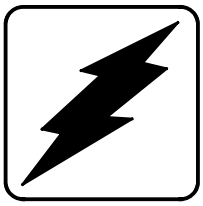
Operation and Service

Commercial Generator Sets



Models:

COM7.5

ISO 9001 KOHLER POWER SYSTEMS NATIONALLY REGISTERED

KOHLER® POWER SYSTEMS

TP-6418 1/11a

California Proposition 65

⚠ WARNING

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

Product Identification Information

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

Generator Set Identification Numbers

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

Model Designation _____

Specification Number _____

Serial Number _____

Accessory Number	Accessory Description

Engine Identification

Record the product identification information from the engine nameplate.

Manufacturer _____

Model Designation _____

Serial Number _____

Table of Contents

Table of Contents, continued

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

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

DANGER

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

WARNING

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

CAUTION

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

NOTICE

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

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

Accidental Starting

WARNING

Accidental starting.
Can cause severe injury or death.

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

Disabling the generator set. Accidental starting can cause severe injury or death. Before working on the generator set or equipment connected to the set, disable the generator set as follows: (1) Place the generator set start/stop switch in the STOP position. (2) Disconnect the power to the battery charger, if equipped. (3) Remove the battery cables, negative (-) lead first. Reconnect the negative (-) lead last when reconnecting the battery. Follow these precautions to prevent the starting of the generator set by the remote start/stop switch.

Battery

WARNING

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

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

WARNING

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

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

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

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

Battery gases. Explosion can cause severe injury or death. Battery gases can cause an explosion. Do not smoke or permit flames or sparks to occur near a battery at any time, particularly when it is charging. Do not dispose of a battery in a fire. To prevent burns and sparks that could cause an explosion, avoid touching the battery terminals with tools or other metal objects. Remove all jewelry before servicing the equipment. Discharge static electricity from your body before touching batteries by first touching a

grounded metal surface away from the battery. To avoid sparks, do not disturb the battery charger connections while the battery is charging. Always turn the battery charger off before disconnecting the battery connections. Ventilate the compartments containing batteries to prevent accumulation of explosive gases.

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

Engine Backfire/Flash Fire

⚠ WARNING

Fire.
Can cause severe injury or death.

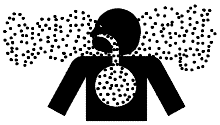
Do not smoke or permit flames or sparks near fuels or the fuel system.

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

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

Exhaust System

⚠ WARNING



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

The exhaust system must be leakproof and routinely inspected.

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

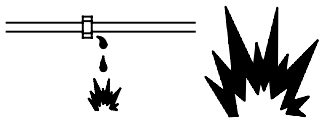
Carbon monoxide symptoms. Carbon monoxide can cause severe nausea, fainting, or death. Carbon monoxide is a poisonous gas present in exhaust gases. Carbon monoxide is an odorless, colorless, tasteless, nonirritating gas that can cause death if inhaled for even a short time. Carbon monoxide poisoning symptoms include but are not limited to the following:

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

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

Fuel System

⚠ WARNING



Explosive fuel vapors.
Can cause severe injury or death.

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

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

Hazardous Noise

⚠ CAUTION

Hazardous noise.
Can cause hearing loss.

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

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

Hazardous Voltage/ Moving Parts

⚠ DANGER

Hazardous voltage.
Will cause severe injury or death.

Only authorized personnel should open the enclosure.

⚠ WARNING

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

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

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

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

High voltage test. Hazardous voltage can cause severe injury or death. Follow the instructions of the test equipment manufacturer when performing high-voltage tests on the rotor or stator. An improper test procedure can damage equipment or lead to generator set failure.

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

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

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

Hot Parts

⚠ WARNING

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

Do not work on the generator set until it cools.

Servicing the alternator. Hot parts can cause severe injury or death. Avoid touching the alternator field or exciter armature. When shorted, the alternator field and exciter armature become hot enough to cause severe burns.

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

Notice

NOTICE

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

NOTICE

Fuse replacement. Replace fuses with fuses of the same ampere rating and type (for example: 3AB or 314, ceramic). Do not substitute clear glass-type fuses for ceramic fuses. Refer to the wiring diagram when the ampere rating is unknown or questionable.

Notes

This manual provides operation, troubleshooting, and repair instructions for COM7.5 generator sets equipped with a microprocessor controller.

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

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

The equipment service requirements are very important to safe and efficient operation. Inspect the parts often and perform required service at the prescribed intervals. Maintenance work must be performed by appropriately skilled and suitably trained maintenance personnel familiar with generator set operation and service.

Emission Information

The Kohler® Model CH640 engine used on the COM7.5 generator set is certified to operate using natural gas or propane fuel.

This engine is certified with engine modifications made by the generator set manufacturer.

The Emission Compliance Period referred to on the Emission Control or Air Index label indicates the number of operating hours for which the engine has been shown to meet CARB or EPA emission requirements. The following table provides the engine compliance period (in hours) associated with the category descriptor, which may be found on the certification label.

Emission Compliance Period (hours)			
EPA	C 250	B 500	A 1000
CARB	Moderate 125	Intermediate 250	Extended 500

Refer to the certification label for engine displacement.

The exhaust emission control system for the CH640 engine used on the COM7.5 generator set is EM for U.S. EPA, California, and Europe.

Maintenance and Service Parts

Figure 1 lists some routine maintenance and service parts for your generator set. Parts Catalog TP-6091 provides a complete list of replacement parts.

Part Description	Part Number
Air cleaner foam element	24 083 02
Air cleaner paper element	24 083 08
Controller fuse	GM22466
Oil filter	12 050 01
Spark plug	12 132 02-S
Oxygen sensor (service only)	A-345052

Figure 1 Maintenance and Service Parts

Service Assistance

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

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

Headquarters Europe, Middle East, Africa (EMEA)
Kohler Power Systems
3 rue de Brennus
93200 Saint Denis
France
Phone: (33) 1 49 178300
Fax: (33) 1 49 178301

Asia Pacific
Power Systems Asia Pacific Regional Office
Singapore, Republic of Singapore
Phone: (65) 6264-6422
Fax: (65) 6264-6455

China
North China Regional Office, Beijing
Phone: (86) 10 6518 7950
(86) 10 6518 7951
(86) 10 6518 7952
Fax: (86) 10 6518 7955

East China Regional Office, Shanghai
Phone: (86) 21 6288 0500
Fax: (86) 21 6288 0550

India, Bangladesh, Sri Lanka
India Regional Office
Bangalore, India
Phone: (91) 80 3366208
(91) 80 3366231
Fax: (91) 80 3315972

Japan, Korea
North Asia Regional Office
Tokyo, Japan
Phone: (813) 3440-4515
Fax: (813) 3440-2727

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

1.1 System Description

The COM7.5 generator set provides reliable backup DC power to cable TV systems or telecommunication sites in place of, or in addition to, batteries. The COM7.5 is available in 48 and 96 VDC models. The generator set nameplate indicates the unit's rated voltage.

The system batteries provide power at 48 or 96 volts. When power fails, the control system signals the generator set to start. The generator set provides DC power for continued or reserve operation of the system.

The COM7.5 generator set has both local and remote control capabilities. The unit runs on natural gas or LP vapor.

1.2 Generator Set Functional Description

The COM7.5 generator set system consists of the generator set (engine and generator) and the control system. The generator set provides regulated DC voltage to the telecommunications power system. The control system provides complete control of the engine and generator, accepts remote control commands, and delivers local and remote annunciation of unit status. Internal control functions include start and stop logic, fault monitoring, unit voltage control, engine speed (rpm) governing, and a local LED for fault annunciation.

Under very light loads, the generator set operates at low speed. As loads increase, the control system maintains constant generator output voltage by increasing the generator set engine speed.

The Kohler CH20 engine drives a direct-connected, variable-speed, 3-phase, voltage-specific generator to produce high-frequency AC power. A 3-phase, full-wave rectifier in the control system rectifies the output to produce low-ripple, unfiltered DC power.

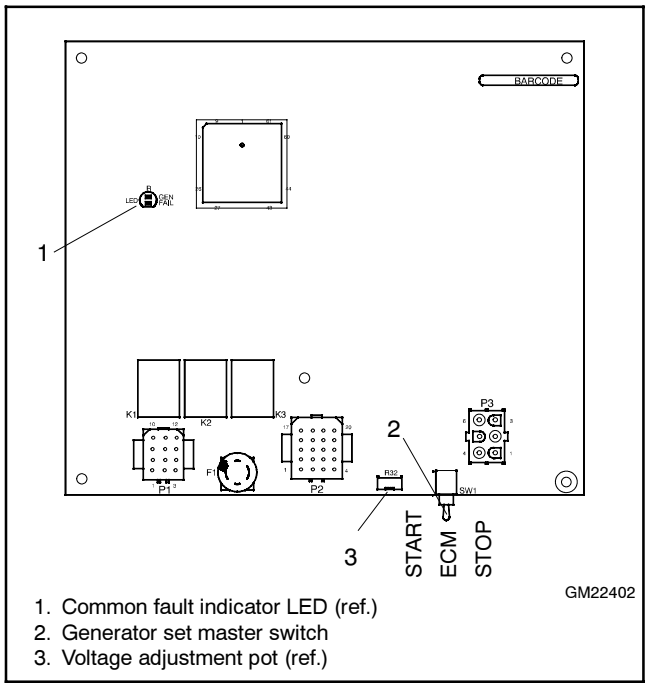
1.3 Generator Set Installation

Kohler Co. designs the generator set for installation into an enclosure by an original equipment manufacturer (OEM). Kohler Co. must review the installation details. The OEM *must* provide the following items:

- Guards for all rotating parts, live electrical components, and high temperature parts, including engine and exhaust system components.
- A mounting plate or bracket to support the controller circuit board.
- A label showing the controller switch positions: START, ECM, and STOP. See Figure 1-1.
- A fuel solenoid valve connected as shown in the wiring diagram in Section 8. The fuel solenoid valve must be UL-listed or UL-recognized for natural gas and LPG fuels.
- A primary fuel regulator.
- A 110- or 120-volt outlet connected to the utility power supply for the carburetor heater and engine block heater.
- Output overcurrent protection (i.e. a fuse) appropriately sized to protect the generator.

  Note: The overcurrent protection device rating should not exceed 125% of the generator set's rated output current. To reduce the risk of fire, replacement fuses must be the same type and rating as the original fuses.

- A label near the fuse location indicating the type, voltage, and current rating of the fuse.



1. Common fault indicator LED (ref.)
2. Generator set master switch
3. Voltage adjustment pot (ref.)

Figure 1-1 Generator Set Master Switch Positions

1.4 Specifications

Figure 1-2, Figure 1-3, and Figure 1-4 contain generator set, alternator, and engine specifications. Refer to the scheduled maintenance section for service details.

Generator Set Specification	48 VDC	96 VDC
Manufacturer	Kohler	
Dimensions, L x W x H, mm (in.)	613 x 413 x 553 (24.1 x 16.3 x 21.8)	
Weight, dry, kg (lb.)	91 (200)	
Rated kW*	7.5	
Rated voltage (after rectifier)	52	104
Rated amps	144	72
* Derate approximately 4% per 300 m (1000 ft.) over 153 m (500 ft.) above sea level. Derate 1% for each 5.5°C (10°F) increase in temperature above 25°C (77°F).		

Figure 1-2 Generator Set Specifications

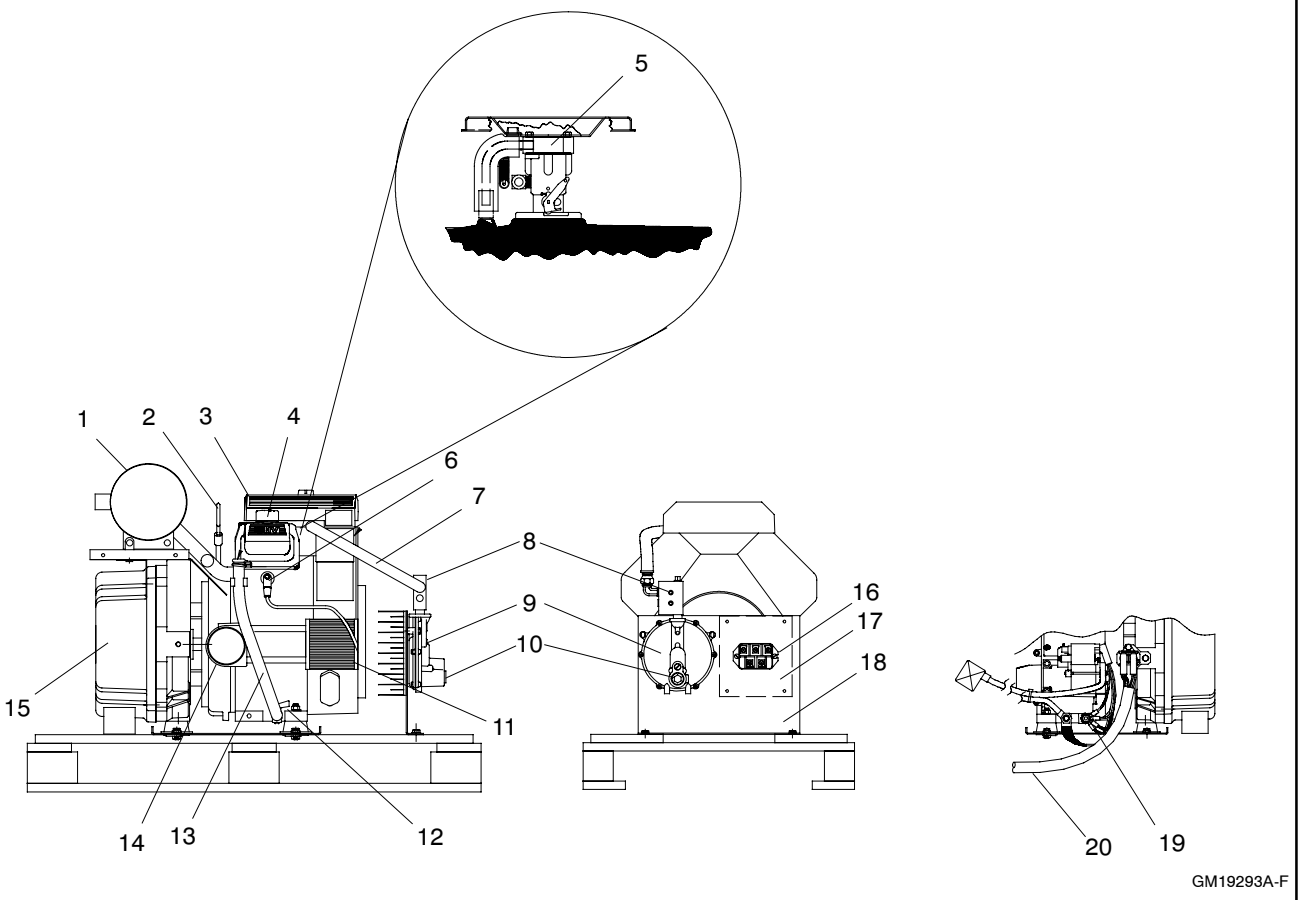
Alternator Specification	48 VDC	96 VDC
Stator resistance, ohms	0.024	0.054
Stator type	3-Phase, 3-Lead, Ungrounded	
Excitation method (rotor)	Permanent-Magnet, Brushless	
Coupling type	Direct-to-Engine	
Insulation (stator)	Class 180, Epoxy Varnish, Vacuum-Impregnated	
Winding material	Copper	

Figure 1-3 Alternator Specifications

Engine Specification	Specification
Manufacturer	Kohler
Make/model	CH20
Cycle	4
Compression ratio	8.5:1
Displacement, cc (cu. in.)	398 (24.3)
Rated horsepower (using natural gas fuel)	13.1
Engine speed, rpm	2500–3650
Bore, mm (in.)	77 (3.08)
Stroke, mm (in.)	67 (2.64)
Valve train	Overhead Valve
Valve material: Intake Exhaust	 Steel Stellite® Face
Number of cylinders	2
Cylinder block material	Aluminum w/Cast Iron Liners
Cylinder head material	Aluminum
Cylinder head tightening torque, Nm (ft. lb.)	41 (30)
Piston rings: quantity, type	2 Compression, 1 Oil
Crankshaft material	Heat Treated, Ductile Iron Casting
Bearings: quantity, type	2, Replaceable Sleeve
Governor	Electronic
Starter motor	Electric, 12 VDC, Solenoid Shift
Lubrication system	Full Pressure
Oil capacity (with filter and cooler), L (qt.)	1.9 (2.0)
Oil type	Synthetic 5W-30
Oil filter tightening torque, Nm (in. lb.)	5.7–9.0 (50–80)
Oil pressure, kPa (psi)	172–241 (25–35)
Low oil pressure, kPa (psi)	24.1 ± 13.8 (3.5 ± 1.5)
Fuel type	Natural Gas or Propane
Fuel pressure, kPa (in. water column)	1.7 to 2.7 (7 to 11)
Fuel consumption at 7.5 kW: Natural gas, 1000 Btu/ft.^{3} Propane, 2516 Btu/ft.^{3}	 150 cfh 50 cfh
Battery voltage	12 VDC
Battery ground	Negative
Battery recommendation (minimum)	585 CCA at –18°C (0°F)
Spark plug type (Kohler Part No.)	12 132 02-S
Spark plug gap, mm (in.)	0.75 (0.030)
Spark plug tightening torque, Nm (ft. lb.)	24.4–29.8 (18–22)
Ignition system	Capacitive Discharge
Cooling system	Air Cooled
High engine temperature, °C (°F)	152 (305)

Figure 1-4 Engine Specifications

1.5 Service Views



1. Silencer
2. Oil check (dipstick)
3. Air cleaner
4. Oil fill
5. Carburetor heater (mounted under the air cleaner)
6. Spark plugs (2)
7. Fuel line
8. Multi-fuel block
9. Gas regulator
10. Fuel supply inlet
11. Oil cooler
12. Oil drain valve
13. Oil drain hose
14. Oil filter
15. Alternator
16. Rectifier
17. Rectifier heat sink (hidden)
18. Shipping bracket (for shipping only)
19. Ground connection
20. Engine harness

Figure 1-5 COM7.5 Service Views

Notes

⚠ WARNING

Fire.
Can cause severe injury or death.

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

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

⚠ CAUTION

Hazardous noise.
Can cause hearing loss.

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

⚠ WARNING

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

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

⚠ WARNING

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

Do not work on the generator set until it cools.

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

2.1 Prestart Checklist

To ensure satisfactory operation, perform the following checks or inspections before or at each startup, as designated, and at the intervals specified in the service schedule. Some checks require verification after the unit starts.

Air Cleaner. Check for a clean and installed air cleaner element to prevent unfiltered air from entering engine.

Air Inlets and Outlets. Check for clean and unobstructed cabinet air inlets and outlets. Check for obstructions that could block the flow of cooling air. Keep the air intake area clean. Do not leave rags, tools, or debris on or near the generator set.

Battery. Check for clean and tight battery connections. Consult the battery manufacturer's instructions regarding battery care and maintenance.

Exhaust System. Check for exhaust leaks and blockages. Check the silencer and piping condition and check for tight exhaust system connections.

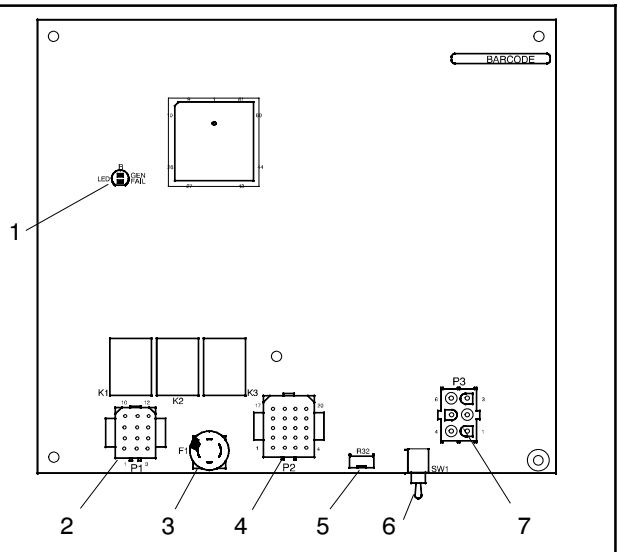
Inspect the exhaust system components (exhaust manifold, exhaust line, flexible exhaust, clamps, silencer, and outlet pipe) for cracks, leaks, and corrosion.

- Check for corroded or broken metal parts and replace them as needed.
- Check for loose, corroded, or missing clamps and hangers. Tighten or replace the exhaust clamps and/or hangers as needed.
- Check that the exhaust outlet is unobstructed.
- Visually inspect for exhaust leaks. Check for carbon or soot residue on exhaust components. Carbon and soot residue indicates an exhaust leak. Replace or repair leaking parts as needed.

Oil Level. Maintain the oil level at or near, not over, the full mark on the dipstick.

2.2 Controller Operation

Microprocessor-based controls provide complete control of the engine and generator. The control system accepts remote control inputs for generator start and run and delivers remote annunciation of unit status and faults. Internal functions of the controls include start and stop logic, fault monitoring, generator voltage and engine speed governing, and fault annunciation through a common fault LED. See Figure 2-1 for the control board component locations.



1. Common fault indicator LED
2. P1
3. Fuse
4. P2
5. Voltage adjustment potentiometer
6. Generator set master switch
7. P3

Figure 2-1 Generator Set Controls

Generator set master switch. A three-position generator set master switch on the control board allows local or remote control of the generator set. Momentary RUN and STOP positions provide local control of the generator set. The STOP position also resets controller faults. The generator set master switch moves to the center position when released, allowing a remote device to start and stop the generator set. See Section 2.2.3 for remote start/stop connection information.

2.2.1 Starting Generator Set

The following procedures describe the actions required to start the generator set. Reset the controller by moving the generator set master switch to the STOP position after applying battery voltage for the first time or after a voltage interruption.

Local Starting. Move the generator set master switch to the RUN position and release it to immediately start the generator set.

Remote Starting. With the generator set master switch in the center position, close a contact between pins 5 and 6 on controller interface connector P6 to start the generator set. See Figure 2-2.

Note: The control board provides up to 75 seconds of cyclic cranking before overcrank shutdown occurs. After a fault shutdown, reset the controller by moving the generator set master switch to the STOP position.

At initial startup, the engine's hydraulic lifters may produce a metallic clicking sound. This is caused by the hydraulic lifter leakdown during storage. Run the generator for 5 minutes. The noise will normally cease in the first minute.

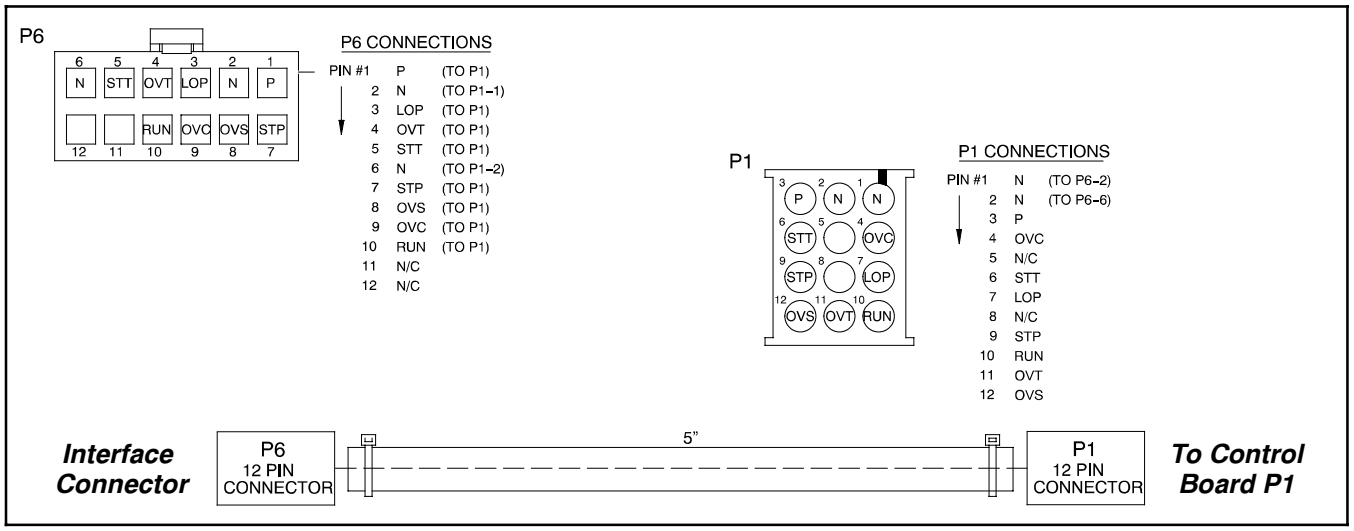


Figure 2-2 Controller Interface Harness, GM14245

2.2.2 Stopping Generator Set

The following procedures describe the actions required to stop the generator set.

Local Stopping. Move the generator set master switch to the STOP position and release it. The generator set stops immediately.

Note: When the generator set master switch is released, it returns to the center position. A start command from a remote control board can restart the generator set when the switch is in the center position.

Remote Stopping. With the generator set master switch in the center position, close a remote contact between pins 6 (N) and 7 (STP) on the controller interface connector, P6. See Figure 2-2.

2.2.3 Remote Start/Stop Connections

Set the generator set master switch to the center position for remote operation. For remote starting and stopping, use a three-wire start/stop switch connected to the controller harness. To start the generator set, open a contact between pins 6 (N) and 7 (STP) on the controller harness connector and close a contact between connector pins 5 (STT) and 6 (N) (see the wiring diagram in Section 8). Close the contact between pins 6 and 7 to stop the generator set.

2.2.4 Control Connections

Wiring harnesses connect the generator set control board to the remote controls and the engine. Figure 2-2, Figure 2-3, and Figure 2-4, show the sensing, engine wiring, and controller harnesses. Wiring diagram GM20551 in Section 8 shows the harness connections.

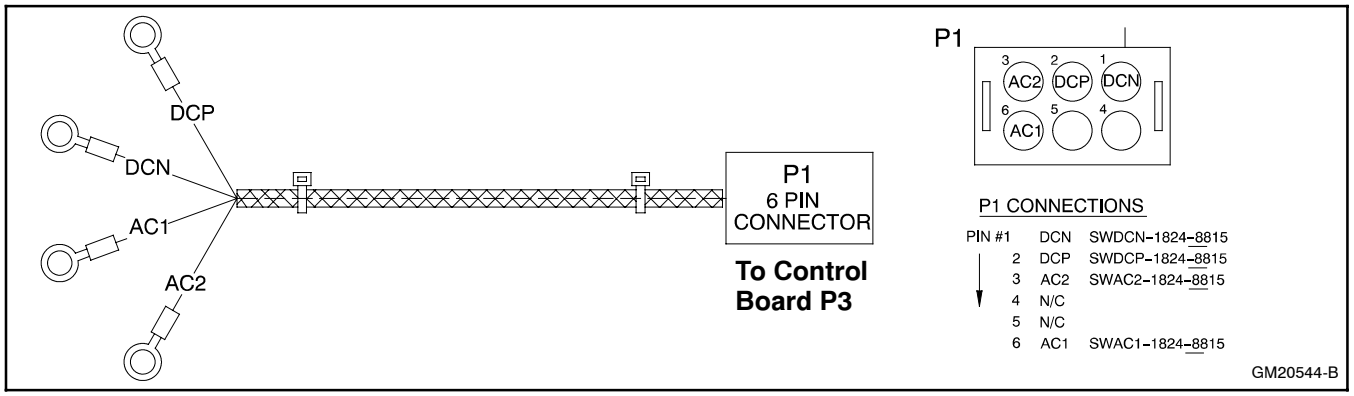


Figure 2-3 Sensing Harness, GM20544

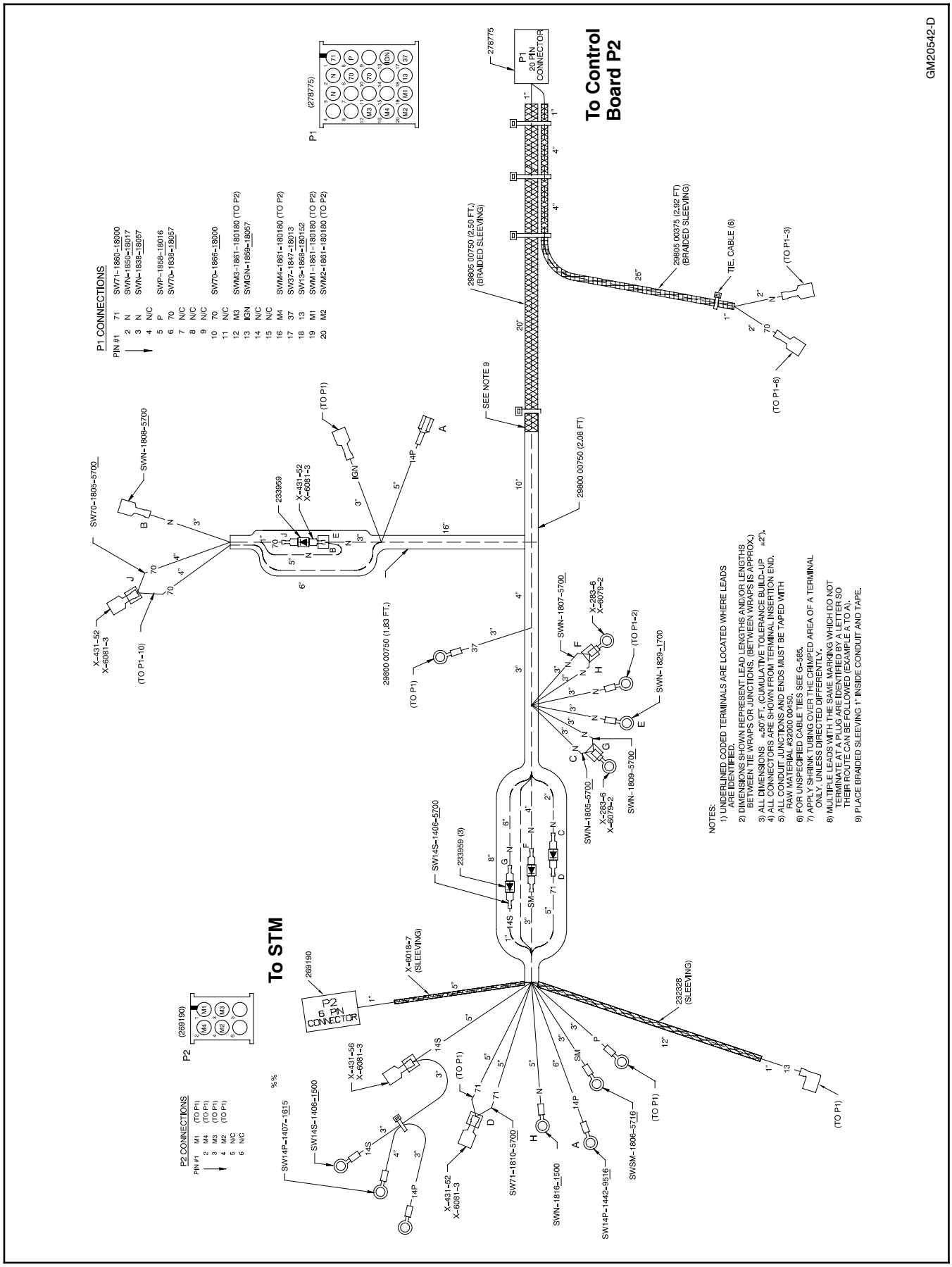


Figure 2-4 Engine Harness, GM20542

Figure 2-6 defines the abbreviations used in the wiring diagram.

2.2.5 Resetting Controller

Move the generator set master switch to the STOP position and then release it to reset the controller. Reset the controller after applying power for the first time or to clear a fault condition. See Section 2.2.6 for more information about faults.

Note: If the power to the controller has been disconnected and reconnected, the controller will require resetting.

2.2.6 Fault Shutdowns

The generator set shuts down automatically under the fault conditions listed in Figure 2-5 and cannot be restarted until the controls are reset. The LED on the control board illuminates to indicate a fault. See Figure 1-1.

Identify and correct the cause of the fault, then reset the controller by placing either the remote control switch or the generator set master switch in the STOP position.

Note: The high engine temperature fault automatically resets and the *engine restarts* when the generator set cools.

Fault	Description
High engine temperature	Shuts down 5 seconds after the fault. When the engine cools, the fault clears and the controller resets automatically. **Note:** The generator set engine restarts after the engine cools. The high engine temperature shutdown does not function during the first 30 seconds after startup.
Low oil pressure	Shuts down 5 seconds after the fault. The low oil pressure shutdown does not function during the first 30 seconds after startup. **Note:** The low oil pressure shutdown does not protect against low oil level. Fault must be corrected, and master switch reset to allow restarting.
Overcrank	Shuts down after three starting attempts: crank 15 seconds, rest 15 seconds, overcrank fault after three attempts to start. Overcrank shutdown also occurs in the case of a locked rotor. Shuts down 1 second after the fault is detected. Fault must be corrected, and master switch reset to allow restarting.
Overspeed	Shuts down immediately if the engine speed exceeds 3850 RPM.

Figure 2-5 Fault Shutdowns

Abbreviation	Definition
70	Run
71	Crank
AC1	Speed sensing
AC2	Speed sensing
BCA	Battery charging alternator
DCN	DC negative
DCP	DC positive
EBG	Engine block ground
GV	Gas valve
HOT	High oil temperature switch
HR	Hourmeter
LOP	Low oil pressure switch
M1	Throttle control
M2	Throttle control
M3	Throttle control
M4	Throttle control
N	Ground
N/C	Not connected
OVC	Overcrank
OVS	Overspeed
OVT	Overtemperature
P	Positive
QCON	Quick connect terminal
RECT	Rectifier (voltage)
SM	Starter motor
SR	Starter relay
SS	Starter solenoid
Stat	Stator
STM	Stepper motor (governor)
STP	Stop
STT	Start

Figure 2-6 Wiring Diagram Abbreviations

2.3 Exercising Generator Set

Operate the generator set under load weekly for at least 30 minutes.

The operator should perform all of the prestart checks before starting the generator set. See Section 2.1. While the generator set is operating, listen for a smooth-running engine and visually inspect the generator set for fluid or exhaust leaks.

2.4 Electronic Governor

The governor system consists of an electronic governor control and an electromechanical actuator. The system regulates engine speed to achieve specified DC output voltage. The generator supplies a speed signal to the governor control unit in the form of AC electrical pulses. The control unit compares the frequency of these pulses to a preset reference in the speed command and provides a control signal to the actuator. The actuator controls the carburetor and, therefore, the engine speed.

Note: *Do not touch or move the throttle linkage between the actuator and carburetor while the engine is running.* Manually increasing the engine speed (rpm) can raise the output voltage high enough to damage the generator and connected equipment.

2.5 Battery Charger

Generator sets that are not exercised regularly require an external battery charger to keep the starting battery fully charged. Obtain a battery charger from your generator set supplier. Observe the battery polarity when connecting the battery charger. Plug the battery charger into a 110 or 120-volt outlet connected to the utility power.

2.6 Carburetor Heater

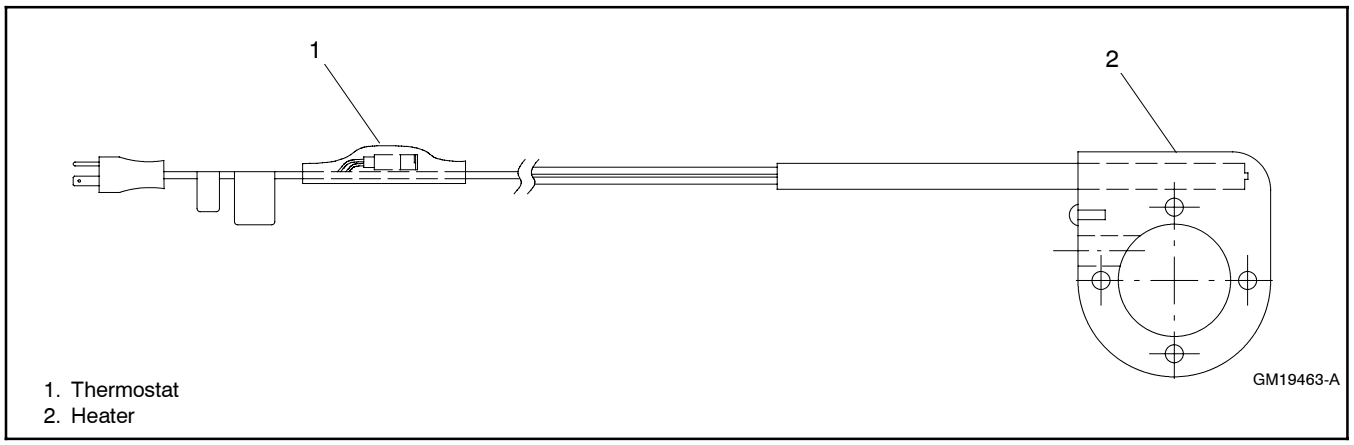
The generator set is equipped with a carburetor heater. The carburetor heater prevents condensation and carburetor icing. The heater turns on when the temperature at the thermostat falls below approximately 4°C (40°F) and turns off when the temperature rises above approximately 16°C (60°F). The thermostat continuously senses temperature and controls the carburetor heater.

The heater is mounted between the carburetor and the air cleaner. See Figure 1-5.

The heater requires a continuous source of 120 volt power. Plug the carburetor heater into an outlet that has continuous 120 volt power.

Figure 2-7 shows the location of the heater thermostat on the power cord. Position the cord so that the thermostat is exposed to the ambient air.

Note: Do not place the heater thermostat inside the generator set engine compartment. The thermostat must be exposed to the ambient air. The thermostat will shut off power to the heater when the ambient temperature reaches approximately 16°C (60°F).



1. Thermostat
2. Heater

Figure 2-7 Heater with Thermostat

⚠ WARNING

Accidental starting.
Can cause severe injury or death.

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

Disabling the generator set. Accidental starting can cause severe injury or death. Before working on the generator set or equipment connected to the set, disable the generator set as follows: (1) Place the generator set start/stop switch in the STOP position. (2) Disconnect the power to the battery charger, if equipped. (3) Remove the battery cables, negative (-) lead first. Reconnect the negative (-) lead last when reconnecting the battery. Follow these precautions to prevent the starting of the generator set by the remote start/stop switch.

⚠ WARNING

Hazardous voltage.
Can cause severe injury or death.

Only authorized personnel should open the enclosure.

(600 volts and under)

⚠ WARNING

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

Do not work on the generator set until it cools.

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

⚠ WARNING

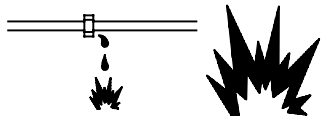
Hazardous voltage. Moving parts.
Can cause severe injury or death.

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

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

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

⚠ WARNING



Explosive fuel vapors.
Can cause severe injury or death.

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

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

3.1 Service Schedule

Perform the service listed in Figure 3-3 at the designated intervals for the life of the generator set. Refer to the service views in Section 1.5 for system component locations. Perform maintenance on each item in the service schedule at the designated interval for the life of the generator set. Service units subject to extreme weather, long operating hours, or dusty or dirty conditions more frequently. Have an authorized distributor/dealer perform all generator set service.

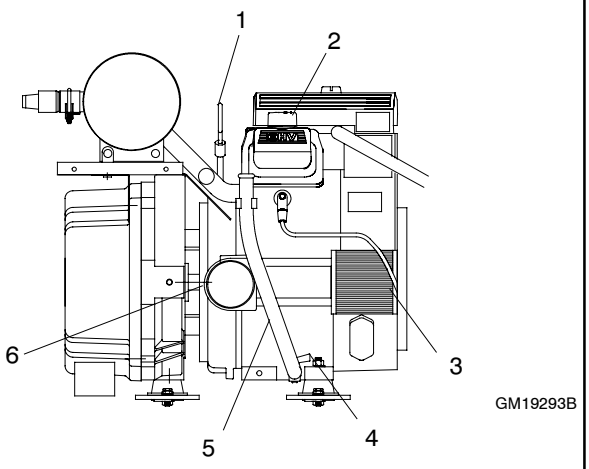
3.2 Lubrication System

See Figure 3-3 for oil change and oil filter replacement intervals. See Figure 3-1 for the lubrication system component locations. See the service views in Section 1.5 for the oil drain, oil check, oil fill, and oil filter locations. The list of routine service parts in the Introduction of this manual shows the oil filter part number.

3.2.1 Oil Check

The generator set is shipped with oil. Before operating a new generator set, check the engine oil in the crankcase. See Figure 3-1. Verify that the oil level is at the F mark on the dipstick. Add oil that has a viscosity appropriate for the climate. See Section 3.2.2 for engine oil recommendations.

Do not check the oil level when the generator set is running. Shut down the generator set and wait several minutes before checking the oil level.



1. Oil check
2. Oil fill
3. Oil Cooler
4. Oil drain valve
5. Oil drain hose
6. Oil filter

Figure 3-1 Lubrication System

3.2.2 Engine Oil Recommendation

The generator set manufacturer recommends American Petroleum Institute (API) Service Class SG, SH, or SJ 5W-30 synthetic oil.

3.2.3 Oil Change Procedure

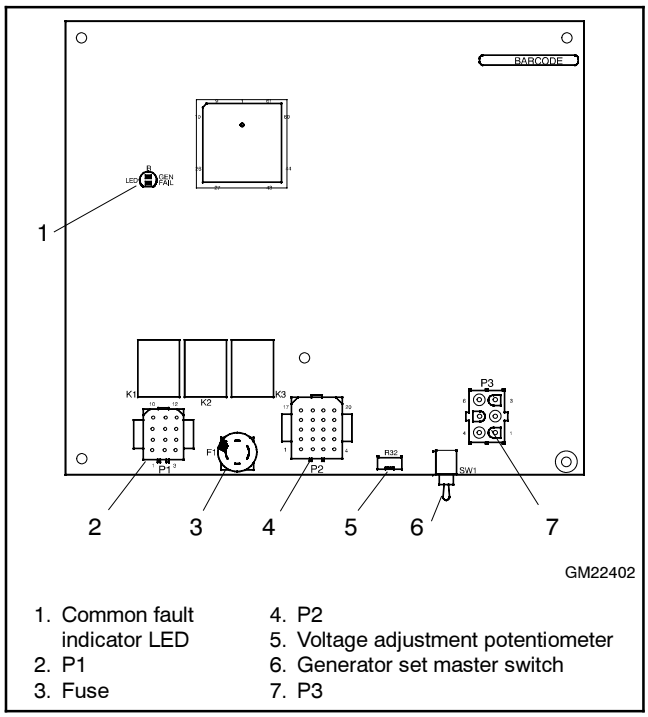
Drain the oil while it is still warm. Follow the enclosure manufacturer's instructions to open the enclosure to gain access to the generator set.

1. Drain the oil.

   a. Move the generator set master switch to the STOP position.

   b. Disconnect the power to the battery charger, if equipped.

   c. Disconnect the generator set engine starting battery, negative (–) lead first;
   or:
   Remove the fuse on the generator set control board or disconnect the P1 connector to prevent generator set startup by a remote switch. See Figure 3-2 for fuse and connector locations.



1. Common fault indicator LED
2. P1
3. Fuse
4. P2
5. Voltage adjustment potentiometer
6. Generator set master switch
7. P3

Figure 3-2 Generator Set Controls

System Component or Procedure	See Section	Procedure					Frequency
		Visually Inspect	Check	Change	Clean	Test	
Fuel							
Inspect flexible lines and connections. Replace cracked or spongy hoses. *	—	X		R			Q
Check main LP tank supply level, if used.	—		X				M
Inspect fuel piping for damage or corrosion.	—	X					Y
Lubrication							
Check oil level.	3.2.1	X	X				M or before use
Change oil.	3.2.2, 3.2.3			R			Y or 100 hr.
Replace oil filter.*	3.2.3			R			Y or 200 hr.
Clean oil cleaner.	3.2.4				X		Y or 100 hr.
Cooling							
Check that air ducts and louvers are clean and unobstructed.	3.8		X		X		Q
Exhaust System							
Check for leakage. Carbon or soot residue indicates a leak. Repair leaks.	3.5	X	X	R			Q
Check for fire hazards.	3.5	X	X		X		Q
Check for loose or broken hangers and supports. Tighten or replace as needed.	—	X	X	R			S
Battery Connections							
Check battery charger operation and charge rate (if equipped).	Battery charger manual	X	X				M
Clean and tighten battery terminals.	—	X	X		X		Y
Remove corrosion, clean and dry battery and rack.	—	X			X		Y
Battery electrolyte level and specific gravity.†	—		X				Q
Electrical System							
Inspect wiring and components for visible wear or damage.	—	X					Q
Check for abrasions where wiring is subject to motion.	—	X	X				S
Check wiring for insulation breakdown.	—	X	X				Y
Tighten power and control wiring connections.	—		X				Y
Wire-cable insulation breakdown.*	—	X					3 Y or 500 hr.
Engine And Mounting							
Inspect for visible wear or damage.	—	X					Q
Inspect air cleaner element; replace if necessary.*	3.3	X		R			Y or 500 hr.
Inspect spark plugs; replace if necessary.*	3.7.2	X		R			Y or 500 hr.
Check carburetor heater and block heater for proper operation.	5.6					X	Y
Control System							
Check remote control operation.	Controller manufacturer's instructions					X	M
Run generator set.	—					X	W
Generator Set							
Check items listed in the Prestart Checklist.	2.1	X					M
Exercise the generator set.	2.3					X	W
General Condition Of Equipment							
Check for signs of vibration, leakage, excessive noise, extreme temperature, or deterioration.	—	X	X		X		Q
Inspect and clean the enclosure interior.	—	X			X		Q

* Consult your local distributor/dealer for parts or service.
† Not necessary for maintenance-free batteries.

X Action
R Replace as necessary

M=Monthly
Q=Quarterly
S=Six Months
Y=Yearly

Figure 3-3 Service Schedule

d. Remove the oil drain hose from its retaining clip. Remove the cap from the oil drain hose and lower the hose into an oil collection container.

e. Open the oil drain valve on the engine.

f. Allow time for the engine oil to drain completely.

g. Close the oil drain valve.

h. Replace the cap on the oil drain hose. Replace the oil drain hose in its retaining clip.

2. Replace the oil filter.

a. Remove the oil filter by rotating it counterclockwise with an oil filter wrench.

b. Clean the gasket sealing surface of the oil filter adapter.

c. Apply a light coat of clean oil to the rubber seal of the new oil filter.

d. Install the new oil filter following the instructions provided with the filter.

Note: Dispose of all waste materials (engine oil, fuel, filter, etc.) in an environmentally safe manner.

3. Fill with oil.

a. Remove the oil fill cap and fill the engine to the F mark on the dipstick. The engine oil capacity is 1.9 L (2.0 qt.). See Section 3.2.2 for oil selection.

b. Reinstall the dipstick and the oil fill cap.

c. Reconnect the generator set engine starting battery, negative (-) lead last, reinstall the controller fuse, and/or reconnect the P1 connector.

d. Reconnect the power to the battery charger, if equipped.

e. Start and run the generator set for a minute to allow the oil pressure to reach the operating range.

f. Stop the generator set, wait 1 minute, and then recheck the oil level. Add oil to bring the level up to the F mark on the dipstick.

4. Check for leaks.

a. Check for oil leaks.

b. Fix leaks and recheck the oil level.

3.2.4 Oil Cooler

Use compressed air or a brush to clean the oil cooler fins after every 100 hours of operation (or more frequently under dusty or dirty conditions). See Figure 3-1 for the oil cooler location.

3.2.5 Low Oil Pressure Shutdown

The low oil pressure shutdown feature protects the engine against internal damage if the oil pressure drops below 24.1 kPa ±13.8 kPa (3.5 psi ±1.5 psi) because of oil pump failure or other malfunction. The shutdown feature does not protect against damage caused by operating with the oil level below the safe range—it is not a low oil level shutdown. Check the oil level regularly and add oil as needed.

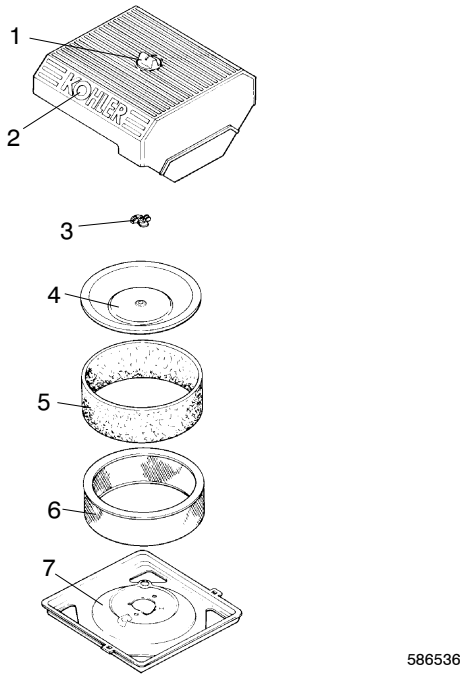
3.3 Air Cleaner Element and Precleaner

The engine has a replaceable high-density paper air cleaner element with an oiled foam precleaner. See Figure 3-4. Refer to the service views in Section 1.5 for the air cleaner's location. Follow the enclosure manufacturer's instructions to open the enclosure and gain access to the air cleaner.

Wash and oil the precleaner and replace the paper element at the intervals shown in the service schedule. Service the air cleaner more often if the generator set operates under dusty or dirty conditions. Refer to Maintenance and Service Parts in the Introduction section of this manual for replacement part numbers.

Keep the area around the air cleaner housing free of dirt and debris.

Note: Operating the engine with loose or damaged air cleaner components could allow unfiltered air into the engine, causing premature wear and failure.



1. Cover knob
2. Air cleaner cover
3. Element cover nut
4. Element cover
5. Foam precleaner
6. Air cleaner element
7. Air cleaner base

Figure 3-4 Air Cleaner Components

3.3.1 Precleaner Service

Wash and reoil the precleaner as indicated in the service schedule. Wash and reoil the precleaner more often under extremely dusty or dirty conditions.

1. Move the generator set master switch to the STOP position.
2. Remove the DC fuse on the generator set control board or disconnect the P1 connector to prevent generator set startup by a remote switch. See Figure 3-2 for fuse and connector locations.
3. Disconnect the power to the battery charger, if equipped.
4. Disconnect the battery, negative (-) lead first.
5. Loosen the cover retaining knob and remove the cover. Remove the precleaner from the paper element. Wash the precleaner in warm water with detergent. Rinse the precleaner thoroughly until all traces of detergent are eliminated. Squeeze out excess water (do not wring). Allow the precleaner to air dry.
6. Saturate the precleaner with new engine oil. Squeeze out all the excess oil.
7. Reinstall the precleaner over the paper element.
8. Reinstall the air cleaner cover. Secure the cover with the cover retaining knob.
9. Reinstall the controller fuse and/or reconnect the P1 connector.
10. Reconnect the generator set engine starting battery, negative (-) lead last.
11. Reconnect the power to the battery charger, if equipped.

3.3.2 Paper Element Service

Replace the paper element at the intervals specified in the service schedule. Replace the paper element more often if the generator set operates under extremely dusty or dirty conditions.

1. Move the generator set master switch to the STOP position.
2. Remove the DC fuse on the generator set control board or disconnect the P1 connector to prevent generator set startup by a remote switch. See Figure 3-2 for fuse and connector locations.
3. Disconnect the power to the battery charger, if equipped.
4. Disconnect the generator set engine starting battery, negative (-) lead first.
5. Loosen the cover retaining knob and remove the cover.
6. Remove the element cover nut, element cover, and the paper element with precleaner.
7. Remove the precleaner from the paper element.

   Note: Do not wash the paper element or clean it with pressurized air, as this will damage the element.

8. Replace the element if it is dirty, bent, or damaged.
9. Check the air cleaner base. Make sure it is secure and not bent or damaged. Also check the element cover for damage and fit. Replace all damaged air cleaner components. Remove any loose dirt or debris from the air cleaner base. Wipe the base carefully so that no dirt drops into the intake throat. Check the condition of the rubber seal on the air cleaner stud and replace the seal if necessary.
10. Reinstall the paper element, precleaner, element cover, element cover nut, and the air cleaner cover. Secure the cover with the cover retaining knob.

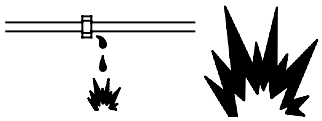
11. Reinstall the controller fuse and/or reconnect the P1 connector.

12. Reconnect the generator set engine starting battery, negative (-) lead last.

13. Reconnect the power to the battery charger, if equipped.

3.4 Fuel System

⚠ WARNING



Explosive fuel vapors.
Can cause severe injury or death.

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

A fuel solenoid valve turns the fuel supply to the fuel pressure regulator on and off. The regulator then reduces fuel pressure for delivery to the fuel metering (fuel mixture adjustment) valve. The fuel flows from the metering valve to the carburetor in a gaseous state. The carburetor mixes the fuel with intake air for consumption by the engine.

3.4.1 Gas Piping

Ensure the gas pipe size meets size specifications in the chart in Figure 3-5. Measure the pipe length from the gas utility pressure regulator (7-11 in. water column output pressure) to the end of the pipe where it connects to the fuel inlet of the generator set. Compare the length with the chart in Figure 3-5. If the pipe used is smaller than the size shown in the chart, replace it with the specified pipe size for that length. Bleed the air from the gas lines at the time of installation.

Maximum Pipe Length	Pipe Size
3.0 m (10 ft.)	1/2 in. NPT
10.7 m (35 ft.)	3/4 in. NPT
30.5 m (100 ft.)	1 in. NPT

Figure 3-5 Gas Pipe Size Specifications

3.4.2 Fuel Conversion

Two fuel metering valves allow field-conversion between natural gas and LP vapor. The fuel metering valves are factory-sealed to comply with applicable emission standards and to provide the best possible hot and cold starting. Do not adjust the fuel metering valves.

The manufacturer ships the generator set with the fuel system set for natural gas. Have trained and qualified personnel convert the fuel system from natural gas to LP (or from LP to natural gas) if necessary. The fuel conversion procedure is explained in Section 5.5.3.

3.5 Exhaust System

Remove all combustible materials from the exhaust location. Combustible materials include building materials as well as natural surroundings. Keep dry field grass, foliage, and combustible landscaping material a minimum of 0.3 m (1 ft.) away from the exhaust outlet.

Periodically inspect the exhaust system components (exhaust manifold, exhaust line, flexible exhaust, clamps, silencer, and outlet pipe) for cracks and corrosion.

- Check for corroded or broken metal parts and replace them as needed.
- Check for loose, corroded, or missing clamps and hangers. Tighten or replace clamps and/or hangers as needed.
- Check for and remove loose insulation in the exhaust duct.
- Check that the exhaust outlet is clear.

3.6 Battery

⚠ WARNING

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

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

⚠ WARNING

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

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

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

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

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

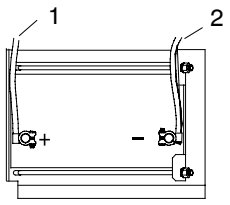
Battery acid cleanup. Battery acid can cause severe injury or death. Battery acid is electrically conductive and corrosive. Add 500 g (1 lb.) of bicarbonate of soda (baking soda) to a container with 4 L (1 gal.) of water and mix the neutralizing solution. Pour the neutralizing solution on the spilled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

Use a starting battery that meets or exceeds the requirements shown in Section 1.4, Specifications. The wiring diagrams in Section 8 show the battery connections. Make sure that the battery is connected correctly and the terminals are tight. See Figure 3-6.

Note: The generator set will not start and circuit board damage may result if the battery is connected in reverse.

Generator sets that are not used regularly require an external battery charger to keep the starting battery fully charged. Observe the battery polarity when connecting the battery charger.

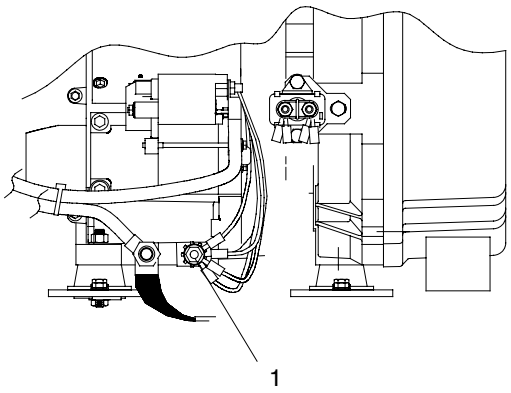
Refer to the battery supplier's instructions for battery maintenance information.



1. To positive (+) terminal on starter solenoid.
2. To ground (-) terminal on or near starter motor.

Figure 3-6 12-Volt Engine Electrical System Single Starter Motor Typical Battery Connection

All generator set models use a negative ground with a 12-volt engine electrical system. See Figure 3-7 for the location of the ground connection.



1. Ground connection on chassis frame

Figure 3-7 Ground Connection

3.7 Ignition System

3.7.1 Ignition System Description

The COM7.5 engine uses a capacitive discharge ignition system. Refer to the CH20 Engine Service Manual for ignition service information.

Maintain the spark plugs using the instructions in Section 3.7.2.

3.7.2 Spark Plug

Reset the spark plug gap or replace the plug if necessary. Replace the plug at the intervals shown in the service schedule, Figure 3-3.

1. Clean the area around the base of the spark plug to keep dirt and debris out of the engine.
2. Remove the spark plug and check its condition. Verify that the insulator is a light toast or gray color. Replace the spark plug if the insulator is discolored, the plug is coated with deposits, or the electrodes are pitted or worn.
3. Check the spark plug gap using a wire feeler gauge. Adjust the gap to 0.76 mm (0.030 in.) by carefully bending the ground electrode. See Figure 3-8 and Figure 3-9.

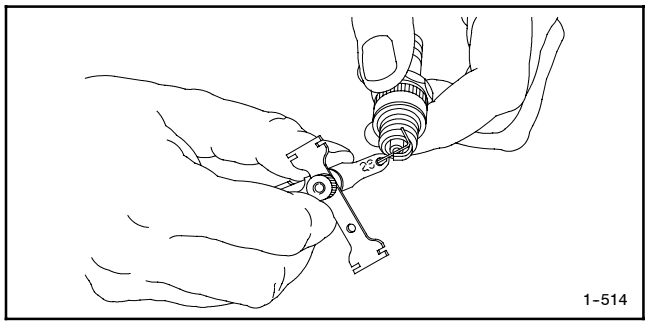


Figure 3-8 Checking the Spark Plug Gap

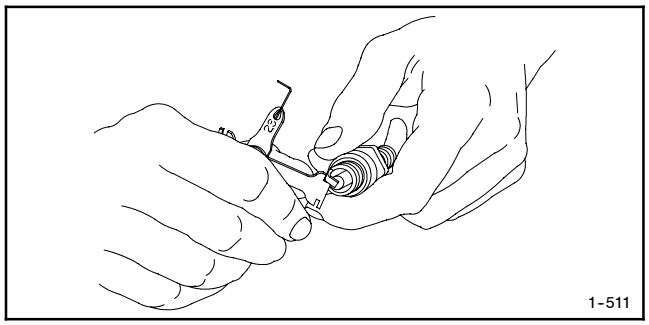


Figure 3-9 Adjusting the Spark Plug Gap

3.8 Cooling System

To prevent generator set damage caused by overheating, keep the housing cooling inlets and outlets clean and unobstructed at all times.

Note: Do not block the generator set cooling air inlet.

3.9 Alternator

Under normal operating conditions, routine alternator maintenance is not required.

3.10 Storage Procedure

Perform the following storage procedure before removing the generator set from service for three months or longer. Follow the engine manufacturer's recommendations for storage, if available.

Note: Run the generator set monthly whenever possible.

3.10.1 Lubricating System

1. Remove the DC fuse on the generator set control board or disconnect the P1 connector. See Figure 3-2 for fuse and connector locations.
2. Operate the generator set until it reaches operating temperature, or about 15 minutes.
3. Stop the generator set.
4. While the engine is still warm, drain the engine lubrication oil from the engine crankcase.
5. Refill the engine crankcase with oil. See Section 3.2.2 for oil recommendations.
6. Run the generator set for a few minutes to distribute the clean oil.
7. Stop the generator set.

3.10.2 Fuel System

1. Start the generator set.
2. With the generator set running, shut off the gas supply.
3. Run the generator set until the engine stops.
4. Place the generator set master switch in the STOP position.

3.10.3 Cylinder Lubrication

1. Remove the spark plugs.
2. Pour approximately one tablespoon of engine oil into each spark plug hole.
3. Install the spark plugs and ground the spark plug leads. *Do not connect the leads to the plugs.*
4. Crank the engine two or three revolutions to lubricate the cylinders.

3.10.4 Exterior Preparation

1. Clean the exterior surface of the generator set.
2. Seal all openings in the engine with nonabsorbent adhesive tape.
3. Mask all areas to be used for electrical contact.
4. Spread a light film of oil over unpainted metallic surfaces to prevent rust and corrosion.

3.10.5 Battery

Perform battery storage last.

1. Disconnect the battery, negative (–) lead first.
2. Follow battery manufacturer's recommendations for cleaning, storing, and charging the battery.

Notes

This section contains generator set troubleshooting and diagnostic information.

Use the following charts to diagnose and correct common problems. First check for simple causes such as a dead engine starting battery or loose connections.

Disconnect the generator set control board from the system controller and use the generator set master switch to operate the generator set. If the problem persists after the system controller is disconnected, use the troubleshooting procedures in this manual to diagnose the problem. If the generator set operates normally when the system controller is disconnected, the system controller may have sent a remote stop command or there may be a problem with the system controller. Instruct the customer to contact the system controller manufacturer for service information.

Note: Use an ohmmeter or continuity tester to check for shorts or open leads in the wiring harnesses before replacing the controller circuit board or other system components.

Follow the enclosure manufacturer's instructions to open or remove the enclosure, if necessary. If the procedures in this manual do not explain how to correct the problem, contact an authorized distributor/dealer. Maintain a record of repairs and adjustments performed on the equipment.

⚠ WARNING

Accidental starting.
Can cause severe injury or death.

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

Disabling the generator set. Accidental starting can cause severe injury or death. Before working on the generator set or equipment connected to the set, disable the generator set as follows: (1) Place the generator set start/stop switch in the STOP position. (2) Disconnect the power to the battery charger, if equipped. (3) Remove the battery cables, negative (-) lead first. Reconnect the negative (-) lead last when reconnecting the battery. Follow these precautions to prevent the starting of the generator set by the remote start/stop switch.

⚠ WARNING

Hazardous voltage.
Can cause severe injury or death.

Only authorized personnel should open the enclosure.

(600 volts and under)

⚠ WARNING

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

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

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

⚠ WARNING

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

Do not work on the generator set until it cools.

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

4.1 Troubleshooting Chart

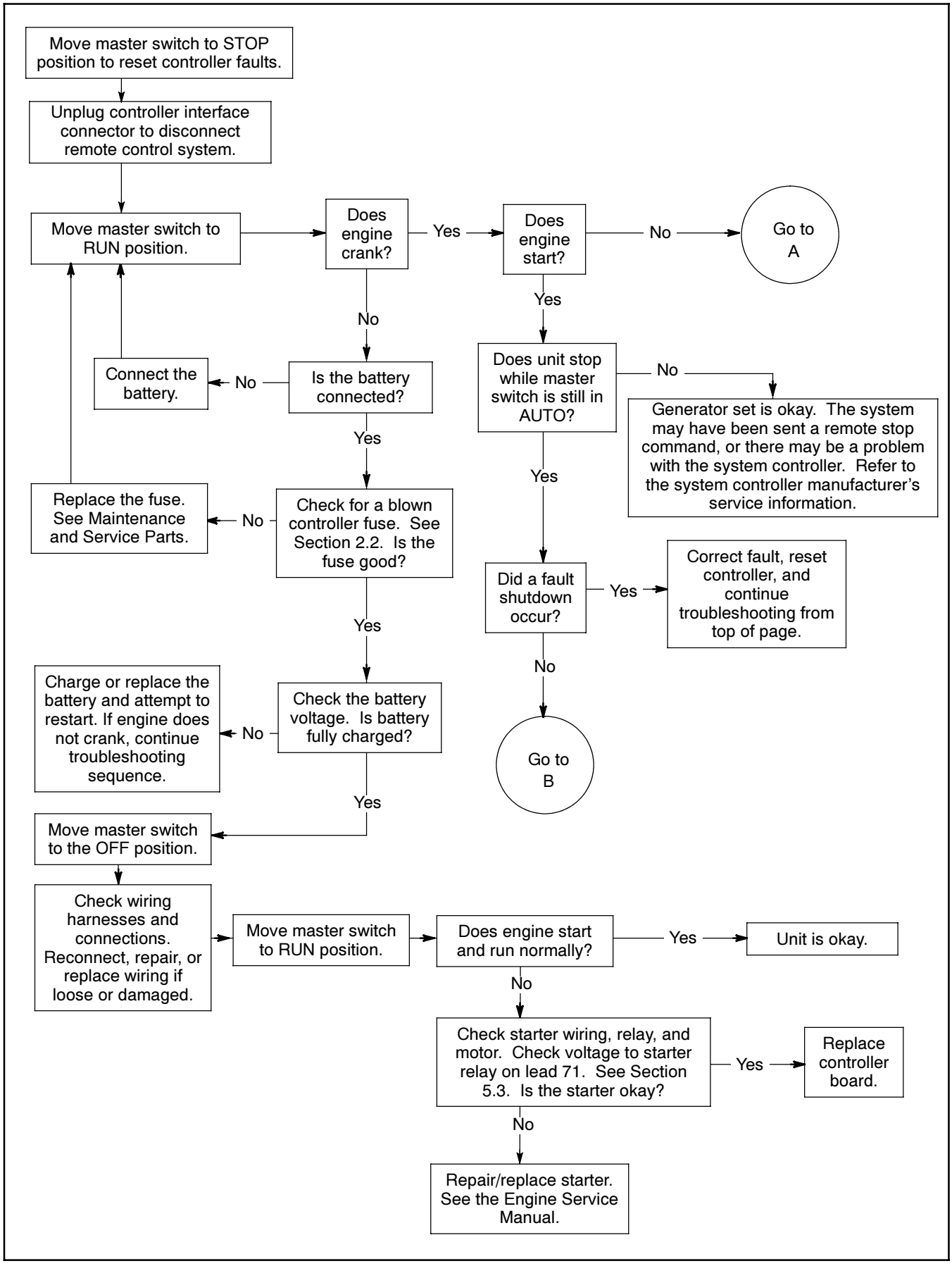
The chart includes a list of common problems, possible causes, and recommended corrective actions.

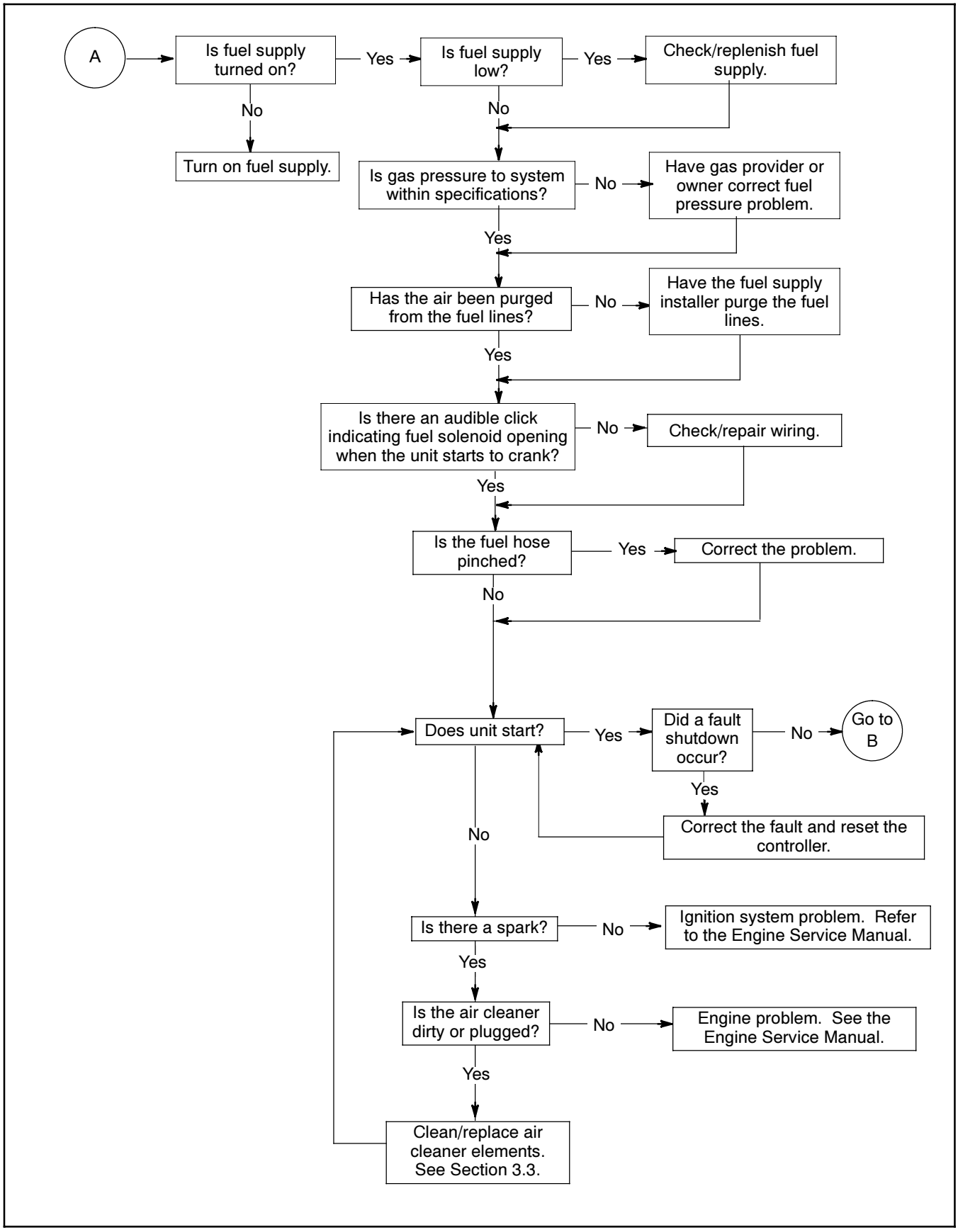
Problem	Possible Cause	Corrective Action	Reference
Unit does not crank	Blown controller fuse	Check the fuse and replace if necessary.	Maintenance and Service Parts
	Weak or dead battery	Recharge or replace the battery.	—
	Engine harness loose connection	Check and tighten connections.	—
	Start switch not in the AUTO position	Move the switch to AUTO.	—
	Controller interface harness disconnected	Reconnect the harness.	—
	Generator set controls are not receiving the remote start command	Check the controller interface harness connections and continuity. Troubleshoot the system controller.	System controller manufacturer's instructions
	Starter problem	Test the starter.	Section 5.3 and the Engine Service Manual, TP-2428-A
	Battery connections loose, dirty or incorrect	Correct, clean, or tighten battery connections.	—
	Fault shutdown	Identify and correct the cause of the fault. Reset the controller.	Section 2.2.6
	Controller board problem	Test the board as described in Section 6.2. Connect a spare control board to verify that the board needs to be replaced.	Sections 6.2 and 6.3
Unit cranks but does not start	Air cleaner clogged	Clean or replace the air cleaner.	Section 3.3
	Block heater nonoperation	Replace.	Section 5.6
	Carburetor heater nonoperation	Replace.	Section 5.6
	Fuel problem	Check the fuel supply and replenish if necessary.	—
		Verify that the fuel valve is open.	—
		Check that the fuel regulator opens.	Section 5.5.1
		Check that the throttle linkage moves freely and opens at start.	Section 5.2
		Check the fuel adjustment (oxygen sensor required for this test).	Section 5.5.4
		Check for the correct fuel and fuel block connection.	Section 5.5
	Faulty spark plug(s)	Replace or regap the spark plugs.	Section 3.7.2
	Loose spark plug wire connection	Reconnect and/or tighten spark plug wires.	—
	Ignition system problem	Test the ignition system.	Sections 6.2.4 and Engine Service Manual
	Weak or dead battery	Recharge or replace the battery.	Section 3.6
Unit starts hard	Air cleaner clogged	Clean or replace the air cleaner element.	Section 3.3
	Block heater nonoperation	Replace.	Section 5.6
	Carburetor heater nonoperation	Replace.	Section 5.6
	Faulty spark plug(s)	Replace or regap the spark plugs.	Section 3.7.2
	Ignition system problem	Test the ignition system and replace faulty components.	Engine Service Manual

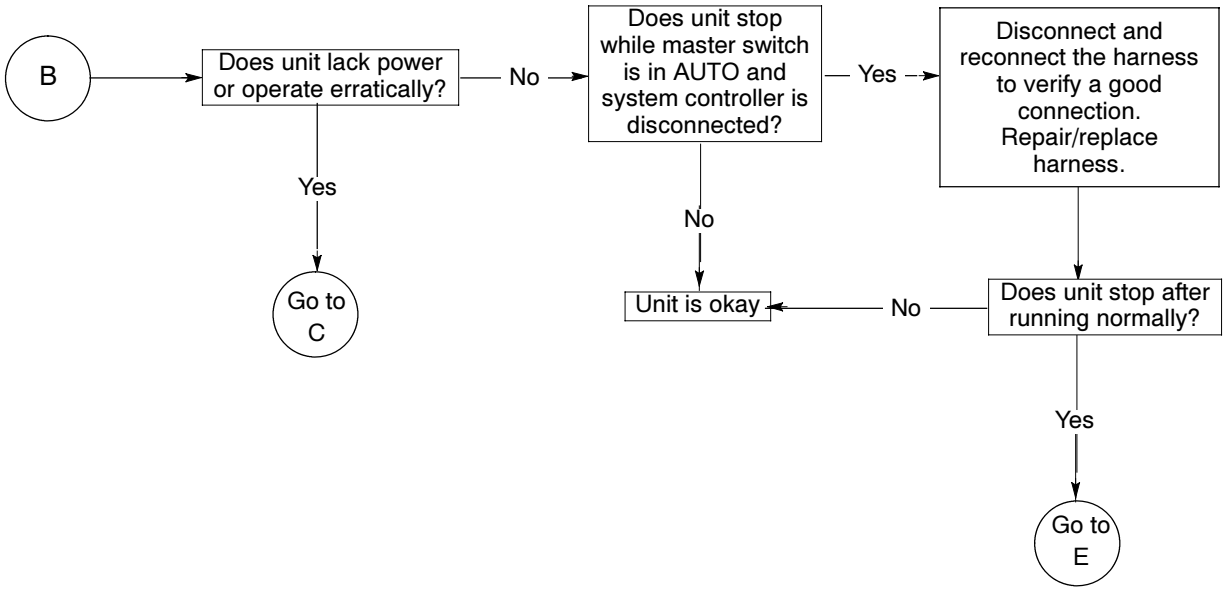
Troubleshooting Chart, continued

Problem	Possible Cause	Corrective Action	Reference
Unit stops suddenly	Air cleaner clogged	Clean or replace the air cleaner element.	Section 3.3
	Faulty spark plug(s)	Replace or regap the spark plugs.	Section 3.7.2
	Fuel starvation	Replenish fuel.	—
	Engine harness loose connection	Check and tighten connections.	—
	Fault shutdown	Check the controller LED. Correct the fault and reset controller. Test shutdown operation.	Sections 2.2.6 and 6.1
	Faulty shutdown switch	Test switches and replace if necessary.	Section 5.8
Unit lacks power or operates erratically	Engine harness loose connection	Check and tighten connections.	—
	Air cleaner clogged	Clean or replace the air cleaner element.	Section 3.3
	Insufficient cooling	Inspect and clean the cooling system.	Section 3.8
	Engine overload	Reduce the load on the generator set.	—
	Faulty spark plug	Replace or regap the spark plugs.	Section 3.7.2
	Fuel supply problem	Check the valves and fuel pressure.	Section 5.5
	Governor system problem	Check the governor and throttle linkage.	Section 5.2
Unit does not supply load	Fuel supply problem	Check for the correct fuel and fuel block connection.	Section 5.5
	Excessive load	Check that the load does not exceed the rating, 3.5 or 5 kW.	—
	Throttle linkage binding	Check that the throttle linkage is free to move and open while engine is running.	Section 5.2
	Undervoltage	Check that the voltage with no load matches the rating shown in Section 1.4, Specifications.	Section 1.4 and Section 5.1
Engine noise	Hydraulic lifter leakdown	Run the unit 5-10 minutes under load.	—
Unit overheats	Air openings clogged	Clean the intake and outlet openings.	Section 3.8
	Air cleaner clogged	Clean or replace the air cleaner element.	Section 3.3
	Overload	Verify that the load is within the specified range. Reduce load.	Section 1.4, Specifications

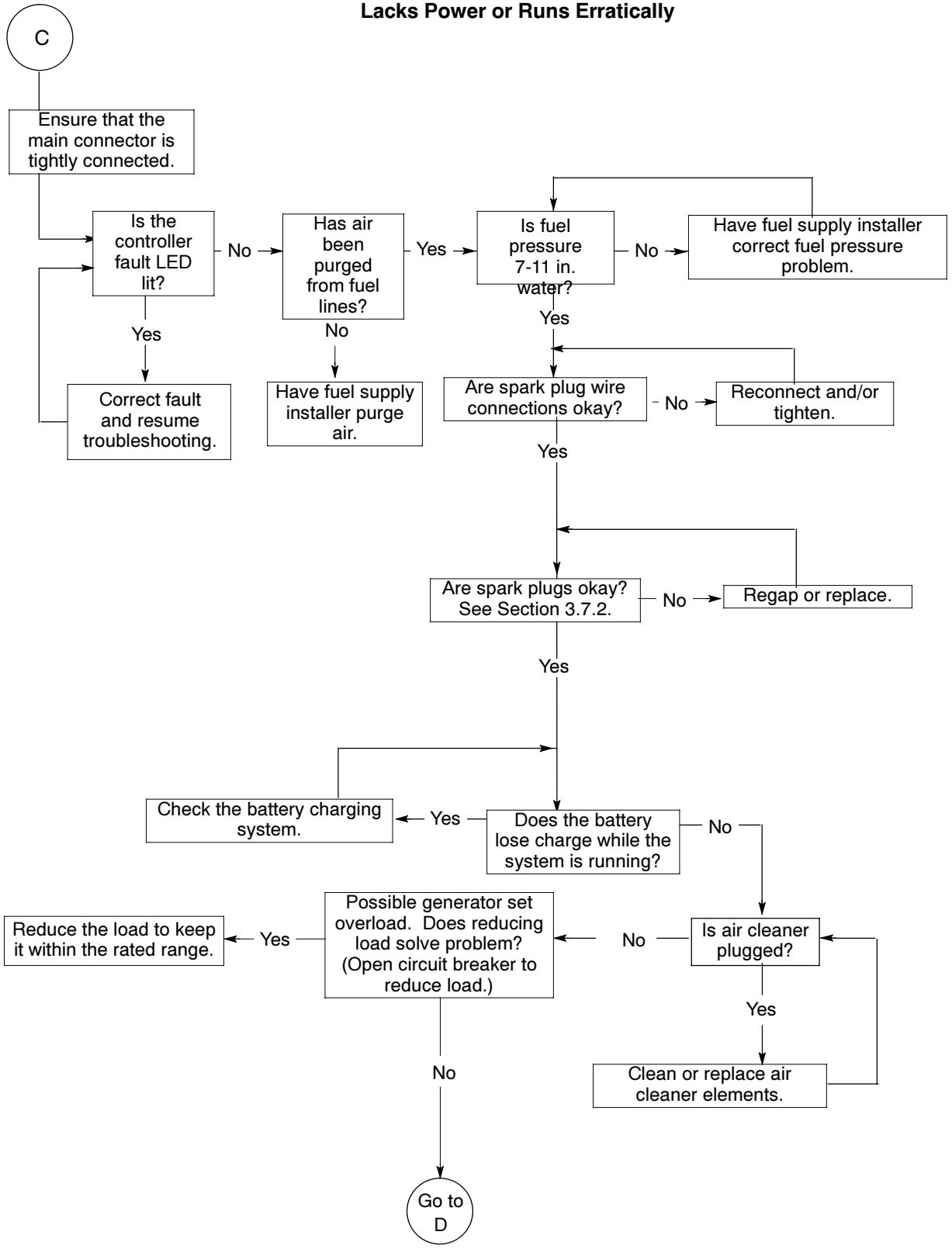
4.2 Generator Set/Controller System Troubleshooting Flowcharts



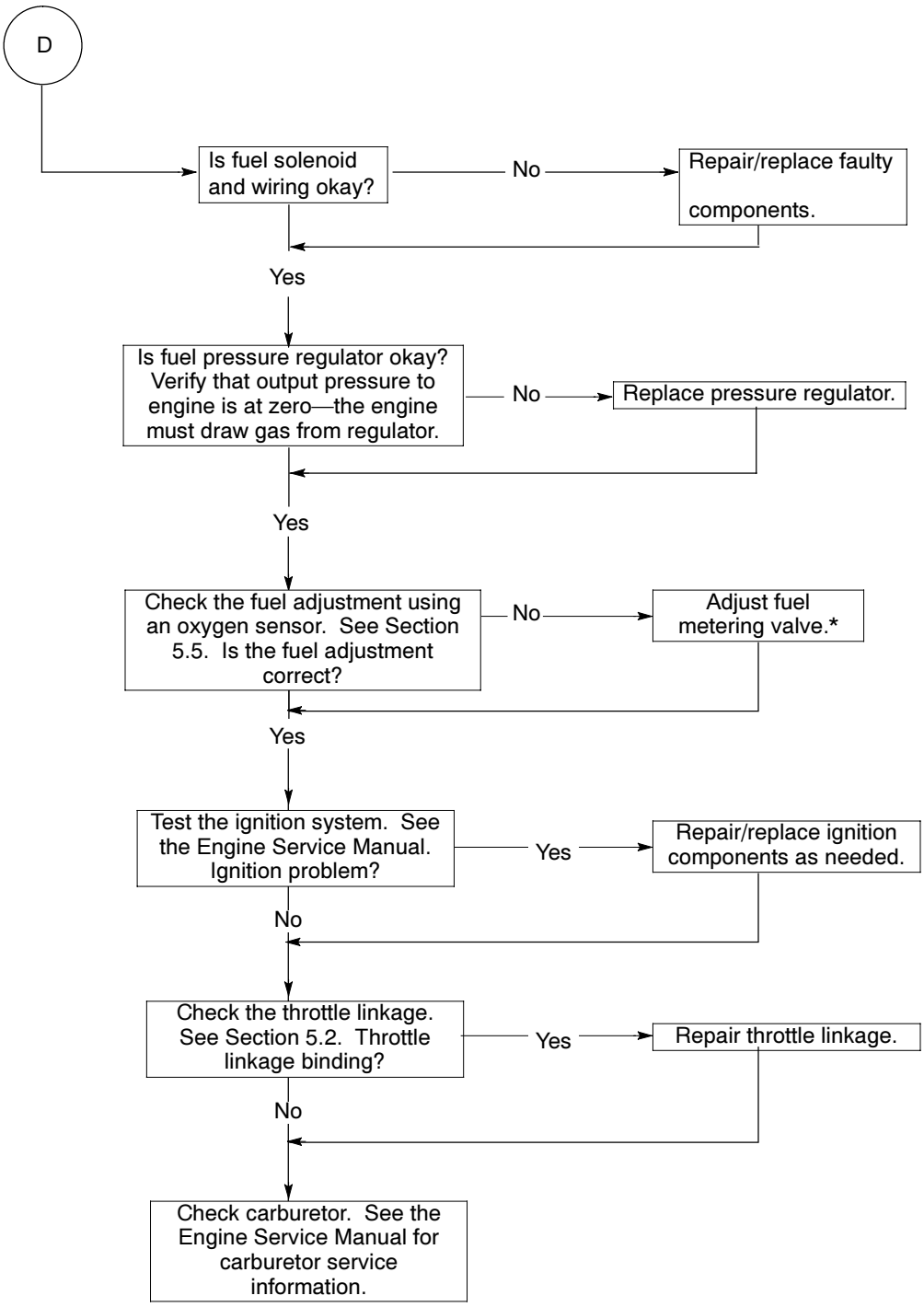

A
Is fuel supply turned on?
Yes
Is fuel supply low?
Yes
Check/replenish fuel supply.
No
No
Turn on fuel supply.
Is gas pressure to system within specifications?
No
Have gas provider or owner correct fuel pressure problem.
Yes
Has the air been purged from the fuel lines?
No
Have the fuel supply installer purge the fuel lines.
Yes
Is there an audible click indicating fuel solenoid opening when the unit starts to crank?
No
Check/repair wiring.
Yes
Is the fuel hose pinched?
Yes
Correct the problem.
No
Does unit start?
Yes
Did a fault shutdown occur?
No
Go to B
Yes
Correct the fault and reset the controller.
No
Is there a spark?
No
Ignition system problem. Refer to the Engine Service Manual.
Yes
Is the air cleaner dirty or plugged?
No
Engine problem. See the Engine Service Manual.
Yes
Clean/replace air cleaner elements. See Section 3.3.


B
Does unit lack power or operate erratically?
No
Does unit stop while master switch is in AUTO and system controller is disconnected?
Yes
Disconnect and reconnect the harness to verify a good connection. Repair/replace harness.
Yes
Go to C
No
Unit is okay
No
Does unit stop after running normally?
Yes
Go to E

Lacks Power or Runs Erratically

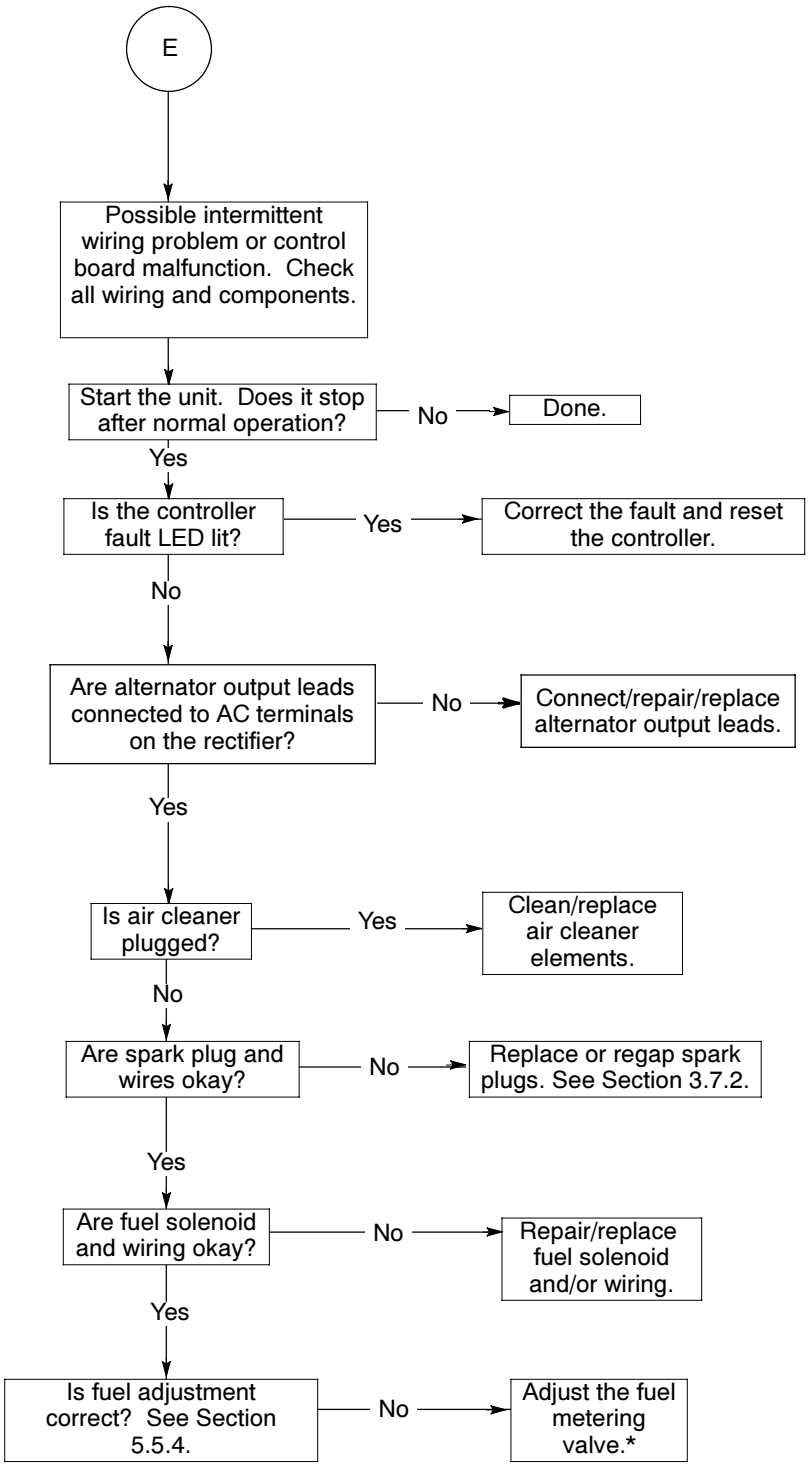


Lacks Power or Runs Erratically, continued



* Adjusting the fuel system may void the emissions certification. Only trained and authorized service technicians should adjust the fuel system. See Section 5.5.4.

Unit Stops After Normal Operation



* Adjusting the fuel system may void the emissions certification. Only trained and authorized service technicians should adjust the fuel system. See Section 5.5.4.

Notes

Use the troubleshooting procedures in Section 4 and the wiring diagrams in Section 8 to diagnose problems with the generator set operation. For controller operation and test, refer to Section 6 of this manual and to the system controller manual. Use the procedures in this section to check generator components for proper operation and adjust components when necessary. See the service views in Section 1.5 for component locations.

⚠ WARNING

Hazardous voltage.
Can cause severe injury or death.

Only authorized personnel should open the enclosure.

(600 volts and under)

⚠ CAUTION

Hazardous noise.
Can cause hearing loss.

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

⚠ WARNING

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

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

⚠ WARNING

Fire.
Can cause severe injury or death.

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

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

5.1 Voltage Rectifier

The voltage rectifier converts AC voltage from the alternator into DC voltage. Figure 5-1 shows the rectifier schematic.

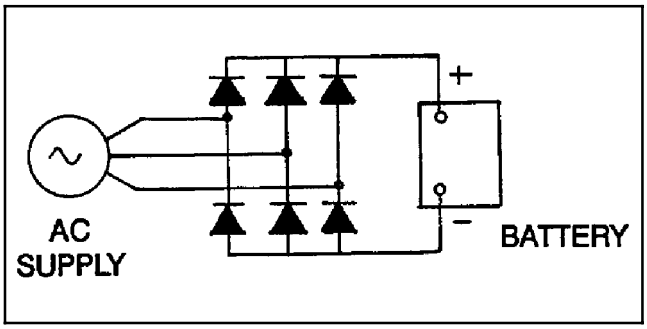


Figure 5-1 Rectifier Schematic

Refer to the wiring diagram in Section 8 for the rectifier connections. Rectifier terminals 1–3 are the AC terminals. Leads AC1 and AC2 connect to the AC side of the rectifier and are used for speed sensing by the controller. Terminal 4 is for the positive (+) DC connection and terminals 5 and 6 are for the negative (–) DC connections.

If there is no DC voltage at the output connector, check the output fuse. Test for output at the rectifier to check the output leads. Check for AC voltage into the rectifier. If there is AC voltage coming into the rectifier, but no DC output, replace the rectifier. The voltage rectifier has no adjustments.

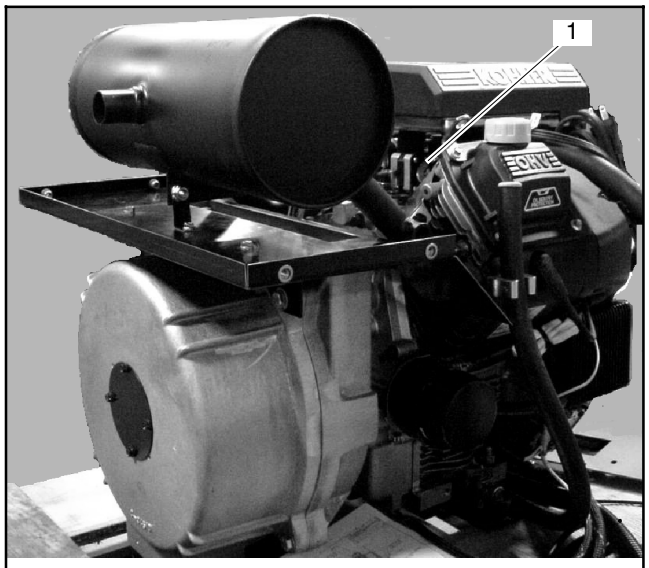
The microprocessor controller monitors the DC output voltage. To verify accurate voltage control, increase and decrease loads while measuring DC output voltage at the output connector. The output voltage should remain fairly steady at the rated voltage as the engine speed increases or decreases in response to load changes.

If voltage falls below the rated value as load increases or decreases, check for the following problems:

- Inadequate fuel supply
- Fuel solenoid malfunction
- Fuel metering valve malfunction
- Stepper motor/throttle linkage binding

5.2 Electronic Governor

The system uses a variable-speed generator to maintain the rated output voltage with varying loads. The governor system regulates the engine speed with changing loads. See Figure 5-2.



1. Governor stepper motor

Figure 5-2 Governor Location

The governor system consists of an electronic governor control and an electromechanical actuator. Leads AC1 and AC2 provide a speed (frequency) signal from the AC side of the voltage rectifier to the control board. The control board signals the actuator, which controls the throttle and hence the engine speed, to maintain the generator nominal output voltage.

5.2.1 Governor Checks

The factory-set electronic governor does not normally require adjustment. If the engine operates erratically, check the following connections and conditions *before* adjusting the governor:

- Check the electrical connections and wire harnesses for clean, tight connections.
- Check the speed-sensing connections at rectifier AC terminals 2 and 3. Poor connections may cause an erratic signal, which could cause the unit to shut down.
- Check the electrical ground connections.
- Check the battery connections. Verify that the connections are clean and tight.
- Check for a good positive 12-volt DC supply.
- Check for stepper motor/throttle shaft linkage binding or wear. The linkage arm and lever arms must not bind or rub against other components while moving.
- Verify that the governor stepper motor operates with steady and smooth movement. If the movement of the stepper motor is erratic or large changes in movement occur, check for shaft misalignment, linkage binding, or loose or broken wiring or plug connections.
- Check the carburetor for dirt, grime, or misadjustment. Check the idle-adjustment screw. The screw should not prevent the throttle plate from completely closing. Also, check the throttle linkage for any binding, dirt, damage, etc.

Note: Often hunting/surging problems thought to be caused by the governor are actually linked to carburetor adjustment. Check the carburetor adjustment before adjusting the governor.

The fuel shutoff solenoid deenergizes and the generator set shuts down with the following electronic governor faults:

- Loss of pickup while running (throttle moves to closed position)
- Engine overspeed
- Broken fuel shutoff solenoid lead
- Loss of DC power to governor assembly
- Broken stepper motor leads (erratic performance)
- Actuator linkage failure (erratic performance)

If none of the above conditions exist, proceed to Section 5.2.2, Stepper Motor Check.

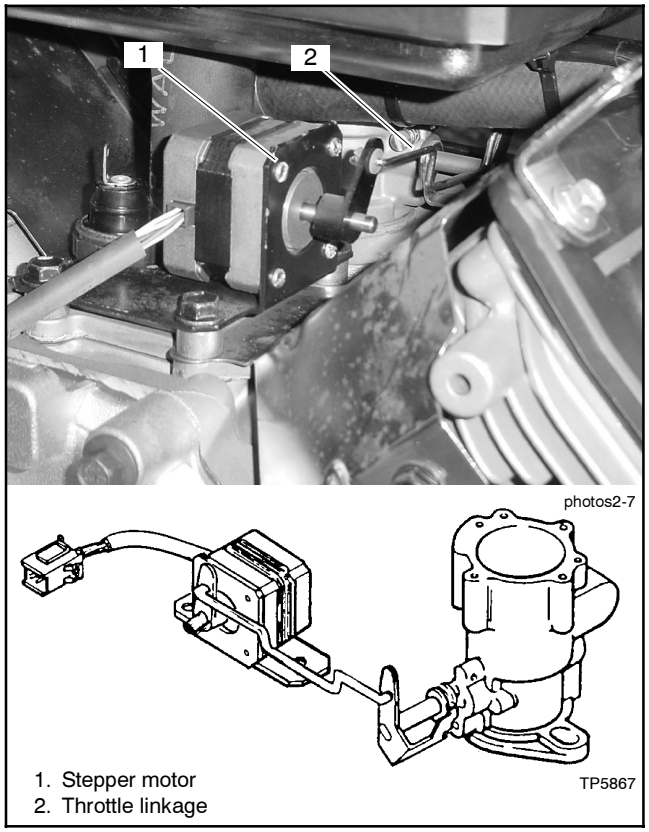
5.2.2 Stepper Motor Check

Use the following procedure to test the operation of the governor stepper motor.

Stepper Motor Test Procedure

1. Stop the generator set and disconnect the battery.

2. Manually move the governor linkage fully counterclockwise (open throttle). See Figure 5-3.



1. Stepper motor
2. Throttle linkage

Figure 5-3 Governor

3. Reconnect the battery. The stepper motor should move clockwise to the closed-throttle position with a noticeable clicking sound. If the stepper motor does not stay in the closed-throttle position, replace the stepper motor.

Only two stepper motor leads of each coil group are utilized (BLACK-YELLOW and RED-WHITE). The resistance per phase is 38.5 ohms. See Figure 5-4.

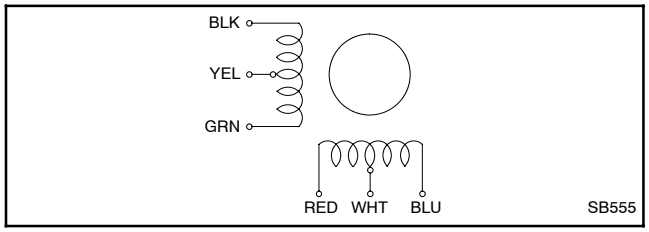


Figure 5-4 Actuator Coil Group

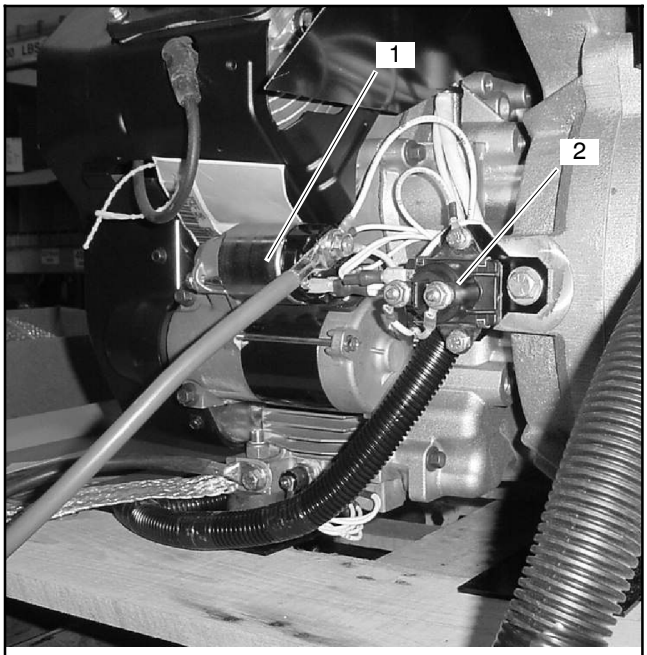
5.3 Starter

Check the starter if the generator set engine does not crank. Check the battery voltage and connections before proceeding. Check for a locked rotor or other fault condition that may have shut down the unit. Correct the fault condition and reset the controller to clear a fault shutdown.

Note: Always check the wiring and connections before replacing components.

The crank cycle attempts to start three times, cranking for 15 seconds and then resting for 15 seconds between attempts. The fault LED on the control board lights to indicate an overcrank shutdown; reset the controller if the LED lights during these tests.

Move the generator set master switch to START and check for 12 VDC to the starter relay on lead 71 during the crank attempt. See Figure 5-5.



1. Starter motor
2. Starter relay (crank relay)

Figure 5-5 Starter Components

If there is no voltage to the starter during the crank cycle, check the connections and the continuity of the wiring harness leads. Then check for voltage from the controller at P2-1 (see the wiring diagram, Section 8). If there is no voltage at P2-1 during cranking, replace the control board.

To test the starter relay, check for 12 VDC to the starter motor during the crank attempt. If there is voltage to the relay but not to the starter motor, check the connection between the relay and the starter motor. If the connection is good, replace the relay.

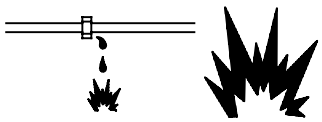
If there is voltage to the starter motor but the starter motor does not crank the engine, refer to the Kohler CH20 Engine Service Manual for starter service information. The generator set engine uses a solenoid shift electric starter.

5.4 Ignition

The COM7.5 engine uses a capacitive discharge ignition system. Refer to Section 3.7 for ignition service information and spark plug information.

5.5 Fuel System

⚠ WARNING



Explosive fuel vapors.
Can cause severe injury or death.

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

⚠ WARNING

Fire.
Can cause severe injury or death.

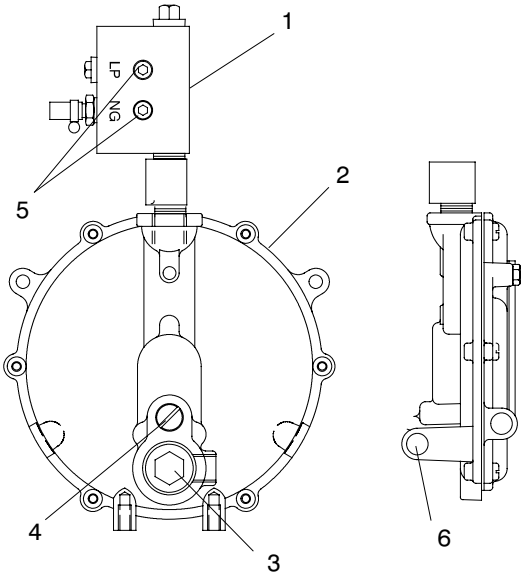
Do not smoke or permit flames or sparks near fuels or the fuel system.

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

5.5.1 Fuel Regulators

The typical gaseous fuel system uses two regulators. The primary regulator reduces the line pressure to an allowable inlet pressure for the secondary regulator. The fuel supplier provides and maintains the primary regulator. The secondary regulator is factory-installed on the generator set and is designed for a maximum inlet pressure of 2.7 kPa (6 oz./in.^{2}) or 280 mm (11 in. water column).

Do not try to adjust the fuel pressure, fuel mixture, or engine speed using the fuel lock-off. See Figure 5-6 for the location of the fuel lock-off. The fuel lock-off prevents fuel flow when the engine is not operating.



1. Dual-fuel block
2. Secondary pressure regulator
3. Fuel inlet
4. Fuel lock-off (Do not adjust.)
5. Fuel metering valves
6. Inlet pressure check location (plug)

Figure 5-6 Secondary Regulator (with fuel block)

Checking the Fuel Pressure

Use a gauge or manometer to check the fuel pressure at the secondary regulator inlet. See Figure 5-6. Measure the fuel pressure with the generator set running at full load. The fuel pressure should be 178–280 mm (7–11 in. water column) or 1.7–2.7 kPa (4–6 oz./in.^{2}). Contact the fuel supplier if the inlet pressure is not within the specified range.

Note: Do not attempt to adjust the fuel mixture or engine speed by adjusting the regulators.

5.5.2 Fuel Solenoid Valve

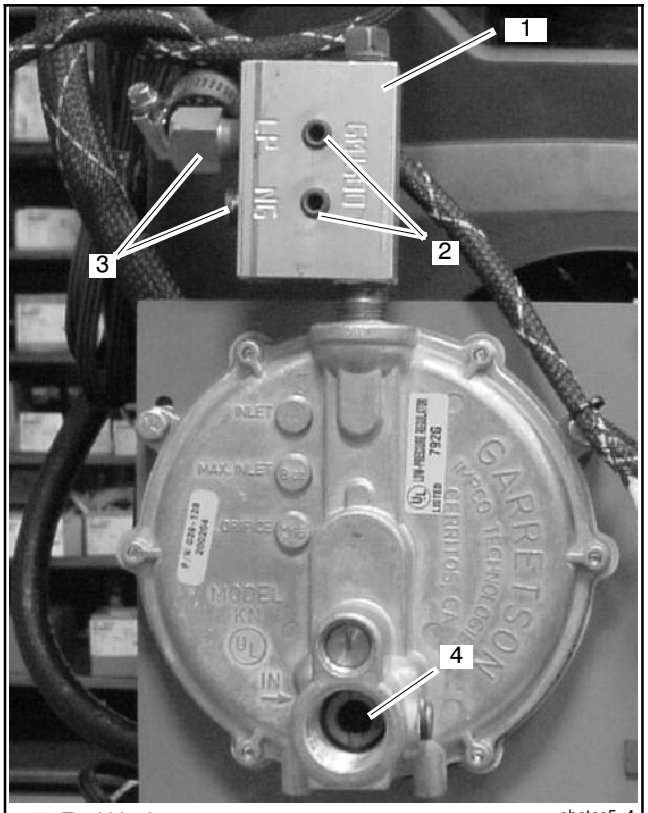
The fuel solenoid valve is a 12 VDC valve energized by lead 70 when the generator set controller is in the crank or the run mode. The fuel solenoid valve is supplied by the enclosure manufacturer.

5.5.3 Fuel Conversion

A dual-fuel block with two fuel metering valves allows field conversion between natural gas and LP vapor. Have the fuel conversion procedure performed by trained and qualified personnel.

Note: The fuel metering valves are factory-sealed to comply with applicable emission standards and to provide the best possible hot and cold starting.

The manufacturer ships the generator set with the fuel system set for natural gas. To convert to LP gas, use the following procedure to move the fuel line from the natural gas outlet port to the LP outlet port in the dual-fuel block (or from the LP outlet to the natural gas outlet to convert from LP to natural gas). See Figure 5-7 for the LP and natural gas fuel connection and fuel block locations. Also see the service views in Section 1.5.



photos5-4

1. Fuel block
2. Fuel metering valves
3. LP and natural gas outlet ports
4. Fuel inlet port

Figure 5-7 Fuel System (shown mounted on the shipping bracket)

Fuel Conversion Procedure

1. Move the remote start/stop switch to the STOP position.
2. Follow the enclosure manufacturer's instructions to open the enclosure to gain access to the fuel system.
3. Verify that the generator set master switch is in the STOP position.
4. Disconnect power to the battery charger, if equipped.
5. Disconnect the battery, negative (–) lead first.
6. Turn off the fuel supply.
7. Remove the hose clamp and fuel line hose from the fitting in the fuel block.
8. Remove the hose fitting from the natural gas (or LP) outlet in the fuel block.
9. Remove the plug from the LP (or natural gas) inlet. Clean the plug with a dry cloth or brush, apply fresh pipe sealant, and install the plug into the natural gas (or LP) outlet.
10. Clean the hose fitting with a dry cloth or brush, apply fresh pipe sealant, and install the fitting into the LP (or natural gas) inlet.
11. Slide the hose onto the hose fitting and secure the hose with the clamp.
12. Turn on the fuel supply and check for leaks using a gas leak detector.
13. Reconnect the battery cable and harness.
14. Follow the enclosure manufacturer's instructions to close the enclosure.

5.5.4 Fuel System Recalibration

The fuel metering valves are factory-set to meet emissions requirements and sealed to discourage field adjustments. If the fuel system requires recalibration, only trained, authorized service technicians may adjust the fuel metering valves. Always use an oxygen sensor, available from Kohler Co., when adjusting the fuel metering valves. See Maintenance and Service Parts in this manual for the sensor part number.

Note: Changing the fuel system adjustments may void the emissions certification.

⚠ WARNING

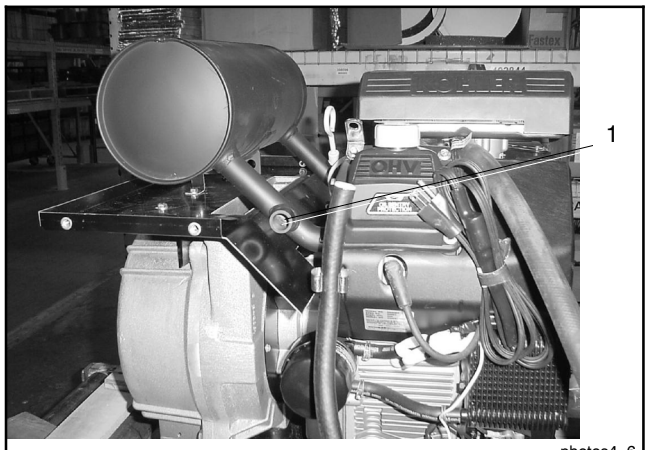
Hot engine and exhaust system. Can cause severe injury or death.

Do not work on the generator set until it cools.

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

Fuel System Recalibration Procedure

1. Remove the plug from the oxygen sensor port in the exhaust tube and install the oxygen sensor. See Figure 5-8.



1. Oxygen sensor port

Figure 5-8 Oxygen Sensor Port Location

2. Run the generator set at full load and check the oxygen sensor reading. At full load, the oxygen sensor output voltage should be between 0.45 and 0.55 VDC.
3. If adjustment is required, remove the seal on the fuel metering valve and adjust the valve to obtain an oxygen sensor reading between 0.45 and 0.55 VDC. See Figure 5-6 for the fuel metering valve location.
4. Reseal the valve after adjustment.
5. Allow the exhaust system to cool. Remove the oxygen sensor from the exhaust tube and reinstall the plug.

5.6 Carburetor and Engine Block Heaters

Both the carburetor and engine block heaters utilize a standard resistance heating element. These elements are designed with a fixed resistance for the desired wattage using a specified voltage. The heaters come equipped with a thermostat that may be open if the ambient temperature is above 0°C (32°F). In order to properly test the heaters, test on a cold day when the temperature is below 0°C (32°F) or use ice to chill the thermostat below 0°C (32°F).

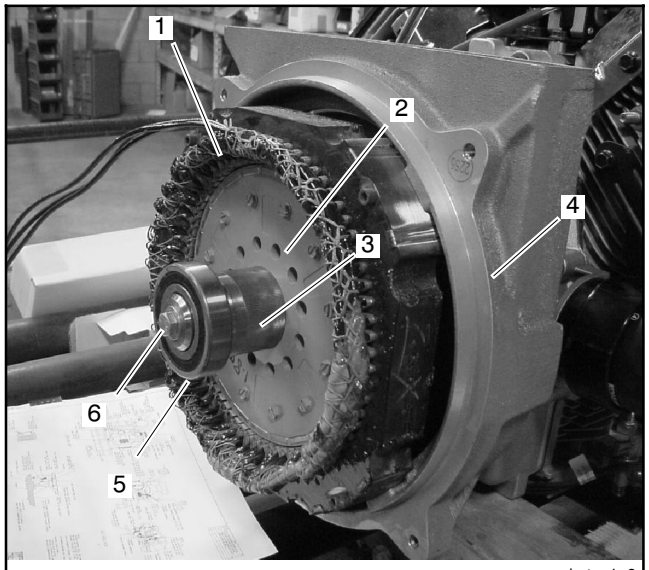
Test Procedure:

1. Disconnect the heater from the power source.
2. Disconnect the generator set engine starting battery, negative (-) lead first.
3. Use a thermometer to verify that the temperature at the thermostat is below 0°C (32°F). Use ice to chill the thermostat, if necessary.
4. Check the resistance across the heater elements using an ohmmeter. The resistance of the carburetor heater, GM19463 (38 watt/120-volt), should be between 365 ohms and 422 ohms. The resistance of the block heater, GM16283 (125 watt/120-volt) should be between 109 ohms and 126 ohms.
5. If there is continuity through the element, check for continuity across the thermostat terminals.
6. If there is no continuity between the element or the thermostat, the heater has failed and should be replaced.
7. If there is continuity through both the element and thermostat, the heater is fine.
8. Warm the thermostat to a temperature above 16°C (60°F).

9. Check for continuity across the thermostat terminals. The thermostat circuit should be open (no continuity). If the thermostat is not open, it has failed. Replace the heater/thermostat assembly.

5.7 Alternator

The alternator is connected directly to the engine. The alternator uses a permanent-magnet rotor and a 3-lead, 3-phase stator. See Figure 5-9.



1. Stator
2. Rotor
3. Shaft
4. Alternator adapter
5. Bearing
6. Thrubolt

Figure 5-9 Alternator (end bracket removed)

5.7.1 Stator

The stator contains coils of wire laid in a laminated steel frame. The three stator leads are connected together in a wye configuration. See Figure 5-10.

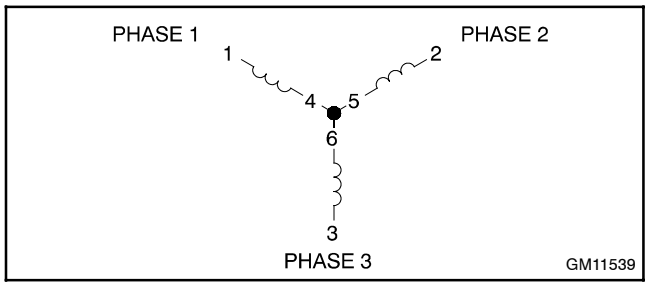


Figure 5-10 Stator Windings

The stator leads supply voltage to the voltage rectifier and the speed-sensing circuit. Before testing, inspect the stator for heat discoloration, visible damage to housing lead wires, exposed coil windings, or exposed areas of frame laminations. Use an ohmmeter to check the continuity of the stator windings using the following procedure.

Stator Test Procedure

1. Disconnect the power to the battery charger, if equipped.

2. Disconnect the generator set engine starting battery, negative (-) lead first.

3. Disconnect the stator leads from the voltage rectifier.

   Note: Disconnect all stator leads from the voltage rectifier before performing the test.

4. Set the ohmmeter on the R x 1 scale. Touch the ohmmeter leads together and adjust the ohmmeter to show zero ohms.

5. Check the cold resistance of the stator windings by connecting the meter leads to stator leads 1 and 2, 1 and 3, and 2 and 3. See Figure 5-11 for stator winding resistance values. Replace the stator if any of the resistance checks reveal an open winding.

   Note: Most ohmmeters do not measure very small resistance values accurately. Check for continuity of the windings with no shorts to ground. The stator is functional if the resistance reading is low (indicating continuity) and there is no evidence (heat discoloration) of shorted windings.

Generator Set Voltage Rating, VDC	Stator Resistance, Ohms
48	0.024
96	0.054

Figure 5-11 Stator Resistance

6. If the resistance test in the previous step is not conclusive, perform a megohmmeter test to determine whether the stator is shorted to ground.

   a. Use a megohmmeter to apply 500 volts DC to any stator lead and the stator's frame. Follow the instructions of the megohmmeter's manufacturer when performing this test. A reading of approximately 500 kOhms (1/2 mOhm) or higher indicates that the stator is in good condition. A reading of less than approximately 500 kOhms (1/2 MOhm) indicates deterioration of the winding insulation and possible current flow to ground.

   b. If the megohmmeter reading is less than 500 kOhms, replace the stator.

5.7.2 Rotor

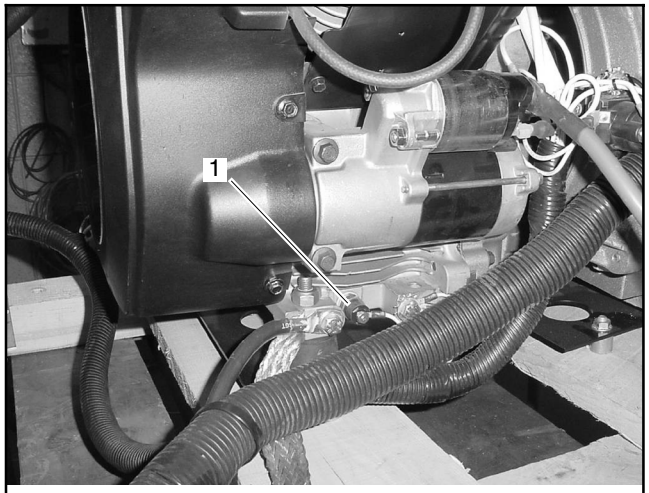
The rotor uses permanent magnets. There are no tests or field adjustments for the rotor.

5.8 Fault Shutdown Switches

Check the continuity of the high oil temperature (HOT) and low oil pressure (LOP) switches. Check for loose connections and open or short circuits in the connecting wires before replacing the switches.

High Oil Temperature (HOT) Switch

The HOT switch is normally open. Shut down the generator set and allow the engine to cool. Use an ohmmeter to measure the resistance from pin P1-18 of the engine harness (lead 37) to ground. The ohmmeter should indicate an open circuit. Any other reading indicates a short; replace the HOT switch. See Figure 5-12.



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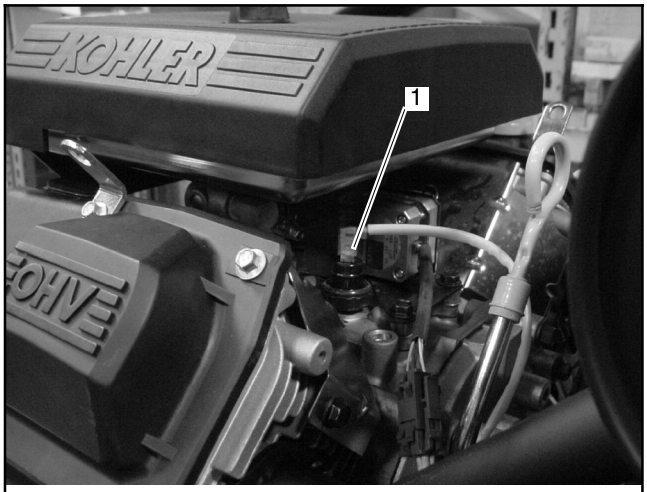
1. High oil temperature switch

Figure 5-12 High Oil Temperature (HOT) Switch

Low Oil Pressure (LOP) Switch

The normally closed LOP switch opens when the engine oil pressure reaches the normal operating level and closes if the oil pressure drops below a preset minimum. Use an ohmmeter to check the continuity between lead 13 (pin P1-18 of the engine harness) and ground. See Figure 2-4. Verify that the switch is closed while the engine is stopped. Start the generator set and check that the switch opens approximately 5 seconds later. If the switch does not open after the engine reaches normal operating speed, check the oil level and test for leaks in the lubrication system before replacing the LOP switch. See Figure 5-13.



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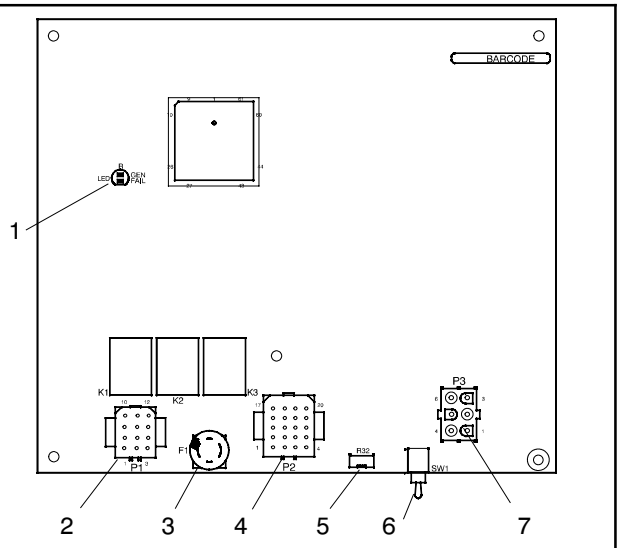
1. Low oil pressure switch

Figure 5-13 Low Oil Pressure (LOP)Switch

This section describes troubleshooting procedures for the generator set control board, shown in Figure 6-1. Refer to Section 2, Operation, for operating instructions. Refer to the remote controller manufacturer's instructions for troubleshooting and servicing remote controllers connected to the generator set.



1. Common fault indicator LED
2. P1
3. Fuse
4. P2
5. Voltage adjustment potentiometer
6. Generator set master switch
7. P3

Figure 6-1 Generator Set Controls

6.1 Fault Shutdown Tests

Verify operation of the controller overspeed, overcrank, low coolant level, low oil pressure, and high engine temperature shutdowns by performing the following tests with the generator set running. Observe the LED on the controller circuit board during the tests. Refer to the service views in Section 1.5 for component locations.

Follow the enclosure manufacturer's instructions to open or remove the enclosure to gain access to the generator set components in the following tests.

Check the continuity of the wiring harness leads before replacing the control board. Refer to the wiring diagrams in Section 8 for the lead codes and connecting terminals.

If these tests are inconclusive, test the individual shutdown circuit components as described in Section 6.2.

⚠ WARNING

Hazardous voltage.
Can cause severe injury or death.

Only authorized personnel should open the enclosure.

(600 volts and under)

⚠ WARNING

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

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

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

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

6.1.1 Low Oil Pressure (LOP) Shutdown

The low oil pressure (LOP) switch closes 5 seconds after the oil pressure drops below 5 psi, shutting down the generator set and lighting the fault LED on the control board. The low oil pressure shutdown does not function during the first 30 seconds after startup.

To test the operation of the LOP shutdown, connect a jumper wire from lead 13 of the controller-to-engine wiring harness to the generator set ground. Start the generator set. After approximately 35 seconds the generator set shuts down and the fault lamp lights. If the generator set does not shut down, replace the control board.

Note: Always check wiring before replacing the control board.

6.1.2 High Oil Temperature (HOT) Shutdown

The high oil temperature (HOT) switch closes 5 seconds after the generator set temperature reaches 305°F, shutting down the generator set and lighting the fault LED on the control board. The high engine temperature shutdown does not function during the first 30 seconds after startup.

To test the HOT shutdown, connect a jumper from the HOT switch (lead) to the generator set ground. Start the generator set. After approximately 35 seconds, the generator set shuts down and the fault LED lights. Five seconds after the jumper is removed, the fault LED goes out and the generator set restarts. If the generator set does not shut down and restart as described, replace the control board.

Note: Always check wiring before replacing the control board.

6.1.3 Overcrank Shutdown

The generator set shuts down and the fault LED lights after approximately 75 seconds of cyclic cranking (three attempts to start). The manufacturer sets the circuit board for three cranking attempts: crank 15 seconds, rest 15 seconds, crank 15 seconds, rest 15 seconds, crank 15 seconds, shutdown. Use the following procedure to test the overcrank shutdown operation.

Overcrank Shutdown Test Procedure

1. Turn off the fuel supply to prevent flooding.
2. Move the generator set master switch to the RUN position.
3. Verify that the generator set stops cranking and the fault lamp lights after the third crank/rest cycle.

6.1.4 Overspeed Shutdown

The generator set shuts down and the fault LED on the control board lights when the engine speed exceeds 3850 rpm.

Use the following procedure to test the operation of the overspeed shutdown.

Overspeed Shutdown Test Procedure

Note: Do not increase the engine speed above 3950 rpm. Increasing the engine speed above 3950 rpm can raise the output voltage high enough to damage the generator and connected equipment.

1. Disconnect the load from the generator set.
2. Connect a tachometer to the engine spark plug lead to measure the engine speed during the test.

   Note: If a tachometer is not available, connect a frequency meter across terminals 2 and 3 on the AC side of the voltage rectifier. Increase the engine speed as instructed in step 3. The generator set should shut down when the output frequency reaches 770 Hz. Do not exceed 790 Hz.

3. With the generator set running, carefully move the throttle linkage to increase the engine speed. Watch the tachometer and note the speed when the generator set shuts down.
4. Reset the controller by moving the master switch to the OFF position and then back to center position.

If the generator set does not shut down when the engine speed exceeds 3850 rpm, replace the control board.

6.2 Control Board Tests

Use the troubleshooting procedures in Section 4 to diagnose generator set and engine problems. If the troubleshooting procedures indicate a problem with the controller circuit board, use the tests in this section to check the board.

Refer to the wiring diagrams in Section 8 when troubleshooting the generator set control circuit board. Circuit board components cannot be repaired or replaced; if the troubleshooting process reveals a faulty component on the circuit board, replace the board.

Note: Use an ohmmeter or continuity tester to check for shorts or open leads in the wiring harnesses before replacing the controller circuit board or other system components.

Disconnect the generator system from the remote control system at controller interface harness GM14245 and use the generator set master switch to operate the generator set. If the generator set operates normally when the controller interface harness is disconnected, then the problem is with the remote control system. Refer to the manufacturer's instructions for the remote control system to troubleshoot the problem. If the problem persists after the controller interface harness is disconnected, use the troubleshooting procedures in Section 4 to diagnose the problem.

⚠ WARNING

Hazardous voltage.
Can cause severe injury or death.

Only authorized personnel should open the enclosure.

(600 volts and under)

⚠ WARNING

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

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

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

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

6.2.1 Fuel Control Circuit

Move the generator set master switch to the START position and check for 12 VDC to the fuel valve on lead 70. If the valve receives voltage but does not open, replace the valve.

If there is no voltage to the valve, check wiring harness. If the wiring harness is good but the fuel valve does not receive voltage, replace the controller circuit board.

6.2.2 Speed Sensing and Governor (Throttle Control) Circuits

The controller monitors the DC voltage from the voltage rectifier to sense and control the engine speed. If the engine speed varies erratically, test the governor operation as described in Section 5.2. If the tests show that the erratic operation is not caused by a faulty governor, replace the controller circuit board.

6.2.3 Start Circuits

Move the generator set master switch to the START or RUN position. If the engine does not crank, check the following components:

1. Check the battery voltage. Recharge or replace a weak or dead battery.

2. Check for 12 VDC to the starter motor. Also verify that the starter motor is grounded. See Section 8, Diagrams and Drawings. If the starter motor is receiving voltage but not functioning, replace it. If there is no voltage to the starter motor, check the harness and connections and then proceed to step 3 to check the starter (crank) relay.

3. Check for 12 VDC to the crank relay. See Section 8, Diagrams and Drawings. If the crank relay is receiving voltage but not functioning, replace it. If there is no voltage to the crank relay, check the harness and connections.

4. Check for 12 VDC from the control board on pin P2-1 (lead 71). If there is no voltage, replace the controller circuit board.

6.2.4 Ignition Circuits

Move the generator set master switch to the START position. If the engine cranks but does not start, check for spark at the spark plugs. Refer to Section 3.7 for ignition system service information. The COM7.5 engine uses a capacitive discharge ignition system.

6.3 Control Board Replacement

NOTICE

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

If the controller tests in this section or the troubleshooting procedures in Section 4 indicate that the control board needs to be replaced, follow these guidelines:

- Keep the new board in its protective wrapping until installation.
- Wear a grounding strap while handling the circuit board to prevent damage to the circuit board components.
- Check that all plug connections are secure.
- Calibrate the new control board after installation.

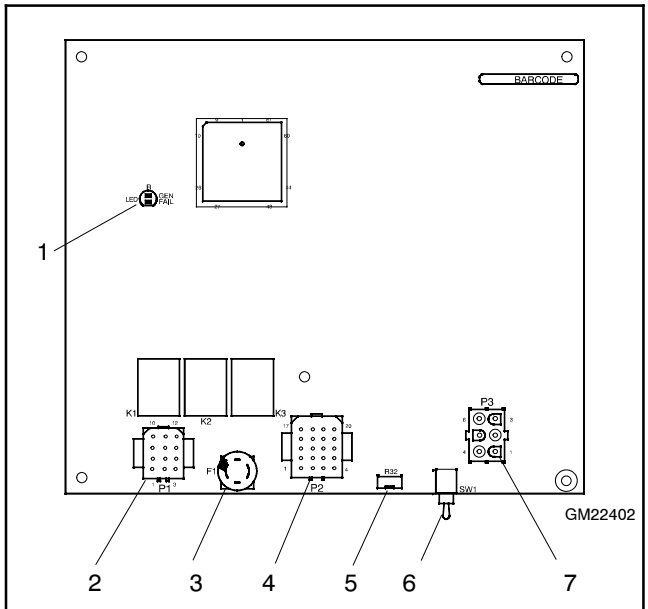
Control Board Replacement Procedure

1. Move the system controller switch to the STOP or OFF position.
2. Move the generator set master switch to the STOP position. (The switch will return to the center position when released.)
3. Disconnect power to the battery charger, if equipped.
4. Disconnect the generator set engine starting battery, negative (-) lead first.
5. Disconnect the three (3) wiring harness connectors from the control board.
6. Carefully remove the board from its mounting.
7. Install the new control board.
8. Reconnect the three wiring harness connectors.
9. Reconnect power to the generator set engine starting battery, negative (-) lead last.
10. Reconnect power to the battery charger, if equipped.
11. Use the following procedure to calibrate the board.

    Note: The new control board *must* be calibrated after installation.

Calibration Procedure

1. Connect a voltmeter to the DC output terminals of the voltage rectifier. (See the wiring diagram in Section 8.)
2. Turn R32 on the circuit board fully clockwise. See Figure 6-2.



1. Common fault indicator LED
2. P1
3. Fuse
4. P2
5. Voltage adjustment potentiometer R32
6. Generator set master switch
7. P3

Figure 6-2 Generator Set Controls

3. Start the generator set with no load.
4. Adjust R32 to obtain the voltage output shown in Figure 6-3.

Generator Set Model, Volt	Measured Output Voltage, VDC
48	52
96	104

Figure 6-3 Output Voltages, VDC

7.1 COM7.5 Disassembly

⚠ WARNING

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

Do not work on the generator set until it cools.

The following steps describe unit disassembly and reassembly and component removal and replacement.

7.1.1 Generator Set Disconnection

Perform the following steps to disconnect the generator set for any maintenance:

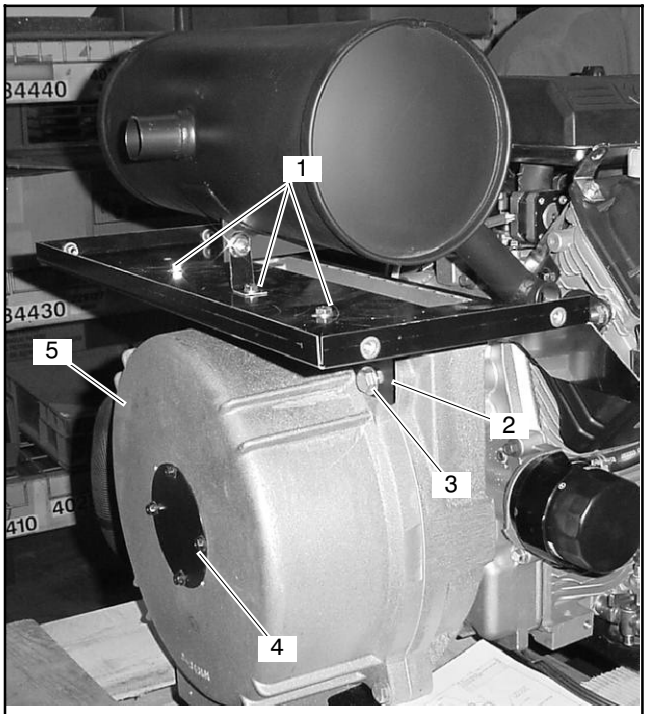
1. Move the remote control switch to the OFF or STOP position.
2. Follow the enclosure manufacturer's instructions to open or remove the enclosure.
3. Check that the generator set master switch (located on the generator set control board) is in the OFF position.
4. Disconnect the battery charger, if equipped.
5. Disconnect the battery, negative (-) lead first.
6. Disconnect the three alternator AC leads from the rectifier.
7. Remove ducting from around the generator set assembly as instructed by the enclosure manufacturer.

7.1.2 Alternator Disassembly

Perform the following steps to disassemble the alternator for maintenance.

1. Remove four screws from the bearing cover. See Figure 7-1.
2. Remove three screws from the exhaust bracket. See Figure 7-1, item 1.
3. Remove the four end bracket bolts.

Note: The exhaust bracket shown in Figure 7-1 is attached by the top two end bracket bolts and will come off when those bolts are removed. Set it aside for reinstallation later. (The silencer remains in place.)



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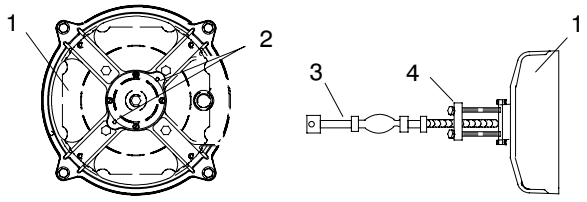
1. Exhaust bracket screws (3 ea.)
2. Exhaust bracket
3. End bracket bolts (4 ea.)
4. Bearing cover
5. Alternator end bracket

Figure 7-1 Generator Set Alternator End

4. Use a puller or slide hammer to remove the end bracket. The end bracket has two 1/4 in. threaded holes, four inches apart, for use with an adapter bar. See Figure 7-2.



1. End bracket
2. Two 1/4-20 in. holes, four inches apart, for use with slide hammer or puller
3. Slide hammer
4. Adapter with long bolts attached to end bracket 1/4 in. holes

Figure 7-2 Remove End Bracket

5. Remove the 4 socket head screws that secure the stator. See Figure 7-3.

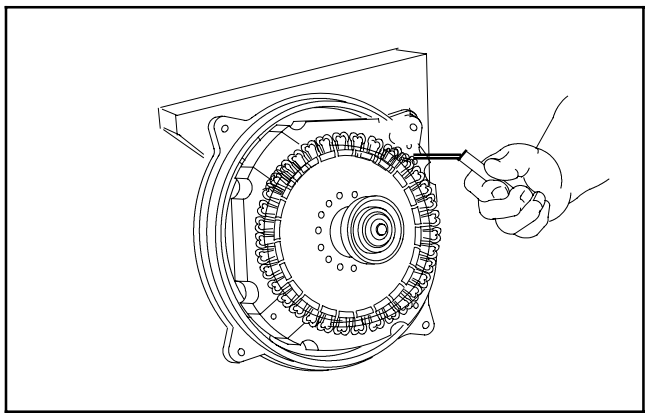


Figure 7-3 Remove Socket Head Screws

6. Grasp the stator firmly. Pull straight out to prevent damage to the stator laminations. See Figure 7-4.

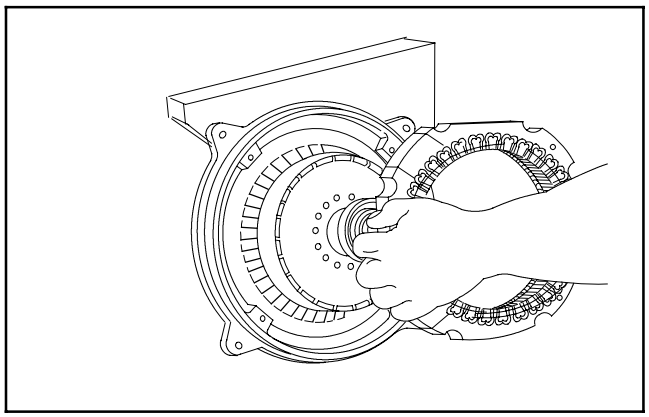


Figure 7-4 Remove Stator

7. Loosen the thrubolt. See Figure 7-5.

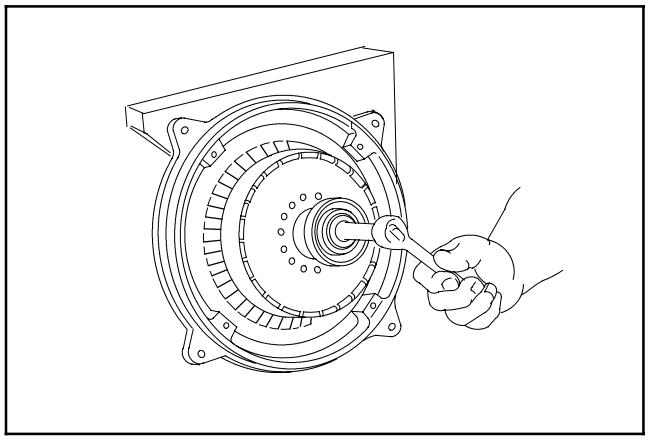


Figure 7-5 Loosen Thrubolt

8. Loosen the rotor/fan assembly by lightly tapping on alternate sides with a rubber mallet. Use only a rubber mallet to prevent damage to the bolt.

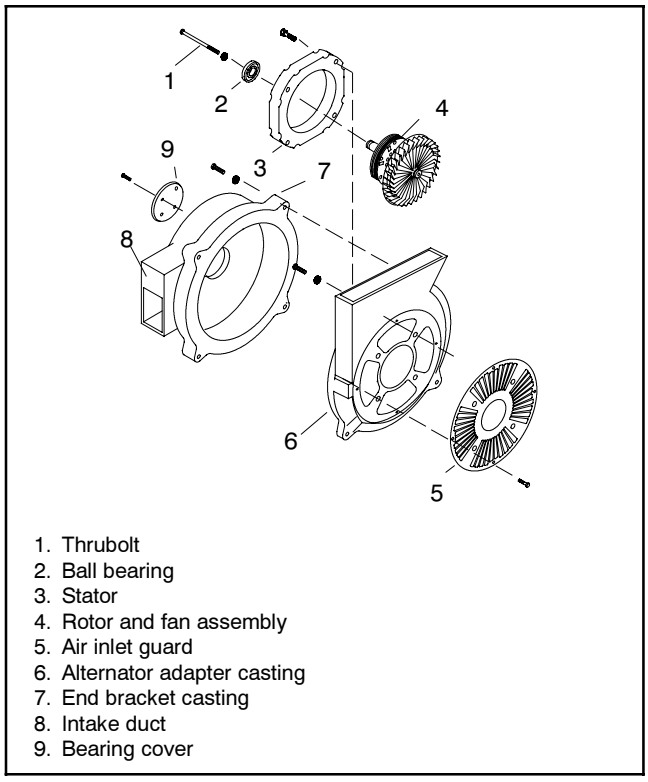
9. Remove the thrubolt and rotor.

7.2 COM7.5 Reassembly

The following sections describe COM7.5 component reinstallation and unit reassembly.

7.2.1 Alternator Reassembly

Follow the step-by-step procedures listed on the following pages. See Figure 7-6 for a diagram on complete alternator reassembly.



1. Thrubolt
2. Ball bearing
3. Stator
4. Rotor and fan assembly
5. Air inlet guard
6. Alternator adapter casting
7. End bracket casting
8. Intake duct
9. Bearing cover

Figure 7-6 Alternator (exploded view)

Reassemble the Alternator

1. Apply antiseize thread compound to the tapered end of the engine crank shaft to ease future removals. See Figure 7-7.

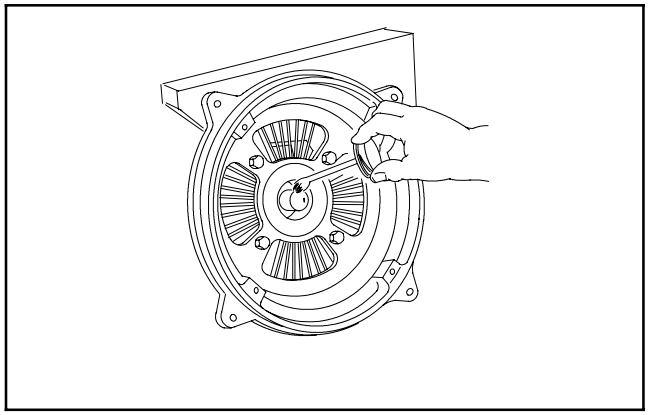


Figure 7-7 Apply Antiseize Compound

2. Clean and reinstall the rotor and thrubolt. Remove any magnetically held debris.

3. With a strap wrench around the rotor, torque the thrubolt to 38 Nm (28 ft. lbs.). See Figure 7-8.

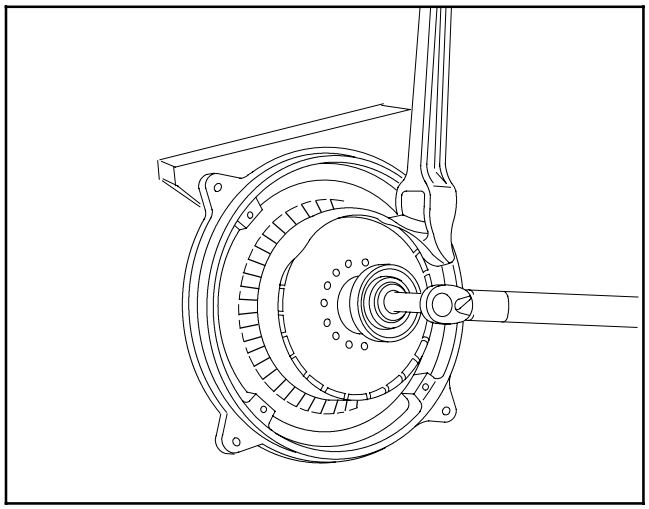


Figure 7-8 Torque Thrubolt

4. Place guide pins or headless bolts in the stator mounting screw holes as a guide for reinstalling the stator. Stator damage can occur if it is not installed correctly.

   Note: The magnets are very strong and cause the stator to quickly snap over the magnetized rotor.

5. Install the stator with the leads in the upper left position Slide the stator over the guide pins until it is fully installed on casting bosses. Be careful not to pinch your fingers between the stator and adapter when the stator snaps into place.

6. Remove the guides. Clean, install, and torque the socket head screws to 10.8 Nm (8 ft. lbs.). See Figure 7-9.

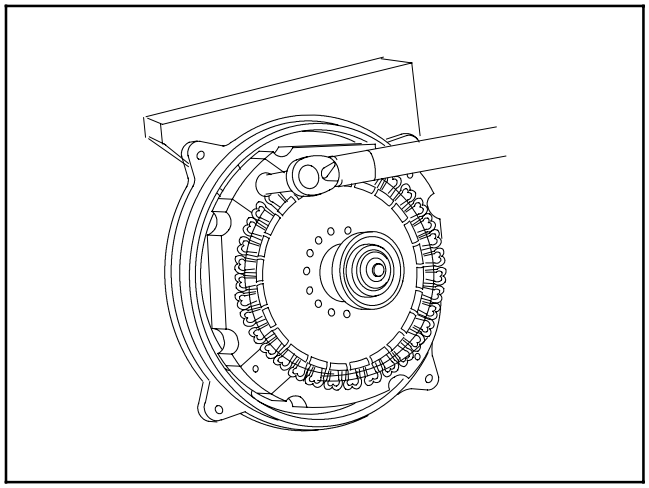


Figure 7-9 Torque Socket Head Screws

7. Route the stator leads through the port in the end bracket. Inspect leads for signs of wear. Repair or replace the stator as needed.

8. Align the end bracket on the stator assembly and rotor bearing. Use a rubber mallet to seat the end bracket casting if necessary.

Note: Do not install the end bracket by tightening the bolts. End bracket, engine, and/or generator adapter damage can result. Fully install and seat the end bracket casting against the mating casting before installing the bolts.

9. Clean and install the end bracket bolts. Tighten the bolts to 38.0 Nm (28 ft. lbs.) using the A, B, C, D tightening sequence shown in Figure 7-10.

10. Replace the bearing cover and install the screws.

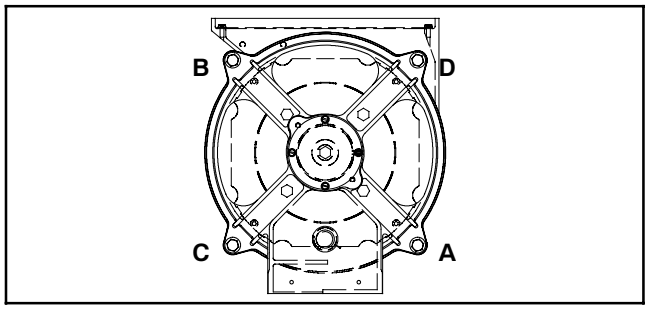


Figure 7-10 End Bracket: A, B, C, D Tightening Sequence

7.2.2 Generator Set Connection

1. Check that the remote start/stop switch is in the STOP position.

2. Reconnect the three alternator AC output leads to the voltage rectifier.

3. Reconnect the generator set engine starting battery, negative (–) lead last.

4. Reconnect the battery charger, if equipped.

5. Follow the enclosure manufacturer's instructions to reinstall the exhaust ductwork and the enclosure.

Notes

Section 8 Diagrams and Drawings

Diagram or Drawing	Drawing Number	Reference
Schematic Diagrams		
Wiring Diagram	GM20551-C	Figure 8-1
Schematic	ADV-6654-A	Figure 8-2

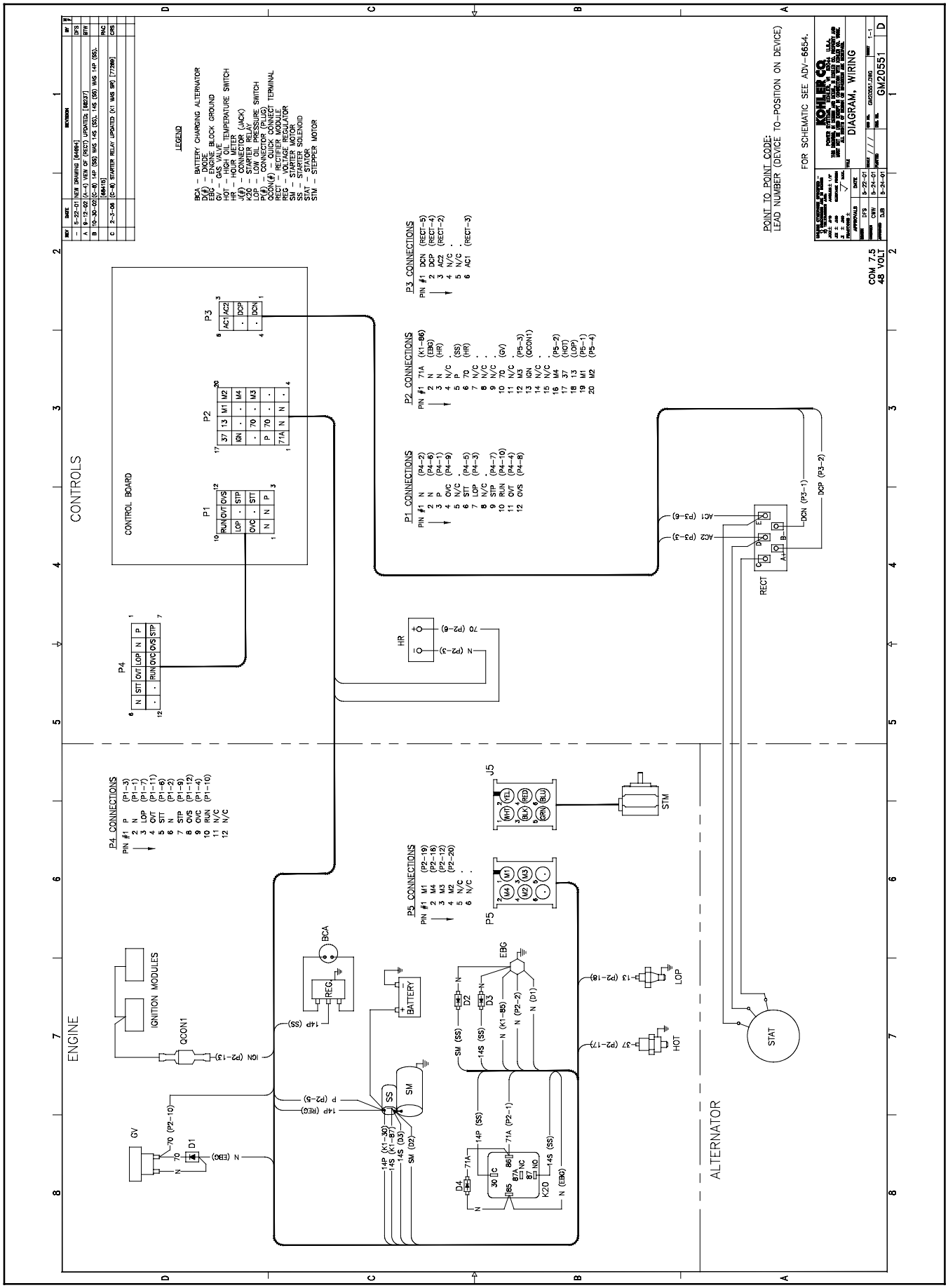


Figure 8-1 Wiring Diagram, GM20551-C

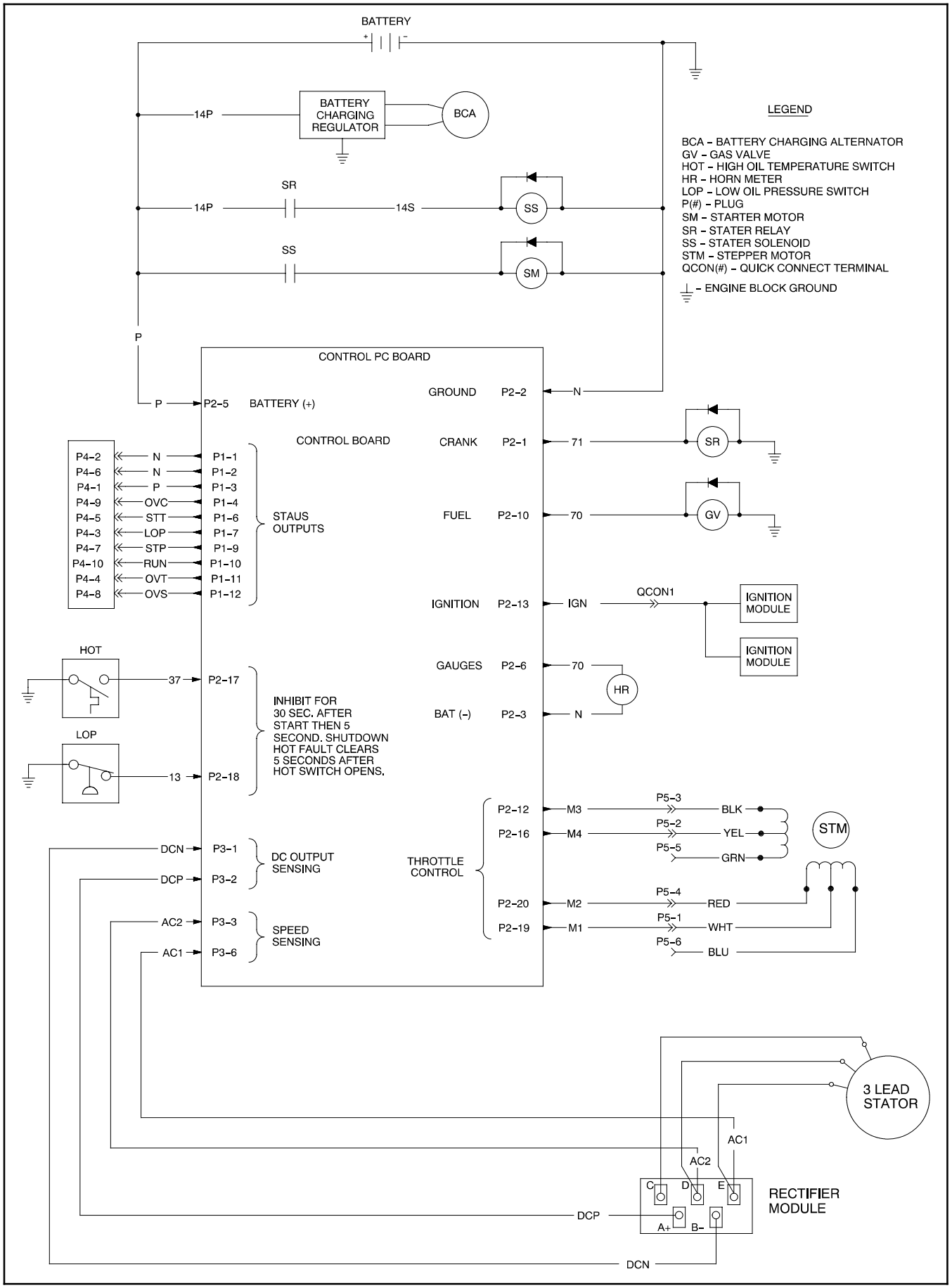


Figure 8-2 Schematic, ADV-6654-A

Notes

Appendix A Abbreviations

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

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

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

Appendix B Common Hardware Application Guidelines

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

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

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

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

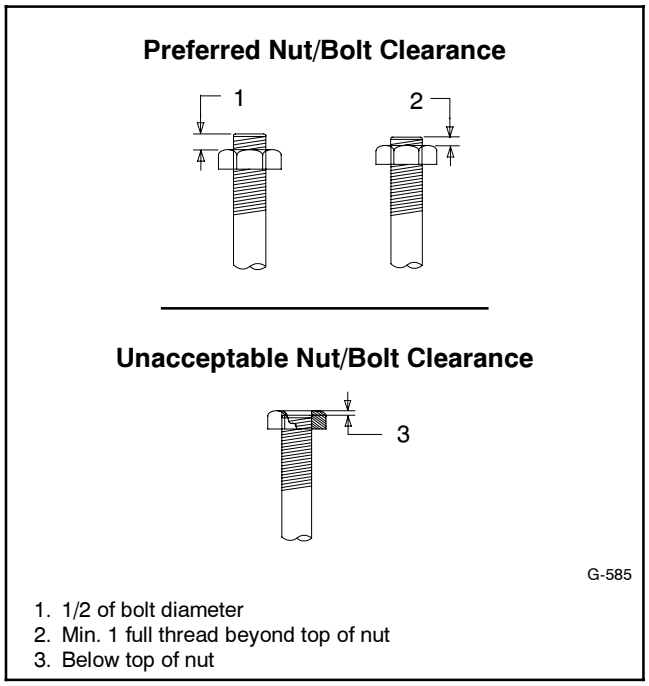


Figure 1 Acceptable Bolt Lengths

Steps for common hardware application:

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

   For round and slotted exit holes, determine if hardware is greater than 1/2 inch in diameter, or 1/2 inch in diameter or less. Hardware that is *greater than 1/2 inch* in diameter takes a standard nut and SAE washer. Hardware *1/2 inch or less* in diameter can take a properly torqued whiz nut or spiralock nut. See Figure 2.
3. Follow these SAE washer rules after determining exit hole type:
   a. Always use a washer between hardware and a slot.
   b. Always use a washer under a nut (see 2 above for exception).
   c. Use a washer under a bolt when the female thread is fixed (weld nut).
4. Refer to Figure 2, which depicts the preceding hardware configuration possibilities.

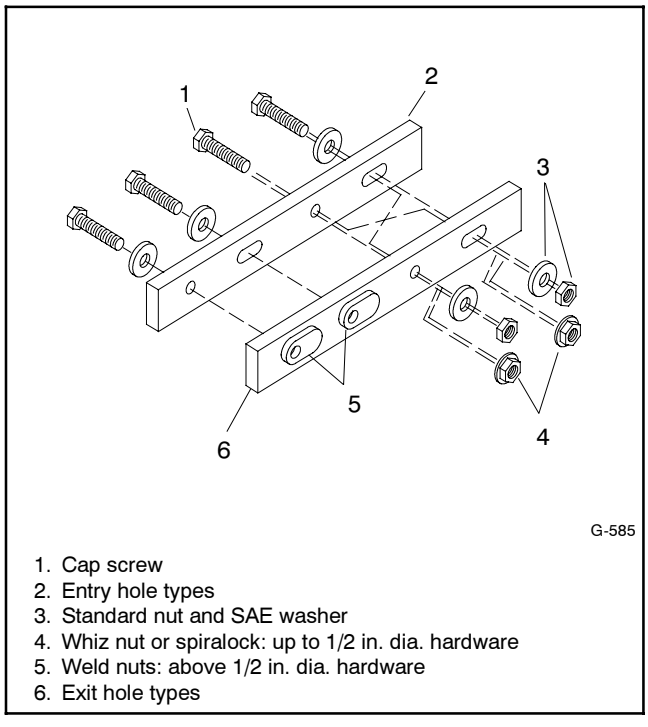


Figure 2 Acceptable Hardware Combinations

Appendix C General Torque Specifications

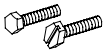
American Standard Fasteners Torque Specifications								
Size	Torque Measurement	Assembled into Cast Iron or Steel						Assembled into Aluminum Grade 2 or 5
		Grade 2		Grade 5		Grade 8		
8-32	Nm (in. lb.)	1.8	(16)	2.3	(20)	—		See Note 3
10-24	Nm (in. lb.)	2.9	(26)	3.6	(32)	—		
10-32	Nm (in. lb.)	2.9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

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

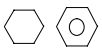
Notes:

1. Do not use these values when the torque values are specified on the assembly drawing.
2. These values are based on new plates threads. Increase values by 15% if non-plated threads are used.
3. Hardware threaded into aluminum must have two diameters of thread engagement or may require 30% or more reduction in the torque.
4. Torques are calculated as equivalent stress loading to American hardware and approximately a preload of 90% of yield strength and friction coefficient of 0.125.

Appendix D Common Hardware Identification

Screw/Bolts/Studs	
Head Styles	
Hex Head or Machine Head	
Hex Head or Machine Head with Washer	
Flat Head (FHM)	
Round Head (RHM)	
Pan Head	
Hex Socket Head Cap or Allen™ Head Cap	
Hex Socket Head or Allen™ Head Shoulder Bolt	
Sheet Metal Screw	
Stud	
Drive Styles	
Hex	
Hex and Slotted	
Phillips®	
Slotted	
Hex Socket	

Nuts	
Nut Styles	
Hex Head	
Lock or Elastic	
Square	
Cap or Acorn	
Wing	
Washers	
Washer Styles	
Plain	
Split Lock or Spring	
Spring or Wave	
External Tooth Lock	
Internal Tooth Lock	
Internal-External Tooth Lock	

Hardness Grades	
American Standard	
Grade 2	
Grade 5	
Grade 8	
Grade 8/9 (Hex Socket Head)	
Metric	
Number stamped on hardware; 5.8 shown	

Allen™ head screw is a trademark of Holo-Krome Co.

Phillips® screw is a registered trademark of Phillips Screw Company.

Sample Dimensions

American Standard (Screws, Bolts, Studs, and Nuts)

1/4-20 x 1

- Length In Inches (Screws and Bolts)
- Threads Per Inch
- Major Thread Diameter In Fractional Inches Or Screw Number Size

Metric (Screws, Bolts, Studs, and Nuts)

M6-1.25 x 20

- Length In Millimeters (Screws and Bolts)
- Distance Between Threads In Millimeters
- Major Thread Diameter In Millimeters

Plain Washers

9/32 x 5/8 x 1/16

- Thickness
- External Dimension
- Internal Dimension

Lock Washers

5/8

- Internal Dimension

Appendix E Common Hardware List

The Common Hardware List lists part numbers and dimensions for common hardware items.

American Standard

Part No.	Dimensions
Hex Head Bolts (Grade 5)	
X-465-17	1/4-20 x .38
X-465-6	1/4-20 x .50
X-465-2	1/4-20 x .62
X-465-16	1/4-20 x .75
X-465-18	1/4-20 x .88
X-465-7	1/4-20 x 1.00
X-465-8	1/4-20 x 1.25
X-465-9	1/4-20 x 1.50
X-465-10	1/4-20 x 1.75
X-465-11	1/4-20 x 2.00
X-465-12	1/4-20 x 2.25
X-465-14	1/4-20 x 2.75
X-465-21	1/4-20 x 5.00
X-465-25	1/4-28 x .38
X-465-20	1/4-28 x 1.00
X-125-33	5/16-18 x .50
X-125-23	5/16-18 x .62
X-125-3	5/16-18 x .75
X-125-31	5/16-18 x .88
X-125-5	5/16-18 x 1.00
X-125-24	5/16-18 x 1.25
X-125-34	5/16-18 x 1.50
X-125-25	5/16-18 x 1.75
X-125-26	5/16-18 x 2.00
230578	5/16-18 x 2.25
X-125-29	5/16-18 x 2.50
X-125-27	5/16-18 x 2.75
X-125-28	5/16-18 x 3.00
X-125-22	5/16-18 x 4.50
X-125-32	5/16-18 x 5.00
X-125-35	5/16-18 x 5.50
X-125-36	5/16-18 x 6.00
X-125-40	5/16-18 x 6.50
X-125-43	5/16-24 x 1.75
X-125-44	5/16-24 x 2.50
X-125-30	5/16-24 x .75
X-125-39	5/16-24 x 2.00
X-125-38	5/16-24 x 2.75
X-6238-2	3/8-16 x .62
X-6238-10	3/8-16 x .75
X-6238-3	3/8-16 x .88
X-6238-11	3/8-16 x 1.00
X-6238-4	3/8-16 x 1.25
X-6238-5	3/8-16 x 1.50
X-6238-1	3/8-16 x 1.75
X-6238-6	3/8-16 x 2.00
X-6238-17	3/8-16 x 2.25
X-6238-7	3/8-16 x 2.50
X-6238-8	3/8-16 x 2.75
X-6238-9	3/8-16 x 3.00
X-6238-19	3/8-16 x 3.25
X-6238-12	3/8-16 x 3.50
X-6238-20	3/8-16 x 3.75
X-6238-13	3/8-16 x 4.50
X-6238-18	3/8-16 x 5.50
X-6238-25	3/8-16 x 6.50

Part No.	Dimensions
Hex Head Bolts, cont.	
X-6238-14	3/8-24 x .75
X-6238-16	3/8-24 x 1.25
X-6238-21	3/8-24 x 4.00
X-6238-22	3/8-24 x 4.50
X-6024-5	7/16-14 x .75
X-6024-2	7/16-14 x 1.00
X-6024-8	7/16-14 x 1.25
X-6024-3	7/16-14 x 1.50
X-6024-4	7/16-14 x 2.00
X-6024-11	7/16-14 x 2.75
X-6024-12	7/16-14 x 6.50
X-129-15	1/2-13 x .75
X-129-17	1/2-13 x 1.00
X-129-18	1/2-13 x 1.25
X-129-19	1/2-13 x 1.50
X-129-20	1/2-13 x 1.75
X-129-21	1/2-13 x 2.00
X-129-22	1/2-13 x 2.25
X-129-23	1/2-13 x 2.50
X-129-24	1/2-13 x 2.75
X-129-25	1/2-13 x 3.00
X-129-27	1/2-13 x 3.50
X-129-29	1/2-13 x 4.00
X-129-30	1/2-13 x 4.50
X-463-9	1/2-13 x 5.50
X-129-44	1/2-13 x 6.00
X-129-51	1/2-20 x .75
X-129-45	1/2-20 x 1.25
X-129-52	1/2-20 x 1.50
X-6021-3	5/8-11 x 1.00
X-6021-4	5/8-11 x 1.25
X-6021-2	5/8-11 x 1.50
X-6021-1	5/8-11 x 1.75
273049	5/8-11 x 2.00
X-6021-5	5/8-11 x 2.25
X-6021-6	5/8-11 x 2.50
X-6021-7	5/8-11 x 2.75
X-6021-12	5/8-11 x 3.75
X-6021-11	5/8-11 x 4.50
X-6021-10	5/8-11 x 6.00
X-6021-9	5/8-18 x 2.50
X-6239-1	3/4-10 x 1.00
X-6239-8	3/4-10 x 1.25
X-6239-2	3/4-10 x 1.50
X-6239-3	3/4-10 x 2.00
X-6239-4	3/4-10 x 2.50
X-6239-5	3/4-10 x 3.00
X-6239-6	3/4-10 x 3.50
X-792-1	1-8 x 2.25
X-792-5	1-8 x 3.00
X-792-8	1-8 x 5.00

Part No.	Dimensions	Type
Hex Nuts		
X-6009-1	1-8	Standard
X-6210-3	6-32	Whiz
X-6210-4	8-32	Whiz
X-6210-5	10-24	Whiz
X-6210-1	10-32	Whiz
X-6210-2	1/4-20	Spiralock
X-6210-6	1/4-28	Spiralock
X-6210-7	5/16-18	Spiralock
X-6210-8	5/16-24	Spiralock
X-6210-9	3/8-16	Spiralock
X-6210-10	3/8-24	Spiralock
X-6210-11	7/16-14	Spiralock
X-6210-12	1/2-13	Spiralock
X-6210-15	7/16-20	Spiralock
X-6210-14	1/2-20	Spiralock
X-85-3	5/8-11	Standard
X-88-12	3/4-10	Standard
X-89-2	1/2-20	Standard

Washers

Part No.	ID	OD	Thick.	Bolt/ Screw
X-25-46	.125	.250	.022	#4
X-25-9	.156	.375	.049	#6
X-25-48	.188	.438	.049	#8
X-25-36	.219	.500	.049	#10
X-25-40	.281	.625	.065	1/4
X-25-85	.344	.687	.065	5/16
X-25-37	.406	.812	.065	3/8
X-25-34	.469	.922	.065	7/16
X-25-26	.531	1.062	.095	1/2
X-25-15	.656	1.312	.095	5/8
X-25-29	.812	1.469	.134	3/4
X-25-127	1.062	2.000	.134	1

Metric

Hex head bolts are hardness grade 8.8 unless noted.

Hex Head Bolts (Partial Thread)

Part No.	Dimensions
M931-05055-60	M5-0.80 x 55
M931-06040-60	M6-1.00 x 40
M931-06055-60	M6-1.00 x 55
M931-06060-60	M6-1.00 x 60
M931-06060-SS	M6-1.00 x 60
M931-06070-60	M6-1.00 x 70
M931-06070-SS	M6-1.00 x 70
M931-06075-60	M6-1.00 x 75
M931-06090-60	M6-1.00 x 90
M931-06145-60	M6-1.00 x 145
M931-06150-60	M6-1.00 x 150
M931-08035-60	M8-1.25 x 35
M931-08040-60	M8-1.25 x 40
M931-08045-60	M8-1.25 x 45
M931-08050-60	M8-1.25 x 50
M931-08055-60	M8-1.25 x 55
M931-08055-82	M8-1.25 x 55*
M931-08060-60	M8-1.25 x 60
M931-08070-60	M8-1.25 x 70
M931-08070-82	M8-1.25 x 70*
M931-08075-60	M8-1.25 x 75
M931-08080-60	M8-1.25 x 80
M931-08090-60	M8-1.25 x 90
M931-08095-60	M8-1.25 x 95
M931-08100-60	M8-1.25 x 100
M931-08110-60	M8-1.25 x 110
M931-08120-60	M8-1.25 x 120
M931-08130-60	M8-1.25 x 130
M931-08140-60	M8-1.25 x 140
M931-08150-60	M8-1.25 x 150
M931-08200-60	M8-1.25 x 200
M931-10040-82	M10-1.25 x 40*
M931-10040-60	M10-1.50 x 40
M931-10045-60	M10-1.50 x 45
M931-10050-60	M10-1.50 x 50
M931-10050-82	M10-1.25 x 50*
M931-10055-60	M10-1.50 x 55
M931-10060-60	M10-1.50 x 60
M931-10065-60	M10-1.50 x 65
M931-10070-60	M10-1.50 x 70
M931-10080-60	M10-1.50 x 80
M931-10080-82	M10-1.25 x 80*
M931-10090-60	M10-1.50 x 90
M931-10090-82	M10-1.50 x 90*
M931-10100-60	M10-1.50 x 100
M931-10110-60	M10-1.50 x 110
M931-10120-60	M10-1.50 x 120
M931-10130-60	M10-1.50 x 130
M931-10140-60	M10-1.50 x 140
M931-10180-60	M10-1.50 x 180
M931-10235-60	M10-1.50 x 235
M931-10260-60	M10-1.50 x 260
M960-10330-60	M10-1.25 x 330
M931-12045-60	M12-1.75 x 45
M960-12050-60	M12-1.25 x 50
M960-12050-82	M12-1.25 x 50*
M931-12050-60	M12-1.75 x 50
M931-12050-82	M12-1.75 x 50*
M931-12055-60	M12-1.75 x 55
M931-12060-60	M12-1.75 x 60
M931-12060-82	M12-1.75 x 60*
M931-12065-60	M12-1.75 x 65
M931-12075-60	M12-1.75 x 75
M931-12080-60	M12-1.75 x 80
M931-12090-60	M12-1.75 x 90
M931-12100-60	M12-1.75 x 100
M931-12110-60	M12-1.75 x 110

Hex Head Bolts (Partial Thread), continued

Part No.	Dimensions
M960-16090-60	M16-1.50 x 90
M931-16090-60	M16-2.00 x 90
M931-16100-60	M16-2.00 x 100
M931-16100-82	M16-2.00 x 100*
M931-16120-60	M16-2.00 x 120
M931-16150-60	M16-2.00 x 150
M931-20065-60	M20-2.50 x 65
M931-20090-60	M20-2.50 x 90
M931-20100-60	M20-2.50 x 100
M931-20120-60	M20-2.50 x 120
M931-20140-60	M20-2.50 x 140
M931-20160-60	M20-2.50 x 160
M931-22090-60	M22-2.50 x 90
M931-22120-60	M22-2.50 x 120
M931-22160-60	M22-2.50 x 160
M931-24090-60	M24-3.00 x 90
M931-24120-60	M24-3.00 x 120
M931-24160-60	M24-3.00 x 160
M931-24200-60	M24-3.00 x 200

Hex Head Bolts (Full Thread)

M933-04006-60	M4-0.70 x 6
M933-05030-60	M5-0.80 x 30
M933-05035-60	M5-0.80 x 35
M933-05050-60	M5-0.80 x 50
M933-06010-60	M6-1.00 x 10
M933-06012-60	M6-1.00 x 12
M933-06014-60	M6-1.00 x 14
M933-06016-60	M6-1.00 x 16
M933-06020-60	M6-1.00 x 20
M933-06025-60	M6-1.00 x 25
M933-06030-60	M6-1.00 x 30
M933-06040-60	M6-1.00 x 40
M933-06050-60	M6-1.00 x 50
M933-07025-60	M7-1.00 x 25
M933-08010-60	M8-1.25 x 10
M933-08012-60	M8-1.25 x 12
M933-08016-60	M8-1.25 x 16
M933-08020-60	M8-1.25 x 20
M933-08025-60	M8-1.25 x 25
M933-08030-60	M8-1.25 x 30
M933-08030-82	M8-1.25 x 30*
M933-10012-60	M10-1.50 x 12
M961-10020-60	M10-1.25 x 20
M933-10020-60	M10-1.50 x 20
M933-10025-60	M10-1.50 x 25
M961-10025-60	M10-1.25 x 25
M933-10025-82	M10-1.50 x 25*
M961-10030-60	M10-1.25 x 30
M933-10030-60	M10-1.50 x 30
M933-10030-82	M10-1.50 x 30*
M961-10035-60	M10-1.25 x 35
M933-10035-60	M10-1.50 x 35
M933-10035-82	M10-1.50 x 35*
M961-10040-60	M10-1.25 x 40

Hex Head Bolts (Full Thread), continued

Part No.	Dimensions
M933-12016-60	M12-1.75 x 16
M933-12020-60	M12-1.75 x 20
M961-12020-60F	M12-1.50 x 20
M933-12025-60	M12-1.75 x 25
M933-12025-82	M12-1.75 x 25*
M961-12030-60	M12-1.25 x 30
M933-12030-82	M12-1.75 x 30*
M961-12030-82F	M12-1.50 x 30*
M933-12030-60	M12-1.75 x 30
M933-12035-60	M12-1.75 x 35
M961-12040-82	M12-1.25 x 40*
M933-12040-60	M12-1.75 x 40
M933-12040-82	M12-1.75 x 40*
M961-14025-60	M14-1.50 x 25
M933-14025-60	M14-2.00 x 25
M961-14050-82	M14-1.50 x 50*
M961-16025-60	M16-1.50 x 25
M933-16025-60	M16-2.00 x 25
M961-16030-82	M16-1.50 x 30*
M933-16030-82	M16-2.00 x 30*
M933-16035-60	M16-2.00 x 35
M961-16040-60	M16-1.50 x 40
M933-16040-60	M16-2.00 x 40
M961-16045-82	M16-1.50 x 45*
M933-16045-82	M16-2.00 x 45*
M933-16050-60	M16-2.00 x 50
M933-16050-82	M16-2.00 x 50*
M933-16060-60	M16-2.00 x 60
M933-16070-60	M16-2.00 x 70
M933-18035-60	M18-2.50 x 35
M933-18050-60	M18-2.50 x 50
M933-18060-60	M18-2.50 x 60
M933-20050-60	M20-2.50 x 50
M933-20055-60	M20-2.50 x 55
M933-24060-60	M24-3.00 x 60
M933-24065-60	M24-3.00 x 65
M933-24070-60	M24-3.00 x 70

Pan Head Machine Screws

M7985A-03010-20	M3-0.50 x 10
M7985A-03012-20	M3-0.50 x 12
M7985A-04010-20	M4-0.70 x 10
M7985A-04016-20	M4-0.70 x 16
M7985A-04020-20	M4-0.70 x 20
M7985A-04050-20	M4-0.70 x 50
M7985A-04100-20	M4-0.70 x 100
M7985A-05010-20	M5-0.80 x 10
M7985A-05012-20	M5-0.80 x 12
M7985A-05016-20	M5-0.80 x 16
M7985A-05020-20	M5-0.80 x 20
M7985A-05025-20	M5-0.80 x 25
M7985A-05030-20	M5-0.80 x 30
M7985A-05080-20	M5-0.80 x 80
M7985A-05100-20	M5-0.80 x 100
M7985A-06100-20	M6-1.00 x 100

Flat Head Machine Screws

M965A-04012-SS	M4-0.70 x 12
M965A-05012-SS	M5-0.80 x 12
M965A-05016-20	M5-0.80 x 16
M965A-06012-20	M6-1.00 x 12

* This metric hex bolt's hardness is grade 10.9.

Metric, continued

Hex Nuts

Part No.	Dimensions	Type
M934-03-50	M3-0.50	Standard
M934-04-50	M4-0.70	Standard
M934-04-B	M4-0.70	Brass
M934-05-50	M5-0.80	Standard
M934-06-60	M6-1.00	Standard
M934-06-64	M6-1.00	Std. (green)
M6923-06-80	M6-1.00	Spiralock
M982-06-80	M6-1.00	Elastic Stop
M934-08-60	M8-1.25	Standard
M6923-08-80	M8-1.25	Spiralock
M982-08-80	M8-1.25	Elastic Stop
M934-10-60	M10-1.50	Standard
M934-10-60F	M10-1.25	Standard
M6923-10-80	M10-1.50	Spiralock
M6923-10-62	M10-1.50	Spiralock†
M982-10-80	M10-1.50	Elastic Stop
M934-12-60	M12-1.75	Standard
M934-12-60F	M12-1.25	Standard
M6923-12-80	M12-1.75	Spiralock
M982-12-80	M12-1.75	Elastic Stop
M982-14-60	M14-2.00	Elastic Stop
M6923-16-80	M16-2.00	Spiralock
M982-16-80	M16-2.00	Elastic Stop
M934-18-80	M18-2.5	Standard
M982-18-60	M18-2.50	Elastic Stop
M934-20-80	M20-2.50	Standard
M982-20-80	M20-2.50	Elastic Stop
M934-22-60	M22-2.50	Standard
M934-24-80	M24-3.00	Standard
M982-24-60	M24-3.00	Elastic Stop
M934-30-80	M30-3.50	Standard

Washers

Part No.	ID	OD	Thick.	Bolt/ Screw
M125A-03-80	3.2	7.0	0.5	M3
M125A-04-80	4.3	9.0	0.8	M4
M125A-05-80	5.3	10.0	1.0	M5
M125A-06-80	6.4	12.0	1.6	M6
M125A-08-80	8.4	16.0	1.6	M8
M125A-10-80	10.5	20.0	2.0	M10
M125A-12-80	13.0	24.0	2.5	M12
M125A-14-80	15.0	28.0	2.5	M14
M125A-16-80	17.0	30.0	3.0	M16
M125A-18-80	19.0	34.0	3.0	M18
M125A-20-80	21.0	37.0	3.0	M20
M125A-24-80	25.0	44.0	4.0	M24

† This metric hex nut's hardness is grade 8.

Notes

Notes

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