Installation

Industrial Generator Sets

Models:

20-2800 kW

ISO 9001
KOHLER POWER SYSTEMS
NATIONALLY REGISTERED

KOHLER®
POWER SYSTEMS

TP-5700 4/06f

California Proposition 65

⚠ WARNING

Engine exhaust from this product contains chemicals known to the State of California to cause cancer, birth defects, or other reproductive harm.

Product Identification Information

Product identification numbers determine service parts. Record the product identification numbers in the spaces below immediately after unpacking the products so that the numbers are readily available for future reference. Record field-installed kit numbers after installing the kits.

Generator Set Identification Numbers

Record the product identification numbers from the generator set nameplate(s).

Model Designation ______________________________

Specification Number ___________________________

Serial Number _________________________________

Accessory Number	Accessory Description

Controller Identification

Record the controller description from the generator set operation manual, spec sheet, or sales invoice.

Controller Description ___________________________

Engine Identification

Record the product identification information from the engine nameplate.

Manufacturer ___________________________________

Model Designation _______________________________

Serial Number __________________________________

Table of Contents

IMPORTANT SAFETY INSTRUCTIONS. Electromechanical equipment, including generator sets, transfer switches, switchgear, and accessories, can cause bodily harm and pose life-threatening danger when improperly installed, operated, or maintained. To prevent accidents be aware of potential dangers and act safely. Read and follow all safety precautions and instructions. SAVE THESE INSTRUCTIONS.

This manual has several types of safety precautions and instructions: Danger, Warning, Caution, and Notice.

DANGER

Danger indicates the presence of a hazard that ***will cause severe personal injury, death***, or ***substantial property damage***.

WARNING

Warning indicates the presence of a hazard that ***can cause severe personal injury, death,*** or ***substantial property damage***.

CAUTION

Caution indicates the presence of a hazard that ***will*** or ***can cause minor personal injury*** or ***property damage***.

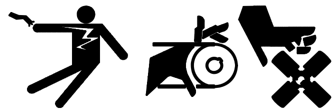
NOTICE

Notice communicates installation, operation, or maintenance information that is safety related but not hazard related.

Safety decals affixed to the equipment in prominent places alert the operator or service technician to potential hazards and explain how to act safely. The decals are shown throughout this publication to improve operator recognition. Replace missing or damaged decals.

Accidental Starting

WARNING



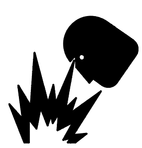
Accidental starting.
Can cause severe injury or death.

Disconnect the battery cables before working on the generator set. Remove the negative (–) lead first when disconnecting the battery. Reconnect the negative (–) lead last when reconnecting the battery.

Disabling the generator set. Accidental starting can cause severe injury or death. Before working on the generator set or connected equipment, disable the generator set as follows: (1) Move the generator set master switch to the OFF position. (2) Disconnect the power to the battery charger. (3) Remove the battery cables, negative (–) lead first. Reconnect the negative (–) lead last when reconnecting the battery. Follow these precautions to prevent starting of the generator set by an automatic transfer switch, remote start/stop switch, or engine start command from a remote computer.

Battery

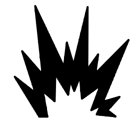
WARNING



Sulfuric acid in batteries.
Can cause severe injury or death.

Wear protective goggles and clothing. Battery acid may cause blindness and burn skin.

WARNING



Explosion.
Can cause severe injury or death. Relays in the battery charger cause arcs or sparks.

Locate the battery in a well-ventilated area. Isolate the battery charger from explosive fumes.

Battery electrolyte is a diluted sulfuric acid. Battery acid can cause severe injury or death. Battery acid can cause blindness and burn skin. Always wear splashproof safety goggles, rubber gloves, and boots when servicing the battery. Do not open a sealed battery or mutilate the battery case. If battery acid splashes in the eyes or on the skin, immediately flush the affected area for 15 minutes with large quantities of clean water. Seek immediate medical aid in the case of eye contact. Never add acid to a battery after placing the battery in service, as this may result in hazardous spattering of battery acid.

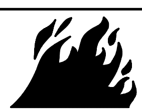
Battery acid cleanup. Battery acid can cause severe injury or death. Battery acid is electrically conductive and corrosive. Add 500 g (1 lb.) of bicarbonate of soda (baking soda) to a container with 4 L (1 gal.) of water and mix the neutralizing solution. Pour the neutralizing solution on the spilled battery acid and continue to add the neutralizing solution to the spilled battery acid until all evidence of a chemical reaction (foaming) has ceased. Flush the resulting liquid with water and dry the area.

Battery gases. Explosion can cause severe injury or death. Battery gases can cause an explosion. Do not smoke or permit flames or sparks to occur near a battery at any time, particularly when it is charging. Do not dispose of a battery in a fire. To prevent burns and sparks that could cause an explosion, avoid touching the battery terminals with tools or other metal objects. Remove all jewelry before servicing the equipment. Discharge static electricity from your body before touching batteries by first touching a grounded metal surface away from the battery. To avoid sparks, do not disturb the battery charger connections while the battery is charging. Always turn the battery charger off before disconnecting the battery connections. Ventilate the compartments containing batteries to prevent accumulation of explosive gases.

Battery short circuits. Explosion can cause severe injury or death. Short circuits can cause bodily injury and/or equipment damage. Disconnect the battery before generator set installation or maintenance. Remove all jewelry before servicing the equipment. Use tools with insulated handles. Remove the negative (–) lead first when disconnecting the battery. Reconnect the negative (–) lead last when reconnecting the battery. Never connect the negative (–) battery cable to the positive (+) connection terminal of the starter solenoid. Do not test the battery condition by shorting the terminals together.

Engine Backfire/Flash Fire

WARNING



Fire.
Can cause severe injury or death.

Do not smoke or permit flames or sparks near fuels or the fuel system.

Servicing the fuel system. A flash fire can cause severe injury or death. Do not smoke or permit flames or sparks near the carburetor, fuel line, fuel filter, fuel pump, or other potential sources of spilled fuels or fuel vapors. Catch fuels in an approved container when removing the fuel line or carburetor.

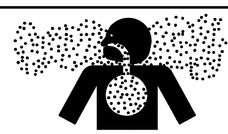
Servicing the fuel system. A flash fire can cause severe injury or death. Do not smoke or permit flames or sparks near the fuel injection system, fuel line, fuel filter, fuel pump, or other potential sources of spilled fuels or fuel vapors. Catch fuels in an approved container when removing the fuel line or fuel system.

Servicing the air cleaner. A sudden backfire can cause severe injury or death. Do not operate the generator set with the air cleaner removed.

Combustible materials. A fire can cause severe injury or death. Generator set engine fuels and fuel vapors are flammable and explosive. Handle these materials carefully to minimize the risk of fire or explosion. Equip the compartment or nearby area with a fully charged fire extinguisher. Select a fire extinguisher rated ABC or BC for electrical fires or as recommended by the local fire code or an authorized agency. Train all personnel on fire extinguisher operation and fire prevention procedures.

Exhaust System

WARNING



Carbon monoxide.
Can cause severe nausea, fainting, or death.

The exhaust system must be leakproof and routinely inspected.

Generator set operation. Carbon monoxide can cause severe nausea, fainting, or death. Carbon monoxide is an odorless, colorless, tasteless, nonirritating gas that can cause death if inhaled for even a short time. Avoid breathing exhaust fumes when working on or near the generator set. Never operate the generator set inside a building unless the exhaust gas is piped safely outside. Never operate the generator set where exhaust gas could accumulate and seep back inside a potentially occupied building.

Carbon monoxide symptoms. Carbon monoxide can cause severe nausea, fainting, or death. Carbon monoxide is a poisonous gas present in exhaust gases. Carbon monoxide poisoning symptoms include but are not limited to the following:

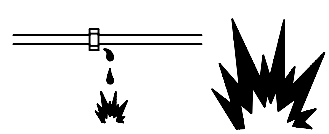
- Light-headedness, dizziness
- Physical fatigue, weakness in joints and muscles
- Sleepiness, mental fatigue, inability to concentrate or speak clearly, blurred vision
- Stomachache, vomiting, nausea

If experiencing any of these symptoms and carbon monoxide poisoning is possible, seek fresh air immediately and remain active. Do not sit, lie down, or fall asleep. Alert others to the possibility of carbon monoxide poisoning. Seek medical attention if the condition of affected persons does not improve within minutes of breathing fresh air.

Copper tubing exhaust systems. Carbon monoxide can cause severe nausea, fainting, or death. Do not use copper tubing in diesel exhaust systems. Sulfur in diesel exhaust causes rapid deterioration of copper tubing exhaust systems, resulting in exhaust leakage.

Fuel System

WARNING



Explosive fuel vapors.
Can cause severe injury or death.

Use extreme care when handling, storing, and using fuels.

WARNING

Avoid high pressure fluids.
Can cause severe injury or death.

Do not work on high pressure fuel or hydraulic systems without protective gloves. Avoid the hazard by relieving pressure before disconnecting fuel injection pressure lines. Search for leaks using a piece of cardboard. Always protect hands and body from high pressure fluids. If an accident occurs, seek medical attention immediately. Any fluid injected in the skin tissues must be surgically removed within a few hours or gangrene may result.

The fuel system. Explosive fuel vapors can cause severe injury or death. Vaporized fuels are highly explosive. Use extreme care when handling and storing fuels. Store fuels in a well-ventilated area away from spark-producing equipment and out of the reach of children. Never add fuel to the tank while the engine is running because spilled fuel may ignite on contact with hot parts or from sparks. Do not smoke or permit flames or sparks to occur near sources of spilled fuel or fuel vapors. Keep the fuel lines and connections tight and in good condition. Do not replace flexible fuel lines with rigid lines. Use flexible sections to avoid fuel line breakage caused by vibration. Do not operate the generator set in the presence of fuel leaks, fuel accumulation, or sparks. Repair fuel systems before resuming generator set operation.

Explosive fuel vapors can cause severe injury or death. Take additional precautions when using the following fuels:

Gasoline—Store gasoline only in approved red containers clearly marked GASOLINE.

Propane (LP)—Adequate ventilation is mandatory. Because propane is heavier than air, install propane gas detectors low in a room. Inspect the detectors per the manufacturer's instructions.

Natural Gas—Adequate ventilation is mandatory. Because natural gas rises, install natural gas detectors high in a room. Inspect the detectors per the manufacturer's instructions.

Fuel tanks. Explosive fuel vapors can cause severe injury or death. Gasoline and other volatile fuels stored in day tanks or subbase fuel tanks can cause an explosion. Store only diesel fuel in tanks.

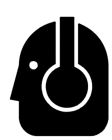
Draining the fuel system. Explosive fuel vapors can cause severe injury or death. Spilled fuel can cause an explosion. Use a container to catch fuel when draining the fuel system. Wipe up spilled fuel after draining the system.

Gas fuel leaks. Explosive fuel vapors can cause severe injury or death. Fuel leakage can cause an explosion. Check the LP vapor gas or natural gas fuel system for leakage by using a soap and water solution with the fuel system test pressurized to 6-8 ounces per square inch (10-14 inches water column). Do not use a soap solution containing either ammonia or chlorine because both prevent bubble formation. A successful test depends on the ability of the solution to bubble.

LP liquid withdrawal fuel leaks. Explosive fuel vapors can cause severe injury or death. Fuel leakage can cause an explosion. Check the LP liquid withdrawal gas fuel system for leakage by using a soap and water solution with the fuel system test pressurized to at least 90 psi (621 kPa). Do not use a soap solution containing either ammonia or chlorine because both prevent bubble formation. A successful test depends on the ability of the solution to bubble.

Hazardous Noise

CAUTION



Hazardous noise.
Can cause hearing loss.

Never operate the generator set without a muffler or with a faulty exhaust system.

Engine noise. Hazardous noise can cause hearing loss. Generator sets not equipped with sound enclosures can produce noise levels greater than 105 dBA. Prolonged exposure to noise levels greater than 85 dBA can cause permanent hearing loss. Wear hearing protection when near an operating generator set.

Hazardous Voltage/ Electrical Shock

DANGER

Hazardous voltage.
Will cause severe injury or death.

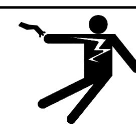
Disconnect all power sources before opening the enclosure.

WARNING

Hazardous voltage. Moving rotor.
Can cause severe injury or death.

Operate the generator set only when all guards and electrical enclosures are in place.

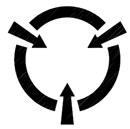
WARNING



Hazardous voltage.
Backfeed to the utility system can cause property damage, severe injury, or death.

If the generator set is used for standby power, install an automatic transfer switch to prevent inadvertent interconnection of standby and normal sources of supply.

CAUTION



Welding the generator set.
Can cause severe electrical equipment damage.

Never weld components of the generator set without first disconnecting the battery, controller wiring harness, and engine electronic control module (ECM).

Grounding electrical equipment. Hazardous voltage can cause severe injury or death. Electrocution is possible whenever electricity is present. Open the main circuit breakers of all power sources before servicing the equipment. Configure the installation to electrically ground the generator set, transfer switch, and related equipment and electrical circuits to comply with applicable codes and standards. Never contact electrical leads or appliances when standing in water or on wet ground because these conditions increase the risk of electrocution.

Welding on the generator set. Can cause severe electrical equipment damage. Before welding on the generator set perform the following steps: (1) Remove the battery cables, negative (–) lead first. (2) Disconnect all engine electronic control module (ECM) connectors. (3) Disconnect all generator set controller and voltage regulator circuit board connectors. (4) Disconnect the engine battery-charging alternator connections. (5) Attach the weld ground connection close to the weld location.

Installing the battery charger. Hazardous voltage can cause severe injury or death. An ungrounded battery charger may cause electrical shock. Connect the battery charger enclosure to the ground of a permanent wiring system. As an alternative, install an equipment grounding conductor with circuit conductors and connect it to the equipment grounding terminal or the lead on the battery charger. Install the battery charger as prescribed in the equipment manual. Install the battery charger in compliance with local codes and ordinances.

Connecting the battery and the battery charger. Hazardous voltage can cause severe injury or death. Reconnect the battery correctly, positive to positive and negative to negative, to avoid electrical shock and damage to the battery charger and battery(ies). Have a qualified electrician install the battery(ies).

Servicing the day tank. Hazardous voltage can cause severe injury or death. Service the day tank electrical control module (ECM) as prescribed in the equipment manual. Disconnect the power to the day tank before servicing. Press the day tank ECM OFF pushbutton to disconnect the power. Notice that line voltage is still present within the ECM when the POWER ON light is lit. Ensure that the generator set and day tank are electrically grounded. Do not operate the day tank when standing in water or on wet ground because these conditions increase the risk of electrocution.

Short circuits. Hazardous voltage/current can cause severe injury or death. Short circuits can cause bodily injury and/or equipment damage. Do not contact electrical connections with tools or jewelry while making adjustments or repairs. Remove all jewelry before servicing the equipment.

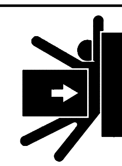
Engine block heater. Hazardous voltage can cause severe injury or death. The engine block heater can cause electrical shock. Remove the engine block heater plug from the electrical outlet before working on the block heater electrical connections.

Electrical backfeed to the utility. Hazardous backfeed voltage can cause severe injury or death. Install a transfer switch in standby power installations to prevent the connection of standby and other sources of power. Electrical backfeed into a utility electrical system can cause severe injury or death to utility personnel working on power lines.

Testing live electrical circuits. Hazardous voltage or current can cause severe injury or death. Have trained and qualified personnel take diagnostic measurements of live circuits. Use adequately rated test equipment with electrically insulated probes and follow the instructions of the test equipment manufacturer when performing voltage tests. Observe the following precautions when performing voltage tests: (1) Remove all jewelry. (2) Stand on a dry, approved electrically insulated mat. (3) Do not touch the enclosure or components inside the enclosure. (4) Be prepared for the system to operate automatically.
(600 volts and under)

Heavy Equipment

WARNING

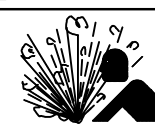


Unbalanced weight.
Improper lifting can cause severe injury or death and equipment damage.

Do not use lifting eyes.
Lift the generator set using lifting bars inserted through the lifting holes on the skid.

Hot Parts

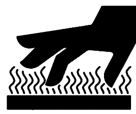
WARNING



Hot coolant and steam.
Can cause severe injury or death.

Before removing the pressure cap, stop the generator set and allow it to cool. Then loosen the pressure cap to relieve pressure.

WARNING



Hot engine and exhaust system.
Can cause severe injury or death.

Do not work on the generator set until it cools.

Checking the coolant level. Hot coolant can cause severe injury or death. Allow the engine to cool. Release pressure from the cooling system before removing the pressure cap. To release pressure, cover the pressure cap with a thick cloth and then slowly turn the cap counterclockwise to the first stop. Remove the cap after pressure has been completely released and the engine has cooled. Check the coolant level at the tank if the generator set has a coolant recovery tank.

Servicing the exhaust system. Hot parts can cause severe injury or death. Do not touch hot engine parts. The engine and exhaust system components become extremely hot during operation.

Servicing the engine heater. Hot parts can cause minor personal injury or property damage. Install the heater before connecting it to power. Operating the heater before installation can cause burns and component damage. Disconnect power to the heater and allow it to cool before servicing the heater or nearby parts.

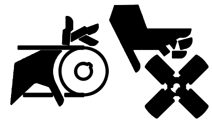
Moving Parts

WARNING

Hazardous voltage. Moving rotor.
Can cause severe injury or death.

Operate the generator set only when all guards and electrical enclosures are in place.

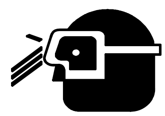
WARNING



Rotating parts.
Can cause severe injury or death.

Operate the generator set only when all guards, screens, and covers are in place.

WARNING



Airborne particles.
Can cause severe injury or blindness.

Wear protective goggles and clothing when using power tools, hand tools, or compressed air.

Tightening the hardware. Flying projectiles can cause severe injury or death. Loose hardware can cause the hardware or pulley to release from the generator set engine and can cause personal injury. Retorque all crankshaft and rotor hardware after servicing. Do not loosen the crankshaft hardware or rotor thrubolt when making adjustments or servicing the generator set. Rotate the crankshaft manually in a clockwise direction only. Turning the crankshaft bolt or rotor thrubolt counterclockwise can loosen the hardware.

Servicing the generator set when it is operating. Exposed moving parts can cause severe injury or death. Keep hands, feet, hair, clothing, and test leads away from the belts and pulleys when the generator set is running. Replace guards, screens, and covers before operating the generator set.

Notice

NOTICE

This generator set has been rewired from its nameplate voltage to

246242

NOTICE

Voltage reconnection. Affix a notice to the generator set after reconnecting the set to a voltage different from the voltage on the nameplate. Order voltage reconnection decal 246242 from an authorized service distributor/dealer.

NOTICE

Hardware damage. The engine and generator set may use both American Standard and metric hardware. Use the correct size tools to prevent rounding of the bolt heads and nuts.

NOTICE

When replacing hardware, do not substitute with inferior grade hardware. Screws and nuts are available in different hardness ratings. To indicate hardness, American Standard hardware uses a series of markings, and metric hardware uses a numeric system. Check the markings on the bolt heads and nuts for identification.

NOTICE

Canadian installations only. For standby service connect the output of the generator set to a suitably rated transfer switch in accordance with Canadian Electrical Code, Part 1.

NOTICE

Electrostatic discharge damage. Electrostatic discharge (ESD) damages electronic circuit boards. Prevent electrostatic discharge damage by wearing an approved grounding wrist strap when handling electronic circuit boards or integrated circuits. An approved grounding wrist strap provides a high resistance (about 1 megohm), *not a direct short*, to ground.

Notes

Introduction

This manual provides installation instructions for industrial generator sets. Operation manuals and wiring diagram manuals are available separately.

Some additional model-specific installation information may be included in the respective generator set controller operation manual.

Information in this publication represents data available at the time of print. Kohler Co. reserves the right to change this publication and the products represented without notice and without any obligation or liability whatsoever.

Read this manual and carefully follow all procedures and safety precautions to ensure proper equipment operation and to avoid bodily injury. Read and follow the Safety Precautions and Instructions section at the beginning of this manual. Keep this manual with the equipment for future reference.

Service Assistance

For professional advice on generator set power requirements and conscientious service, please contact your nearest Kohler distributor or dealer.

- Consult the Yellow Pages under the heading Generators—Electric
- Visit the Kohler Power Systems website at KohlerPowerSystems.com
- Look at the labels and stickers on your Kohler product or review the appropriate literature or documents included with the product
- Call toll free in the US and Canada 1-800-544-2444
- Outside the US and Canada, call the nearest regional office

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Bangalore, India
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(91) 80 3366231
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Japan, Korea
North Asia Regional Office
Tokyo, Japan
Phone: (813) 3440-4515
Fax: (813) 3440-2727

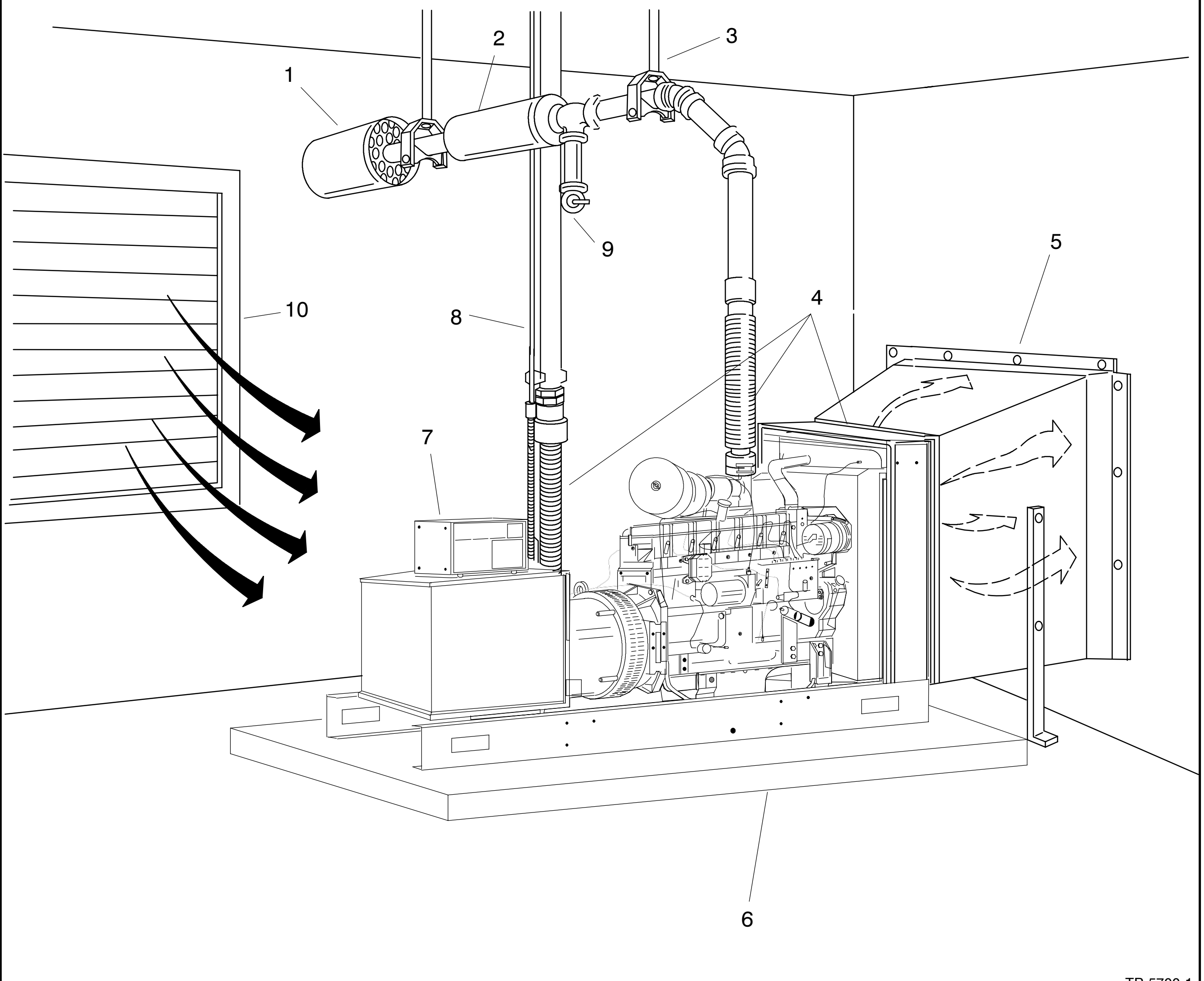
Latin America
Latin America Regional Office
Lakeland, Florida, USA
Phone: (863) 619-7568
Fax: (863) 701-7131

Notes

Section 1 General

Industrial power systems give years of dependable service if installed using the guidelines provided in this manual and in applicable codes. Incorrect installation can cause continuing problems. Figure 1-1 illustrates a typical installation.

Your authorized generator set distributor/dealer may also provide advice about or assistance with your installation.



1. Exhaust thimble (for wall or ceiling)
2. Silencer
3. Supports
4. Flexible sections
5. Duct work for cooling air outlet
6. Mounting base
7. Controller
8. Electrical conduit
9. Water trap with drain
10. Fresh air intake

Figure 1-1 Typical Stationary-Duty Generator Set Installation

This manual references several organizations and their codes that provide installation requirements and guidelines such as the National Fire Protection Association (NFPA) and Underwriter's Laboratories Inc. (UL).

- NFPA 54 National Fuel Gas Code
- NFPA 70 National Electrical Code®; the National Electrical Code is a registered trademark of the NFPA
- NFPA 99 Standard for Health Care Facilities
- NFPA 101 Life Safety Code
- NFPA 110 Emergency and Standby Power Systems
- UL 486A-486B Wire Connectors
- UL 486E Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors
- UL 2200 Stationary Engine Generator Assemblies

These organizations provide information specifically for US installations. Installers must comply with their respective national and local codes.

Before beginning generator set installation, record the following data from the generator set's specification sheet and keep this data accessible for reference during installation:

- Dimensions and weight (verify dimensions and weight using the submittal data)
- Exhaust outlet size and maximum allowable backpressure
- Battery CCA rating and quantity
- Fuel supply line size and fuel pressure requirement (gas models)
- Air requirements

The loading and transporting processes expose the generator set to many stresses and the possibility of improper handling. Therefore, after transporting industrial generator sets:

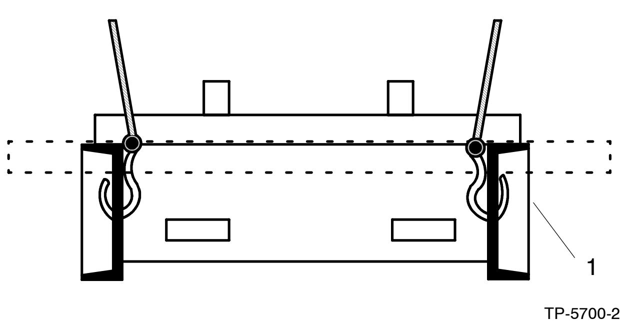
- Check the alignment of the radiator and supports to ensure that the radiator is evenly spaced from the generator and that supports are square and of even length. Check the radiator fan for uniform alignment and equal clearance within the radiator shroud. Adjust if necessary.
- After confirming the correct alignment, tighten the hardware to its specified torque. Reference Appendix C, General Torque Specifications.

2.1 Generator Set Lifting

2.1.1 General Precautions

Follow these general precautions when lifting all generator sets.

- Do not lift the generator set using the lifting eyes attached to the engine and/or alternator. These eyes cannot support the generator set's weight. Instead, use the four holes in the mounting skid of each generator set that are intended for attaching lifting hooks. The placement of the holes prevents the lifting cables from damaging the generator set components and maintains balance during lifting.
- If the lifting cables contact air cleaners, shrouds, or other protruding components, use spreader bars on the cables as outlined in subsequent sections. If the cables still do not clear the protruding component(s), remove the component(s).
- Generator sets above 1000 kW may have reinforcing plates on the skid. See Figure 2-1.



1. Reinforcing plate

Figure 2-1 Lifting Hook Placement (above 1000 kW)

Do not attach lifting hooks to the outside reinforcing plate of the skid. Attach lifting hooks as shown in Figure 2-1 to use the strongest portion of the mounting skid and prevent the lifting hooks from slipping. To raise generator sets not equipped with skid reinforcing plates, attach lifting hooks to either the inside or outside of the skid.

2.1.2 Determining Weights

Refer to the respective specification sheet and/or the submittal drawing for the weight of the generator set and accessories. Contact your distributor/dealer if weights are not shown. Specification sheets typically show weights for the following components:

- Generator set
- Weather housing
- Sound shield
- Subbase fuel tank

When the subbase fuel tank contains fuel, use the following formula to determine the weight of the diesel fuel:

Fuel in L x 0.848 = fuel weight in kg

Fuel in gal. x 7.08 = fuel weight in lb.

2.1.3 Lifting Methods

The distributor/lifting contractor should choose one of the following methods to lift the generator set depending upon the location circumstances and the generator set's weight and size. The hook and cable apparatus method may not be appropriate for heavier or bulkier generator sets; therefore, choose the lifting fixture method if there is any doubt regarding the ability of the hook and cable apparatus method to support the generator set's weight or to accommodate its size.

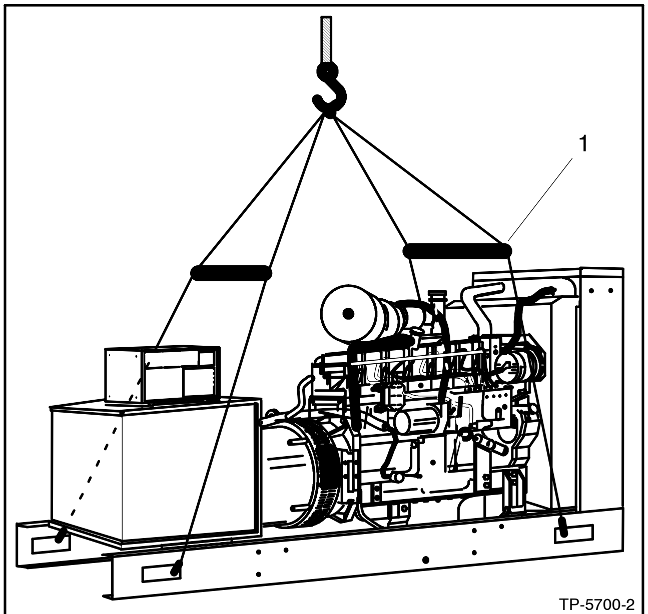
Hook and Cable Apparatus Method

- Lift the generator set by inserting lifting hooks in the skid's lifting holes. Use an apparatus of hooks and cables joined at a single rigging point. See Figure 2-2. If the cables contact any component of the generator set, use spreader bars slightly wider than the generator set skid to avoid damage to the generator set. Apply only vertical force to the skid while lifting.

- Lift the generator set by inserting bars that extend through the skid's lifting holes and then attaching lifting hooks to the bars. See Figure 2-3. Choose bars sized to support the weight of the generator set and secure the lifting hooks to prevent them from sliding off the ends of the bars. Use spreader bars if the lifting cables contact the generator set components.

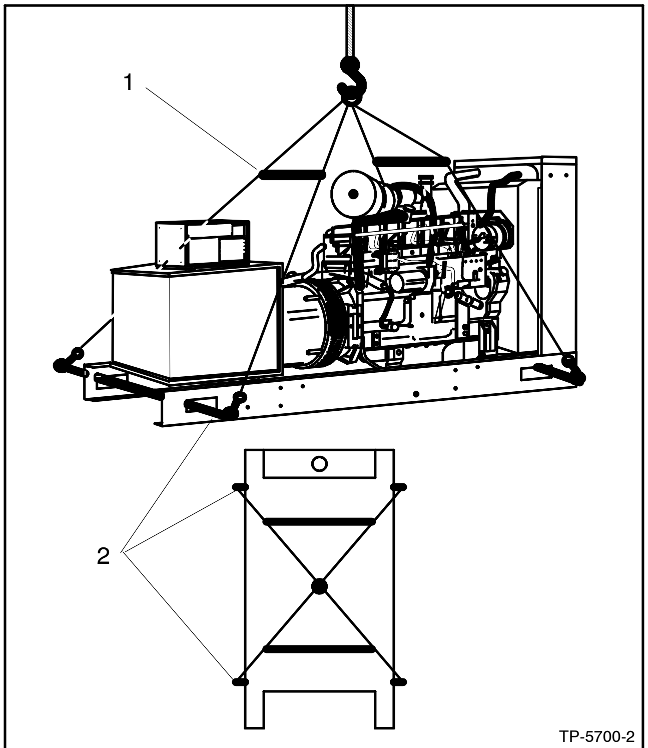
Lifting Fixture Method

Use a lifting fixture with adjustable cables to adapt to different size generator sets and to compensate for unit imbalance. See Figure 2-4. Select equipment (cables, chains, and bars) capable of handling the weight of the generator set.



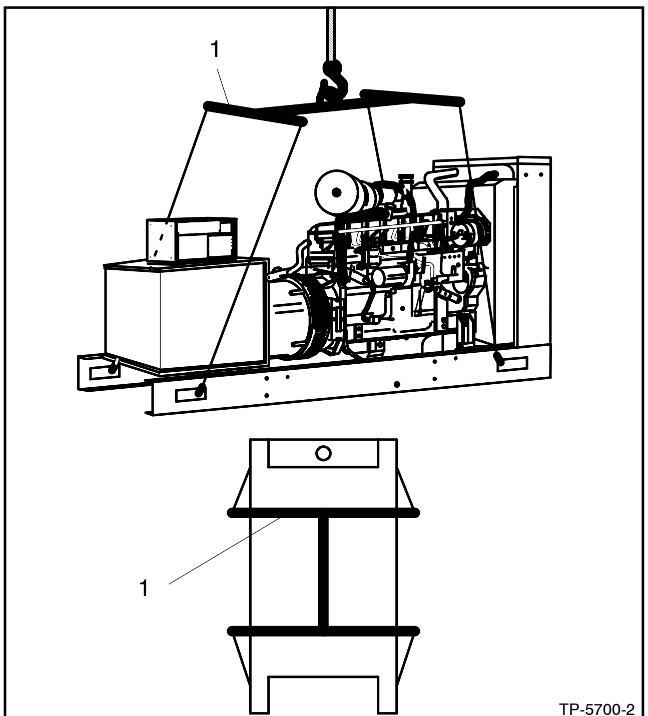
1. Spreader bars may be necessary to protect generator set

Figure 2-2 Generator Set with Lifting Hooks in Skid



1. Spreader bars may be necessary to protect generator set
2. Lifting bars

Figure 2-3 Generator Set with Lifting Bars in Skid



1. Lifting fixture

Figure 2-4 Generator Set with Lifting Fixture

2.1.4 Lifting Subbase Fuel Tank

The distributor and/or lifting contractor determines the type of subbase fuel tank lifting device. Lift the subbase fuel tank as one unit if the tank is not installed on the generator set. When lifting the fuel tank, use the subbase fuel tank's lifting eyes, if equipped; otherwise use chains or cables wrapped around the subbase fuel tank. If using lifting straps, protect the straps from the sharp edges of the fuel tank.

Generator sets to 400 kW. If the fuel tank is empty and does not extend outside the perimeter of the generator set skid, lift the generator set and the subbase fuel tank together. If the tank is not empty or extends outside the perimeter of the skid, use the next procedure.

Generator sets 400 kW and above. Uninstall the subbase fuel tank by removing the mounting hardware and wiring between the generator set and the subbase fuel tank. Lift the generator set and subbase fuel tank separately. It is not necessary to drain the fuel tank when lifting just the fuel tank.

2.1.5 Lifting Weather Housing

Lift the weather housing and generator set together as one unit while observing the general precautions in Section 2.1.1.

2.1.6 Lifting Sound Shield Installed on a Mounting Base (Concrete Slab)

If the generator set has an installed sound shield and subbase fuel tank, lift the set as one unit only if the subbase fuel tank has lifting eyes installed, the fuel tank is empty, and the tank does not extend outside the perimeter of the generator set skid. In all other cases, *remove the sound shield.*

Sound Shield Removal Procedure

Refer to the sound shield's installation instructions for general considerations and reference figures.

1. Remove the sound shield's attaching bolts. These bolts may be hidden by the sound shield insulation; if so, carefully lift the insulation near the skid to locate the bolts.
2. Lift the sound shield by the eyebolts to remove it from the wood skid. Use the sound shield eyebolts to lift *only* the sound shield.
3. Reinstall the sound shield after installing the generator set.

2.1.7 Lifting Sound Shield with Integral Structural Steel Mounting to Generator Set Skid

If the generator set has an installed sound shield that mounts directly to the generator set skid using structural steel components, the assembly can be lifted as a unit. This type of configuration typically provides a single top-lifting eye for lifting the entire assembly.

Remove the generator set from the shipping pallet before lifting the generator set assembly using the single lifting eye.

2.2 Generator Set Transporting

Follow these guidelines when transporting the generator set:

- Select the transporting vehicle/trailer based on the dimensions and weight of the generator set as specified in the generator set dimension drawing or specification sheet. Ensure that the gross weight and overall height of the generator set and vehicle/trailer in transport does not exceed applicable transportation codes.
- Use low boy-type trailers that meet clearance requirements when transporting units larger than 1000 kW. Load large (unboxed) radiator-equipped generator sets with the radiator facing the rear to reduce wind resistance during transit. Secure fans to prevent fan rotation in transit.
- Securely fasten the generator set to the vehicle/trailer and cover. Even the heaviest of generator sets can move during shipment unless they are secured. Fasten the generator set to the vehicle/trailer bed with a correctly-sized chain routed through the mounting holes of the generator set skid. Use chain tighteners to remove slack from the mounting chain. Cover the entire unit with a heavy-duty canvas or tarpaulin secured to the generator set or trailer.

Notes

3.1 Location Factors

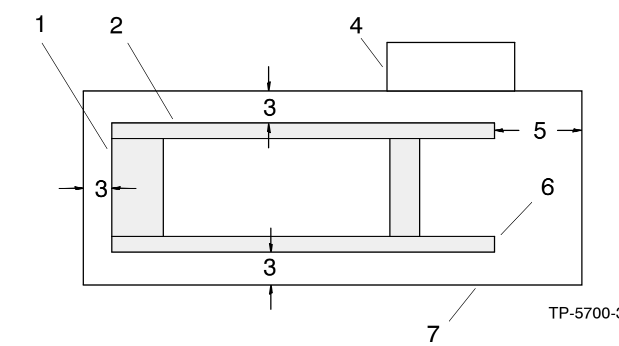
Ideally, the generator set should be mounted on concrete at ground level. For above-ground installations, including roof installations, weight considerations are especially important. The building engineer determines whether the structure can support the weight of the generator set.

The location of the generator set must:

- Support the weight of the generator set and related equipment such as fuel storage tanks, batteries, radiators, and mounting pad(s). Keep in mind that the mounting pad weight may exceed the weight of the generator set.
- Meet applicable fire rating codes and standards.
- Position the generator set over a noncombustible surface. If the mounting surface directly under or near the generator set is porous or deteriorates from exposure to engine fluids, construct a containment pan for spilled fuel, oil, coolant, and battery electrolyte. Do not allow accumulation of combustible materials under the generator set.
- Permit vibration isolation and dampening to reduce noise and prevent damage.
- Be clean, dry, and not subject to flooding.
- Provide easy access for service and repair.
- Allow ventilation with a minimum amount of ductwork.
- Allow safe expulsion of exhaust.
- Allow for storage of sufficient fuel to sustain emergency operation. See the generator set specification sheet for fuel consumption.
- Allow for locating the fuel tank within the vertical lift capabilities of the fuel pump and any auxiliary pumps. See Section 6, Fuel Systems.
- Minimize the risk of public or unauthorized access.

3.2 Mounting Surface

Figure 3-1 shows typical mounting surface details for sizing the concrete surface beyond the generator set and allowing for clearances during generator set service. Follow the dimensional details provided in Figure 3-2, Figure 3-3, or Figure 3-4 depending upon the mounting method.



1. Engine end
2. Generator set skid
3. Extend the concrete surface a minimum of 152 mm (6 in.) beyond the generator set
4. Battery rack
5. Allow at least 457 mm (18 in.) between the generator set and adjacent walls or other obstructions *on all sides* for ease of servicing the generator set
6. Alternator end
7. Mounting pad (concrete surface)

Figure 3-1 Mounting Surface Detail (top view)

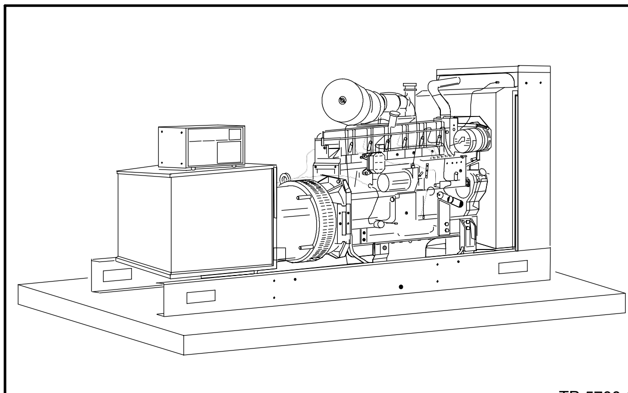


Figure 3-2 Single-Pad Mounting

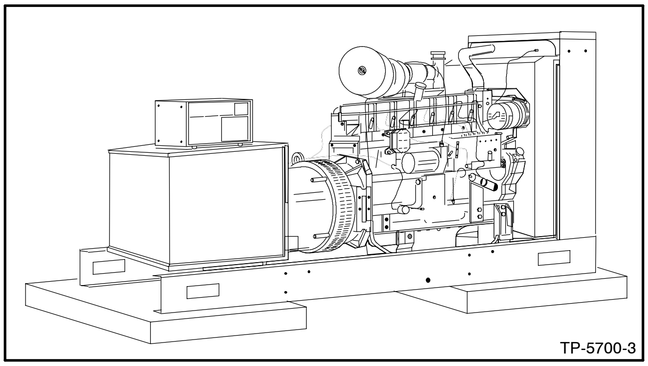


Figure 3-3 Dual-Pad Mounting

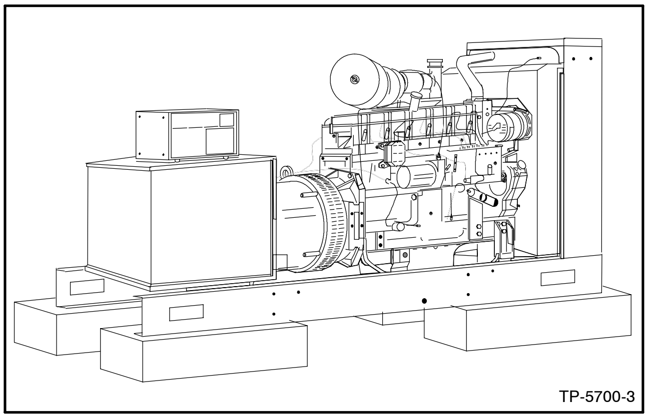


Figure 3-4 Four-Pad Mounting

3.2.1 Single-Pad Mounting

The manufacturer recommends a single, level concrete mounting pad as shown in Figure 3-2. This method provides maximum stability for the generator set; however, draining the oil and servicing the generator set may require raising the set from the pad.

Use an oil drain pump if clearance below the oil drain or extension is insufficient for a pan large enough to hold all the engine's oil.

3.2.2 Dual-Pad Mounting

The two-pad arrangement shown in Figure 3-3 provides easy access to conveniently drain the oil. Follow the oil draining considerations outlined in Section 3.2.1.

3.2.3 Four-Pad Mounting

The four-pad arrangement shown in Figure 3-4 provides more room under the engine for service than the previous two methods. Follow the oil draining considerations outlined in Section 3.2.1.

3.2.4 Mounting Pad Specifications

Mounting pad weight. The weight of the single mounting pad or combined weight of multiple mounting pads should equal or exceed the combined weight of the generator set and attached accessories.

To determine the weight of the mounting pad(s), determine the volume (length x width x height) of each pad in cubic meters (cubic feet). Multiply this result by 2400 kg (150 lb.) to determine a pad's weight. In multiple-pad installations, add the weights of all pads to determine the total mounting pad weight.

Mounting pad specifications. Mounting pad composition should follow standard practice for the required loading. Typical specifications call for 17238–20685 kPa (2500–3000 psi) concrete reinforced with eight-gauge wire mesh or No. 6 reinforcing bars on 305 mm (12 in.) centers.

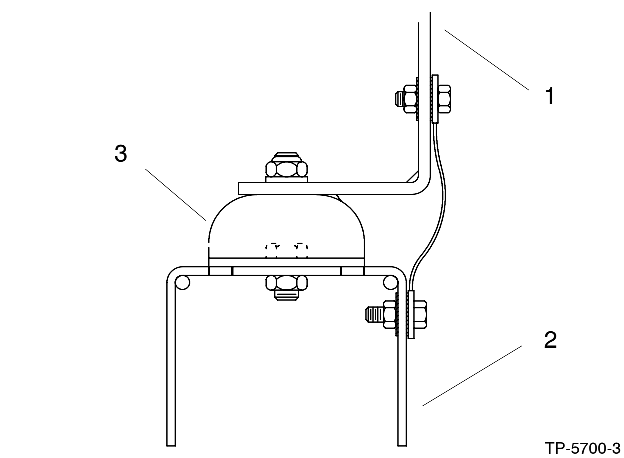
The recommended concrete mixture by volume is 1:2:3 parts of cement, sand, and aggregate, respectively. Surround the pad with a 200–250 mm (8–10 in.) layer of sand or gravel for proper support and isolation of a pad located at or below grade. Anchor the generator set to the concrete using bolts cast into the surface of the pad. Do not use expansion-type anchors.

Note: Refer to the generator set and accessory dimension drawings for conduit and fuel-line placement. The drawings give dimensions for electrical and fuel connection roughins and stubups.

3.3 Vibration Isolation

Use one of the vibration isolation types detailed in the following paragraphs. Also, connections between the generator set or its skid and any conduits, fuel lines, or exhaust piping must include flexible sections to prevent breakage and to isolate vibration. These connections are detailed in subsequent sections.

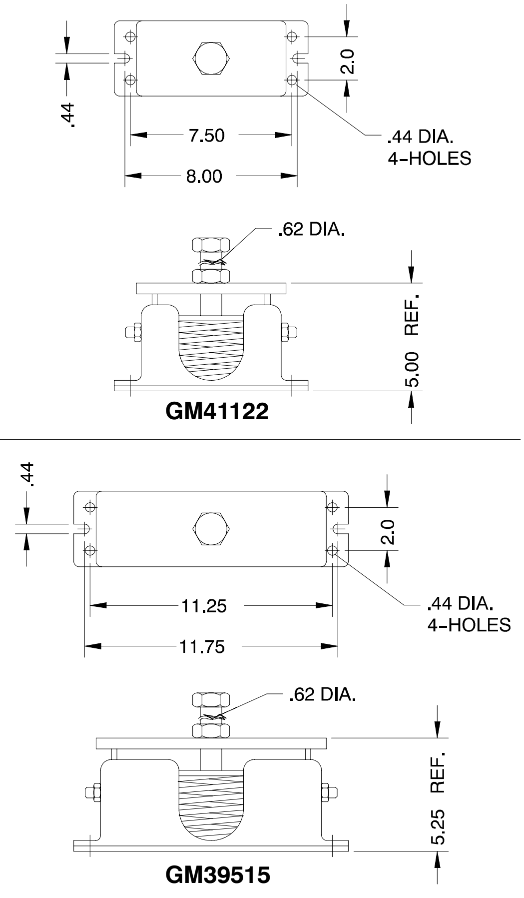
Isolator types. The two primary types of isolators are neoprene and spring-type. Figure 3-5 shows neoprene isolators between the engine-generator and the skid, referred to as integral vibration isolation mounting. Integral vibration isolation units come from the factory with neoprene vibration isolation. Neoprene isolators provide 90% vibration isolation efficiency and are sufficient for installations at or below grade.



1. To engine-generator
2. Skid crossmember
3. Neoprene vibration isolator

Figure 3-5 Neoprene-Type Integral Vibration Isolators

Figure 3-6 shows the spring-type isolator kit installed *with* direct-mounted units. Direct-mounted units have no factory vibration isolation. Spring-type isolators provide 98% vibration efficiency, are suitable for any installation, and are required for above grade installations.



Note: Dimensions are inches; in. x 25.4 = mm

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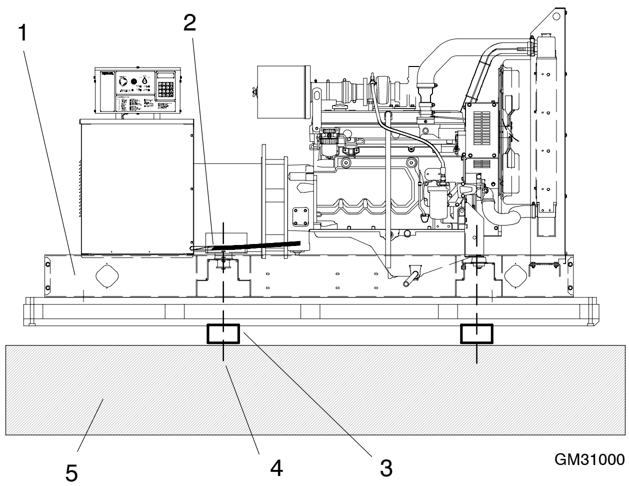
Figure 3-6 Vibration Spring Isolators

Generator sets with integral vibration isolation. Skids for generator sets 20 kW and larger use I or C section-fabricated steel with a width of 52–76 mm (2–3 in.) per channel. The length varies with the size of the unit, resulting in a static load on the generator set skid of 69–172 kPa (10–25 psi) if the total bottom surface of the channel is in contact with the mounting pad.

Generator sets with direct mounting. Larger generator sets typically mount directly to a structural steel base. For these units, install the recommended vibration isolators between the base and the mounting pad in the holes provided. Because of the reduced mounting surface area of these individual mounts, the static load on the mounting surface increases to the range of 345–690 kPa (50–100 psi).

Special requirements. If state or local codes require seismic or earthquake-proof mounts, or in critical applications where the generator set is installed above grade, it is also necessary to install spring-type vibration isolators under the generator set skid. Accessory vibration mounts used under formed sheet metal skids should equal the number of neoprene isolators and be located in the skid rails vertically inline with the existing neoprene isolators. See Figure 3-7.



1. Generator set skid
2. Generator set neoprene integral vibration isolators
3. Accessory vibration mounts
4. Locate accessory vibration mounts vertically inline
5. Concrete mounting pad

Figure 3-7 Accessory Vibration Mount Location

3.4 Dual-Bearing Alternator Alignment

Generator sets equipped with dual-bearing alternators require alignment after mounting the generator set skid to a mounting pad. Refer to Service Bulletin SB-566 for details.

4.1 General

Combustion and heat dissipation require an ample flow of clean, cool air regardless of whether the generator set is air- or liquid-cooled. Approximately 70% of the heat value of fuel consumed by an engine is lost through the cooling and exhaust systems.

Battery compartment ventilation. To prevent the accumulation of explosive gases, ventilate compartments containing batteries.

4.2 Air-Cooled Engines

Refer to the generator set specification sheet for air requirements. Generally, airflow requirements do not present a problem since air-cooled models are designed for outside installation.

When planning outside installation, consider how buildings and landscaping affect airflow. Also consider seasonal changes such as snow or foliage accumulation and potential flooding conditions. Follow a regular maintenance routine to remove snow and foliage accumulations.

4.3 Liquid-Cooled Engines

4.3.1 System Features

Generator sets designed for interior installation feature liquid cooling systems. The three most common liquid cooling systems are unit-mounted radiator, remote radiator, and city-water cooling. Observe the common installation considerations outlined below as well as the installation considerations for your generator set's cooling system as detailed in subsequent sections.

4.3.2 Installation Considerations

Intake and outlet openings. Provide air intake and air outlet openings for generator sets located in a building or enclosure. Keep air inlets and outlets clean and unobstructed. Position the air inlet into the prevailing wind and the air outlet in the opposite direction.

Ventilating fans. Some buildings tend to restrict airflow and may cause generator set overheating. Use ventilating fans and/or ductwork to increase airflow in the building if the generator set's cooling fan does not provide adequate cooling. See Figure 4-1. Remote radiator and city-water cooled models require ventilating fans. When using ductwork and ventilating fans, check the exhaust fan capacity in m^3/min. (cfm). If using exhaust fans, install fan-operated louvers with exhaust fans to regulate airflow. See Figure 4-2. Follow the fan manufacturer's recommendations to determine the size of the inlet and outlet openings.

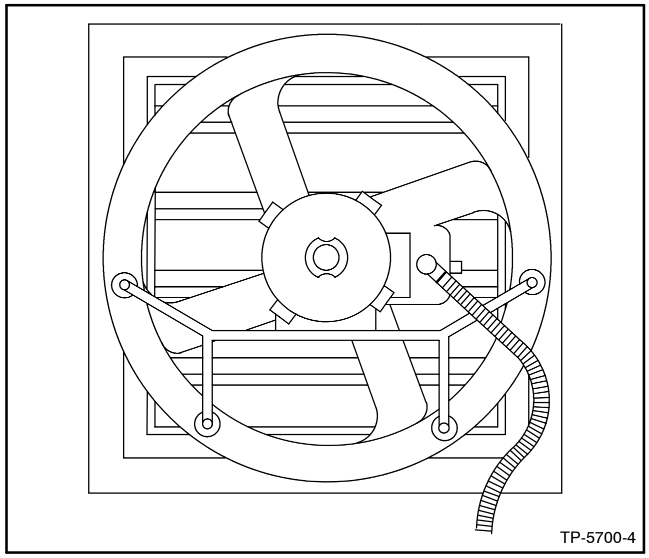


Figure 4-1 Ventilating Fan

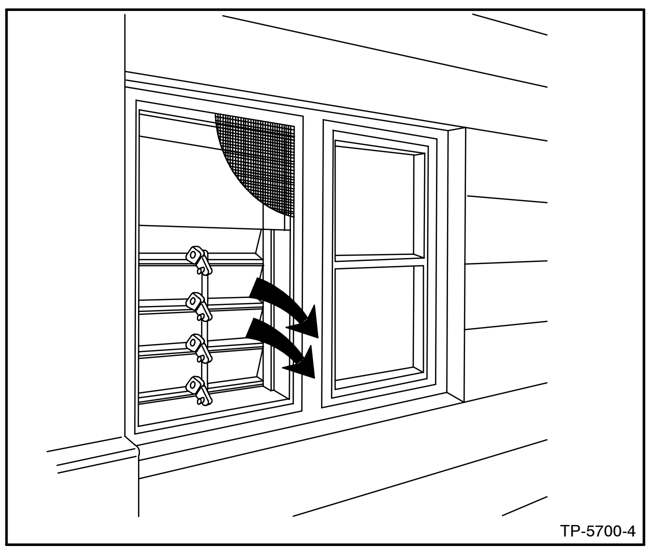


Figure 4-2 Exhaust Fan-Operated Louvers

Thermostatically-controlled louvers. Do not allow uncontrolled recirculation of air within an enclosure. The ventilation system must provide a temperature differential sufficient to prevent high engine temperature shutdown on even the hottest days.

In areas of great temperature variation, install movable louvers to thermostatically regulate airflow and room temperature. See Figure 4-3 and Figure 4-4. Refer to 4.4.2, Installation Considerations, Louver use for further information.

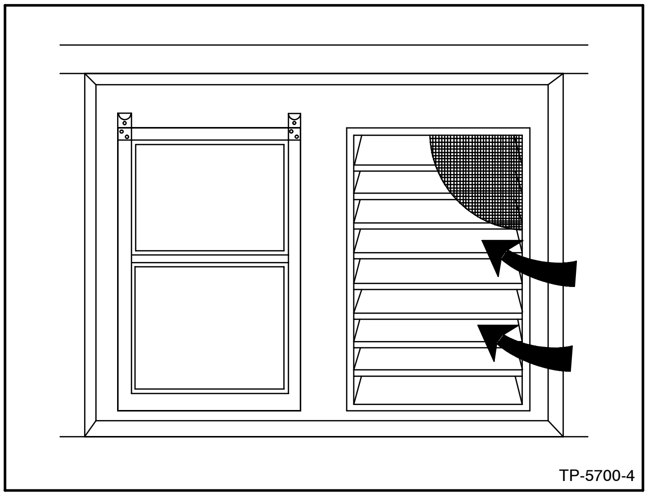


Figure 4-3 Stationary Air Inlet Louvers

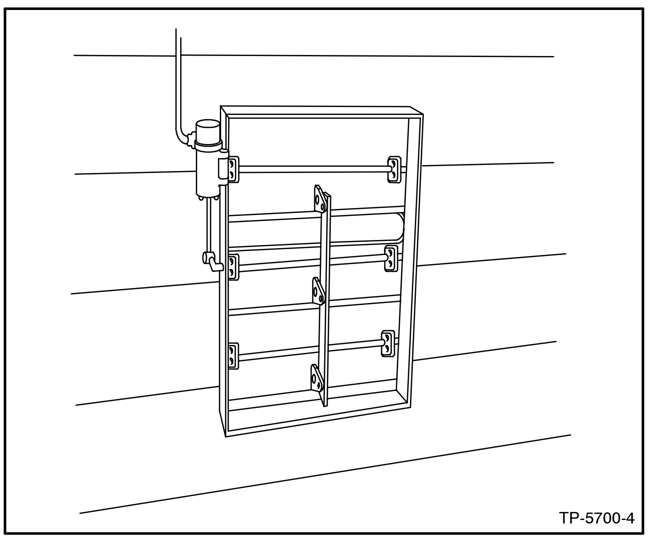


Figure 4-4 Moveable Air Inlet Louvers

In cold climate interior installations using controlled recirculation to recover heat, install thermostatically activated louvers and fans to prevent the generator set and engine room from overheating.

Electric louvers are usually connected to the optional generator set run relay. Typically, the louvers are energized to open when the generator set is operating. However, some louvers are energized to close and when deenergized are spring-actuated to open when the generator set is operating.

Filters. Install a furnace-type or similar filter in the inlet opening if the generator set operates in an atmosphere highly contaminated with impurities such as dust and chaff.

Air restrictions. When using a filter, screen, or other air restriction, increase the inlet opening size by the following amounts to compensate for diminished airflow:

- Louvers**:** Enlarge the opening 50%.
- Window screening: Enlarge the opening 80%.
- Furnace-type filters: Enlarge the opening 120%.

4.3.3 Recommended Coolant

Most applications require antifreeze/coolant protection. Add antifreeze before starting the generator set or energizing the block heater(s).

The generator set manufacturer recommends a solution of 50% ethylene glycol and 50% clean, softened water to provide freezing protection to −37°C (−34°F) and boiling protection to 129°C (256°F). A 50/50 solution also inhibits corrosion. Consult the engine manufacturer's operation manual for engine coolant specifications.

Most diesel engine manufacturers require the addition of an inhibitor additive to the coolant to prevent cavitation erosion. Refer to the engine operation manual for inhibitor selection and concentration level recommendations.

4.4 Unit-Mounted Radiator Cooling

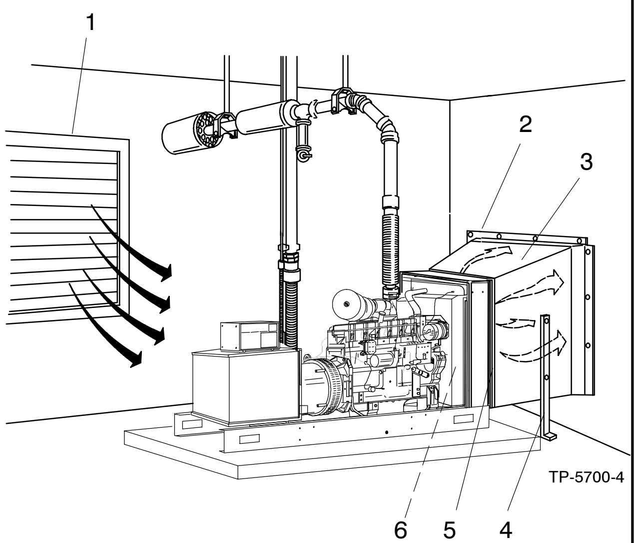
The unit-mounted radiator is the most common cooling system for engine-driven generator sets 20 kW and larger.

4.4.1 System Features

The system's major components include an engine-driven fan and circulating water pump, a radiator, and a thermostat. The pump circulates water through the engine until it reaches operating temperature. Then the engine thermostat opens, allowing water circulation through the radiator. The thermostat restricts water flow as necessary to prevent overcooling. The fan blows air from the engine side of the radiator across the cooling surface.

4.4.2 Installation Considerations

Figure 4-5 shows a typical unit-mounted radiator installation. Note the direction of airflow and refer to the figure as needed during installation.



1. Air inlet opening
2. Ductwork mounting flange
3. Air outlet duct
4. Support legs
5. Flexible section with radiator duct flange
6. Pusher fan

Figure 4-5 Radiator-Cooled Generator Set Installation

Avoid suction fan use. The alterator airflow should move in the same direction as the engine's standard pusher fan. Using a suction fan to reverse airflow is not recommended because it may interfere with the alternator cooling airflow. This in turn reduces the maximum engine power available because higher temperature combustion air is drawn into the air cleaner.

Use ductwork to direct airflow. Direct the radiator air outside the room or enclosure using sheet metal ductwork with structural supports. Keep ductwork as short, straight, and unobstructed as possible. Combined static pressure restrictions greater than 0.12 kPa or 13 mm (0.5 in.) water column on the radiator inlet and outlet openings cause reduced airflow and contribute to overheating especially in high ambient air temperatures. Use heavy canvas, silicone rubber, or similar flexible material for the connection between the radiator duct flange and the ductwork to reduce noise and vibration transmission.

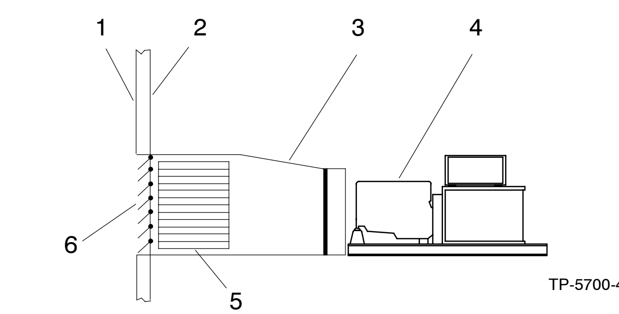
Outlet and inlet location and sizing. Size the outlet duct area 150% larger than the radiator duct flange area. Size the inlet air opening at least as large but preferably 50% larger than the outlet.

If screens, louvers, or filters are used on either the inlet or outlet, increase the inlet or outlet size according to the recommendations given in Section 4.3.2 Installation Considerations.

Since the exhaust air of larger units is both high volume and high velocity, direct the exhaust flow away from areas occupied by people or animals.

Louver use. Design temperature-controlling louvers to prevent air inlet restrictions and air pressure reductions inside the building. Low building pressure can extinguish pilot lights on gas-fired appliances or cause problems with the building ventilation system.

Additionally, bringing large quantities of winter air into a building wastes building heat and risks frozen water pipes in normally heated spaces. Use dampers and controlled air outlet louvers as shown in Figure 4-6 to eliminate these problems and allow recovery of engine heat to reduce building heat loss. Close the louvers to the exterior and open the interior louvers when the outdoor temperature is below 18°C–21°C (65°F–70°F). Reverse the louver settings when the outdoor temperature is above 21°C–24°C (70°F–75°F).



1. Exterior
2. Interior
3. Air outlet duct
4. Generator set
5. Dampers
6. Controlled air outlet louvers

Figure 4-6 Air Control Louvers

4.5 Remote Radiator Cooling

A remote radiator system allows installation of generator sets in locations where it would otherwise be difficult to bring the volume of air required to cool a unit-mounted radiator. In these systems, the engine water pump pushes coolant through a radiator mounted remotely from the generator set and, typically, in an open area. An electric motor-driven fan mounted on the radiator circulates air across the radiator's cooling fins.

In order to assess a remote radiator cooling system, the cooling system designer needs the following data. From the respective generator set specification sheet, obtain the:

- Engine jacket water flow, Lpm (gpm)
- Cooling air required for generator set based on 14°C (25°F) rise and an ambient temperature of 29°C (85°F), m^3/min. (cfm)
- Maximum static (vertical) head allowable above engine, kPa (ft. H_2O)

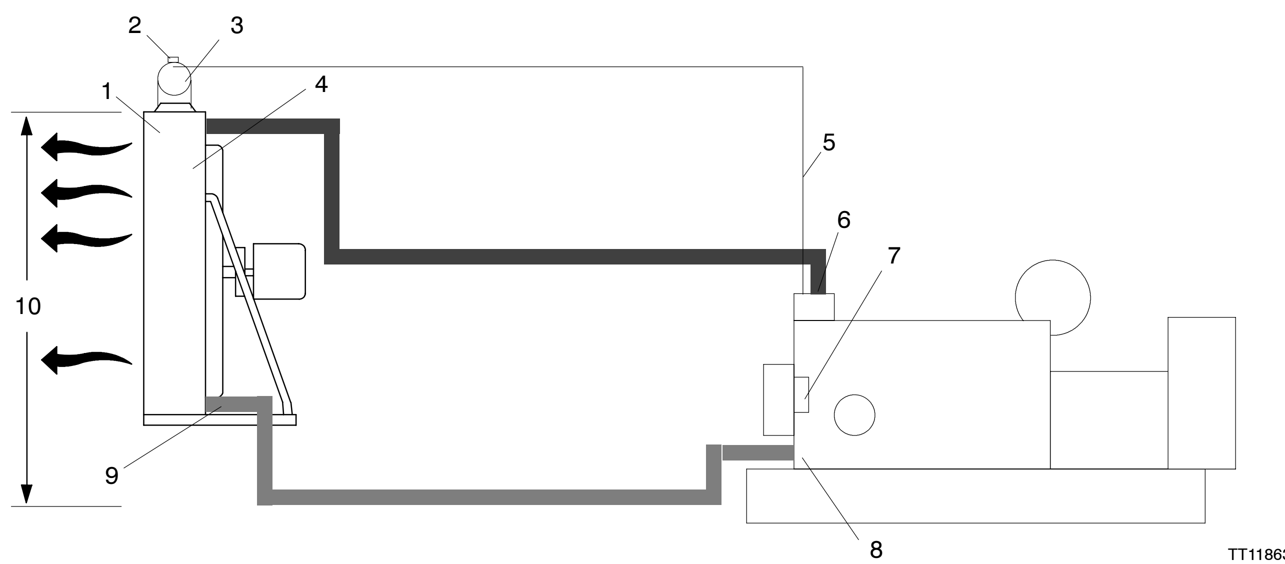
From the engine and/or radiator data sheet, obtain the:

- Maximum water pump inlet restriction kPa (psi)
- Maximum allowable coolant pressure differential external to engine kPa (psi)
- Pressure drop of water flow through radiator, kPa (psi) at 50°C (122°F)

The following subsections provide general design guidelines for a remote radiator system.

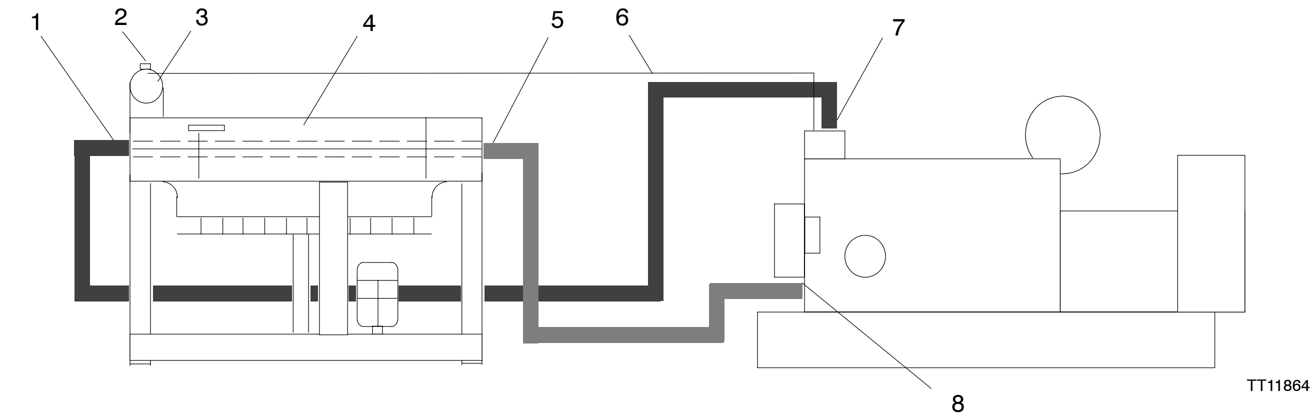
4.5.1 General

System limitations. Cooling systems are limited by radiator cap ratings. The maximum radiator operating pressure is 138 kPa (20 psi) and the maximum operating temperature is 121°C (250°F). Radiators are available for vertical or horizontal discharge. See Figure 4-7 and Figure 4-8.



1. Remote vertical radiator
2. Pressure cap
3. Surge tank/expansion tank
4. Radiator inlet
5. 3/8 in. vent line
6. Engine outlet
7. Engine water pump
8. Suction side
9. Radiator outlet
10. Maximum allowable static (vertical) head (varies with engine)

Figure 4-7 Remote Vertical Radiator System



1. Radiator inlet
2. Pressure cap
3. Surge tank/expansion tank
4. Horizontal radiator
5. Radiator outlet
6. 3/8 in. vent line
7. Engine outlet
8. Engine inlet

Figure 4-8 Remote Horizontal Radiator System

Air requirements. Refer to the generator set specification sheet for radiator air and engine/alternator air requirements. Cooling air required for generator sets equipped with a remote radiator is based on a 14°C (25°F) rise and an ambient temperature of 29°C (85°F). The amount of air required to ventilate the generator set room or enclosure determines the size of the air inlet and outlet. Configure the ventilation air inlet and outlet so that air flows across the generator set. Use a ventilating fan, if necessary, to dissipate alternator and engine heat loss.

Note: All remote radiators are sized for mounting in an open area with no additional external devices attached. Attached devices, confined installation, louvers, dampers, ductwork, or other inlet or outlet air restriction require resizing the radiator to compensate for reduced airflow.

Static (vertical) head. If the vertical distance from the engine water pump to the radiator (known as *static head*) is within the engine manufacturer's recommendations, and the pressure drop through the piping and remote radiator does not exceed the engine manufacturer's limits, use the engine water pump to circulate water through the remote radiator. The allowable static head ranges from 5.2 m-15.2 m (17 ft.-50 ft.) and is listed on the generator set specification sheet. Exceeding the allowable static head causes excessive pressure on engine components resulting in problems such as leaking water pump seals.

Note: Size the pressure relief valve or cap to remain under the engine pressure limit. Consider a nonpressurized vented cap system for radiators mounted beyond the maximum static head specification.

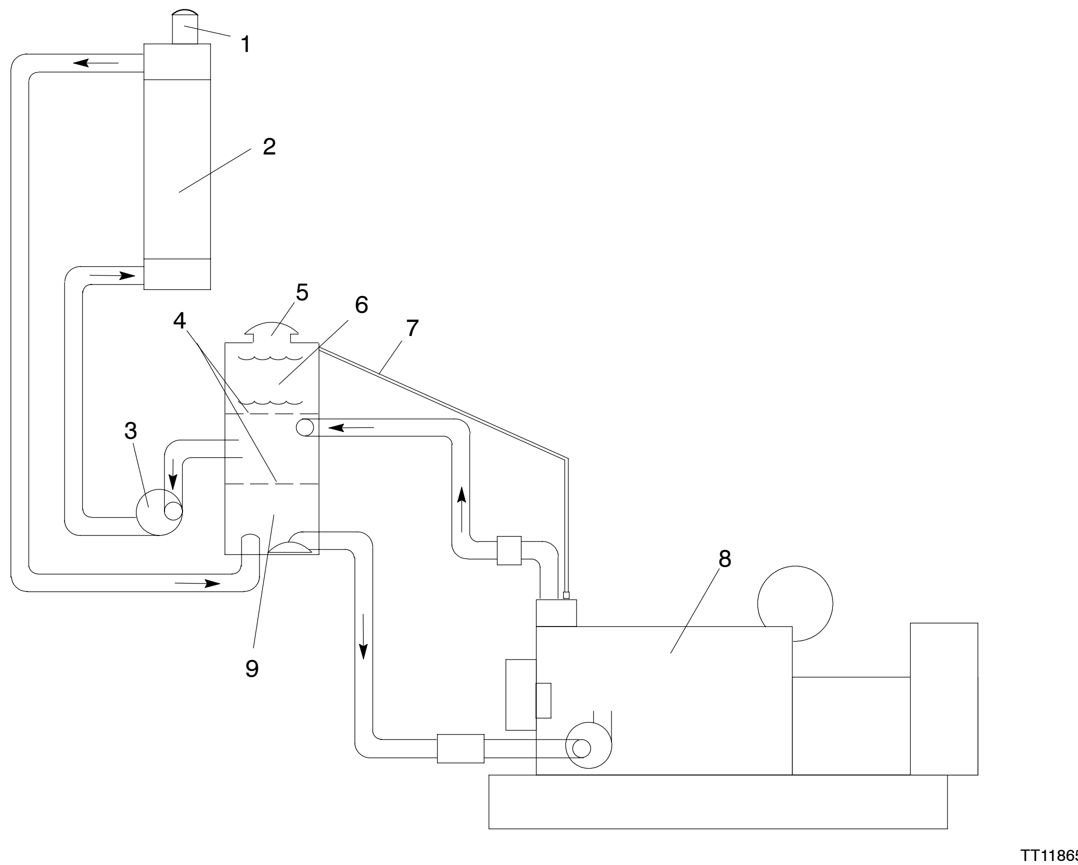
Vent lines. Remove trapped air from the cooling system by installing a vent line from the engine to the radiator.

Hot well tank/heat exchanger. When the static (vertical) head exceeds the distance stated in the specification sheet, use a hot well tank or heat exchanger and auxiliary circulating pump as shown in Figure 4-9 or Figure 4-10. Always wire the circulating pump in parallel with the remote radiator fan so that both operate whenever the generator set operates.

A partial baffle divides a hot well tank into two or more compartments. The engine pump forces heated water into the hot side, and the auxiliary pump then draws the water off and forces it into the radiator. After circulating through the radiator, coolant drains back to the cold side of the well where the engine water pump removes it. A hot well or heat exchanger also isolates head pressures from the engine.

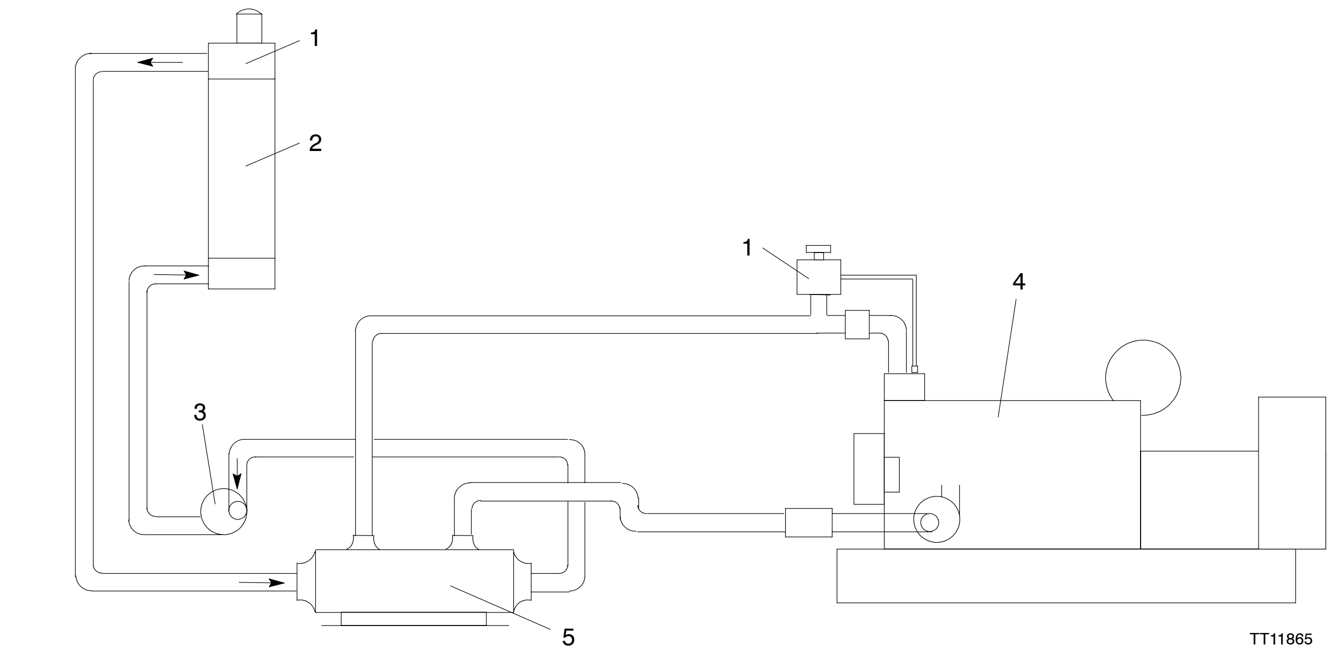
Note: The water in the hot well tank drains into the radiator when the generator set is not running.

Note: Determine the size requirements of the remote radiator and hot well tank/heat exchanger for each application. Do not use a standard remote radiator with a hot well tank/heat exchanger.



1. Vacuum relief check valve
2. Remote radiator
3. Auxiliary water pump
4. Baffles
5. High volume breather
6. Expansion space
7. Vent line(s)
8. Generator set
9. Hot well tank

Figure 4-9 Compound Remote Radiator/Hot Well Tank Cooling System



1. Expansion/surge tank
2. Remote radiator
3. Auxiliary pump
4. Generator set
5. Heat exchanger

Figure 4-10 Compound Remote Radiator/Heat Exchanger Cooling System

4.5.2 Radiator Location

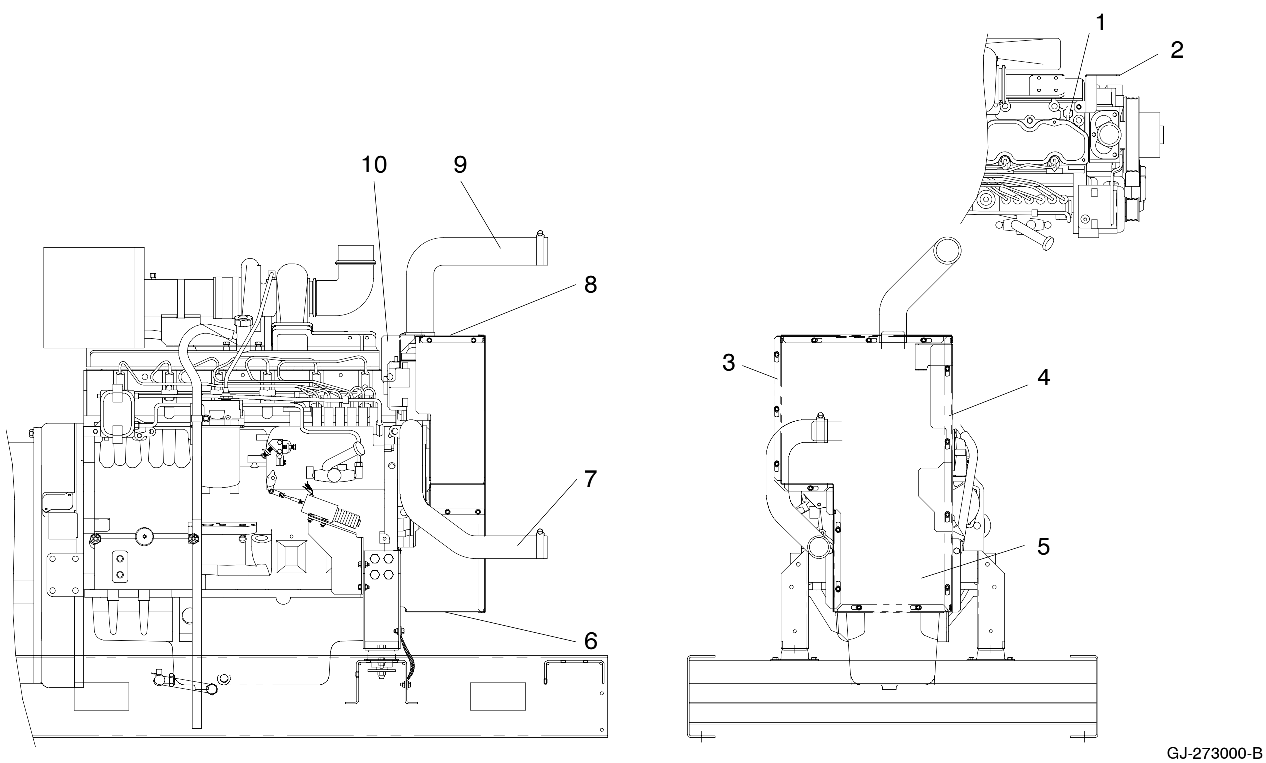
When choosing the radiator's location:

- For economical installation and operation, locate the radiator as close as practical to the engine and at the same elevation to reduce piping, coolant, and wiring costs.
- Locate the radiator surge tank fill opening and vent line(s) at the highest point in the cooling system.
- Locate the radiator no closer than one fan diameter from a wall, another radiator, or any other obstruction that would restrict air movement and future service access.
- Locate the radiator to prevent recirculation of the heated exhaust air back into the intake stream.
- Mount the radiator in an area where prevailing winds do not hamper free airflow.
- Choose an installation area that is not subject to deep snow or ice accumulation, flooding, industrial fallout, leaf accumulation, heavy dust and chaff, or other detrimental seasonal or environmental conditions.
- For rooftop installations, do not locate the radiator near critical sound areas, building ventilation, or hood exhausts.

4.5.3 Installation

When installing the remote radiator:

- Use a remote radiator setup kit to aid installation. See Figure 4-11.
- Wire the cooling fan motor to the generator set output so that the fan operates whenever the generator set operates. There is no need for a thermostatic control of the fan motor because the engine thermostat prevents overcooling as it does on generator set-mounted radiator systems. Follow all applicable national and local codes when wiring the cooling fan.
- Follow the wiring diagram on the remote radiator's fan motor. The motor rotation must match the fan blade design. The manufacturer supplies most units with counterclockwise fan rotation as viewed from motor side. The fan is a blower type, moving air from the fan side of the radiator, through the core, and out the front side.
- Preferably, connect no devices to either side of the radiator. Resize the radiator if adding louvers or duct work to the radiator to compensate for reduced airflow.
- Ensure that the radiator is level and securely bolted to a firm, solid foundation.
- Brace the radiator as needed, especially in areas with strong winds.
- Use isolators to keep area vibration from affecting the radiator or to keep vibration produced by the radiator from affecting surrounding areas.
- Use hose clamps on all nonthreaded connections.



1. Drain valve
2. Belt guard bracket
3. Right-hand belt guard
4. Left-hand belt guard
5. Front belt guard
6. Bottom belt guard
7. Lower radiator hose inlet
8. Top belt guard
9. Upper radiator hose outlet
10. Top mounting bracket

Figure 4-11 Remote Radiator Setup Kit, Typical

4.5.4 Surge (Expansion) Tank for Horizontal Discharge Radiator

A horizontal discharge remote radiator requires the use of a surge (expansion) tank as shown in Figure 4-8. Locate the tank at the highest point in the cooling system. The surge tank provides venting, surge/expansion protection, and filling/makeup functions.

- Equip the surge tank with a sight-glass gauge, overflow tube, and pressure cap.
- Size the surge tank to handle 6%–10% of the total cooling system volume.
- Connect the main line from the surge tank to the highest point of the remote radiator. Most vertical core radiators have the surge tank as part of the radiator top tank. The setup illustrated in Figure 4-8 provides for radiator and engine deaeration and a positive pressure at the pump suction inlet.
- Use a strainer to filter dirt, scale, and core sand from the coolant line.

Piping. Size water piping between the engine and the remote radiator large enough to eliminate the need for a booster pump. If the cooling system requires a booster pump, contact your distributor/dealer.

Use piping of ample size and with as few short sweep bends or elbows, tees, and couplings as possible. Use long sweep elbows or long bends, if bends are required.

Installation. Support piping externally, not from the radiator or engine.

On standard remote radiators, connect radiator bottom outlets only to the suction side of the pump. Plumb the lines to prevent air from becoming trapped in the lines. Route piping in one general direction, either upward or downward. A combination of both upward and downward piping creates air pockets in the piping. Route vent lines to the expansion/surge tank without creating low spots in the lines.

Flexible connections. Provide flexible connections when connecting piping to the radiator assembly. Use hose clamps at all nonthreaded connections.

Shutoff valves. Locate shutoff valves between the engine and cooling system to allow for isolation of both the radiator and the engine. A shutoff valve eliminates the need to drain the entire cooling system during service.

4.5.5 Procedure to Fill with Deaeration

For radiators designed for full deaeration, fill the radiator according to the following procedure:

1. Fill the radiator at the filler neck.
2. Next, fill the radiator through one of the top tank or expansion/surge tank inlets located before the final hose connection.
3. Continue filling the system to cover the filler neck bottom until coolant appears in the sight glass located in the radiator top tank.
4. Check and correct any leaks in the system.

4.5.6 Procedure to Fill without Deaeration

For radiators designed without deaeration, fill the radiator according to the following procedure:

1. Initially, fill the radiator through one of the top tank inlets located before the final hose connection for faster and more complete fillup.
2. Continue filling the system to cover the filler neck bottom until coolant appears in the sight glass located in the radiator top tank.
3. Check for and correct any leaks in the system.

4.5.7 Startup

If any problems arise during startup, immediately shut down the generator set. See Figure 4-12, Cooling System Checklist. Even after a successful startup, shut down the generator set after 5–10 minutes and recheck the belt tension to make sure no hardware has loosened during operation. Perform another recheck after 8–12 hours of operation.

✓	Operation
	Verify the cooling fan's position in the fan shroud.
	Check the mounting hardware.
	Check the fan motor for free rotation.
	Check V-belts for alignment and tension.
	Fill the system with coolant and check all connections for tightness and leaks.
	Verify that all electrical connections are secure and that the power source matches the motor nameplate.
	Verify that no foreign material is loose in the fan's air stream.
	With the unit running, check for:
	fan clearance
	excessive vibration
	excessive noise
	coolant leaks

Figure 4-12 Cooling System Checklist

4.6 City Water Cooling

4.6.1 System Features

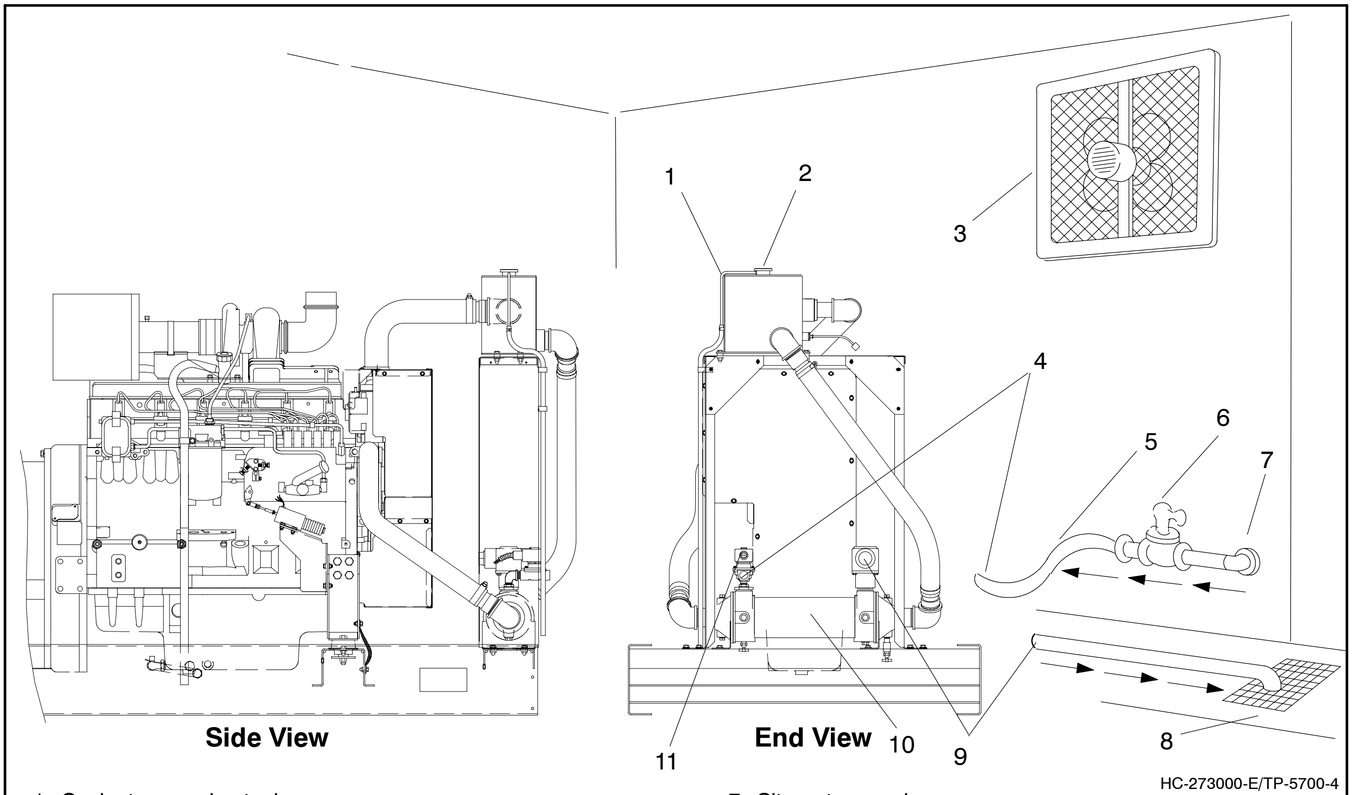
City water-cooling systems use city water and a heat exchanger for cooling. They are similar to remote radiator systems because they require less cooling air than unit-mounted radiator systems. Figure 4-13 shows some of the elements of a typical installation.

The heat exchanger limits the adverse effects of city water chemistry to one side of a heat exchanger, which is relatively easy to clean or replace, while engine coolant circulates in a closed system similar to the radiator system. The heat exchanger allows engine temperature control, permits the use of antifreeze and coolant conditioners, and is suited to the use of an engine block heater as a starting aid.

4.6.2 Installation Considerations

Vibration isolation requirements. Water inlet and outlet connections are mounted on the generator set skid and isolated from engine vibration by flexible sections. If the generator set is vibration-mounted to the skid and the skid is bolted directly to the mounting base, no additional flexible sections are needed between connection points on the skid and city water lines. If the generator set skid is mounted to the base with vibration isolators, use flexible sections between the connection points on the skid and city water lines.

Shutoff valve location. A solenoid valve mounted at the inlet connection point automatically opens when the generator set starts, providing the engine cooling system with pressurized water from city water mains. This valve automatically closes when the unit shuts down. Use an additional customer-supplied valve ahead of the entire system to manually shut off city water for generator set service.



1. Coolant expansion tank
2. Coolant expansion tank pressure cap
3. Ventilation fan (for heat rejected from exhaust and engine)
4. Connect heat exchanger inlet to city water supply
5. Flexible section
6. Manual shutoff valve
7. City water supply
8. Heated city water into floor drain
9. Connect heat exchanger outlet to floor drain
10. Heat exchanger
11. Solenoid valve

Figure 4-13 City-Water Cooling System with Heat Exchanger

4.7 Cooling Tower

A cooling tower system is a variation of a city water cooling with heat exchanger system. In warm, dry climates, a cooling tower is a suitable source of generator set cooling water.

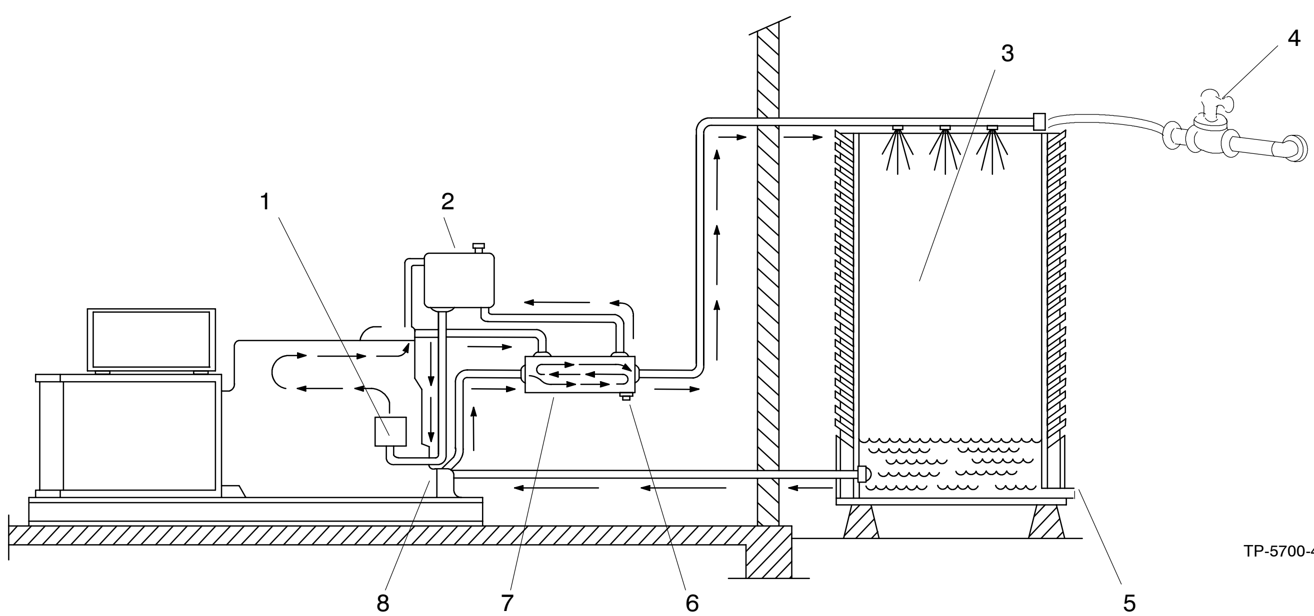
A cooling tower system consists of the engine cooling system plus a raw-water system. The engine cooling system usually includes the engine water pump, a heat exchanger, a surge tank, and the engine water jacket. The raw-water system consists of the cooling tower, a raw-water pump, and the tube portion of the heat exchanger. A typical system is shown in Figure 4-14.

The engine cooling system circulates coolant through the heat exchanger outer shell. Raw water circulates through the heat exchanger tubes absorbing heat from the engine coolant. The heated raw water flows into a pipe at the top of the cooling tower and sprays down into the tower to cool by evaporation. Because some water is constantly being lost through evaporation, the system must provide makeup water.

4.8 Block Heaters

Block heaters are available as installed accessories on all generator sets. Use block heaters on all standby applications where the generator set is subject to temperatures below 16°C (60°F). Connect the block heater to a power source that is energized when the generator set is not running.

Note: Block heater damage. The block heater will fail if the energized heater element is not immersed in coolant. Fill the cooling system before turning on the block heater. Run the engine until it is warm and refill the radiator to purge the air from the system before energizing the block heater.



1. Engine water pump
2. Surge tank
3. Cooling tower
4. Makeup water connection
5. Cooling tower drain
6. Heat exchanger drain
7. Heat exchanger
8. Auxiliary water pump

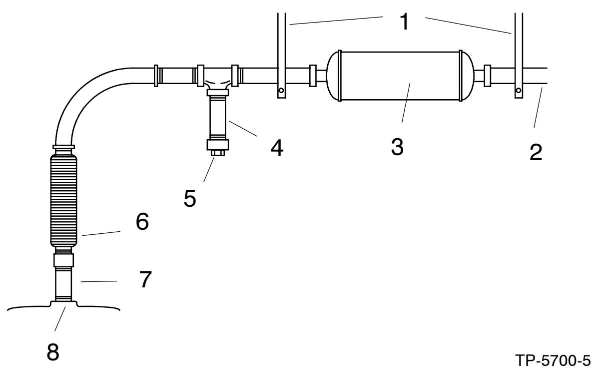
Figure 4-14 Cooling Tower System

Notes

Satisfactory generator set performance requires proper exhaust system installation. Figure 5-1 and Figure 5-2 show typical arrangements of recommended exhaust systems. The following sections detail exhaust system components.

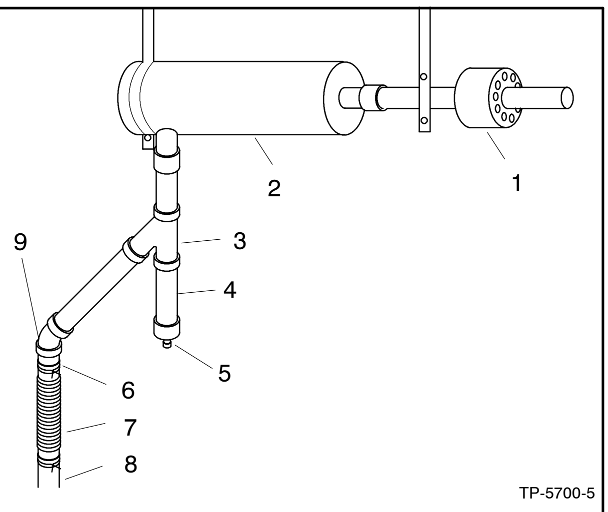
5.1 Flexible Exhaust Line

Install a section of seamless stainless steel flexible exhaust line at least 305 mm (12 in.) long within 610 mm (2 ft.) of the engine exhaust outlet. See Figure 5-1 and Figure 5-2.



1. Supports
2. Pitch line downward
3. Silencer
4. Water trap
5. Drain petcock
6. Flexible section
7. Solid section 152–203 mm (6–8 in.)
8. Manifold

Figure 5-1 Exhaust System, End Inlet Silencer



1. Exhaust wall thimble
2. Silencer
3. 45° Y fitting
4. Water trap
5. Drain petcock
6. Outer diameter adapter and clamp
7. Flexible section
8. Manifold
9. 45° elbow

Figure 5-2 Exhaust System, Side Inlet Silencer

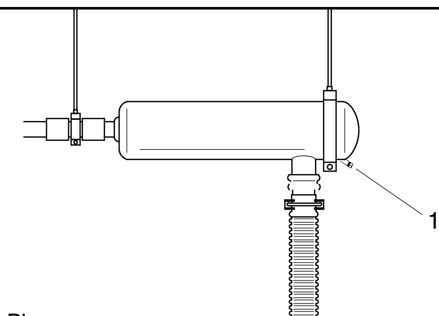
The flexible line limits stress on the engine exhaust manifold or turbocharger. Never allow the engine manifold or turbocharger to support the silencer or exhausting piping.

Note: Do not bend the flexible section or use it to compensate for misalignment between the engine exhaust and the exhaust piping.

When using threaded flexible exhaust connectors, place a 152–203 mm (6–8 in.) length of pipe between the flexible exhaust connectors and the exhaust manifold. See Figure 5-1. The pipe reduces the temperature of the flexible connection, simplifies flexible section removal, and reduces strain on the engine exhaust manifold.

5.2 Condensation Trap

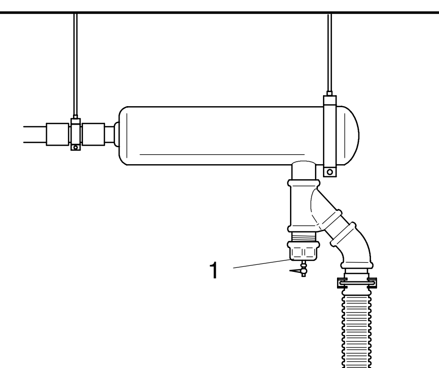
Some silencers are equipped with a drain pipe plug for draining condensation, see Figure 5-3. Otherwise, install a wye- or tee-type condensation trap with a drain plug or petcock between the engine and the exhaust silencer as shown in Figure 5-4. The trap prevents condensed moisture in the engine exhaust from draining into the engine after shutdown. Periodically drain collected moisture from the trap.



1. Pipe Plug

TP-5700-5

Figure 5-3 Silencer Condensation Drain Plug



1. Condensation trap

TP-5700-5

Figure 5-4 Condensation Trap

5.3 Piping

Note: Select piping with a diameter that is the same size as or larger than the manifold outlet's inside diameter.

- Keep exhaust lines as short and straight as possible.
- Use schedule 40 black-iron pipe.
- Use sweep elbows with a radius of at least three times the pipe diameter.
- Use exhaust piping that conforms to applicable codes.
- Support the exhaust piping securely, allowing for thermal expansion.
- Insulate the exhaust piping with high-temperature insulation to reduce the heat rejected by exhaust piping and consequently the amount of ventilating air required.

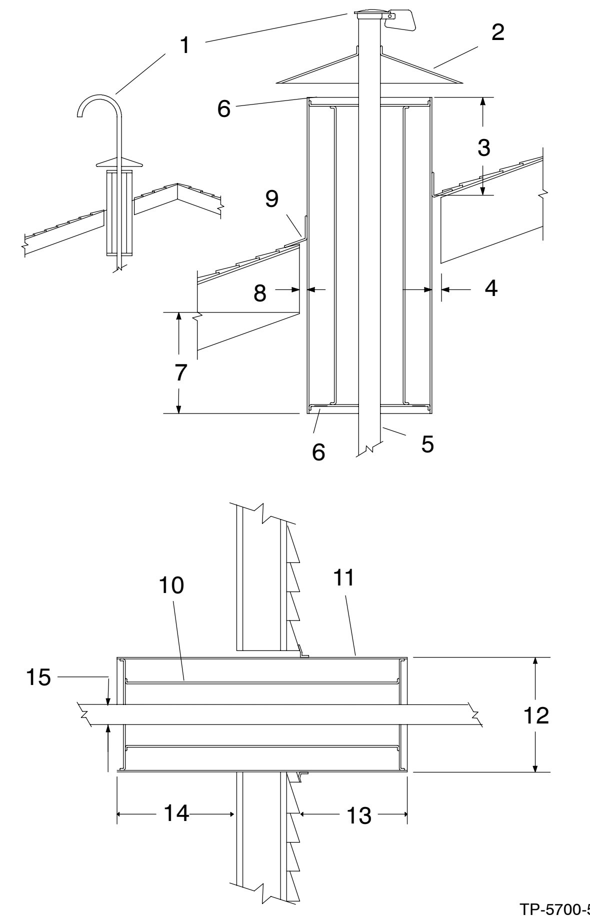
In general, exhaust temperatures measured at the engine's exhaust outlet are less than 538°C (1000°F), except for infrequent brief periods; therefore, low-heat appliance standards apply. Each generator set specification sheet provides exhaust temperatures.

For units with exhaust temperatures below 538°C (1000°F), route the exhaust piping a minimum of 457 mm (18 in.) from combustible material, including building materials and natural surroundings. If exhaust temperatures exceed 538°C (1000°F), the minimum distance is 914 mm (36 in.).

When planning exhaust silencer and piping placement, consider the location of combustible materials. If the proximity of the exhaust system to the combustible materials cannot be avoided, follow a regular maintenance schedule to ensure that combustible materials are kept away from the exhaust pipes after installation. Combustible materials include building materials as well as natural surroundings. Keep dry field grass, foliage, and combustible landscaping material a safe distance from the exhaust system.

5.4 Double-Sleeved Thimbles

If the exhaust pipe passes through a wall or roof, use a double-sleeved exhaust thimble to prevent the transmission of exhaust pipe heat to the combustible material. Figure 5-5 shows construction details of a typical double-sleeved thimble in which exhaust piping passes through a combustible structure. Sheet metal shops usually fabricate thimbles using installation engineer's specifications and drawings.



1. Rain cap (or gradual U bend)
2. Rain shield
3. 254 mm (10 in.) minimum
4. 25 mm (1 in.) minimum
5. Exhaust pipe
6. Ventilation holes at both ends
7. 254 mm (10 in.) minimum
8. 25 mm (1 in.) minimum
9. Flashing
10. Inner sleeve
11. Outer sleeve
12. Thimble outer diameter
13. 254 mm (10 in.) minimum outside
14. 254 mm (10 in.) minimum inside
15. Exhaust pipe diameter

Figure 5-5 Double-Sleeved Thimbles and Rain Cap

Construct the thimble so it extends at least 254 mm (10 in.) both inside and outside the structure's surface. Openings at both ends of the thimble allow cooling air to circulate through the thimble. If screening is used on the outer end to keep birds and animals from entering the thimble, use a mesh large enough to allow unrestricted air circulation through the thimble. See Section 5.5 for additional exhaust outlet location and protection considerations.

5.5 Exhaust Outlet

Outlet location. Engine performance and efficiency depend on the location of the exhaust outlet. Direct the exhaust outlet away from the air inlet to prevent exhaust gases from entering the air inlet and clogging the dry-type air filter elements. Hot exhaust drawn through the radiator adversely affects engine cooling. Locate the exhaust outlet to prevent exhaust fumes from entering a building or enclosure.

Noise reduction. The exhaust outlet configuration affects the apparent noise level for people or animals in the vicinity. An upward-directed outlet seems quieter than one directed downward or horizontally. Additionally, a 30- to 45-degree angled cut at the end of a horizontal exhaust outlet pipe reduces turbulence at the outlet, thereby reducing the noise level.

Rain cap. To prevent precipitation from entering the exhaust pipe, install a rain cap on vertical outlets. See Figure 5-5. In a climate where freezing is common, do not use a rain cap. Instead, extend the exhaust piping at least 610 mm (24 in.) beyond the roof line and create a gradual U bend at the end to direct the exhaust outlet downward. Keep the pipe outlet at least 457 mm (18 in.) from the roof to prevent hot exhaust from igniting the roof material.

Note: Do not use a rain cap in areas subject to freezing temperatures.

5.6 Exhaust System Backpressure

Exhaust backpressure limits engine power and excessive backpressure causes serious engine damage. Excessive backpressure usually results from one or more of the following reasons:

- The exhaust pipe diameter is too small.
- The exhaust pipe is too long.
- The exhaust system has too many sharp bends.
- The exhaust silencer is too small.
- The exhaust silencer is not the correct design for the application.

Use the following procedure to verify that the installed exhaust system does not exceed the engine's maximum exhaust backpressure limit as specified in the generator set specification sheet.

Exhaust System Backpressure Calculation Procedure

Determine the total backpressure by calculating the effects of the individual exhaust system components and adding the results. Make calculations using either English or metric units. Exhaust pipe references are nominal pipe NPT (in.) sizes. The procedure shows an example with *italic* text. Calculations relate to end inlet silencers.

Note: When calculating backpressure drop for *side* inlet silencers, use the *end* inlet values shown and add 0.75 kPa (0.25 in. of mercury or 3.4 in. of water) to backpressure calculations.

1. Select the exhaust silencer type for the application—hospital, critical, residential, or industrial. See the silencer specification sheet for definitions for each exhaust silencer type. Confirm silencer type availability for your generator set with your authorized distributor/dealer, as some generator sets do not use all four types.

   Example: Determine the silencer backpressure for the recommended critical silencer on a 230 kW, 60 Hz diesel generator set.

2. Refer to the generator set specification sheet for:

   a. Engine exhaust flow at rated kW in m^3/min. (cfm)

   Example: 57.5 m^3/min. (2030 cfm)

   b. Maximum allowable backpressure in kPa (in. of Hg)

   Example: 10.2 kPa (3.0 in. Hg)

3. Refer to the submittal catalog for:

   a. The recommended critical silencer part number
   Example: 343616

   b. Silencer inlet diameter in mm (in.)
   Example: 152 mm (6 in.)

   c. Silencer inlet position (end or side)
   Example: end inlet

   d. The flexible exhaust adapter part number
   Example: 343605

   e. Flexible exhaust adapter, flexible section length
   Example: 857 mm (33.75 in.)

4. Determine the exhaust gas velocity through the silencer as follows:

   a. Using the exhaust silencer inlet diameter determined in step 3, determine the corresponding inlet area using Figure 5-6.

      Example: 0.0187m^2 (0.201 sq. ft.)

   b. Use this data to calculate the exhaust gas velocity. Divide the engine exhaust flow from step 2 in m^3/min. (cfm) by the silencer inlet area m^2 (sq. ft.) to get flow velocity in m (ft.) per minute.

      Example:
      57.5 m^3/min. / 0.0187 m^2 = 3075 m/min.
      (2030 cfm / 0.201 sq. ft. = 10100 ft./min.)

Nominal Pipe Size, in. NPT	Inlet Area, m^2	Inlet Area, ft^2
1	0.00056	0.0060
1 1/4	0.00097	0.0104
1 1/2	0.00131	0.0141
2	0.00216	0.0233
2 1/2	0.00308	0.0332
3	0.00477	0.0513
4	0.00821	0.0884
5	0.0129	0.139
6	0.0187	0.201
8	0.0322	0.347
10	0.0509	0.548
12	0.0722	0.777
14	0.0872	0.939
16	0.1140	1.227
18	0.1442	1.553

Figure 5-6 Cross Sectional Area for Standard Silencer Sizes

5. Refer to Figure 5-7. Use the exhaust gas velocity determined in step 4 and find the exhaust gas velocity value in thousands on the bottom scale. Move vertically up until this value intersects the curve of the corresponding silencer type as determined in step 1. Move left on the horizontal axis and determine the backpressure drop value in kPa (in. of Hg).

   Example: Exhaust velocity, 3075 m/min. (10100 ft./min.) intersects with critical silencer curve B and the corresponding backpressure value is approximately 2.8 kPa (0.85 in. of mercury). Silencer type is end inlet from step 3 information with no additional backpressure drop value per the following note.

Note: When calculating backpressure drop for *side* inlet silencers, use the *end* inlet values shown and add 0.75 kPa (0.25 in. of mercury or 3.4 in. of water) to backpressure calculations.

Note: Refer to Figure 5-8 to calculate in inches of water and feet per minute.

6. Total the number of elbows and flexible sections in the exhaust system between the engine and the exhaust system outlet. Compare the radius of the bend (R) to the pipe diameter where (D) is the nominal pipe diameter in inches. Determine the equivalent length in m (ft.) of straight pipe for the elbows and flexible sections from the following:

Bend Angle	Type	Bend Radius	Conversion Factor
90°	Close	R = D	32 x D* / 12
90°	Medium	R = 2D	10 x D* / 12
90°	Sweep	R = 4D	8 x D* / 12
45°	Close	R = D	15 x D* / 12
45°	Sweep	R = 4D	9 x D* / 12
	Flex Sections		2 x Length† / 12

* Use the diameter of the silencer inlet in *inches* from step 3 for the initial calculation. If the results from step 9 indicate excessive backpressure drop, then recalculate using the larger-diameter pipe size selected.

† Use the flexible exhaust adapter length from step 3 and add any additional flex sections in the exhaust system expressed in *inches*.

Convert the equivalent pipe length calculated in feet to meters using ft. x 0.305 = m, as needed.

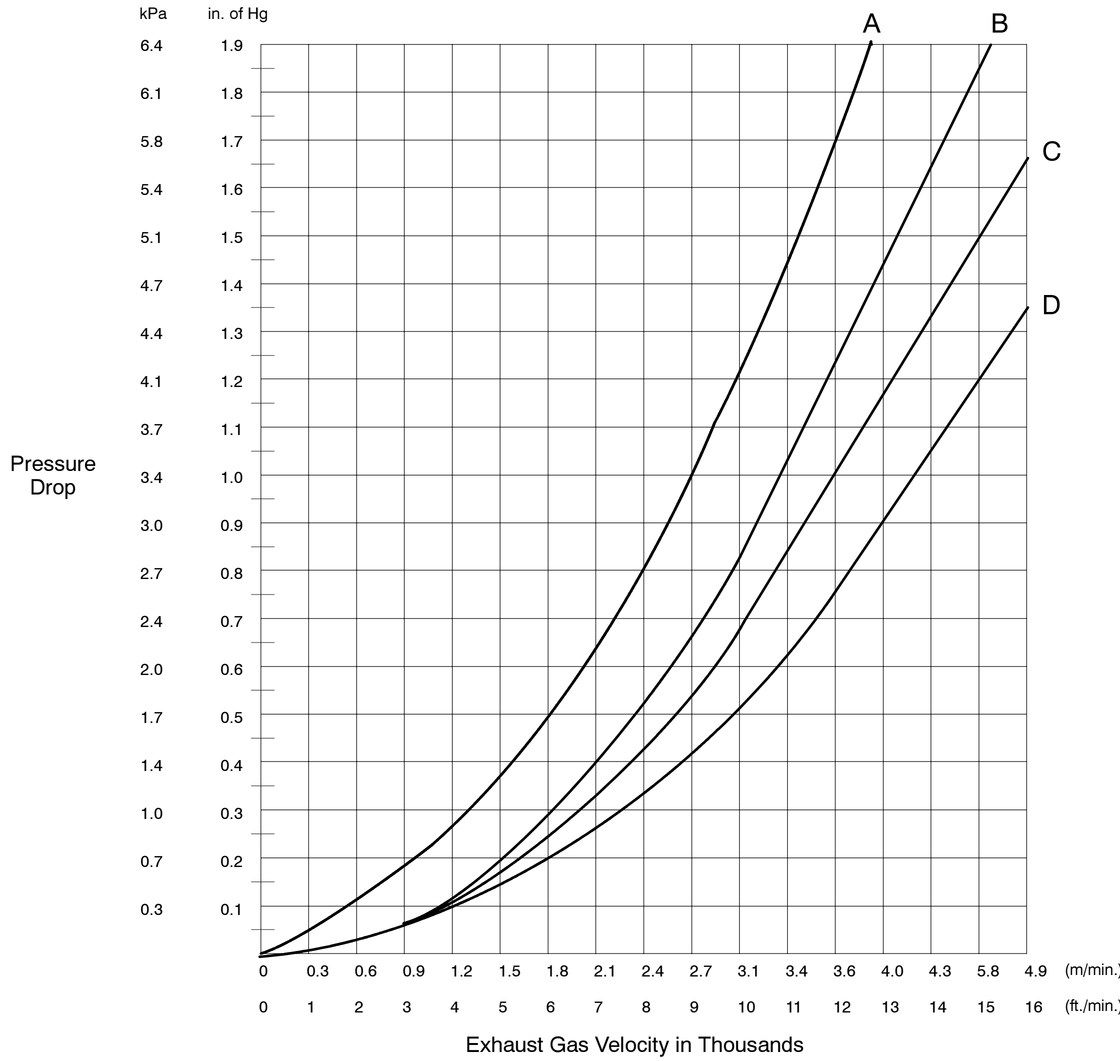
Examples:

45° sweep elbows:
9 x 6.0 in. / 12 = 4.5 equiv. ft. or 1.4 equiv. m

90° close elbows:
32 x 6.0 in. / 12 = 16.0 equiv. ft. or 4.9 equiv. m

Flexible sections:
2 x 33.75 in. / 12 = 5.6 equiv. ft. or 1.7 equiv. m

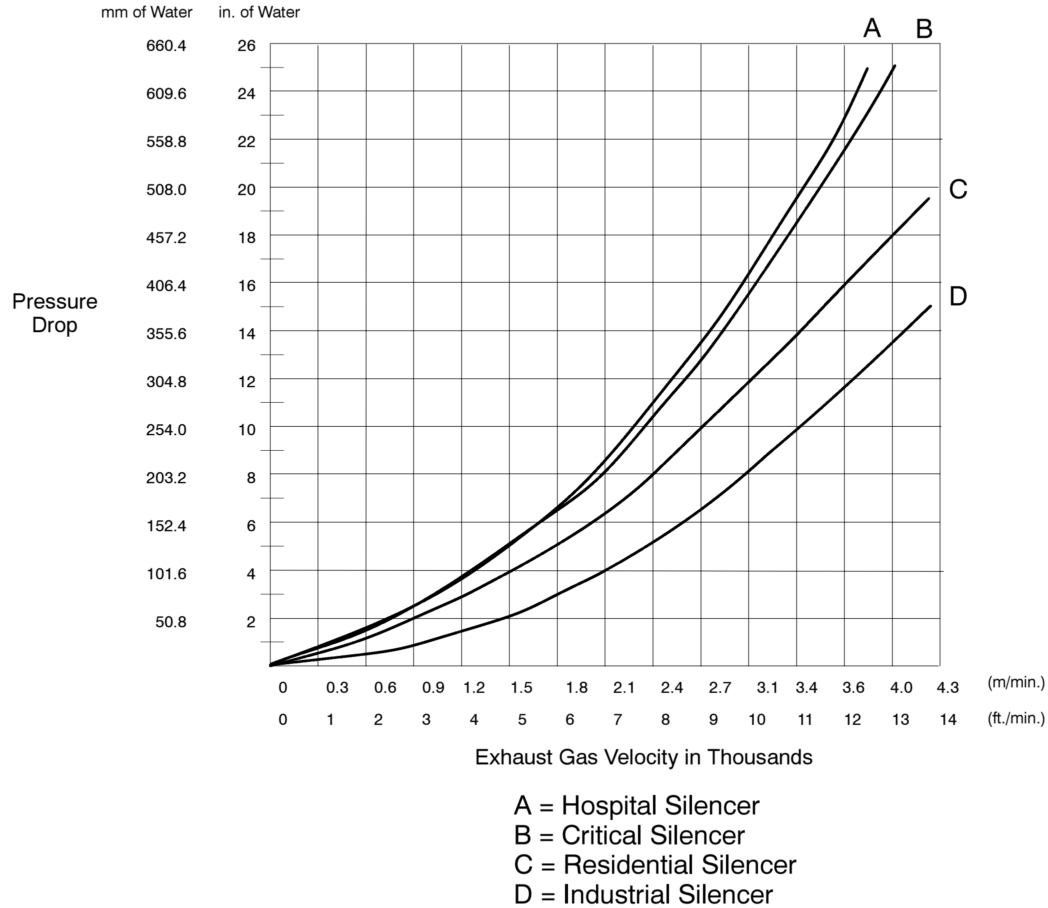
Equivalent of straight pipe:
4.5 + 16.0 + 5.6 = 26.1 equiv. straight ft.
1.4 + 4.9 + 1.7 = 8.0 equiv. straight m



A = Hospital Silencer
B = Critical Silencer
C = Residential Silencer
D = Industrial Silencer

Note: When figuring the silencer pressure drop for side inlet, add 0.75 kPa (0.25 in. of mercury or 3.4 in. of water) to the backpressure.

Figure 5-7 Silencer Backpressure Drop (in. of Hg)



Note: When figuring the silencer pressure drop for side inlet, add 0.75 kPa (86 mm of water or 3.4 in. of water) to the backpressure.

Figure 5-8 Silencer Backpressure Drop (in. of water)

7. Determine the total length of straight pipe used in the exhaust system. Add this calculation to the equivalent length for elbows and flexible sections obtained in step 6.

   Example:

   Straight pipe = 3.0 m (10 ft.).
   Equivalent straight pipe from step 6: 8.0 m (26.1 ft.)

   3.0 m + 8.0 m = 11.0 m or
   10 ft. + 26.1 ft. = 36.1 ft. total

8. Refer to Figure 5-9 if the pipe size is 102 mm (4 in.) or less or Figure 5-10 if the pipe size is 127 mm (5 in.) or larger.

   Place a straight edge across the chart with the edge in line with the pipe size in inches (D) on the right column from step 3 and the engine exhaust flow (Q) from step 2 on the left column.

   Read backpressure kPa/m or in. of Hg/ft. (ΔP) from the center column. Calculate the total piping system backpressure by multiplying the total equivalent straight pipe in m (ft.) from step 7 by the kPa/m or in. of Hg/ft. of pipe from this step.

   Example:

   11.0 equiv. m x 0.04 kPa/m =
   0.4 total system backpressure in kPa

   36.1 equiv. ft. x 0.004 in. Hg/ft. =
   0.14 total system backpressure in inches of Hg.

9. Add the backpressure of the piping determined in step 8 to the backpressure of the silencer determined in step 5. The total should not exceed the engine manufacturer's maximum allowable system backpressure determined in step 2 or on the generator set's specification sheet. If the total exceeds the maximum, use a larger pipe size or silencer or both. Repeat the calculation if new components are selected to verify that the system backpressure would not exceed the limit using the larger component(s).

   Example:

   0.4 kPa (step 8) + 2.8 kPa (step 5) = 3.2 kPa
   Maximum allowable backpressure = 10.2 kPa
   3.2<10.2 backpressure drop is acceptable

   0.14 in. Hg. (step 8) + 0.85 in. Hg. (step 5) =
   0.99 in. Hg.
   Maximum allowable backpressure = 3.0 in. of Hg.
   0.99< 3.0 backpressure drop is acceptable

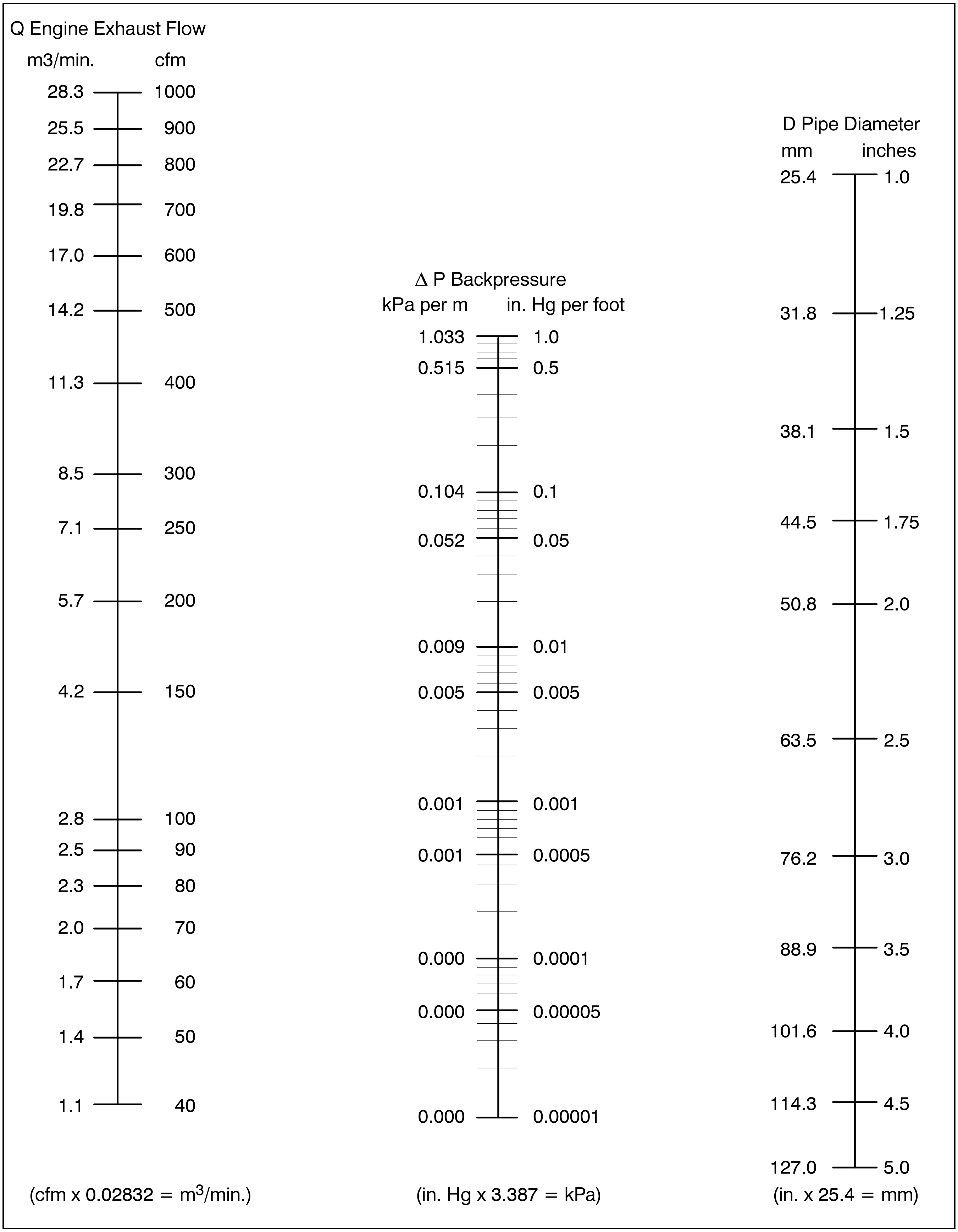


Figure 5-9 Backpressure using Pipe Size 4 in. (102 mm) or Less

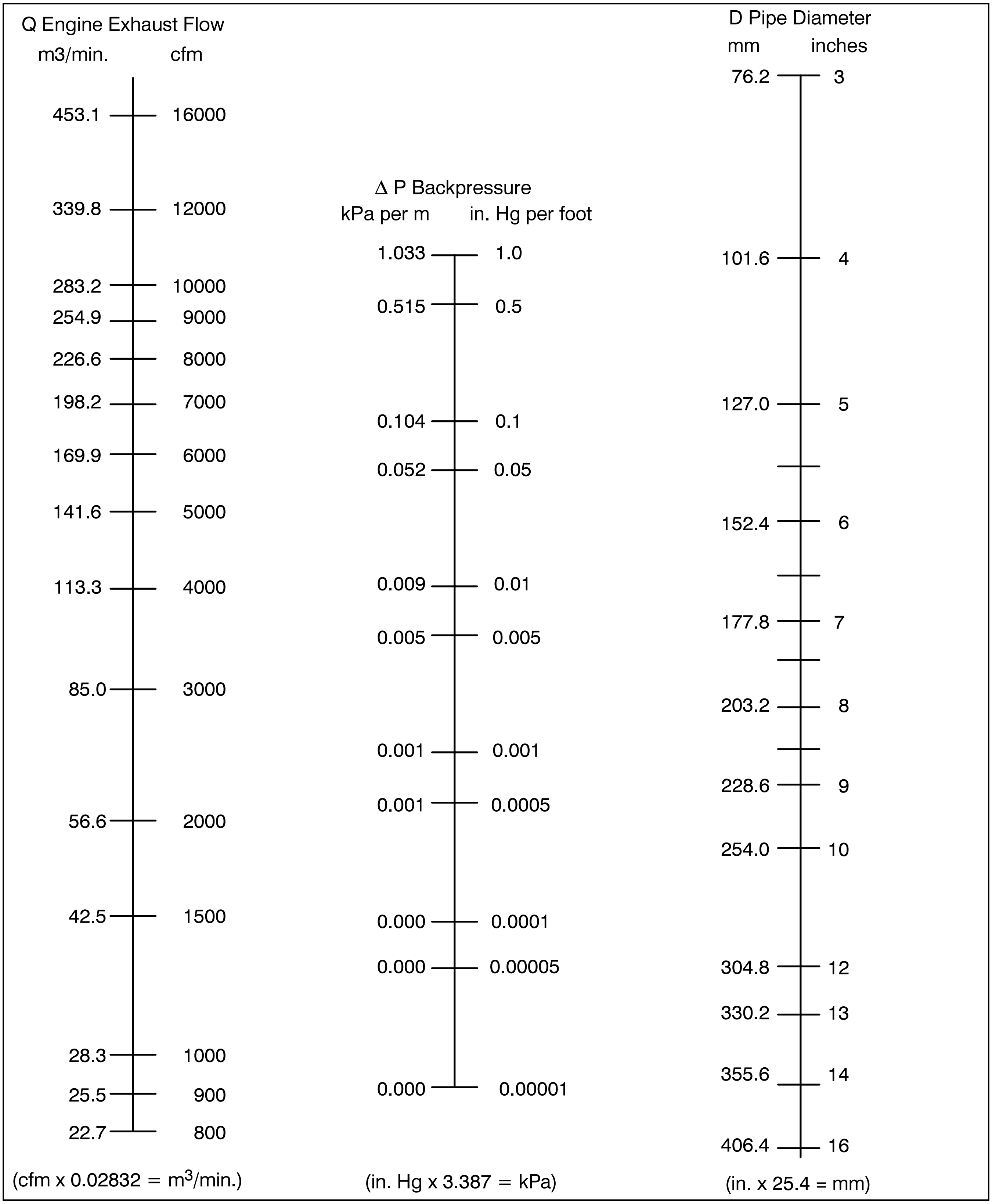


Figure 5-10 Backpressure using Pipe Size 5 in. (127 mm) or Larger

Notes

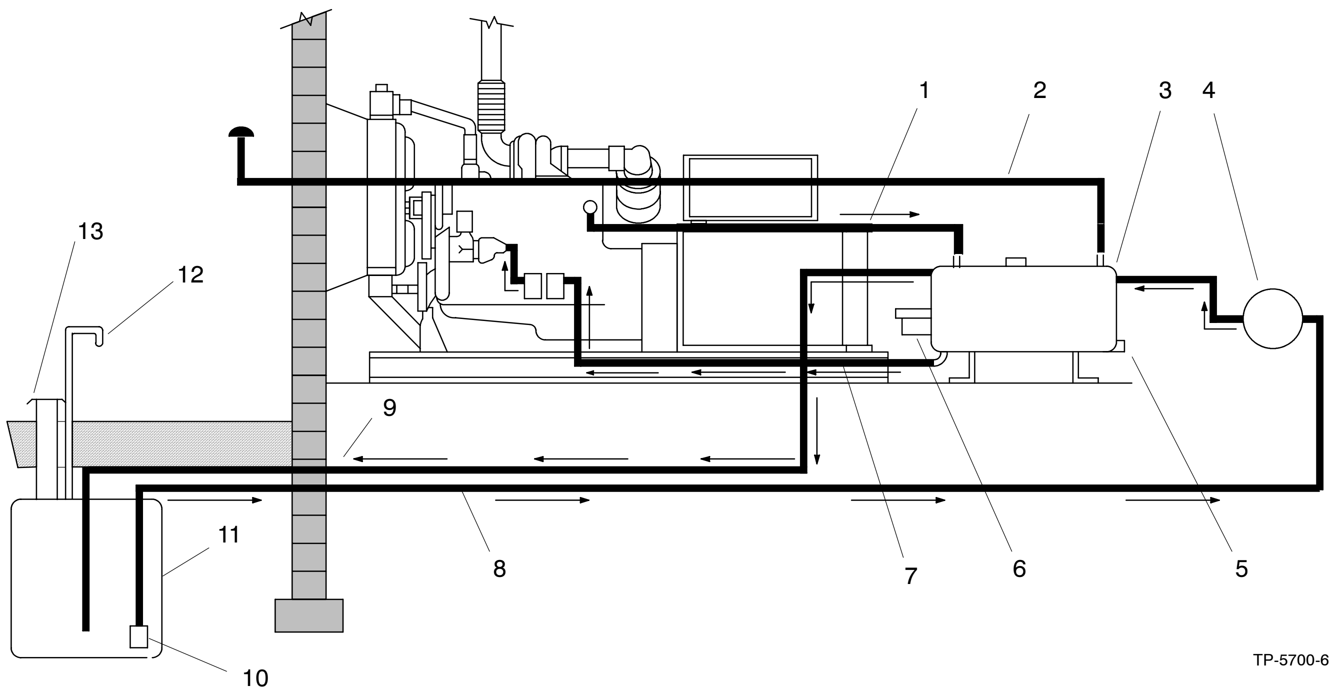
Comply with applicable state and local codes when installing any fuel system.

6.1 Diesel Fuel Systems

The main components of a typical diesel fuel system are a main fuel storage tank, a day tank, fuel lines, and an auxiliary fuel pump. See Figure 6-1.

6.1.1 Main Tank

Storage. Because it is less volatile than gas or gasoline, diesel fuel is safer to store and handle. Regulations for diesel storage tank placement are less stringent than the regulations for gas or gasoline storage. In some locations, large main tanks are permitted inside the building or enclosure.



1. Injector return line
2. Day tank vent
3. Day tank
4. Auxiliary fuel pump
5. Tank drain
6. Electric fuel level control switch
7. Fuel supply line from day tank to engine connection
8. Fuel supply line from main fuel tank to day tank
9. Overflow line
10. Foot valve
11. Main fuel storage tank
12. Fuel tank vent
13. Tank filling inlet

Figure 6-1 Diesel Fuel System

Tank location. Locate fuel storage tanks above ground or bury them underground in accordance with applicable codes. Figure 6-2 shows a commonly used above-ground subbase tank contained in the generator set mounting base.

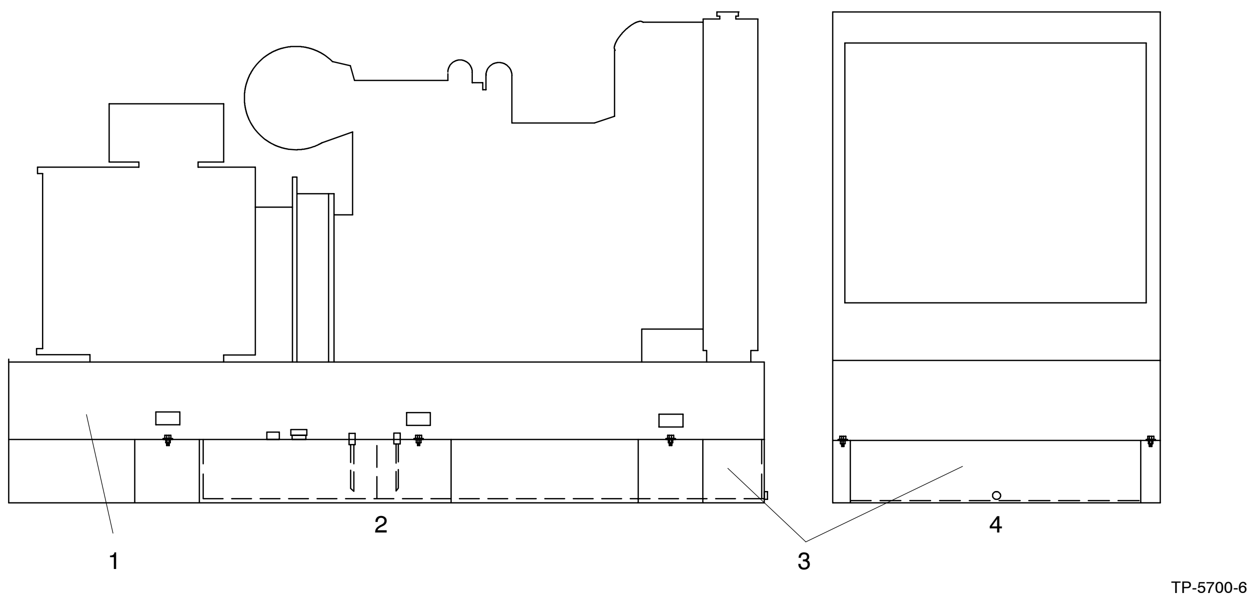
Provide easy access to fuel filters and sediment drains for regular and frequent service. Clean fuel is especially important to diesel engines, which have easily clogged fuel injectors and pumps.

Tank size. Codes requiring standby power often specify a minimum onsite fuel supply. Such requirements are included in NFPA 70, National Electrical Code, and NFPA 99, Standard for Health Care Facilities. Diesel fuel deteriorates if stored for more than one year; therefore, size the tank to ensure that regular generator set exercising will use the tank's contents within one year. If there are no applicable code requirements, the manufacturer recommends a tank sized for eight hours of operation at rated load. Refer to the generator set specification sheet for fuel consumption data.

Tank venting. Vent the main fuel tanks to allow air and other gases to escape to the atmosphere without allowing dust, dirt, and moisture to enter the tank.

Fuel expansion. Never fill the tank more than 95% full to allow for fuel expansion. On overhead main tanks, use a fuel shutoff solenoid to prevent hydraulic lock or tank overflow caused by excessive static head fuel pressures.

Fuel alternatives. Most diesel engines operate satisfactorily on No. 2 domestic burner oil available in most parts of the United States. If the site heating system is oil-fired, consider supplying the engine with fuel from the same tank used for heating oil to reduce costs and to ensure a continually fresh fuel supply for the engine. This practice necessitates that the fuel oil meets the engine manufacturer's minimum requirements for wax point, pour point, sulfur content, and cetane number as these factors influence cold weather starting and generator set power output. When supplying multiple applications from the same main fuel tank, provide each with a separate supply line.



1. Generator set skid
2. Side view
3. Subbase fuel tank
4. End view

Figure 6-2 Subbase Fuel Tank

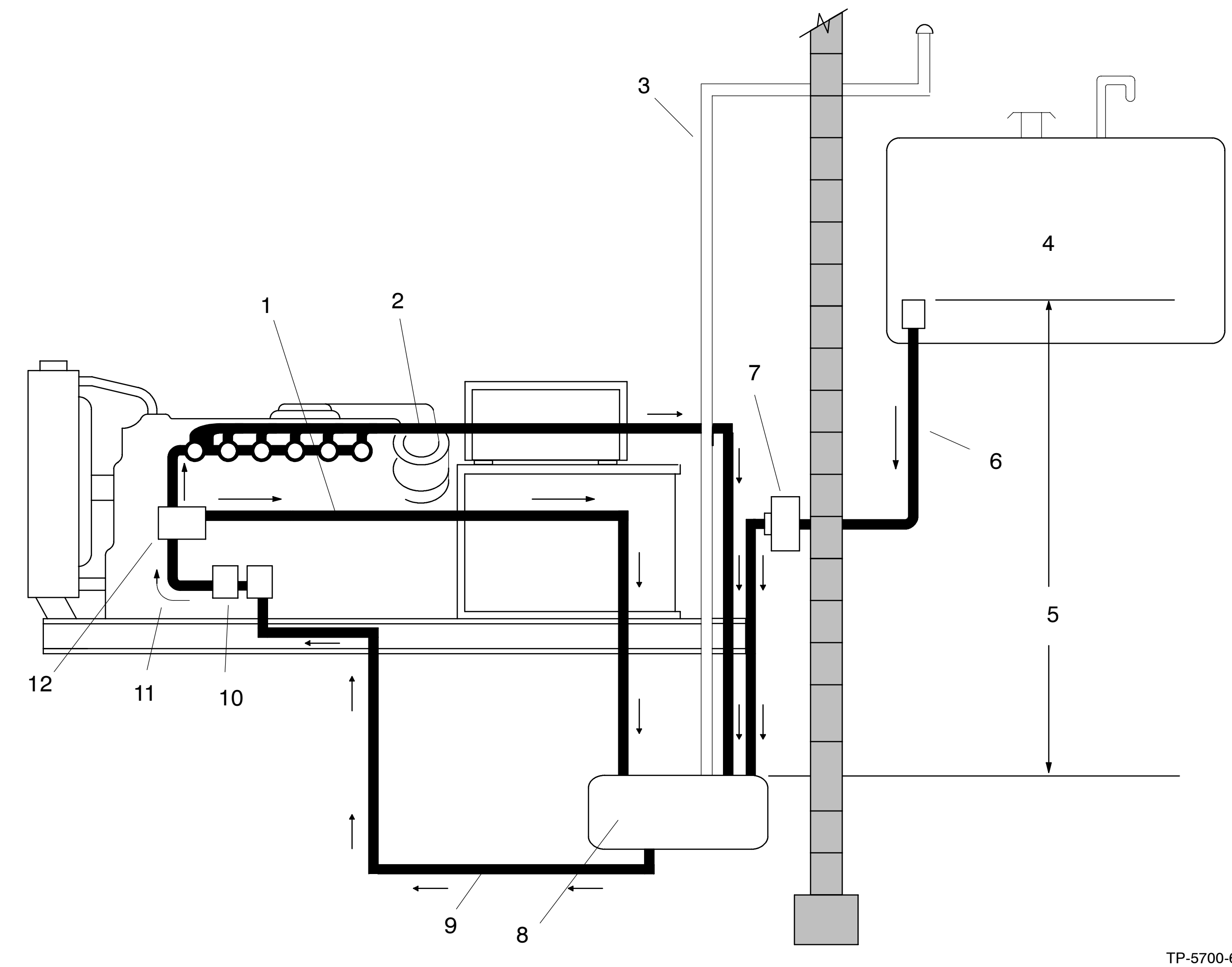
6.1.2 Day Tanks

The terms *day tank* and *transfer tank* are interchangeable. Having a day tank adjacent to the engine allows the engine fuel transfer pump to easily draw fuel during startup and provides a convenient location to connect fuel injector return lines. See Figure 6-3.

Connect a float-switch-controlled solenoid antisiphon valve or a float valve to prevent siphoning fuel from the main storage tank if the main tank fuel level is above the day tank inlet.

Tank size. Standard tanks are available in sizes from 38 to 3952 L (10 to 1044 gal.) with or without integral electric fuel transfer pumps. Because engines are subject to fuel temperature deration above 38°C (100°F) and are subject to damage if operated with fuel temperatures above 60°C (140°F), a day tank providing at least four hours of fuel consumption should be used to provide enough capacity to cool the fuel returning from the engine. If smaller day tanks are used, the generator set manufacturer may recommend installing a fuel cooler or routing engine fuel return lines to the main storage tank. See Figure 6-3.

Optional equipment includes fuel level gauges, manual priming pumps, float switches for pump control, float valves, rupture basins, and low level alarms.



1. Return line from fuel pump
2. Return line from fuel injectors/fuel rack
3. Vent (to outside)
4. Overhead main tank
5. Maximum 76 m (25 ft.), minimum 25 mm (1 in.)
6. Fuel supply line from main fuel tank to day tank
7. Fuel shutoff solenoid
8. Day tank
9. Fuel supply line from day tank to engine connection
10. Filter
11. Flexible line
12. Fuel pump

Figure 6-3 Diesel Fuel System with Overhead Main Tank and Day Tank

6.1.3 Fuel Lines

The following items describe fuel line selection and application. Never use the fuel piping or fuel line clamps to ground any electrical equipment.

Line Type. Use Schedule 40 black-iron pipe, steel tubing, or copper tubing for diesel fuel systems. Diesel fuel reacts adversely with galvanized tanks and piping, producing flaking sediment that quickly clogs filters and causes fuel pump and fuel injector failure. Ensure that any flexible fuel lines used are approved for diesel fuel.

Line size. Use the smallest diameter fuel line that still delivers enough fuel to the engine with an acceptable pressure drop of 6.9 kPa (1.0 psi). Using oversize piping increases the chance of air introduction into the fuel system during engine priming, which increases the potential for fuel pump damage and hard starting.

Flexible connectors. Use flexible connections spanning a minimum of 152 mm (6 in.) between the stationary piping and the engine fuel inlet connection.

Return lines. A diesel system delivers more fuel to the injectors than the engine uses; therefore, a system has one supply line from the fuel tank and at least one return line from the fuel injectors. Size the fuel return lines no smaller than the fuel supply lines.

Route the return fuel line to either the day tank or the main storage tank. Place the return lines as far away from the pickup or fuel diptube as possible to prevent air entry and to keep warm fuel from being reintroduced to the engine. If fuel lines are routed to the day tank, note the day tank size requirements in Section 6.1.2, Day Tanks.

A properly designed fuel return line is unrestricted and as short as possible, and it allows gravity return of fuel to the storage tanks. In installations where gravity return is not possible, obtain approval of the design from the generator set supplier based upon the engine's specifications before installing a fuel system with static head pressure on the return lines. Fuel return line restriction can cause engine hydraulic lock or uncontrollable overspeed on some systems.

6.1.4 Auxiliary Fuel Pumps

Primary, engine-driven fuel pumps typically develop a maximum of 48 kPa (7 psi) pressure and draw fuel to approximately 1.2–1.4 m (4–5 ft.) vertically or 6 m (20 ft.) horizontally. When the main tank is located a greater distance from the engine or for a more reliable fuel system, use an auxiliary pump alone or in connection with a day tank. See Figure 6-3. Limit auxiliary fuel pump pressure to approximately 35 kPa (5 psi).

Use a shutoff solenoid valve wired into the engine run circuit or a check valve to help keep the fuel line primed. Install the check valve on the outlet side of the auxiliary fuel pump to minimize inlet restriction.

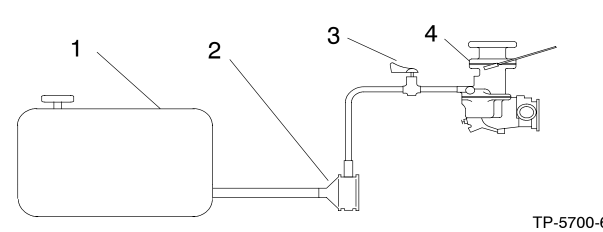
Auxiliary fuel pump options. On engines using less than 38 L (10 gal.) of fuel per hour (approximately 100 kW or less), connect an engine starting battery-powered electric fuel transfer pump in series with the engine-driven transfer pump. Locate the electric pump nearer to the fuel tank than to the engine. An auxiliary pump located at the fuel tank approximately doubles the horizontal and vertical distance limits of a single engine-driven pump.

On engines using more than 38 L (10 gal.) of fuel per hour or when drawing fuel more than 1.8 m (6 ft.) vertically or 12 m (40 ft.) horizontally, use an electric motor-driven positive displacement pump with a day tank and float switch. Electrically connect the fuel pump to the transfer switch load side for maximum reliability. This type of pump can typically lift fuel 5.5 m (18 ft.) or draw it horizontally up to 61 m (200 ft.).

Where vertical runs exceed 5.5 m (18 ft.) or horizontal runs exceed 61 m (200 ft.), remote-mount the pump adjacent to the fuel storage tank. This type of installation allows these pumps to push fuel over 305 m (1000 ft.) horizontally or more than 31 m (100 ft.) vertically and deliver adequate fuel for generator sets up to 2000 kW. Always connect a positive-displacement pump directly to a day tank and float switch to protect the engine fuel system from excessive fuel pressures.

6.2 Gasoline Fuel Systems

The main components of a typical gasoline fuel system are a fuel storage tank, fuel lines, and a fuel pump. See Figure 6-4.



1. Fuel tank
2. Fuel pump
3. Gasoline shut-off
4. Gasoline carburetor

Figure 6-4 Gasoline Fuel System

6.2.1 Fuel Storage Tank

Gasoline fuel systems are usually limited to outdoor or portable trailer-mounted generator sets because codes typically restrict or prohibit storing more than 3.8 L (1.0 gal.) of gasoline inside a building.

If a fuel storage tank is located higher than the engine, install an antisiphon fuel solenoid valve or air bleed hole in the fuel tank diptube (near the top of the tube inside the tank) to prevent siphoning.

Gasoline deteriorates after six months; therefore, use the smallest storage tank allowed by code.

6.2.2 Fuel Lines

Never use fuel piping to ground electrical equipment.

Line type. Use Schedule 40 black-iron pipe, steel tubing, or copper tubing for gasoline fuel systems. Do not use galvanized pipe and fittings.

Line size. Use the smallest diameter fuel line that will not restrict the required fuel flow.

Flexible connectors. Use flexible connections spanning a minimum of 152 mm (6 in.) between the stationary piping and the engine fuel inlet connection.

6.2.3 Fuel Pumps

Engine fuel pumps usually lift fuel up to 1.2 m (4 ft.) or draw it horizontally up to 6 m (20 ft.). Connect auxiliary engine starting battery-powered electric pumps in series with the engine-driven pump. See Figure 6-4. An auxiliary pump located at the fuel tank approximately doubles the horizontal and vertical distance limits of a single engine-driven pump. Limit auxiliary fuel pump pressure to approximately 35 kPa (5 psi).

6.3 Gas Fuel Systems, Common Components

Gas fuel systems operate on either LP (liquefied petroleum) or natural gas.

Note: Design and install gas fuel systems in accordance with NFPA 54, National Fuel Gas Code, and applicable local codes.

All gas systems include a carburetor, secondary gas regulator, electric gas fuel solenoid shutoff valve, and flexible fuel connector.

6.3.1 Gas Lines

Never use fuel piping to ground electrical equipment. The gas supplier is responsible for installation, repair, and alteration to gas piping.

Line type. Use Schedule 40 black-iron pipe for gas piping. Copper tubing may be used if the fuel does not contain hydrogen sulfide or other ingredients that react chemically with copper.

Line size. Size piping according to the requirements of the equipment. Refer to the generator set specification sheet or the dimension drawing for detailed information on your system. In addition to the actual fuel consumption, consider the following pressure loss factors:

- Pipe length
- Other appliances on the same fuel supply
- Number of fittings

Flexible connections. Rigid-mount the piping but protect it from vibration. Use flexible connections spanning a minimum of 152 mm (6 in.) between the stationary piping and the engine fuel inlet connection.

6.3.2 Gas Regulators

Gas regulators reduce high incoming fuel pressures to lower levels acceptable for engines. Refer to the generator set spec sheet for fuel supply pressures. Typical gas fuel pressures are shown in Figure 6-5. Install a solenoid valve upstream from the gas regulator and the flexible fuel connector to prevent the accumulation of an explosive mixture of gas and air caused by leaks in the flexible connection or the gas regulator. The generator set installer normally wires the engine battery-powered solenoid valve to the engine starting controls to open the valve when the engine cranks or runs.

For UL compliance, the fuel solenoid valves are needed per UL 2200, Section 35.3.2.2.1.

Generator Set Model	Engine	Fuel Supply Pressure	
		kPa (oz./in.^{2})	Water Column, cm (in.)
20 kW	Ford	1.7-2.74 (4-6)	18-28 (7-11)
30-125 kW	GM	1.7-2.74 (4-6)	18-28 (7-11)
135-275 kW	Detroit Diesel Series 50/60	1.2-5 (2.9-11.6)	13-51 (5-20)
400-800 kW	Waukesha	2-34 (4.6-80)	20-348 (8-137)

Figure 6-5 Recommended Gas Fuel Supply Pressures

The typical gas system uses two gas regulators:

- **Primary gas regulator.** Provides initial control of gas from the fuel supply. The primary gas regulator reduces the high pressure from a tank or transmission line to the low pressure required by the secondary gas regulator(s). Typically, the primary gas regulator is set at the higher pressure value when a range is given. The gas supplier typically provides the primary gas regulator, as conditions that dictate the type of gas regulator used vary depending on the method of supplying fuel. The supplier is also responsible for providing sufficient gas pressure to operate the primary gas regulator. The primary gas regulator must be vented to the outside if installed within any building.

- **Secondary gas regulator.** This low-pressure gas regulator is mounted on the engine and limits the maximum inlet pressure to the engine. The engine operates satisfactorily at the lower pressure value when a range is given, but these lower pressures may result in poor response to load changes or a lack of power if the primary gas regulator is not near the engine.

Modification for fuel type. Many gas regulators are compatible with both natural gas and LP gas. Typically, the user installs the spring and retainer in the gas regulator when connecting to natural gas and removes it from the gas regulator when connecting to LP vapor gas. Refer to the appropriate generator set's operation manual and/or the decal attached to the generator set for information regarding spring/adjustment screw usage for specific models. Some models may require new diaphragm kits and/or inverting the gas regulator when changing fuel type.

Installation position for fuel type. The gas regulator functions normally pointing downward for both natural gas and LP gas. If only natural gas fuel is used, the gas regulator may be installed pointing upward.

Pressure testing. Some gas regulators provide for installation of a pressure gauge to test inlet and outlet pressures. If no such provision is available, install pipe tees in the fuel line to test pressure and use pipe plugs to plug unused openings.

6.4 LP Fuel Systems

Fuel characteristics. LP fuel exists as a vapor and a liquid in pressurized tanks. Since LP fuel does not deteriorate in storage, a large supply of fuel can be kept onsite indefinitely for operation during emergency conditions. This makes LP gas ideal for applications with uninterrupted (onsite) fuel supply requirements.

Fuel mixture. LP gas is propane, butane, or a mixture of the two gases. The ratio of butane to propane is especially important when the fuel flows from a large outdoor tank. A fuel supplier may fill the tank in the warm summer months with a mixture composed mainly of butane; however, this mixture may not provide sufficient vaporized pressure at cold temperatures to start and operate the engine. A local fuel supplier is likely to be the best source of information on what size tank is necessary to provide adequate fuel vapor.

The fuel mixture and vaporization pressure at the anticipated temperatures influence the selection of gas regulator equipment. Pure butane gas has little or no vaporization pressure in temperatures below 4°C (40°F). Even at 21°C (70°F), the pressure is approximately 124 kPa (18 psi). Some primary gas regulators do not operate at tank pressures below 207 kPa (30 psi) while others operate at incoming pressures as low as 20.7–34.5 kPa (3–5 psi).

Fuel consumption and tank size. Since LP fuel is supplied in pressurized tanks in liquid form, it must be converted to a vapor state before being introduced into the carburetor. The amount of vapor contained in 3.8 L (1.0 gal.) of liquid (LP) fuel is:

Butane Gas	0.88 m^3 (31.26 cu. ft.)
Propane Gas	1.03 m^3 (36.39 cu. ft.)

See the generator set specification sheets for fuel consumption at different loads, and contact your fuel supplier for information regarding tank sizes.

System types. Single-source gas fuel systems include LP gas vapor-withdrawal and LP gas liquid-withdrawal.

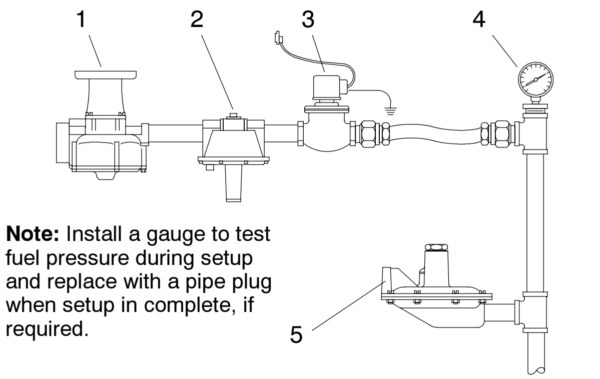
6.4.1 LP Gas Vapor-Withdrawal Systems

A vapor-withdrawal system draws on the fuel vapor that collects in the space above the liquid fuel. Consider the following during installation:

- Generally, allow 10%–20% of tank capacity for fuel expansion from a liquid to a vapor state. The liquid level in LP gas tanks must never exceed 90% of the tank capacity.
- Maintain air temperature surrounding the tank high enough to vaporize the liquid fuel.

Applications in colder climates may require an independent heat source to increase natural vaporization within the tank. Withdraw liquid fuel and vaporize it in an electrically heated, engine water jacket-heated, or LP gas-heated vaporizer.

Figure 6-6 shows the components of the vapor-withdrawal system used in a typical stationary application. The LP gas regulator is typically installed in the inverted position (pointing downward).



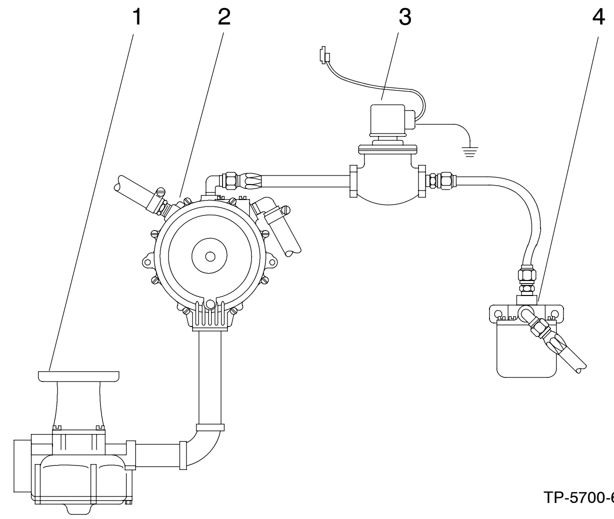
1. Carburetor
2. Secondary gas regulator
3. Solenoid valve (quantity of two in series may be required for UL applications)
4. Pressure gauge
5. Primary gas regulator (supplied by gas supplier or installer)

Figure 6-6 Typical LP Gas Vapor-Withdrawal System

6.4.2 LP Gas Liquid-Withdrawal Systems

LP liquid-withdrawal fuel systems are available for generator sets but are not recommended for automatic standby service. With liquid-withdrawal systems, liquid LP at 1034–1379 kPa (150–200 psi) flows to the engine. A combination of converters (vaporizers) and gas regulators then reduces the pressure to a usable level.

In Figure 6-7, a converter (a combination of a vaporizer and primary and secondary gas regulators) changes the liquid to vapor using heat from the engine's cooling system. For a period following startup, a liquid-withdrawal system may be unable to vaporize enough fuel for an engine running under load until the engine reaches operating temperature. The engine needs time to warm sufficiently to provide adequate heat to vaporize the fuel.



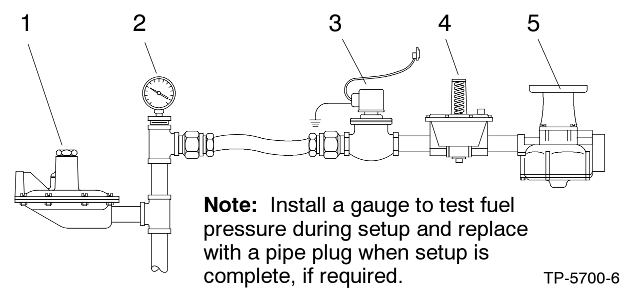
1. Carburetor
2. Converter (vaporizer)
3. Solenoid valve (quantity of two in series may be required for UL applications)
4. LP gas filter (supplied by gas supplier or installer)

Figure 6-7 LP Gas Liquid Withdrawal System

Some codes prohibit gas fuel pressurization greater than 34.5 kPa (5 psi) inside buildings. This might preclude the use of a liquid-withdrawal system. To ensure code compliance, converters are sometimes located outside the building housing the generator set. However, the great length of pipe between the converter and the carburetor does not allow sufficient heat buildup and heat retention to maintain the fuel in its vapor state, which can cause startup problems.

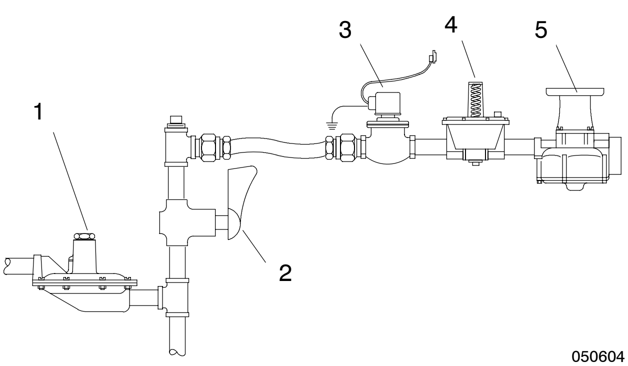
6.5 Natural Gas Systems

The utility supplies natural gas in a vapor state. A natural gas fuel system consists of the same basic components and operates with the same general sequence as LP gas vapor-withdrawal systems. See Figure 6-8 and Figure 6-9. Note that when the heat content of the fuel falls below 1000 Btu, as it does with sewage-derived and some other natural gas fuels, the generator set will not produce its rated power. The natural gas regulator is typically installed in the upright position (pointing upward).



1. Primary gas regulator (supplied by gas supplier or installer)
2. Pressure gauge
3. Solenoid valve (quantity of two in series may be required for UL applications)
4. Secondary regulator
5. Carburetor

Figure 6-8 Natural Gas Fuel System with Pressure Gauge



1. Primary gas regulator (supplied by gas supplier or installer)
2. Manual shutoff valve
3. Solenoid valve (quantity of two in series may be required for UL applications)
4. Secondary gas regulator
5. Carburetor

Figure 6-9 Natural Gas Fuel System without Pressure Gauge and with Manual Shutoff Valve

6.6 Combination Systems

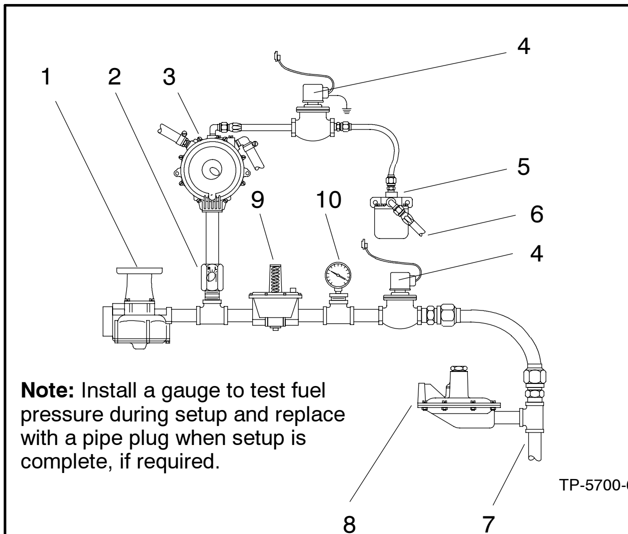
Combination fuel source systems include:

- Natural gas and LP gas
- LP gas or natural gas and gasoline

6.6.1 Combination Natural Gas and LP Gas

Some applications use natural gas as the main fuel and LP gas as the emergency fuel when natural gas is not available.

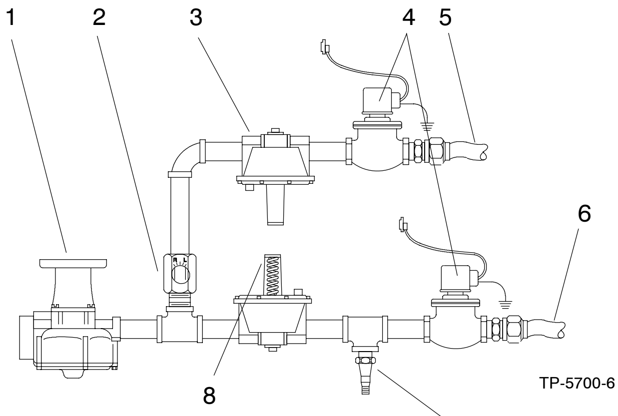
The natural gas and *LP gas, liquid withdrawal* system uses a converter (vaporizer) to change the LP liquid to gas vapor. A pressure switch on the primary fuel source closes when fuel pressure drops, which energizes a relay that closes the primary fuel solenoid and opens the secondary or emergency fuel solenoid. A separate LP gas load adjustment valve ensures the right fuel-to-air mixture in the carburetor. The load adjustment valve is located inline between the converter (vaporizer) and the carburetor. See Figure 6-10.



1. Carburetor
2. Load adjustment valve
3. Converter (vaporizer)
4. Solenoid valve (quantity of two in series may be required for UL applications)
5. LP gas filter (supplied by gas supplier or installer)
6. LP gas supply
7. Natural gas supply
8. Primary gas regulator (supplied by gas supplier or installer)
9. Secondary natural gas regulator
10. Pressure gauge

Figure 6-10 Natural Gas and LP Gas System, Liquid Withdrawal

The natural gas and *LP gas, vapor withdrawal* system contains a separate secondary gas regulator and solenoid valve for each fuel. The LP gas regulator typically mounts in the inverted position. A pressure switch on the primary fuel source closes when fuel pressure drops, which energizes a relay that closes the primary fuel solenoid and opens the secondary or emergency fuel solenoid. A separate LP gas load adjustment valve ensures the right fuel-to-air mixture in the carburetor. The load adjustment valve is located inline between the secondary gas regulator and the carburetor. See Figure 6-11.



1. Carburetor
2. Load adjustment valve
3. Secondary LP gas regulator
4. Solenoid valve (quantity of two in series may be required for UL applications)
5. LP gas supply
6. Natural gas supply
7. Low pressure switch
8. Secondary natural gas regulator

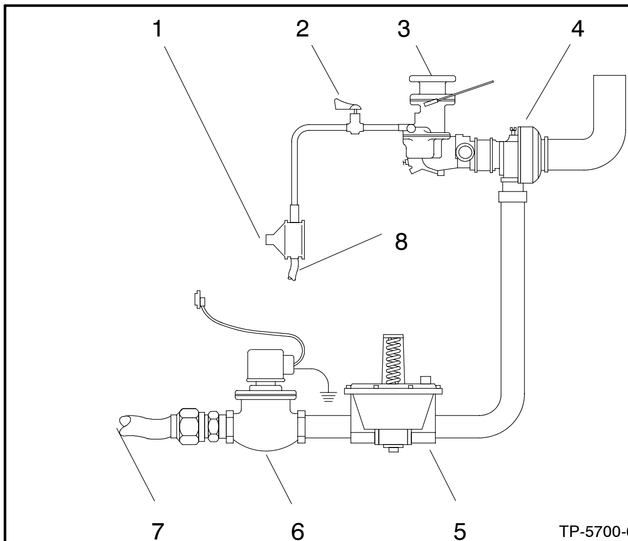
Figure 6-11 Natural Gas and LP Gas System, Vapor Withdrawal

6.6.2 Combination LP Gas or Natural Gas and Gasoline

Combination LP gas or natural gas and gasoline systems normally use a gas fuel as the primary fuel and use gasoline for emergency operation. Combination natural gas and gasoline fuel systems are sometimes used with gasoline as a standby fuel to meet code requirements for an onsite fuel supply. Since gasoline deteriorates after six months of storage, do not use a combination system unless it is operated on gasoline often enough to ensure that the fuel does not deteriorate and that the carburetor is not subsequently clogged by accumulated gum deposits.

These systems use either a combination gas-gasoline carburetor or a gasoline carburetor with a gas adapter. With the exception of the carburetor, the combination gas-gasoline systems use the same basic components as those in the natural and LP gas systems. See Figure 6-12.

Change fuel supplies manually at the generator set. Most engines, especially the smaller models, operate successfully on gas or gasoline without extensive modification or complicated mechanical changeover. With a combination gas-gasoline fuel system, changeover involves a few simple steps as outlined in the generator set's operation manual.



1. Fuel pump
2. Gasoline shutoff
3. Gasoline carburetor
4. Fuel mixer
5. Secondary gas regulator
6. Solenoid valve (quantity of two in series may be required for UL applications)
7. Gas fuel supply
8. Gasoline fuel supply

Figure 6-12 Combination Gas/Gasoline Fuel System

When installing this combination system, follow the installation considerations outlined for LP gas, natural gas, and gasoline systems.

6.7 Pipe Size Requirements for Gas Fuel Systems

The type of fuel, the distance it must travel from gas meter/tank to fuel shutoff solenoid, and the amount consumed by the engine must be considered when determining fuel line pipe size.

To find the correction necessary for the different specific gravity of the particular fuel used, refer to Figure 6-13.

Fuel	Specific Gravity	Correction Factor
Sewage Gas	0.55	1.040
Natural Gas	0.65	0.962
Air	1.00	0.775
Propane (LP)	1.50	0.633
Butane	2.10	0.535

Figure 6-13 Fuel Correction Factors

Figure 6-14 is based on gas pressures of 3.4 kPa (0.5 psi, 13.8 in. water column) or less and a pressure drop of 0.12 kPa (0.018 psi, 0.5 in. water column) with a 0.60 specific gravity and with a normal amount of restriction from fittings. To calculate the correct pipe size for a specific installation, refer to the chart and follow the procedure outlined below.

Nominal Iron Pipe Size (IPS), In.	Internal IPS Diameter, mm (in.)	Length of Pipe, m (ft.)						
		3.0 (10)	6.1 (20)	9.1 (30)	12.2 (40)	15.2 (50)	18.3 (60)	21.3 (70)
		Fuel Consumption Value, m^3/hr. (ft^3/hr.)						
1/4	9.25 (0.364)	1.2 (43)	0.82 (29)	0.68 (24)	0.57 (20)	0.51 (18)	0.45 (16)	0.42 (15)
3/8	12.52 (0.493)	2.7 (95)	1.8 (65)	1.5 (52)	1.3 (45)	1.1 (40)	1.0 (36)	0.93 (33)
1/2	15.80 (0.622)	5.0 (175)	3.4 (120)	2.7 (97)	2.3 (82)	2.1 (73)	1.9 (66)	1.7 (61)
3/4	20.93 (0.824)	10.2 (360)	7.1 (250)	5.7 (200)	4.8 (170)	4.3 (151)	3.9 (138)	3.5 (125)
1	26.64 (1.049)	19.3 (680)	13.2 (465)	10.6 (375)	9.1 (320)	8.1 (285)	7.4 (260)	6.8 (240)
1 1/4	35.05 (1.380)	39.6 (1400)	26.9 (950)	21.8 (770)	18.7 (660)	16.4 (580)	13.9 (490)	13.0 (460)
1 1/2	40.89 (1.610)	59.5 (2100)	41.3 (1460)	33.4 (1180)	28.0 (990)	25.5 (900)	22.9 (810)	21.2 (750)
2	52.50 (2.067)	111.9 (3950)	77.9 (2750)	62.3 (2200)	53.8 (1900)	47.6 (1680)	43.0 (1520)	39.6 (1400)
2 1/2	62.71 (2.469)	178.4 (6300)	123.2 (4350)	99.7 (3520)	85.0 (3000)	75.0 (2650)	68.0 (2400)	63.7 (2250)
3	77.93 (3.068)	311.5 (11000)	218.0 (7700)	177.0 (6250)	150.0 (5300)	134.6 (4750)	121.8 (4300)	110.4 (3900)
4	102.26 (4.026)	651.2 (23000)	447.4 (15800)	362.5 (12800)	308.7 (10900)	274.7 (9700)	249.1 (8800)	229.4 (8100)

Nominal Iron Pipe Size (IPS), In.	Internal IPS Diameter, mm (in.)	Length of Pipe, m (ft.)						
		24.4 (80)	27.4 (90)	30.5 (100)	38.1 (125)	45.7 (150)	53.3 (175)	61.0 (200)
		Fuel Consumption Value, m^3/hr. (ft^3/hr.)						
1/4	9.25 (0.364)	0.39 (14)	0.37 (13)	0.34 (12)	0.31 (11)	0.28 (10)	0.25 (9)	0.23 (8)
3/8	12.52 (0.493)	0.88 (31)	0.82 (29)	0.76 (27)	0.68 (24)	0.62 (22)	0.57 (20)	0.54 (19)
1/2	15.80 (0.622)	1.6 (57)	1.5 (53)	1.4 (50)	1.2 (44)	1.1 (40)	1.0 (37)	0.99 (35)
3/4	20.93 (0.824)	3.3 (118)	3.1 (110)	2.9 (103)	2.6 (93)	2.4 (84)	2.2 (77)	2.0 (72)
1	26.64 (1.049)	6.2 (220)	5.8 (205)	5.5 (195)	5.0 (175)	4.5 (160)	4.1 (145)	3.8 (135)
1 1/4	35.05 (1.380)	13.0 (460)	12.2 (430)	11.3 (400)	10.2 (360)	9.2 (325)	8.5 (300)	7.9 (280)
1 1/2	40.89 (1.610)	19.5 (690)	18.4 (650)	17.6 (620)	15.6 (550)	14.2 (500)	13.0 (460)	12.2 (430)
2	52.50 (2.067)	36.8 (1300)	34.5 (1220)	32.6 (1150)	28.9 (1020)	26.9 (950)	24.1 (850)	22.7 (800)
2 1/2	62.71 (2.469)	58.1 (2050)	55.2 (1950)	52.4 (1850)	46.7 (1650)	42.5 (1500)	38.8 (1370)	36.2 (1280)
3	77.93 (3.068)	104.8 (3700)	97.7 (3450)	92.0 (3250)	83.5 (2950)	75.0 (2650)	69.4 (2450)	64.6 (2280)
4	102.26 (4.026)	212.4 (7500)	203.9 (7200)	189.7 (6700)	169.9 (6000)	155.7 (5500)	141.6 (5000)	130.3 (4600)

Note: When the fuel has a specific gravity of 0.7 or less no correction factor is necessary—use this table without a correction factor.

Figure 6-14 Maximum Flow Capacity of Pipe in Cubic Meters (Cubic Feet) of Gas per Hour

1. Refer to the fuel consumption on the generator set specification sheet. Note type of fuel used, generator set application rating, and the m^3/hr. (ft^3/hr.) consumption at 100% load.

   Example:
   80 kW, propane gas, 60 Hz standby rating = 12.0 m^3/hr. (425 ft^3/hr.).

2. Refer to the Fuel Correction Factors in Figure 6-13. Locate the correction factor for specific gravity of the selected fuel.

   When the fuel has a specific gravity of 0.7 or less no correction factor is necessary—use Figure 6-14 without a correction factor.

   Example:
   propane gas specific gravity = 1.50
   fuel correction factor = 0.633.

3. Divide the consumption value from step 1 by the correction factor from step 2.

   Example:
   12.0 m^3/hr. (425 ft^3/hr.) divided by 0.633 =
   19.0 m^3/hr. (671 ft^3/hr.).

4. Determine the length of pipe between the gas meter/tank and the fuel shutoff solenoid at the generator set.

   Example:
   34.7 m (114 ft.).

5. Find the value closest to pipe length in the Length of Pipe column in Figure 6-14.

   Example:
   38.1 m (125 ft.).

6. Move vertically down the table in Figure 6-14 from the determined value in Length of Pipe column.

   Example:
   38.1 m (125 ft.)

   Stop at the value that is equal to or greater than corrected consumption value from step 3.

   Example:
   28.9m^3/hr. (1020 ft.^{3}/hr.).

7. Move to the left column from the value in step 6 to determine the correct pipe size.

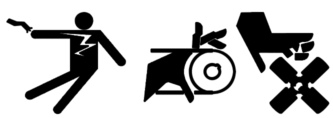
   Example:
   At 28.9 m^3/hr. (1020 ft^3/hr.) the pipe size = 2 in. IPS.

Notes

Before installing the generator set, provide for electrical connections through conduit to the transfer switch and other accessories for the generator set. Carefully install the selected generator set accessories. Route wiring to the generator set through flexible connections. Comply with all applicable codes when installing a wiring system.

AC circuit protection. All AC circuits must include circuit breaker or fuse protection. Select a circuit breaker for up to 125% of the rated generator set output current. The circuit breaker must open all ungrounded connectors. The circuit breaker or fuse must be mounted within 7.6 m (25 ft.) of the alternator output terminals.

WARNING



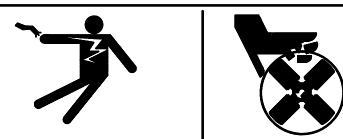
Accidental starting.
Can cause severe injury or death.

Disconnect the battery cables before working on the generator set. Remove the negative (–) lead first when disconnecting the battery. Reconnect the negative (–) lead last when reconnecting the battery.

Disabling the generator set. Accidental starting can cause severe injury or death. Before working on the generator set or equipment connected to the set, disable the generator set as follows: (1) Turn the generator set master switch and switchgear engine control switch to the OFF position. (2) Disconnect the power to the battery charger. (3) Remove the battery cables, negative (–) lead first. Reconnect the negative (–) lead last when reconnecting the battery. Follow these precautions to prevent the starting of the generator set by an automatic transfer switch or a remote start/stop switch.

Disabling the generator set. Accidental starting can cause severe injury or death. Before working on the generator set or connected equipment, disable the generator set as follows: (1) Move the generator set master switch to the OFF position. (2) Disconnect the power to the battery charger. (3) Remove the battery cables, negative (–) lead first. Reconnect the negative (–) lead last when reconnecting the battery. Follow these precautions to prevent starting of the generator set by an automatic transfer switch, remote start/stop switch, or engine start command from a remote computer.

WARNING



Hazardous voltage. Moving rotor.
Can cause severe injury or death.

Operate the generator set only when all guards and electrical enclosures are in place.

Short circuits. Hazardous voltage/current can cause severe injury or death. Short circuits can cause bodily injury and/or equipment damage. Do not contact electrical connections with tools or jewelry while making adjustments or repairs. Remove all jewelry before servicing the equipment.

7.1 Generator Set Voltage Reconnection

To change the voltage of 10- or 12-lead generator sets, **use the procedure shown in the Operation Manual containing the respective controller setup.** Adjust the governor and voltage regulator for frequency changes. Consult the generator set service manual for frequency adjustment information.

Voltage reconnection. Affix a notice to the generator set after reconnecting the set to a voltage different from the voltage on the nameplate. Order voltage reconnection decal 246242 from an authorized service distributor/ dealer.

Equipment damage. Verify that the voltage ratings of the transfer switch, line circuit breakers, and other accessories match the selected line voltage.

Reconnect the generator set stator leads to change the output phase or voltage. Reference the connection schematics shown in Figure 7-1, Figure 7-2, Figure 7-3, and Figure 7-4.

Follow the safety precautions at the front of this manual and in the text and observe National Electrical Code (NEC) guidelines.

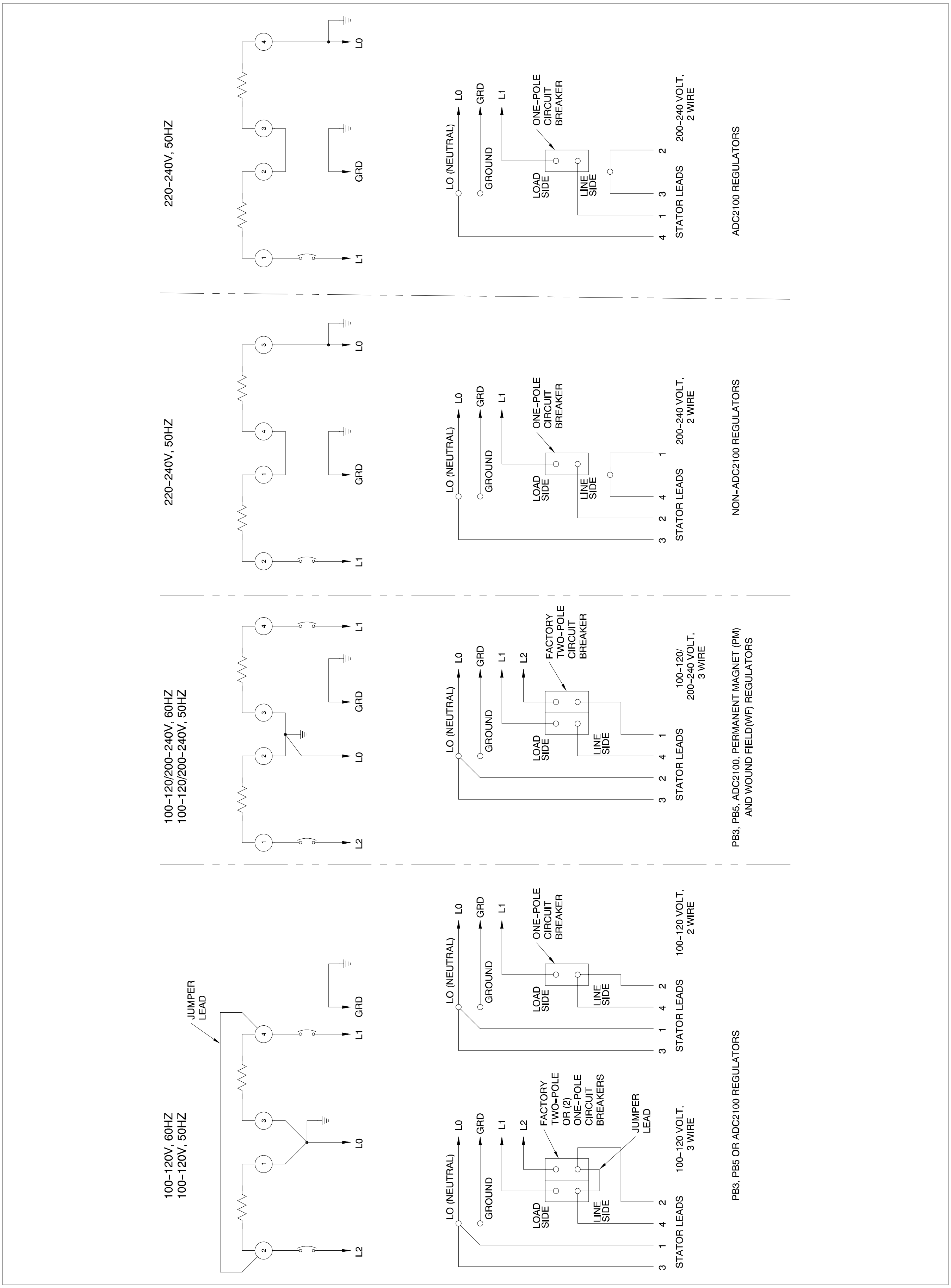


Figure 7-1 20–150 kW Permanent Magnet and Wound Field Single-Phase Alternators, ADV-5857-B

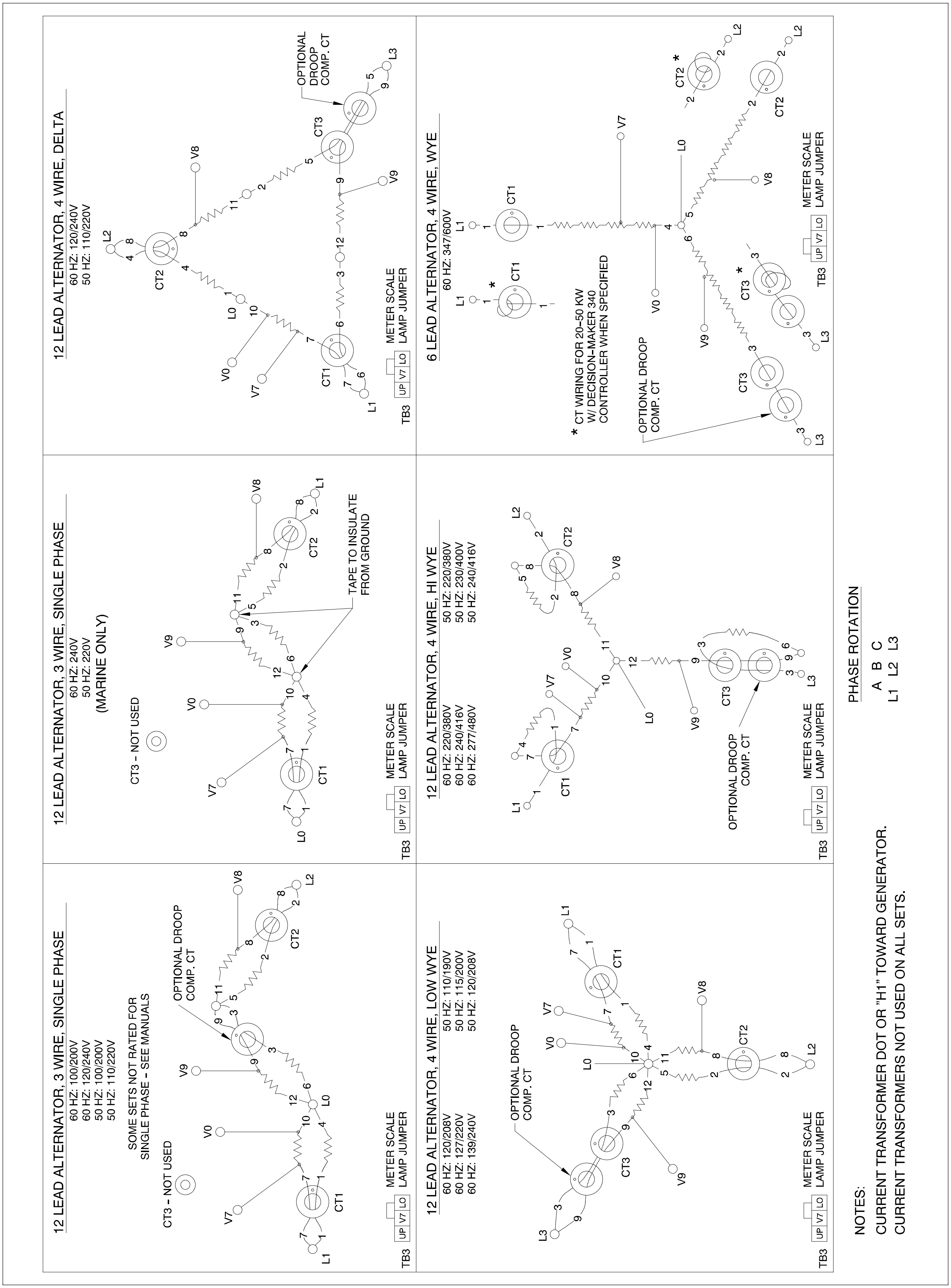


Figure 7-2 20-300 kW Permanent Magnet and 20-60 kW Wound Field Alternators, ADV-5875A-G

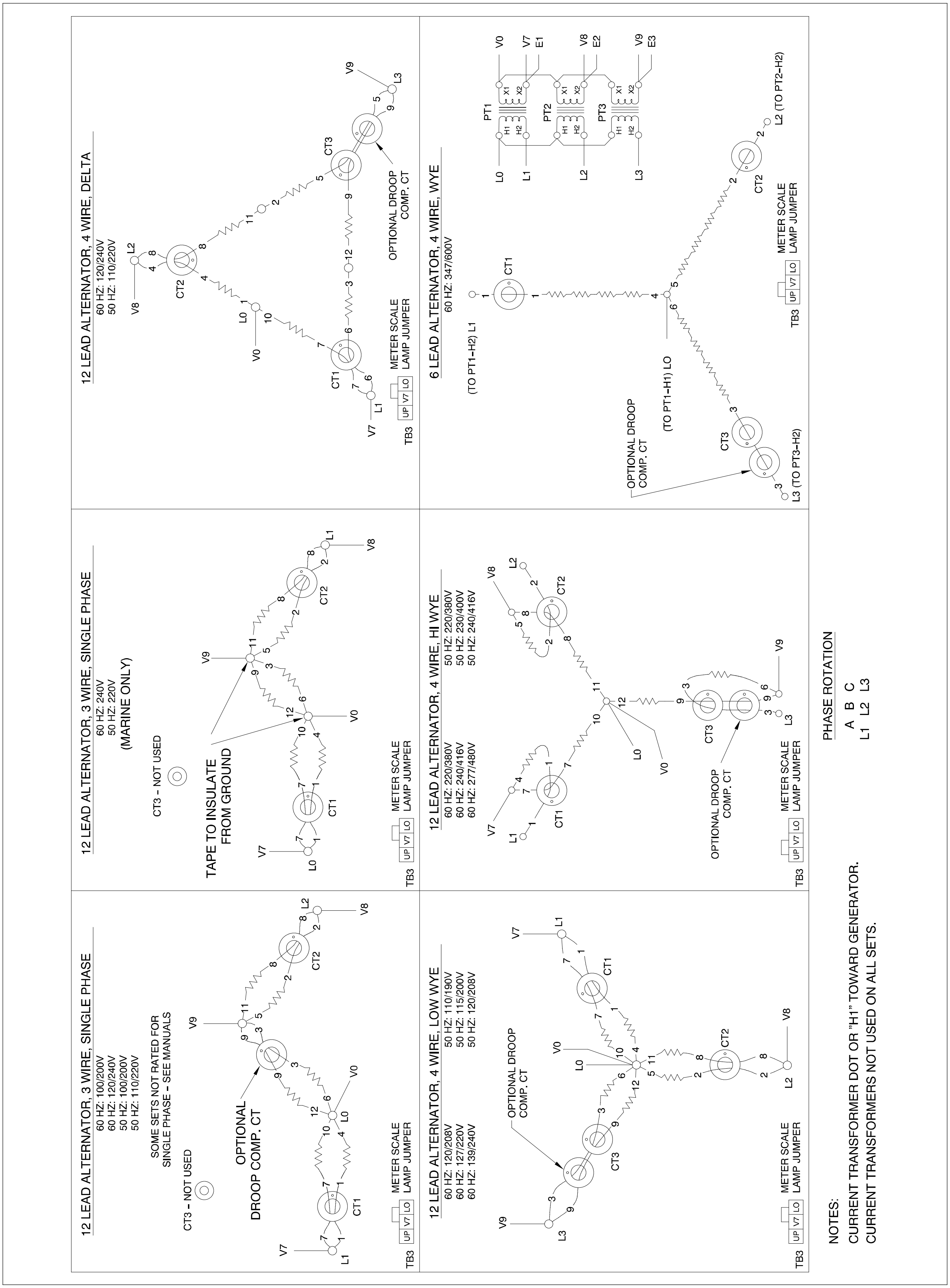


Figure 7-3 60 (with Oversize Alternator)-300 kW Wound Field Alternators, ADV-5875B-G

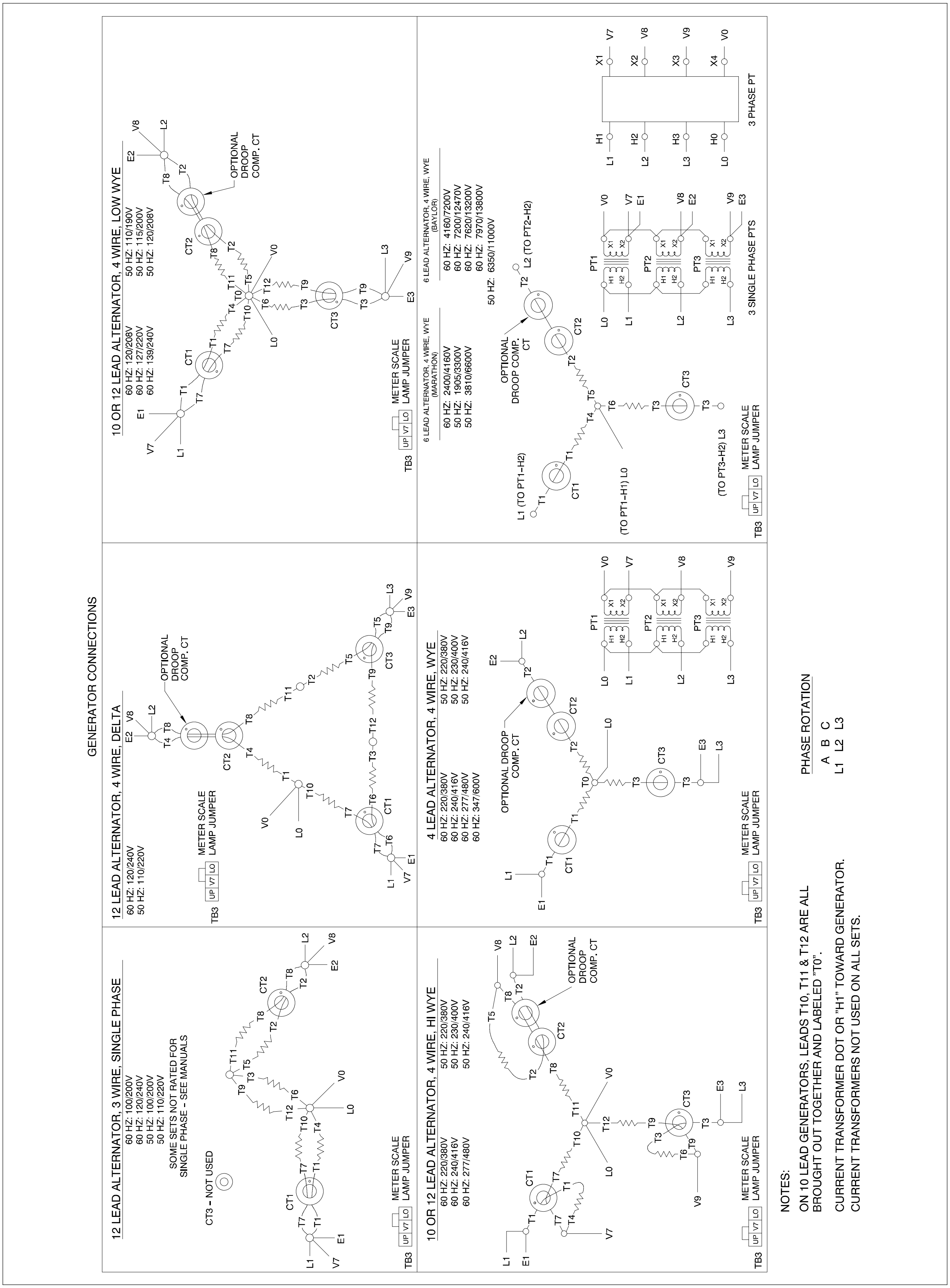


Figure 7-4 350–2800 kW Pilot-Excited, Permanent Magnet Alternator, ADV-5875C-G

7.2 Electrical Connections

Several electrical connections must be made between the generator set and other components of the system for proper operation. Because of the large number of accessories and possible combinations, this manual does not address specific applications. Refer to the submittal catalog accessory drawings and wiring diagrams for connection and location. Most field-installed accessory kits include installation instructions.

For customer-supplied wiring, select the wire temperature rating in Figure 7-5 based upon the following criteria:

- Select row 1, 2, 3, or 4 if the circuit rating is 110 amperes or less or requires #1 AWG (42.4 mm^2) or smaller conductors.
- Select row 3 or 4 if the circuit rating is greater than 110 amperes or requires #1 AWG (42.4 mm^2) or larger conductors.

Comply with applicable national and local codes when installing a wiring system.

Row	Temp. Rating	Copper (Cu) Only	Cu/Aluminum (Al) Combinations	Al Only
1	60°C (140°F) or 75°C (167°F)	Use No. * AWG, 60°C wire or use No. * AWG, 75°C wire	Use 60°C wire, either No. * AWG Cu, or No. * AWG Al or use 75°C wire, either No. * AWG Cu or No. * AWG Al	Use 60°C wire, No. * AWG or use 75°C wire, No. * AWG
2	60°C (140°F)	Use No. * AWG, 60°C wire	Use 60°C wire, either No. * AWG Cu or No. * AWG Al	Use 60°C wire, No. * AWG
3	75°C (167°F)	Use No. *† AWG, 75°C wire	Use 75°C wire, either No. *† AWG Cu or No. *† AWG Al	Use 75°C wire, No.*† AWG
4	90°C (194°F)	Use No. *† AWG, 90°C wire	Use 90°C wire, either No. *† AWG Cu or No. *† AWG Al	Use 90°C wire, No.*† AWG

* The wire size for 60°C (140°F) wire is not required to be included in the marking. If included, the wire size is based on ampacities for the wire given in Table 310-16 of the National Electrical Code®, in ANSI/NFPA 70, and on 115% of the maximum current that the circuit carries under rated conditions. The National Electrical Code® is a registered trademark of the National Fire Protection Association, Inc.

† Use the larger of the following conductors: the same size conductor as that used for the temperature test or one selected using the guidelines in the preceding footnote.

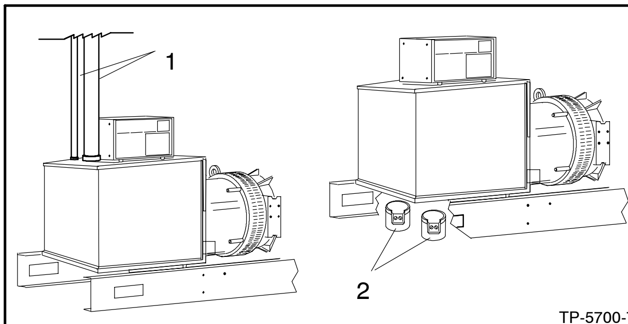
Figure 7-5 Terminal Markings for Various Temperature Ratings and Conductors

7.3 Load Lead Connections

Feed load leads to the generator junction box from one of several different areas. Generator sets rated 300 kW and below commonly use the bottom entry where conduit is stubbed up into the junction box from the concrete slab. Other methods include flexible conduit roughed into the sides or top of the junction box. When using flexible conduit, do not block the front or rear of the controller. See Figure 7-6.

Generator sets larger than 300 kW have the junction box mounted on the rear of the generator set. Larger sets may have oversized junction boxes supplied as an option or to accommodate bus bar connections. Refer to the generator set dimension drawing and/or the electrical contractor prints for detailed information including stub-up area recommendations.

The four bus bars contained in the optional bus bar kits simplify the connection process by offering a neutral bus bar in addition to the three load bars. Optional bus lugs offer an array of terminal and wire connections.



1. Conduit from ceiling
2. Conduit *stubbed up* from below

Figure 7-6 Typical Load Lead Connection

7.4 Grounding and Grounded Conductor (Neutral) Connections

Connect the electrical system grounding conductor to the equipment grounding connector on the alternator. See Figure 7-7. Depending upon code requirements, the grounded conductor (neutral) connection is typically grounded.

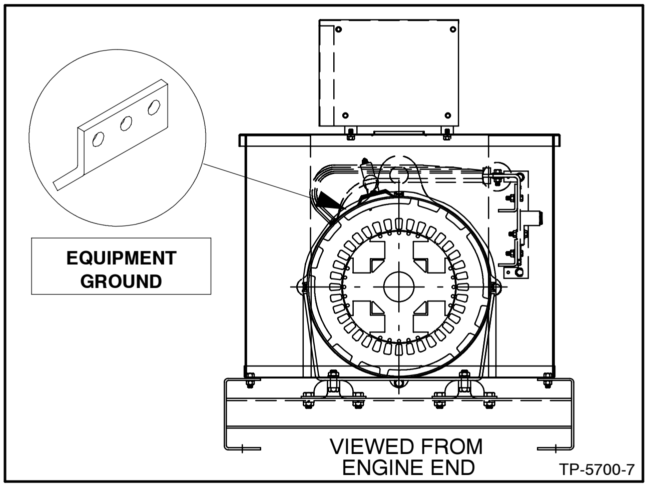


Figure 7-7 Generator Set Equipment Grounding Connection

Ungrounded neutral connections use an insulated standoff (not supplied) to isolate the neutral connection from the grounding connection. For grounding lug selection, see Figure 7-8.

The four bus bars contained in the optional bus bar kits simplify the connection process by offering a neutral bus bar in addition to the three load bars. Optional bus lugs offer an array of terminal and wire connections.

Generator sets are typically shipped from the factory with the neutral attached to the alternator in the junction box for safety reasons per NFPA 70. At installation, the neutral can remain grounded at the alternator or be lifted from the grounding stud and isolated if the installation requires an ungrounded neutral connection at the generator set. The generator set will operate properly in either configuration.

Various regulations and site configurations including the National Electrical Code® (NEC), local codes, and the type of transfer switch used in the application determine the grounding of the neutral at the generator set.

Allowable Ampacity, Amps	Min. Size of Equipment Copper Grounding Conductor, AWG or kcmil	Recommended Compression Lug, ILISCO Part No. or Equivalent (UL Listed)
20	12	SLUH-90
60	10	SLUH-90
90	8	SLUH-90/125
100	8	SLUH-90/125
150	6	SLUH-90/125/225
200	6	SLUH-90/125/225
300	4	SLUH-90/125/225
400	3	SLUH-90/125/225
500	1	SLUH-125/225
600	1	SLUH-125/225
800	1/0	SLUH-225/300/400
1000	2/0	SLUH-225/300/400
1200	3/0	SLUH-225/300/400
1600	4/0	SLUH-225/300/400/650
2000	250	SLUH-225/300/400/650
2500	350	SLUH-300/400/650
3000	400	SLUH-400/650
4000	500	SLUH-400/650
5000	700	SLUH-650
6000	800	SLUH-650

Figure 7-8 Grounding Lug Selection

7.5 Automatic Transfer Switches

A typical standby system has at least one automatic transfer switch connected to the generator set output to automatically transfer the electrical load to the generator set if the normal source fails. When normal power returns, the switch transfers the load back to the normal power source and then signals the generator set to stop.

The transfer switch uses a set of contacts to signal the engine/generator to start. When the normal source fails and the generator set master switch is in the AUTO position, the transfer switch contacts close to start the generator set.

The engine start terminals are usually located near the transfer switch contactor with an engine start decal identifying the terminals. Refer to the transfer switch decal, operation/installation manual, or wiring diagram manual to identify the engine start terminals prior to making connections.

Make connections to the transfer switch engine-start terminals and remote manual engine-start switch using wire run through conduit. Use separate conduits for engine-start leads, generator set load cables, battery charger leads, and remote annunciator wiring.

7.6 Terminal Connector Torque

Use the torque values shown in Figure 7-9 or Figure 7-10 for terminal connectors. Refer to UL 486A-486B and UL 486E for information on terminal connectors for aluminum and/or copper conductors. See Section 7.2, Electrical Connections, for information on the temperature rating of customer-supplied wire. Comply with applicable national and local codes when installing a wiring system.

If a connector has a clamp screw such as a slotted, hexagonal head screw with more than one means of tightening, test the connector using both applicable torque values provided in Figure 7-10.

Socket Size Across Flats, mm (in.)	Tightening Torque, Nm (in. lb.)
3.2 (1/8)	5.1 (45)
4.0 (5/32)	11.4 (100)
4.8 (3/16)	13.8 (120)
5.6 (7/32)	17.0 (150)
6.4 (1/4)	22.6 (200)
7.9 (5/16)	31.1 (275)
9.5 (3/8)	42.4 (375)
12.7 (1/2)	56.5 (500)
14.3 (9/16)	67.8 (600)

Note: For values of slot width or length not corresponding to those specified, select the largest torque value associated with the conductor size. Slot width is the nominal design value. Slot length is to be measured at the bottom of the slot.

Figure 7-9 Tightening Torque for Pressure Wire Connectors with Internal-Drive Socket-Head Screws

Wire Size for Unit Connection	Tightening Torque, Nm (in. lb.)			
	Slot Head 4.7 mm (No. 10) or Larger*		Hexagonal Head—External Drive Socket Wrench	
AWG, kcmil (mm^2)	Slot Width <1.2 mm (0.047 in.) Slot Length <6.4 mm (0.25 in.)	Slot Width >1.2 mm (0.047 in.) Slot Length >6.4 mm (0.25 in.)	Split-Bolt Connectors	Other Connections
18-10 (0.82-5.3)	2.3 (20)	4.0 (35)	9.0 (80)	8.5 (75)
8 (8.4)	2.8 (25)	4.5 (40)	9.0 (80)	8.5 (75)
6-4 (13.3-21.2)	4.0 (35)	5.1 (45)	18.6 (165)	12.4 (110)
3 (26.7)	4.0 (35)	5.6 (50)	31.1 (275)	16.9 (150)
2 (33.6)	4.5 (40)	5.6 (50)	31.1 (275)	16.9 (150)
1 (42.4)	—	5.6 (50)	31.1 (275)	16.9 (150)
1/0-2/0 (53.5-67.4)	—	5.6 (50)	43.5 (385)	20.3 (180)
3/0-4/0 (85.0-107.2)	—	5.6 (50)	56.5 (500)	28.2 (250)
250-350 (127-177)	—	5.6 (50)	73.4 (650)	36.7 (325)
400 (203)	—	5.6 (50)	93.2 (825)	36.7 (325)
500 (253)	—	5.6 (50)	93.2 (825)	42.4 (375)
600-750 (304-380)	—	5.6 (50)	113.0 (1000)	42.4 (375)
800-1000 (406-508)	—	5.6 (50)	124.3 (1100)	56.5 (500)
1250-2000 (635-1016)	—	—	124.3 (1100)	67.8 (600)

* For values of slot width or length not corresponding to those specified, select the largest torque value associated with the conductor size. Slot width is the nominal design value. Slot length is to be measured at the bottom of the slot.

Note: If a connector has a clamp screw such as a slotted, hexagonal head screw with more than one means of tightening, test the connector using both applicable torque values.

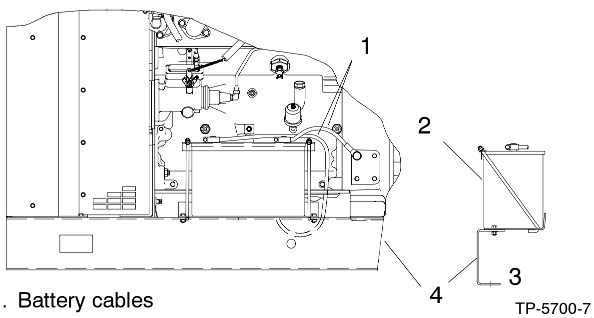
Figure 7-10 Tightening Torque for Screw-Type Pressure Wire Connectors

7.7 Batteries

Battery location. When determining battery placement, ensure that the location:

- Is clean, dry, and not exposed to extreme temperatures
- Provides easy access to battery caps for checking the electrolyte level (when using maintenance type batteries)
- Is close to the generator set to keep cables short, ensuring maximum output

Refer to the submittal drawings for the generator set when choosing a battery rack. Figure 7-11 shows a typical battery system.



1. Battery cables
2. Battery secured in mounting rack
3. End view
4. Generator set skid

Figure 7-11 Typical Battery System, Side View

Battery type. Starting batteries are usually the lead-acid type and are sized according to the engine manufacturer's recommendation for a particular ambient temperature and required cranking time. NFPA 110 recommends cranking periods, including a single 45-second cycle for generator sets below 15 kW and three 15-second crank cycles separated by 15-second rests for larger models. Refer to the respective generator set specification sheet for the required battery cold-cranking ampere (CCA) rating.

Nickel-cadmium batteries are sometimes used for standby generator sets because of their long life (20 years). However, initial high cost, larger space requirements, and special charging requirements can offset this benefit. Therefore, conventional lead-acid batteries have proven satisfactory for the majority of generator set applications.

Battery cables. A UL 2200 listed generator set requires battery cables with positive (+) lead boots. Factory-supplied and optional battery cables include positive (+) lead boots. When battery cables are not factory-supplied, source battery cables with positive (+) lead boots for UL 2200 compliance.

7.8 Battery Chargers

Engine-driven, battery-charging alternators charge the batteries whenever the generator set operates. Engine-driven systems are normally capable of charge rates of 30 amps or more and can quickly restore the charge used in a normal cranking cycle.

When the engine is not operating, a very low charge rate from an AC-powered battery charger is usually sufficient to maintain a full charge on the batteries. Some small industrial generator sets have no battery-charging alternators and, therefore, require a separate AC-powered battery charger.

Select an automatic or manual battery charger with a high charge rate of 2 amps and a trickle charge rate up to 300 milliamps. The low maximum charge rate makes the charger ill-suited to restore fully discharged batteries. For full recovery capability independent of the engine-driven charging system, use an automatic float battery charger with a high charge rate of at least 10 amps.

Use separate, self-contained battery chargers or units built into the automatic transfer switch. Run leads from a transfer switch-mounted battery charger in conduit separate from the conduit that holds the generator load cables or remote engine-start circuits.

Note: Digital controllers with microprocessor circuitry and vacuum fluorescent displays typically draw more than 300 milliamps, making trickle charge battery chargers inappropriate for systems with these controllers. Select only automatic float/equalize battery chargers with a 3 amp or greater rating for units with digital controllers.

Battery failure is the most common reason for emergency generator set start failure. Two common battery failure causes are a manual charge rate set too low to maintain the battery and a manual charge rate set too high, resulting in loss of battery electrolyte. To avoid battery failure, use an automatic float charger, which varies the charge rate in response to battery condition.

For large engines with two starters, use either one bank of batteries and chargers for both starters or use separate battery systems. The latter system is preferable because it reduces the chance of a single component failure rendering the entire system inoperative.

7.9 Optional Accessories

The generator set manufacturer offers optional accessories that require connection to other components in the system. These accessories enable the generator set to meet standards for local and national codes, make operation and service more convenient, or satisfy specific customer installation requirements.

Accessories vary with each generator set model and controller. Accessories are available factory-installed and/or shipped loose. Some accessories are available only with the microprocessor and digital controllers. Obtain the most current list of accessories from the respective generator set specification sheet or by contacting your local authorized service distributor/ dealer. The following sections detail a few common accessories and their functions.

Accessory kits generally include installation instructions. See the wiring diagrams manual for electrical connections not shown in this section. See the installation instructions and drawings supplied with the kit for information on the kit mounting location.

The instructions provided with the accessory kit supersede these instructions, if different. In general, run AC and DC wiring in separate conduit. Use shielded cable for all analog inputs. Observe all applicable national and local electrical codes during accessory installation.

Accessory wiring. To determine the appropriate size for the customer-supplied wiring of the engine battery-powered accessories, use the guidelines in Figure 7-12.

Use 18–20 gauge wire for *signal wires* up to 305 m (1000 ft.).

Length, m (ft.)	Wire Gauge
30.5 (100)	18–20
152.4 (500)	14
304.8 (1000)	10

Figure 7-12 Wire Length and Size, Lead N and 42B

Match the wire terminals to the terminal strip conductor screw size. Use a maximum of two wire terminals per terminal strip screw unless otherwise noted on the respective accessory drawing or installation instruction.

Accessory connections. Do not direct-connect accessories to the controller terminal strip. Connect accessories to either a single-relay dry contact kit or ten-relay dry contact kit. Connect the dry contact kit(s) to the controller (customer) connection kit. Connect all accessories except the emergency stop kit to the connection kit terminal strip(s).

Terminal strips and available connections vary by controller. Refer to the respective controller operation manual and the accessory wiring diagrams in the wiring diagram manual for connection of kits. Field-installed accessories include installation instructions and/or wiring diagrams.

7.9.1 Audiovisual Alarm

An audiovisual alarm warns the operator at a remote location of fault shutdowns and prealarm conditions (except battery charger fault and low battery voltage) at the generator set. Audiovisual alarms include an alarm horn, an alarm silence switch, and a common fault lamp. See Figure 7-13.

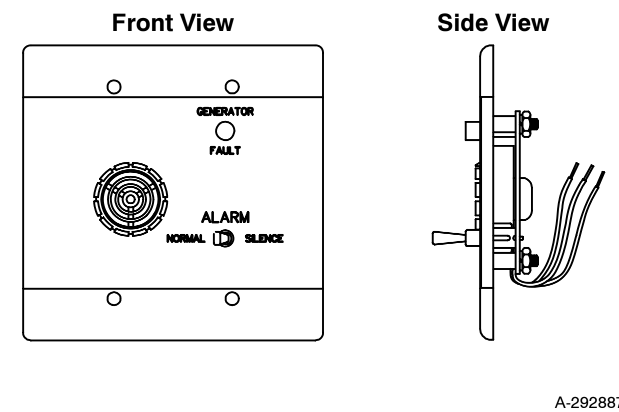


Figure 7-13 Audiovisual Alarm

7.9.2 Bus Bar Kits/Bus Lugs

The four bus bars contained in the optional bus bar kits simplify the connection process by offering a neutral bus bar in addition to the three load bars. Optional bus lugs offer an array of terminal and wire connections. See Figure 7-14.

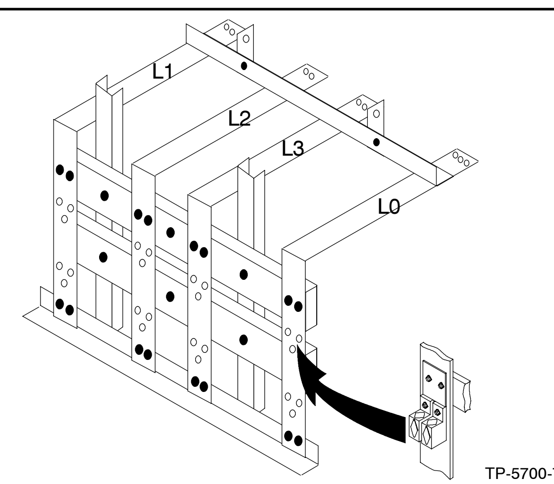


Figure 7-14 Bus Bar Kits/Bus Lugs

7.9.3 Common Failure Relay Kit

The common failure relay kit provides one set of contacts to trigger customer-provided warning devices if a fault occurs. The user defines common failure relay faults. Connect up to three defined common fault relay kits to the controller output. See Figure 7-15.

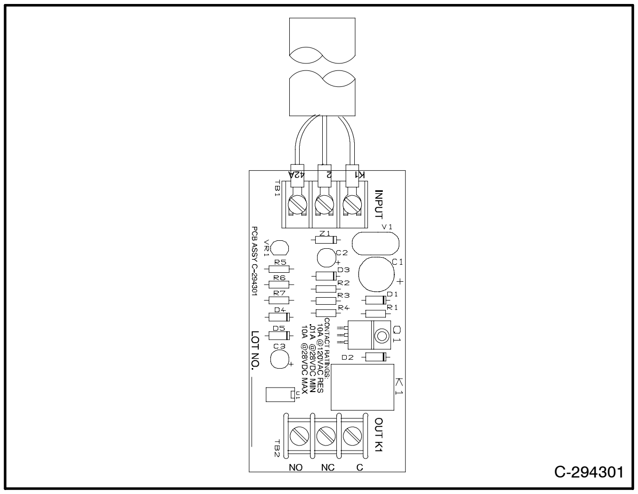


Figure 7-15 Common Failure Relay Kit

7.9.4 Controller (Customer) Connection Kit

The controller connection kit allows easy connection of controller accessories without accessing the controller terminal strip. The kit uses a wiring harness to link the controller terminal strip(s) with a remote terminal strip. With the exception of a few terminals, the remote terminal strip has connections similar to the controller. Connect all accessories except the emergency stop kit to the connection kit terminal strip(s).

7.9.5 Float/Equalize Battery Charger Kit with Alarm Option

The float/equalize battery charger with alarm option charges the engine start battery(ies) and connects to the controller for fault detection. Your distributor/dealer offers battery chargers for 12- or 24-volt models. See Figure 7-16.

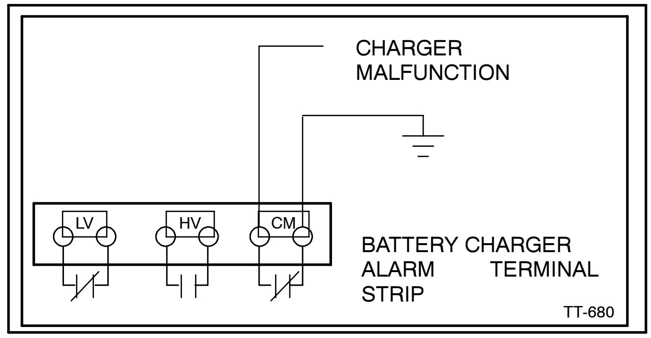


Figure 7-16 Float/Equalize Battery Charger Connections

7.9.6 Line Circuit Breaker

The line circuit breaker interrupts generator output if an overload or short circuit occurs. Use the line circuit breaker to manually disconnect the generator set from the load during generator set service. See Figure 7-17.

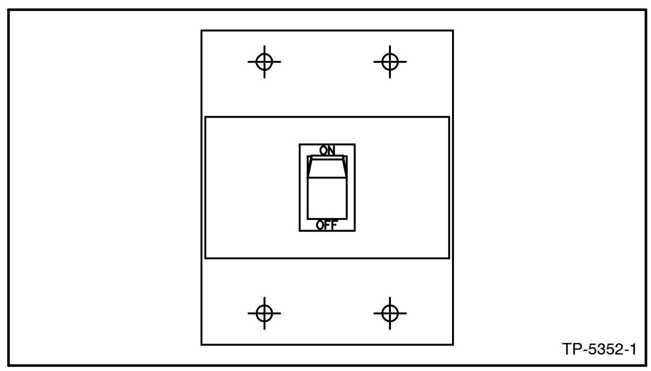


Figure 7-17 Line Circuit Breaker

The circuit breaker must open all ungrounded connectors. Refer to Service Bulletin 611 for circuit breaker instantaneous overcurrent trip adjustment information.

7.9.7 Low Fuel (Level or Pressure) Switch

Some gaseous-fueled models offer a low fuel pressure switch. The low fuel pressure switch connects to the same terminal as the low fuel *level* switch on diesel- or gasoline-fueled models. See Figure 7-18.

Note: The main tank or the transfer/day tank includes the low fuel level switch. The fuel tank supplier typically provides the low fuel level switch.

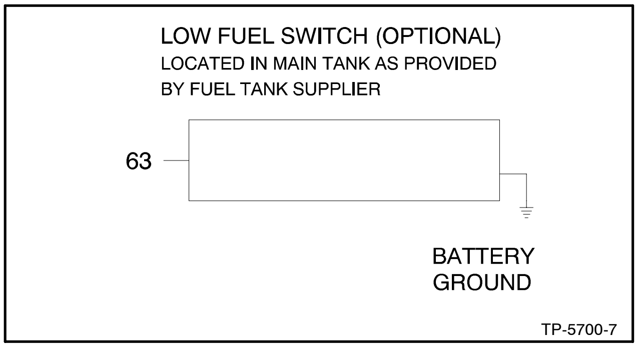


Figure 7-18 Low Fuel Switch (level or pressure)

7.9.8 Remote Annunciator Kit

A remote annunciator allows convenient monitoring of the generator set's condition from a remote location. See Figure 7-19.

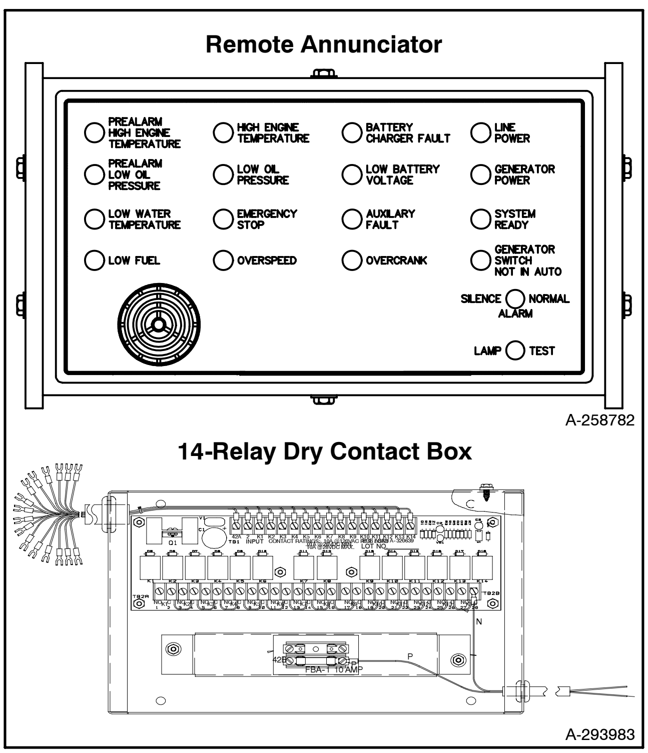


Figure 7-19 Remote Annunciator with 14-Relay Dry Contact Kit

The remote annunciator includes an alarm horn, an alarm silence switch, a lamp test, and the same lamp indicators (except air damper and auxiliary prealarm/high battery voltage) as the microprocessor controller, plus the following:

- **Line power.** Lamp illuminates to indicate that the power source is a commercial utility.
- **Generator set power.** Lamp illuminates to indicate that the power source is the generator set.

7.9.9 Remote Serial Annunciator (RSA)

The remote serial annunciator (RSA 1000) (Figure 7-20) monitors the condition of the generator set from a location remote from the generator set using RS 485 connection. If a generator alarm condition occurs, the remote annunciator alerts the operator through visual and audible signals.

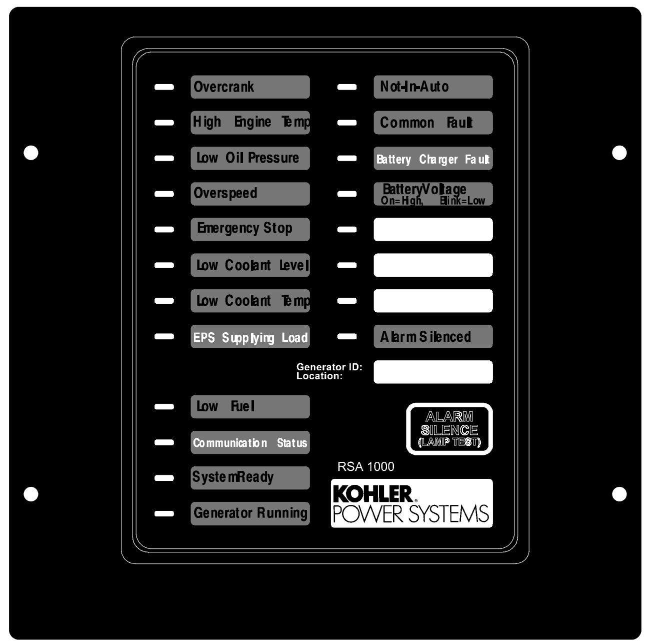


Figure 7-20 Remote Serial Annunciator (RSA 1000)

The remote serial annunciator kit includes components for flush and surface mounting. One RSA (master) can support up to a maximum of three additional RSAs (slaves). The RSA will function as master or slave by changing the DIP switch position on the RSA board. If a generator set fault occurs, the RSA 1000 horn activates and the corresponding LED illuminates.

Figure 7-21 shows the status of the system ready LED, generator running LED, communication status LED, common fault LED, common fault output, and horn for each fault or status condition. See Figure 7-22, Figure 7-23, and Figure 7-24 for RSA wiring connections.

The RSA requires connection to the controller Modbus® RS-485 port. If the RS-485 port is needed for switchgear monitoring or a wireless monitor, the RSA cannot be connected to the controller. If the RS-485 port is unavailable, please select an alternate annunciator kit.

Fault and Status Condition	Fault LEDs	System Monitoring LEDs and Functions					
		System Ready LED	Generator Running LED	Comm. Status LED	Common Fault LED	Common Fault Output	Horn
Overcrank Shutdown	Red	Red SF	Off	Green	Off	On	On
High Engine Temperature Warning	Yellow	Red SF	Green	Green	Off	On	On
High Engine Temperature Shutdown	Red	Red SF	Off	Green	Off	On	On
Low Oil Pressure Warning	Yellow	Red SF	Green	Green	Off	On	On
Low Oil Pressure Shutdown	Red	Red SF	Off	Green	Off	On	On
Overspeed Shutdown	Red	Red SF	Off	Green	Off	On	On
Emergency Stop	Red	Red SF	Off	Green	Off	On	On
Low Coolant Level	Red	Red SF	Off	Green	Off	On	On
Low Coolant Temperature	Yellow	Red SF	Off	Green	Off	On	On
Low Fuel—Level or Pressure *	Yellow	Red SF	Green	Green	Off	On	On
EPS Supplying Load (550 Controller)	Yellow	Green	Green	Green	Off	Off	Off
EPS Supplying Load (RSA)	Yellow	Green	Green or Off	Green	Off	Off	Off
System Ready	Green	Green	Green or Off	Green	Off	Off	Off
System Not Ready	Red	Red SF	Green or Off	Green	Off	On	On
No Device at Powerup	Red	Off	Off	Red SF	Off	On	On
Loss of Controller Comm. (Master RSA)	Red	Off	Off	Red FF	Off	On	On
Loss of Controller Comm. (Slave RSA)	Red	Off	Off	Red SF	Off	On	On
Not-In-Auto	Red	Red SF	Green or Off	Green	Off	On	On
Battery Charger Fault *	Yellow	Red SF	Green or Off	Green	Off	On	On
High Battery Voltage	Yellow	Green	Green or Off	Green	Off	Off	Off
Low Battery Voltage	Yellow	Green	Green or Off	Green	Off	Off	Off
User Input #1 (RSA)	Red	Green	Green or Off	Green	Off	On	On
User Input #2 (RSA)	Red	Green	Green or Off	Green	Off	On	On
User Input #1 (550 Controller)	Red	Red SF	Green or Off	Green	Off	On	On
User Input #2 (550 Controller)	Red	Red SF	Green or Off	Green	Off	On	On
User Input #3 (550 Controller)	Red	Red SF	Green or Off	Green	Off	On	On
Common Fault	Red	Green	Green or Off	Green	Red SF	On	On

SF = Slow Flash, FF = Fast Flash
* May require optional kit or user-provided device to enable function and LED indication.

Figure 7-21 System Monitoring LEDs and Functions

Modbus® is a registered trademark of Schneider Electric.

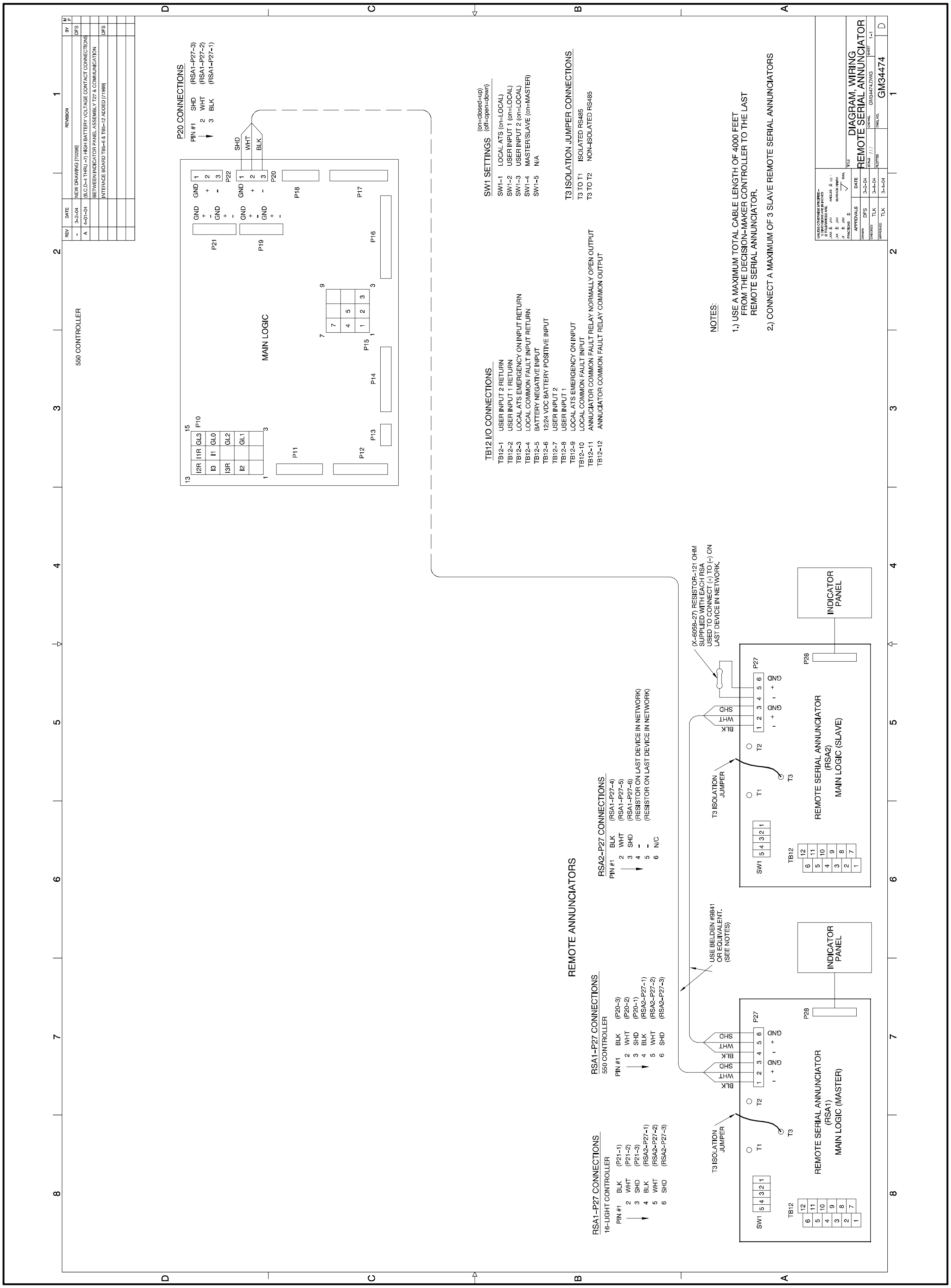


Figure 7-22 RSA Wiring Connections

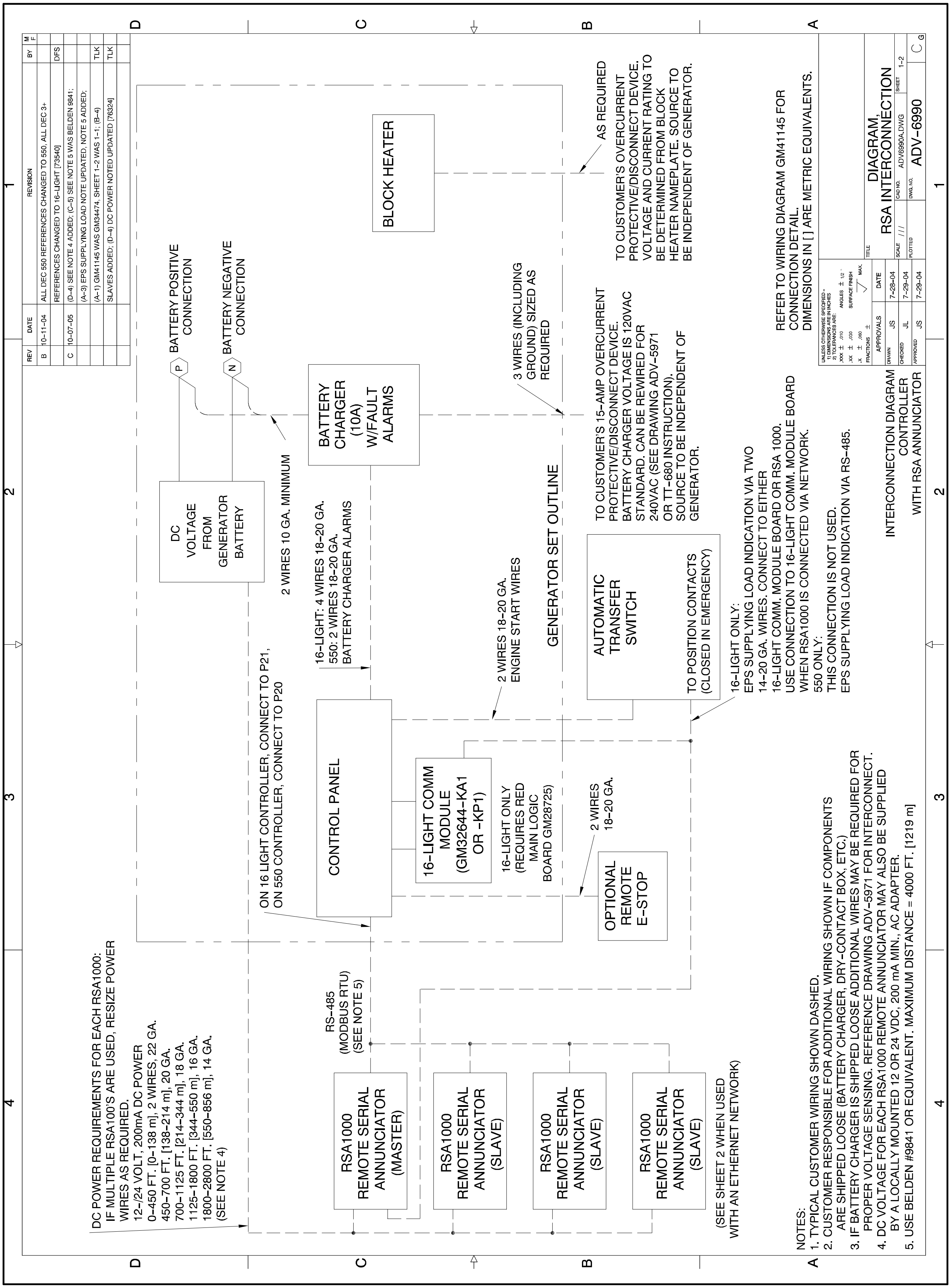


Figure 7-23 RSA Interconnection Diagram ADV-6990A-C

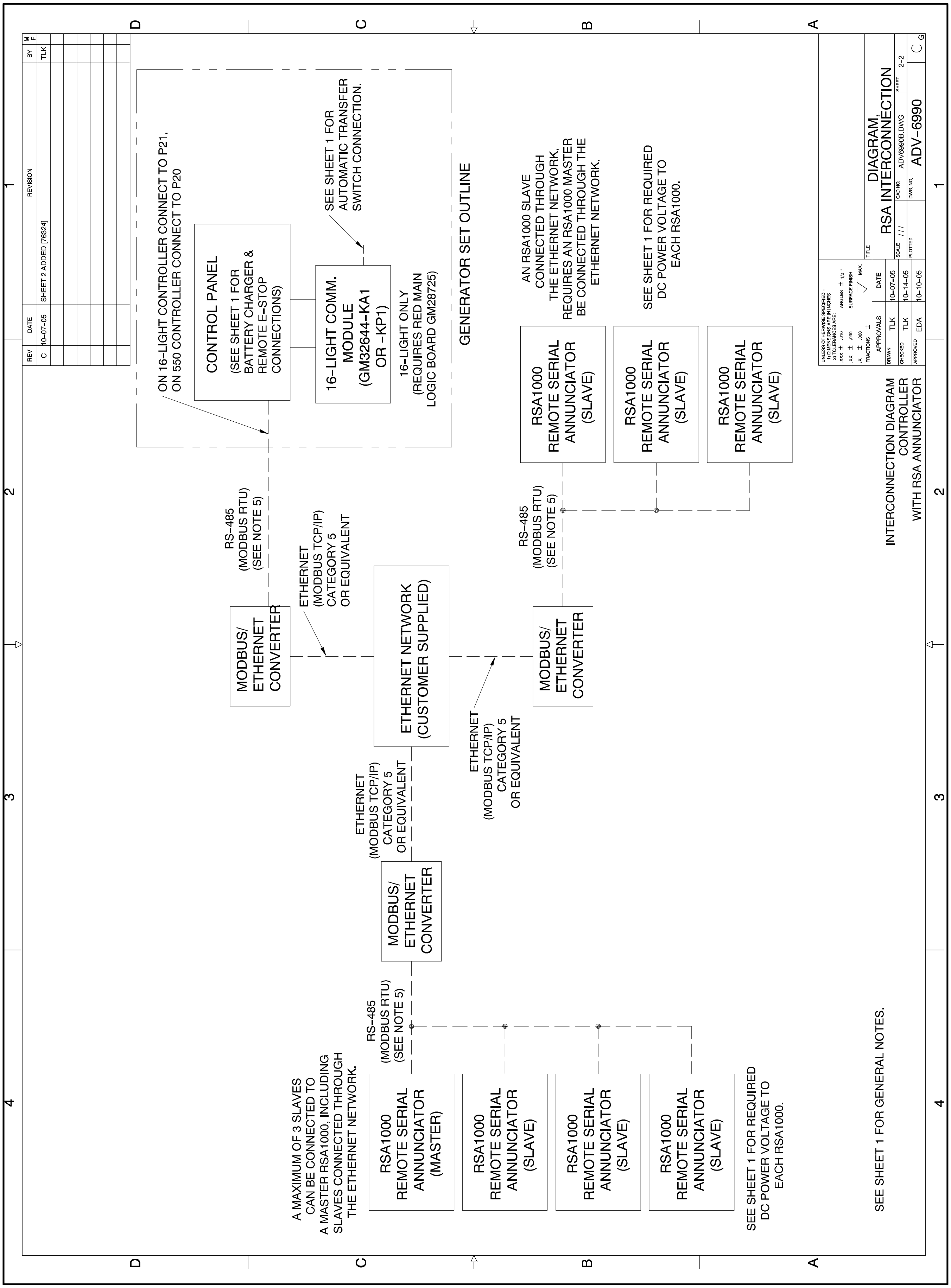


Figure 7-24 RSA Interconnection Diagram ADV-6990B-C

7.9.10 Remote Emergency Stop Kit

Figure 7-25 shows the remote emergency stop switch. Activating the emergency stop switch in the remote emergency stop kit lights the controller lamp and shuts down the unit. Before restarting the generator set, reset the emergency stop switch by replacing the glass piece and reset the generator set by placing the master switch in the OFF/RESET position. The switch holds a single replacement glass piece. Order additional replacement glass as a service part.

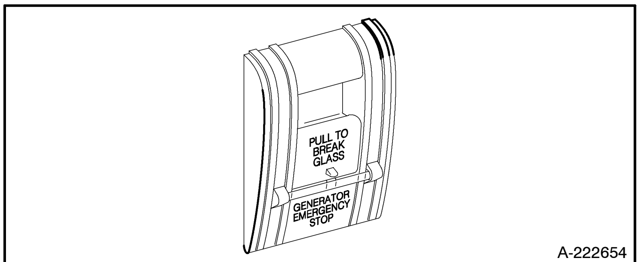


Figure 7-25 Emergency Stop Kit

7.9.11 Run Relay Kit

The run relay kit energizes only during generator set operation. The three sets of contacts typically control air intake and/or radiator louvers. However, alarms and other signaling devices can also connect to the contacts. See Figure 7-26.

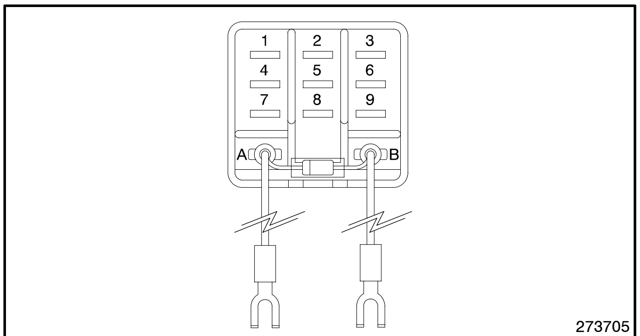


Figure 7-26 Run Relay Kit

7.9.12 Safeguard Breaker

The safeguard breaker senses output current on each generator phase and shuts off the AC voltage regulator if a sustained overload or short circuit occurs. It is not a line circuit breaker and does not disconnect the generator from the load. See Figure 7-27.

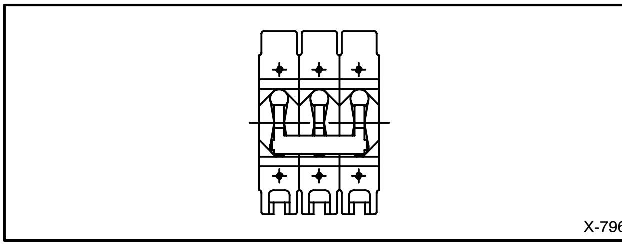


Figure 7-27 Safeguard Breaker

7.9.13 Single-Relay Dry Contact Kit

The single-relay dry contact kit has a common fault relay that uses one set of contacts to trigger customer-provided warning devices if a fault condition occurs. Any controller fault output can connect to the single-relay kit. The kit typically signals the following common fault conditions:

- Emergency stop
- High coolant temperature
- Low oil pressure
- Overcrank
- Overspeed
- Low oil pressure
- High engine temperature

A total of three dry contact kits may connect to a single controller output. Figure 7-28 shows the single-relay dry contact kit.

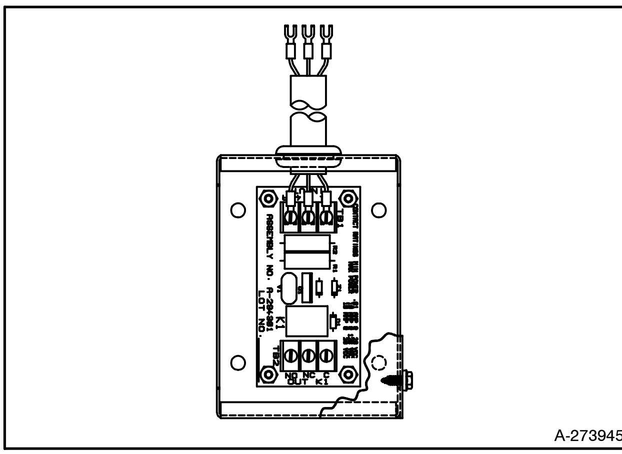


Figure 7-28 Single-Relay Dry Contact Kit

7.9.14 Ten-Relay Dry Contact Kit

The ten-relay dry contact kit allows monitoring of the generator set and/or activating accessories. The kit includes ten sets of relay contacts for connecting customer-provided devices to desired generator set functions. A total of three dry contact kits may connect to a single output on the controller. Refer to Figure 7-29 for an internal view of the contact kit.

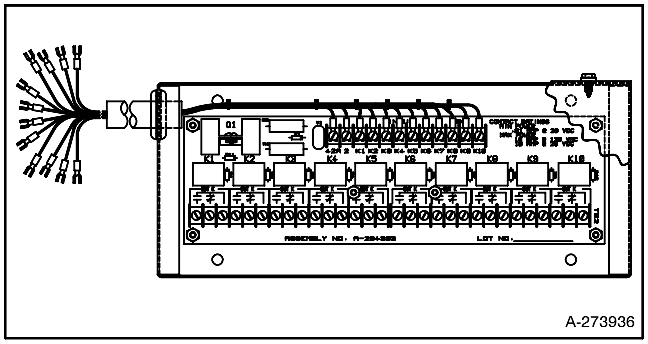


Figure 7-29 Ten-Relay Dry Contact Kit

Warning devices (lamp and/or audible alarms) and other accessories typically connect to the following controller outputs:

- Overspeed
- Overcrank
- High engine temperature
- Low oil pressure
- Low water temperature
- Auxiliary fault
- Air damper, if equipped
- Anticipatory high engine temperature
- Anticipatory low oil pressure
- Emergency stop

7.10 Wiring Connections

Although equipment and connections vary, Figure 7-30 shows examples of the options and wire connections necessary to make an industrial system operational. Always refer to the wiring diagram for details of wire size, location, and number.

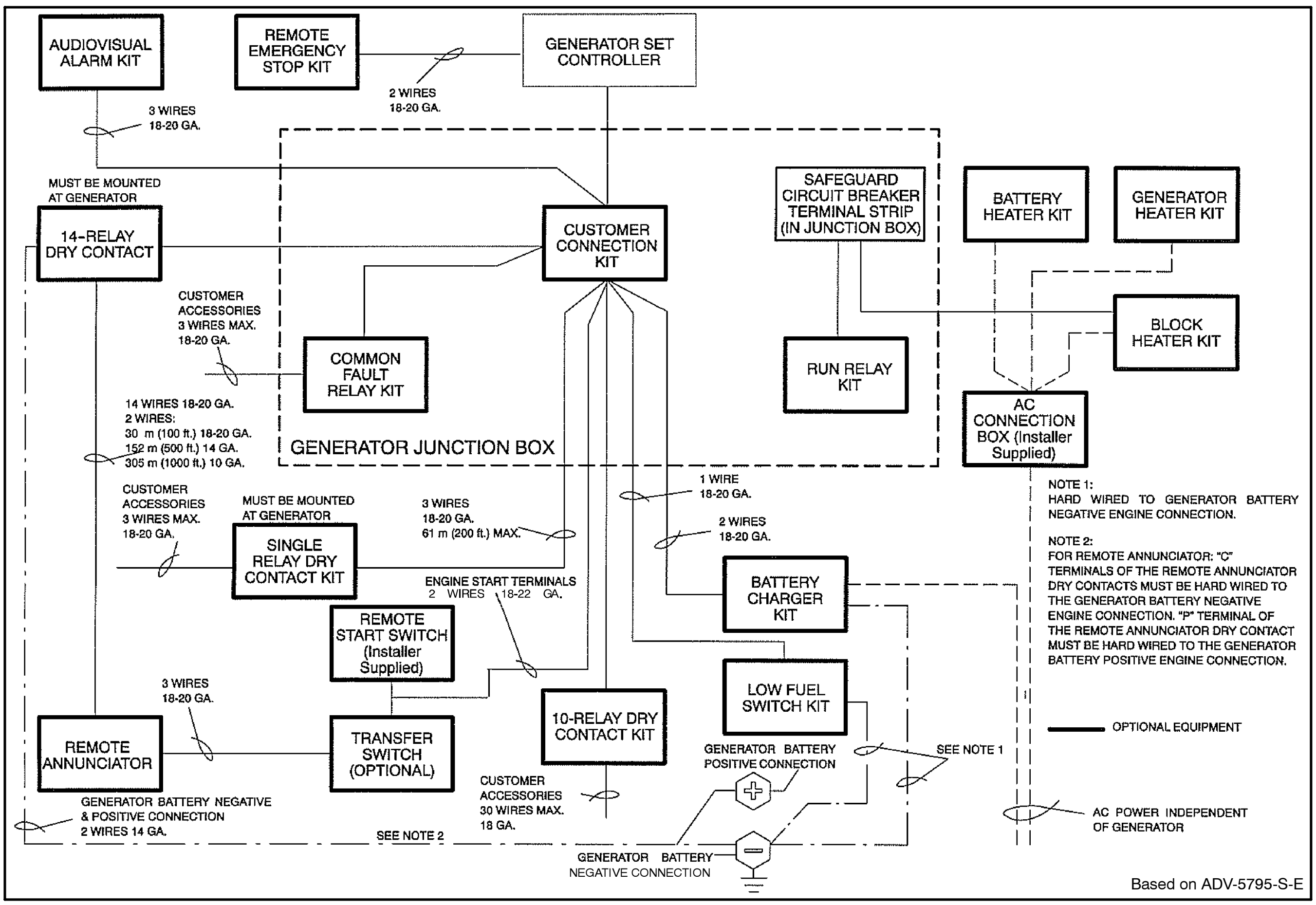


Figure 7-30 Generator Set Connections, Typical

Appendix A Abbreviations

The following list contains abbreviations that may appear in this publication.

A, amp	ampere
ABDC	after bottom dead center
AC	alternating current
A/D	analog to digital
ADC	analog to digital converter
adj.	adjust, adjustment
ADV	advertising dimensional drawing
AHWT	anticipatory high water temperature
AISI	American Iron and Steel Institute
ALOP	anticipatory low oil pressure
alt.	alternator
Al	aluminum
ANSI	American National Standards Institute (formerly American Standards Association, ASA)
AO	anticipatory only
API	American Petroleum Institute
approx.	approximate, approximately
AR	as required, as requested
AS	as supplied, as stated, as suggested
ASE	American Society of Engineers
ASME	American Society of Mechanical Engineers
assy.	assembly
ASTM	American Society for Testing Materials
ATDC	after top dead center
ATS	automatic transfer switch
auto.	automatic
aux.	auxiliary
A/V	audiovisual
avg.	average
AVR	automatic voltage regulator
AWG	American Wire Gauge
AWM	appliance wiring material
bat.	battery
BBDC	before bottom dead center
BC	battery charger, battery charging
BCA	battery charging alternator
BCI	Battery Council International
BDC	before dead center
BHP	brake horsepower
blk.	black (paint color), block (engine)
blk. htr.	block heater
BMEP	brake mean effective pressure
bps	bits per second
br.	brass
BTDC	before top dead center
Btu	British thermal unit
Btu/min.	British thermal units per minute
C	Celsius, centigrade
cal.	calorie
CARB	California Air Resources Board
CB	circuit breaker
cc	cubic centimeter
CCA	cold cranking amps
ccw.	counterclockwise
CEC	Canadian Electrical Code
cert.	certificate, certification, certified
cfh	cubic feet per hour
cfm	cubic feet per minute
CG	center of gravity
CID	cubic inch displacement
CL	centerline
cm	centimeter
CMOS	complementary metal oxide substrate (semiconductor)
cogen.	cogeneration
com	communications (port)
coml	commercial
Coml/Rec	Commercial/Recreational
conn.	connection
cont.	continued
CPVC	chlorinated polyvinyl chloride
crit.	critical
CRT	cathode ray tube
CSA	Canadian Standards Association
CT	current transformer
Cu	copper
cu. in.	cubic inch
cw.	clockwise
CWC	city water-cooled
cyl.	cylinder
D/A	digital to analog
DAC	digital to analog converter
dB	decibel
dBA	decibel (A weighted)
DC	direct current
DCR	direct current resistance
deg., °	degree
dept.	department
dia.	diameter
DI/EO	dual inlet/end outlet
DIN	Deutsches Institut fur Normung e. V. (also Deutsche Industrie Normenausschuss)
DIP	dual inline package
DPDT	double-pole, double-throw
DPST	double-pole, single-throw
DS	disconnect switch
DVR	digital voltage regulator
E, emer.	emergency (power source)
EDI	electronic data interchange
EFR	emergency frequency relay
e.g.	for example *(exempli gratia)*
EG	electronic governor
EGSA	Electrical Generating Systems Association
EIA	Electronic Industries Association
EI/EO	end inlet/end outlet
EMI	electromagnetic interference
emiss.	emission
eng.	engine
EPA	Environmental Protection Agency
EPS	emergency power system
ER	emergency relay
ES	engineering special, engineered special
ESD	electrostatic discharge
est.	estimated
E-Stop	emergency stop
etc.	et cetera (and so forth)
exh.	exhaust
ext.	external
F	Fahrenheit, female
fglass.	fiberglass
FHM	flat head machine (screw)
fl. oz.	fluid ounce
flex.	flexible
freq.	frequency
FS	full scale
ft.	foot, feet
ft. lb.	foot pounds (torque)
ft./min.	feet per minute
g	gram
ga.	gauge (meters, wire size)
gal.	gallon
gen.	generator
genset	generator set
GFI	ground fault interrupter
GND, ⏚	ground
gov.	governor
gph	gallons per hour
gpm	gallons per minute
gr.	grade, gross
GRD	equipment ground
gr. wt.	gross weight
H x W x D	height by width by depth
HC	hex cap
HCHT	high cylinder head temperature
HD	heavy duty
HET	high exhaust temperature, high engine temperature
hex	hexagon
Hg	mercury (element)
HH	hex head
HHC	hex head cap
HP	horsepower
hr.	hour
HS	heat shrink
hsg.	housing
HVAC	heating, ventilation, and air conditioning
HWT	high water temperature
Hz	hertz (cycles per second)
IC	integrated circuit
ID	inside diameter, identification
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IMS	improved motor starting
in.	inch
in. H_2O	inches of water
in. Hg	inches of mercury
in. lb.	inch pounds
Inc.	incorporated
ind.	industrial
int.	internal
int./ext.	internal/external
I/O	input/output
IP	iron pipe
ISO	International Organization for Standardization
J	joule
JIS	Japanese Industry Standard
k	kilo (1000)
K	kelvin

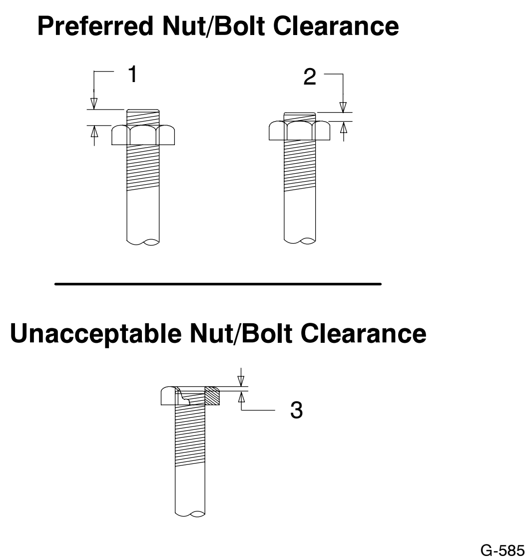
kA	kiloampere
KB	kilobyte (2^{10} bytes)
kg	kilogram
kg/cm^2	kilograms per square centimeter
kgm	kilogram-meter
kg/m^3	kilograms per cubic meter
kHz	kilohertz
kJ	kilojoule
km	kilometer
kOhm, kΩ	kilo-ohm
kPa	kilopascal
kph	kilometers per hour
kV	kilovolt
kVA	kilovolt ampere
kVAR	kilovolt ampere reactive
kW	kilowatt
kWh	kilowatt-hour
kWm	kilowatt mechanical
L	liter
LAN	local area network
L x W x H	length by width by height
lb.	pound, pounds
lbm/ft^3	pounds mass per cubic feet
LCB	line circuit breaker
LCD	liquid crystal display
ld. shd.	load shed
LED	light emitting diode
Lph	liters per hour
Lpm	liters per minute
LOP	low oil pressure
LP	liquefied petroleum
LPG	liquefied petroleum gas
LS	left side
L_{wa}	sound power level, A weighted
LWL	low water level
LWT	low water temperature
m	meter, milli (1/1000)
M	mega (10^6 when used with SI units), male
m^3	cubic meter
m^3/min.	cubic meters per minute
mA	milliampere
man.	manual
max.	maximum
MB	megabyte (2^{20} bytes)
MCM	one thousand circular mils
MCCB	molded-case circuit breaker
meggar	megohmmeter
MHz	megahertz
mi.	mile
mil	one one-thousandth of an inch
min.	minimum, minute
misc.	miscellaneous
MJ	megajoule
mJ	millijoule
mm	millimeter
mOhm, mΩ	milliohm
MOhm, MΩ	megohm
MOV	metal oxide varistor
MPa	megapascal
mpg	miles per gallon
mph	miles per hour
MS	military standard
m/sec.	meters per second
MTBF	mean time between failure
MTBO	mean time between overhauls
mtg.	mounting
MW	megawatt
mW	milliwatt
µF	microfarad
N, norm.	normal (power source)
NA	not available, not applicable
nat. gas	natural gas
NBS	National Bureau of Standards
NC	normally closed
NEC	National Electrical Code
NEMA	National Electrical Manufacturers Association
NFPA	National Fire Protection Association
Nm	newton meter
NO	normally open
no., nos.	number, numbers
NPS	National Pipe, Straight
NPSC	National Pipe, Straight-coupling
NPT	National Standard taper pipe thread per general use
NPTF	National Pipe, Taper-Fine
NR	not required, normal relay
ns	nanosecond
OC	overcrank
OD	outside diameter
OEM	original equipment manufacturer
OF	overfrequency
opt.	option, optional
OS	oversize, overspeed
OSHA	Occupational Safety and Health Administration
OV	overvoltage
oz.	ounce
p., pp.	page, pages
PC	personal computer
PCB	printed circuit board
pF	picofarad
PF	power factor
ph., ∅	phase
PHC	Phillips head crimptite (screw)
PHH	Phillips hex head (screw)
PHM	pan head machine (screw)
PLC	programmable logic control
PMG	permanent-magnet generator
pot	potentiometer, potential
ppm	parts per million
PROM	programmable read-only memory
psi	pounds per square inch
pt.	pint
PTC	positive temperature coefficient
PTO	power takeoff
PVC	polyvinyl chloride
qt.	quart, quarts
qty.	quantity
R	replacement (emergency) power source
rad.	radiator, radius
RAM	random access memory
RDO	relay driver output
ref.	reference
rem.	remote
Res/Coml	Residential/Commercial
RFI	radio frequency interference
RH	round head
RHM	round head machine (screw)
rly.	relay
rms	root mean square
rnd.	round
ROM	read only memory
rot.	rotate, rotating
rpm	revolutions per minute
RS	right side
RTV	room temperature vulcanization
SAE	Society of Automotive Engineers
scfm	standard cubic feet per minute
SCR	silicon controlled rectifier
s, sec.	second
SI	*Systeme international d'unites,* International System of Units
SI/EO	side in/end out
sil.	silencer
SN	serial number
SPDT	single-pole, double-throw
SPST	single-pole, single-throw
spec, specs	specification(s)
sq.	square
sq. cm	square centimeter
sq. in.	square inch
SS	stainless steel
std.	standard
stl.	steel
tach.	tachometer
TD	time delay
TDC	top dead center
TDEC	time delay engine cooldown
TDEN	time delay emergency to normal
TDES	time delay engine start
TDNE	time delay normal to emergency
TDOE	time delay off to emergency
TDON	time delay off to normal
temp.	temperature
term.	terminal
TIF	telephone influence factor
TIR	total indicator reading
tol.	tolerance
turbo.	turbocharger
typ.	typical (same in multiple locations)
UF	underfrequency
UHF	ultrahigh frequency
UL	Underwriter's Laboratories, Inc.
UNC	unified coarse thread (was NC)
UNF	unified fine thread (was NF)
univ.	universal
US	undersize, underspeed
UV	ultraviolet, undervoltage
V	volt
VAC	volts alternating current
VAR	voltampere reactive
VDC	volts direct current
VFD	vacuum fluorescent display
VGA	video graphics adapter
VHF	very high frequency
W	watt
WCR	withstand and closing rating
w/	with
w/o	without
wt.	weight
xfmr	transformer

Use the information below and on the following pages to identify proper fastening techniques when no specific reference for reassembly is made.

Bolt/Screw Length: When bolt/screw length is not given, use Figure 1 as a guide. As a general rule, a minimum length of one thread beyond the nut and a maximum length of 1/2 the bolt/screw diameter beyond the nut is the preferred method.

Washers and Nuts: Use split lock washers as a bolt locking device where specified. Use SAE flat washers with whiz nuts, spiralock nuts, or standard nuts and preloading (torque) of the bolt in all other applications.

See Appendix C, General Torque Specifications, and other torque specifications in the service literature.



1. 1/2 of bolt diameter
2. Min. 1 full thread beyond top of nut
3. Below top of nut

Figure 1 Acceptable Bolt Lengths

Steps for common hardware application:

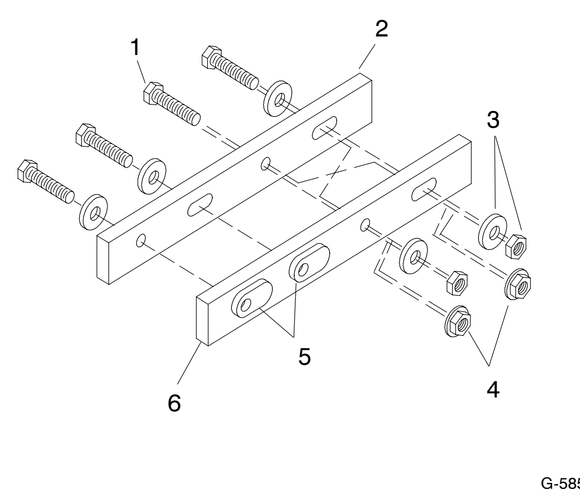
1. Determine entry hole type: round or slotted.
2. Determine exit hole type: fixed female thread (weld nut), round, or slotted.

   For round and slotted exit holes, determine if hardware is greater than 1/2 inch in diameter, or 1/2 inch in diameter or less. Hardware that is *greater than 1/2 inch* in diameter takes a standard nut and SAE washer. Hardware *1/2 inch or less* in diameter can take a properly torqued whiz nut or spiralock nut. See Figure 2.
3. Follow these SAE washer rules after determining exit hole type:

   a. Always use a washer between hardware and a slot.

   b. Always use a washer under a nut (see 2 above for exception).

   c. Use a washer under a bolt when the female thread is fixed (weld nut).
4. Refer to Figure 2, which depicts the preceding hardware configuration possibilities.



1. Cap screw
2. Entry hole types
3. Standard nut and SAE washer
4. Whiz nut or spiralock: up to 1/2 in. dia. hardware
5. Weld nuts: above 1/2 in. dia. hardware
6. Exit hole types

Figure 2 Acceptable Hardware Combinations

Appendix C General Torque Specifications

American Standard Fasteners Torque Specifications								
		Assembled into Cast Iron or Steel						Assembled into Aluminum
Size	Torque Measurement	Grade 2		Grade 5		Grade 8		Grade 2 or 5
8-32	Nm (in. lb.)	1.8	(16)	2.3	(20)	—		See Note 3
10-24	Nm (in. lb.)	2.9	(26)	3.6	(32)	—		
10-32	Nm (in. lb.)	2.9	(26)	3.6	(32)	—		
1/4-20	Nm (in. lb.)	6.8	(60)	10.8	(96)	14.9	(132)	
1/4-28	Nm (in. lb.)	8.1	(72)	12.2	(108)	16.3	(144)	
5/16-18	Nm (in. lb.)	13.6	(120)	21.7	(192)	29.8	(264)	
5/16-24	Nm (in. lb.)	14.9	(132)	23.1	(204)	32.5	(288)	
3/8-16	Nm (ft. lb.)	24.0	(18)	38.0	(28)	53.0	(39)	
3/8-24	Nm (ft. lb.)	27.0	(20)	42.0	(31)	60.0	(44)	
7/16-14	Nm (ft. lb.)	39.0	(29)	60.0	(44)	85.0	(63)	
7/16-20	Nm (ft. lb.)	43.0	(32)	68.0	(50)	95.0	(70)	
1/2-13	Nm (ft. lb.)	60.0	(44)	92.0	(68)	130.0	(96)	
1/2-20	Nm (ft. lb.)	66.0	(49)	103.0	(76)	146.0	(108)	
9/16-12	Nm (ft. lb.)	81.0	(60)	133.0	(98)	187.0	(138)	
9/16-18	Nm (ft. lb.)	91.0	(67)	148.0	(109)	209.0	(154)	
5/8-11	Nm (ft. lb.)	113.0	(83)	183.0	(135)	259.0	(191)	
5/8-18	Nm (ft. lb.)	128.0	(94)	208.0	(153)	293.0	(216)	
3/4-10	Nm (ft. lb.)	199.0	(147)	325.0	(240)	458.0	(338)	
3/4-16	Nm (ft. lb.)	222.0	(164)	363.0	(268)	513.0	(378)	
1-8	Nm (ft. lb.)	259.0	(191)	721.0	(532)	1109.0	(818)	
1-12	Nm (ft. lb.)	283.0	(209)	789.0	(582)	1214.0	(895)	

Metric Fasteners Torque Specifications, Measured in Nm (ft. lb.)							
	Assembled into Cast Iron or Steel						Assembled into Aluminum
Size (mm)	Grade 5.8		Grade 8.8		Grade 10.9		Grade 5.8 or 8.8
M6 x 1.00	6.2	(4.6)	9.5	(7)	13.6	(10)	See Note 3
M8 x 1.25	15.0	(11)	23.0	(17)	33.0	(24)	
M8 x 1.00	16.0	(11)	24.0	(18)	34.0	(25)	
M10 x 1.50	30.0	(22)	45.0	(34)	65.0	(48)	
M10 x 1.25	31.0	(23)	47.0	(35)	68.0	(50)	
M12 x 1.75	53.0	(39)	80.0	(59)	115.0	(85)	
M12 x 1.50	56.0	(41)	85.0	(63)	122.0	(90)	
M14 x 2.00	83.0	(61)	126.0	(93)	180.0	(133)	
M14 x 1.50	87.0	(64)	133.0	(98)	190.0	(140)	
M16 x 2.00	127.0	(94)	194.0	(143)	278.0	(205)	
M16 x 1.50	132.0	(97)	201.0	(148)	287.0	(212)	
M18 x 2.50	179.0	(132)	273.0	(201)	390.0	(288)	
M18 x 1.50	189.0	(140)	289.0	(213)	413.0	(305)	

Notes:

1. The torque values above are general guidelines. Always use the torque values specified in the service manuals and/or assembly drawings when they differ from the above torque values.
2. The torque values above are based on new plated threads. Increase torque values by 15% if non-plated threads are used.
3. Hardware threaded into aluminum must have either two diameters of thread engagement or a 30% or more reduction in the torque to prevent stripped threads.
4. Torque values are calculated as equivalent stress loading on American hardware with an approximate preload of 90% of the yield strength and a friction coefficient of 0.125.

Physical Property @ 15°C (60°F)	Butane	Propane	Natural Gas	Manufactured or Sewage Gas	Gasoline	Diesel Fuel
Normal atmospheric state	Gas	Gas	Gas	Gas	Liquid	Liquid
Boiling point,						
Initial, °C (°F)	—	—	—	—	36 (97)	177 (350)
End, °C (°F)	0 (32)	42 (-44)	-162 (-259)	—	216 (420)	357 (675)
Heating value, Btu						
/gal. (net, LHV*)	94670	83340	63310	—	116400	130300
/gal. (gross)	102032	91500	—	—	124600	139000
/ft^3 (gas)	3264	2516	1000	600-700	6390	—
Density, Ft^3 of gas/gal.	31.26	36.39	57.75	—	19.5	—
Wt./gal. liquid, lb.	4.81	4.24	2.65	—	6.16	7.08
Octane Number						
Research	94	110+	110+	—	80-100	—
Motor	90	97	—	—	75-90	—
* Lower Heating Value						

Figure 3 Engine Fuels, Physical Properties

Characteristic, LP Gas*	Butane	Propane
Formula	C_4H_{10}	C_3H_8
Boiling point, °C (°F)	0 (32)	-42 (-44)
Specific gravity of gas (air = 1.00)	2.00	1.53
Specific gravity of liquid (water = 1.00)	0.58	0.51
Btu/lb. of gas	21221	21591
Ft^3 of vapor at 16°C (60°F)/lb. of liquid at 16°C (60°F)	6.506	8.547
Latent heat of vaporization at boiling point, Btu/gal.	808.0	785.0
Combustion Data:		
Ft^3 air required to burn 1 ft^3 of gas	31.02	23.86
Flash point, °C (°F)	N/A	-104 (-156)
Ignition temperature in air, °C (°F)	482-538 (900-1000)	493-549 (920-1020)
Max. flame temperature in air, °C (°F)	1991 (3615)	1979 (3595)
Limits of inflammability, percentage of gas in air mixture:		
At lower limit, %	1.9	2.4
At upper limit, %	8.6	9.6
Octane Number (ISO-Octane = 100)	92	Over 100
* Commercial quality. Figures shown in this chart represent average values.		

Figure 4 Additional LP Gas Characteristics

Appendix E Gas Fuel Vapor Pressures

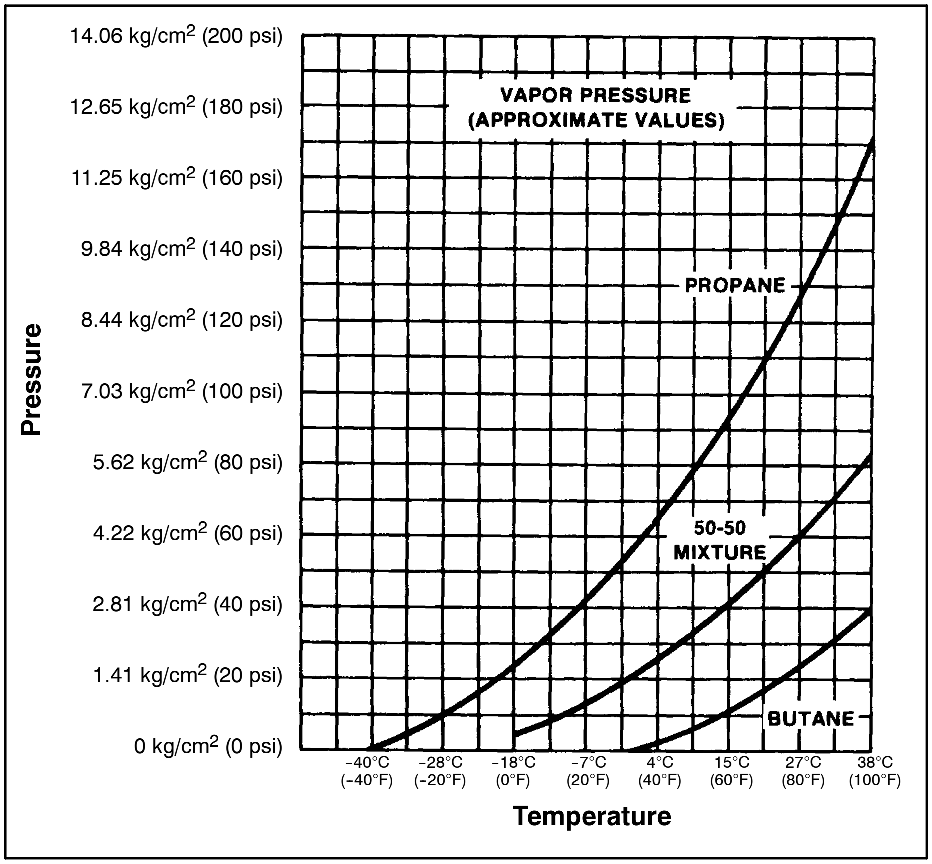


Figure 1 Vapor Pressures of LP Gases Graph

Temperature, °C (°F)	Approximate Pressure, kg/cm² (PSIG)		
	Propane	50/50 Mixture	Butane
-40 (-40)	0.1 (1)	—	—
-36 (-33)	0.4 (5)	—	—
-28 (-20)	0.7 (10)	—	—
-23 (-10)	1.2 (17)	0.2 (3)	—
-18 (0)	1.7 (24)	0.4 (5)	—
-12 (10)	2.2 (32)	0.6 (8)	—
-7 (20)	3.0 (42)	0.9 (13)	—
-1 (30)	3.7 (52)	1.3 (19)	—
4 (40)	4.6 (65)	1.8 (26)	0.1 (2)
10 (50)	5.5 (78)	2.4 (34)	0.5 (7)
15 (60)	6.5 (93)	3.0 (42)	0.8 (12)
21 (70)	7.7 (109)	3.5 (50)	1.2 (17)
27 (80)	9.6 (136)	4.2 (60)	1.7 (24)
32 (90)	10.3 (147)	5.1 (72)	2.2 (32)
38 (100)	11.9 (169)	6.0 (85)	2.8 (40)
43 (110)	14.1 (200)	7.0 (100)	3.5 (50)

Figure 2 Vapor Pressures of LP Gases Table

Determining Propane Cylinder Quantity

Guide for Installing 100 lb. Cylinders

For continuous draws where temperatures may reach -18°C (-0°F). Assume the vaporization rate of 100 lb. cylinder as approximately 50000 Btu/hr.

Number of cylinders/side = $\frac{\text{Total load in Btu}}{50000}$

Example:

Assume total load = 20000 Btu/hour.

Cylinders/side = $\frac{20000}{50000}$ = 4 cylinders/side

The chart in Figure 1 shows the vaporization rate of containers in terms of the temperature of the liquid and the wet surface area of the container. When the temperature is lower or if the container contains less liquid, the vaporization rate of the container is a lower value.

Lb. of Propane in Cyl.	Maximum Continuous Draw In Btu/Hour At Various Temperatures In °C (°F)				
	-18°C (0°F)	-7°C (20°F)	4°C (40°F)	16°C (60°F)	21°C (70°F)
100	113000	167000	214000	277000	300000
90	104000	152000	200000	247000	277000
80	94000	137000	180000	214000	236000
70	83000	122000	160000	199000	214000
60	75000	109000	140000	176000	192000
50	64000	94000	125000	154000	167000
40	55000	79000	105000	131000	141000
30	45000	66000	85000	107000	118000
20	36000	51000	68000	83000	92000
10	28000	38000	49000	60000	66000

Figure 1 Vaporization Rate, 100 lb. Propane Cylinders, Approximate

Determining Propane Vaporization Capacity

Guide for ASME LP Gas Storage Containers

% of Container Filled	K Equals	Propane* Vaporization Capacity at -18°C (0°F) in Btu/Hr.†
60	100	D x L x 100
50	90	D x L x 90
40	80	D x L x 80
30	70	D x L x 70
20	60	D x L x 60
10	45	D x L x 45

* These formulae allow for the temperature of the liquid to refrigerate to -29°C (-20°F), producing a temperature differential of -7°C (20°F) for the transfer of heat from the air to the container's *wetted* surface and then into the liquid. The vapor space area of the vessel is not considered since its effect is negligible.

† D=outside diameter in inches
L=overall length in inches
K=constant for percent volume of liquid in container.

Figure 2 Propane Vaporization Capacity

Vaporizing Capacities for Other Air Temperatures

Multiply the results obtained with the formulae in Figure 2 by one of the factors in the following table for the prevailing air temperature.

Prevailing Air Temperature	Multiplier
-26°C (-15°F)	0.25
-23°C (-10°F)	0.50
-21°C (-5°F)	0.75
-18°C (0°F)	1.00
-15°C (5°F)	1.25
-12°C (10°F)	1.50
-26°C (15°F)	1.75
-7°C (20°F)	2.00

Figure 3 Propane Vaporization Temperature

Notes

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