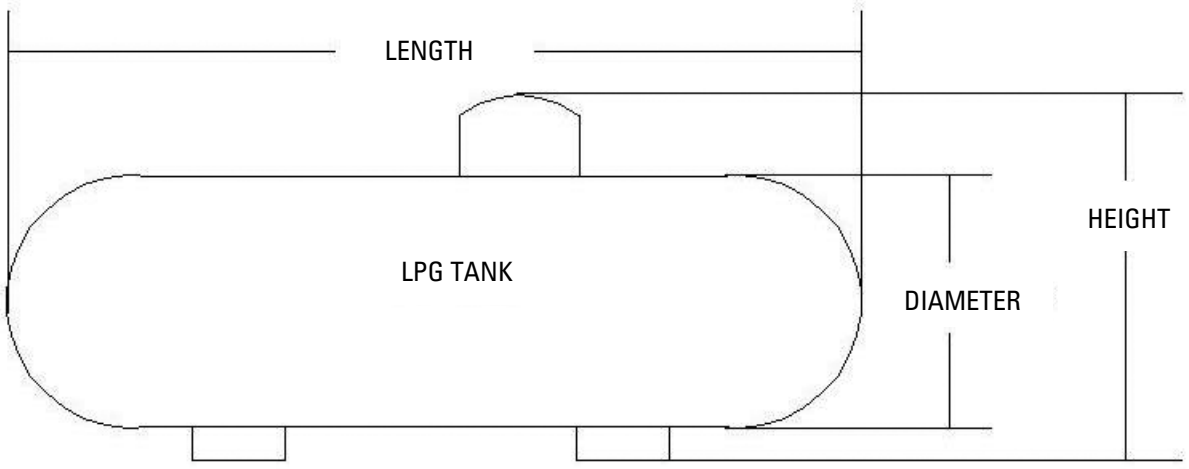


Figure 2.6 – Typical Propane Tank Dimensions

Propane conversion figures:

- 36.38 ft^3 = 90,500 BTU = 1 gal
- 1 lb = 21,500 BTU = 8.56 cu. ft.
- 2500 BTU = 1 cu. ft.

2.6.7 Determining Propane Vaporization Capacity of ASME Storage Containers

This is a general method which can be used to determine the vaporization rate of ASME LPG storage containers at different fill capacities and temperatures. To determine the vaporization rate the following information is needed:

- Length of container – inches (see Figure 2.6)
- Diameter of container – inches (see Figure 2.6)
- Constant for percent of volume in the container (see Table 2.10)
- Temperature factor multiplier (see Table 2.11)

Percentage of Container Filled K Equals: Propane Vaporization Capacity at 0° F (in BTU/hour)

Percentage of Container Filled	K Equals	K Equals: Propane Vaporization Capacity at 0° F (in BTU/hr)
50	90	D X L X 90
40	80	D X L X 80
30	70	D X L X 70
20	60	D X L X 60
10	45	D X L X 45

Table 2.10

Temperature Factor for Determining Vaporization Rate

Air Temperature (° F)	Multiplier	Air Temperature (° F)	Multiplier
-15	0.25	+5	1.25
-10	0.20	+10	1.50
-5	0.75	+15	1.75
0	1.00	+20	2.00

Table 2.11

For example, a 500 gallon tank with a length of 119 inches and a diameter of 37 inches is filled to 50% capacity. What is the vaporization rate of the tank if the ambient temperature is 10°F?

Calculate the vaporization rate for 50% fill using the tank dimensions and information from Table 2.10:

119 x 37 x 90 = 417,690 BTU/hour

Multiply that answer by the temperature multiplier from Table 2.11:

417,690 x 1.5 = 626,535 BTU/hour

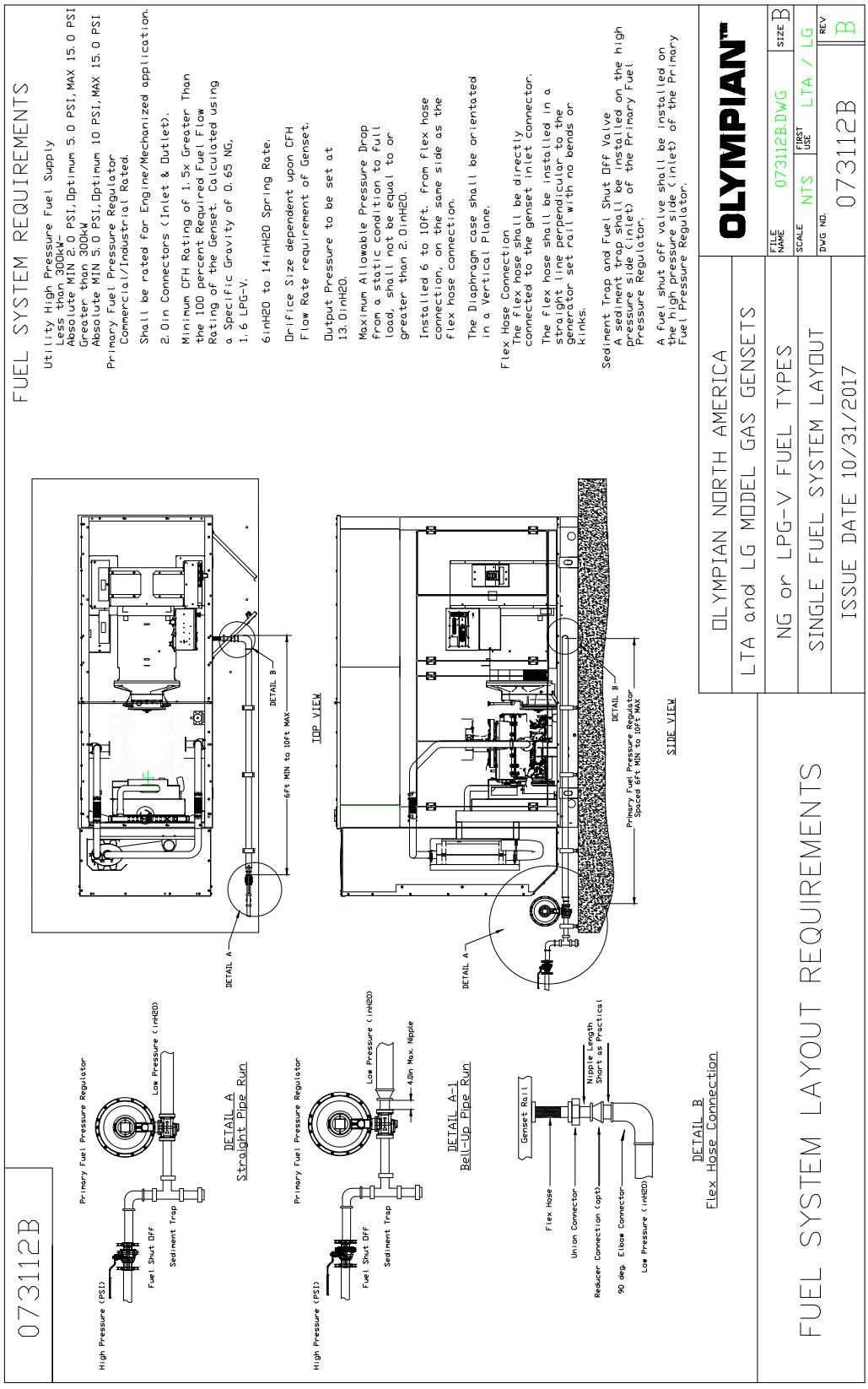
Propane conversion figures:

- 36.38 ft^3 = 90,500 BTU = 1 gal
- 1 lb = 21,500 BTU = 8.56 ft^3
- 2500 BTU = 1 ft^3

Other practical LPG tank sizing solutions. Always consult with a reputable LPG supplier when sizing LPG tanks. LPG tanks can be buried (in ground). The advantage of burying the LPG tank is the constant ground temperature to provide for vaporization. Multiple LPG tanks can also be used, with all outlets piped to a common supply manifold. Always consult the local codes and regulations before attempting to bury or install single or multiple LPG tanks.

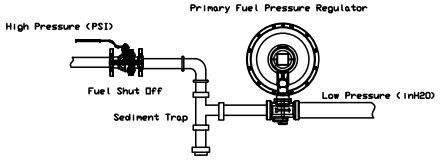
3.0 Fuel System Installation Layout

3.1 Unit Drawings

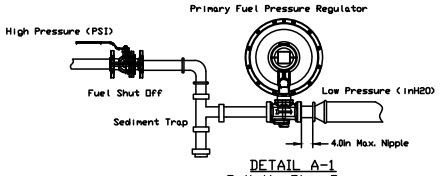


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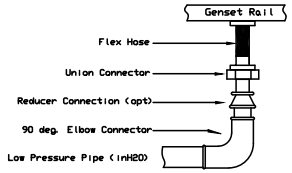
FUEL SYSTEM LAYOUT REQUIREMENTS



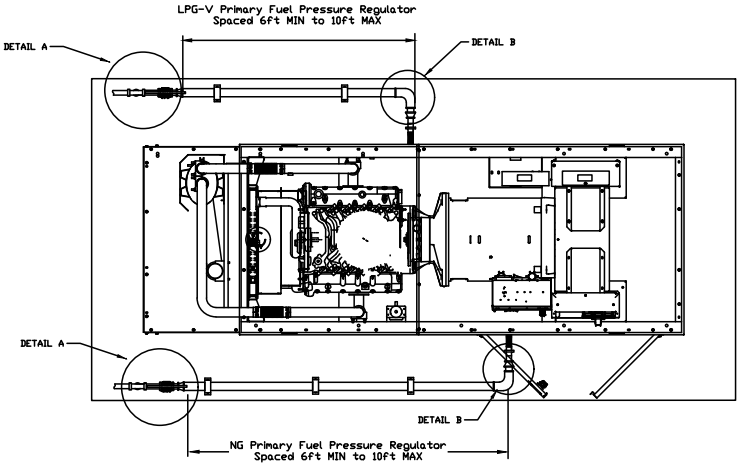
DETAIL A
Straight Pipe Run



DETAIL A-1
Bell-Up Pipe Run



DETAIL B
Flex Hose Connection



DUAL FUEL OPTION - TOP VIEW
Specific Fuel Source Input Labeled on Genset

FUEL SYSTEM REQUIREMENTS

Utility High Pressure Fuel Supply
Less than 300kW-
Absolute MIN 2.0 PSI, Optimum 5.0 PSI, MAX 15.0 PSI
Greater than 300kW-
Absolute MIN 5.0 PSI, Optimum 10 PSI, MAX 15.0 PSI

Primary Fuel Pressure Regulator
Commercial/Industrial Rated.

Shall be rated for Engine/Mechanized application.

2.0in Connectors (Inlet & Outlet).

Minimum CFH Rating of 1.5x Greater Than the 100 percent Required Fuel Flow Rating of the Genset. Calculated using a Specific Gravity of 0.65 NG, 1.6 LPG-V.

6inH2O to 14inH2O Spring Rate.

Orifice Size dependent upon CFH Flow Rate requirement of Genset.

Output Pressure to be set at 13.0inH2O.

Maximum Allowable Pressure Drop from a static condition to full load, shall not be equal to or greater than 2.0inH2O.

Installed 6 to 10ft. from flex hose connection, on the same side as the flex hose connection.

The Diaphragm case shall be orientated in a Vertical Plane.

Flex Hose Connection
The flex hose shall be directly connected to the genset inlet connector.

The flex hose shall be installed in a straight line perpendicular to the generator set rail with no bends or kinks.

Sediment Trap and Fuel Shut Off Valve
A sediment trap shall be installed on the high pressure side (inlet) of the Primary Fuel Pressure Regulator.

A fuel shut off valve shall be installed on the high pressure side (inlet) of the Primary Fuel Pressure Regulator.

Caterpillar, Inc.		
CAT Compact Retail Gensets		
NG and LPG-V DUAL FUEL OPTION	FILE NAME 051916B.DWG	SIZE B
DUAL FUEL SYSTEM LAYOUT	SCALE NTS	FIRST USE CAT Compact
ISSUE DATE 11/7/2017	DWG NO. 051916B	REV B

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