GENERAC®

Installation Guidelines

For

Stationary Industrial Generators

Standalone Gas or Diesel

SAVE THIS MANUAL FOR FUTURE REFERENCE

⚠WARNING

CANCER AND REPRODUCTIVE HARM

www.P65Warnings.ca.gov.

(000393a)

⚠WARNING

Breathing diesel engine exhaust exposes you to chemicals known to the State of California to cause cancer and birth defects or other reproductive harm.

- Always start and operate the engine in a well-ventilated area.
- If in an enclosed area, vent the exhaust to the outside.
- Do not modify or tamper with the exhaust system.
- Do not idle the engine except as necessary.

For more information go to www.P65Warnings.ca.gov/diesel. (000394)

The information in this manual is accurate based on products produced at the time of publication. The manufacturer reserves the right to make technical updates, corrections, and product revisions at any time without notice.

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Section 1 Introduction and Safety

Introduction

Thank you for purchasing a Generac Power Systems Inc. product. This unit has been designed to provide high-performance, efficient operation, and years of use when maintained properly.

The information in this manual is accurate based on products produced at the time of publication. The manufacturer reserves the right to make technical updates, corrections, and product revisions at any time without notice.

Read This Manual Thoroughly

⚠WARNING

Consult Manual. Read and understand manual completely before using product. Failure to completely understand manual and product could result in death or serious injury.

(000100a)

If any section of this manual is not understood, contact the nearest Independent Authorized Service Dealer (IASD) or Generac Customer Service at 1-888-436-3722 (1-888-GENERAC), or visit ***www.generac.com*** for starting, operating, and servicing procedures. The owner is responsible for correct maintenance and safe use of the unit.

This manual must be used in conjunction with all other supporting product documentation supplied with the product.

SAVE THESE INSTRUCTIONS for future reference. This manual contains important instructions that must be followed during placement, operation, and maintenance of the unit and its components. Always supply this manual to any individual that will use this unit, and instruct them on how to correctly start, operate, and stop the unit in case of emergency.

Safety Rules

The manufacturer cannot anticipate every possible circumstance that might involve a hazard. The alerts 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 that the manufacturer does not specifically recommend, verify that it is safe for others and does not render the equipment unsafe.

Throughout this publication, and on tags and decals affixed to the unit, DANGER, WARNING, CAUTION, and NOTE blocks are used to alert personnel to special instructions about a particular operation that may be hazardous if performed incorrectly or carelessly. Observe them carefully. Alert definitions are as follows:

⚠DANGER

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

(000001)

⚠WARNING

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

(000002)

⚠CAUTION

Indicates a hazardous situation which, if not avoided, could result in minor or moderate injury.

(000003)

NOTE: Notes contain additional information important to a procedure and will be found within the regular text of this manual.

These safety alerts cannot eliminate the hazards that they indicate. Common sense and strict compliance with the special instructions while performing the action or service are essential to preventing accidents.

How to Obtain Service

When the unit requires servicing or repairs, contact Generac Customer Service at 1-888-GENERAC (1-888-436-3722) or visit ***www.generac.com*** for assistance.

When contacting Generac Customer Service about parts and service, always supply the complete model and serial number of the unit as given on its data decal located on the unit. Record the model and serial numbers in the spaces provided on the front cover of this manual.

General Hazards

⚠DANGER

Loss of life. Property damage. Installation must always comply with applicable codes, standards, laws and regulations. Failure to do so will result in death or serious injury.

(000190)

⚠DANGER

Automatic start-up. Disconnect utility power and render unit inoperable before working on unit. Failure to do so will result in death or serious injury.

(000191)

⚠WARNING

Electrocution. Potentially lethal voltages are generated by this equipment. Render the equipment safe before attempting repairs or maintenance. Failure to do so could result in death or serious injury.

(000187)

⚠WARNING

Accidental Start-up. Disconnect the negative battery cable, then the positive battery cable when working on unit. Failure to do so could result in death or serious injury.

(000130)

⚠WARNING

Equipment damage. Only qualified service personnel may install, operate, and maintain this equipment. Failure to follow proper installation requirements could result in death, serious injury, and equipment or property damage.

(000182a)

⚠WARNING

Personal Injury. Fuel lines are pressurized. Servicing the fuel lines may release high pressure fuel and could result in death or serious injury.

(000501)

⚠WARNING

Electric shock. Only a trained and licensed electrician should perform wiring and connections to unit. Failure to follow proper installation requirements could result in death, serious injury, and equipment or property damage.

(000155a)

⚠WARNING

Moving Parts. Do not wear jewelry when starting or operating this product. Wearing jewelry while starting or operating this product could result in death or serious injury.

(000115)

⚠WARNING

Moving Parts. Keep clothing, hair, and appendages away from moving parts. Failure to do so could result in death or serious injury.

(000111)

⚠WARNING

Hot Surfaces. When operating machine, do not touch hot surfaces. Keep machine away from combustibles during use. Hot surfaces could result in severe burns or fire.

(000108)

⚠WARNING

Equipment and property damage. Do not alter construction of, installation, or block ventilation for generator. Failure to do so could result in unsafe operation or damage to the generator.

(000146)

⚠WARNING

Risk of injury. Do not operate or service this machine if not fully alert. Fatigue can impair the ability to service this equipment and could result in death or serious injury.

(000215)

⚠WARNING

Injury and equipment damage. Do not use generator as a step. Doing so could result in falling, damaged parts, unsafe equipment operation, and could result in death or serious injury.

(000216)

- Inspect the generator regularly, and contact the nearest IASD for parts needing repair or replacement.

Exhaust Hazards

⚠DANGER

Asphyxiation. Running engines produce carbon monoxide, a colorless, odorless, poisonous gas. Carbon monoxide, if not avoided, will result in death or serious injury. (000103)

⚠WARNING

Equipment and property damage. Do not alter construction of, installation, or block ventilation for generator. Failure to do so could result in unsafe operation or damage to the generator. (000146)

⚠WARNING

Asphyxiation. Always use a battery operated carbon monoxide alarm indoors and installed according to the manufacturer's instructions. Failure to do so could result in death or serious injury. (000178a)

- The generator must be installed and operated outdoors only.

Electrical Hazards

⚠DANGER

Electrocution. Contact with bare wires, terminals, and connections while generator is running will result in death or serious injury. (000144)

⚠DANGER

Electrocution. Never connect this unit to the electrical system of any building unless a licensed electrician has installed an approved transfer switch. Failure to do so will result in death or serious injury. (000150)

⚠DANGER

Electrical backfeed. Use only approved switchgear to isolate generator from the normal power source. Failure to do so will result in death, serious injury, and equipment damage. (000237)

⚠DANGER

Electrocution. Verify electrical system is properly grounded before applying power. Failure to do so will result in death or serious injury. (000152)

⚠DANGER

Electrocution. Do not wear jewelry while working on this equipment. Doing so will result in death or serious injury. (000188)

⚠DANGER

Electrocution. Water contact with a power source, if not avoided, will result in death or serious injury. (000104)

⚠DANGER

Electrocution. In the event of electrical accident, immediately shut power OFF. Use non-conductive implements to free victim from live conductor. Apply first aid and get medical help. Failure to do so will result in death or serious injury. (000145)

Lifting Hazards

⚠WARNING

Personal injury. Failure to properly connect lifting cables, chains, or straps could result in death, serious injury, or property damage.

(000346)

⚠WARNING

Personal Injury. Do not use lifting hook if there are signs of damage or corrosion. Doing so could result in death, serious injury, or property damage.

(000349)

⚠WARNING

Personal Injury. Do not use lifting hook other than as directed. Failure to do so could result in death, serious injury, or property damage.

(000350)

⚠WARNING

Personal Injury. Verify all fasteners are properly tightened prior to lifting unit. Failure to do so could result in death, serious injury, or property damage.

(000351)

⚠WARNING

Personal injury. Excessive weight. Use only appropriate lifting eyes and lifting equipment to lift unit. Improper lifting techniques could result in equipment damage, death or serious injury. (000224)

Fire Hazards

⚠WARNING

Fire risk. Fuel and vapors are extremely flammable. Do not operate indoors. Doing so could result in death, serious injury, or property or equipment damage. (000281)

⚠WARNING

Fire hazard. Do not obstruct cooling and ventilating airflow around the generator. Inadequate ventilation could result in fire hazard, possible equipment damage, death or serious injury. (000217)

⚠WARNING

Fire and explosion. Installation must comply with all local, state, and national electrical building codes. Noncompliance could result in unsafe operation, equipment damage, death or serious injury.

(000218)

⚠WARNING

Fire hazard. Use only fully-charged fire extinguishers rated “ABC” by the NFPA. Discharged or improperly rated fire extinguishers will not extinguish electrical fires in automatic standby generators.

(000219)

⚠WARNING

Electrocution. Refer to local codes and standards for safety equipment required when working with a live electrical system. Failure to use required safety equipment could result in death or serious injury. (000257)

⚠WARNING

Risk of Fire. Unit must be positioned in a manner that prevents combustible material accumulation underneath. Failure to do so could result in death or serious injury. (000147)

Comply with regulations the Occupational Safety and Health Administration (OSHA) has established, or with equivalent standards. Also, verify that the unit is applied, used, and maintained in accordance with the manufacturer's instructions and recommendations. Do nothing that might alter safe application/usage and render the unit in noncompliance with the aforementioned codes, standards, laws, and regulations.

Explosion Hazards

⚠DANGER

Explosion and fire. Fuel and vapors are extremely flammable and explosive. No leakage of fuel is permitted. Keep fire and spark away. Failure to do so will result in death or serious injury.

(000192)

⚠DANGER

Explosion and fire. Connection of fuel source must be completed by a qualified professional technician or contractor. Incorrect installation of this unit will result in death, serious injury, and property and equipment damage.

(000151a)

⚠DANGER

Risk of fire. Allow fuel spills to completely dry before starting engine. Failure to do so will result in death or serious injury.

(000174)

⚠WARNING

Risk of Fire. Hot surfaces could ignite combustibles, resulting in fire. Fire could result in death or serious injury.

(000110)

Battery Hazards

⚠DANGER

Electrocution. Do not wear jewelry while working on this equipment. Doing so will result in death or serious injury.

(000188)

⚠WARNING

Explosion. Do not dispose of batteries in a fire. Batteries are explosive. Electrolyte solution can cause burns and blindness. If electrolyte contacts skin or eyes, flush with water and seek immediate medical attention.

(000162)

⚠WARNING

Explosion. Batteries emit explosive gases while charging. Keep fire and spark away. Wear protective gear when working with batteries. Failure to do so could result in death or serious injury.

(000137a)

⚠WARNING

Electrical shock. Disconnect battery ground terminal before working on battery or battery wires. Failure to do so could result in death or serious injury.

(000164)

⚠WARNING

Risk of burns. Batteries contain sulfuric acid and can cause severe chemical burns. Wear protective gear when working with batteries. Failure to do so could result in death or serious injury.

(000138a)

⚠WARNING

Risk of burn. Do not open or mutilate batteries. Batteries contain electrolyte solution which can cause burns and blindness. If electrolyte contacts skin or eyes, flush with water and seek immediate medical attention.

(000163a)

⚠WARNING

Environmental Hazard. Always recycle batteries at an official recycling center in accordance with all local laws and regulations. Failure to do so could result in environmental damage, death or serious injury.

(000228)

Always recycle batteries in accordance with local laws and regulations. Contact your local solid waste collection site or recycling facility to obtain information on local recycling processes. For more information on battery recycling, visit the Battery Council International website at: ***http://batterycouncil.org***

General Rules

⚠DANGER

Loss of life. Property damage. Installation must always comply with applicable codes, standards, laws and regulations. Failure to do so will result in death or serious injury.

(000190)

⚠DANGER

Electrical backfeed. Use only approved switchgear to isolate generator from the normal power source. Failure to do so will result in death, serious injury, and equipment damage.

(000237)

⚠WARNING

Equipment damage. Only qualified service personnel may install, operate, and maintain this equipment. Failure to follow proper installation requirements could result in death, serious injury, and equipment or property damage.

(000182a)

⚠WARNING

Electrocution. Refer to local codes and standards for safety equipment required when working with a live electrical system. Failure to use required safety equipment could result in death or serious injury.

(000257)

⚠WARNING

Consult Manual. Read and understand manual completely before using product. Failure to completely understand manual and product could result in death or serious injury. (000100a)

- Follow all safety precautions in the owner's manual, installation guidelines manual, and other documents included with your equipment.
- Never energize a new system without opening all disconnects and breakers.
- Always consult your local code for additional requirements for the area in which the unit is being installed.
- Incorrect installation can result in personal injury and damage to the generator. It may also result in the warranty being suspended or voided. All the instructions listed below must be followed including location clearances and pipe sizes.

Before You Begin

- Contact the local inspector or city hall to be aware of all federal, state, and local codes which could impact installation. Secure all required permits before installing.
- Carefully read and follow all procedures and safety precautions detailed in this installation manual. Contact an IASD for assistance if any portion of the installation manual, technical manual, or other factory-supplied documents is not completely understood,
- Fully comply with all relevant NEC, NFPA, and OSHA standards, as well as all federal, state, and local building and electric codes. This unit must be installed in accordance with current NFPA 37 and NFPA 70 standards, and any other federal, state, and local codes for minimum distances from other structures.
- Verify the capacity of the natural gas meter or LP tank in regards to providing sufficient fuel for both the generator and other household and operating appliances.

Standards Index

⚠WARNING

Loss of life. This product is not intended to be used in a critical life support application. Failure to adhere to this warning could result in death or serious injury. (000209b)

- Strictly comply with all applicable national, state, and local laws, as well as codes or regulations pertaining to the installation of this engine-generator power system. Use the most current version of applicable codes or standards relevant to the local jurisdiction, generator used, and installation site.

NOTE: Not all codes apply to all products and this list is not all-inclusive. In the absence of pertinent local laws and standards, the following publications may be used as a guide (these apply to localities which recognize NFPA and ICC).

1. National Fire Protection Association (NFPA) 70: The NATIONAL ELECTRIC CODE (NEC) *
2. NFPA 10: 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. Article X, NATIONAL BUILDING CODE
18. ASAE EP-364.2 Installation and Maintenance of Farm Standby Electric Power ****
19. ICC:IFGC

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 your jurisdiction. 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

Unit Drawings

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.

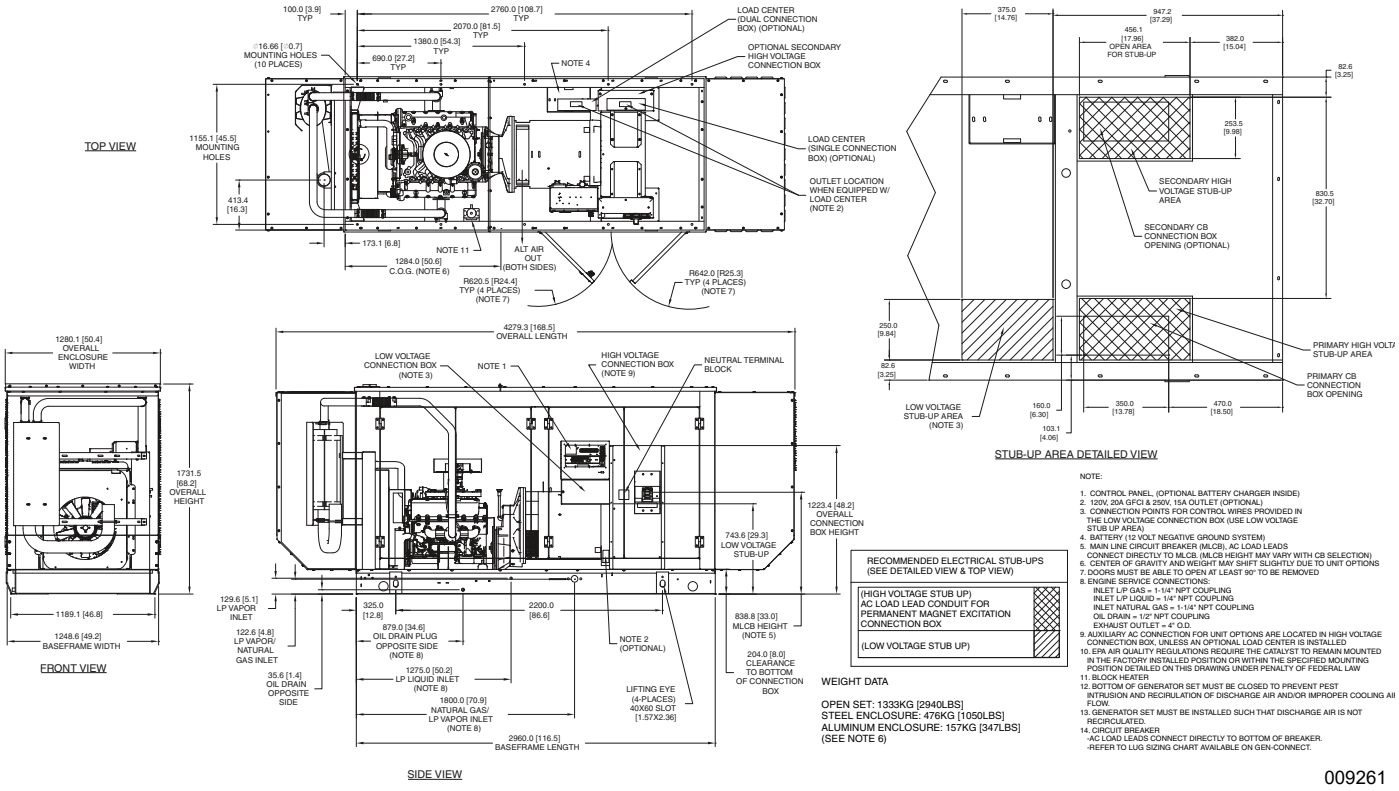

Figure 2-1. Typical Installation Drawing

Wiring Diagrams

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

Receiving

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.

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.

Storage Before Installation

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 an IASD to obtain the Long Term Preservation and Storage Manual (Part No. 0G4018) and the Preservation Checklist (Part No. 0G4018A).

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, and rodents.
- 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, and dust.

Lifting

⚠WARNING

Personal injury. Failure to properly connect lifting cables, chains, or straps could result in death, serious injury, or property damage.

(000346)

⚠WARNING

Personal Injury. Do not use lifting hook if there are signs of damage or corrosion. Doing so could result in death, serious injury, or property damage.

(000349)

⚠WARNING

Personal Injury. Do not use lifting hook other than as directed. Failure to do so could result in death, serious injury, or property damage.

(000350)

⚠WARNING

Personal Injury. Verify all fasteners are properly tightened prior to lifting unit. Failure to do so could result in death, serious injury, or property damage.

(000351)

⚠WARNING

Personal injury. Excessive weight. Use only appropriate lifting eyes and lifting equipment to lift unit. Improper lifting techniques could result in equipment damage, death or serious injury. (000224)

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.

IMPORTANT NOTE: 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.

IMPORTANT NOTE: See *Figure 2-2*. Do not use the lifting points of the engine or alternator (A) to move the generator set. Use the lifting eyes (B).

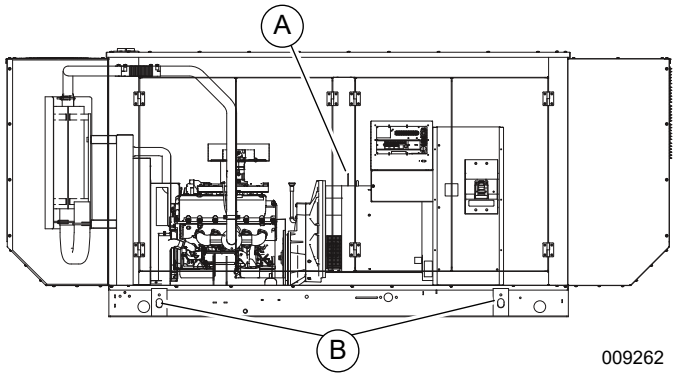

Figure 2-2. Lifting Points (Example)

Generator Location

Locate the generator set so 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, and proximity to combustible materials.

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. Contact a structural engineer for recommendations.
- Verify the site is clean, dry, not subject to flooding, and provided with adequate drainage in the event of heavy rains.
- Verify the location permits noise and vibration to be effectively isolated.
- Verify 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.
- Verify 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.
- Verify 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 the unit is securely fastened to the mounting pad to prevent movement caused by vibration.
- Verify 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.

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.

IMPORTANT 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.

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Section 3 Foundations and Mounting

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.

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 2,500 psi concrete reinforced with 8 gauge wire mesh or number 6 reinforcing bars on 12 in (30.5 cm) centers.

Dimensions

Extend the concrete pad beyond the frame of the unit at least 18 in (457 mm) and above the surrounding surface by 3 to 8 in (76 to 203 mm). 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 and all fluids in the generator set.
- Flat and level to within 1/2 in (13 mm).
- Capable of withstanding severe torque reactions on those units which are part of a paralleling system.

Unit Clearance

Verify the site provides easy access to the generator set for maintenance, repair, and firefighting purposes. Keep a minimum of 5 ft (152 cm) of clearance around each side of the generator set to facilitate the repair or replacement of major components.

Roof Installation and Protection

Contact a structural engineer to verify the roof design is capable of supporting the full weight of the generator and of handling any vibration or movement produced by the application of load.

IMPORTANT NOTE: While consultations with a qualified structural engineer are necessary for specific recommendations regarding support strength for roof top installations, the generator set must be supported at every anchor bolt hole location on the frame.

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 in (30.5 cm) on all sides. See ***Figure 3-1***.

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

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 in (30.5 cm) on all sides. See ***Figure 3-1***.

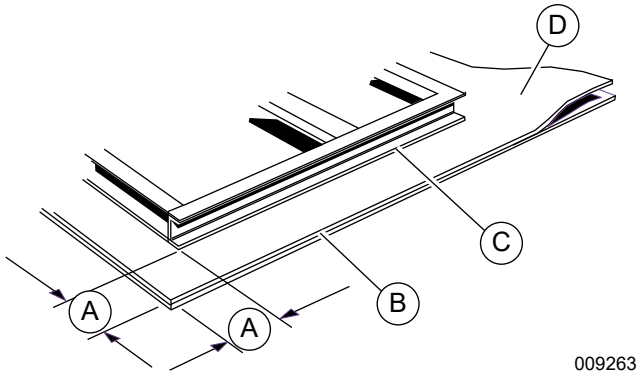

Figure 3-1. Combustible Floor and Roof Protection

A	12 in (30.5 cm) minimum
B	Insulation
C	Generator mounting base
D	Sheet metal

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***.

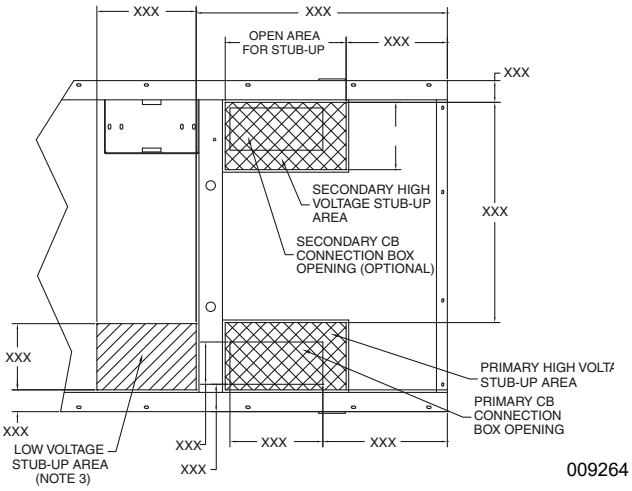

Figure 3-2. Typical Installation Drawing Stub Up Detail

Mounting

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.

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 (example: steel I-beams or grating surfaces), 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.

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.

Tie Down Holes

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

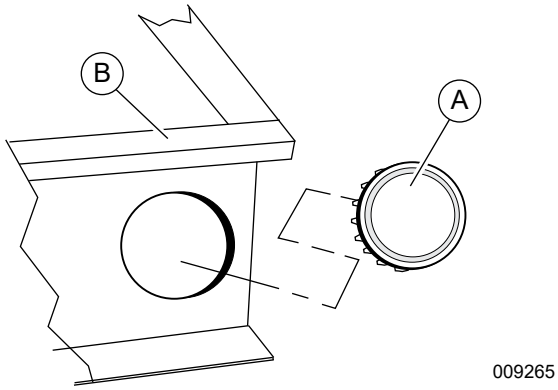

Figure 3-3. Frame Tie-Down Hole Plugs

Section 4 Ventilation System

General

⚠WARNING

Equipment and property damage. Do not alter construction of, installation, or block ventilation for generator. Failure to do so could result in unsafe operation or damage to the generator.

(000146)

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.

Outdoor Installations

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

Clearance

Keep a minimum of 5 ft (152 cm) of clearance around the unit to facilitate service and maintenance, and to ensure adequate air circulation for air intakes and cooling of exhaust discharges.

Indoor Installations

Ventilation

Adequate ventilation is a key consideration for indoor installations 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.

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.
- Verify 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.
- Verify 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 which may inhibit air flow.

Air Flow

See ***Figure 4-1***. The air intake inlets (A) and exhaust outlets (B) 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.

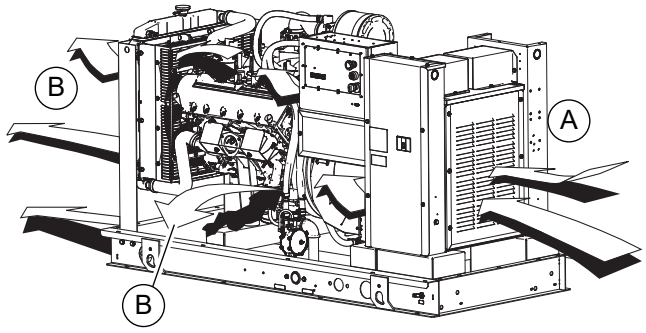

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Figure 4-1. Generator Airflow

Louvers

See ***Figure 4-2***. Louvers prevent entry of wind driven rain, snow, and debris. Face intake louvers into the prevailing wind and angle all louvers so 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. Verify louvers face inward for air intake. Verify 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.

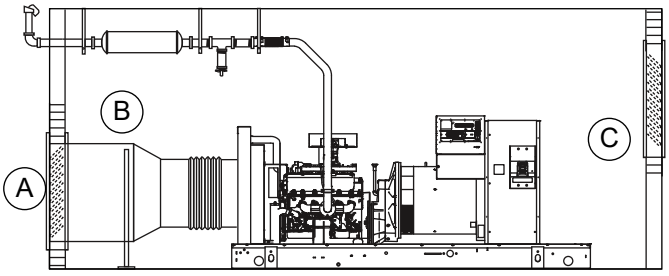

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Figure 4-2. Indoor Installation Example

A	Exhaust louvre
B	Radiator duct
C	Intake louvre

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:

- Verify 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.

Section 5 Exhaust System

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 1,500 °F (816 °C) 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.
- Verify the system does not stress engine components such as turbochargers and exhaust manifolds with excess weight.
- Use flexible bellows to allow for linear or axial movement of rigid piping due to thermal expansion or contraction.
- Use sweep elbows with a radius at least three times the pipe diameter.
- Verify exhaust system components are able to reject heat energy.
- Properly support and connect exhaust piping and mufflers. Verify 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 muffler or 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 muffler is also recommended.
- Properly terminate exhaust piping outside a structure housing a generator set, so 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 9 in (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 clear of fuel tanks and fuel lines.
- 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.
- Verify 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.
- Verify any motorized louvers have power during all modes of operation.
- For outdoor units, verify there are no obstructions at the exhaust discharge which may cause exhaust gases to circulate back to the air intakes. Recirculation of exhaust air will cause the unit to overheat.

Emissions Compliance

Closed Units

The exhaust system is installed at the factory on units with enclosures. If safe operation requires the exhaust to be extended, contact an IASD 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 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 muffler. See the installation drawings for length of piping from the engine connection to the muffler, size of engine exhaust outlet, and any other unit specific requirements.

System Components

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

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.

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 designed and supplied by Generac are suitable for this purpose. Any customer supplied and fitted shields must be carefully designed and installed so 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.

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.

NOTE: If equipped with an O_2 sensor, the insulation must clear the sensor a minimum of 4 in (10 cm) on either side.

Table 5-1. Recommended Exhaust Insulation Blankets

Manufacturer and Product	Maximum Continuous Use Temperature Rating
INSULFAB IF 1950 High Temperature	Up to 1,832 °F (1,000 °C)
INSULFAB IF 1953 Treated Glass Fabric	Up to 1,300 °F (704 °C)
INSULFAB IF 1954 Coated Glass Fabric	Up to 600 °F (316 °C)

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.

Turbochargers

Turbochargers are used to achieve higher engine power output by converting some of the energy (heat) 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.

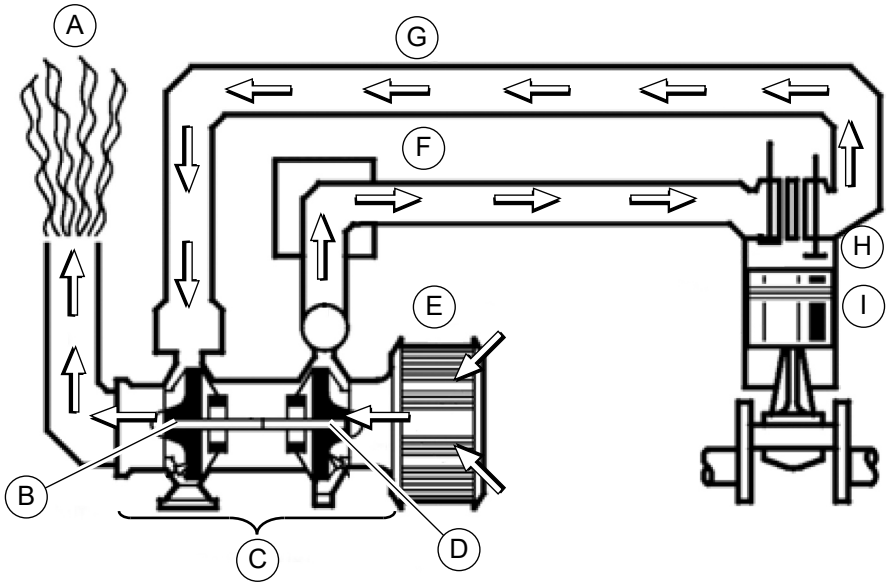

Figure 5-1. Turbocharger Operation

A	Exhaust	**F**	Aftercooler
B	Turbine blades	**G**	Exhaust gases
C	Turbocharger	**H**	Combustion chamber
D	Compressor blades	**I**	Piston
E	Air filter		

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.

IMPORTANT NOTE: 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.

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 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.

Flexible Metal Hose and Bellows

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

The primary functions of flexible exhaust connections 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.

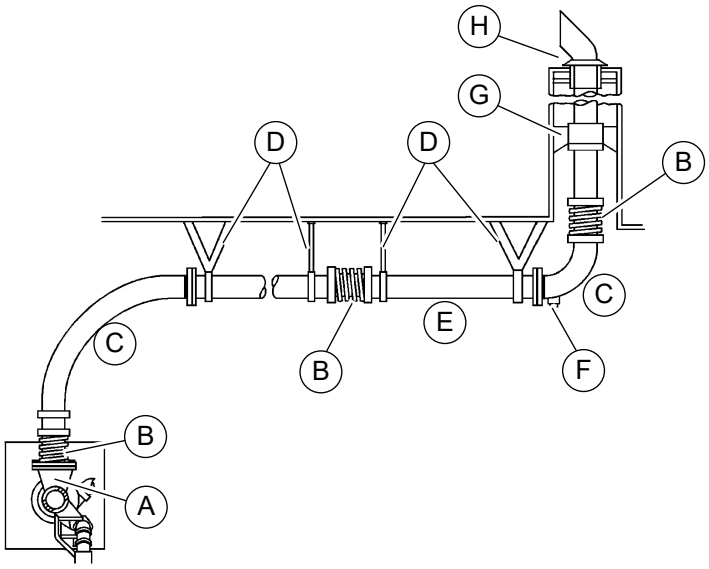

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Figure 5-2. Typical Exhaust Piping Layout

A	Engine exhaust outlet	**E**	Slight tilt away from engine
B	Flexible pipe connection	**F**	Drain
C	Long sweep elbow	**G**	Vertical pipe support
D	Pipe support	**H**	Expansion sleeve with spray shield

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 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.

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	
	in	mm	in	mm	in	mm
4 and 5	1.0	25.4	0.25	6.25	0.25	6.25
6	1.5	38.1	0.25	6.25	0.25	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	
	in	mm	in	mm	in	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

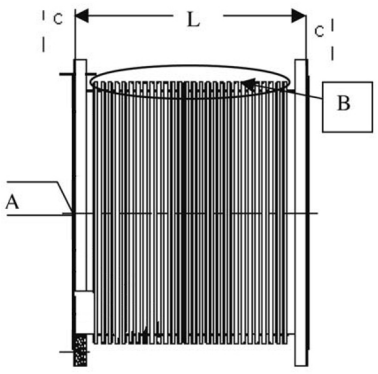

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Figure 5-3. Slip Joint (Typical)

Muffler

The muffler 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 muffler surfaces. A well designed and matched exhaust system significantly reduces noise from these sources. The muffler 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.

Muffler Rating

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

Table 5-5. Muffler 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.

Muffler Selection

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

To select a muffler, use muffler supplier data, corrected for outlet temperature and velocity, to determine the muffler 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 muffler, or a different pipe size, before an optimum combination is found.

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

Muffler Installation

⚠WARNING

Equipment damage. Only qualified service personnel may install, operate, and maintain this equipment. Failure to follow proper installation requirements could result in death, serious injury, and equipment or property damage. (000182a)

⚠WARNING

Personal injury. Excessive weight. Use only appropriate lifting eyes and lifting equipment to lift unit. Improper lifting techniques could result in equipment damage, death or serious injury. (000224)

⚠WARNING

Personal Injury. Unit has a high center of gravity. Use caution when lifting and transporting unit. Failure to do so could result in death or serious injury. (000312)

See the unit specific drawings included with the unit for information on installing the muffler.

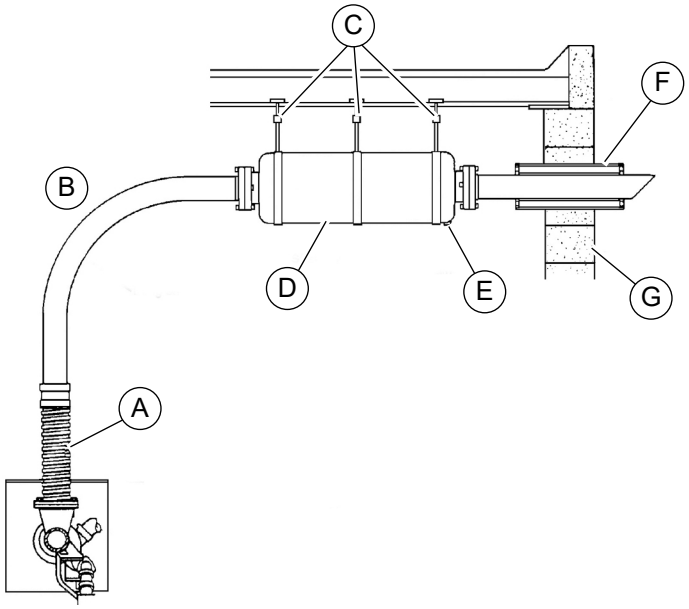

Figure 5-4. Typical Muffler

A	Flexible elbow	**E**	Drain
B	Long sweep elbow	**F**	Thimble
C	Brackets with vibration isolators	**G**	Outside wall
D	Muffler		

Exhaust System Piping

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

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. Verify 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.

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 muffler, 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 in (22.9 cm) from combustible materials.
- Properly support the exhaust piping. This is especially important adjacent to the engine, so 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 which passes through wooden walls or roofs. Size the thimble guards so they are 12 in (30.5 cm) greater in diameter than the exhaust pipes. See ***Figure 5-4***.

- 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 5-6***.
- Arrange exhaust outlets to keep water out of the piping system.
- Verify the muffler does not inhibit access to filters, engine, or add heat to radiator.

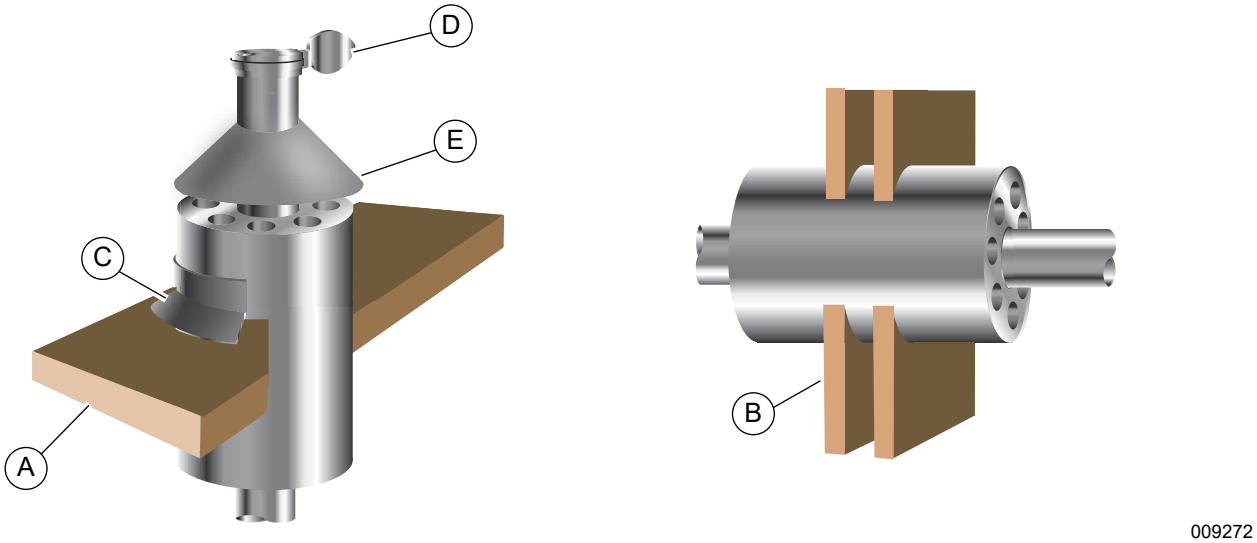

Figure 5-5. Exhaust Pipe Thimble Installation

A	Roof	**D**	Rain cap
B	Wall	**E**	Drip shield
C	Flashing		

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***.

Exhaust Thimbles

See ***Figure 5-5***. 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 in (30.5 cm) larger than the exhaust pipe. Double thimbles with both inner and outer sleeves should have outside diameters at least 6 in (15.2 cm) larger than the exhaust pipe.

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 muffler 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.

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 which must be taken into account when calculating system backpressure.

One method used primarily with horizontal exhaust pipes is to angle cut the end as shown by A of ***Figure 5-6***.

A common method used with vertical exhaust pipes is to angle the pipe 45° or 90° from vertical, as shown by B of ***Figure 5-6***, using a suitable elbow, and then angle cut the end as just described.

Another practice that may be used with either method is to cut water drain slots into the exhaust pipe. Bend the engine side of the slots (C) inward and the downstream side of the slots (D) outward. 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.

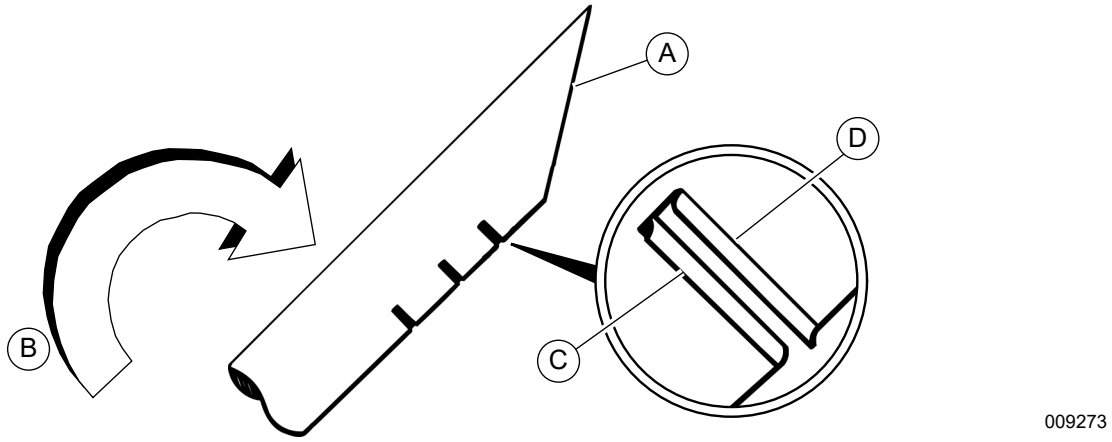

Figure 5-6. Water Drain Slots

A	Angle cut	**C**	Push engine side slot edges in
B	Angle pipe 45°	**D**	Pull discharge side slot edges out

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, muffler, 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.
- Muffler resistance too high.

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

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 muffler 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 in (10 cm) diameter pipe, place the tap no closer than 12 in (30 cm) downstream of a bend or section change. See A of ***Figure 5-7***.

Backpressure Tap Installation

See ***Figure 5-7***. If an uninterrupted straight length of at least five diameters (D and E) 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 in (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 in (76.2 mm) (B).
6. Orient the probe so the groove in the tip is parallel with the exhaust gas flow (C).

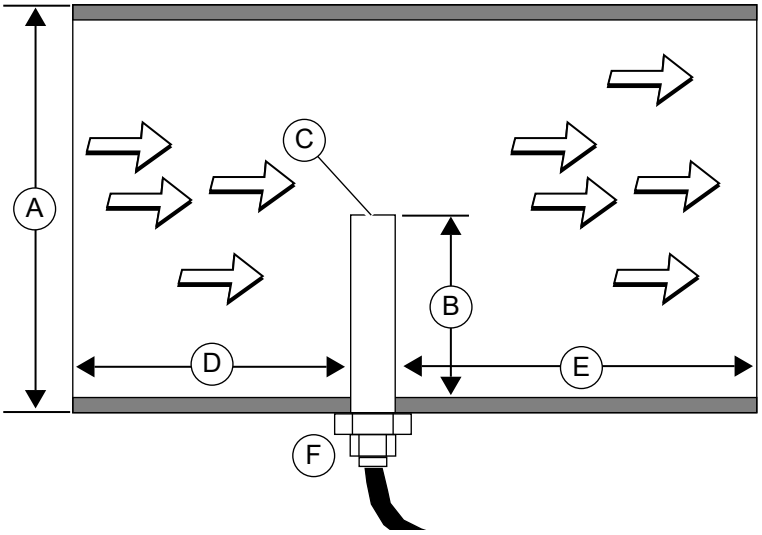

Figure 5-7. Install Backpressure Test Port

A	Pipe diameter	**D**	2x pipe diameter
B	3 in minimum or 1/2 pipe diameter	**E**	3x pipe diameter
C	Probe tip cut parallel to exhaust flow	**F**	Pressure tap

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 muffler (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

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 1,000 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.

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.

Pipe Support Considerations

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 (38 °C) rise of exhaust temperature. This amounts to 0.65 in (16.5 mm) expansion for each 10 ft (3.05 m) of pipe from 100 °F to 950 °F (35 °C 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.

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 verify the 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 5-8***.

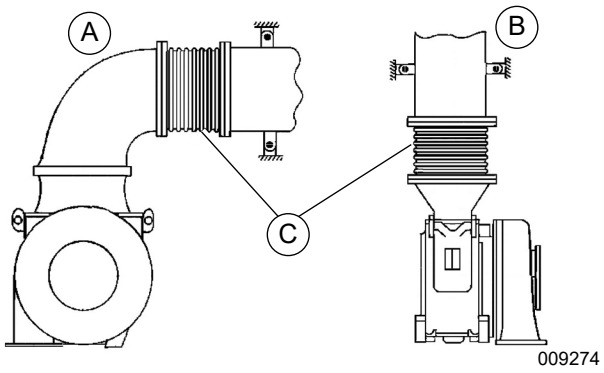

Figure 5-8. Horizontal and Vertical Exhaust Bellow

A	Horizontal
B	Vertical
C	Bellow

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 5-9***.

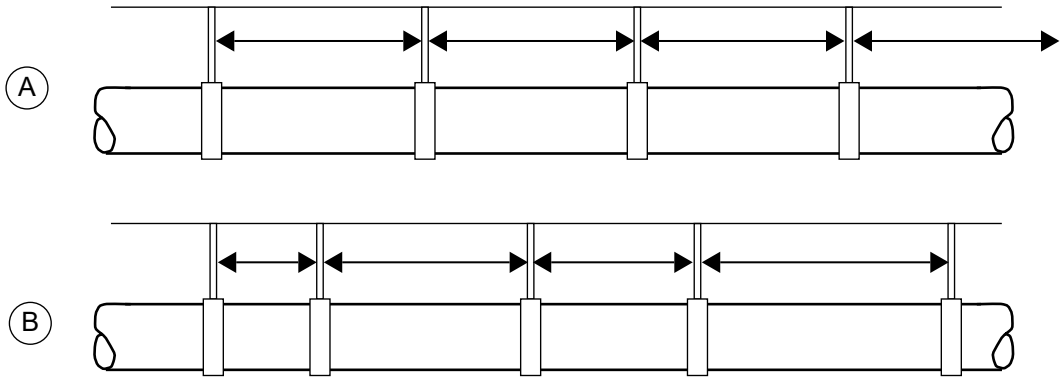

Figure 5-9. Support Pipe Runs at Unequal Distances

A	**Incorrect** - Support pipe runs at equal distances
B	**Correct** - Support pipe runs at unequal distances

Exhaust Discharge

Design exhaust outlets, whether exhaust pipe or stack, to ensure engine exhaust gas does not circulate 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 5-10*** and ***Figure 5-11*** for exhaust piping systems designed to avoid recirculation of exhaust gases.

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 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. Verify 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 exhaust is routed upward into the atmosphere. Verify any motorized louvers have power during all modes of operation.

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 the rising radiator air tends to cool exhaust system components within the stack. See ***Figure 5-10***.

The muffler 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.

See ***Figure 5-10*** for a vertically mounted and a horizontally mounted exhaust muffler. In both examples, the exhaust pipe and radiator air use a common stack.

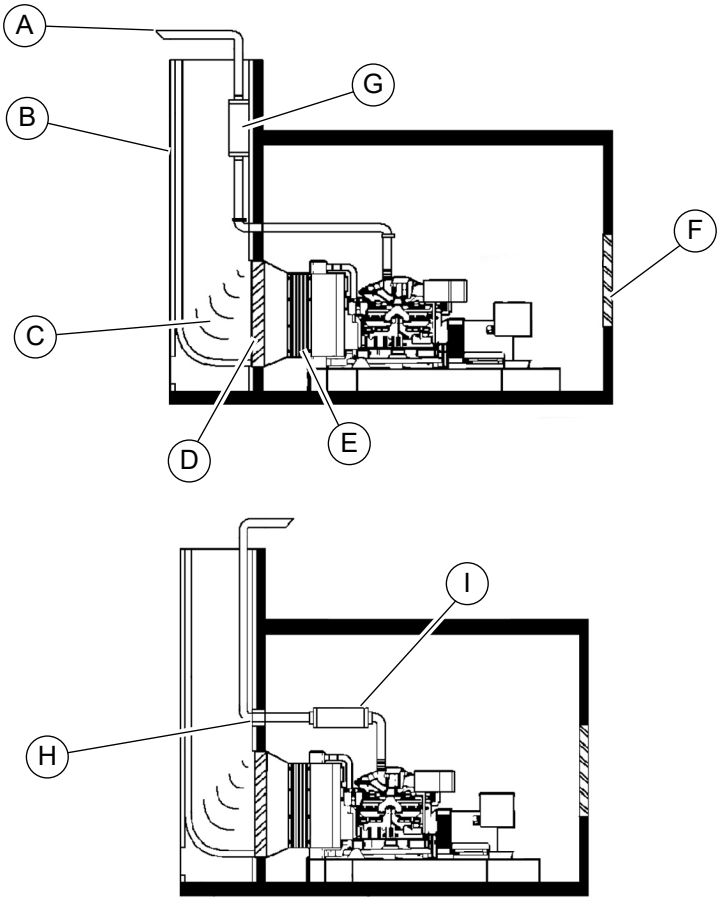

Figure 5-10. Typical Vertical (Top) and Horizontal (Bottom) Muffler

A	Horizontal pipe with angle cut	**F**	Air inlet louvers
B	Sound reducing material	**G**	Vertical muffler
C	Air guide valves	**H**	Sleeve and expansion joint
D	Exhaust louvers	**I**	Horizontal muffler
E	Pusher fan		

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 5-11***.

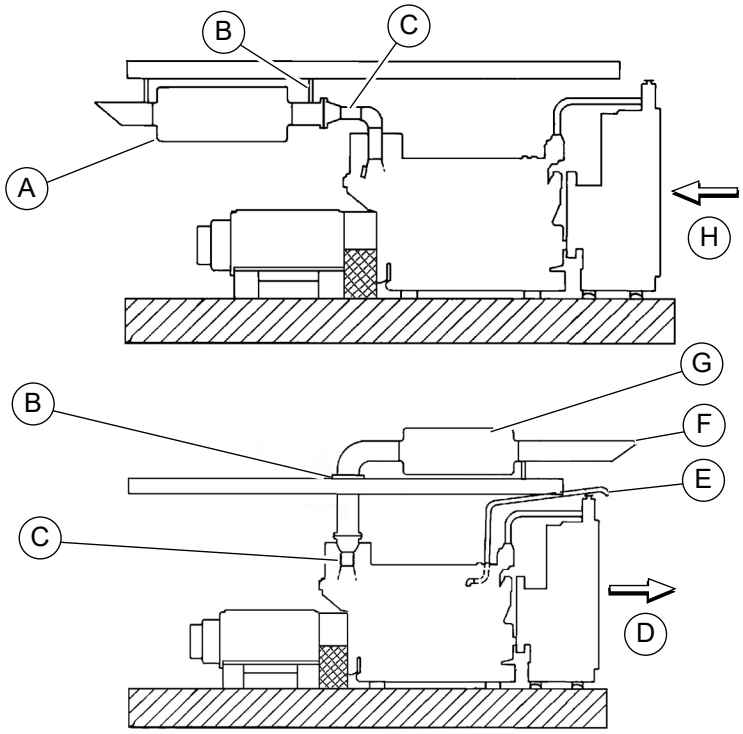

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Figure 5-11. Internal and External Muffler

A	Insulated exhaust and muffler	**E**	Crankcase breather discharge tube
B	Exhaust support	**F**	Angle cut for noise reduction, bottom cut for drainage
C	Flex joint	**G**	Muffler
D	Blower fan	**H**	Suction fan

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 it must be removed before the engine is started.

Slobber or Wet Stacking

Exhaust slobber is the black oily fluid which can leak from exhaust system joints. It consists of fuel and 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 which may have accumulated in the exhaust manifold.

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Section 6 Gaseous Fuel Systems

General

⚠DANGER

Explosion and fire. Fuel and vapors are extremely flammable and explosive. No leakage of fuel is permitted. Keep fire and spark away. Failure to do so will result in death or serious injury. (000192)

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

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), contact your local IASD.

Gaseous Fuel Properties

Natural Gas

⚠DANGER

Explosion and fire. Fuel and vapors are extremely flammable and explosive. No leakage of fuel is permitted. Keep fire and spark away. Failure to do so will result in death or serious injury. (000192)

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 and 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 or 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.

Propane Vapor (LPV) and Propane Liquid (LPL)

⚠DANGER

Explosion and fire. Fuel and vapors are extremely flammable and explosive. No leakage of fuel is permitted. Keep fire and spark away. Failure to do so will result in death or serious injury. (000192)

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 of -44 ºF (-42 °C) 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 (1,379 kPa). 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.

Gaseous Fuel Systems

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 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 (noted on the unit specification sheet) when it is operating at 100% of its rated load.

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

NOTE: Allow a minimum of 10 ft (305 cm) between the primary regulator and generator.

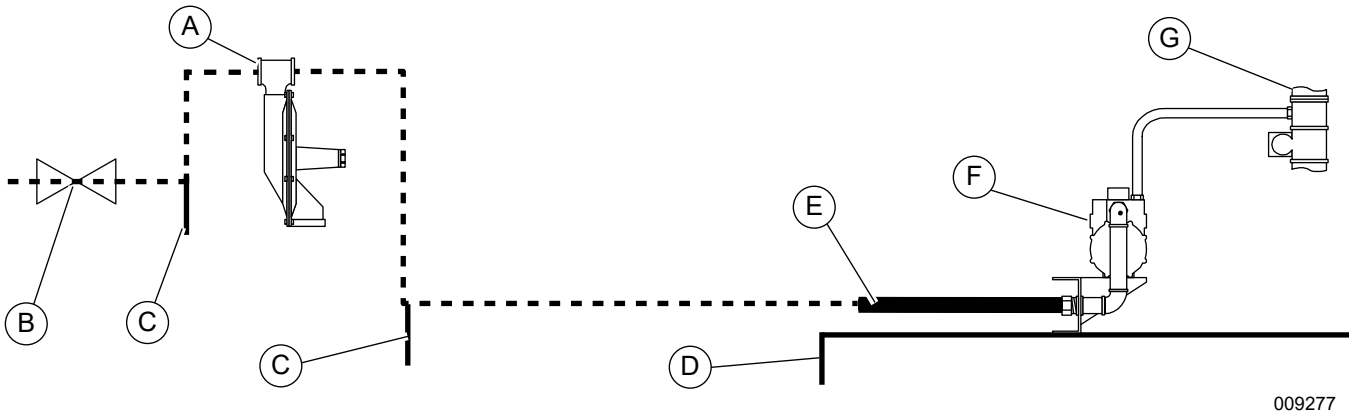

Figure 6-1. Typical NG Fuel System

A	Primary regulator	**E**	Flexible fuel line
B	Full flow shut off valve	**F**	Unit mounted regulator
C	Sediment trap	**G**	Actuator
D	Generator base		

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.

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

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

NOTE: Allow a minimum of 10 ft (305 cm) between the primary regulator and generator.

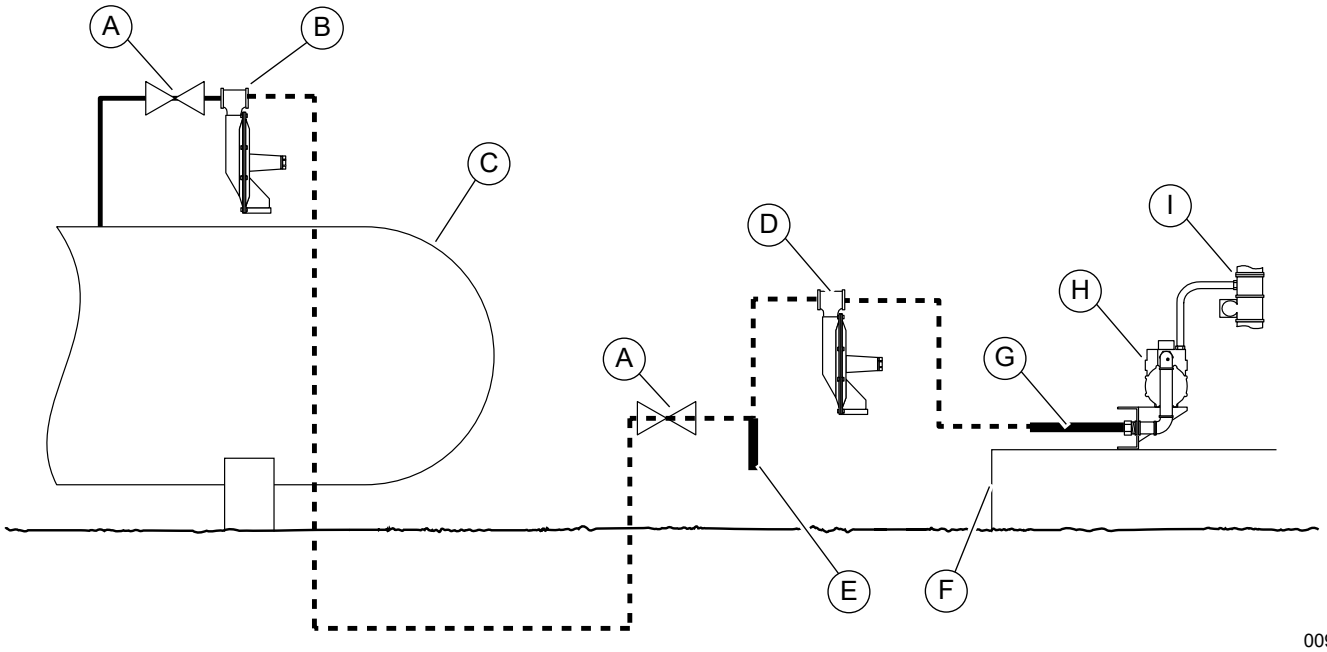

Figure 6-2. Typical LP-Vapor Withdrawal Fuel System

A	Full flow shut off valve	**F**	Generator base
B	First stage regulator with relief valve and pressure tap	**G**	Flexible fuel line
C	Fuel tank	**H**	Unit mounted regulator
D	Second stage regulator	**I**	Mixer
E	Sediment trap		

LPG-Liquid Withdrawal System

This system delivers LPG-Liquid to the connection point on the generator set. For the generator to use the LPG-Liquid fuel, the fuel must be vaporized prior to being delivered to the fuel mixer (carburetor). LPG-Liquid will vaporize at a temperature of -44 °F (-42 °C). The generator set LPG-Liquid fuel system delivery pressure shall have a typical operating range of 58 to 180 psi (400 to 1,242 kPa) (liquid line pressure), depending on the ambient temperature and liquid level in the storage tank.

LPG-Liquid enters the vaporizer and passes into a “flash” chamber. The pressure drop in this chamber vaporizes the liquid tank pressure (max 312 psi (2,152 kPa)) to approximately 11 to 14 in H_2O (2.9 to 3.5 kPa).

Engine coolant is used to heat the flash chamber to increase the temperature and more importantly, to keep it from icing up.

The outlet port of the vaporizer is connected to the Anti-Backfire Solenoid (ABS), if equipped, and then to the Varifuel mixer inlet. The outlet is based on demand and will vary by engine from approximately -1.5 to -7.5 in H_2O (-0.4 to -1.9 kPa).

The piping system connecting the liquid line from the tank connection to the connection on the generator set must be sized to provide the correct volume of liquid propane (gallons per hour) to the generator set as specified in the unit specification sheet.

NOTE: LP tanks set up to provide liquid fuel are equipped with a dip tube connection to provide liquid withdrawal of fuel from the tank.

NOTE: 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.

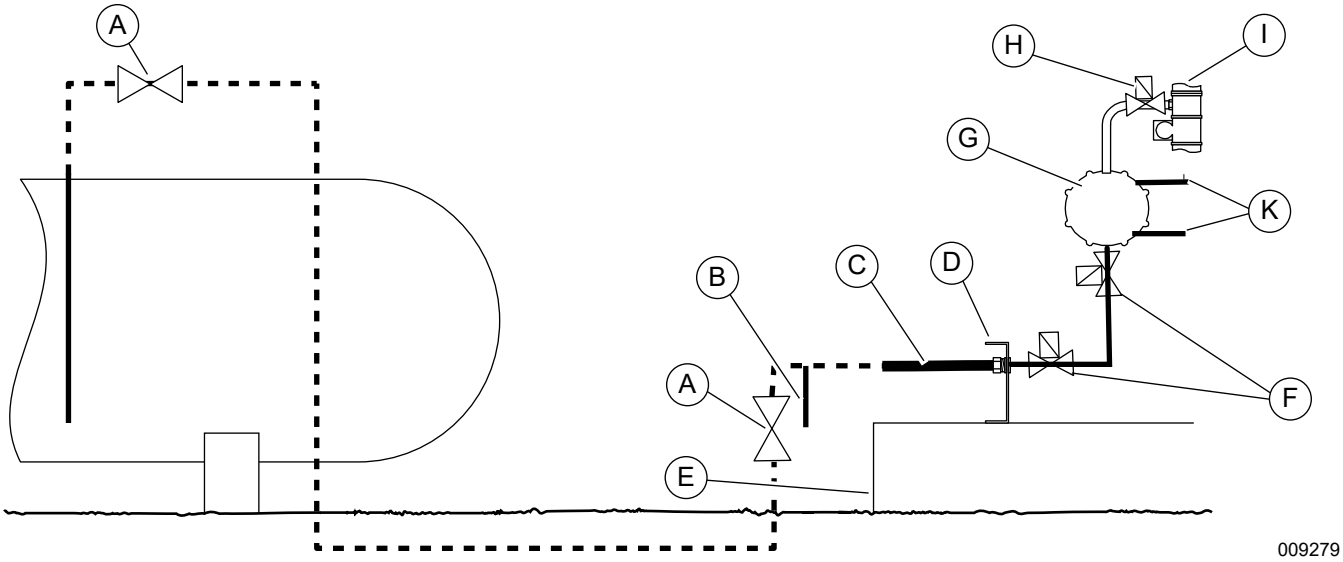

Figure 6-3. Typical LPG-Liquid Withdrawal Fuel System

A	Full flow shut off valve	**G**	Liquid vaporizer regulator
B	Sediment trap	**H**	ABS (Anti-backfire solenoid)
C	Flexible fuel line	**I**	Mixer
D	Generator frame	**J**	Heated coolant connections
E	Generator base	**K**	Coolant lines
F	Unit mounted solenoid stop valve		

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 LPG-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***.

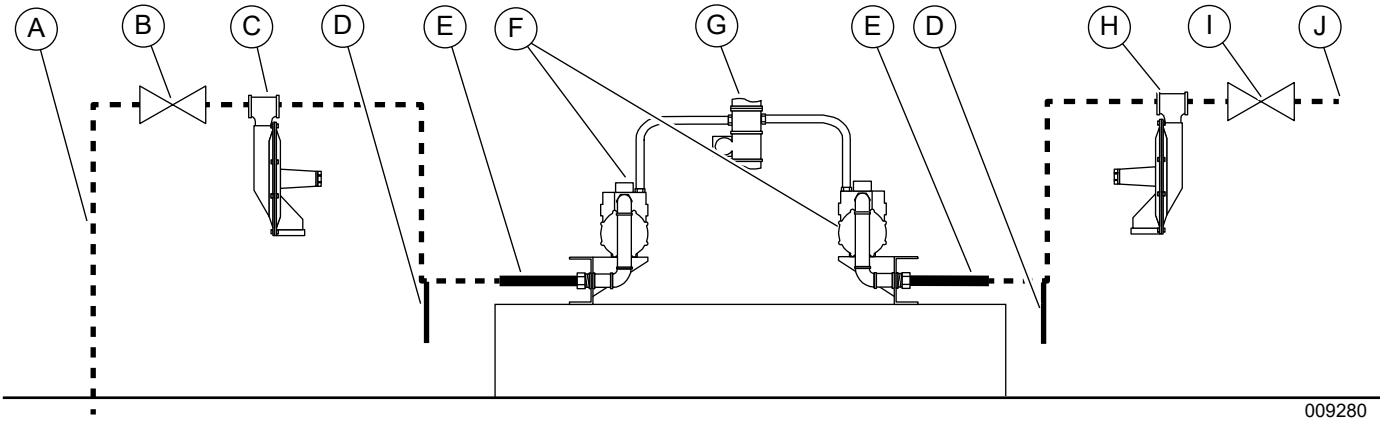

Figure 6-4. Dual-Fuel System

A	Piping from LP tank First stage regulator	**F**	Unit mounted regulators
B	Full flow shut off valve	**G**	Mixer
C	Second stage regulator	**H**	Primary regulator
D	Sediment trap	**I**	Full flow shut off valve
E	Flexible fuel line	**J**	NG supply

Sediment Trap

Install at least one sediment trap before the unit to separate sediment, debris, and condensation from the gas flow. A sediment trap is also recommended at the bottom of a vertical pipe run and after each change in direction. Sediment traps protect downstream equipment, such as the primary or second stage pressure regulators, from clogging and contamination. Some installations or jurisdictions may require multiple sediment traps. Contact the local authority having jurisdiction for requirements.

Fuel Pressure Regulators

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.

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 ^oF saturated with water vapor and under a pressure equivalent to 30 in H_2O.
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 and psig	Measure of pressure in pounds per square inch and pounds per square inch gauge.
Inches of Water Column (in H_2O)	Measure of pressure in inches of water column. 14 in H_2O = 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 H_2O 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.

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 ensure the 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 ft (305 cm) 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 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 in pipe port in the pressure regulator body, or in the piping just before the pressure regulator, is provided for this purpose. See ***Gas Pressure Test Port Location***.
- 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 40 ºF (4 °C), 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.

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 to 2 in H_2O (0.25 to 0.50 kPa) as measured at the primary fuel pressure regulator. For definitions of each condition, see ***Final Test Procedure***.

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 1,000 = BTU per hour
- **LP-Vapor:** cfh x 2,500 = BTU per hour

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 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 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 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 to 2 in H_2O (0.25 to 0.50 kPa) 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.

Recommended Fuel Pressure Regulators

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

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 ft (305 cm) of pipe length from the generator set connection point.
2. Verify 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, or has a maximum allowable pressure droop rate of 1 to 2 in H_2O (0.25 to 0.50 kPa).

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 to 2 in H_2O (0.25 to 0.50 kPa) 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 specified range of the generator, typically 7 to 11 in H_2O (1.7 to 2.7 kPa) or 11 to 15 H_2O (2.7 to 3.7 kPa).

3. Verify the generator has a dedicated fuel supply which is not shared with any other appliances (examples: furnace, water heaters, ranges).
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. Verify 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 30 ºF and 45 ºF (-1 ºC and 7 ºC), particularly with LPV 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. Use the next nominal pipe size for every 10 ft (305 cm) of vent line, and use 3 ft (91 cm) 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.

Pipe Sizing Considerations

General

Contact 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, verify 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 ***Gas Pressure Test Port Location***. 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 in H_2O (0.12 kPa) or less). This will ensure 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 sediment trap.
- 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.

Minimum Recommended Pipe Length

Mount the primary pressure regulator no less than 10 ft (305 cm) 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 the generator sees during starting and load changes.

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.

Short Runs with Few or No Bends

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

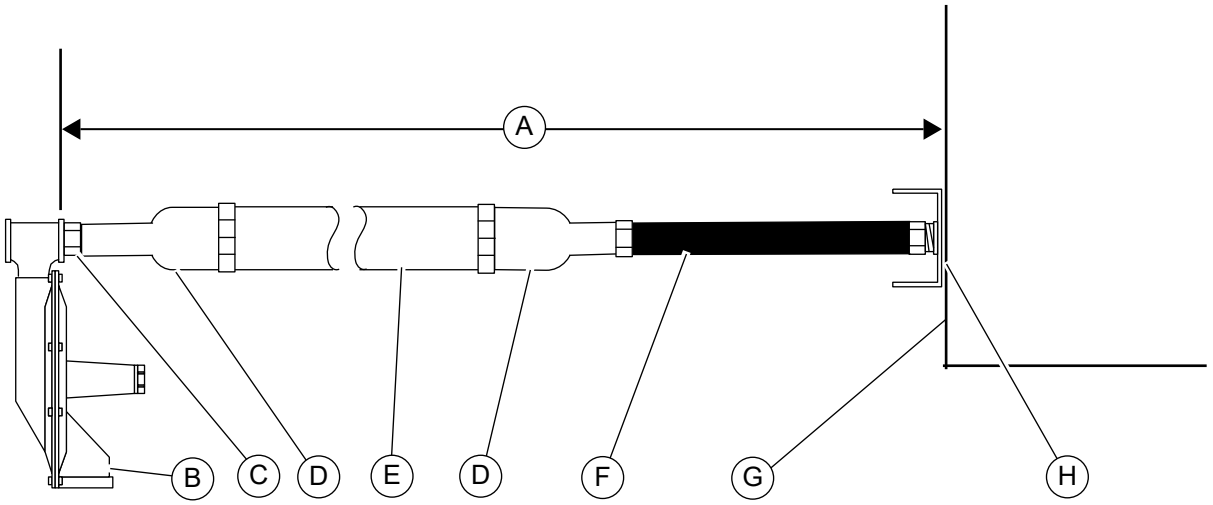

Figure 6-5. Pipe Sizing Based on Regulator Outlet Diameter

A	10 feet minimum	**E**	Pipe diameter one size larger than regular outlet (C)
B	Fuel pressure regulator	**F**	Flexible connection - same diameter as regular outlet (C)
C	Regulator outlet	**G**	Generator
D	Adapter	**H**	Manifold header

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) 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.

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 per 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 per hour, multiply the cfh value by 2,500.

2. Verify 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 to 2 in H_2O (0.25 to 0.50 kPa) 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 (305 cm), 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 in, 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 ***Figure 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 (example: if the calculated length is 41 ft (1,250 cm), select a pipe length of 45 ft (1,372 cm) from the table).
10. Move across the table to the selected pipe size and 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 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 to 2 in H_2O (0.25 to 0.50 kPa) as measured at the primary fuel pressure regulator. For definitions of each condition, see ***Final Test Procedure***.

Table 6-2. Iron Pipe Sizing for Natural Gas (NG)

Specific Gravity: 0.60 (contact local supplier for specific gravity of local supply)								
Inlet Pressure (at beginning of pipe run) less than 1.5 psi (10.3 kPa). For generator applications this will be not greater than the maximum pressure allowed for the unit (typically 14 in H_2O (0.5 psi). See unit specification sheet for correct range.								
Nominal Pressure Drop 0.3 in H_2O (0.07 kPa) 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	1,060	1,580	3,050	4,860	8,580	17,500
15	219	413	848	1,270	2,446	3,899	6,893	14,060
20	188	353	726	1,087	2,094	3,337	5,900	12,034
25	166	313	643	964	1,856	2,958	5,229	10,665
30	151	284	583	873	1,681	2,680	4,738	9,663
35	139	261	536	803	1,547	2,466	4,359	8,890
40	129	243	499	747	1,439	2,294	4,055	8,271
45	121	228	468	701	1,350	2,152	3,805	7,760
50	114	215	442	662	1,280	2,030	3,590	7,330
60	104	195	400	600	1,160	1,840	3,260	6,640
70	95	179	368	552	1,060	1,690	3,000	6,110
80	89	167	343	514	989	1,580	2,790	5,680
90	83	157	322	482	928	1,480	2,610	5,330
100	79	148	304	455	877	1,400	2,470	5,040
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 H_2O (0.07 kPa) 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***.								

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

Specific Gravity: 1.50 (contact local supplier for Specific Gravity of local supply)								
Inlet Pressure less than 11 in H_2O (2.7 kPa) For generator applications this will be not greater than the maximum pressure allowed for the unit (typically 14 in H_2O (3.5 kPa) See unit specification sheet for correct range.								
Nominal Pressure Drop 0.5 in H_2O (0.12 kPa) 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	1,150	2,350	3,520	67,900	10,800	19,100	39,000
20	418	787	1,620	2,420	4,660	7,430	13,100	26,800
30	336	632	1,300	1,940	3,750	5,970	10,600	21,500
40	287	541	1,110	1,660	3,210	5,110	9,030	18,400
50	255	480	985	1,480	2,840	4,550	8,000	16,300
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 H_2O (2.7 kPa) at a nominal pressure drop from one end to the other of 0.5 in H_2O (0.12 kPa) For pipe length and diameters or flow rates not shown, contact a local gas supplier or installer. The values in the table are in thousands of BTU/hr, so multiply the values shown by 1,000 to get the actual value. To convert cubic feet per hour (cfh) to BTU/hr, multiply by a factor of 2,500. To convert BTU per hour to cubic feet per hour (cfh), divide by a factor of 2,500.								

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, contact a local gas supplier or installer.					

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	2.00	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).

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 (345 and 1,241 kPa). 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.

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 in	3/8 in	1/2 in	3/4 in
360	10	729			
540	15	324			
720	20	182	825		
1,440	40	46	205	745	
2,160	60	20	92	331	
2,880	80	11	51	187	735
3,600	100	7	33	119	470

Sizing LP Tanks for Vapor Withdrawal

The manufacturer recommends the installer contact 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” to restore the pressure equilibrium. The liquid in the tank uses the temperature difference between its boiling point (-44 ºF (-42 °C) for Propane and 15 ºF (-9 °C) 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 40 ºF (4 °C), 20 ºF (-7 °C), and 0 ºF (-18 °C). For temperatures below 0 ºF (-18 °C) contact a reputable LP dealer for options.
- The mean relative humidity.

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

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 2,500.
- 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 91,502.
- 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 (946 liters), 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 1,050 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.

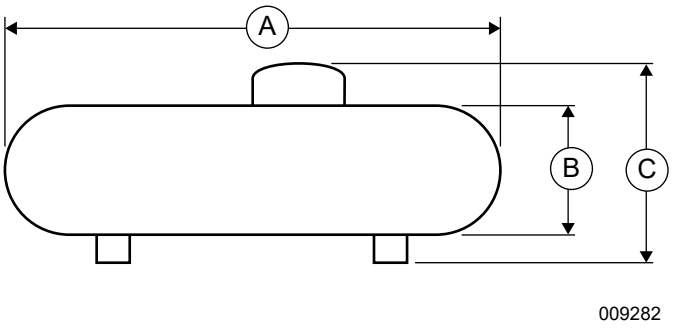

Figure 6-6. Typical Propane Tank Dimensions

A	Length
B	Diameter
C	Height

NOTE: The minimum LP tank size is 250 gallons (946 liters), 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 1,050 pound vertical tank minimum).

Propane conversion figures:

- 36.38 ft^3 = 90,500 Btu = 1 gal
- 1 lb = 21,500 Btu = 8.56 ft^3
- 2,500 Btu = 1 ft^3

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.

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 factory installed 1/8 in pipe port in a tee fitting connected to the low pressure switch.

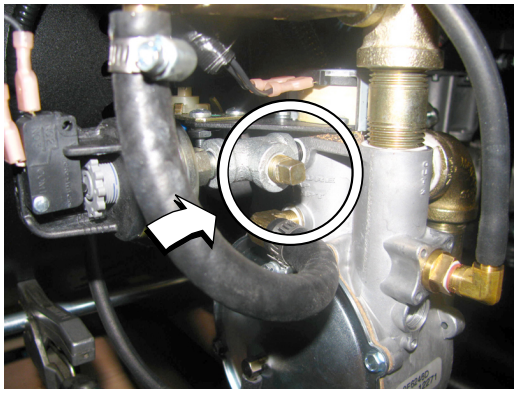

Figure 6-7. 1/8 in Pipe Port Location

See ***Figure 6-8***. 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. 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.

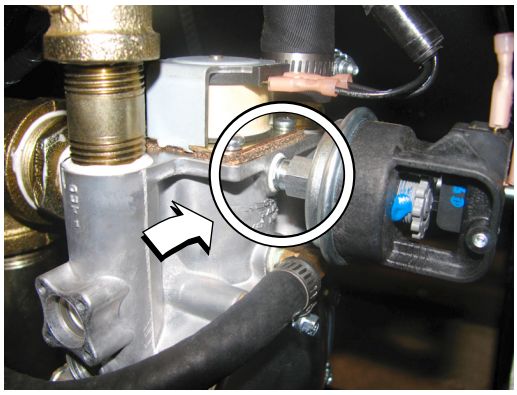

Figure 6-8. Tee and Plug Location

See ***Figure 6-9***. On 150 kW and larger units using the dual fuel shutoff solenoids, the low pressure switch is located in the piping as shown. Remove the switch and install an appropriately sized tee and plug between it and the fuel line.

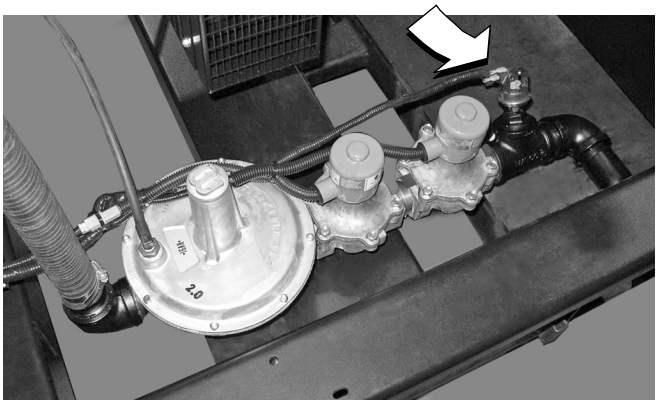

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Figure 6-9. Low Pressure Switch Location

Factory installed at the test point, some units may be equipped with a special test port plug known as a “Pete’s Plug.” (***Figure 6-10***). The plug allows fuel pressure test readings to be taken quickly without leaving costly gauges installed in the line.

Use the “Pete’s Plug” as follows:

1. Clean and lubricate gauge adapter probe with a small amount of petroleum jelly or silicone grease.
2. Assemble gauge adapter (***Figure 6-11***).

NOTE: Gauge adapter is a 1/8 in diameter probe, part no. 0K2341.

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

NOTE: Quickly tighten the cap if escaping gas or liquid is heard or felt. Replace the plug if defective.

6. Insert gauge adapter into test port plug and secure.

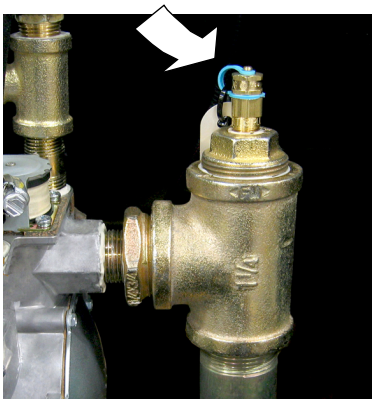

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Figure 6-10. Pete’s Plug Location

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Figure 6-11. Gauge Adapter

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

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

NOTE: Below 45 ºF (7 °C). the neoprene core of the plug does not recover it's original shape as rapidly as it would at higher temperatures. Therefore, upon removal of the gauge adapter probe, the valves may not close fully and immediately, or they may remain slightly open until the operating temperature is above 45 ºF (7 °C). Lower pressures and the length of time the gauge adapter probe is inserted also can affect the valve closing rate. The protective cap is provided to eliminate the small amount of leakage that might occur following removal of the gauge adapter probe.

8. Tighten protective cap to prevent tampering.

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 H_2O (0.25 kPa) 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 to 2 in H_2O (0.25 to 0.50 kPa) 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

General Information

⚠WARNING

Personal Injury. Fuel lines are pressurized. Servicing the fuel lines may release high pressure fuel and could result in death or serious injury.

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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 verify all components remain in good working order.

Diesel Fuel Base Tank

Units provided are typically mounted on their own base or 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).
- Single wall or double wall construction with rupture basin and level indicator switch.
- Emergency vent on main tank and rupture basin, if equipped.

Diesel Fuel Recommendations

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

Beginning October 1, 2010, diesel fuel used by owners and operators must meet:

1. Sulfur content of 15 parts per million (ppm) maximum.
2. Minimum cetane index of 40 or a maximum aromatic content of 35 volume percent.

IMPORTANT NOTE: Allow at least five percent of the tank capacity for fuel expansion. Do not overfill.

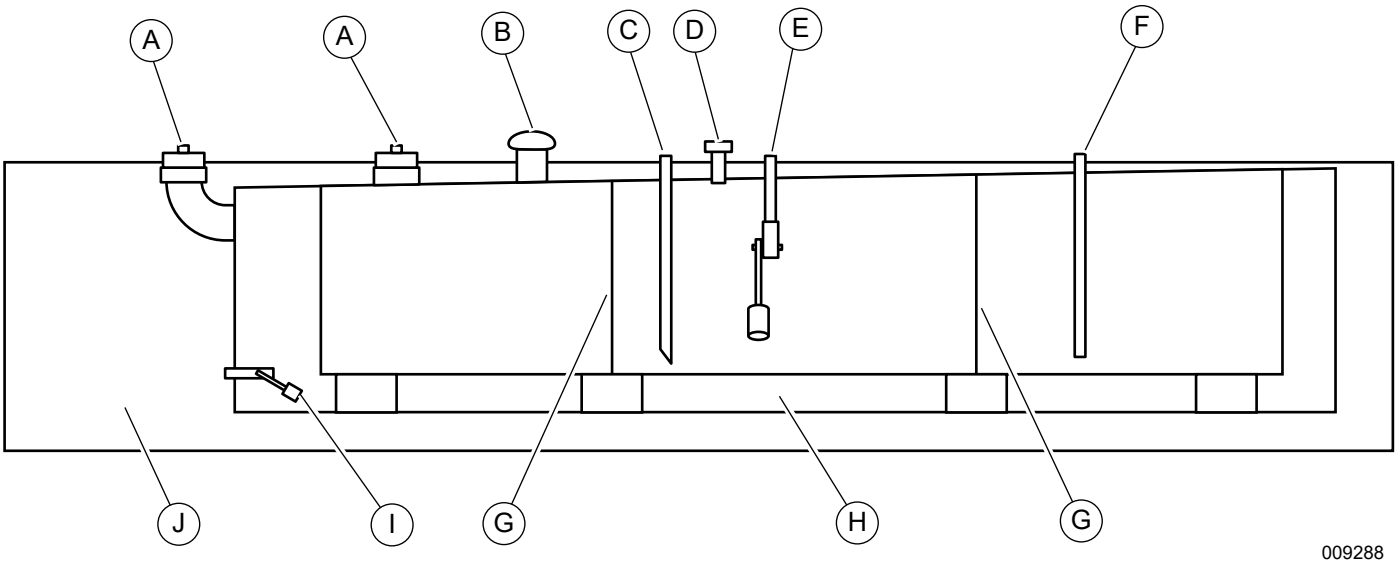

Figure 7-1. Typical Diesel Fuel Base Tank

A	Emergency vent	**F**	Fuel supply
B	Vent	**G**	Baffle
C	Fuel return	**H**	Leak containment area
D	Fuel fill	**I**	Rupture basin leak detector
E	Fuel level sensor	**J**	Stub up area

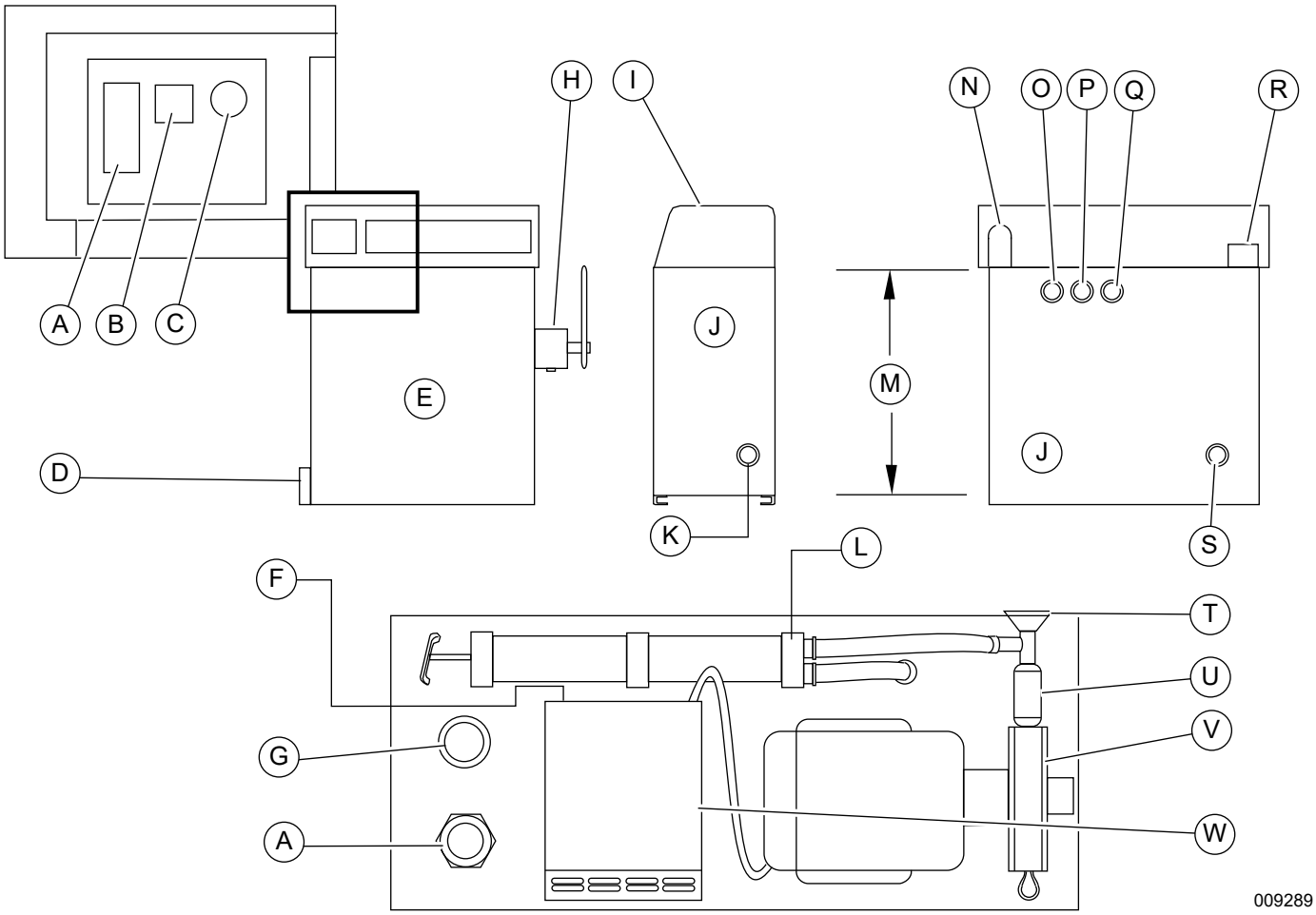

Figure 7-2. Typical Day Tank

A	Fuel level gauge	**M**	Usable fuel
B	“Push to test”	**N**	Fuel supply to pump
C	Pump running lamp	**O**	Vent
D	Drain	**P**	Overflow
E	Front view of unit	**Q**	Fuel return
F	Electric in	**R**	Opening for electrical connections
G	Optional fill cap	**S**	Alternate fuel return
H	Optional hand pump	**T**	Fuel in
I	Removable cover	**U**	Optional inlet check valve
J	Right end view	**V**	Pump
K	Engine fuel supply	**W**	Electric control module
L	Optional hand pump		

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, and water drain. See ***Figure 7-2***.

- Mount day tanks so their fuel level is lower than the engine fuel injectors. The vertical lift between the day tank and the engine must not exceed 40 in (102 cm). 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 in (102 cm). 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.

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 or separators, secondary filter systems are available to provide added functionality: water and fuel separators, fuel heaters and coolers, and additional fine filtration capacity.

Always prime engines before starting. Once started, run at no load long enough to ensure air is evacuated from the fuel lines and that fuel filters are full.

Section 8 Electrical System

General Information

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

Panels are provided to 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.

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. Verify the 120/240, 120/208 auxiliary power circuit to the unit is de-energized.

Verify wires are de-energized (using appropriate safety gear and a meter) before handling.

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 (12-24 VDC) 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). 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.

High Voltage Customer Connections

The high voltage customer connection panel contains the terminals to connect all of the high voltage wiring, greater than 30 VAC/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, and Enclosure Lighting.
- 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

Breaker Frame	Circuit Breaker Range (A)	Wire Type	Wire Temperature Rating	Circuit Breaker Lug AWG Wire Range/(Number of Conductors)	Torque to Wire
Series G - JG Frame	20 - 250	Cu	167 ºF (75 ºC)	4-350 kcmil (1)	180 **in-lb** (20.3 Nm)
Series G - LG Frame	160 - 600	Cu/Al	167 ºF (75 ºC)	2-500 kcmil (2)	375 **in-lb** (42.4 Nm)
Series C - F Frame	15 - 100	Cu/Al	167 ºF (75 ºC)	14-1/0 (1)	(#14-10) 35 **in-lb** (4 Nm)
					(#8) 40 **in-lb** (4.5 Nm)
					(#6-4) 45 **in-lb** (5.1 Nm)
					(#3-1/0) 50 **in-lb** (5.6 Nm)
	60 - 200	Cu/Al		4-4/0 (1)	120 **in-lb** (13.6 Nm)
	100 - 225	Cu/Al		6-300 kcmil (1)	120 **in-lb** (13.6 Nm)
Series C - J Frame	250	Cu	167 ºF (75 ºC)	4-350 kcmil (1)	275 **in-lb** (13.1 Nm)
Series C - K Frame	225	Cu/Al	167 ºF (75 ºC)	3-350 kcmil (1)	275 **in-lb** (13.1 Nm)
	300	Cu/Al		250-500 kcmil (1)	375 **in-lb** (42.4 Nm)
	350 - 400	Cu/Al		3/0-250 kcmil (2)	275 **in-lb** (13.1 Nm)
Series C - L Frame	450 - 500	Cu/Al	167 ºF (75 ºC)	3/0-350 kcmil (2)	275 **in-lb** (13.1 Nm)
	600	Cu/Al		400-550 kcmil (2)	275 **in-lb** (13.1 Nm)
Series C - M Frame	700 - 800	Cu/Al	167 ºF (75 ºC)	3/0-400 kcmil (3)	375 **in-lb** (42.4 Nm)
Series C - N Frame	900 - 1,000	Cu/Al	167 ºF (75 ºC)	4/0-500 kcmil (4)	375 **in-lb** (42.4 Nm)
	1,200	Cu/Al		500-750 kcmil (3)	450 **in-lb** (50.8 Nm)
Series C - R Frame	1,400 - 1,600	Cu/Al	167 ºF (75 ºC)	500-1000 kcmil (4)	550 **in-lb** (62.1 Nm)

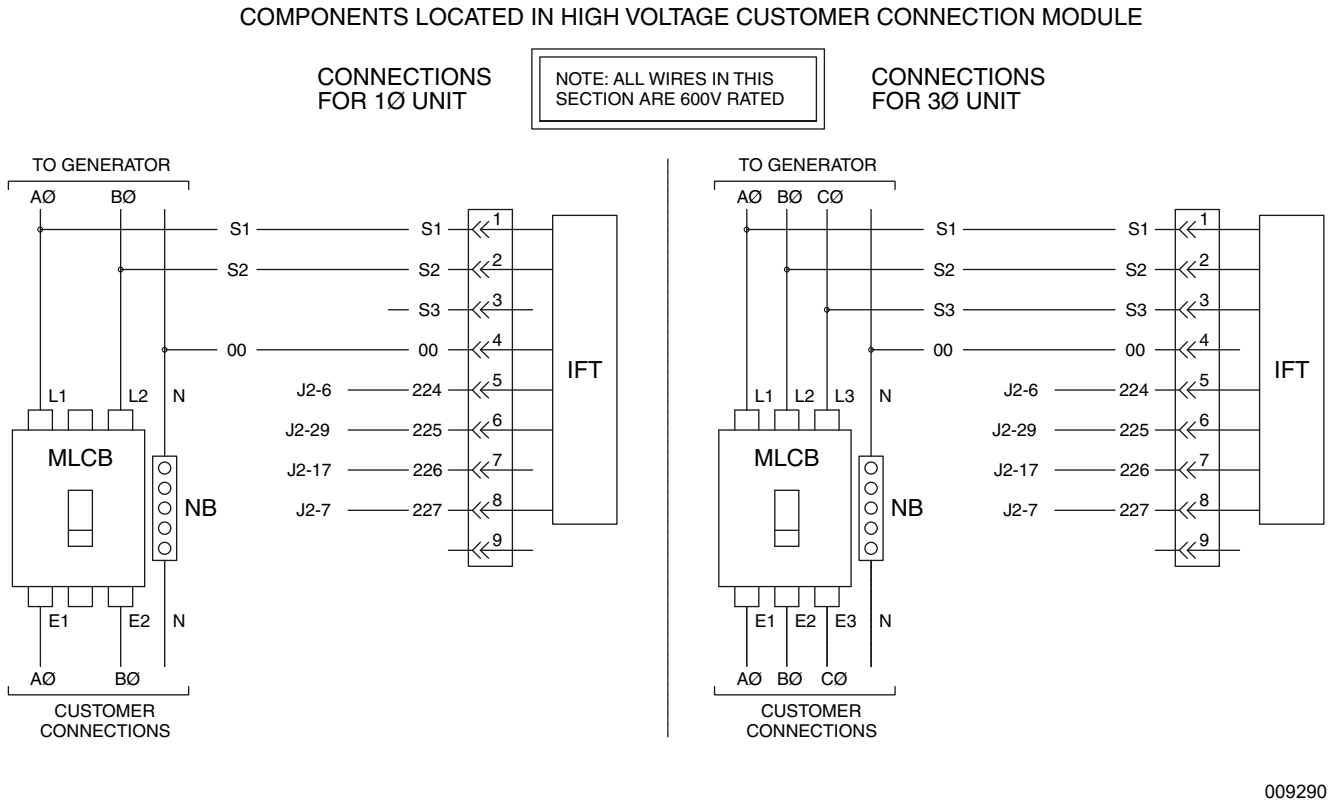

Figure 8-1. Typical Industrial Diagram Showing Load Lead Connections to MLCB

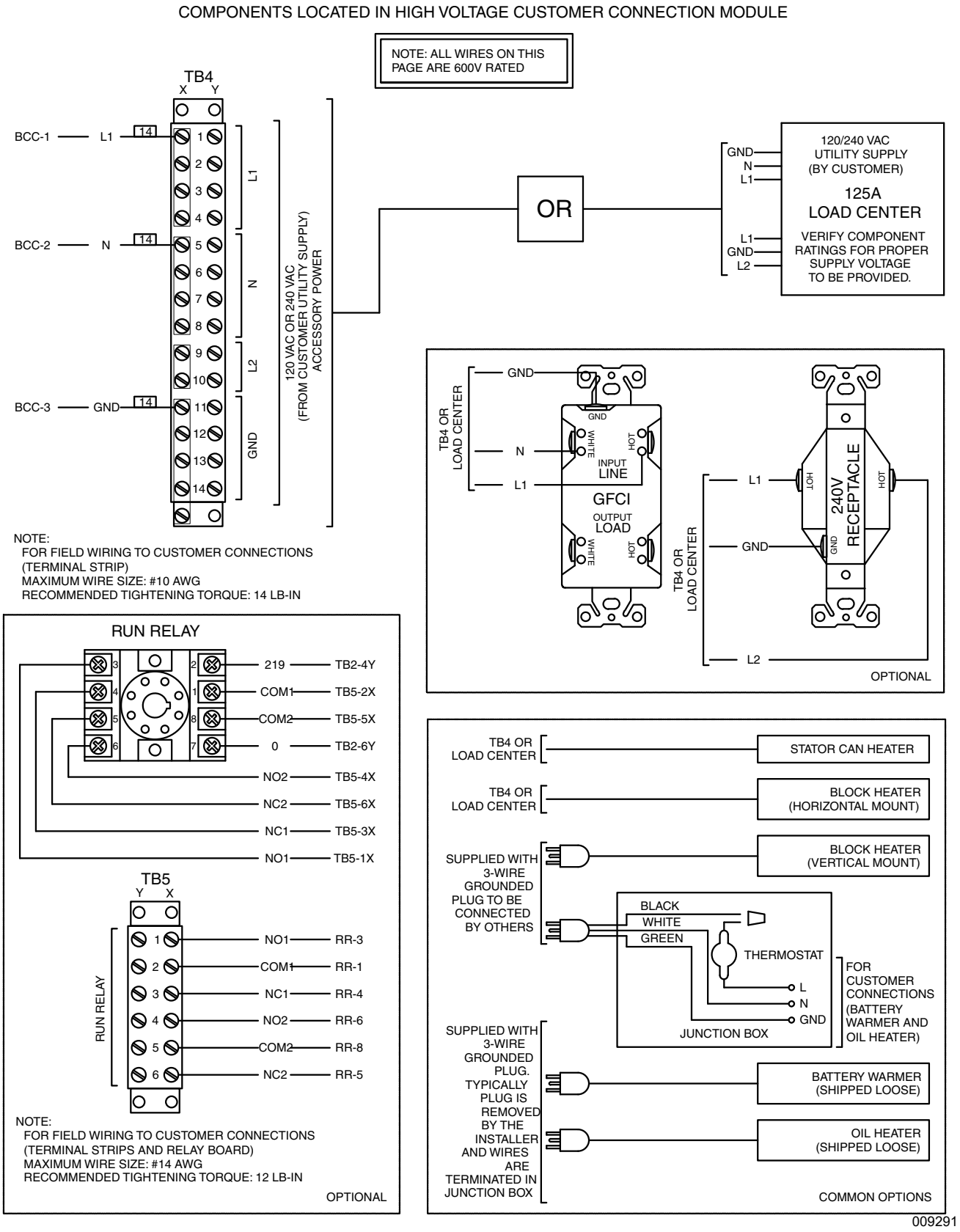

Figure 8-2. Typical Customer Connection in High Voltage Connection Module

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***.

Field Wiring Connections to Buss Bars

Units supplied with Series C - R Frame Breakers rated 1,400, 1,600, 2,000, and 2,500A 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 in studs spaced 1-3/4 in apart.
- **Wire Size:** 600 kcmil.
- **Hardware and 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 (101.7 Nm), Lubed 58 ft-lbs (78.6 Nm)
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 (115.2 Nm), Lubed 65 ft-lbs (88.1 Nm)

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 (5 VDC 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 5 VDC 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 24 VDC) or 15A (fused 12 VDC). 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 30 VAC/30 VDC. The relays are programmed using Genlink-DCP software working with the control panel.

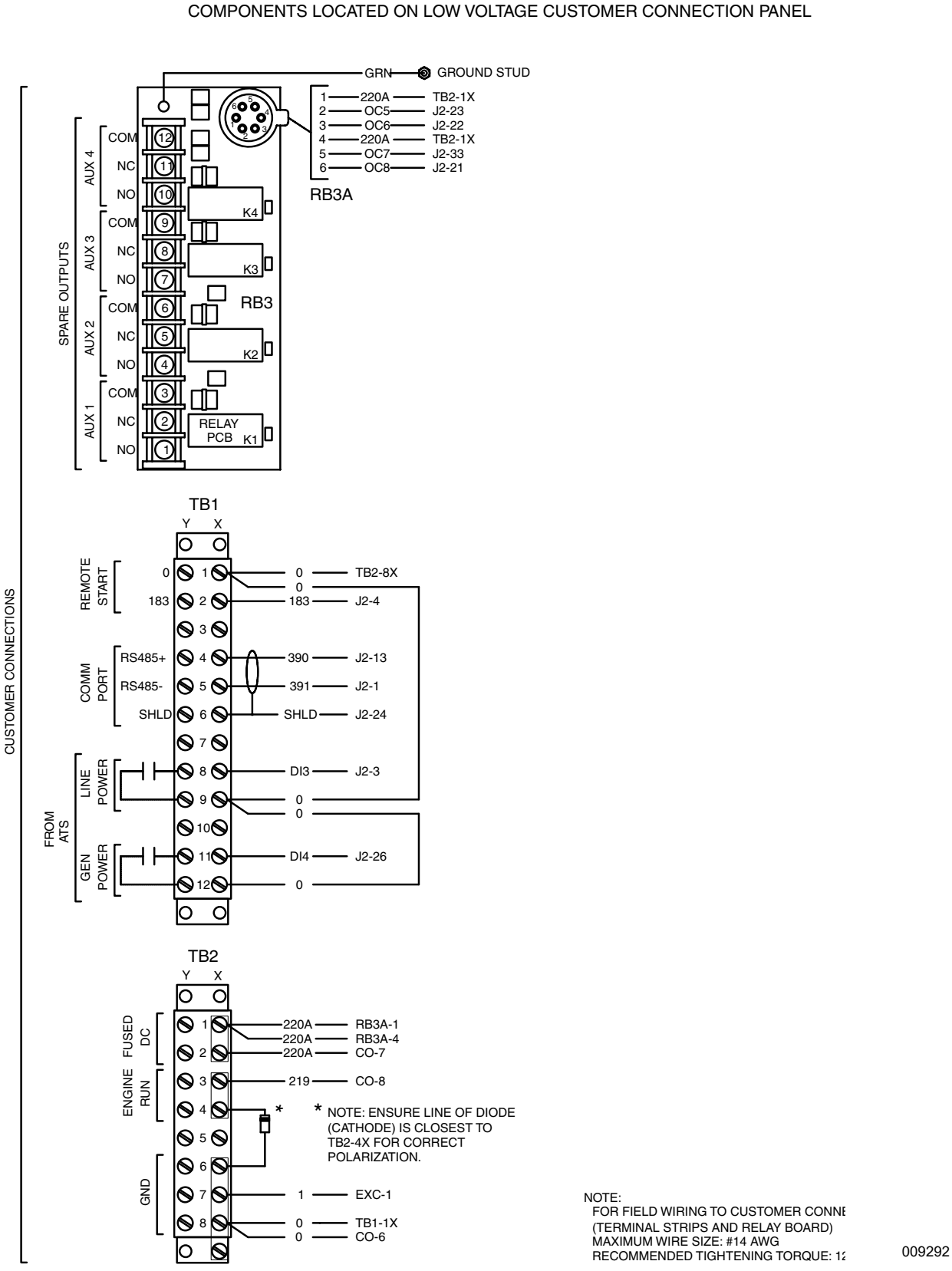

Figure 8-3. Typical Industrial Low Voltage Connection Panel Diagram

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

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

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, and insulation 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 transmitted to the surrounding areas of the building and maintain site fire code rating.

Battery

⚠DANGER

Electrocution. Do not wear jewelry while working on this equipment. Doing so will result in death or serious injury.

(000188)

⚠WARNING

Explosion. Do not dispose of batteries in a fire. Batteries are explosive. Electrolyte solution can cause burns and blindness. If electrolyte contacts skin or eyes, flush with water and seek immediate medical attention.

(000162)

⚠WARNING

Explosion. Batteries emit explosive gases while charging. Keep fire and spark away. Wear protective gear when working with batteries. Failure to do so could result in death or serious injury.

(000137a)

⚠WARNING

Equipment damage. Only qualified service personnel may install, operate, and maintain this equipment. Failure to follow proper installation requirements could result in death, serious injury, and equipment or property damage.

(000182a)

⚠WARNING

Electrical shock. Disconnect battery ground terminal before working on battery or battery wires. Failure to do so could result in death or serious injury.

(000164)

⚠WARNING

Risk of burns. Batteries contain sulfuric acid and can cause severe chemical burns. Wear protective gear when working with batteries. Failure to do so could result in death or serious injury.

(000138a)

⚠WARNING

Risk of burn. Do not open or mutilate batteries. Batteries contain electrolyte solution which can cause burns and blindness. If electrolyte contacts skin or eyes, flush with water and seek immediate medical attention.

(000163a)

⚠WARNING

Environmental Hazard. Always recycle batteries at an official recycling center in accordance with all local laws and regulations. Failure to do so could result in environmental damage, death or serious injury.

(000228)

Always recycle batteries in accordance with local laws and regulations. Contact your local solid waste collection site or recycling facility to obtain information on local recycling processes. For more information on battery recycling, visit the Battery Council International website at: ***http://batterycouncil.org***

IMPORTANT NOTE: 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.

IMPORTANT NOTE: Verify the AUTO/OFF/MANUAL switch is set to OFF 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.

IMPORTANT NOTE: Verify 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.

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

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.

Battery Size

The ability to start the engine depends upon battery capacity, ambient temperatures and coolant and oil temperatures. The engine and 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.

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 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.

Battery Cables

⚠CAUTION

Equipment damage. Do not make battery connections in reverse. Doing so will result in equipment damage.

(000167a)

The wire size (wire gauge) of the cables connecting the starter to the batteries must be large enough to ensure the resistance 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.

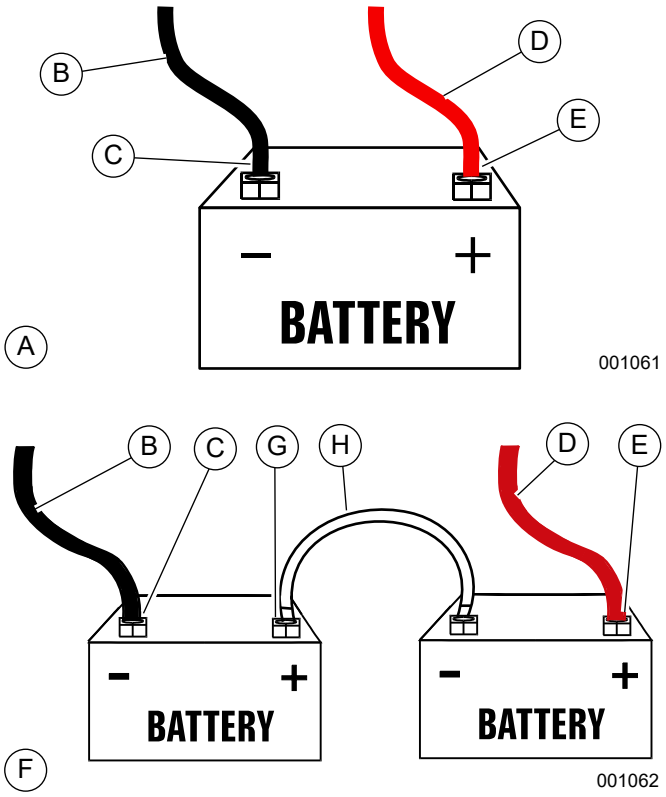

Figure 8-4. Battery Cable Connections

A	12 VDC system
B	Black lead to frame
C	Black (-)
D	Red lead from starter contactor
E	Red (+)
F	24 VDC system
G	Red or black jumper
H	Wire 13

Battery Installation and Replacement

When required, the battery must be replaced with one of equivalent size, voltage, and CCA (cold crank amp capacity). See the Unit Specification Sheet or contact an IASD for proper battery sizing.

A new battery must be filled with the proper electrolyte and be fully charged before installing.

Preliminary Instructions

1. Set the AUTO/OFF/MANUAL switch on the generator control panel to OFF.
2. Turn OFF utility power supply to the battery charger circuit.
3. Remove the 10A fuse from the generator control panel.
4. Remove 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***.

12 VDC System

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

24 VDC System

1. Connect the red battery cable from the starter contactor to the positive (+) post of the first battery (E).
2. Connect the black battery cable to the frame ground to the negative (-) post of the second battery (C).

NOTE: See ***Figure 8-4***. On 24V gaseous units, center tap wire number 13 (G) between the batteries.

3. Connect either a black or red jumper cable from the negative (-) post of battery A to the positive (+) post of battery B.

Final Instructions

1. Install the ATC style fuse in the battery charger.
2. Install the 10A fuse in the generator control panel.
3. Turn on the utility power supply to the battery charger circuit.
4. If the unit was previously operational, turn the AUTO/OFF/MANUAL switch on the generator control panel to AUTO.

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Section 9 Installation Checklists

Safety Checklist

NOTE: See ***Introduction and Safety*** 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?

Installation Planning Checklist

NOTE: See ***Installation Planning*** 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 5 ft (152 cm) 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?

Foundations and Mounting Checklist

NOTE: See ***Foundations and Mounting*** 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 in (46 cm) and above the surrounding surface by 3 to 8 in (8 to 20 cm)?
- ☐ Is the concrete pad flat and level to within 1/2 in (13 mm)?
- ☐ 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 in (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?

Ventilation System Checklist

NOTE: See ***Ventilation System*** 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, and battery warmers)?
- ☐ Do these parameters meet all applicable codes and local jurisdiction?

Exhaust System Checklist

NOTE: See ***Exhaust System*** 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 muffler installed in the exhaust system to reduce noise levels?
- ☐ Does the exhaust outlet direct exhaust gases toward any openings (such as doors, windows, or vents) 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 have its own exhaust system?
- ☐ Does the system use flanged exhaust pipe rated for at least 1,500 °F (816 °C) 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 axial movement of rigid piping due to thermal expansion and 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 mufflers 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 muffler?
- ☐ Are exhaust discharges directed away from combustible surfaces and inhabited areas?
- ☐ Are there at least 9 in (22.9 cm) of clearance between exhaust piping and any combustible surface?
- ☐ Is exhaust piping kept clear of fuel tanks and fuel lines?
- ☐ 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 muffler 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 muffler 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?

Gaseous Fuel System Checklist

NOTE: See ***Gaseous Fuel Systems*** 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 ft (305 cm) 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 have a maximum allowable pressure drop of 1 to 2 in H_2O (0.25 to 0.50 kPa) 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 to 15 in H_2O (1.7 to 3.7 kPa)?
- ☐ 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 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?

Diesel Fuel System Checklist

NOTE: See ***Diesel Fuel Systems*** 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 in (102 cm)?
- ☐ 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?

Electrical System Checklist

NOTE: See ***Electrical System*** 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 items such as block heaters and battery charger 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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