Fuel Supply

Diesel Fuel Supply

Diesel engine–driven generator sets are generally designed to operate on ASTM D975 number 2 diesel fuel. Other fuels may be suitable for short term operation, if the fuel meets the quality and physical characteristics described in **Table 6–6**. Consult engine manufacturer for use of other fuels.

Care should be taken in the purchase of fuel and filling of tanks to prevent ingress of dirt and moisture into the diesel fuel system. Dirt will clog injectors and cause accelerated wear in the finely machined components of the fuel system. Moisture can cause corrosion and failure of these components.

Diesel generator sets consume approximately 0.07 gal/hr per rated–kW (0.26 liters/hr per rated–kW) of fuel at full load, based on their standby rating. For example, a 1000 kW standby generator set will consume approximately 70 gal/hr (260 liters/hr) of fuel. The main fuel tank for a diesel generator set may be either a sub–base tank (mounted under the generator set skid), or a remote fuel tank. If the main (bulk) fuel tank is remote from the generator set, an intermediate (day) tank may be required to properly supply the generator set. There are considerable differences in engine capabilities between suppliers, so the fuel system design should be reviewed for the specific generator set installed at a site.

The primary advantage of sub–base fuel tanks is that the system can be factory designed and assembled to minimize site work. However, they may not be a practical (or possible) selection based on main fuel tank capacity requirements and code limitations, and the ability to access the tank for re–filling. When selecting a sub–base fuel tank, be aware that the generator set control system and other service maintenance points may be raised to an impractical height. This may require structures to be added to the installation to allow convenient service or meet operational requirements.

Because of the limitations of the mechanical fuel pumps on most engines, many installations that require remote main (bulk) fuel tanks will also require intermediate (day) tanks. The main tank may be either above the generator set, or below it, and each of these installations will require slightly different intermediate tank designs and fuel control systems.

Figures 6–29 and 6–30 illustrate typical diesel fuel supply systems.

PIPE DIAMETER INCHES (mm)	HEAT FROM PIPE BTU/MIN-FOOT (kJ/Min-Meter)	HEAT FROM MUFFLER BTU/MIN (kJ/Min)
1.5 (38)	47 (162)	297 (313)
2 (51)	57 (197)	490 (525)
2.5 (64)	70 (242)	785 (828)
3 (76)	84 (291)	1,100 (1,160)
3.5 (98)	96 (332)	1,408 (1,485)
4 (102)	108 (374)	1,767 (1,864)
5 (127)	132 (457)	2,500 (2,638)
6 (152)	156 (540)	3,550 (3,745)
8 (203)	200 (692)	5,467 (5,768)
10 (254)	249 (862)	8,500 (8,968)
12 (305)	293 (1,014)	10,083 (10,638)

Table 6–5. Heat Losses From Uninsulated Exhaust Pipes and Mufflers

PROPERTY	SPECIFICATIONS	GENERAL DESCRIPTION
Viscosity (ASTM D445)	1.3–1.5 centisokes (mm/sec) at 40° C (104° F)	The injection system works most effectively when the fuel has the proper ”body” or viscosity. Fuels that meet the requirements of ASTM 1–D or 2–D fuels are satisfactory with Cummins fuel systems.
Cetane Number (ASTM D613)	42 minimum above C (32° F) 45 minimum below 0° C (32° F)	Cetane number is a measure of the starting and warm–up characteristics of a fuel. In cold weather or in service with prolonged low loads, a higher cetane number is desirable.
Sulphur Content (ASTM D129 or 1552)	Not to exceed 0.5 mass percent (see note)	Diesel fuels contain varying amounts of various sulphur compounds which increase oil acidity. A practical method of neutralizing high acids from higher sulphur is to change oil more frequently or use a higher TBN oil (TBN = 10 to 20) or both. The use of high sulphur fuel (above 0.5 mass percent)will result in sulfate formation in the exhaust gas under high load continuous conditions. High sulphur fuel will also shorten the life of certain components in the exhaust system, including the oxidation catalyst.
Active Sulphur (ASTM D130)	Copper strip corrosion not to exceed No.2 rating after three hours at 50° C (122° F)	Some sulphur compounds in fuel are actively corrosive. Fuels with a corrosion rating of three or higher can cause corrosion problems.
Water and Sediment (ASTM D1796)	Not to exceed 0.05 volume percent	The amount of water and solid debris in the fuel is generally classified as water and sediment. It is good practice to filter the fuel while it is being put into the fuel tank. More water vapor condenses in partially filled tanks due to tank breathing caused by temperature changes. Filter elements, fuel screens in the fuel pump, and fuel inlet connections on injectors, must be cleaned or replaced whenever they become dirty. These screens and filters, in performing their intended function, will become clogged when using a poor or dirty fuel and will need replacing more often.
Carbon Residue (Ramsbottom, ASTM D254 or Conradson, ASTM D189)	Not to exceed 0.35 mass percent on 10 volume percent residuum	The tendency of a diesel fuel to form carbon deposits in an engine can be estimated by determining the Ramsbottom or Conradson carbon residue of the fuel after 90 percent of the fuel has been evaporated.
Density (ASTM D287)	42–30 degrees API gravity at 60° F (0.816–0.876 g/cc at 15° C)	Gravity is an indication of the high density energy content of the fuel. A fuel with a high density (low API gravity) contains more BTUs per gallon than a fuel with a low density (higher API gravity). Under equal operating conditions, a higher density fuel will yield better fuel economy than a low density fuel.
Cloud Point (ASTM D97)	6° C (10° F) below lowest ambient temperature at which fuel expected to operate.	The cloud point of the fuel is the temperature at which crystals of paraffin wax first appear. Crystals can be detected by a cloudiness of the fuel. These crystals will cause a filter to plug.
Ash (ASTM D482)	Not to exceed 0.02 mass percent (0.05 percent with lubricating oil blending)	The small amount of non–combustible metallic material found in almost all petroleum products is commonly called ash.
Distillation (ASTM D86)	The distillation curve must be smooth and continuous.	At least 90 percent of the fuel must evaporate at less than 360° C (680° F). All of the fuel must evaporate at less than 385° C (725° F).
Acid Number (ASTM D664)	Not to exceed 0.1 Mg KOH per 100ML	Using fuel with higher acid numbers can lead to higher levels of wear than is desirable. The total acid number is located in ASTM D664
Lubricity	3100 grams or greater as measured by US Army scuffing BOCLE test or Wear Scar Diameter (WSD) less than 0.45mm at 60° C (WSD less than 0.38mm at 25° C) as measured by HFRR method.	Lubricity is the ability of a liquid to provide hydrodynamic and/or boundary lubrication to prevent wear between moving parts.
NOTE: Federal or local regulations may require a lower sulphur content than is recommended in this table. Consult all application regulations before selecting a fuel for a given engine application.		

Table 6–6. Diesel Fuel Specifications

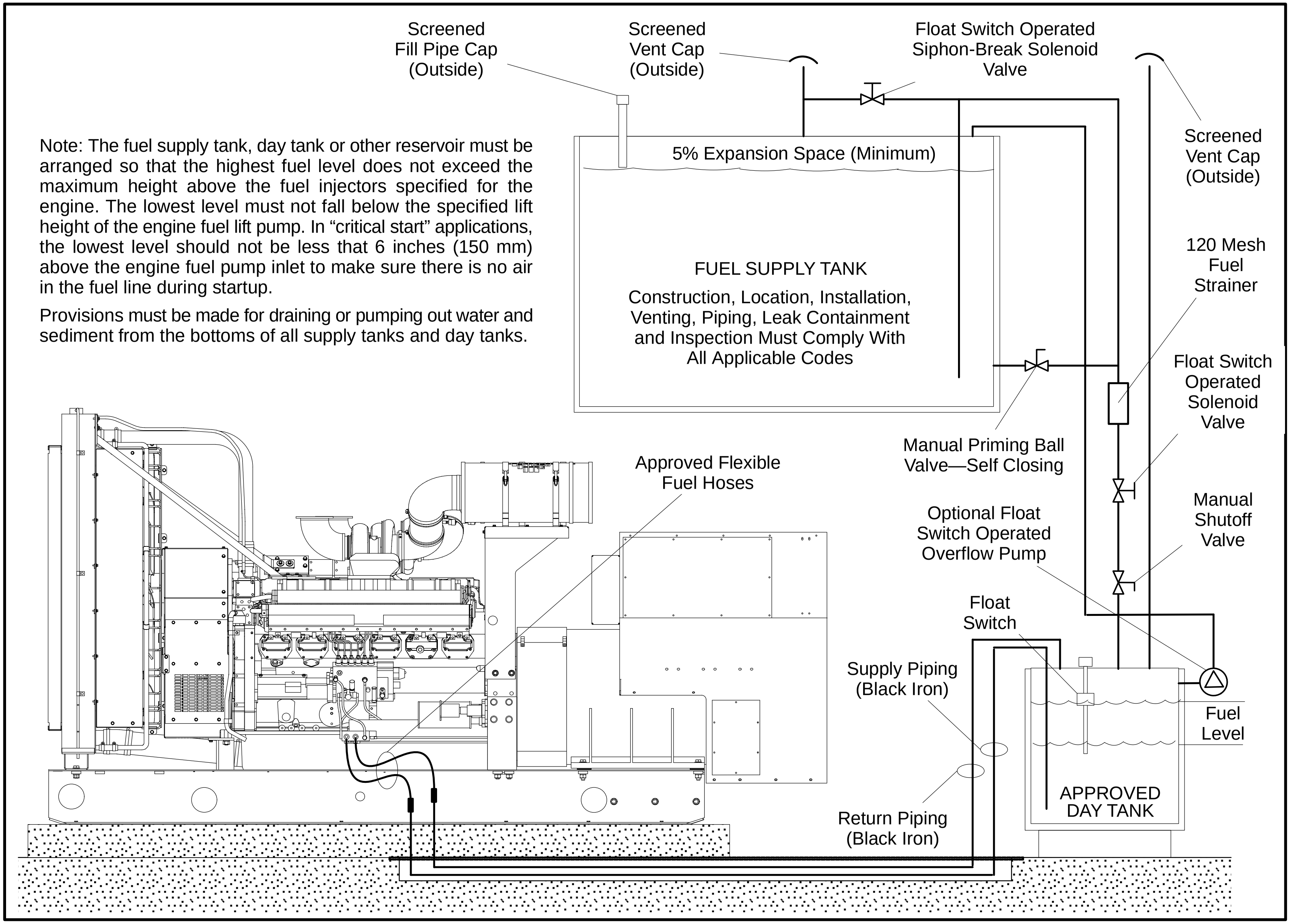
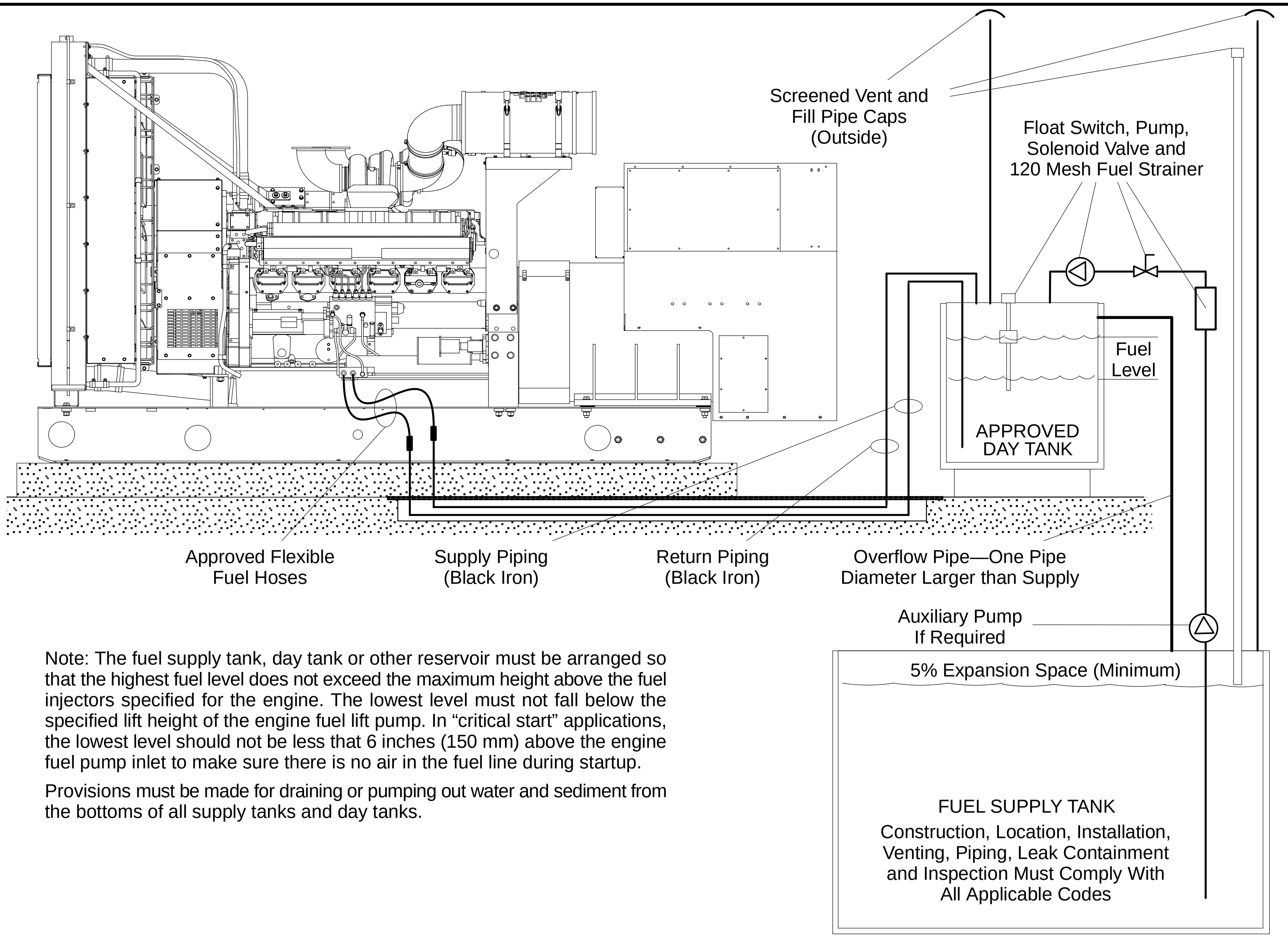


Figure 6–29. Typical Fuel Supply System—Supply Tank Above Generator Set



Note: The fuel supply tank, day tank or other reservoir must be arranged so that the highest fuel level does not exceed the maximum height above the fuel injectors specified for the engine. The lowest level must not fall below the specified lift height of the engine fuel lift pump. In "critical start" applications, the lowest level should not be less that 6 inches (150 mm) above the engine fuel pump inlet to make sure there is no air in the fuel line during startup.

Provisions must be made for draining or pumping out water and sediment from the bottoms of all supply tanks and day tanks.

Figure 6–30. Typical Fuel Supply System—Supply Tank Below Generator Set

The following should be considered when designing and installing any diesel fuel supply system:

- Fuel supply tank capacity, construction, location, installation, venting, piping, testing, and inspection must comply with all applicable codes and their local interpretation[15]. Local environmental regulations generally require secondary containment (called a "rupture basin", "dike", or "bund") to prevent leaking fuel from entering the soil or the sewer system. The secondary containment area will normally include features to sense and sound an alarm when the main tank is leaking.
- Location should be chosen with consideration for accessibility for refilling and whether supply lines will need to be heated (in cold climates).
- The fuel supply tank must hold enough fuel to run the set for the prescribed number of hours[16] without refueling. Tank sizing calculations can be based on the hourly fuel consumption rates, tempered with the knowledge that full load operation of most generator sets is rare. Other considerations for tank sizing include the duration of expected power outages vs. availability of fuel deliveries and the storage life of the fuel. The storage life for diesel fuel is 1–1/2 to 2 years, when properly maintained.
- Fuel supply tanks must be adequately vented to prevent pressurization. There may be both primary and emergency venting requirements in a tank, depending on local codes and interpretations. They also must have provisions for manually draining or pumping out water and sediment, and have at least a five–percent expansion space to prevent spillage when the fuel warms up.
- The fuel lift pump, day tank transfer pump or float valve seat should be protected from fuel supply tank debris by a pre–filter or sediment bowl with a 100 to 120 mesh element.
- For emergency power systems, codes might not permit the fuel supply to be used for any other purpose, or may specify a draw–down level for other equipment that guarantees the fuel supply for emergency power use.
- The Cetane rating of No. 2 heating oil is not high enough for dependable starting of diesel engines in cold weather. Therefore, separate supply tanks for emergency power and building heating systems might be required.
- Separate fuel return lines to the day tank or supply tank must be provided for each generator set in a multiple–set installation to prevent pressurizing the return lines of idle sets. Also, a fuel return line must not include a shutoff device. Engine damage will occur if the engine is run with the line shut off.
- A day tank is required whenever pipe friction and/or supply tank elevation, either below the fuel pump inlet or above the fuel injectors, would cause an excessive fuel inlet or return restriction. Some generator set models are available with an integral skid–mounted or sub–base day tank.

NOTE: Where generator sets are paralleled or must satisfy short emergency start–time requirements, it is a requirement that a fuel tank or reservoir be located such that the lowest possible fuel level is not less than 6 inches (150 mm) above the fuel pump inlet. This will prevent air from accumulating in the fuel line while the set is not running, eliminating the period during startup when the air has to be purged. Options are available on some models for eliminating this requirement.

- Day tank fuel temperature limits may be exceeded in some applications when the warm fuel from the engine is returned to the day tank. As fuel temperature increases, fuel density and lubricity decrease, reducing maximum power output and lubrication of fuel handling parts such as pumps and injectors. One solution is to pipe the fuel back to the supply tank rather than to the day tank. Other designs might require a fuel cooler to reduce the return fuel temperature to a safe level for return to the day tank. Consult the engine manufacturer for more information on the engine used, and its return fuel requirements[17].
- The day tank fuel transfer pump capacity and supply piping should be sized on the basis of

15 **US CODE NOTE:** In North America, NFPA Standards No. 30 and No. 37 are typical.

16 **US CODE NOTE:** NFPA110 defines number of required operating hours as the *Class* of an installation. Typical requirements are 2 hours if for emergency egress from the building, 8 hours for the duration of most outages.

17 In general, Cummins engines may be installed with the fuel return plumbed to the day tank. The location of the return line varies with the engine provided.

the maximum fuel flow indicated on the recommended generator set Specification Sheet.

- Use **Table 6–6** as a guide for diesel fuel selection to obtain best performance.
- All fuel systems should have provisions for containment of fuel if a tank leaks, and also for situations where it is “overfilled”.
- Consider means to manually fill tanks if auto tank filling system fails.
- The supply pump from the main tank may be a duplex type to improve system reliability.
- Local fire codes may include specific requirements for the generator set, such as means to prevent fuel flow into the generator set room if a fire is sensed, and means to return fuel to the main tank if a fire occurs in the generator set room.

Diesel Fuel Piping

- Diesel fuel lines should be constructed from black iron pipe. Cast iron and aluminum pipe and fittings must not be used because they are porous and can leak fuel. Galvanized fuel lines, fittings, and tanks must not be used because the galvanized coating is attacked by the sulfuric acid that forms when the sulfur in the fuel combines with tank condensate, resulting in debris that can clog fuel pumps and filters. Copper lines should not be used because fuel polymerizes (thickens) in copper tubing during long periods of disuse and can clog fuel injectors. Also, copper lines are less rugged than black iron, and thus more susceptible to damage.

Note: Never use galvanized or copper fuel lines, fittings or fuel tanks. Condensation in the tank and lines combines with the sulfur in the diesel fuel to produce sulfuric acid. The molecular structure of the copper or galvanized lines or tanks reacts with the acid and contaminates the fuel.

- Approved flexible fuel hose must be used for connections at the engine to take up generator set movement and vibration.
- Piping from a day tank to the engine should run “down hill” all the way from the tank to the engine, with no overhead loops that can allow air to be entrained in the system.
- Fuel system piping should be properly supported to prevent vibration and breakage due to vibration. The piping should not run close to heating pipes, electrical wiring, or engine exhaust system components. The piping system design should include valves at appropriate locations to allow isolation of system components for repair without draining the entire fuel system.
- Piping systems should be regularly inspected for leaks and general condition. The piping system should be flushed before operation of the engine to remove dirt and other impurities that could damage the engine. Use of plugged “T” connections rather than elbows allows for easier cleaning of the piping system.
- The engine manufacturer’s data indicates the maximum fuel inlet and return restrictions, the maximum fuel flow, supply and return, and the fuel consumption. **Table 6–7** indicates minimum hose and pipe sizes for connections to a supply tank or day tank when it is within 50 feet (15 meters) of the set and at approximately the same elevation.

Hose and pipe size should be based on the maximum fuel flow rather than on the fuel consumption. It is highly recommended that the fuel inlet and return restrictions be checked before the generator set is placed in service.

Max Fuel Flow Rate GPH (L/hr)	Flex Hose No.*	NPS Pipe Size (in)	DN Pipe Size (mm)
Less than 80 (303)	10	½	15
81–100 (304–378)	10	½	15
101–160 (379–604)	12	¾	20
161–230 (605–869)	12	¾	20
231–310 (870–1170)	16	1	25
311–410 (1171–1550)	20	1–1/4	32
411–610 (1550–2309)	24	1–1/2	40
611–920 (2309–3480)	24	1–1/2	40

* Generic fuel hose suppliers’ size specification.

Table 6–7. Minimum Fuel Hose and Pipe Sizes; Up to 50 Feet (15 Meters) Equivalent Length.

Sub–Base Fuel Tank

When a generator set is mounted on a sub–base fuel tank, the vibration isolators must be installed between the generator set and the fuel tank. The fuel tank must be able to support the weight of the set and resist the dynamic loads. It is required that the tank be mounted such that an air space is provided between the bottom of the tank and the floor underneath to reduce corrosion and permit visual inspections for leaks.

Day Tanks

When an intermediate day tank is required in an application, it is typically sized for approximately 2 hours of operation for the generator set at full load. (Subject to code limitations for fuel in the generator set equipment room.) Multiple generator sets may be fed from one day tank, but it is preferred that there be one day tank for each generator set in the system. The day tank should be located as close to the generator set as is practical. Position the tank to allow for manually filling the tank, should it become necessary.

The height of the day tank should be sufficient to put a positive head on the engine fuel pump. (Minimum level in tank not less than 6 inches [150 mm] above engine fuel inlet.) The maximum height of fuel in the day tank should not be sufficient to put a positive head on the engine fuel return lines.

Fuel return line location in the day tank is different depending on the type of engine used. Some engines require the fuel to be returned above the maximum tank level, others require fuel to be returned to the tank at the bottom (or below the minimum tank level). The engine manufacturer supplies these specifications.

Important features, either required or desired, of day tanks include:

- Rupture basin or bund. (Option, but required by law in many areas.)
- Float switch used for tank filling to control: a solenoid valve, if the bulk tank is above the day tank, or a pump, if the bulk tank is below the day tank.
- Vent pipe, same size as fill, routed to highest point in system.
- Drain valve.
- Level gage or sight glass.
- Low level alarm (option).
- High level float switch to control: the solenoid, if the bulk tank is above the day tank, or the pump control, if the bulk tank is below the day tank.
- Overflow to bulk tank if the tank is below the day tank.

Local laws and standards often control day tank construction as well as federal codes so it is essential to check with the local authority.

Gaseous Fuel Supply

See section 2 of this manual for information regarding general advantages and disadvantages of gaseous fuel systems compared to other available alternatives.

Gaseous fueled generator sets (also called “spark–ignited generator sets”) may utilize natural gas or liquid–propane (LP) gas, or both. Dual fuel systems with natural gas as primary fuel and propane as a backup can be used in seismic risk areas and where there is concern that a natural event could disrupt a public utility gas system.

Regardless of the fuel used, the primary factors in successful installation and operation of a gas fuel system are:

- The gas supplied to the generator set must be of acceptable quality.
- The gas supply must have sufficient pressure. Care must be taken to be sure that the gas supply *at the generator set*, not just at the source, is of proper pressure for operation. The specified pressure must be available while the generator set is running at full load.
- The gas must be supplied to the genset in sufficient volume to support operation of the generator set. This is normally a matter of selecting fuel line size to be large enough to transport the volume of fuel needed. For LP vapor–withdrawal fuel systems the size and temperature of the fuel tank also affects this requirement.

Failure to meet the minimum requirements of the generator set in these areas will result in the inability of the generator set to operate, or inability to carry rated load, or poor transient performance.

Gaseous Fuel Quality

Gaseous fuels are actually a mixture of several different hydrocarbon gases such as methane, ethane, propane, and butane; other gaseous elements such as oxygen and nitrogen; vaporized water; and various contaminants, some of which are potentially damaging to an engine over time. The quality of the fuel is based on the amount of energy per unit volume in the fuel and the amount of contaminants in the fuel.

Energy Content: One of the most important characteristics of the gaseous fuel used in a generator set is the heat value of the fuel. The heat value of a fuel describes how much energy is stored in a specific volume of the fuel. Gaseous fuel has a low heat value (LHV) and a high heat value (HHV). The low heat value is the heat available to do work in an engine after the water in the fuel is vaporized. If the low heat value of a fuel is too low, even if a sufficient volume of fuel reaches the engine, the engine will not be able to maintain full output power, because sufficient energy is not available in the engine to convert to mechanical energy. If the LHV is below 905 BTU/ft^3 the engine may not produce rated power at standard ambient temperature conditions.

If the local fuel has a higher energy content than 1000 BTU/ft^3, the actual flow requirements in cu ft/min will be lower and the pressure requirements drop slightly. Conversely if the local fuel has a lower energy content than 1000 BTU/ ft^3, the actual flow requirements in ft^3/min will be higher and a higher minimum supply pressure will be needed to meet published performance for any given generator set

Each engine may have slightly different performance characteristics based on the type of fuel provided, due to differences in engine compression ratio, and whether the engine is naturally aspirated or turbocharged.

Pipeline Natural Gas: The most common fuel for generator sets is called "Pipeline natural gas". In the US, "dry pipeline natural gas" has specific qualities, based on federal requirements. In other countries, pipeline gas may vary in content, so fuel characteristics should be verified prior to use with a generator set. US pipeline gas is a mixture composed of approximately 98% methane and ethane with the other 2% being hydrocarbons such as propane and butane, nitrogen, carbon dioxide, and water vapor. "Dry" means that it is free of liquid hydrocarbons such as gasoline, but NOT that it is free of water vapor. Dry pipeline gas typically has a LHV of 936 BTU/ft^3, and a HHV of 1,038 BTU/ft^3.

Field Gas: The composition of "Field natural gas" varies considerably by region and by continent. Careful analysis is necessary prior to using field natural gas in an engine. Field natural gas can contain "heavier" hydrocarbon gases such as pentane, hexane, and heptane, which may require derating of the output of the engine. Other contaminants, such as sulfur, may also be present in the fuel. A typical field gas might have a LHV of 1203 BTU/ft^3, and a HHV of 1,325 BTU/ft^3.

Propane (LPG): Propane is available in two grades, either commercial, or special duty. Commercial propane is used where high volatility is required. Not all spark–ignition engines will operate acceptably with this fuel due to its volatility. Special duty propane (also called HD5) is a mixture of 95% propane and other gases such as butane that allow better engine performance due to the reduction pre–ignition due to reduced volatility. Special duty propane fuel gas that meets the ASTM D 1835 specification for special–duty propane (equivalent to HD–5 propane of Gas Producers Association Standard 2140) is suitable for most engines. Propane has a LHV of approximately 2,353 BTU/ft^3, and an HHV of 2,557 BTU/ft^3. The higher heating value of the fuel necessitates mixing of different volumes of air in the fuel system for propane vs. natural gas applications, so dual fuel engines essentially have two fuel arrangements for this purpose.

Contaminants: The most harmful contaminants in gaseous fuels are water vapor and sulfur.

Water vapor is damaging to an engine because it may cause uncontrolled burning, pre–ignition, or other effects that can damage an engine. Liquid vapor or droplets must be removed from the fuel prior to entry into the engine by use of a "dry filter" that is mounted in the fuel system prior to the primary fuel pressure regulator. The dew point of fuel gas should be at least 20F (11C) below the minimum ambient temperature at the installation site.

Sulfur and hydrogen sulfides will cause corrosion and serious damage to an engine over a relative short period of time. Different engines have different levels of tolerance to sulfur contamination, and some engines simply should not be operated with fuel that contains significant sulfur content. Contact the engine manufacturer for approval of specific engines with specific fuels. The effects of sulfur in the fuel can be counteracted in part by use of high–ash natural gas lubricating oils. In general, engines should not be operated with fuels in excess of 10 parts per million (ppm).

Certain fuels, such as those derived from land fill applications, can have useful chemical energy content, but very high sulfur levels (>24 ppm). These fuels are often termed “sour gas”. If this fuel is scrubbed of the sulfur content, it can be used as a fuel for many engines, provided that it has sufficient BTU content.

Fuel Analysis: The gaseous fuel supplier can provide a fuel analysis that describes the chemical makeup of the fuel to be provided. This fuel analysis can be used to be certain that the fuel is suitable for use in the specific engine proposed for a specific application, and also to verify that the BTU content of the fuel is sufficient to provide necessary kW output of the machine. Gas suppliers may change the pipeline natural gas composition without notice, so there is no long–term guarantee of performance, but the process of evaluation of the fuel can be briefly described as:

- List the percent of each gas constituent in the fuel.
- Calculate the percent of the total fuel that is combustible. The combustible portion of the fuel is 100% less the inert component percentages. Inert components include oxygen, carbon dioxide and water vapor.
- Calculate the percent of each combustible component of the fuel.
- Verify acceptability of the fuel by checking the percent of each combustible element vs. the recommendations of the engine manufacturer.

  For example, for a gas analysis of:

  90% Methane
  6% Ethane
  2% Hydrogen
  1% Normal Pentane
  1% Nitrogen

  – Total percent inert elements = 1%.
  – Total combustible =100%–1% = 99%.
  – % Methane = 90%/99% = 91%.
  – % Ethane = 6%/99% = 6.1%.
  – % Hydrogen = 2%/99% = 2%.
  – % Normal Pentane = 1%/99% = 1%.

  See **Table 6–8** for a typical listing of Maximum Permissible Combustibles in Cummins Gas generator sets. Note that in this example, the analysis shows the fuel will be acceptable for a lower compression ratio engine (typically around 8.5:1) but not for a higher compression engine. A higher compression engine will have more stringent fuel composition requirements but may operate satisfactorily with a derating of its output – consult the engine manufacturer.
- Verify the rating of the generator set based on use of the proposed fuel.

The total BTU content of the fuel will determine the rating of the generator set when using fuel of a specific composition. If any component of the fuel has more than the specific value allowed derating will be required. Consult the engine manufacturer for fuel requirements and derating instructions.

Note that the fuel derating and the altitude/temperature derating[18] are not additive. Only the maximum value of the fuel derate or the altitude/temperature derate need be applied.

Turbocharged engines have unique fuel composition requirements due to higher cylinder pressures. To avoid problems with pre–ignition or detonation, power output derating is required if propane and/or Iso–Butane content exceed the percentages listed in **Table 6–9**.

18 Consult the engine or generator set manufacturer for temperature/altitude derating factors.

	8.5:1 Compression Ratio	10.5:1 Compression Ratio
Methane (C_1)	100	100
Ethane (C_2)	100	100
Propane (C_3)	10	2
ISO–Butane (IC_4)	7	0.2
Hydrogen (H_2)	7	trace
Normal Butane (NC_4)	3	0.2
ISO–Pentane (IC_5)	3	0.2
Normal Pentane (NC_5)	1	0.1
Hexane (C_6)	1	0.1
Heptane (C_7)	1	0.1

Table 6–8. Maximum Allowable Percentages for Engine Fuel Combustibles

	8.5:1 Compression Ratio	10.5:1 Compression Ratio
Methane	NA	NA
Ethane	NA	NA
Propane	5%	*
Iso-butane	2%	*
*High compression ratio turbocharged engines cannot consume any propane or iso–butane.		

Table 6–9. Maximum Allowable Percentages of Constituent Gases Before Derating Turbocharged Engines

Generator Set Fuel System Design

Figure 6–31 illustrates the typical gas line components in an automatic–transfer, dual–fuel system (natural gas and LPG). Single fuel systems (natural gas or LPG) use the noted portions of the components on this drawing. Not shown is the LPG vaporizer supplied with Cummins Power Generation generator sets equipped for liquid withdrawal of LPG (engine–mounted on outdoor sets only). Service pressure regulators, dry gas filters and manual shutoff valves are typically provided by the installer but are available as accessories from Cummins Power Generation.

Site Fuel System Design

The following should be considered when installing a natural gas and/or LPG fuel system:

- Gaseous–fuel supply system design, materials, components, fabrication, assembly, installation, testing, inspection, operation and maintenance must comply with all applicable codes[19].

19 In North America, NFPA Standards No. 30, No. 37, No. 54 and No. 58 are typical.

- The layout and sizing of gas piping must be adequate for handling the volume of gas required by the generator set and all other equipment, such as building heating boilers, supplied by the same source. Full–load gas flow (see the recommended generator set Specification Sheet) must be available at not less than the minimum required supply pressure, typically from 5 to 10 inches WC (water column), depending on model. Final determination of pipe sizes must, however, be based upon the method approved by the authority having jurisdiction (see NFPA No. 54).
- Most installations will require a service gas pressure regulator. Gas supply pressure should not exceed 13.8 or 20 inches WC, depending on model, at the inlet to the generator set. Depending on distribution gas pressure, more than one stage of pressure regulation may be required. High–pressure gas piping is not permitted inside buildings (5 psig for natural gas and 20 psig for LPG, unless higher pressures are approved by the authority having jurisdiction). Gas pressure regulators must be vented to the outdoors according to code.

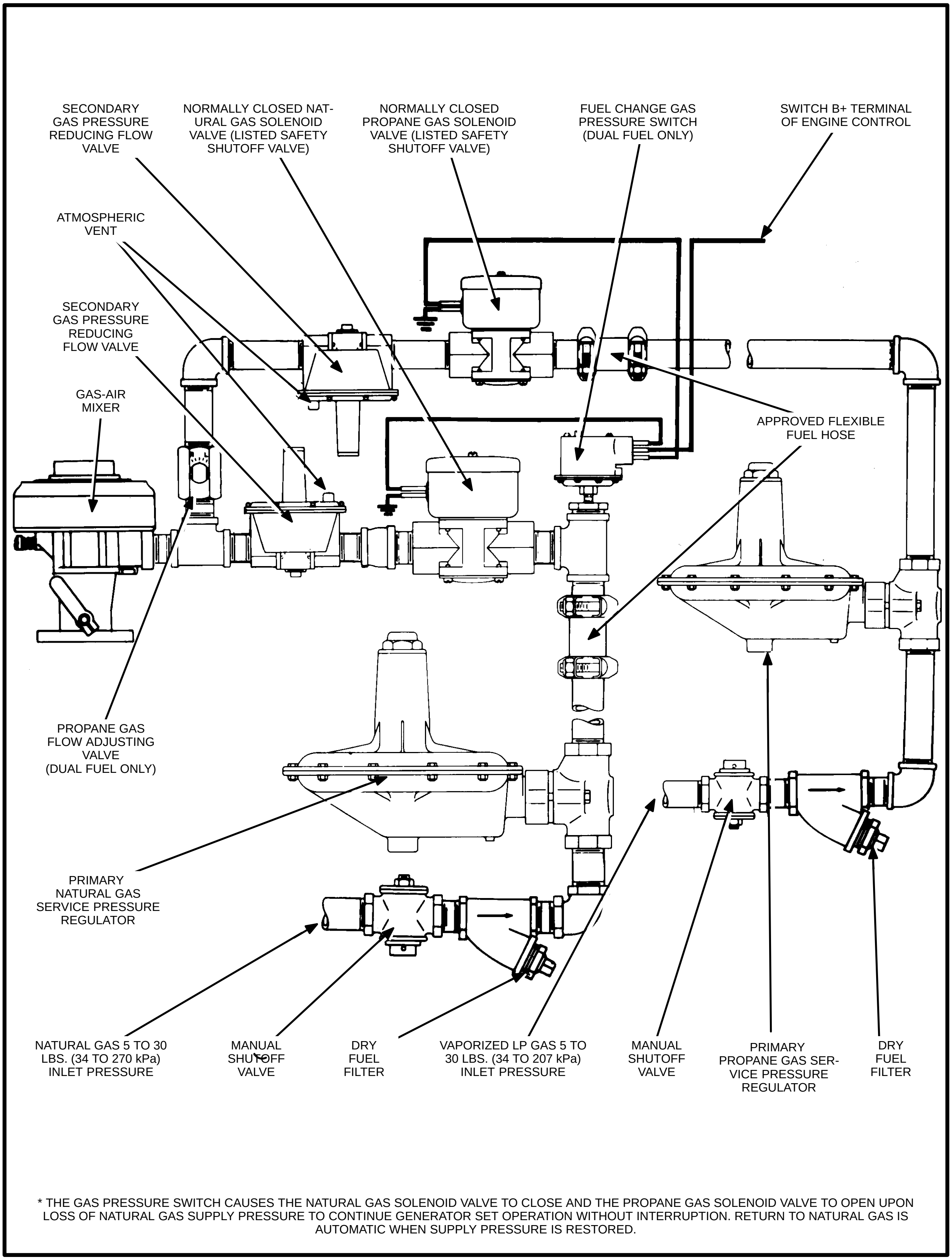


Figure 6–31. Typical Gaseous Fuel System

- The pressure regulator installed on the supply line at the gas source for generator applications should never be a “pilot” regulator. A “pilot” style regulator is the type where the regulator requires a pressure line from the regulator housing to the downstream gas pipe to “sense” when downstream pressure has dropped. Pilot regulators do not work because the response time is unacceptable compared to the large–instantaneous changes in demand from the generator set.
- Approved flexible fuel hose must be used for connections at the engine to take up generator set movement and vibration.
- Most codes require both manual and electric (battery–powered) shutoff valves ahead of the flexible fuel hose(s). The manual valve should be of the indicating type.
- A dry fuel filter should be installed in each line as shown in **Figure 6–31** to protect the sensitive pressure regulating components and orifices downstream from harmful foreign substances carried along in the gas stream (rust, scale, etc.).
- An LPG fuel supply system must be dedicated for the emergency power system if it is the required alternative fuel.
- An LPG vaporizer heated by engine coolant is factory installed on Cummins Power Generation generator sets equipped for a liquid–withdrawal of LPG. Because high pressure (20 psig or greater) gas piping is not permitted inside buildings, generator sets equipped for liquid withdrawal of LPG must not be installed inside the building. (Weather–protective housings for outdoor installation are available for most LPG models.)
- The rate of vaporization in an LPG tank depends upon the outdoor air temperature, unless the tank is equipped with a heater, and the quantity of fuel in the tank. Even on cold days outdoor air heats and vaporizes LPG (mostly through the wetted tank surface) when air temperature is higher than LPG temperature. Withdrawing vapor causes tank temperature and pressure to drop. (At –37° F [–38° C] LPG has zero vapor pressure.) Unless there is enough fuel and enough heat available from ambient air, the vaporization rate will drop off, as the generator set runs, to less than that required to continue running properly.

Gaseous Fuel System Calculations Fuel Pressure

Tank Size: Use **Figure 6–32** as a quick reference for sizing an LPG tank on the basis of the lowest ambient temperature expected. For example, on a 40F day, withdrawal at 1000 ft^3/h requires a 2000 gallon tank at least half full. Note: In many instances the amount of fuel required for proper vaporization is far greater than that required for the number of hours of operation stipulated by code.

For instance, in an NFPA 110 Class 6 application, there must be enough fuel for the generator set to run for 6 hours before refilling the tank. LPG yields approximately 36.5 cubic feet of gas per gallon of liquid. If the generator set withdrawal rate is 1000 ft^3/h:

$$\text{Fuel Consumed in 6 hours} = \frac{1000\ ft^3/hr \bullet 6\ hours}{36.5\ ft^3/gal} = 164\ \text{gallons}$$

In this instance the tank must be sized for at least 2000 gallons based on the lowest expected temperature rather than on the fuel consumed in 6 hours (164 gallons).

Gas Pipe Sizing: Sizing of gas piping for proper fuel delivery, both flow and pressure, can become quite complex. However, a simplified method, as with other piping for exhaust and coolant, is to convert all fittings, valves, etc. to equivalent lengths of pipe in the diameter(s) being considered. The total equivalent length can then be related to flow capacity.

Table 6–3, Equivalent Lengths of Pipe Fittings and Valves applies to gas as well as liquid piping. **Tables 6–10 through 6–14** show maximum gas capacity for equivalent length for various pipe sizes. Tables 6–10 through 6–14 are reproduced from NFPA 54–2002, National Fuel Gas Code, and are selected considering the general fuel system operating requirements for generator sets. Tables are included for natural gas, propane liquid withdrawal and propane vapor withdrawal under specified conditions. Consult NFPA 54 or other applicable codes for other operating conditions or other fuel system installation requirements.

A calculation of minimum pipe size is fairly straightforward:

- Make a list of al the fittings and valves in a proposed system and sum their equivalent lengths using the table.
- Add to this total, all lengths of straight pipe to arrive at a total equivalent length.
- Choose the applicable table based on the fuel system.
- Obtain the maximum fuel requirements for the specific generator set(s) from the manufacturer's specification sheets. Convert to ft^3/hr as needed (Be cognizant of BTU content as discussed earlier in this section.)
- Locate the equivalent length of pipe (or next larger equivalent length) in the left hand column. Move across to the columns to where the number is as large or larger than the total equivalent length calculated above. At the top of that column is the minimum nominal pipe size or tubing size required for the system as designed.

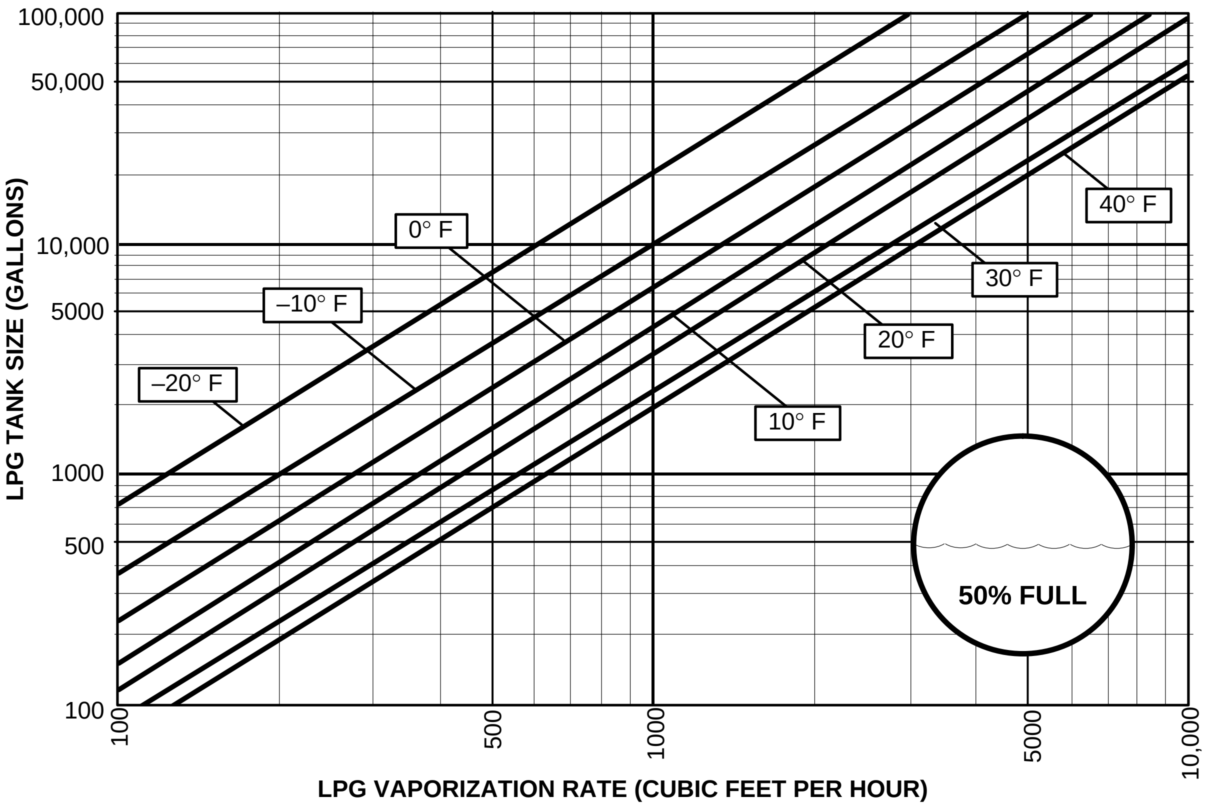


Figure 6–32. Minimum LPG Tank Size (50% Full) Required to Maintain 5 PSIG at Specific Withdrawal Rate and Minimum Expected Winter Temperature

Gas: Natural
Inlet Pressure: 0.5 psi or less
Pressure Drop: 0.5 in. w.c.
Specific Gravity: 0.60

	Pipe Size (in.)										
Nominal	1/4	3/8	1/2	3/4	1	1 1/4	1 1/2	2	2 1/2	3	4
Actual ID	(0.364)	(0.493)	(0.622)	(0.824)	(1.049)	(1.380)	(1.610)	(2.067)	(2.469)	(3.068)	(4.026)
Length (ft)	**Maximum Capacity in Cubic Feet of Gas per Hour**										
10	43	95	175	360	680	1400	2100	3950	6300	11000	23000
20	29	65	120	250	465	950	1460	2750	4350	7700	15800
30	24	52	97	200	375	770	1180	2200	3520	6250	12800
40	20	45	82	170	320	660	990	1900	3000	5300	10900
50	18	40	73	151	285	580	900	1680	2650	4750	9700
60	16	36	66	138	260	530	810	1520	2400	4300	8800
70	15	33	61	125	240	490	750	1400	2250	3900	8100
80	14	31	57	118	220	460	690	1300	2050	3700	7500
90	13	29	53	110	205	430	650	1220	1950	3450	7200
100	12	27	50	103	195	400	620	1150	1850	3250	6700
125	11	24	44	93	175	360	550	1020	1650	2950	6000
150	10	22	40	84	160	325	500	950	1500	2650	5500
175	9	20	37	77	145	300	460	850	1370	2450	5000
200	8	19	35	72	135	280	430	800	1280	2280	4600

Table 6–10. Natural Gas Schedule 40 Iron Pipe Sizing[20]

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Gas: Natural
Inlet Pressure: 0.5 psi or less
Pressure Drop: 0.5 in. w.c.
Specific Gravity: 0.6 0

		Tube Size (in.)									
Nominal	**K & L**	1/4	3/8	1/2	5/8	3/4	1	1 1/4	1 1/2	2	2 1/2
	ACR	3/8	1/2	5/8	3/4	7/8	1 1/8	1 3/8	1 5/8	2 1/8	2 5/8
Outside		0.375	0.500	0.625	0.750	0.875	1.125	1.375	1.625	2.125	2.625
Inside*		0.305	0.402	0.527	0.652	0.745	0.995	1.245	1.481	1.959	2.435
Length (ft)		**Maximum Capacity in Cubic Feet of Gas per Hour**									
10		27	55	111	195	276	590	1062	1675	3489	6173
20		18	38	77	134	190	406	730	1151	2398	4242
30		15	30	61	107	152	326	586	925	1926	3407
40		13	26	53	92	131	279	502	791	1648	2916
50		11	23	47	82	116	247	445	701	1461	2584
60		10	21	42	74	105	224	403	635	1323	2341
70		9.3	19	39	68	96	206	371	585	1218	2154
80		8.6	18	36	63	90	192	345	544	1133	2004
90		8.1	17	34	59	84	180	324	510	1063	1880
100		7.6	16	32	56	79	170	306	482	1004	1776
125		6.8	14	28	50	70	151	271	427	890	1574
150		6.1	13	26	45	64	136	245	387	806	1426
175		5.6	12	24	41	59	125	226	356	742	1312
200		5.2	11	22	39	55	117	210	331	690	1221
250		4.7	10	20	34	48	103	186	294	612	1082
300		4.2	8.7	18	31	44	94	169	266	554	980

***** Table capacities are based on Type K copper tubing inside diameter (shown), which has the smallest inside diameter of the copper tubing products.

Table 6–11. Natural Gas Semi–Rigid Copper Tubing Sizing[21]

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Gas: Undiluted Propane
Inlet Pressure: 11.0 in. w.c.
Pressure Drop: 0.5 in. w.c.
Specific Gravity: 1.50
Special Use: Pipe sizing between single or second stage (low pressure regulator) and appliance.

	Pipe Size (in.)								
Nominal Inside	1/2	3/4	1	1 1/4	1 1/2	2	3	3 1/2	4
Actual:	0.622	0.824	1.049	1.38	1.61	2.067	3.068	3.548	4.026
Length (ft)	**Maximum Capacity in Thousands of Btu per Hour**								
10	291	608	1145	2352	3523	6786	19119	27993	38997
20	200	418	787	1616	2422	4664	13141	19240	26802
30	160	336	632	1298	1945	3745	10552	15450	21523
40	137	287	541	1111	1664	3205	9031	13223	18421
50	122	255	480	984	1475	2841	8004	11720	16326
60	110	231	434	892	1337	2574	7253	10619	14793
80	94	197	372	763	1144	2203	6207	9088	12661
100	84	175	330	677	1014	1952	5501	8055	11221
125	74	155	292	600	899	1730	4876	7139	9945
150	67	140	265	543	814	1568	4418	6468	9011
200	58	120	227	465	697	1342	3781	5536	7712
250	51	107	201	412	618	1189	3351	4906	6835
300	46	97	182	373	560	1078	3036	4446	6193
350	42	89	167	344	515	991	2793	4090	5698
400	40	83	156	320	479	922	2599	3805	5301

Table 6–12. Propane Vapor Schedule 40 Iron Pipe Sizing[22]

22 Reprinted with permission from NFPA 54–2002, National Fuel Gas Code, Copyright © 2002, *National Fire Protection Association*, Quincy, MA 02169. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

Gas: Undilute Propane **Inlet Pressure:** 11.0 in w.c. **Pressure Drop:** 0.5 in. w.c. **Specific Gravity:** 1.50 **Special Use:** Sizing between single or second stage (low pressure regulator) and appliance											
		Tube Size (in.)									
Nominal	**K & L**	1/4	3/8	1/2	5/8	3/4	1	1 1/4	1 1/2	2	2 1/2
	ACR	3/8	1/2	5/8	3/4	7/8	1 1/8	1 3/8	1 5/8	2 1/8	2 5/8
Outside		0.375	0.500	0.625	0.750	0.875	1.125	1.375	1.625	2.125	2.625
Inside*		0.305	0.402	0.527	0.652	0.745	0.995	1.245	1.481	1.959	2.435
Length (ft)		**Maximum Capacity in Cubic Feet of Gas per Hour**									
10		45	93	188	329	467	997	1795	2830	5895	10429
20		31	64	129	226	321	685	1234	1945	4051	7168
30		25	51	104	182	258	550	991	1562	3253	5756
40		21	44	89	155	220	471	848	1337	2784	4926
50		19	39	79	138	195	417	752	1185	2468	4366
60		17	35	71	125	177	378	681	1074	2236	3956
70		16	32	66	115	163	348	626	988	2057	3639
80		15	30	61	107	152	324	583	919	1914	3386
90		14	28	57	100	142	304	547	862	1796	3177
100		13	27	54	95	134	287	517	814	1696	3001
125		11	24	48	84	119	254	458	722	1503	2660
150		10	21	44	76	108	230	415	654	1362	2410
175		10	20	40	70	99	212	382	602	1253	2217
200		8.9	18	37	65	92	197	355	560	1166	2062
225		8.3	17	35	61	87	185	333	525	1094	1935
250		7.9	16	33	58	82	175	315	496	1033	1828
275		7.5	15	31	55	78	166	299	471	981	1736
300		7.1	15	30	52	74	158	285	449	936	1656

***** Table capacities are based on Type K copper tubing inside diameter (shown), which has the smallest inside diameter of the copper tubing products.

Table 6–13. Propane Vapor Semi–Rigid Copper Tubing Sizing[23]

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Equivalent Length of Pipe, ft.	Schedule 40 Iron Pipe Size, in.: Nominal (Inside Diameter)								
	1/2 (0.622)	3/4 (0.824)	1 (1.049)	1 1/4 (1.38)	1 1/2 (1.61)	2 (2.067)	3 (3.068)	3 1/2 (3.548)	4 (4.026)
30	733	1532	2885	5924	8876	17094	48164	70519	98238
40	627	1311	2469	5070	7597	14630	41222	60355	84079
50	556	1162	2189	4494	6733	12966	36534	53492	74518
60	504	1053	1983	4072	6100	11748	33103	48467	67519
70	463	969	1824	3746	5612	10808	30454	44589	62116
80	431	901	1697	3484	5221	10055	28331	41482	57787
90	404	845	1593	3269	4899	9434	26583	38921	54220
100	382	798	1504	3088	4627	8912	25110	36764	51216
150	307	641	1208	2480	3716	7156	20164	29523	41128
200	262	549	1034	2122	3180	6125	17258	25268	35200
250	233	486	916	1881	2819	5428	15295	22395	31198
300	211	441	830	1705	2554	4919	13859	20291	28267
350	194	405	764	1568	2349	4525	12750	18667	26006
400	180	377	711	1459	2186	4209	11861	17366	24193
450	169	354	667	1369	2051	3950	11129	16295	22700
500	160	334	630	1293	1937	3731	10512	15391	21442
600	145	303	571	1172	1755	3380	9525	13946	19428
700	133	279	525	1078	1615	3110	8763	12830	17873
800	124	259	488	1003	1502	2893	8152	11936	16628
900	116	243	458	941	1409	2715	7649	11199	15601
1000	110	230	433	889	1331	2564	7225	10579	14737
1500	88	184	348	713	1069	2059	5802	8495	11834
2000	76	158	297	611	915	1762	4966	7271	10128

Table 6–14. Propane Schedule 40 Iron Pipe Sizing, Liquid Withdrawal – Maximum Capacity of Pipe in Cubic Feet of Gas per Hour. Pipe size recommendations are based on schedule 40 black iron pipe.