GENERAC®

Installation Guidelines

For

Stationary Standby Industrial Generators

⚠ DANGER!

⚠ **NOT INTENDED FOR USE IN CRITICAL LIFE SUPPORT APPLICATIONS.**

⚠ **ONLY QUALIFIED ELECTRICIANS OR CONTRACTORS SHOULD ATTEMPT INSTALLATION!**

⚠ **DEADLY EXHAUST FUMES! OUTDOOR INSTALLATION ONLY!**

This manual should remain with the unit.

This manual must be used in conjunction with the appropriate owner's manual.

Forward

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 Generac Industrial Service 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 this generator is used to power electrical load circuits normally powered by a utility power source, it is required by code to install a transfer switch. The transfer switch must effectively isolate the electrical system from the utility distribution system when the generator is operating. Failure to isolate an electrical system by such means may result in damage to the generator and may also result in injury or even death to utility power workers due to backfeed of electrical energy.

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 non-compliance 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

Engine exhaust and some of its constituents are known to the state of California to cause cancer, birth defects, and other reproductive harm.

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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Section 1 Safety

1.1 — Introduction

Read this manual thoroughly. If any portion is not understood, contact the nearest Authorized Generac Industrial Service Dealer for clarification. The manufacturer also requires that the dealer 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:

DANGER!

Indicates a hazardous situation or action that, if not avoided, will result in death or serious injury.

WARNING!

Indicates a hazardous situation or action that, if not avoided, could result in death or serious injury.

CAUTION!

Indicates 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.

The manufacturer cannot anticipate every possible circumstance that might involve a hazard. The warnings in this manual, and on tags and decals affixed to the unit, are not all-inclusive. If using a procedure, work method, or operating technique the manufacturer does not specifically recommend, ensure that it is safe for others. Also make sure the procedure, work method, or operating technique used does not render the generator unsafe.

- Despite the safe design of this generator, operating this equipment imprudently, neglecting its maintenance, or being careless can cause possible injury or death. Permit only responsible and capable persons to install, operate, and maintain this equipment.
- Parts of the generator are rotating and/or hot during operation. Exercise care near running generators.
- If this generator is used to power electrical load circuits normally powered by a utility power source, install a transfer switch. The transfer switch must effectively isolate the electrical system from the utility distribution system when the generator is operating. Failure to isolate an electrical system by such means will result in damage to the generator and also may result in injury or death to utility power workers due to backfeed of electrical energy.

Generators produce potentially lethal voltages. Ensure all steps are taken to make the generator safe before operation or service.

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.

1. National Fire Protection Association (NFPA) 70: The National Electric Code (NEC)*
2. NFPA10: Standard for Portable Fire Extinguishers*
3. NFPA 30: Flammable and Combustible Liquids Code*
4. NFPA 37: Standard for Stationary Combustion Engines and Gas Turbines*
5. NFPA 54: National Fuel Gas Code*
6. NFPA 58: Standard for Storage and Handling of Liquefied Petroleum Gases*
7. NFPA 68: Standard on Explosion Protection by Deflagration Venting*
8. NFPA 70E: Standard for Electrical Safety in the Workplace*
9. NFPA 99: Health Care Facilities Code*
10. NFPA 101: Life Safety Code*
11. NFPA 110: Standard for Emergency and Standby Power Systems*
12. NFPA 211: Standard for Chimneys, Fireplaces, Vents, and Solid Fuel Burning Appliances*
13. NFPA 220: Standard on Types of Building Construction*
14. NFPA 5000: Building Code*
15. International Building Code**
16. Agricultural Wiring Handbook***
17. ASAE EP-364.2 Installation and Maintenance of Farm Standby Electric Power****

This list is not all inclusive. Check with the Authority Having Local Jurisdiction (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

Section 2 *Installation Planning*

2.1 — Unit Drawings

2.1.1— Installation Drawings

Installation drawings show weights, dimensions, clearances, exhaust details, connection locations, wiring stub-ups, lifting locations, and other information. Use the unit specific installation drawings when designing a site installation plan. Thoroughly read the NOTES section of each drawing for important details.

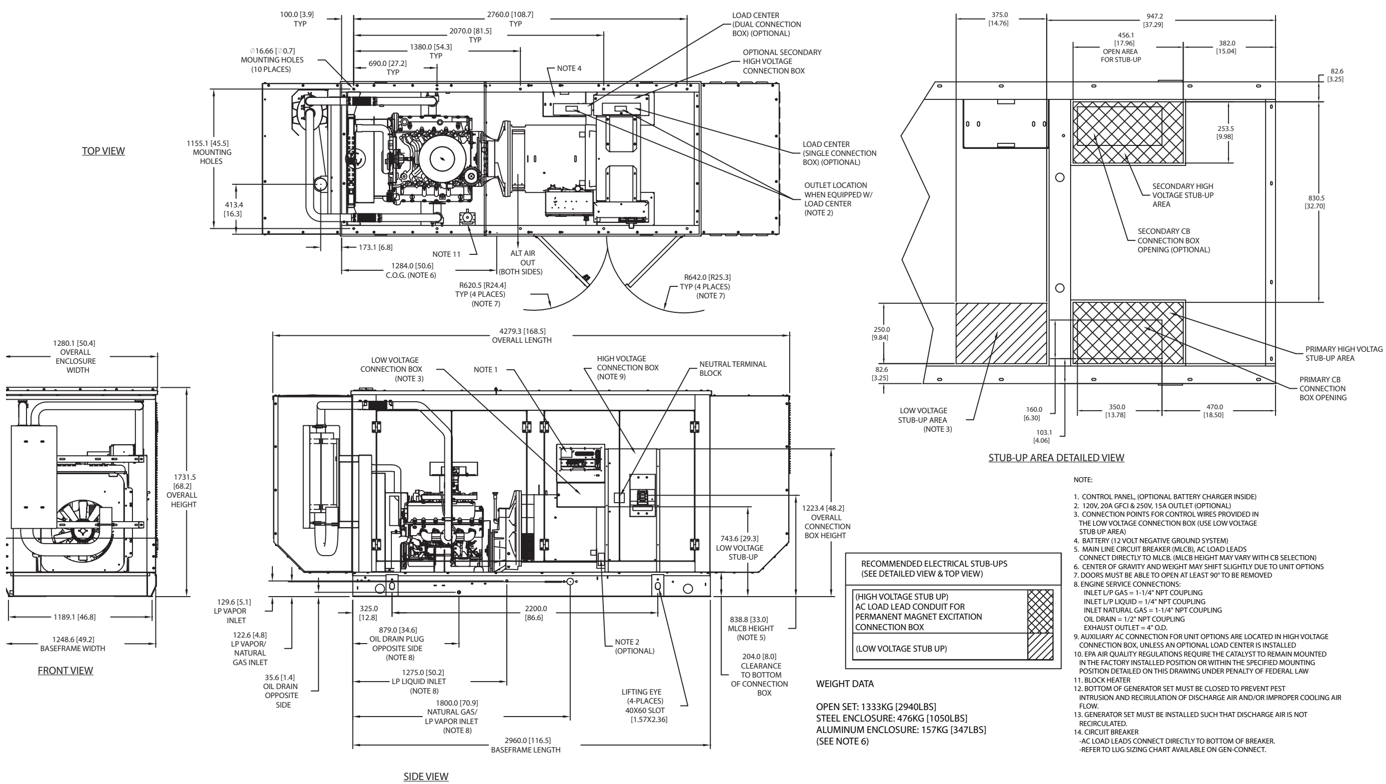

Figure 2-1. Typical Installation Drawing

2.1.2— Wiring Diagrams

Wiring and schematic diagrams show the connection points for control wiring, load wiring, and any service power supply required for battery chargers, block heaters, etc. Always use the unit specific wiring diagrams during planning and installation.

2.2 — Receiving

2.2.1— Receiving and Unpacking

Handle shipping cartons and crates with care to avoid damage. Store and unpack cartons with the correct side up, as noted by the label on the shipping carton.

2.2.2— Inspection

Carefully inspect the generator set and all contents of cartons for any damage that may have occurred during shipment. See the shipping documentation for any provisions or guidance when damage is incurred. Correct all damage or deficiencies before installation of the generator set.

2.3 — Storage Before Installation

2.3.1— Long Term Storage

If the unit is to be stored (or installed and not started-up) for six months or more, preserve in accordance with the manufacturer's instructions. Contact the local Authorized Service Dealer to obtain the Long Term Preservation and Storage Manual (Part No. 0G4018) and the Preservation Checklist (Part No. 0G4018A).

2.3.2— Short Term Storage

If the unit is to be stored (or installed and not started-up) for less than six months, proceed as follows:

- Place the unit on a smooth flat surface. Do not leave unit on the shipping pallet, as it leaves the bottom open for entry of dirt, debris, insects, rodents, etc.
- Leave exhaust system openings covered.
- Leave plastic plugs in fuel connection points.
- Use anti-rodent plugs and other enclosure features to prevent entry of birds, small animals, and foreign objects.
- If it is an open unit exposed to the elements (stored outside or the surrounding structure is not completed), completely cover to prevent entry of water, dirt, dust, etc.

2.4 — Lifting

To ensure personal safety and prevent damage to the unit, use only personnel experienced with rigging, lifting and moving heavy machinery.

Use a spreader bar to prevent damage to the unit. **Failure to use a spreader bar will result in scratches and damage to painted surfaces on closed generator sets. Likely equipment or component damage may occur on open generator sets.**

Installation drawings show the lifting points and the CG (center of gravity) location for rigging and lifting purposes. Always attach lifting and rigging devices at the designated points on the generator set. Do not use the lifting points of the engine or alternator to move the generator set. See Figure 2-2.

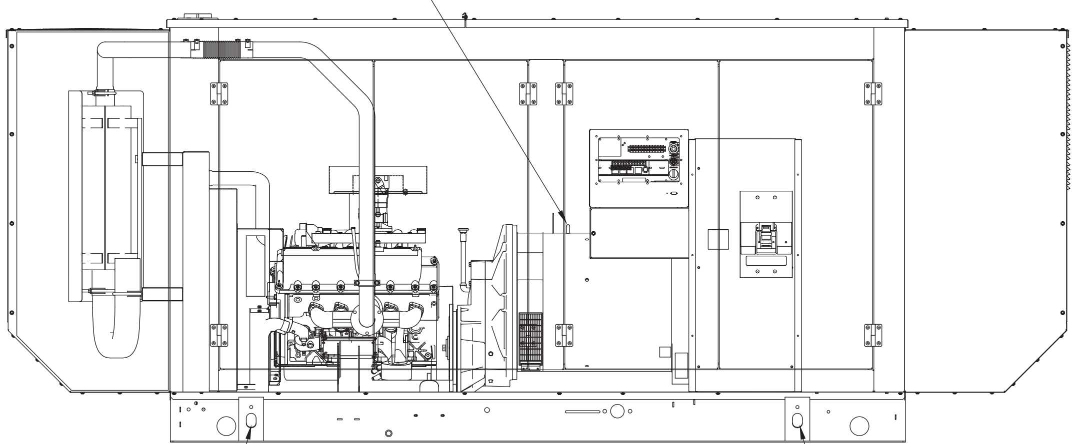

Figure 2-2. Lifting Points (Example)

2.5 — 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.

2.5.1— 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. For gaseous units, 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. For diesel units, consider the ease of accessibility for refueling purposes.
- 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.

2.5.2— 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.

NOTE: Failure to comply with the location guidelines can result in damage to the generator or surrounding area and may cause the warranty to be suspended or voided. Extra repair labor or equipment may not be covered under the warranty if service access is difficult or restricted.

Section 3 *Foundations & Mounting*

3.1 — Generator Foundations

Install the generator set on a concrete pad or base slab able to support its weight and accessories. A proper foundation is needed to resist dynamic loading and reduce transmitted noise and vibration. The exact composition of the mounting pad must follow standard engineering practices for the required loading and application. **Securely fasten the generator set to the foundation using suitable grade, size and style fasteners.** Holes are provided in the steel frame rails for this purpose.

3.1.1— Concrete Pad

Seat the concrete pad or base slab on a prepared solid subsurface and use appropriate reinforcing bar or expanded wire mesh. A common specification calls for 2500 psi concrete reinforced with 8 gauge wire mesh or number 6 reinforcing bars on 12 inch centers.

3.1.2— Dimensions

Extend the concrete pad beyond the frame of the unit at least 18 inches and above the surrounding surface by 3-8 inches. This provides a mounting surface for fuel line support, as well as space for maintenance and repair.

The base pad must be:

- Capable of supporting 125% of the unit wet weight for single unit applications. Wet weight is the dry weight plus the weight of the fuel in the base tank.
- Flat and level to within 1/2 inch.
- Capable of withstanding severe torque reactions on those units that are part of a paralleling system.

3.1.3— Unit Clearance

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.

3.1.4— Roof Installation and Protection

Consult a design engineer to ensure that the roof structure is capable of supporting the full weight of the generator and of handling any vibration or movement produced by the application of load. Install a layer of non-combustible insulation and a layer of sheet metal under the unit. Extend both the layer of insulation and sheet metal beyond the generator base at least 12 inches (30.5 cm) on all sides. See Figure 3-1.

A containment dike with specific capacities for fuel and/or oil spillage is also required.

3.1.5— Combustible Floor Protection

Install a layer of non-combustible insulation topped with a layer of sheet metal under the unit. Extend both the layer of insulation and sheet metal beyond the generator base at least 12 inches (30.5 cm) on all sides. See Figure 3-1.

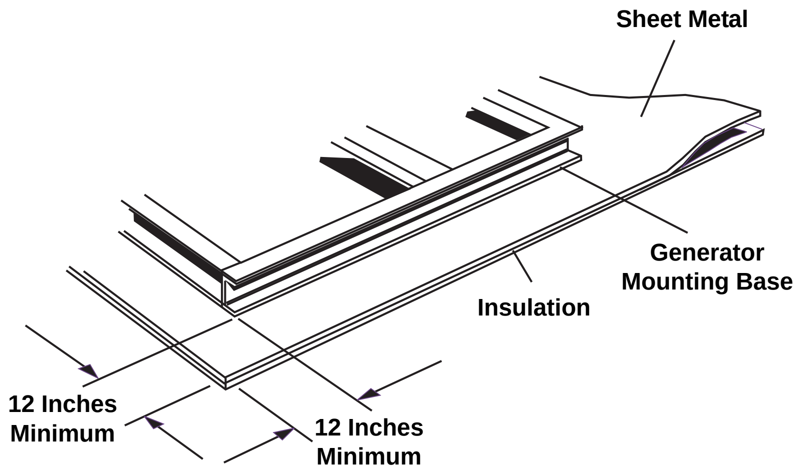

Figure 3-1. Combustible Floor and Roof Protection

3.1.6— Stub Up Area

For load conduit, auxiliary power conduit (high voltage), and control wiring conduit (low voltage), see the installation drawings for the location and dimensions of the stub up areas. See Figure 3-2.

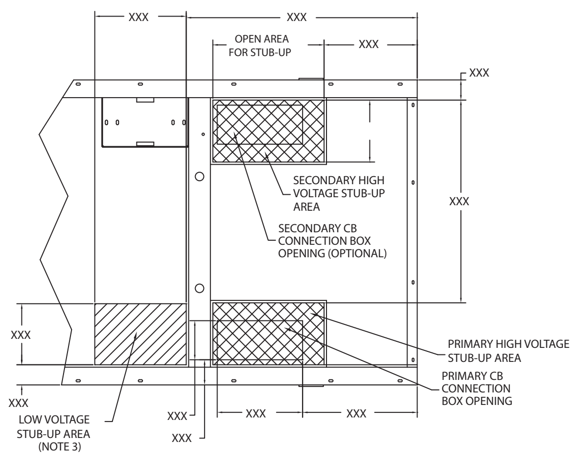

Figure 3-2. Typical Installation Drawing Stub Up Detail

3.2 — Mounting

3.2.1— Fixed Foundation

Use mounting holes in the base frame to fasten the unit to the foundation. Always use hardware of a suitable grade, size and style.

3.2.2— Spring Isolators

Always adjust spring isolators after installation following the manufacturer's instructions. The spring isolators are used to level a unit within a reasonable distance. Typically, the mounting pad must be flat and level to within 1/2 inch. Secure the spring isolator to both the generator base and foundation with appropriate grade, size and style fasteners. See Figure 3-3.

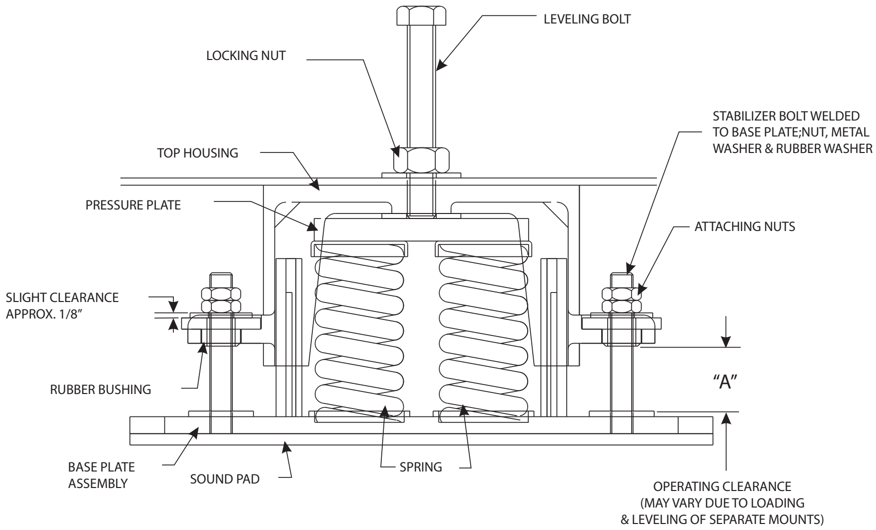

Figure 3-3. Typical Spring Isolator

3.2.3— Bottom Enclosure

For generator sets with open bottoms using spring mounts between the frame rails and the mounting surface, or mounted on an open bottom foundation (steel I-beams and/or grating surfaces, etc.), the bottom of the unit must be enclosed to prevent entry of foreign objects and to prevent recirculation of hot radiator exhaust air. It must be covered with a metal plate to keep out foreign objects (birds, rodents, insects, dirt and debris) and to protect internal components and wiring.

3.2.4— Connections

All fuel, coolant, exhaust, and electrical connections must have flexible sections where they connect to the unit to isolate vibration. Cracks, fractures, and leaks can develop without proper vibration isolation. Properly support and secure all piping before installing the flexible connection.

3.2.5— Tie Down Holes

To protect internal components and wiring, and to prevent entry of dirt, debris and other foreign objects, plugs are provided (as applicable) to cover tie-down holes in the frame rail. See Figure 3-4.

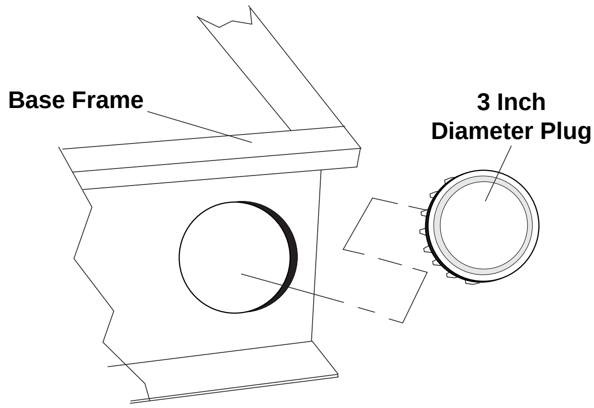

Figure 3-4. Frame Tie-Down Hole Plugs

Section 4 *Ventilation System*

4.1 — General

Adequate and unobstructed flow of cooling and ventilating air is critical to prevent buildup of explosive gases and to ensure safe generator operation. Do not alter the installation or permit even partial blockage of ventilation provisions. Keep area around the generator clean and uncluttered, and remove any materials that may pose a hazard.

4.2 — Outdoor Installations

For units installed outdoors in their factory provided enclosures, the installation design must ensure that there are no obstructions at any of the air intakes that may impede intake airflow.

4.2.1— Clearance

Keep a minimum of five feet of clearance around the unit to facilitate service and maintenance, and to ensure adequate air circulation for air intakes and cooling of exhaust discharges.

4.3 — Indoor Installations

4.3.1— Ventilation

Adequate ventilation is a key consideration for indoor installations in order to meet cooling requirements and to supply sufficient air for combustion. The unit specification sheets provide the cooling and combustion air requirements.

- **Cooling Air** is required to remove heat generated by the unit during operation. It passes through the alternator, over the engine, through the radiator and is then evacuated through appropriate ducting.
- **Combustion Air** is required by the engine for combustion. It flows through the air filter, the engine intake and combustion chambers and then exits through the engine exhaust system.

4.3.2— Ventilation Practices

- Louvers have resistance to air flow. Openings with louvers should be twice the area of an unobstructed opening to provide proper air flow. At times duct work is necessary to provide cooling air for the room. Duct work must be sized and installed according to acceptable standards.
- Exercise care to be sure that any motorized louvers have power during all modes of operation.
- In some extreme cold weather applications, the opening of louvers immediately upon startup can cause carburetor icing and vaporizing problems with engines using gaseous fuels. Consider thermostatically controlled louvers to reduce the problems encountered in cold weather applications.
- Be sure the location permits sufficient air flow for cooling and ventilation. For indoor applications, keep supply air ducting to a minimum. For outdoor applications, consider the proximity of any walls, fences, or other noise abatement or security barriers that may inhibit air flow.

4.3.3— Air Flow

The intake and exhaust air inlets and outlets in an engine room or enclosure should be in-line to provide engine cooling airflow parallel with the generator. Air flow travels through the alternator, across the engine, through the radiator and then out through exhaust ducting. See Figure 4-1.

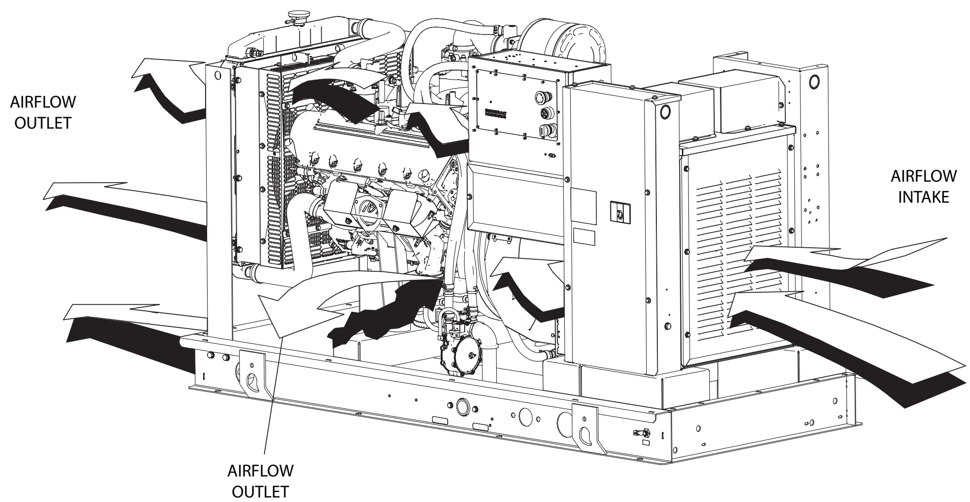

Figure 4-1. Generator Airflow

4.3.4— Louvers

Louvers prevent entry of wind driven rain, snow, and debris. Face intake louvers into the prevailing wind and angle all louvers so that rain and snow do not pass directly through.

Size louvers to provide more than the required air flow. Louvers have resistance to air flow, so openings with louvers should be twice the area of an unobstructed opening. Louver manufacturers will provide flow rate capacities to match size of louver openings to airflow requirements.

Use motor operated louvers or properly designed and sized gravity louvers to minimize static pressure drop. Be sure louvers face inward for air intake. Exercise care to be sure that any motorized louvers have power during all modes of operation.

Intake louvers in engine rooms are usually located high on a wall, but the required quantity of air flow may necessitate an entire wall of louvers. Use ducting to direct fresh intake air toward the generator to help promote the correct air flow.

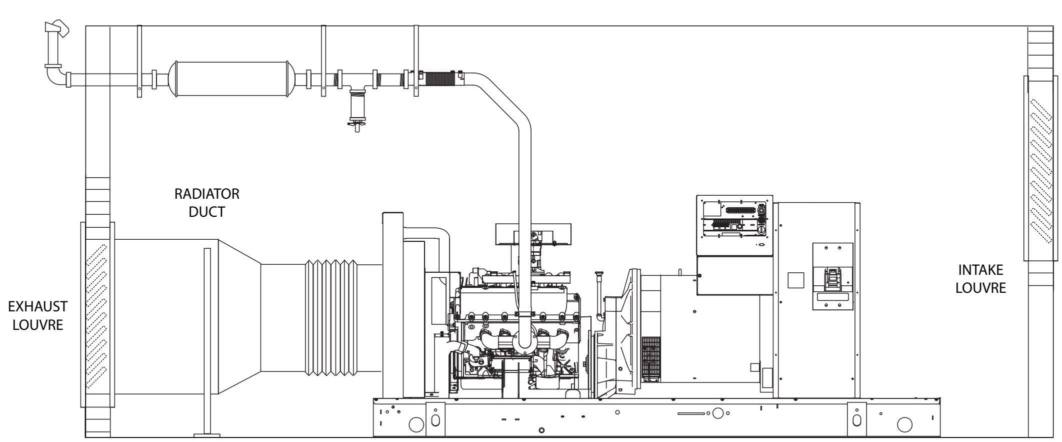

Figure 4-2. Indoor Installation Example

4.3.5— Motorized Louvers

Motorized louvers may be used in extremely cold climates to improve ambient temperature within the generator space when the unit is not operating. The following requirements apply to the use of motorized louvers:

- Be sure the louvers open automatically when the generator starts. This may be accomplished with a spring loaded mechanism that does not require power. When the generator shuts down, the louvers “power” to a reset or closed position.
- Connect the power circuit for the louvers to a circuit powered by the generator.
- Wind blowing against intake openings can blow open gravity louvers causing low temperature and moisture problems in bad weather. In cold climates, the high volume of outside air drawn into the room can quickly reduce temperatures to freezing. Any water piping or other equipment susceptible to freeze damage should be properly insulated or located elsewhere. Thermostatically controlled louvers can be used to help maintain stable engine room temperatures in cold climate conditions. Again, connect the louver power circuit to a circuit powered by the generator.

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Section 5 Exhaust System

5.1 — Best Practices

A well-designed exhaust system collects exhaust gases from the engine cylinders and discharges it safely and efficiently. For optimal performance, the exhaust system must conform to the following.

- Use flanged exhaust pipe rated for at least 1500° F and constructed of schedule 40 black iron, steel, or other suitable materials having adequate strength and durability.
- Minimize resistance to exhaust gas flow (backpressure) and keep it within the specified limits.
- Reduce exhaust noise to meet local regulations.
- Provide adequate clearance between exhaust system components and engine parts, machine structures, enclosures and building structures to minimize the impact of high exhaust temperatures.
- Use a flex joint between the engine connection point and the rigid piping.
- Ensure the system does not stress engine components such as turbochargers and exhaust manifolds with excess weight.
- Use flexible bellows to allow for linear and/or axial movement of rigid piping due to thermal expansion/contraction.
- Use sweep elbows with a radius at least three times the pipe diameter.
- Ensure that exhaust system components are able to reject heat energy.
- Properly support and connect exhaust piping and silencers. Verify that no strain or excessive weight is placed on the flex coupling connected to the engine. Flex couplings are only used to isolate vibration. Do not use flex couplings to correct alignment problems or carry the weight of a silencer/piping system.
- Slope exhaust piping away from the engine outlet and install a water trap with drain at the lowest point. Installation of a water (condensate) drain at the outlet of the silencer is also recommended.
- Properly terminate exhaust piping outside a structure housing a generator set, so that hot gases are harmlessly discharged and do not come into contact with any combustible surface or material.
- Do not terminate exhaust piping under loading platforms, structures, or near any opening in a building.
- Provide at least nine inches (22.9 cm) of clearance between exhaust piping and any combustible surface.
- Guard exhaust piping to prevent burns, where necessary.
- Do not wrap or shield “dry” turbochargers and exhaust manifolds.
- Keep exhaust piping well clear of fuel tanks, fuel lines, etc.
- Use a ventilated thimble to guard exhaust piping if routing through combustible walls or roofs.
- Terminate piping on horizontal exhaust stacks with a 45º tailpipe.
- Size the effective opening area of exhaust louvers 25% to 50% larger than the engine radiator core effective opening.
- Be sure the backpressure measured at the air-out side of the radiator never exceeds the maximum allowable backpressure specified by the manufacturer.
- Keep the ductwork from the radiator outlet flange to the exhaust vent opening as short and straight as possible.
- Install the ductwork from the radiator outlet flange to the exhaust vent opening in a manner that prevents any recirculation of exhaust air back to the generator area.
- Design extended exhaust ductwork with as few bends as possible. Where bends are necessary, they should be in the form of gradual sweeps (large radius bends) to allow airflow with minimum restriction.
- Exercise care to be sure that any motorized louvers have power during all modes of operation.
- For outdoor units, ensure that there are no obstructions at the exhaust discharge that may cause exhaust gases to circulate back to the air intakes. Recirculation of exhaust air will cause the unit to overheat.

5.1.1— Emissions Compliance

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.

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.

5.2 — System Components

The main components of the exhaust system are the exhaust manifold, turbocharger, wastegate, exhaust piping and silencer.

5.2.1— Exhaust Manifold

Engine exhaust manifolds collect exhaust gases from each cylinder and channel them to an exhaust outlet. The manifold is designed to give minimum backpressure and turbulence. Generac uses a dry manifold design. Dry manifolds are cost effective and provide the maximum possible exhaust energy to the turbocharger, but they also radiate the most heat and reach the highest surface temperatures.

Gas engines run with a higher exhaust temperature compared to diesel engines. Due to high exhaust temperatures, heat shields and blankets are used to lower surface temperatures where required.

5.3 — Heat Shields

NOTE: Installing non-approved heat shields or soft wrap can cause exhaust system damage. Damage from non-approved components is not covered under warranty.

Heat shielding is used to shield hot surfaces to protect components and operators from excessive heat. The use of heat shields depends on many factors including installation type, as well as environmental and legislative requirements.

Guards may also be an effective means of providing protection. Shields that are designed and supplied by Generac are suitable for this purpose. Any customer supplied and fitted shields must be carefully designed and installed to ensure that damage to the engine does not result. Customer supplied wraps and shields may increase component skin temperature possibly resulting in premature failure. Providing significant airflow around the shield can help reduce risk of damage.

5.3.1— Blankets (Soft Manifold Shields)

Blankets are made of an insulating layer of material spun of calcium, silica, magnesium or other special fibers with a thermal cloth outer layer, and can be used to isolate both heat and noise. Blankets are held in place with stainless steel springs or wire laces.

Do not install blankets on exhaust manifolds, turbocharger housings or other engine components. The use of manifold blankets can result in premature failure of exhaust manifold components.

Table 5-1. Recommended Exhaust Insulation Blankets

Manufacturer and Product	Maximum Continuous Use Temperature Rating
INSULFAB IF 1950 High Temperature	Up to 1832° F.
INSULFAB IF 1953 Treated Glass Fabric	Up to 1300° F.
INSULFAB IF 1954 Coated Glass Fabric	Up to 600° F.

5.3.2— Guards and Shields

Guards and shields are usually made of perforated sheet metal, and are installed with an air gap between the shield and the hot surface. With adequate airflow around the engine, the heat transfer from iron to air will lower the temperature of the shield considerably.

CAUTION: All heat shielding must be designed so that engine components do not reach critical temperatures which can lead to premature engine failure.

5.4 — Turbochargers

Turbochargers are employed to achieve higher engine power output by converting some of the energy in the exhaust gas stream into energy in the inlet system (resulting in raised inlet pressure or boost). The raised inlet pressure forces more air into the engine cylinders, thereby allowing more fuel to be burned, which results in higher power output.

See Figure 5-1. Hot exhaust gases exit the cylinder and enter the turbine side of the turbocharger. The exhaust gases drive the turbine blades which in turn drive the compressor blades on the air intake side. High speed rotation compresses the intake air to provide more oxygen for combustion.

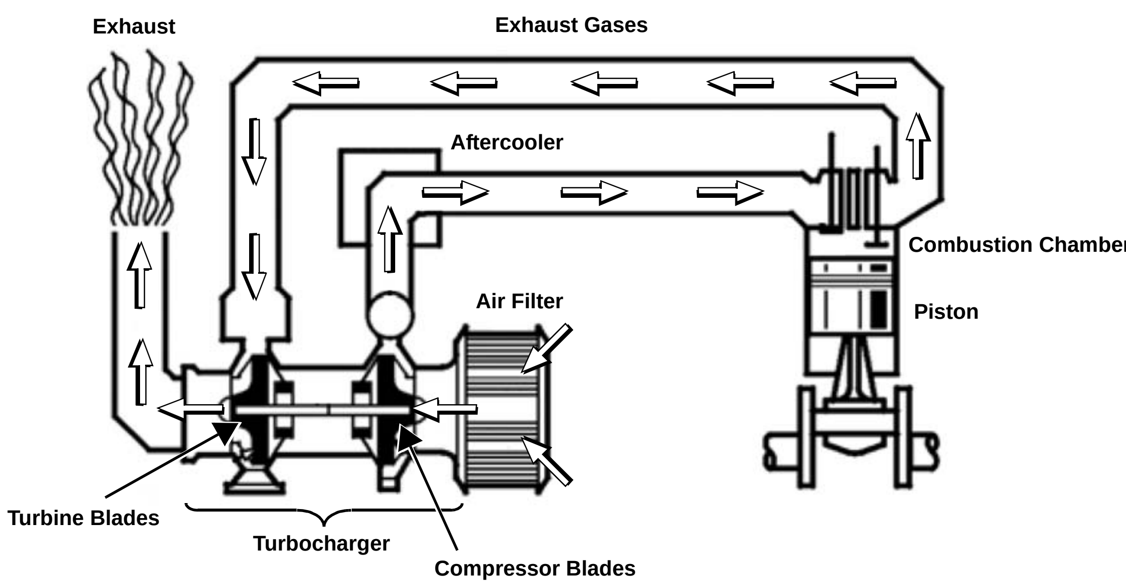


Figure 5-1. Turbocharger Operation

5.4.1— Wastegate

Turbochargers equipped with a wastegate can efficiently operate in a much broader range of altitudes and ambient temperature conditions. The wastegate opens at a predetermined pressure and vents some of the exhaust flow away from the turbocharger. The reduced exhaust flow slows the turbocharger to avoid overspeed and excessive boost pressure.

CAUTION: Tampering with the boost line to the wastegate will raise aftercooler heat rejection, increase turbocharger speed and peak engine cylinder pressure. These conditions may adversely affect engine stability, durability, emissions, and overall performance.

5.4.2— Flexible Exhaust Connections

Isolate the exhaust piping system from the engine with flexible connections designed for zero leakage. The flexible metal hose and bellow are the two types of flexible connections most commonly used.

The flexible metal hose allows for sideways or lateral deflection of the exhaust system due to vibration, while the flexible bellow permits linear and/or axial movement due to thermal expansion and contraction. The bellow, which is manufactured from stainless steel or other material suitable for high temperatures, is made up of a series of one or more convolutions, with the shape of the convolution designed to withstand the internal pressures of the pipe, but flexible enough to accept the axial and lateral angular deflections associated with thermal expansion and contraction.

5.4.3— Flexible Metal Hose and Bellows

The flexible metal hose is commonly used for exhaust systems with a pipe diameter of 6 inches (150 mm) or less. The bellow type is typically used for exhaust systems with a diameter of 8 inches (200 mm) or greater. Install flexible connections as close to the engine exhaust outlet as possible.

The primary functions of flexible exhaust connection are:

- To isolate the weight of the exhaust piping from the engine exhaust outlet.
- To protect exhaust components from excessive vibrational stresses.
- To allow some shifting of exhaust components due to thermal expansion and contraction, settling, or by torque reactions.

See Figure 5-2 for a typical exhaust piping layout using flexible connections,

Flexible pipe connections, when insulated, must expand and contract freely within the insulation. This generally requires a soft material or insulated sleeve to encase the connection.

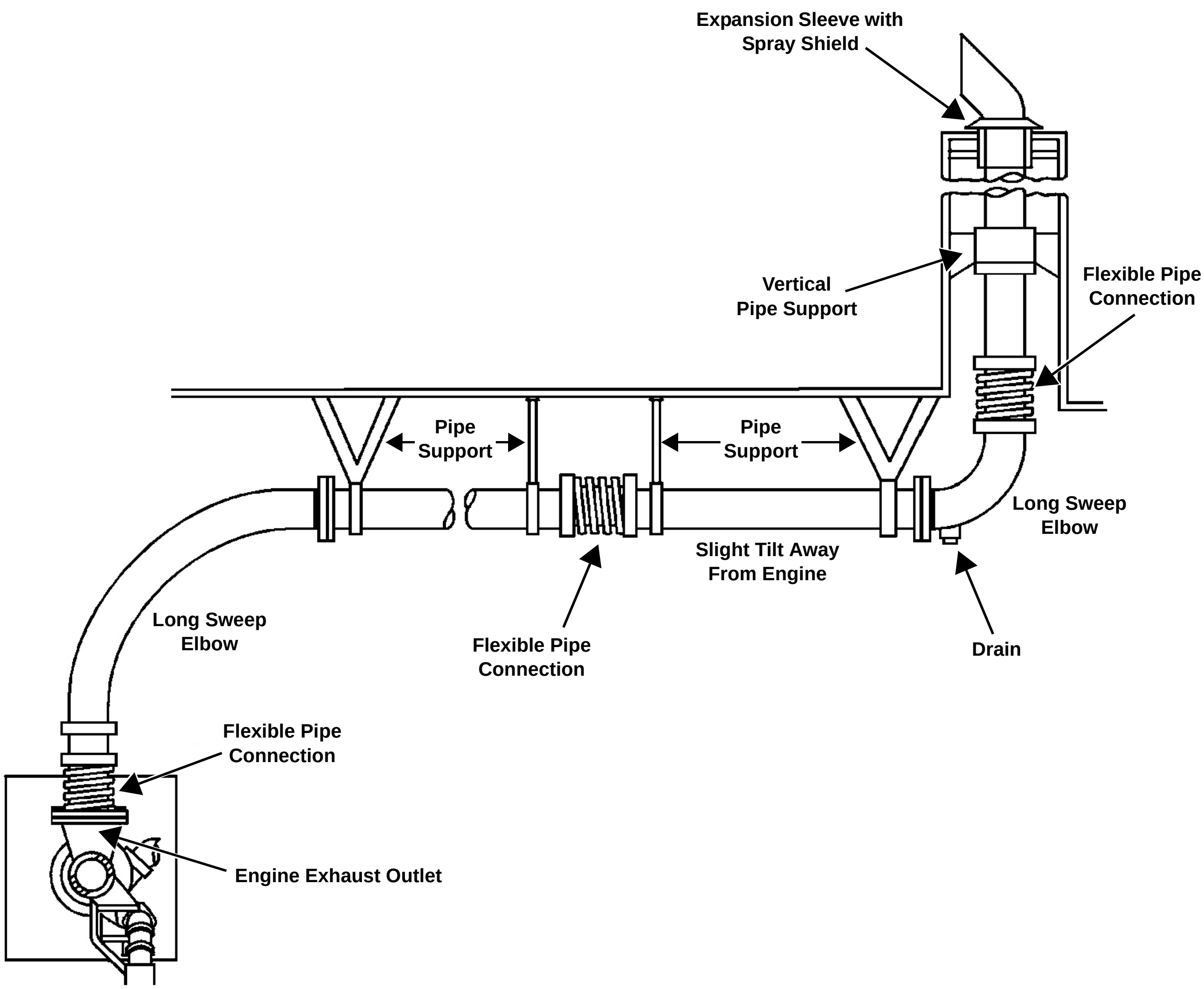


Figure 5-2. Typical Exhaust Piping Layout

5.4.4— Installing Flexible Connections

Pre-stretch flexible connections during installation to allow for expected thermal growth. Four small straps can be tack-welded between the two end flanges to hold the engine exhaust flexible connection or bellows in a rigid position during installation of exhaust piping. This prevents the bellows from being installed in a flexed condition. Attach a warning tag to the bellows noting that the weld straps must be removed before starting the engine.

All flexible connections must have good fatigue resistance. They should give acceptable service life while withstanding vibratory stress and should be soft enough to prevent transmission of vibration beyond the connection.

For maximum durability, allow the bellows type connection to operate as close as possible to its free state.

5.4.5— Slip Joints

Slip joints are another method of handling the expansion and contraction of exhaust systems. Slip joints are designed to have controlled leakage when the system is cold. When the engine starts and the exhaust pipes warm up, the joints expand to make a gas-tight fit. The slip joints are flexible in only one direction and require good support on each side.

Generac does not normally recommend the use of slip joints due to disadvantages, such as leaking exhaust fumes, exhaust slobber and the inability of the joint to flex in more than one direction.

Table 5-2. Installation Limits of Flexible Metal Hose

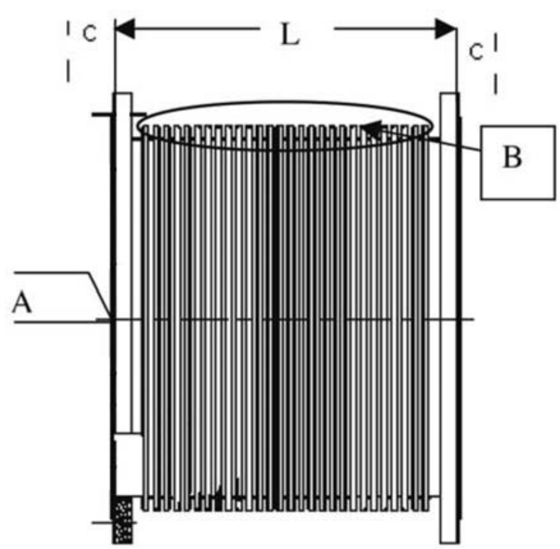
Hose Diameter (Inches)	A Maximum Offset Between Flanges		B Maximum Compression From Free Length		C Maximum Extension From Free Length	
	Inches	mm	Inches	mm	Inches	mm
4 and 5	1.0	25.4	.25	6.25	.25	6.25
6	1.5	38.1	.25	6.25	.25	6.25

Table 5-3. Installation Limits of Bellows

Bellow Diameter (Inches)	A Maximum Offset Between Flanges		B** Minimum Acceptable Convolution Gap		C Maximum Extension From Free Length	
	Inches	**mm**	**Inches**	**mm**	**Inches**	**mm**
	0.04	1.00	0.089	2.27	0.08	2.00
8 and 12	0.75	19.05	0.121	3.07	1.00	25.40
14	0.75	19.05	0.314	7.97	1.00	25.40
18	0.90	22.86	0.310	7.87	1.75	44.45
**DO NOT allow gaps in convolutions to be less than value indicated on part.						

Table 5-4. Spring Rate of Flexible Bellow

Bellow Diameter (Inches)	A Maximum Offset Between Flanges — Spring Rate	
	lb/in.	kN/m
6	799	140.0
8	170	29.7
12	194	33.9
14	391	68.5
18	110	19.3



5.4.6— Silencer

The silencer reduces exhaust noise before it is released to the atmosphere. Exhaust noise arises from the intermittent release of high pressure exhaust gas from the engine cylinders, causing strong gas pressure fluctuations in the exhaust system. This leads to discharge noise at the exhaust outlet, and also to noise radiation from exhaust pipe and silencer surfaces. A well designed and matched exhaust system significantly reduces noise from these sources. The silencer makes a major contribution to exhaust noise reduction.

Excessive noise is objectionable at most locations. The required degree of silencing depends on factors such as the application type, whether it is stationary or mobile and whether there are any local regulations regarding noise emissions. For example, excessive noise is objectionable in a hospital or residential area, but may be acceptable at an isolated pumping station.

5.4.7— Silencer Rating

Silencers are rated according to their degree of silencing as shown in Table 5-5.

Table 5-5. Silencer Ratings

Level	Rating	Sound Reduction	Description
1	Industrial	up to 12-18 dB	Suitable for industrial areas where background noise level is relatively high or for remote areas where partly muffled noise is permissible.
2	Residential	up to 18-25 dB	Reduces exhaust noise to an acceptable level in localities where moderately effective silencing is required, such as semi-residential areas where moderate background noise is always present.
3	Critical	up to 25-35 dB	Reduces exhaust noise to an acceptable level in localities where background noise level is low and more effective silencing is required, such as residential areas.
4	Hospital	up to 32-42 dB	Provides maximum silencing for residential, hospital, school, hotel, store, apartment building and other areas where background noise level is lowest and generator set noise must be kept to a minimum.

5.4.8— Silencer Selection

The silencer is usually the largest single contributor to exhaust backpressure. Therefore, required noise reduction and permissible backpressure are both considered when selecting a silencer. Application type, available space, cost and appearance also need to be taken into account.

To select a silencer, use silencer supplier data, corrected for outlet temperature and velocity, to determine the silencer size and type that satisfies noise reduction criteria with an acceptable maximum pressure drop.

After calculating pressure loss, it may be necessary to check a different silencer, or a different pipe size, before an optimum combination is found.

Silencer design is a highly specialized art. Responsibility for design and construction details should be left to the silencer manufacturer.

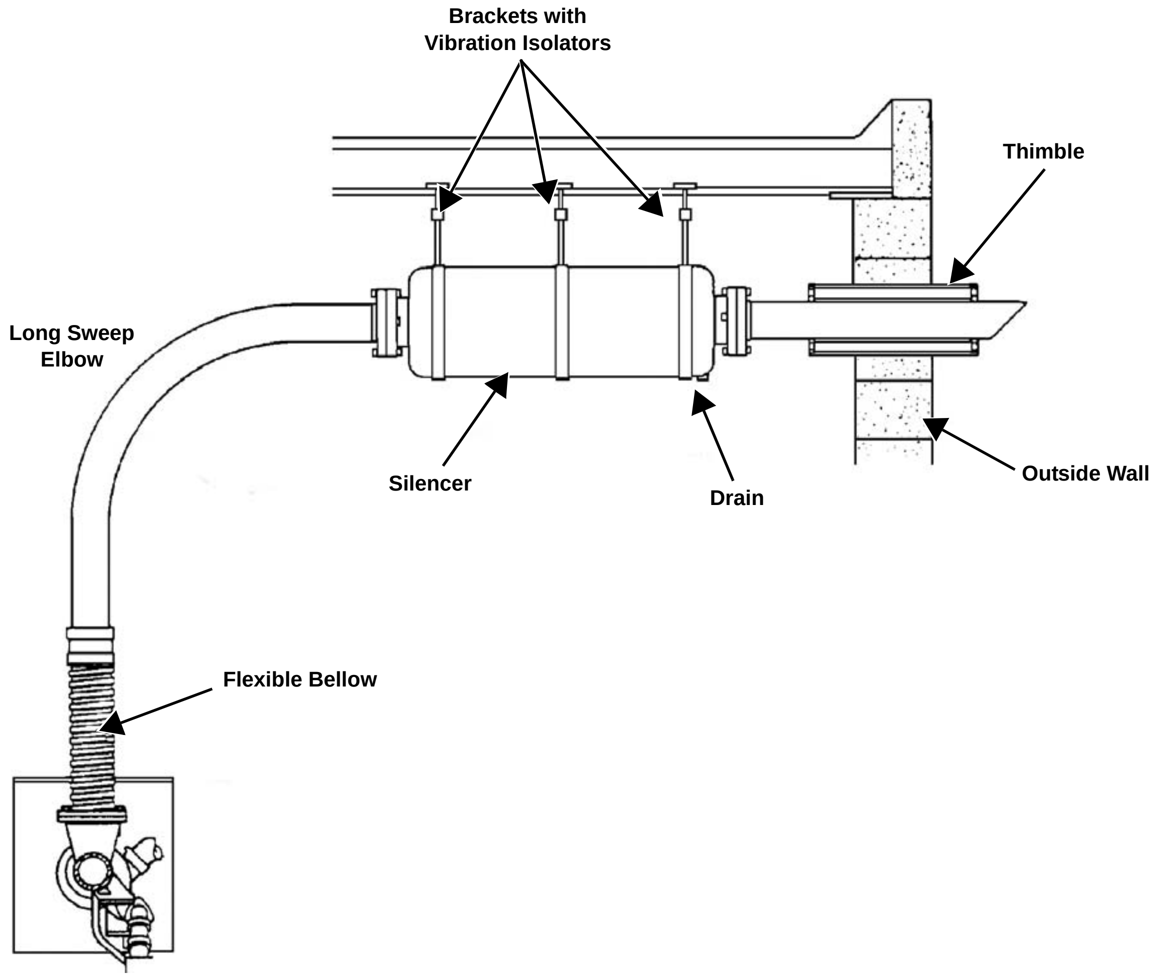


Figure 5-3. Typical Silencer

5.5 — Exhaust System Piping

The function of the exhaust piping is to convey the exhaust gases from the engine exhaust outlet to the silencer and the exhaust system outlet. Piping is a key feature in overall exhaust system layout.

5.5.1— Exhaust System Design

The physical characteristics of the engine room determine the exhaust system layout. Design exhaust piping to minimize exhaust backpressure while also keeping engine serviceability in mind. Be sure exhaust piping is securely supported. Use suitable flexible components to allow for system movement and to isolate vibration.

Design exhaust piping with engine service in mind. An overhead crane may be needed to service the heavy components on larger engines.

5.5.2— Other Considerations

The minimum requirements for the design of the exhaust system should be to contain explosions that could be encountered during the operation of the engine. The use of explosion relief valves is recommended on all gas engines, particularly the larger size engines due to high fuel volumes.

Locate pressure relief valves as close to the engine as possible (typically at piping elbows) to minimize potential exhaust system damage in the event of an exhaust explosion. Additional pressure relief valves can be used prior to the silencer, catalytic converter, or heat recovery equipment to add protection for these devices. Pressure relief valves are fitted on the exhaust pipe to relieve pressure in a safe manner and must be vented to a safe area. See local codes for details. Pressure relief valves can be purchased from after market suppliers.

- Install all piping with a minimum clearance of 9 inches (229 mm) from combustible materials.
- Properly support the exhaust piping. This is especially important adjacent to the engine, so that the weight of the exhaust piping is not borne by the engine or the turbocharger.
- Size exhaust piping according to the specified maximum backpressure limit.
- Where necessary, reduce heat radiation by covering off-engine exhaust piping with suitable, high temperature insulation blankets.
- Install metal thimble guards on exhaust piping that passes through wooden walls or roofs. Size the thimble guards so that they are 12 inches (305 mm) greater in diameter than the exhaust pipes. See Figure 5-3.
- If used, extend exhaust stacks upward and away from the engine room to avoid heat, fumes and odors.
- Locate exhaust pipe outlets away from the air intake system. Engine air cleaners, turbochargers and aftercoolers in contact with exhaust byproducts can experience premature failure.
- Avoid routing exhaust piping close to fuel pumps, fuel lines, fuel filters, fuel tanks and other combustible materials.
- Cut exhaust pipe outlets at 30° to 45° angles (rather than 90°) to reduce exhaust gas turbulence and noise. See Figure 5-5.
- Arrange exhaust outlets to keep water out of the piping system.
- Be sure that silencer does not inhibit access to filters, engine, or add heat to radiator.

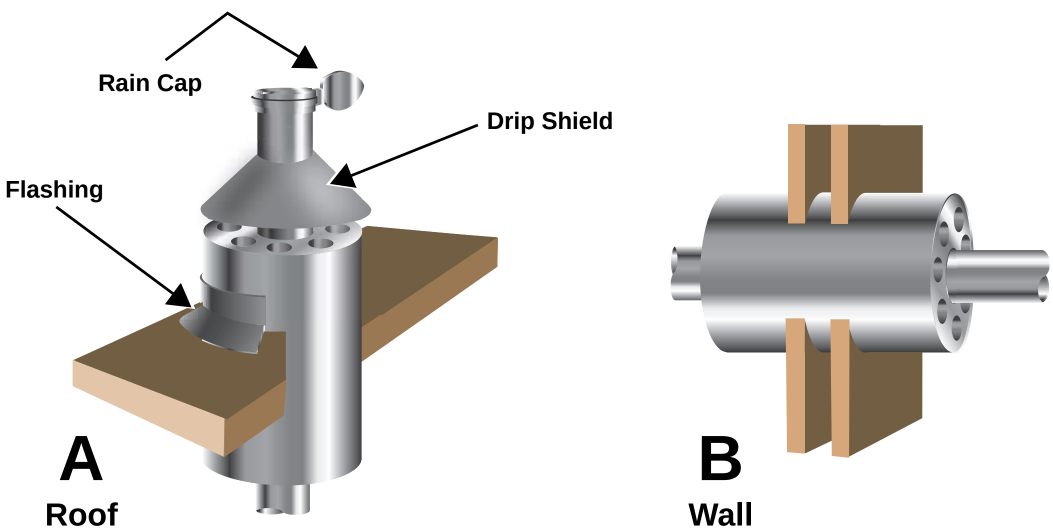


Figure 5-4. Exhaust Pipe Thimble Installation

5.5.3— Condensate Traps

Exhaust systems can accumulate a considerable amount of condensed moisture. For example, engines burning natural gas produce one pound of water for each 10 ft^3 of natural gas burned. Long runs of exhaust piping require traps to drain moisture. Install traps at the lowest point of the line near the exhaust outlet to prevent rain water from reaching the engine. Slope exhaust lines away from engine toward the trap, so condensation drains properly. See Figure 5-2.

5.5.4— Exhaust Thimbles

See Figure 5-4. Use exhaust thimbles for wall or ceiling penetrations. The thimble separates the exhaust pipe from the wall or ceilings to provide mechanical and thermal isolation. Single sleeve thimbles must have diameters at least 12 inches (305 mm) larger than the exhaust pipe. Double thimbles with both inner and outer sleeves should have outside diameters at least 6 inches (152 mm) larger than the exhaust pipe.

5.5.5— Exhaust Pipe Insulation

Do not locate exposed parts of the exhaust system near wood or other combustible material. Cover exhaust piping inside the engine room (and the silencer if mounted inside) with suitable insulation materials to protect personnel and to reduce room temperature and exhaust noise. Retain insulating material with a stainless steel or aluminum sheath.

5.5.6— Water Ingress Prevention

Design the exhaust system to prevent snow or rain from entering the engine through the exhaust outlet. Note that the method selected imposes restrictions that have to be taken into account when calculating system backpressure.

One method used primarily with horizontal exhaust pipes is to angle cut the end as shown in A of Figure 5-5.

A common method used with vertical exhaust pipes is to angle the pipe 45° or 90° from vertical using a suitable elbow, and then angle cut the end as just described. See B of Figure 5-5.

Another practice that may be employed with either method is to cut water drain slots into the exhaust pipe. Bend the engine side of the slots inward and the downstream side of the slots outward, as shown in C of Figure 5-5. Do not slot more than a 60° arc of the pipe circumference, however, or the integrity of the pipe may be compromised.

For applications where the above methods are not possible, it may be necessary to fit some form of rain cap to the end of the vertical pipe section. While this method can effectively prevent the entry of water, it may also impose an unacceptable backpressure restriction.

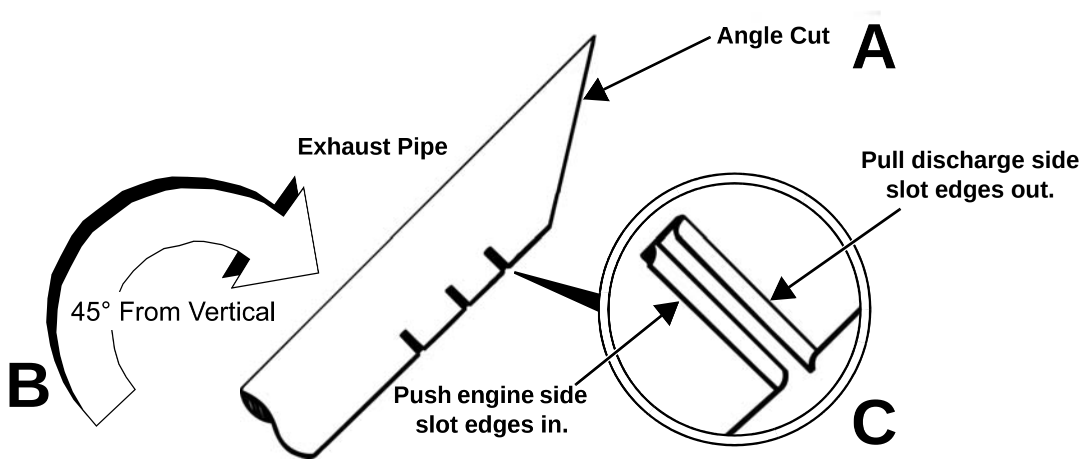


Figure 5-5. Water Drain Slots

5.6 — Exhaust System Backpressure

Excessive exhaust restriction adversely affects performance, resulting in reduced power and increased fuel consumption, exhaust temperatures and emissions. It also reduces exhaust valve and turbocharger life. Keep exhaust backpressure within specified limits. When designing an exhaust system, the target should be half the maximum allowable system backpressure.

Backpressure includes restrictions due to pipe size, silencer, system configuration, and other exhaust related components. Excessive backpressure can be caused by one or more of the following factors:

- Exhaust pipe diameter too small.
- Excessive number of sharp bends in the system.
- Exhaust pipe too long.
- Silencer resistance too high.

Engines with a vee type cylinder configuration should be designed so the exhaust piping gives equal backpressure to each bank.

5.6.1— Measuring Backpressure

Exhaust backpressure is measured as the engine is operating under full rated load and speed. Use either a water manometer or a gauge measuring inches of water.

Many engine installations are already equipped with a fitting for measuring backpressure. If the system is not equipped with a fitting, use the following guidelines to locate and install a pressure tap.

- Locate the pressure tap in a straight length of exhaust pipe before the silencer and as close to the turbocharger as possible.
- Locate the tap at least three pipe diameters from any upstream pipe transition.
- Locate the tap at least two pipe diameters from any downstream pipe transition.

For example, in a 4 inch (100 mm) diameter pipe, place the tap no closer than 12 inches (300 mm) downstream of a bend or section change. See A of Figure 5-6.

5.6.2— Backpressure Tap Installation

If an uninterrupted straight length of at least five diameters is not available, care should be taken to locate the probe as close as possible to the neutral axis of the exhaust gas flow. This is necessary because measurements taken on the outside of a 90° bend at the pipe surface will be higher than a similar measurement taken on the inside of the pipe bend.

1. Weld or braze a 1/8 NPT “half coupling” to the desired location on the exhaust pipe.
2. Drill a 0.12 inch (3.05 mm) diameter hole through the exhaust pipe wall.
3. Remove any burrs on the inside of the pipe wall so that gas flow is not restricted.
4. Attach the gauge or gauge hose to the half coupling.
5. Insert the probe to a depth equal to half the diameter of the pipe or a minimum of 3 inches (76.2 mm). See B of Figure 5-6.
6. Orient the probe so that the groove in the tip is parallel with the exhaust gas flow.

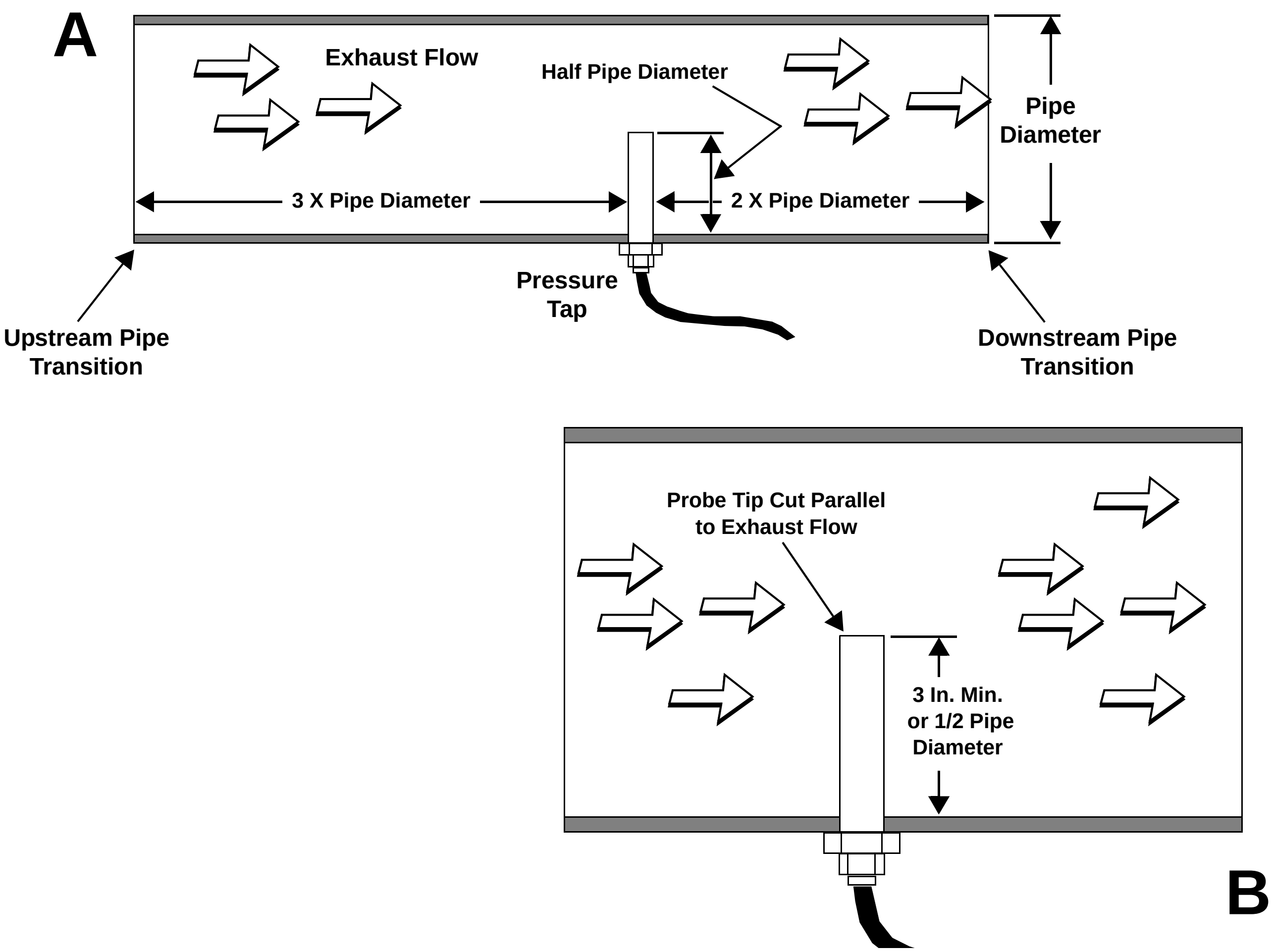


Figure 5-6. Install Backpressure Test Port

5.6.3— Calculating Backpressure

Backpressure is calculated by:

$$P\ (kPa) = \frac{L \times S \times Q^2 \times 3.6 \times 10^6}{D^5} + P_S$$

$$P\ (in.\ H_2O) = \frac{L \times S \times Q^2}{187 \times D^5} + P_S$$

Where:

P = Backpressure (kPa), (in. H_2O)

psi = 0.0361 x in. water column

kPa = 0.00981 x mm water column

L = Total Equivalent Length of pipe (m) (ft)

Q = Exhaust gas flow (m^3/min), (cfm)

D = Inside diameter of pipe (mm), (in.)

S = Density of gas (kg/m^3), (lb/ft^3)

Ps = Pressure drop of silencer (kPa), (in. H_2O)

Useful Conversion Factors:

psi = 0.0361 x in. of water column

psi = 0.00142 x mm of water column

psi = 0.491 x in. of mercury column

kPa = 0.0098 x mm of water column

kPa = 0.25 x in. of water column

kPa = 3.386 x in. of mercury column

kPa = 0.145 psi

5.6.4— Equivalent Length of Straight Pipe

To obtain equivalent length of straight pipe for various elbows:

$$L = \frac{33D}{X}$$ Standard Elbow
elbow radius = pipe diameter

$$L = \frac{20D}{X}$$ Long Elbow
radius = 1.5 diameter

$$L = \frac{15D}{X}$$ 45° elbow

$$L = \frac{66D}{X}$$ square elbow

Where X = 12 in. or 1000 mm

As shown by the equations, if 90° elbows are required, long radius elbows with a radius of 1.5 times the pipe diameter helps to lower resistance.

5.6.5— Combined Exhaust Systems

A common exhaust system for multiple installations is not acceptable. Combined exhaust systems with boilers or other engines forces exhaust gases into engines not operating. Water vapor created during combustion condenses in cold engines and causes engine damage. Duct valves separating engine exhausts is also discouraged, as high temperatures warp valve seats causing leakage.

Exhaust draft fans have been applied successfully in combined exhaust ducts, but most operate only whenever exhaust is present. To prevent turbocharger windmilling (without lubrication), draft fans should not be operable when the engine is shut down. The exhaust system of engines not running must be closed and vented.

360° vee engines have two exhaust outlets, one for each bank. Combining these together with a Y-type fabrication may result in unequal thermal growth and backpressure from one bank to the other. This unequal growth can put unwanted loading onto the turbocharger mounting or the flex bellows. The unequal backpressure can adversely affect the operation and performance of the engine. If the exhaust outlets are joined, these problems may be minimized by providing a flexible connection on each leg and by keeping each leg equal in length.

5.7 — Pipe Support Considerations

5.7.1— Thermal Growth

Thermal growth of exhaust piping must be taken into account to avoid excessive load on supporting structures.

Steel exhaust pipe expands 0.0076 in/ft (1.13 mm/m) for each 100° F (100° C) rise of exhaust temperature. This amounts to 0.65 inches (16.5 mm) expansion for each 10 feet (3.05 m) of pipe from 100° to 950° F (35° to 510° C).

Design piping systems and locate supports so thermal growth expands away from the engine. Supports can reduce strains or distortions to connected equipment and can allow component removal without additional support.

A restraint member may be used to keep the ends of a long pipe run fixed in place, forcing all thermal growth towards the expansion joints.

Insulated flexible pipe connections must expand and contract freely within the insulation. This generally requires a soft material or insulated sleeve to encase the connection.

5.7.2— Turbocharger Loading

Carefully consider the load external piping may place on the turbocharger. To minimize the load carried by the turbocharger housing, place a bellows as close as possible to the turbocharger outlet and ensure that downstream exhaust piping is self supporting. The thermal growth of horizontal piping connected to the turbocharger exhaust must also be taken into account.

Typically, the bellows and adapter, or elbow and bellows, is the maximum allowable loading on the turbocharger. All other external piping must be self-supporting. See Figure 5-7.

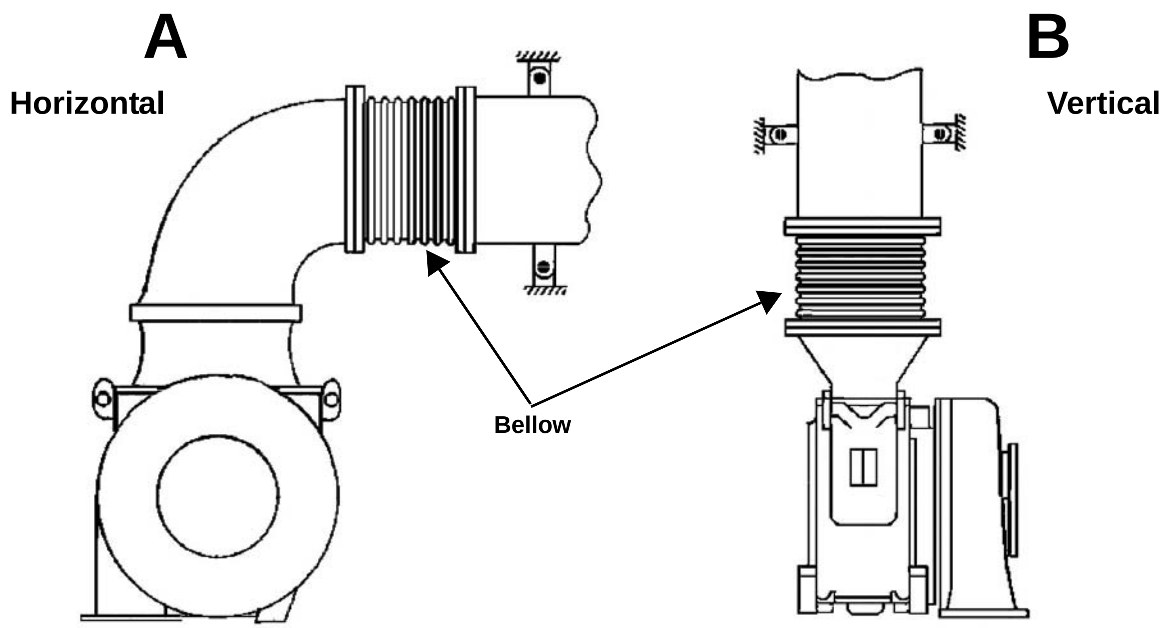


Figure 5-7. Horizontal and Vertical Exhaust Bellow

5.7.3— Vibration Transmission

Piping connected to stationary engines requires isolation, particularly when resilient mounts are used. Without isolation, pipes can transmit vibrations long distances. Isolator pipe supports should have springs to attenuate low frequencies and rubber or cork to minimize high frequency transmissions.

To prevent build up of resonant pipe vibrations, support long piping runs at unequal distances as shown in Figure 5-8.

5.7.4— Exhaust Discharge

Design exhaust outlets, whether exhaust pipe or stack, to ensure that engine exhaust gas does not recirculate back into the engine area. Engine air cleaners, turbochargers and aftercoolers contaminated with combustion byproducts, such as hydrocarbons and soot, can experience premature failure.

Recirculation of hot exhaust gas can also adversely affect the ambient capability of the installation. This can occur when air that is significantly above ambient is drawn through radiator equipped cooling systems. See Figure 5-9 and Figure 5-10 for exhaust piping systems designed to avoid recirculation of exhaust gases.

5.7.5— Exhaust Louvers

Louvers prevent entry of wind driven rain, snow, dust and debris. Do not face exhaust louvers into the prevailing wind and angle all louvers so that rain and snow do not pass through. Where the radiator and fan are located on the engine, wind blowing against an exhaust opening also creates restriction to the fan.

Size louvers to provide more than the required air flow. Louvers have resistance to air flow, so openings with louvers should be twice the area of an unobstructed opening. Louver manufacturers will provide flow rate capacities to match size of louver openings to airflow requirements.

Use motor operated louvers or properly designed and sized gravity louvers to minimize static pressure drop. Be sure louvers face outward for exhaust discharge. Air guide or turning vanes can prevent exhaust air recirculation between the exhaust louvers and any barrier surface, so that exhaust is routed upward into the atmosphere. Exercise care to be sure that any motorized louvers have power during all modes of operation.

5.7.6— Common Exhaust Stack

The exhaust can be directed into a special stack that also serves as the outlet for radiator discharge air and may be sound insulated. In such instances the radiator discharge air enters below the exhaust gas inlet so that the rising radiator air tends to cool exhaust system components within the stack. See Figure 5-9.

The silencer may be located within the stack or in the room with its tail pipe extending through the stack and then outward. Install air guide vanes in the stack to turn radiator discharge airflow upward and to reduce radiator fan air flow restriction. Alternatively the sound insulation lining may have a curved contour to direct air flow upward.

An exhaust stack remains cooler and cleaner if the engine exhaust is contained within the exhaust piping throughout its run through the stack. If the exhaust pipe terminates short of the stack outlet, the discharged ventilation air will tend to cool the exhaust stack downstream of the point where it mixes with the exhaust gases.

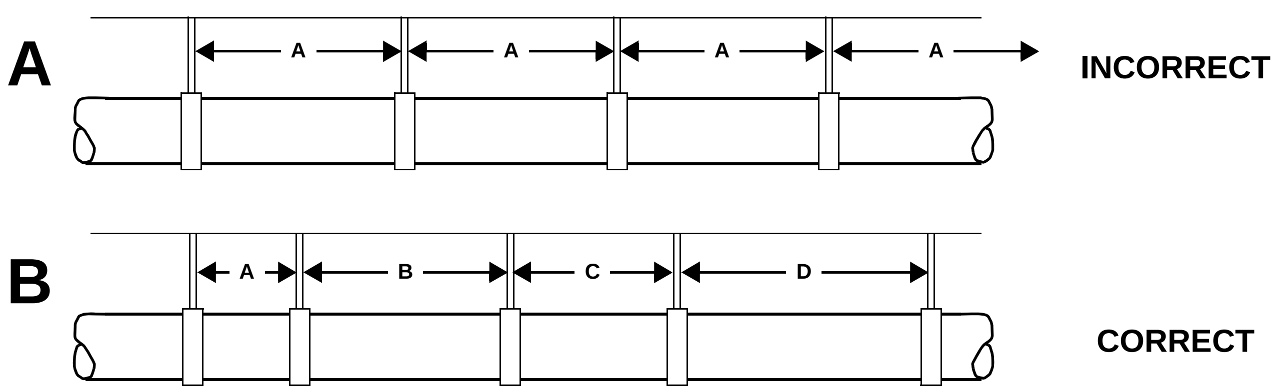


Figure 5-8. Support Pipe Runs at Unequal Distances

See A and B of Figure 5-9 for a vertically mounted and a horizontally mounted exhaust silencer. In both examples, the exhaust pipe and radiator air use a common stack.

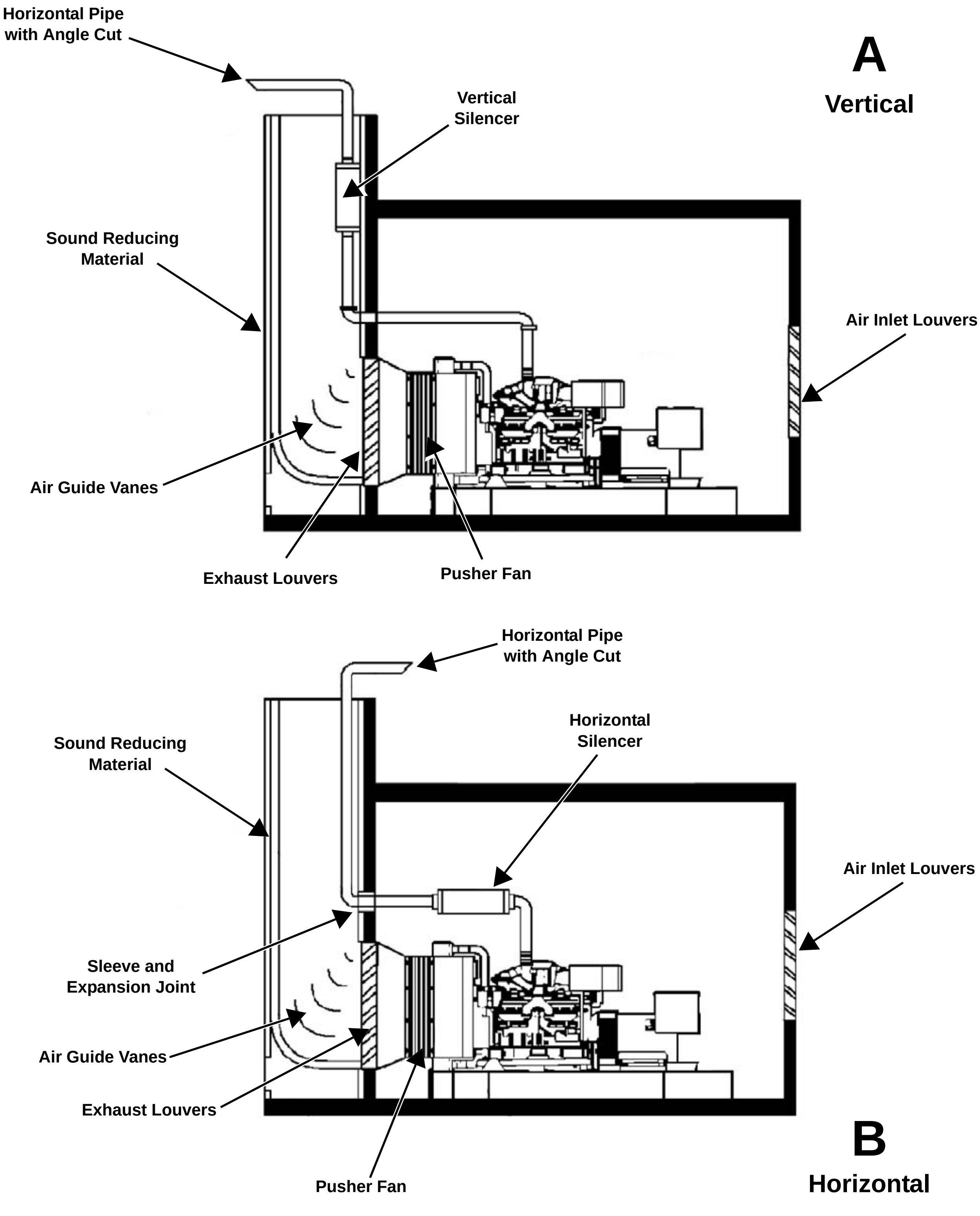


Figure 5-9. Typical Silencer

5.7.7— Power Module or Drop-Over Enclosure

For a generator set enclosed in a power module or drop-over enclosure, the exhaust and radiator discharges should flow together, either above or below the enclosure without a stack.

This arrangement prevents the recirculation of exhaust gases back into the module or enclosure. Sometimes, for this purpose, the radiator can be mounted horizontally, and the fan driven by an electric motor to discharge air vertically as shown in Figure 5-10.

5.7.8— Cleanliness During Installation

During exhaust system assembly, cover all openings on the turbocharger with an identifiable blanking plate to prevent the entry of dirt and debris. Attach a warning tag to the plate to indicate that it must be removed before the engine is started.

5.7.9— Slobber or Wet Stacking

Exhaust slobber is the black oily fluid that can leak from exhaust system joints. It consists of fuel and/or oil mixed with soot from the inside of the exhaust system.

Oil leakage may be the result of worn valve guides, piston rings or turbocharger seals, while fuel leakage usually occurs with combustion problems.

Engines are designed to operate at loaded conditions. Extended engine operation at no load or lightly loaded conditions (less than 15% load) reduces the sealing capability of some integral engine components, even when the engine is new.

If slobber occurs, external signs of slobber will be evident, unless the exhaust system is completely sealed.

Exhaust slobber is not usually harmful to the engine, but can be unsightly. If extended idle or light load periods of engine operation are mandatory, the objectionable effect can be avoided by loading the engine to at least 30% load for approximately ten minutes every four hours. This removes any fluids that may have accumulated in the exhaust manifold.

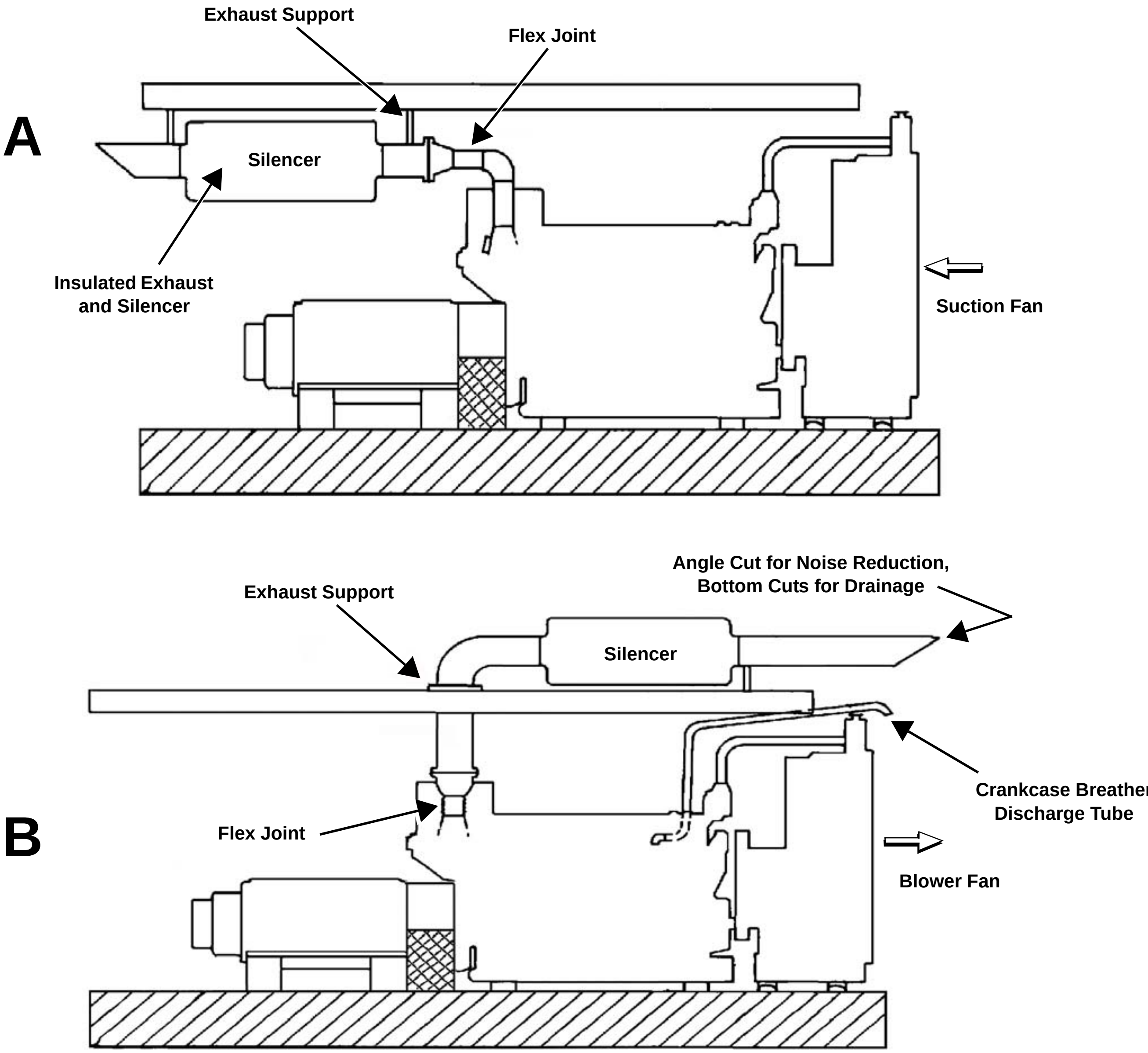


Figure 5-10. Internal/External Silencer

Section 6 Gaseous Fuel Systems

Gaseous fuels, such as LP and natural gas, are highly volatile and their vapors are explosive. LP gas is heavier than air and will settle in low areas. Natural gas is lighter than air and will settle in high areas. Even the slightest spark can ignite these fuels and cause an explosion.

6.1 — 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 Subsection 1.7.

6.1.1— 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:

- Natural Gas (NG)
- LP-Vapor Withdrawal
- LP-Liquid Withdrawal
- Dual-Fuel Consisting of NG (Primary) and LP-Vapor Withdrawal
- Dual-Fuel Consisting of NG (Primary) and LP-Liquid Withdrawal

To convert to a different fuel (for example, from NG to LP-Gas Vapor), see your local Authorized Service Dealer.

6.2 — Gaseous Fuel Properties

6.2.1— Natural Gas

Natural gas 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.

6.2.2— Propane Vapor (LPV) and Propane Liquid (LPL)

Liquefied Petroleum gas is heavier than air. The gas vapors are explosive and can be ignited by the slightest spark. LP Vapor is supplied by liquid propane stored in tanks. Propane exists in its liquid form at or below its boiling point (-44º F) as well as when it is stored under pressure. LP tank pressure is dependent on the ambient temperature and the liquid volume in the tank, and can be over 200 psi. For liquid propane vapor withdrawal (LPV), 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 (LPL), the tank uses a special fitting to allow for withdrawal of the liquid propane.

6.3 — Gaseous Fuel Systems

6.3.1— Natural Gas 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 Subsection 6.7.1. 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.

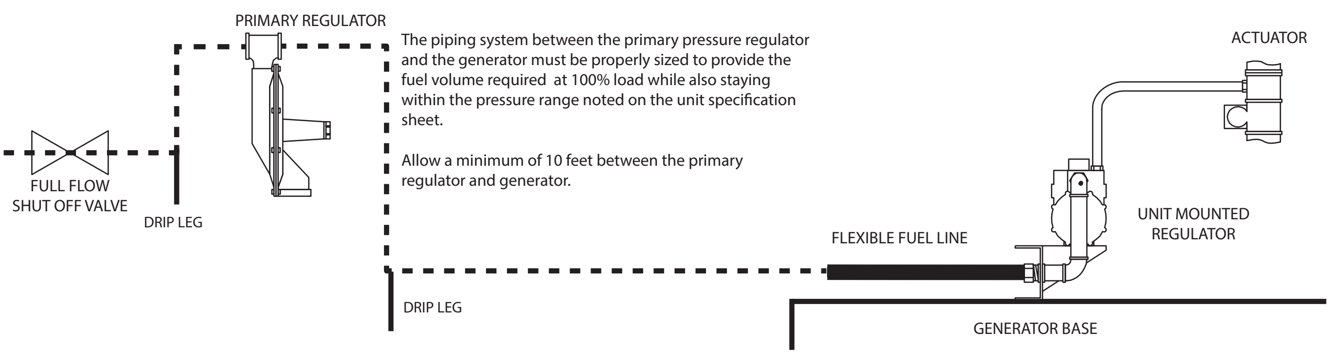


Figure 6-1. Typical NG Fuel System

6.3.2— LP-Vapor 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 LP-Gas vapor 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.

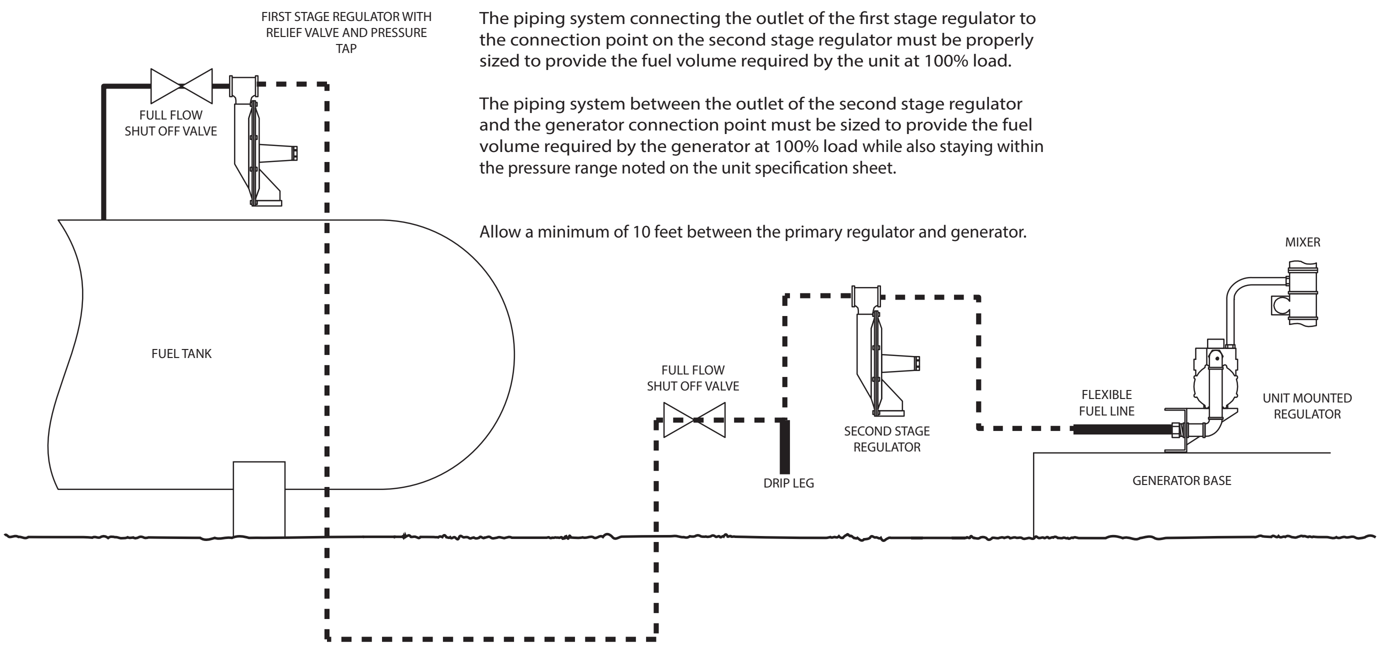


Figure 6-2. Typical LP-Vapor Withdrawal Fuel System

6.3.3— LP-Liquid Withdrawal System

This system delivers LP in liquid form to the connection point on the generator set. The liquid fuel must be vaporized before being delivered to the fuel mixer (carburetor). Liquid withdrawal fuel systems must use a heated “vaporizer/regulator” to convert the liquid fuel to its gaseous (vapor) state. All liquid withdrawal fuel systems provided by the manufacturer use an engine coolant heater to provide a regulated heated coolant supply to the Vaporizer-Regulator. The heated engine coolant keeps the Vaporizer-Regulator plate continuously warm so when the liquid fuel enters the vaporizer chamber the fuel is immediately changed to its gaseous state. See Figure 6-3. The heated coolant also prevents the vaporizer from freezing up during operation. The typical fuel system delivery pressure of an LP-Liquid system will range from 58 psi to 180 psi (liquid line pressure) depending on ambient temperature and liquid level in the tank.

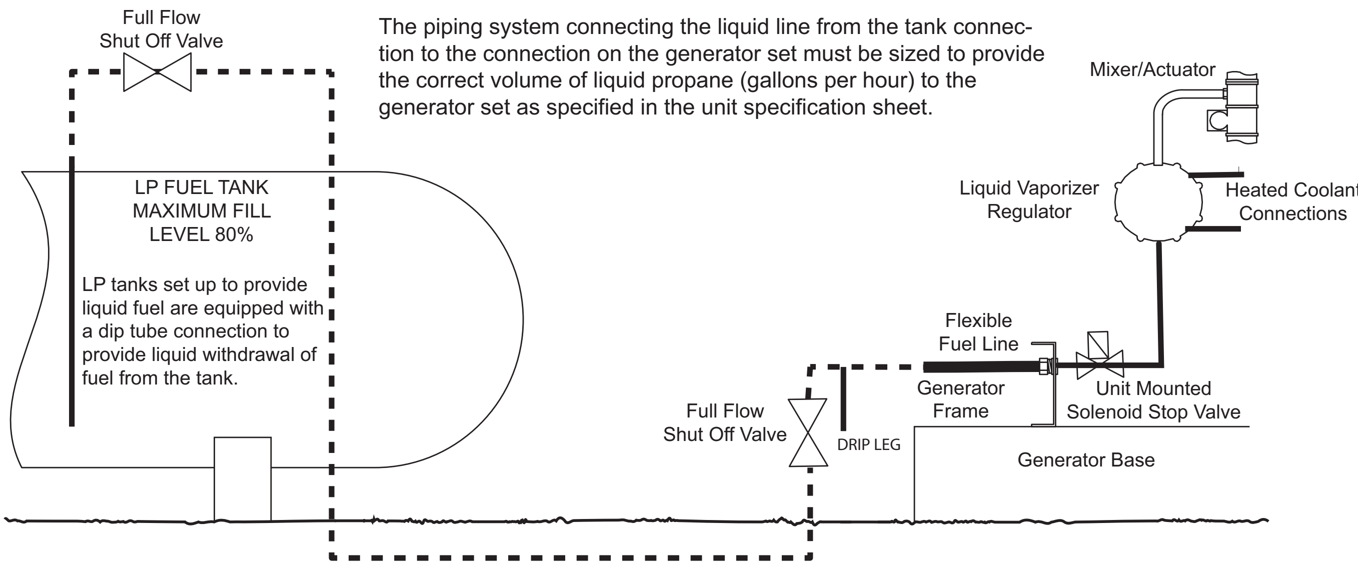


Figure 6-3. LP-Liquid Withdrawal Fuel System

6.3.4— Dual Fuel NG-LP 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 LP-Vapor or LP-Liquid 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 6-4.

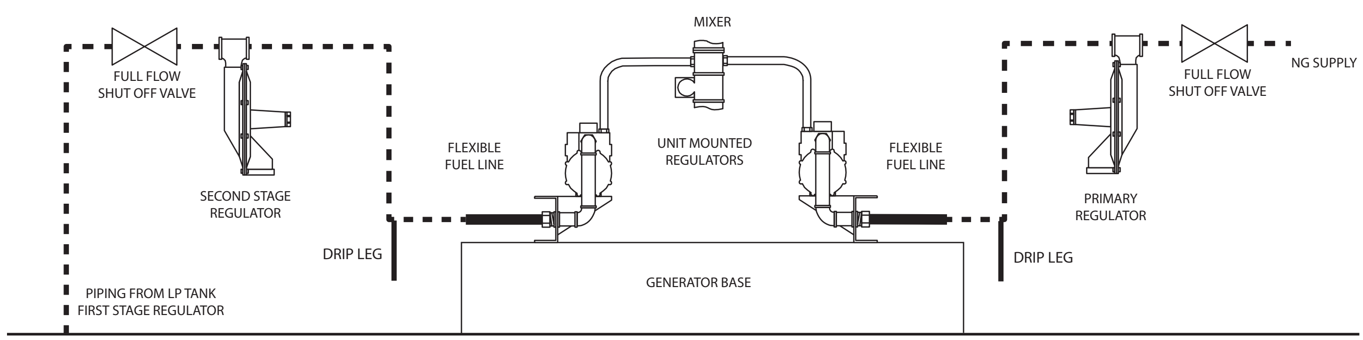


Figure 6-4. Dual-Fuel System

6.3.5— Drip Leg

Install at least one drip leg (sediment trap) before the unit to separate sediment, debris, and condensation from the gas flow. A drip leg is also recommended at the bottom of a vertical pipe run and after each change in direction. Drip legs protect downstream equipment, such as the primary or second stage pressure regulators, from clogging and contamination. Some installations and/or jurisdictions may require multiple drip legs. Consult the local AHJ for requirements.

6.4 — Fuel Pressure Regulators

6.4.1— General

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 and 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.

6.4.2— Definitions

The following definitions are provided for use in this manual.

Table 6-1. Definitions

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 600° F 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. An elbow and short nipple have been incorporated to allow the flexible hose to be positioned parallel to the unit base frame. The size of the connection point on the base frame is shown in each unit's installation drawing; the size of the flexible hose (and any elbow and nipple) must be equal to or larger than this connection point. The flexible hose must be installed straight without bending, twisting or kinking.
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.
Primary Regulator	A pressure regulator installed between the service regulator (NG) or first-stage regulator (LP-Gas vapor) sized to provide the pressure and volume required by the generator at its full rated load capacity.
Regulator (for LP-Gas vapor)	
First-Stage Regulator	A pressure regulator for LP-Gas vapor service designed to reduce pressure from a container to 10.0 psig or less.
High-Pressure Regulator	A pressure regulator for LP-Gas liquid 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 LP-Gas vapor 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)	
Pressure Regulator	Device placed in a gas line for reducing, controlling, and maintaining pressure in downstream piping
Service Regulator	A pressure regulator installed by the servicing gas supplier to reduce and limit the service line gas pressure to delivery pressure.

6.4.3— Best Practices

These are the manufacturer recommended best practices for configuring and sizing 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 help to ensure the generator set engine will operate properly under dynamic conditions.

- The minimum distance from the primary pressure regulator outlet to the generator connection point must not be less than 10 feet of properly sized pipe. Do not connect the pressure regulator directly to the flexible fuel line on the generator. The piping between the primary pressure 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 before the fuel shutoff solenoids at the inlet to the unit mounted regulator. A 1/8 inch pipe port in the pressure regulator body, or in the piping just before the pressure regulator, is provided for this purpose. See Subsection 6.7.1.
- Seasonal supply pressure changes to the primary pressure regulator can affect the proper operation of the generator. The fuel supply pressure to the unit must remain within the specified operating parameters as stated in the unit specification sheet. Contact the local utility to find out what can be done to correct seasonal changes.
- Use water traps.
- The generator set must have its own dedicated fuel supply. Do not connect any other loads to the outlet of the primary pressure regulator.

For LP-Vapor systems, due to the nature of the conversion process from LP liquid to LP vapor, consider the following:

- The vaporization rate of a given LP 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 below 40º F, engine fuel consumption is high, and sufficient humidity is present, condensation can occur resulting in frosting of the tank at the liquid level. This condition can lead to a reduced rate of vaporization. See the LP tank sizing section for more information.

6.4.4— Operating Fuel Pressure

The unit specification sheet lists the operating fuel pressure range, as well as the 100% load fuel consumption rate. The pressure range is the minimum and maximum acceptable pressures for proper operation of the unit under all operating conditions. The maximum fuel system pressure drop at each condition, that is, static, cranking, running at no load, and running at full load, is 1-2 in. w.c. as measured at the primary fuel pressure regulator. For definitions of each condition, see Subsection 6.7.2.

6.4.5— Engine Fuel Consumption

The volume of gaseous fuel consumed at various loads is listed in the unit specification sheet. Both Natural Gas and LP-Vapor values are provided in Cubic Feet per Hour (CFH). LP-Liquid values are provided in Gallons Per Hour (GPH). International units of measure are also provided.

Use the following formulas if it becomes necessary to convert CFH to BTUs per Hour:

- **Natural Gas:** CFH x 1000 = BTU per hour
- **LP-Vapor:** CFH x 2500 = BTU per hour

6.4.6— Fuel Pressure Regulator Sizing

Fuel 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 to provide the required flow at the rated pressure to the generator at its full load capacity. The generator fuel consumption values and required operating pressures are listed in the unit specification sheet.

The manufacturer recommends that the primary pressure regulator be sized for at least 110% of the generator’s required fuel consumption at 100% load, and that the regulator provide no more than a 1-2 inch w.c. pressure drop at each operating condition, that is, static, cranking, running at no load, and running at full load.

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

6.4.7— Recommended Fuel Pressure Regulators

Use only direct acting fuel pressure regulators, such as those made by **Fisher** or **Maxitrol**.

6.4.8— Primary Fuel Pressure Regulator

The following are the recommended “best practices” with regard to specifying, sizing, and installing the primary fuel pressure regulator.

1. Locate the primary fuel pressure regulator no less than 10 feet of pipe length from the generator set connection point.
2. Verify that the regulator:
   - Is sized to have a fuel flow delivery rating (CFH) at least 10% greater than the 100% rated kW fuel consumption requirement of the generator.

     NOTE: The recommended selection for orifice diameters is to use the smallest orifice that will still provide a CFH fuel flow rate at least 1.1 times greater than the required full load CFH rating of the generator set.
   - Is approved for a mechanized engine application. A standard HVAC type regulator or standard appliance regulator is prohibited.
   - Has an accuracy rating of 1% or less and/or have a maximum allowable pressure droop rate of 1-2 inches w.c.

     NOTE: 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. For proper generator operation, a maximum of 1-2 in. w.c. droop is required at each operating condition, that is, static, cranking, running at no load, and running at full load.
   - Has a spring rating within the range of 7 to 15 inches w.c.
3. Be sure that the generator has a dedicated fuel supply which is not shared with any other appliances (furnace, water heaters, ranges, etc.).
4. Check the inlet pressure measured at the regulator body inlet connection when the regulator appears unable to pass the published flow rate. Supply piping up to the regulator can cause significant flowing pressure losses.
5. Be sure the regulator is flowing at least five percent of the normal operating flow when adjusting the pressure set point.
6. Expect approximately a one degree drop in gas temperature for every 15 psid (differential) across the regulator due to the natural refrigeration effect.

NOTE: Freezing is often a problem when the ambient temperature is between 30º and 45º F (-1º and 7º C), particularly with LP-V systems.

7. Point vents down to help avoid the accumulation of water condensation or other materials in the spring case.
8. Keep vents open. Do not use long, small diameter vent lines. Follow the rule-of-thumb: use the next nominal pipe size for every ten feet of vent line, and use three feet of vent line for every elbow in the line.
9. The connection point on the generator is the end of the manufacturer supplied flex hose. The flex hose is the same size as the connection point on the generator frame rail (see installation drawings). It is permissible to install one elbow (90º) and a short nipple between the flex hose and frame rail connection point to allow the flex hose to parallel the frame rail for installation purposes.

6.5 — Pipe Sizing Considerations

6.5.1— General

Consult a local gas distributor or licensed installer when sizing and installing the piping for any gaseous fuel supply system. When using a local gas distributor or installer, be sure they have the proper documentation to support their recommendations. 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 test of the system is measuring the fuel pressure as described in Subsection 6.7.1. If the pressure requirements are not met, then the fuel supply system is not correct.

There are several pipe sizing programs available for use on the Internet and from various manufacturers. If used it is highly recommended that the minimum pressure drop value always be used (0.5 inches w.c or less). This will ensure that the piping system is sized correctly to handle the generator set volume at full load, and during cranking and load transients, while also remaining above the minimum operating pressure.

The following general rules apply to piping of gaseous fuel systems:

- Use black iron piping rigidly mounted and protected against vibration.
- Install the supplied or recommended length of flexible hose between the generator connection point and the rigid supply piping. Install the flexible hose straight without bends, twists or kinks. Do not install the flexible hose underground or in contact with the ground.
- Install a drip leg.
- Correctly size the piping to maintain the required supply pressure and volume under varying load conditions.
- Properly purge and leak test installed piping.
- Use an approved pipe sealant or joint compound on all threaded fittings to reduce the possibility of leakage.
- Make provision for a fuel shutoff valve near the unit. Verify that the fuel shutoff valve is installed correctly and works properly.

6.5.2— Minimum Recommended Pipe Length

Mount the primary pressure regulator no less than **ten** feet of total pipe length from the generator connection point. The volume of piping between the regulator and the load acts as a mechanical “capacitor” which stores gas and will minimize changes in delivery pressure that the generator sees during starting and load changes.

6.6 — Pipe Sizing Practices

Two methods of sizing pipe are provided. One is for short pipe runs with minimal or no bends and is based on the size of the fuel pressure regulator outlet. The second method is for long pipe runs with multiple bends and is based on the actual length of the run and the specific number and type of pipe fittings.

6.6.1— Short Runs with Few or No Bends

Size fuel supply piping so that it is one pipe size larger than the fuel pressure regulator outlet. For example, if the fuel pressure regulator outlet is 1-1/2 inches in diameter, install a 2 inch diameter pipe run using suitable adapters. See Figure 6-5.

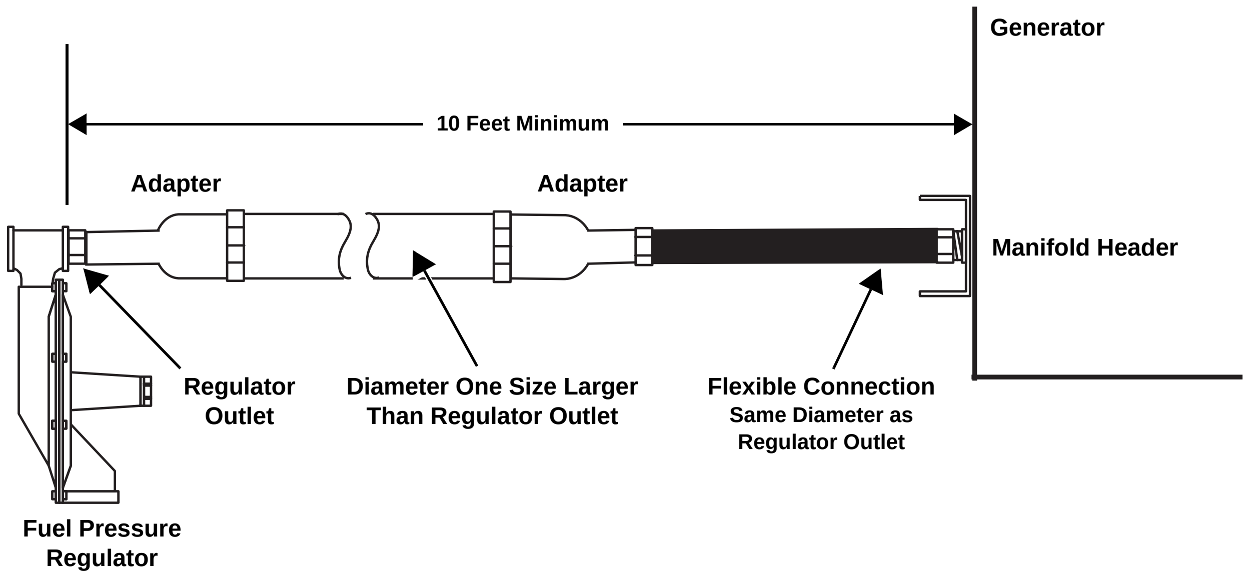


Figure 6-5. Pipe Sizing Based on Regulator Outlet Diameter

6.6.2— Long Runs with Multiple Bends

The *Equivalent Pipe Length Method* is another way to calculate the required pipe size for a generator installation. The method converts pressure losses inherent in pipe fittings into a *length of pipe* value, which is then added to the total linear run of estimated pipe length used in the fuel supply system.

The total linear run of pipe length is measured from the primary fuel pressure regulator outlet to the fuel inlet connection point on the generator. The planned system is broken up into straight pipe runs, and the total length of straight pipe determined by adding each straight pipe run section together.

Pipe fittings (elbows, tees, couplings, unions, etc.) create a pressure loss due to the inherent resistance coefficient special to each fitting, and must be accounted for separately and individually. Various tables are available which provide the equivalent length of straight pipe for each fitting.

6.6.3— Natural Gas and LP-Vapor Pipe Sizing

To calculate pipe size for a generator set operating on NG or LP-Vapor fuel, proceed as follows:

1. From the unit specification sheet, obtain the fuel consumption rate stated in cubic feet/hour (CFH) when operating the generator set at 100% rated kW. Multiply the CFH value by 1.10 to size the regulator, piping and pipe fittings to 110% of the units full load fuel consumption volume.

NOTE: For LP-Vapor units, the table values are shown in thousands of BTUs per hour. To convert the LP-Vapor fuel consumption from CFH to BTU/hour, multiply the CFH value by 2500.

2. Verify that the primary fuel pressure regulator (or LPV second stage regulator) selected provides the necessary volume of flow at the pressure required (with no more than 1-2 in. w.c. pressure drop at each operating condition, that is, static, cranking, running at no load, and running at full load).
3. Write down the linear or run distances (in feet of pipe) from the primary fuel pressure regulator outlet to the fuel inlet connection on the generator set.

   NOTE: The pipe run distance used to calculate proper sizing is never less than 10 ft., which is the minimum acceptable distance between the regulator outlet and the generator connection point.
4. Record the total number and size of all pipe fittings between the primary fuel pressure regulator outlet and the generator fuel inlet connection. Since the equivalent pipe length of fittings is determined by the fitting size, start with a pipe size equal or larger than the fittings on the body of the selected regulator. For example, if the regulator has a fitting size of 1-1/2 inch, start with same size pipe and fittings.
5. Convert each pipe fitting into its Equivalent Pipe Length value. For the most common types of fittings, see Table 6-4. Also it is important to note that there is a significant difference in equivalent pipe length between tee fittings when the flow is straight through and tee fittings when the flow is through the branch. For valves, most valve manufacturers provide either CV values or the equivalent pipe length.
6. Add up the equivalent pipe lengths for all the different pipe fittings used.
7. Add the linear or run distances noted in step 3 to the calculated equivalent pipe lengths of all fittings calculated in step 6. This is the Total Calculated Pipe Length for the fuel supply system.
8. Move to Table 6-2 for NG fuel (specific gravity 0.60) or Table 6-3 for LP-Vapor fuel systems (specific gravity 1.50).
9. From the first column of the appropriate table, locate the Total Calculated Pipe Length that most closely matches the actual length calculated in step 7. Always round up to the next longer pipe length listed in the table (e.g., if the calculated length is 41 ft., select a pipe length of 45 ft. from the table).
10. Move across the table to the selected pipe size/fittings. If the CFH figure equals or exceeds the value calculated in step 1, then the selected pipe size is adequate. If the figure is below the calculated CFH, then go to the next larger size pipe and repeat the calculations starting at step 5.
11. Verify the actual specific gravity of the gas with the supplier, as all calculations performed are based on a specific gravity of 0.60. If the specific gravity of the gas is different, multiply the CFH value calculated in step 1 by the appropriate multiplier listed in Table 6-5. With the revised CFH, return to step 2 to repeat the calculations for sizing the regulator, pipe size and fittings.

    NOTE: A properly configured and sized fuel system provides the required fuel volume and pressure for the generator set to operate correctly under all conditions. Verify that the maximum fuel system pressure drop at each operating condition, that is, static, cranking, running at no load, and running at full load, does not exceed 1-2 in. w.c. as measured at the primary fuel pressure regulator. For definitions of each condition, see Subsection 6.7.2.

Table 6-2. Iron Pipe Sizing for Natural Gas (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. as Measured at End of Pipe Run								
Schedule 40 Pipe Size (in.)								
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**							
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
This table shows the flow capacity of Natural Gas with a specific gravity of 0.60 in cubic feet per hour through standard schedule 40 pipe at a pressure drop of 0.3 in. w.c. from one end of the pipe run to the other. For gases with specific gravity other than 0.60, apply the corresponding multiplier shown in Table 6-5.								

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Table 6-3. Iron Pipe Sizing for Undiluted LPG Vapor

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. as Measured at End of Pipe Run								
Intended use for piping between Second-Stage regulator and generator connection point								
Schedule 40 Pipe Size (in.)								
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 Thousands of Btu per Hour**							
10	608	1150	2350	3520	67900	10800	19100	39000
20	418	787	1620	2420	4660	7430	13100	26800
30	336	632	1300	1940	3750	5970	10600	21500
40	287	541	1110	1660	3210	5110	9030	18400
50	255	480	985	1480	2840	4550	8000	16300
This table shows the flow capacity, in thousands of Btu per hour, of undiluted LP-Gas vapor, with a specific gravity of 1.50, through standard schedule 40 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. For pipe length and diameters or flow rates not shown, consult a local gas supplier/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 per hour (CFH) to BTU per hour, multiply by a factor of 2500. To convert BTU per hour to cubic feet per hour (CFH), divide by a factor of 2500.								

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Table 6-4. Standard Screw Fittings

Pipe Size (in.)	I.D. (in.)	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
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.					

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Table 6-5. 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 Natural Gas (Typical)	1.00	1.50 LP-Vapor (Typical)	0.63
0.65	0.96	1.60	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
This table shows the multipliers for gases with a specific gravity different from that used in Table 6-2 and Table 6-3. To use the table, obtain the specific gravity (SG) of the gas used from the gas supplier. Find the SG value in the table, and use the multiplier provided in the next column. Apply the multiplier to the flow rate for the pipe size and length found in either Table 6-2 (Natural Gas flow rates in CFH) or Table 6-3 (LP-Vapor flow rates in thousand of BTU/hr).			

6.6.4— LP-Liquid Pipe Sizing

Sizing pipe for LP-Liquid withdrawal is slightly simpler than for vapor withdrawal. The liquid will be supplied from the source (tank) at a pressure usually between 50 and 180 psi. The size of the connection point on the generator base frame is shown in the installation drawing for the unit.

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

1. Obtain the Gallon Per Hour (GPH) fuel consumption rating of the generator set when operating at 100% rated kW from the unit 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.
3. Using Table 6-4, 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.
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 Table 6-6, locate the gas flow required for the unit (volume at 100% load) in the left hand column. Column-1 provides flow rates in CFH, and Column-2 provides flow rates in GPH. Move across the table row until you come to a pipe length value greater than the calculated pipe distance found in Step 4.
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.

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Table 6-6. LP-Liquid Pipe Sizing

Liquid Gas Flow (CFH)	Liquid Gas Flow (GPH)	Maximum Pipe Length in Feet (Standard sch 40 Pipe)			
		1/4 inch	3/8 inch	1/2 inch	3/4 inch
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

6.6.5— Sizing LP Tanks for Vapor Withdrawal

The manufacturer recommends that the installer consult with a reputable LP supplier when sizing LP storage tanks and their associated pressure regulators and piping systems. Many factors come into play when working with LP in either its vapor or liquid form.

The operation of an LP-Vapor 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 (-44º F for Propane, and 15º F 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 condition further inhibits the heat transfer required to sustain vaporization.

Several factors affect the rate of vaporization for LP 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 LP 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 lowest normal temperature expected. Typical tank tables provide vaporization rates at 40º F, 20º F, and 0º F. For temperatures below 0º F consult a reputable LP dealer for options.
- The mean relative humidity.

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

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

The most important thing to consider when sizing LP 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 Table 6-7 are based on the tank at 20% of its fill capacity.

1. Multiply the gallons per hour fuel consumption rate of the generator at 100% load by the longest run time expected/desired.
2. Determine the fuel consumption in BTU/hr with the generator at 100% load.
3. Determine the lowest expected operating temperature.
4. See Table 6-7. Using both the Minimum Operating Temperature and the Tank Vaporization Capacity columns, find the BTU/hr vaporization rate of the generator at 100% load that corresponds to the lowest expected operating temperature.
5. Look back at column 2, note the Available Tank Capacity. If it is greater than the total run time fuel consumption refer back to column 1- this is the correct size tank required. If it is less than the total run time fuel consumption, then go to the next larger tank size. Recheck the lowest operating temperature and the tank vaporization capacity.

Table 6-7. Vaporization Rates

Tank Capacity Total (gal) See Note 1	Available Tank Capacity (gal) See Note 2	Minimum Operating Temperature (° F)	Tank Vaporization Capacity (BTU/hr) See Note 3	Length (In.)	Diameter (In.)
250	150	40 20 0	507,600 338,400 169,200	94	30
325	195	40 20 0	642,600 428,400 214,200	119	30
500	300	40 20 0	792,540 528,360 264,180	119	37
850	510	40 20 0	1,217,700 811,800 405,900	165	41
1000	600	40 20 0	1,416,960 944,640 472,620	192	41

Note 1: The minimum LP tank size is 250 gallons, unless unit calculations dictate use of a larger tank. Vertical tanks, which are measured in pounds, will not usually meet the minimum tank size (250 Gallons x 4.20 Pounds = approximately a 1050 pound vertical tank minimum).

Note 2: 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 3: The vaporization capacity shown 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 and the vaporization rate increases.

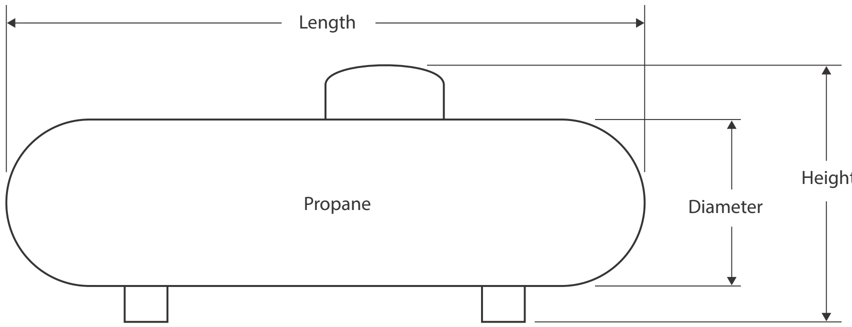

Figure 6-6. Typical Propane Tank Dimensions

NOTE: The minimum LP tank size is 250 gallons, unless unit calculations dictate use of a larger tank. Vertical tanks, which are measured in pounds, will not usually meet the minimum tank size (250 Gallons x 4.20 Pounds = approximately a 1050 pound vertical tank minimum).

Propane conversion figures:

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

6.7 — 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.

6.7.1— Gas Pressure Test Port Location

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

See Figure 6-7. On units using the demand type regulator(s), there may be a 1/8 inch pipe port in a tee fitting connected to the low pressure switch. If the unit has a low pressure switch without the tee, install a tee and plug between the low pressure switch and the test port on the regulator body using a suitable pipe dope. See Figure 6-8. Use only the upper port on the regulator body, as it detects supply gas pressure even when the unit solenoid valve is closed. This allows static pressure to be measured, as well as pressure when cranking, while running at no load, and while running at full load.

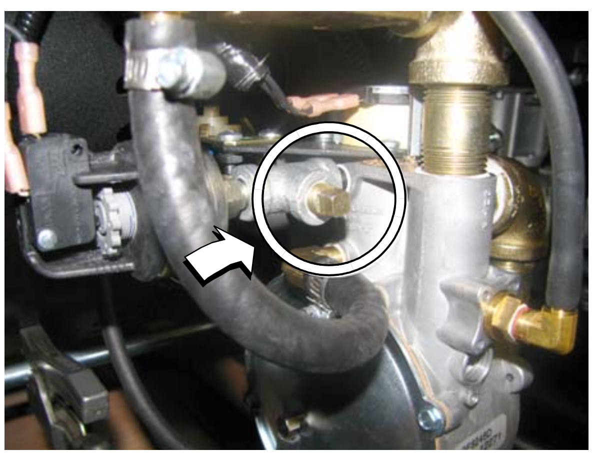

Figure 6-7. Factory Provided Fuel Pressure Test Port Tee With Plug.

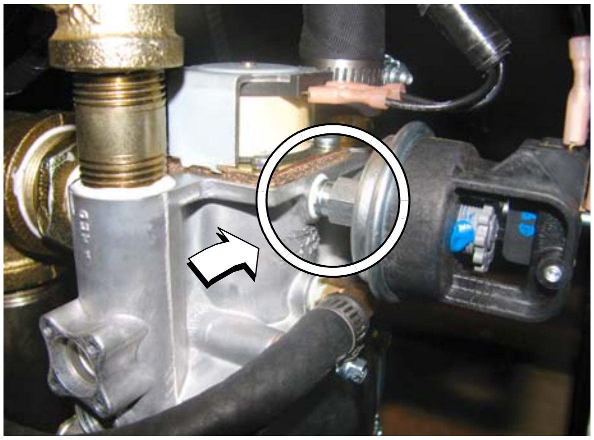

Figure 6-8. Install Appropriately Sized Tee With Plug At This Location.

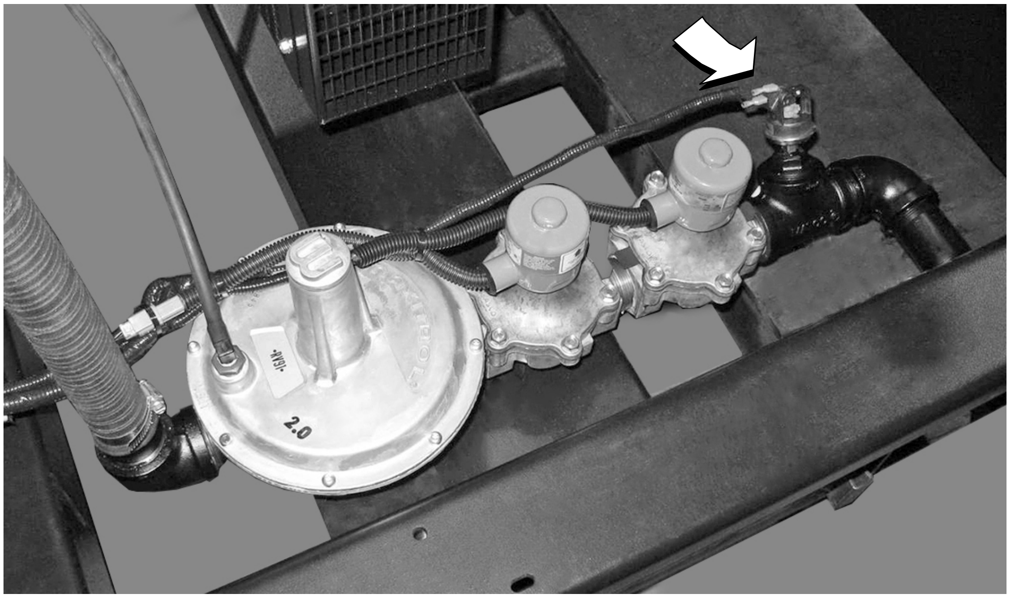

Figure 6-9. Fuel Pressure Test Point on 150kW and Larger Units.

On large units using the dual fuel shutoff solenoids, the low pressure switch is located in the piping as shown in Figure 6-9. Remove the switch and install an appropriately sized tee and plug between it and the fuel line.

6.7.2— Final Test Procedure

The following test must be performed at startup to document and validate fuel system operation. It requires a 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.

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

1. **Static Pressure.** Pressure when the unit is not running. Must not exceed the maximum pressure listed in the unit specification sheet.
2. **Cranking Pressure.** Pressure when the unit is cranking. Must not drop more than 1 in. w.c. below *Static Pressure* or below the minimum pressure listed in the unit specification sheet. If it does, it may indicate that fuel supply piping is not correctly sized, or that primary regulator is improperly sized or mounted too close to the generator connection point. The unit may experience hard starting, or will not perform as expected at full load or during load transients.

3. **Running- No Load Pressure.** Pressure when the unit is running at rated frequency and voltage with no load. Should be at or slightly below the maximum pressure as listed in the unit specification sheet.
4. **Running- Full Load Pressure.** Pressure when the unit is running with full rated load applied (**kW**). Pressure should not drop more than 1-2 in. w.c. from the *Running- No Load Pressure* and must **NEVER** drop below the minimum pressure listed in the unit specification sheet.

Section 7 Diesel Fuel Systems

7.1 — General Information

Since diesel fuels are less volatile than gasoline or gaseous fuels, they are sometimes considered safer. Due to this perception, careless installation practices can occur, which may lead to serious problems with generator set performance and reliability.

Periodically inspect and test the system to be sure all components remain in good working order.

⚠ DANGER!

Be aware that the fuel systems in modern diesel engines are highly pressurized, with fuel pressures reaching as high as 5000 psi. Escaping fuel at these pressures can easily and instantly penetrate clothes and skin causing fuel to be injected into body tissues, possibly resulting in amputation or death.

7.2 — Diesel Fuel Base Tank

Units provided are typically mounted on their own base/fuel tank. See Figure 7-1. These are plumbed at the factory. The base tank is the main fuel tank and incorporates the following items:

- Fill Line – some are equipped with overflow containment.
- Vent Line – some applications require extending the vent line outside of an enclosure or to outside air along with adequate spill containment.
- Fuel supply line to engine pump with in-line check valve.
- Fuel return line from engine, sometimes supplied with a check valve.
- Fuel level indication (electrical, mechanical or both).
- Double wall construction with rupture basin and level indicator switch.
- Emergency vent on main tank and rupture basin.

7.3 — Diesel Fuel Recommendations

Use **No.1D** diesel fuel when temperatures are below freezing. Use **No. 2D** diesel fuel when temperatures are above freezing. Diesel fuel must also meet the requirements described below.

1. Beginning October 1, 2007, diesel fuel used by owners and operators must meet:
   A. Sulfur content of 500 parts per million (ppm) maximum.
   B. Minimum cetane index of 40 or a maximum aromatic content of 35 volume percent.
2. Beginning October 1, 2010, diesel fuel used by owners and operators must meet:
   A. Sulfur content of 15 parts per million (ppm) maximum.
   B. Maximum cetane index of 40 or a maximum aromatic content of 35 volume percent.

Allow at least 5 percent of the tank capacity for fuel expansion. **DO NOT OVERFILL!**

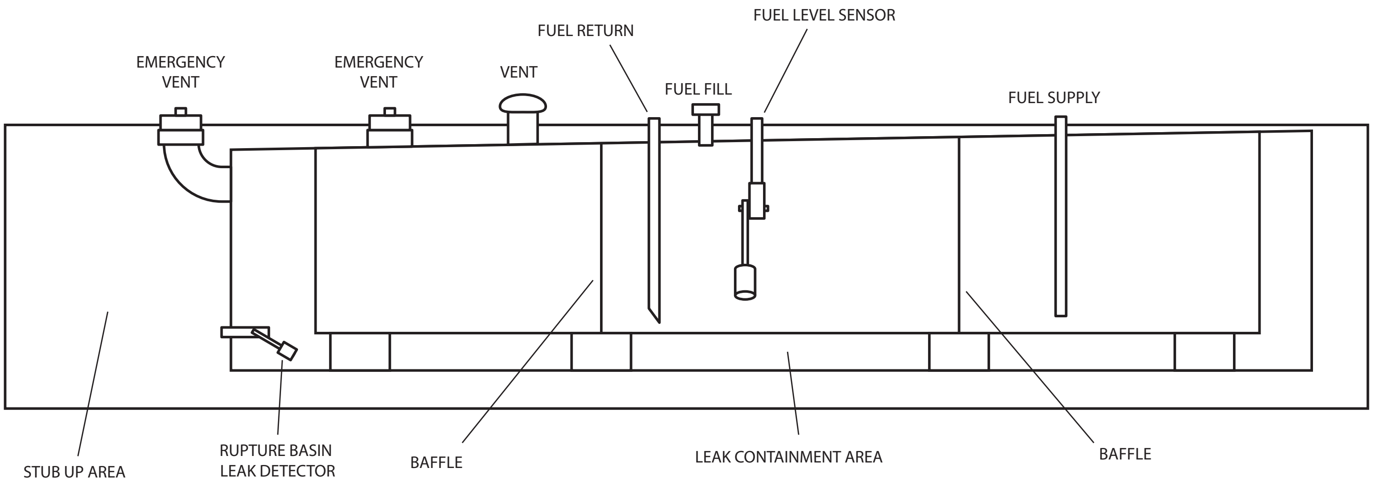

Figure 7-1. ***A Typical Diesel Fuel Base Tank***

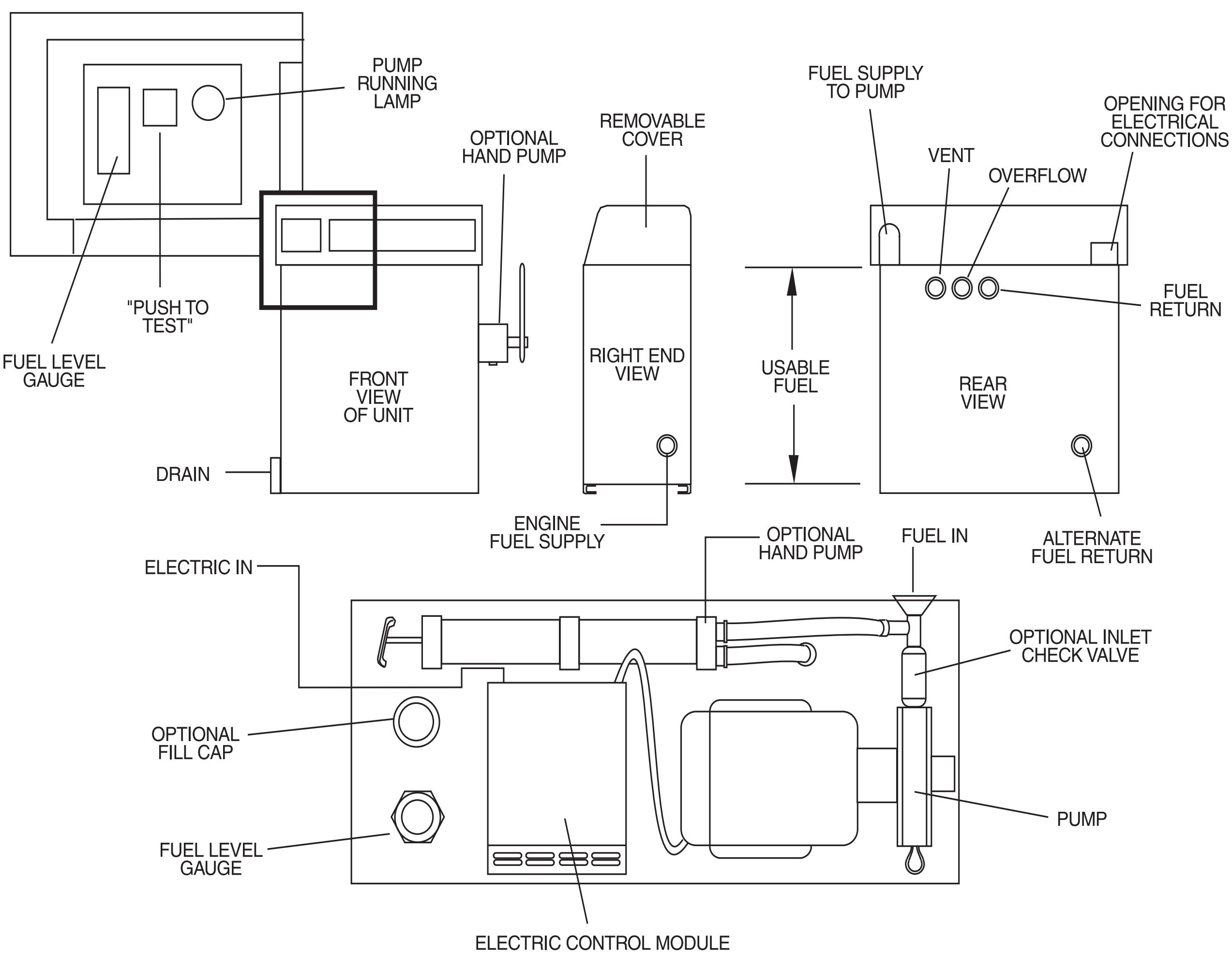

Figure 7-2. Typical Day Tank

7.4 — Day Tanks

A day tank is a diesel fuel tank located inside a structure that supplies fuel to the generator set. Day tanks typically incorporate fuel transfer pumps and controls to replenish their fuel supply from an even larger fuel supply tank. Day tanks incorporate the same features found in a typical base tank, such as fuel fill, fuel vent, supply and return connections, safety vent, double wall for fuel containment, fuel level gauge, water drain, etc. See Figure 7-2.

- Mount day tanks so that their fuel level is lower than the engine fuel injectors. The vertical lift between the day tank and the engine must not exceed 40 inches. Avoid excessive pipe run between the day tank and engine connection points. Pipe run that is too long can provide too much resistance causing poor operation or premature failure of the engine mounted fuel pump, in addition to problems with the engine starting, running, and carrying load.
- The size of the connection points on the base rail of the unit are given in the NOTES section of the unit installation drawing. To prevent leaks or breakage caused by vibration, shifting or settling, install a flexible length of APPROVED fuel line between the base rail connection point and the rigid supply piping.
- Numerous guidelines apply to open set generators installed inside buildings or other structures. Foremost is fire safety. The following are some general guidelines that apply to diesel fuel supply requirements for indoor applications or applications with units that do not use a base tank.
- Use black iron or steel piping for lines from the fuel source to the base connections. Do not use galvanized pipe for diesel fuel applications.
- Avoid cast iron and aluminum fittings and pipe as they are porous and can leak.
- Install a flexible length of fuel line between the rigid fuel supply piping and the generator fuel connection.
- The best location for diesel fuel supply tanks is at the same level as the engine fuel pump, but lower than the fuel injectors. If the fuel supply level is higher than the fuel injectors, it could allow leakage through the nozzles into the cylinders causing hydraulic lock and other engine damage.
- Vertical lift between the engine fuel pump and the fuel level in the tank should not exceed 40 inches. If vertical lift is greater, or the supply piping run is too long, an auxiliary pump or a day tank may be necessary.
- Locate fuel filters and drains in easily accessible areas to promote regular and frequent service. Cleanliness of the fuel is critical for diesel engines, which have precision fuel injectors and pumps that are easily clogged or damaged.

7.5 — Other Options and Considerations

Most diesel engines today incorporate primary and secondary fuel filters designed to protect the engine fuel system components from contamination. In addition to the built-in fuel filters/separators, secondary filter systems are available to provide added functionality: water/fuel separators, fuel heaters/coolers, and additional fine filtration capacity.

Always prime engines before starting. Once started, run at no load long enough to ensure that air is evacuated from the fuel lines and that fuel filters are full. See the Start Up and Commissioning Addendum (Part No. 0166430MMM) for details.

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Section 8 *Electrical System*

8.1 — General Information

All wiring must be properly routed, supported, and connected. Wiring also must be properly sized to carry the maximum load current to which it will be subjected.

The generator utilizes Customer Connection Interface (CCI) panels which separate the high and low voltage wiring connections. These two panels are clearly labeled. The wiring diagrams for each specific unit show the connection points in their corresponding sections. Terminal boards are clearly labeled and correspond to the same terminal connections shown in the wiring diagrams. Always use the unit specific wiring diagrams when making wiring connections.

8.2 — Wiring Installation-Connection Safety

It is highly recommended that the installer review the safety rules at the beginning of this manual for specific dangers, cautions, and hazards associated with the installation of any industrial product.

When installing the generator set and connecting any of the wiring it is important to keep the generator and system de-energized and disabled. Disable the generator by placing the AUTO/OFF/MANUAL switch in the OFF position, de-energize the battery charger, and disconnect the negative lead from the negative battery terminal. Make sure the 120/240, 120/208 auxiliary power circuit to the unit is de-energized.

It is common electrical safety practice to verify that wires are de-energized (using appropriate safety gear and a meter) before handling.

8.3 — General Wiring Requirements

The following are some general wiring requirements to be considered during the installation.

- Load Wiring - Properly size and select wiring.
- Accessory Power Wiring - Size and select wiring using the appropriate tables in the NEC and per the connection requirements in the individual control panel wiring diagram.
- Control Wiring - Typically low DC voltage wiring (12-24Vdc) that includes the 2-wire start and signal wiring (ATS Position, backup wiring for MPS), spare output customer wiring to the auxiliary relay board, power for remote annunciators, and backup power to the System Controller (MPS), etc. Use multi-strand wire appropriately sized for the length of run. Do not exceed #14 AWG when connecting to the customer connection terminals.
- Communication Wiring - For RS-485 communications to remote annunciators (RAP), HUIO, HTS and MTS transfer switches, and between MPS generators and the System Controller. Use shielded wire sized for the length of run. See the wiring recommendations in the applicable annunciator and controller owner's manuals.
- Correctly tighten all terminals using the torque specifications on the unit wiring diagram or on the labels inside the control panel.

8.4 — High Voltage Customer Connections

The high voltage customer connection panel contains the terminals to connect all of the high voltage wiring, greater than 30 VAV/ 60 VDC, between the unit and the customer load and service panels. It contains connection points for the following items:

- MLCB - E1, E2, E3, and Neutral for customer load wiring.
- TB4 -120/240 VAC terminals for accessory power. This power should come from a customer utility supply source (with appropriate sized breaker) which is also powered by emergency power during an outage. This power is for the unit battery charger as well as any of several optional items shown in the Common Options block of the wiring diagram. Read the notes regarding the maximum wire size and tightening torque for the field wiring to the customer connection terminal strip (TB4).

- 120/240 or 120/208 VAC Optional Load Center. Provides circuit protected power for various options including Coolant Heaters, Oil Heaters, Battery Charger, Alternator Heaters, Enclosure Lighting, etc.
- Optional GFCI and 240 VAC receptacles. Provides a place to plug in optional coolant heater, battery warmers, and oil heaters.
- Optional Run Relay and its related terminal connections (TB5).

Table 8-1. Field Wiring

<table>
<tr><th>Breaker Frame</th><th>Circuit Breaker Range (A)</th><th>Wire Type</th><th>Wire Temperature Rating</th><th>Circuit Breaker Lug AWG Wire Range/(Number of Conductors)</th><th>Torque to Wire</th></tr>
<tr><td>Series G - JG Frame</td><td>20 - 250</td><td>Cu</td><td>75º C/167º F</td><td>4-350 kcmil (1)</td><td>180 in-lb</td></tr>
<tr><td>Series G - LG Frame</td><td>160 - 600</td><td>Cu/Al</td><td>75º C/167º F</td><td>2-500 kcmil (2)</td><td>375 in-lb</td></tr>
<tr><td rowspan="6">Series C - F Frame</td><td rowspan="4">15 - 100</td><td rowspan="4">Cu/Al</td><td rowspan="6">75º C/167º F</td><td rowspan="4">14-1/0 (1)</td><td>(#14-10) 35 in-lb</td></tr>
<tr><td>(#8) 40 in-lb</td></tr>
<tr><td>(#6-4) 45 in-lb</td></tr>
<tr><td>(#3-1/0) 50 in-lb</td></tr>
<tr><td>60 - 200</td><td>Cu/Al</td><td>4-4/0 (1)</td><td>120 in-lb</td></tr>
<tr><td>100 - 225</td><td>Cu/Al</td><td>6-300 kcmil (1)</td><td>120 in-lb</td></tr>
<tr><td>Series C - J Frame</td><td>250</td><td>Cu</td><td>75º C/167º F</td><td>4-350 kcmil (1)</td><td>275 in-lb</td></tr>
<tr><td rowspan="3">Series C - K Frame</td><td>225</td><td>Cu/Al</td><td rowspan="3">75º C/167º F</td><td>3-350 kcmil (1)</td><td>275 in-lb</td></tr>
<tr><td>300</td><td>Cu/Al</td><td>250-500 kcmil (1)</td><td>375 in-lb</td></tr>
<tr><td>350 - 400</td><td>Cu/Al</td><td>3/0-250 kcmil (2)</td><td>275 in-lb</td></tr>
<tr><td rowspan="2">Series C - L Frame</td><td>450 - 500</td><td>Cu/Al</td><td rowspan="2">75º C/167º F</td><td>3/0-350 kcmil (2)</td><td>275 in-lb</td></tr>
<tr><td>600</td><td>Cu/Al</td><td>400-550 kcmil (2)</td><td>275 in-lb</td></tr>
<tr><td>Series C - M Frame</td><td>700 - 800</td><td>Cu/Al</td><td>75º C/167º F</td><td>3/0-400 kcmil (3)</td><td>375 in-lb</td></tr>
<tr><td rowspan="2">Series C - N Frame</td><td>900 - 1000</td><td>Cu/Al</td><td rowspan="2">75º C/167º F</td><td>4/0-500 kcmil (4)</td><td>375 in-lb</td></tr>
<tr><td>1200</td><td>Cu/Al</td><td>500-750 kcmil (3)</td><td>450 in-lb</td></tr>
<tr><td>Series C - R Frame</td><td>1400 - 1600</td><td>Cu/Al</td><td>75º C/167º F</td><td>500-1000 kcmil (4)</td><td>550 in-lb</td></tr>
</table>

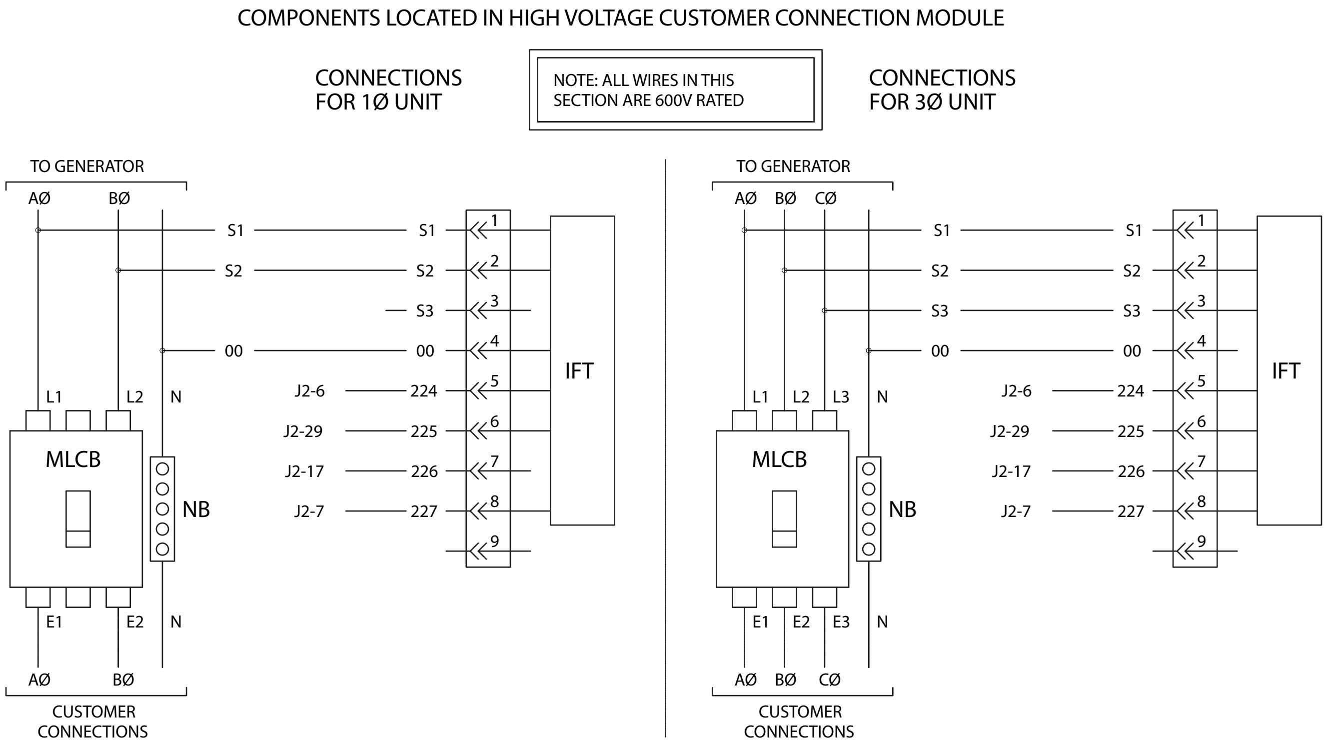

Figure 8-1. Typical Industrial Diagram Showing Load Lead Connections to MLCB

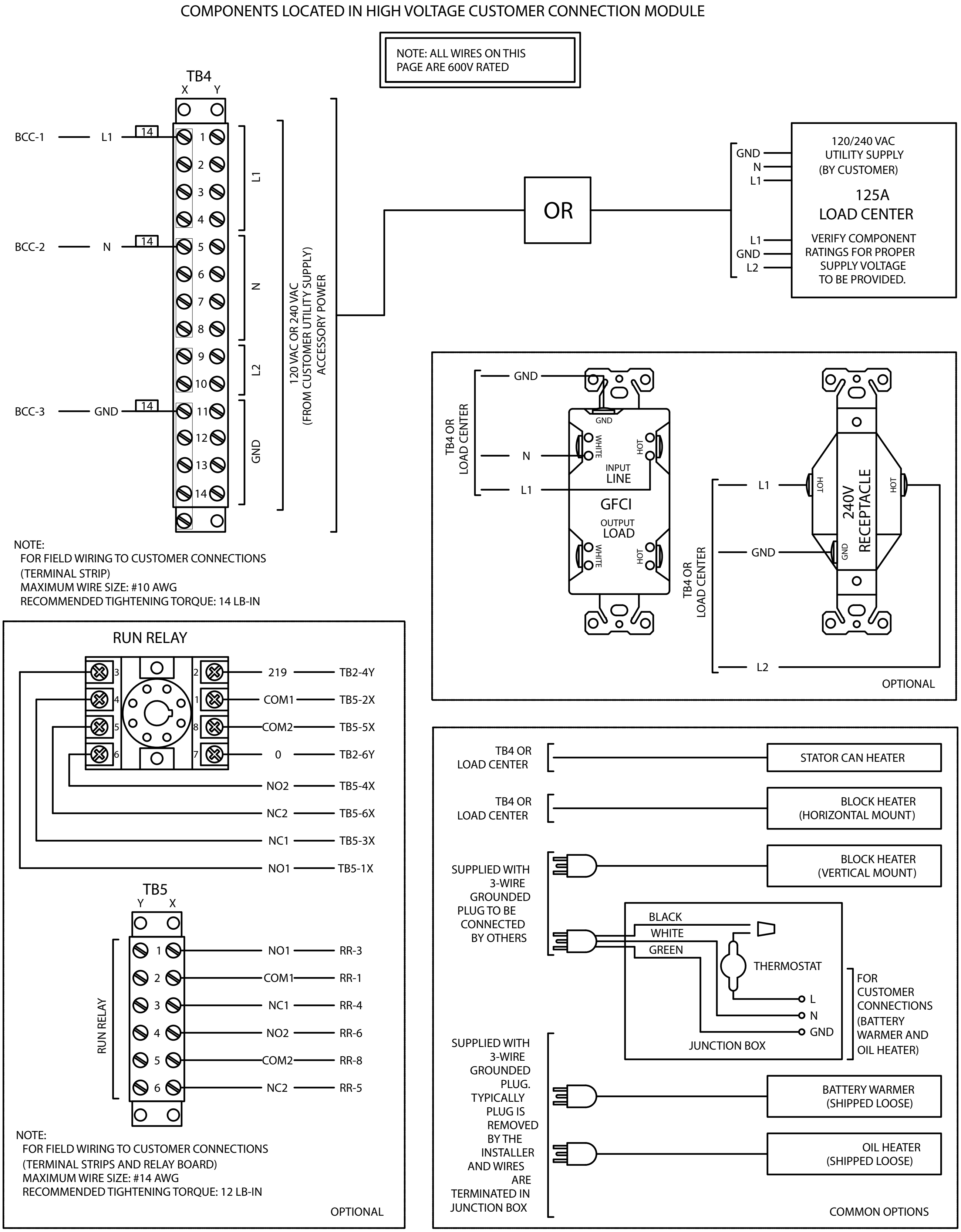

Figure 8-2. Typical Customer Connection in High Voltage Connection Module

Customer load wiring consists of the single-phase or three-phase connections between the transfer switch and the generator Main Line Circuit Breaker (MLCB). The wiring connects to the lugs on the E1, E2, E3, and neutral terminals of the MLCB. For general information regarding wire type, temperature rating, size range, and wire lug torque specifications, see Table 8-1.

8.5 — Field Wiring Connections to Buss Bars

Units supplied with Series C - R Frame Breakers rated 1400, 1600, 2000, and 2500A have buss bars supplied in the connection module for connection of the field conductors. To obtain a suitable electrical connection at the buss bars, take note of the following information.

- **Conductor Lugs:** Buss bars accept aluminum compression lugs suitable for copper or aluminum strand wire.
- **Suggested Manufacturer:** Penn Union Corporation.
- **Manufacturer's Part Number:** BLUA060D2.
- **Type:** Dual rated (AL/Cu), two 1/2" studs spaced 1-3/4" apart.
- **Wire Size:** 600 kcmil.
- **Hardware/Torque**:

  Fasten lugs to buss bars using either M12 or 1/2 in. fasteners as follows:

Hardware	Torque
M12 X 65 mm Grade 8.8 Hex Head Cap Screw, with M12 Flat Washers, Lock Washer and Nut	Dry 75 ft-lbs, Lubed 58 ft-lbs
1/2" -20 X 2.5" Grade SAE 5 Hex Head Cap Screw, with 1/2" Flat Washers, Lock Washer and Nut	Dry 85 ft-lbs, Lubed 65 ft-lbs

8.6 — Low Voltage Customer Connections

The Low Voltage Customer Connection Panel is where all of the low voltage control and communication wiring is connected. This wiring includes the following, depending on the type of system. Stand-alone and MPS system share some similar wiring requirements, with MPS systems having additional requirements depending on options used.

The low voltage customer connections typically use Class 1 Wiring Methods (NEC Article 725). Always follow the standards and methods appropriate to the circuits being wired.

Observe the maximum wire size and torque values for the terminal strip connections shown in the unit wiring diagram.

- Two-Wire Start - Typically labeled REMOTE START or 2-WIRE START; on the control side consists of wires 183 (5VDC signal) and wire 0 (control ground). This control circuit is looking for remote start contact closure at the transfer switch.
- Line Power, Gen Power - 3 wires from the Automatic Transfer Switch auxiliary contacts indicating switch position. The wires on the control side are labeled DI-3 (Line Power), DI-4 (Gen Power), and 0 (Control Ground). DI-3 and DI-4 carry a 5VDC signal looking for contact closure to control ground (wire 0) at the transfer switch.
- Communications RS-485 - Typically labeled COMM PORT RS485 +, -, and SHLD. On the control side they are labeled 390, 391, and SHLD. Communication wire must be stranded, twisted, shielded wire. The shield is typically grounded at only one end of each run. This communication wire connects to Remote Annunciator Panels (RAP) and Remote Annunciator Relay Panels (RRP), HTS and MTS transfer switches.
- DC power for remote annunciator panels - Typically labeled FUSED DC. On the control side it is labeled 220A (fused 24VDC) or 15A (fused 12VDC). The GND on the same terminal strip must be used to complete the circuit.
- Spare Outputs, Customer Configurable Relays - Typically labeled SPARE OUTPUTS, these output relays can be configured to provide contact change for up to four status indicators. The output relay contacts are rated for 5A at 30VAC/30VDC. The relays are programmed using Genlink-DCP software working with the control panel.

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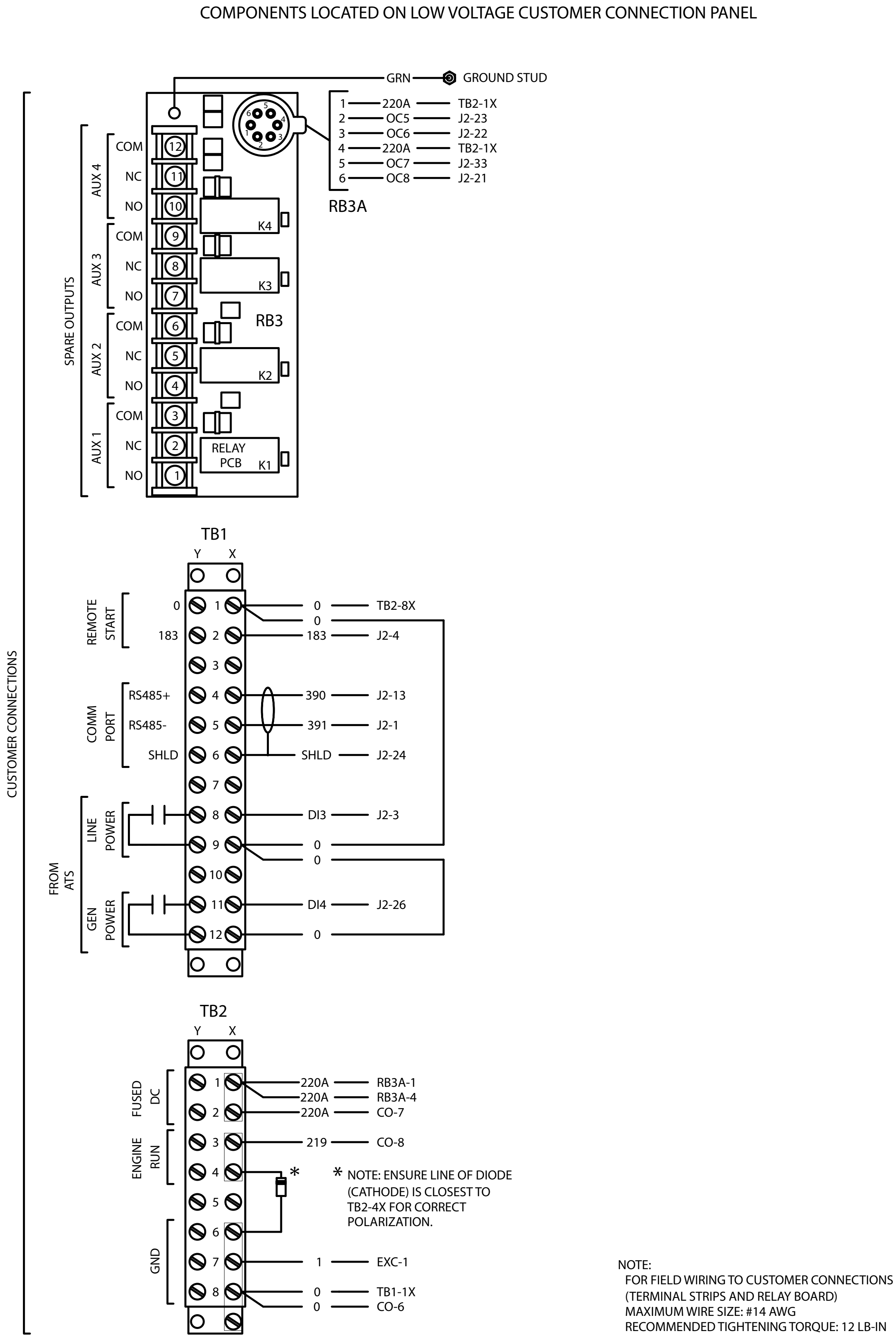

Figure 8-3. Typical Industrial Low Voltage Connection Panel Diagram

Table 8-2. Low Voltage Control Wiring Length/Size

Maximum Cable Length	Recommended Wire Size
Up to 460 feet (140m)	No. 18 AWG
461 to 730 feet (141 to 223m)	No. 16 AWG
731 to 1,160 feet (223 to 354m)	No. 14 AWG
1,161 to 1,850 feet (354 to 565m)	No. 12 AWG

8.7 — Transfer Switch Location

The location of the transfer switch is important. Consider the following:

1. Locate the transfer switch as close to the emergency load as practical to avoid interruptions of the emergency power system due to natural disasters or equipment failures.
2. Locate the transfer switch in a clean, dry, well ventilated location, away from excessive heat. When the ambient air is above 104° F (40° C), fuses and circuit breakers must be derated. Allow adequate working space around the transfer switch.
3. Install a circuit breaker (or fuses) in the line between the generator and the transfer switch. Generator sets are available with properly sized circuit breaker built into the generator control. The circuit breaker can be separately mounted. In the case of very large circuit breakers, a separate floor mounted circuit breaker is easier to wire up than a wall mounted breaker.
4. Install power and control wires in separate solid conduit with flexible sections at the generator set. The flexible sections prevent vibration from damaging the conduit. All power conduits from the generator set must contain all three phases.
5. Never install control wires in the same conduit as power conductors.
6. Conduit, wire, circuit protective device sizes, insulation etc. must conform to applicable local and national codes and regulations.
7. Be certain to seal around conduits that penetrate the walls of the generator set room to reduce the amount of noise that is transmitted to the surrounding areas of the building and maintain site fire code rating.

8.8 — Battery

8.8.1— General Information

DANGER!

Stationary emergency generators installed with automatic transfer switches 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 to personnel, do not connect battery cables until NORMAL source voltage at the transfer switch is correct and the system is ready to be placed into operation.

Storage batteries give off EXPLOSIVE hydrogen gas. This gas can form an explosive mixture around the battery for several hours after charging. The slightest spark can ignite the gas and cause an explosion. An explosion can shatter the battery and cause blindness or other injury. Any area that houses a storage battery must be properly ventilated. Do not allow smoking, open flame, sparks, or any spark producing tools or equipment near the battery.

Battery electrolyte fluid is an extremely caustic sulfuric acid solution that can cause severe burns. Do not permit fluid to contact eyes, skin, clothing, painted surfaces, etc. Wear protective goggles, protective clothing and gloves when handling a battery. If fluid is spilled, flush the affected area immediately with clear water.

WARNING!

DO NOT dispose of the battery in a fire. The battery is capable of exploding.

DO NOT open or mutilate the battery. Released electrolyte can be toxic and harmful to the skin and eyes.

The battery represents a risk of high short circuit current. When working on the battery, always remove watches, rings, or other metal objects, and only use tools that have insulated handles.

An authorized operator should inspect the engine battery system monthly. At this time, the battery fluid level should be checked and distilled water added if needed. Battery cables and connections also should be inspected for cleanliness and corrosion.

Once every six months, an Authorized Service Technician should inspect the battery system. At this time the battery condition and state of charge should be checked using a battery hydrometer. The battery should be recharged or replaced as required.

WARNING!

Servicing of the battery is to be performed or supervised by personnel knowledgeable of batteries and the required precautions. Keep unauthorized personnel away from batteries. Observe the following precautions when working on batteries:

- **Remove the 10A F2 fuse from the generator control panel.**
- **Remove watches, rings, or other metal objects.**
- **Use tools with insulated handles.**
- **Wear rubber gloves and boots.**

- **Do not lay tools or metal parts on top of the battery.**
- **Disconnect the charging source prior to connecting or disconnecting battery terminals. Remove the battery charger fuse (ATC style fuse, 5 amp on the 2.5 charger and 15 amp on the 10A charger).**
- **Wear full eye protection and protective clothing.**
- **Where electrolyte contacts the skin, wash it off immediately with water.**
- **Where electrolyte contacts the eyes, flush thoroughly and immediately with water and seek medical attention.**
- **Spilled electrolyte is to be washed down with an acid neutralizing agent. A common practice is to use a solution of 1 pound (500 grams) bicarbonate of soda to 1 gallon (4 liters) of water. The bicarbonate of soda solution is to be added until the evidence of reaction (foaming) has ceased. The resulting liquid is to be flushed with water.**

Lead-acid batteries present a risk of fire because they generate hydrogen gas.

- **DO NOT SMOKE when near the battery.**
- **DO NOT cause flame or spark in battery area.**
- **Discharge static electricity from the body before touching the battery by first touching a grounded metal surface.**

Be sure the AUTO/OFF/MANUAL switch is set in the OFF position before connecting the battery cables. If the switch is set to AUTO or MANUAL, the generator can crank and start as soon as the battery cables are connected.

Be sure the utility power supply to the battery charger is turned OFF and the 10A and 15A fuses are removed from the generator control panel and the ATC style fuse removed from the battery charger, or sparking may occur at the battery posts as the cables are attached and cause an explosion.

A negative ground system is used. Battery connections are shown on the wiring diagrams. Verify that the battery is correctly connected and terminals are tight. Observe battery polarity when connecting the battery to the generator set.

8.8.2— Battery Location

Locate batteries as close as possible to the generator set to minimize starting circuit resistance. High starting circuit resistance reduces starting cranking ability. The generator set data sheet lists the maximum allowable cranking system resistance. Mount batteries on a level rack away from dirt and liquids. Allow space for servicing (checking water level and level of charge). Cold ambient temperatures at the battery location substantially reduces the battery output.

8.8.3— Battery Size

The ability to start the engine depends upon battery capacity, ambient temperatures and coolant and oil temperatures. The engine/generator set Data Sheet lists minimum recommended battery capacity at various ambient temperatures. The recommended battery capacities are listed under cold cranking amps (CCA) at 0 °F (−18 °C). Battery capacities decrease as ambient temperatures decrease so it is important to specify batteries with the appropriate CCA rating at a temperature no higher than the minimum ambient temperature for the application.

8.8.4— Battery Charger

An engine mounted alternator to charge the batteries during operation is an available option. Standby generator sets require a solid state battery charger that is connected to utility power so the battery is charged continuously while the generator set is not running. The battery charger should be connected to the emergency circuit. The batteries on prime power generator sets are charged by the engine mounted alternator, if equipped.

Harmonic wave forms from solid state battery charges and belt driven alternators can cause the electronic governor on the engine to act erratically. To avoid this, the output of the battery charger or the belt driven alternator must be connected directly to the battery or to the battery terminals on the starter. Make control connections to the generator set control using a conduit with a flexible section at the generator set to avoid damage due to generator set vibrations.

NOTE: Thermostatically controlled coolant heaters are recommended on all after cooled standby generator sets. Oil pan immersion heaters are recommended for standby generator sets housed outside where ambient temperatures may drop below 0° F (−18° C). Coolant heaters and oil pan immersion heaters also are available.

8.8.5— Battery Cables

The wire size (wire gauge) of the cables connecting the starter to the batteries must be large enough to ensure the resistance of the cranking circuit is less than the maximum allowable resistance of the cranking circuit. The total cranking circuit resistance includes the resistance of the cables from the starting motor to the battery and the resistance of all relays, solenoids, switches, and connections. For purposes of calculating cranking circuit resistance to select cable size, the resistance of each connection can be taken as 0.00001 ohms and the resistance of each relay, solenoid, and switch as 0.0002 ohms.

8.8.6— Battery Installation and Replacement

NOTE: For gaseous engine and diesel engine battery replacement, consult the unit specification sheet for battery size.

Fill the battery with the proper electrolyte fluid if necessary and have the battery fully charged before installing.

Before installing and connecting the battery:

Preliminary Instructions

1. Set the generator control panel's AUTO/OFF/MANUAL switch to OFF.
2. Turn off utility power supply to the battery charger circuit.
3. Remove the F2 10A fuse from the generator control panel, and the ATC style fuse from the battery charger.

Battery cables are connected to the generator connection points at the factory. Connect the cables to the battery posts as shown in Figure 8-4.

12VDC System

1. Connect the red battery cable from the starter contactor to the positive (POS or +) battery post.
2. Connect the black battery cable to the frame ground to the negative (NEG or -) battery post.

24VDC System

1. Connect the red battery cable from the starter contactor to the positive (POS or +) post of battery A.
2. Connect the black battery cable to the frame ground to the negative (NEG or -) post of battery B.
3. Connect either a black or red jumper cable from the negative (NEG or -) post of battery A to the positive (POS or +) post of battery B.

Final Instructions

1. Reinstall the fuses into their correct positions inside the control panel.
2. Turn on the utility power supply to the battery charger circuit.
3. If the unit was previously operational, turn the AUTO/OFF/MANUAL switch to the AUTO position.

WARNING!

Damage will result if the battery connections are made in reverse.

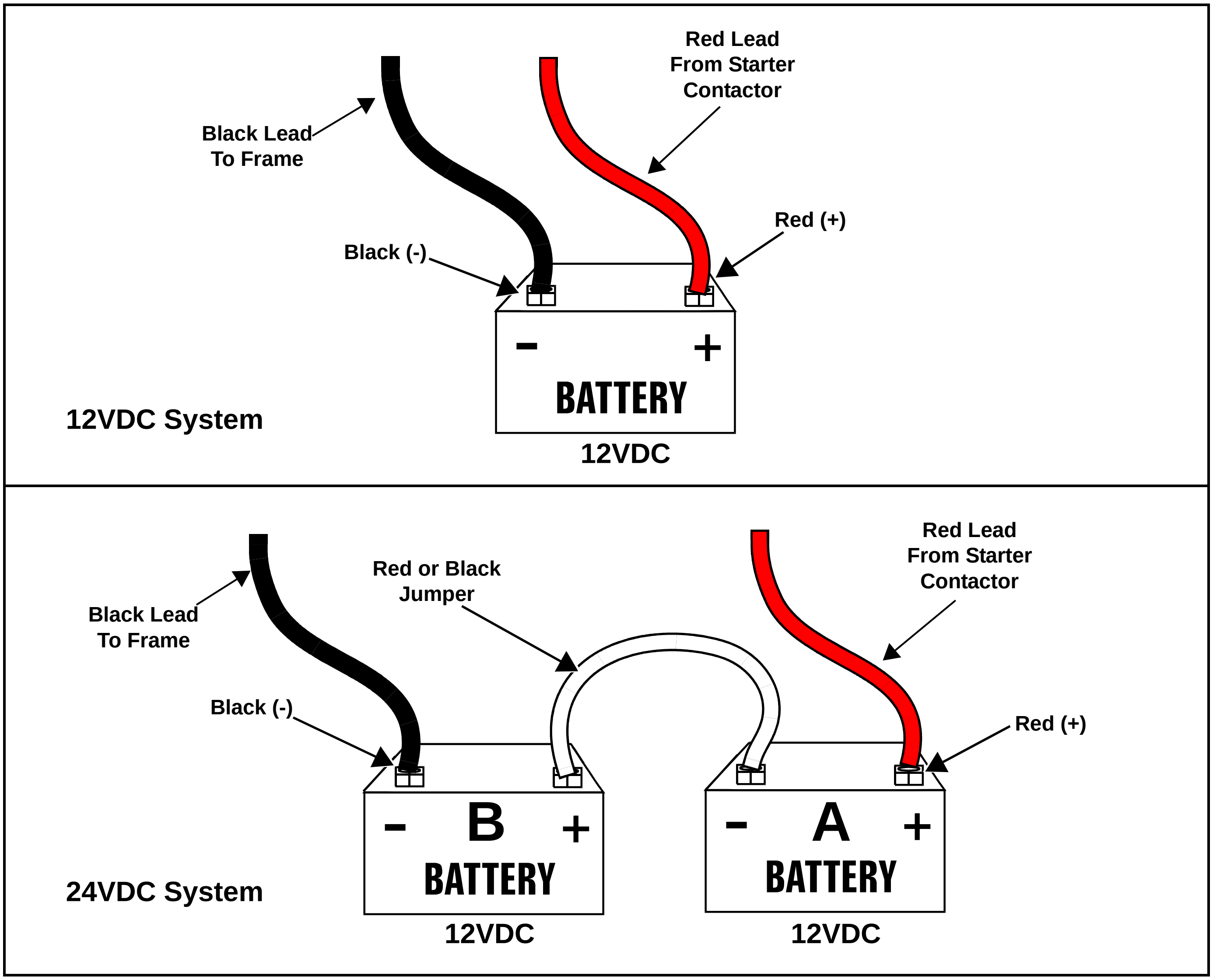

Figure 8-4. Battery Cable Connections

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Section 9 Installation Checklists

9.1 — Safety Checklist

NOTE: See Chapter 1 for more information.

☐ Are manuals, wiring diagrams and other documentation readily available?

☐ Is there any evidence of freight damage?

☐ Does the enclosure have scratches or damage to painted surfaces (which would indicate lifting without a spreader bar)?

☐ Are all guards, covers, insulation blankets and other protective devices in place?

☐ Are any parts or components worn, damaged or missing?

☐ Is the generator properly grounded?

☐ Is a fire extinguisher kept near the generator?

☐ Is the room or building housing the generator properly ventilated?

☐ Is there any evidence of fuel, oil or coolant leaks?

☐ Are any combustible materials left in the generator compartment?

☐ Is the area surrounding the generator clean and free of debris?

☐ Do these parameters meet all applicable codes and local jurisdiction?

9.2 — Installation Planning Checklist

NOTE: See Chapter 2 for more information.

☐ Is the generator set readily accessible for maintenance, repair, and firefighting purposes?

☐ Is the site clean and dry? Is the site provided with adequate drainage?

☐ Is there a minimum of five feet of clearance around the generator set to facilitate the repair or replacement of major components?

☐ Have adequate provisions been made for delivery of a fuel supply?

☐ Do these parameters meet all applicable codes and local jurisdiction?

9.3 — Foundations & Mounting Checklist

NOTE: See Chapter 3 for more information.

- ☐ Is the generator set installed on a concrete pad capable of supporting its weight and accessories?
- ☐ Is the generator securely fastened to the concrete pad using suitable grade, size and style fasteners?
- ☐ Is the concrete pad seated on a prepared solid subsurface using appropriate reinforcing bar or expanded wire mesh?
- ☐ Does the concrete pad extend beyond the frame rails at least 18 inches and above the surrounding surface by 3-8 inches?
- ☐ Is the concrete pad flat and level to within 1/2 inch?
- ☐ Are plugs installed in the tie-down holes of the frame rail?
- ☐ Is a containment dike provided for fuel and oil spillage?
- ☐ If installed on a roof or combustible floor, is the generator seated on a layer of sheet metal and non-combustible insulation? Do the sheet metal and insulation extend beyond the generator base at least 12 inches (30.5 cm) on all sides?
- ☐ Is the bottom of the generator set enclosed?
- ☐ Do all fuel, coolant, exhaust, and electrical lines have flexible sections where they connect to the generator?
- ☐ Is all piping properly supported and secured?
- ☐ Do these parameters meet all applicable codes and local jurisdiction?

9.4 — Ventilation System Checklist

NOTE: See Chapter 4 for more information.

- ☐ Is there sufficient air flow for cooling and ventilation?
- ☐ Does the room in which the generator set is installed have adequate air flow for combustion and for removal of heat from the engine, exhaust system and generator?
- ☐ Does the air inlet face the direction of prevailing winds?
- ☐ Has system piping been properly sized? Have all heat loads been taken into consideration?
- ☐ Has system been properly protected from freeze up and corrosion?
- ☐ Have standby equipment heaters been specified?
- ☐ Have all electrically driven devices been connected to load side of EPS connection points?
- ☐ Have system drain valves and air eliminators been installed?
- ☐ Does the air outlet face noise sensitive areas without noise attenuating devices?
- ☐ Do gravity louvers face inward for air intake and outward for discharge?

- ☐ Are louvers and other mechanical linkages operational? Are louvers properly wired to engine run relay?
- ☐ Are electrically operated ventilation devices powered under all operating modes?
- ☐ For indoor applications, is supply air and radiator outlet air ducting kept to a minimum?
- ☐ For indoor units with supply air ventilation, is there a means to control ambient air temperature in extreme cold conditions?
- ☐ Does the installation appear to have the necessary accessories to enable fast, reliable starting and operation in adverse weather conditions (such as engine jacket water heaters, lube oil heaters, battery warmers, etc.)?
- ☐ Do these parameters meet all applicable codes and local jurisdiction?

9.5 — Exhaust System Checklist

NOTE: See Chapter 5 for more information.

- ☐ Is the exhaust outlet located upwind or near any building air intakes?
- ☐ Is a section of flexible piping used at the engine exhaust outlet?
- ☐ Is the exhaust piping sizing adequate to prevent backpressure?
- ☐ Are the exhaust piping components insulated where necessary to prevent operator burns and reduce pipe radiant heat losses?
- ☐ Are thimbles, pipe sleeves or fire proof materials used where the exhaust pipe passes through building materials, such as walls or roofs?
- ☐ Is the exhaust outlet pipe horizontal to prevent entry of snow or rain?
- ☐ Is the proper silencer installed in the exhaust system to reduce noise levels?
- ☐ Does the exhaust outlet direct exhaust gases toward any openings (doors, windows, vents, etc.) of an occupied building?
- ☐ Does the exhaust outlet direct exhaust gases toward any material that could be combustible?
- ☐ On installations with more than one engine, does each engine must have its own exhaust system?
- ☐ Does the system use flanged exhaust pipe rated for at least 1500° F and constructed of schedule 40 black iron steel?
- ☐ Are flex joints used between the engine connection point and the rigid piping?
- ☐ Are flexible bellows used to allow for linear and/or axial movement of rigid piping due to thermal expansion/contraction?
- ☐ Does any extended exhaust ductwork have as few bends as possible?
- ☐ Do all bends employ sweep elbows with a radius at least three times the pipe diameter?
- ☐ Are exhaust piping and silencers properly supported and connected?
- ☐ Has all strain and excessive weight been removed from the flex coupling connected to the engine?

- ☐ Is exhaust piping sloped away from the engine outlet?
- ☐ Is a water trap with drain installed at the lowest point of the exhaust piping?
- ☐ Has a condensate drain been installed at the outlet of the silencer?
- ☐ Are exhaust discharges directed away from combustible surfaces and inhabited areas?
- ☐ Are there at least nine inches (22.9 cm) of clearance between exhaust piping and any combustible surface?
- ☐ Is exhaust piping kept clear of fuel tanks, fuel lines, etc.?
- ☐ Is the exhaust backpressure within specification?
- ☐ Does the exhaust outlet piping on horizontal exhaust stacks terminate with a 45º tailpipe?
- ☐ Is the ductwork from the radiator outlet flange to the exhaust vent opening as short and straight as possible?
- ☐ Is any exhaust air recirculated back to the generator area?
- ☐ Do motorized louvers have power during all modes of operation?
- ☐ Is the O_2 sensor and catalyst correctly installed, if provided?
- ☐ Are heat shields and blankets used to lower surface temperatures where required?
- ☐ Are there any unauthorized customer supplied and fitted heat shields that may increase surface temperatures?
- ☐ Is the exhaust piping isolated from the engine with flexible connections?
- ☐ If required, is a properly rated silencer installed?
- ☐ Is the exhaust piping properly supported?
- ☐ Is off-engine exhaust piping covered with high temperature insulation blankets where necessary?
- ☐ Are insulation blankets improperly installed on exhaust manifolds, turbocharger housings or other engine components?
- ☐ Is exhaust piping routed away from fuel pumps, fuel lines, fuel filters, fuel tanks and other combustible materials?
- ☐ Is exhaust pipe outlet cut to a 30° to 45° angle to reduce exhaust gas turbulence and noise?
- ☐ Is the exhaust system designed to prevent snow or rain from entering the engine through the exhaust outlet?
- ☐ Is the exhaust pipe diameter too small?
- ☐ Does the exhaust system have an excessive number of sharp bends?
- ☐ Is the exhaust piping too long?
- ☐ Is the system provided with a tap to measure exhaust backpressure? Is the pressure tap located in a straight length of exhaust pipe before the silencer and as close to the turbocharger as possible?
- ☐ Is the system combined with the exhaust systems of boilers or other engines?

- ☐ Do exhaust louvers face opposite the prevailing wind? Are louvers angled so that rain and snow do not pass through? Are louvers properly sized and face outward for exhaust discharge? Do any motorized louvers have power during all modes of operation?
- ☐ Do these parameters meet all applicable codes and local jurisdiction?

9.6 — Gaseous Fuel System Checklist

NOTE: See Chapter 6 for more information.

- ☐ Are fuel supply lines properly sized and installed? Were fuel supply lines purged and leak tested?
- ☐ Are water traps and drip legs installed to remove water and condensate from the gas flow?
- ☐ Is the fuel pressure regulator properly sized?
- ☐ Is the primary fuel pressure regulator outlet at least 10 feet from the generator connection point?
- ☐ Is a pressure test port installed before the fuel shutoff solenoids at the inlet to the unit mounted regulator?
- ☐ Does the generator have a dedicated fuel supply which is not shared with any other appliances?
- ☐ Is the regulator sized to have a fuel flow delivery rating (CFH) at least 10% greater than the 100% rated kW fuel consumption requirement of the generator?
- ☐ Is the fuel pressure regulator approved for a mechanized engine application?
- ☐ Does the fuel pressure regulator have an accuracy rating of 1% or less and/or have a maximum allowable pressure drop of 1-2 inches w.c. under all operating conditions, that is, static, cranking, running at no load, and running at full load (as measured at the primary fuel pressure regulator)?
- ☐ Does the fuel pressure regulator have a spring rating of 7-15 inches w.c.?
- ☐ Does the system use black iron piping rigidly mounted and protected against vibration?
- ☐ Is a length of flexible hose installed between the generator connection point and the rigid supply piping? Is the flexible hose straight without bends, twists or kinks?
- ☐ Is the piping correctly sized to maintain the required supply pressure and volume under varying load conditions?
- ☐ Was an approved pipe sealant or joint compound used on all threaded fittings?
- ☐ Is a fuel shutoff valve installed near the unit? Was proper operation of the fuel shutoff valve verified?
- ☐ Was the Final Operating Test performed to verify that the system operates correctly in all modes of operation?
- ☐ Is there any evidence of leakage at any hoses, clamps or fittings?
- ☐ Do these parameters meet all applicable codes and local jurisdiction?

9.7 — Diesel Fuel System Checklist

NOTE: See Chapter 7 for more information.

☐ Is black iron or steel piping used from the fuel source to the flexible connection at the generator?

☐ Is any galvanized pipe used for diesel fuel applications?

☐ Are any pipe or fittings constructed of cast iron or aluminum?

☐ Is a flexible length of fuel line installed between the rigid fuel supply piping and the generator fuel connection?

☐ Are the diesel fuel supply tanks at the same level as the engine fuel pump, but lower than the fuel injectors?

☐ Is the vertical lift between the engine fuel pump and the fuel level in the tank less than 40 inches?

☐ Are fuel filters and drains located in easily accessible areas?

☐ Is there evidence of leakage or damage at any hoses, clamps or fittings?

☐ Has the fuel system been primed (bled of air)?

☐ Do these parameters meet all applicable codes and local jurisdiction?

9.8 — Electrical System Checklist

NOTE: See Chapter 8 for more information.

☐ Is all wiring correctly sized for load and length of run?

☐ Is all wiring correctly routed?

☐ Is all wiring correctly supported?

☐ Is all wiring correctly connected?

☐ Are wire lugs fastened to buss bars using appropriate hardware? Is hardware properly tightened to specified torque?

☐ Are all other terminals correctly tightened using the specified torque?

☐ Are batteries correctly sized?

☐ Are batteries correctly installed?

☐ Are the battery fluid levels correct?

☐ Are battery cables and connections clean and free of corrosion?

☐ Are the battery cables correctly connected? Are the terminal lugs correctly tightened?

☐ Is the battery condition and state of charge acceptable?

☐ Is area housing storage battery properly ventilated?

☐ Are batteries located near a source of flame or spark?

☐ Are AC wire sizes and connections correct?

☐ Are DC and communication wire sizes and connections correct?

☐ Are DC and communication wires routed separately from AC wires?

☐ Are block heaters, battery charger, etc. properly matched with utility supply voltage?

☐ Are battery charger and block heater properly connected?

☐ Are remote start Wires 0 & 183 pulled and connected inside lower control panel of generator and inside transfer switch?

☐ Are communications wires (RS-485) and power wires (for RAP/RRP) pulled and terminated correctly inside control panel, remote annunciator, and transfer switch?

☐ Is the AUTO/OFF/MANUAL switch in the “OFF” position?

☐ Is the grounding rod installed?

☐ Is the block heater operational?

☐ Is the battery charger operational?

☐ Are all AC electrical connections tight at the circuit breaker and transfer switch?

☐ Are all electrical connections (wiring, wire ties, clamps, terminal ends, connectors) on the generator tight?

☐ Are all electrical plugs throughout the generator seated correctly and fully inserted into their receptacles?

☐ Is there proper voltage and phase rotation at the transfer switch?

☐ Is manual operation of the transfer switch smooth and non-binding?

☐ Are dip switch settings in transfer switch OK?

☐ Do these parameters meet all applicable codes and local jurisdiction?

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