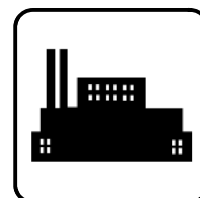


# Service

## Industrial Generator Sets



Models:

**20–200 kW**

Alternators:

Fast-Response™ X  
(Permanent Magnet Alternator)

4P\_X

4Q\_X

4R\_X

4S\_X

4T\_X

**KOHLER®**  
POWER SYSTEMS

**9001**  
**KOHLER**  
POWER SYSTEMS  
NATIONALLY REGISTERED

TP-6783 12/11a

---

## California Proposition 65

### **WARNING**

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

---

## Product Identification Information

---

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

### Generator Set Identification Numbers

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

Model Designation \_\_\_\_\_

Specification Number \_\_\_\_\_

Serial Number \_\_\_\_\_

| Accessory Number | Accessory Description |
|------------------|-----------------------|
|------------------|-----------------------|

|       |       |
|-------|-------|
| _____ | _____ |
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| _____ | _____ |
| _____ | _____ |
| _____ | _____ |

### Controller Identification

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

Controller Description \_\_\_\_\_

### Engine Identification

Record the product identification information from the engine nameplate.

Manufacturer \_\_\_\_\_

Model Designation \_\_\_\_\_

Serial Number \_\_\_\_\_

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## Notes

# Safety Precautions and Instructions

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

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

## DANGER

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

## WARNING

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

## CAUTION

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

## NOTICE

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

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

## Accidental Starting

### WARNING



**Accidental starting.  
Can cause severe injury or death.**

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

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

**(Decision-Maker® 550)**

**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) Press the generator set off/reset button to shut down the generator set. (2) Disconnect the power to the battery charger, if equipped. (3) Remove the battery cables, negative (-) lead first. Reconnect the negative (-) lead last when reconnecting the battery. Follow these precautions to prevent the starting of the generator set by the remote start/stop switch.

**(Decision-Maker® 3000 and 6000)**

## Battery

### WARNING



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

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

### WARNING



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

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

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

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

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

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

## Engine Backfire/Flash Fire

|                                                                                                                                                 |
|-------------------------------------------------------------------------------------------------------------------------------------------------|
|  <b>WARNING</b>                                                |
|                                                                |
| <p><b>Fire.</b><br/> <b>Can cause severe injury or death.</b></p> <p>Do not smoke or permit flames or sparks near fuels or the fuel system.</p> |

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

### (Gas-fueled model)

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

### (Diesel-fueled model)

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

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

## Exhaust System

|                                                                                                                                                              |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------|
|  <b>WARNING</b>                                                           |
|                                                                           |
| <p><b>Carbon monoxide.</b><br/> <b>Can cause severe nausea, fainting, or death.</b></p> <p>The exhaust system must be leakproof and routinely inspected.</p> |

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

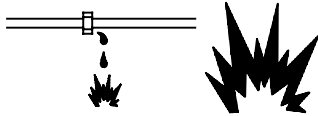
**Carbon monoxide symptoms. Carbon monoxide can cause severe nausea, fainting, or death.** Carbon monoxide is a poisonous gas present in exhaust gases. Carbon monoxide is an odorless, colorless, tasteless, nonirritating gas that can cause death if inhaled for even a short time. Carbon monoxide poisoning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

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

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

## Fuel System

### WARNING



**Explosive fuel vapors.**  
**Can cause severe injury or death.**

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

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

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

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

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

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

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

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

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

## Hazardous Noise

### CAUTION



**Hazardous noise.**  
**Can cause hearing loss.**

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

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

## Hazardous Voltage/ Moving Parts

### DANGER



**Hazardous voltage.**  
**Will cause severe injury or death.**

Disconnect all power sources before opening the enclosure.

### WARNING



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

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

### WARNING



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

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

### CAUTION



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

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

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

**Disconnecting the electrical load. Hazardous voltage can cause severe injury or death.** Disconnect the generator set from the load by turning off 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.

**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.

**Testing the photo transistor circuit board. Hazardous voltage can cause severe injury or death.** When the end cover is removed, do not expose the photo transistor circuit board mounted on the generator set end bracket to any external light source, as exposure to light causes high voltage. Keep foreign sources of light away from the photo transistor circuit board during testing. Place black electrical tape over the LED on the circuit board before starting the generator set.

**Installing the photo transistor circuit board. Hazardous voltage can cause severe injury or death.** Ensure that the foil side of the photo transistor circuit board, the end of the shaft, and the threaded holes are clean and free of metal particles and chips. Metal debris may short-circuit the photo transistor circuit board and cause hazardous voltage in the generator set. Do not reconnect the generator set to the load until the AC voltmeter shows the correct output.

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

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

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

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

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

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

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

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

---

## **⚠ WARNING**



**Airborne particles. Can cause severe injury or blindness.**

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

---

## Heavy Equipment

|                                                                                                                                                                                                                                        |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>⚠ WARNING</b>                                                                                                                                                                                                                       |
|                                                                                                                                                       |
| <p><b>Unbalanced weight. Improper lifting can cause severe injury or death and equipment damage.</b></p> <p>Do not use lifting eyes.<br/>Lift the generator set using lifting bars inserted through the lifting holes on the skid.</p> |

## Hot Parts

|                                                                                                                                                                                                                |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>⚠ WARNING</b>                                                                                                                                                                                               |
|                                                                                                                               |
| <p><b>Hot coolant and steam. Can cause severe injury or death.</b></p> <p>Before removing the pressure cap, stop the generator set and allow it to cool. Then loosen the pressure cap to relieve pressure.</p> |

|                                                                                                                                        |
|----------------------------------------------------------------------------------------------------------------------------------------|
| <b>⚠ WARNING</b>                                                                                                                       |
|                                                       |
| <p><b>Hot engine and exhaust system. Can cause severe injury or death.</b></p> <p>Do not work on the generator set until it cools.</p> |

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

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

## Notice

|                                                                                                                                                                                                                                 |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>NOTICE</b>                                                                                                                                                                                                                   |
| <p>This generator set has been rewired from its nameplate voltage to</p> <div style="border: 1px solid black; height: 40px; width: 150px; margin: 10px auto;"></div> <p style="text-align: right; font-size: small;">246242</p> |

### 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

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

## Notes

This manual provides troubleshooting and repair instructions for the generator set models listed on the front cover using permanent magnet alternators.

Wiring diagram manuals are available separately.

Refer to the generator set controller operation manual for operating instructions. Refer to the engine operation manual for generator set engine scheduled maintenance information. Refer to the engine service manual for generator set engine repair and overhaul information.

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.

## List of Related Materials

Separate literature contains voltage regulator setup information not provided in this manual. Figure 1 lists the available literature part numbers.

| Manual Description                                          | Literature Part No. |
|-------------------------------------------------------------|---------------------|
| Decision-Maker® 550 Controller Operation Manual             | TP-6200             |
| Decision-Maker® 550 Controller Setup and Application Manual | TP-6140             |
| Decision-Maker® 3000 Controller Operation Manual            | TP-6694             |
| Decision-Maker® 6000 Controller Operation Manual            | TP-6750             |
| Controller Service Manual                                   | TP-6356             |

**Figure 1** Related Literature

# Service Assistance

---

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

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

## **Headquarters Europe, Middle East, Africa (EMEA)**

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## **Asia Pacific**

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

## **China**

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

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

## **India, Bangladesh, Sri Lanka**

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

## **Japan, Korea**

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

## **Latin America**

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

### 1.1 Introduction

The specification sheets for each generator set provide specific alternator and engine information. Refer to the respective specification sheet for data not supplied in this manual. Consult the generator set operation manual, installation manual, engine operation manual, and engine service manual for additional specifications.

A permanent magnet alternator is identified with one of the following designations: 4P\_X, 4Q\_X, 4R\_X, 4S\_X, or 4T\_X. Example: Gen. Model 4S12X. The first alpha character (S) identifies the alternator family and the last character (X) denotes the Fast-Response™ X alternator.

The generator set has a rotating-field alternator with a smaller rotating-armature alternator turned by a common shaft. The main rotating-field alternator supplies current to load circuits while the rotating-armature (exciter) alternator supplies DC to excite the main alternator's field.

The generator set has a 4-pole, rotating-field with brushless, permanent magnet alternator excitation system. The PM system provides short-circuit excitation current up to 300% at 60 Hz (approximately 275% at 50 Hz) for a minimum of 10 seconds to allow selective circuit breaker tripping.

Voltage regulation is provided by the generator set controller. Refer to the respective Controller Operation Manual and Controller Service Manual for additional voltage regulator information.

### 1.2 20-200 kW/25-250 kVA Permanent Magnet Alternator Concept

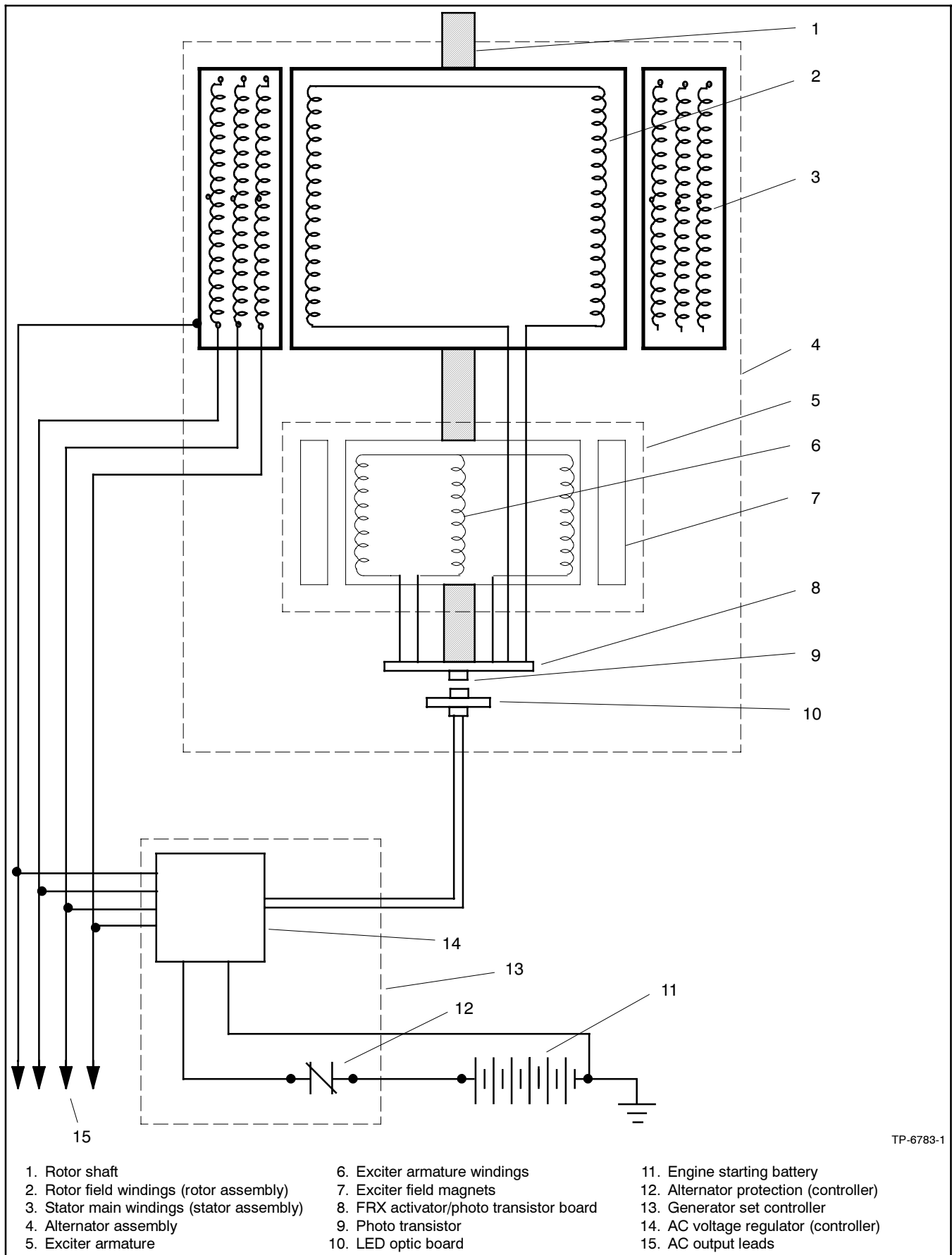
The alternator excitation system uses a permanent, rare-earth magnet exciter with a silicon controlled rectifier (SCR) assembly which controls the amount of DC current fed to the alternator field. This type of system uses a controller voltage regulator which signals the SCR assembly through an optical coupling. The controller voltage regulator monitors engine speed and alternator output voltage to turn a stationary light emitting diode (LED) on or off, according to engine speed and output voltage. The LED is mounted on the end bracket opposite a photo transistor board which rotates on the shaft. The photo transistor picks up the signal from the LED and tells the SCR assembly to turn on or off, depending upon the need, as dictated by the controller voltage regulator. See Figure 1-1.

The voltage recovery period of this type of alternator is several times faster than the conventionally wound field brushless alternator because it does not have to contend with the inductance of the exciter field. It also has better recovery characteristics than the static excited machine because it is not dependent upon the generator set output voltage for excitation power. Possibly the greatest advantage of this type machine is its inherent ability to support short-circuit current and allow system coordination for tripping downstream branch circuit breakers.

The alternator system delivers exciter current to the main field within 0.05 seconds of a change in load demand.

### 1.3 Short Circuit Performance

When a short circuit occurs in the load circuit(s) being served, output voltage drops and amperage momentarily rises to 600%-1000% of the generator set's rated current until the short is removed. The SCR assembly sends full exciter power to the main field. The alternator then sustains up to 300% of its rated current. Sustained high current will cause correspondingly rated load circuit fuses/breakers to trip. The *controller alternator protection* feature serves to collapse the alternator's main field in the event of a sustained heavy overload or short circuit.



**Figure 1-1** Alternator Schematic

## 1.4 Electrical Values

| Alternator Models->                    | 4P4X/4Q4X                       | 4P5X/4Q5X | 4P7BX/4Q7BX | 4P8X/4Q8X | 4P10X/4Q10X |
|----------------------------------------|---------------------------------|-----------|-------------|-----------|-------------|
| Component Specification                | Cold Resistance Value (in ohms) |           |             |           |             |
| Stator windings, 12 lead 4PX           | 0.134                           | 0.101     | 0.069       | 0.047     | 0.035       |
| Stator windings, 6 lead (600 volt) 4PX | 0.219                           | 0.149     | 0.118       | 0.088     | 0.055       |
| Stator windings, 4 lead (1 PH) 4QX     | 0.049                           | 0.034     | 0.025       | 0.024     | 0.016       |
| Rotor windings                         | 4.20                            | 4.83      | 5.65        | 6.08      | 6.84        |
| Exciter armature windings              | 0.9                             | 0.9       | 0.8         | 0.8       | 0.8         |

| Alternator Models->                | 4R9X/4T9X                       | 4R12X/4T12X | 4R13X/4T13X | 4S12X | 4S13X |
|------------------------------------|---------------------------------|-------------|-------------|-------|-------|
| Component Specification            | Cold Resistance Value (in ohms) |             |             |       |       |
| Stator windings, 12 lead           | 0.033                           | 0.020       | 0.017       | 0.018 | 0.015 |
| Stator windings, 6 lead (600 volt) | 0.110                           | 0.076       | 0.043       | 0.070 | 0.059 |
| Stator windings, 4 lead (1 PH) 4TX | 0.040                           | 0.026       | 0.022       | —     | —     |
| Rotor windings                     | 4.93                            | 5.88        | 6.37        | 4.50  | 4.80  |
| Exciter armature windings          | 0.5                             | 0.5         | 0.5         | 0.4   | 0.4   |

## 1.5 Torque Values and Assembly Specifications

Use the torque values shown below during alternator assembly. For assembly torque values not shown, use the guidelines in Appendix C, General Torque Specifications.

| Alternator Models->                                         | 4PX, 4QX                                                                     | 4RX, 4TX                    | 4SX                    |
|-------------------------------------------------------------|------------------------------------------------------------------------------|-----------------------------|------------------------|
| Component Specification                                     | Torque Value                                                                 |                             |                        |
| LED optic board holder to end bracket screws                | 6.2 Nm (4.6 ft. lb.)                                                         |                             |                        |
| End bracket to stator assembly bolts                        | 45 Nm (34 ft. lb.)                                                           |                             |                        |
| Generator adapter to stator assembly bolts                  | 45 Nm (34 ft. lb.)                                                           |                             |                        |
| Alternator fan to rotor assembly bolts                      | 26.4 Nm (19.5 ft. lb.)                                                       |                             |                        |
| Drive discs to rotor assembly bolts                         | 65 Nm (48 ft. lb.)                                                           |                             | 115 Nm (85 ft. lb.)    |
| Ground lug to stator assembly bolts                         | 9.5 Nm (7.0 ft. lb.)                                                         | 22.7 Nm (16.8 ft. lb.)      | 45.0 Nm (34.0 ft. lb.) |
| Exciter armature to rotor assembly bolt                     | 194 Nm (43 ft. lb.)                                                          |                             |                        |
| Ground lead to ground stud M6 bolt                          | 4PX: 9.5 Nm (7.0 ft. lb.)                                                    | —                           | —                      |
| Ground lead to ground stud M8 bolt                          | 4QX: 22.7 Nm (16.8 ft. lb.)                                                  | 4RX: 22.7 Nm (16.8 ft. lb.) | —                      |
| Ground lead to ground stud M10 bolt                         | —                                                                            | 4TX: 45 Nm (34 ft. lb.)     | 45 Nm (34 ft. lb.)     |
| Activator board hex nuts                                    | 1.3 Nm (12 in. lb.)                                                          |                             |                        |
| Exciter armature leads to activator board elastic stop nuts | 1.3 Nm (12 in. lb.)                                                          |                             |                        |
| Rotor shaft bearing location                                | Tight with rotor shaft shoulder at approx. 85.7 mm (3.37 in.) from shaft end |                             |                        |
| End bracket to bearing outer race clearance                 | 6.35 mm (0.25 in.)                                                           |                             |                        |
| Alternator adapter to flywheel housing bolts                | See chart following                                                          |                             |                        |
| Drive discs to flywheel bolts                               | See chart following                                                          |                             |                        |

## 1.6 Alternator Adapter to Flywheel Housing Torque Values

| Model      | Engine     | Alternator | Hardware Type,        | Torque,<br>Nm (ft. lb.) | Hardware<br>Sequence  |
|------------|------------|------------|-----------------------|-------------------------|-----------------------|
| 50-80 kW   | GM         | 4PX, 4QX   | 3/8-16, grade 8 bolt  | 53 (39)                 | Bolt, hardened washer |
| 50-80 kW   | John Deere |            | 3/8-16, grade 8 bolt  | 53 (39)                 |                       |
|            |            |            | M10, grade 10.9 bolt  |                         |                       |
| 100-150 kW | GM         | 4RX, 4TX   | 3/8-16 grade 8 bolt   | 53 (39)                 |                       |
| 100-150 kW | John Deere |            | 3/8-16 grade 8 bolt   | 53 (39)                 |                       |
|            |            |            | 7/16-14, grade 8 bolt | 60 (44)                 |                       |
|            |            |            | M10, grade 10.9 bolt  | 65 (48)                 |                       |
| 180/200 kW | John Deere | 4SX        | 3/8-16, grade 8 bolt  | 53 (39)                 |                       |
|            |            |            | 7/16-14, grade 8 bolt | 85 (63)                 |                       |
|            |            |            | M10, grade 10.9 bolt  | 65 (48)                 |                       |

## 1.7 Drive Discs to Flywheel Torque Values

| Model                    | Engine           | Alt.        | Hardware<br>Type,    | Torque,<br>Nm (ft. lb.) | Hardware<br>Sequence               |
|--------------------------|------------------|-------------|----------------------|-------------------------|------------------------------------|
| 50-80 kW<br>50-80 kW     | GM<br>John Deere | 4PX,<br>4QX | 3/8-16, grade 8 stud | 53 (39)                 | Stud, spacer, hardened washer, nut |
| 100-150 kW<br>100-150 kW | GM<br>John Deere | 4RX,<br>4TX | 3/8-16, grade 8 stud | 53 (39)                 |                                    |
| 180/200 kW               | John Deere       | 4SX         | 1/2-13, grade 8 bolt | 130 (96)                | Bolt, hardened washer              |

## Section 2 Troubleshooting

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This section contains generator set troubleshooting, diagnostic, and repair information.

Use the chart on the following page to diagnose and correct common problems. First check for simple causes such as a dead engine starting battery or an open circuit breaker. The chart includes a list of common problems, possible causes of the problem, recommended corrective actions, and references to detailed information or repair procedures.

Maintain a record of repairs and adjustments performed on the equipment. If the procedures in this manual do not explain how to correct the problem, contact an authorized distributor/dealer. Use the record to help describe the problem and repairs or adjustments made to the equipment.

| Trouble Symptoms                                                                                                                                                                                                                                                                                      |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                    | Probable Causes                                     | Recommended Actions                                                                                                                   | Section or Publication Reference* |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|-------------|--------------------------|----------------|-------------|-----------|------------------|-----------------------|-----------------------------|---------------------------------|----------------------------------------------------|-----------------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------|-----------------------------------|
| Does not crank                                                                                                                                                                                                                                                                                        | Cranks but does not start | Starts hard | No or low output voltage | Stops suddenly | Lacks power | Overheats | Low oil pressure | High fuel consumption | Excessive or abnormal noise | Displays error message/locks up | Exercise run time and/or event records inoperative |                                                     |                                                                                                                                       |                                   |
| Alternator (FR-X)                                                                                                                                                                                                                                                                                     |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                    |                                                     |                                                                                                                                       |                                   |
|                                                                                                                                                                                                                                                                                                       |                           |             | x                        |                |             |           |                  |                       |                             |                                 |                                                    | AC output circuit breaker open                      | Reset the breaker and check for AC voltage at the generator set side of the circuit breaker.                                          | —                                 |
| x                                                                                                                                                                                                                                                                                                     |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                    | Transfer switch test switch in the OFF position     | Move the transfer switch test switch to the AUTO position.                                                                            | ATS O/M                           |
|                                                                                                                                                                                                                                                                                                       |                           |             | x                        |                |             |           |                  |                       |                             |                                 |                                                    | Transfer switch fails to transfer load              | Move the ATS test switch to the AUTO position. Troubleshoot the transfer circuit and time delays.                                     | ATS O/M, S/M                      |
|                                                                                                                                                                                                                                                                                                       |                           |             | x                        |                |             |           |                  |                       |                             |                                 |                                                    | Wiring, terminals, or pin in the exciter field open | Check for continuity.                                                                                                                 | Gen. S/M, W/D                     |
|                                                                                                                                                                                                                                                                                                       |                           |             | x                        |                |             |           |                  |                       |                             |                                 |                                                    | Main field (rotor) inoperative (open or grounded)   | Test and/or replace the rotor.†                                                                                                       | Gen. S/M                          |
|                                                                                                                                                                                                                                                                                                       |                           |             | x                        |                |             |           |                  |                       |                             |                                 |                                                    | Stator inoperative (open or grounded)               | Test and/or replace the stator.†                                                                                                      | Gen. S/M                          |
|                                                                                                                                                                                                                                                                                                       |                           |             |                          |                |             |           |                  |                       | x                           |                                 |                                                    | Vibration excessive                                 | Tighten loose components.†                                                                                                            | —                                 |
|                                                                                                                                                                                                                                                                                                       |                           |             | x                        |                |             |           |                  |                       |                             |                                 |                                                    | Voltage regulator digital settings incorrect        | Adjust the voltage regulator.                                                                                                         | Gen. O/M, S/M                     |
| Controller (Decision-Maker® 550)                                                                                                                                                                                                                                                                      |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                    |                                                     |                                                                                                                                       |                                   |
| x                                                                                                                                                                                                                                                                                                     | x                         |             |                          |                |             |           |                  |                       |                             |                                 |                                                    | Controller circuit board(s) inoperative             | Replace the controller circuit board.                                                                                                 | Gen. S/M                          |
|                                                                                                                                                                                                                                                                                                       |                           |             |                          | x              |             |           |                  |                       |                             |                                 |                                                    | Controller fault                                    | Troubleshoot the controller.†                                                                                                         | Gen. S/M                          |
| x                                                                                                                                                                                                                                                                                                     | x                         |             |                          | x              |             |           |                  |                       |                             |                                 |                                                    | Controller fuse blown                               | Replace the blown controller fuse. If the fuse blows again, troubleshoot the controller.†                                             | Gen. O/M, W/D                     |
| x                                                                                                                                                                                                                                                                                                     |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                    | Controller master switch inoperative                | Replace the controller master switch.                                                                                                 | —                                 |
| x                                                                                                                                                                                                                                                                                                     |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                    | Controller master switch in the OFF/RESET position  | Move the controller master switch to the RUN or AUTO position.                                                                        | Gen. O/M                          |
| x                                                                                                                                                                                                                                                                                                     |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                    | Engine start circuit open                           | Move the controller master switch to the RUN position to test the generator set. Troubleshoot the auto start circuit and time delays. | Gen. O/M, W/D, ATS O/M, S/M       |
|                                                                                                                                                                                                                                                                                                       |                           |             | x                        | x              |             |           |                  |                       |                             |                                 |                                                    | Voltage regulation inoperative                      | Replace the controller fuse, if the fuse blows again, troubleshoot the controller.                                                    | Gen. O/M, Gen. S/M                |
|                                                                                                                                                                                                                                                                                                       |                           |             |                          |                |             |           |                  |                       |                             | x                               |                                                    | Controller firmware error                           | Review the controller display troubleshooting chart.                                                                                  | Gen. O/M                          |
|                                                                                                                                                                                                                                                                                                       |                           |             |                          |                |             |           |                  |                       |                             |                                 | x                                                  | Controller clock not set                            | Reset time and date.                                                                                                                  | Gen. O/M                          |
| * Sec./Section—numbered section of this manual; ATS—Automatic Transfer Switch; Eng.—Engine; Gen.—Generator Set; I/M—Installation Manual; O/M—Operation Manual; S/M—Service Manual; S/S—Spec Sheet; W/D—Wiring Diagram Manual<br>† Have an authorized service distributor/dealer perform this service. |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                    |                                                     |                                                                                                                                       |                                   |

| Trouble Symptoms                  |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                    | Probable Causes                                        |                                                                                                                                | Recommended Actions         | Section or Publication Reference* |
|-----------------------------------|---------------------------|-------------|--------------------------|----------------|-------------|-----------|------------------|-----------------------|-----------------------------|---------------------------------|----------------------------------------------------|--------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|-----------------------------|-----------------------------------|
| Does not crank                    | Cranks but does not start | Starts hard | No or low output voltage | Stops suddenly | Lacks power | Overheats | Low oil pressure | High fuel consumption | Excessive or abnormal noise | Displays error message/locks up | Exercise run time and/or event records inoperative |                                                        |                                                                                                                                |                             |                                   |
| Controller (Decision-Maker® 3000) |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                    |                                                        |                                                                                                                                |                             |                                   |
| x                                 | x                         |             |                          |                |             |           |                  |                       |                             |                                 |                                                    | Controller circuit board(s) inoperative                | Replace the controller.                                                                                                        | Gen. S/M                    |                                   |
| x                                 | x                         |             |                          |                |             |           |                  |                       |                             |                                 |                                                    | Controller circuit board(s) wiring fault               | Check the wiring.                                                                                                              | W/D                         |                                   |
|                                   |                           |             |                          | x              |             |           |                  |                       |                             |                                 |                                                    | Controller fault                                       | Troubleshoot the controller.†                                                                                                  | Gen. S/M                    |                                   |
| x                                 | x                         |             |                          | x              |             |           |                  |                       |                             |                                 |                                                    | Controller fuse blown                                  | Check for continuity across fuse. If fuse is blown, troubleshoot the controller wiring and replace circuit board.†             | Gen. O/M, W/D               |                                   |
| x                                 |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                    | Controller master control buttons inoperative          | Replace the controller master control button circuit board.                                                                    | —                           |                                   |
| x                                 |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                    | Controller master control button in the OFF/RESET mode | Press the controller master control RUN or AUTO button.                                                                        | Gen. O/M                    |                                   |
| x                                 |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                    | Engine start circuit open                              | Press the controller master control RUN button to test the generator set. Troubleshoot the auto start circuit and time delays. | Gen. O/M, W/D, ATS O/M, S/M |                                   |
|                                   |                           |             | x                        | x              |             |           |                  |                       |                             |                                 |                                                    | Voltage regulation inoperative                         | Replace the junction box sensing fuses. If the fuse blows again, troubleshoot the controller.                                  | W/D, Gen. S/M               |                                   |
|                                   |                           |             |                          |                |             |           |                  |                       |                             | x                               |                                                    | Controller firmware error                              | Review the controller display troubleshooting chart.                                                                           | Gen. O/M                    |                                   |
| Controller (Decision-Maker® 6000) |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                    |                                                        |                                                                                                                                |                             |                                   |
| x                                 | x                         |             |                          |                |             |           |                  |                       |                             |                                 |                                                    | Controller circuit board(s) inoperative                | Replace the controller circuit board.                                                                                          | Gen. S/M                    |                                   |
|                                   |                           |             |                          | x              |             |           |                  |                       |                             |                                 |                                                    | Controller fault                                       | Troubleshoot the controller.†                                                                                                  | Gen. S/M                    |                                   |
| x                                 | x                         |             |                          | x              |             |           |                  |                       |                             |                                 |                                                    | Controller fuse blown                                  | Replace the blown controller fuse. If the fuse blows again, troubleshoot the controller.†                                      | Gen. O/M, W/D               |                                   |
| x                                 |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                    | Controller master control buttons inoperative          | Replace the controller master switch.                                                                                          | —                           |                                   |
| x                                 |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                    | Controller master control button in the OFF/RESET mode | Press the controller master control RUN or AUTO button.                                                                        | Gen. O/M                    |                                   |
| x                                 |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                    | Engine start circuit open                              | Press the controller master control RUN button to test the generator set. Troubleshoot the auto start circuit and time delays. | Gen. O/M, W/D, ATS O/M, S/M |                                   |
|                                   |                           |             | x                        | x              |             |           |                  |                       |                             |                                 |                                                    | Voltage regulation inoperative                         | Replace the controller fuse. If the fuse blows again, troubleshoot the controller.                                             | Gen. O/M, Gen. S/M          |                                   |
|                                   |                           |             |                          |                |             |           |                  |                       |                             | x                               |                                                    | Controller firmware error                              | Review the controller display troubleshooting chart.                                                                           | Gen. O/M                    |                                   |
|                                   |                           |             |                          |                |             |           |                  |                       |                             |                                 | x                                                  | Controller clock not set                               | Reset time and date.                                                                                                           | Gen. O/M                    |                                   |

\* Sec./Section—numbered section of this manual; ATS—Automatic Transfer Switch; Eng.—Engine; Gen.—Generator Set; I/M—Installation Manual; O/M—Operation Manual; S/M—Service Manual; S/S—Spec Sheet; W/D—Wiring Diagram Manual

† Have an authorized service distributor/dealer perform this service.

\* Sec./Section—numbered section of this manual; ATS—Automatic Transfer Switch; Eng.—Engine; Gen.—Generator Set; I/M—Installation Manual; O/M—Operation Manual;

S/M—Service Manual; S/S—Spec Sheet; W/D—Wiring Diagram Manual

† Have an authorized service distributor/dealer perform this service.

| Trouble Symptoms                                                                                                                                                                                                             |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                    | Probable Causes                                   | Recommended Actions                                                                      | Section or Publication Reference* |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------------------|-------------|--------------------------|----------------|-------------|-----------|------------------|-----------------------|-----------------------------|---------------------------------|----------------------------------------------------|---------------------------------------------------|------------------------------------------------------------------------------------------|-----------------------------------|
| Does not crank                                                                                                                                                                                                               | Cranks but does not start | Starts hard | No or low output voltage | Stops suddenly | Lacks power | Overheats | Low oil pressure | High fuel consumption | Excessive or abnormal noise | Displays error message/locks up | Exercise run time and/or event records inoperative |                                                   |                                                                                          |                                   |
| Electrical System (DC Circuits)                                                                                                                                                                                              |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                    |                                                   |                                                                                          |                                   |
| x                                                                                                                                                                                                                            | x                         |             |                          |                |             |           |                  |                       |                             |                                 |                                                    | Battery connections loose, corroded, or incorrect | Verify that the battery connections are correct, clean, and tight.                       | Gen. O/M                          |
| x                                                                                                                                                                                                                            | x                         |             |                          |                |             |           |                  |                       |                             |                                 |                                                    | Battery weak or dead                              | Recharge or replace the battery. The spec sheet provides recommended battery CCA rating. | Gen. O/M, S/S                     |
| x                                                                                                                                                                                                                            | x                         |             |                          |                |             |           |                  |                       |                             |                                 |                                                    | Starter/starter solenoid inoperative              | Replace the starter or starter solenoid.                                                 | Eng. S/M                          |
| x                                                                                                                                                                                                                            |                           |             |                          | x              |             |           |                  |                       |                             |                                 |                                                    | Engine harness connector(s) not locked tight      | Disconnect the engine harness connector(s) then reconnect it to the controller.          | W/D                               |
|                                                                                                                                                                                                                              |                           |             |                          | x              |             |           |                  |                       |                             |                                 |                                                    | High water temperature switch inoperative         | Replace the inoperative switch.                                                          | Gen. S/M, W/D                     |
|                                                                                                                                                                                                                              |                           |             |                          | x              |             |           |                  |                       |                             |                                 |                                                    | Fault shutdown                                    | Reset the fault switches and troubleshoot the controller.                                | Gen. O/M                          |
|                                                                                                                                                                                                                              |                           |             |                          | x              |             |           |                  |                       |                             |                                 |                                                    | High exhaust temperature switch inoperative       | Replace the inoperative switch.                                                          | Gen. S/M, W/D                     |
| Engine                                                                                                                                                                                                                       |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                    |                                                   |                                                                                          |                                   |
|                                                                                                                                                                                                                              | x                         | x           |                          |                | x           |           |                  | x                     |                             |                                 |                                                    | Air cleaner clogged                               | Clean or replace the filter element.                                                     | Eng. O/M                          |
|                                                                                                                                                                                                                              | x                         | x           |                          |                |             | x         |                  | x                     | x                           |                                 |                                                    | Compression weak                                  | Check the compression.†                                                                  | Eng. S/M                          |
|                                                                                                                                                                                                                              |                           |             | x                        |                | x           | x         |                  | x                     | x                           |                                 |                                                    | Engine overload                                   | Reduce the electrical load. See the generator set spec sheet for wattage specifications. | S/S                               |
|                                                                                                                                                                                                                              |                           |             |                          |                |             |           |                  |                       | x                           |                                 |                                                    | Exhaust system leak                               | Inspect the exhaust system. Replace the inoperative exhaust system components.†          | I/M                               |
|                                                                                                                                                                                                                              |                           |             |                          |                |             |           |                  |                       | x                           |                                 |                                                    | Exhaust system not securely installed             | Inspect the exhaust system. Tighten the loose exhaust system components.†                | I/M                               |
|                                                                                                                                                                                                                              |                           | x           | x                        | x              | x           |           |                  | x                     |                             |                                 |                                                    | Governor inoperative                              | Adjust the governor.†                                                                    | Gen. S/M                          |
|                                                                                                                                                                                                                              |                           |             |                          | x              | x           |           |                  |                       | x                           |                                 |                                                    | Valve clearance incorrect                         | Adjust the valves.†                                                                      | Eng. S/M                          |
|                                                                                                                                                                                                                              |                           |             |                          |                |             |           |                  |                       | x                           |                                 |                                                    | Vibration excessive                               | Tighten all loose hardware.                                                              | —                                 |
|                                                                                                                                                                                                                              | x                         | x           |                          |                | x           |           |                  |                       |                             |                                 |                                                    | Ignition system inoperative (gas only)            | Check the ignition system (spark plugs, spark plug wires, etc.).                         | Eng. O/M, S/M                     |
| * Sec./Section—numbered section of this manual; ATS—Automatic Transfer Switch; Eng.—Engine; Gen.—Generator Set; I/M—Installation Manual; O/M—Operation Manual; S/M—Service Manual; S/S—Spec Sheet; W/D—Wiring Diagram Manual |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                    |                                                   |                                                                                          |                                   |
| † Have an authorized service distributor/dealer perform this service.                                                                                                                                                        |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                    |                                                   |                                                                                          |                                   |

| Trouble Symptoms |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                                       | Probable Causes                                                              | Recommended Actions  | Section or Publication Reference* |
|------------------|---------------------------|-------------|--------------------------|----------------|-------------|-----------|------------------|-----------------------|-----------------------------|---------------------------------|-----------------------------------------------------------------------|------------------------------------------------------------------------------|----------------------|-----------------------------------|
| Does not crank   | Cranks but does not start | Starts hard | No or low output voltage | Stops suddenly | Lacks power | Overheats | Low oil pressure | High fuel consumption | Excessive or abnormal noise | Displays error message/locks up | Exercise run time and/or event records inoperative                    |                                                                              |                      |                                   |
| Cooling System   |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                                       |                                                                              |                      |                                   |
|                  |                           |             |                          |                |             | x         |                  | x                     |                             |                                 | Air openings clogged                                                  | Clean the air openings.                                                      | —                    |                                   |
|                  |                           |             |                          |                |             | x         |                  |                       |                             |                                 | Coolant level low                                                     | Restore the coolant to normal operating level.                               | Engine O/M, Gen. O/M |                                   |
|                  |                           |             |                          |                |             | x         |                  |                       |                             |                                 | Cooling water pump inoperative                                        | Tighten or replace the belt. Replace the water pump.                         | Eng. O/M, S/M        |                                   |
|                  |                           |             |                          | x              |             |           |                  |                       |                             |                                 | High temperature shutdown                                             | Allow the engine to cool down. Then troubleshoot the cooling system.         | Gen. O/M, Eng. O/M   |                                   |
|                  |                           |             |                          | x              |             |           |                  |                       |                             |                                 | Low coolant level shutdown, if equipped                               | Restore the coolant to normal operating level.                               | Gen. O/M             |                                   |
|                  |                           |             |                          |                | x           |           |                  |                       |                             |                                 | Thermostat inoperative                                                | Replace the thermostat.                                                      | Eng. S/M             |                                   |
| Fuel System      |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                                       |                                                                              |                      |                                   |
|                  | x                         | x           |                          |                |             | x         |                  |                       |                             |                                 | Air in fuel system (diesel only)                                      | Bleed the diesel fuel system.                                                | Eng. O/M             |                                   |
|                  | x                         | x           |                          |                |             |           |                  |                       |                             |                                 | Ether canister empty or system inoperative, if equipped (diesel only) | Replace or repair the ether starting system.                                 | Eng. O/M             |                                   |
|                  | x                         |             |                          |                | x           |           |                  |                       |                             |                                 | Fuel tank empty or fuel valve shut off                                | Add fuel and move the fuel valve to the ON position.                         | —                    |                                   |
|                  | x                         |             |                          |                | x           |           |                  | x                     |                             |                                 | Fuel feed or injection pump inoperative (diesel only)                 | Rebuild or replace the injection pump.†                                      | Eng. S/M             |                                   |
|                  | x                         | x           |                          |                | x           |           |                  |                       |                             |                                 | Fuel or fuel injectors dirty or faulty (diesel only)                  | Clean, test, and/or replace the inoperative fuel injector.†                  | Eng. S/M             |                                   |
|                  | x                         | x           |                          |                | x           |           |                  |                       |                             |                                 | Fuel filter restriction                                               | Clean or replace the fuel filter.                                            | Eng. O/M             |                                   |
|                  | x                         |             |                          |                |             |           |                  |                       |                             |                                 | Fuel solenoid inoperative                                             | Troubleshoot the fuel solenoid.†                                             | Eng. S/M             |                                   |
|                  | x                         |             |                          |                | x           |           |                  |                       |                             |                                 | Fuel pressure insufficient (gas only)                                 | Check the fuel supply and valves.†                                           | S/S, Gen. O/M        |                                   |
|                  | x                         | x           |                          |                | x           |           |                  | x                     |                             |                                 | Fuel injection timing out of adjustment (diesel only)                 | Adjust the fuel injection timing. †                                          | Eng. S/M             |                                   |
| Lube System      |                           |             |                          |                |             |           |                  |                       |                             |                                 |                                                                       |                                                                              |                      |                                   |
|                  | x                         | x           |                          |                |             |           | x                |                       | x                           |                                 | Crankcase oil type incorrect for ambient temperature                  | Change the oil. Use oil with a viscosity suitable for the operating climate. | Eng. O/M             |                                   |
|                  |                           |             |                          |                |             | x         | x                |                       | x                           |                                 | Oil level low                                                         | Restore the oil level. Inspect the generator set for oil leaks.              | Eng. O/M             |                                   |
|                  |                           |             |                          | x              |             |           |                  |                       |                             |                                 | Low oil pressure shutdown                                             | Check the oil level.                                                         | Eng. O/M             |                                   |

\* Sec./Section—numbered section of this manual; ATS—Automatic Transfer Switch; Eng.—Engine; Gen.—Generator Set; I/M—Installation Manual; O/M—Operation Manual; S/M—Service Manual; S/S—Spec Sheet; W/D—Wiring Diagram Manual

† Have an authorized service distributor/dealer perform this service.

| Trouble Symptoms                                                                                                                                                                                                             | Probable Causes                                                                                      | Recommended Actions                                                                                                                 | Section or Publication Reference*        |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|
| <b>Controller Display and Voltage Regulator (Decision-Maker® 550)</b>                                                                                                                                                        |                                                                                                      |                                                                                                                                     |                                          |
| Display is black                                                                                                                                                                                                             | No/low battery charge                                                                                | Recharge/replace battery                                                                                                            | Gen. O/M                                 |
|                                                                                                                                                                                                                              | Controller F2 fuse is blown                                                                          | Check and replace fuse as needed                                                                                                    | Gen. O/M, W/D                            |
|                                                                                                                                                                                                                              | Incorrect wiring applying a ground signal to controller terminal strip TB2 terminals 1–6             | Check wiring and connections (controller F2 fuse is okay)                                                                           | W/D                                      |
|                                                                                                                                                                                                                              | Incorrect wiring applying a ground to controller terminal strip TB3 terminals 2, 4, 6, 8, 10, 12, 14 |                                                                                                                                     |                                          |
| Display shows single segment                                                                                                                                                                                                 | Low battery voltage                                                                                  | Recharge battery                                                                                                                    | Gen. O/M                                 |
| Display shows an error message                                                                                                                                                                                               | Loaded new firmware without powering down controller                                                 | Power down controller, then power up controller per procedure                                                                       | Gen. O/M, TT-1285                        |
|                                                                                                                                                                                                                              | Main logic board non-functional                                                                      | Troubleshoot main logic board, connections, and wiring. Repair wiring and/or replace main logic board                               | Controller S/M                           |
|                                                                                                                                                                                                                              | Controller firmware or keypad entry error                                                            | Review the Request and Error Message Section                                                                                        | Gen. O/M                                 |
|                                                                                                                                                                                                                              | EEPROM fault caused by a component failure, lightning strike, or voltage spike                       | Reinitialize the problem data block †                                                                                               | Contact an Authorized Distributor/Dealer |
| Display locks up                                                                                                                                                                                                             | No/low battery charge                                                                                | Recharge/replace battery                                                                                                            | Gen. O/M                                 |
| Emergency stop (E-Stop) shutdown message does not clear                                                                                                                                                                      | Low battery voltage                                                                                  | Recharge battery                                                                                                                    | Gen. O/M                                 |
|                                                                                                                                                                                                                              | Incorrect wiring applying a ground signal to controller terminal strip TB2 terminals 1–6             | Check wiring and connections                                                                                                        | W/D                                      |
|                                                                                                                                                                                                                              | Incorrect wiring applying a ground to controller terminal strip TB3 terminals 2, 4, 6, 8, 10, 12, 14 |                                                                                                                                     |                                          |
|                                                                                                                                                                                                                              | Non-functional exciter winding                                                                       | Troubleshoot alternator components and wiring †                                                                                     | Gen. S/M                                 |
| Output voltage ramps                                                                                                                                                                                                         | Voltage regulation calibration incorrect                                                             | Readjust voltage regulation †                                                                                                       | Gen. O/M                                 |
| Output voltage unstable                                                                                                                                                                                                      | Analog input A07 description does not match <i>Analog Volt Adjust</i>                                | Change description to <i>Analog Volt Adjust</i> using Monitor II or Monitor III software or enable analog voltage adjust in Menu 11 | Monitor II Software manual, Gen. O/M     |
| <b>Controller Display and Voltage Regulator (Decision-Maker® 3000)</b>                                                                                                                                                       |                                                                                                      |                                                                                                                                     |                                          |
| Display is black                                                                                                                                                                                                             | No/low battery charge                                                                                | Recharge/replace battery                                                                                                            | Gen. O/M                                 |
| Display shows single segment                                                                                                                                                                                                 | Low battery voltage                                                                                  | Recharge battery                                                                                                                    | Gen. O/M                                 |
| Display shows an error message                                                                                                                                                                                               | Controller firmware or pushbutton/rotary selector dial entry error                                   | Review the Error Message Section                                                                                                    | Gen. O/M                                 |
| Display locks up                                                                                                                                                                                                             | No/low battery charge                                                                                | Recharge/replace battery                                                                                                            | Gen. O/M                                 |
| Output voltage ramps                                                                                                                                                                                                         | Non-functional exciter winding                                                                       | Troubleshoot alternator components †                                                                                                | Gen. S/M                                 |
| Output voltage unstable                                                                                                                                                                                                      | Voltage regulation calibration incorrect                                                             | Readjust voltage regulation †                                                                                                       | Gen. O/M                                 |
| * Sec./Section—numbered section of this manual; ATS—Automatic Transfer Switch; Eng.—Engine; Gen.—Generator Set; I/M—Installation Manual; O/M—Operation Manual; S/M—Service Manual; S/S—Spec Sheet; W/D—Wiring Diagram Manual |                                                                                                      |                                                                                                                                     |                                          |
| † Have an authorized service distributor/dealer perform this service.                                                                                                                                                        |                                                                                                      |                                                                                                                                     |                                          |

| Trouble Symptoms                                                                                                                                                                                                                                                                                                 | Probable Causes                                                                                      | Recommended Actions                                                                                                                 | Section or Publication Reference*        |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------|------------------------------------------|
| <b>Controller Display and Voltage Regulator (Decision-Maker® 6000)</b>                                                                                                                                                                                                                                           |                                                                                                      |                                                                                                                                     |                                          |
| Display is black                                                                                                                                                                                                                                                                                                 | No/low battery charge                                                                                | Recharge/replace battery                                                                                                            | Gen. O/M                                 |
|                                                                                                                                                                                                                                                                                                                  | Controller F2 fuse is blown                                                                          | Check and replace fuse as needed                                                                                                    | Gen. O/M, W/D                            |
|                                                                                                                                                                                                                                                                                                                  | Incorrect wiring applying a ground signal to controller terminal strip TB2 terminals 1–6             | Check wiring and connections (controller F2 fuse is okay)                                                                           | W/D                                      |
| Display shows single segment                                                                                                                                                                                                                                                                                     | Incorrect wiring applying a ground to controller terminal strip TB3 terminals 2, 4, 6, 8, 10, 12, 14 |                                                                                                                                     |                                          |
|                                                                                                                                                                                                                                                                                                                  | Low battery voltage                                                                                  | Recharge battery                                                                                                                    | Gen. O/M                                 |
|                                                                                                                                                                                                                                                                                                                  | Loaded new firmware without powering down controller                                                 | Power down controller, then power up controller per procedure                                                                       | Gen. O/M, TT-1285                        |
| Display shows an error message                                                                                                                                                                                                                                                                                   | Main logic board non-functional                                                                      | Troubleshoot main logic board, connections, and wiring. Repair wiring and/or replace main logic board                               | Controller S/M                           |
|                                                                                                                                                                                                                                                                                                                  | Controller firmware or keypad entry error                                                            | Review the Request and Error Message Section                                                                                        | Gen. O/M                                 |
|                                                                                                                                                                                                                                                                                                                  | EEPROM fault caused by a component failure, lightning strike, or voltage spike                       | Reinitialize the problem data block †                                                                                               | Contact an Authorized Distributor/Dealer |
| Display locks up                                                                                                                                                                                                                                                                                                 | No/low battery charge                                                                                | Recharge/replace battery                                                                                                            | Gen. O/M                                 |
| Emergency stop (E-Stop) shutdown message does not clear                                                                                                                                                                                                                                                          | Low battery voltage                                                                                  | Recharge battery                                                                                                                    | Gen. O/M                                 |
|                                                                                                                                                                                                                                                                                                                  | Incorrect wiring applying a ground signal to controller terminal strip TB2 terminals 1–6             | Check wiring and connections                                                                                                        | W/D                                      |
|                                                                                                                                                                                                                                                                                                                  | Incorrect wiring applying a ground to controller terminal strip TB3 terminals 2, 4, 6, 8, 10, 12, 14 |                                                                                                                                     |                                          |
| Output voltage ramps                                                                                                                                                                                                                                                                                             | Non-functional exciter winding                                                                       | Troubleshoot alternator components and wiring †                                                                                     | Gen. S/M                                 |
| Output voltage unstable                                                                                                                                                                                                                                                                                          | Voltage regulation calibration incorrect                                                             | Readjust voltage regulation †                                                                                                       | Gen. O/M                                 |
| Voltage adjust does not function for paralleling applications                                                                                                                                                                                                                                                    | Analog input A07 description does not match <i>Analog Volt Adjust</i>                                | Change description to <i>Analog Volt Adjust</i> using Monitor II or Monitor III software or enable analog voltage adjust in Menu 11 | Monitor II Software manual, Gen. O/M     |
| Unit does not shutdown with protective relay(s) settings                                                                                                                                                                                                                                                         | Time delay value(s) are set to 99.99                                                                 | Change time delay value(s)                                                                                                          | Gen. O/M                                 |
| <p>* Sec./Section—numbered section of this manual; ATS—Automatic Transfer Switch; Eng.—Engine; Gen.—Generator Set; I/M—Installation Manual; O/M—Operation Manual; S/M—Service Manual; S/S—Spec Sheet; W/D—Wiring Diagram Manual</p> <p>† Have an authorized service distributor/dealer perform this service.</p> |                                                                                                      |                                                                                                                                     |                                          |

## Notes

## Section 3 Component Testing and Adjustment

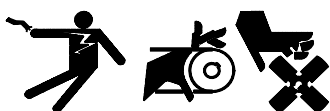
### 3.1 Introduction

This section provides information on troubleshooting the alternator and testing components of the generator set. Contact an authorized service distributor/dealer for the appropriate technical manuals for the controller and integrated voltage regulator.

To troubleshoot the alternator assembly components, the following equipment is needed for many of the tests:

- Multimeter (Voltmeter/Ohmmeter)
- Megohmmeter

#### WARNING



**Accidental starting.**  
**Can cause severe injury or death.**

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

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

#### WARNING



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

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

**Disconnecting the electrical load. Hazardous voltage can cause severe injury or death.** Disconnect the generator set from the load by turning off 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.

**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.

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

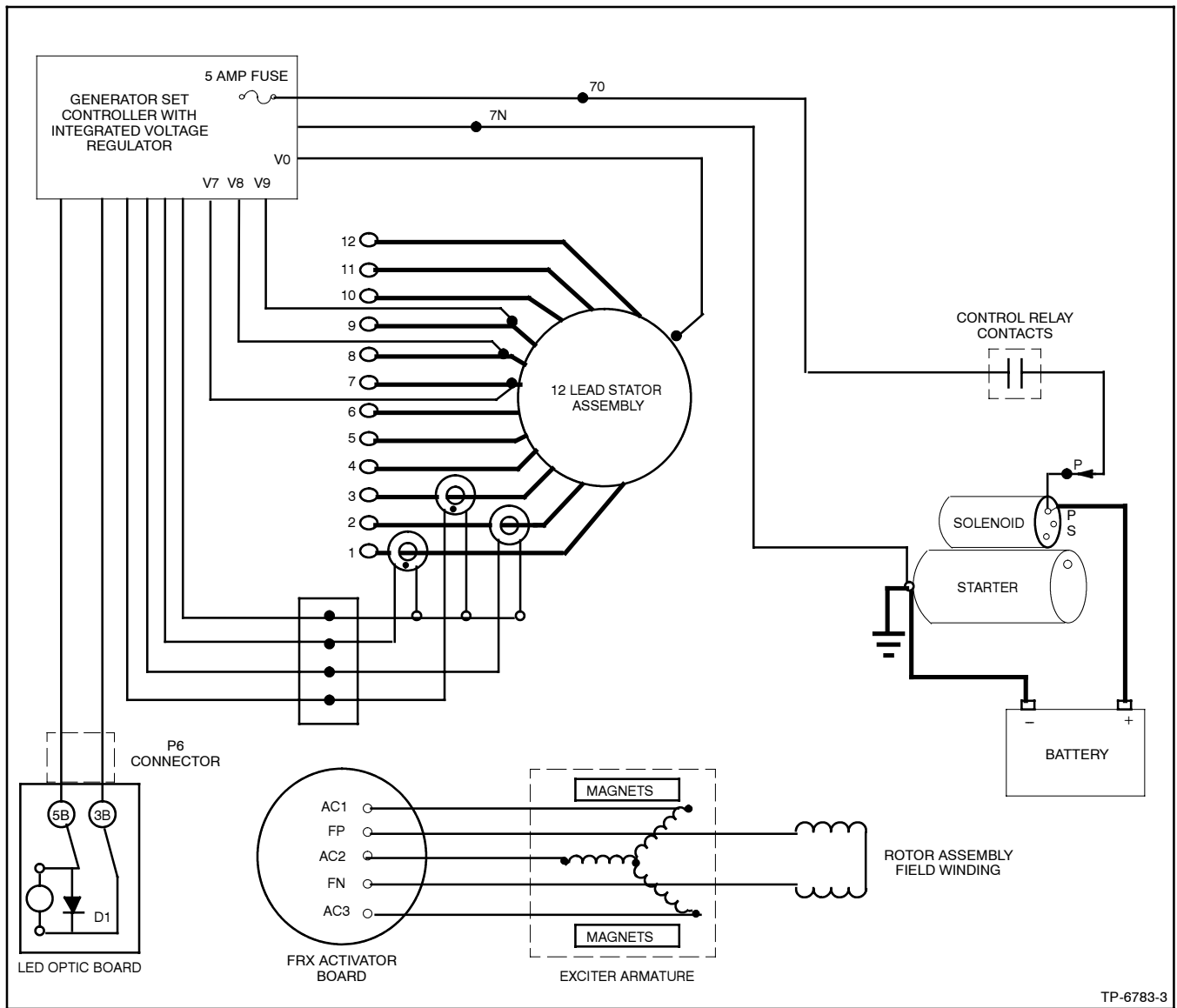
### 3.2 Alternator Troubleshooting

Follow all safety precautions listed in the front of this manual and the additional precautions within the text. Refer to Figure 3-1, AC Voltage Control, for assistance in troubleshooting. Figure 3-2 lists various alternator output conditions and component tests.

Use the following flowcharts to troubleshoot the generator set when voltage problems are detected. The remaining parts of this section give additional and more detailed information about the individual checks/tests mentioned in the flowcharts. Use the flowcharts to initially isolate the possible problem.

This section covers alternator testing for the following conditions:

- No voltage output on any phase (Section 3.2.1)
- Overvoltage (Section 3.2.2)
- Fluctuating voltage (Section 3.2.3)



TP-6783-3

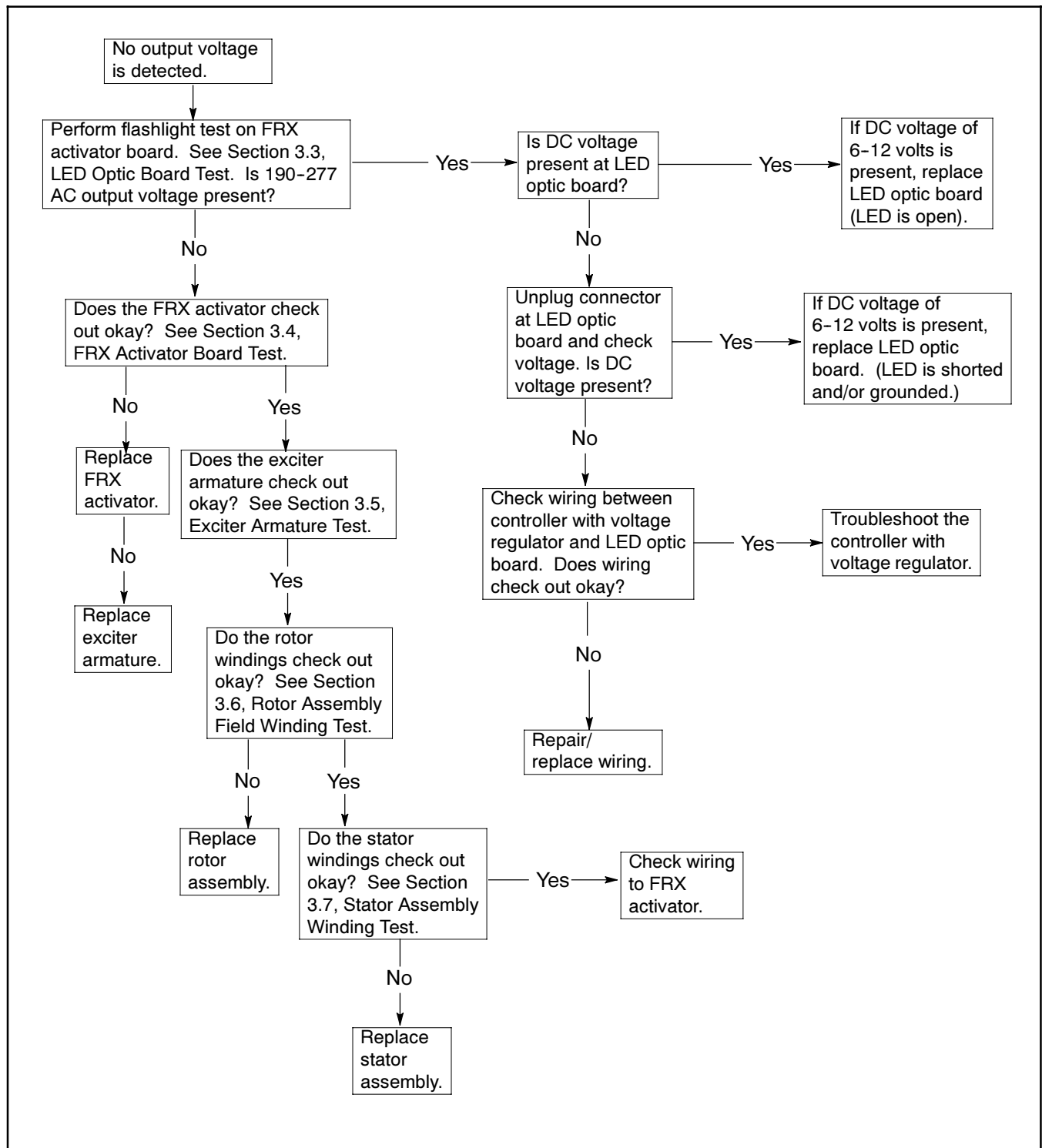
**Figure 3-1** AC Voltage Control Components

| Components and Circuits to Test Under Certain Alternator Output Conditions |                                     |                 |                     |                  |                              |                          |
|----------------------------------------------------------------------------|-------------------------------------|-----------------|---------------------|------------------|------------------------------|--------------------------|
| Alternator Output Condition                                                | Controller with Voltage Regulator † | LED Optic Board | FRX Activator Board | Exciter Armature | Rotor Assembly Field Winding | Stator Assembly Windings |
| No Output                                                                  | •                                   | •               | •                   | •                | •                            | •                        |
| Overvoltage                                                                | •                                   |                 | • *                 |                  |                              |                          |
| Fluctuating Voltage                                                        | •                                   | •               | •                   | •                | •                            | •                        |

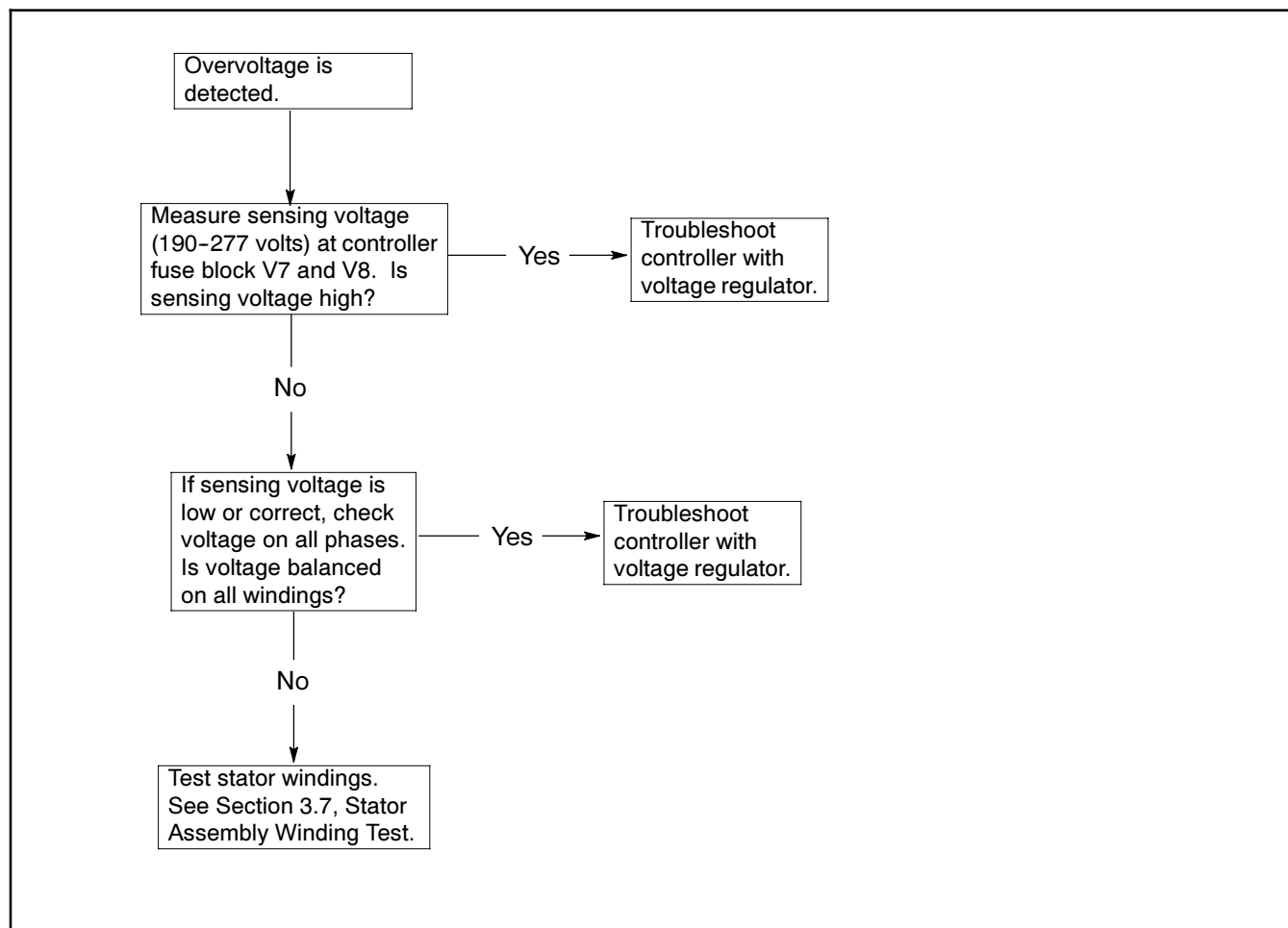
\* Overvoltage will occur if an outside light source is present when the LED board is removed.  
† See the controller operation or service manual for operation, setup, and/or troubleshooting.

**Figure 3-2** Alternator Assembly Troubleshooting Guide

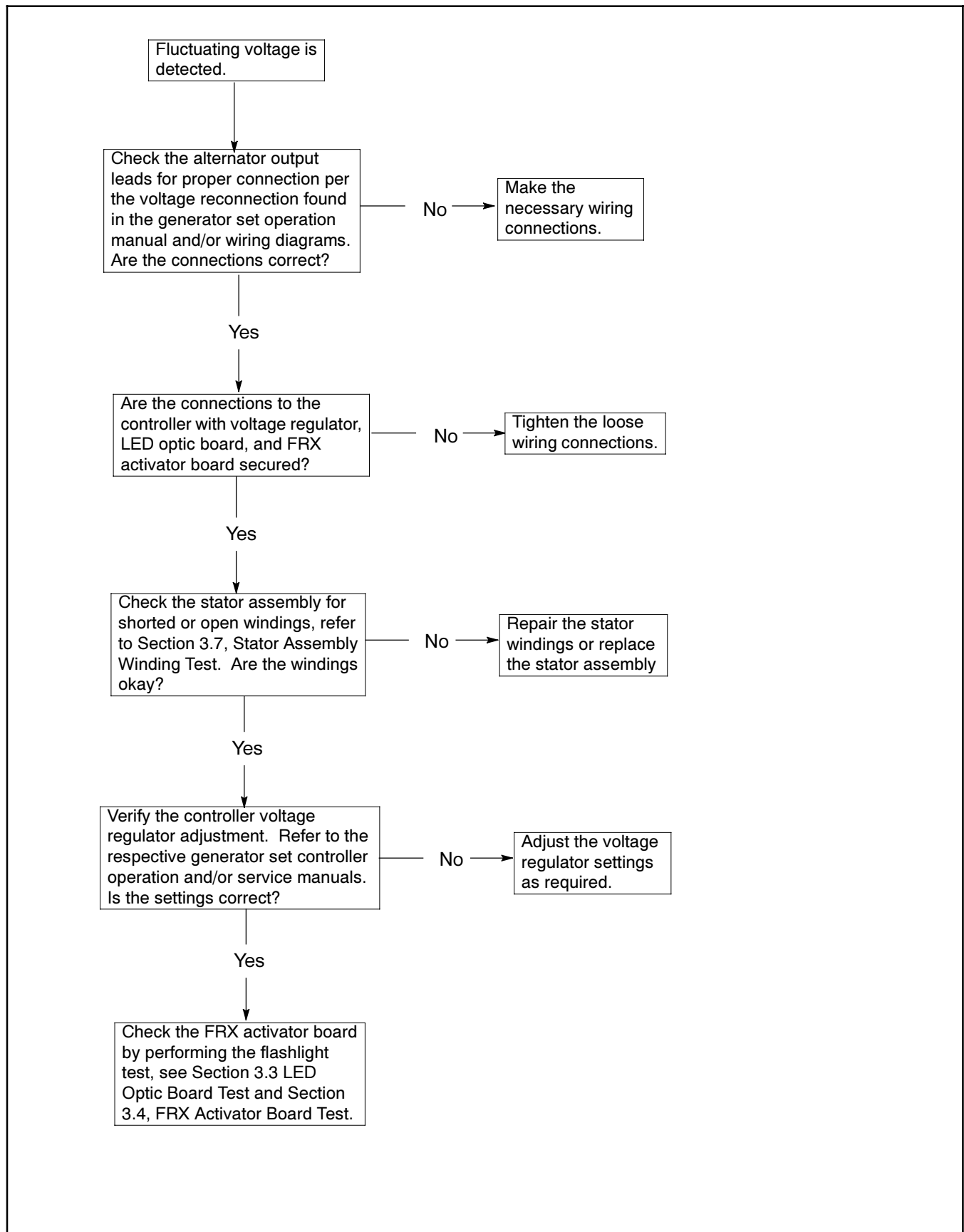
### 3.2.1 Troubleshooting Alternator, No Output Voltage



### 3.2.2 Troubleshooting Alternator, Overvoltage



### 3.2.3 Troubleshooting Alternator, Fluctuating Voltage



### 3.3 LED Optic Board Test

The following procedure provides information on testing the LED optic board. Certain steps require that the generator set be running. When the generator set is not running, disable the generator set. See the safety precautions listed below. Disconnect all load from the generator set during this test.

To test the LED optic board, the following item is needed:

- Flashlight

#### **⚠ WARNING**



**Accidental starting.  
Can cause severe injury or death.**

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

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

#### **⚠ WARNING**



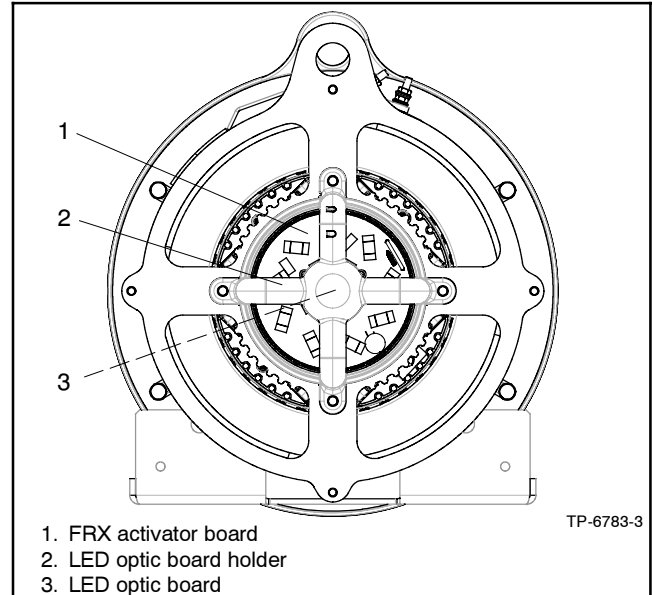
**Hazardous voltage. Moving parts.  
Can cause severe injury or death.**

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

**Disconnecting the electrical load. Hazardous voltage can cause severe injury or death.** Disconnect the generator set from the load by turning off 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.

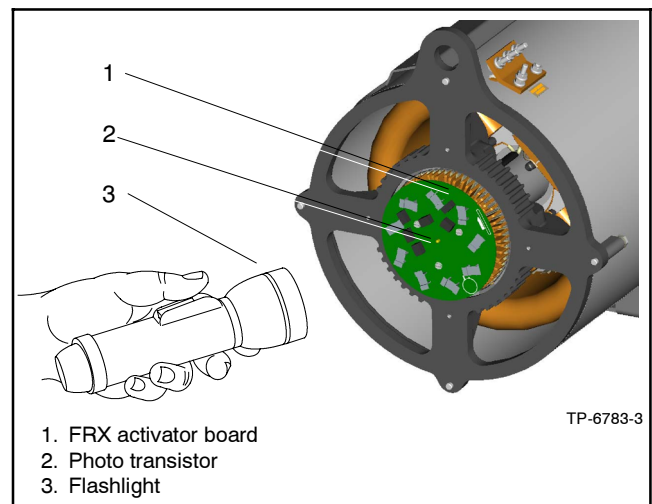
**Testing the photo transistor circuit board. Hazardous voltage can cause severe injury or death.** When the end cover is removed, do not expose the photo transistor circuit board mounted on the generator set end bracket to any external light source, as exposure to light causes high voltage. Keep foreign sources of light away from the photo transistor circuit board during testing. Place black electrical tape over the LED on the circuit board before starting the generator set.

1. Remove the junction box panels from the generator end of unit and remove the LED optic board holder/LED optic board. See Figure 3-3.



**Figure 3-3** FRX Activator Board with LED Optic Board Installed.

2. Refer to the respective generator set controller operation manual for starting/stopping procedures. With the generator set running at no load, shine a flashlight at the exposed photo transistor on the FRX activator board. See Figure 3-4.



**Figure 3-4** Flashlight Test on FRX Activator Board

3. Observe the AC output voltage controller display or connect a voltmeter to the output leads. High AC output voltage indicates the FRX activator board is functioning properly. The fault is likely in the wiring, controller with voltage regulator, or LED optic board as the output voltage should drop to low level when the flashlight is removed. If no output is observed, check the FRX activator board.

4. If high output voltage exists with the flashlight off, stop the generator set and place a small piece of black electrical tape over the photo transistor. Restart the unit.

If the output voltage is reduced, there is a source of external light contamination. STOP the generator set. Find the external light source and eliminate it or block it from reaching the photo transistor.

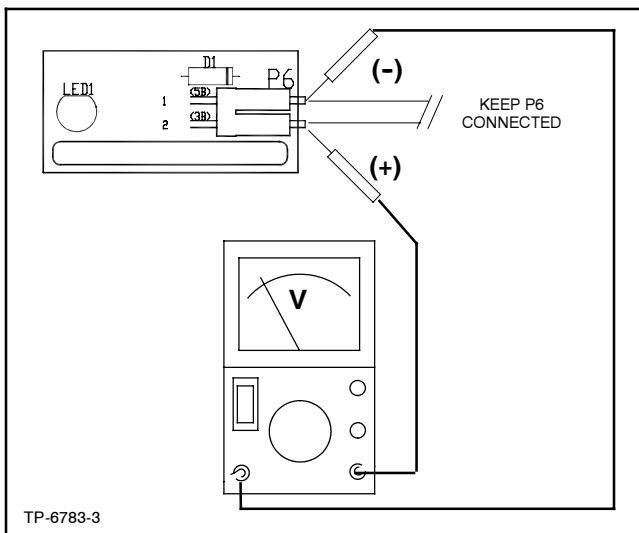
If the output voltage remains high, there is a failure in the FRX activator board.

5. With the generator set running at no load, approximately 1-2 volts DC should be observed at 3B (+) and 5B (-) at the LED optic board. See Figure 3-5.

6. Shine the flashlight on the photo transistor. The DC voltage reading should drop, showing that the controller with voltage regulator is functioning.

If voltages are not observed, check the F3 fuse in the controller and refer to the controller operation and/or service manuals for further information regarding the voltage regulator adjustment and troubleshooting.

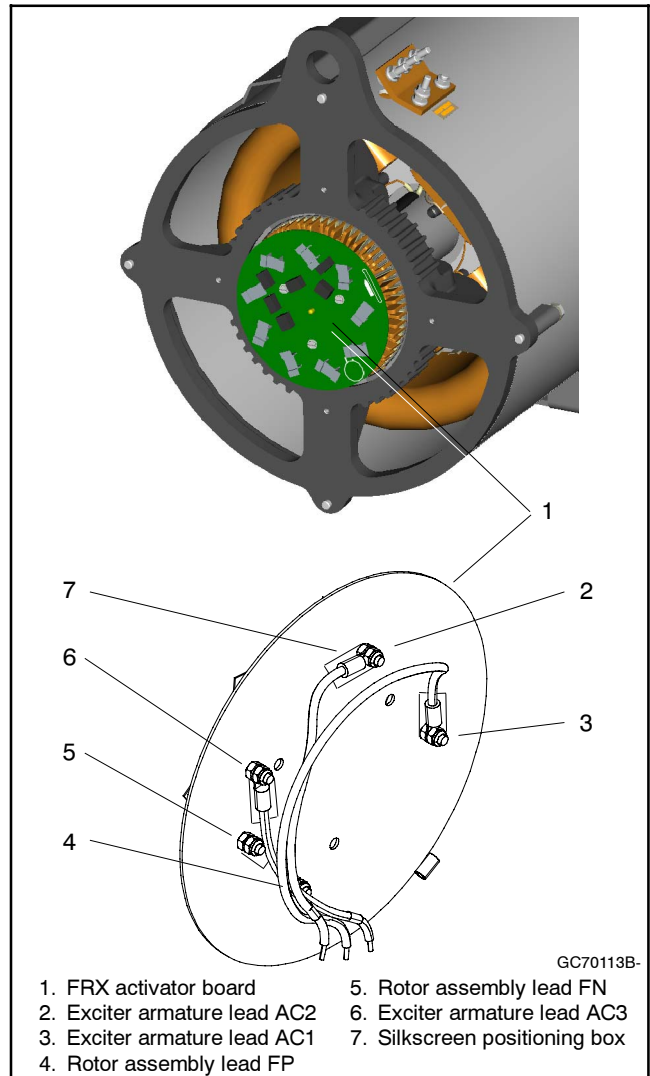
7. STOP the generator set.



**Figure 3-5** Checking LED Optic Board Voltage

### 3.4 FRX Activator Board Test

The FRX activator board is mounted on the exciter armature and controls current flow to the alternator field. See Figure 3-6.



**Figure 3-6** FRX Activator Board and Connections

The following test determines if the FRX activator board is non-functional.

See Section 3.1, Alternator Troubleshooting. Examine the photo transistor board for visible signs of damage (open foil patterns and heat discoloration) before testing.

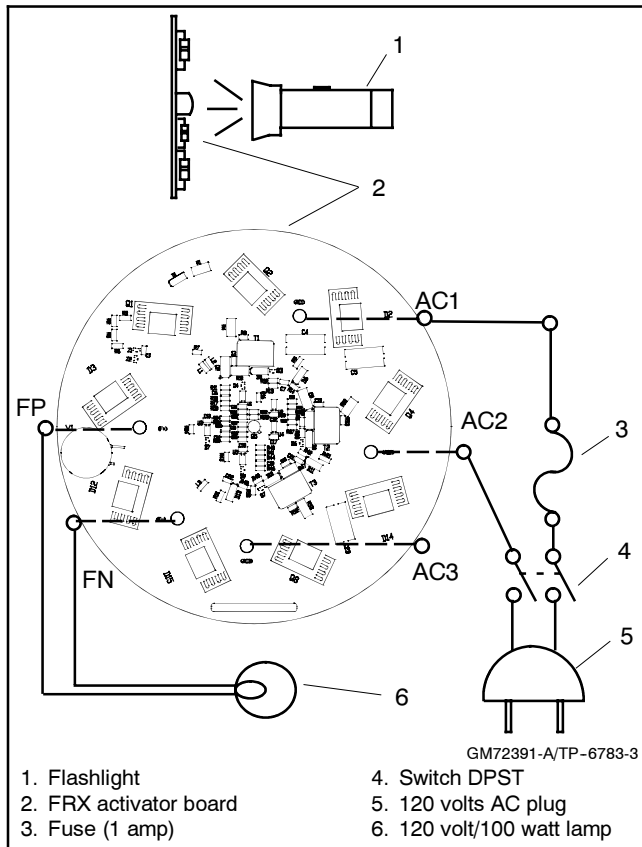
To test the FRX activator board, the following components are needed:

- One 120-volt/110-watt light bulb with socket
- Switch, DPST (double-pole/single-throw) 120 volt 10 amp minimum)
- Fuse, 1 amp (in holder)
- 120 volt AC plug with cord
- Flashlight

This test simulates the normal operation of the components when the alternator is running.

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

1. Connect components as illustrated in Figure 3-7, Test A.



**Figure 3-7** FRX Activator Board Test A

**Note:** Connect 120 VAC power source to AC1 and AC2.

Connections to the FRX activator board are made to the threaded inserts located on the underside of the board. Secure all connections with terminal nuts to ensure good electrical contact with threaded inserts during testing. Do not exceed 1.3 Nm (12 in. lb.) when tightening the terminal nuts. Place FRX activator board on a non-conductive surface when performing the test.

2. With the cord switch in the OFF position, plug in the electrical cord.

3. Turn the cord switch to the ON position.
4. Apply light source directly to the photo transistor located in the center of the FRX activator board. Shield the photo transistor from all other sources of light during this test.

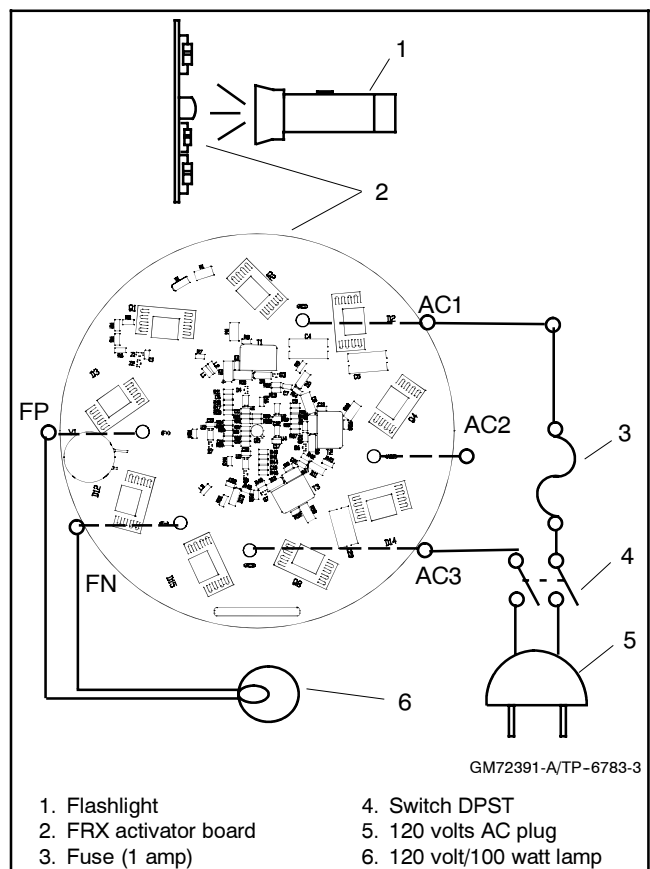
If the FRX activator board is *functional*, the test fixture light bulb will light when the external light source is applied to the photo transistor. Remove the light source; the fixture light bulb should go out.

If the test fixture light bulb does not light or is lit prior to receiving external light source, the FRX activator board is non-functional.

5. Turn the cord switch to the OFF position and unplug the electrical cord.
6. Connect components as illustrated in Figure 3-8, Test B.

**Note:** Connect 120 VAC power source to AC1 and AC3.

7. Repeat steps 2-5. Replace the FRX activator board if it fails either test.



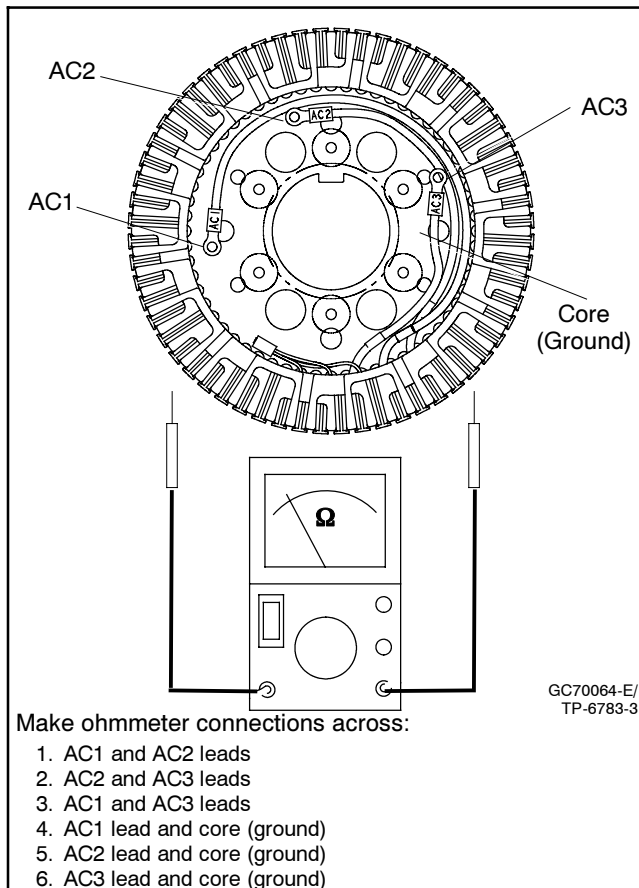
**Figure 3-8** FRX Activator Board Test B

### 3.5 Exciter Armature Test

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

**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.

1. Disconnect the battery (negative lead first).
2. Disconnect leads AC1, AC2, and AC3 from the FRX activator board.
3. Visually check the exciter armature for shorted or open winding(s)
4. With an ohmmeter, check for continuity across the AC1/AC2, AC2/AC3, and AC1/AC3. Check for continuity across AC1/core (ground), AC2/core (ground), and AC3/core (ground). See Figure 3-9. See Section 1.4, Specifications, Electrical Values for exciter armature resistance values.



**Figure 3-9** Exciter Armature Continuity Check

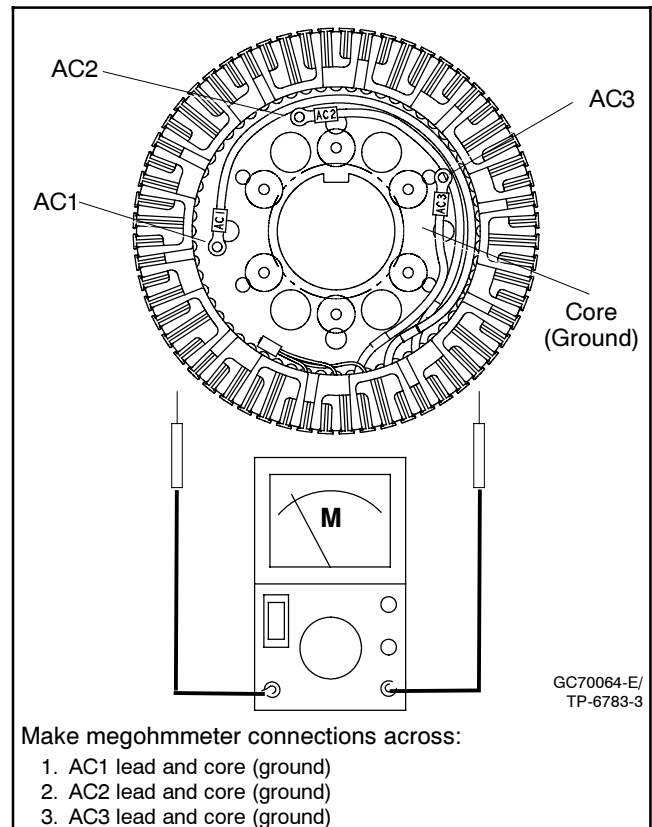
Out of specification readings indicate a non-functional exciter armature requiring replacement. Low resistance readings indicate a shorted winding. High resistance readings indicate an open winding. No continuity should exist between any lead and ground.

5. Repair the leads if damaged or open. Solder and insulate the splices. Use new sleeving as needed when tying leads to the core.
6. Using a megohmmeter, apply 500 volts DC to the exciter armature core and each lead. See Figure 3-10. Place the exciter armature on a non-conductive surface when performing the test. Follow the instructions of the megohmmeter manufacturer when performing this test.

A reading of approximately 500 kOhms (1/2 megohm) and higher indicates the winding is good.

A reading of less than 500 kOhms (approximately) indicates deterioration of winding insulation and possible current flow to ground.

7. Repair or replace exciter armature if the test shows a winding is shorted to ground. Repair the leads if damaged or open. Solder and insulate the splices. Use new sleeving as needed when tying leads to the core.



**Figure 3-10** Exciter Armature High Voltage Test

### 3.6 Rotor Assembly Field Winding Test

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

**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.

1. Disconnect the battery (negative lead first).
2. Disconnect leads FP and FN from the FRX activator board.
3. Visually check the rotor assembly field for shorted or open winding(s)
4. With an ohmmeter, check for continuity across the FN/FN leads. Check for continuity across FN/rotor shaft and FP/rotor shaft. See Figure 3-11. See Section 1.4, Specifications, Electrical Values for rotor assembly field resistance values.

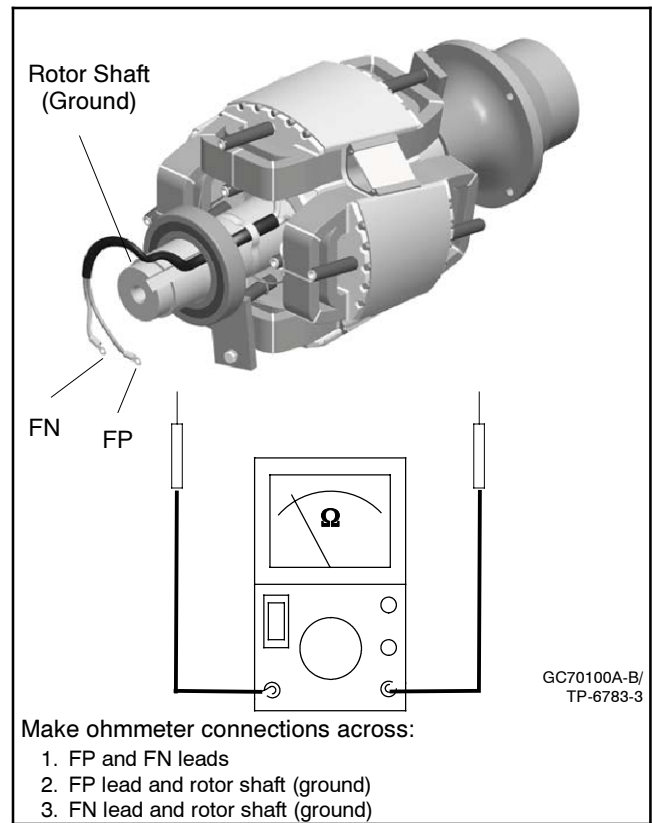
Out-of-specification readings indicate a non-functional rotor assembly requiring replacement. Low resistance readings indicate a shorted winding. High resistance readings indicate an open winding. No continuity should exist between any lead and rotor shaft (ground).

5. Repair the leads if damaged or open. Solder and insulate the splices. Use new sleeving as needed when tying leads to the core.
6. Using a megohmmeter, apply 500 volts DC to the two leads and then the rotor shaft and each lead. See Figure 3-12. Place the rotor assembly on a non-conductive surface when performing the test. Follow the instructions of the megohmmeter manufacturer when performing this test.

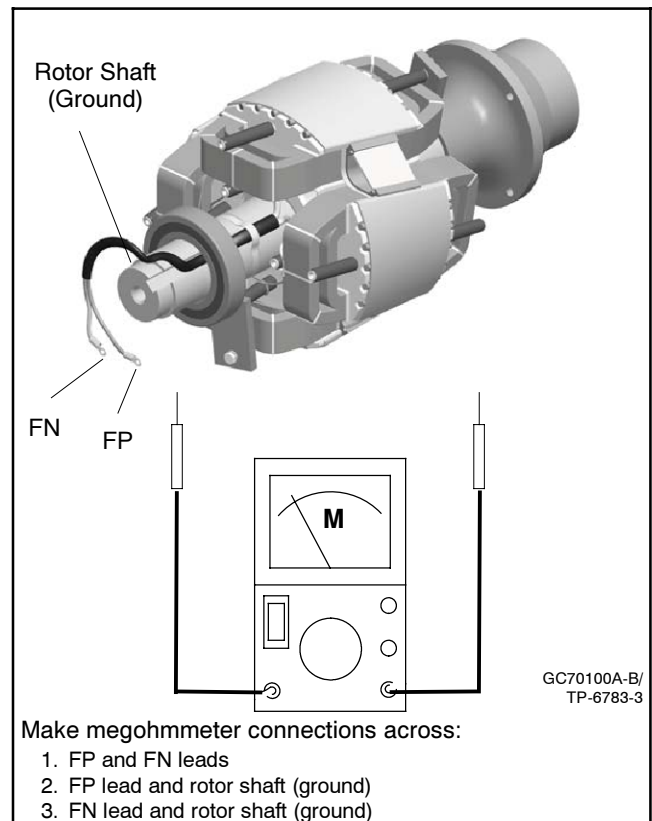
A reading of approximately 500 kOhms (1/2 megohm) and higher indicates the winding is good.

A reading of less than 500 kOhms (approximately) indicates deterioration of winding insulation and possible current flow to ground.

7. Repair or replace the rotor assembly if the test shows a winding is shorted to ground. Repair the leads if damaged or open. Solder and insulate the splices. Use new sleeving as needed when tying leads to the core.



**Figure 3-11** Rotor Field Continuity Check



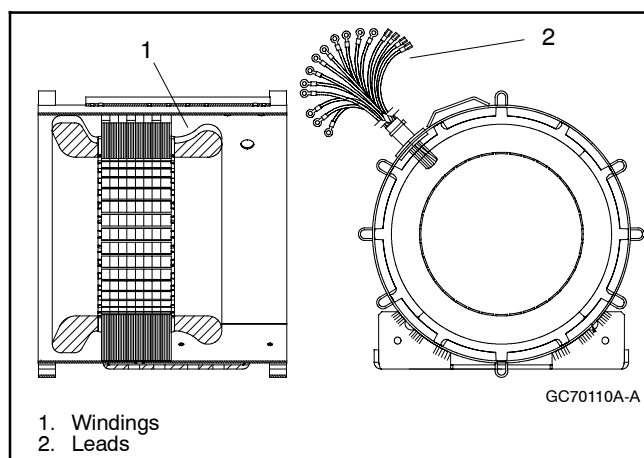
**Figure 3-12** Rotor Field High Voltage Test

### 3.7 Stator Assembly Winding Test

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

**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.

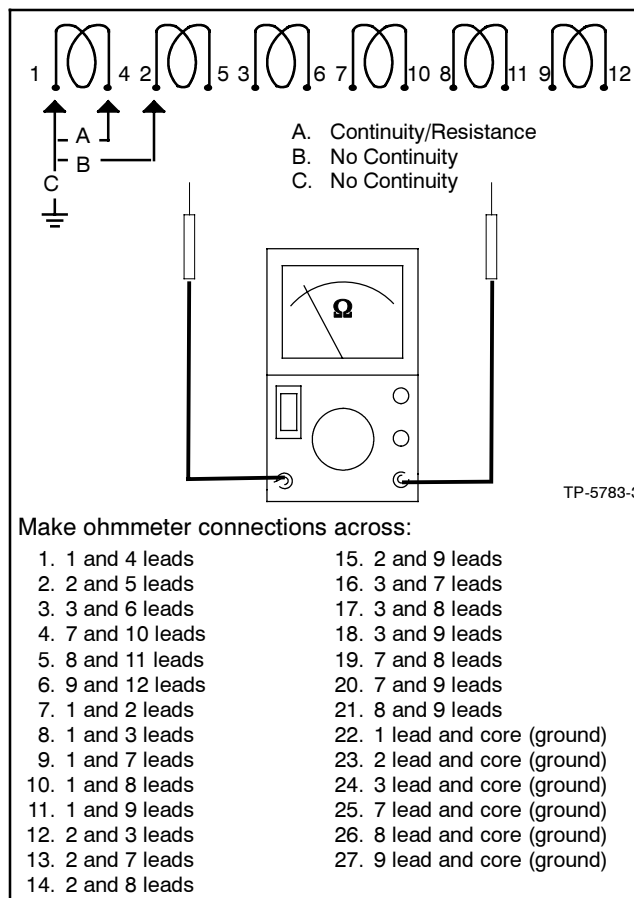
1. Disconnect the battery (negative lead first).
2. Disconnect V7, V8, V9, V0 stator leads at generator set controller terminal block before doing test. Tape to insulate the terminals.
3. Disconnect the 12 leads (three-phase alternator), 6 leads (600 volt), or 4 leads (single-phase alternator). Keep each lead isolated from each other and ground.
4. Visually check the stator assembly for shorted or open winding(s). See Figure 3-13.



**Figure 3-13** Stator Assembly

5. With ohmmeter, check **each pair** of leads for low resistance readings (continuity). High resistance across A or low resistance (continuity) across B and the stator core (ground) indicates a faulty stator; replace stator. See Figure 3-14 and Figure 3-15. See Section 1.4, Specifications, Electrical Values for stator assembly resistance values.

Out of specification readings indicate a non-functional stator assembly requiring replacement. Low resistance readings indicate a shorted winding. High resistance readings indicate an open winding. No continuity should exist between any lead and ground.



**Figure 3-14** Stator Winding Continuity Test

| Ohmmeter Connections, Leads: |      |      | Continuity |
|------------------------------|------|------|------------|
| 1-4                          | 2-5  | 3-6  | Yes        |
| 7-10                         | 8-11 | 9-12 |            |
| 1-2                          | 1-3  | 1-7  | No         |
| 1-8                          | 1-9  | 2-3  |            |
| 2-7                          | 2-8  | 2-9  |            |
| 3-7                          | 3-8  | 3-9  |            |
| 7-8                          | 7-9  | 8-9  |            |
| 1 and core (ground)          |      |      | No         |
| 2 and core (ground)          |      |      |            |
| 3 and core (ground)          |      |      |            |
| 7 and core (ground)          |      |      |            |
| 8 and core (ground)          |      |      |            |
| 9 and core (ground)          |      |      |            |

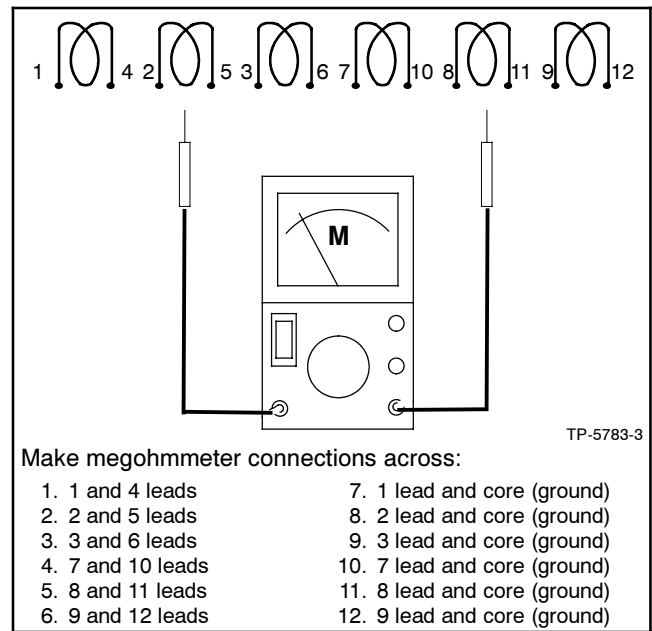
**Figure 3-15** Test Connections and Continuity Results for a Functional Stator Assembly

6. Repair the leads if damaged or open. Solder and insulate the splices. Use new sleeving as needed when tying leads to the core.
7. Using a megohmmeter, apply 500 volts DC to each set of windings and then to each winding and the stator core (ground). See Figure 3-16. Place the stator assembly on a non-conductive surface when performing the test. Follow the instructions of the megohmmeter manufacturer when performing this test.

A reading of approximately 500 kOhms (1/2 megohm) and higher indicates the winding is good.

A reading of less than 500 kOhms (approximately) indicates deterioration of winding insulation and possible current flow to ground.

8. Repair or replace the stator assembly if the test shows a winding is shorted to ground. Repair the leads if damaged or open. Solder and insulate the splices. Use new sleeving as needed when tying leads to the core.



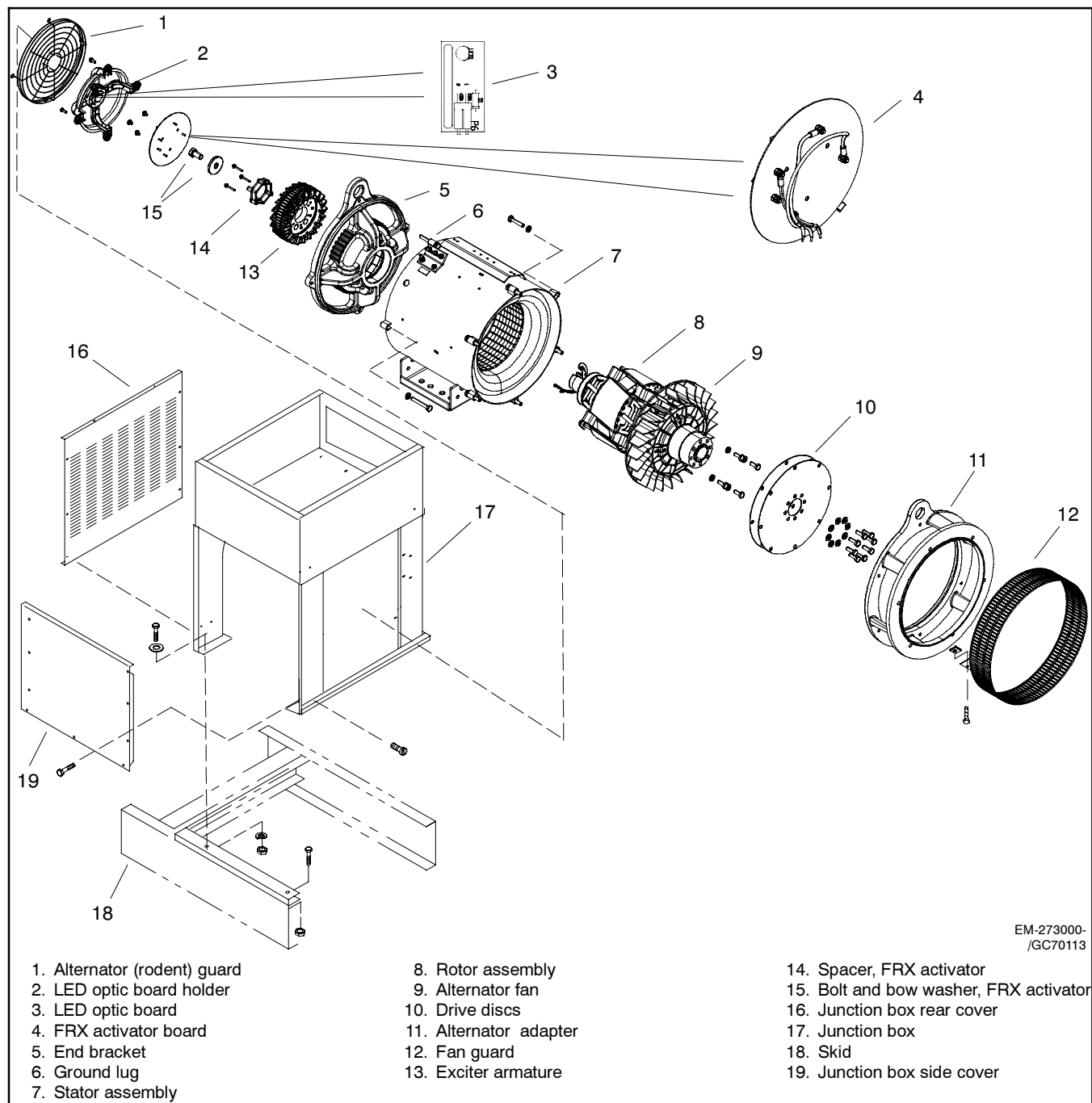
**Figure 3-16** Stator Winding High Voltage Test

## Section 4 Alternator Disassembly/Reassembly

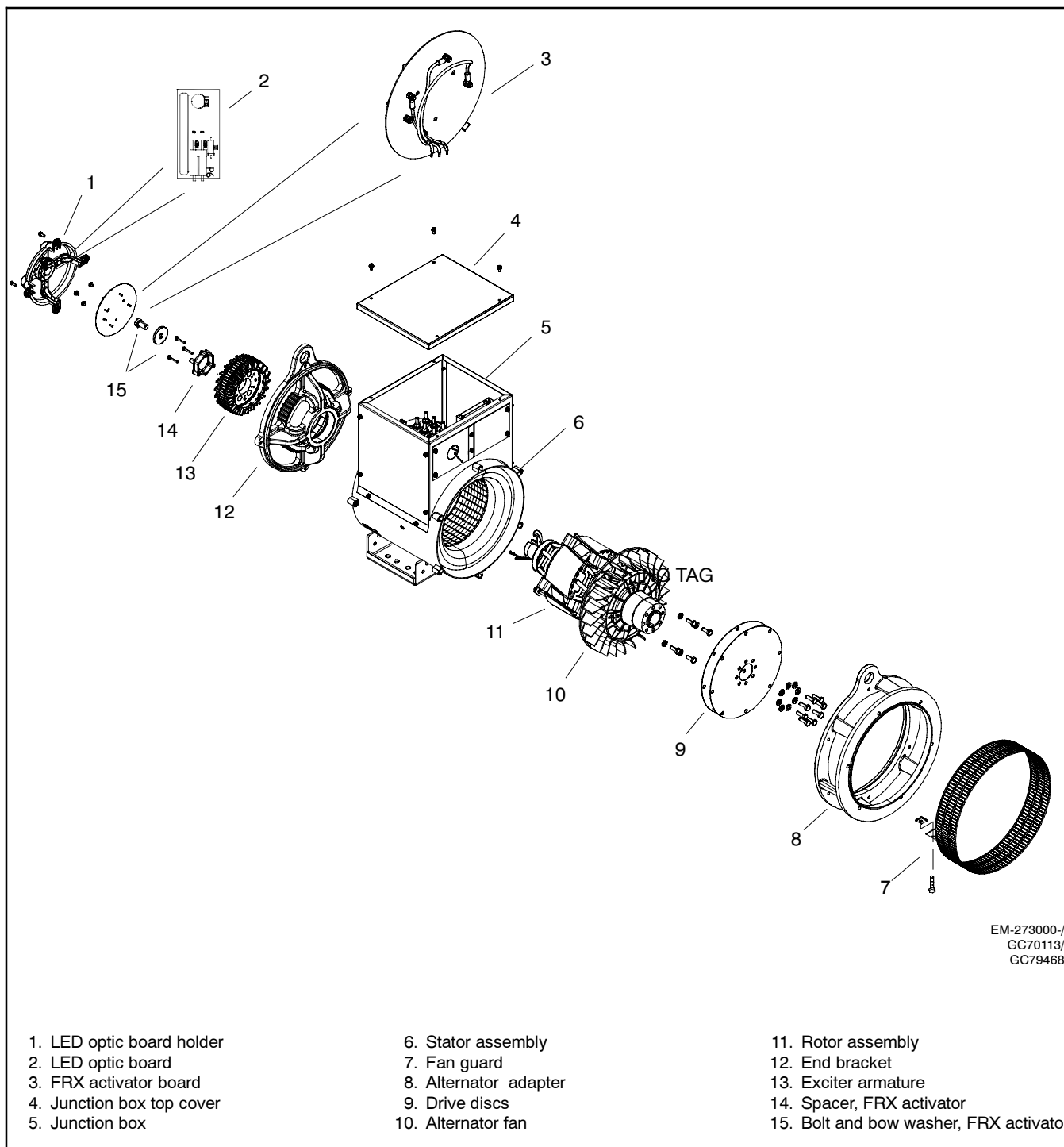
Before beginning the alternator disassembly procedure, carefully read all safety precautions at the beginning of this manual. Please observe these precautions and those included in the text during the disassembly/reassembly procedure.

The following procedures cover many models and some steps may not apply to a particular engine. Use Figure 4-1 or Figure 4-2 to help understand component descriptions and general configuration of the alternator.

Use disassembly procedure as a step-by-step means to help disassemble the alternator. The disassembly procedure provides important information to minimize disassembly time and indicates where special configurations exist that may require taking notes. The reassembly procedure includes important alignment steps and provides critical torque specs.



**Figure 4-1** Alternator Components, Typical



**Figure 4-2** Alternator Components (International Spec.), Typical

---

**⚠ WARNING**



**Accidental starting.  
Can cause severe injury or death.**

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

---

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

**⚠ WARNING**



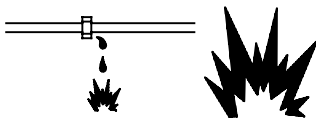
**Hot engine and exhaust system.  
Can cause severe injury or death.**

Do not work on the generator set until it cools.

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

---

**⚠ WARNING**



**Explosive fuel vapors.  
Can cause severe injury or death.**

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

---

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

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

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

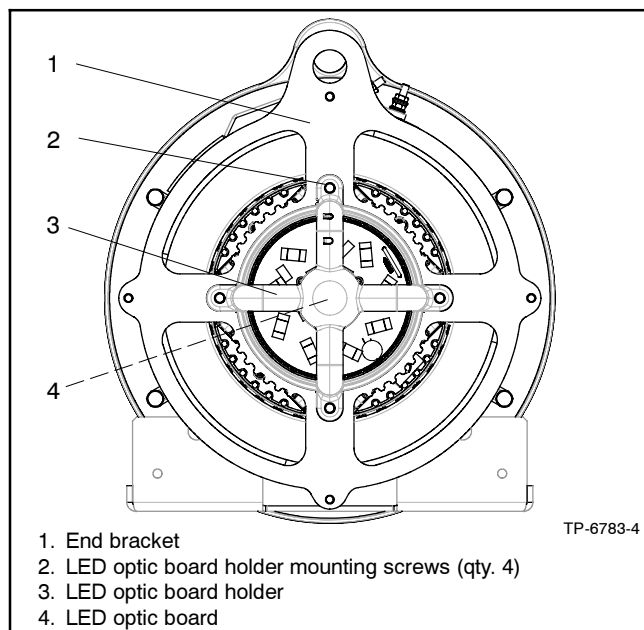
**Natural Gas**—Adequate ventilation is mandatory. Because natural gas rises, install natural gas detectors high in a room. Inspect the detectors per the manufacturer's instructions.

Perform the following steps prior to disassembling the generator set.

1. Disconnect (negative lead first) and remove starting batteries from work area to prevent fire hazard. Disconnect AC-powered accessories, such as battery charger, block heater, battery heater, and fuel transfer pump (if equipped).
2. Shut off fuel supply. Drain fuel system as necessary by emptying fuel into proper containers. Remove fuel containers from work area to prevent fire hazard. Ventilate the work area to clear fumes.
3. Disconnect fuel, cooling, and exhaust systems as necessary to tilt generator set. Disconnect output leads or load circuit cables at generator set.
4. Any cranes, hoists, or other lifting devices used in the disassembly or reassembly procedure must be rated for the weight of the generator set. Check generator set nameplate or spec sheet for weight.

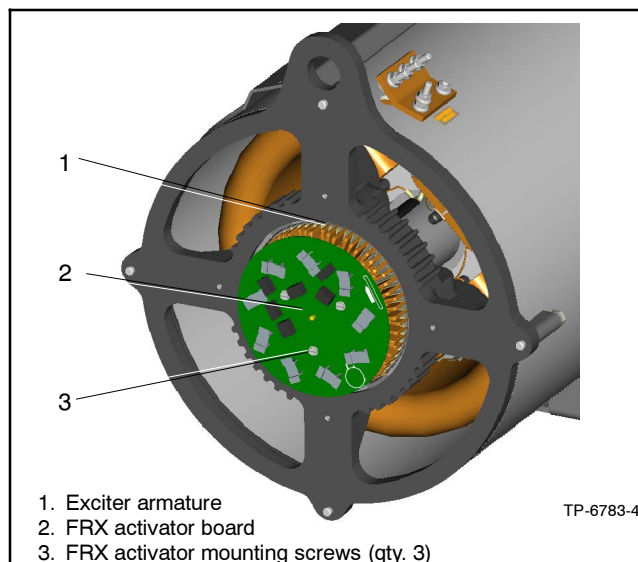
## 4.1 Disassembly

1. Remove the junction box panels. Disconnect all controller-to-engine and engine-to-alternator harnesses and wiring. Remove the junction box and controller as a unit.
2. Remove the fan guard from the alternator adapter.
3. Remove the alternator (rodent) guard from the end bracket (if equipped).
4. Disconnect the two-lead P6 connector at the LED optic board.
5. Remove the LED optic board holder from the end bracket (four screws). See Figure 4-3.

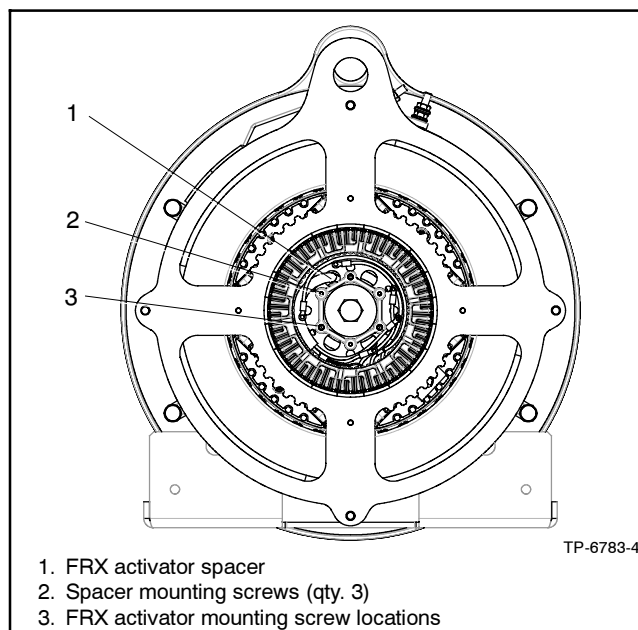


**Figure 4-3** Removing LED Optic Board Holder

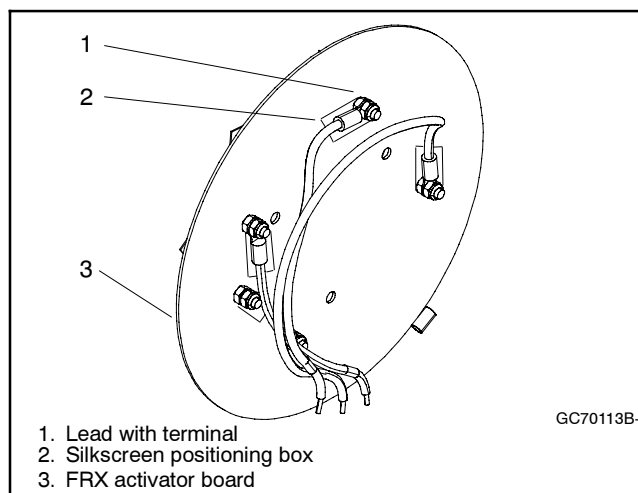
6. Remove the LED optic board from the LED optic board holder (one screw).
7. Remove the FRX activator board from the exciter armature assembly (three screws). See Figure 4-4.
8. Remove the FRX activator spacer from the exciter armature (three screws). See Figure 4-5.
9. Access the back of the FRX activator and remove the exciter armature leads (AC1, AC2, and AC3) by removing three elastic stop nuts. Note the lead terminals and their positioning on the FRX activator board silkscreen boxes for assembly later. See Figure 4-6.



**Figure 4-4** Removing FRX Activator Board



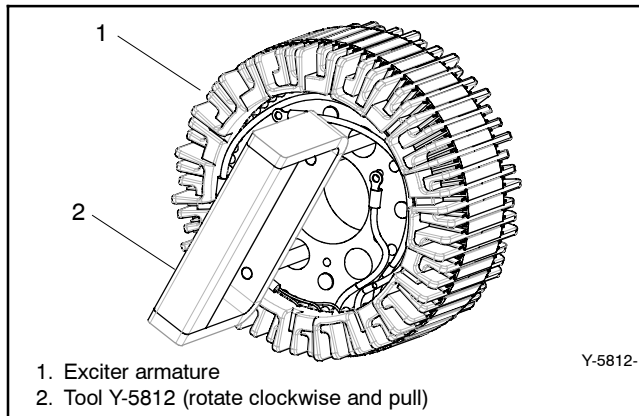
**Figure 4-5** Removing FRX Activator Spacer



**Figure 4-6** FRX Activator Board Silkscreen Boxes

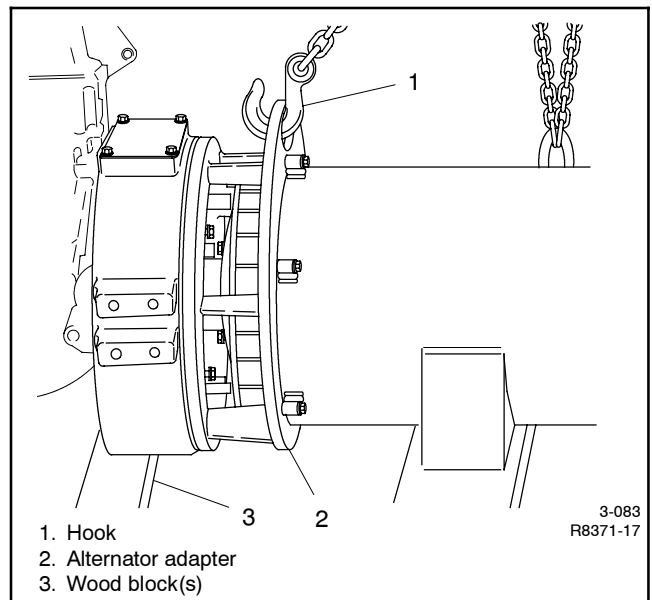
10. Remove the rotor assembly leads (FN and FP) by removing two elastic stop nuts. Note the lead terminals and their positioning on the FRX activator board silkscreen boxes for assembly later.
11. Remove the bolt and bow washer from the rotor assembly shaft.
12. Note the location of the rotor assembly leads (FN and FP) going through the hole in the exciter armature for assembly later.
13. Use tool Y-5812 or equivalent to remove the exciter armature from the rotor assembly shaft. Insert tool, rotate tool clockwise where washers grip the back of exciter armature core, and pull to remove the exciter armature. See Figure 4-7.

**Note:** Procure or fabricate service tool Y-5812 using Appendix F information.



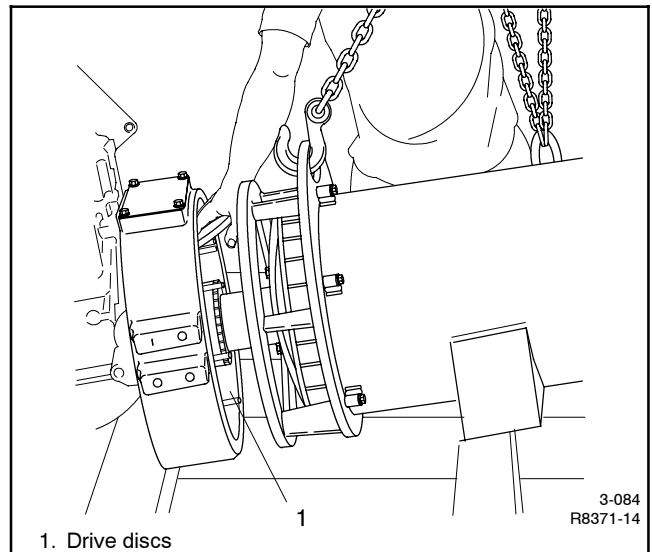
**Figure 4-7** Removing Exciter Armature

14. Remove bolts from the alternator vibromounts.
15. Suspend the alternator at both ends with hooks in lifting eyes. Use a hoist to raise the alternator end off the vibromounts. See Figure 4-8.
16. Support the engine by placing wood blocks under the flywheel housing. Lower the alternator end until the alternator flywheel housing rests on the wood blocks. See Figure 4-8.
17. Remove bolts holding the alternator adapter to the flywheel housing.
18. Remove hardware holding the drive discs to the flywheel.



**Figure 4-8** Hoisting Alternator

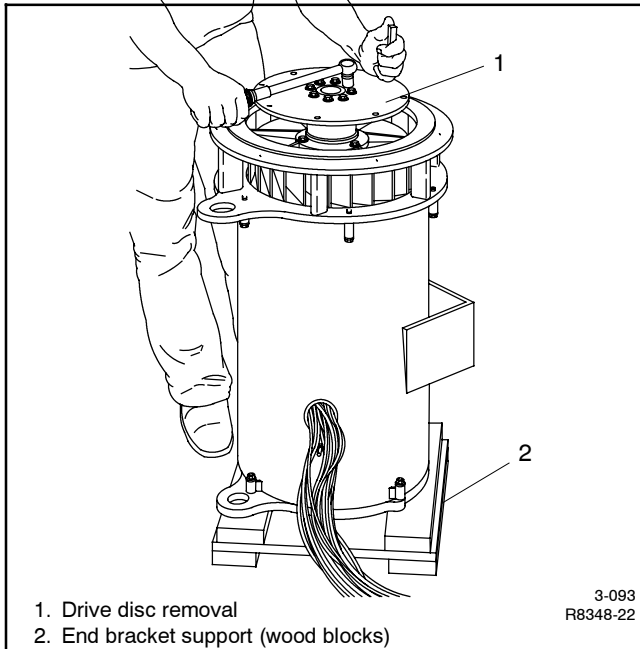
19. Work the drive discs over the studs (if equipped) to separate the alternator from the engine. See Figure 4-9.



**Figure 4-9** Separating Alternator and Engine

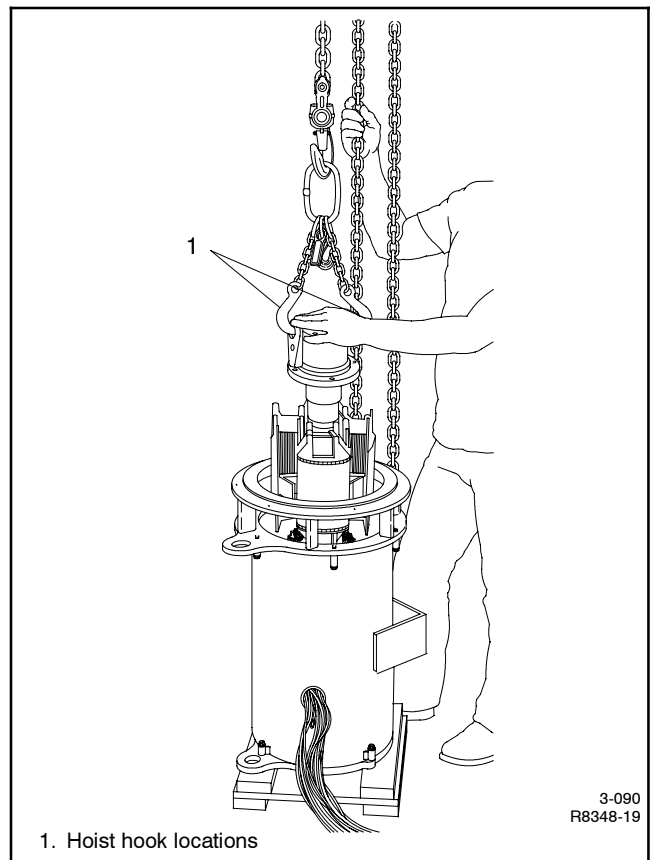
20. Use a stud remover and remove the studs from the flywheel, if damaged.
21. Set alternator assembly on the floor in a horizontal position. Remove the support slings or chains.

22. To remove the rotor assembly, hook hoist to adapter and place the alternator assembly on the floor in a vertical position. See Figure 4-10. Before lowering assembly, place wood blocks along edge of end bracket to stabilize the stator assembly.
23. Remove the drive discs from the rotor assembly. See Figure 4-10.

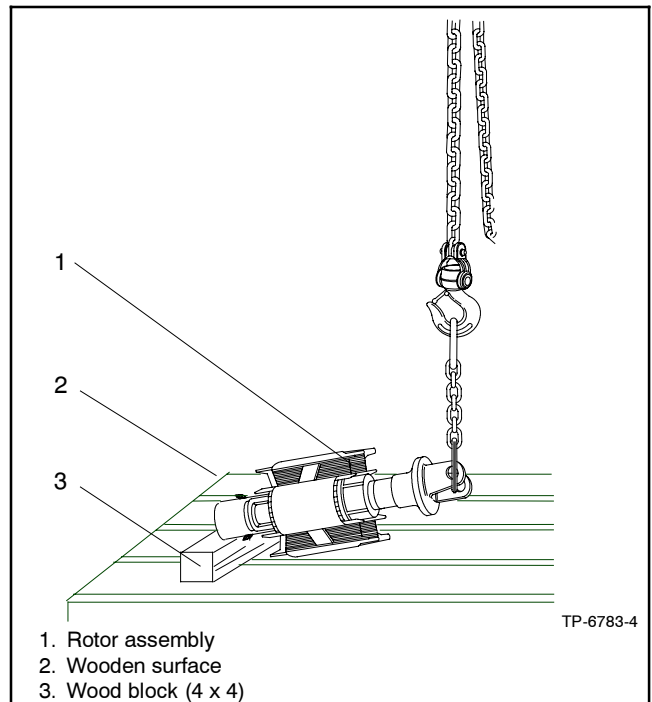


**Figure 4-10** Alternator Support, Drive Disc, and Fan Removal

24. Remove the alternator fan from the rotor assembly.
25. Fasten the lifting eye and hoist hook to the rotor flange. Hoist the rotor assembly carefully to avoid damaging the windings, laminations, or bearing. See Figure 4-11.
26. Place a 100 mm (4 in.) wood block under the rotor shaft end to prevent the coil end turns from coming in contact with the surface before the core stack as it is lowered. This procedure prevents damage to the rotor windings. Slowly lower the rotor to the horizontal position. Set the rotor on a wooden surface. Take care not to damage the windings, laminations, or bearing. See Figure 4-12.
27. Use a bearing puller to remove the bearing. Make note of the bearing location dimensions from the rotor shaft end for reference during installation.

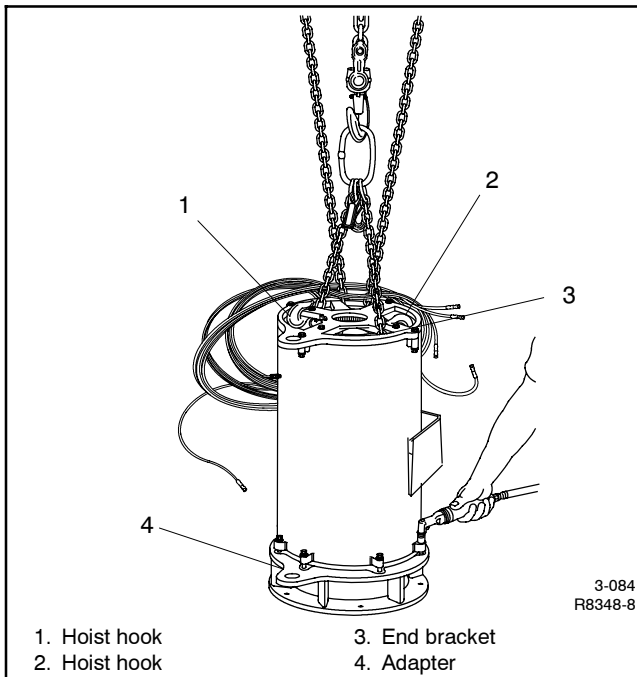


**Figure 4-11** Rotor Removal



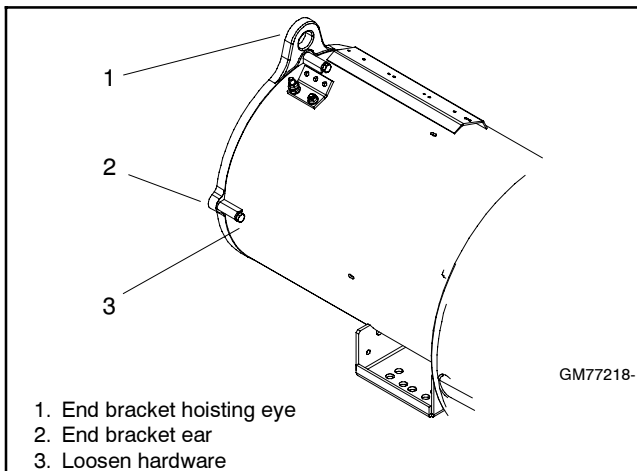
**Figure 4-12** Lowering Rotor

28. Place the alternator assembly on the alternator adapter end in order to remove the alternator adapter and end bracket from the stator. Fasten chains to the alternator adapter and lower to a horizontal position. Fasten hook to the end bracket eye and hoist to a vertical position. See Figure 4-13.



**Figure 4-13** Removing Alternator Adapter

29. Remove the alternator adapter mounting bolts. Fasten the hoist hooks to the end bracket and raise the assembly slightly. Tap the alternator adapter loose by using a rubber mallet.
30. Lower the stator assembly. Loosen the end bracket mounting bolts. Separate the end bracket from the stator by tapping loose with a rubber mallet at the hoisting eye and mounting ears. Remove the end bracket mounting bolts. See Figure 4-14.



**Figure 4-14** Removing End Bracket

## 4.2 Reassembly

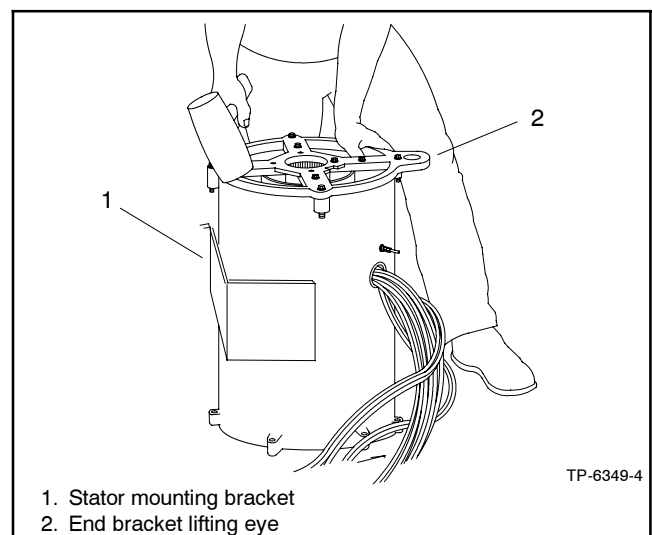
Refer to Section 1, Specifications for torque specifications and Appendix C, General Torque Specifications during reassembly.

1. Place the stator assembly in a vertical position with the end bracket side up.

**Note:** The end bracket side of the stator assembly has four mounting bosses.

2. Place the end bracket on the stator assembly lip, position the end bracket housing eye opposite of the stator mounting bracket, and use the bolts to align the holes.

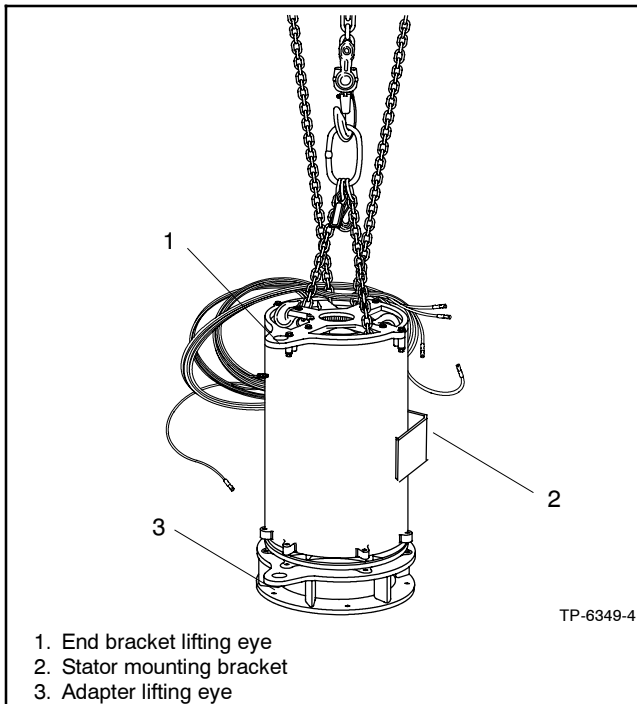
Use a rubber mallet to mount the end bracket flush with the stator assembly. See Figure 4-15.



**Figure 4-15** Mounting End Bracket on Stator

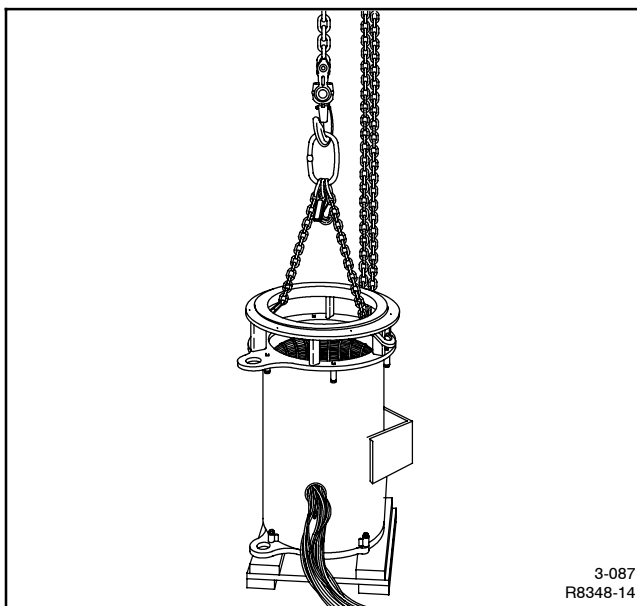
3. Attach the end bracket to the stator using the original hardware. Torque to specifications.
4. Attach hoist hooks to the end bracket and suspend the stator. Place the alternator adapter on the floor and lower the stator to within 6-12 mm (1/4-1/2 in.) of the adapter lip. See Figure 4-16.
5. Position the adapter hoisting eye opposite of the stator mounting bracket and directly below the end bracket hoisting eye.

Align the adapter with the stator and start the bolts with washers. Lower the stator onto the alternator adapter and tighten the bolts. Torque to specifications.



**Figure 4-16** Aligning Adapter and Stator

6. Fasten the hoisting hook to the end bracket eye and lower the alternator assembly to a horizontal position.
7. Attach hoisting hooks to the alternator adapter as shown in Figure 4-17. Suspend the alternator assembly. Before lowering the alternator, place wood blocks along the edge of end bracket to stabilize the stator assembly and to allow space for the rotor shaft extending from the end bracket.

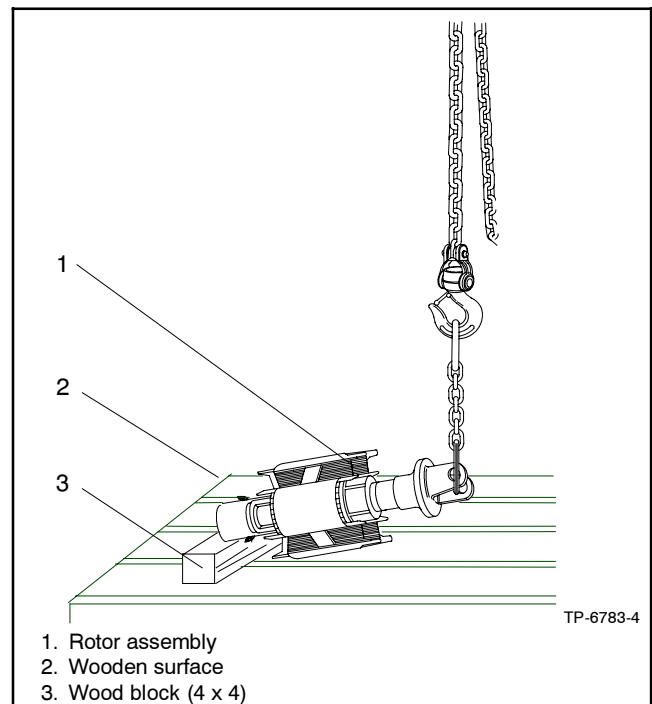


**Figure 4-17** Supporting Stator Assembly

8. Rotor shaft bearing installation. Use a hydraulic press, bearing heater, or heavy rubber mallet and a

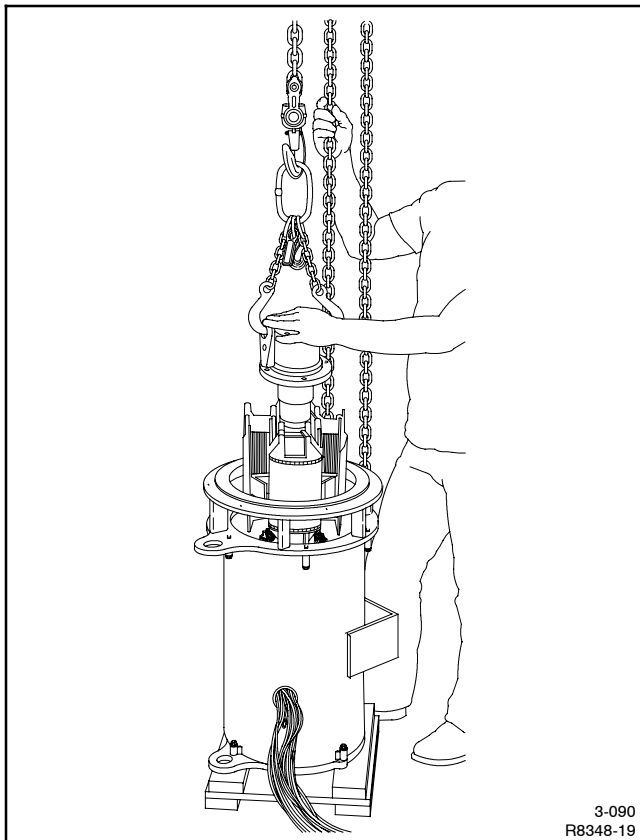
piece of round steel stock with an outside diameter less than the bearing inner race to install the new bearing tight against rotor shaft shoulder using measurements taken during the disassembly procedure. See bearing location value in Section 1.5, Torque Values and Assembly Specifications.

9. Place the stator assembly on the end bracket end when installing the rotor.
10. Fasten the lifting eye and hoist hook to the rotor flange. Use a wood block allowing the rotor shaft end to make contact with the surface prior to the rotor windings as it is tilted. See Figure 4-18. Hoist the rotor to a vertical position taking care not to damage windings, laminations, or bearing.



**Figure 4-18** Hoisting Rotor

11. Suspend the rotor over the stator assembly. Secure the rotor leads (FN/FP) to prevent damage. Lower the rotor field into the stator. Be extremely careful while lowering the rotor to avoid damaging the field magnets, stator windings, or rotor laminations. See Figure 4-19.
12. Carefully align rotor bearing into end bracket. Check for an outer race measurement of 6.35 mm (1/4 in.) from bracket to bearing.
13. Place the fan over the rotor flange and torque bolts to specifications.

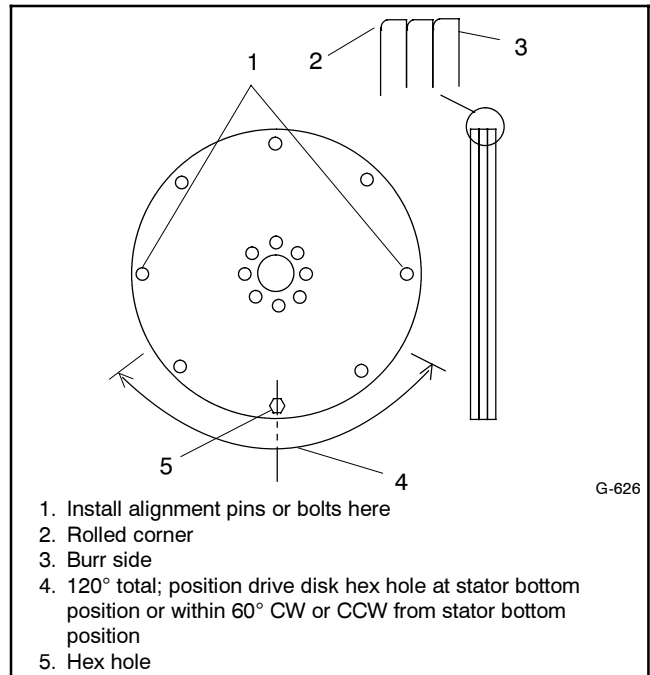


**Figure 4-19** Installing Rotor

14. Align the individual drive disks with the hex holes together and with the hole burr sides facing the same direction. Temporarily place two alignment pins (not supplied) or bolts in the outer holes at opposite ends and 90° from the hex hole before installing the drive disk to the rotor shaft. The pins help maintain concentric alignment of the individual drive disks during installation. See Figure 4-20.

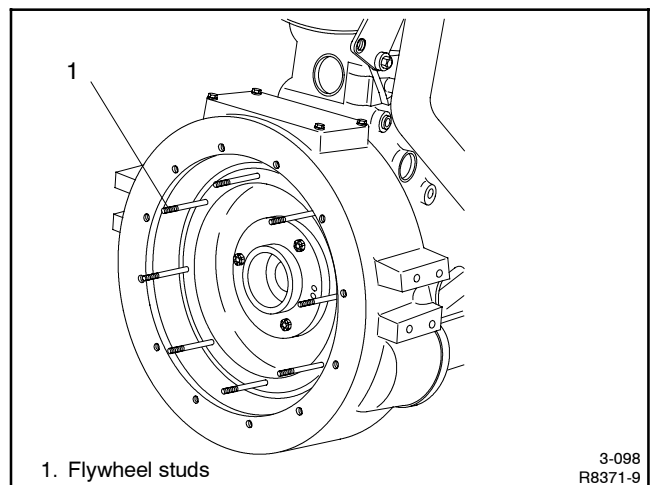
**Note:** User-supplied pins should be no smaller than 0.025 mm (0.001 in.) of disc hole.

15. Attach the drive disc(s) to the end of the rotor shaft with the hole burr side toward the alternator fan and with the hex hole at the stator bottom position or within 60° clockwise (CW) or counterclockwise (CCW) of the bottom position as viewed when the stator is installed on the skid. Torque the drive disc(s) mounting bolts to specifications. Remove the two alignment pins or bolts.
16. Attach the hoist to adapter eye and place the alternator assembly in a horizontal position. Take care not to damage the rotor or stator. Place the hoisting eyes of alternator assembly to the top.



**Figure 4-20** Aligning and Mounting Drive Disks

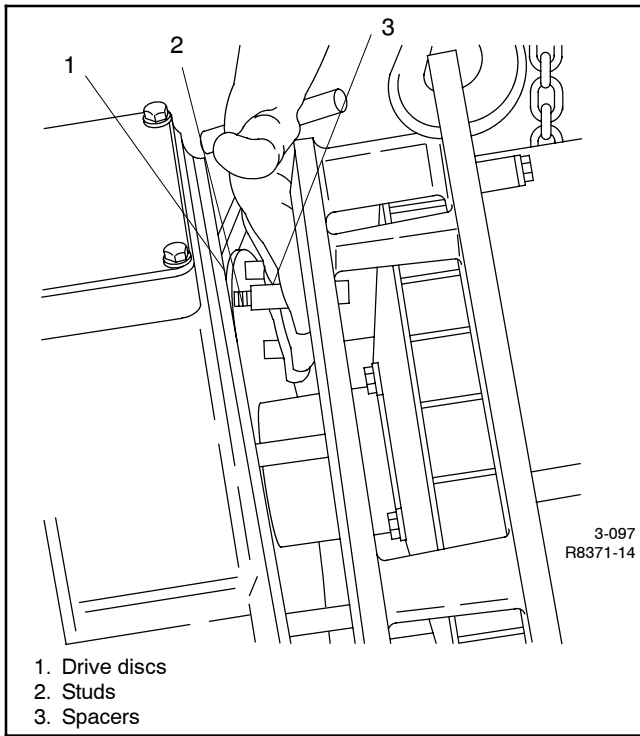
17. If studs are used, apply Loctite® No. 271 red to stud threads and install into flywheel as shown in Figure 4-21. Install studs completely into flywheel. Apply Loctite® No. 242 blue to stud threads on nut side.



**Figure 4-21** Flywheel Studs

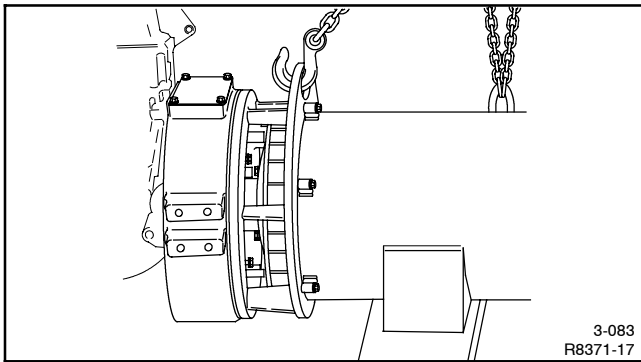
18. Place hoist hooks into the end bracket and adapter eye. Raise the alternator assembly and align the studs with the drive discs by turning the flywheel. Move the alternator as necessary to work the drive discs over studs. When the drive discs are about 25 mm (1 in.) over the studs, install spacers if so equipped. See Figure 4-22.

Loctite® is a registered trademark of Henkel-Loctite Corporation.



**Figure 4-22** Installing Spacers

19. Move the alternator as necessary to align the alternator adapter and the flywheel housing. Fasten and final tighten the adapter to the flywheel housing using bolts and hardened lock washers. See Figure 4-23. Torque bolts to specifications.



**Figure 4-23** Aligning Adapter and Flywheel Housing

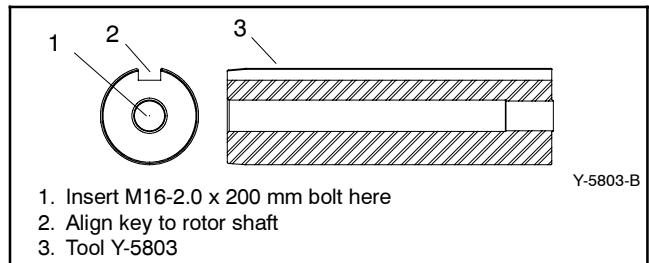
20. Install the hardware attaching the drive discs to the flywheel. Do not final tighten at this time.

**Note:** Some models mount drive discs to flywheel using bolts. Some applications use hardened washers.

21. Hoist the alternator and engine slightly to remove the wood block(s) from under the flywheel housing. Align the alternator assembly and skid. Lower the alternator and tighten the vibromount mounting bolts.

22. Remove the chains or slings used for suspending the alternator. Final tighten the drive discs to the flywheel. Torque hardware to specifications.
23. Apply anti-seize compound to rotor shaft.
24. Install tool Y-5803 or equivalent on the rotor shaft and attach using an M16-2.0 x 200 mm bolt. Align tool with rotor shaft keyway. See Figure 4-24.

**Note:** Procure or fabricate service tool Y-5803 using Appendix F information. Requires (qty. 1) M16-2.0 x 200 mm bolt.

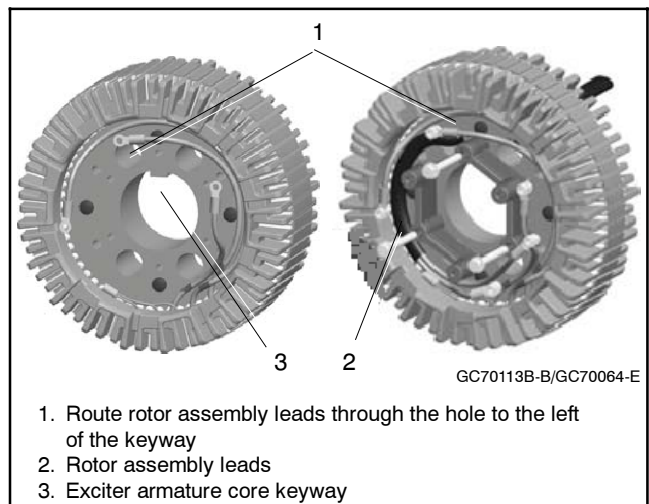


**Figure 4-24** Installing Tool Y-5803

25. Install exciter armature with leads to the outside over service tool Y-5803. Route the rotor leads through the hole to the left of the keyway in the exciter armature core. See Figure 4-25.

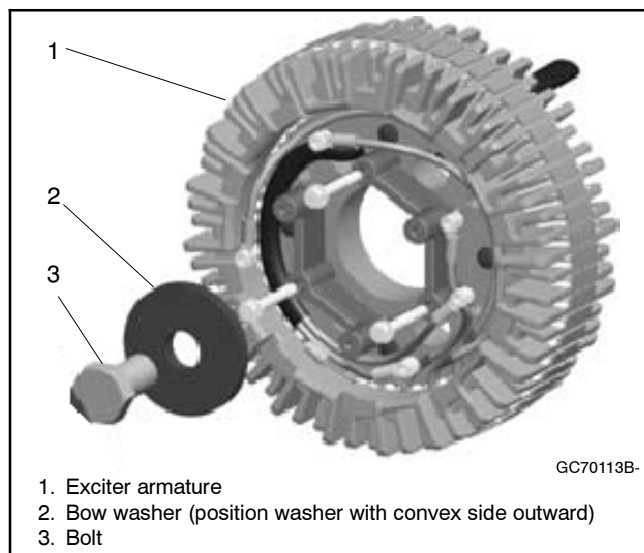
Slide the exciter armature slowly onto stub shaft towards the end bracket magnets while pulling the rotor leads snug to remove slack and prevent pinching the rotor leads. When the exciter armature gets close to the magnets, the magnets will pull the exciter armature along the rotor shaft and the exciter armature will snap into the end bracket magnets.

26. Remove the M16-2.0 x 200 bolt and tool Y-5803.



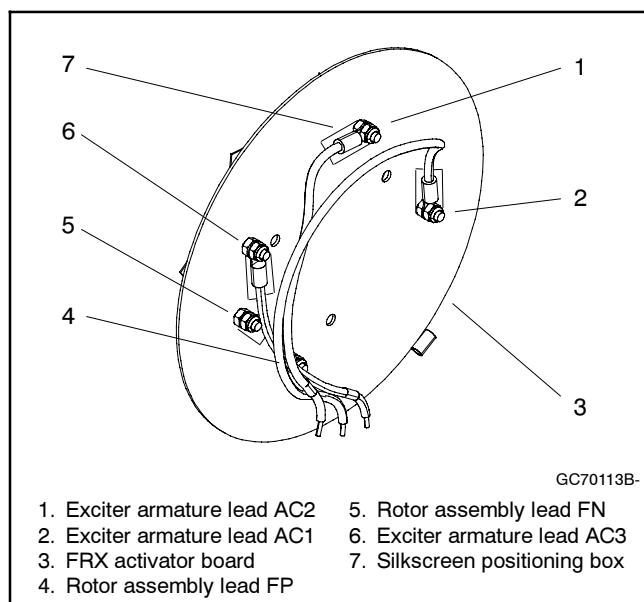
**Figure 4-25** Exciter Armature/Rotor Leads

27. Install exciter armature hardware with bow washer (convex side outward) and torque to specifications. See Figure 4-26.



**Figure 4-26** Installing Exciter Armature Hardware

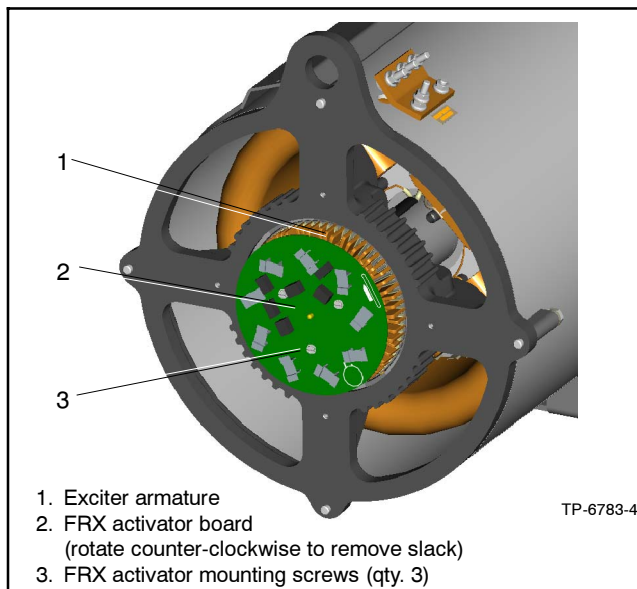
28. Attach rotor assembly leads (FN and FP) to FRX activator board using elastic stop nuts. See Figure 4-27. Position leads as shown on silkscreen box and torque to specifications.



**Figure 4-27** FRX Activator Board

29. Attach exciter armature leads (AC1, AC2, and AC3) to FRX activator board using elastic stop nuts. Position leads as shown on silkscreen box and torque to specifications. See Figure 4-27.
30. Install the FRX activator spacer to the exciter armature using three screws and torque to specifications.

31. Position the FRX activator leads around FRX spacer to prevent pinching and push FRX activator board against FRX spacer while aligning mounting holes. Mount FRX activator board to FRX spacer using three screws and torque to specifications. See Figure 4-28.



**Figure 4-28** Turn FRX Activator Board Leads Counter-Clockwise to Remove Slack

32. Mount the LED optic board to the LED optic board holder using one screw.
33. Attach the LED optic board holder to the end bracket using four screws and torque to specifications.
34. Reconnect the two-lead P6 connector at the LED optic board.
35. Install the fan guard to the alternator adapter.
36. Install the alternator (rodent) guard to the end bracket (if equipped).
37. Reinstall the junction box and controller.
38. Reconnect all controller-to-engine and engine-to-alternator harnesses and wiring. Refer to the wiring diagrams as required.
39. Reconnect the fuel, cooling, and exhaust systems disconnected during disassembly. Reconnect the output leads or load circuit cables at the alternator. Open the fuel supply valve.
40. Replace the junction box panels.
41. Reconnect the starting batteries, negative lead last. Connect any AC-powered accessories such as the battery charger, block heater, fuel transfer pump, etc.

## Notes

# Appendix A Abbreviations

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

|           |                                                                                            |          |                                                                                      |                      |                                                      |
|-----------|--------------------------------------------------------------------------------------------|----------|--------------------------------------------------------------------------------------|----------------------|------------------------------------------------------|
| A, amp    | ampere                                                                                     | cfm      | cubic feet per minute                                                                | est.                 | estimated                                            |
| ABDC      | after bottom dead center                                                                   | CG       | center of gravity                                                                    | E-Stop               | emergency stop                                       |
| AC        | alternating current                                                                        | CID      | cubic inch displacement                                                              | etc.                 | et cetera (and so forth)                             |
| A/D       | analog to digital                                                                          | CL       | centerline                                                                           | exh.                 | exhaust                                              |
| ADC       | advanced digital control;<br>analog to digital converter                                   | cm       | centimeter                                                                           | ext.                 | external                                             |
| adj.      | adjust, adjustment                                                                         | CMOS     | complementary metal oxide<br>substrate (semiconductor)                               | F                    | Fahrenheit, female                                   |
| ADV       | advertising dimensional<br>drawing                                                         | cogen.   | cogeneration                                                                         | fglass.              | fiberglass                                           |
| Ah        | amp-hour                                                                                   | com      | communications (port)                                                                | FHM                  | flat head machine (screw)                            |
| AHWT      | anticipatory high water<br>temperature                                                     | coml     | commercial                                                                           | fl. oz.              | fluid ounce                                          |
| AISI      | American Iron and Steel<br>Institute                                                       | Coml/Rec | Commercial/Recreational                                                              | flex.                | flexible                                             |
| ALOP      | anticipatory low oil pressure                                                              | conn.    | connection                                                                           | freq.                | frequency                                            |
| alt.      | alternator                                                                                 | cont.    | continued                                                                            | FS                   | full scale                                           |
| Al        | aluminum                                                                                   | CPVC     | chlorinated polyvinyl chloride                                                       | ft.                  | foot, feet                                           |
| ANSI      | American National Standards<br>Institute (formerly American<br>Standards Association, ASA) | crit.    | critical                                                                             | ft. lb.              | foot pounds (torque)                                 |
| AO        | anticipatory only                                                                          | CRT      | cathode ray tube                                                                     | ft./min.             | feet per minute                                      |
| APDC      | Air Pollution Control District                                                             | CSA      | Canadian Standards<br>Association                                                    | ftp                  | file transfer protocol                               |
| API       | American Petroleum Institute                                                               | CT       | current transformer                                                                  | g                    | gram                                                 |
| approx.   | approximate, approximately                                                                 | Cu       | copper                                                                               | ga.                  | gauge (meters, wire size)                            |
| AQMD      | Air Quality Management District                                                            | cUL      | Canadian Underwriter's<br>Laboratories                                               | gal.                 | gallon                                               |
| AR        | as required, as requested                                                                  | CUL      | Canadian Underwriter's<br>Laboratories                                               | gen.                 | generator                                            |
| AS        | as supplied, as stated, as<br>suggested                                                    | cu. in.  | cubic inch                                                                           | genset               | generator set                                        |
| ASE       | American Society of Engineers                                                              | cw.      | clockwise                                                                            | GFI                  | ground fault interrupter                             |
| ASME      | American Society of<br>Mechanical Engineers                                                | CWC      | city water-cooled                                                                    | GND, ⊕               | ground                                               |
| assy.     | assembly                                                                                   | cyl.     | cylinder                                                                             | gov.                 | governor                                             |
| ASTM      | American Society for Testing<br>Materials                                                  | D/A      | digital to analog                                                                    | gph                  | gallons per hour                                     |
| ATDC      | after top dead center                                                                      | DAC      | digital to analog converter                                                          | gpm                  | gallons per minute                                   |
| ATS       | automatic transfer switch                                                                  | dB       | decibel                                                                              | gr.                  | grade, gross                                         |
| auto.     | automatic                                                                                  | dB(A)    | decibel (A weighted)                                                                 | GRD                  | equipment ground                                     |
| aux.      | auxiliary                                                                                  | DC       | direct current                                                                       | gr. wt.              | gross weight                                         |
| avg.      | average                                                                                    | DCR      | direct current resistance                                                            | H x W x D            | height by width by depth                             |
| AVR       | automatic voltage regulator                                                                | deg., °  | degree                                                                               | HC                   | hex cap                                              |
| AWG       | American Wire Gauge                                                                        | dept.    | department                                                                           | HCHT                 | high cylinder head temperature                       |
| AWM       | appliance wiring material                                                                  | DFMEA    | Design Failure Mode and<br>Effects Analysis                                          | HD                   | heavy duty                                           |
| bat.      | battery                                                                                    | dia.     | diameter                                                                             | HET                  | high exhaust temp., high<br>engine temp.             |
| BBDC      | before bottom dead center                                                                  | DI/EO    | dual inlet/end outlet                                                                | hex                  | hexagon                                              |
| BC        | battery charger, battery<br>charging                                                       | DIN      | Deutsches Institut für Normung<br>e. V. (also Deutsche Industrie<br>Normenausschuss) | Hg                   | mercury (element)                                    |
| BCA       | battery charging alternator                                                                | DIP      | dual inline package                                                                  | HH                   | hex head                                             |
| BCI       | Battery Council International                                                              | DPDT     | double-pole, double-throw                                                            | HHC                  | hex head cap                                         |
| BDC       | before dead center                                                                         | DPST     | double-pole, single-throw                                                            | HP                   | horsepower                                           |
| BHP       | brake horsepower                                                                           | DS       | disconnect switch                                                                    | hr.                  | hour                                                 |
| blk.      | black (paint color), block<br>(engine)                                                     | DVR      | digital voltage regulator                                                            | HS                   | heat shrink                                          |
| blk. htr. | block heater                                                                               | E, emer. | emergency (power source)                                                             | hsg.                 | housing                                              |
| BMEP      | brake mean effective pressure                                                              | ECM      | electronic control module,<br>engine control module                                  | HVAC                 | heating, ventilation, and air<br>conditioning        |
| bps       | bits per second                                                                            | EDI      | electronic data interchange                                                          | HWT                  | high water temperature                               |
| br.       | brass                                                                                      | EFR      | emergency frequency relay                                                            | Hz                   | hertz (cycles per second)                            |
| BTDC      | before top dead center                                                                     | e.g.     | for example ( <i>exempli gratia</i> )                                                | IC                   | integrated circuit                                   |
| Btu       | British thermal unit                                                                       | EG       | electronic governor                                                                  | ID                   | inside diameter, identification                      |
| Btu/min.  | British thermal units per minute                                                           | EGSA     | Electrical Generating Systems<br>Association                                         | IEC                  | International Electrotechnical<br>Commission         |
| C         | Celsius, centigrade                                                                        | EIA      | Electronic Industries<br>Association                                                 | IEEE                 | Institute of Electrical and<br>Electronics Engineers |
| cal.      | calorie                                                                                    | EI/EO    | end inlet/end outlet                                                                 | IMS                  | improved motor starting                              |
| CAN       | controller area network                                                                    | EMI      | electromagnetic interference                                                         | in.                  | inch                                                 |
| CARB      | California Air Resources Board                                                             | emiss.   | emission                                                                             | in. H <sub>2</sub> O | inches of water                                      |
| CB        | circuit breaker                                                                            | eng.     | engine                                                                               | in. Hg               | inches of mercury                                    |
| cc        | cubic centimeter                                                                           | EPA      | Environmental Protection<br>Agency                                                   | in. lb.              | inch pounds                                          |
| CCA       | cold cranking amps                                                                         | ES       | emergency power system                                                               | Inc.                 | incorporated                                         |
| ccw.      | counterclockwise                                                                           | ESD      | electrostatic discharge                                                              | ind.                 | industrial                                           |
| CEC       | Canadian Electrical Code                                                                   |          |                                                                                      | int.                 | internal                                             |
| cert.     | certificate, certification, certified                                                      |          |                                                                                      | int./ext.            | internal/external                                    |
| cfh       | cubic feet per hour                                                                        |          |                                                                                      | I/O                  | input/output                                         |
|           |                                                                                            |          |                                                                                      | IP                   | iron pipe                                            |
|           |                                                                                            |          |                                                                                      | ISO                  | International Organization for<br>Standardization    |
|           |                                                                                            |          |                                                                                      | J                    | joule                                                |
|           |                                                                                            |          |                                                                                      | JIS                  | Japanese Industry Standard                           |

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

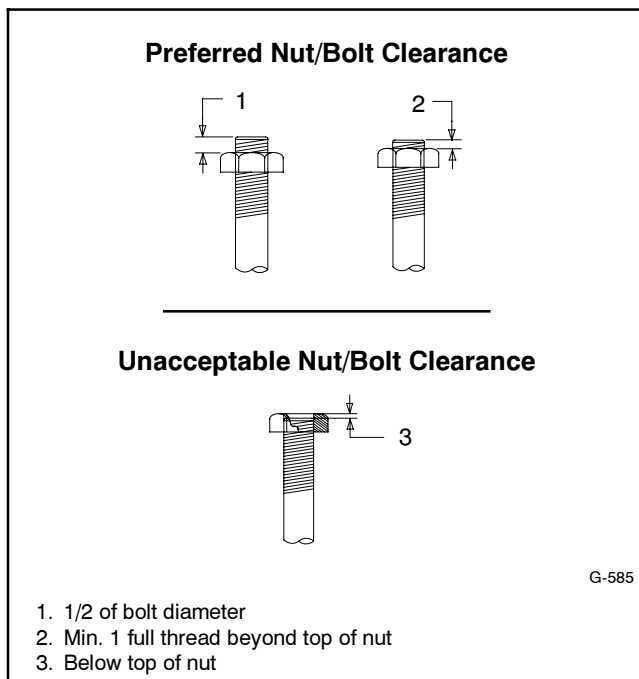
## Appendix B Common Hardware Application Guidelines

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

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

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

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



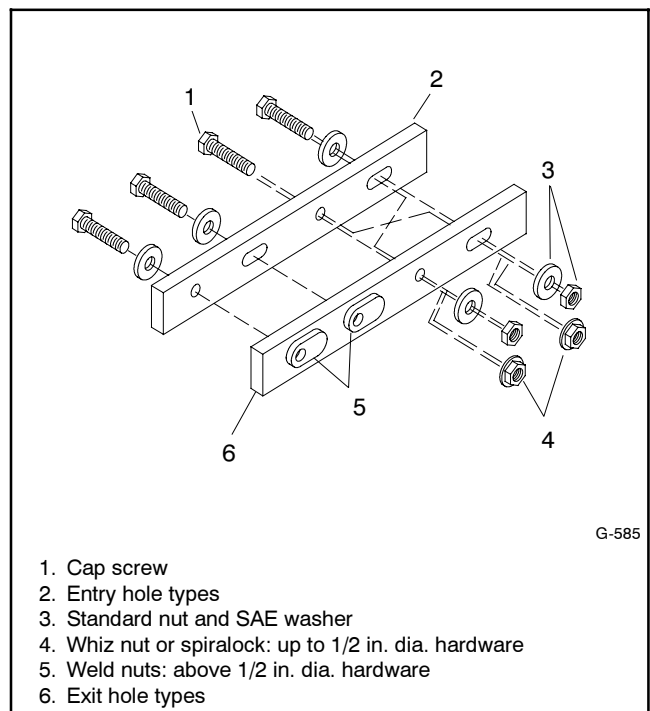
**Figure 1** Acceptable Bolt Lengths

Steps for common hardware application:

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

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

3. Follow these SAE washer rules after determining exit hole type:
  - a. Always use a washer between hardware and a slot.
  - b. Always use a washer under a nut (see 2 above for exception).
  - c. Use a washer under a bolt when the female thread is fixed (weld nut).
4. Refer to Figure 2, which depicts the preceding hardware configuration possibilities.



**Figure 2** Acceptable Hardware Combinations

## Appendix C General Torque Specifications

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

| Metric Fasteners Torque Specifications, Measured in Nm (ft. lb.) |                                   |            |             |                                          |  |
|------------------------------------------------------------------|-----------------------------------|------------|-------------|------------------------------------------|--|
| Size (mm)                                                        | Assembled into Cast Iron or Steel |            |             | Assembled into Aluminum Grade 5.8 or 8.8 |  |
|                                                                  | Grade 5.8                         | Grade 8.8  | Grade 10.9  |                                          |  |
| M6 x 1.00                                                        | 6.2 (4.6)                         | 9.5 (7)    | 13.6 (10)   | See Note 3                               |  |
| M8 x 1.25                                                        | 15 (11)                           | 23 (17)    | 33 (24)     |                                          |  |
| M8 x 1.00                                                        | 16 (11)                           | 24 (18)    | 34 (25)     |                                          |  |
| M10 x 1.50                                                       | 30 (22)                           | 45 (34)    | 65 (48)     |                                          |  |
| M10 x 1.25                                                       | 31 (23)                           | 47 (35)    | 68 (50)     |                                          |  |
| M12 x 1.75                                                       | 53 (39)                           | 80 (59)    | 115 (85)    |                                          |  |
| M12 x 1.50                                                       | 56 (41)                           | 85 (63)    | 122 (90)    |                                          |  |
| M14 x 2.00                                                       | 83 (61)                           | 126 (93)   | 180 (133)   |                                          |  |
| M14 x 1.50                                                       | 87 (64)                           | 133 (98)   | 190 (140)   |                                          |  |
| M16 x 2.00                                                       | 127 (94)                          | 194 (143)  | 278 (205)   |                                          |  |
| M16 x 1.50                                                       | 132 (97)                          | 201 (148)  | 287 (212)   |                                          |  |
| M18 x 2.50                                                       | 179 (132)                         | 273 (201)  | 390 (288)   |                                          |  |
| M18 x 1.50                                                       | 189 (140)                         | 289 (213)  | 413 (305)   |                                          |  |
| M20 x 2.50                                                       | 245 (181)                         | 374 (276)  | 535 (395)   |                                          |  |
| M20 x 1.50                                                       | 264 (195)                         | 402 (297)  | 576 (425)   |                                          |  |
| M22 x 2.50                                                       | 332 (245)                         | 507 (374)  | 725 (535)   |                                          |  |
| M22 x 1.50                                                       | 351 (259)                         | 535 (395)  | 766 (565)   |                                          |  |
| M24 x 3.00                                                       | 425 (314)                         | 649 (479)  | 928 (685)   |                                          |  |
| M24 x 2.00                                                       | 447 (330)                         | 682 (503)  | 976 (720)   |                                          |  |
| M27 x 3.00                                                       | —                                 | 937 (692)  | 1341 (990)  |                                          |  |
| M27 x 2.00                                                       | —                                 | 985 (727)  | 1409 (1040) |                                          |  |
| M30 x 3.50                                                       | —                                 | 1278 (943) | 1829 (1350) |                                          |  |
| M30 x 2.00                                                       | —                                 | 1349 (996) | 1931 (1425) |                                          |  |

### Notes:

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

# 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

# Appendix E Common Hardware List

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

## American Standard

### Part No. Dimensions Hex Head Bolts (Grade 5)

|           |                |
|-----------|----------------|
| X-465-17  | 1/4-20 x .38   |
| X-465-6   | 1/4-20 x .50   |
| X-465-2   | 1/4-20 x .62   |
| X-465-16  | 1/4-20 x .75   |
| X-465-18  | 1/4-20 x .88   |
| X-465-7   | 1/4-20 x 1.00  |
| X-465-8   | 1/4-20 x 1.25  |
| X-465-9   | 1/4-20 x 1.50  |
| X-465-10  | 1/4-20 x 1.75  |
| X-465-11  | 1/4-20 x 2.00  |
| X-465-12  | 1/4-20 x 2.25  |
| X-465-14  | 1/4-20 x 2.75  |
| X-465-21  | 1/4-20 x 5.00  |
| X-465-25  | 1/4-28 x .38   |
| X-465-20  | 1/4-28 x 1.00  |
|           |                |
| X-125-33  | 5/16-18 x .50  |
| X-125-23  | 5/16-18 x .62  |
| X-125-3   | 5/16-18 x .75  |
| X-125-31  | 5/16-18 x .88  |
| X-125-5   | 5/16-18 x 1.00 |
| X-125-24  | 5/16-18 x 1.25 |
| X-125-34  | 5/16-18 x 1.50 |
| X-125-25  | 5/16-18 x 1.75 |
| X-125-26  | 5/16-18 x 2.00 |
| 230578    | 5/16-18 x 2.25 |
| X-125-29  | 5/16-18 x 2.50 |
| X-125-27  | 5/16-18 x 2.75 |
| X-125-28  | 5/16-18 x 3.00 |
| X-125-22  | 5/16-18 x 4.50 |
| X-125-32  | 5/16-18 x 5.00 |
| X-125-35  | 5/16-18 x 5.50 |
| X-125-36  | 5/16-18 x 6.00 |
| X-125-40  | 5/16-18 x 6.50 |
|           |                |
| X-125-43  | 5/16-24 x 1.75 |
| X-125-44  | 5/16-24 x 2.50 |
| X-125-30  | 5/16-24 x .75  |
| X-125-39  | 5/16-24 x 2.00 |
| X-125-38  | 5/16-24 x 2.75 |
|           |                |
| X-6238-2  | 3/8-16 x .62   |
| X-6238-10 | 3/8-16 x .75   |
| X-6238-3  | 3/8-16 x .88   |
| X-6238-11 | 3/8-16 x 1.00  |
| X-6238-4  | 3/8-16 x 1.25  |
| X-6238-5  | 3/8-16 x 1.50  |
| X-6238-1  | 3/8-16 x 1.75  |
| X-6238-6  | 3/8-16 x 2.00  |
| X-6238-17 | 3/8-16 x 2.25  |
| X-6238-7  | 3/8-16 x 2.50  |
| X-6238-8  | 3/8-16 x 2.75  |
| X-6238-9  | 3/8-16 x 3.00  |
| X-6238-19 | 3/8-16 x 3.25  |
| X-6238-12 | 3/8-16 x 3.50  |
| X-6238-20 | 3/8-16 x 3.75  |
| X-6238-13 | 3/8-16 x 4.50  |
| X-6238-18 | 3/8-16 x 5.50  |
| X-6238-25 | 3/8-16 x 6.50  |

### Part No. Dimensions Hex Head Bolts, cont.

|           |                |
|-----------|----------------|
| X-6238-14 | 3/8-24 x .75   |
| X-6238-16 | 3/8-24 x 1.25  |
| X-6238-21 | 3/8-24 x 4.00  |
| X-6238-22 | 3/8-24 x 4.50  |
|           |                |
| X-6024-5  | 7/16-14 x .75  |
| X-6024-2  | 7/16-14 x 1.00 |
| X-6024-8  | 7/16-14 x 1.25 |
| X-6024-3  | 7/16-14 x 1.50 |
| X-6024-4  | 7/16-14 x 2.00 |
| X-6024-11 | 7/16-14 x 2.75 |
| X-6024-12 | 7/16-14 x 6.50 |
|           |                |
| X-129-15  | 1/2-13 x .75   |
| X-129-17  | 1/2-13 x 1.00  |
| X-129-18  | 1/2-13 x 1.25  |
| X-129-19  | 1/2-13 x 1.50  |
| X-129-20  | 1/2-13 x 1.75  |
| X-129-21  | 1/2-13 x 2.00  |
| X-129-22  | 1/2-13 x 2.25  |
| X-129-23  | 1/2-13 x 2.50  |
| X-129-24  | 1/2-13 x 2.75  |
| X-129-25  | 1/2-13 x 3.00  |
| X-129-27  | 1/2-13 x 3.50  |
| X-129-29  | 1/2-13 x 4.00  |
| X-129-30  | 1/2-13 x 4.50  |
| X-463-9   | 1/2-13 x 5.50  |
| X-129-44  | 1/2-13 x 6.00  |
|           |                |
| X-129-51  | 1/2-20 x .75   |
| X-129-45  | 1/2-20 x 1.25  |
| X-129-52  | 1/2-20 x 1.50  |
|           |                |
| X-6021-3  | 5/8-11 x 1.00  |
| X-6021-4  | 5/8-11 x 1.25  |
| X-6021-2  | 5/8-11 x 1.50  |
| X-6021-1  | 5/8-11 x 1.75  |
| 273049    | 5/8-11 x 2.00  |
| X-6021-5  | 5/8-11 x 2.25  |
| X-6021-6  | 5/8-11 x 2.50  |
| X-6021-7  | 5/8-11 x 2.75  |
| X-6021-12 | 5/8-11 x 3.75  |
| X-6021-11 | 5/8-11 x 4.50  |
| X-6021-10 | 5/8-11 x 6.00  |
|           |                |
| X-6021-9  | 5/8-18 x 2.50  |
|           |                |
| X-6239-1  | 3/4-10 x 1.00  |
| X-6239-8  | 3/4-10 x 1.25  |
| X-6239-2  | 3/4-10 x 1.50  |
| X-6239-3  | 3/4-10 x 2.00  |
| X-6239-4  | 3/4-10 x 2.50  |
| X-6239-5  | 3/4-10 x 3.00  |
| X-6239-6  | 3/4-10 x 3.50  |
|           |                |
| X-792-1   | 1-8 x 2.25     |
| X-792-5   | 1-8 x 3.00     |
| X-792-8   | 1-8 x 5.00     |

### Part No. Dimensions Type

#### Hex Nuts

|           |         |           |
|-----------|---------|-----------|
| X-6009-1  | 1-8     | Standard  |
|           |         |           |
| X-6210-3  | 6-32    | Whiz      |
| X-6210-4  | 8-32    | Whiz      |
| X-6210-5  | 10-24   | Whiz      |
| X-6210-1  | 10-32   | Whiz      |
|           |         |           |
| X-6210-2  | 1/4-20  | Spiralock |
| X-6210-6  | 1/4-28  | Spiralock |
| X-6210-7  | 5/16-18 | Spiralock |
| X-6210-8  | 5/16-24 | Spiralock |
| X-6210-9  | 3/8-16  | Spiralock |
| X-6210-10 | 3/8-24  | Spiralock |
| X-6210-11 | 7/16-14 | Spiralock |
| X-6210-12 | 1/2-13  | Spiralock |
| X-6210-15 | 7/16-20 | Spiralock |
| X-6210-14 | 1/2-20  | Spiralock |
|           |         |           |
| X-85-3    | 5/8-11  | Standard  |
| X-88-12   | 3/4-10  | Standard  |
| X-89-2    | 1/2-20  | Standard  |

#### Washers

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

## Metric

Hex head bolts are hardness grade 8.8 unless noted.

### Part No. Dimensions Hex Head Bolts (Partial Thread)

|               |                |
|---------------|----------------|
| M931-05055-60 | M5-0.80 x 55   |
| M931-06040-60 | M6-1.00 x 40   |
| M931-06055-60 | M6-1.00 x 55   |
| M931-06060-60 | M6-1.00 x 60   |
| M931-06060-SS | M6-1.00 x 60   |
| M931-06070-60 | M6-1.00 x 70   |
| M931-06070-SS | M6-1.00 x 70   |
| M931-06075-60 | M6-1.00 x 75   |
| M931-06090-60 | M6-1.00 x 90   |
| M931-06145-60 | M6-1.00 x 145  |
| M931-06150-60 | M6-1.00 x 150  |
| M931-08035-60 | M8-1.25 x 35   |
| M931-08040-60 | M8-1.25 x 40   |
| M931-08045-60 | M8-1.25 x 45   |
| M931-08050-60 | M8-1.25 x 50   |
| M931-08055-60 | M8-1.25 x 55   |
| M931-08055-82 | M8-1.25 x 55*  |
| M931-08060-60 | M8-1.25 x 60   |
| M931-08070-60 | M8-1.25 x 70   |
| M931-08070-82 | M8-1.25 x 70*  |
| M931-08075-60 | M8-1.25 x 75   |
| M931-08080-60 | M8-1.25 x 80   |
| M931-08090-60 | M8-1.25 x 90   |
| M931-08095-60 | M8-1.25 x 95   |
| M931-08100-60 | M8-1.25 x 100  |
| M931-08110-60 | M8-1.25 x 110  |
| M931-08120-60 | M8-1.25 x 120  |
| M931-08130-60 | M8-1.25 x 130  |
| M931-08140-60 | M8-1.25 x 140  |
| M931-08150-60 | M8-1.25 x 150  |
| M931-08200-60 | M8-1.25 x 200  |
| M931-10040-82 | M10-1.25 x 40* |
| M931-10040-60 | M10-1.50 x 40  |
| M931-10045-60 | M10-1.50 x 45  |
| M931-10050-60 | M10-1.50 x 50  |
| M931-10050-82 | M10-1.25 x 50* |
| M931-10055-60 | M10-1.50 x 55  |
| M931-10060-60 | M10-1.50 x 60  |
| M931-10065-60 | M10-1.50 x 65  |
| M931-10070-60 | M10-1.50 x 70  |
| M931-10080-60 | M10-1.50 x 80  |
| M931-10080-82 | M10-1.25 x 80* |
| M931-10090-60 | M10-1.50 x 90  |
| M931-10090-82 | M10-1.50 x 90* |
| M931-10100-60 | M10-1.50 x 100 |
| M931-10110-60 | M10-1.50 x 110 |
| M931-10120-60 | M10-1.50 x 120 |
| M931-10130-60 | M10-1.50 x 130 |
| M931-10140-60 | M10-1.50 x 140 |
| M931-10180-60 | M10-1.50 x 180 |
| M931-10235-60 | M10-1.50 x 235 |
| M931-10260-60 | M10-1.50 x 260 |
| M960-10330-60 | M10-1.25 x 330 |
| M931-12045-60 | M12-1.75 x 45  |
| M960-12050-60 | M12-1.25 x 50  |
| M960-12050-82 | M12-1.25 x 50* |
| M931-12050-60 | M12-1.75 x 50  |
| M931-12050-82 | M12-1.75 x 50* |
| M931-12055-60 | M12-1.75 x 55  |
| M931-12060-60 | M12-1.75 x 60  |
| M931-12060-82 | M12-1.75 x 60* |
| M931-12065-60 | M12-1.75 x 65  |
| M931-12075-60 | M12-1.75 x 75  |
| M931-12080-60 | M12-1.75 x 80  |
| M931-12090-60 | M12-1.75 x 90  |
| M931-12100-60 | M12-1.75 x 100 |
| M931-12110-60 | M12-1.75 x 110 |

### Part No. Dimensions Hex Head Bolts (Partial Thread), continued

|               |                 |
|---------------|-----------------|
| M960-16090-60 | M16-1.50 x 90   |
| M931-16090-60 | M16-2.00 x 90   |
| M931-16100-60 | M16-2.00 x 100  |
| M931-16100-82 | M16-2.00 x 100* |
| M931-16120-60 | M16-2.00 x 120  |
| M931-16150-60 | M16-2.00 x 150  |
| M931-20065-60 | M20-2.50 x 65   |
| M931-20090-60 | M20-2.50 x 90   |
| M931-20100-60 | M20-2.50 x 100  |
| M931-20120-60 | M20-2.50 x 120  |
| M931-20140-60 | M20-2.50 x 140  |
| M931-20160-60 | M20-2.50 x 160  |
| M931-22090-60 | M22-2.50 x 90   |
| M931-22120-60 | M22-2.50 x 120  |
| M931-22160-60 | M22-2.50 x 160  |
| M931-24090-60 | M24-3.00 x 90   |
| M931-24120-60 | M24-3.00 x 120  |
| M931-24160-60 | M24-3.00 x 160  |
| M931-24200-60 | M24-3.00 x 200  |

### Hex Head Bolts (Full Thread)

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

### Part No. Dimensions Hex Head Bolts (Full Thread), continued

|                |                |
|----------------|----------------|
| M933-12016-60  | M12-1.75 x 16  |
| M933-12020-60  | M12-1.75 x 20  |
| M961-12020-60F | M12-1.50 x 20  |
| M933-12025-60  | M12-1.75 x 25  |
| M933-12025-82  | M12-1.75 x 25* |
| M961-12030-60  | M12-1.25 x 30  |
| M933-12030-82  | M12-1.75 x 30* |
| M961-12030-82F | M12-1.50 x 30* |
| M933-12030-60  | M12-1.75 x 30  |
| M933-12035-60  | M12-1.75 x 35  |
| M961-12040-82  | M12-1.25 x 40* |
| M933-12040-60  | M12-1.75 x 40  |
| M933-12040-82  | M12-1.75 x 40* |
| M961-14025-60  | M14-1.50 x 25  |
| M933-14025-60  | M14-2.00 x 25  |
| M961-14050-82  | M14-1.50 x 50* |
| M961-16025-60  | M16-1.50 x 25  |
| M933-16025-60  | M16-2.00 x 25  |
| M961-16030-82  | M16-1.50 x 30* |
| M933-16030-82  | M16-2.00 x 30* |
| M933-16035-60  | M16-2.00 x 35  |
| M961-16040-60  | M16-1.50 x 40  |
| M933-16040-60  | M16-2.00 x 40  |
| M961-16045-82  | M16-1.50 x 45* |
| M933-16045-82  | M16-2.00 x 45* |
| M933-16050-60  | M16-2.00 x 50  |
| M933-16050-82  | M16-2.00 x 50* |
| M933-16060-60  | M16-2.00 x 60  |
| M933-16070-60  | M16-2.00 x 70  |
| M933-18035-60  | M18-2.50 x 35  |
| M933-18050-60  | M18-2.50 x 50  |
| M933-18060-60  | M18-2.50 x 60  |
| M933-20050-60  | M20-2.50 x 50  |
| M933-20055-60  | M20-2.50 x 55  |
| M933-24060-60  | M24-3.00 x 60  |
| M933-24065-60  | M24-3.00 x 65  |
| M933-24070-60  | M24-3.00 x 70  |

### Pan Head Machine Screws

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

### Flat Head Machine Screws

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

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

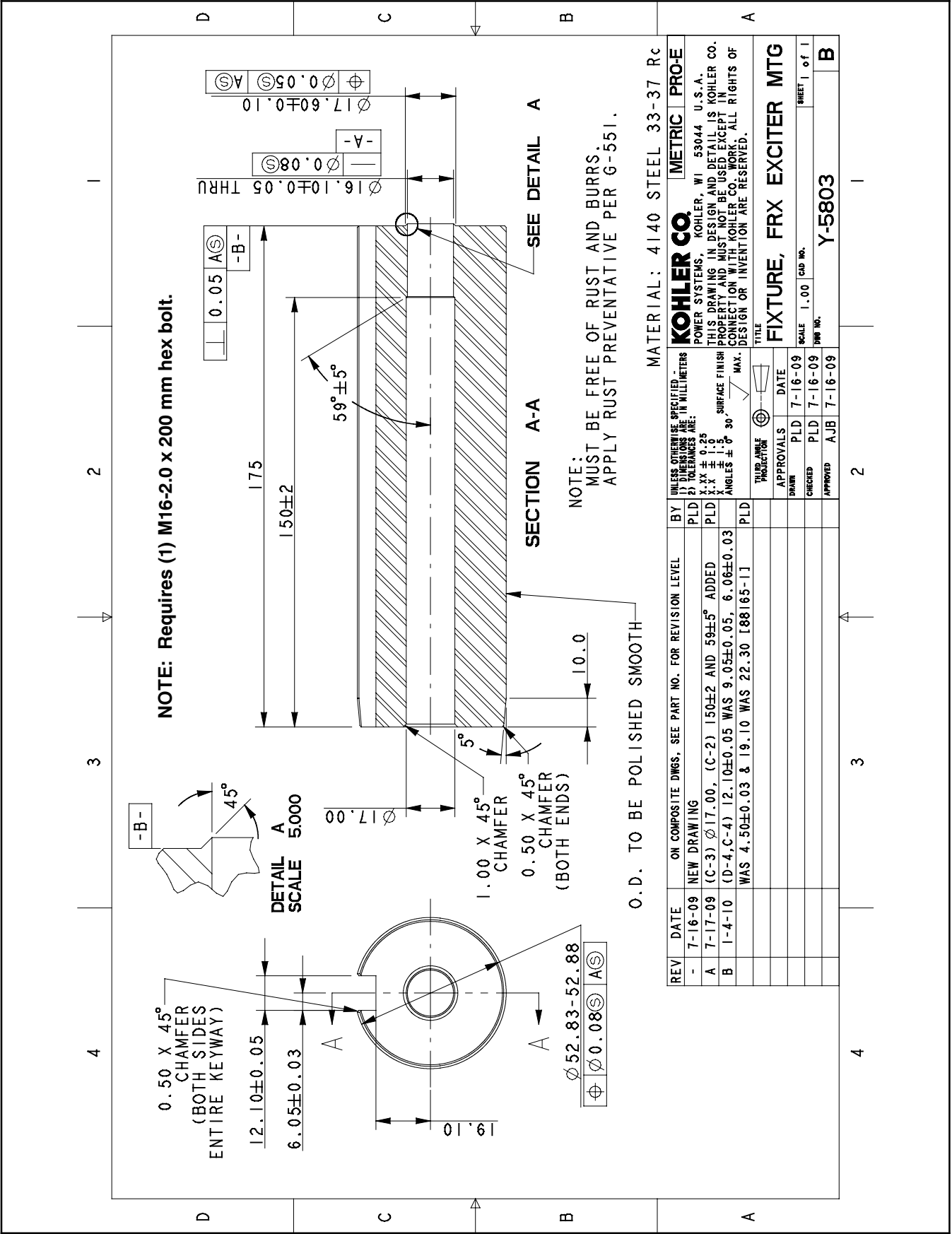
## Metric, continued

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

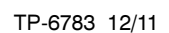
## Washers

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

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



## 58 Appendix





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