Service

Marine Generator Sets



Models:

13EOZ/11EFOZ
14EOZ/11.5EFOZ
15.5EOZ/13EFOZ
20EOZ/16EFOZ
20EOZ/17.5EFOZ
23EOZ/19EFOZ
24EOZ/20EFOZ

ISO 9001
KOHLER GENERATORS
INTERNATIONALLY REGISTERED

KOHLER®
POWER SYSTEMS

TP-6071 3/00

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

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

DANGER

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

WARNING

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

CAUTION

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

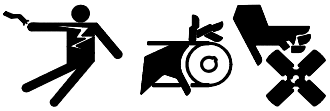
NOTICE

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

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

Accidental Starting

WARNING



Accidental starting.
Can cause severe injury or death.

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

Disabling the generator set. Accidental starting can cause severe injury or death. Before working on the generator set or equipment connected to the set, disable the generator set as follows: (1) Disconnect the power to the battery charger, if equipped. (2) 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.

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 wristwatch, rings, and other 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.

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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 wristwatch, rings, and other 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.

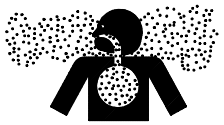
Servicing the air cleaner. A sudden backfire can cause severe injury or death. Do not operate the generator set with the air cleaner/silencer removed.

Combustible materials. A sudden flash fire can cause severe injury or death. Do not smoke or permit flames or sparks near the fuel system. Keep the compartment and the generator set clean and free of debris to minimize the risk of fire. Wipe up spilled fuels and engine oil.

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.

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

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

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

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

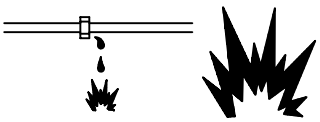
Inspecting the exhaust system. Carbon monoxide can cause severe nausea, fainting, or death. For the safety of the craft's occupants, install a carbon monoxide detector. Consult the boat builder or dealer for approved detector location and installation. Inspect the detector before each generator set use. In addition to routine exhaust system inspection, test the carbon monoxide detector per the manufacturer's instructions and keep the detector operational at all times.

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Operating the generator set. 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. Use the following precautions when installing and operating the generator set. Do not install the exhaust outlet where exhaust can be drawn in through portholes, vents, or air conditioners. If the generator set exhaust discharge outlet is near the waterline, water could enter the exhaust discharge outlet and close or restrict the flow of exhaust. Never operate the generator set without a functioning carbon monoxide detector. Be especially careful if operating the generator set when moored or anchored under calm conditions because gases may accumulate. If operating the generator set dockside, moor the craft so that the exhaust discharges on the lee side (the side sheltered from the wind). Always be aware of others, making sure your exhaust is directed away from other boats and buildings. Avoid overloading the craft.

Fuel System

⚠ WARNING



Explosive fuel vapors.
Can cause severe injury or death.

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

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

Installing the fuel system. Explosive fuel vapors can cause severe injury or death. Fuel leakage can cause an explosion. Do not modify the tank or the propulsion engine fuel system. Equip the craft with a tank that allows one of the two pickup arrangements described in the installation section. The tank and installation must conform to USCG Regulations.

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

Pipe sealant. Explosive fuel vapors can cause severe injury or death. Fuel leakage can cause an explosion. Use pipe sealant on all threaded fittings to prevent fuel leakage. Use pipe sealant that resists gasoline, grease, lubrication oil, common bilge solvents, salt deposits, and water.

Ignition-protected equipment. Explosive fuel vapors can cause severe injury or death. Gasoline vapors can cause an explosion. USCG Regulation 33CFR183 requires that all electrical devices (ship-to-shore transfer switch, remote start panel, etc.) must be ignition protected when used in a gasoline and gaseous-fueled environment. The electrical devices listed above are not ignition protected and are not certified to operate in a gasoline and gaseous-fueled environment such as an engine room or near fuel tanks. Acceptable locations are the wheelhouse and other living areas sheltered from rain and water splash.

Hazardous Noise

⚠ CAUTION



Hazardous noise.
Can cause hearing loss.

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

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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

⚠ WARNING





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

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

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

Disconnecting the electrical load. Hazardous voltage can cause severe injury or death. Disconnect the generator set from the load by opening the line circuit breaker or by disconnecting the generator set output leads from the transfer switch and heavily taping the ends of the leads. High voltage transferred to the load during testing may cause personal injury and equipment damage. Do not use the safeguard circuit breaker in place of the line circuit breaker. The safeguard circuit breaker does not disconnect the generator set from the load.

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 wristwatch, rings, and jewelry before servicing the equipment.

Testing the voltage regulator. Hazardous voltage can cause severe injury or death. High voltage is present at the voltage regulator heat sink. To prevent electrical shock do not touch the voltage regulator heat sink when testing the voltage regulator. *(PowerBoost™, PowerBoost™ III, and PowerBoost™ V voltage regulator models only)*

Electrical backfeed to the utility. Hazardous backfeed voltage can cause severe injury or death. Connect the generator set to the building/marina electrical system only through an approved device and after the building/marina main switch is opened. Backfeed connections can cause serious injury or death to utility personnel working on power lines and/or personnel near the work area. Some states and localities prohibit unauthorized connection to the utility electrical system. Install a ship-to-shore transfer switch to prevent interconnection of the generator set power and shore power.

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 rings, wristwatch, and jewelry. (2) Stand on a dry, approved electrically insulated mat. (3) Do not touch the enclosure or components inside the enclosure. (4) Be prepared for the system to operate automatically. *(600 volts and under)*

Heavy Equipment

⚠ WARNING



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

Do not use lifting eyes.
Use slings under the skid to balance and lift the generator set.

Hot Parts

⚠ WARNING



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

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

⚠ WARNING



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

Do not work on the generator set until it cools.

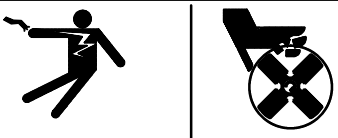
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Checking the coolant level. Hot coolant can cause severe injury or death. Allow the engine to cool. Release pressure from the cooling system before removing the pressure cap. To release pressure, cover the pressure cap with a thick cloth and then slowly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

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

Moving Parts

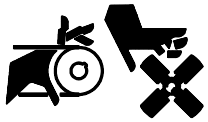
⚠ WARNING



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

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

⚠ WARNING



Rotating parts.
Can cause severe injury or death.

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

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

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

Sound shield removal. Exposed moving parts can cause severe injury or death. The generator set must be operating in order to perform some scheduled maintenance procedures. Be especially careful if the sound shield has been removed, leaving the belts and pulleys exposed. *(Sound-shield-equipped models only)*

Notice

NOTICE

This generator set has been rewired from its nameplate voltage to

246242

NOTICE

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

NOTICE

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

NOTICE

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

NOTICE

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

NOTICE

Saltwater damage. Saltwater quickly deteriorates metals. Wipe up saltwater on and around the generator set and remove salt deposits from metal surfaces.

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Notes

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Introduction

This manual provides troubleshooting and repair instructions for 13-24EOZ and 11-20EFOZ model generator sets (4-lead and 12-lead), controllers, and accessories.

Refer to the engine service manual for generator set engine service information.

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This manual may be used for models not listed on the front cover.

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.

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Service Assistance

Service Information

Please contact a local authorized distributor/dealer for sales, service, or other information about Kohler Generator Division products.

To locate a local authorized distributor/dealer inside the U.S.A. and Canada

- Look on the product or in the information included with the product
- Consult the Yellow Pages under the heading Generators— Electric
- Visit the Kohler Generator Division web site at www.kohlergenerators.com
- Call 1-800-544-2444

To locate a local authorized distributor/dealer outside the U.S.A. and Canada

- Look on the product or in the information included with the product
- Consult the telephone directory under the heading Generators—Electric
- Visit the Kohler Generator Division web site at www.kohlergenerators.com
- Contact the nearest regional office

Africa, Europe, Middle East
London Regional Office
Langley, Slough, England
Phone: (44) 1753-580-771
Fax: (44) 1753-580-036

Australia
Australia Regional Office
Queensland, Australia
Phone: (617) 3893-0061
Fax: (617) 3893-0072

China
China Regional Office
Shanghai, People's Republic of China
Phone: (86) 21-6482 1252
Fax: (86) 21-6482 1255

India, Bangladesh, Sri Lanka
India Regional Office
Bangalore, India
Phone: (91) 80-2284270
(91) 80-2284279
Fax: (91) 80-2284286

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

Latin America
Latin America Regional Office
Lakeland, Florida, U.S.A.
Phone: (941) 619-7568
Fax: (941) 701-7131

South East Asia
Singapore Regional Office
Singapore, Republic of Singapore
Phone: (65) 264-6422
Fax: (65) 264-6455

Product 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 Number _____

Specification Number _____

Serial Number _____

Accessory Number	Accessory Description

Engine Identification

Record the product identification information from the engine nameplate.

Manufacturer _____

Model Number _____

Serial Number _____

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1.1 General

This manual covers maintenance, troubleshooting, and repair of the alternating current marine generator sets listed in Figure 1-1.

Models	Voltage	Phase
13/15.5/20/23EOZ	100/200-120/240 (60 Hz)	1
14/20/24EOZ	120/208-277/480 (60 Hz broadrange)	3
11/13/16/19EFOZ	220-240, 100/200-110/220 (50 Hz)	1
11.5/17.5/20EFOZ	110/190-240/416 (50 Hz broadrange)	3

Figure 1-1 Generator Model Coverage

The 13EOZ/11EFOZ is powered by a three-cylinder, water-cooled, four-cycle diesel engine with a heat exchanger.

The 14EOZ/11.5EFOZ and 15.5EOZ/13EFOZ are powered by a three-cylinder, water-cooled, turbocharged diesel engine with a heat exchanger.

The 20EOZ/16EFOZ and 20EOZ/17.5EFOZ are powered by a four-cylinder, water-cooled, four-cycle diesel engine with a heat exchanger.

The 23EOZ/19EFOZ and 24EOZ/20EFOZ are powered by a four-cylinder, water-cooled, four-cycle, turbocharged diesel engine with a heat exchanger.

Heat exchanger cooling consists of a heat exchanger with a coolant recovery tank, thermostat, rubber impeller seawater pump, centrifugal type engine circulating pump, water-cooled exhaust manifold, and an exhaust mixer.

Kohler Co. develops all Kohler® marine generator set ratings using accepted reference conditions of 25°C (77°F) and pressure of 29.2 in. Hg dry barometer. ISO 3046 and ISO 8528-1 include reference conditions and output calculations. Obtain the technical information bulletin on ratings guidelines (TIB-101) for complete ratings definitions.

Read this manual, then carefully follow all service recommendations. See Figure 1-2 for identification and location of components.

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1.2 Engine

Generator Model	13EOZ	11EFOZ	14/15.5EOZ	11.5/13EFOZ
Engine manufacturer	Yanmar			
Engine model	3TNE88		3TNE84-T	
Number of cylinders	3			
Cylinder block material	Cast iron			
Cylinder head material	Cast iron			
Piston rings	2 compression/1 oil			
Connecting rod material	Forged carbon steel			
Governor	Centrifugal, mechanical			
Bore x stroke, mm (in.)	88 (3.46) x 90 (3.54)		84 (3.31) x 90 (3.54)	
Displacement L (CID)	1.642 (100.2)		1.496 (91.3)	
Compression ratio	18.0:1			
Horsepower 60/50 Hz	23.0	18.1	25.4	21.2
RPM 60/50 Hz	1800	1500	1800	1500
Lubrication system	Pressure, trochoid pump			
Lube oil capacity, w/filter L (U.S. qts)	4.7 (5.0)			
Low oil pressure shutdown	0.5 kg/cm^2 ± 0.1 kg/cm^2			
Oil recommendation (API)	CD or CC class of API service classification			
Battery voltage	12 volts (standard) 24 volts (optional)			
Battery charging	40-amp alternator			
Battery recommendation (minimum)	500 CCA, 100 amp hr.			
Starter motor	1.8 kW Bendix, gear-reduction automotive type			

Generator Model	20EOZ	16/17.5EFOZ	23/24EOZ	19/20EFOZ
Engine manufacturer	Yanmar			
Engine model	4TNE88		4TNE84-T	
Number of cylinders	4			
Cylinder block material	Cast iron			
Cylinder head material	Cast iron			
Piston rings	2 compression/1 oil			
Connecting rod material	Forged carbon steel			
Governor	Centrifugal, mechanical			
Bore x stroke, mm (in.)	88 (3.46) x 90 (3.54)		84 (3.31) x 90 (3.54)	
Displacement L (CID)	2.189 (133.58)		1.995 (121.74)	
Compression ratio	18.0:1			
Horsepower 60/50 Hz	30.5	24.7	38.5	30.2
RPM 60/50 Hz	1800	1500	1800	1500
Lubrication system	Pressure, trochoid pump			
Lube oil capacity, w/filter L (U.S. qts)	5.8 (6.1)			
Low oil pressure shutdown	0.5 kg/cm^2 ± 0.1 kg/cm^2			
Oil recommendation (API)	CD or CC class of API service classification			
Battery voltage	12 volts (standard) 24 volts (optional)			
Battery charging	40-amp alternator			
Battery recommendation (minimum)	500 CCA, 100-amp hr.			
Starter motor	1.8 kW Bendix, gear-reduction automotive type			

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1.3 Fuel

Fuel System	All Models
Fuel recommendation	Diesel ISO 8217DMA, BS 2869A1 or A2
Fuel feed pump	Electric
Fuel pump operating kPa (psi)	27.6–41.4 (4–6)
Fuel pump inlet	0.25-18 NPT

1.4 Cooling

Cooling System	13–15.5 kW	20–24 kW
Recommended coolant	50% ethylene glycol; 50% clean, softened water	
Coolant capacity, approx. L (U.S. qts.) add 0.24L (8 oz.) for the coolant recovery tank.	4.4 (4.6)	6.0 (6.3)
Thermostat	71°C (160°F)	
Pressure cap rating	97 kPa (14 psi)	
High temperature shutdown	111°C (232°F)	
High exhaust temperature shutdown	102°C (215°F)	
Seawater pump inlet water line hose ID,mm (in.)	25 (1.00)	
Mixing elbow outlet exhaust hose ID,mm (in.)	76 (3.00)	

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1.5 Generator, 4 Lead

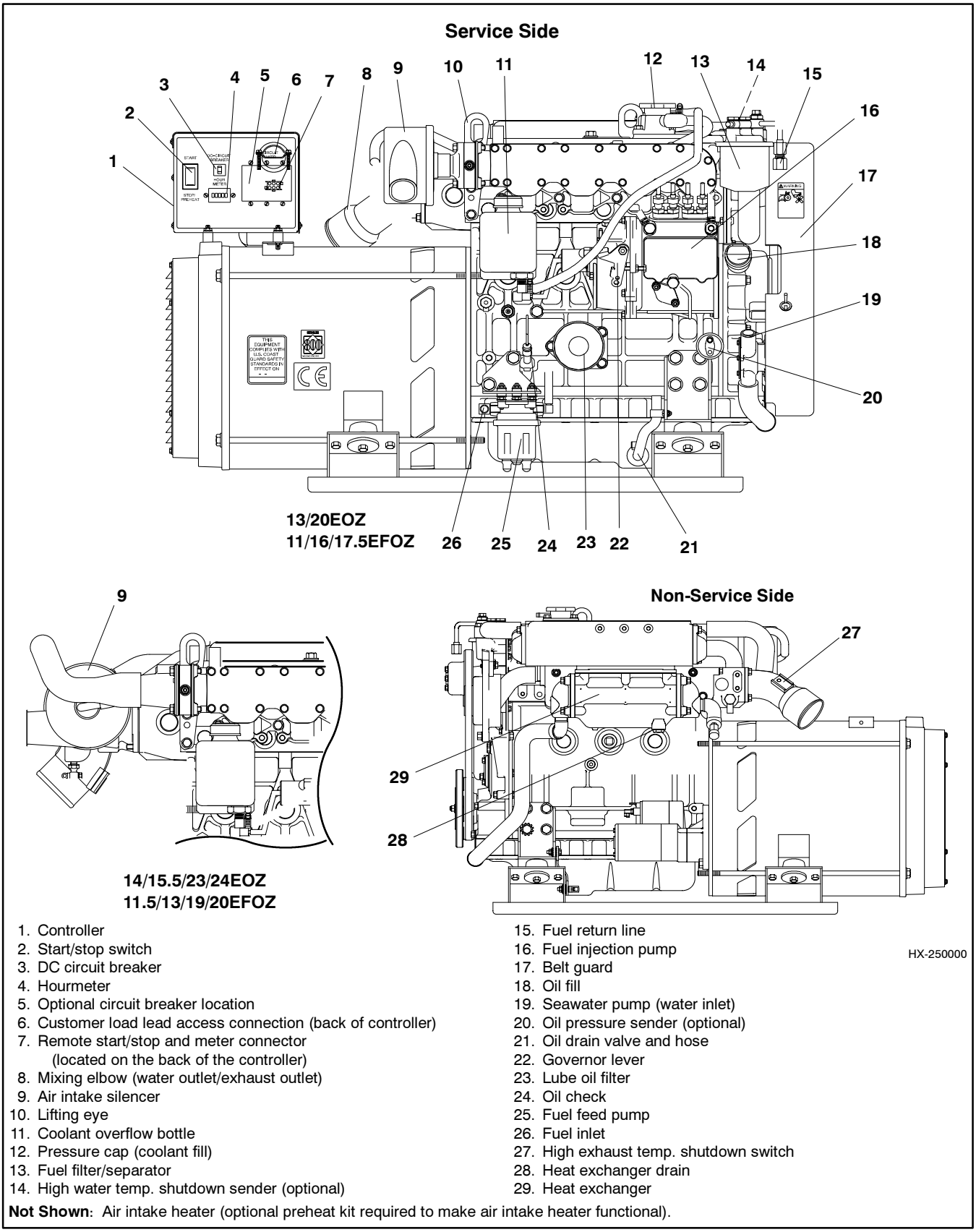
Component Specification	13EOZ 11EFOZ	15.5EOZ 13EFOZ	20-23EOZ 16-19EFOZ
Hot exciter field voltage/amperage readings at rated voltage			
No load (63 Hz)	4/0.7	4/0.7	6/1.0
Full load (60 Hz)	12/1.8	14/2.3	16/2.4
Exciter field resistance (cold)	5.8	5.8	5.8
Exciter armature resistance (cold)	0.5	0.5	0.5
Main field (rotor) resistance (cold)	4.3	2.9	3.0
Stator output voltages with separately excited generator, using 12-volt battery (60 Hz only)			
1-2, 3-4, 33-44	135	135	95
55-66	180	180	125
B1-B2	17	17	12
Cold stator resistance, ohms			
1-2, 3-4, (V1-V4)	0.12	0.12	0.07
55-66	1.5	1.5	1.3
B1-B2	0.07	0.07	0.06

1.6 Generator, 12 Lead

Component Specification	14EOZ 11.5EFOZ	20-24EOZ 17.5-20EFOZ
Hot exciter field voltage/amperage readings at rated voltage		
No load (63 Hz)	6/0.9	8/1.4
Full load (60 Hz)	17/2.6	16/2.4
Exciter field resistance (cold)	5.5	5.8
Exciter armature resistance (cold)	0.5	0.5
Main field (rotor) resistance (cold)	4.3	3.0
Stator output voltages with separately excited generator, using 12-volt battery (60 Hz only)		
1-4, 2-5, 3-6, 7-10, 8-11, 9-12, V1-V2	110	70
55-66	125	90
B1-B2	12	9
Cold stator resistance, ohms		
1-2, 3-4, (V1-V4)	0.06	0.04
55-66	1.5	1.3
B1-B2	0.06	0.05

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1.7 Service Views



1. Controller
2. Start/stop switch
3. DC circuit breaker
4. Hourmeter
5. Optional circuit breaker location
6. Customer load lead access connection (back of controller)
7. Remote start/stop and meter connector (located on the back of the controller)
8. Mixing elbow (water outlet/exhaust outlet)
9. Air intake silencer
10. Lifting eye
11. Coolant overflow bottle
12. Pressure cap (coolant fill)
13. Fuel filter/separator
14. High water temp. shutdown sender (optional)
15. Fuel return line
16. Fuel injection pump
17. Belt guard
18. Oil fill
19. Seawater pump (water inlet)
20. Oil pressure sender (optional)
21. Oil drain valve and hose
22. Governor lever
23. Lube oil filter
24. Oil check
25. Fuel feed pump
26. Fuel inlet
27. High exhaust temp. shutdown switch
28. Heat exchanger drain
29. Heat exchanger

Not Shown: Air intake heater (optional preheat kit required to make air intake heater functional).

Figure 1-2 Service Views, Typical

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Notes

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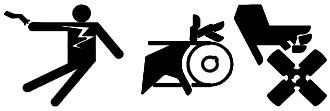
2.1 General

Schedule routine maintenance using the service schedule located in the generator set operatation manual and the hourmeter located on the controller. If the generator set will be subject to extreme operating conditions, service the unit accordingly.

Note: See the generator set operation manual for the service schedule and other service not included in this manual.

Note: High-mineral content seawater (salt water) can cause rapid destruction of metals. Wipe up all salt water spillage on and around the generator set and keep metal surfaces free from accumulated salt deposits.

⚠ WARNING

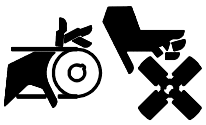


Accidental starting.
Can cause severe injury or death.

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) Disconnect the power to the battery charger, if equipped. (2) 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



Rotating parts.
Can cause severe injury or death.

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

Sound shield removal. Exposed moving parts can cause severe injury or death. The generator set must be operating in order to perform some scheduled maintenance procedures. Be especially careful if the sound shield has been removed, leaving the belts and pulleys exposed.
(Sound-shield-equipped models only)

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2.2 Lubrication System

The selection of engine oil is very important to a diesel engine. If an unsuitable oil is used or an oil change is neglected, it may result in damage and a shorter engine life. Oil must meet the API classification of CD or CC. Recommended SAE viscosity designation for given temperature ranges is listed in Figure 2-1.

Note: Failure to observe these standards may cause inadequate lubrication or oil pressure and cold starting difficulties.

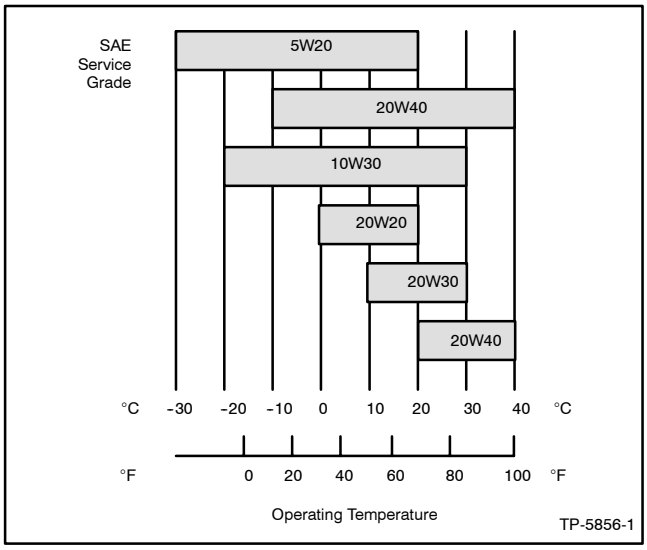


Figure 2-1 Engine Oil Selection

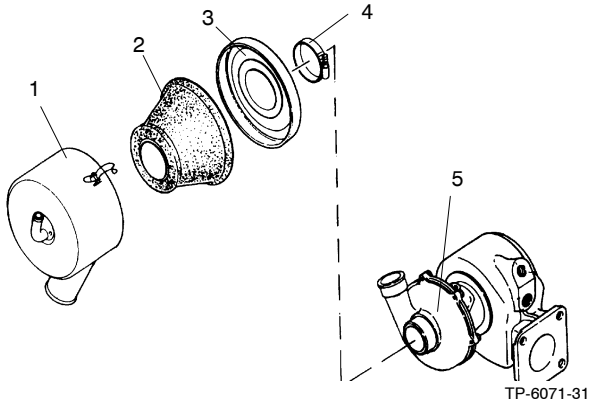
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3.1 Air Intake Silencer

The 13–24EOZ models use a round, polyurethane, sound-absorbing-type intake silencer to silence the intake air drawn into the cylinder head from the intake port. Besides providing a silencing effect, the silencer also acts as an air cleaner. Clean the silencer more frequently if operating in dirty, dusty conditions. See Figure 3-1 and refer to the following procedure.

Air Intake Silencer Cleaning Procedure:

1. Remove the intake silencer cover.
2. Remove the element from the cover and inspect it. To clean the element, continue to step 3. If the element is damaged or in poor condition, replace the element; skip step 3 and go to step 4. If the element is clean go to step 6.



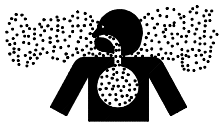
1. Air intake silencer cover
2. Air intake silencer element
3. Base
4. Clamp
5. Turbocharger

Figure 3-1 Air Intake Silencer

3. Wash the element in mild detergent and water solution. Rinse the element and allow it to air dry.
4. Lightly coat the foam element with oil.
5. Squeeze out any excess oil.
6. Wipe the cover and base with a clean rag to remove any dirt. Replace the base if it is damaged.
7. Reassemble the element and cover assembly to the intake silencer base. Make sure the sealing surfaces fit properly.
8. Direct the air intake silencer duct down and away from engine.

3.2 Exhaust System Inspection

⚠ WARNING



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

The exhaust system must be leakproof and routinely inspected.

Inspecting the exhaust system. Carbon monoxide can cause severe nausea, fainting, or death. For the safety of the craft's occupants, install a carbon monoxide detector. Consult the boat builder or dealer for approved detector location and installation. Inspect the detector before each generator set use. In addition to routine exhaust system inspection, test the carbon monoxide detector per the manufacturer's instructions and keep the detector operational at all times.

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, mixing elbow, exhaust line, hose clamps, silencer, and outlet flapper) for cracks, leaks, and corrosion.

- Check the hoses for softness, cracks, leaks, or dents. Replace the hoses as needed.
- Check for corroded or broken metal parts and replace them as needed.
- Check for loose, corroded, or missing clamps. Tighten or replace the hose clamps and/or hangers as needed.
- Check that the exhaust outlet is unobstructed.
- Visually inspect for exhaust leaks *(blowby)*. Check for carbon or soot residue on exhaust components. Carbon and soot residue indicates an exhaust leak. Seal leaks as needed.
- Ensure that the carbon monoxide detector is (1) in the craft, (2) functional. and (3) energized whenever the generator set operates.

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3.3 Servicing Mixing Elbow

The mixing elbow combines high-temperature exhaust with cooling seawater. The mixture when exposed to engine vibration makes conditions conducive to rapid deterioration and failure if the elbow is not properly maintained.

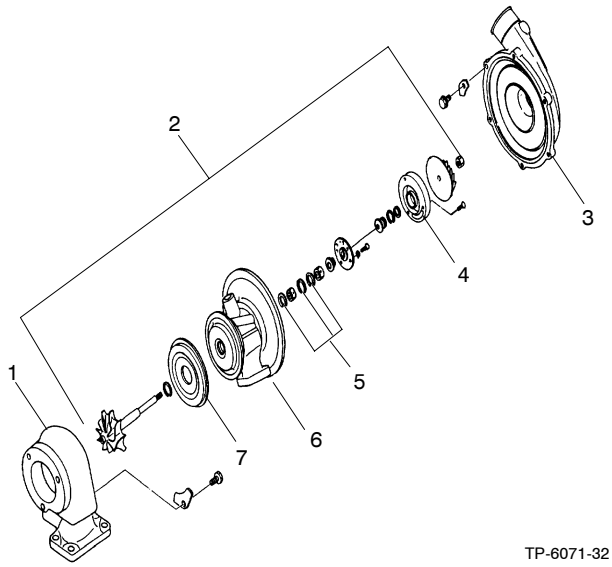
1. Check the mixing elbow for carbon buildup and corrosion inside the pipe.
2. Clean or replace the mixing elbow as necessary.
3. Inspect the exhaust manifold mounting threads for cracking and corrosion.

3.4 Turbocharger (Models: 14/15.5/23/24EOZ and 11.5/13/19/20EFOZ)

Inspect the compressor (blower) at the specified interval for build-up of carbon residue. Perform all other turbocharger inspection and service as described in the service schedule of the Yanmar service manuals. See Figure 3-2 and Figure 3-3 to inspect the compressor.

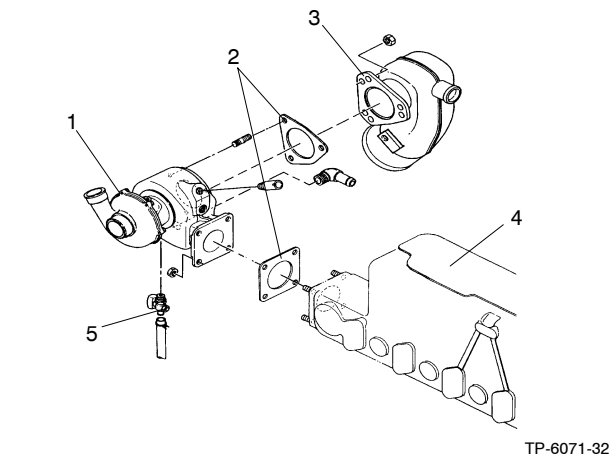
Compressor Inspection:

1. Remove the breather hose from the air intake silencer connector, if equipped.
2. Remove the air intake silencer.
3. Inspect the compressor (blower) housing and the impeller (blower wheel) for buildup of carbon residue. Use a Yanmar approved turbocharger cleaner, if cleaning is required.
4. Place the air intake silencer over the turbocharger compressor housing inlet and tighten the clamp.
5. Attach the breather hose to the air intake silencer connector, if equipped.



1. Compressor housing
2. Rotor assembly (turbo)
3. Housing assembly (blower)
4. Plate assembly (seal)
5. Circlips
6. Housing assembly (bearing)
7. Heat protector

Figure 3-2 Turbocharger Inspection



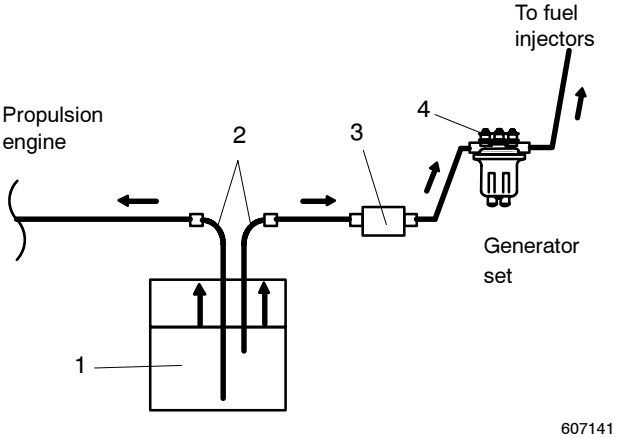
1. Turbocharger assembly
2. Gaskets
3. Exhaust elbow
4. Exhaust manifold
5. Petcock PT 1/8

Figure 3-3 Turbocharger Components, Typical

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4.1 General

In most installations, both the generator set and the propulsion engine operate from a common fuel tank with a dual dip tube arrangement. The generator set's dip tube is shorter than the propulsion engine's dip tube. With this arrangement fuel may not be available to the generator set when the fuel supply is low. See Figure 4-1 for a fuel system schematic.



1. Fuel tank
2. Dual dip tubes
3. Fuel filter
4. Fuel feed pump

Figure 4-1 Fuel System Schematic, Typical

4.2 Fuel Filter

Clean the fuel filter with fresh fuel oil and compressed air. The filter's useful life will be determined largely by the quality and condition of the fuel used. Under normal conditions, replace the fuel filter element at the specified interval in the generator set's operation manual. Use the following procedure to replace the fuel filter.

Fuel Filter Replacement Procedure:

1. Close the fuel valve.
2. Remove the fuel filter.
3. Clean the contact surface of the fuel oil filter adapter.
4. Lightly lubricate the gasket surface of the new fuel filter with fresh fuel oil. Thread the filter on the adapter until the gasket makes contact; hand tighten the filter an additional one-half turn.
5. Open the fuel valve.
6. Bleed the fuel system. See Section 4.3.

4.3 Bleeding

If the generator set engine runs out of fuel, if air leaks develop in the suction side of the fuel system, or if the fuel filter is replaced, it will be necessary to bleed the entire system to prevent starting failures and/or erratic operation.

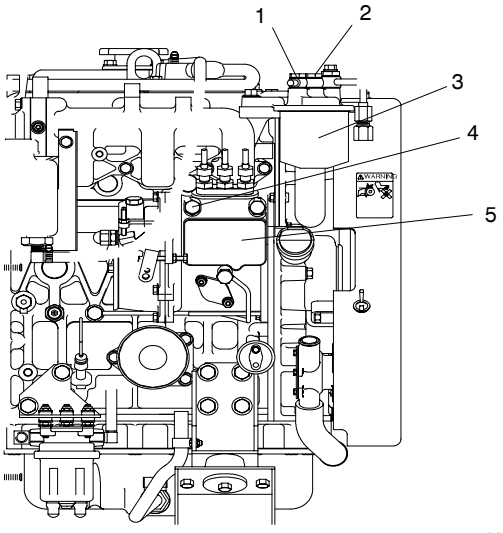
Note: The bleeding procedure requires the battery to be connected so that engine cranking will occur. Do not allow the engine/generator to start. To prevent engine starting, disconnect line 71A from the starter motor solenoid (spade terminal).

Fuel System Bleeding Procedure:

1. Loosen vent screw A at the fuel filter. See Figure 4-2.
2. Toggle the start/stop switch by placing the start/stop switch in the START position for a few seconds and then placing the switch in the STOP position until fuel, free of air bubbles, flows from vent screw A. Tighten the vent screw.
3. Loosen vent screw B at the fuel filter.
4. Toggle the start/stop switch until fuel, free of air bubbles, flows from vent screw B. Tighten the vent screw.
5. Loosen vent screw C at the fuel injection pump.

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6. Toggle the start/stop switch until fuel, free of air bubbles, flows from vent screw C. Tighten the vent screw.



1. Vent screw B
2. Vent screw A
3. Fuel filter
4. Vent screw C
5. Fuel injection pump

Figure 4-2 Bleeding the Fuel System

4.4 Fuel Pump

The fuel pump transfers fuel from a source to the injection pump.

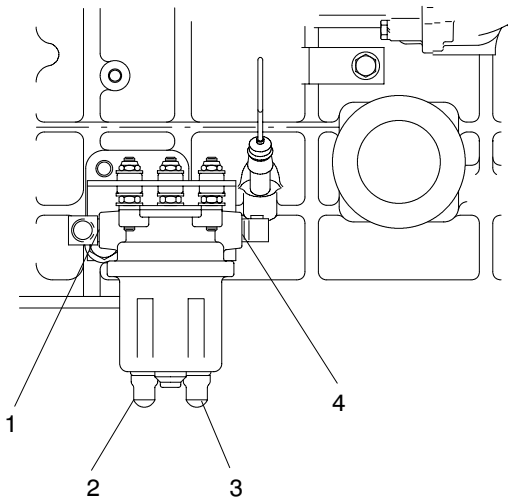
Fuel Pump Test Procedure:

1. Remove the two leads at the bottom of the fuel pump. The pump terminals are labeled (-) and (+). See Figure 4-3.

2. Connect the inlet side of the pump to a fuel source. Disconnect the outlet hose from the fuel filter and place the hose end in a container to catch the fuel.

3. Connect the positive (+) terminal of a 12-volt battery to the positive terminal of the fuel pump. Connect the negative terminal of the fuel pump to the negative (-) terminal of the battery. You should hear the pump operate and see fuel discharge from the pump outlet. Replace the pump if it does not operate.

4. Connect a pressure gauge to the outlet side of the fuel pump. Repeat step 3. See Section 1.3 for the specified fuel pump pressure ratings.



1. Fuel inlet
2. Negative (-) terminal
3. Positive (+) terminal
4. Fuel outlet

Figure 4-3 Fuel Pump

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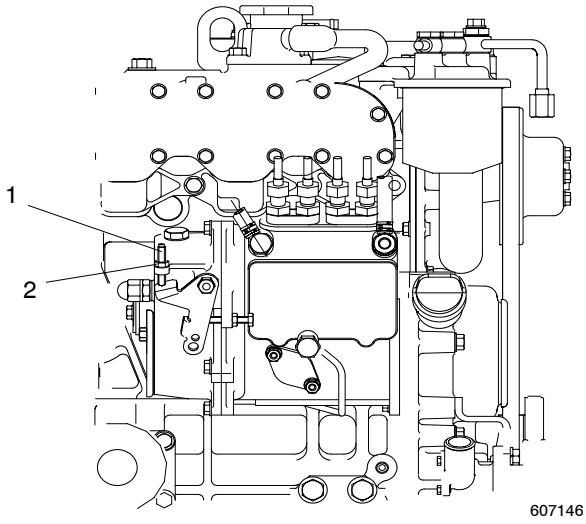
4.5 Governor

The centrifugal, mechanical governor keeps the engine speed constant by automatically adjusting the amount of fuel supplied to the engine according to changes in the load. The govorner requires no regular service. The factory adjustes the governor during run-in, and further adjustment should not be needed unless greatly varying load conditions are encountered or if poor governor control develops after extended usage.

60 Hz generator sets are designed to operate in the range of 57-63 Hz (1800 rpm under full load and 1890 rpm under no load).

50 Hz generator sets are designed to operate in the range of 47.5-52.5 Hz ± 5% (1500 rpm under full load and 1590 rpm under no load).

To check the engine speed, use a frequency meter connected to the load leads or use a hand tachometer. If adjustment is needed, loosen the locking nut on the speed adjusting screw. Turn the screw clockwise to increase the speed (and frequency). To decrease the speed, turn the screw counterclockwise. Tighten the locking nut when the correct setting is reached. See Figure 4-4.



1. Speed adjusting screw
2. Locking nut

Figure 4-4 Governor Adjustment

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Notes

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5.1 General

Heat exchanger cooling consists of a heat exchanger with coolant recovery tank, thermostat, rubber impeller seawater pump, centrifugal-type engine circulating pump, water-cooled exhaust manifold, and an exhaust mixer. See Figure 5-1 for cooling system components.

⚠ WARNING



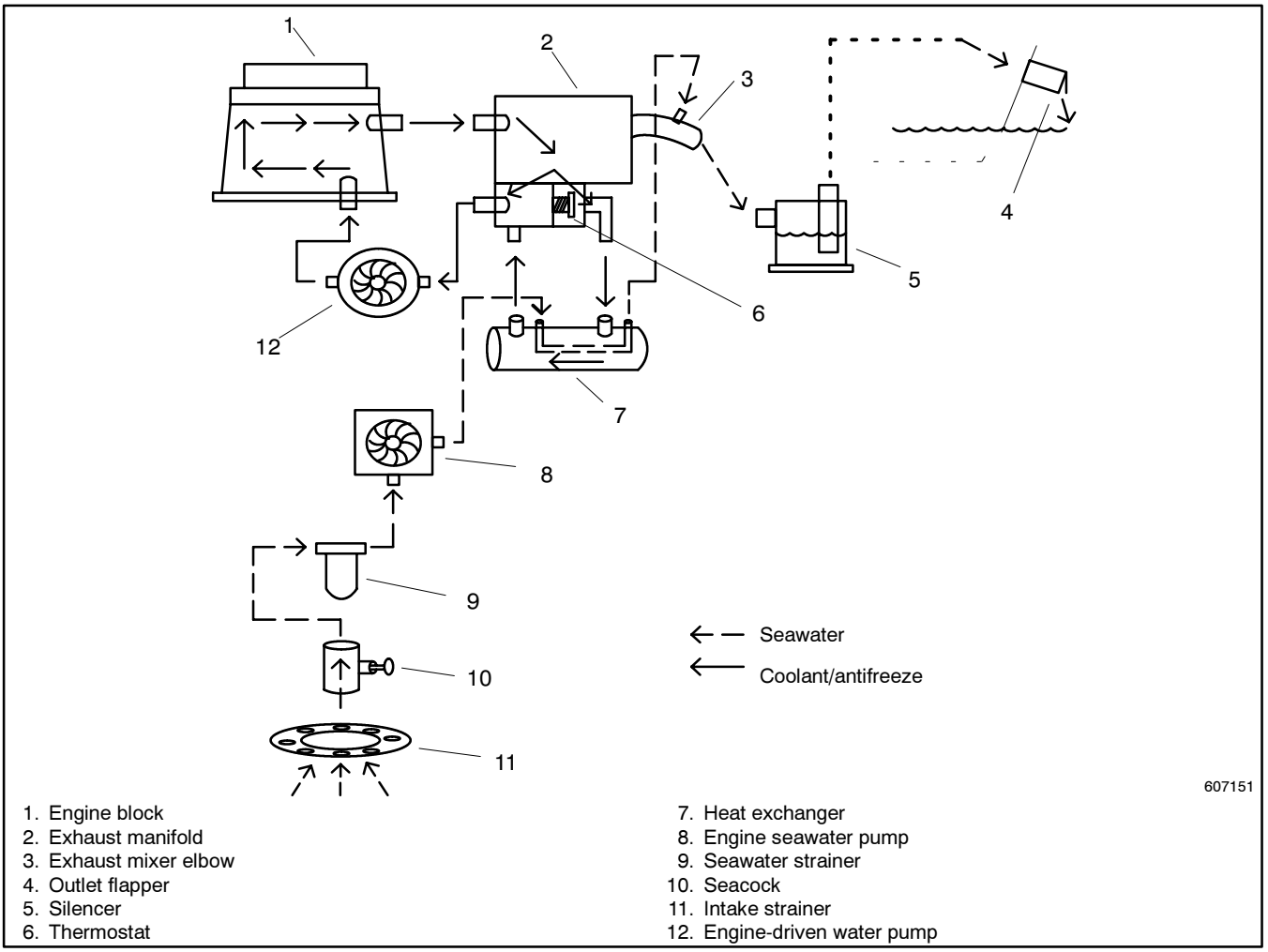
Hot coolant and steam.
Can cause severe injury or death.

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

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

NOTICE

Saltwater damage. Saltwater quickly deteriorates metals. Wipe up saltwater on and around the generator set and remove salt deposits from metal surfaces.



1. Engine block
2. Exhaust manifold
3. Exhaust mixer elbow
4. Outlet flapper
5. Silencer
6. Thermostat
7. Heat exchanger
8. Engine seawater pump
9. Seawater strainer
10. Seacock
11. Intake strainer
12. Engine-driven water pump

Figure 5-1 Cooling System Components

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5.2 Closed Heat Exchanger

In a closed cooling system, seawater circulates through separate chambers within the heat exchanger to cool the engine coolant. The seawater then mixes with engine exhaust and ejects out of the exhaust outlet. See Section 1.4 for coolant capacity, thermostat and pressure cap ratings.

Note: Coolant solution. A coolant solution of 50% ethylene glycol provides freezing protection to -37°C (-34°F) and overheating protection to 129°C (265°F). A coolant solution with less than 50% ethylene glycol may not provide adequate freezing and overheating protection. A coolant solution with more than 50% ethylene glycol can cause engine or component damage. Do not use alcohol or methanol antifreeze or mix them with the specified coolant. Consult the engine manufacturer's operation manual for engine coolant specifications.

5.3 Check and Fill Coolant

Note: Do not add coolant to a hot engine. Adding coolant to a hot engine can cause the cylinder block or cylinder head to crack. Wait until the engine has cooled.

Maintain the coolant level in the coolant recovery tank at approximately 1/4 full. Before filling the cooling system, close all petcocks and tighten all hose clamps. Use a solution of 50% ethylene glycol and 50% clean, softened water to inhibit rust/corrosion and prevent freezing. Add coolant, as necessary, to the coolant recovery tank. Periodically check the coolant level on closed systems by removing the pressure cap. Do not rely solely on the level in the coolant recovery tank. Add fresh coolant until level is just below the overflow tube opening.

5.4 Flush and Clean Cooling System

For optimum protection, drain, flush, and refill the cooling system at the interval listed in the service schedule.

Pay special attention to the coolant level. When refilling the cooling system, allow time for complete refill of the engine water jacket. Check the coolant level as described in Section 5.3.

Flush and Clean Procedure:

1. Remove the pipe plug water drain located at the heat exchanger and completely drain the system.
2. Remove the pressure cap to make draining easier.
3. Drain, clean, and flush the cooling system and the coolant recovery tank with clean water.
4. Replace the pipe plug water drain.
5. Fill the cooling system with recommended coolant.
6. Replace the pressure cap.

5.5 Pressure Cap

Closed heat exchanger systems utilize a pressure cap to raise the boiling point of the coolant, enabling higher operating temperatures. If the cap leaks, replace it with a cap of the same rating. Find the pressure cap rating in Section 1.4, Cooling.

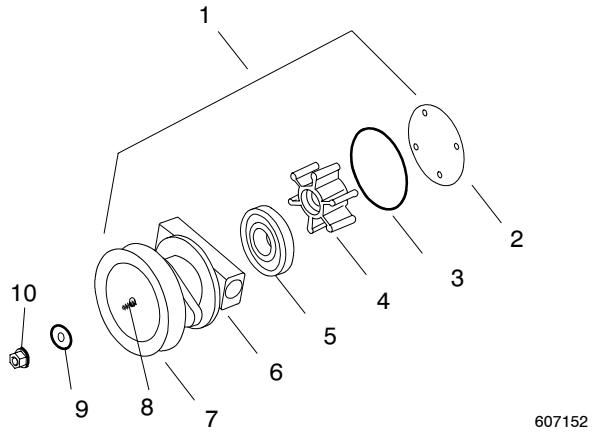
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5.6 Impeller Inspection and Replacement

The belt-driven seawater pump is located on the service side of the generator set. Check and change the seawater pump impeller at the interval specified in the service schedule. Follow the instructions included with the impeller kit. If the instructions are not included with the kit, use the following procedure.

Impeller Inspection and Replacement Procedure:

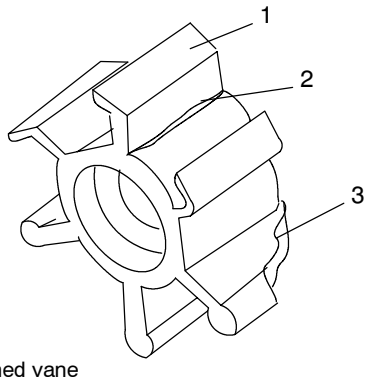
1. Close the seacock.
2. Remove the seawater pump coverplate. See Figure 5-2.



1. Seawater pump
2. Coverplate
3. Gasket
4. Impeller
5. Bearing
6. Housing
7. Pulley
8. Drive shaft
9. Washer
10. Nut

Figure 5-2 Seawater Pump, Typical

3. Remove the impeller.
4. Inspect the impeller for damage, including cracks, broken or flattened vanes. The impeller vanes should be straight and flexible. See Figure 5-3.



1. Flattened vane
2. Crack
3. Broken vane

Figure 5-3 Worn Impeller

5. Lubricate the impeller with soapy water before installation.
6. While installing the impeller, always rotate the drive shaft and the impeller together in the same direction as the engine rotation.
7. Inspect the coverplate and gasket for corrosion and/or damage. Replace components as necessary.
8. Lubricate the gasket with silicon grease and attach the gasket and coverplate to the seawater pump housing.
9. Open the seacock.
10. Start the generator set and check for leaks.
11. Stop the generator set and repair leaks or replace components as necessary.

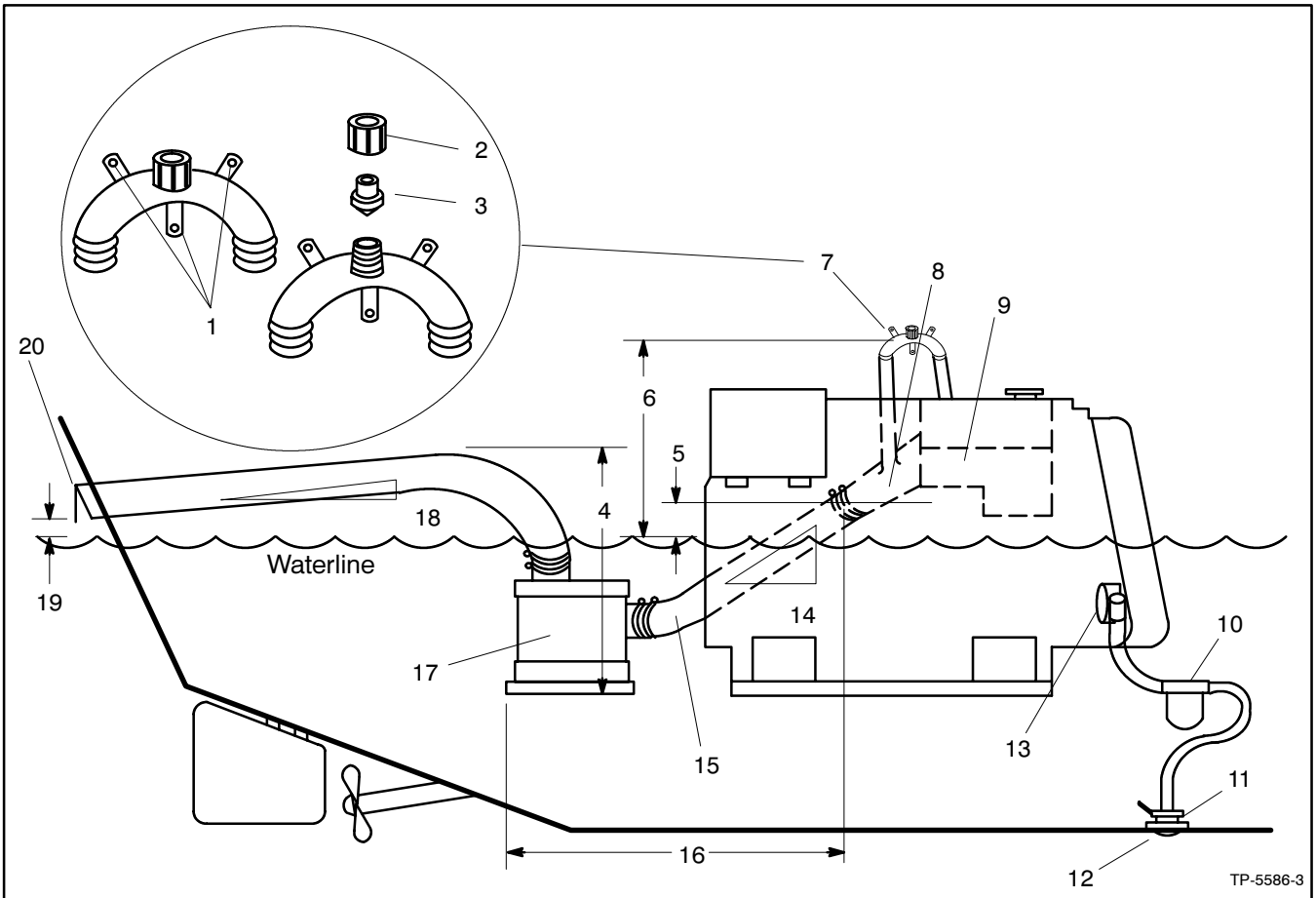
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5.7 Siphon Break

A siphon break prevents seawater entry into the engine when the engine exhaust manifold outlet is less than 23 cm (9 in.) above the waterline of a fully-loaded, shut-down craft. Use the following procedure to inspect the siphon break.

Siphon Break Inspection Procedure:

1. Stop the generator set.
2. Remove the retaining cap and lift out the reed valve assembly for inspection. See Figure 5-4.
3. Use a light detergent to clean the reed valve to remove residue and oxidation.
4. Check that the reed valve opening is clear.
5. Replace the siphon break if it is cracked or if the reed valve material has hardened or deteriorated.
6. Install the reed valve into the mounting base with the valve downward.
7. Install the retaining cap and finger-tighten only. Do not overtighten.



1. Mounting base
2. Retaining cap
3. Reed valve assembly
4. Silencer vertical lift 1.2 m (4 ft.) max.
5. Exhaust mixer elbow distance above waterline; if less than 23 cm (9 in.), siphon break is required
6. Siphon break distance above waterline 30.5 cm (1 ft.) min.
7. Siphon break
8. Exhaust mixer elbow
9. Heat exchanger (locations vary by model)
10. Seawater strainer
11. Seacock
12. Intake strainer
13. Engine-driven seawater pump
14. Exhaust hose pitch 1.3 cm per 30.5 cm (0.5 in./ft.) min.
15. Water lock (optional)
16. Silencer distance from exhaust mixer elbow 3 m (10 ft.) max.
17. Silencer (customer-supplied)
18. Exhaust hose pitch 1.3 cm per 30.5 cm (0.5 in./ft.) min.
19. Exhaust outlet distance above waterline 10 cm (4 in.) min.
20. Seawater outlet

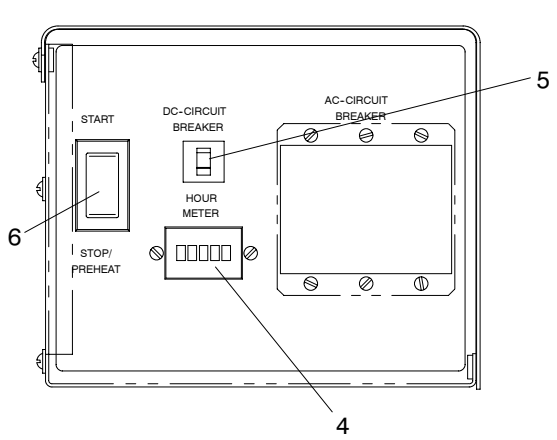
NOTE: Consult the installation manual for complete explanation of dimensions and other installation considerations.

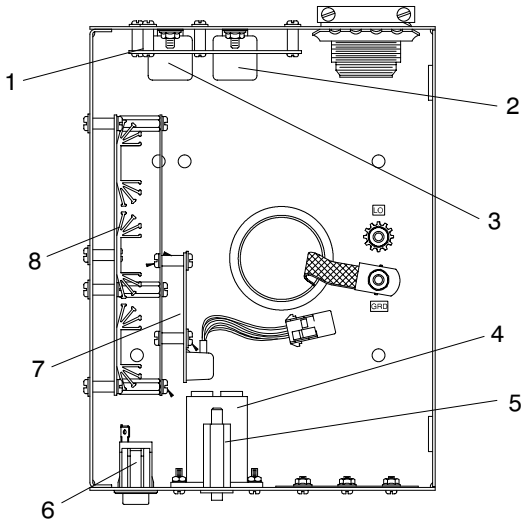
Figure 5-4 Siphon Break (Plastic “U” Type)

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6.1 Controller

This section covers the controller troubleshooting procedure for generator sets equipped with a relay controller and related engine components. Refer to the operation manual to identify the controller's external components. Refer to Figure 6-1 to identify the controller's internal components.





1. Controller circuit board
2. K25 relay
3. K20 relay
4. Hourmeter
5. DC circuit breaker
6. Start/stop switch
7. Voltage regulator circuit board
8. Overspeed circuit board (opt.)

Figure 6-1 Controller Internal Components

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6.2 Controller Sequence of Operation

Sections 6.2.1–6.3.3 describe the controller sequence of operation during generator start, run, stop, and fault shutdown modes. Use the LEDs on the controller circuit board to assist in the troubleshooting process. An illuminated LED indicates that the respective relay is receiving power; the LED does not indicate whether that relay is energized. Refer to the wiring diagrams in Section 10 to assist in the troubleshooting procedure.

6.2.1 Start

Close the start/stop switch between N and 47 (local or remote starting).

The K2 relay energizes (LED2 lights).

The normally open K2 contacts close to energize the K3 relay (LED3 lights), K25 (fuel solenoid) relay, controller hourmeter, and generator armature exciter field.

The normally open K3 relay contacts close to energize the K20 (starter) relay. The normally open K20 relay contacts close to energize the S relay (starter solenoid). The normally open S relay contacts close to energize the starter motor.

The normally open K25 contacts close to energize the fuel solenoid and the battery charging alternator (BCA).

As the engine builds oil pressure during cranking, the normally closed LOP contacts open.

6.2.2 Run

The K1 relay energizes (LED1 lights) when the B1 and B2 windings receive AC output from the stator main field. After a 5–10 second time delay, the K5 relay energizes (LED5 lights).

Note: The bridge rectifier (BR1) and the voltage regulator (VR1) provide 12 volts DC to the K1 and K5 relays.

The stator winding V1-V4 provides a voltage sensing source to the voltage regulator.

The normally open K1 contacts close to maintain voltage to the K2 relay (LED2 remains lit).

The normally open K2 contacts remain closed to maintain voltage to the fuel solenoid and controller hourmeter.

The normally open K1 contacts close to energize the (optional) oil pressure, coolant temperature, battery voltmeter, and hourmeter gauges and the generator “ON” light.

The normally open K5 contacts close to permit the high water temperature (HWT), high exhaust temperature (HET), and low oil pressure (LOP) switches to function.

Note: The low oil pressure (LOP) switch contacts open when the engine develops proper oil pressure.

One set of normally closed K1 contacts opens to disconnect the circuit to the (+) connection of the exciter fields (field flashing).

A set of normally closed K1 contacts opens to disconnect the circuit to the negative (–) connection of the exciter field (field flashing). The normally closed K1 contacts open to deenergize the K3 relay (LED3 goes out) and prevent accidental reenergizing of the starter motor. The K3 contacts open to deenergize the K20 relay. The K20 contacts open to deenergize the S relay. The S contacts open to deenergize the starter motor.

When the generator set is running, the start switch contacts N and 47 open by releasing the start/stop rocker switch.

6.2.3 Stop

Close the start/stop switch between N and 43 (local or remote).

The K4 relay energizes (LED4 lights).

The normally closed K4 contacts open to deenergize the K25 relay. The closed (normally open) K25 contacts open to deenergize the fuel solenoid.

The normally open K4 contacts close to maintain a ground to the K4 relay.

As the generator set shuts down, the K1 relay deenergizes (LED1 goes out). The normally open K1 contacts open to deenergize the K2 relay (LED2 goes out). The normally closed K2 contacts close to ground the circuit to the K4 relay until the generator set comes to a complete stop.

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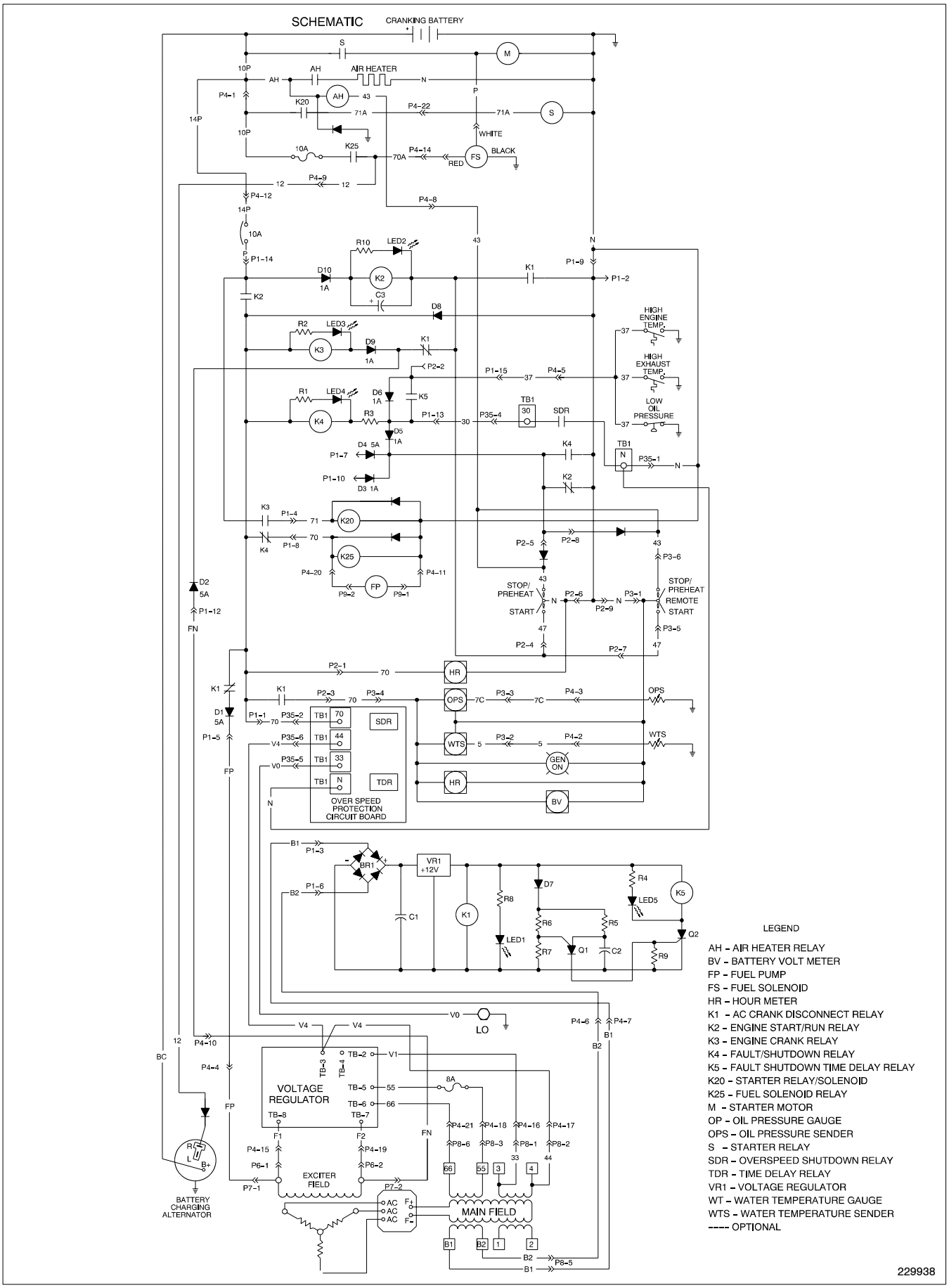


Figure 6-2 Sequence of Operation Wiring Diagram

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6.3 Engine Safety Shutdown Switches

6.3.1 Low Oil Pressure (LOP) Shutdown Switch

When low oil pressure occurs, the LOP shutdown switch contacts close and energize the K4 relay (LED4 lights).

Note: During cranking, the low oil pressure shutdown switch is deactivated until the K5 relay energizes. This delay allows the engine to reach normal operating oil pressure. The normally closed LOP contacts open when the generator set develops oil pressure.

The normally closed K4 contacts open to deenergize the K25 relay. The closed (normally open) K25 contacts open to deenergize the fuel solenoid.

The normally open K4 contacts close to maintain a ground to the K4 relay.

As the generator set shuts down, the K1 relay deenergizes (LED1 goes out). The normally open K1 contacts open to deenergize the K2 relay (LED2 goes out). The normally closed K2 contacts close to ground the circuit to the K4 relay until the generator set comes to a complete stop.

6.3.2 High Water Temperature (HWT) and High Exhaust Temperature (HET) Shutdown Switch

When a high temperature occurs, the shutdown switch contacts close and energize the K4 relay (LED4 lights).

The normally closed K4 contacts open to deenergize the K25 relay. The closed (normally open) K25 contacts open to deenergize the fuel solenoid.

The normally open K4 contacts close to maintain a ground to the K4 relay.

As the generator set shuts down, the K1 relay deenergizes (LED1 goes out). The normally open K1 contacts open to deenergize the K2 relay (LED2 goes out). The normally closed K2 contacts close to ground the circuit to the K4 relay until the generator set comes to a complete stop.

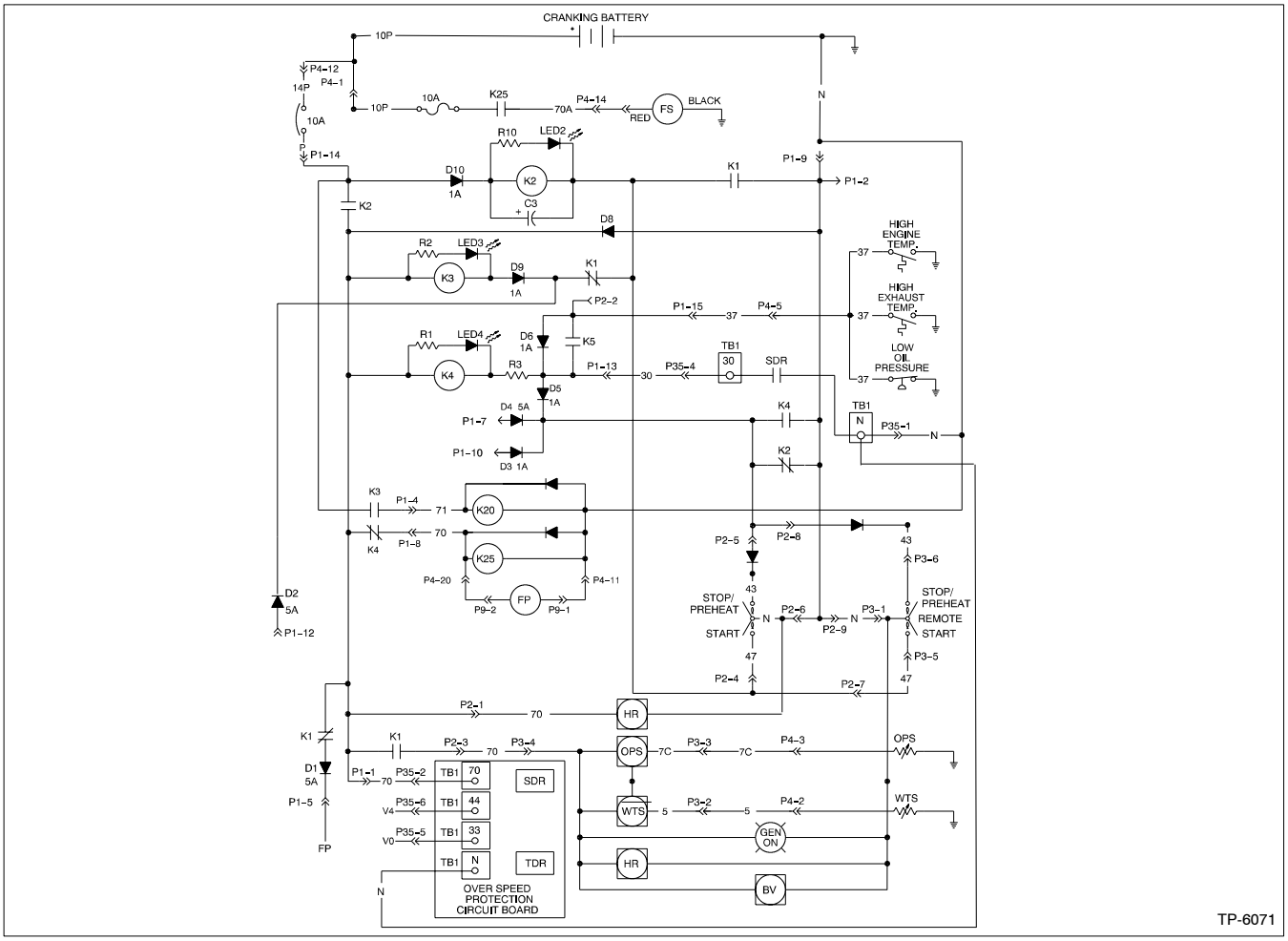


Figure 6-3 Safety Shutdown Circuit Schematic

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6.3.3 Overspeed Safety Shutdown (SDR)

When the engine speed exceeds 70 Hz (2100 rpm), the shutdown relay (SDR) on the overspeed protection circuit board energizes. The normally open SDR contacts close to complete the circuit and energize the K4 relay (LED4 lights).

The normally closed K4 contacts open to deenergize the K25 relay. The closed (normally open) K25 contacts open to deenergize the fuel solenoid.

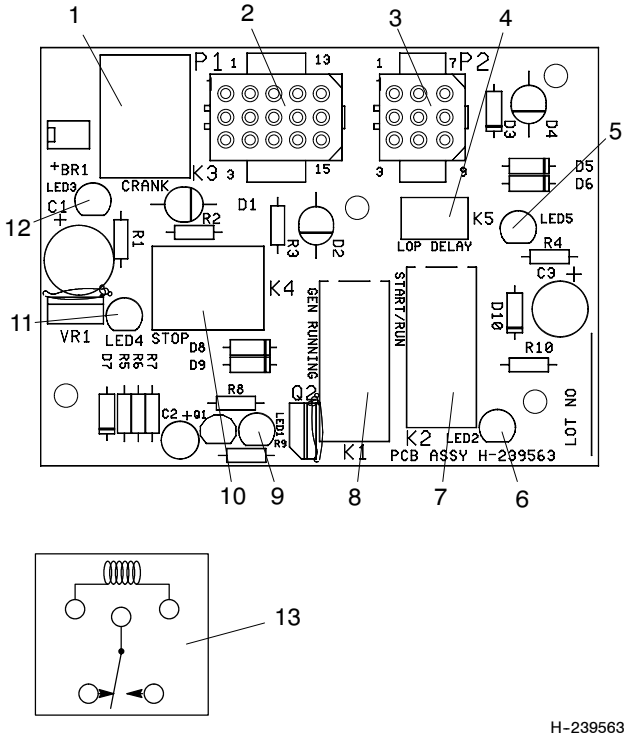
The normally open K4 contacts close to maintain a ground to the K4 relay.

As the generator set shuts down, the K1 relay deenergizes (LED1 goes out). The normally open K1 contacts open to deenergize the K2 relay (LED2 goes out). The normally closed K2 contacts close to ground the circuit to the K4 relay until the generator set comes to a complete stop.

6.4 Controller Circuit Board

Some controller circuit board components can be tested without removing the component from the circuit board. Test the components before replacing the circuit board. Refer to Section 6.5, Troubleshooting Flow Chart.

The controller circuit board has light-emitting diodes (LEDs) that indicate relay coil power and aid in circuit board and generator fault detection. When any of relays K1–K5 receives power the corresponding LED lights. The LED does not indicate whether the relay coil is energized. Determine if the relay coil is energized by analyzing the generator faults by performing a continuity test on the relay coil. See Figure 6-4.



1. Engine crank control relay (K3)
2. P1 connector
3. P2 connector
4. Time delay relay (K5)
5. LED5
6. LED2
7. Engine run relay (K2)
8. AC crank disconnect relay (K1)
9. LED1
10. Fault shutdown relay (K4)
11. LED4
12. LED3
13. Relay schematic

Figure 6-4 Controller Circuit Board

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6.5 Troubleshooting Flow Chart

Use the following flow chart as an aid in troubleshooting the main circuit board and the entire generator set.

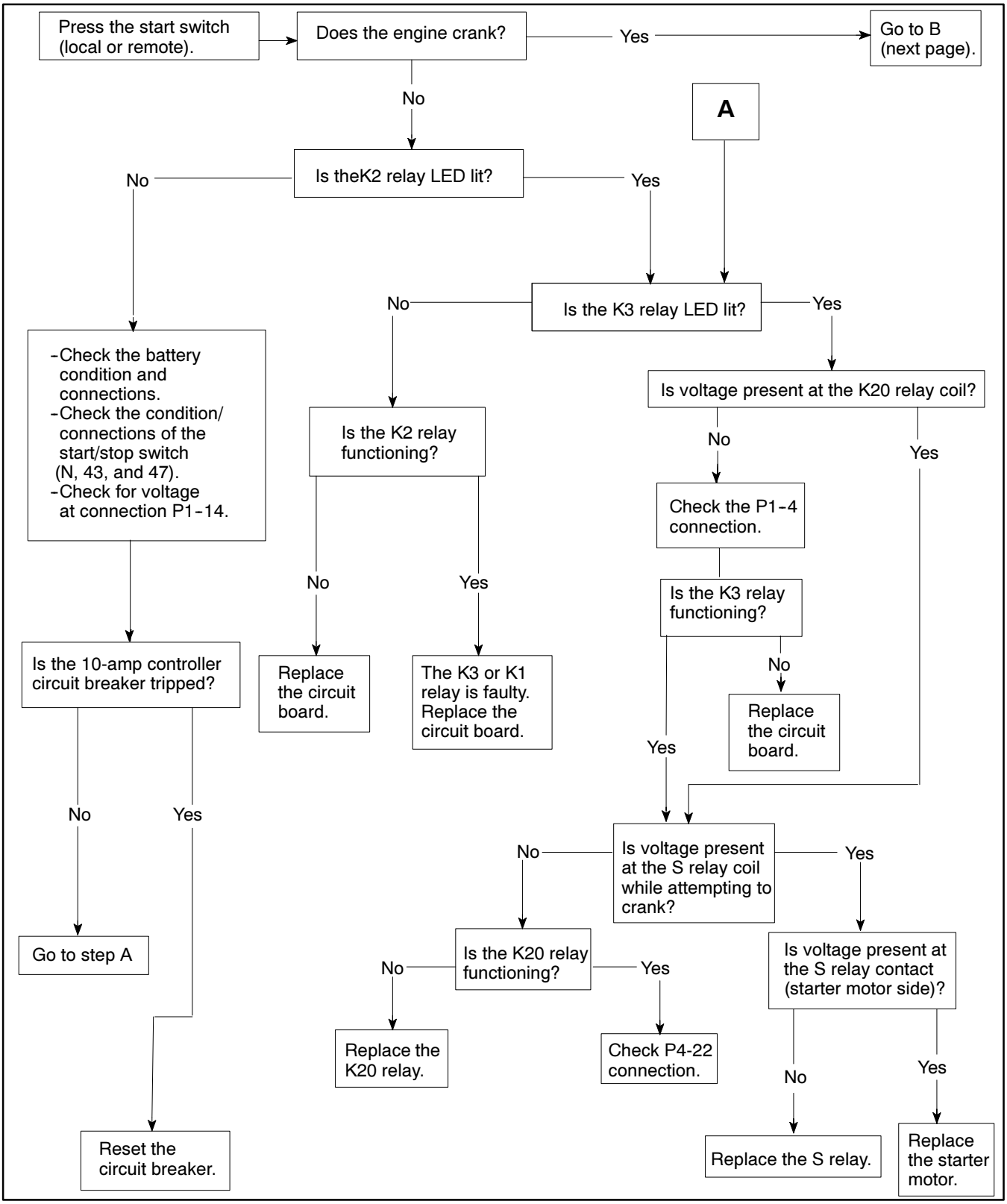


Figure 6-5 Troubleshooting Relay Controller Circuit Board (1 of 5)

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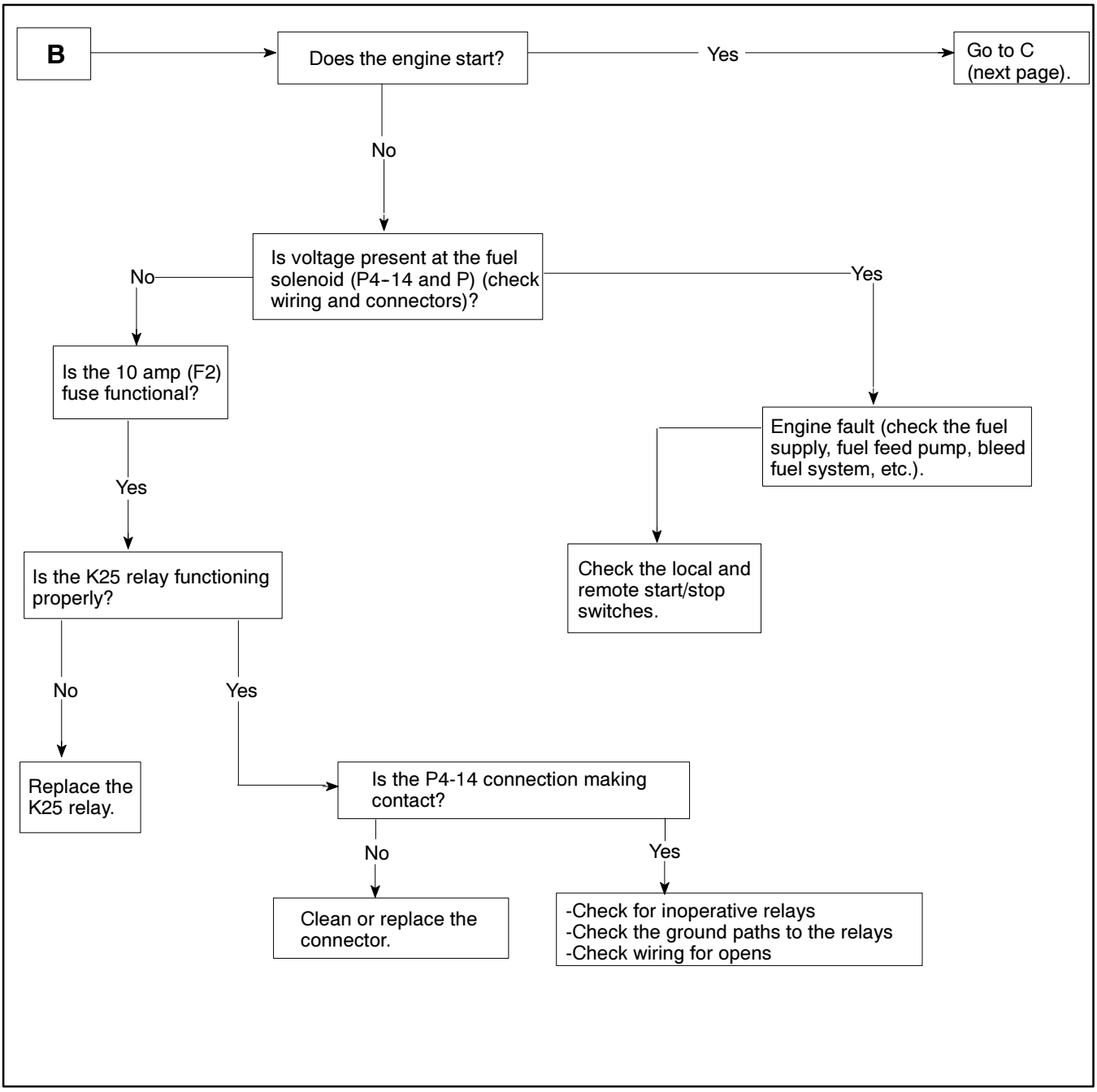


Figure 6-6 Troubleshooting Relay Controller Circuit Board (2 of 5)

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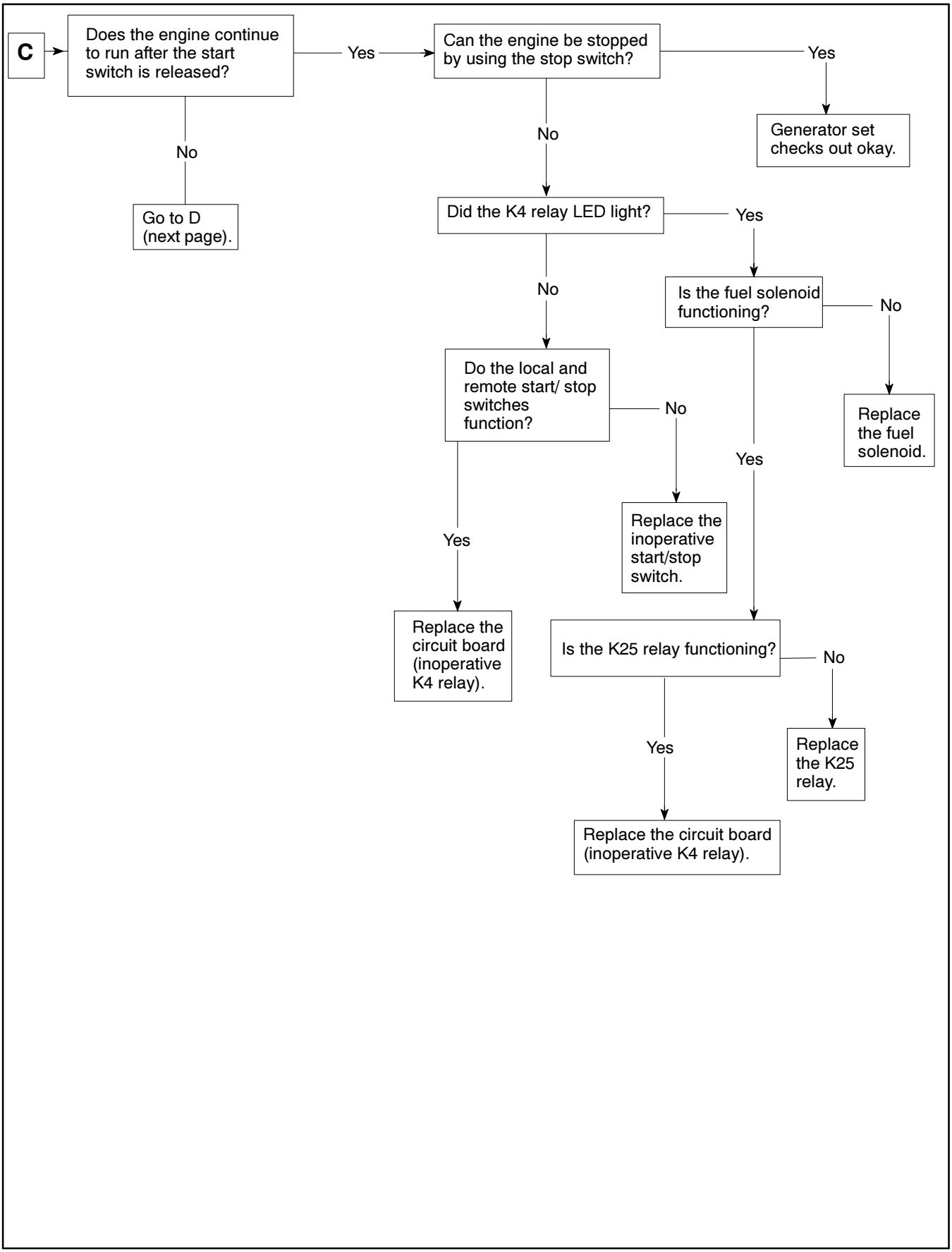


Figure 6-7 Troubleshooting Relay Controller Circuit Board (3 of 5)

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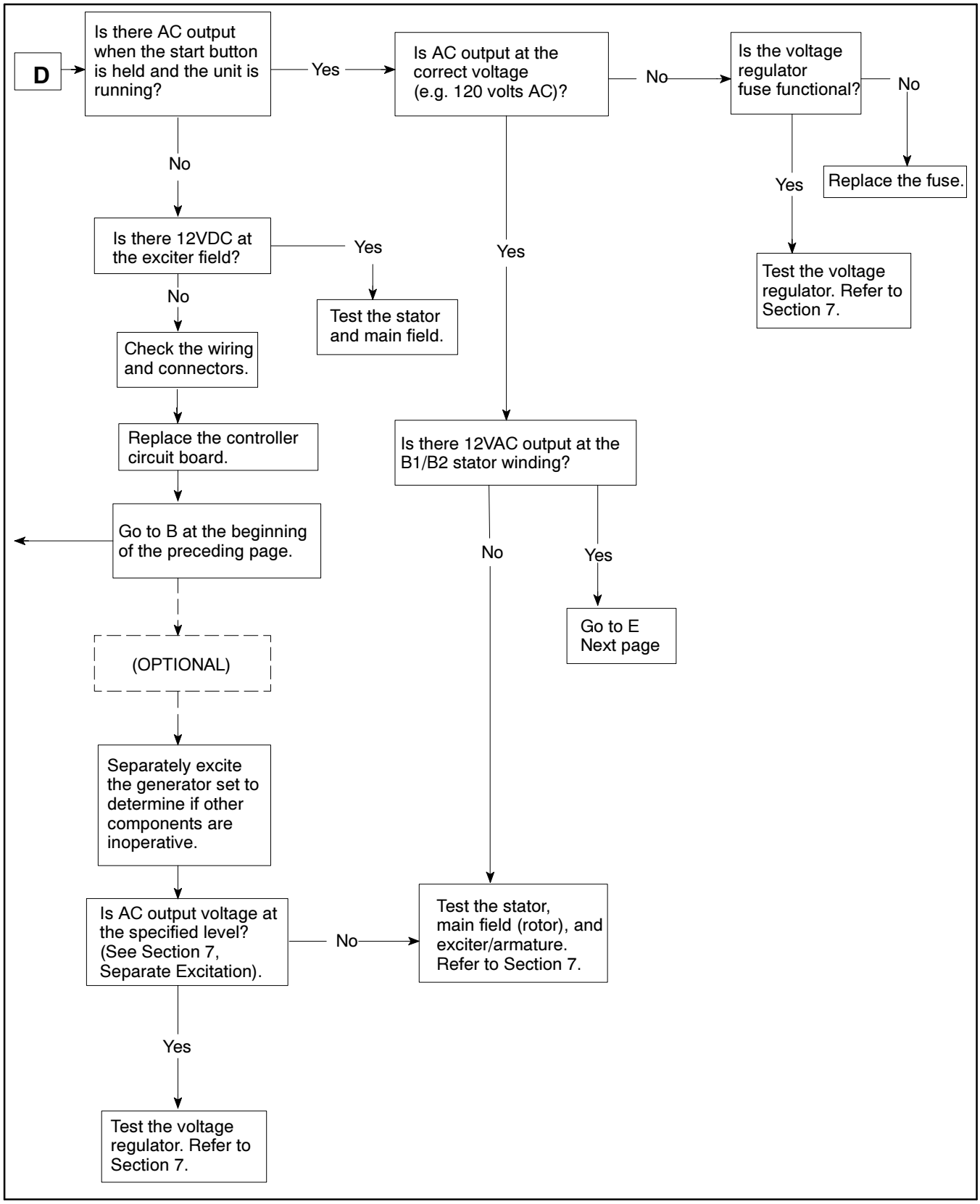


Figure 6-8 Troubleshooting Relay Controller Circuit Board (4 of 5)

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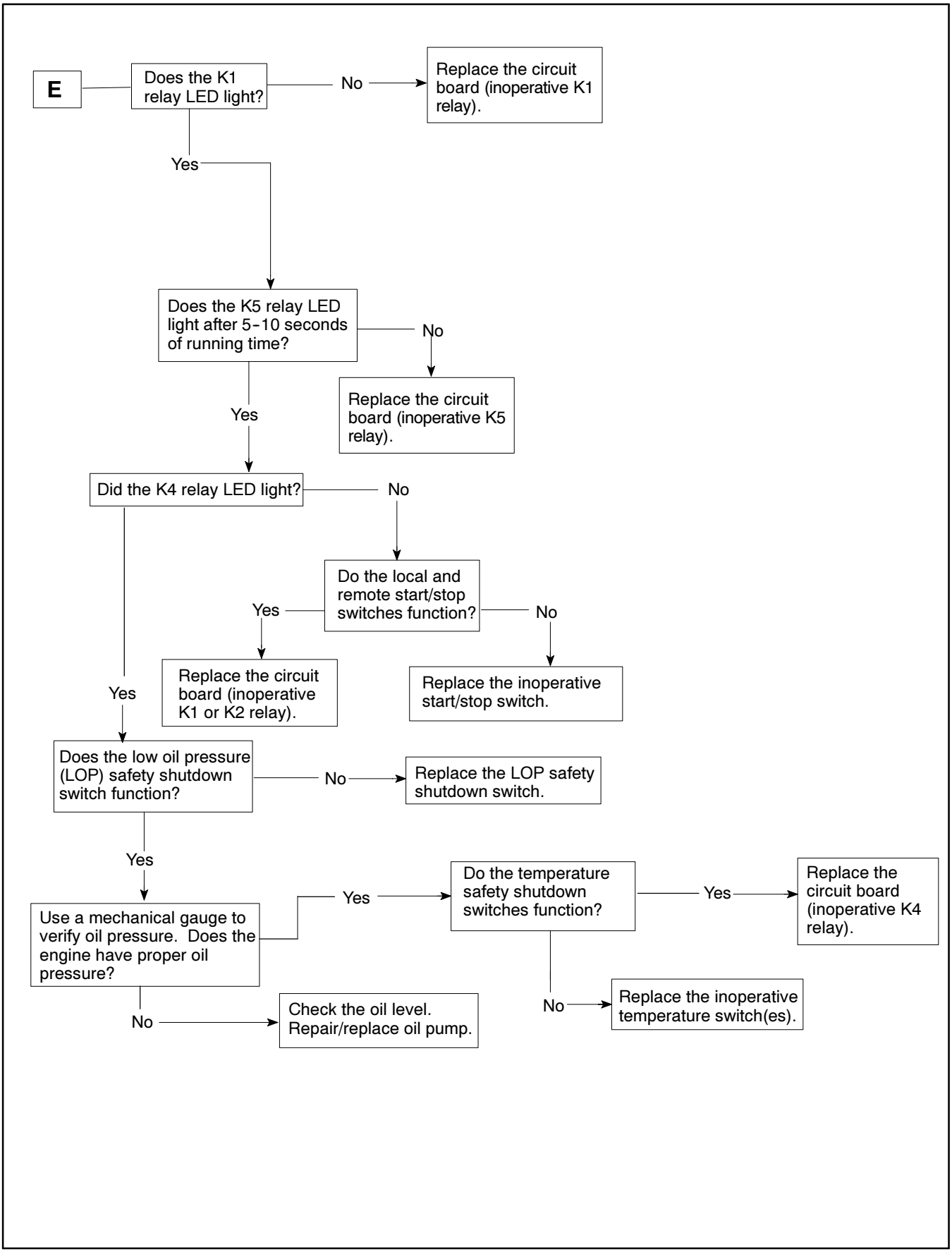
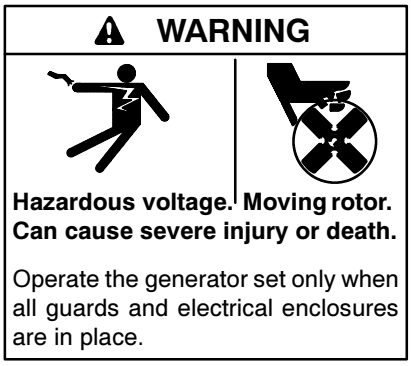


Figure 6-9 Troubleshooting Relay Controller Circuit Board (5 of 5)

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7.1 General

Before beginning the troubleshooting procedures, read all the safety precautions at the beginning of this manual. The following tests include additional safety precautions; OBSERVE THESE PRECAUTIONS!



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

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 wristwatch, rings, and jewelry before servicing the equipment.

7.2 Generator Troubleshooting

To determine the cause of no- or low-AC output, check the condition of the voltage regulator 8-amp fuse. If the fuse is functional, separately excite the generator. See Section 7.3. The separate excitation test duplicates the role of the voltage regulator in providing excitation current to the rotor.

Refer to the troubleshooting flow chart (Figure 7-1).

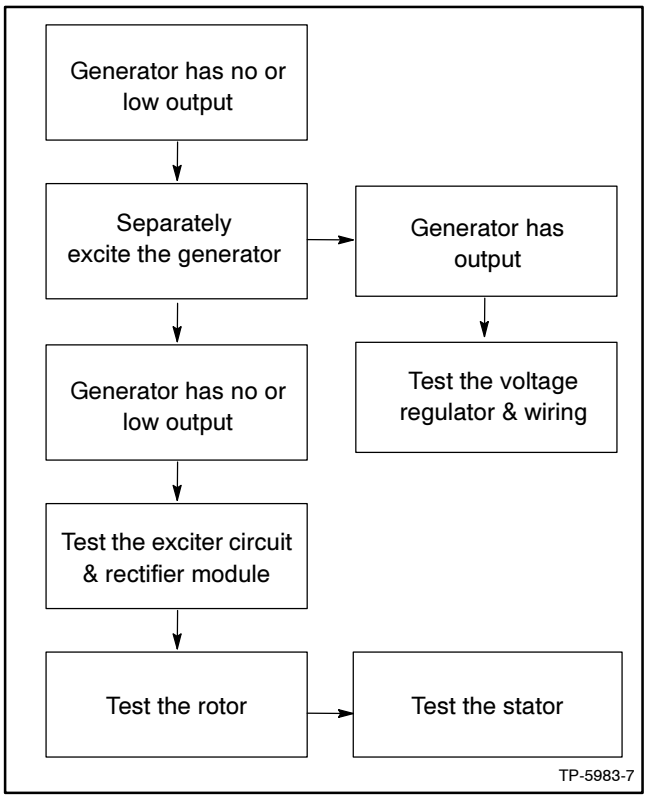


Figure 7-1 General Troubleshooting

7.3 Separate Excitation

By separately exciting the generator to determine the presence of a faulty generator component, it is possible to determine if a running fault exists in the rotor and/or stator. A generator component that appears functional while static (stationary) may exhibit a running open or short circuit while dynamic (moving). Short circuits can be caused by centrifugal forces acting on the windings during rotation or insulation breakdown as temperatures increase.

Separate Excitation Procedure:

1. Disconnect all the leads from the voltage regulator.
2. Disconnect the P6 (F1, F2) connector.

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3. Connect a separate excitation circuit as shown in Figure 7-2. Connect an ammeter and a 10-amp fuse in series with F1. Note and record the ammeter reading.

4. The approximate ammeter reading should equal battery voltage divided by the sum of the specified exciter resistances (cold). Disconnect the resistor leads and determine the exciter current value using an ohmmeter. See Section 1, Specifications for the normal values.

$$\text{Exciter Current} = \frac{\text{Battery Voltage}}{\text{Exciter Resistance}}$$

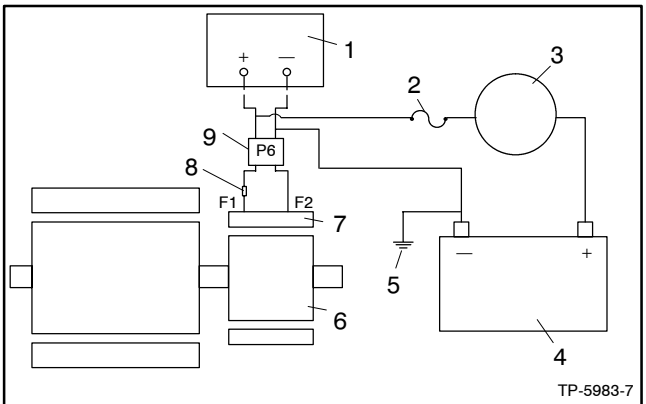
$$\text{Example}: \frac{12\ \text{VDC}}{3.5\ \text{Ohms}} = 0.6\ \text{Amps}$$

5. Start the engine and check that the ammeter remains stable. An increasing meter reading indicates a shorted exciter field. A decreasing meter reading to zero or an unstable reading suggests a running open in the exciter. If the ammeter is stable, continue with step 6.

6. Check for AC output across the stator leads and compare the output to the values in Section 1, Specifications. If the output varies considerably from those listed, a faulty stator, rotor, rectifier module, or armature is the likely cause.

If the AC output is not within specifications, the voltage regulator is probably inoperative. If there is no generator output during normal operation, but output is available when the generator set is separately excited, the voltage regulator is probably inoperative.

Note: See Section 1, Specifications for the stator output voltages (with separately excited generator). These specifications are based on a battery voltage of 12 volts. Should the battery voltage vary (11–14 volts), the resulting stator output values will also vary.



1. Voltage regulator
2. 10-amp fuse
3. DC ammeter
4. Battery
5. Ground
6. Exciter armature
7. Exciter field
8. 10- or 15-ohm resistor
9. P6 connector

Figure 7-2 Separate Excitation Connections

7.4 PowerBoost™ V Voltage Regulators

The generator set is equipped with a PowerBoost™ V voltage regulator. See Figure 7-3. The PowerBoost™ V voltage regulator monitors output voltage to control the current to the generator exciter field. The voltage regulator has an underfrequency unloading feature that is referred to as volts-per-Hz (V/Hz). To determine if the voltage regulator is functioning, reduce the engine speed (Hz) and watch for a corresponding drop in the AC voltage. The AC voltage should remain constant until the engine speed drops below 57.5 Hz on 60 Hz models, or 47.5 Hz on 50 Hz models. When the frequency drops below either 57.5 or 47.5 Hz, the AC voltage should decline. Perform the following test to check the regulator output.

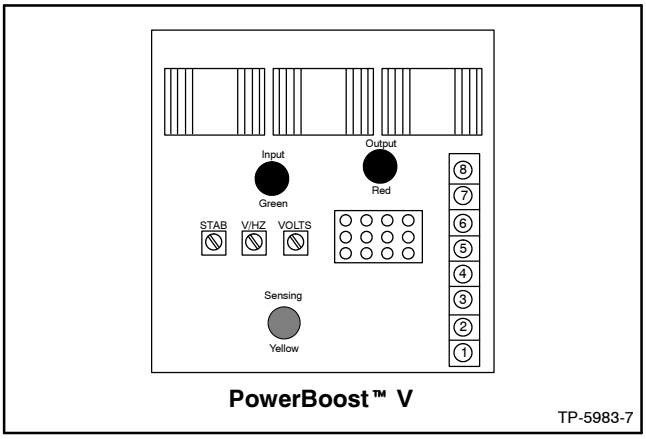


Figure 7-3 PowerBoost™ V Voltage Regulator

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7.5 Voltage Regulator Test

The following components will be needed to test the voltage regulator:

- Step-up transformer, 1:2, 120–240 volts (1.0 amp min.)
- Variable transformer, 0–140 volts (1.0 amp min.)
- 250-volt, 100-watt lamp
- AC voltmeter, 250-volt minimum
- 1-amp fuse
- 1 single-pole single-throw (SPST) switch, 1 amp (minimum)
- 120-volt AC plug (200–240-volt AC plug optional)
- #14 AWG copper wire (minimum)

⚠ WARNING



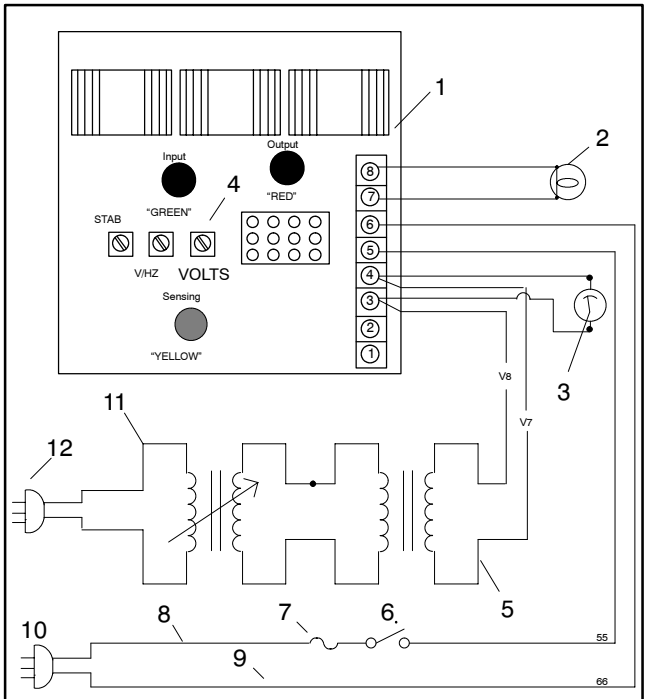
Hazardous voltage. Moving rotor. Can cause severe injury or death.

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

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.

Voltage Regulator Test Procedure:

1. Connect components as shown in Figure 7-4.
2. If plug (item 10) is 250 volts, use 250 volt lamp. If plug is 120 volts, use 120 volt lamp.
3. Turn the volts potentiometer (pot) fully clockwise.
4. Set the variac to zero or minimum volt.
5. Plug the power cord into outlet.
6. Turn the power variac on. The AC voltmeter should indicate a power supply voltage of zero volts. The lamp should be off.
7. Slowly increase the variac. The light should begin to illuminate at approximately 90 volts.
8. Adjust the variac to 240 volts. Do not exceed 300 volts. The lamp should illuminate brightly. Replace the voltage regulator if the lamp does not light.
9. Turn volts pot fully counterclockwise. The lamp should go out. If it remains lit, the voltage regulator is inoperative.
10. Turn the volts pot clockwise. The lamp should be lit.
11. Turn power supply off and disconnect power cord.
12. See Voltage Regulator Adjustment Procedure.



1. Voltage regulator PowerBoost™ V
2. 250 volt, 75-100-watt lamp
3. AC voltmeter, 250 volt (minimum)
4. Volts potentiometer
5. 1:2 step-up transformer
6. Single-pole single-throw switch
7. 1-amp fuse
8. Black wire
9. White wire
10. 250 vac
11. Variable transformer (variac)
12. 120 vac

Figure 7-4 PowerBoost™ V Voltage Regulator Test

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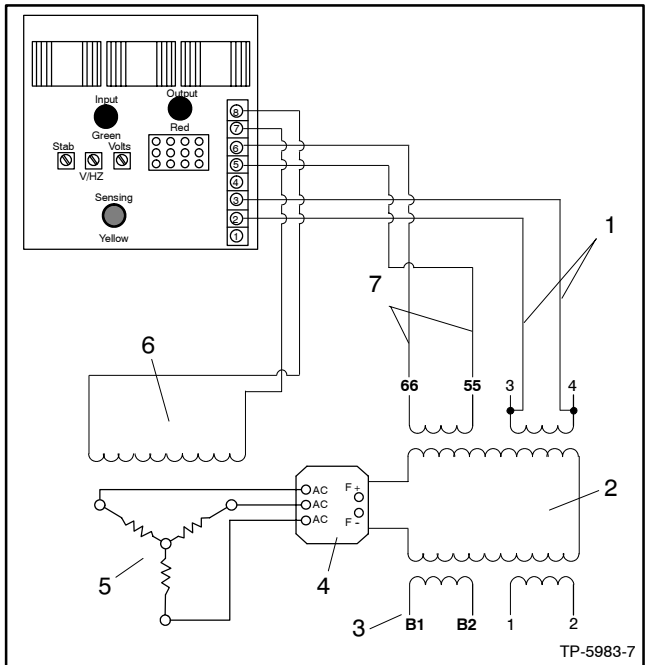
7.6 Voltage Regulator Adjustment

The voltage regulator is factory-set and under normal circumstances requires no further adjustment. However, if the voltage regulator has been replaced or tampered with, or if voltage/frequency reconnection has been done, readjust the voltage regulator according to the following procedure. The voltage regulator components are identified and described in the following paragraphs. See Figure 7-5 for voltage regulator connection.

Voltage Adjustment Potentiometer. Potentiometer adjusts the generator output.

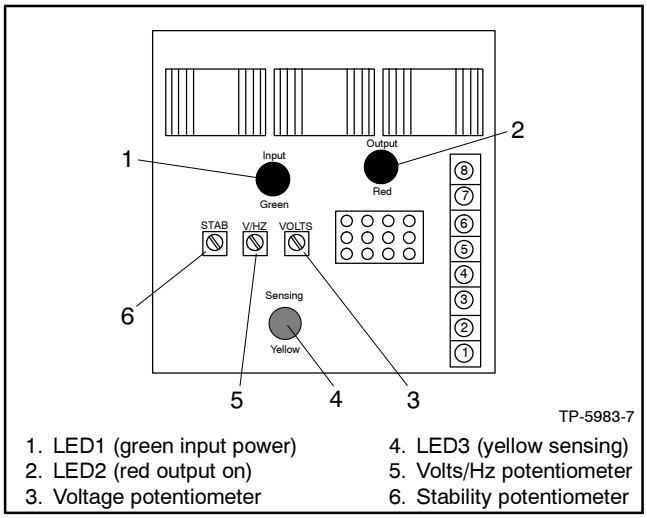
Stability Potentiometer. Potentiometer fine-tunes the regulator circuitry to reduce light flicker.

Volts/Hz Potentiometer. Potentiometer adjustment determines the engine speed (Hz) at which the generator output begins to drop.



1. Sensing leads
2. Main field (rotor)
3. Stator windings
4. Rectifier
5. Armature
6. Exciter field
7. Voltage regulator power supply leads

Figure 7-5 PowerBoost™ V Voltage Regulator Connection



1. LED1 (green input power)
2. LED2 (red output on)
3. Voltage potentiometer
4. LED3 (yellow sensing)
5. Volts/Hz potentiometer
6. Stability potentiometer

Figure 7-6 PowerBoost™ V Voltage Regulator

Voltage Regulator Adjustment Procedure:

1. Place the generator set controller start/stop switch in the STOP position.

2. Turn the Volts/Hz and the stability potentiometers fully counterclockwise. Connect the voltmeter to the AC circuit or an electrical outlet. Refer to Figure 7-6.

3. Start the generator set and rotate the voltage adjustment potentiometer clockwise (increase voltage) or counterclockwise (decrease voltage) until the desired output voltage is achieved.

4. Connect a 120-volt test light to the generator receptical. Rotate the stability potentiometer clockwise until the test light flickers minimally.

5. Readjust the voltage adjustment potentiometer until the desired output voltage is achieved.

6. Adjust the engine speed to the specified cut-in frequency as measured on the frequency meter. The factory setting is 57.5–58 Hz for 60 Hz models and 47.5–48 Hz for 50 Hz models.

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7. Rotate the volts/Hz potentiometer clockwise until the voltage level as measured on the voltmeter begins to drop. When the regulator is set to these specifications the generator will attempt to maintain normal output until the engine speed drops below the frequency set in step 6.

8. Readjust the engine speed to 63 Hz or 52 Hz.

9. Readjust the voltage adjustment potentiometer until the desired output is achieved.

10. Readjust the stability potentiometer until the test light flickers minimally.

11. Place the generator set controller start/stop switch in the STOP position.

7.7 Exciter Field

Direct current from the battery magnetizes the exciter field. When the exciter armature rotates within the magnetized exciter field windings, an electrical current develops within the exciter armature. Test the exciter field according to the following procedure.

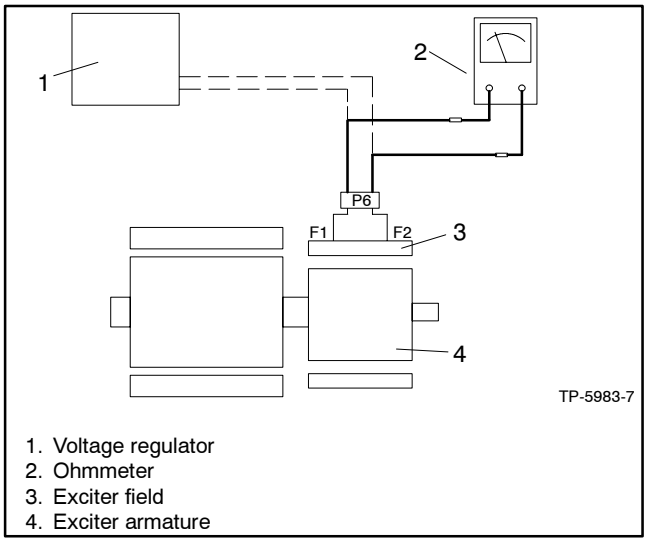
Exciter Field Test Procedure:

1. Place the start/stop switch in the STOP position.

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

3. Disconnect the P6 connector (F1/F2 leads).

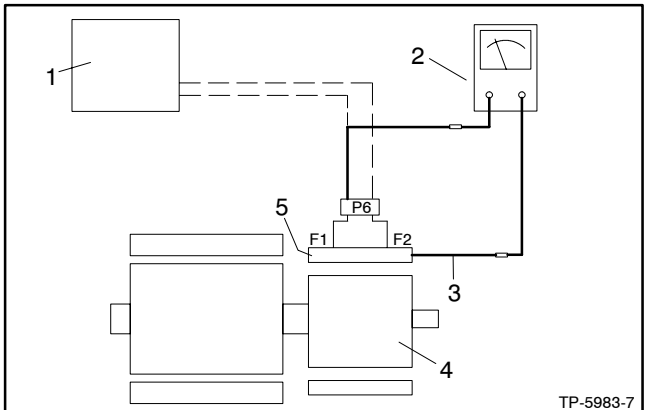
4. Check the exciter field resistance by connecting an ohmmeter across exciter field F1 and F2 leads. See Figure 7-7. See Section 1, Specifications for the resistance reading of a cold exciter field. A low reading indicates an internal short and a high reading indicates an open winding. Repair or replace the exciter field if the ohmmeter readings indicate a inoperative exciter field (refer to Section 9 for removal). If the resistance test is inconclusive, perform a megohmmeter test on the exciter field as described in the next step.



1. Voltage regulator
2. Ohmmeter
3. Exciter field
4. Exciter armature

Figure 7-7 Exciter Field Resistance Test

5. Check the exciter field for a short-to-ground condition. Use a megohmmeter to apply 500-volts DC to the F1 or F2 lead and the exciter field frame. See Figure 7-8. Follow the megohmmeter manufacturer's instructions for using the megohmmeter. A reading of approximately 1.5 MOhms and higher indicates the field winding is functional. A reading of less than approximately 1.5 MOhms indicates deterioration of the winding insulation and possible current flow to ground; If so, replace the exciter field.



1. Voltage regulator
2. Megohmmeter
3. Frame connection
4. Exciter armature
5. Exciter field

Figure 7-8 Megohmmeter Connections on the Exciter Field

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7.8 Exciter Armature

The exciter armature supplies excitation current to the generator main field through the rectifier module. Test the exciter armature as described in the following steps.

Exciter Armature Test Procedure:

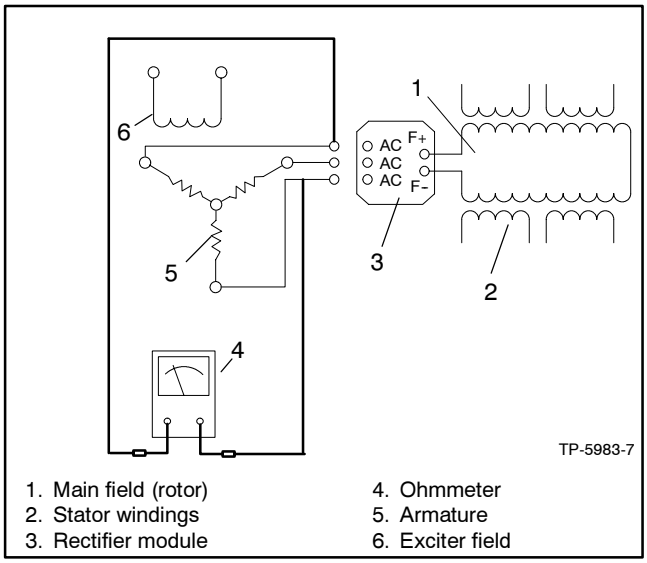
1. Disassemble the alternator. Refer to Section 9.

2. With the alternator disassembled, disconnect the armature leads from the rectifier module AC terminals. Refer to Section 9.

3. With an ohmmeter on the R x 1 scale, check the resistance across the exciter armature leads. See Figure 7-9. See Section 1, Specifications for the armature resistance. No continuity indicates an open armature winding. If the resistance test is inconclusive, perform a megohmmeter test on the exciter armature as described in the next step.

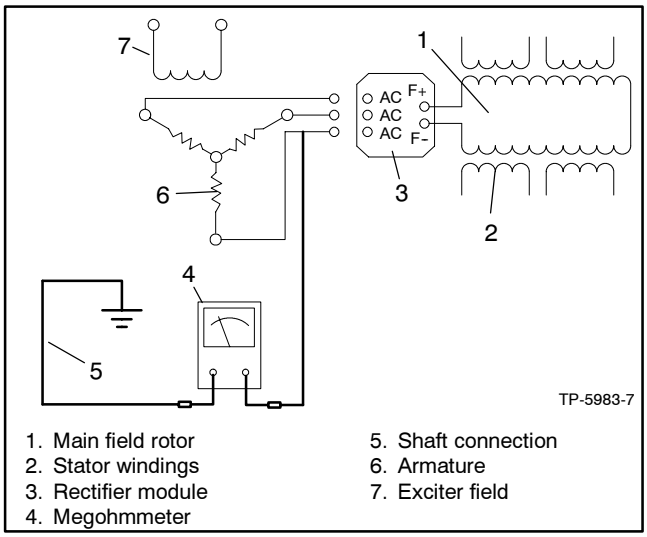
   Note: Most ohmmeters will not accurately measure less than one ohm. Consider the exciter armature functional if the resistance reading (continuity) is low and there is no evidence of a shorted winding (heat discoloration).

4. Check the exciter armature winding for a short-to-ground condition. Use a megohmmeter to apply 500 volts DC to either armature lead and the armature frame. Follow the megohmmeter manufacturer's instructions for using the megohmmeter. See Figure 7-10. A reading of approximately 1.5 MOhms and higher indicates the exciter armature is functional. A reading of less than approximately 1.5 MOhms indicates deterioration of the winding insulation and possible current flow to ground; If so, replace the exciter armature.



1. Main field (rotor)
2. Stator windings
3. Rectifier module
4. Ohmmeter
5. Armature
6. Exciter field

Figure 7-9 Exciter Armature Ohmmeter Test



1. Main field rotor
2. Stator windings
3. Rectifier module
4. Megohmmeter
5. Shaft connection
6. Armature
7. Exciter field

Figure 7-10 Megohmmeter Connections on Exciter Armature

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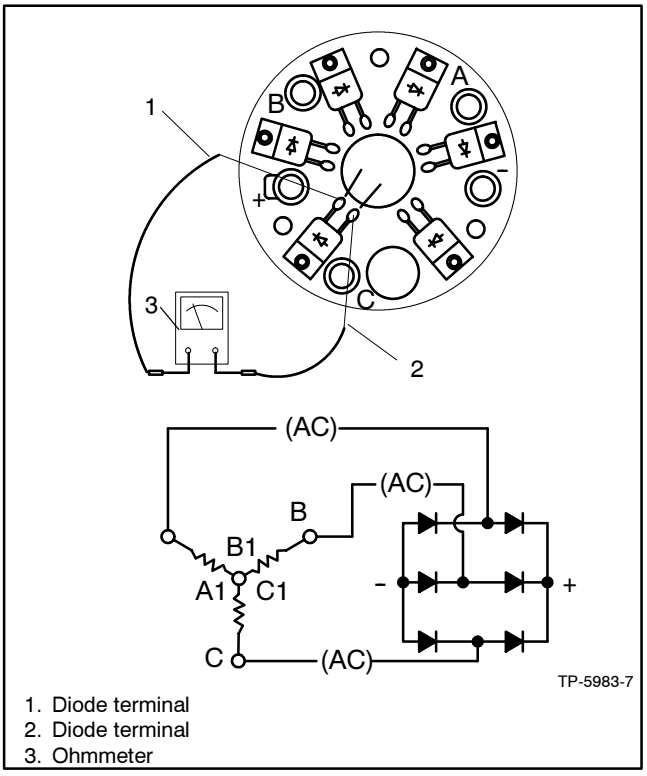
7.9 Rectifier Module

The rectifier module located between the exciter armature and the main field converts AC from the exciter armature to DC, which magnetizes the generator main field. Test the rectifier module as described in the following steps.

Rectifier Module Test Procedure:

1. Disconnect the exciter armature and the main field leads from the rectifier module.

2. Use an ohmmeter on the R x 100 scale to check the resistance between all the rectifier diodes as shown in Figure 7-11. The ohmmeter should show a low resistance in one direction and, upon reversing the ohmmeter leads, a high resistance in the other direction. Replace the rectifier module if any of the diodes tests differently than described.



1. Diode terminal
2. Diode terminal
3. Ohmmeter

Figure 7-11 Rectifier Module Test

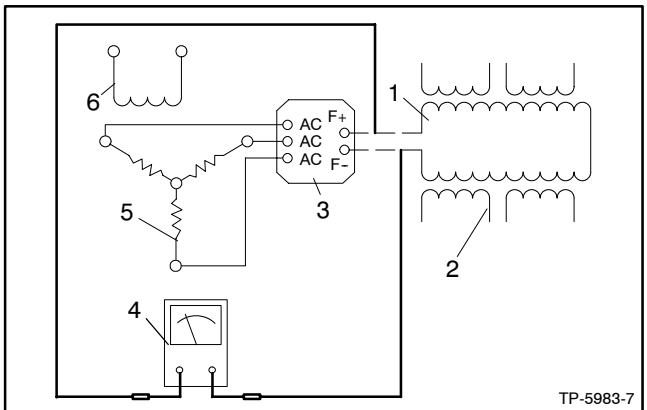
7.10 Rotor

The generator rotor (magnetized by DC from the rectifier module) rotating within the stator windings induces AC in the stator windings. Test the generator rotor (main field) as described in the following steps. Disassemble the generator prior to performing this test. See Section 9.

Generator Main Field (Rotor) Test Procedure:

1. With the generator disassembled, disconnect the generator main field windings at the rectifier module terminals F+ and F–.

2. Check the main field resistance by connecting an ohmmeter across the main field F+ and F– leads. See Figure 7-12. See Section 1, Specifications for the resistance reading. A low reading indicates an internal short and a high reading indicates an open winding. Repair or replace the main field if the ohmmeter readings indicate the main field is inoperative. If the resistance test is inconclusive, perform a megohmmeter test on the main field as described in the next step.

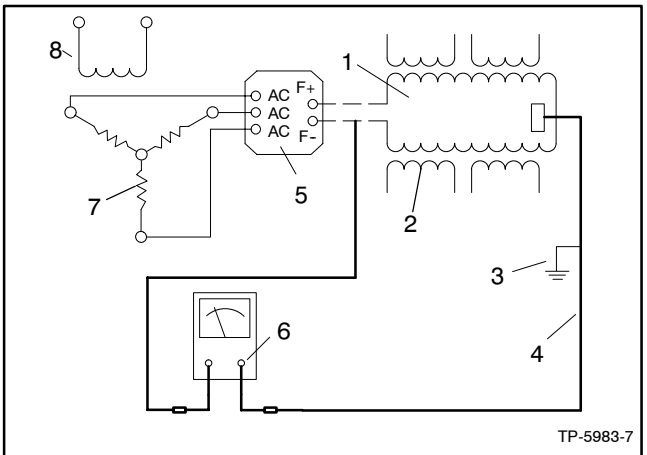


1. Main field (rotor)
2. Stator windings
3. Rectifier module
4. Ohmmeter
5. Armature
6. Exciter field

Figure 7-12 Ohmmeter Connections on Main Field

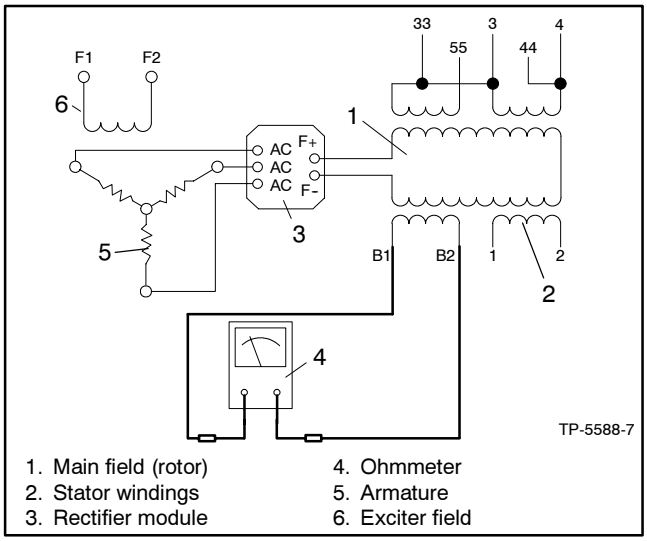
3. Check the main field for a short-to-ground condition by using a megohmmeter. Apply 500-volts DC to either field lead and the main field frame. Follow the megohmmeter manufacturers instructions for using the megohmmeter. See Figure 7-13. A reading of 1.5 MOhms and higher indicates the main field is functional. A reading of less than 1.5 MOhms indicates deterioration of the winding insulation and possible current flow to ground; If so, replace the main field.

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1. Main field (rotor)
2. Stator windings
3. Frame connection
4. Shaft connection
5. Rectifier module
6. Megohmmeter
7. Armature
8. Exciter field

Figure 7-13 Megohmmeter Connections on Main Field



1. Main field (rotor)
2. Stator windings
3. Rectifier module
4. Ohmmeter
5. Armature
6. Exciter field

Figure 7-14 Stator Ohmmeter Connections

7.11 Stator

The stator consists of a series of coils of wire laid in a laminated steel frame. The stator leads supply voltage to the AC load and exciter regulator.

Before testing the stator, inspect it for heat discoloration and visible damage to the housing lead wires and exposed and varnished areas of the frame laminations. Be sure the stator is securely fastened in the stator housing.

The stator produces electrical output (AC) as the magnetized main field rotates within the stator windings. Test the condition of the stator according to the following procedure.

Leads 1, 2, 3, and 4 are the generator output leads. Leads 55 and 66 are the voltage regulator supply and sensing leads. The output of leads B1 and B2 is rectified by BR1 to supply the control voltage. BR1 is located on the controller circuit board. Refer to the schematic in Figure 7-14 when performing the following tests.

Stator Test Procedure:

1. Place the start/stop switch in the STOP position.
2. Disconnect the generator set engine starting battery, negative (-) lead first.
3. Check the generator output lead connections. See Section 10, Wiring Diagrams.
4. Disconnect all the stator leads to isolate the windings. To check the stator continuity, set the ohmmeter on the R x 1 scale. Check the stator continuity by connecting the meter leads to the stator leads as shown in Figure 7-14. See Figure 7-15 for single-phase and Figure 7-16 for three-phase values. Perform the stator tests on all the stator windings.

Between leads	Continuity
1 and 2	Yes
3 and 4	Yes
55 and 66	Yes
B1 and B2	Yes
1 and 3, 4, 33, 44	No
1 and 55, B1, and B2	No
4 and B1 and B2	No
55 and B1 and B2	No
Any stator lead and ground	No

Figure 7-15 Stator Continuity 1-Phase

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Between leads	Continuity
1 and 4	Yes
2 and 5	Yes
3 and 6	Yes
7 and 10	Yes
8 and 11	Yes
9 and 12	Yes
55 and 66	Yes
B1 and B2	Yes
1 and 2, 3, 7, 8, 9	No
1 and 55, B1, and B2	No
4 and B1 and B2	No
55 and B1 and B2	No
Any stator lead and ground	No

Figure 7-16 Stator Continuity 3-Phase

5. Check the cold resistance of the stator windings by connecting the meter leads to the stator leads 1-2, 3-4, etc. See Section 1, Specifications for the stator resistance values. If the stator resistance test is inconclusive, perform a megohmmeter test on the stator as described in the next step.

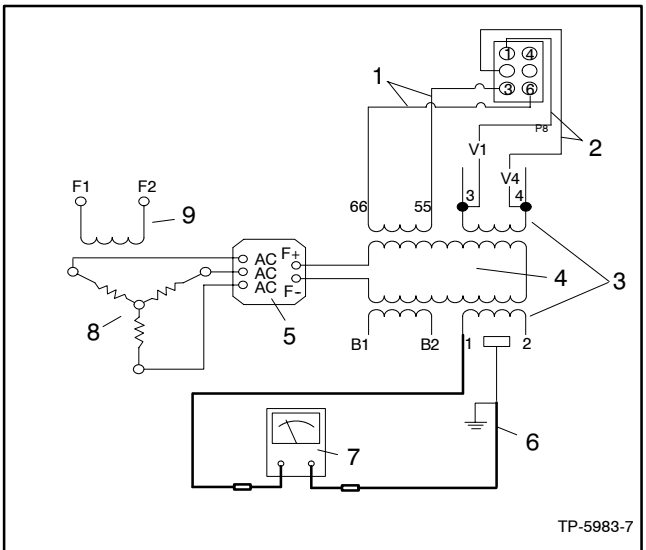
   Note: Consider the stator functional if the resistance reading (continuity) is low and there is no evidence of shorted windings (heat discoloration).

   Note: When taking an ohmmeter reading using lead 55, make the connection prior to the in-line fuse.

   Note: The stator resistance can vary directly with increased temperature.

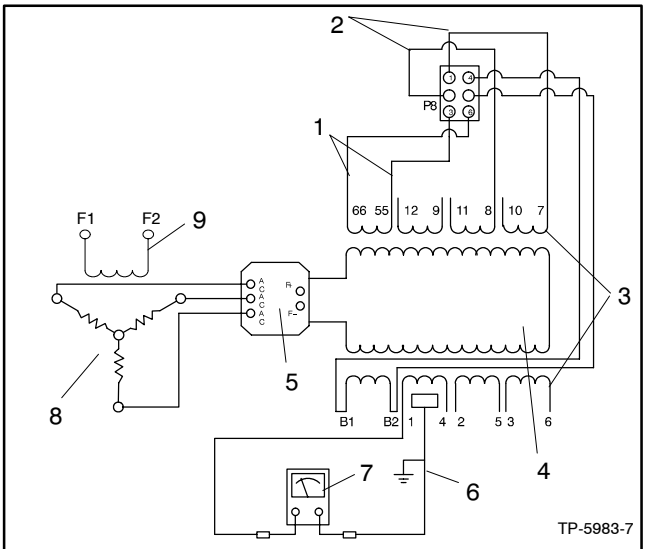
If any of the stator readings vary during the previous checks, replace the stator.

6. Check the stator for a short-to-ground condition using a megohmmeter. See Figure 7-17 for a single-phase megohmmeter connections and Figure 7-18 for three-phase megohmmeter connections. Apply 500 volts DC to any stator lead from each winding and the stator frame. Follow the megohmmeter manufacturer's instructions for using the megohmmeter. Repeat the test on the other leads until all of the stator windings have been tested. A reading of 1.5 MOhms and higher indicates the stator is functional. A reading of less than 1.5 MOhms indicates deterioration of the winding insulation and possible current flow to ground; If so, repair or replace the stator.



1. Voltage regulator power supply leads
2. Sensing leads (208-240 volts nominal)
3. Stator windings
4. Main field (rotor)
5. Rectifier module
6. Frame connection
7. Megohmmeter
8. Armature
9. Exciter field

Figure 7-17 Megohmmeter Connections on 1-Phase Stator



1. Voltage regulator power supply leads
2. Sensing leads (208-240 volts nominal)
3. Stator windings
4. Main field (rotor)
5. Rectifier module
6. Frame connection
7. Megohmmeter
8. Armature
9. Exciter field

Figure 7-18 Megohmmeter Connections on 3-Phase Stator

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Notes

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8.1 General

See Figure 8-1 through Figure 8-3 for component testing.

With the generator set battery connected, check the generator wiring harness and the components listed in the following tables. Check each component using a multimeter to verify that the switches function and that voltage is present at each component.

Component	Voltmeter Connections	Procedure	Results
Hourmeter and wiring	Connect the red test lead to the hourmeter positive (+) terminal. Connect the black test lead to the hourmeter negative (-) terminal.	Set the voltmeter to 12 volts DC or greater. Start the generator set.	A 12 volt DC reading indicates the wiring harness is functional.
	None (see Procedure)	Disconnect the hourmeter leads and apply 12 volts DC to the hourmeter. The hourmeter is polarity sensitive.	If functional—hourmeter operates.
Stator auxiliary winding B1 and B2	Connect the AC voltmeter leads to the B1 and B2 windings at connector P11.	Stop the generator set. Connect a voltmeter to the B1 and B2 windings. Crank the generator set and allow the set to reach its rated speed.	A reading of 12-15 volts AC indicates a functional B1/B2 winding.

Figure 8-1 Engine/Generator Component Testing—Relay Controller (Sheet 1 of 3)

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To further check the generator set components, disconnect the battery and remove the wiring harness plugs from the controller circuit board. Use an ohmmeter to check the continuity of the components and to isolate inoperative components. Refer to Figure 8-2 and Figure 8-3.

Note: Before performing ohmmeter checks, disconnect the generator set battery to prevent damage to the ohmmeter.

Component	Ohmmeter Connections	Procedure	Results
Start/stop switch	Connect the ohmmeter to the P2-6 and P2-4 leads.	Place the ohmmeter on the R x 1000 scale. Place the rocker switch in the START position.	If the switch is functional, zero ohms continuity. Any resistance other than zero or very low ohms—replace the switch.
	Connect the ohmmeter to the P2-6 and P2-5 leads.	Place the ohmmeter on the R x 1000 scale. Place the rocker switch in the STOP position.	If the switch is functional, zero ohms continuity. Any resistance other than zero or very low ohms—replace the switch.
K20 relay coil and wiring	Connect the ohmmeter to the P1-4 and P1-9 leads.	Place the ohmmeter on the R x 1 scale.	If functional—85 ohms. Low resistance—shorted C relay coil and/or wiring. High resistance—open C relay and/or wiring. Replace the controller board.
Starter solenoid (S relay)	Connect the ohmmeter to the P4-22 lead and the battery positive (+) cable. **Note:** The J4 and P4 leads must be disconnected to perform this test.	Place the ohmmeter on the R x 1 scale.	If functional—approximately 0.5–0.6 ohms at 27°C (80°F).
Controller 10-amp circuit breaker and wiring	Connect the ohmmeter to the battery positive (+) cable and the P1-14 lead. **Note:** The J4 and P4 leads must be connected to perform this test.	Place the ohmmeter on the R x 1000 scale.	If functional—zero or very low ohms. No reading (infinity)—open circuit or circuit breaker tripped.
Exciter field windings	P7 (FP/FN) **Note:** Disconnect P7 connector for this test	Ohmmeter on R x 1 scale. Disconnect the exciter field leads to voltage regulator at P6.	If functional—see Section 1, Specifications. Low resistance—exciter shorted. High resistance—exciter open.
Exciter armature windings	Disconnect the armature leads from the rectifier. Connect the ohm leads. Repeat the test on the third lead.	Ohmmeter on R x 1 scale	If functional—see Section1, Specifications. Low resistance—armature windings shorted. High resistance—armature windings open.

Figure 8-2 Engine/Generator Component Testing—Relay Controller (Sheet 2 of 3)

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Component	Ohmmeter Connections	Procedure	Results
Main field (rotor)	Disconnect the P10 and P11 connectors and connect the ohmmeter to P10-1 and P10-2 leads.	Place the ohmmeter on the R x 1 scale.	If the resistance readings match those specified in Section 1, Specifications, the rotor is functional. Low resistance—rotor windings shorted. High resistance—rotor windings open.
B1/B2 stator windings	Connect the ohmmeter to the P11-1 and P11-2 leads. **Note:** Disconnect P11 and J11 to perform this test.	Place the ohmmeter on the R x 1 scale.	If the resistance readings match those specified in Section 1, Specifications, the B1/B2 windings are functional. Low resistance—B1/B2 windings shorted. High resistance— B1/B2 windings open.
P1 ground connection	Connect the ohmmeter to the P1-9 and ground.	Place the ohmmeter on the R x 1 scale.	If functional—zero ohms (continuity). Any other reading indicates a poor ground connection.
High exhaust temperature (HET), low coolant (LCS) safety shutdown switches	Connect the ohmmeter to the P1-15 and engine block (ground). **Note:** Remove and isolate the LOP switch lead.	Place the ohmmeter on the R x 1000 scale.	If functional—open circuit. Any continuity suggests an inoperative temperature switch(es). Replace the switch(es).
Low oil pressure (LOP) safety shutdown switch	Connect the ohmmeter to the P13-1 and engine block (ground).	Place the ohmmeter on the R x 1000 scale. This test is not conclusive until the temperature shutdown switches are checked.	If functional—zero ohms (continuity). Then, disconnect the LOP switch lead and isolate the terminal. Meter reading should show an open circuit.

Figure 8-3 Engine/Generator Component Testing—Relay Controller (Sheet 3 of 3)

8.2 Remote Panels (Optional)

Kohler Co. offers three remote panels for connection to the generator set:

- a panel with a start/stop switch
- a panel with a start/stop switch and two gauges (engine oil pressure and water temperature)
- a panel with a start/stop switch and four gauges (DC voltmeter, engine oil pressure, water temperature, and hourmeter)

If difficulty with the remote operation occurs, test the switch, gauges, and gauge senders using the following procedures. See Section 10.3-10.5 for wiring diagrams.

Troubleshooting Remote Start Panels

Generally, if the sender changes its resistance values as its respective pressure/temperature changes, it is working correctly. An inoperative sender will either be open or shorted. Refer to Figure 8-4 and Figure 8-5 for resistance values.

2-Meter and 4-Meter Panels	
Temperature	**Resistance**
60°C (140°F)	134 ± 10 ohms
90°C (194°F)	51.5 ± 4 ohms
100°C (212°F)	38 ± 3 ohms

Figure 8-4 Water Temperature Sender Resistance

2-Meter and 4-Meter Panels	
Pressure	**Resistance**
0 kPa (0 psi)	10 ohms
345 kPa (50 psi)	80 ohms
690 kPa (100 psi)	135 ohms

Figure 8-5 Oil Pressure Sender Resistance

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Refer to Figure 8-6 for troubleshooting information on the remote start panels.

Component	Ohmmeter Connections	Procedure	Results
Remote start/stop switch	Remote switch: yellow/red wire terminal and black wire terminal.	Place the ohmmeter on the R x 1 scale. Press the rocker switch to the START position.	Continuity—the switch is functional. Open—replace switch.
	Remote switch: grey/black wire terminal and black wire terminal.	Place the ohmmeter on the R x 1 scale. Press the rocker switch to the STOP position.	Continuity—the switch is functional.
Genset ON light, gauge lights, DC voltmeter, and hourmeter	Connect the red test lead to P3-4 and black test lead to P3-1.	Place the controller rocker switch to the START position. Stop the generator set when the test is complete. Generator set does not need to be running, just cranking for this test. **Note:** If the hourmeter is not illuminated, test it by connecting it to a 12-volt battery. **Note:** The hourmeter is polarity sensitive.	If 12-volts DC is present and the component does not function after the J3 is connected to the controller P3, replace the component(s).
Water temperature gauge	Connect the red test lead to P3-4 (socket side) and black test lead to P3-2 (socket side).	Start the generator set for the test.	If 0.5–12-volts DC is present and the gauge does not function after the J3 is connected to controller—replace the gauge.
Oil pressure gauge	Connect the red test lead to P3-4 (socket side) and black test lead to P3-3 (socket side).	Start the generator set for the test.	If 0.5–12-volts DC is present and the gauge does not function after the J3 is connected to the controller—replace the gauge.
Note: Check continuity of gauge wiring and extension harness before replacing components.			

Figure 8-6 Remote Start Panels Troubleshooting

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9.1 Disassembly

Disconnect all of the external connections—battery cables at the battery (negative (–) lead first), AC-output leads in the controller, remote start panel at the controller P3 connector, water line at the seawater pump, fuel line at the fuel pump filter inlet, and exhaust line at the mixing elbow. Observe all of the safety precautions listed at the beginning of this manual during the disassembly/reassembly procedures.

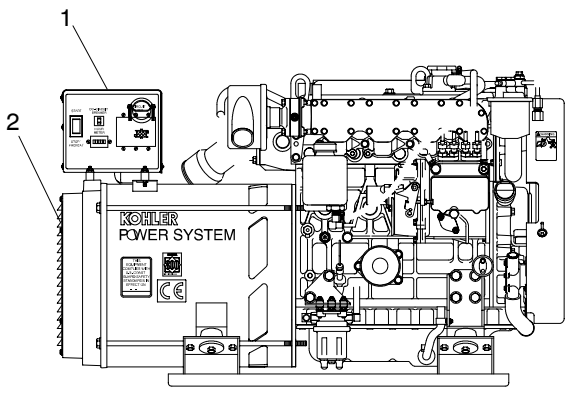
Note: Because this manual covers several models, the procedure for disassembly may vary because of product updates and the assembly variations.

Note: The voltage regulator is located in the controller box. Remove the controller cover to service the voltage regulator. Adjustments are possible without removing the voltage regulator from the controller.

Disassembly Procedure:

1. Remove the end panel from the alternator end of the generator set. See Figure 9-1.

2. Loosen the four screws and lift off the controller cover. See Figure 9-1.



1. Controller cover
2. Alternator end panel

Figure 9-1 Covers

3. Disconnect the P4 (22-pin) connector from J4.

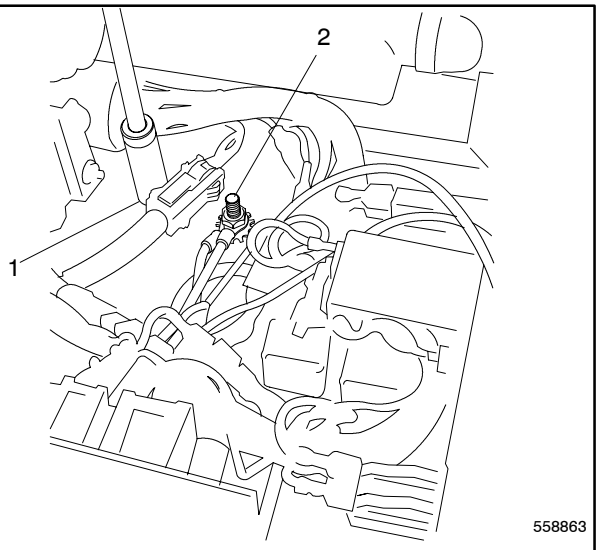
4. Remove the ground strap.

   Note: It is possible to connect the output leads in various positions for different voltage configurations. Mark leads 1, 2, 3, and 4 for correct reconnection.

5. Disconnect generator output leads 1, 2, 3, and 4 from the circuit breaker and neutral stud (L0). See Figure 9-2.

6. Remove the four controller mount locknuts. See Figure 9-2.

7. Lift the controller from the rubber mounts while guiding the leads through the bottom hole of the controller box.



1. Controller mount locknut
2. Neutral stud (L0)

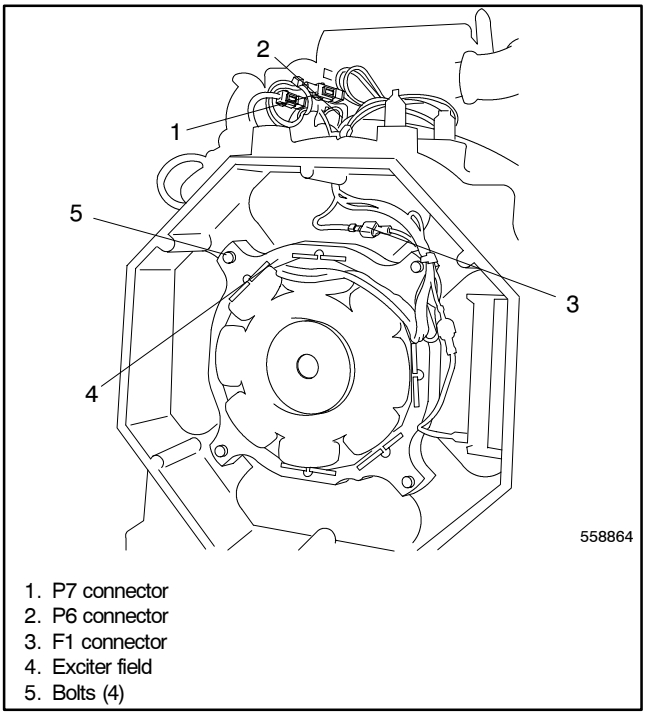
Figure 9-2 Controller Removal

8. Remove the tie wraps from the wiring harness as necessary. Disconnect the F1 connectors from the resistor leads.

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9. Disconnect the P7 (FP and FN) and P6 (F1 and F2) connectors. See Figure 9-3.

10. Remove the four bolts to remove the exciter field. See Figure 9-3.



1. P7 connector
2. P6 connector
3. F1 connector
4. Exciter field
5. Bolts (4)

Figure 9-3 Exciter Field Removal

11. Remove the three bolts and spacers from the rectifier board.

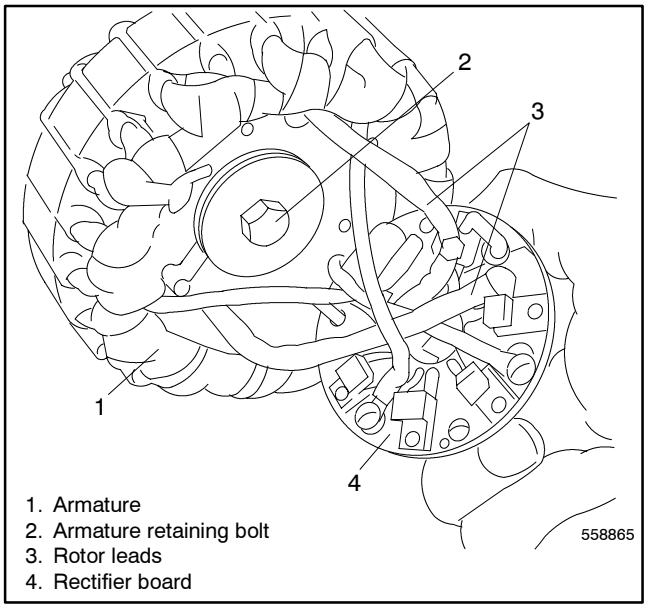
12. Disconnect the main field rotor leads from the rectifier board positive/negative terminals. Remove the armature retaining bolt and washer. See Figure 9-4.

13. Remove the armature from the shaft, guiding the rotor leads through the armature bores. See Figure 9-4.

14. Remove the tie wraps and disconnect the P8 (33, 44, 55, B1, and B2) wire connector.

15. Attach a hoist hook to the generator lifting eye. See Figure 9-5.

    Note: The hoist capacity rating should be one-half ton or greater.



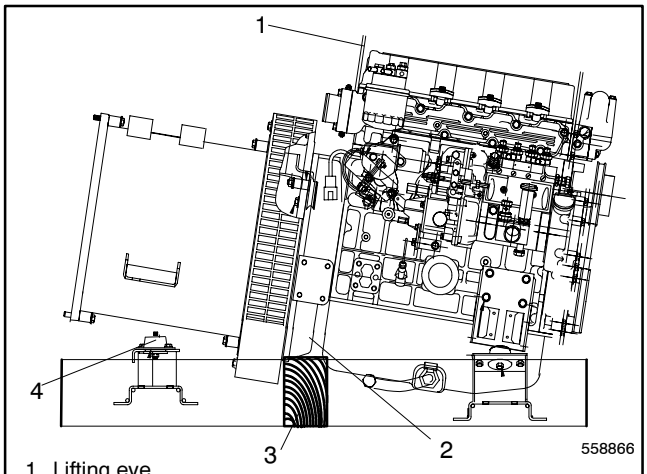
1. Armature
2. Armature retaining bolt
3. Rotor leads
4. Rectifier board

Figure 9-4 Armature Removal

16. Remove the two vibromount bolts. See Figure 9-5.

17. Raise the alternator end and place a wood block under the locator plate. Lower the alternator until the wood block supports the backplate. See Figure 9-5.

18. Remove the four overbolts from the end bracket.



1. Lifting eye
2. Backplate
3. Wood block
4. Vibromounts

Figure 9-5 Supporting the Generator, Typical

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19. Install a sling capable of handling the weight of the stator housing on the stator housing. See Figure 9-6.

20. Use a two-jaw puller to pull the end bracket/stator assembly from the bearing on the rotor shaft. See Figure 9-6.

21. Remove the stator assembly from the rotor. Remove or rotate the fan guard, if necessary, to clear the vibromounts.

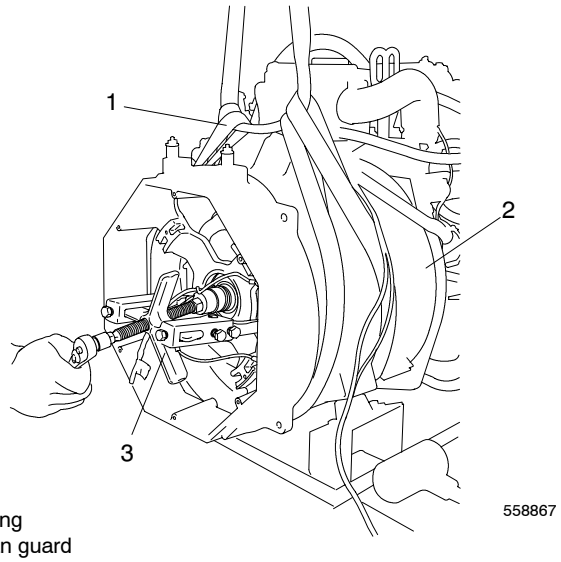
22. Mark the fans position on the rotor/drive disc assembly with a permanent marker.

23. Remove the four screws with spacers and the four screws without spacers. See Figure 9-7.

24. Remove the fan and fan spacers. See Figure 9-7.

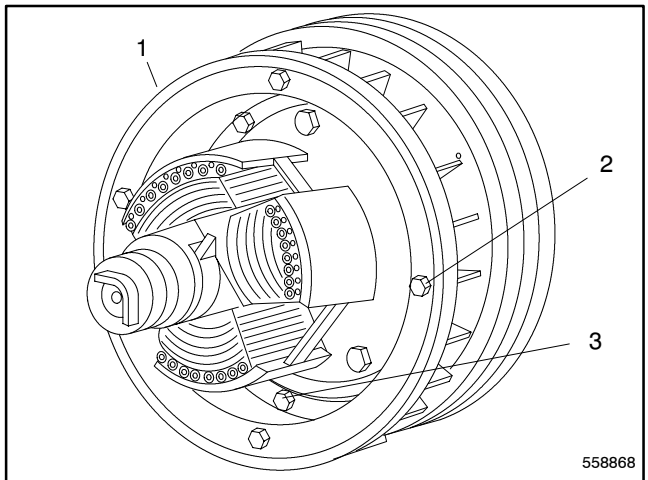
25. Remove the eight bolts and remove the drive disc/rotor assembly from the engine flywheel. See Figure 9-8.

26. Clamp the rotor in a soft-jaw vise. Remove the eight bolts and remove the drive disc assembly from the rotor. See Figure 9-9.



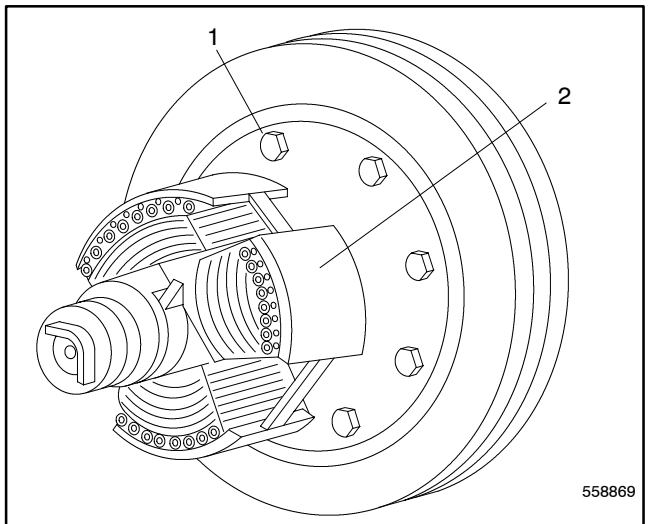
1. Sling
2. Fan guard
3. Two-jaw puller

Figure 9-6 Stator Assembly Removal



1. Fan
2. Screws with spacers (4)
3. Screws without spacers (4)

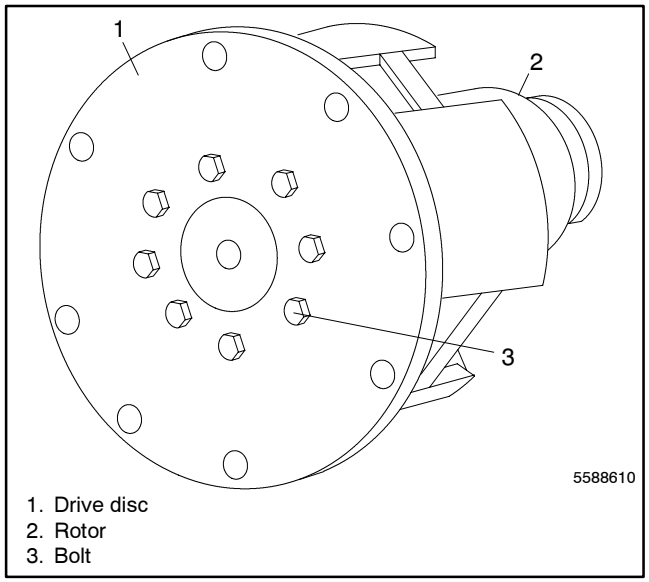
Figure 9-7 Fan Removal



1. Bolts (8)
2. Rotor assembly

Figure 9-8 Disc/Rotor Assembly

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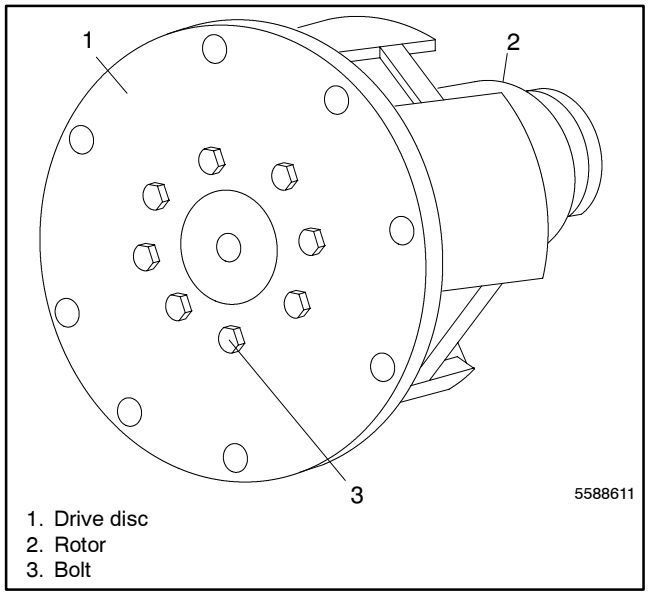


1. Drive disc
2. Rotor
3. Bolt

Figure 9-9 Drive Disc

9.2 Reassembly

1. Clamp the rotor in a soft-jaw vise. Install a new drive disc on the rotor. Tighten the eight bolts to 38 Nm (28 ft. lbs.) See Figure 9-10.



1. Drive disc
2. Rotor
3. Bolt

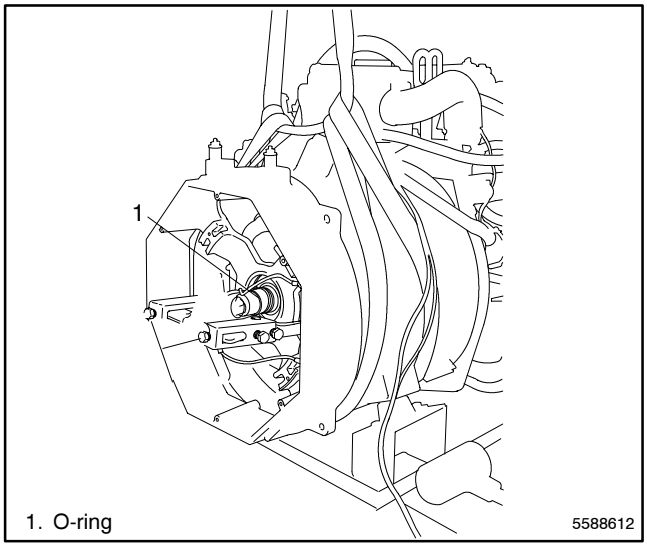
Figure 9-10 Drive Disc Installation

2. Install the rotor/drive disc assembly on the engine flywheel using eight washers and bolts. Tighten the bolts to 19 Nm (14 ft. lbs.)

3. Align the fan to the rotor/drive disc assembly using the mark created in the disassembly procedure. Install the fan to the drive disc using eight screws, four spacers, washers, and locknuts.

Note: Install the fan with the flange side facing away from the flywheel.

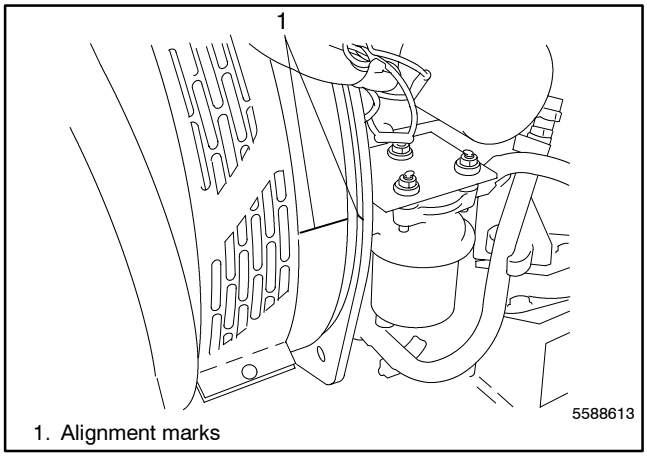
4. Replace the O-ring in the end bracket bearing bore. Use a sling to support the stator assembly while installing the stator over the rotor. Do not damage the rotor. See Figure 9-11.



1. O-ring

Figure 9-11 Stator Installation

5. Install the four overbolts (the two long bolts in the lower holes). Check that the alignment marks on the stator housing and locator plate match. See Figure 9-12. Tighten the overbolts to 33.9 Nm (25 ft. lbs.)



1. Alignment marks

Figure 9-12 Alignment Marks

6. Use the hoist to raise the alternator end. Remove the wood block from under the locator plate. Lower the generator set and install a bolt, a large washer, two small washers, and a locknut on each vibromount. Tighten the mounting bolts to 28 Nm (20 ft. lbs.).

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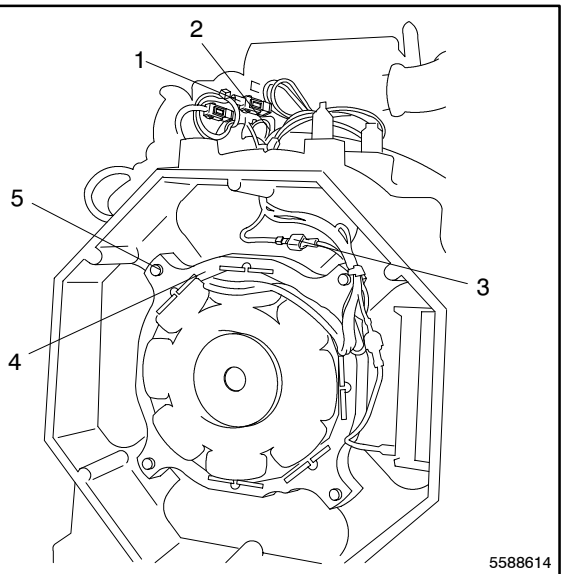
7. Apply antiseize compound to the keyed end of the rotor shaft. Bring the rotor leads through the bores in the armature while installing the armature on the shaft. Check the keyway of the shaft and key of the armature for damage. Install the armature retaining bolt and washer.

8. Use screws and lock washers to install the rotor leads to the rectifier board at the positive (+) and negative (-) terminals.

   Note: Position the lock washers against the rectifier board.

9. Install the three spacers and bolts to mount the rectifier board to the armature.

10. Position the field leads at the top. Install the exciter field using four bolts and washers. Connect P5, P6, P7, and F1 connectors. See Figure 9-13.



1. P7 connector
2. P6 connector
3. F1 connector
4. Exciter field
5. Exciter field bolts (4)

Figure 9-13 Installing Exciter Field

11. Install tie wraps to secure the wires as necessary.

12. Route the output leads 1, 2, 3, and 4 through the bottom of the controller box. Check that the grommet is intact and there are no sharp edges exposed that could damage the wiring. Install the controller box on the rubber mounts and install the four locknuts. Connect the leads to the circuit breaker and neutral stud (LO) as marked during disassembly.

    Note: Check the generator set nameplate to verify the original voltage configuration.

13. Connect the P4 (22-pin) connector. Connect the ground strap using bolt, washer, and lock washer (install the lock washer against the ground strap).

14. Install the controller cover.

15. Install the end panel with the louvered openings down.

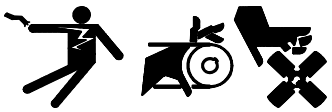
16. Reconnect all of the external connections—the exhaust line to the mixing elbow, the fuel line to the fuel pump filter inlet, the water line to the seawater pump, the remote start panel to the controller P3 connector, the AC output leads in controller, and the battery cables to the battery (negative (-) lead last).

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Notes

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⚠ WARNING

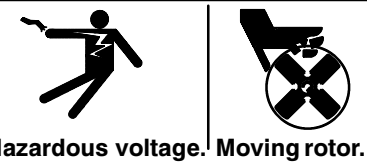


Accidental starting.
Can cause severe injury or death.

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) Disconnect the power to the battery charger, if equipped. (2) 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. Moving rotor.
Can cause severe injury or death.

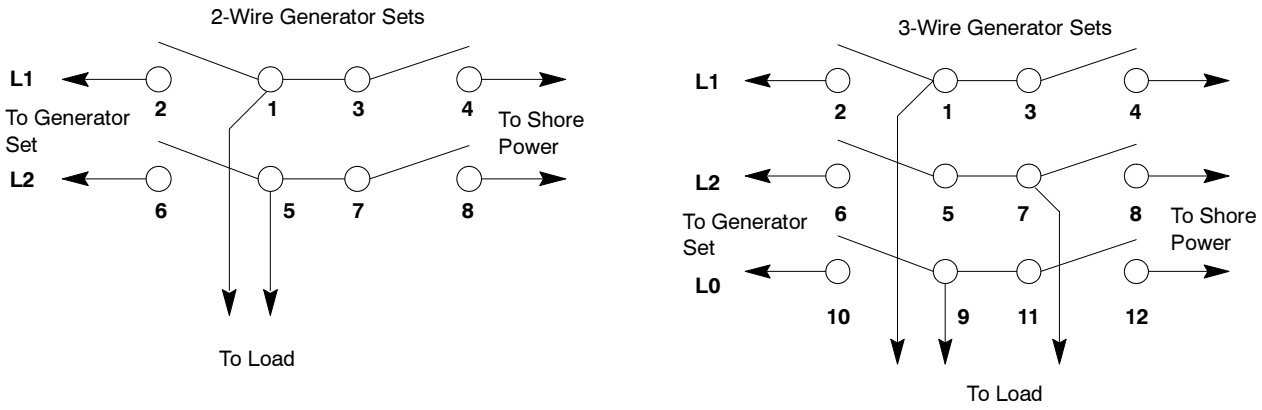
Operate the generator set only when all guards and electrical enclosures are in place.

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, transfer switch, and related equipment and electrical circuits to comply with applicable codes and standards. Never contact electrical leads or appliances when standing in water or on wet ground because these conditions increase the risk of electrocution.

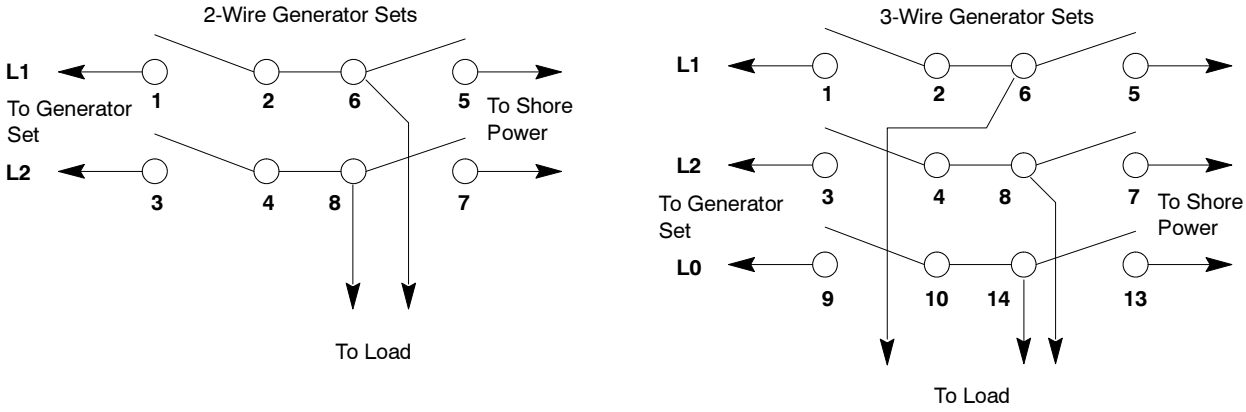
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10.1 Manual Marine (Ship-to-Shore) 2 Wire and 3 Wire Transfer Switches

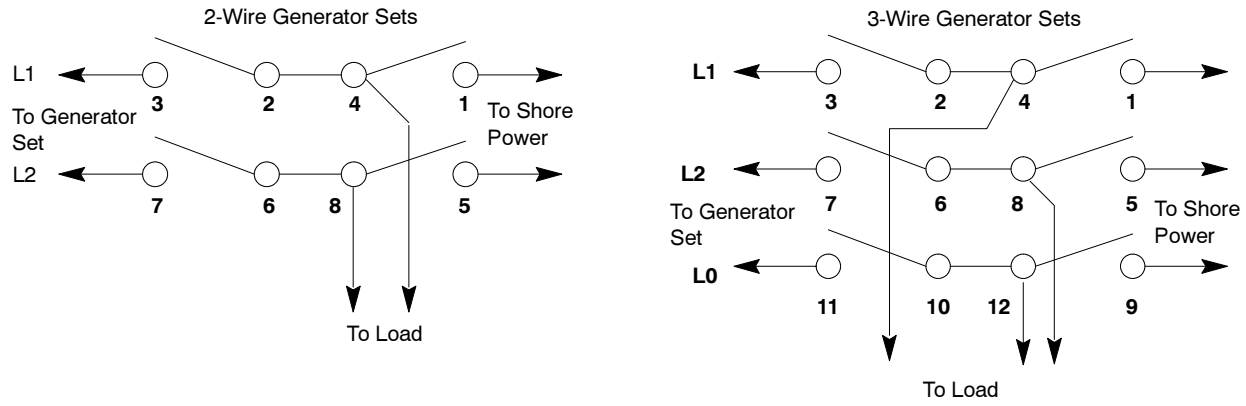
Electro Switch



Kraus Naimler/American Solenoid (Early Rectangular Design)



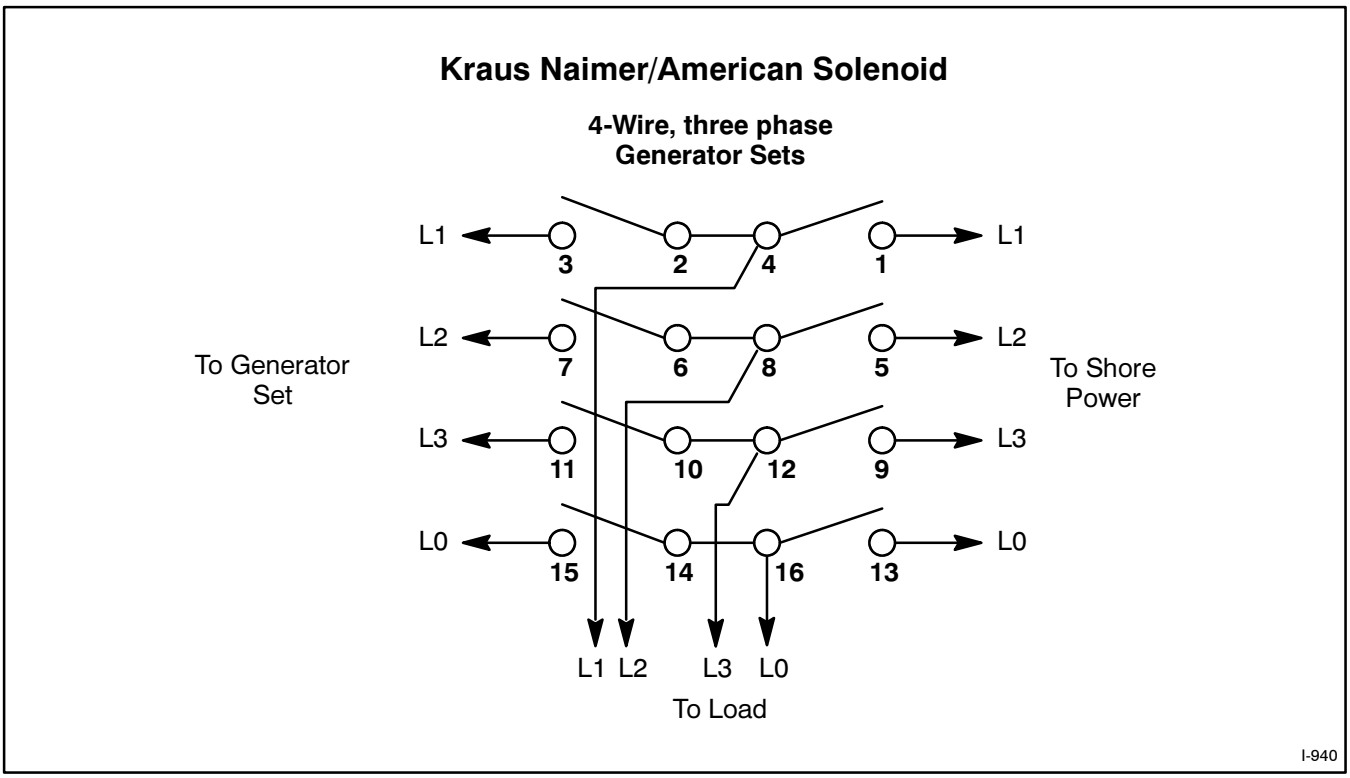
Kraus Naimler/American Solenoid (Newer Round Design)



TP-5399-5

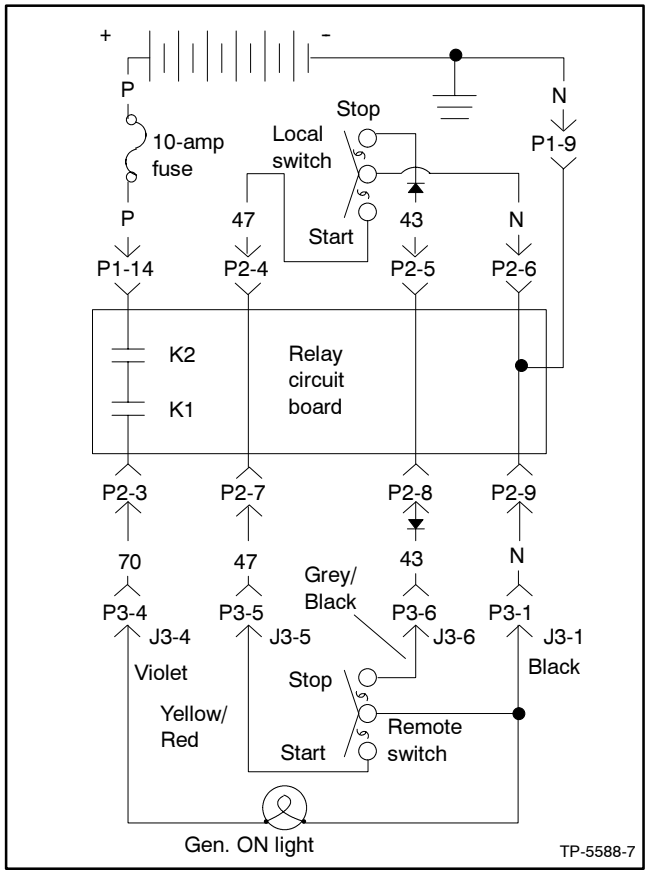
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10.2 Manual Marine (Ship-to-Shore) 4 Wire Transfer Switch

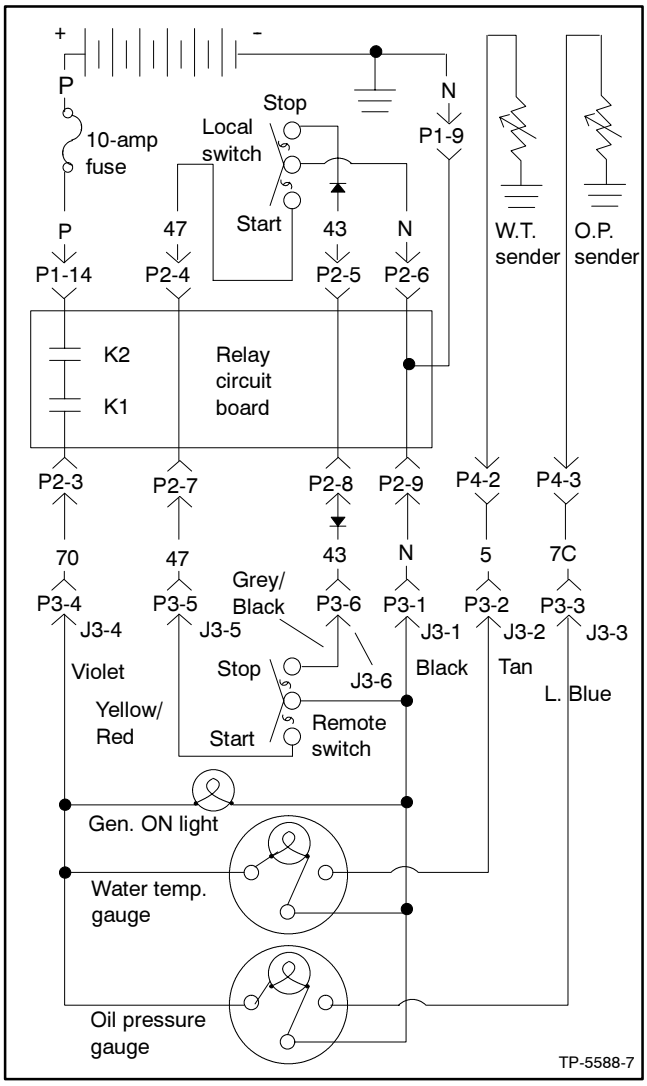


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10.3 Remote Start Panel

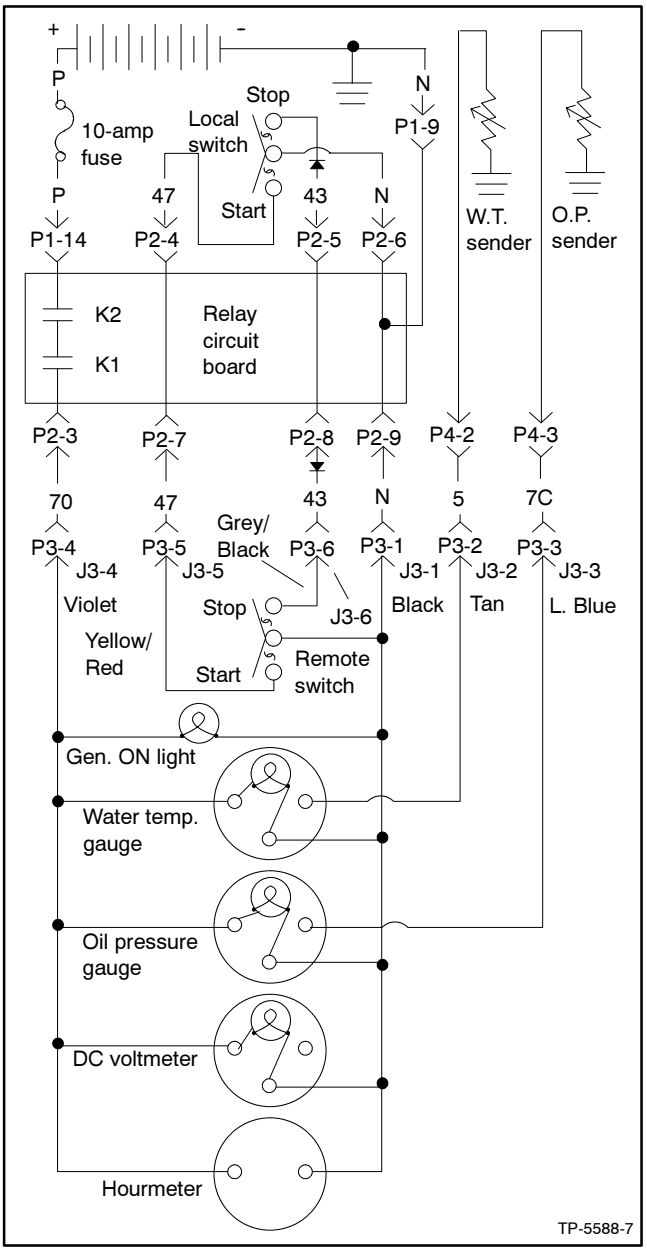


10.4 Remote Start and Two-Meter Panel



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10.5 Remote Start and Four-Meter Panel

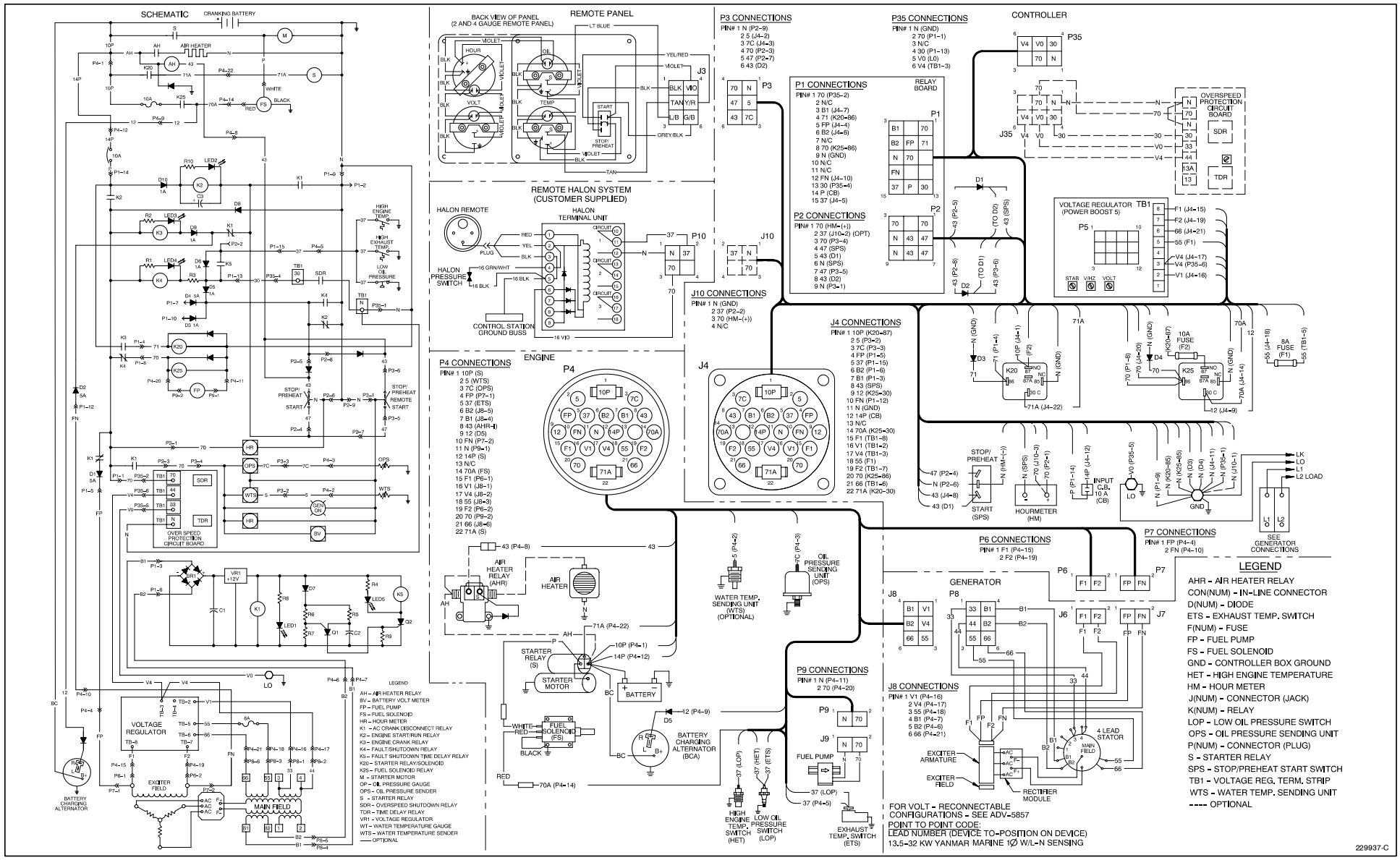


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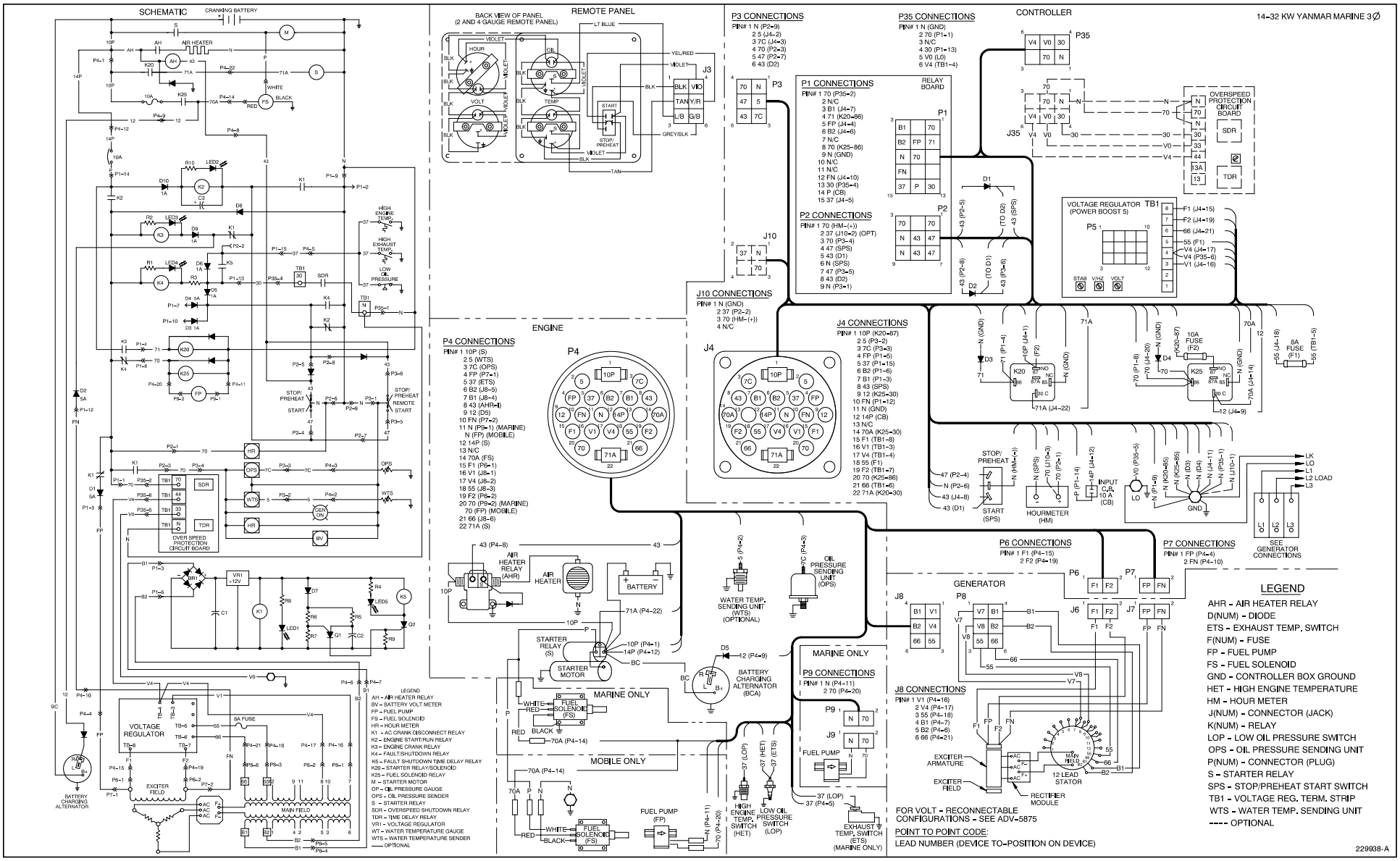
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10.7 Wiring Diagram 12-Lead



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	audio/visual
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
cfh	cubic feet per hour
cfm	cubic feet per minute
CG	center of gravity
CID	cubic inch displacement
CL	centerline
cm	centimeter
cmm	cubic meters per minute
CMOS	complementary metal oxide substrate (semiconductor)
cogen.	cogeneration
COM	communications (port)
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. lbs.	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
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
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. lbs.	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

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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
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
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
O/C	overcrank
OD	outside diameter
OEM	original equipment manufacturer
O/F	overfrequency
opt.	option, optional
O/S	oversize, overspeed
OSHA	Occupational Safety and Health Administration
O/V	overvoltage
oz.	ounce
p., pp.	page, pages
PA	packed accessory
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
qty.	quantity
R	replacement (emergency) power source
rad.	radiator, radius
RAM	random access memory
RDO	relay driver output
ref.	reference
rem.	remote
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)
U/F	underfrequency
UHF	ultrahigh frequency
UL	Underwriter's Laboratories, Inc.
UNC	unified coarse thread (was NC)
UNF	unified fine thread (was NF)
univ.	universal
U/S	undersize, underspeed
UV	ultraviolet
U/V	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

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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 General Torque Specifications and other torque specifications in the service literature.

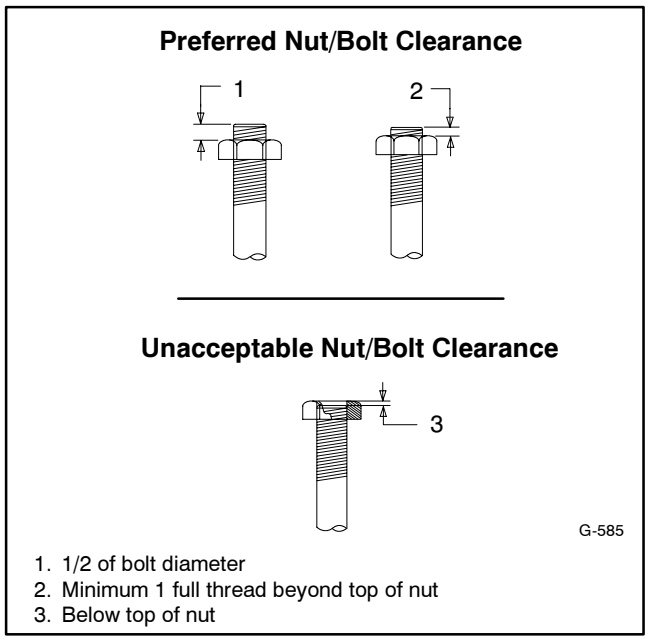


Figure 1 Acceptable Bolt Lengths

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 the diagram below.
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 the diagram below, which depicts the preceding hardware configuration possibilities.

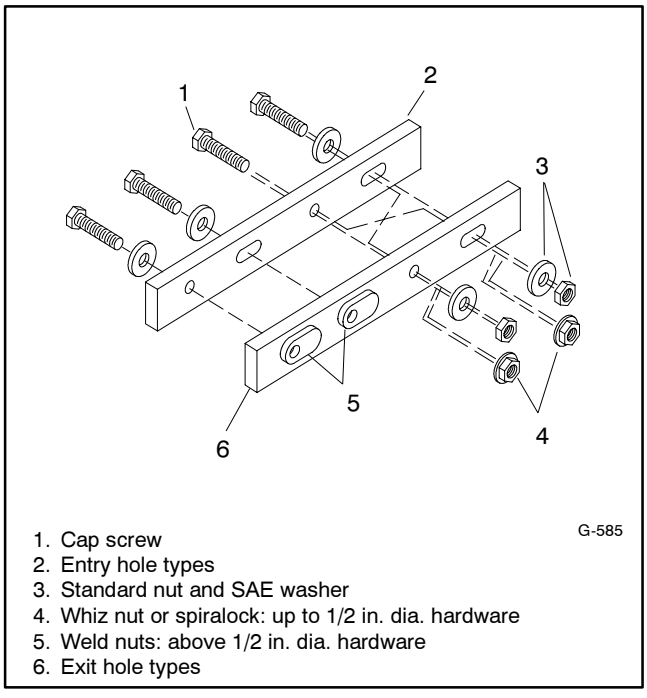


Figure 2 Acceptable Hardware Combinations

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Appendix C General Torque Specifications

Use the following torque specifications when service literature instructions give no specific torque values. The charts list values for new plated, zinc phosphate, or oiled threads. Increase values by 15% for nonplated threads. All torque values are +0%/–10%.

American Standard Fasteners Torque Specifications

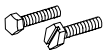
Size	Torque Measurement	Assembled into Cast Iron or Steel			Assembled into Aluminum
		Grade 2	Grade 5	Grade 8	Grade 2 or 5
8-32	in. lbs. (Nm)	16 (1.8)	20 (2.3)	—	16 (1.8)
10-24	in. lbs. (Nm)	26 (2.9)	32 (3.6)	—	26 (2.9)
10-32	in. lbs. (Nm)	26 (2.9)	32 (3.6)	—	26 (2.9)
1/4-20	in. lbs. (Nm)	60 (6.8)	96 (10.8)	132 (14.9)	60 (6.8)
1/4-28	in. lbs. (Nm)	72 (8.1)	108 (12.2)	144 (16.3)	72 (8.1)
5/16-18	in. lbs. (Nm)	120 (13.6)	192 (21.7)	264 (29.8)	120 (13.6)
5/16-24	in. lbs. (Nm)	132 (14.9)	204 (23.1)	288 (32.5)	132 (14.9)
3/8-16	ft. lbs. (Nm)	18 (24)	28 (38)	39 (53)	18 (24)
3/8-24	ft. lbs. (Nm)	20 (27)	31 (42)	44 (60)	20 (27)
7/16-14	ft. lbs. (Nm)	29 (39)	44 (60)	63 (85)	—
7/16-20	ft. lbs. (Nm)	32 (43)	50 (68)	70 (95)	—
1/2-13	ft. lbs. (Nm)	44 (60)	68 (92)	96 (130)	—
1/2-20	ft. lbs. (Nm)	49 (66)	76 (103)	108 (146)	—
9/16-12	ft. lbs. (Nm)	60 (81)	98 (133)	138 (187)	—
9/16-18	ft. lbs. (Nm)	67 (91)	109 (148)	154 (209)	—
5/8-11	ft. lbs. (Nm)	83 (113)	135 (183)	191 (259)	—
5/8-18	ft. lbs. (Nm)	94 (128)	153 (208)	216 (293)	—
3/4-10	ft. lbs. (Nm)	147 (199)	240 (325)	338 (458)	—
3/4-16	ft. lbs. (Nm)	164 (222)	268 (363)	378 (513)	—
1-8	ft. lbs. (Nm)	191 (259)	532 (721)	818 (1109)	—
1-12	ft. lbs. (Nm)	209 (283)	582 (789)	895 (1214)	—

Metric Fasteners Torque Specifications, Measured in ft. lbs. (Nm)

Size (mm)	Assembled into Cast Iron or Steel			Assembled into Aluminum
	Grade 5.8	Grade 8.8	Grade 10.9	Grade 5.8 or 8.8
M6 x 1.00	4 (5.6)	7 (9.9)	10 (14)	4 (5.6)
M8 x 1.25	10 (13.6)	18 (25)	26 (35)	10 (13.6)
M8 x 1.00	16 (21)	18 (25)	26 (35)	16 (21)
M10 x 1.50	20 (27)	35 (49)	50 (68)	20 (27)
M10 x 1.25	29 (39)	35 (49)	50 (68)	29 (39)
M12 x 1.75	35 (47)	61 (83)	86 (117)	—
M12 x 1.50	48 (65)	65 (88)	92 (125)	—
M14 x 2.00	55 (74)	97 (132)	136 (185)	—
M14 x 1.50	74 (100)	103 (140)	142 (192)	—
M16 x 2.00	85 (115)	148 (200)	210 (285)	—
M16 x 1.50	104 (141)	155 (210)	218 (295)	—
M18 x 2.50	114 (155)	203 (275)	288 (390)	—
M18 x 1.50	145 (196)	225 (305)	315 (425)	—

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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)

M8-1.25 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

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Appendix E Common Hardware List

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

American Standard

Hex Head Bolts (Grade 5)

Part No.	Dimensions
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

Hex Head Bolts, cont.

Part No.	Dimensions
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

Hex Nuts

Part No.	Dimensions	Type
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		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

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Metric

Hex head bolts are hardness grade 8.8 unless noted.

Hex Head Bolts (partial thread)

Part No.	Dimensions
M931-06040-60	M6-1.00 x 40
M931-06055-60	M6-1.00 x 55
M931-06060-60	M6-1.00 x 60
M931-06070-60	M6-1.00 x 70
M931-06075-60	M6-1.00 x 75
M931-06090-60	M6-1.00 x 90
M931-08035-60	M8-1.25 x 35
M931-08040-60	M8-1.25 x 40
M931-08040-82	M8-1.25 x 40*
M931-08045-60	M8-1.25 x 45
M931-08050-60	M8-1.25 x 50
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
M931-10040-60	M10-1.50 x 40
M931-10045-60	M10-1.50 x 45
M931-10050-60	M10-1.50 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
M931-10090-60	M10-1.50 x 90
M931-10100-60	M10-1.50 x 100
M931-12045-60	M12-1.75 x 45
M931-12050-60	M12-1.75 x 50
M931-12055-60	M12-1.75 x 55
M931-12060-60	M12-1.75 x 60
M931-12065-60	M12-1.75 x 65
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
M931-16090-60	M16-2.00 x 90
M931-20065-60	M20-2.50 x 65
M931-20120-60	M20-2.50 x 120
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

Hex Head Bolts (full thread)

Part No.	Dimensions
M933-04006-60	M4-0.70 x 6
M933-05050-60	M5-0.80 x 50
M933-06010-60	M6-1.00 x 10
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
M933-06040-60	M6-1.00 x 40
M933-06050-60	M6-1.00 x 50
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
M933-10012-60	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
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
M933-12016-60	M12-1.75 x 16
M933-12020-60	M12-1.75 x 20
M933-12025-60	M12-1.75 x 25
M933-12025-82	M12-1.75 x 25*
M933-12030-60	M12-1.75 x 30
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
M961-16025-60	M16-1.50 x 25
M933-16025-60	M16-2.00 x 25
M933-16030-82	M16-2.00 x 30*
M933-16035-60	M16-2.00 x 35
M933-16040-60	M16-2.00 x 40
M933-16050-60	M16-2.00 x 50
M933-16050-82	M16-2.00 x 50*
M933-16060-60	M16-2.00 x 60
M933-18050-60	M18-2.50 x 50
M933-18060-60	M18-2.50 x 60

Pan Head Machine Screws

M7985A-03010-20	M3-0.50 x 10
M7985A-03012-20	M3-0.50 x 12
M7985A-04020-20	M4-0.70 x 20
M7985A-05010-20	M5-0.80 x 10
M7985A-05012-20	M5-0.80 x 12

Flat Head Machine Screws

M965A-05016-20	M5-0.80 x 16

Hex Nuts

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

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 bolt's hardness is grade 10.9.

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