Installation Manual

Our energy working for you.™

Cummins Power Generation

Generator Set

Ford V-10 6.8L Engine with PowerCommand® 2100 Control

GGHG (Spec L)
GGHH (Spec L)

English
Original Instructions

9-2011

A034G612 (Issue 3)

Table of Contents

1 Important Safety Instructions

SAVE THESE INSTRUCTIONS - This manual contains important instructions that should be followed during installation and maintenance of the generator set and batteries.

Safe and efficient operation can be achieved only if the equipment is properly operated and maintained. Many accidents are caused by failure to follow fundamental rules and precautions.

1.1 Warning, Caution and Note Styles Used In This Manual

The following safety styles and symbols found throughout this manual indicate potentially hazardous conditions to the operator, service personnel or the equipment.

DANGER: Warns of a hazard that will result in severe personal injury or death.

WARNING: Warns of a hazard that may result in severe personal injury or death.

CAUTION: Warns of a hazard or an unsafe practice that can result in product or property damage.

NOTE: A short piece of text giving information that augments the current text.

1.2 General Information

This manual should form part of the documentation package supplied by Cummins Power Generation with specific generator sets. In the event that this manual has been supplied in isolation please contact your authorized distributor.

NOTE: It is in the Operator's interest to read and understand all Warnings and Cautions contained within the documentation relevant to the generator set, its operation and daily maintenance.

1.2.1 General Safety Precautions

WARNING: Coolants under pressure have a higher boiling point than water. DO NOT open a radiator or heat exchanger pressure cap while the engine is running. Allow the generator set to cool and bleed the system pressure first. To prevent severe scalding, let the engine cool down before removing the coolant pressure cap. Turn the cap slowly, and do not open it fully until the pressure has been relieved.

WARNING: Used engine oils have been identified by some state or federal agencies as causing cancer or reproductive toxicity. When checking or changing engine oil, take care not to ingest, breathe the fumes, or contact used oil.

NOTE: Keep multi-class ABC fire extinguishers handy. Class A fires involve ordinary combustible materials such as wood and cloth; Class B fires involve combustible and flammable liquid fuels and gaseous fuels; Class C fires involve live electrical equipment. (ref. NFPA No. 10 in applicable region)

CAUTION: Make sure that rags are not left on or near the engine.

CAUTION: Make sure the generator set is mounted in a manner to prevent combustible materials from accumulating under the unit.

CAUTION: Remove all unnecessary grease and oil from the unit. Accumulated grease and oil can cause overheating and engine damage which present a potential fire hazard.

CAUTION: Keep the generator set and the surrounding area clean and free from obstructions. Remove any debris from the set and keep the floor clean and dry.

WARNING: Do not work on this equipment when mentally or physically fatigued, or after consuming any alcohol or drug that makes the operation of equipment unsafe.

WARNING: Substances in exhaust gases have been identified by some state or federal agencies as causing cancer or reproductive toxicity. Take care not to breath, ingest, or come into contact with exhaust gases.

WARNING: Do not store any flammable liquids, such as fuel, cleaners, oil, etc., near the generator set. A fire or explosion could result.

WARNING: Wear hearing protection when going near an operating generator set.

WARNING: To prevent serious burns, avoid contact with hot metal parts such as the radiator, the turbo charger, and the exhaust system.

WARNING: Use personal protective equipment when maintaining or installing the generator set. Examples of personal protective equipment include but are not limited to: safety glasses, protective gloves, hard hats, steel-toed boots, and protective clothing.

WARNING: Do not use starting fluids that evaporate. They are highly explosive.

CAUTION: Do not step on the generator set when entering or leaving the generator room. Parts can bend or break leading to electrical shorts, or to fuel, coolant, or exhaust leaks.

CAUTION: To prevent accidental or remote starting while working on the generator set, disconnect the negative (-) battery cable at the battery.

WARNING: Ethylene glycol, used as engine coolant, is toxic to humans and animals. Clean up spills and dispose of used engine coolant in accordance with local environmental regulations.

WARNING: Moving parts can cause severe personal injury or death. Hot exhaust parts can cause severe burns. Make sure all protective guards are properly in place before starting the generator set.

1.3 Generator Set Safety Code

Before operating the generator set, read the manuals and become familiar with them and the equipment. **Safe and efficient operation can be achieved only if the equipment is properly operated and maintained.** Many accidents are caused by failure to follow fundamental rules and precautions.

WARNING: Improper operation and maintenance can lead to severe personal injury or loss of life and property by fire, electrocution, mechanical breakdown, or exhaust gas asphyxiation. Read and follow all Safety Precautions, Warnings and Cautions throughout this manual and the documentation supplied with your generator set.

WARNING: Lifting and repositioning of the generator set must only be carried out using suitable lifting equipment, shackles, and spreader bars, in accordance with local guidelines and legislation, by suitably trained and experienced personnel. Incorrect lifting can result in severe personal injury, death and/or equipment damage. For more information, contact your authorized distributor.

1.3.1 Moving Parts Can Cause Severe Personal Injury Or Death

- Keep your hands, clothing, and jewelry away from moving parts.
- Before starting work on the generator set, disconnect the battery charger from its AC source, then disconnect the starting batteries, negative (**–**) cable first. This will prevent accidental starting.
- Make sure that fasteners on the generator set are secure. Tighten supports and clamps; keep guards in position over fans, drive belts, etc.
- Do not wear loose clothing or jewelry in the vicinity of moving parts or while working on electrical equipment. Loose clothing and jewelry can become caught in moving parts.
- If any adjustments must be made while the unit is running, use extreme caution around hot manifolds, moving parts, etc.

1.3.2 Positioning of Generator Set

The area for positioning the set should be adequate and level and the area immediately around the set must be free of any flammable material.

WARNING: On an enclosed generator set, the canopy doors must be locked before re-positioning and they must remain locked during transportation and sitting.

1.3.3 Positioning of Generator Set - Open Sets

The area for positioning the set should be adequate and level and the area immediately around the set must be free of any flammable material.

1.4 Electrical Shocks and Arc Flashes Can Cause Severe Personal Injury or Death

WARNING: Any work with exposed energized circuits with potentials of 50 Volts AC or 75 Volts DC or higher poses a significant risk of electrical shock and electrical arc flash. These silent hazards can cause severe injuries or death. Refer to standard NFPA 70E or equivalent safety standards in corresponding regions for details of the dangers involved and for the safety requirements.

Guidelines to follow when working on de-energized electrical systems:

- Use proper PPE. Do not wear jewelry and ensure that any conductive items are removed from pockets as these items can fall into equipment and the resulting short circuit can cause shock or burning. Refer to standard NFPA 70E for PPE standards.
- De-energize and lockout/tagout electrical systems prior to working on them. Lockout/Tagout is intended to prevent injury due to unexpected start-up of equipment or the release of stored energy. Please refer to the lockout/tagout section for more information.

- De-energize and lockout/tagout all circuits and devices before removing any protective shields or making any measurements on electrical equipment.
- Follow all applicable regional electrical and safety codes.

Guidelines to follow when working on energized electrical systems:

NOTE: **It is the policy of Cummins Inc. to perform all electrical work in a de-energized state. However, employees or suppliers may be permitted to occasionally perform work on energized electrical equipment only when qualified and authorized to do so and when troubleshooting, or if de-energizing the equipment would create a greater risk or make the task impossible and all other alternatives have been exhausted.**

NOTE: **Exposed energized electrical work is only allowed as per the relevant procedures and must be undertaken by a Cummins authorized person with any appropriate energized work permit for the work to be performed while using proper PPE, tools and equipment. In summary:**

- **Do not tamper with or bypass interlocks unless you are authorized to do so.**
- **Understand and assess the risks - use proper PPE. Do not wear jewelry and ensure that any conductive items are removed from pockets as these items can fall into equipment and the resulting short circuit can cause shock or burning. Refer to standard NFPA 70E for PPE standards.**
- **Ensure that an accompanying person who can undertake a rescue is nearby.**

1.4.1 AC Supply and Isolation

It is the sole responsibility of the customer to provide AC power conductors for connection to load devices and the means to isolate the AC input to the terminal box; these must comply to local electrical codes and regulations. Refer to the wiring diagram supplied with the generator set.

NOTE: **Local electrical codes and regulations (for example BS EN 12601:2001) may require the installation of a disconnect means for the generator set, either on the generator set or where the generator set conductors enter a facility.**

NOTE: **The AC supply must have the correct over current and earth fault protection according to local electrical codes and regulations. This equipment must be earthed (grounded).**

The disconnecting device is not provided as part of the generator set, and Cummins Power Generation accepts no responsibility for providing the means of isolation.

1.4.2 Medium Voltage Equipment (601 V to 15 kV)

- Medium voltage acts differently than low voltage. Special equipment and training is required to work on or around medium voltage equipment. Operation and maintenance must be done only by persons trained and experienced to work on such devices. Improper use or procedures will result in severe personal injury or death.
- Do not work on energized equipment. Unauthorized personnel must not be permitted near energized equipment. Due to the nature of medium voltage electrical equipment, induced voltage remains even after the equipment is disconnected from the power source. Plan the time for maintenance with authorized personnel so that the equipment can be de-energized and safely grounded.

1.5 Fuel And Fumes Are Flammable

Fire, explosion, and personal injury or death can result from improper practices.

- DO NOT fill fuel tanks while the engine is running, unless the tanks are outside the engine compartment. Fuel contact with hot engine or exhaust is a potential fire hazard.
- DO NOT permit any flame, cigarette, pilot light, spark, arcing equipment, or other ignition source near the generator set or fuel tank.
- Fuel lines must be adequately secured and free of leaks. Fuel connection at the engine should be made with an approved flexible line. Do not use copper piping on flexible lines as copper will become brittle if continuously vibrated or repeatedly bent.
- Be sure all fuel supplies have a positive shutoff valve.
- Be sure the battery area has been well-ventilated prior to servicing near it. Lead-acid batteries emit a highly explosive hydrogen gas that can be ignited by arcing, sparking, smoking, etc.

1.5.1 Gaseous Fuels

- Natural gas is lighter than air, and will tend to gather under hoods. Propane is heavier than air, and will tend to gather in sumps or low areas. NFPA code requires all persons handling propane to be trained and qualified.

1.5.2 Spillage

Any spillage that occurs during fueling or during oil top-off or oil change must be cleaned up before starting the generator set.

1.5.3 Fluid Containment

If fluid containment is incorporated into the bedframe, it must be inspected at regular intervals. Any liquid present should be drained out and disposed of in line with local health and safety regulations. Failure to perform this action may result in spillage of liquids which could contaminate the surrounding area.

Any other fluid containment area must also be checked and emptied, as described above.

NOTE: Where spillage containment is not part of a Cummins supply, it is the responsibility of the installer to provide the necessary containment to prevent contamination of the environment, especially water courses/sources.

1.5.4 Do Not Operate in Flammable and Explosive Environments

Flammable vapor can cause an engine to overspeed and become difficult to stop, resulting in possible fire, explosion, severe personal injury and death. Do not operate a generator set where a flammable vapor environment can be created by fuel spill, leak, etc., unless the generator set is equipped with an automatic safety device to block the air intake and stop the engine. The owners and operators of the generator set are solely responsible for operating the generator set safely. Contact your authorized Cummins Power Generation distributor for more information.

1.6 Exhaust Gases Are Deadly

- Provide an adequate exhaust system to properly expel discharged gases away from enclosed or sheltered areas and areas where individuals are likely to congregate. Visually and audibly inspect the exhaust daily for leaks per the maintenance schedule. Make sure that exhaust manifolds are secured and not warped. Do not use exhaust gases to heat a compartment.
- Be sure the unit is well ventilated.

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

1.6.1 Exhaust Precautions

WARNING: Exhaust pipes and charge air pipes are very hot and they can cause severe personal injury or death from direct contact or from fire hazard.

WARNING: Hot exhaust gas can cause burns resulting in severe personal injury.

The exhaust outlet may be sited at the top or bottom of the generator set. Make sure that the exhaust outlet is not obstructed. Personnel using this equipment must be made aware of the exhaust position. Position the exhaust away from flammable materials - in the case of exhaust outlets at the bottom, make sure that vegetation is removed from the vicinity of the exhaust.

WARNING: Inhalation of exhaust gases can result in serious personal injury or death. Be sure deadly exhaust gas is piped outside and away from windows, doors, or other inlets to buildings. Do not allow to accumulate in habitable areas.

WARNING: Contaminated insulation is a fire risk which can result in severe personal injury.

The exhaust pipes may have some insulating covers fitted. If these covers become contaminated by fuel or oil, they must be replaced before the generator set is run.

To minimize the risk of fire, make sure the following steps are observed:

- Make sure that the engine is allowed to cool thoroughly before topping off the oil or draining the fuel filters.
- Clean the exhaust pipe thoroughly.

1.7 Earthing Rod Connection

Although this generator set may be supplied with an earthing rod, it may not be suitable for all local conditions.

The neutral of the generator set may be required to be bonded to earth ground at the generator location, or at a remote location depending on system design requirements. Consult the engineering drawings for the facility or a qualified electrical design engineer for proper installation.

NOTE: The end user is responsible for ensuring that an earthing arrangement that is compliant with local conditions is established and tested before the equipment is used.

1.8 Decommissioning and Disassembly

NOTE: **Decommissioning and disassembly of the generator set at the end of its working life must comply with local guidelines and legislation for disposal/recycling of components and contaminated fluids. This procedure must only be carried out by suitably trained and experienced service personnel. For more information contact your authorized distributor.**

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2 Introduction

2.1 About This Manual

The purpose of this manual is to provide the users with sound, general information. It is for guidance and assistance with recommendations for correct and safe procedures. Cummins Power Generation (CPG) cannot accept any liability whatsoever for problems arising as a result of following recommendations in this manual.

The information contained within the manual is based on information available at the time of going to print. In line with Cummins Power Generation policy of continuous development and improvement, information may change at any time without notice. The users should therefore make sure that before commencing any work, they have the latest information available.

Users are respectfully advised that, in the interests of good practice and safety, it is their responsibility to employ competent persons to carry out any installation work. Consult your authorized distributor for further installation information. It is essential that the utmost care is taken with the application, installation, and operation of any engine due to their potentially hazardous nature. Careful reference should also be made to other Cummins Power Generation literature. A generator set must be operated and maintained properly if you are to expect safe and reliable operation.

Should you require further assistance, contact your authorized distributor.

2.1.1 Additional Installation Manual Information

The purpose of this manual is to provide the Installation Engineer with sound, general information for the installation of the generator set. Refer to the Generator Set Operator Manual for additional information which must also be read before operating the set.

This manual provides installation instructions for the generator set models listed on the front cover. This includes the following information:

- **Mounting Recommendations** - for fastening the generator set to a base and space requirements for normal operation and service.
- **Mechanical and Electrical Connections** - covers most aspects of the generator set installation.
- **Prestart** - checklist of items or procedures needed to prepare the generator set for operation.
- **Installation Checklist** - reference checks upon completion of the installation.

This manual **DOES NOT** provide application information for selecting a generator set or designing the complete installation. If it is necessary to design the various integrated systems (fuel, exhaust, cooling, etc.), additional information is required. Review standard installation practices. For engineering data specific to the generator set, refer to the Specification and Data Sheets. For application information, refer to Application Manual T-030, "Liquid Cooled Generator Sets." To find this manual online:

1. Go to **www.cumminspower.com**
2. Click on "Application Engineering" under heading, Technical Information.
3. Click on "Liquid Cooled Genset Application Manual"

2.2 Schedule of Abbreviations

This list is not exhaustive. For example, it does not identify units of measure or acronyms that appear only in parameters, event/fault names, or part/accessory names.

AmpSentry and InPower are trademarks of Cummins Inc. PowerCommand is a registered trademark of Cummins Inc.

ACRONYM	DESCRIPTION	ACRONYM	DESCRIPTION
AC	Alternating Current	LED	Light-emitting Diode
AMP	AMP, Inc., part of Tyco Electronics	Mil Std	Military Standard
ASTM	American Society for Testing and Materials (ASTM International)	MMHG	Millimeters of Mercury
ATS	Automatic Transfer Switch	NC	Not Connected
AVR	Automatic Voltage Regulator	NC	Normally Closed
AWG	American Wire Gauge	NFPA	National Fire Protection Agency
CAN	Controlled Area Network	NO	Normally Open
CB	Circuit Breaker	NWF	Network Failure
CE	Conformité Européenne	OEM	Original Equipment Manufacturer
CFM	Cubic Feet per Minute	OOR	Out of Range
CGT	Cummins Generator Technologies	OORH / ORH	Out of Range High
CMM	Cubic Meters per Minute	OORL / ORL	Out of Range Low
CT	Current Transformer	PSI	Pounds per square inch
DC	Direct Current	PB	Push Button
ECM	Engine Control Module	PC	Personal Computer
ECS	Engine Control System	PCC	PowerCommand® Control
EMI	Electromagnetic interference	PGI	Power Generation Interface
EN	European Standard	PGN	Parameter Group Number
EPS	Engine Protection System	PI	Proportional/Integral
E-Stop	Emergency Stop	PID	Proportional/Integral/Derivative
FAE	Full Authority Electronic	PLC	Programmable Logic Controller
FMI	Failure Mode Identifier	PMG	Permanent Magnet Generator
FSO	Fuel Shutoff	PT	Potential Transformer
Genset	Generator Set	PTC	Power Transfer Control
GCP	Generator Control Panel	PWM	Pulse-width Modulation
GND	Ground	RFI	Radio Frequency Interference
HMI	Human-machine Interface	RH	Relative Humidity
IC	Integrated Circuit	RMS	Root Mean Square
INHG	Inches of Mercury	RTU	Remote Terminal Unit
ISO	International Organization for Standardization	SAE	Society of Automotive Engineers
kPA	kilo-Pascal	SPN	Suspect Parameter Number

ACRONYM	DESCRIPTION	ACRONYM	DESCRIPTION
LBNG	Lean-burn Natural Gas	SW_B+	Switched B+
LCD	Liquid Crystal Display	UL	Underwriters Laboratories
LCL	Low Coolant Level	UPS	Uninterruptible Power Supply
LCT	Low Coolant Temperature		

2.3 Related Literature

Before any attempt is made to operate the generator set, the operator should take time to read all of the manuals supplied with the generator set, and to familiarize themselves with the warnings and operating procedures.

CAUTION: A generator set must be operated and maintained properly if you are to expect safe and reliable operation. The Operator manual includes a maintenance schedule and a troubleshooting guide

The relevant manuals appropriate to your generator set are also available:

- Operator Manual for GGHG/GGHH (A034G614)
- Installation Manual for GGHG/GGHH (A034G612)
- *Specification* and *Data Sheet* (For engineering data specific to the generator set)
- Application Manual T-030, *Liquid Cooled Generator Sets* (For application information)
- Parts Manual for GGHG/GGHH (0928-0245)
- Recommended Spares List (RSL) for GGHG/GGHH (RSL_458)
- Warranty Manual (F1117-0002)
- Global Commercial Warranty Statement (A028U870)
- Ford V10 Wiring Diagram (WH-0000-15)

2.3.1 Further Information - Literature

Contact your authorized distributor for more information regarding related literature for this product.

2.4 After Sales Services

We offer a full range of maintenance and warranty services.

2.4.1 Maintenance

WARNING: Incorrect service or parts replacement can result in severe personal injury, death, and/or equipment damage. Service personnel must be trained and experienced to perform electrical and/or mechanical service.

For customers who wish to have their generator sets expertly serviced at regular intervals your local distributor offers a complete maintenance contract package. This covers all items subject to routine maintenance and includes a detailed report on the condition of the generator set. In addition, this can be linked to a 24-hour call-out arrangement, providing year-round assistance if necessary. Specialist engineers are available to maintain optimum performance levels from customer's generator sets, and it is recommended that maintenance tasks are only undertaken by trained and experienced technicians provided by your authorized distributor.

2.4.2 Warranty

For details of the warranty coverage for your generator set, refer to the Global Commercial Warranty Statement (A028U870).

Extended warranty coverage is also available. In the event of a breakdown, prompt assistance can normally be given by factory trained service technicians with facilities to undertake all minor and many major repairs to equipment on site.

For further warranty details, contact your authorized distributor.

NOTE: Damage caused by failure to follow the correct coolant recommendations will not be covered by the warranty. Please contact your authorized distributor.

2.4.2.1 Warranty Limitations

For details of the warranty limitations for your generator set, refer to the Warranty Statement applicable to the generator set application.

3 System Overview

This section provides an overview of the Generator Set.

3.1 Generator Set Identification

Each generator set is provided with a nameplate similar to that shown below. This provides information unique to each generator set.

3.1.1 Nameplate

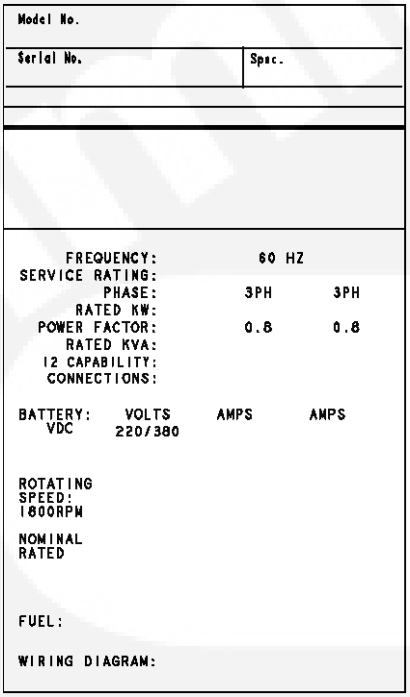
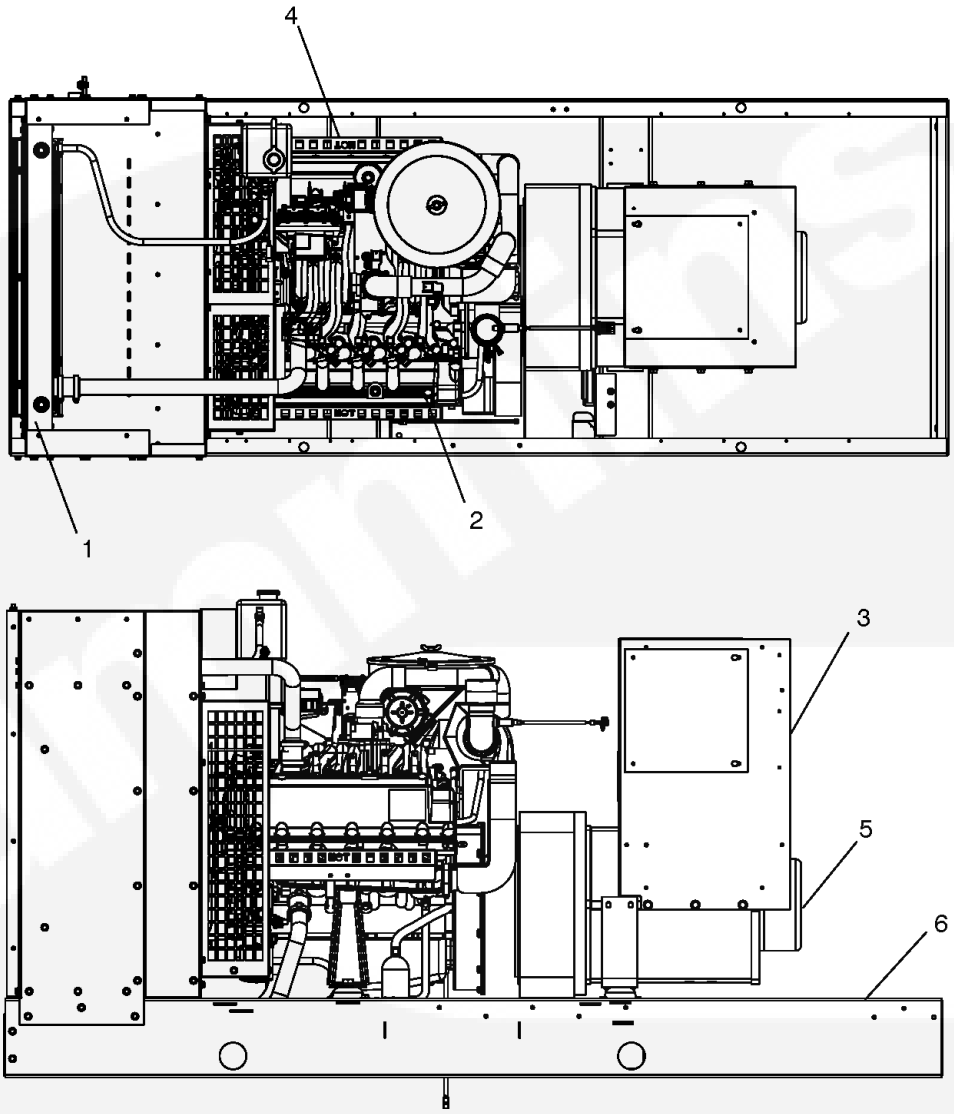


FIGURE 1. TYPICAL GENERATOR SET NAMEPLATE

3.2 Generator Set Components

The main components of a typical Ford V-10 6.8L engine generator set are shown below, and referred to within this section.

There are various options are listed although they may not be available for all models.



1	Radiator		(Not indicated)
2	Engine		Battery and Tray
3	Controller		Alarm Module
4	Battery		Battery Charger
5	Alternator		Engine Coolant Heater
6	Bed Frame		Alternator Heater

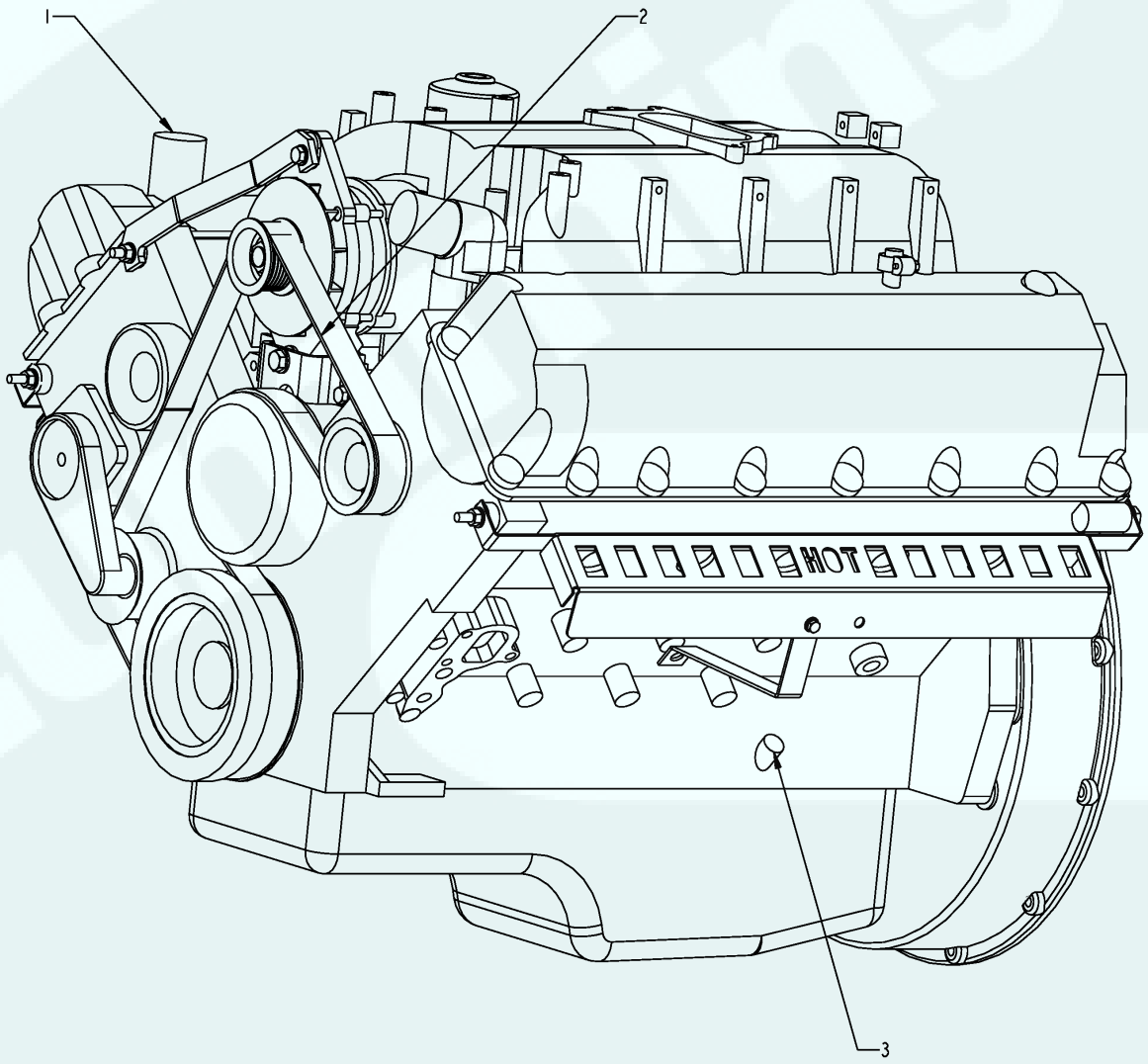
FIGURE 2. TYPICAL FORD V-10 6.8L ENGINE GENERATOR SET

3.3 Generator Set Rating

For details of your generator set rating refer to the generator set nameplate. Refer to the Operator manual for operation at temperatures or altitudes above those stated on the nameplate.

3.4 Engine

For additional engine specific information, refer to the relevant engine manual for your generator set.



1	Oil filler cap
2	Fan belt
3	Dipstick

FIGURE 3. TYPICAL ENGINE COMPONENTS (FORD V-10 6.8L)

3.5 Sensors

Various generator set parameters are measured by sensors, and the resulting signals are processed by the control board.

Engine-mounted sensors monitor a number of different systems, including:

- Lube Oil Pressure
- Cooling System Temperature

3.6 System Options

The system options available with this installation include:

- Annunciator - see Section 9.11.1 on page 75.
- Battery Charger - see Section 3.6.2.
- Heaters:
  - Alternator Heater - see Section 9.7.2 on page 71.
  - Control Cabinet Heater - see Section 3.6.3.3 on page 17.
  - Oil Pan Heaters - see Section 9.10.

3.6.1 Annunciators

An annunciator provides lamps and a horn to annunciate the operating status and fault conditions of an emergency power system. For more information, see Section 9.11 on page 75.

3.6.2 Battery Charger

A battery charger can be wall mounted or bench mounted. For more information, see Section 9.8.

3.6.3 Heaters

CAUTION: Energizing heater(s) when the coolant system has been drained or if there is a suspicion that the coolant is frozen can result in equipment damage. Always make sure the radiator is filled to the recommended level before energizing the heater(s).

3.6.3.1 Heater Supply and Isolation

A heater supply is required for the operation of the engine and alternator heaters (if fitted). See Section 9.7 on page 70.

NOTE: It is the sole responsibility of the customer to provide the power supply and the means to isolate the AC input to the terminal box. Cummins Power Generation accepts no responsibility for providing the means of isolation.

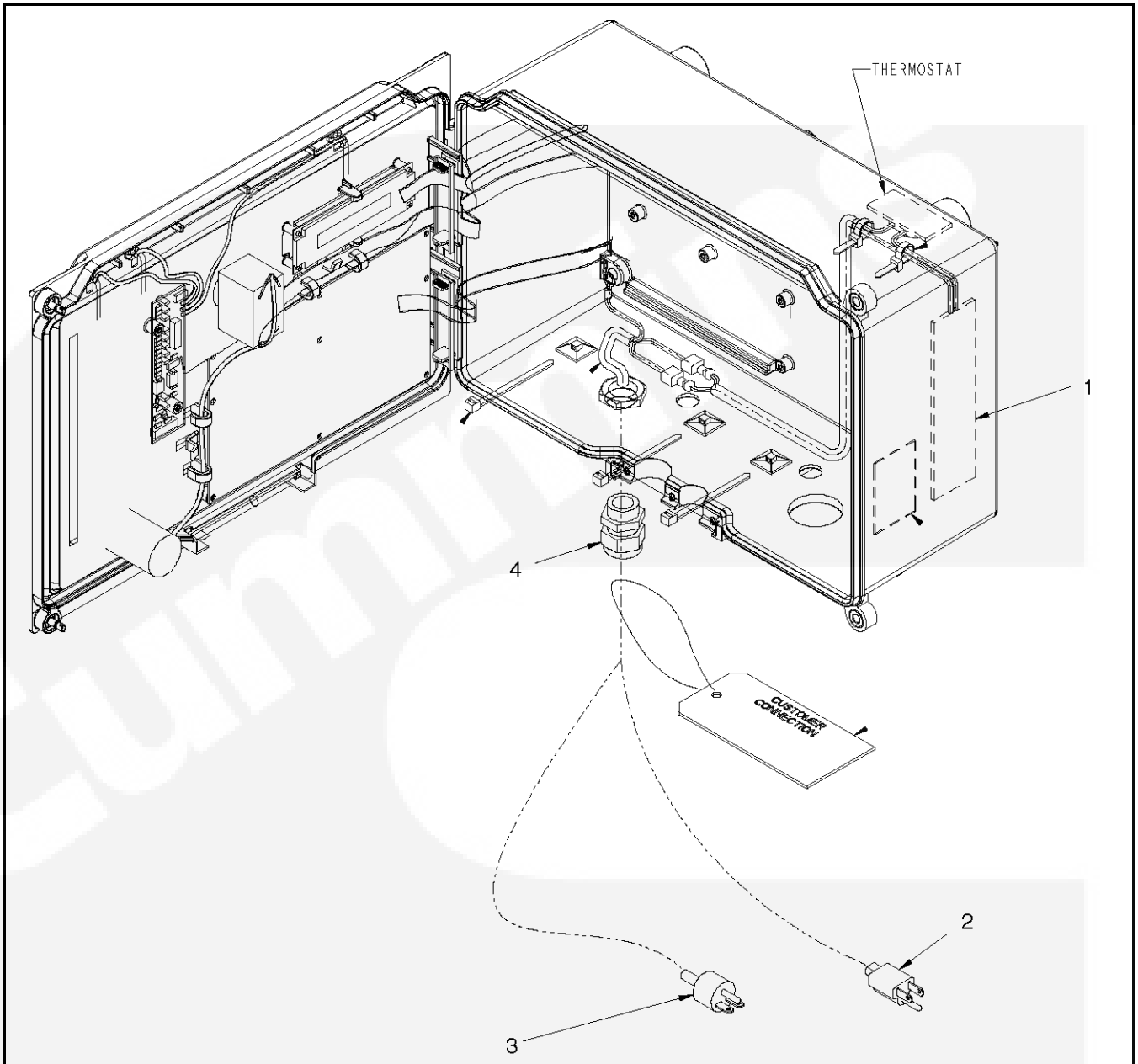
NOTE: This disconnecting device is not provided as part of the generator set.

3.6.3.2 Coolant Heater

A coolant heater keeps the engine coolant warm when the engine is shut down. For more information on coolant heater components and specifications, see **Section 9.6 on page 68**.

3.6.3.3 Control Cabinet Heaters

A thermostat heater is installed inside the control cabinet. Both 120V and 240V heaters are available.



No.	Description	No	Description
1	Heater Assembly	3	Cable Assembly
2	Cable Assembly	4	Strain Relief

FIGURE 4. TYPICAL CONTROL CABINET HEATER

3.6.3.4 Oil Pan Heaters

Three 300W oil pan heaters are available.

- 120V single phase
- 208/240V single phase
- 480V single phase

NOTE: For 120V applications, the optional location is shown. The primary location is on the left hand side of the oil pan.

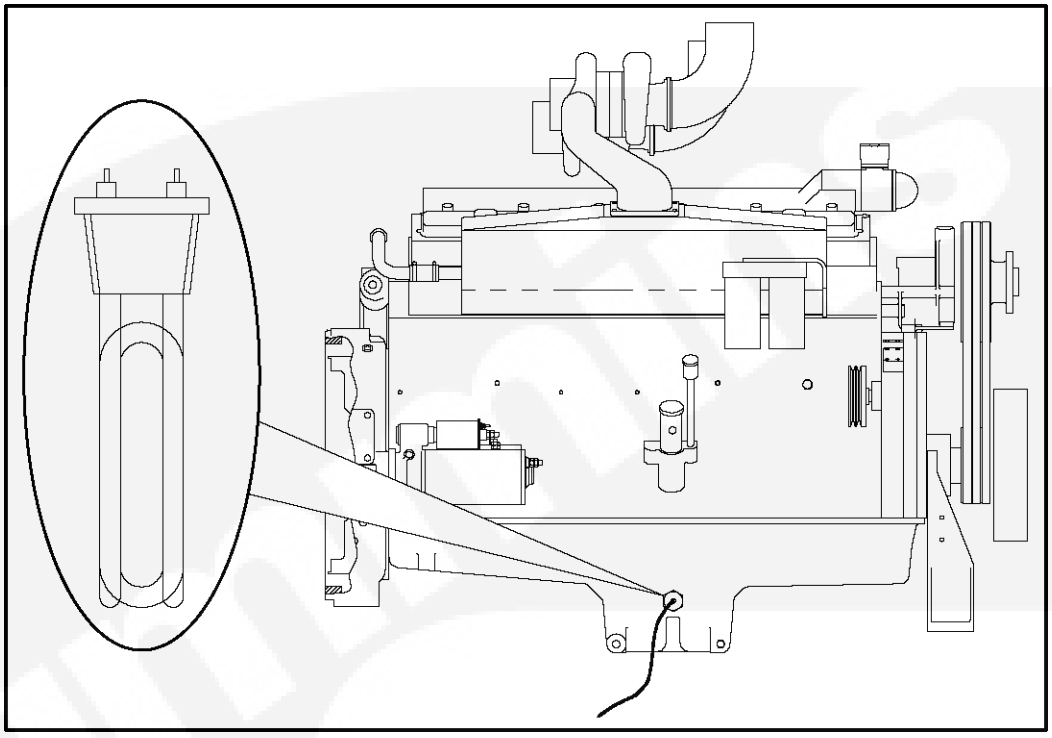


FIGURE 5. OIL PAN HEATER USED IN 120V AND 208/240V APPLICATIONS

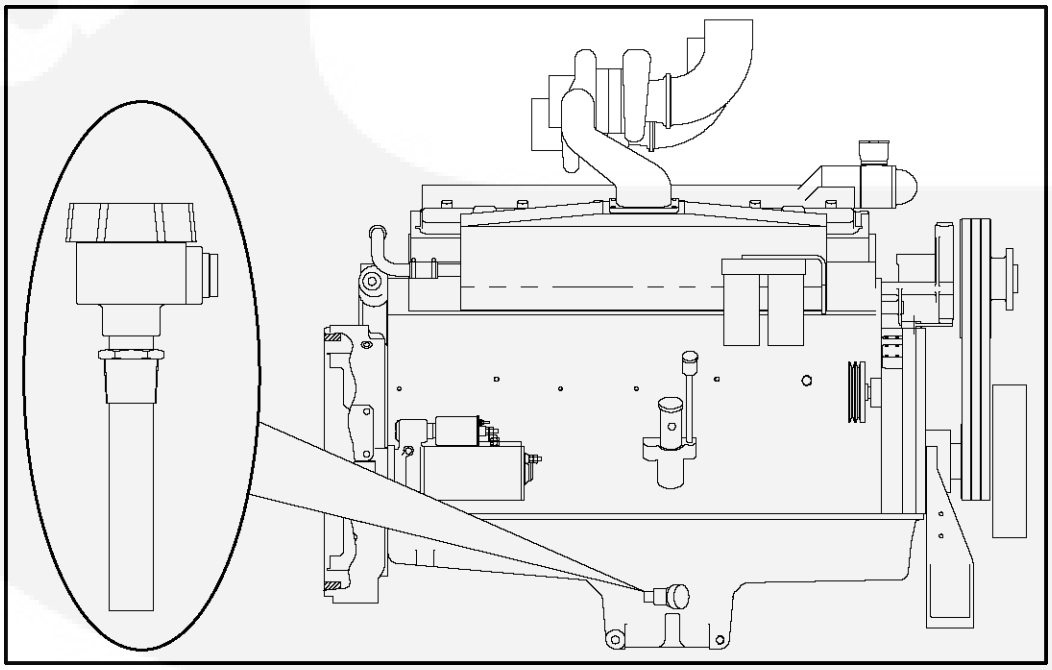


FIGURE 6. OIL PAN HEATER USED IN 480V APPLICATIONS

3.6.4 Seismic Installation Requirements

Seismically certified generator set installations have special requirements. For more information, refer to **Section 4.5 on page 22** and **Appendix E on page 105**.

4 Installation Overview

These installation recommendations apply to typical installations with standard model generator sets. Whenever possible, these recommendations also cover factory designed options or modifications. However, because of the many variables in any installation, it is not possible to provide specific recommendations for every situation. If there are any questions not answered by this manual, contact your nearest authorized distributor for assistance.

4.1 Application and Installation

A power system must be carefully planned and correctly installed for proper operation. This involves two essential elements.

- **Application** (as it applies to generator set installations) refers to the design of the complete power system that usually includes power distribution equipment, transfer switches, ventilation equipment, mounting pads, cooling, exhaust, and fuel systems. Each component must be correctly designed so the complete system will function as intended. Application and design is an engineering function generally done by specifying engineers or other trained specialists. Specifying engineers or other trained specialists are responsible for the design of the complete power system and for selecting the materials and products required.
- **Installation** refers to the actual set-up and assembly of the power system. The installers set up and connect the various components of the system as specified in the system design plan. The complexity of the system normally requires the special skills of qualified electricians, plumbers, sheet-metal workers, etc. to complete the various segments of the installation. This is necessary so that all components are assembled using standard methods and practices.

4.2 Safety Considerations

The generator set has been carefully designed to provide safe and efficient service when properly installed, maintained, and operated. However, the overall safety and reliability of the complete system is dependent on many factors outside the control of the generator set manufacturer. To avoid possible safety hazards, make all mechanical and electrical connections to the generator set exactly as specified in this manual. All systems external to the generator (fuel, exhaust, electrical, etc.) must comply with all applicable codes. Make certain all required inspections and tests have been completed and all code requirements have been satisfied before certifying the installation is complete and ready for service.

4.3 Standby Heating Devices

Cummins Power Generation recommends installing standby generator sets (life safety systems) equipped with engine jacket water coolant heaters in locations where the minimum ambient temperature is below 40 °F (4 °C). Cummins Power Generation also requires that the engine be heated as necessary to maintain the water jacket temperature determined by the manufacturer for cold start and load acceptance for the type of system. Although most Cummins Power Generation generator sets will start in temperatures down to –25 °F (–32 °C) when equipped with engine jacket water coolant heaters, it might take more than 10 seconds to warm the engine before a load can be applied when ambient temperatures are below 40 °F (4 °C).

On generator sets equipped with a graphic display, the **Low Coolant Temperature** message, in conjunction with illumination of the Warning LED, is provided to meet the current requirements. The engine cold sensing logic initiates a warning when the engine jacket water coolant temperature falls below 70 °F (21 °C). In applications where the ambient temperature falls below 40 °F (4 °C), a cold engine may be indicated even though the coolant heaters are connected and operating correctly. Under these conditions, although the generator set may start, it may not be able to accept load within 10 seconds. When this condition occurs, check the coolant heaters for proper operation. If the coolant heaters are operating properly, other precautions may be necessary to warm the engine before applying a load.

4.4 Product Modifications

Agency certified products purchased from Cummins Power Generation comply only with those specific requirements and as noted on company product specification sheets. Subsequent modifications must meet commonly accepted engineering practices and/or local and national codes and standards. Product modifications must be submitted to the local authority having jurisdiction for approval.

4.5 Seismic Installations

Seismically certified generator set installations have special requirements, as defined by IAA-VMC (Independent Approval Agency, the VMC Group).

For special installation requirements, refer to the tabulated and written seismic requirements listed in **Appendix E on page 105**.

The installation of the seismically certified generator set should be overseen by the installation project structural engineer of record.

The "Seismic Certificate of Compliance" should be kept with the Warranty and other generator set documents.

The seismic requirements installation drawing and the Seismic Certificate of Compliance for generator sets are included in the literature package of each seismically certified generator set.

4.5.1 Seismic Installation Notes

1. The design of post-installed anchors in concrete used for the component anchorage is pre-qualified for seismic applications in accordance with "ACI 355.2" and documented in a report by a reputable testing agency. (ex. the evaluation service report issued by the International Code Council)
2. Anchors must be installed to an embedment depth as recommended in the pre-qualification test report as defined in Note 1. For "IBC 2000" and "IBC 2003" applications, the minimum embedment must be 8X for the anchor diameter.
3. Anchors must be installed in minimum 4000 PSI compressive strength normal weight concrete. Concrete aggregate must comply with "ASTM C33". Installation in structural lightweight concrete is not permitted unless otherwise approved by the structural engineer of record.
4. Anchors must be installed to the torque specification as recommended by the anchor manufacturer to obtain maximum loading.
5. Anchors must be installed in locations specified in this section.

6. Wide washers must be installed at each anchor location between the anchor head and equipment for tension load distribution. Wide washers must be Series "W" of American National Standard Type "A" plain washers (ANSI B18.22.1-1965, R1975) with the nominal washer size selected to match the specified nominal anchor diameter.
7. Concrete floor slab and concrete housekeeping pads must be designed and rebar reinforced for seismic applications in accordance with "ACI 318". The design loads shall be taken as those specified in this section.
8. All housekeeping pad thicknesses must be designed in accordance with the pre-qualification test report as defined in Note 1 or a minimum of 1.5X the anchor embedment depth, whichever is largest.
9. All housekeeping pads must be dowelled or cast into the building structural floor slab and designed for seismic application per "ACI 318" and as approved by the structural engineer of record.
10. Wall mounted equipment must be installed to a rebar reinforced structural concrete wall that is seismically designed and approved by the engineer of record to resist the added seismic loads from components being anchored to the wall.
11. Floor mounted equipment (with or without a housekeeping pad) must be installed to a rebar reinforced structural concrete floor that is seismically designed and approved by the engineer of record to resist the added seismic loads from components being anchored to the floor.
12. When installing to a floor or wall, rebar interference must be considered.
13. Attaching seismic certified equipment to any floor or wall other than those constructed of structural concrete and designed to accept the seismic loads from said equipment is not permitted by this specification and beyond the scope of this certification.
14. Attaching seismic certified equipment to any floor constructed of light weight concrete over steel decking is not permitted by this specification and beyond the scope of this certification.
15. Attaching the seismic certified equipment to any concrete block walls or cinder block walls is not permitted by this specification and beyond the scope of this certification.
16. Installation upon a rooftop steel dunnage shall be coordinated with the structural engineer of record.
17. Installation upon any rooftop curb shall be coordinated with the curb manufacturer and the structural engineer of record. Any curb or concrete pad that supports the genset unit is beyond the scope of this certification.
18. Connections to the equipment, including but not limited to conduit, wiring from cable trays, other electrical services, ducting, piping such as exhaust, steam, water, coolant, refrigerant, fuel, or other connections, are the responsibility of the installing contractor and beyond the scope of this document. Typical requirements for these connections are stated in the equipment installation manual. Special considerations for seismic applications are as follows; connections to non-isolated components or equipment may be installed as typical for that particular application. Connections to isolated components (ex. breaker box bolted directly to an isolated genset) or isolated equipment (ex. an enclosed genset mounted on external isolators) must be flexibly attached. The flexible attachment must provide for enough relative displacement to remain connected to the equipment and functional during and after a seismic event.

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5 Specifications

5.1 Generator Set Specifications

TABLE 1. GGHG AND GGHH SPECIFICATIONS

MODELS	GGHG, GGHH	
Engine	Ford V-10 6.8L	
Generator kW Rating	See generator set nameplate for rating information.	
Engine Fuel Connection Inlet/Outlet Thread Size	Refer to generator get outline drawing supplied (0500-4087)	
Fuel Flow (Inlet Pressure) Max. Fuel Inlet Restriction Max. Fuel Return Restriction	7.0 in. Hg. (127 mmHg) 13.6 in. Hg. (254 mmHg)	
Exhaust Outlet Size Max. Allowable Back Pressure Exhaust Flow at Rated Load Exhaust Temperature	1500 RPM 12 in. NB 2 in. (50 mm) Hg 15273 cfm (7208L/s at SBY) x °C (800 °F)	1800 RPM 12 in. NB 2 in. (50 mm) Hg 15273 cfm (7208L/s at SBY) x °C (800 °F)
Electrical System Starting Voltage Battery Group Number CCA (minimum) Cold Soak @ 0 °F (-18 °C)	24 Volts DC 31 37 A at -18 °C to 0 °C	
Cooling System Capacity with Standard Radiator	For 50 °C radiator; x l HT; x l LT; G9 HT x l HT; x l LT For 40 °C radiator; x l HT; x l LT; G9 HT x l HT; x l LT	
Lubricating System Oil Capacity with Filters	5.5 liters (1.5 US gal)	

5.2 Engine Fuel Consumption

TABLE 2. FUEL CONSUMPTION (L/HR) AT 1500 RPM (50 HZ)

Model	GGHH	GGHH
Engine	**NG**	**LP**
Engine Performance Data at 60Hz[1]	**30.1**	**11.3**

1. Standby/Full Load

Refer to Data Sheets for other applications. In line with the CPG policy of continuous improvement, these figures are subject to change.

TABLE 3. FUEL CONSUMPTION (STANDBY/PRIME/50 HZ)

Model	GGHH

Standby	
cfh (m3/hr)	
LPG (Vapor or Liquid)	399.4 (11.3)
Natural Gas	1062.5 (30.1)

TABLE 4. FUEL CONSUMPTION (L/HR) AT 1800 RPM (60 HZ)

Model	**GGHG**	**GGHG**	**GGHH**	**GGHH**
Engine	**NG**	**LP**	**NG**	**LP**
Engine Performance Data at 60Hz[1]	**33.2**	**12.4**	**30.9**	**13.2**

1. Standby/Full Load
Refer to Data Sheets for other applications. In line with the CPG policy of continuous improvement, these figures are subject to change.

TABLE 5. FUEL CONSUMPTION (STANDBY/PRIME/60 HZ)

Model	**GGHG**	**GGHH**
Standby		
cfh (m3/hr)		
LPG (Vapor or Liquid)	439.7 (12.4)	467 (13.2)
Natural Gas	1173 (33.2)	1090 (30.9)

6 Installing the Generator Set

Generator set installations must be engineered so that the generator set will function properly under the expected load conditions. Use these instructions as a general guide only. Follow the instructions of the consulting engineer when locating or installing any components. The complete installation must comply with all local and state building codes, fire regulations, and other applicable regulations.

Requirements to be considered prior to installation are:

- Level mounting surface
- Adequate cooling air
- Adequate fresh induction air
- Discharge of generator set air
- Non-combustible mounting surface
- Discharge of exhaust gases
- Electrical connections
- Accessibility for operation and servicing
- Noise levels
- Vibration isolation

CAUTION: Depending on your location and intended use, ensure that international, national or local laws and regulations regarding Air Quality Emissions have been observed and complied with. Be sure to consult local pollution control or air quality authorities before completing your construction plans.

CAUTION: Operating the generator set with the shipping brackets installed has an effect on engine performance because viabration increases. Shipping brackets, which are mared in red, are for transportation of the generator set only. Remove all shipping brackets before starting the generator set.

6.1 Location

Generator set location is decided mainly by related systems such as ventilation, wiring, fuel, and exhaust. The set should be located as near as possible to the main power service entrance. Exhaust gases must not be able to enter or accumulate around inhabited areas.

Provide a location away from extreme ambient temperatures and protect the generator set from adverse weather conditions.

WARNING: Incorrect installation, service or parts replacement can result in severe personal injury, death, and/or equipment damage. Service personnel must be trained and experienced to perform electrical and mechanical component installation.

NOTE: Depending on your location and intended use, additional laws and regulations may require for you to obtain an air quality emissions permit before beginning installation of your generator set. Be sure to consult local pollution control or air quality authorities before completing your construction plans.

6.2 Mounting

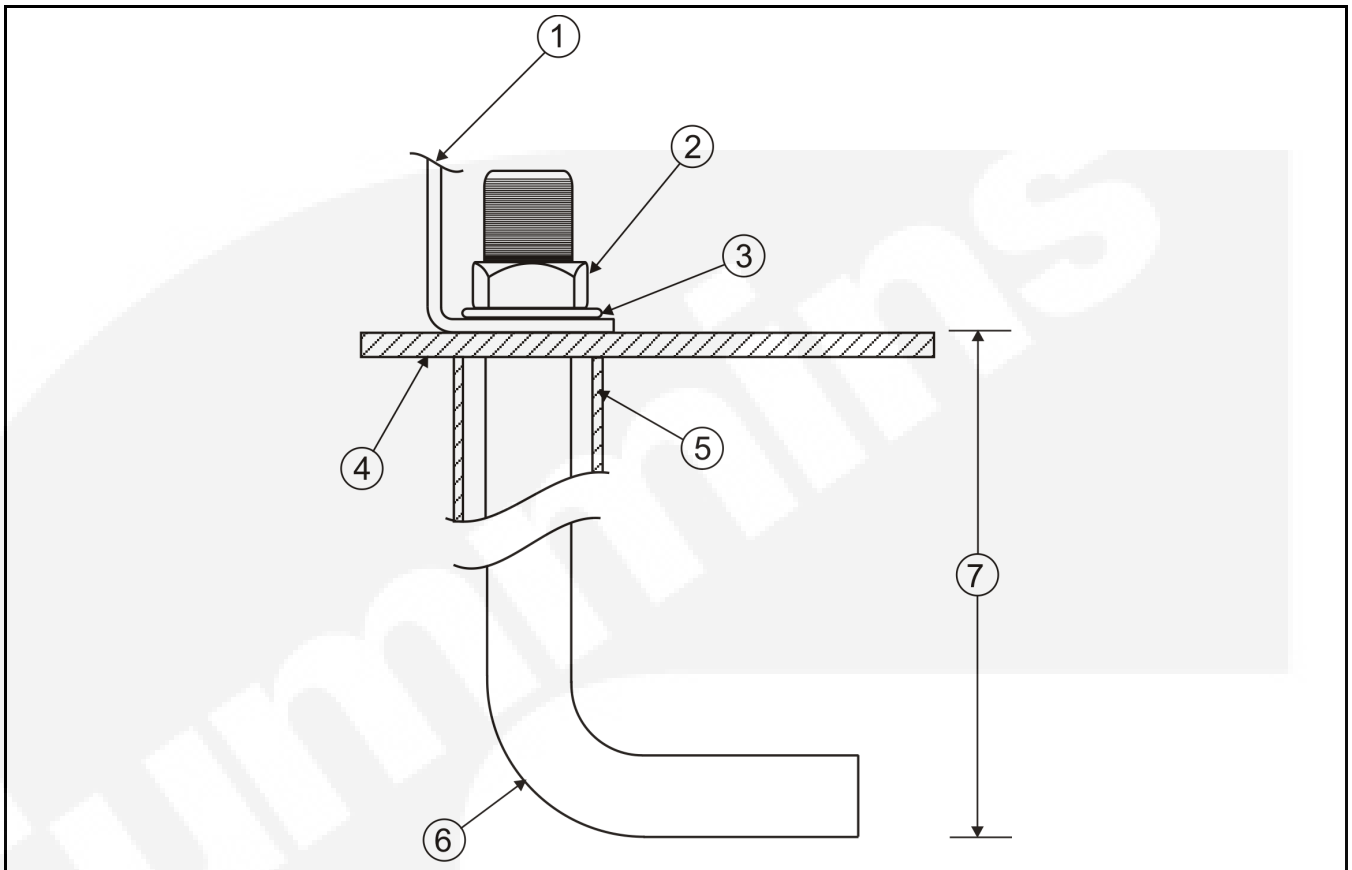
Generator sets are mounted on a steel skid that provides proper support. The engine-generator assembly is isolated from the skid frame by rubber mounts that provide adequate vibration isolation for normal installations. Where required by building codes or special isolation needs, generator sets may be mounted on rubber pads or mechanical spring isolators.

WARNING: The use of unapproved isolators may result in harmful resonances and may void the generator set warranty.

Mount the generator set on a substantial and level base such as a concrete pad. A non-combustible material must be used for the pad.

Use 16 mm ($^5/_8$ inch) or anchored mounting bolts to secure the generator bedframe to the base. Secure the generator bedframe to the skid using flat washer and hexagonal nut for each bolt (see **Figure 7**). The 38 mm x 152 mm ($1^1/_2$ x 6 inch) pipe inserted over the mounting bolts allows minor adjustment of the bolts to align them to the holes in the bedframe.

The fixing centers for the mounting bolts can be found on the generator set *Outline Drawing* referenced in the *Data Sheet*.



No.	Description	No.	Description
1	Generator Bedframe Flange	5	38 mm x 152 mm Pipe (1½ inch x 6 inch)
2	Hexagonal Nut	6	Mounting Bolt Set in Concrete
3	Flat or Bevel Washer	7	305 mm (12 inch)
4	Mounting Base on Concrete		

FIGURE 7. BOLT DIAGRAM

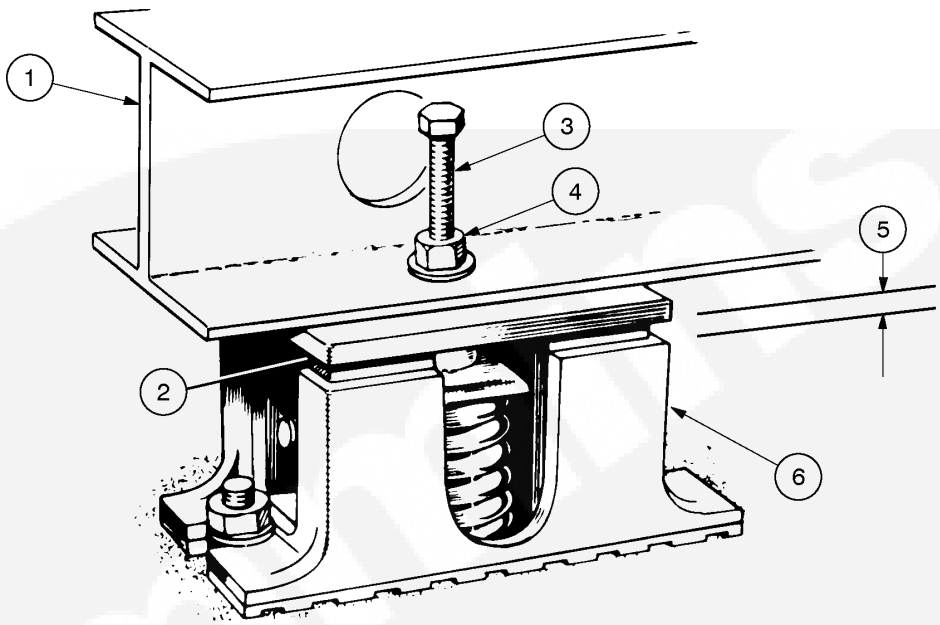
6.3 Access to Set

Generally, at least 1 meter (3.3 feet) of clearance should be provided on all sides of the generator set for maintenance and service access. (Increase clearance by width of door if optional housing is used.) A raised foundation or slab of 152 mm (6 inches) or more above floor level will make servicing easier. Lighting should be adequate for operation, maintenance and service operations and should be connected on the load side of the transfer switch so that it is available at all times.

6.4 Vibration Isolator Installation and Adjustment Procedure

1. Place the vibration isolators (see **Figure 8 on page 31**) on the generator set support structure. The isolators should be shimmed or grouted to make sure that all of the isolator bases are within 0.25 inch (6 mm) elevation of each other. The surface that the isolator bases rest on must also be flat and level.
2. Loosen the side snubber lock nuts so that the top plate of the isolator is free to move vertically and horizontally. Be sure that the top plate is correctly aligned with the base and springs.
3. Place the generator set onto the isolators while aligning the skid's mounting with the threaded isolator hole. The top plates will move down and approach the base of the isolator as load is applied.
4. Once the generator set is in position, the isolators may require adjusting so that the set is level. The isolators are adjusted by inserting the leveling bolt through the skid and into the isolator (the leveling bolt's locking nut should be threaded up towards the bolt head).

   The leveling bolt will adjust the clearance between the top plate and the isolator base. A nominal clearance of 0.25 inch (6 mm) or greater is desired. This will provide sufficient clearance for the rocking that occurs during startup and shutdown. If the 0.25 inch (6 mm) clearance is not present, turn the leveling bolt until the desired clearance is achieved.
5. If the radiator and engine are mounted on separate skids, make sure the radiator skid and engine/alternator skid are level with each other after adjusting the isolators. If not level, proper fan belt alignment cannot be achieved.
6. The generator set may not be level yet; therefore, adjust the leveling bolts until the set is level and sufficient clearance still remains. (Clearance on all isolators should be roughly equal). Once all isolators have been set, lock the leveling bolt in place with the lock nut.
7. The snubber nuts must remain loose and therefore provide better isolation between the generator set and the support structure.



No.	Description	No.	Description
1	Skid	4	Lock Nut
2	Snubber	5	Clearance
3	Leveling Bolt	6	Base

FIGURE 8. VIBRATION ISOLATOR INSTALLATION

6.5 Rigging Instructions

WARNING: Incorrect generator set installation can result in severe personal injury, death, and/or equipment damage. Personnel must be trained and experienced in rigging and hoisting.

WARNING: Improper lifting can result in severe personal injury or death. Do not stand under or near the generator set when lifting. Failing to follow these instructions can result in load rotating without warning.

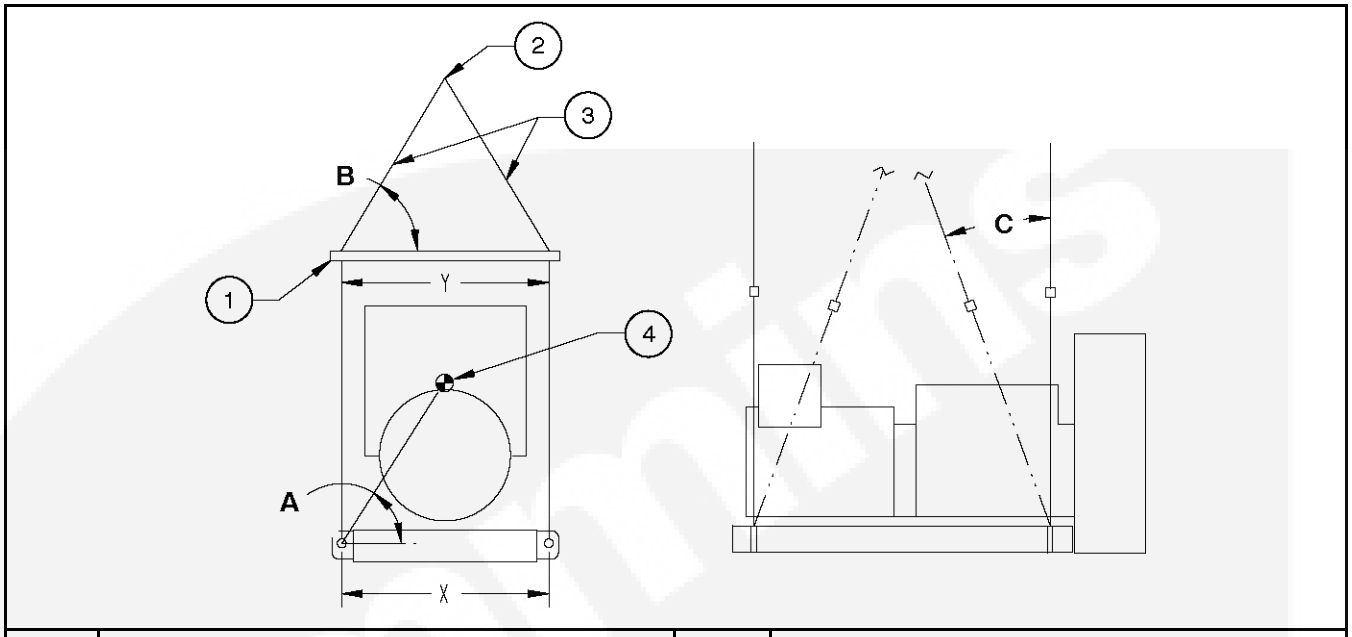
1. Consult the generator set outline drawing for weight and center-of-gravity information.
2. Attach cables from the lifting lugs to a spreader bar. Never make the spreader bar cable attachment points wider than the attachment points on the skid or the bars. Make sure cables do not touch any other part of the generator set other than the skid.

NOTE: Spreader bar cable attach points width "Y" must never be wider than skid cable attach points "X." Distance "X" is the narrowest width.

NOTE: Angle B must be slightly greater than angle A. Angle B should be as close to 90 degrees as possible to provide a stable lift.

3. With pedestal box (not shown), the spreader bars (front and back) should be used to clear the pedestal box and the attachment cables must be as vertical as possible.

NOTE: The lifting angle (angle C) must not exceed 20 degrees from vertical.



Item	Description	Item	Description
A	Angle A	1	Spreader Bar
B	Angle B	2	Lifting Point
C	Angle C (20 Degrees Maximum)	3	Lifting Cables
X	The Narrowest Width (On the Skid)	4	Center of Gravity
Y	This distance must be less than distance "X"		

FIGURE 9. RIGGING

6.6 Moving the Generator Set

WARNING: Transportation and handling of generator sets must only be undertaken by suitably trained and experienced personnel.

It is essential that there are sufficient trained and experienced personnel in attendance to ensure the lifting and transportation of the generator set is undertaken in a safe and appropriate manner and in accordance to local guidelines and legislation.

WARNING: Do not lift the generator set by attaching to the engine or alternator lifting points. Improper handling of the generator set may cause serious damage to the generator set and its components and can result in severe personal injury or death.

Before lifting the generator set, lifting points, angle of slings, mass, access to intended site, and the distance of movement should all be taken into account when organizing a suitable crane/hoist. Consult the generator set information supplied with your generator set for details of dimensions and mass.

- Ensure that the crane operating area is able to support the mass of the crane and the generator set.

WARNING: Do not use the generator set as a means of access when attaching lifting shackles, chains etc. Use as access may damage the generator set and/or can result in severe personal injury or death.

WARNING: On an enclosed generator set, the canopy doors must be locked before re-positioning and they must remain locked during transportation and sitting.

- Ensure the equipment used for lifting is adequate to support the weight of the generator set.
- Attach the lifting device to the lifting points only, using suitable shackles, chains and spreader bars.
- Slowly tighten the slings. Inspect the lifting attachments before commencing a full lift to ensure they are attached correctly.
- Hoist the generator set slowly using the indicated lifting points only.

WARNING: Never stand underneath a lifted generator set. Contact with a lifted generator set can result in severe personal injury or death.

- Guide the generator set with ropes at a safe distance, to prevent uncontrolled rotation when positioning the generator set.
- Move the generator set to the desired location and place in position, bringing the set down slowly.
- Loosen the slings; unhook and remove the shackles.

6.6.1 Positioning a Generator Set Using a Forklift Truck

WARNING: Transportation and handling of generator sets by forklift trucks must only be undertaken by suitably trained and experienced personnel who are familiar with the transport of these items.

If using a forklift truck to transport/position the generator set, the dimensions, mass, and route must be taken into account when selecting an appropriate lifting truck.

WARNING: Do not attempt to lift a generator set with an undersized forklift truck. Improper handling of the generator set may cause serious damage to the generator set and its components and can result in severe personal injury or death.

It is essential that there are sufficient trained and experienced personnel in attendance to ensure the lifting and transportation of the generator set is undertaken in a safe and appropriate manner and in accordance to local guidelines and legislation.

WARNING: A generator set must not be moved with a forklift truck if it is attached to the trailer. Improper handling of the generator set may cause serious damage to the generator set and its components and can result in severe personal injury or death.

WARNING: On an enclosed generator set, the canopy doors must be locked before re-positioning and they must remain locked during transportation and sitting.

- Fully insert the arms of the forklift into the forklift pockets, making sure the generator set completely rests on the forklift arms.
- Lift and handle the equipment slowly.
- Slowly set down the generator set in its final position.

6.7 Transportation

WARNING: Transportation and handling of generator sets must only be undertaken by suitably trained and experienced personnel who are familiar with the transport of these items.

WARNING: Do not lift the generator set by attaching to the engine or alternator lifting points. Improper handling of the generator set may cause serious damage to the generator set and its components and can result in severe personal injury or death.

WARNING: On an enclosed generator set, the canopy doors must be locked before re-positioning and must remain locked during transportation and siting.

- Ensure the generator set is prepared for transport. If necessary drain fluids and ensure that acid or fumes do not leak from the battery (where applicable).
- If the generator set is transported over along distances, protect it against environmental influences by sealing it in a plastic cover or similar.
- For lifting procedures, see **Section 6.6 on page 32**.
- Ensure the generator set is secured to the vehicle with suitable securing straps. Wooden chocks and pallets alongside the securing straps can prevent movement during transportation.
- If required, attached impact indicators to the generator set. Upon delivery, check these impact indicators and contact the transport company immediately if an impact has been detected. Impacts can cause serious damage to the generator set and its components.
- Ensure that the generator set cannot turn over during transportation.
- Do not overload the transport vehicle. Under no circumstances should the generator set be started while inside a truck.
- Lifting eyes where fitted are to be checked at regular intervals to ensure they are damage free and tight.

7 Mechanical Connections

The generator set mechanical system installation includes connecting the fuel, exhaust, ventilation, and cooling systems. Before starting any type of fuel installation, all pertinent state and local codes must be complied with and the installation must be inspected before the unit is put in service.

7.1 Fuel System

In all fuel system installations, cleanliness is of the utmost importance. Make every effort to prevent entrance of moisture, dirt, or contaminants of any kind into the fuel system. Clean all fuel system components before installing. Use only compatible metal fuel lines to avoid electrolysis when fuel lines must be buried. Buried fuel lines must be protected from corrosion.

7.1.1 Gaseous Fuel Supply

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

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

- The gas supplied to the generator set must be of acceptable quality. Refer to the Application Manual T-030, "Liquid Cooled Generator Sets" for more detailed information about Cummins approved fuel types and quality.
- The gas supply must have sufficient pressure (defined for each generator set on the respective data-sheets). Care must be taken to be sure that the gas supply *at the generator set*, not just at the source, is of proper pressure for operation. The specified pressure must be available while the generator set is running at full load.
- The gas must be supplied to the generator set in sufficient volume to support operation of the generator set. This is normally a matter of selecting fuel line size to be large enough to transport the volume of fuel needed. For LP vapor-withdrawal fuel systems the size and temperature of the fuel tank also affects this requirement.

Failure to meet the minimum requirements of the generator set in these areas will result in the inability of the generator set to operate, or inability to carry rated load, or poor transient performance. Insufficient flow can also result in engine damage or catastrophic failure.

7.1.2 Gaseous Fuel Quality

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

7.1.2.1 Energy Content

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

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

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

7.1.2.2 Pipeline Natural Gas

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

7.1.2.3 Field Gas

The composition of Field Natural Gas varies considerably by region and by continent. Careful analysis is necessary prior to using Field Natural Gas in an engine. Field Natural Gas can contain heavier hydrocarbon gases such as Pentane, Hexane and Heptane, which may require derating of the output of the engine. Other contaminants, such as Sulfur, may also be present in the fuel. A typical Field Gas might have an LHV of 1203 BTU/ft^3, and an HHV of 1,325 BTU/ft^3.

7.1.2.4 Propane/Liquid Petroleum Gas (LPG)

Propane is available in two grades, either commercial or special duty. Commercial Propane is used where high volatility is required. Not all spark-ignition engines will operate acceptably with this fuel due to its volatility. Special duty Propane (also called HD5) is a mixture of 95% Propane and other gases, such as Butane, that allow better engine performance due to the reduction pre-ignition due to reduced volatility. Special duty Propane fuel gas that meets the ASTM D 1835 specification for special-duty Propane (equivalent to HD-5 Propane of Gas Producers Association Standard 2140) is suitable for most engines. Propane has an LHV of approximately 2,353 BTU/ft3, and an HHV of 2,557 BTU/ft3. The higher heating value of the fuel necessitates mixing of different volumes of air in the fuel system for Propane vs. Natural Gas applications, so dual fuel engines essentially have two fuel arrangements for this purpose.

NOTE: ***Clarification of abbreviations often seen*:**

LP - Liquid Petroleum or Propane

LPV - Propane Vapor (gaseous fuel)

LPL - Propane Liquid (liquid fuel)

LPG - Liquid Petroleum Gas

****LPG and LP are the same and are often used interchangeably.****

7.1.2.5 Contaminants

The most harmful contaminants in gaseous fuels are water vapor and Sulfur.

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

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

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

7.1.2.6 Fuel Analysis

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

1. List the percent of each gas constituent in the fuel.
2. Calculate the percent of the total fuel that is combustible. The combustible portion of the fuel is 100% less the inert component percentages. Inert components include Oxygen, Carbon Dioxide and water vapor.
3. Calculate the percent of each combustible component of the fuel.
4. Verify acceptability of the fuel by checking the percent of each combustible element vs. the recommendations of the engine manufacturer.

   For example, for a gas analysis of:

   90% Methane

   6% Ethane

   2% Hydrogen

   1% Normal Pentane

1% Nitrogen

- Total percent inert elements: 1%
- Total combustible: 100% - 1% = 99%
- % Methane: 90% ÷ 99% = 91%
- % Ethane: 6% ÷ 99% = 6.1%
- % Hydrogen: 2% ÷ 99% = 2%
- % Normal Pentane: 1% ÷ 99% = 1%

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

5. Verify the rating of the generator set based on the use of the proposed fuel.

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

Note that the fuel derating and the altitude/temperature derating 21 are not additive. Only the maximum value of the fuel derate or the altitude/temperature derate need be applied.

Turbocharged engines have unique fuel composition requirements due to higher cylinder pressures. To avoid problems with pre-ignition or denotation, power output derating is required if propane and/or ISO-Butane content exceed the percentages listed in the following tables.

TABLE 6. MAXIMUM ALLOWABLE PERCENTAGES FOR ENGINE FUEL COMBUSTIBLES

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

TABLE 7. MAXIMUM ALLOWABLE PERCENTAGES OF CONSTITUENT GASES BEFORE DERATING TURBOCHARGED ENGINES

	8.5:1 Compression Ratio	**10.5:1 Compression Ratio**

Methane	N/A	N/A
Ethane	N/A	N/A
Propane	5%	*
ISO-Butane	2%	*
*High compression ratio turbocharged engines cannot consume any Propane or ISO-Butane.		

7.1.3 Site Fuel System Design

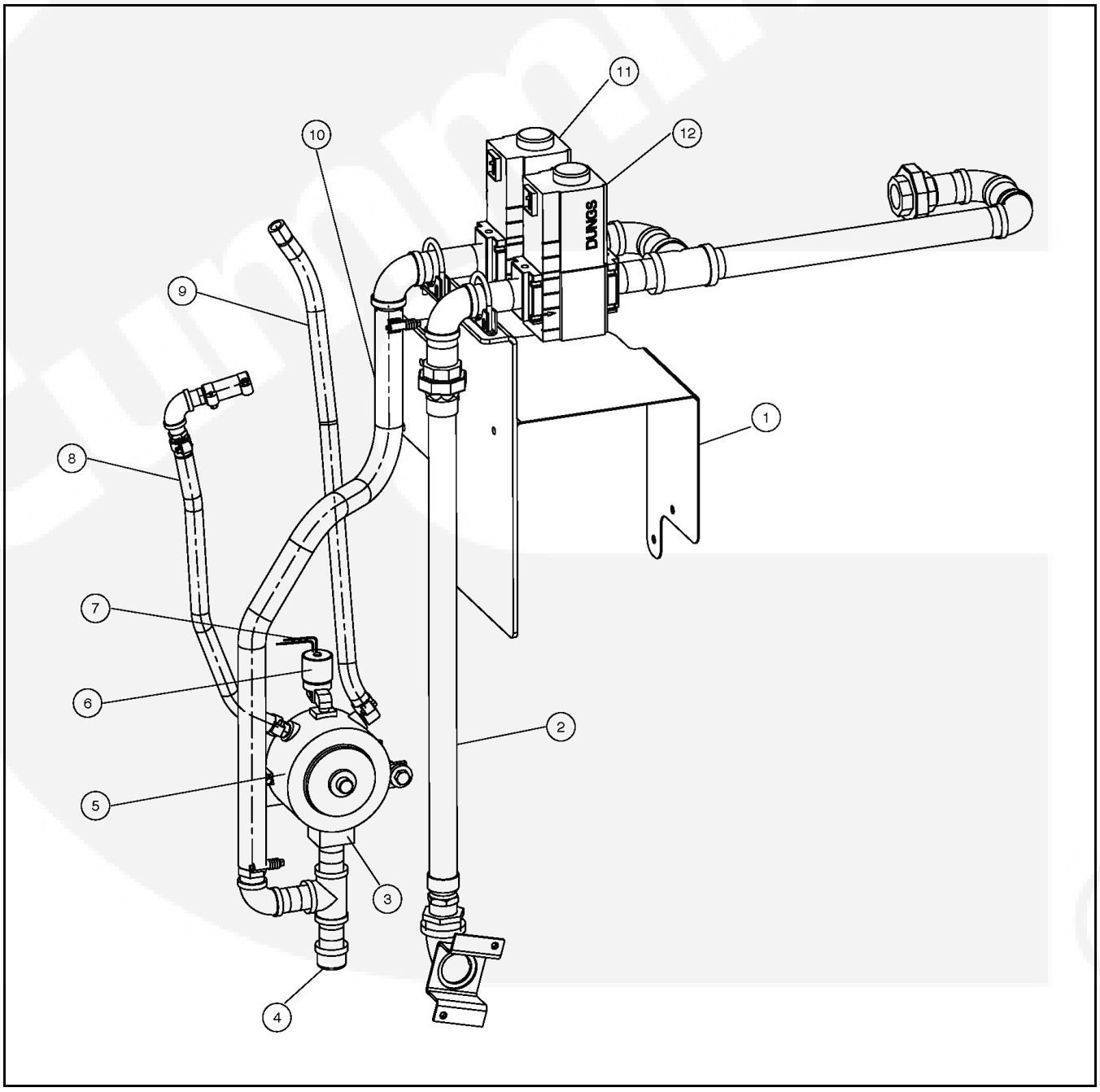
The following should be considered when installing a natural gas and/or LPG fuel system:

- Gaseous-fuel supply system design, materials, components, fabrication, assembly, installation, testing, inspection, operation, and maintenance must comply with all applicable codes (In North America, NFPA Standards No.30, No.37, No.54 and No. 58 are typical).
- The layout and sizing of gas piping must be adequate for handling the volume of gas required by the generator set and all other equipment, such as building heating boilers, supplied by the same source. Full-load gas flow (see the recommended generator set Data Sheet) must be available at not less than the minimum required supply pressure, typically from 7 to 13.6 inches WC (water column), depending on model. Final determination of pipe sizes must, however, be based upon the method approved by the authority having jurisdiction (see NFPA No.54).
- Most installations will require a service gas pressure regulator. Gas supply pressure should not exceed 14 inches WC, depending on model, at the inlet to the generator set. Refer to the generator set data sheet for model specific details. Depending on distribution gas pressure, more than one stage of pressure regulation may be required. High-pressure gas piping is not permitted inside buildings (5 psig for natural gas and 20 psig for LPG, unless higher pressures are approved by the authority having jurisdiction). Gas pressure regulators must be vented to the outdoors according to code.
- The pressure regulator installed on the supply line at the gas source for generator applications should never be a "pilot" regulator. A "pilot" style regulator is the type where the regulator requires a pressure line from the regulator housing to the downstream gas pipe to "sense" when downstream pressure has dropped. Pilot regulators do not work because the response time is unacceptable compared to the large instantaneous changes in demand from the generator set.
- Approved fuel hose must be used for connections at the engine to take up generator set movement and vibration.
- Most codes require both manual and electric (battery-powered) shutoff valves ahead of the flexible fuel hose(s). The manual valve should be of the indicating type.
- A dryer fuel filter should be installed in each line as shown in **Figure 6-69** to protect the sensitive pressure regulating components and orifices downstream from harmful foreign substances carried along in the gas stream (rust, scale, etc.)
- An LPG fuel supply system must be dedicated for the emergency power system if it is the required alternative fuel.
- An LPG vaporizer heated by engine coolant is factory installed on Cummins Power Generation generator sets equipped for a liquid-withdrawal of LPG. Because high pressure (20 psig or greater) gas piping is not permitted inside buildings, generator sets equipped for liquid withdrawal of LPG must not be installed inside the building. (Weather-protective housings for outdoor installation are available for most LPG models.)

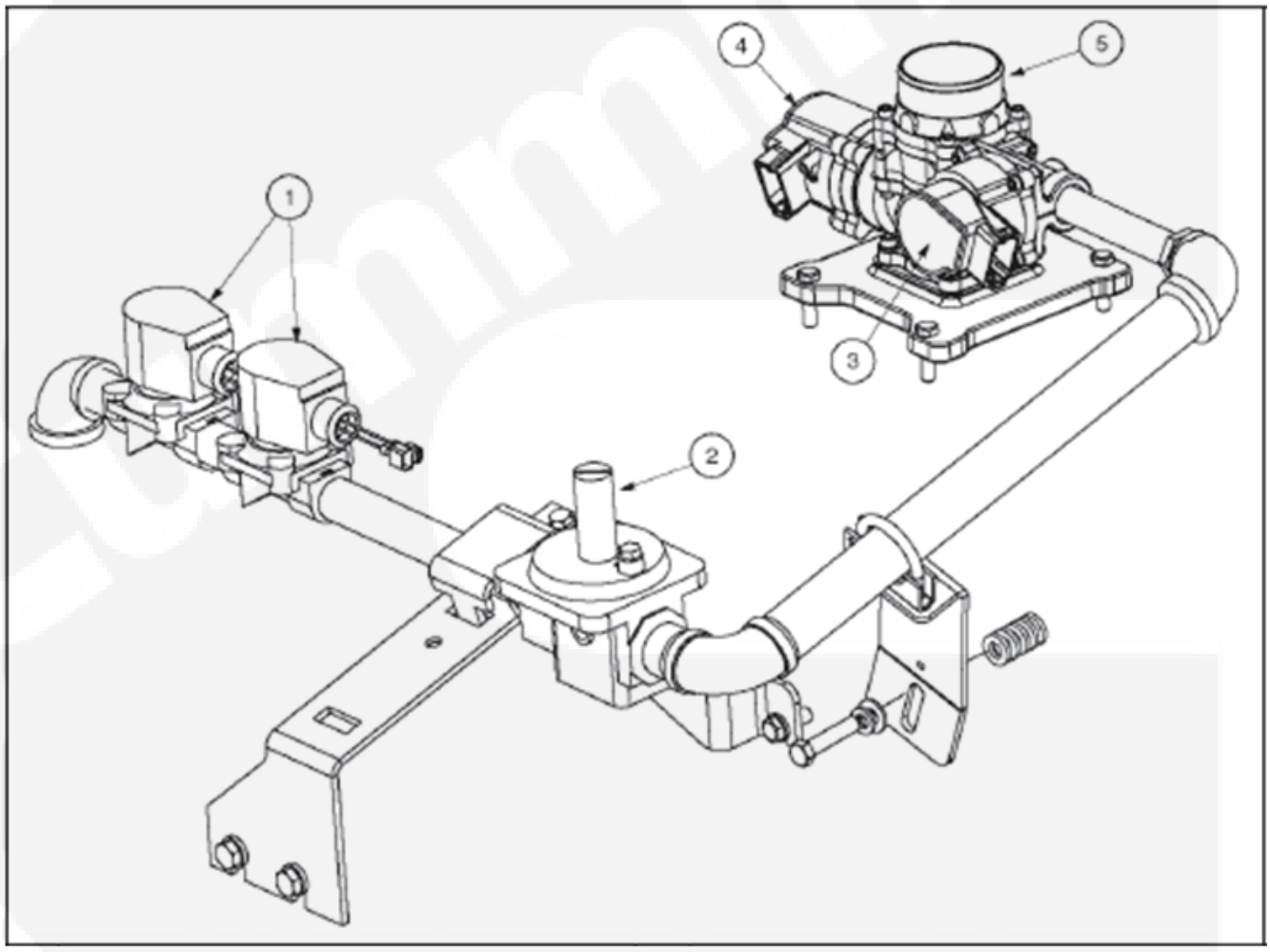
- The rate of vaporization in an LPG tank depends upon the outdoor air temperature, unless the tank is equipped with a heater, and the quality of fuel in the tank. Even on cold days outdoor air heats and vaporizes LPG (mostly through the wetted tank surface) when air temperature is higher than LPG temperature. Withdrawing vapor causes tank temperature and pressure to drop. (At -37°F [-38°C] LPG has zero vapor pressure.) Unless there is enough fuel and enough heat available from ambient air, the vaporization rate will drop off, as the generator set runs, to less than that required to continue running properly.

Refer to Application Manual T-030 "Liquid Cooled Generator Sets" or Cummins Sales Application Engineering for more information on Site Fuel System Design.

FIGURE 10. GASEOUS FUEL SYSTEM.



No.	Description	No.	Description
1	Heat shield	7	Wire leads
2	Fuel line (Natural Gas)	8	Coolant hose
3	Vapor outlet	9	Fuel hose (Propane vapor)
4	Pipe cap	10	Coolant hose
5	Converter	11	Fuel shutoff solenoid (Propane vapor)
6	Solenoid valve	12	Fuel shutoff solenoid (Natural Gas)



No.	Description	No.	Description
1	Solenoid Valve	4	Governor Actuator
2	Pressure Regulator	5	Fuel Mixer
3	Fuel Control		

FIGURE 11. TYPICAL GASEOUS FUEL SYSTEM

7.1.4 Gaseous Fuel System Calculations

Tank Size

Use the "Minimum LPG Tank Size (50% Full) Required to Maintain 5 PSIG at Specific Withdrawal Rate and Minimum Expected Winter Temperature" figure as a quick reference for sizing an LPG tank on the basis of the lowest ambient temperature expected. For example, on a 40F day, withdrawal at 1000 ft^3/hr requires a 2000 gallon tank at least half full. Note: In many instances the amount of total fuel required for proper vaporization is far greater than that required for the number of hours of operation stipulated by code.

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

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

FIGURE 12. TANK SIZE EQUATION.

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

Gas Pipe Sizing

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

Notes about the following tables:

- Equivalent Lengths of Pipe Fittings and Valves applies to gas as well as liquid piping.
- Show maximum gas capacity for equivalent length for various pipe sizes.
- Show maximum gas capacity for equivalent length for various pipe sizes.
- Reproduced from NFPA 54-2002, National Fuel Gas Code, and are selected considering the general fuel system operating requirements for generator sets.
- Included for natural gas, propane liquid withdrawal and propane vapor withdrawal under specified conditions.
- Consult NFPA 54 or other applicable codes for other operating conditions or other fuel system installation requirements.

A calculation of minimum pipe size is fairly straightforward:

- Make a list of all the fittings and valves in a proposed system and sum their equivalent lengths using the table.
- Add to this total, all lengths of straight pipe to arrive at a total equivalent length.
- Choose the applicable table based on the fuel system.
- Obtain the maximum fuel requirements for the specific generator set(s) from the manufacturer's specification sheets. Convert to ft3/hr as needed (Be cognizant of BTU content as discussed earlier in this section.)

- Locate the equivalent length of pipe (or next larger equivalent length) in the left hand column. Move across to the columns to where the number is as large or larger than the total equivalent length calculated above. At the top of that column is the minimum nominal pipe size or tubing size required for the system as designed.

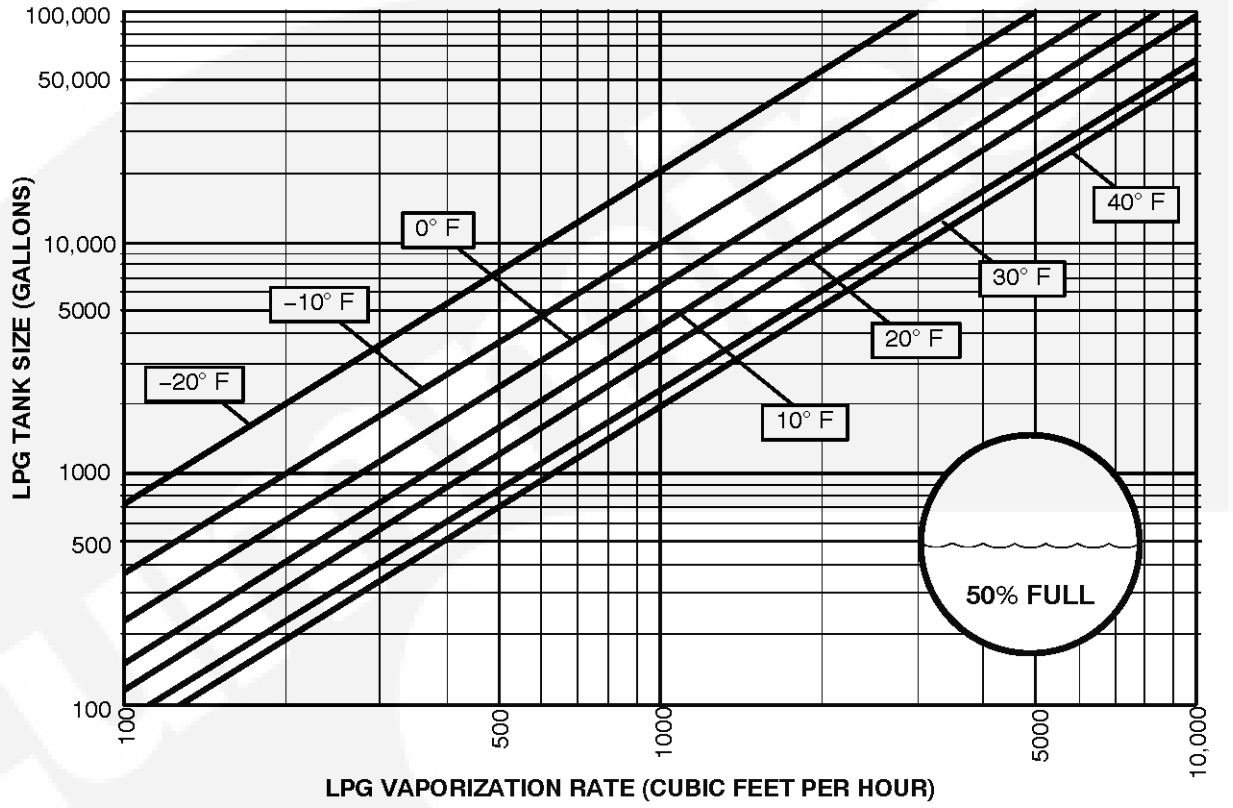


FIGURE 13. MINIMUM LPG TANK SIZE (50% FULL) REQUIRED TO MAINTAIN 5 PSIG AT SPECIFIC WITHDRAWAL RATE AND MINIMUM EXPECTED WINTER TEMPERATURE

TABLE 8. NATURAL GAS SCHEDULE 40 IRON PIPE SIZING (1/4-3/4 IN.)

Gas: Natural **Inlet Pressure: 0.5 psi or less** **Pressure Drop: 0.5 in. w.c.** **Specific Gravity: 0.60**				
	Pipe Size (in.)			
Nominal	1/4	3/8	1/2	3/4
Actual ID	(0.364)	(0.493)	(0.622)	(0.824)
Length (ft.)	**Maximum Capacity in Cubic Feet of Gas per Hour**			
10	43	95	175	360
20	29	65	120	250
30	24	52	97	200
40	20	45	82	170

50	18	40	73	151
60	16	36	66	138
70	15	33	61	125
80	14	31	57	118
90	13	29	53	110
100	12	27	50	103
125	11	24	44	93
150	10	22	40	84
175	9	20	37	77
200	8	19	35	72

TABLE 9. NATURAL GAS SCHEDULE 40 IRON PIPE SIZING (1-2 IN.)

Gas: Natural **Inlet Pressure: 0.5 psi or less** **Pressure Drop: 0.5 in. w.c.** **Specific Gravity: 0.60**				
	Pipe Size (in.)			
Nominal	1	1 1/4	1 1/2	2
Actual ID	(1.049)	(1.380)	(1.610)	(2.067)
Length (ft.)	**Maximum Capacity in Cubic Feet of Gas per Hour**			
10	680	1400	2100	3950
20	465	950	1460	2750
30	375	770	1180	2200
40	320	660	990	1900
50	285	580	900	1680
60	260	530	810	1520
70	240	490	750	1400
80	220	460	690	1300
90	205	430	650	1220
100	195	400	620	1150
125	175	360	550	1020
150	160	325	500	950
175	145	300	460	850
200	135	280	430	800

TABLE 10. NATURAL GAS SCHEDULE 40 IRON PIPE SIZING (2 1/2-4 IN.)

Gas: Natural **Inlet Pressure: 0.5 psi or less** **Pressure Drop: 0.5 in. w.c.** **Specific Gravity**			
	Pipe Size (in.)		
Nominal	2 1/2	3	4
Actual ID	(2.469)	(3.068)	(4.026)
Length (ft.)	**Maximum Capacity in Cubic Feet of Gas per Hour**		
10	6300	11000	23000
20	4350	7700	15800
30	3520	6250	12800
40	3000	5300	10900
50	2650	4750	9700
60	2400	4300	8800
70	2250	3900	8100
80	2050	3700	7500
90	1950	3450	7200
100	1850	3250	6700
125	1650	2950	6000
150	1500	2650	5500
175	1370	2450	5000
200	1280	2280	4600

TABLE 11. NATURAL GAS SEMI-RIGID COPPER TUBING SIZING (1/4-3/4IN.)
*TABLE CAPACITIES ARE BASED ON TYPE K COPPER TUBING INSIDE DIAMETER (SHOWN), WHICH HAS THE SMALLEST INSIDE DIAMETER OF THE COPPER TUBING PRODUCTS.

Gas: Natural **Inlet Pressure: 0.5 psi or less** **Pressure Drop: 0.5 in. w.c.** **Specific Gravity: 0.6**						
		Tube Size (in.)				
Nominal	**K&L**	1/4	3/8	1/2	5/8	3/4
	ACR	3/8	1/2	5/8	3/4	7/8
Outside		0.375	0.500	0.625	0.750	0.875
Inside*		0.305	0.402	0.527	0.652	0.745
Length (ft.)		**Maximum Capacity in Cubic Feet of Gas per Hour**				
10		27	55	111	195	276
20		18	38	77	134	190
30		15	30	61	107	152

40	13	26	53	92	131
50	11	23	47	82	116
60	10	21	42	74	105
70	9.3	19	39	68	96
80	8.6	18	36	63	90
90	8.1	17	34	59	84
100	7.6	16	32	56	79
125	6.8	14	28	50	70
150	6.1	13	26	45	64
175	5.6	12	24	41	59
200	5.2	11	22	39	55
250	4.7	10	20	34	48
300	4.2	8.7	18	31	44

TABLE 12. NATURAL GAS SEMI-RIGID COPPER TUBING SIZING (1-2 1/2IN.)
***TABLE CAPACITIES ARE BASED ON TYPE K COPPER TUBING INSIDE DIAMETER (SHOWN), WHICH HAS THE SMALLEST INSIDE DIAMETER OF THE COPPER TUBING PRODUCTS.**

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

		Tube Size (in.)				
Nominal	**K&L**	1	1 1/4	1 1/2	2	2 1/2
	ACR	1 1/8	1 3/8	1 5/8	2 1/8	2 5/8
Outside		1.125	1.375	1.625	2.125	2.625
Inside*		0.995	1.245	1.481	1.959	2.435
Length (ft.)		**Maximum Capacity in Cubic Feet of Gas per Hour**				
10		590	1062	1675	3489	6173
20		406	730	1151	2398	4242
30		326	586	925	1926	3407
40		279	502	791	1648	2916
50		247	445	701	1461	2584
60		224	403	635	1323	2341
70		206	371	585	1218	2154
80		192	345	544	1133	2004
90		180	324	510	1063	1880
100		170	306	482	1004	1776
125		151	271	427	890	1574
150		136	245	387	806	1426
175		125	226	356	742	1312

200	117	210	331	690	1221
250	103	186	294	612	1082
300	94	169	266	554	980

TABLE 13. PROPANE VAPOR SCHEDULE 40 IRON PIPE SIZING (1/2-1 1/2IN.)

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

	Pipe Size (in.)				
Nominal Inside	1/2	3/4	1	1 1/4	1 1/2
Actual:	0.622	0.824	1.049	1.38	1.61
Length (ft.)	**Maximum Capacity in Thousands of Btu per Hour**				
10	291	608	1145	2352	3523
20	200	418	787	1616	2422
30	160	336	632	1298	1945
40	137	287	541	1111	1664
50	122	255	480	984	1475
60	110	231	434	892	1337
80	94	197	372	763	1144
100	84	175	330	677	1014
125	74	155	292	600	899
150	67	140	265	543	814
200	58	120	227	465	697
250	51	107	201	412	618
300	46	97	182	373	560
350	42	89	167	344	515
400	40	83	156	320	479

TABLE 14. PROPANE VAPOR SCHEDULE 40 IRON PIPE SIZING (2-4IN.)

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

	Pipe Size (in.)			
Nominal Inside	2	3	3 1/2	4
Actual:	2.067	3.068	3.548	4.026

Length (ft.)	Maximum Capacity in Thousands of Btu per Hour			
10	6786	19119	27993	38997
20	4664	13141	19240	26802
30	3745	10552	15450	21523
40	3205	9031	13223	18421
50	2841	8004	11720	16326
60	2574	7253	10619	14793
80	2203	6207	9088	12661
100	1952	5501	8055	11221
125	1730	4876	7139	9945
150	1568	4418	6468	9011
200	1342	3781	5536	7712
250	1189	3351	4906	6835
300	1078	3036	4446	6193
350	991	2793	4090	5698
400	922	2599	3805	5301

TABLE 15. PROPANE VAPOR SEMI-RIGID COPPER TUBING SIZING (1/4-3/4IN.)
***TABLE CAPACITIES ARE BASED ON TYPE K COPPER TUBING INSIDE DIAMETER (SHOWN), WHICH HAS THE SMALLEST INSIDE DIAMETER OF THE COPPER TUBING PRODUCTS.**

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

		Tube Size (in.)				
Nominal	**K&L**	1/4	3/8	1/2	5/8	3/4
	ACR	3/8	1/2	5/8	3/4	7/8
Outside		0.375	0.500	0.625	0.750	0.875
Inside*		0.305	0.402	0.527	0.652	0.745
Length (ft.)		Maximum Capacity in Thousands of Btu per Hour				
10		45	93	188	329	467
20		31	64	129	226	321
30		25	51	104	182	258
40		21	44	89	155	220
50		19	39	79	138	195
60		17	35	71	125	177
70		16	32	66	115	163
80		15	30	61	107	152
90		14	28	57	100	142

100	13	27	54	95	134
125	11	24	48	84	119
150	10	21	44	76	108
175	10	20	40	70	99
200	8.9	18	37	65	92
225	8.3	17	35	61	87
250	7.9	16	33	58	82
275	7.5	15	31	55	78
300	7.1	15	30	52	74

TABLE 16. PROPANE VAPOR SEMI-RIGID COPPER TUBING SIZING (1-2 1/2IN.)
***TABLE CAPACITIES ARE BASED ON TYPE K COPPER TUBING INSIDE DIAMETER (SHOWN), WHICH HAS THE SMALLEST INSIDE DIAMETER OF THE COPPER TUBING PRODUCTS.**

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

		Tube Size (in.)				
Nominal	**K&L**	1	1 1/4	1 1/2	2	2 1/2
	ACR	1 1/8	1 3/8	1 5/8	2 1/8	2 5/8
Outside		1.125	1.375	1.625	2.125	2.625
Inside*		0.995	1.245	1.481	1.959	2.435
Length (ft.)		**Maximum Capacity in Thousands of Btu per Hour**				
10		997	1795	2830	5895	10429
20		685	1234	1945	4051	7168
30		550	991	1562	3253	5756
40		471	848	1337	2784	4926
50		417	752	1185	2468	4366
60		378	681	1074	2236	3956
70		348	626	988	2057	3639
80		324	583	919	1914	3386
90		304	547	862	1796	3177
100		287	517	814	1696	3001
125		254	458	722	1503	2660
150		230	415	654	1362	2410
175		212	382	602	1253	2217
200		197	355	560	1166	2062
225		185	333	525	1094	1935
250		175	315	496	1033	1828

275	166	299	471	981	1736
300	158	285	449	936	1656

TABLE 17. PROPANE SCHEDULE 40 IRON PIPE SIZING, LIQUID WITHDRAWAL - MAXIMUM CAPACITY OF PIPE IN CUBIC FEET OF GAS PER HOUR. PIPE SIZE RECOMMENDATIONS ARE BASED ON SCHEDULE 40 BLACK IRON PIPE. (1/2 -1 1/2IN.)

Equivalent Length of Pipe, ft.	Schedule 40 Iron Pipe Size, in.: Nominal (Inside Diameter)				
	1/2 (0.622)	**3/4 (0.824)**	**1 (1.049)**	**1 1/4 (1.38)**	**1 1/2 (1.61)**
30	733	1532	2885	5924	8876
40	627	1311	2469	5070	7597
50	556	1162	2189	4494	6733
60	504	1053	1983	4072	6100
70	463	969	1824	3746	5612
80	431	901	1697	3484	5221
90	404	845	1593	3269	4899
100	382	798	1504	3088	4627
150	307	641	1208	2480	3716
200	262	549	1034	2122	3180
250	233	486	916	1881	2819
300	211	441	830	1705	2554
350	194	405	764	1568	2349
400	180	377	711	1459	2186
450	169	354	667	1369	2051
500	160	334	630	1293	1937
600	145	303	571	1172	1755
700	133	279	525	1078	1615
800	124	259	488	1003	1502
900	116	243	458	941	1409
1000	110	230	433	889	1331
1500	88	184	348	713	1069
2000	76	158	297	611	915

TABLE 18. PROPANE SCHEDULE 40 IRON PIPE SIZING. LIQUID WITHDRAWAL - MAXIMUM CAPACITY OF PIPE IN CUBIC FEET OF GAS PER HOUR. PIPE SIZE RECOMMENDATIONS ARE BASED ON SCHEDULE 40 BLACK IRON PIPE. (2-4IN.)

Equivalent Length of Pipe, ft.	Schedule 40 Iron Pipe Size, in.: Nominal (Inside Diameter)			
	2 (2.067)	**3 (3.068)**	**3 1/2 (3.548)**	**4 (4.026)**

30	17094	48164	70519	98238
40	14630	41222	60355	84079
50	12966	36534	53492	74518
60	11748	33103	48467	67519
70	10808	30454	44589	62116
80	10055	28331	41482	57787
90	9434	26583	38921	54220
100	8912	25110	36764	51216
150	7156	20164	29523	41128
200	6125	17258	25268	35200
250	5428	15295	22395	31198
300	4919	13859	20291	28267
350	4525	12750	18667	26006
400	4209	11861	17366	24193
450	3950	11129	16295	22700
500	3731	10512	15391	21442
600	3380	9525	13946	19428
700	3110	8763	12830	17873
800	2893	8152	11936	16628
900	2715	7649	11199	15601
1000	2564	7225	10579	14737
1500	2059	5802	8495	11834
2000	1762	4966	7271	10128

TABLE 19. EQUIVALENT LENGTHS OF PIPE FITTINGS IN FEET (METERS) (2-6IN.)

Type of Fitting	**Nominal Inch (Millimeter) Pipe Size**						
	2 (50)	**2 1/2 (65)**	**3 (80)**	**3 1/2 (90)**	**4 (100)**	**5 (125)**	**6 (150)**
90° Standard Elbow	5.2 (1.6)	6.2 (1.9)	7.7 (2.3)	9.6 (2.9)	10 (3.0)	13 (4.0)	15 (4.6)
90° Medium Radius Elbow	4.6 (1.4)	5.4 (1.6)	6.8 (2.1)	8 (2.4)	9 (2.7)	11 (3.4)	13 (4.0)
90° Long Radius Elbow	3.5 (1.1)	4.2 (1.3)	5.2 (1.6)	6 (1.8)	6.8 (2.1)	8.5 (2.6)	10 (3.0)
45° Elbow	2.4 (0.7)	2.9 (0.9)	3.6 (1.1)	4.2 (1.3)	4.7 (1.4)	5.9 (1.8)	7.1 (2.2)
TEE, Side Inlet or Outlet	10 (3.0)	12 (3.7)	16 (4.9)	18 (5.5)	20 (6.1)	25 (7.6)	31 (9.4)

18 Inch Flexible Tube	3 (0.9)	3 (0.9)	3 (0.9)	3 (0.9)	3 (0.9)	3 (0.9)	3 (0.9)
24 Inch Flexible Tube	4 (1.2)	4 (1.2)	4 (1.2)	4 (1.2)	4 (1.2)	4 (1.2)	4 (1.2)

TABLE 20. EQUIVALENT LENGTHS OF PIPE FITTINGS IN FEET (METERS) (8-18IN.)

Type of Fitting	Nominal Inch (Millimeter) Pipe Size					
	8 (200)	**10 (250)**	**12 (300)**	**14 (350)**	**16 (400)**	**18 (450)**
90° Standard Elbow	21 (6.4)	26 (7.9)	32 (9.8)	37 (11.3)	42 (12.8)	47 (14.3)
90° Medium Radius Elbow	18 (5.5)	22 (6.7)	26 (7.9)	32 (9.8)	35 (10.7)	40 (12.2)
90° Long Radius Elbow	14 (4.3)	17 (5.2)	20 (6.1)	24 (7.3)	26 (7.9)	31 (9.4)
45° Elbow	6 (1.8)	8 (2.4)	9 (2.7)	17 (5.2)	19 (5.8)	22 (6.7)
TEE, Side Inlet or Outlet	44 (13)	56 (17)	67 (20)	78 (23.8)	89 (27.1)	110 (33.5)
18 Inch Flexible Tube	3 (0.9)	3 (0.9)	3 (0.9)	3 (0.9)	3 (0.9)	3 (0.9)
24 Inch Flexible Tube	4 (1.2)	4 (1.2)	4 (1.2)	4 (1.2)	4 (1.2)	4 (1.2)

7.2 Exhaust System

Pipe exhaust gases to the outside of any enclosure. Locate the exhaust outlets away from any air inlets to avoid gases re-entering the enclosure. Exhaust installations are subject to various detrimental conditions such as extreme heat, infrequent operation, and light loads. Regularly inspect the exhaust system both visually and audibly to see that the entire system remains fume tight and safe for operation.

WARNING: Inhalation of exhaust gasses can result in severe personal injury or death. Use extreme care during installation to provide a tight exhaust system. Terminate exhaust pipes away from enclosed or sheltered areas, windows, doors, and vents.

For indoor installation, the exhaust system should use sealed joint type fittings where possible to provide a tight exhaust system. Use of slip type fittings (secured with a clamp) may allow leakage of exhaust gases into the building if not fitted correctly fitted. Check to make sure there are no exhaust leaks.

Use an approved thimble (see **Figure 14 on page 54**) where exhaust pipes pass through wall or partitions. Insulated wall/roof thimbles are used where exhaust pipes pass through a combustible roof or wall. This includes structures, such as wood framing or insulated steel decking, etc. Uninsulated wall/roof thimbles are used where exhaust pipes pass through a non-combustible wall or roof, such as concrete. Where applicable, refer to NFPA 37, Section 6-3, *Stationary Combustion Engines and Gas Turbines,* for accepted design practices. Build according to the code requirements in effect at the installation site.

WARNING: Hot exhaust pipes can start a fire and cause severe injury or death if improperly routed through walls. Use an approved thimble where exhaust pipes pass through wall or partitions.

WARNING: Inhalation of exhaust gases can result in severe personal injury or death. Do not use exhaust heat to warm a room, compartment, or storage area.

Rain caps are available for the discharge end of vertical exhaust pipes. The rain cap clamps onto the end of the pipe and opens due to exhaust discharge force from the generator set. When the generator set is stopped, the rain cap automatically closes, protecting the exhaust system from rain, snow, etc.

Use a section of flexible exhaust pipe between the engine and remainder of exhaust system. Support the exhaust system to prevent weight from being applied to engine exhaust outlet elbow/turbocharger connection.

CAUTION: Weight applied to the engine manifold can result in turbocharger damage. Support the silencer and exhaust piping so no weight or stress is applied to the engine exhaust elbow.

The exhaust system design should meet local code requirements.

NOTE: ***Liability for injury, death, damage, and warranty expense due to use of unapproved silencers or modifications to the exhaust system becomes the responsibility of the person installing the unapproved silencer or performing the modification. Contact your authorized distributor for approved exhaust system parts.***

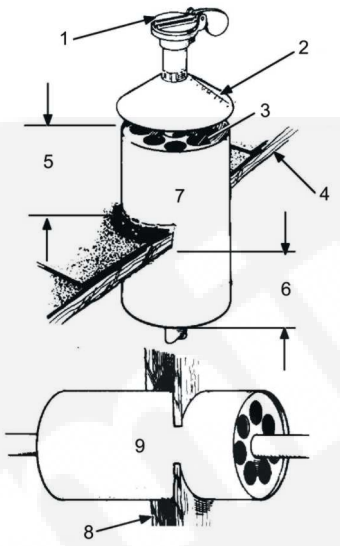
Avoid sharp bends by using sweeping, long radius elbows and provide adequate support for the silencer and tailpipe. Pitch a horizontal run of exhaust pipe downward (away from engine) to allow any moisture condensation to drain away from the engine. If an exhaust pipe must be turned upward, install a condensation trap at the point where the rise begins see **Figure 15 on page 54**.

CAUTION: Gaseous fuels are susceptible to high condensaion levels in the exhaust and therefore it is important to have properly routed/sized exhaust systems to prevent harm to turbochargers and Oxygen sensors (HEGO).

Shield or insulate exhaust lines if there is danger of personal contact. Allow at least 305 mm (12 inches) of clearance if the pipes pass close to a combustible wall or partition. Before installing insulation on exhaust system components, check the exhaust system for leaks while operating the generator set under full load and correct all leaks.

WARNING: Exhaust pipes are very hot and they can cause severe personal injury or death from direct contact or from fire hazard. Shield or insulate exhaust pipes if there is danger of personal contact or when routed through walls or near other combustible materials.

Refer to Application Manual T-030, "Liquid Cooled Generator Sets" for more detailed information about sizes of exhaust system pipes and fittings.



NO	Description	NO	Description
1	Rain Cap	6	230 mm (9 inches)
2	Drip Cap	7	Vertical Alignment
3	Holes in End of Inner Sleeve	8	Wall or Partition
4	Roof	9	Horizontal Alignment
5	230 mm (9 inches)		

FIGURE 14. MOUNTING EXHAUST THIMBLE

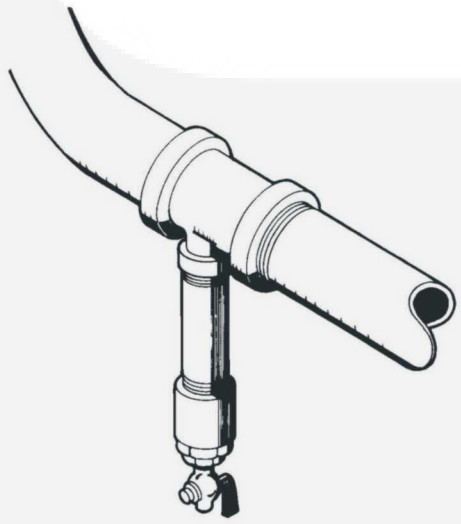


FIGURE 15. CONDENSATION TRAP

7.3 Ventilation and Cooling

Generator sets create considerable heat that must be removed by proper ventilation.

Generator sets in factory-mounted housings for outdoor installation are designed for proper cooling and ventilation.

Indoor installations require careful design with respect to cooling and ventilation. In an indoor installation, all radiator cooling air must be discharged to the out-of-doors. Duct adapter kits are available.

Outdoor installations normally rely on natural air circulation but indoor installations need properly sized and positioned vents for required airflow.

WARNING: Engine or radiator cooling air may carry deadly carbon monoxide gas which can cause asphyxiation and death. All engine or radiator cooling air must be discharged to the out-of-doors. Do not use it for heating a room or compartment.

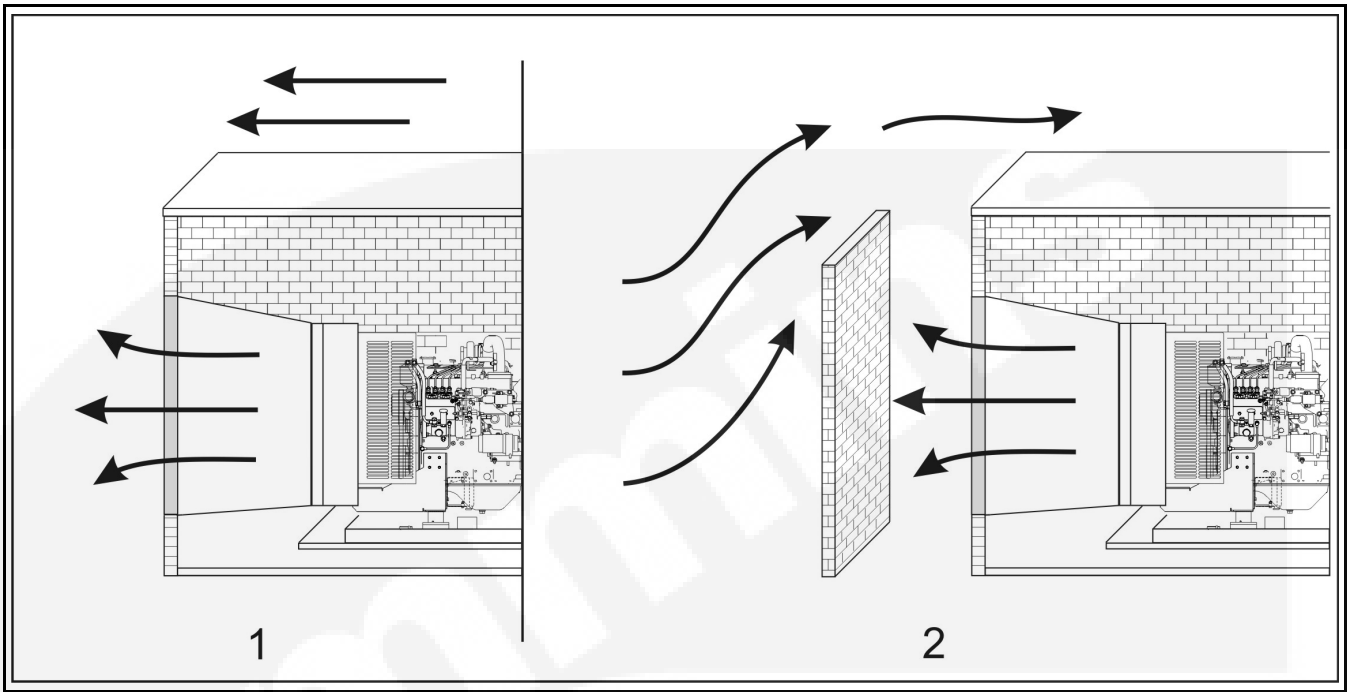
7.4 Vents and Ducts

For indoor installations, locate vents so incoming air passes through the immediate area of the installation before exhausting. Install the air outlet higher than the air inlet to allow for convection air movement.

Size the vents and ducts so they are large enough to allow the required flow rate of air.

NOTE: ***The 'free area' of ducts must be as large as the exposed area of the radiator. Refer to the generator set Specification Sheet for the airflow requirements and allowed airflow restriction.***

Wind will restrict free airflow if it blows directly into the air outlet vent. Locate the outlet vent so the effects of wind are eliminated, or if outlet vent cannot be located as mentioned, install a wind barrier, see **Figure 16**.



1	Prevailing Wind Away from Air Outlet Vent
2	Prevailing Wind Towards Air Outlet Vent, Wind Barrier Installed

FIGURE 16. WIND BARRIER

7.5 Dampers

Dampers or louvers protect the generator set and equipment room from the outside environment. Their operation of opening and closing should be controlled by operation of the generator set.

In cold climates, the radiator exhaust air can be recirculated to modulate the ambient air temperature in the generator set room. This will help the generator set warm up faster, and help to keep fuel temperatures higher than the cloud point of the fuel. If recirculation dampers are used, they should be designed to 'fail closed', with the main exhaust dampers open, so that the generator set can continue to operate when required. Designers should be aware that the generator set room operating temperature will be very close to the outdoor temperature, and either not route water piping through the generator set room, or protect it from freezing.

7.6 Air Inlet and Outlet Openings

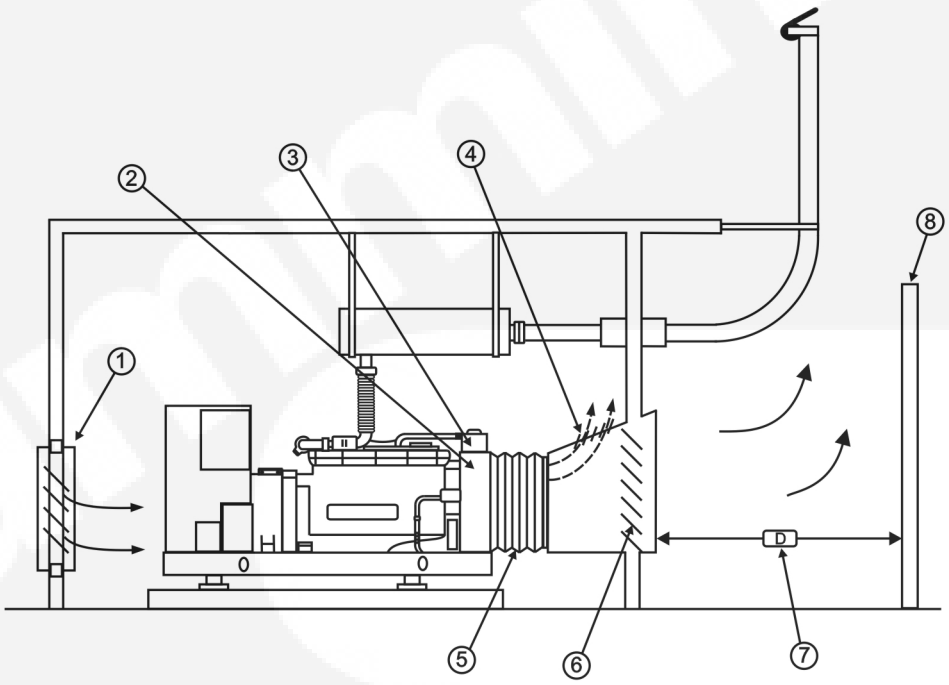
Louvers and screens over air inlet and outlet openings restrict air flow and vary widely in performance.

A louver assembly with narrow vanes, for example, tends to be more restrictive than one with wide vanes. The effective open area specified by the louver or screen manufacturer should be used.

Radiator set cooling air is drawn past the control end of the set by a pusher fan that blows air through the radiator. Locate the air inlet to the rear of the set. Make the inlet vent opening 1.5 times larger than the radiator area.

Locate the cooling air outlet directly in front of the radiator and as close as possible. The outlet opening must be at least as large as the radiator area. Length and shape of the air outlet duct should offer minimum restriction to airflow.

A flexible duct connector must be provided at the radiator to prevent exhaust air recirculation around the radiator, to take up generator set movement and vibration, and to prevent transmission of noise. Attach the flexible duct using screws and nuts so that the duct can be removed for maintenance purposes. Before installing the duct, remove the radiator core guard.



1	Cool Air Inlet Damper	5	Flexible Duct Connector
2	Engine Driven Fan	6	Hot Air Outlet Damper
3	Radiator	7	Distance Should Not be Less Than Height of Radiator
4	Thermostat Controlled Re-circulating Damper	8	Wind / Noise Barrier

FIGURE 17. TYPICAL RADIATOR SET INSTALLATION

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8 DC Control Wiring

WARNING: ***AC voltages and currents present an electrical shock hazard that can result in severe personal injury or death. Avoid contact with the voltage sense and bus sense leads; voltages of up to 600 VAC may still be present. These voltages could be live even when the generator set is switched off.***

The generator set control box contains connection points for remote control and monitor options.

CAUTION: *Stranded copper wire must be used for all customer connections to the control panel. Solid copper wire may break due to the generator set vibration.*

Use flexible conduit for all wiring connections to the generator set.

WARNING: ***Hazardous voltage! Touching uninsulated high voltage parts inside the control box can result in severe personal injury or death. Make sure all power is off before performing control wire installation.***

WARNING: ***To prevent accidental electrocution, stand on a clean dry wooden platform or clean rubber insulating mat, make sure your clothing and shoes are dry, remove all jewelry, and use tools with insulated handles.***

CAUTION: *Always run control circuit wiring in a separate metal conduit from the AC power cables to avoid inducing currents that could cause problems within the control.*

Use cable ties to keep control wiring away from sharp edges and AC power cables within the control housing.

8.1 Guidelines for Customer Connections to the Control

- Torque terminals to 0.5 Nm (4.4 in-lb)
- Wire type: Use 60 C rated minimum copper wire
- Terminal screws are slotted 0.6 mm
- Use flat bladed screwdriver with 2.5 mm blade
- Strip wire length to 6.0 mm (0.236 in)

8.2 Digital Connections

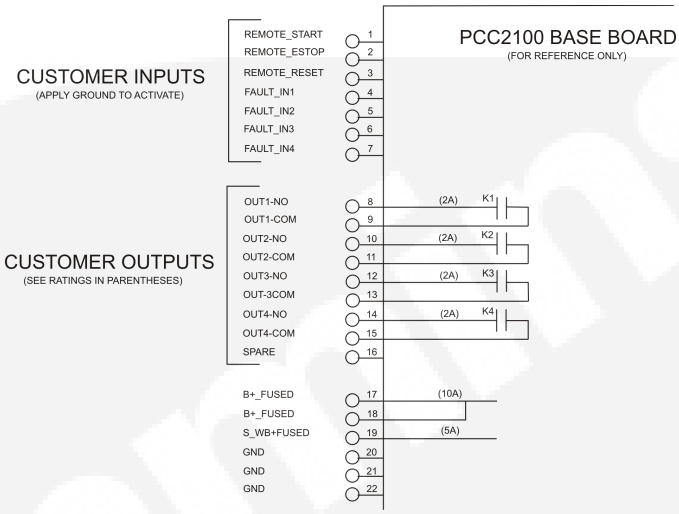
Connection points, other than relayed outputs and network are considered digital connections. The type/gauge wire to use for these connections are:

- Less than 305 meters (1000 feet), use 20 gauge stranded copper wire.
- 305 to 610 meters (1000 to 2000 feet), use 18 gauge stranded copper wire.

8.3 Relay Connections

Due to the wide variety of devices that can be attached to the relay outputs, the electrical contractor must determine the gauge of the stranded copper wire that is used at this installation site.

8.4 PCC 2100 TB1 Customer Connections



No.	Description	No.	Description
1	Remote start	12	Configurable output 3
2	Remote emergency stop	13	Configurable output 3 (common)
3	Remote fault reset	14	Configurable output 4
4	Configurable input 1	15	Configurable output 4 (common)
5	Configurable input 2	16	Not used
6	Configurable input 3	17	B+
7	Configurable input 4	18	B+
8	Configurable output 1	19	Switched B+
9	Configurable output 1 (common)	20	Ground
10	Configurable output 2	21	Ground
11	Configurable output 2 (common)	22	Ground

FIGURE 18. PCC 2100 TB1 CUSTOMER CONNECTIONS

8.4.1 Remote Start

When the control is in Auto/Remote mode, grounding this input initiates the engine cranking and start sequence. This circuit must be opened to permit resetting a shutdown condition with the Reset input. (The remote stop is actually the removal of the remote start signal to the control.)

8.4.2 Remote Emergency Stop

Opening this input causes an immediate shutdown. Emergency stop must be reset at the front panel.

8.4.3 Remote Fault Reset

Ground this input to acknowledge faults after they have been corrected. The control must be in Auto mode.

NOTE: **Faults are re-announced if they are detected again after being acknowledged.**

NOTE: **Using the InPower service tool or accessing the Setup submenus is required to modify the customer outputs. Contact an authorized distributor for assistance.**

8.4.4 Configurable Inputs

Grounding any one of these inputs activates the corresponding warning or shutdown sequence.

External sensing equipment must be connected to the designated digital input.

The nature of the fault is an optional customer selection. Example inputs: Low Coolant Level, Low Fuel Level, Ground Fault, etc.

NOTE: ***The InPower service tool or access to the Setup submenus is required to modify the customer fault inputs. Contact your authorized distributor for assistance.***

8.4.5 Configurable Outputs

Each output has normally-open contacts. The contacts can be used to control small devices, indicator lamps, or relays.

The contacts are programmed to energize by entering a code number for the desired event.

NOTE: ***Using the InPower service tool or accessing the Setup submenus is required to modify the customer outputs. Contact an authorized distributor for assistance.***

8.4.6 Contact Ratings for Configurable Outputs

TABLE 21. CONTACT RATINGS FOR CONFIGURABLE OUTPUTS

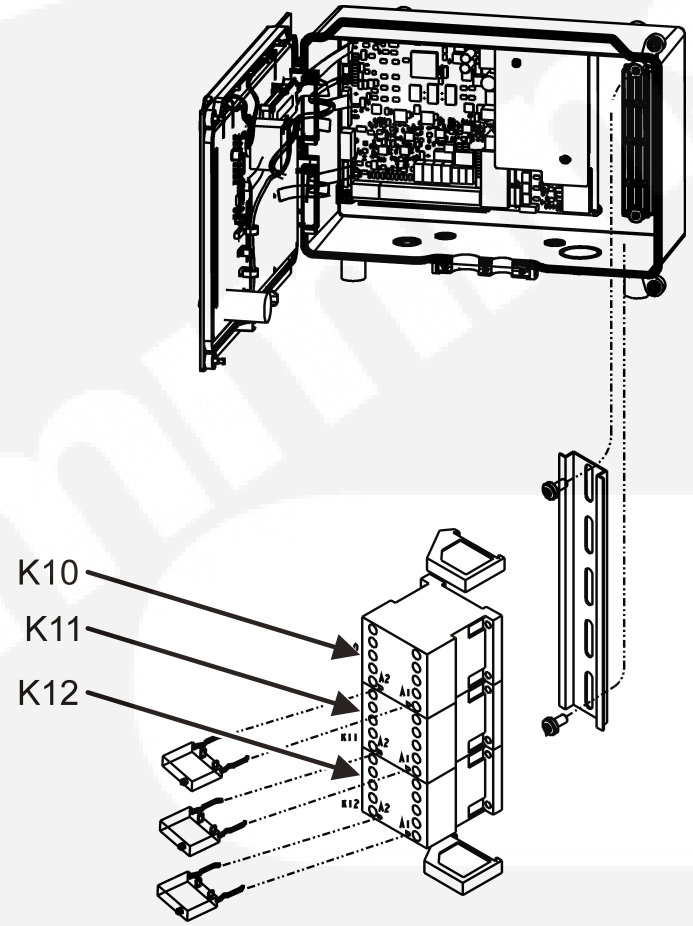
Description	Value
Maximum voltage	30 VDC
Maximum current	2 Amps

8.4.7 Switched B+

This output is active when the control receives a run command, for example, a remote start signal in Auto mode or the Start button in Manual mode.

8.5 Customer Relays

8.5.1 Location of Customer Relays



No.	Description	No.	Description
K10	Configurable Output 1	K12	Configurable Output 3
K11	Configurable Output 2		

FIGURE 19. LOCATION OF CUSTOMER RELAYS

8.5.1.1 Configurable Outputs

This relay is connected to the corresponding configurable output on the control. If the configurable output is active, the relay is active. If the configurable output is inactive, the relay is inactive.

This relay allows the configurable output to control larger devices, and it isolates the control from these devices.

8.5.1.2 Contact Specifications

The contacts are rated at 10 A at 600 VAC.

8.5.1.3 Schematic

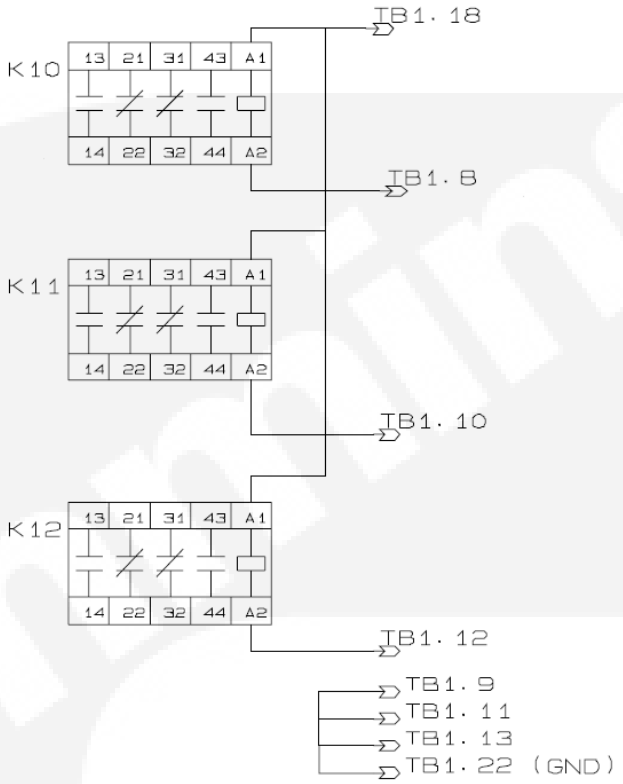


FIGURE 20. SCHEMATIC

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9 AC Electrical Connections

This section provides the procedure that is used to connect the AC electrical system of the generator set.

WARNING: AC voltages and currents present an electrical shock hazard that can result in severe personal injury or death. Avoid contact with the voltage sense and bus sense leads; voltages of up to 600 VAC may still be present. These voltages could be live even when the generator set is switched off.

Before making any AC electrical connections, make certain the generator set cannot be accidentally started. Make sure the Operator Panel is in OFF mode. Turn off or remove AC power from the battery charger and then remove the negative (**–**) battery cable from the set starting battery.

If the generator set is being installed in an application where it may parallel with other generators or utility sources, the generator set control system may be energized from an external source. Lock out tag out any external source that can provide AC power to the generator set.

WARNING: Ignition of explosive battery gases can cause severe personal injury or death. Arcing at battery terminals, light switch or other equipment, flame, pilot lights and sparks can ignite battery gas. Do not smoke, or switch a trouble light ON or OFF near a battery. Discharge static electricity from body before touching the batteries by first touching a grounded metal surface.

WARNING: Ventilate the battery area before working on or near battery. Wear goggles. Stop the generator set and disconnect the battery charger before disconnecting battery cables. Disconnect negative (–) cable first and reconnect last.

CAUTION: Disconnect battery charger from AC source before disconnecting battery cables. Otherwise, disconnecting cables can result in voltage spikes damaging to DC control circuits of the set.

WARNING: Accidental starting of the generator set can cause severe personal injury or death. Prevent accidental starting by disconnecting the negative (–) cable from the battery terminal.

WARNING: Each of the operations described in this section should be done only by persons trained and experienced in electrical maintenance. Improper procedures may result in property damage, bodily injury or death.

WARNING: Electric current can cause severe personal injury or death. The AC sensing harness and other cabling will become energized when the generator set is in operation.

Connecting the generator set AC electrical system involves:

- Installation of transfer switch
- Installation or verification of paralleling switchboard
- Generator output voltage selection
- Load cable connection
- Standard and optional AC equipment connections (e.g., control box heater, coolant heater, etc.).

Local regulations often require that wiring connections be made by a licensed electrician, and that the installation be inspected and approved before operation. All connections, wire sizes, materials used, etc. must conform to the requirements of electrical codes in effect at the installation site.

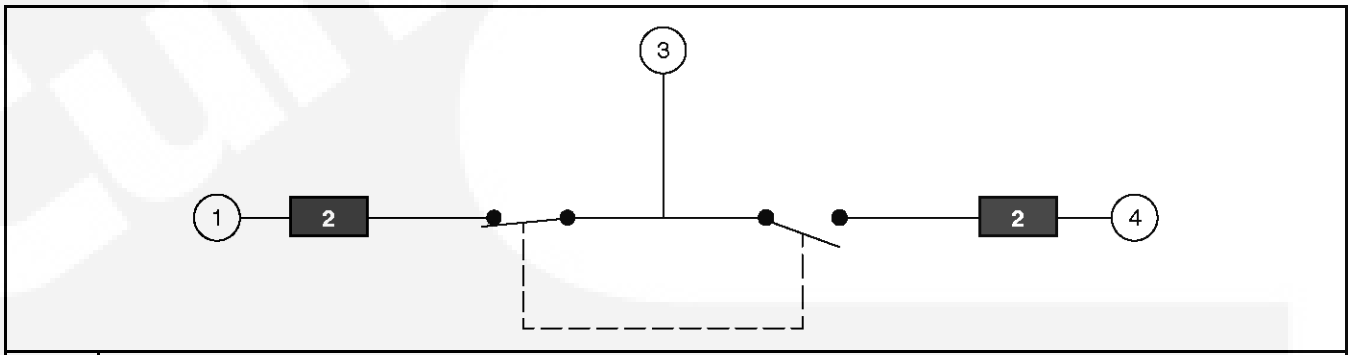
WARNING: Improper wiring can cause a fire or electrical hazard, resulting in severe personal injury or death and/or property and equipment damage.

Before starting the generator set, check to make sure that all electrical connections are secure, and that all wiring is complete. Replace and secure any access panels that have been removed during installation. Check that the load cables from the generator set are properly connected.

WARNING: Backfeed to a utility system can cause electrocution or property damage. Do not connect to any building electrical system except through an approved device and after the building main switch is opened.

9.1 Transfer Switch

If the installation is for standby service, a transfer switch must be used for switching the load from the normal power source to the generator set (see Figure 21 on page 66). Follow the installation instructions provided with the transfer switch when connecting the load and control wiring.



No.	Description
1	Normal Power Source
2	Overcurrent Protective Device
3	Load
4	Emergency Power Source

FIGURE 21. TYPICAL LOAD TRANSFER FUNCTION

9.2 Generator Voltage Connections

The available generator output voltages and maximum current ratings are specified on the generator set nameplate.

These generators can be configured to the nameplate voltages as shown on the Reconnection Diagram decal, attached to the backside of the control box cover. Many of the voltages listed will require reconfiguration of the generator output leads on the connection terminal block. This reconfiguration must only be done by service personnel that are trained and experienced to perform electrical installation. The generator set was adjusted to produce a specified voltage during production verification testing prior to shipment. The installer must always check the stator lead terminal block connections and perform any necessary reconnect to obtain the voltage required.

Some generator sets are capable of producing a wide range of voltages and connection configurations; others have specific limited capabilities. Refer to wiring diagram and generator voltages (from the nameplate) when reviewing the voltage connection information and use the wiring diagram supplied with your generator set when actually performing load connections.

CAUTION: Reconfiguring generator sets to higher voltages can exceed the voltage capability of the specific generator windings and damage the generator and also decrease line current, rendering line circuit breakers too large. Consult with your authorized distributor before performing reconnection for a different voltage.

CAUTION: Reconfiguring generator sets to lower voltages can reduce generator set ratings, and also increase line current, rendering line circuit breakers too small. Consult with your authorized distributor before performing reconnection for a different voltage.

9.3 Load Connections

WARNING: Flexible conduit and stranded conductors must be used for connections to take up movement of the generator set.

All loads are connected to the generator by bolting stranded load wires to the appropriate terminals on the generator reconnection terminal block or circuit breaker lugs. The terminals are marked with designations shown in table Table 22 on page 67.

TABLE 22. LINE DESIGNATIONS

Lines	Line Designations L1 through L3 and N	Line Designations A through C and N	Line Designations U through W and N
Line 1	L1	A	U
Line 2	L2	B	V
Line 3	L3	C	W
Line 0 or Neutral	N	N	N

9.4 Load Balancing

When connecting loads to the generator set, balance the loads so that the current flow from each line terminal (L1, L2, and L3) is about the same. This is especially important if both single phase and three phase loads are connected. Any combination of single phase and three phase loading can be used as long as each line current is about the same, within 10 percent of median value and no line current exceeds the name plate rating of the generator. Check the current flow from each line after connections by observing the Operator Panel ammeter.

9.5 Current Transformers

Current transformers (CTs) are used to display generator set load in kVA and alternator amperage. The CTs must be installed as noted in the following *CT Installation Requirements*.

Refer to the Reconnection Diagram to identify the generator output leads/phase that must be routed through each CT, and also appropriate transformer post selection for control sensing leads. The transformers are labeled CT1, CT2, and CT3 on the re-connection wiring diagram.

9.5.1 CT Installation Requirements

The CT has a dot on one side. This dot must be facing toward the generator reconnection terminal block (conventional current flowing into the dot). A dot is also used to indicate pin 1 of the CT.

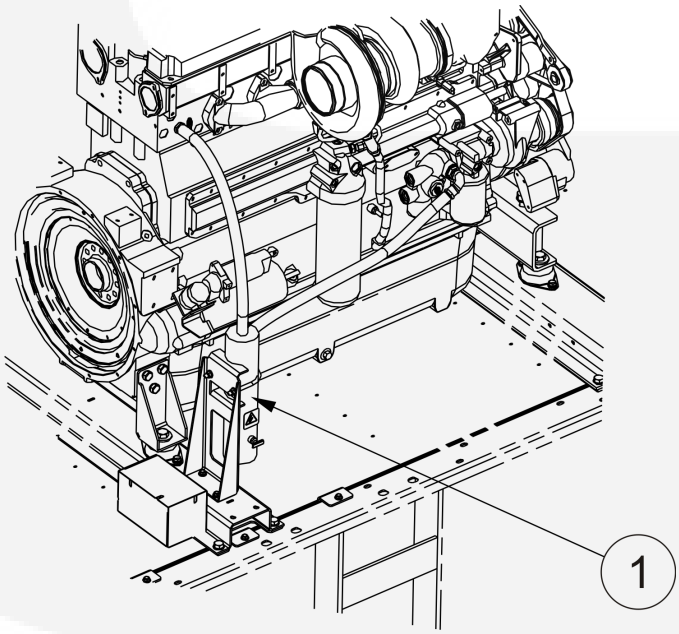
Route the load lead through the appropriate CT (refer to Reconnection Diagram).

The CTs have dual secondary's (3 pins). The CT secondary wire marked 1 is connected to pin 1 of the CT. CT secondary wire marked 2/3 is connected to pin 3 for low voltage generator sets.

9.6 Coolant Heater

9.6.1 Coolant Heater Installation

A coolant heater keeps the engine coolant warm when the engine is shut down. It heats and circulates the coolant within the engine. This reduces start-up time and lessens engine wear caused by cold starts. It is electrically operated and thermostatically controlled.

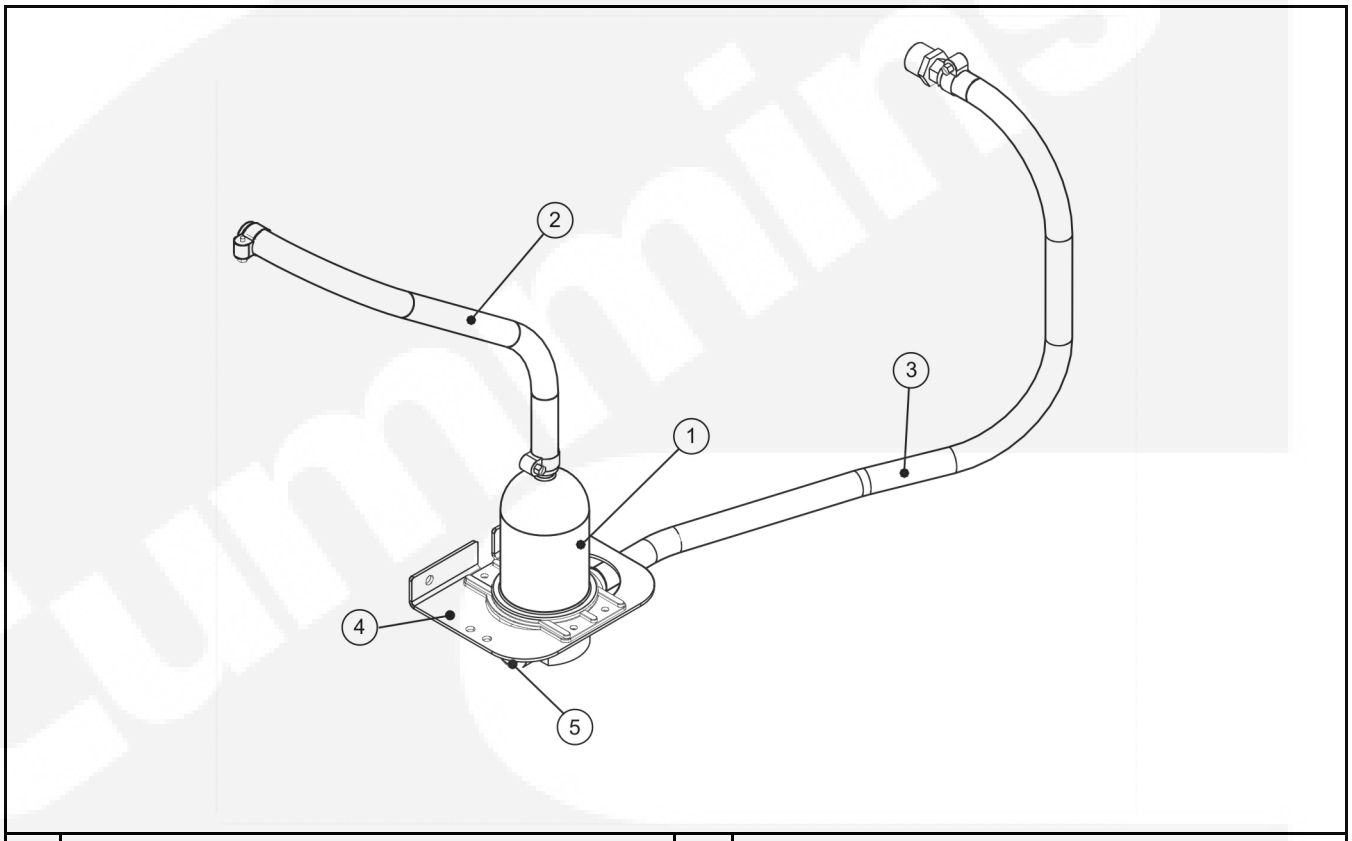


No.	DESCRIPTION
1	Coolant Heater

FIGURE 22. TYPICAL COOLANT HEATER MOUNTED ON THE GENERATOR SET

⚠ *CAUTION: The coolant heater must not be operated while the cooling system is empty or damage to the heater will occur.*

Figure 23 shows the heater line connection. Connect the heater to a source of power that will be on during the time the engine is not running. Ensure the supply voltage and circuit current is correct for the heater element rating.



No.	DESCRIPTION	No.	DESCRIPTION
1	Heater – Engine Coolant	4	Mounting Bracket
2	Heated Coolant to Engine	5	Electrical Connection
3	Coolant from Engine		

FIGURE 23. COOLANT HEATER

9.6.2 Coolant Heater Specifications

The coolant heaters are designed to allow the generator set to start and pick up load within 10 seconds in a 40 °F (4.4 °C) environment. In colder ambient temperature environments the starting time may be longer.

An installation may include one of two types of coolant heaters.

- 4990 watt at nominal voltage - This coolant heater is used in an environment where the minimum temperature is 40 °F (4 °C).

- 6420 watt at nominal voltage - This coolant heater is used in an environment where the temperature is less than 40 °F (4 °C).

A coolant heater can be set up for 480 V or 240-208 V configurations.

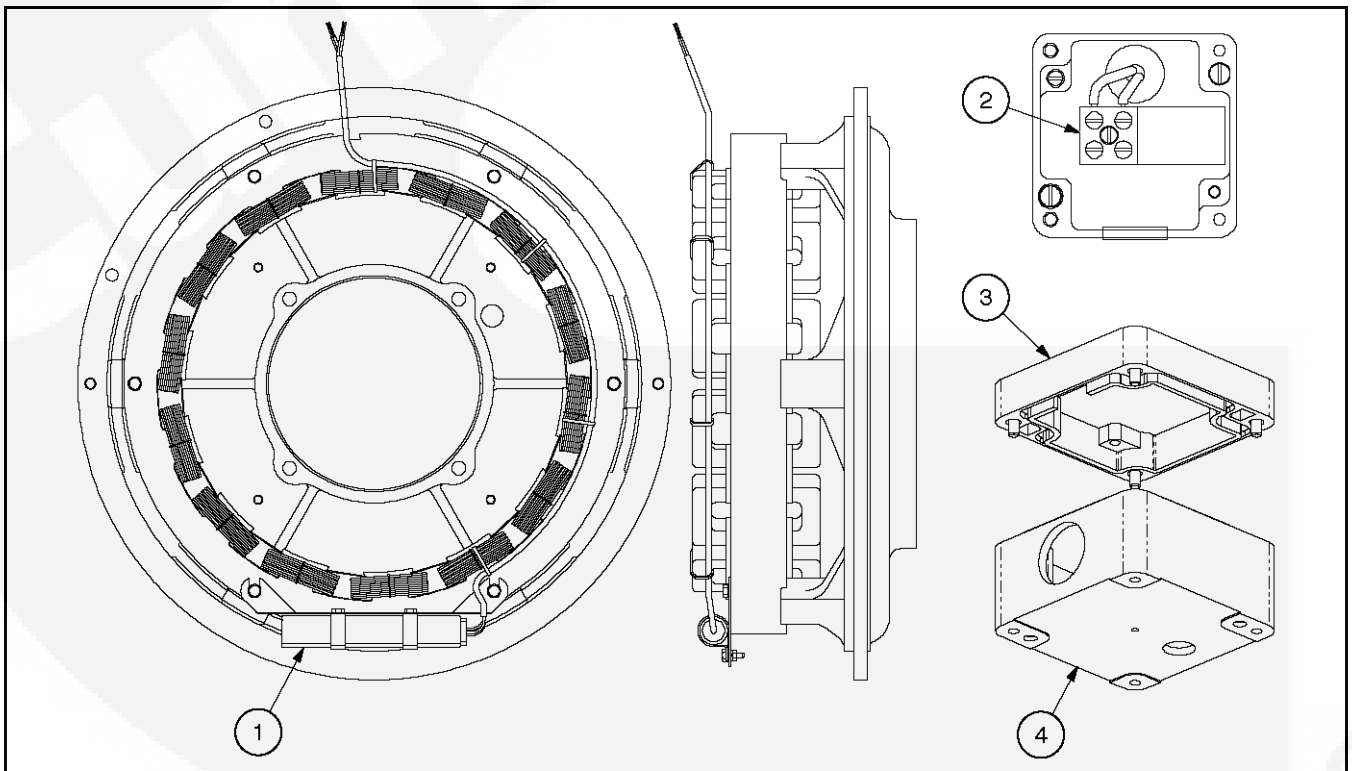
9.7 Alternator Heaters

9.7.1 Alternator Heater Installation

An alternator heater(s) is used to help keep the alternator free of condensation when the generator set is not running. During cool and humid conditions, condensation can form within a alternator, creating flashing and shock hazards.

WARNING: Water or moisture inside an alternator increases the possibility of flashing and electrical shock, which can cause equipment damage and severe personal injury or death. Do not use a alternator which is not dry inside and out.

Figure 24 on page 70 shows the installation of a heater element. Connect the heater(s) terminals to a source of power that will be on during the time the engine is not running. Be sure the supply voltage and circuit amperage is correct for the heater element rating.



No.	Description	No.	Description
1	Heater Cartridge	3	Terminal Box Cover
2	Terminal Block	4	Terminal Box (Mounted on the Alternator Housing)

FIGURE 24. TYPICAL ALTERNATOR HEATER

9.7.2 Alternator Heater Specifications

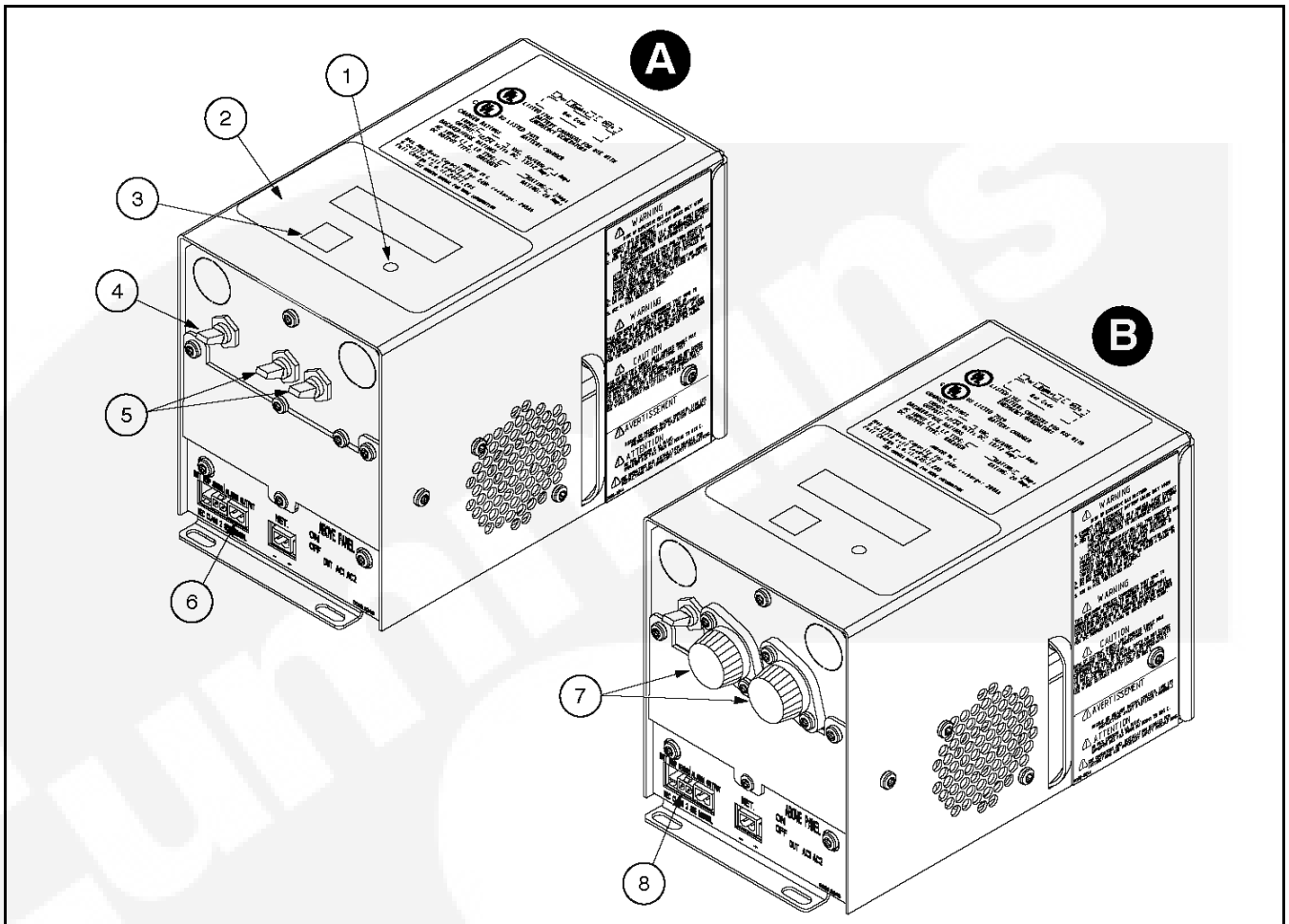
The 120V alternator heater is used with UCD22 alternators.

The 240V alternator heater is used with UCD27 alternators.

9.8 Battery Charger

9.8.1 PowerCommand Battery Charger - 15 Amp @ 12 Volt and 12 Amp @ 24 Volt

The two available types of 15/12-amp PowerCommand battery chargers are shown below. For more information, refer to the battery charger owner's manual.



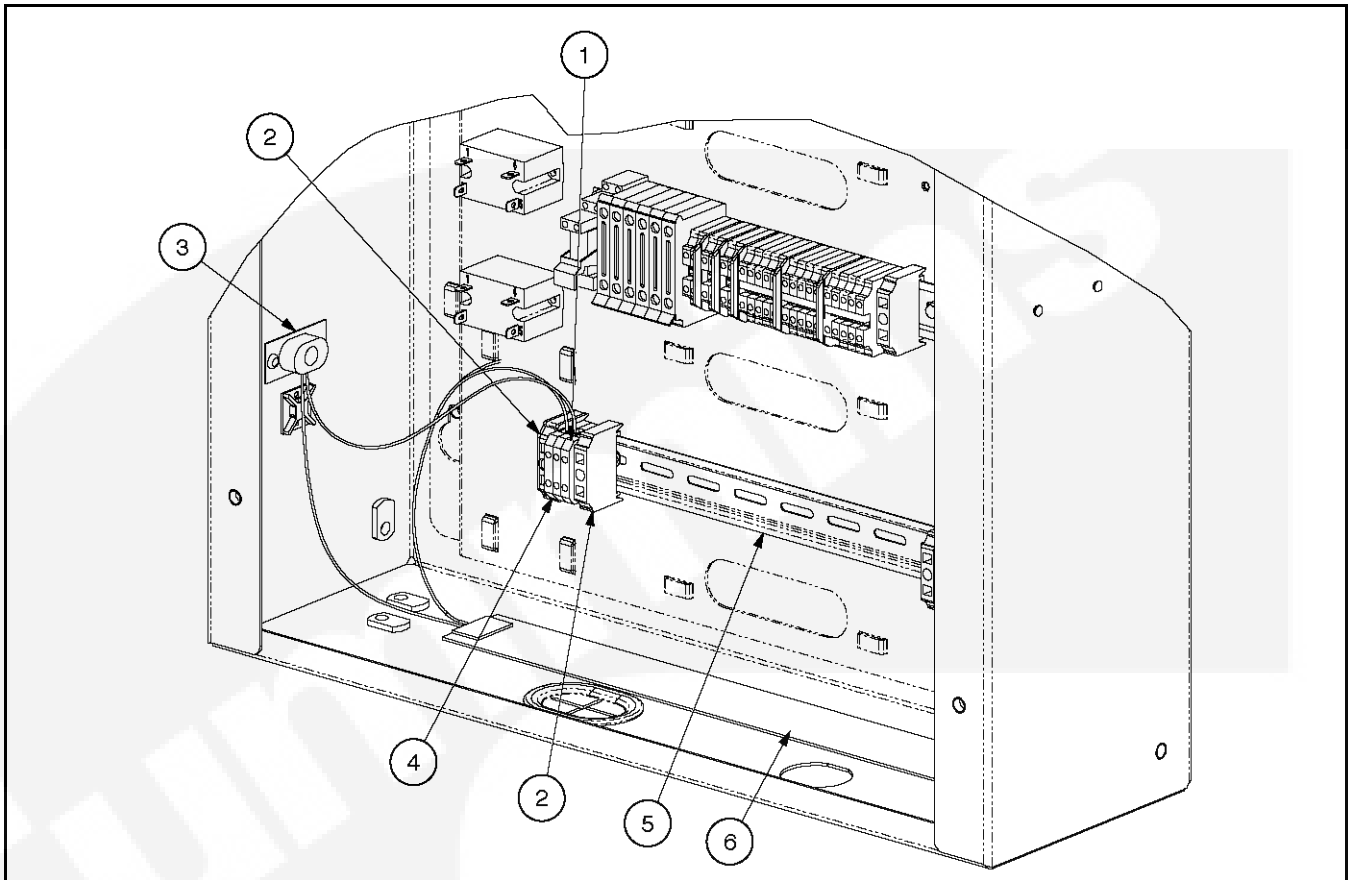
A	120, 208, and 240 VAC Battery Charger	4	20 Amp DC Circuit Breaker Switch (Shown in the "On" position)
B	277, 380, 416, 480, and 600 VAC Battery Charger	5	10 Amp AC Circuit Breaker Switches (Shown in the "On" position)
1	Status LED	6	Fault Alarm Output Connector
2	Control Panel	7	10 Amp AC Fuse Holders
3	Reset Button	8	Connector for Optional Battery Temperature Sensor

FIGURE 25. 15/12-AMP POWERCOMMAND BATTERY CHARGERS

9.9 Control Box Heater

9.9.1 Control Cabinet Heaters

A thermostat heater is installed inside the control cabinet. Both 120V and 240V heaters are available.



No.	Description	No	Description
1	Terminal Block (Ground)	4	Terminal Block
2	Terminal Endplate	5	Terminal DIN Rail
3	Thermostat	6	Flexible Heater Pad

FIGURE 26. TYPICAL CONTROL CABINET HEATER

9.10 Oil Heaters

9.10.1 Oil Pan Heaters

Three 300W oil pan heaters are available.

- 120V single phase
- 208/240V single phase
- 480V single phase

NOTE: For 120V applications, the optional location is shown. The primary location is on the left hand side of the oil pan.

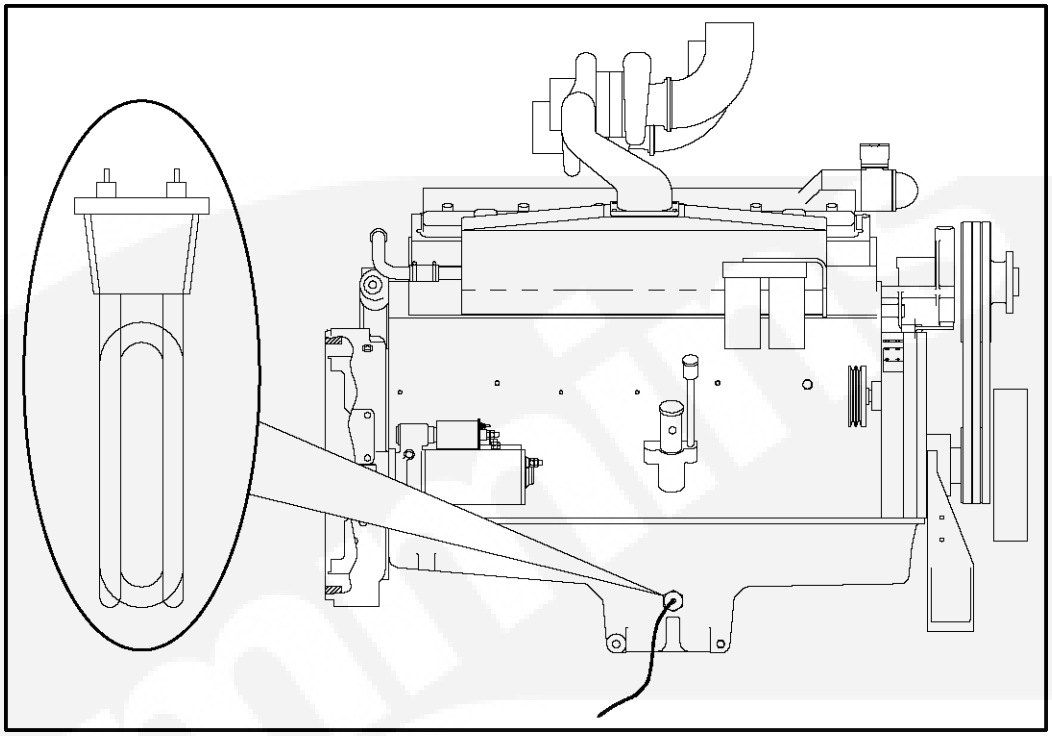


FIGURE 27. OIL PAN HEATER USED IN 120V AND 208/240V APPLICATIONS

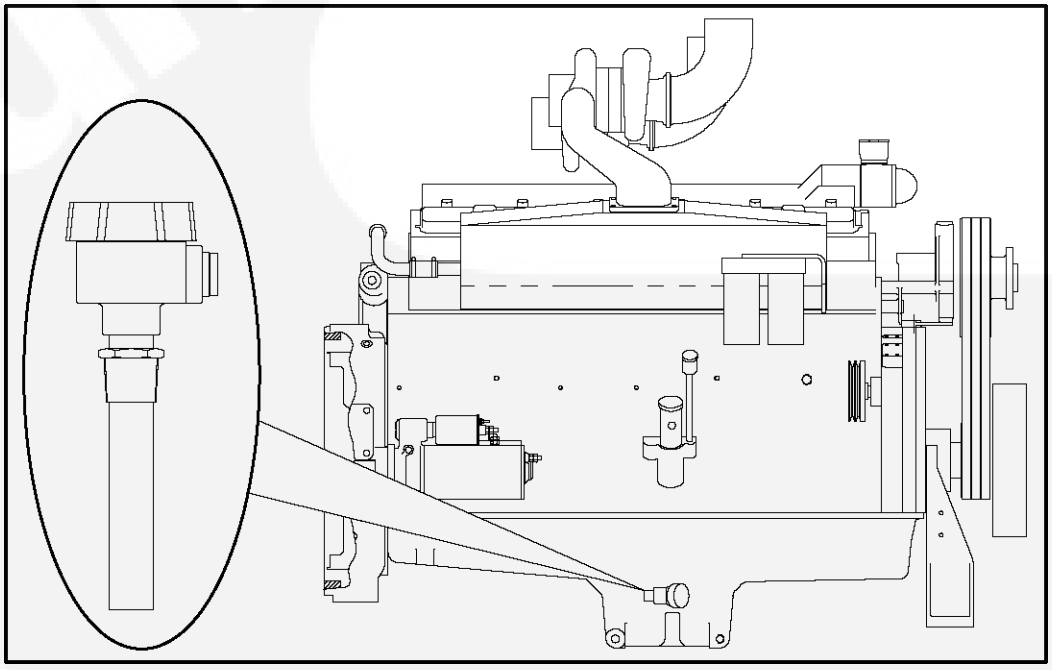


FIGURE 28. OIL PAN HEATER USED IN 480V APPLICATIONS

9.11 Annunciators

9.11.1 PowerCommand Universal Annunciator

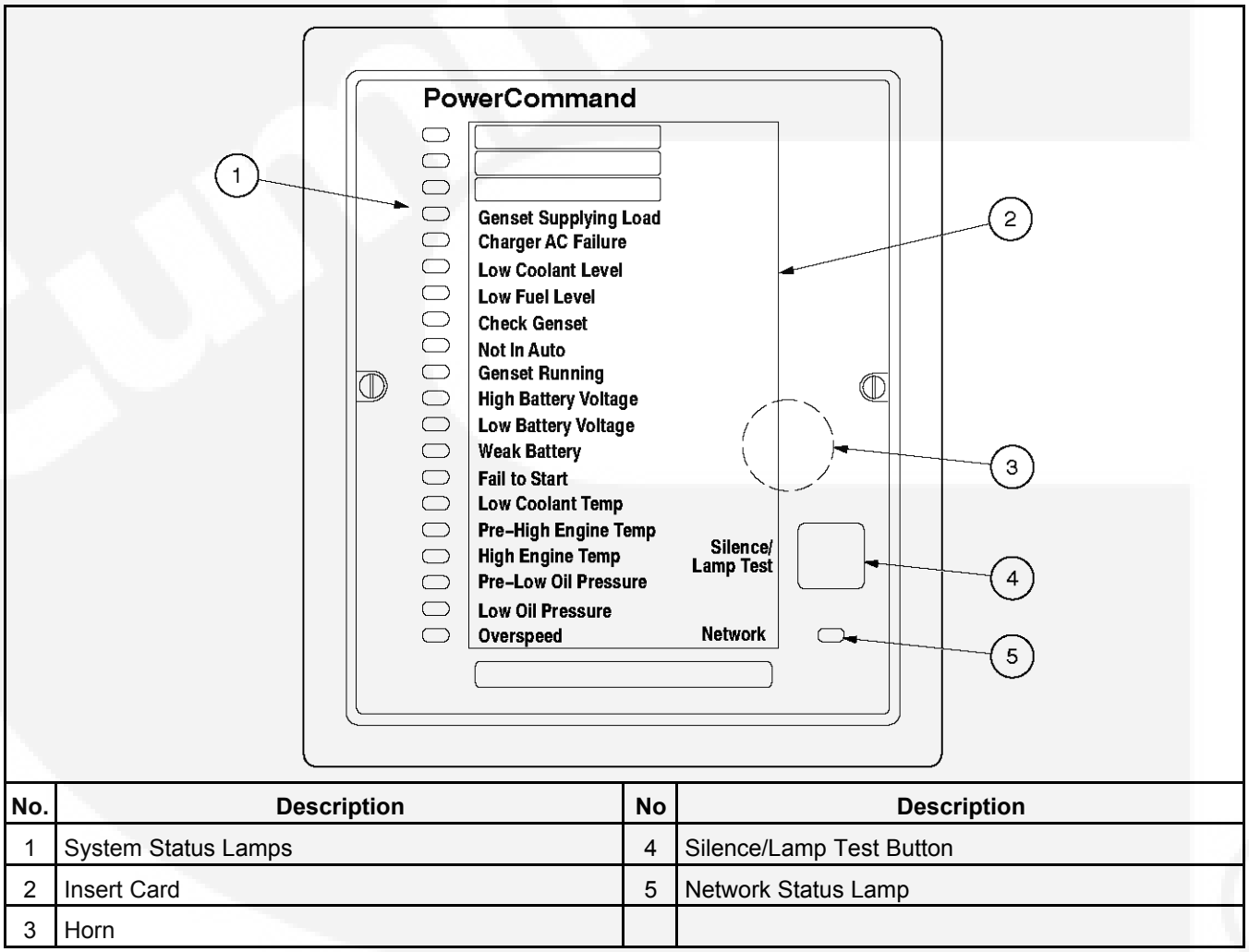
A universal annunciator provides lamps and a horn to annunciate the operating status and fault conditions of an emergency power system. It is designed for connection to either a 12 VDC or a 24 VDC control system. It can be configured to be either a positive or negative signal device.

Two versions of the PowerCommand universal annunciator are available.

- Panel Mounted
- Panel with Enclosure

The universal annunciator can communicate using either a PCCNet or a Modbus network.

Refer to the annunciator owner's manual for more information.



No.	Description	No	Description
1	System Status Lamps	4	Silence/Lamp Test Button
2	Insert Card	5	Network Status Lamp
3	Horn		

FIGURE 29. ANNUNCIATOR COMPONENTS

9.12 Grounding

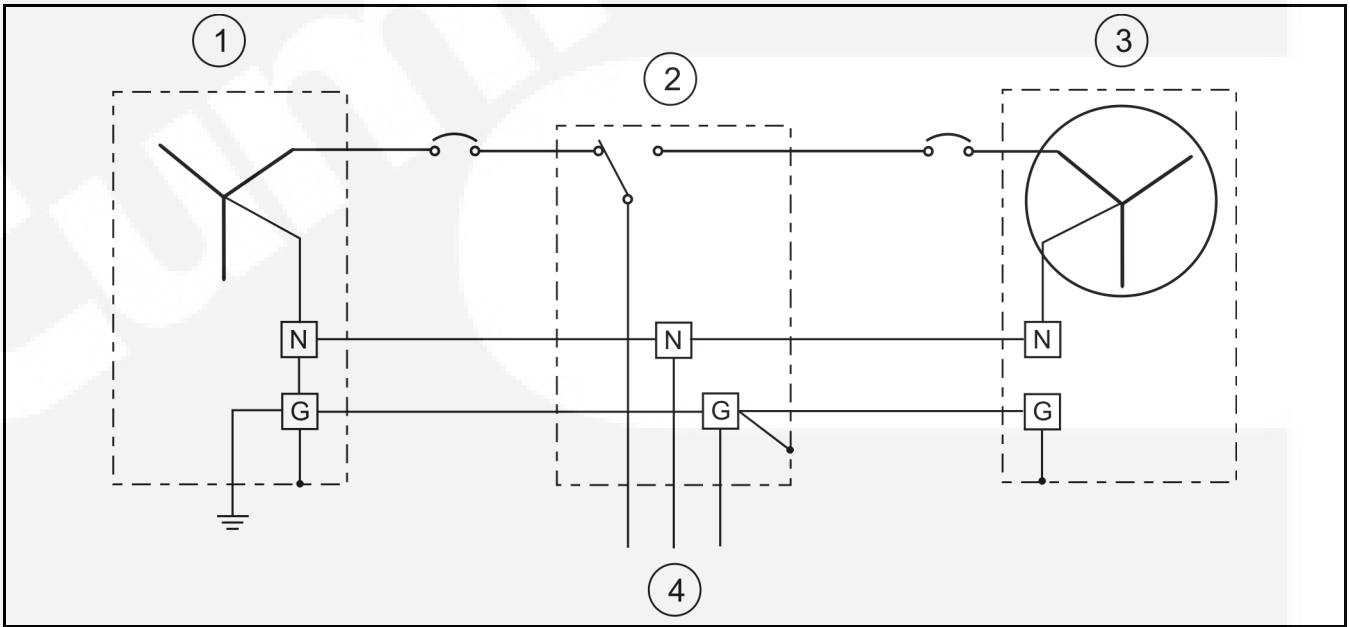
The following is a brief description of system and equipment grounding of permanently installed AC generators within a facility wiring system.

NOTE: ***It is important to follow the requirements of the local electrical code.***

Figure 30 and Figure 31 illustrate typical system grounding for a 3-pole and a 4-pole Automatic Transfer Switch (ATS). In the 3-pole ATS, note that the generator neutral is connected to the ATS and is NOT bonded to ground at the generator. In the 4-pole ATS system, a grounding electrode conductor and a bonding jumper are used to connect the generator neutral to ground.

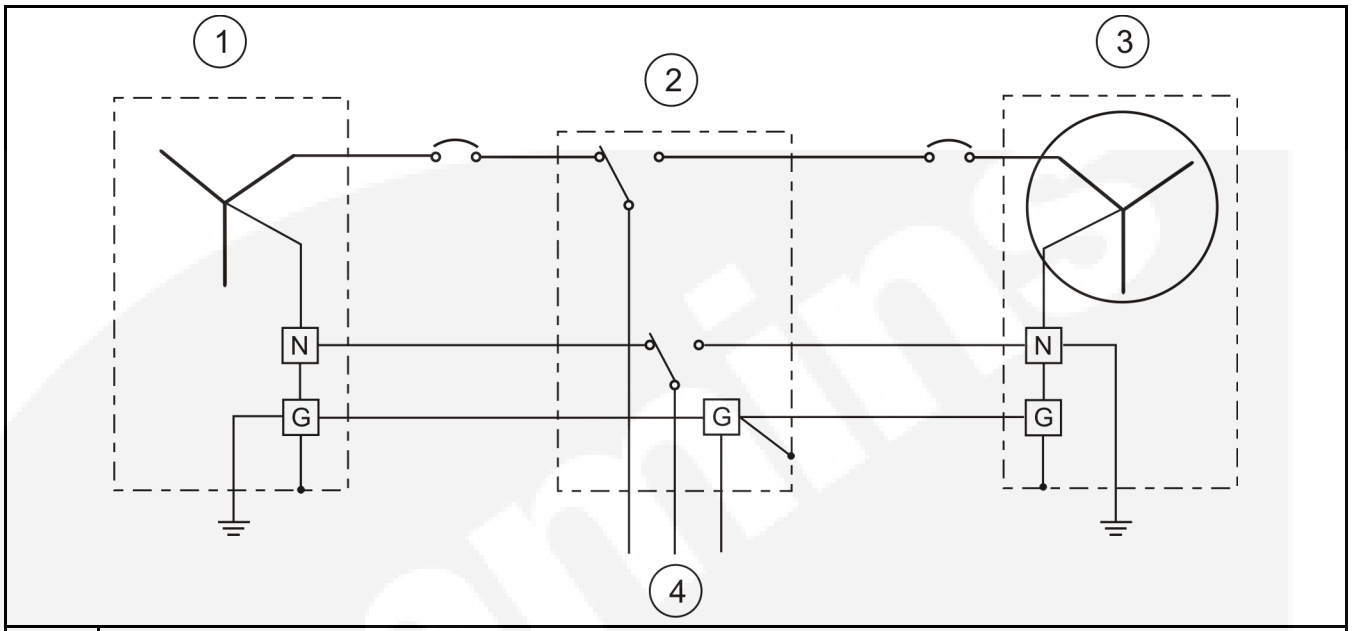
Make sure the generator set is grounded to earth in one location only. On generator sets without a circuit breaker, ground to the point indicated on the top of the generator. On generator sets with circuit breakers, use the ground lug provided in the circuit breaker box.

WARNING: Electric current can cause severe personal injury or death. Bonding and grounding must be done properly. All metallic parts that could become energized under abnormal conditions must be properly grounded.



No.	Description
1	Service Entrance
2	3-Pole ATS
3	Generator Set
4	Load

FIGURE 30. TYPICAL SYSTEM - THREE-PHASE, FOUR WIRE UTILITY, THREE-POLE ATS



No.	Description
1	Service Entrance
2	4-Pole ATS
3	Generator Set
4	Load

FIGURE 31. TYPICAL SYSTEM - THREE-PHASE, FOUR WIRE UTILITY, FOUR-POLE ATS

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10 Pre-Start Preparation

Before attempting an initial start of the generator set, be sure to complete the Installation Checklist, see **Chapter 11 on page 81**.

WARNING: Make sure that all items listed in the Installation Checklist are carried out before starting the generator set. The failure to do a complete installation can result in equipment damage and severe personal injury or death.

10.1 Electrical System

Verify all electrical connections are secure and all wiring is complete and inspected. Replace and secure any access panels that may have been removed during installation.

10.2 Site-specific Configuration

NOTE: Site-specific configuration is to be undertaken by suitably trained and qualified service personnel only.

Some configuration is done by the factory. Any site-specific configuration should be done by qualified service personnel before starting the generator set.

10.3 Starting

Refer to the generator set Operator manual for important safety precautions and recommended procedures for starting the generator set and verifying proper operation. Start the generator set and verify all engine and generator menus are displaying the correct values.

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11 Installation Checklist

11.1 Installation Checklist

Tick	General Items
	Generator set wattage capacity is sufficient to handle maximum anticipated load.
	At least 3 feet (914.4 mm) of clearance (or greater for housing door) is provided around the entire generator set for service and ventilation.
	The generator set is located in an area not subject to flooding.
	All operating personnel have read and are familiar with the generator set Operator manual, all health and safety procedures, warnings, cautions, precautions, and the other documentation supplied with the generator set.
	All operators have been thoroughly briefed on preventative maintenance procedures.
	All operators have read and understand all important safety instructions.
	Generator Set Support
	The floor, roof, or earth on which the generator set rests is strong enough and will not allow shifting or movement. Observe local codes on soil bearing capacity due to freezing and thawing.
	The generator set is properly supported and retained to an approved base
	The supporting base is large enough and is of non-combustible material, extending 6 inches (152.4 mm) all around the generator set.
	Cooling Air Flow
	Generator set air inlet is faced into direction of strongest, prevailing winds.
	Air inlet openings are unrestricted and are at least 1 to $1^{1}/_{2}$ times larger than air outlet area.
	Cooling air outlet is on downwind side of building (if not, wind barrier is constructed).
	Proper ducting material (sheet metal, canvas) is used between radiator and air outlet.
	Diesel Fuel System (if applicable)
	Fuel tanks meet or exceed all Local, State, or National codes (if applicable).
	Fuel lines are properly installed, supported, and protected against damage.
	The fuel filters have been installed.
	Approved flexible fuel line is installed between the main fuel supply and the generator set's fuel system near the generator set, to protect it against damage caused by vibration, expansion, and contraction.
	Strainer or fuel screen (100 to 200 mesh) is installed in the fuel supply line to protect the fuel lift pump, day tank transfer pump, or float valve seat from fuel tank debris (if applicable).
	The fuel filter assembly shipped with the generator set is installed and operational (if applicable).
	Fuel supply shutoff valves are installed to prevent fuel flow in case of leaks.
	No shutoff valves are installed on engine fuel return line (if applicable).
	External fuel pumps are connected and operational at all times - generator set started or shut down (if applicable).
	Fuel tanks are filled with the correct grade / type of fuel (if applicable).
	Fuel system is properly primed.
	No fuel leaks are found in supply line or engine fuel system.

	Gaseous Fuel System (if applicable)
	Check fuel line and use equatios to verify it has proper volume capability.
	Check if fuel pressure is between 7-13 inches water column.
	Check for any gas leaks.
	If necessary, perform initial demand regulator adjustment procedure.
	Make sure furl pressure does not drop below 7 inches water column under full load.
	Exhaust System
	The breather tube routing is set up to blow the fumes away from the generator set (if applicable)
	Operators are thoroughly briefed on the dangers of carbon monoxide gas.
	If the installation includes a heavy duty air cleaner, it has been installed.
	Areas around generator set are well ventilated. No possibility of exhaust fumes entering building doors, windows, or intake fans.
	Exhaust gases are piped safely outside and away from building.
	The correct length of approved rigid pipe is connected to the generator set flexible pipe using approved securing methods with no weight resting on engine exhaust components. There are no bends in flex section.
	Condensation drain is provided in lowest section of exhaust piping.
	Exhaust piping is insulated to guard against burns to personnel.
	Exhaust piping passing through walls or ceilings have approved fire-proof materials and are in compliance with all codes.
	Exhaust piping is large enough in diameter to prevent excessive back pressure on engine.
	AC and DC Wiring
	For bottom entry circuit breaker installations, the cable chute has been installed (if applicable).
	Wire sizes, insulation, conduits and connection methods all meet applicable codes.
	AC and DC wires are separated in their own conduit to prevent electrical induction.
	All load, line and generator connections are well made and correct.
	Flexible conduit is used between the generator and the building or surrounding structure.
	Check phase rotation.
	Generator Set Pre-Start
	Generator set engine is properly serviced with oil and coolant.
	Battery charger is installed using the appropriate cable size and is operational.
	Battery charger is configured for the proper DC battery voltage, battery type, and float voltage.
	Batteries are properly installed, serviced and charged.
	Battery temperature sensor is connected and operational (if applicable).
	Engine coolant heater is connected and operational.
	All generator set covers and safety shields are installed correctly.
	All fuel and coolant shutoff valves are operational.
	Radiator fan and other external moving parts including drive belts are unrestricted.

12 Manufacturing Facilities

NORTH AMERICA	EMEA, CIS	ASIA PACIFIC
Cummins Power Generation Limited 1400 73rd Ave. NE Minneapolis, MN 55432 USA	Cummins Power Generation Limited Columbus Avenue Manston Park Manston, Ramsgate Kent CT12 5BF United Kingdom	Cummins Power Generation Limited 10 Toh Guan Road #07-01 TT International Tradepark Singapore 608838
Phone +1 763 574 5000 Toll Free +1 800 888 6626 Fax +1 763 574 5298	Phone +44 1843 255000 Fax +44 1843 255902	Phone +65 6417 2388 Fax +65 6417 2399
BRAZIL	**CHINA**	**INDIA**
Rua Jati, 310, Cumbica Guarulhos, SP 07180-900 Brazil	Cummins Power Generation 2 Rongchang East Street, Beijing Economic – Technological Development Area Beijing 100176, P.R.China	35A/1/2, Erandawana Pune 411 038 India
Phone +55 11 2186 4195 Fax +55 11 2186 4729	Phone +86 10 5902 3000 Fax +86 10 5902 3199	Phone +91 020 6602 7525 Fax +91 020 6602 8090
LATIN AMERICA	**MEXICO**	
3350 Southwest 148th Ave. Suite 205 Miramar, FL 33027 USA	Eje 122 No. 200 Zona Industrial San Luis Potosi, S.L.P. 78395 Mexico	
Phone +1 954 431 551 Fax +1 954 433 5797	Phone +52 444 870 6700 Fax +52 444 824 0082	

12.1 How to Obtain Service

When a product requires servicing, contact your nearest Cummins Power Generation distributor. To locate your local Cummins Power Generation distributor, refer to **www.cumminspower.com** and select Distributor Locator. When contacting your distributor, always supply the complete Model, Specification, and Serial Number as shown on the nameplate.

12.1.1 Locating Your Distributor

In North America

Telephone +1-800-888-6626 (this is an automated service for touch-tone phones only) to contact the nearest Cummins Power Generation distributor in the United States or Canada. By selecting Option 1 (press 1), you will be automatically connected to the distributor nearest you.

If you are unable to contact a distributor using the automated service, consult the Yellow Pages. Typically, our distributors are listed under:

GENERATORS – ELECTRIC or

ENGINES – GASOLINE OR DIESEL

If you have difficulty arranging service or resolving an issue, please contact the Service Manager at the nearest Cummins Power Generation distributor for assistance.

When contacting your distributor, always supply the complete Model, Specification, and Serial Number as shown on the product nameplate.

Outside North America

If you are outside North America, telephone Cummins Power Generation at +1-763-574-5000 from 7:30 am to 4:00 pm, Central Standard Time, Monday through Friday, or fax +1-763-528-7229.

Appendix A. Wiring Diagrams

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Wiring Diagrams

The drawings included in this section are representative. For current complete information, refer to the drawing package that was shipped with the unit.

GGHG/H Wiring Diagram with PowerCommand 2100 Control

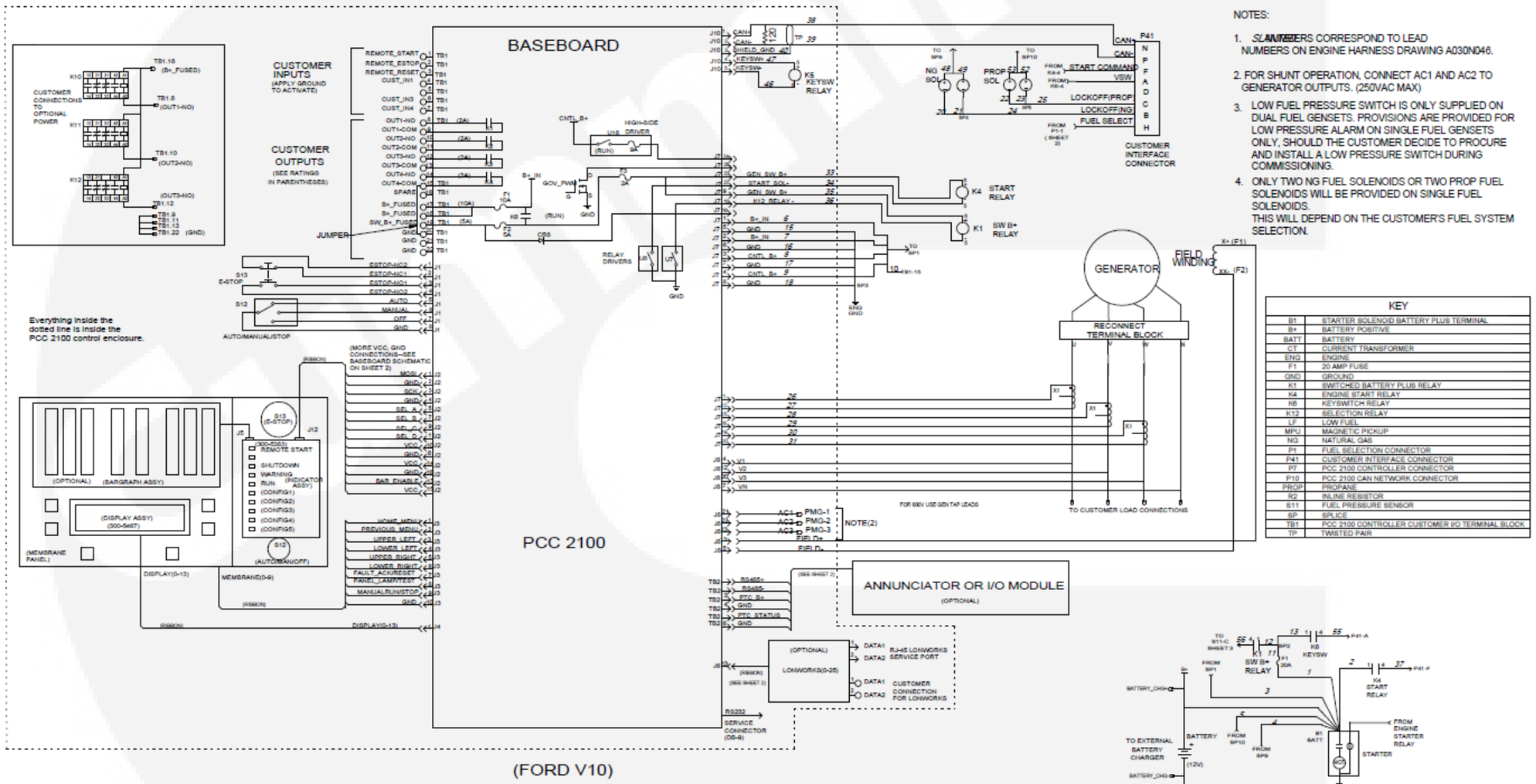

FIGURE 32. A032Y198 SHEET 1

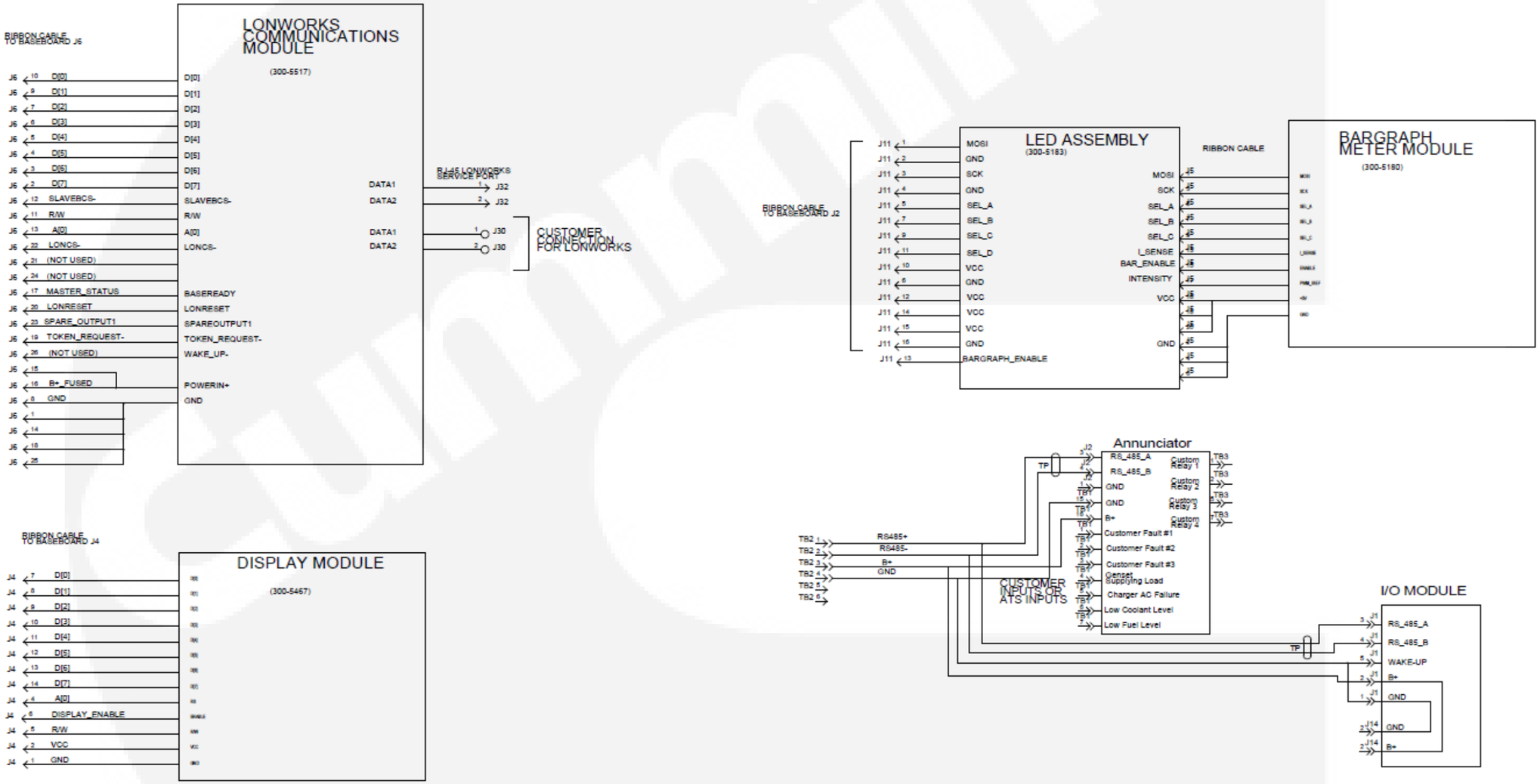

FIGURE 33. A032Y198 SHEET 2

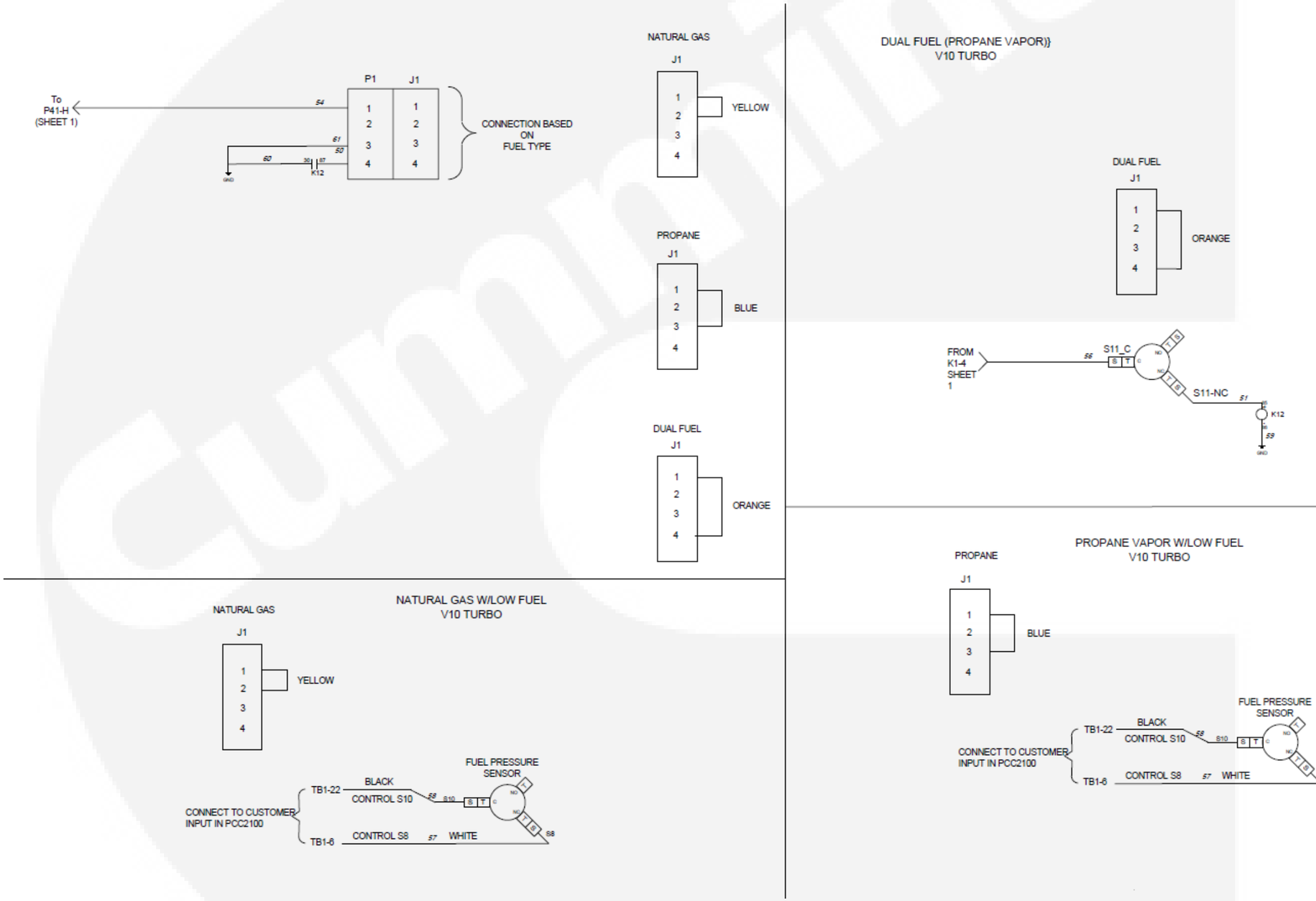

FIGURE 34. A032Y198 SHEET 3

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Appendix B. Customer Connections

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Wiring Diagrams

The drawings included in this section are representative. For current complete information, refer to the drawing package that was shipped with the unit.

GGHG/H Customer Connections with PowerCommand 2100 Control

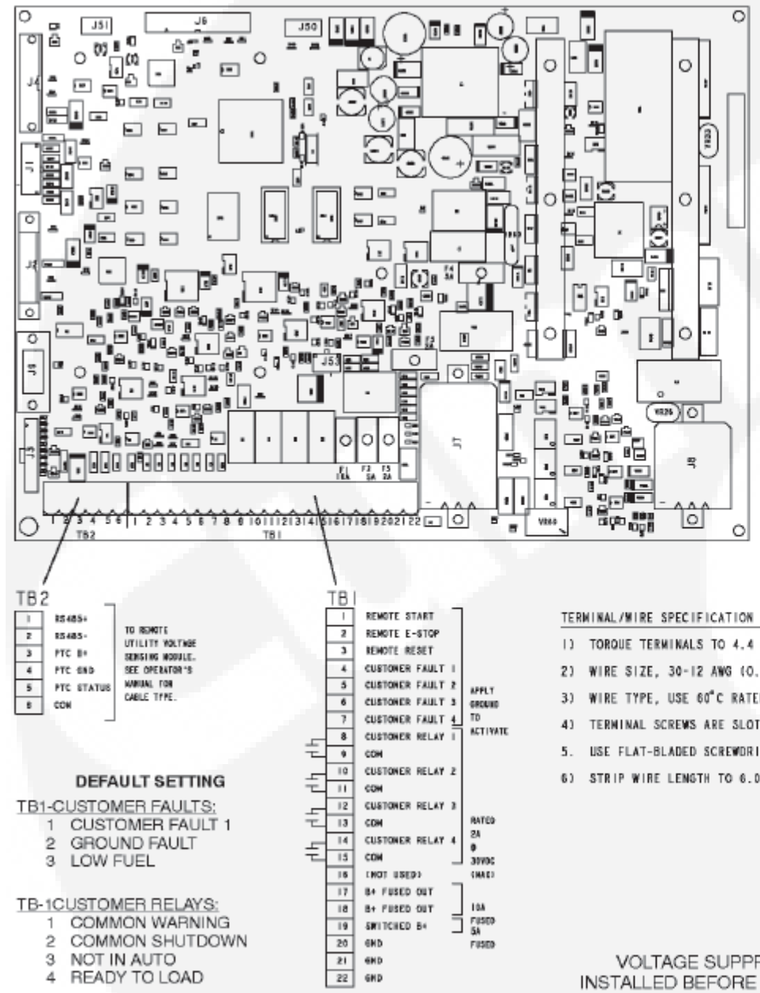
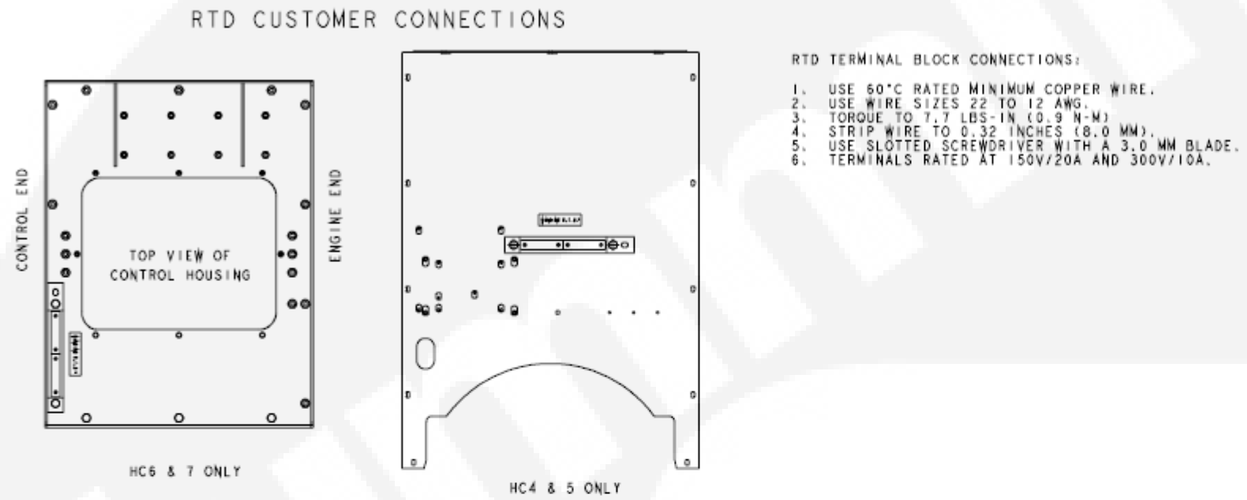


FIGURE 35. CUSTOMER CONNECTIONS DRAWING - 620-0247 SHEET 1



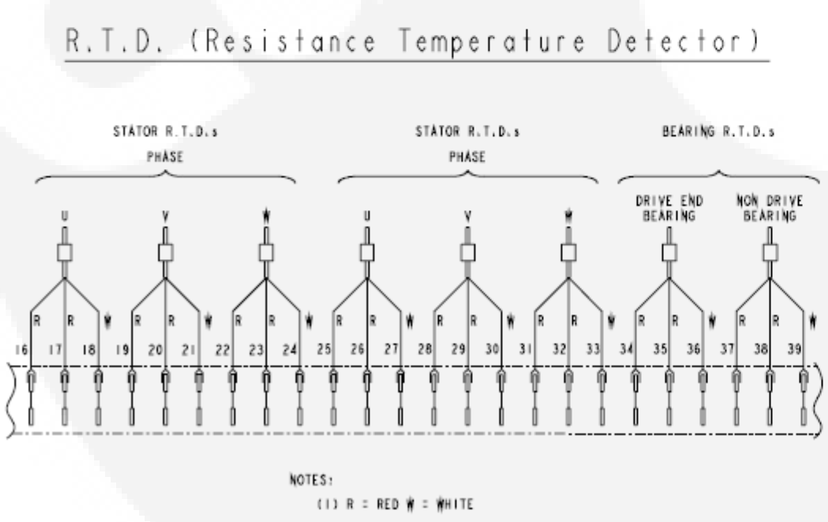


FIGURE 36. CUSTOMER CONNECTIONS DRAWING - 620-0247 SHEET 2

Appendix C. Outline Drawings

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Wiring Diagrams

The drawings included in this section are representative. For current complete information, refer to the drawing package that was shipped with the unit.

GGHG/GGHH Outline Drawing with PowerCommand 2100 Control

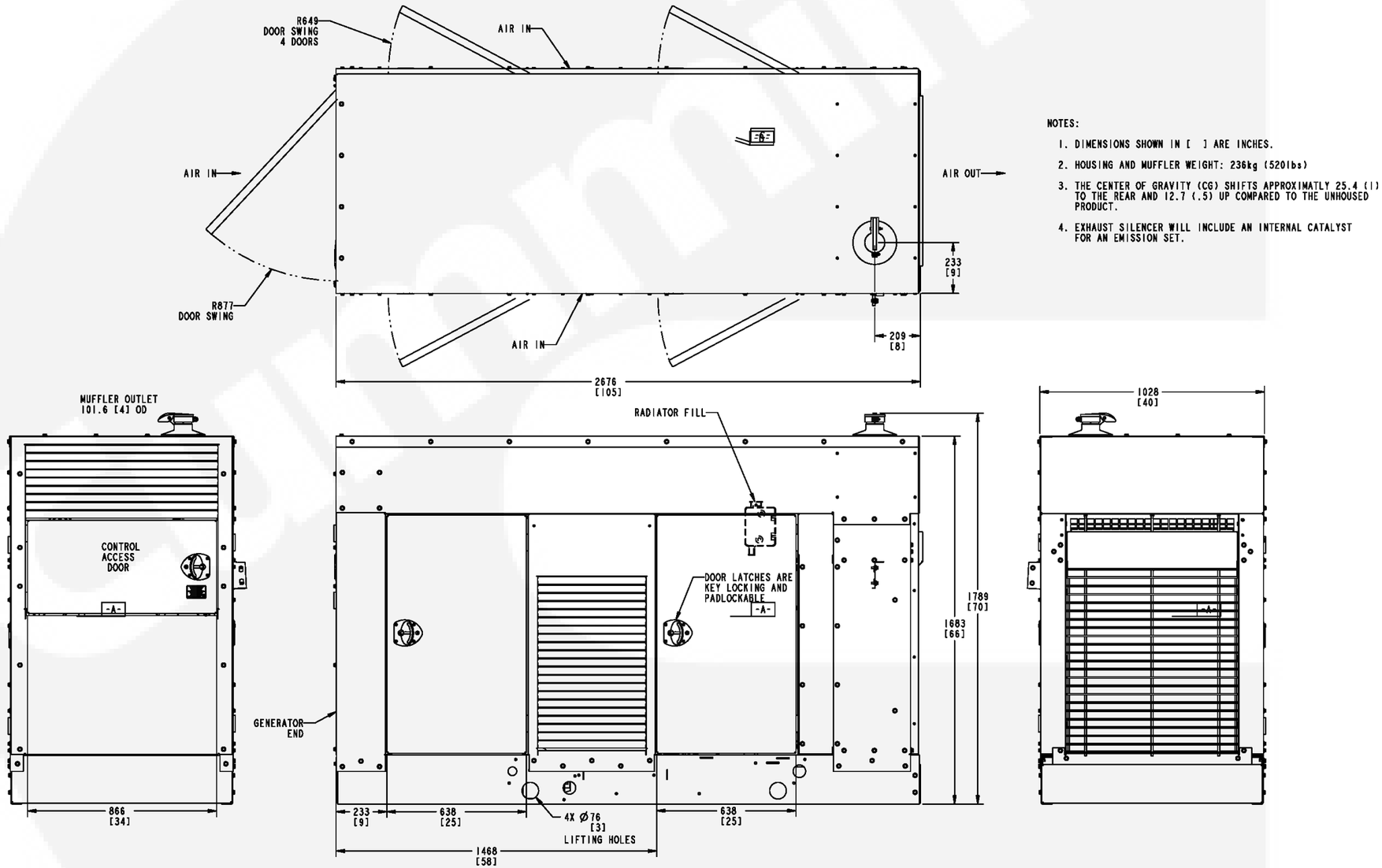

FIGURE 37. OUTLINE DRAWING - WEATHER HOUSED WITH EXHAUST (F182)

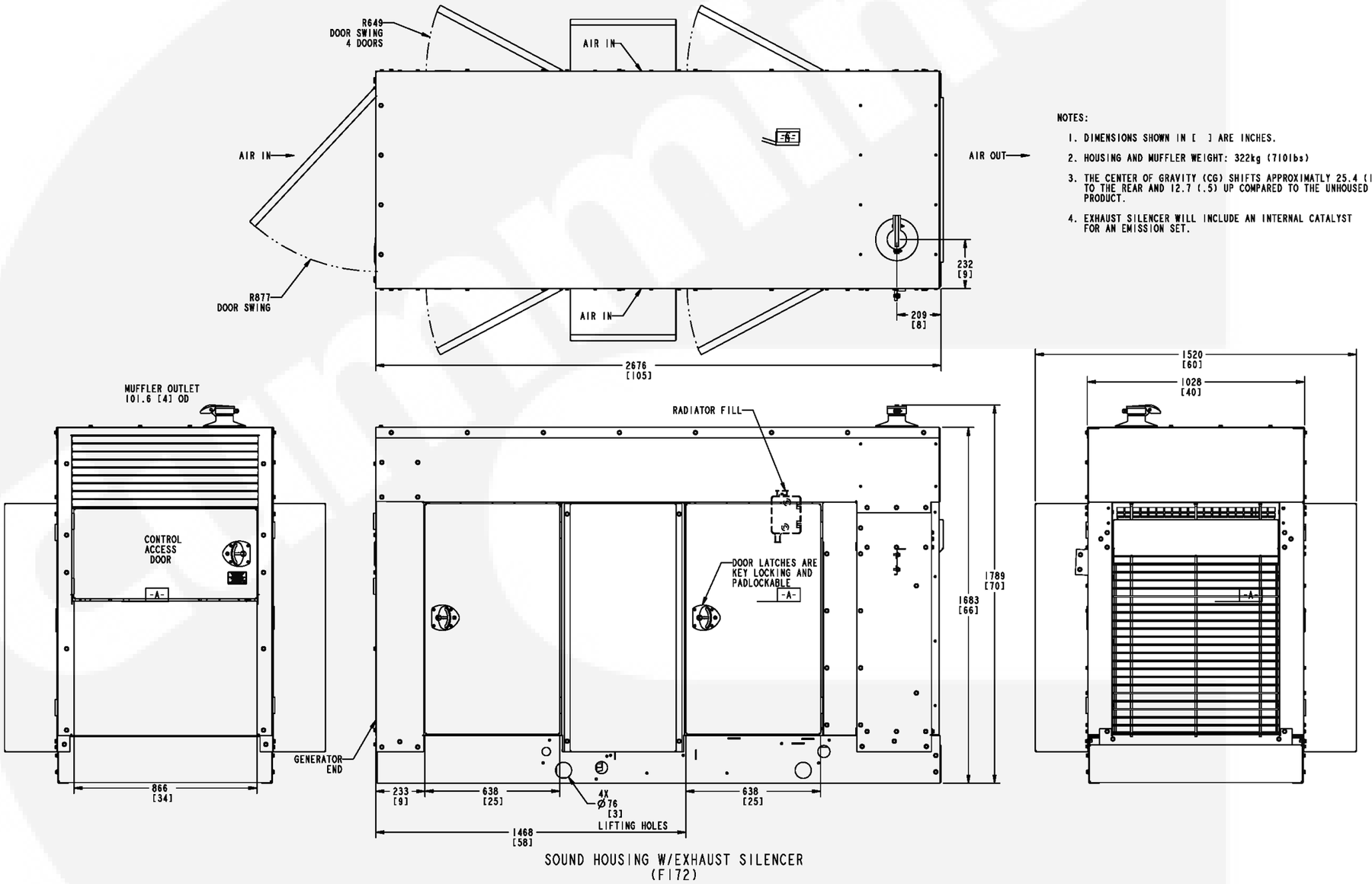

FIGURE 38. OULINE DRAWING - SOUND HOUSED WITH EXHAUST (F172)

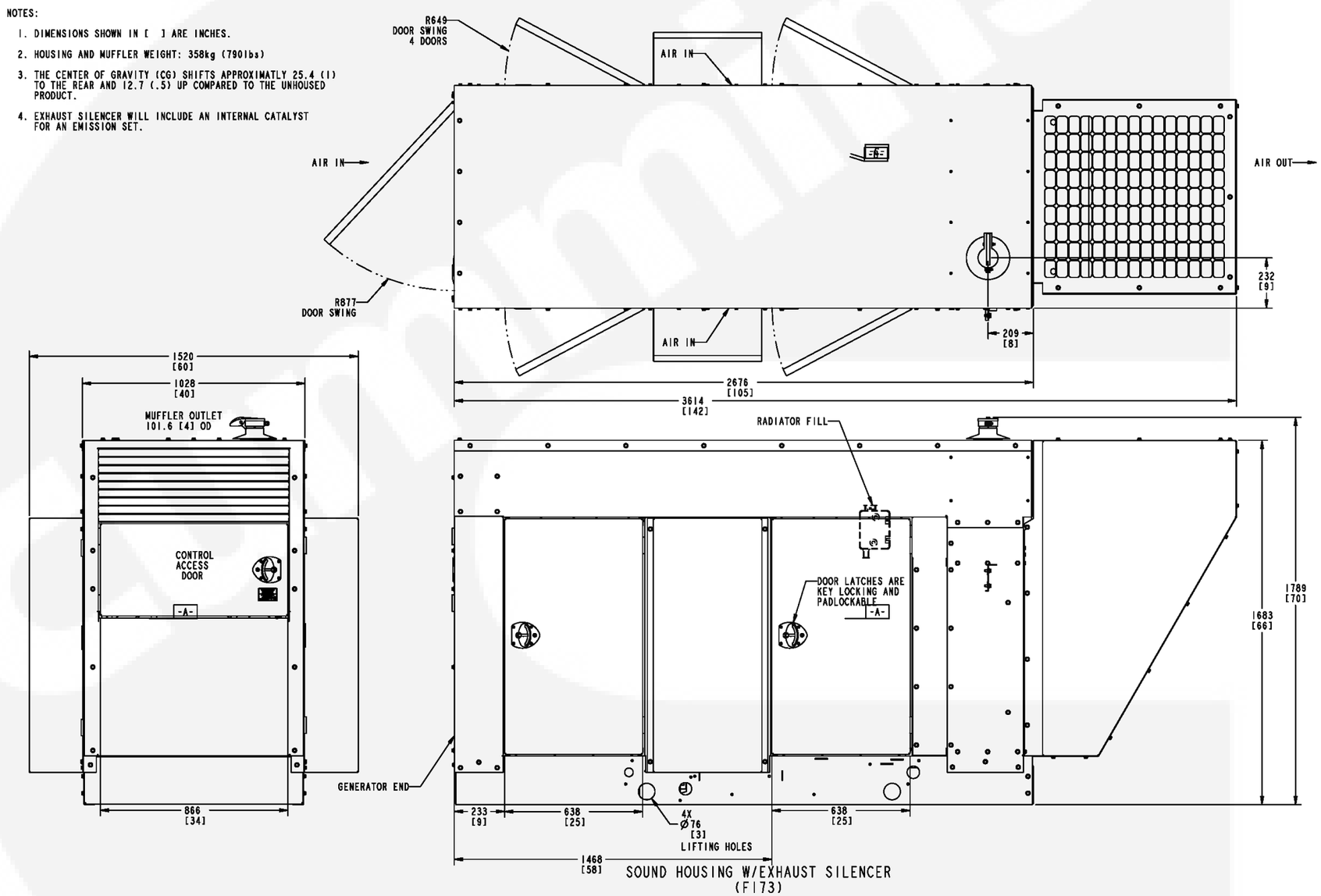

FIGURE 39. OUTLINE DRAWING - SOUND HOUSED WITH EXHAUST (F173)

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Appendix D. Alternator Reconnect Drawing

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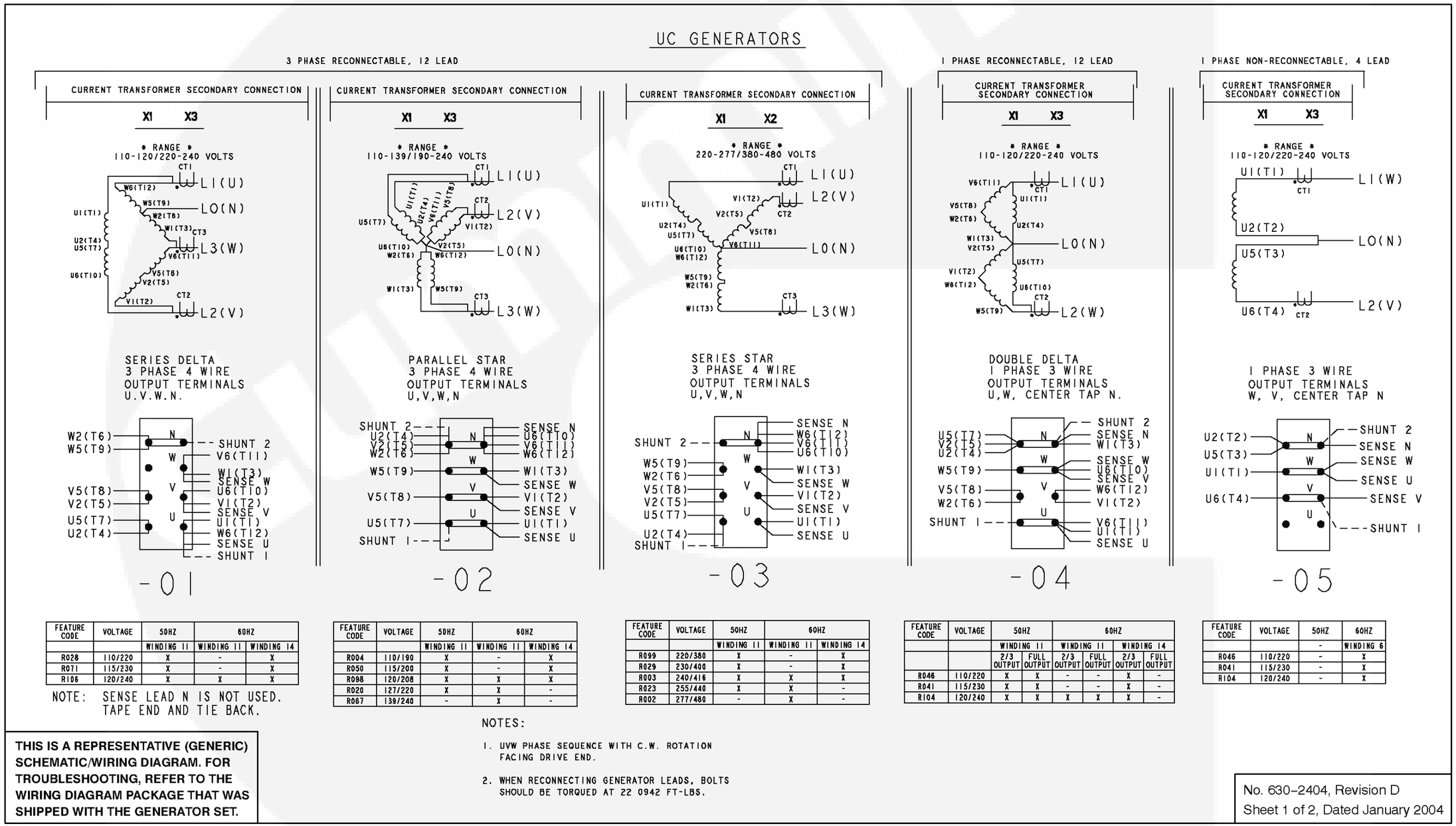
Wiring Diagrams

The drawings included in this section are representative. For current complete information, refer to the drawing package that was shipped with the unit.

GGHG/GGHH Alternator Reconnect Drawing



FEATURE CODE	VOLTAGE	50HZ	60HZ	
		WINDING 11	WINDING 11	WINDING 14
R028	110/220	X	-	X
R071	115/230	X	-	X
R105	120/240	X	X	X

NOTE: SENSE LEAD N IS NOT USED. TAPE END AND TIE BACK.

FEATURE CODE	VOLTAGE	50HZ	60HZ	
		WINDING 11	WINDING 11	WINDING 14
R004	110/190	X	-	X
R050	115/200	X	-	X
R098	120/208	X	X	X
R020	127/220	X	X	-
R067	139/240	-	X	-

FEATURE CODE	VOLTAGE	50HZ	60HZ	
		WINDING 11	WINDING 11	WINDING 14
R099	220/380	X	-	X
R029	230/400	X	-	X
R003	240/416	X	X	X
R023	255/440	X	X	-
R002	277/480	-	X	-

FEATURE CODE	VOLTAGE	50HZ	60HZ			
		WINDING 11		WINDING 11		WINDING 14
		2/3 OUTPUT	FULL OUTPUT	2/3 OUTPUT	FULL OUTPUT	2/3 OUTPUT	FULL OUTPUT
R046	110/220	X	X	-	-	X	-
R041	115/230	X	X	-	-	X	-
R104	120/240	X	X	X	X	X	-

FEATURE CODE	VOLTAGE	50HZ	60HZ
		-	WINDING 6
R046	110/220	-	X
R041	115/230	-	X
R104	120/240	-	X

NOTES:

1. UVW PHASE SEQUENCE WITH C.W. ROTATION FACING DRIVE END.
2. WHEN RECONNECTING GENERATOR LEADS, BOLTS SHOULD BE TORQUED AT 22 0942 FT-LBS.

THIS IS A REPRESENTATIVE (GENERIC) SCHEMATIC/WIRING DIAGRAM. FOR TROUBLESHOOTING, REFER TO THE WIRING DIAGRAM PACKAGE THAT WAS SHIPPED WITH THE GENERATOR SET.

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Sheet 1 of 2, Dated January 2004

FIGURE 40. ALTERNATOR RECONNECNT DRAWING 630-2402 SHEET 1

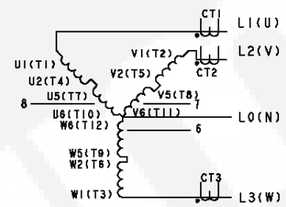
THIS IS A REPRESENTATIVE (GENERIC) SCHEMATIC/WIRING DIAGRAM. FOR TROUBLESHOOTING, REFER TO THE WIRING DIAGRAM PACKAGE THAT WAS SHIPPED WITH THE GENERATOR SET.

UC GENERATORS

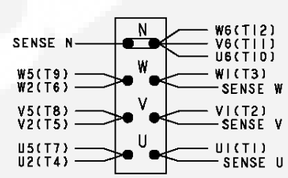
3 PHASE RECONNECTABLE

CURRENT TRANSFORMER SECONDARY CONNECTION

X1 X2



SERIES STAR
3 PHASE 4 WIRE
OUTPUT TERMINALS
U,V,W,N



NOTE: FOR SHUNT OPERATION, CONNECT AC HARNESS LEADS:
PMG2 TO GENERATOR TAP LEAD 8
PMG3 TO GENERATOR TAP LEAD 7

PMG4 NOT CONNECTED
TAPE & TIE BACK PMG4 AND LEAD 6

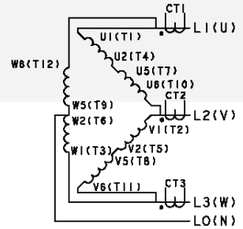
-06

FEATURE CODE	VOLTAGE	50HZ	60HZ
R114	600	-	X

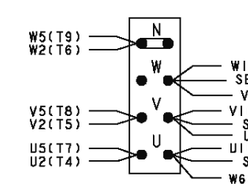
3 PHASE NON-RECONNECTABLE

CURRENT TRANSFORMER SECONDARY CONNECTION

X1 X2



SERIES DELTA
3 PHASE 4 WIRE
OUTPUT TERMINALS
U,V,W,N



NOTES:
1. SENSE LEAD N IS NOT USED.
   TAPE END AND TIE BACK.
2. PMG MUST BE USED.
   SHUNT NOT ALLOWED

-07

FEATURE CODE	VOLTAGE	50HZ	60HZ
R019	120/240	X	-
R119	240/480	-	X

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Sheet 2 of 2, Dated January 2004

FIGURE 41. ALTERNATOR RECONNECT DRAWING - 630-2404 SHEET 2

Appendix E. Seismic Requirements

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Wiring Diagrams

The drawings included in this section are representative. For current complete information, refer to the drawing package that was shipped with the unit.

Seismic Installation Instructions

SEISMIC INSTALLATIONS NOTES:

1. THE DESIGN OF POST-INSTALLED ANCHORS IN CONCRETE USED FOR THE COMPONENT ANCHORAGE IS PRE-QUALIFIED FOR SEISMIC APPLICATIONS IN ACCORDANCE WITH "ACI 355.2" AND DOCUMENTED IN A REPORT BY A REPUTABLE TESTING AGENCY. (EX. THE EVALUATION SERVICE REPORT ISSUED BY THE INTERNATIONAL CODE COUNCIL)
2. ANCHORS MUST BE INSTALLED TO AN EMBEDMENT DEPTH AS RECOMMENDED IN THE PER-QUALIFICATION TEST REPORT AS DEFINED IN NOTE 1. FOR "IBC 2000" AND "IBC 2003" APPLICATIONS, THE MINIMUM EMBEDMENT MUST BE 8X THE ANCHOR DIAMETER.
3. ANCHORS MUST BE INSTALLED IN MINIMUM 4000 PSI COMPRESSIVE STRENGTH NORMAL WEIGHT CONCRETE. CONCRETE AGGREGATE MUST COMPLY WITH "ASTM C33". INSTALLATION IN STRUCTURAL LIGHTWEIGHT CONCRETE IS NOT PERMITTED UNLESS OTHERWISE APPROVED BY THE STRUCTURAL ENGINEER OF RECORD.
4. ANCHORS MUST BE INSTALLED TO THE TORQUE SPECIFICATION AS RECOMMENDED BY THE ANCHOR MANUFACTURER TO OBTAIN MAXIMUM LOADING.
5. ANCHORS MUST BE INSTALLED IN LOCATIONS SPECIFIED ON THIS INSTALLATION DRAWING.
6. WIDE WASHERS MUST BE INSTALLED AT EACH ANCHOR LOCATION BETWEEN THE ANCHOR HEAD AND EQUIPMENT FOR TENSION LOAD DISTRIBUTION. WIDE WASHERS MUST BE SERIES "W" OF AMERICAN NATIONAL STANDARD TYPE "A" PLAIN WASHERS (ANSI B18.22.1-1965, R1975) WITH THE NOMINAL WASHER SIZE SELECTED TO MATCH THE SPECIFIED NOMINAL ANCHOR DIAMETER.
7. CONCRETE FLOOR SLAB AND CONCRETE HOUSEKEEPING PADS MUST BE DESIGNED AND REBAR REINFORCED FOR SEISMIC APPLICATIONS IN ACCORDANCE WITH "ACI 318". THE DESIGN LOADS SHALL BE TAKEN AS THOSE PUBLISHED ON THIS CUMMINS INSTALLATION DRAWING.
8. ALL HOUSEKEEPING PAD THICKNESSES MUST BE DESIGNED IN ACCORDANCE WITH THE PRE-QUALIFICATION TEST REPORT AS DEFINED IN NOTE 1 OR A MINIMUM OF 1.5X THE ANCHOR EMBEDMENT DEPTH, WHICHEVER IS LARGEST.
9. ALL HOUSEKEEPING PADS MUST BE DOWELLED OR CAST INTO THE BUILDING STRUCTURAL FLOOR SLAB AND DESIGNED FOR SEISMIC APPLICATION PER "ACI 318" AND AS APPROVED BY THE STRUCTURAL ENGINEER OF RECORD.
10. WALL MOUNTED EQUIPMENT MUST BE INSTALLED TO A REBAR REINFORCED STRUCTURAL CONCRETE WALL THAT IS SEISMICALLY DESIGNED AND APPROVED BY THE ENGINEER OF RECORD TO RESIST THE ADDED SEISMIC LOADS FROM COMPONENTS BEING ANCHORED TO THE WALL.
11. FLOOR MOUNTED EQUIPMENT (WITH OR WITHOUT A HOUSEKEEPING PAD) MUST BE INSTALLED TO A REBAR REINFORCED STRUCTURAL CONCRETE FLOOR THAT IS SEISMICALLY DESIGNED AND APPROVED BY THE ENGINEER OF RECORD TO RESIST THE ADDED SEISMIC LOADS FROM COMPONENTS BEING ANCHORED TO THE FLOOR.
12. WHEN INSTALLING TO A FLOOR OR WALL, REBAR INTERFERENCE MUST BE CONSIDERED.
13. ATTACHING SEISMIC CERTIFIED EQUIPMENT TO ANY FLOOR OR WALL OTHER THAN THOSE CONSTRUCTED OF STRUCTURAL CONCRETE AND DESIGNED TO ACCEPT THE SEISMIC LOADS FROM SAID EQUIPMENT IS NOT PERMITTED BY THIS SPECIFICATION AND BEYOND THE SCOPE OF THIS CERTIFICATION.
14. ATTACHING SEISMIC CERTIFIED EQUIPMENT TO ANY FLOOR CONSTRUCTED OF LIGHT WEIGHT CONCRETE OVER STEEL DECKING IS NOT PERMITTED BY THIS SPECIFICATION AND BEYOND THE SCOPE OF THIS CERTIFICATION.
15. ATTACHING SEISMIC CERTIFIED EQUIPMENT TO ANY CONCRETE BLOCK WALLS OR CINDER BLOCK WALLS IS NOT PERMITTED BY THIS SPECIFICATION AND BEYOND THE SCOPE OF THIS CERTIFICATION.
16. INSTALLATION UPON A ROOFTOP STEEL DUNNAGE SHALL BE COORDINATED WITH THE STRUCTURAL ENGINEER OF RECORD.
17. INSTALLATION UPON ANY ROOFTOP CURB SHALL BE COORDINATED WITH THE CURB MANUFACTURER AND THE STRUCTURAL ENGINEER OF RECORD. ANY CURB OR CONCRETE PAD THAT SUPPORTS THE GENSET UNIT IS BEYOND THE SCOPE OF THIS CERTIFICATION.
18. CONNECTIONS TO THE EQUIPMENT, INCLUDING BUT NOT LIMITED TO CONDUIT, WIRING FROM CABLE TRAYS, OTHER ELECTRICAL SERVICES, DUCTING, PIPING SUCH AS EXHAUST, STEAM, WATER, COOLANT, REFRIGERANT, FUEL, OR OTHER CONNECTIONS, ARE THE RESPONSIBILITY OF THE INSTALLING CONTRACTOR AND BEYOND THE SCOPE OF THIS DOCUMENT. TYPICAL REQUIREMENTS FOR THESE CONNECTIONS ARE STATED IN THE EQUIPMENT INSTALLATION MANUAL. SPECIAL CONSIDERATIONS FOR SEISMIC APPLICATIONS ARE AS FOLLOWS; CONNECTIONS TO NON-ISOLATED COMPONENTS OR EQUIPMENT MAY BE INSTALLED AS TYPICAL FOR THAT PARTICULAR APPLICATION. CONNECTIONS TO ISOLATED COMPONENTS (EX. BREAKER BOX BOLTED DIRECTLY TO AN ISOLATED GENSET) OR ISOLATED EQUIPMENT (EX. AN ENCLOSED GENSET MOUNTED ON EXTERNAL ISOLATORS) MUST BE FLEXIBLY ATTACHED. THE FLEXIBLE ATTACHMENT MUST PROVIDE FOR ENOUGH RELATIVE DISPLACEMENT TO REMAIN CONNECTED TO THE EQUIPMENT AND FUNCTIONAL DURING AND AFTER A SEISMIC EVENT.

REQUIREMENTS FOR GENSETS
DSGAA, DSGAB, DSGAC
DSFAE, DSFAD, DSFAC, DSFAB, DSFAA

PARAMETERS	IBC 2009/2006	IBC 2009/2006	IBC 2003/2000	IBC 2003/2000
	Sds<=1.93	1.93<Sds<=2.28	Sds<=2.41	Sds<=2.46
	Ip<=1.5	Ip<=1.5	Ip<=1.5	Ip<=1.5
	ap/Rp<=1.25	ap/Rp<=1.25	ap/Rp<=1.0	ap/Rp<=1.0
	z/h<=1.00	z/h<=0.77	z/h<=1.0	z/h<=0.97

REQUIREMENTS FOR GENSETS
DSHAD, DSHAC, DSHAB
DGHE, DGHD, DGGD
DSKCA, DSKBA, DSKAB, DSKAA
GGLB, GGLA) (GGMC, GGMB, GGMA
GGHH, GGHG, GGHF, GGHE, GGFE, GGFD
GGPA, GGPB, GGPC

PARAMETERS	IBC 2009	IBC 2006	IBC 2003	IBC 2000
	Sds<=2.28	Sds<=2.28	Sds<=2.46	Sds<=2.46
	Ip<=1.5	Ip<=1.5	Ip<=1.5	Ip<=1.5
	ap/Rp<=1.25	ap/Rp<=1.25	ap/Rp<=1.0	ap/Rp<=1.0
	z/h<=1.0	z/h<=1.0	z/h<=1.0	z/h<=1.0

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FIGURE 42. SEISMIC INSTALLATION INSTRUCTIONS (SHEET 1 OF 5)

	ROOF MOUNTED GENERATOR SETS							
	CUMMINS GENSET MODEL	RANGE	CONFIGURATION	CONCRETE ANCHORS	ANCHOR EMBEDMENT	ANCHOR SPACING	DISTANCE TO THE NEAREST EDGE	CONCRETE SLAB THICKNESS
1	DSHAD, DSHAC, DSHAB	(0<Sds<=1.36)	SKID/TANK/ENCLOSURE	(QTY 4) 3/4" DIA. USP DUC34-1000H CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	10" MIN. 254mm MIN.	30" MIN. 762mm MIN.	15" MIN. 381mm MIN.	15" MIN. 381mm MIN.
2	DSHAD, DSHAC, DSHAB	(1.36<Sds<=2.28)	SKID/TANK/ENCLOSURE	FOR THIS APPLICATION SEE DIAGRAM ON SHEET #4	SEE TABLE ON SHEET #4	SEE TABLE ON SHEET #4	SEE TABLE ON SHEET #4	SEE TABLE ON SHEET #4
3	DSHAD, DSHAC, DSHAB	(0<Sds<=2.28)	SKID WITH OR WITHOUT ENCLOSURE	(QTY 4) 3/4" DIA. USP DUC34-1000H CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	10" MIN. 254mm MIN.	30" MIN. 762mm MIN.	15" MIN. 381mm MIN.	15" MIN. 381mm MIN.
4	DSGAA, DSGAB, DSGAC	(0<Sds<=1.35)	SKID/TANK/ENCLOSURE	(QTY 4) 3/4" DIA. USP DUC34-1000H CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	10" MIN. 254mm MIN.	30" MIN. 762mm MIN.	15" MIN. 381mm MIN.	15" MIN. 381mm MIN.
5	DSGAA, DSGAB, DSGAC	(1.35<Sds<=1.93)	SKID/TANK/ENCLOSURE	FOR THIS APPLICATION SEE DIAGRAM ON SHEET #5	SEE TABLE ON SHEET #5	SEE TABLE ON SHEET #5	SEE TABLE ON SHEET #5	SEE TABLE ON SHEET #5
6	DSGAA, DSGAB, DSGAC	(0<Sds<=1.93)	SKID WITH OR WITHOUT ENCLOSURE	(QTY 4) 3/4" DIA. USP DUC34-1000H CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	10" MIN. 254mm MIN.	30" MIN. 762mm MIN.	15" MIN. 381mm MIN.	15" MIN. 381mm MIN.
7	DSFAE, DSFAD, DSFAC, DSFAB, DSFAA, DGHE, DGHD, DGGD	(0<Sds<=2.28)	SKID/TANK/ENCLOSURE	(QTY 4) 3/4" DIA. USP DUC34-1000H CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	10" MIN. 254mm MIN.	30" MIN. 762mm MIN.	15" MIN. 381mm MIN.	15" MIN. 381mm MIN.
8	DSFAE, DSFAD, DSFAC, DSFAB, DSFAA, DGHE, DGHD, DGGD	(0<Sds<=2.28)	SKID WITH OR WITHOUT ENCLOSURE	(QTY 4) 3/4" DIA. USP DUC34-1000H CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	10" MIN. 254mm MIN.	30" MIN. 762mm MIN.	15" MIN. 381mm MIN.	15" MIN. 381mm MIN.
9	DSKCA, DSKBA, DSKAB, DSKAA	(0<Sds<=2.28)	SKID/TANK/ENCLOSURE	(QTY 4) 3/4" DIA. USP DUC34-500L CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	5" MIN. 127mm MIN.	15" MIN. 381mm MIN.	7.5" MIN. 190.5mm MIN.	7.5" MIN. 190.5mm MIN.
10	DSKCA, DSKBA, DSKAB, DSKAA	(0<Sds<=2.28)	SKID WITH OR WITHOUT ENCLOSURE	(QTY 4) 3/4" DIA. HILTI KB-TZ CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	3-3/4" MIN. 95.25mm MIN.	7.5" MIN. 190.5mm MIN.	10" MIN. 254mm MIN.	6" MIN. 152.4mm MIN.
11	GGHH, GGHG, GGHF, GGHE	(0<Sds<=2.28)	SKID WITH OR WITHOUT ENCLOSURE	(QTY 4) 3/4" DIA. USP DUC34-1000H CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	10" MIN. 254mm MIN.	30" MIN. 762mm MIN.	15" MIN. 381mm MIN.	15" MIN. 381mm MIN.
12	GGFE, GGFD	(0<Sds<=2.28)	SKID WITH OR WITHOUT ENCLOSURE	(QTY 4) 3/4" DIA. HILTI KB-TZ CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	4-3/4" MIN. 120.65mm MIN.	9.5" MIN. 241.3mm MIN.	9" MIN. 228.6mm MIN.	8" MIN. 203.2mm MIN.
13	GGMC, GGMB, GGMA, GGMD	(0<Sds<=2.28)	SKID WITH OR WITHOUT ENCLOSURE	(QTY 4) 5/8" DIA. HILTI KB-TZ CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	3-1/8" MIN. 79.38mm MIN.	6-1/4" MIN. 158.75mm MIN.	7" MIN. 177.8mm MIN.	5" MIN. 127mm MIN.
14	GGLB, GGLA	(0<Sds<=2.28)	SKID WITH OR WITHOUT ENCLOSURE	(QTY 4) 3/4" DIA. USP DUC34-1000H CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	10" MIN. 254mm MIN.	30" MIN. 762mm MIN.	15" MIN. 381mm MIN.	15" MIN. 381mm MIN.
15	GGPA, GGPB, GGPC	(0<Sds<=2.27)	SKID WITH OR WITHOUT ENCLOSURE	(QTY 4) M16X190/40 HILTI HDA-P CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	7.5" MIN. 190.5mm MIN.	39" MIN. 990.6mm MIN.	12" MIN. 304.8mm MIN.	12" MIN. 304.8mm MIN.

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FIGURE 43. SEISMIC INSTALLATION INSTRUCTIONS (SHEET 2 OF 5)

	GRADE MOUNTED GENERATOR SETS							
	CUMMINS GENSET MODEL	RANGE	CONFIGURATION	CONCRETE ANCHORS	ANCHOR EMBEDMENT	ANCHOR SPACING	DISTANCE TO THE NEAREST EDGE	CONCRETE SLAB THICKNESS
1	DSHAD, DSHAC, DSHAB	(0<Sds<=2.28)	SKID/TANK/ENCLOSURE	(QTY 4) 3/4" DIA. USP DUC34-500L CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	5" MIN. 127mm MIN.	15" MIN. 381mm MIN.	7.5" MIN. 190.5mm MIN.	7.5" MIN. 190.5mm MIN.
2	DSHAD, DSHAC, DSHAB	(0<Sds<=2.28)	SKID WITH OR WITHOUT ENCLOSURE	(QTY 4) 3/4" DIA. HILTI KB-TZ CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	3-3/4" MIN. 95.25mm MIN.	7.5" MIN. 190.5mm MIN.	10" MIN. 254mm MIN.	6" MIN. 152.4mm MIN.
3	DSGAA, DSGAB, DSGAC	(0<Sds<=1.93)	SKID/TANK/ENCLOSURE	(QTY 4) 3/4" DIA. USP DUC34-500L CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	5" MIN. 127mm MIN.	15" MIN. 381mm MIN.	7.5" MIN. 190.5mm MIN.	7.5" MIN. 190.5mm MIN.
4	DSGAA, DSGAB, DSGAC	(0<Sds<=1.93)	SKID WITH OR WITHOUT ENCLOSURE	(QTY 4) 3/4" DIA. USP DUC34-500L CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	5" MIN. 127mm MIN.	15" MIN. 381mm MIN.	7.5" MIN. 190.5mm MIN.	7.5" MIN. 190.5mm MIN.
5	DSFAE, DSFAD, DSFAC, DSFAB, DSFAA, DGHE, DGHD, DGGD	(0<Sds<=2.28)	SKID/TANK/ENCLOSURE	(QTY 4) 3/4" DIA. HILTI KB-TZ CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	3-3/4" MIN. 95.25mm MIN.	7.5" MIN. 190.5mm MIN.	10" MIN. 254mm MIN.	6" MIN. 152.4mm MIN.
6	DSFAE, DSFAD, DSFAC, DSFAB, DSFAA, DGHE, DGHD, DGGD	(0<Sds<=2.28)	SKID WITH OR WITHOUT ENCLOSURE	(QTY 4) 3/4" DIA. HILTI KB-TZ CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	3-3/4" MIN. 95.25mm MIN.	7.5" MIN. 190.5mm MIN.	10" MIN. 254mm MIN.	6" MIN. 152.4mm MIN.
7	DSKCA, DSKBA, DSKAB, DSKAA	(0<Sds<=2.28)	SKID/TANK/ENCLOSURE	(QTY 4) 3/4" DIA. HILTI KB-TZ CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	3-3/4" MIN. 95.25mm MIN.	7.5" MIN. 190.5mm MIN.	10" MIN. 254mm MIN.	6" MIN. 152.4mm MIN.
8	DSKCA, DSKBA, DSKAB, DSKAA	(0<Sds<=2.28)	SKID WITH OR WITHOUT ENCLOSURE	(QTY 4) 3/4" DIA. HILTI KB-TZ CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	3-3/4" MIN. 95.25mm MIN.	7.5" MIN. 190.5mm MIN.	10" MIN. 254mm MIN.	6" MIN. 152.4mm MIN.
9	GGHH, GGHG, GGHF, GGHE	(0<Sds<=2.28)	SKID WITH OR WITHOUT ENCLOSURE	(QTY 4) 3/4" DIA. HILTI KB-TZ CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	3-3/4" MIN. 95.25mm MIN.	7.5" MIN. 190.5mm MIN.	10" MIN. 254mm MIN.	6" MIN. 152.4mm MIN.
10	GGFE, GGFD	(0<Sds<=2.28)	SKID WITH OR WITHOUT ENCLOSURE	(QTY 4) 3/4" DIA. HILTI KB-TZ CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	3-3/4" MIN. 95.25mm MIN.	7.5" MIN. 190.5mm MIN.	10" MIN. 254mm MIN.	6" MIN. 152.4mm MIN.
11	GGMC, GGMB, GGMA, GGMD	(0<Sds<=2.28)	SKID WITH OR WITHOUT ENCLOSURE	(QTY 4) 5/8" DIA. HILTI KB-TZ CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	3-1/8" MIN. 79.38mm MIN.	6-1/4" MIN. 158.75mm MIN.	7" MIN. 177.8mm MIN.	5" MIN. 127mm MIN.
12	GGLB, GGLA	(0<Sds<=2.28)	SKID WITH OR WITHOUT ENCLOSURE	(QTY 4) 3/4" DIA. HILTI KB-TZ CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	3-3/4" MIN. 95.25mm MIN.	7.5" MIN. 190.5mm MIN.	10" MIN. 254mm MIN.	6" MIN. 152.4mm MIN.
13	GGPA, GGPB, GGPC	(0<Sds<=2.27)	SKID WITH OR WITHOUT ENCLOSURE	(QTY 4) 5/8" DIA. HILTI KB-TZ CONCRETE ANCHORS THRU THE BASE RAIL MOUNTING HOLES.	3-1/8" MIN. 79.38mm MIN.	39" MIN. 990.6mm MIN.	6" MIN. 152.4mm MIN.	6" MIN. 152.4mm MIN.

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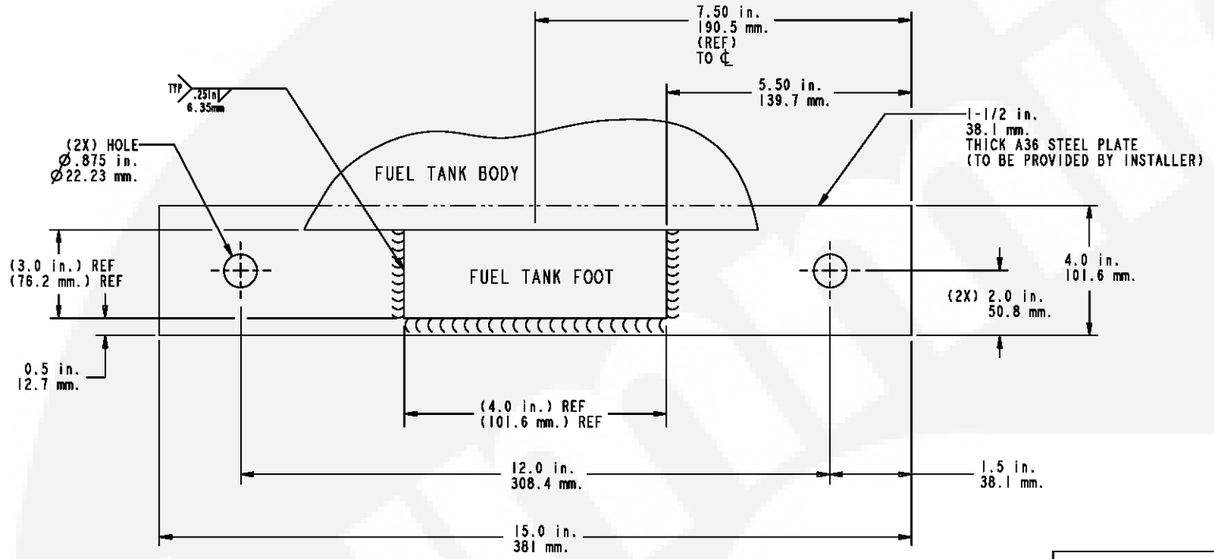
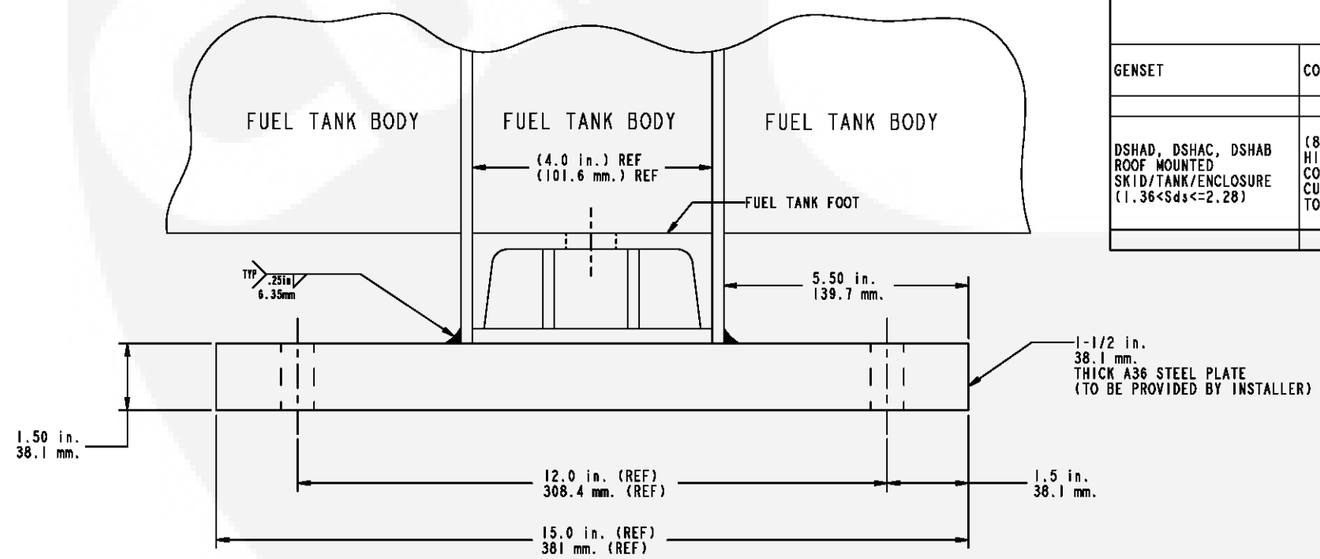
FIGURE 44. SEISMIC INSTALLATION INSTRUCTIONS (SHEET 3 OF 5)





ANCHORAGE REQUIREMENTS
HIGH SEISMIC AREAS
ROOF MOUNTED

GENSET	CONCRETE ANCHORS	ANCHOR EMBEDMENT	ANCHOR SPACING	DISTANCE TO THE NEAREST EDGE	CONCRETE SLAB THICKNESS
DSHAD, DSHAC, DSHAB ROOF MOUNTED SKID/TANK/ENCLOSURE (1.36<Sds<=2.28)	(8) 20MM DIA. HILTI HDA-P-M20 CONCRETE ANCHORS WITH CUSTOM PLATE ATTACHED TO SKID BASE RAILS	10" in. MIN 254 mm. MIN	12 in. MIN 304.8 mm. MIN	12 in. MIN 304.8 mm. MIN	15 in. MIN 381 mm. MIN

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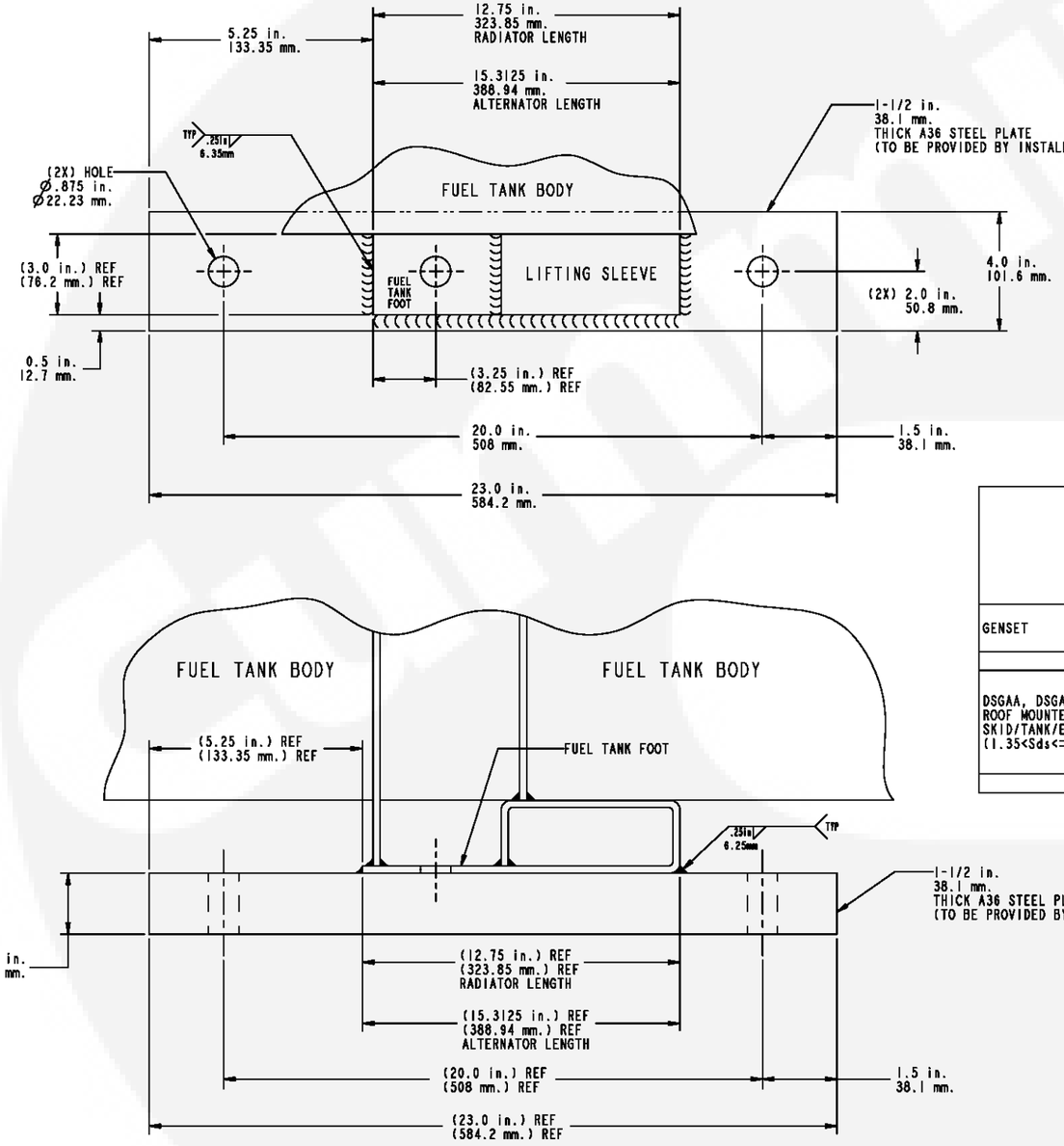
FIGURE 45. SEISMIC INSTALLATION INSTRUCTIONS (SHEET 4 OF 5)



ANCHORAGE REQUIREMENTS
HIGH SEISMIC AREAS
ROOF MOUNTED

GENSET	CONCRETE ANCHORS	ANCHOR EMBEDMENT	ANCHOR SPACING	DISTANCE TO THE NEAREST EDGE	CONCRETE SLAB THICKNESS
DSGAA, DSGAB, DSGAC ROOF MOUNTED SKID/TANK/ENCLOSURE (1.35<Sds<=1.93)	(8) 20MM DIA. HILTI HDA-P-M20 CONCRETE ANCHORS WITH CUSTOM PLATE ATTACHED TO SKID BASE RAILS	10 in. MIN 254 mm. MIN	12 in. MIN 304.8 mm. MIN	12 in. MIN 304.8 mm. MIN	15 in. MIN 381 mm. MIN

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FIGURE 46. SEISMIC INSTALLATION INSTRUCTIONS (SHEET 5 OF 5)

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