Service and Parts

DETROIT DIESEL®

mtu

Automatic Transfer Switches

Models:
R220

Electrical Controls:
Solid-State

Power Switching Device
Contactors:
100 and 200 Amperes

DETROIT DIESEL ISO CERTIFIED ORGANIZATION 9001 CORPORATION

MP-6322 9/04

Product Identification Information

Transfer Switch Identification Numbers

Record the product identification numbers from the transfer switch nameplate.

Model Designation _____

Serial Number _____

Accessory Number	Accessory Description

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

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

DANGER

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

WARNING

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

CAUTION

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

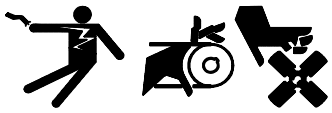
NOTICE

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

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

Accidental Starting

WARNING



Accidental starting.
Can cause severe injury or death.

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

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

Battery

WARNING

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

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

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.

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 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.

Hazardous Voltage/ Electrical Shock

⚠ DANGER

Hazardous voltage.
Will cause severe injury or death.

Disconnect all power sources before opening the enclosure.

⚠ WARNING

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

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

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

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).

Making line or auxiliary connections. Hazardous voltage can cause severe injury or death. To prevent electrical shock deenergize the normal power source before making any line or auxiliary connections.

Servicing the transfer switch. Hazardous voltage can cause severe injury or death. Deenergize all power sources before servicing. Open the main circuit breakers of all transfer switch power sources and disable all generator sets as follows: (1) Move all generator set master controller switches to the OFF position. (2) Disconnect power to all battery chargers. (3) Disconnect all battery cables, negative (–) leads first. Reconnect negative (–) leads last when reconnecting the battery cables after servicing. Follow these precautions to prevent the starting of generator sets by an automatic transfer switch, remote start/stop switch, or engine start command from a remote computer. Before servicing any components inside the enclosure: (1) Remove all jewelry. (2) Stand on a dry, approved electrically insulated mat. (3) Test circuits with a voltmeter to verify that they are deenergized.

Servicing the transfer switch controls and accessories within the enclosure. Hazardous voltage can cause severe injury or death. Disconnect the transfer switch controls at the inline connector to deenergize the circuit boards and logic circuitry but allow the transfer switch to continue to supply power to the load. Disconnect all power sources to accessories that are mounted within the enclosure but are not wired through the controls and deenergized by inline connector separation. Test circuits with a voltmeter to verify that they are deenergized before servicing.

⚠ DANGER

Hazardous voltage.
Will cause severe injury or death.

Only authorized personnel should open the enclosure.

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

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

Heavy Equipment

⚠ WARNING

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

Use adequate lifting capacity.
Never leave the transfer switch standing upright unless it is securely bolted in place or stabilized.

Moving Parts

⚠ WARNING

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

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

Notice

NOTICE

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

NOTICE

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

NOTICE

Improper operator handle usage. Use the manual operator handle on the transfer switch for maintenance purposes only. Return the transfer switch to the normal position. Remove the manual operator handle, if used, and store it in the place provided on the transfer switch when service is completed.

NOTICE

Foreign material contamination. Cover the transfer switch during installation to keep dirt, grit, metal drill chips, and other debris out of the components. Cover the solenoid mechanism during installation. After installation, use the manual operating handle to cycle the contactor to verify that it operates freely. Do not use a screwdriver to force the contactor mechanism.

NOTICE

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

Notes

Introduction

This manual provides service and parts information for DDC/MTU Power Generation Model R220 transfer switches with solid-state electrical controls and 100 and 200 ampere contactor power switching devices. This manual includes operation, troubleshooting, repair, and maintenance procedures for the transfer switch including the power switching device and electrical controls. This manual is intended for the use only by persons trained and qualified to work on electrical equipment.

Information in this publication represents data available at the time of print. The manufacturer of DDC/MTU Power Generation products reserves the right to change this literature 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 parts often and perform required service at the prescribed intervals. Obtain service from an authorized service distributor/ dealer to keep equipment in top condition.

List of Related Materials

Separate literature contains operation and installation information not provided in this manual. The following table lists the available literature part numbers.

Document	Part Number
Model R220 Operation and Installation Manual	MP-6321
Specification Sheet	M11-88

Service Assistance

For professional advice on generator power requirements and conscientious service, please contact your nearest DDC/MTU Power Generation distributor.

- Consult the Yellow Pages under the heading Generators—Electric
- Visit the DDC/MTU Power Generation website at ddcmtupowergeneration.com
- Look at the labels and stickers on your DDC/MTU Power Generation product or review the appropriate literature or documents included with the product

Notes

1.1 Purpose

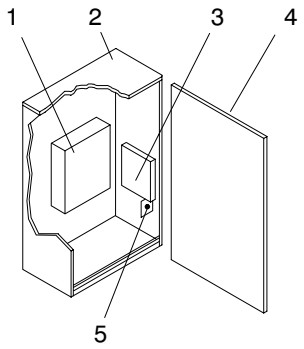
An automatic transfer switch (ATS) transfers electrical loads from a normal (preferred or utility) source of electrical power to an emergency (standby or replacement) source when the normal source fails to maintain a minimum power quality level.

When the normal source fails, the ATS signals the emergency source generator set to start. When the emergency source reaches a minimum quality level, the ATS transfers the load from the normal source to the emergency source. The ATS continuously monitors the normal source and transfers the load back to the normal source when the normal source returns. After transferring the load back to the normal source, the ATS removes the generator start signal, allowing the generator set to shut down.

1.2 Components

The ATS documented in this manual contains several components. See Figure 1-1. The contactor power switching device connects the load to the normal or emergency sources of power. The electrical controls monitor power sources, control the contactor, and signal the generator to start when needed. The exerciser switch controls the operation of the exerciser function.

The contactor power switching device transfers power from the normal or emergency power sources to the load. The electrical controls electrically actuate the contactor to select a power source, and the contactor mechanically latches in the selected position. The contactor also includes a provision for manual operation in emergency nonpowered conditions.



1. Power switching device (contactor)
2. Enclosure
3. Electrical controls (solid-state)
4. Enclosure cover
5. Exerciser switch

Figure 1-1 ATS Components

The contactor power switching device uses two sets of multipole contacts. See Figure 1-2. One set of contacts connects the load to the normal source and the other set connects the load to the emergency source. The double-throw, inherently interlocked design of the contactor prevents simultaneous closing of both sets of contacts and cross-coupling of power sources.

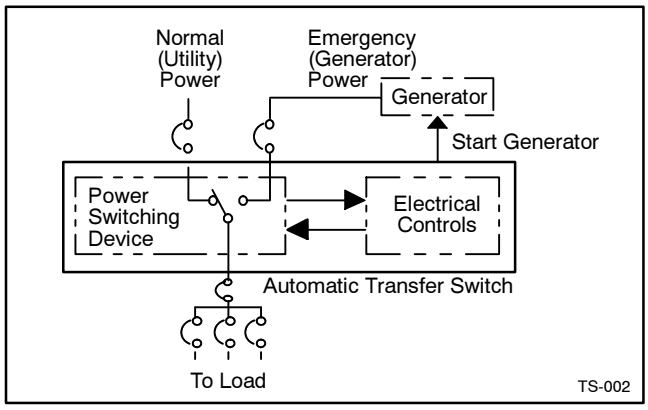
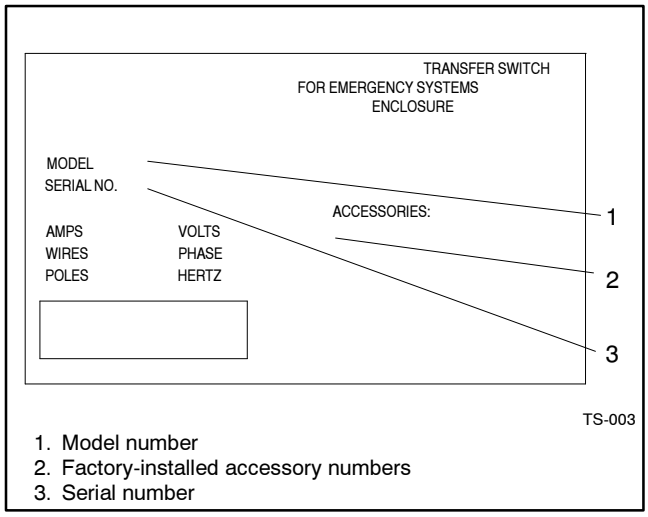


Figure 1-2 Typical ATS Block Diagram

1.3 Nameplate

A nameplate attached to the inside of the enclosure door or cover includes a model number, a serial number, ratings, and other information that may be needed for operation, installation, service, or to order parts. See Figure 1-3.



1. Model number
2. Factory-installed accessory numbers
3. Serial number

Figure 1-3 Typical Transfer Switch Nameplate

Copy the model number, serial number, and accessory information from the nameplate into the spaces provided inside the front cover for use when requesting service or parts. Copy the model number into the blank spaces in Figure 1-5 and use the figure to interpret the model number code.

Copy the model number and serial number from the nameplate into the spaces provided in the Service Assistance section of this manual for use when requesting service or parts.

1.4 Model Number

See Figure 1-5 to interpret the transfer switch model number.

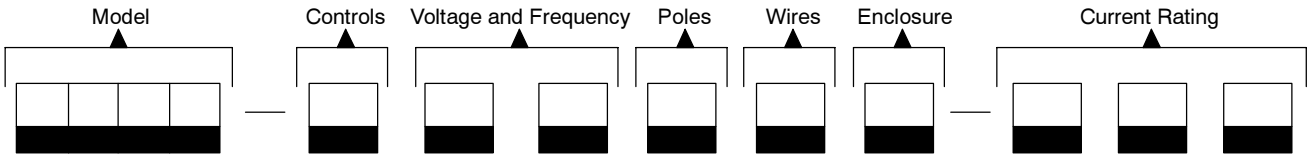
1.5 Application Data

See Figure 1-4 for the range of wire sizes for transfer switch power terminals.

UL-Listed Solderless Screw-Type Terminals for External Power Connections		
Switch Rating (amps)	**Normal, Emergency, and Load Terminals**	
	Cables per Pole	**Range of Wire Sizes**
100	1	#8 to 3/0 (copper or aluminum)
200	1	#8 to 3/0 (copper only)

Figure 1-4 Application Data

Record the transfer switch part number in the boxes below. The transfer switch part number defines characteristics and ratings as explained in the accompanying chart.



DDC/MTU Power Generation Model Number Key

This chart explains the DDC/MTU Power Generation transfer switch model number code. The sample model number shown is for a Model R220 automatic transfer switch that uses a 250-volt maximum contactor power switching device with solid-state electrical controls rated at 240 volts, 60 hertz, 1 phase, 2 pole, and 3 wires in a NEMA Type 3R enclosure with a current rating of 100 amperes. Not all possible combinations are available.

SAMPLE PART NUMBER

R220-164233-0100

Model
R220: Model R220 transfer switch, 250-volt maximum contactor

Electrical Controls
1: Solid-state

Voltage and Frequency
63: 220 Volt, 50 Hz
64: 240 Volt, 60 Hz

Number of Poles and Phases
2: 2 Pole, 1 Phase

Number of Wires
3: 3 Wire

Enclosure
3 = NEMA type 3R

Current Rating
Numbers indicate the current rating of the switch in amperes.

Figure 1-5 Transfer Switch Model Number Code

⚠ DANGER

Hazardous voltage.
Will cause severe injury or death.

Disconnect all power sources before opening the enclosure.

Have preventive maintenance performed on the transfer switch at regular intervals after installation. See Section 3 for instructions.

Contact an authorized distributor/dealer to inspect and service the transfer switch when any wear, damage, deterioration, or malfunction of the transfer switch or its components is evident or suspected; *do not energize the switch.*

2.1 Startup

Perform the following powerup procedure after maintenance or service of the standby system that requires disconnection of power sources from the transfer switch, *not for initial startup.*

For initial startup, follow the instructions in the Installation section in the operation and installation manual for the transfer switch. See List of Related Materials in the Introduction section of this manual for the manual part number.

Read and understand documentation provided with the switch and labels affixed to the switch. Review the operation of installed accessories.

Follow the steps below to power up the transfer switch and prepare it for automatic operation.

Powerup Procedure

1. Place the generator set master switch in the OFF position to prevent starting the generator set.
2. Disconnect *both* the normal and emergency power sources by opening circuit breakers or switches leading to the transfer switch.
3. Open the enclosure and check that the contactor wiring harness is connected to the electrical controls at connector P1. See Figure 4-2.
4. Follow the manual operation procedure to prepare the transfer switch for automatic operation. See Section 2.4 for instructions.
5. Replace the transfer switch enclosure cover. Lock NEMA type 3R enclosures with a padlock. Replace and tighten the fastening screws on the enclosure cover.
6. Prepare the standby generator set for operation. Check the oil level, coolant level, fuel supply, batteries, and items specified by the generator set Prestart Checklist or similar instructions in the operation manual.
7. Place the generator set master switch in the AUTO position. The generator set should start.
8. When loads are ready to be energized, close circuit breakers or switches leading to the transfer switch.

   Note: When applying power to the transfer switch whose electrical controls have lost power, the engine-start contact remains closed and the engine start LED stays off, signaling the generator to run at least until the ATS's time delay engine cooldown (TDEC) ends.

9. Perform an automatic operation test. With normal power present, disconnect the normal power source and verify that the system responds as described in Section 2.2.1, starting the generator set automatically and transferring the load to the emergency power source. When the transfer switch has transferred the load to the emergency source, reconnect the normal power source and verify that the system operates as described in Section 2.2.2, retransferring the load to the normal source and shutting down the generator set after TDEC.

2.2 Automatic Operation

The ATS controller monitors the normal and emergency power sources and determines when a power source has failed or is acceptable and controls the system accordingly. See Figure 4-2. Failure of a power source occurs when its voltage on one or more phases falls below the dropout voltage level. A power source is acceptable when its voltage on sensed phases rise above the pickup voltage level and stay above the dropout voltage level. A power source is restored when it becomes acceptable again after failure. Typical ATS operation occurs in two separate automatic sequences.

- **Failure of normal power** and the resulting transfer to emergency power.
- **Restoration of normal power** and the resulting transfer back to normal power.

2.2.1 Failure of Normal Power

The main controller circuit board monitors phase A-C of the normal power source. The normal available (NA) LED on the main controller circuit board lights when the normal power source is acceptable.

On single-phase switches the jumper JP3 connects terminals GND and 3PH on the main controller circuit board. See Figure 2-1. The controller considers the normal source unacceptable when the normal source voltage on phase A-C drops below the single-phase dropout specification and acceptable when it rises above the single-phase pickup specification.

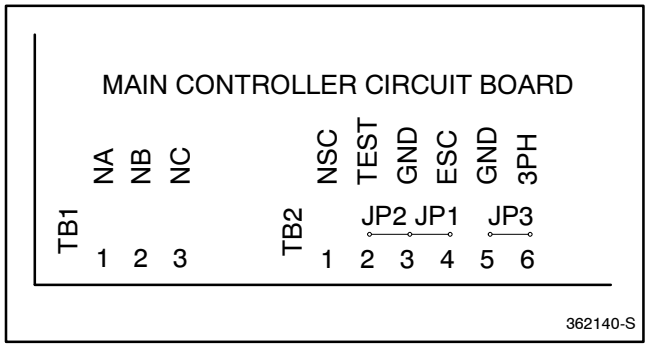


Figure 2-1 Single-phase Configuration

When the normal power source fails, the normal relay (NR) on the main controller circuit board is no longer held, the NA LED turns off, and the controller starts a time delay called time delay engine start (TDES). TDES prevents unnecessary generator startup during short utility power interruptions. The controller maintains internal control circuits including the plant exerciser setting for up to 90 seconds without the normal or emergency power source. If the normal power source is restored before TDES ends, the controller resets the time delay. If the normal power failure persists and TDES ends, the controller issues a signal to start the standby (emergency) generator to produce the emergency power source by closing the engine-start contact between terminals ES3 and ES4 and the engine start (ES) LED on the main controller circuit board turns off.

After signalling the generator to start, the controller monitors the voltage on phase A-C of the emergency source. The emergency acceptable (EA) LED on the main controller circuit board lights when the voltage rises above the emergency source pickup specification. The controller considers the emergency source acceptable and the EA LED remains lit when the emergency source voltage remains above the emergency source dropout level specification. When the emergency source becomes available, the controller starts a time delay called time delay normal-to-emergency (TDNE). TDNE allows emergency power source stabilization before load connection. When TDNE ends, the controller lights the ER LED and energizes the emergency relay (ER). The emergency relay signals the contactor to connect the load to the emergency source operating the contactor solenoid TS through a bridge rectifier BR and coil-clearing contact SCE. When the contactor moves away from the normal position, coil-clearing contact SCE opens to remove power from the solenoid. The contactor mechanism's inertia carries it through the top of the cycle and into the emergency position. A contactor mechanically latches in the emergency position until normal power source restoration and stabilization.

2.2.2 Restoration of Normal Power

When the normal power source is restored, the controller lights the NA LED and starts a time delay called time delay emergency-to-normal (TDEN). If the normal source fails before TDEN ends, the NA LED turns off and the time delay resets. TDEN ensures normal power source stabilization before load reconnection.

When the controller determines that the normal power source has maintained an acceptable level and TDEN ends, the controller signals the contactor to reconnect the load to the normal source. It does this by lighting the NR LED and energizing the NR relay to operate the contactor solenoid TS through bridge rectifier BR and coil-clearing contact SCN. When the contactor moves away from the emergency position, coil-clearing contact SCN opens to remove power from the solenoid. The

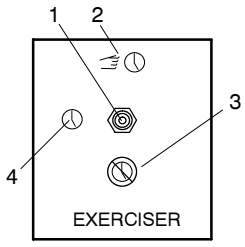
contactor mechanism's inertia carries it through the top of the cycle and into the normal position. The contactor is mechanically latched in the normal position until the next normal power source failure. The controller starts a time delay called time delay engine cooldown (TDEC). TDEC allows the engine and generator to run unloaded and cool down before shutdown. When TDEC ends, the controller signals the generator set to shut down by opening the engine-start contact between terminals ES3 and ES4 and the ES LED on the main controller circuit board lights. When the generator set shuts down, the EA LED turns off.

2.3 Exerciser Function

The exerciser function, when enabled, automatically starts and runs the generator set unloaded (the ATS does not transfer the load to the emergency source) for 20 minutes once a week. Exercising the generator set helps to ensure that the generator set starts when emergency power is needed. An exerciser switch selects exerciser functions. Automatic operation overrides the exerciser function. The loss of all power sources for more than 90 seconds will result in the loss of the exerciser set time. See Section 2.3.2.

2.3.1 Exerciser Switch

An exerciser switch is located inside the ATS enclosure. See Figure 1-1 and Figure 2-2.



1. Exerciser switch
2. Set position (momentary, up)
3. Disable position (down)
4. Enable position (middle)

Figure 2-2 Exerciser Switch

⚠ DANGER

Hazardous voltage.
Will cause severe injury or death.

Only authorized personnel should open the enclosure.

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.

Note: The exerciser switch is set during installation and normally does not require adjustment. Line voltage is present on some components inside the ATS enclosure when power sources are applied. Only trained and qualified personnel should open the ATS enclosure when power is present. Read and follow all safety decals inside the enclosure and avoid contact with line voltage.

The exerciser switch selects the following exerciser functions when power is available. See Section 2.3.2.

- **Set (⏲).** Placing the switch in the momentary (spring-loaded) set position and releasing the switch to the run position sets the exerciser: the exerciser's internal one-week timer is set and the exerciser starts and runs the generator set for a 20-minute period. Subsequent weekly 20-minute exercise periods start at the same day and time the exerciser was released from the set position.

- **Enable (⏲).** Placing the switch is the enable position causes the exerciser to start and run the generator set unloaded for 20 minutes on the same day and time each week the exerciser was last set.

- **Disable (⊘).** Placing the switch in the disable position prevents the exerciser from starting and running the generator. The exerciser's internal one-week timer continues to run and the exerciser's set day and time are not lost. The ATS, however,

starts the generator automatically when the normal power source fails.

Replace the enclosure cover on the ATS enclosure and tighten the screws that hold it in place after viewing or making changes to the exerciser switch setting.

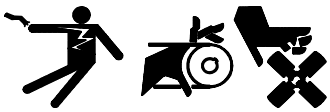
2.3.2 Exerciser Power Requirements

An internal one-week timer for the exerciser function maintains its setting for up to 90 seconds after power loss of both the normal and emergency sources. When the normal power source fails, the generator must start and run to provide emergency power within approximately 90 seconds or the system loses the previously set day and time and the exerciser is set to the day and time that either power source returns. Then, if the exerciser switch is in the Enable (⏲) position, the controller starts and runs the generator set unloaded for 20 minutes one week from the day and time of power source return and on subsequent weeks at the same day and time.

2.4 Manual Operation

To test or troubleshoot the transfer switch, manually operate the contactor using the procedure described below.

⚠ 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.

⚠ DANGER

Hazardous voltage.
Will cause severe injury or death.

Only authorized personnel should open the enclosure.

Servicing the transfer switch. Hazardous voltage can cause severe injury or death. Deenergize all power sources before servicing. Open the main circuit breakers of all transfer switch power sources and disable all generator sets as follows: (1) Move all generator set master controller switches to the OFF position. (2) Disconnect power to all battery chargers. (3) Disconnect all battery cables, negative (-) leads first. Reconnect negative (-) leads last when reconnecting the battery cables after servicing. Follow these precautions to prevent the starting of generator sets by an automatic transfer switch, remote start/stop switch, or engine start command from a remote computer. Before servicing any components inside the enclosure: (1) Remove all jewelry. (2) Stand on a dry, approved electrically insulated mat. (3) Test circuits with a voltmeter to verify that they are deenergized.

Manual Operation Procedure

1. Prevent the generator set that provides the emergency power source to the transfer switch from starting.
   a. Move the generator set master switch to the OFF position.
   b. Disconnect power to the generator engine start battery charger, if installed.
   c. Disconnect all generator engine start batteries, negative (-) leads first.
2. Disconnect or turn off both the normal and emergency power sources by opening upstream circuit breakers or switches to the transfer switch.

   Note: The manual operation handle is provided for maintenance purposes only. Do not attempt to use the manual operation handle to transfer the load.
3. Remove the cover on front of the transfer switch enclosure.

4. Slide the large end of the manual operation handle over the manual operation lever on the left side of the contactor. See Figure 2-3. Move the handle up to place the transfer switch in the Normal Source position, or down to place the contactor in the Emergency Source position.

   Note: Do not attempt to move the manual operation lever without using the handle.

5. Move the handle up to place the transfer switch in the Normal Source position for normal operation.

6. Remove the handle and store it in a convenient location near the transfer switch.

7. Replace the cover on the transfer switch enclosure and tighten the screws that hold it in place.

8. Reconnect power supplies to the transfer switch.

   Note: When power is applied to the transfer switch, the engine start contacts remain closed until Time Delay Engine Cooldown (TDEC) ends.

9. Return the generator set to automatic operation.

   a. Reconnect the generator engine start battery cables, negative (-) leads last.

   b. Reconnect power to the generator engine start battery charger, if installed.

   c. Move the generator set master switch to the AUTO (automatic) position. The generator set may start and run until the Time Delay Engine Cooldown (TDEC) ends (see **Note** above).

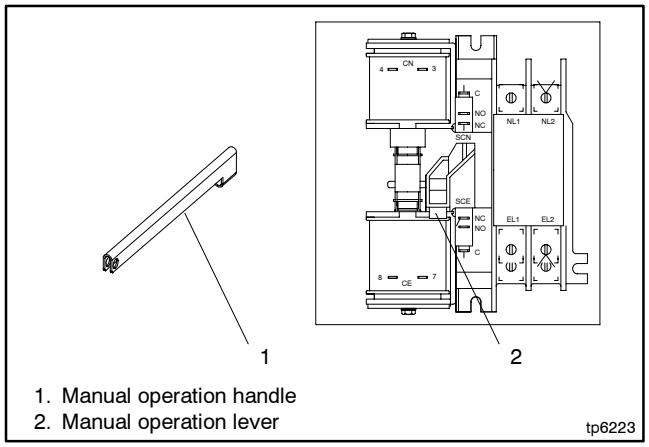


Figure 2-3 Contactor with Manual Operation Handle

2.5 External Test Switch

A provision on the main controller circuit board allows the connection of a customer-supplied, normally closed external test switch. This test switch connects between the TEST and GND terminals after cutting the jumper JP2 on the controller circuit board. See Figure 2-4. When the test switch contact is open, normal-source single-phase power is disconnected from the controller, and the controller follows the same sequence of operation as when the normal source fails.

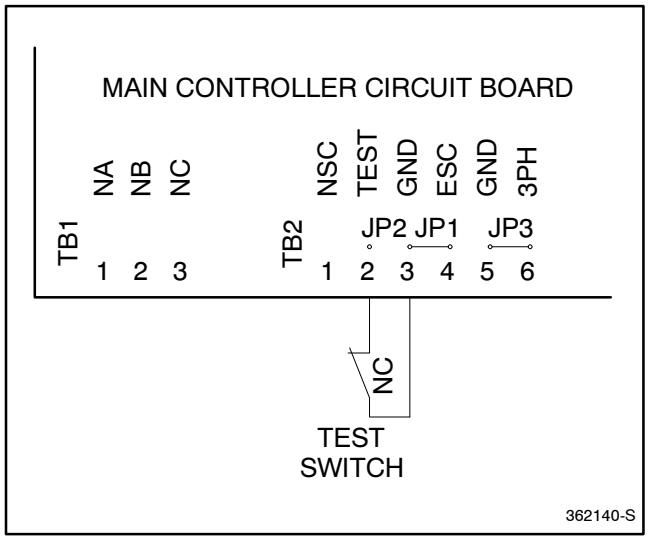


Figure 2-4 External Test Switch

Notes

Scheduled preventive maintenance ensures safe and reliable operation and extends the life of the transfer switch. Preventive maintenance includes periodic testing, cleaning, inspecting, and replacing of worn or missing components.

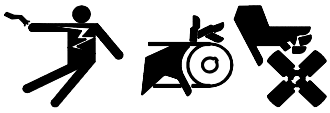
A local authorized distributor/dealer can provide complete preventive maintenance and services to keep the transfer switch in top condition. Contact a local distributor/dealer for additional information. See the Service Assistance section in the Introduction for how to locate a local distributor/dealer.

Read this entire section carefully before attempting any maintenance or service. Unless otherwise specified, have maintenance or service performed by an authorized distributor/dealer that has trained and qualified personnel who follow all applicable codes and standards.

Keep records of all maintenance or service.

Replace all barriers and close and lock the enclosure door after maintenance or service and before reapplying power.

⚠ 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.

⚠ DANGER

Hazardous voltage.
Will cause severe injury or death.

Only authorized personnel should open the enclosure.

⚠ WARNING

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

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

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

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

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

Servicing the transfer switch. Hazardous voltage can cause severe injury or death. Deenergize all power sources before servicing. Open the main circuit breakers of all transfer switch power sources and disable all generator sets as follows: (1) Move all generator set master controller switches to the OFF position. (2) Disconnect power to all battery chargers. (3) Disconnect all battery cables, negative (–) leads first. Reconnect negative (–) leads last when reconnecting the battery cables after servicing. Follow these precautions to prevent the starting of generator sets by an automatic transfer switch, remote start/stop switch, or engine start command from a remote computer. Before servicing any components inside the enclosure: (1) Remove all jewelry. (2) Stand on a dry, approved electrically insulated mat. (3) Test circuits with a voltmeter to verify that they are deenergized.

Servicing the transfer switch controls and accessories within the enclosure. Hazardous voltage can cause severe injury or death. Disconnect the transfer switch controls at the inline connector to deenergize the circuit boards and logic circuitry but allow the transfer switch to continue to supply power to the load. Disconnect all power sources to accessories that are mounted within the enclosure but are not wired through the controls and deenergized by inline connector separation. Test circuits with a voltmeter to verify that they are deenergized before servicing.

NOTICE

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

NOTICE

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

NOTICE

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

3.1 Inspection and Service

Contact an authorized distributor/dealer to inspect and service the transfer switch when any wear, damage, deterioration, or malfunction of the transfer switch or its components is evident or suspected.

3.1.1 General Inspection

External Inspection. Keep the transfer switch clean and in good condition by performing a weekly general external inspection of the transfer switch for any condition of vibration, leakage, excessive noise, temperature, contamination, or deterioration. Remove accumulations of dirt, dust, and other contaminants from the transfer switch's exterior with a vacuum cleaner or by wiping with a dry cloth or brush. *Do not use compressed air to clean the switch because it can cause debris to lodge in and damage the components.* Replace any worn, missing, or broken external components with manufacturer-recommended replacement parts. Contact a local authorized distributor/dealer for part information and part ordering. Tighten loose external hardware.

3.1.2 Internal Inspections, Procedures, and Tests

Internal Inspection. Disconnect all power sources, remove the transfer switch enclosure cover, and inspect internal components every six months (more frequently in dusty or dirty areas) or when any condition noticed during an external inspection may have affected internal components. Inspect for:

- Accumulations of dirt, dust, moisture, or other contaminants
- Signs of corrosion
- Worn, missing, or broken components
- Loose hardware
- Wire or cable insulation deterioration, cuts, or abrasion
- Signs of overheating or loose connections: discoloration of metal, melted plastic, or a burning odor
- Other evidence of wear, damage, deterioration, or malfunction of the transfer switch or its components.

Cleaning. Remove contaminants from internal components with a vacuum cleaner or by wiping with a dry cloth or brush if possible. *Do not use compressed air to clean the switch because it can cause debris to lodge in and damage the components.*

Lubrication. The outer mechanism of the contactor is lubricated for the life of the contactor and requires no further lubrication under normal use. If the outer mechanism is contaminated, clean it with a soft cloth and relubricate it with Lubriplate 105 lubricant.

Manually operate the contactor mechanism to be sure that it operates smoothly without binding. If applying lubricant to the outer mechanism of the contactor does not eliminate binding, replace the contactor assembly.

Periodically oil the screws that secure covers in place. Apply a thin layer of grease to the top edge of a NEMA type 3R enclosure cover to aid in positioning it. Periodically oil the padlock clasp on a NEMA type 3R enclosure.

Part Replacement and Tightening. Replace worn, missing, broken, deteriorated, or corroded internal components with manufacturer-recommended replacement parts. Contact a local authorized distributor/dealer for part information and part ordering. Tighten loose internal hardware.

Wire Repair or Replacement. Have damage to power circuit wiring evaluated and repaired or replaced by a qualified electrician. Replace wiring when there is any doubt about its condition. Tape minor control circuit wire insulation cuts or abrasions less than 0.04 in. (1 mm) across by wrapping the section tightly with three layers of UL-listed 3/4 in. (19 mm) wide electrical tape. Repair moderately damaged leads, where conductors are cut or insulation is damaged over sections shorter than about 4 in. (100 mm) or less than about 25% of the length of the wire by cutting out the damaged section and splicing in wire of the same type using UL-listed insulated (250 V minimum) connectors and follow the connector manufacturer's instructions. Replace extensively damaged or deteriorated leads completely. If the leads are part of a wiring harness, replace the entire wiring harness. Fabricate new leads using the same type of wire and UL-listed insulated (250 V minimum) connectors and follow the connector manufacturer's instructions.

Terminal Tightening. Loose connections on the power circuits can lead to overheating or explosion. Tighten all contactor terminal lugs to 200 in. lb. (16.7 ft. lb. or 22.6 Nm) of torque. Tighten the neutral lugs to the torque values shown in Figure 3-1.

Tighten the terminal strip terminals on the controller assembly including the engine-start connections on terminals ES3 and ES4 on terminal strip TB3 to 9 in. lb. (1.0 Nm) of torque.

Tighten the ground screw terminal to the torque values shown in Figure 3-2.

Wire Size (AWG or MCM)	Torque		
	in. lb.	ft. lb.	Nm
8	75	6.2	8.5
6	110	9.2	12
4	110	9.2	12
2	150	13	17
1	150	13	17
1/0	180	15	20
2/0	180	15	20
3/0	250	21	28
4/0	250	21	28
250	325	27	37

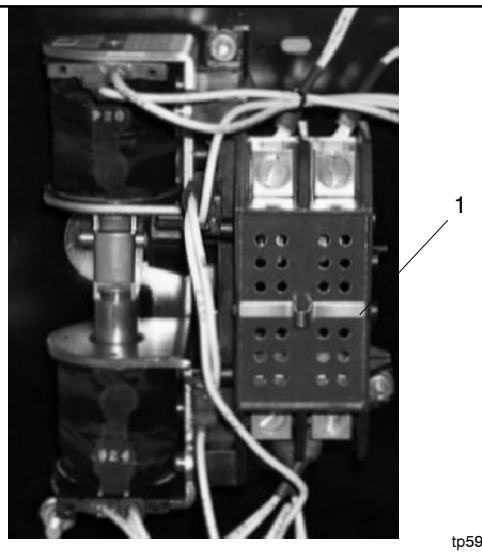
Figure 3-1 Tightening Torque for Neutral Terminal Lugs

Wire Size (AWG or MCM)	Torque		
	in. lb.	ft. lb.	Nm
14	35	2.9	4.0
12	35	2.9	4.0
10	35	2.9	4.0
8	40	3.3	4.5
6	45	3.8	5.1
4	45	3.8	5.1

Figure 3-2 Tightening Torque for Ground Screw Terminal

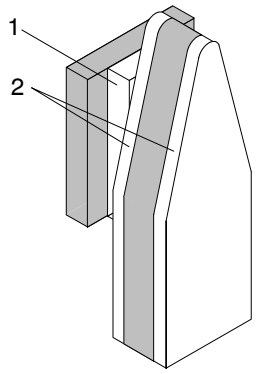
Contactor Inspection. Remove the covers or arc chute assemblies at the front of the contactor and inspect the main contacts inside the contactor. See Figure 3-3. Remove surface deposits with a clean cloth. *Do not use emery cloth or a file.* If the contacts are pitted, show signs of overheating, or are worn, replace the contactor assembly. See Figure 3-4 for how each pole of the main contacts should appear when closed. The contacts are worn if the contact surface material, a layer of silvery-colored metal, is removed.

Signs of Overheating. Replace components damaged by overheating and locate the cause of the overheating. Overheating could be caused by loose power connections, overloading, or a short circuit in the system. After tightening power terminals perform a millivolt drop test to locate areas with high contact resistance. See Section 3.2.3. Check the line circuit breakers in the system to be sure that they do not allow the load to exceed the switch rating. Use the controller troubleshooting and schematics to locate a control circuit short.



1. Cover retainer

Figure 3-3 Contact Cover and Retainer, Model R220



1. Stationary contact surface material (normal and emergency)
2. Moving (center) contact surface material

Figure 3-4 Main Contacts

3.2 Testing

Periodic testing is important in any transfer switch application. It helps to ensure that the generator will start and the transfer switch mechanisms and control circuits will operate when needed.

3.2.1 Weekly Generator Set Exercise

Use the plant exerciser to start and run the generator set once a week to maximize the reliability of the emergency power system. See Section 2.

3.2.2 Monthly Automatic Operation Test

Test the transfer switch's automatic control system monthly. See Section 2. Verify that the expected sequence of operations occurs as the switch transfers the load to the emergency source when a normal source failure occurs or is simulated. When the switch transfers the load to the emergency source, end the test and verify that the expected sequence of operations occurs as the transfer switch retransfers to the available normal source and signals the generator set to shut down after a cooldown period.

3.2.3 Other Tests

DANGER

Hazardous voltage.
Will cause severe injury or death.

Only authorized personnel should open the enclosure.

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)

Every Year

Use a millivolt drop test to help locate high-resistance contacts in the ATS under a moderate and balanced load. The objective is to locate a contact that is of significantly higher-resistance than others. This manual cannot give an exact value to look for because the value is a function of the physical condition of the contactor and the loading of the unit, which is impossible to predict.

Millivolt Drop Test Procedure

1. Carefully measure the voltage on each phase from the source lugs to the load lugs when a balanced load of at least 10% of the switch rating is connected to each source. To obtain accurate readings, keep the meter as far as possible from current-carrying conductors and the meter leads as short, direct, and at right angles to current-carrying conductors as possible. This minimizes the effect of induced voltages (transformer effect) in the vicinity of the current-carrying conductors. The reading may be erratic because of the small voltage measured, load fluctuations, and meter circuit contact resistances, so take several readings to ensure accuracy. Look for approximately 0.1 mV per ampere of load current.

2. The highest voltage on a phase should be within 1.5 times the lowest voltage measured on other phases of the same source. This factor is high because all lines may not be exactly balanced, the construction of each contactor circuit may be slightly different, and there may be residual heating from prior load conditions. If an unusually high voltage is found, disconnect power, check the connections and lug torques, and repeat the test. If the problem cannot be found, replace the contactor assembly.

Every Three Years

Perform a wire insulation breakdown test.

Wire Insulation Breakdown Test Procedure

1. Disconnect all power sources by opening upstream circuit breakers or switches to the transfer switch. Disconnect the load from the transfer switch by opening circuit breakers or switches leading from the transfer switch. Disconnect the contactor wiring harness from the controller at connector P1. See Figure 4-2.

2. Use a hi-pot tester or meggar to check the insulation resistance phase-to-phase and phase-to-neutral, and phase-to-ground if neutral and ground are isolated. If using a hi-pot tester, the maximum potential is 500 VAC and the maximum test time is 1 second. The insulation resistance must exceed 1.24 MΩ. If the hi-pot tester indicates wire insulation breakdown or if the measured resistance is less than the minimum, use an instrument designed for this purpose to isolate the leakage current and replace the faulty components with voltage breakdown. It may require disconnecting power conductors from the lugs to isolate the problem. If the power conductors are disconnected from the lugs, see Section 6.2.2 for reconnection instructions.

Every Five Years

Check normal and emergency source setpoint calibration according to the procedures in Section 4.9 and 4.10.

3.3 Service Schedule

Follow the service schedule below for the recommended service intervals. Have all service performed by an authorized distributor/dealer except for items designated by an X.

System Component or Procedure	See Section	Visually Inspect	Check	Change	Clean	Test	Interval
Electrical System							
Check for signs of overheating or loose connections: discoloration of metal, melted plastic, or a burning odor	3.1.2	X	X				S
Check the contactor's external operating mechanism for cleanliness. Clean and relubricate if dirty *	3.1.2	X		D, R (lubricant)	D		Y
Check wiring insulation for deterioration, cuts, or abrasion and repair or replace wiring to regain the properties of the original wiring	3.1.2	X		D, R (wiring)			S
	3.1.2	D	D				Y
Check the transfer switch's main power switching mechanisms' mechanical operation and integrity	3.1.2	D	D			D	Y
Tighten control and power wiring connections to specifications	3.1.2		D			D	Y
Check the transfer switch's main power switching contacts' condition. Clean or replace the main contacts or replace the contactor assembly as necessary	3.1.2	D		D, R	D		Y
Perform a millivolt drop test to check for high contact resistances on power circuits. Tighten connections, clean main contacts, adjust or replace main contacts or contactor assembly to eliminate high contact resistances	3.2.3		D	D, R	D	D	Y
Test wire and cable insulation for electrical breakdown	3.2.3					D	Every 3 Years
Check calibration of voltage-sensing circuitry and setpoints, and recalibrate circuitry as necessary	4.9, 4.10		D			D	Every 5 Years
Control System							
Exercise the generator set unloaded	3.2.1					X	W
Test the transfer switch's automatic control system	2, 3.2.2, 4.8	X				X	M
Test all LED indicators, time delays, and remote control systems for operation	2, 4.8	D	D	D, R		D	Y
General Equipment Condition							
Inspect the outside of the transfer switch for any condition of vibration, leakage, noise, temperature, contamination, or deterioration to keep the transfer switch clean and in good condition *	3.1.1	X			X		W
Check that all external hardware is in place, tightened, and not badly worn	3.1.1	X	X	R			W
Inspect the inside of transfer switch for any condition of vibration, leakage, noise, temperature, contamination, or deterioration to keep the inside of the transfer switch clean, dry, and in good condition *	3.1.2	D	D		D		S or Y
Check that all internal hardware is in place, tightened, and not badly worn	3.1.2	D	D				S or Y

***** Service more frequently if operated in dusty or dirty areas.

See Section Read these sections carefully for additional information before attempting maintenance or service.

Visually Inspect Examine these items visually.

Check Requires physical contact with or movement of system components, or the use of nonvisual indications.

Change May require replacement of components depending upon the severity of the problem.

Clean Remove accumulations of dirt and contaminants from external transfer switch's components or enclosure with a vacuum cleaner or by wiping with a dry cloth or brush. *Do not use compressed air to clean the switch because it can cause debris to lodge in the components and cause damage.*

Test May require tools, equipment, or training available only through an authorized distributor/dealer.

D Have service performed by an authorized distributor/dealer.

X Operator action.

R May require replacement of components.

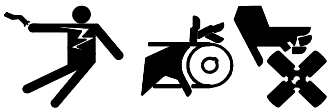
W=Week
M=Month
Q=Quarter
S=Six Months
Y=Year

This section contains transfer switch troubleshooting information. Only trained qualified personnel following all applicable codes and standards should attempt to service the transfer switch covered by this manual. Improper repairs can be hazardous and lead to additional repairs.

Refer first to the troubleshooting chart in Figure 4-1. Possible causes of problems are listed generally in the order of likelihood. See Figure 4-2 for the location of LEDs and connection terminals referred to in Figure 4-1. See the schematic and interconnection diagrams in Section 5, the parts drawings in Section 7, and the labeling on system components to identify and troubleshoot system components.

Use the sections after the troubleshooting chart and the theory of operation to methodically test and troubleshoot the system. The sections are presented in a recommended sequence. Read and be familiar with all sections as some are interdependent.

⚠ WARNING

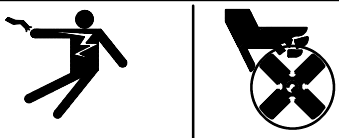


Accidental starting.
Can cause severe injury or death.

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 rotor.
Can cause severe injury or death.

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

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

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

Servicing the transfer switch. Hazardous voltage can cause severe injury or death. Deenergize all power sources before servicing. Open the main circuit breakers of all transfer switch power sources and disable all generator sets as follows: (1) Move all generator set master controller switches to the OFF position. (2) Disconnect power to all battery chargers. (3) Disconnect all battery cables, negative (-) leads first. Reconnect negative (-) leads last when reconnecting the battery cables after servicing. Follow these precautions to prevent the starting of generator sets by an automatic transfer switch, remote start/stop switch, or engine start command from a remote computer. Before servicing any components inside the enclosure: (1) Remove all jewelry. (2) Stand on a dry, approved electrically insulated mat. (3) Test circuits with a voltmeter to verify that they are deenergized.

Servicing the transfer switch controls and accessories within the enclosure. Hazardous voltage can cause severe injury or death. Disconnect the transfer switch controls at the inline connector to deenergize the circuit boards and logic circuitry but allow the transfer switch to continue to supply power to the load. Disconnect all power sources to accessories that are mounted within the enclosure but are not wired through the controls and deenergized by inline connector separation. Test circuits with a voltmeter to verify that they are deenergized before servicing.

⚠ DANGER

Hazardous voltage.
Will cause severe injury or death.

Disconnect all power sources before opening the enclosure.

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

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

NOTICE

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

4.1 General Notes on Connections

Many service problems are caused by faulty connections due to corrosion, loose terminals, and damaged wiring or connectors. With all power supplies disconnected, perform the following general checks while troubleshooting.

- Unplug connectors and check terminals and leads for corrosion. Remove corrosion from terminals and leads.
- Tighten loose terminals.
- Carefully wiggle the wires in wiring harnesses near sockets or plugs while making continuity measurements at terminals that should be connected through the wiring harness. Replace wiring harnesses with breaks in continuity.
- Recrimp or replace loosely connected lead terminals. See Section 3.1.2 for instructions on wiring repair and replacement.

4.2 System Power

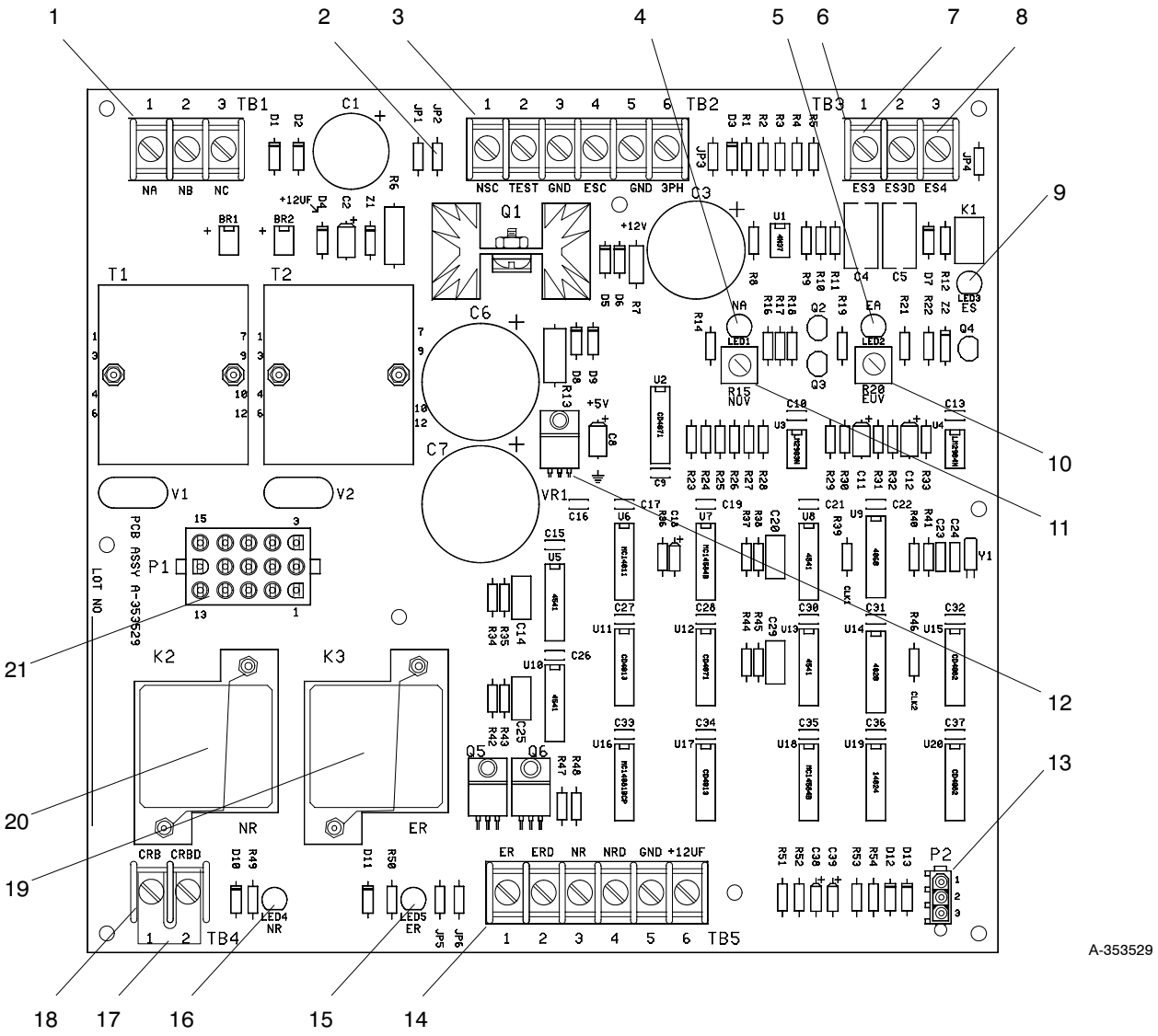
Follow this section when the normal source is available and the transfer switch

- None of the LEDs on the controller lights and the relays or contactor do not operate.
- Operates erratically.

Return to this section after making repairs that have restored operation to verify that controller DC voltages are within specifications.

Problem	Possible Cause	Corrective Action
ATS fails to operate and no LEDs are lit	No power to the transfer switch/controller.	Close circuit breakers leading from power sources to the transfer switch. Troubleshoot power to the system. See Section 4.2.
Generator set does not start when the normal source fails	Generator set master switch is in the OFF position or the batteries are not charged or connected.	Place the generator set master switch in the AUTO position. Check that the generator set batteries are charged and connected.
	Engine start circuit is malfunctioning.	Troubleshoot. See Section 4.5.
	Generator set is malfunctioning.	See the generator set operation or service manual.
Generator set does not start with the exerciser	Exerciser switch is in the Disable position.	Place the exerciser switch in the Enable position to enable normal exerciser operation. Move the exerciser switch to the Set position to test the exerciser and reset the exerciser timer. See Section 2.3 for exerciser operation.
	Generator set master switch is in the OFF position or the batteries are not charged or connected.	Place the generator set master switch in the AUTO position. Check that the generator set batteries are charged and connected.
	Engine start or exerciser circuit is malfunctioning.	See Section 4.5 first to troubleshoot the engine start circuit, then see Section 4.6 to troubleshoot the exerciser.
	Generator set is malfunctioning.	See the generator set operation or service manual.
Generator set does not shut down	Generator set master switch is in the RUN position.	Place the generator set master switch in the AUTO position.
	The engine start circuit is malfunctioning, the exerciser is operating, or the exerciser circuit is malfunctioning.	If the exerciser has recently been in the Set position or is in the Enable position, wait for the exerciser period of 20 minutes to end. If the generator set continues to run, see Section 4.5 first to troubleshoot the engine start circuit, then see Section 4.6 to troubleshoot the exerciser.
	Time delay engine cooldown (TDEC) has not timed out. (after retransferring the load to the normal source)	Check operation. Enough time must pass for the time delay engine cooldown (TDEC, 2 minutes) timer to time out.
	Generator set is malfunctioning.	See the generator set operation or service manual.
ATS starts the generator when normal fails but fails to transfer the load to the emergency source	Generator set circuit breaker is open.	Close circuit breakers leading from the generator set to the ATS.
	Time delay normal-to-emergency (TDNE) has not timed out.	Check operation. Enough time must pass for the time delay normal-to-emergency (TDNE, 2 seconds) to time out.
	Generator voltage is out of range or emergency source sensing circuits are malfunctioning.	Check the emergency source voltage. Repair or adjust generator set if the output voltage is it is out of range, otherwise see Section 4.9.
	Contactor operation problems.	Troubleshoot. See Section 4.3.
ATS fails to retransfer the load to the normal source after the normal source returns	Normal source circuit breaker is open.	Close circuit breakers leading from the normal source to the transfer switch.
	Time delay emergency-to-normal (TDEN) has not timed out.	Check operation. Enough time must elapse for the time delay emergency-to-normal (TDEN, 12 seconds) timer to time out.
	Normal source voltage levels are out of range or the normal source sensing circuits are malfunctioning.	Check the normal source voltage. If the normal source voltage is within range see Section 4.10.
	Contactor operation problems.	Troubleshoot. See Section 4.4.
Contactor mechanism is binding	Debris is in the contactor mechanism.	Clean the contactor assembly. See Section 3.1.2.
	Outer mechanism needs lubrication.	Lubricate the outer mechanism. See Section 3.1.2.
	Contactor mechanism is damaged.	Replace the contactor assembly.
ATS operates erratically or operates out of specifications	Power supply problems/loose connections, incorrect transfer switch controller operation/calibration.	For erratic operation, check wiring for loose connections especially those that supply power to the controller or in the affected circuit. Check the power supply. See Section 4.2. See Section 4.8 for problems related to time delays in the operating sequence except for the exerciser. See Section 4.6 for problems related to exerciser time delays. For problems related to dropout and pickup specifications see Section 4.9 for the emergency source or Section 4.10 for the normal source.

Figure 4-1 Troubleshooting Chart



1. Normal source line voltage terminal strip TB1
2. PCB jumper JP2 (cut to install test switch)
3. Terminal strip TB2
4. Normal acceptable (NA) LED
5. Emergency acceptable (EA) LED
6. Terminal strip TB3 (engine start)
7. Engine start terminal ES3
8. Engine start terminal ES4
9. Engine start (ES) LED
10. Emergency undervoltage (EUV) adjustment pot (factory-set)
11. Normal undervoltage (NUV) adjustment pot (factory-set)
12. VR1, +5 VDC
13. Exerciser switch wiring harness connector P2
14. Power supply and relay status terminal strip TB5
15. Emergency relay (ER) LED
16. Normal relay (NR) LED
17. Jumper
18. Terminal strip TB4
19. Emergency relay (ER)
20. Normal relay (NR)
21. Contactor wiring harness connector P1

Figure 4-2 Controller Terminals and Components

4.4.1 AC System Voltages

1. Disconnect all power sources and check that the controller is connected to the contactor assembly wiring harness at connector P1.

2. Check that the circuit breakers leading to the transfer switch from the normal and emergency sources are closed.

3. The transfer switch needs at least one source present to transfer the load to an available source. If the normal source is available, check for nominal line voltage between lugs NA and NC on the contactor assembly. If the emergency source is available, check for line voltage between lugs EA and EC on the contactor assembly. If not all phases are present on the corresponding source, the problem lies upstream of the transfer switch.

4. If all phases are present on the normal source lugs, check for nominal line voltage between terminals J1-12 and J1-15 on the contactor wiring harness connector on the controller assembly. If all phases are present, check for nominal line voltage between terminals NA and NC on TB1 on the controller assembly. If voltage is present on J1 but not on TB1, replace the controller assembly.

5. If all phases are present on the emergency source lugs, check for nominal line voltage between terminals J1-3 and J1-6 on the contactor wiring harness connector on the controller assembly.

6. If the voltage on any phase at the controller is not steady and correct, the problem could lie in the connection between the contactor and the controller. Check the contactor wiring harness and connections.

4.4.2 DC Controller Voltages

1. If AC voltage is present at terminals NA-NC on TB1 on the controller assembly, check the DC voltage between terminals GND and the +12UF on TB5 on the controller assembly. A good controller assembly should have between 12.0 and 14.0 VDC between these terminals. If the voltage is higher or zero, replace the controller assembly.

2. If the voltage on terminal +12UF is low, disconnect any customer load connected to terminal +12UF on TB5 and remeasure. If voltage is restored the problem is an excessive load on +12UF. If voltage is not restored, replace the controller assembly.

3. If the +12UF terminal voltage is within specifications, check the voltage between terminal GND on TB5 and the +5VDC (right-most) terminal on voltage regulator VR1 located near the center of the controller circuit board. It may be necessary to scrape the +5VDC terminal slightly with the test probe due to the conformal coating on the circuit board to make good contact. A good controller should have 5 ± 5% VDC at the +5VDC terminal, otherwise replace the controller assembly.

4. If the +5VDC terminal voltage is within specifications, disconnect customer loads connected to terminal +12UF on TB5 on the controller assembly, and disconnect all power sources to the transfer switch. The 5 VDC supply should stay within specifications for at least 90 seconds. If this voltage is not held, replace the controller assembly, otherwise reconnect customer loads to terminal +12UF.

4.5 Engine Start Circuit

Follow this section first when the transfer switch does not start the generator set engine when it should or the generator set engine is signalled to run when it should not.

This procedure will also verify that the ES LED on the controller assembly correctly reflects the engine start circuit status. The ES LED should be off when the engine start circuit between terminals ES3 and ES4 on the controller assembly is closed to signal the engine to start. See Figure 4-3. The ES LED should light when the engine start circuit is open to signal the engine to shut down.

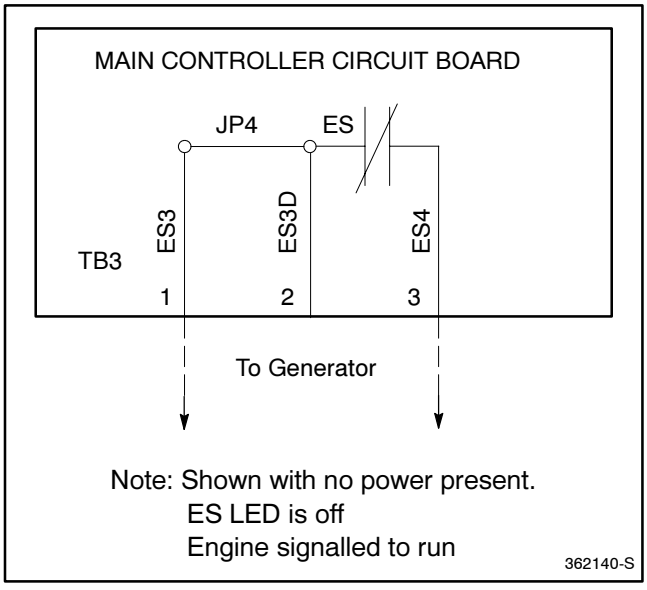


Figure 4-3 Engine Start Circuit

Engine Start Circuit Troubleshooting

1. Disconnect all power sources and wait at least five minutes.
2. Manually operate contactor to the normal position.
3. Disconnect the exerciser switch wiring harness from connector P2 on the controller assembly.
4. Remove the engine start wires from engine start terminals ES3 and ES4 on TB3 on the controller assembly. The engine should shut down after the generator set's time delay engine cooldown (TDEC, if equipped) ends.
5. If the engine continues to run when it is not supposed to, check for continuity on the engine start wires. If there is continuity, a short in the wiring leading to the generator set controller or a short on the generator set controller or other generator set problem could be causing the engine to run.
6. If the engine would not start when it was supposed to, connect the engine start wires together. This should signal the engine to start. If this doesn't, there could be an open circuit in the wiring leading to the generator set controller, loose wires on the generator set controller, or other generator set problem.
7. Tape the ends of the engine start wires.
8. Check for continuity between terminals ES3 and ES4 on TB3 on the controller assembly. The ES LED should be off and the engine-start contact should be closed. If not, check that jumper JP4 is installed on the circuit board by checking for continuity between terminals ES3 and ES3D on TB3 on the controller assembly. If the jumper is not in place, install a jumper wire between terminals ES3 and ES3D on TB3. If the jumper is in place and there is no continuity between terminals ES3 and ES4, replace the controller assembly.
9. Apply the normal power source and wait for TDEC. If the NA LED does not light, see Section 4.10. If the NA LED lights and the ES LED does not light, or the engine-start contact does not open within ±10% of the TDEC specification, replace the controller assembly.

After completing troubleshooting in this section and the ES LED correctly reflects the engine start circuit status:

- See Section 4.6 to troubleshoot engine starting problems with the exerciser.
- See Section 4.8 to troubleshoot engine starting problems in the automatic operation sequence.

Note: When engine start circuit troubleshooting is complete, disconnect all power sources and reconnect the exerciser switch wiring harness to connector P2, and the engine start wires to terminals ES3 and ES4 on TB3 on the controller assembly.

4.6 Exerciser Circuits

Follow this section when:

- The plant exerciser does not start the engine at the appropriate time when the exerciser switch is in the Set or Enable position.
- The engine does not shut off when the exerciser switch is in the Enable position after the exerciser period ends.
- The engine does not shut off when the exerciser switch is in the Disable position.

Within the exerciser switch there are two normally open contacts which are both open when in the maintained Enable position. When the switch is in the momentary Set position, the contact from terminal COM to SET on the main controller circuit board is closed. When the switch is in the maintained Disable position, the contact from terminal COM to DISABLE on the main controller circuit board is closed. See Figure 4-4.

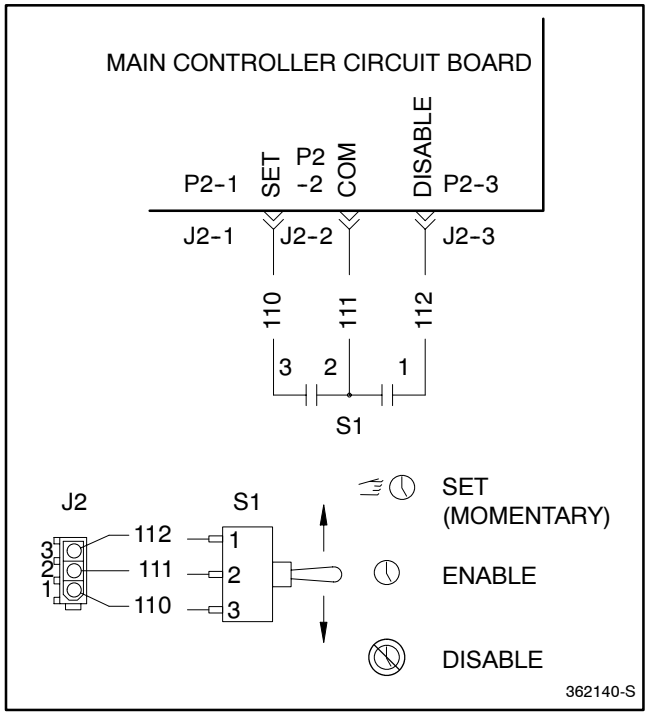


Figure 4-4 Exercise Circuit

Exerciser Circuit Troubleshooting

1. Disconnect all power sources.

2. Disconnect the exerciser switch from connector P2 on the controller assembly.

3. Check the exerciser switch wiring harness for loose, dirty, or corroded connections.

4. Check that connector J2 is wired to the correct terminals on the exerciser switch according to Figure 4-4.

5. Check the exerciser switch continuity. If any of these continuity readings is wrong, replace the damaged exerciser switch.

   a. Place the exerciser switch in the Enable position and check for open circuits between terminals J2-2 to J2-1 and J2-3.

   b. Toggle the exerciser switch to the momentary Set position and check that terminals J2-1 and J2-2 are connected and terminals J2-2 to J2-3 are not connected.

   c. Toggle the exerciser switch to the Disable position and check that terminals J2-2 and J2-3 are connected and the terminals J2-1 to J2-2 is are not connected.

6. See Sections 4.5 and 4.8 first, to verify that the transfer switch is starting the generator set and the ES LED correctly reflects the engine-start contact status in the automatic operation sequence.

7. If the switch is correctly wired, and the switch operates correctly, reconnect J2 to P2.

8. Review the instructions for exerciser operation. If the exerciser is still not operating properly, replace the controller assembly.

4.7 Contactor Operation

Follow this section when the switch fails to transfer or transfers improperly when one source fails and the other source is available and is indicated by the corresponding source-available LED.

There may be both mechanical and electrical causes of contactor operation problems. If the contactor is binding, the contactor solenoid TS and other components could be damaged.

4.7.1 Mechanical Check

Manually operate the contactor to check that it operates smoothly without binding. If it does not, clean and relubricate the contactor. See Section 3.1.2. Replace the contactor assembly if cleaning or relubrication does not solve the binding problem.

If the contactor assembly was replaced, check the solenoid on the damaged contactor assembly before reapplying power. See Section 4.7.5. If the solenoid was damaged, follow the instructions in Section 4.7.3 to check other system components not replaced with the contactor assembly for damage.

4.7.2 Solenoid Troubleshooting

The solenoid coils on model R220 switches require 120 VAC for operation. The rectifier is sealed inside the coil assembly and not accessible for testing. Refer to Section 4.7.5 for instructions to check the coil voltage and operation.

4.7.3 After Solenoid Replacement

A contactor solenoid is not designed to operate continuously. When operated continuously the solenoid coil windings first tend to short circuit, then eventually burn up, and the solenoid becomes an open circuit. Therefore, a damaged solenoid most likely indicates that the contactor was mechanically binding or that something in the control circuit failed and allowed the solenoid to operate over a longer period than it should.

After Solenoid Replacement

1. Check that the contactor operates freely without binding.

2. Check the coil-clearing contacts (SCN and SCE). See Section 4.7.4.

3. Visually check other components for evidence of overheating (discolored metal, burning odor or melted plastic) and replace damaged components. Check the wiring, coil-clearing contacts, bridge rectifier BR, NR and ER relay contacts, and the controller assembly.

4.7.4 SCN and SCE Contacts

Contact SCE is closed in Normal and opens when the main shaft of the contactor reaches the Emergency position. See Figure 4-5. Contact SCN is closed in Emergency and opens when the main shaft of the contactor reaches the Normal position. See Figure 4-6.

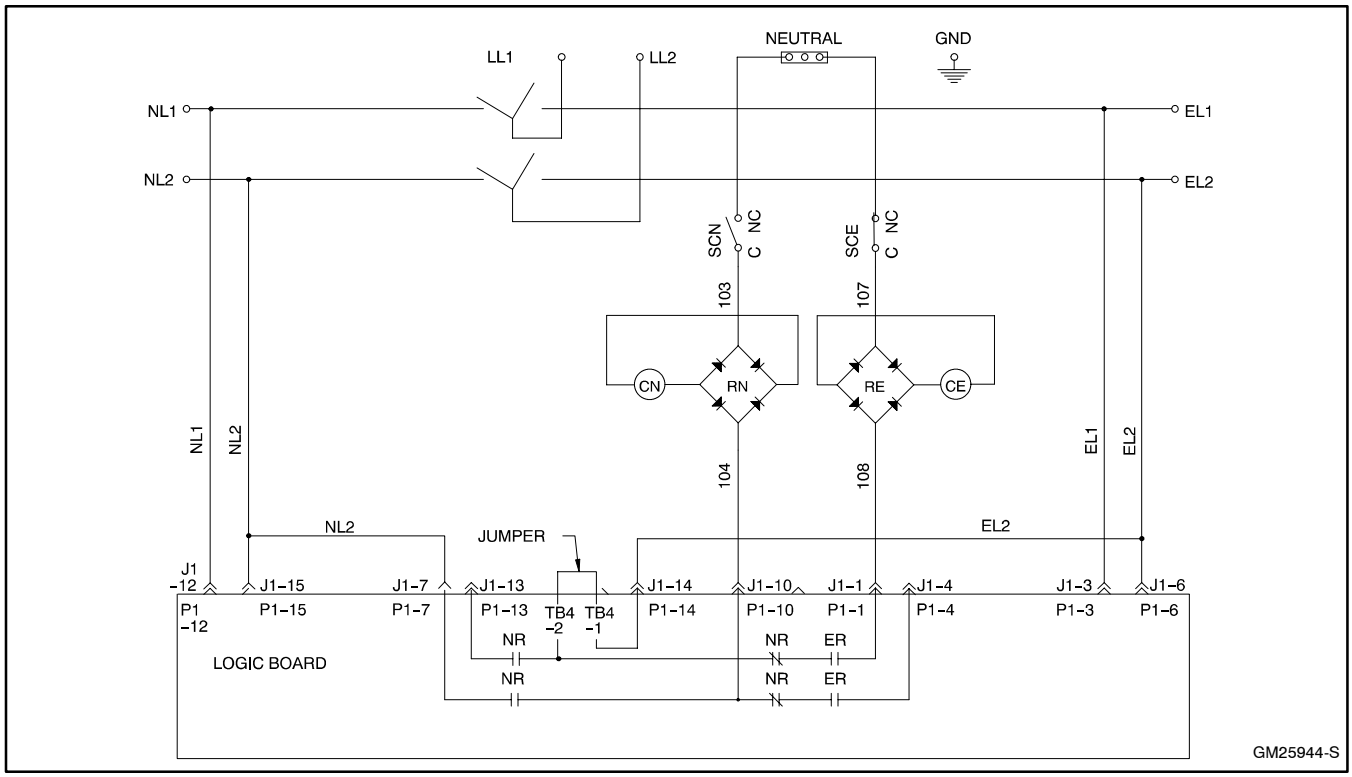


Figure 4-5 R220 Contactor in Normal Position, No Power Present

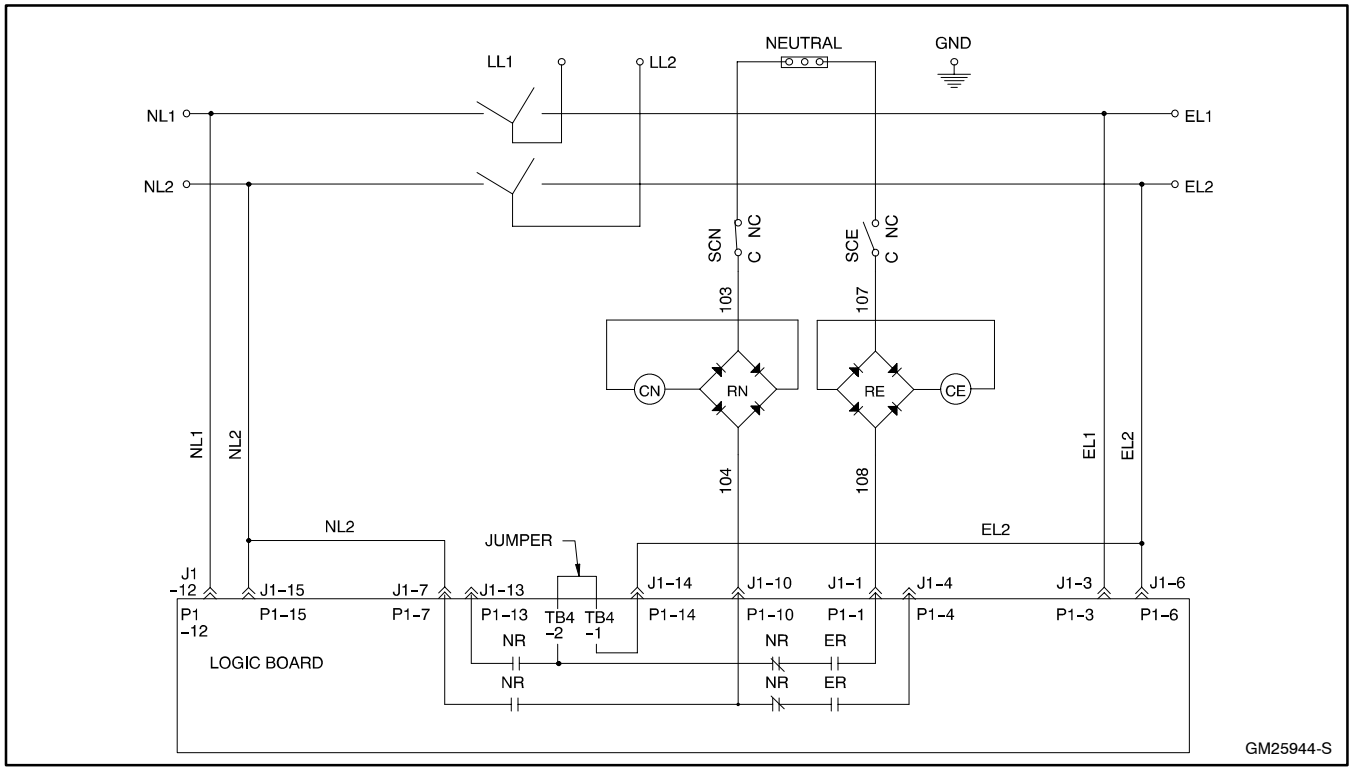


Figure 4-6 R220 Contactor in Emergency Position, No Power Present

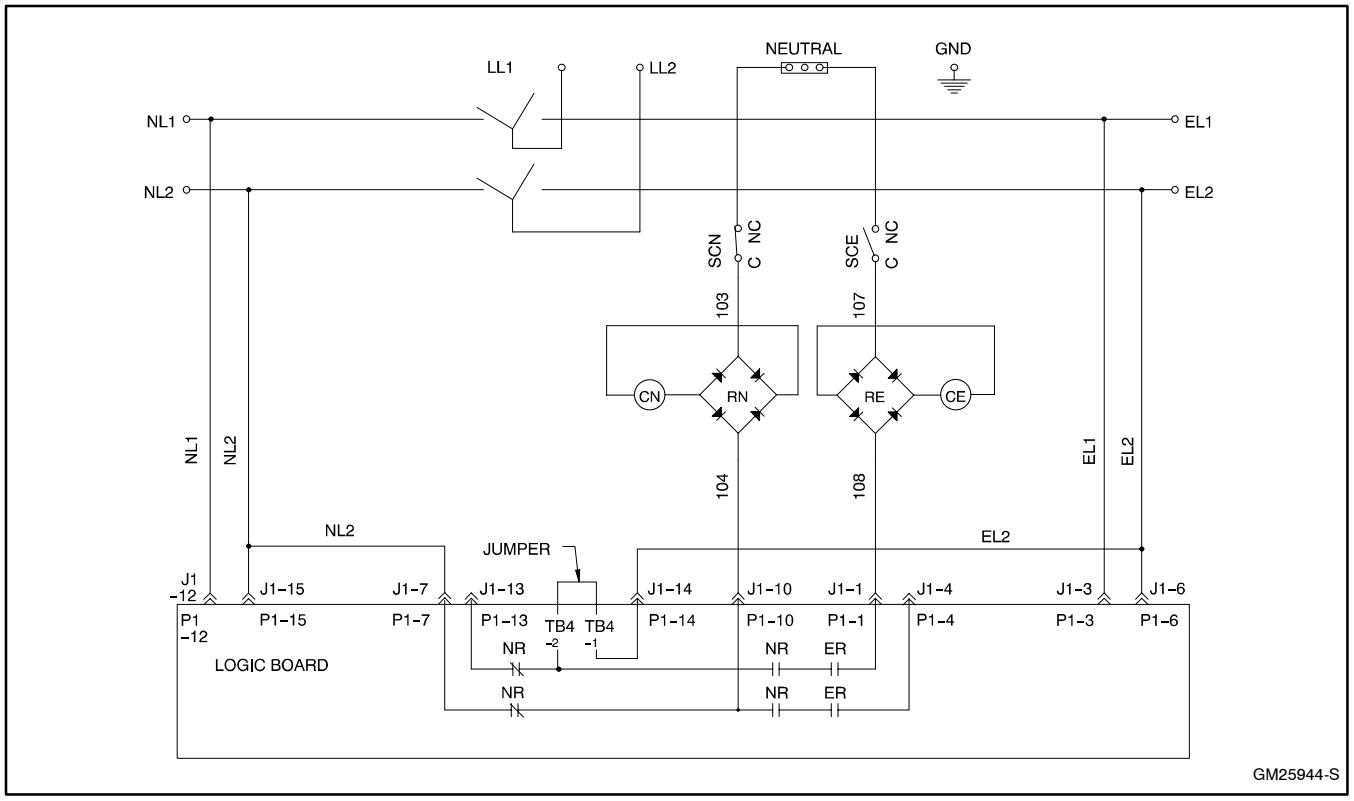


Figure 4-7 R220 Contactor in the Emergency Position, Emergency Present, Normal Returns, TDEN Ends, Transferring to the Normal Position

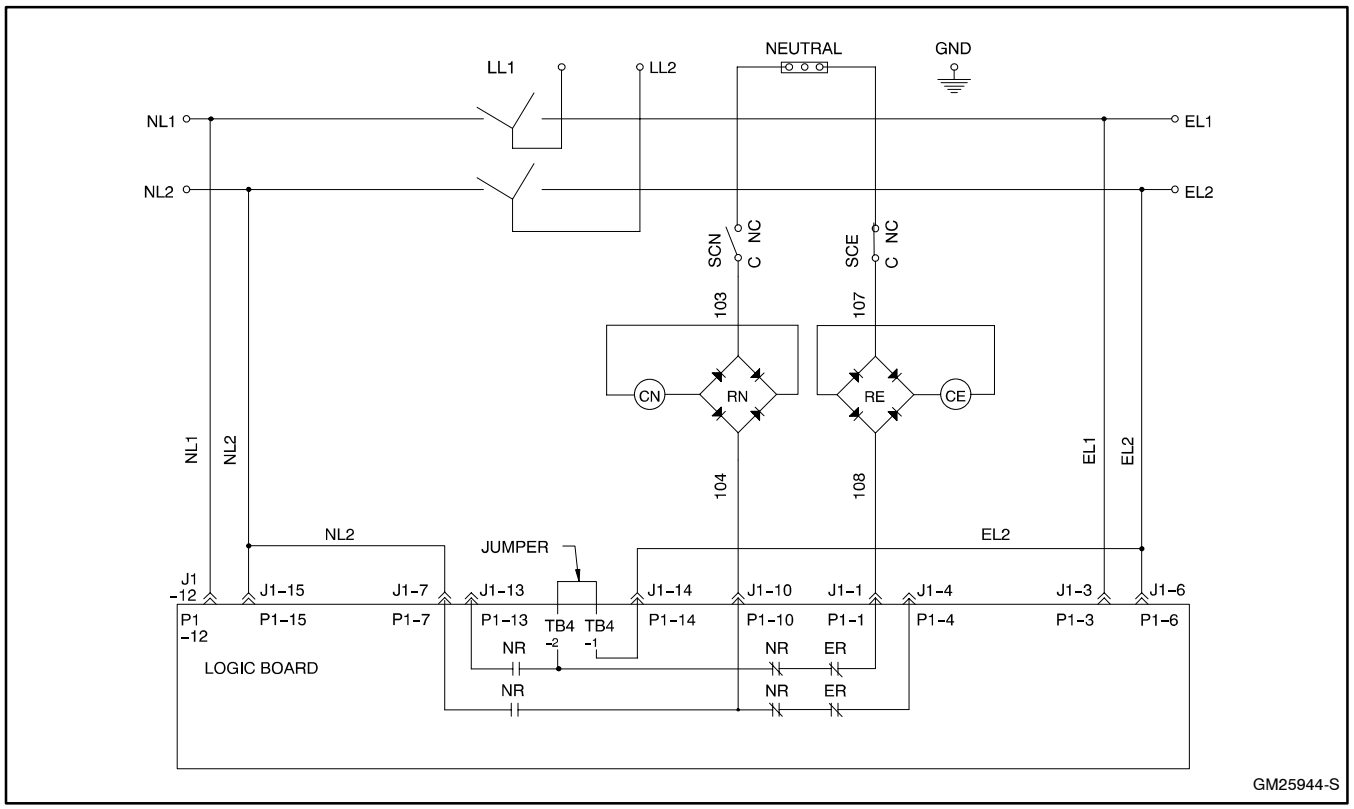


Figure 4-8 R220 Contactor in the Normal Position, Normal Fails, Emergency Available, TDNE Ends, Transferring to the Emergency Position

4.7.5 NR/ER Relays, Coils, and Controller Circuitry

Use the following steps to troubleshoot controller circuits when voltage is not appearing on terminals AC1 and AC2 of the bridge rectifier BR to energize the solenoid when a transfer is supposed to occur.

NR/ER Relay, Coil, and Controller Circuit Troubleshooting

1. Disconnect all power sources.

2. Check that the jumper on terminals CRB and CRBD (TB4-1 and TB4-2) is installed. If not, reinstall a permanent jumper wire between these terminals and test the system.

3. Manually operate the contactor to the normal position and check for continuity between terminals J1-7 and J1-10 on the controller assembly. There should be no connection, replace the NR relay if there is. See Figure 4-5.

4. Coil-clearing contact SCE should be closed. Check for continuity across contact SCE between coil terminal 7 and neutral. Check the contactor wiring harness and connections or replace coil-clearing contact SCE if there is no continuity. See Figure 4-5.

5. Manually operate the contactor to the emergency position.

6. Coil-clearing contact SCN should be closed. Check for continuity across SCN between coil terminal 3 and neutral. Check the contactor wiring harness and connections or replace coil-clearing contact SCN if there is no continuity. See Figure 4-6.

7. Apply the normal power source. The NA LED should light. If the NA LED does not light, see Section 4.10.

8. When the NA LED lights, wait for TDEN, listen to the NR relay energize, and observe the NR LED. If 120 volts is not applied between terminals J1-15 and neutral and the contactor does not transfer to the normal source, check the following. See Figure 4-7.

   a. If the NR LED does not light, replace the controller assembly.

   b. If the NR LED lights but the NR relay does not energize, replace the NR relay. If the replacement NR relay does not cause 120 volts to be applied between terminals J1-15 and neutral, replace the controller assembly.

9. If the NA LED is lit, NR is energized, and 120 volts appears between J1-15 and neutral but the contactor does not transfer to the normal position, check the contactor wiring harness and connections to terminals 3 and 4 on the CN coil. Replace the CN coil if the wiring harness and connections are good.

10. When the contactor transfers the load to the normal power source, disconnect the normal source and allow the generator set to start.

11. When the generator starts the EA LED should light. If the EA LED does not light, see Section 4.9.

12. When the EA LED lights, wait for TDNE, listen to the ER relay energize, and observe the ER LED. If 120 volts is not applied between terminals J1-6 and neutral and the contactor does not transfer to the emergency source, check the following. See Figure 4-8.

    a. If the ER LED does not light, replace the controller assembly.

    b. If the ER LED lights but the ER relay does not energize, or if the ER relay energizes and the NR relay was replaced, replace the ER relay.

    c. Replace the NR or ER relay if it has not been replaced already. It is difficult to access the contacts to determine the faulty relay in-circuit.

13. If voltage appears between terminals J1-6 and neutral but the contactor does not transfer to the emergency position, check the contactor wiring harness and connections to terminals 7 and 8 on coil CE. Replace the CE coil if the wiring harness and connections are good.

4.8 Controller Operation

Follow this section to check the controller's automatic operation sequence including engine starting, time delays, contactor operation, and LEDs.

Controller Operation Test

1. Disconnect all power sources for at least five minutes.

2. Manually operate the contactor to the normal position.

3. Disconnect the exerciser switch wiring harness from connector P2 on the controller assembly.

4. Apply the normal power source and wait for TDEC. If the NA LED does not light, see Section 4.10. If the NA LED lights and the ES LED does not light or the engine-start contact does not open within ±10% of the TDEC specification, replace the controller assembly.

5. Disconnect the normal power source and wait for TDES. If the ES LED does not turn off and the engine-start contact does not close within ±10% of the TDES specification, replace the controller assembly.

6. Reconnect the emergency source and check the EA LED. If the EA LED does not light, see Section 4.9. Wait for TDNE and the switch to transfer to the emergency source. If the switch fails to transfer, see Section 4.7. If the switch transfers but not within ±10% of the TDNE specification, replace the controller assembly.

7. Reconnect the normal power source and wait for TDEN and for the switch to transfer back to the normal source. If the switch fails to transfer, see Section 4.7. If the switch transfers but not within ±10% of the TDEN specification, replace the controller assembly.

8. Wait for TDEC. If the ES LED does not light and the engine-start contact does not open within ±10% of the TDEC specification after transfer to normal, replace the controller assembly.

9. Reconnect the exerciser switch wiring harness to connector P2 on the controller assembly.

4.9 Emergency Source Sensing

Follow this section when the transfer switch starts the generator set but does not recognize the emergency source as available by lighting the EA LED, or it fails to recognize emergency power source failure.

This section requires a voltmeter with a minimum accuracy of ±1% on the scale being measured.

Initial Emergency Source Sensing Troubleshooting

Use this section to initially troubleshoot emergency source sensing. This procedure requires emergency source availability. See Section 4.5 if the generator set does not start.

1. Disconnect the emergency source. If the EA LED remains lit more than a few seconds, replace the controller assembly.

2. Reconnect the emergency source and check for nominal line voltage on phase EA-EC between terminals P1-3 and P1-6 on the controller assembly.

   a. If voltage is not present at the controller, check for voltage on lugs EA and EC on the contactor assembly. If voltage is not present at the lugs, check the emergency source and the emergency source wiring and circuit breaker. If voltage is present at the lugs, check the contactor wiring harness connections from the lugs to the controller.

   b. If the voltage on phase EA-EC on P1 on the controller exceeds the single-phase pickup voltage specification in Figure 4-9 then the EA LED on the controller assembly should light; replace the controller assembly if the LED does not light.

Dropout Voltage (VAC)	Pickup Voltage (VAC)
160	190

Figure 4-9 Single-Phase Emergency Source Undervoltage Specifications

Use the following procedure to test emergency source sensing operation and calibration.

Emergency Source Single-Phase Sensing Test

Follow the next steps to check single-phase sensing of the emergency source on both single- and three-phase switches.

1. Disconnect the normal and emergency power sources and the load from the transfer switch.

2. Connect a variable voltage source that ranges from about 5% below the dropout specification to about 5% above the pickup specification to lugs EA-EC on the contactor assembly.

3. Increase the voltage until the EA LED lights or the voltage is 5% above the pickup voltage specification. If the EA LED does not light, replace the controller assembly. Otherwise, reduce the voltage until the EA LED turns off or the voltage is 5% below the dropout voltage specification.

4. If the EA LED remains lit, replace the controller assembly. If the LED turns off, check the voltage. If the voltage is not within ±5% of the dropout voltage specification, replace the controller assembly.

5. Increase the voltage until the EA LED lights. If the voltage is not within ±5% of the pickup voltage specification, replace the controller assembly.

4.10 Normal Source Sensing

Follow this section when the system fails to recognize the normal power source as available by lighting the NA LED, or when it fails to recognize normal power source failure.

This section requires a voltmeter with a minimum accuracy of ±1% on the scale being measured.

Initial Normal Source Sensing Troubleshooting

Use this section to initially troubleshoot normal source sensing. This procedure requires normal source availability.

1. Disconnect all power sources.
2. On single-phase switches, check for continuity between terminals GND and 3PH on TB2 on the controller assembly. If the circuit is open, install a permanent jumper between these terminals, then reapply power and test the system.
3. On three-phase switches, disconnect the three-phase module from terminals GND and 3PH on TB2 on the controller assembly and install a temporary jumper between these terminals on the controller assembly. Remove the temporary jumper and reconnect the three-phase module when normal source sensing troubleshooting and testing is complete.
4. Disconnect the normal source. If the NA LED remains lit for more than a few seconds, replace the controller assembly.
5. Reconnect the normal source and check for nominal line voltage on phase NA-NC on terminals P1-12 and P1-15 on the controller assembly.
   a. If voltage is not present on phase NA-NC on P1 on the controller, check for voltage on lugs NA and NC on the contactor assembly. If voltage is not present on the lugs, check the normal source and the normal source wiring and circuit breaker. If voltage is present on the lugs, check the contactor wiring harness connections from the lugs to the controller assembly.
   b. If the voltage on phase NA-NC on P1 on the controller exceeds the single-phase pickup voltage specification in Figure 4-10 then the NA LED on the controller assembly should light; replace the controller assembly if the LED does not light.

Dropout Voltage (VAC)	Pickup Voltage (VAC)
160	190

Figure 4-10 Single-Phase Normal Source Undervoltage Specifications

Use the following procedures to test normal source sensing operation and calibration.

Normal Source Single-Phase Sensing Test

Follow the next steps to check single-phase sensing of the normal source on both single- and three-phase switches.

1. Disconnect the normal and emergency power sources and the load from the transfer switch.
2. Connect a variable voltage source that ranges from about 5% below the dropout specification to about 5% above the pickup specification to lugs NA-NC on the contactor assembly. Increase the voltage until the NA LED lights or the voltage is 5% above the pickup voltage specification in Figure 4-10
3. If the NA LED does not light, replace the controller assembly.
4. If the NA LED lights, reduce the voltage until the NA LED turns off or is 5% below the dropout voltage specification. If the NA LED remains lit, replace the controller assembly. If the LED turns off, check the voltage. If the voltage is not within ±5% of the dropout voltage specification, replace the controller assembly.
5. Increase the voltage until the NA LED lights. If the voltage is not within ±5% of the pickup specification, replace the controller assembly.

Section 5 Drawings and Diagrams

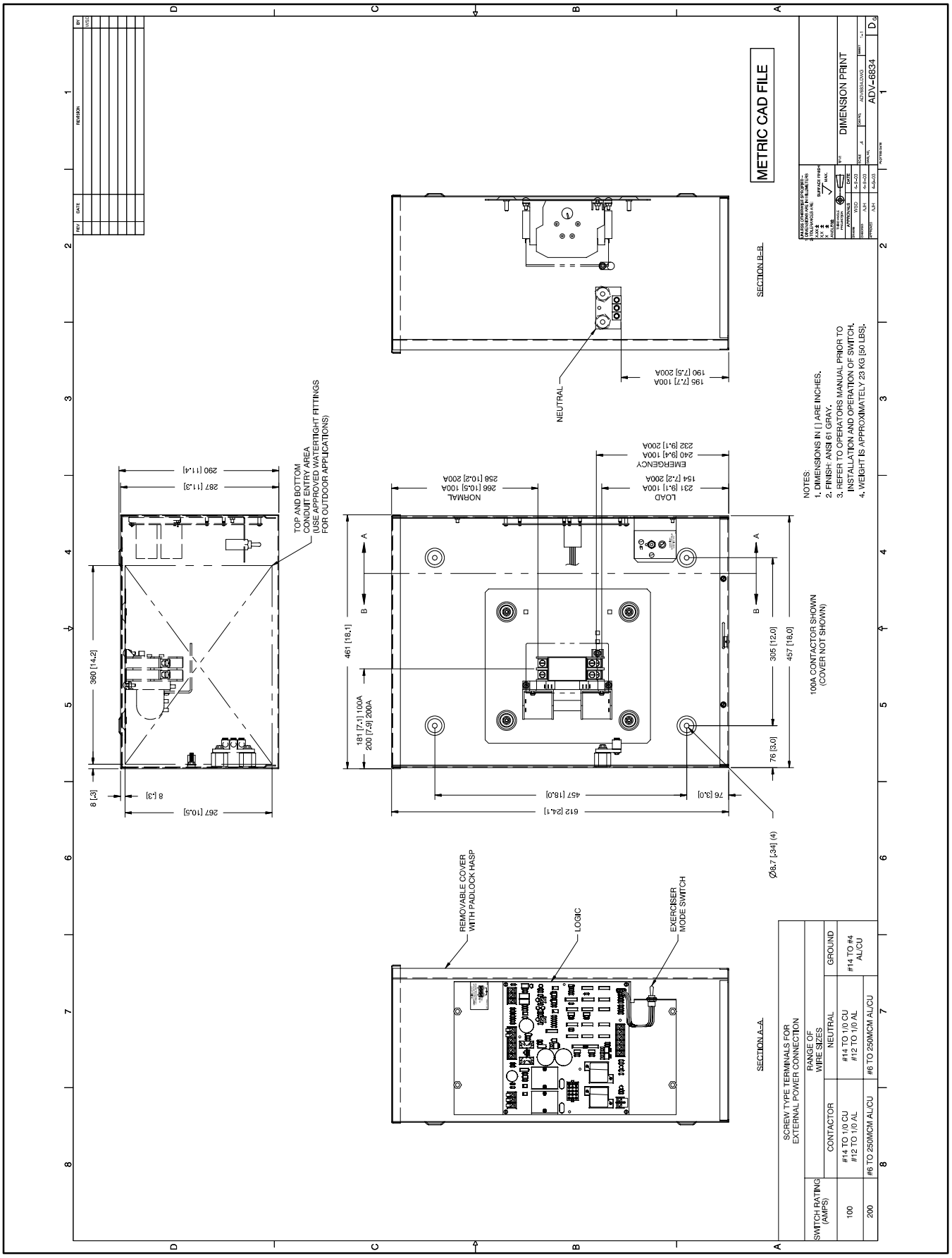


Figure 5-1 Enclosure Dimension Drawing, ADV-6834-S

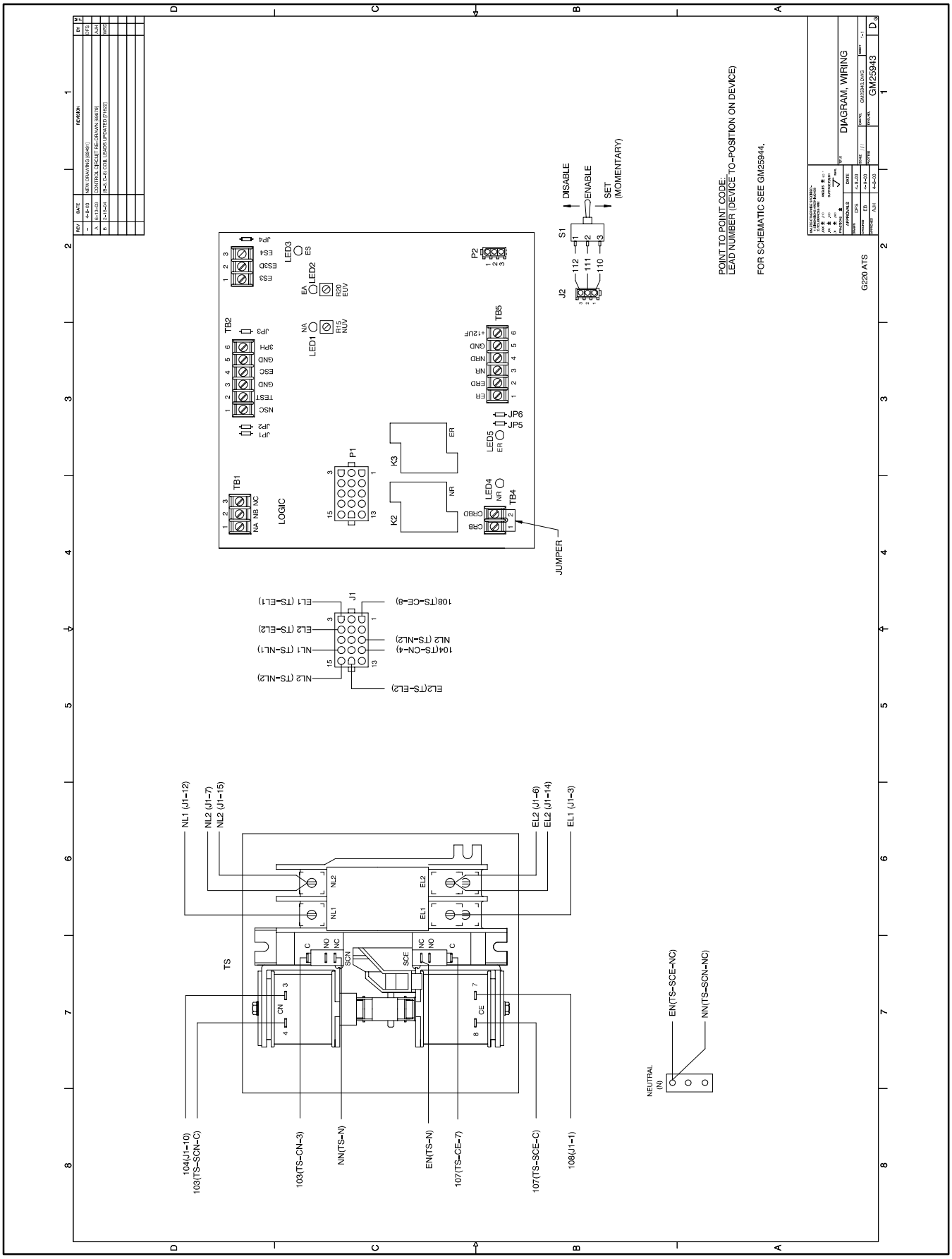


Figure 5-2 Wiring Diagram, 100 and 200 Ampere, GM25943-S-B

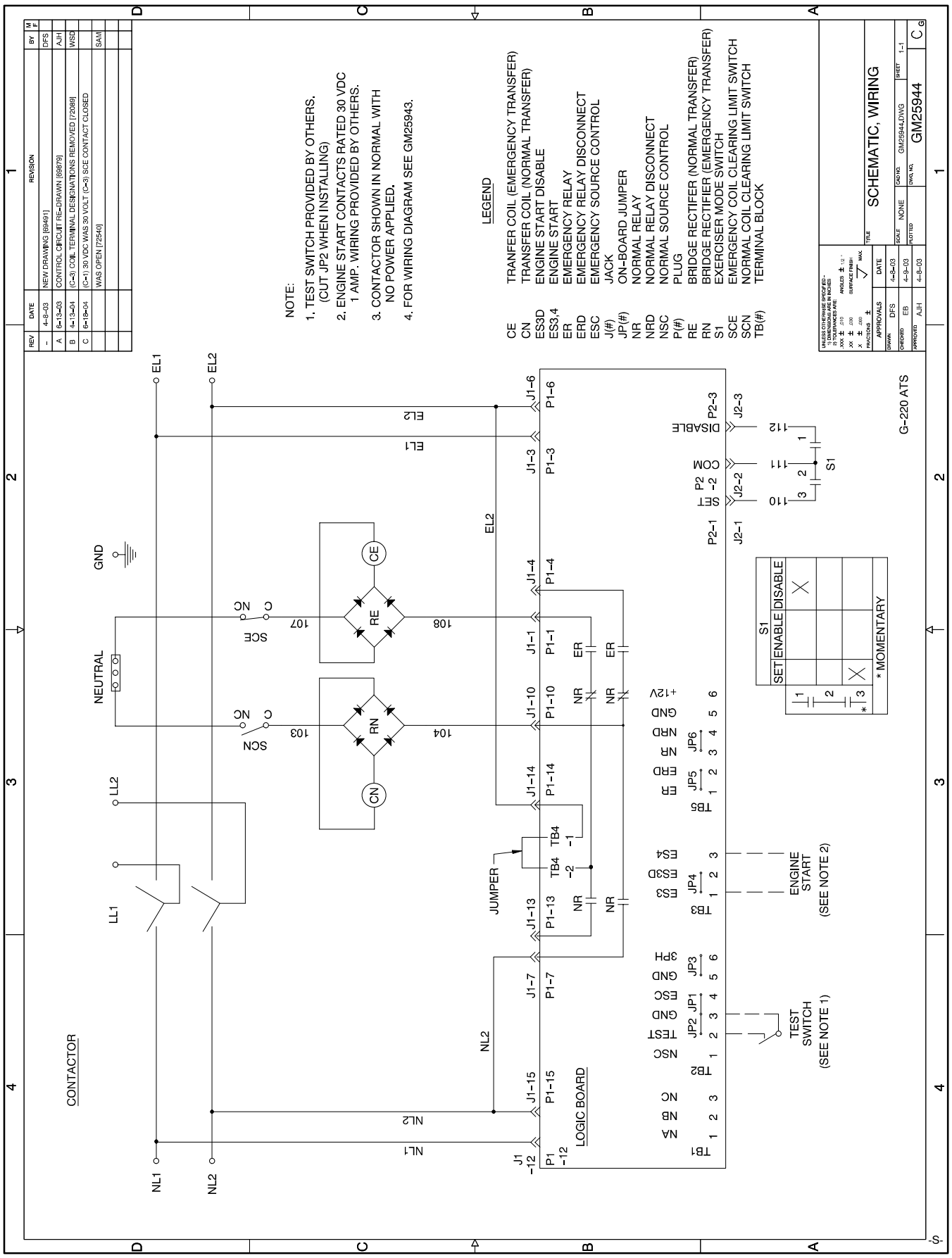
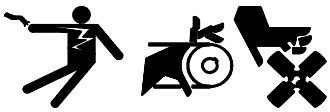


Figure 5-3 Schematic Diagram, 100 and 200 Amperes, GM25944-S-C

Use the instructions in this section for transfer switch service part replacement. See Section 7 for service parts.

⚠ 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.

⚠ DANGER

Hazardous voltage.
Will cause severe injury or death.

Disconnect all power sources before opening the enclosure.

⚠ DANGER

Hazardous voltage.
Will cause severe injury or death.

Only authorized personnel should open the enclosure.

Servicing the transfer switch. Hazardous voltage can cause severe injury or death. Deenergize all power sources before servicing. Open the main circuit breakers of all transfer switch power sources and disable all generator sets as follows: (1) Move all generator set master controller switches to the OFF position. (2) Disconnect power to all battery chargers. (3) Disconnect all battery cables, negative (-) leads first. Reconnect negative (-) leads last when reconnecting the battery cables after servicing. Follow these precautions to prevent the starting of generator sets by an automatic transfer switch, remote start/stop switch, or engine start command from a remote computer. Before servicing any components inside the enclosure: (1) Remove all jewelry. (2) Stand on a dry, approved electrically insulated mat. (3) Test circuits with a voltmeter to verify that they are deenergized.

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)

Making line or auxiliary connections. Hazardous voltage can cause severe injury or death. To prevent electrical shock deenergize the normal power source before making any line or auxiliary connections.

Servicing the transfer switch controls and accessories within the enclosure. Hazardous voltage can cause severe injury or death. Disconnect the transfer switch controls at the inline connector to deenergize the circuit boards and logic circuitry but allow the transfer switch to continue to supply power to the load. Disconnect all power sources to accessories that are mounted within the enclosure but are not wired through the controls and deenergized by inline connector separation. Test circuits with a voltmeter to verify that they are deenergized before servicing.

⚠ WARNING

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

Use adequate lifting capacity.
Never leave the transfer switch standing upright unless it is securely bolted in place or stabilized.

NOTICE

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

NOTICE

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

NOTICE

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

6.1 Before and After Servicing Components

Before Service. Follow these instructions before opening the enclosure and servicing the transfer switch.

1. Prevent the emergency power source generator set from starting by placing the generator set master switch in the OFF position; disconnecting power to the generator set battery charger, if installed; and removing the generator set engine start battery cables, negative (–) lead first.

2. Disconnect or turn off *both* the normal and emergency power sources before opening the enclosure door. Check circuits with a voltmeter to verify that the power is off before servicing components inside the enclosure.

After Service Follow these instructions after servicing the transfer switch.

1. Reinstall barriers.

2. Remove debris from the enclosure.

3. See Section 2.1 for startup instructions.

6.2 Contactor Assembly

Note: Serviceable contactor assembly parts can be replaced without removing the contactor assembly from the enclosure.

6.2.1 Contactor Assembly Removal

1. Disable the generator set and disconnect all power sources as described in Section 6.1 before opening the transfer switch enclosure.

2. Loosen the power terminal lugs and disconnect the normal, emergency, and load power conductors, and label and tape the ends of the conductors.

3. Disconnect the contactor wiring harness from the controller at connector P1.

4. Remove the nuts and lock washers located at the four corners of the contactor's back plate that secure the contactor assembly to the back wall of the enclosure.

5. Lift and pull the contactor assembly from the enclosure.

6.2.2 Contactor Assembly Installation

1. Position the contactor assembly on the mounting studs inside the transfer switch enclosure.

2. Reinstall the nuts and lock washers that secure the contactor assembly.

3. Reconnect the power source and load conductors to the lugs. Tighten the connections to the torques shown in Section 3.1.2 of this manual.

   Note: Connect the source and load phases as indicated by the markings and drawings. Improper connections may cause short circuits or cause phase-sensitive load devices to malfunction or operate in reverse.

4. Reconnect the contactor wiring harness to the controller at connector P1.

6.3 Solenoid Assembly

Disable the generator set and disconnect all power sources as described in Section 6.1 before opening the transfer switch enclosure.

Procedures shown are for the Normal source coil. Use the same procedures for the Emergency source coil. Perform the coil replacement procedures on one source side at a time.

- To replace the Normal source coil, first move the contactor to the Emergency source position.
- To replace the Emergency source coil, first move the contactor to the Normal source position.

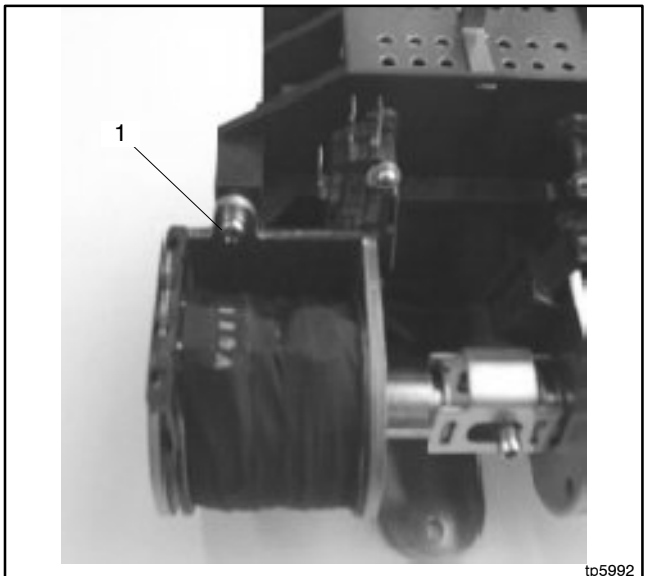
6.3.1 Solenoid Assembly Removal

1. Remove two mounting screws from the assembly. See Figure 6-1.

   Note: Two square nuts will be released when the mounting screws are removed. Save the screws and nuts for reinstallation later.

6.3.2 Disassembly, 200 Amp Models

1. Remove two screws from the core plate. See Figure 6-2.



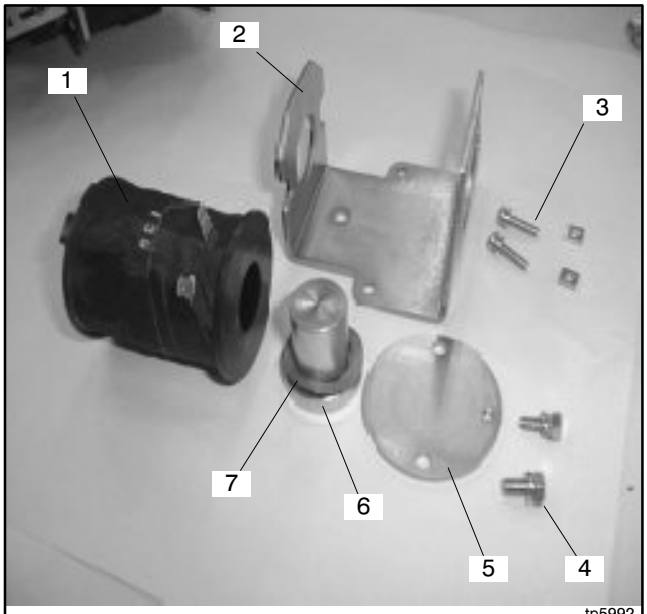
1. Remove screws, 2 locations

Figure 6-1 Solenoid Assembly, Model R220, Typical

2. Remove the core plate and the steel core with washer. See Figure 6-3.
3. Remove the coil from the coil bracket. See Figure 6-3.

1. Remove 2 screws

Figure 6-2 Disassembling the Coil Assembly



1. Coil
2. Coil bracket
3. Assembly mounting screws and nuts
4. Core plate screws
5. Core plate
6. Steel core
7. Washer

Figure 6-3 Coil Assembly Parts

6.3.3 Reassembly, 200 Amp Models

1. Position the coil in the bracket with the tab on the top of the coil and operating circuit terminal oriented as shown in Figure 6-4 for the Normal source coil or in Figure 6-5 for the Emergency source coil.

2. Insert the steel core with washer into the coil. See Figure 6-4.

3. Install the core plate and tighten the two core plate screws. See Figure 6-2.

6.3.4 Solenoid Assembly Installation

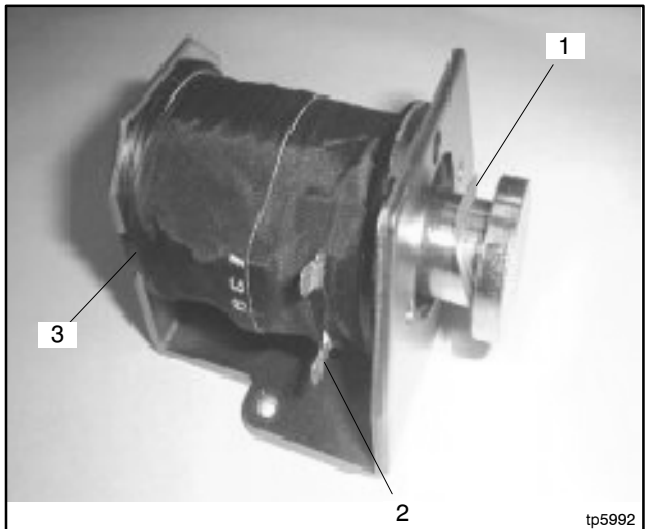
1. Insert the two square nuts into the grooves on the frame. See Figure 6-6.

2. Align locating hole in the solenoid bracket with the locating protrusion in the frame. See Figure 6-7.

3. Install and tighten the two mounting screws. Use pliers to hold the nuts while inserting and tightening the screws. See Figure 6-8.

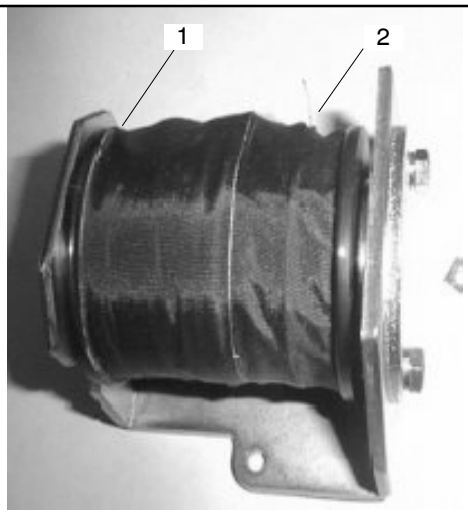
4. Operate the contactor using the manual operating handle to verify that the mechanism operates smoothly without binding.

5. Follow the instructions under **After Service** in Section 6.1.



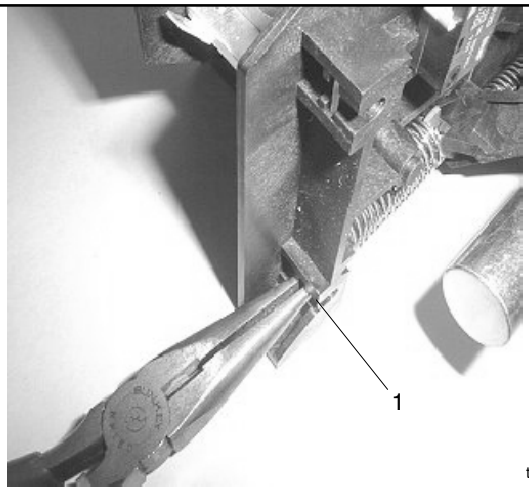
1. Core and washer
2. Operating circuit terminal
3. Coil orientation tab, Normal source coil

Figure 6-4 Coil Assembly, Normal Source Coil Shown (note the coil orientation)



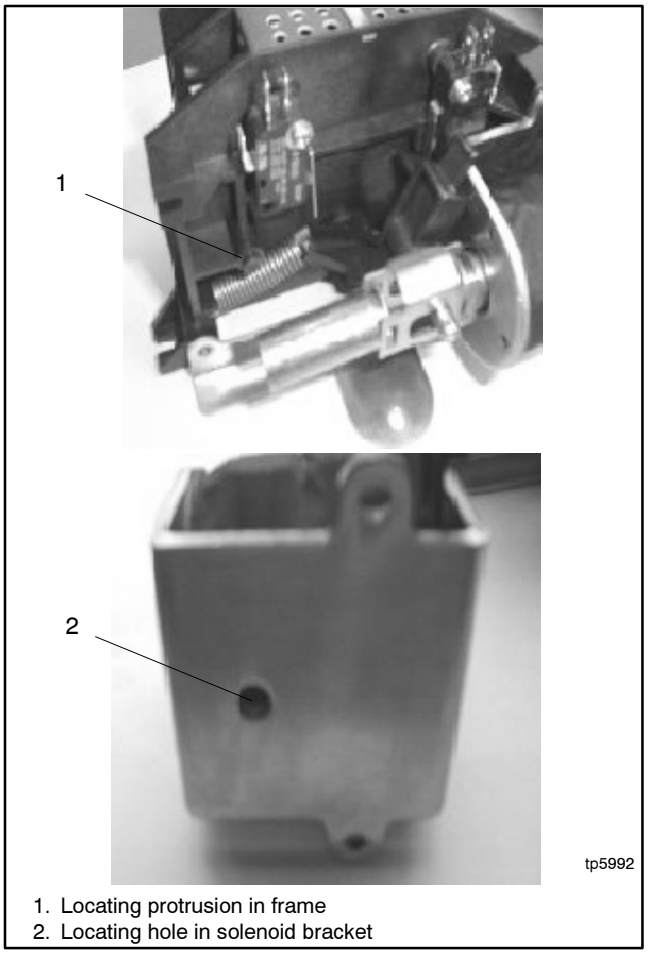
1. Coil orientation tab, Emergency source coil
2. Operating circuit terminal

Figure 6-5 Emergency Source Coil Assembly (note the coil orientation)



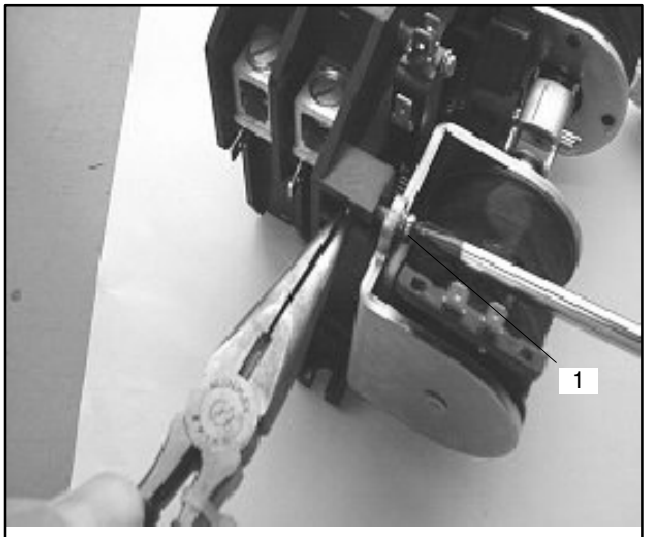
1. Insert square nuts into the grooves in the frame (two locations)

Figure 6-6 Reinstalling the Coil Assembly Nuts



1. Locating protrusion in frame
2. Locating hole in solenoid bracket

Figure 6-7 Locating the Solenoid Assembly, Typical



1. Install and tighten 2 mounting screws

Figure 6-8 Installing the Coil Assembly,Typical

6.4 Microswitch Replacement

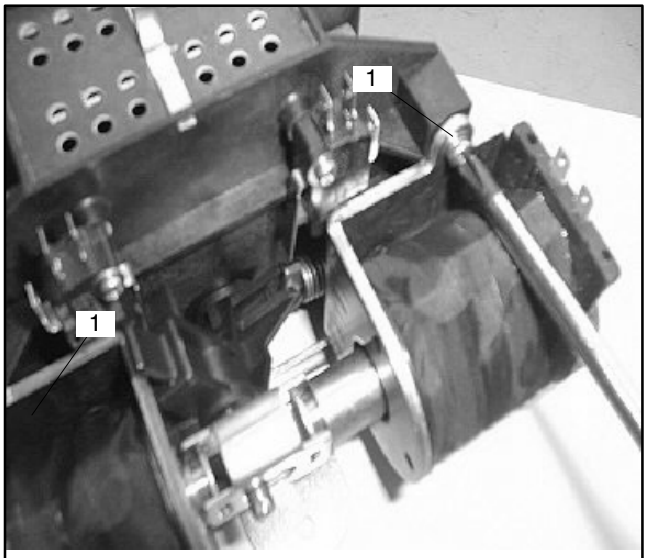
Procedures shown are for the microswitch at the Emergency source coil. Use the same procedures for the microswitch at the Normal source coil.

Perform the switch replacement procedures on one source side at a time.

- To replace the microswitch at the Normal source coil, first move the contactor to the Emergency source position.
- To replace the microswitch at the Emergency source coil, first move the contactor to the Normal source position.

6.4.1 100 Amp Models

1. Loosen the four coil mounting screws (two for each coil) by two full rotations. Do not remove the coils. See Figure 6-9.



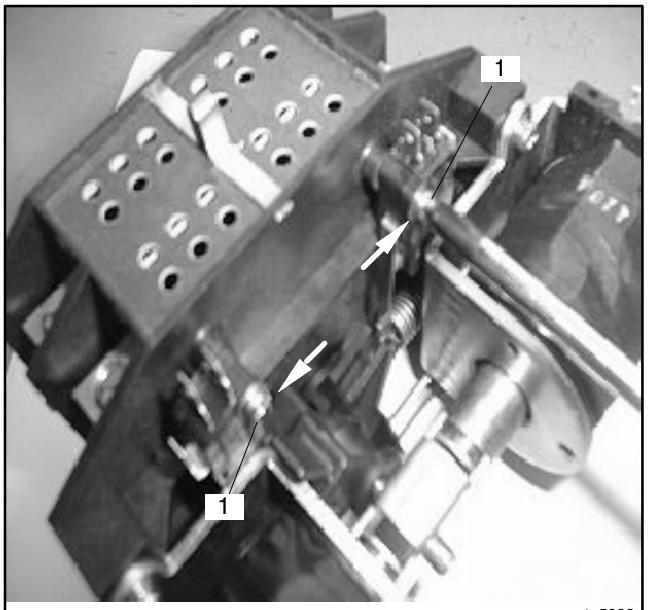
1. Coil mounting screws

Figure 6-9 Loosen Coil Mounting Screws, 100 Amp Models

2. Remove the microswitch mounting screw and microswitch. See Figure 6-10 and Figure 6-11.

3. Install the new microswitch. Push the microswitch mounting screw in the direction of the arrow shown in Figure 6-10 and tighten it to 0.44 Nm (4 in. lb.).

4. Tighten the four coil mounting screws.



1. Microswitch mounting screw

Figure 6-10 Microswitch Mounting Screw

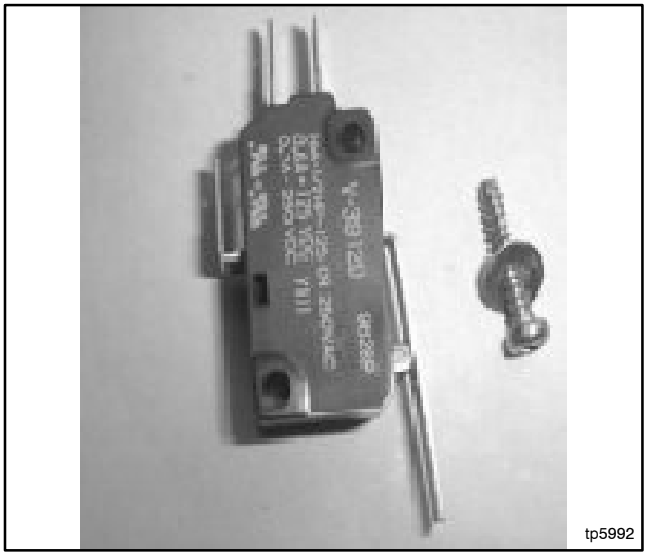
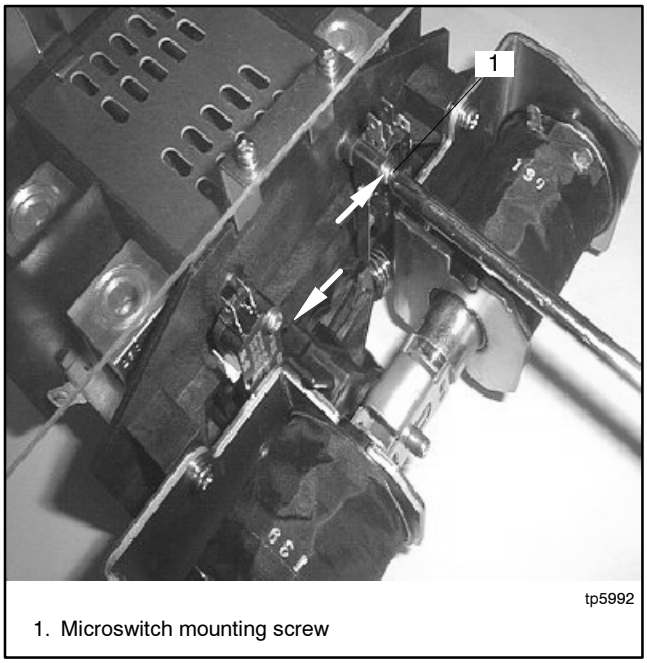


Figure 6-11 Microswitch and Mounting Screw

6.4.2 200 Amp Models

1. Remove the microswitch mounting screw and microswitch. See Figure 6-12.

2. Install the new microswitch. Push the microswitch mounting screw in the direction of the arrow shown in Figure 6-12 and tighten it to 0.44 Nm (4 in. lb.).



1. Microswitch mounting screw

Figure 6-12 Install new Microswitch, 200 Amp Models

6.5 Controller PCB Assembly

Electronic printed circuit boards (PCBs) are sensitive to a variety of elements and can be damaged during removal, installation, transportation, or storage. Observe the following when working with circuit boards.

Circuit Board Handling

- Store circuit boards in the anti-static, cushioned packaging provided by the factory in a clean environment away from moisture, vibration, static electricity, corrosive chemicals, solvents, or fumes until installation.

- Wear an approved grounding, anti-static wrist strap when handling circuit boards or components.

- Carefully hold the circuit board only by its edges, not by any of its components.

- Don't bend or drop the circuit board or any of its components.
- Don't strike the circuit board or any of its components with a hard object.
- Clean dusty or dirty circuit boards only with a vacuum cleaner or dry brush.
- Never attempt component-level circuit repairs.
- Never remove or install a circuit board with power connected.
- Label wiring when disconnecting it for reconnection later.

6.5.1 Controller PCB Removal

1. Disable the generator set and disconnect all power sources as described in Section 6.1 before opening the transfer switch enclosure.

1. Remove the four screws located at the four corners of the main controller circuit board assembly.

2. Five push-on PCB standoffs at various locations on the mounting plate also holds the circuit board. Carefully pry the circuit board away from each standoff at the locations shown by the arrows in Figure 6-13. Pry near the standoff located below terminal strip TB2 first and work clockwise.

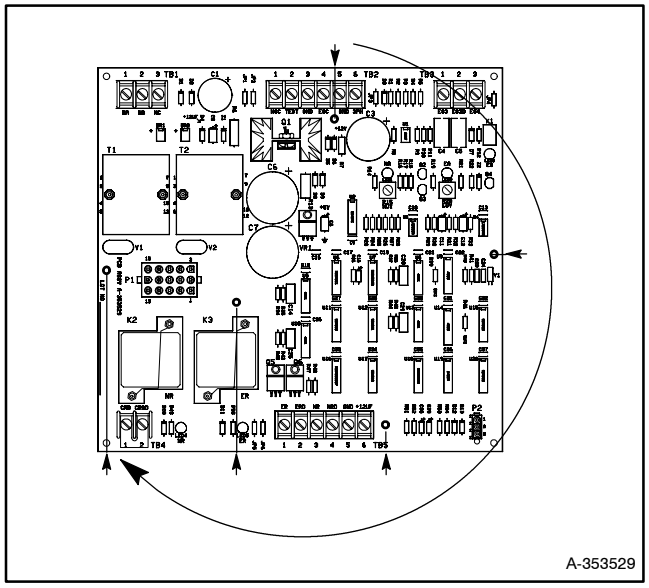


Figure 6-13 PCB Removal

6.5.2 Controller PCB Installation

1. Position the circuit board over the push-on PCB standoffs on the mounting plate.

2. Gently push the circuit board onto the standoffs.

3. Replace and tighten the four screws at the corners of the circuit board.

4. Follow the instructions under **After Service** in Section 6.1.

6.6 Other Service Parts

The removal and installation of other service parts listed in Section 7, such as plug-in relays, auxiliary switches, brackets, and other hardware, for which removal and installation instructions are not previously given is covered by the following generic procedures.

6.6.1 Other Service Part Removal

1. Disable the generator set and disconnect all power sources as described in section 6.1 before opening the transfer switch enclosure.

2. Disconnect wiring from the part(s), noting the locations from which wiring was removed for later reconnection. Tape and label the wires.

3. Note the position of the part(s) and loosen or remove hardware that holds the part(s) in place. Note the location, type, and condition of hardware removed and compare it with the parts list. Replace damaged or missing hardware.

4. Carefully remove the part(s) from the unit. Gently rock plug-in parts, such as relays, from side to side while pulling straight out to remove them without bending circuit boards.

6.6.2 Other Service Part Installation

1. Position the part(s) in place in the same manner that the old part was installed. Support the back of circuit boards when installing plug-in parts, such as relays, to avoid bending the circuit board.

2. Tighten or reinstall hardware that holds the part(s) in place to the general torque specifications in the appendix unless otherwise noted.

3. Reconnect wiring to the same locations from which they where removed, torquing terminals to the specifications given in the maintenance section of this manual.

4. Follow the instructions under **After Service** in Section 6.1.

Use this section to locate and identify serviceable parts for the transfer switch model covered by this manual.

7.1 General Information

7.1.1 Finding Parts Information

1. Decode the transfer switch model number from the nameplate to determine the transfer switch's electrical controls, voltage and frequency, poles and phases, wires, enclosure type, and current rating. See Section 1.4.
2. Locate the section that illustrates the part(s) that are needed.
3. Locate the part(s) in the illustration.
4. When there are multiple possibilities for parts, use the transfer switch characteristics determined in step 1 to locate the part number and quantity required. The quantity is shown either at the end of the description in parentheses, or in a separate column when there are alternatives.

7.1.2 Leads

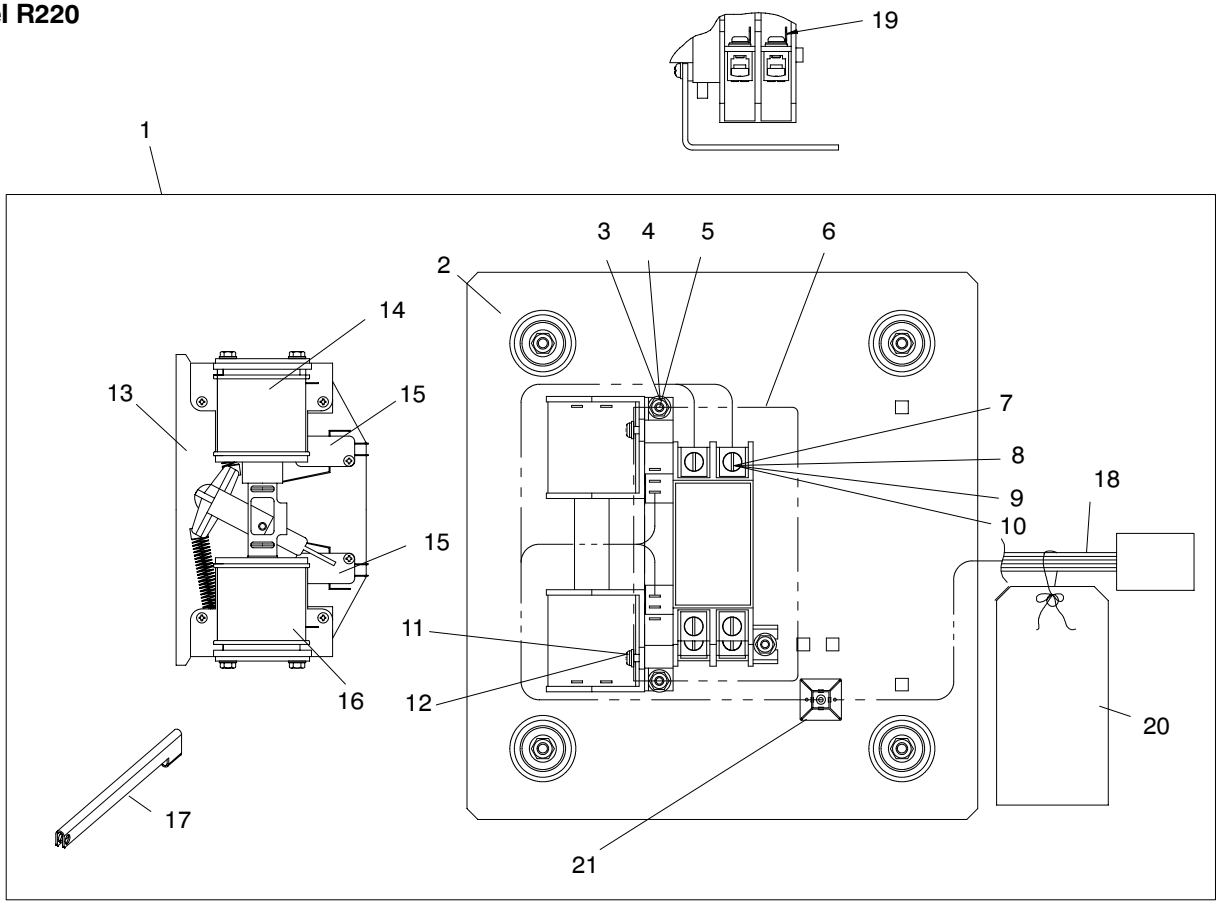
Fabricate replacement leads using the same type of wire as the old leads. Add terminals and lead markers at each end of the new lead. See Section 3.1.2 for instructions on wiring repair and and replacement.

7.1.3 Common Hardware

Common hardware such as nuts, bolts, screws, and washers are Grade 2 unless otherwise noted and can be obtained locally if the same type and grade is available. Refer to Appendices B through E for general torque specifications and to help to identify parts that may not be shown in the parts lists.

7.2 Contactor R220

Model R220

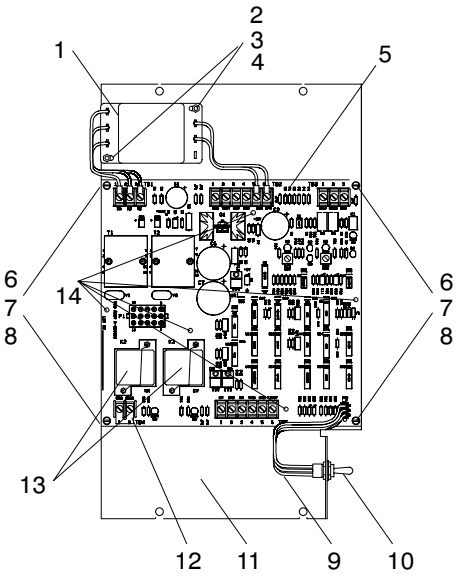


GM29885

Item	Part Number	Description	Qty. Amp 100	Qty. Amp 200
1	GM29860	Contactor assembly, 100 A, 2 pole (includes items 2–18)	1	
	GM29862	Contactor assembly, 200 A, 2 pole (includes item 2–10, 13–18)		1
2	GM28409	Plate, contactor mounting	1	1
3	X-6224-17	Bolt, 1/2-13 x 2.25 in.	3	3
4	295010	Retainer	3	3
5	X-6210-5	Nut, flange whiz, 10-24	3	3
6	GM29825	Guard, contactor	1	
7	GM28412	Lug, terminal	6	
	297712	Lug, terminal		6
8	X-25-36	Washer, plain, .219 ID x .5 in. OD	6	
	X-25-20	Washer, plain, .312 ID x.75 OD		6
9	X-6086-23	Washer	6	
	X-6086-24	Washer		6
10	X-50-2	Screw, pan head, 10-32 x 3/8	6	
	X-465-6	Bolt, hex cap		6

Item	Part Number	Description	Qty. Amp 100	Qty. Amp 200
11	M7985A-04020-20	Screw, pan head machine	2	
12	X-25-9	Washer, plain, .156 ID x .375 in. OD	2	
13	GM28402	Contactor, 100 A, 2P, 120 V	1	
	GM28406	Contactor, 200 A, 2P, 120 V		1
14	GM29863	Coil (upper)	1	
	GM29865	Coil		1
15	GM29867	Switch, limit	2	2
16	GM29864	Coil (lower)	1	
	GM29865	Coil		1
17	GM30062	Handle, contactor manual trip	1	1
18	GM29854	Harness, contactor	1	1
19	GM31593	Terminal, ATS lug sensing	4	
20	297949	Tang, hang	1	1
21	298776	Base, tie, wrap	2	2

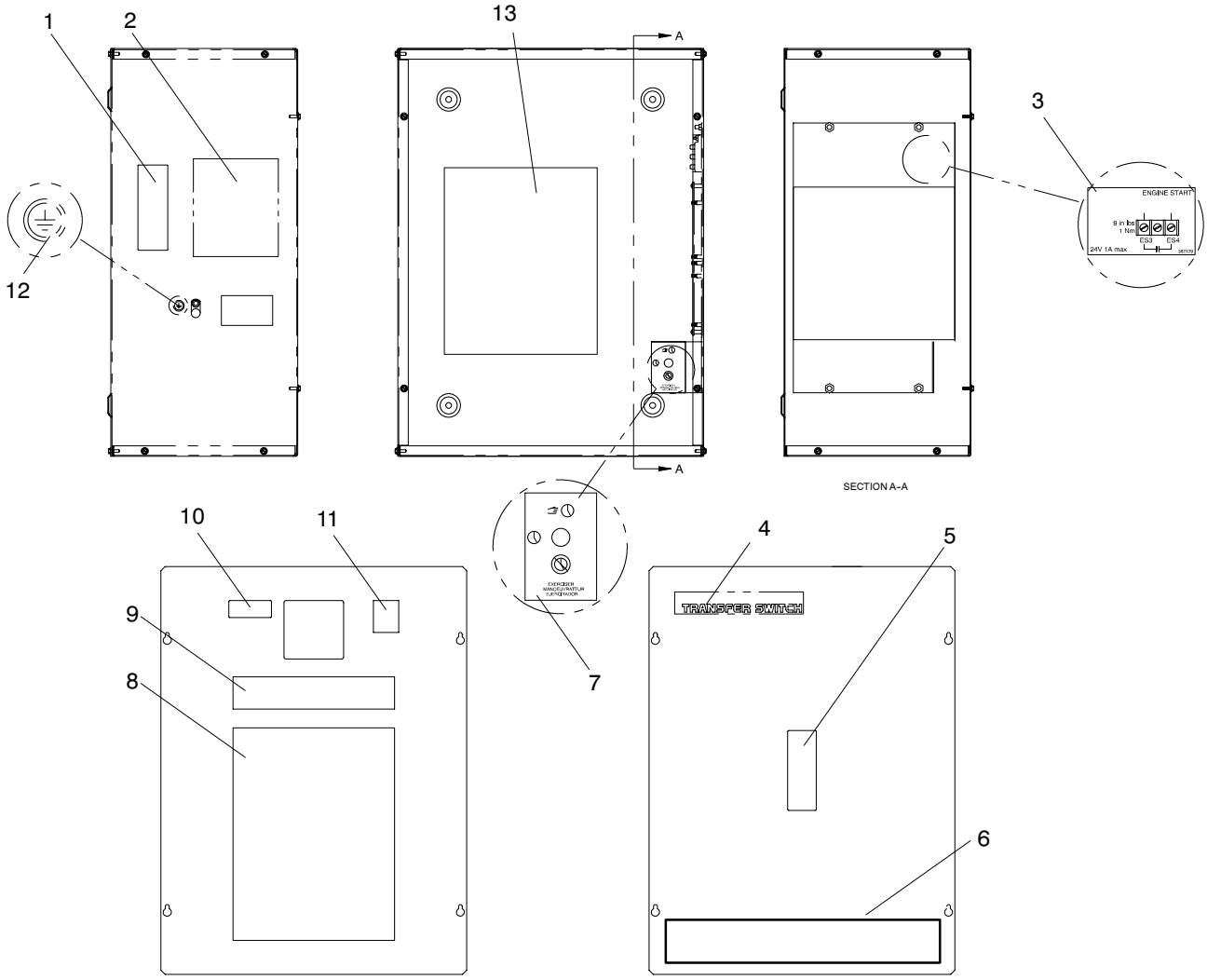
7.3 Controls



DP-295000

Item	Part Number	Description	Quantity by Characteristic			
			3 Phase			
			208 V	220 V	240 V	1-Phase
1	362107	Three-phase module, 208 V	1			
	362138	Three-phase module, 220 V		1		
	362108	Three-phase module, 240 V			1	
2	X-71-2	Nut, hex machine screw, 6-32	2	2	2	
3	—	Washer, #6	2	2	2	
4	282831	Stud, blind self-clinching, 6-32 x .500	2	2	2	2
5	A-353529	PCB assembly, solid-state ATS controls; includes relays 295253 (2)	1	1	1	1
6	X-22-6	Washer, lock, .146 ID x .285 in. OD	4	4	4	4
7	X-49-2	Screw, cross recess pan head machine, #6-32 x .375	4	4	4	4
8	353619	Standoff, blind self-clinching, 6-32 x 0.500	4	4	4	4
9	362143	Wiring harness, exerciser	1	1	1	1
10	362141	Switch, toggle, SPDT pole, exerciser	1	1	1	1
11	353618	Panel, mounting	1	1	1	1
12	X-6048-2	Jumper, term block 2 pos	1	1	1	1
13	295253	Relay, 10 A, NR/ER, 120 Ω coil	2	2	2	2
14	337441	Standoff, PCB push-on, .146 dia., 0.5 tall	5	5	5	5

7.4 Decals

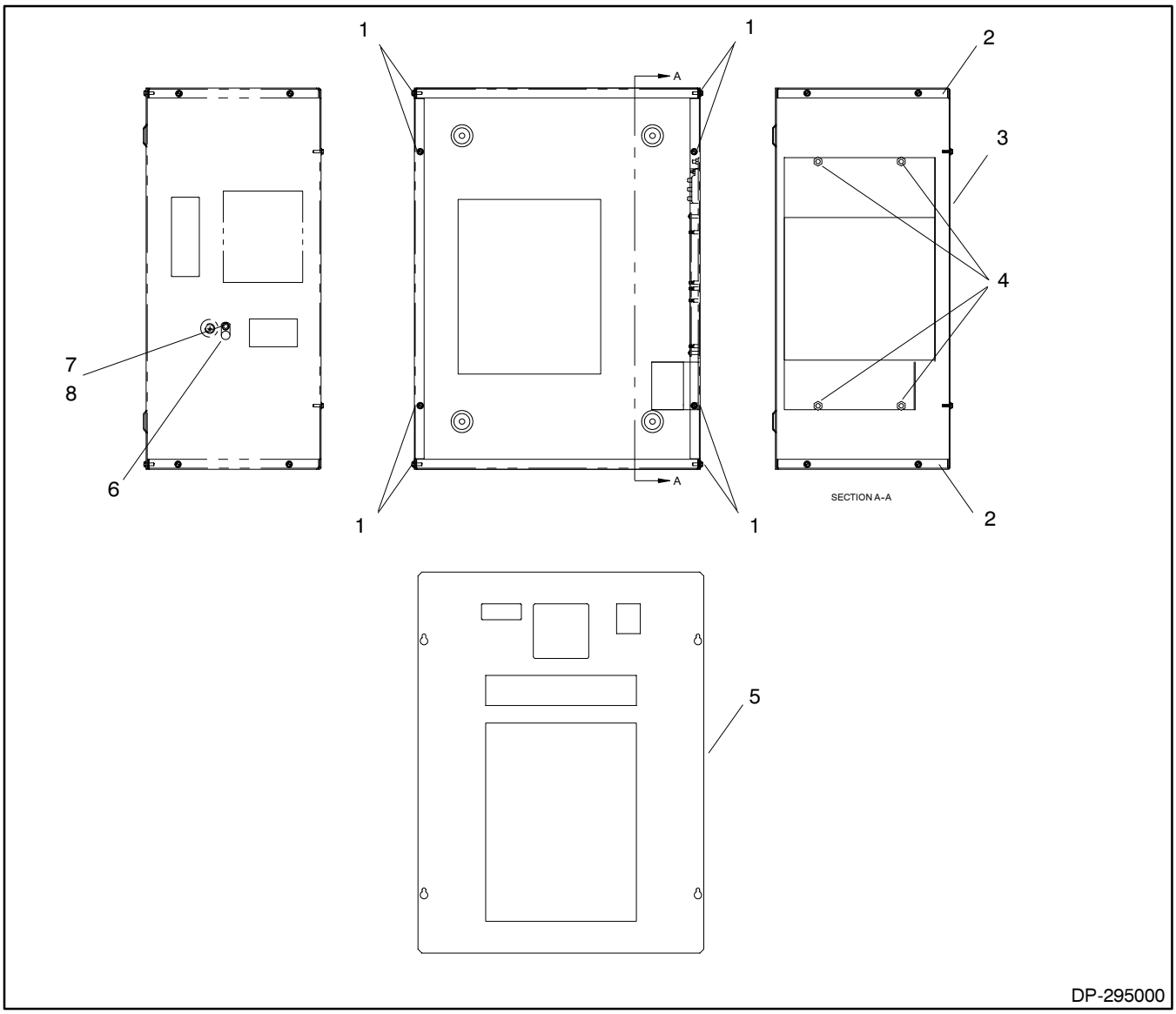


Note: NEMA type 1 enclosure shown

DP-295000

Item	Part Number	Description	Quantity by NEMA Enclosure Type	
			1	3R
1	362112	Decal, ATS rating	1	1
2	297556	Decal, torque	1	1
3	362129	Decal, engine start	1	1
4	X-6303-3	Decal, TRANSFER SWITCH	1	1
5	362176	Decal, danger	1	1
6	X-6301-8	Decal, logo	1	1
7	362145	Decal, exerciser ATS	1	1
8	298777	Envelope, manual	1	1
9	362144	Decal, logic ATS	1	1
10	362130	Decal, NEMA 3R rating ATS		1
	362131	Decal, NEMA 1 rating ATS	1	
11	224233	Decal, 1-800 number	1	1
12	345211	Decal, ground	1	1
13	294328	Decal, danger high voltage	1	1

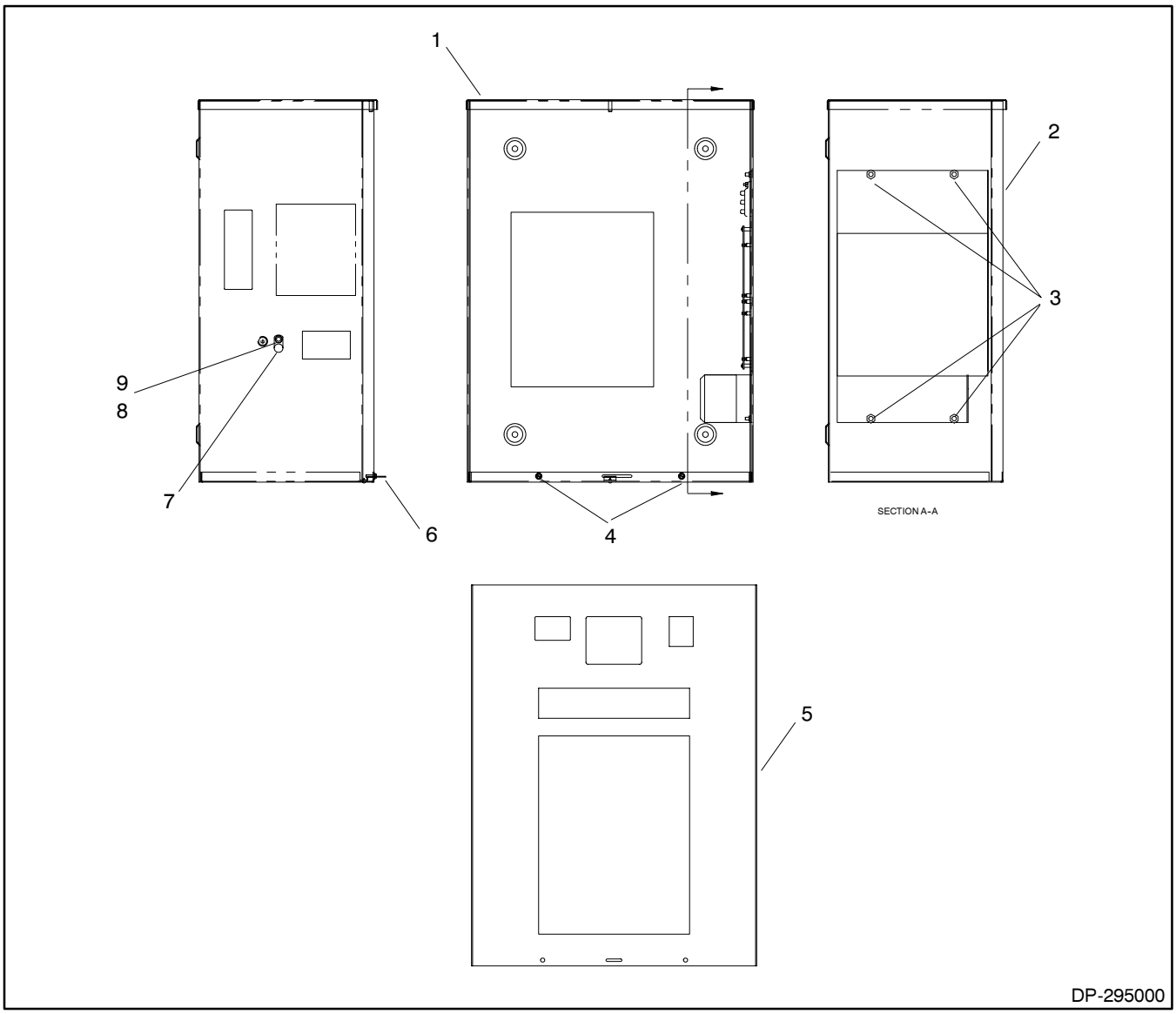
7.5 Enclosure, NEMA Type 1



Item	Part Number	Description
1	X-67-52	Screw, hex washer, thread-forming (16)
2	353617	Panel, ATS, top and bottom (2)
3	353616	Box, ATS
4	#	Nut, hex, 10-32 (4)
5	353615	Cover, ATS
6	362126	Lug, terminal, copper
7	X-22-11	Washer, lock, .262 ID x .469 in. OD
8	X-81-8	Nut, hex, 1/4-20

Common hardware. Procure locally.

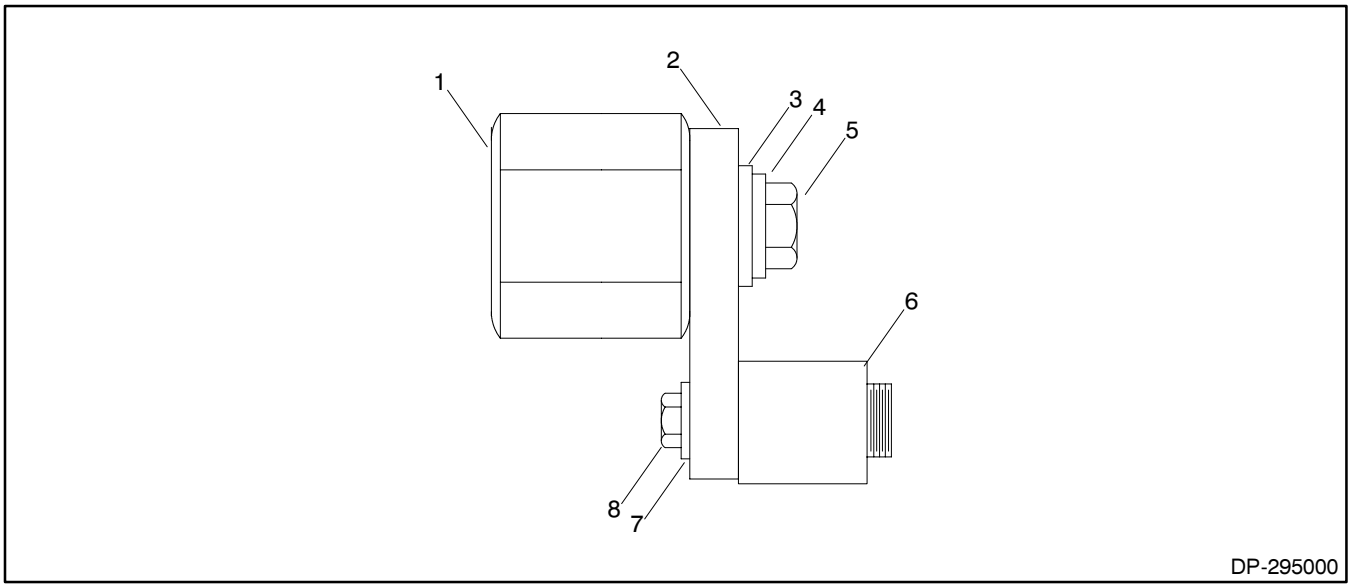
7.6 Enclosure, NEMA Type 3R



Item	Part Number	Description
1	362441	Enclosure (includes 353613, 353614, and 353708)
2	353613	Box
3	#	Nut, hex, 10-32 (4)
4	X-67-52	Screw, hex washer, thread-forming, 10-32 x 0.500 (2)
5	353614	Cover
6	353708	Hasp
7	362126	Lug, terminal, copper
8	X-81-8	Nut, hex, 1/4-20
9	X-22-11	Washer, lock, .262 ID x .469 in. OD

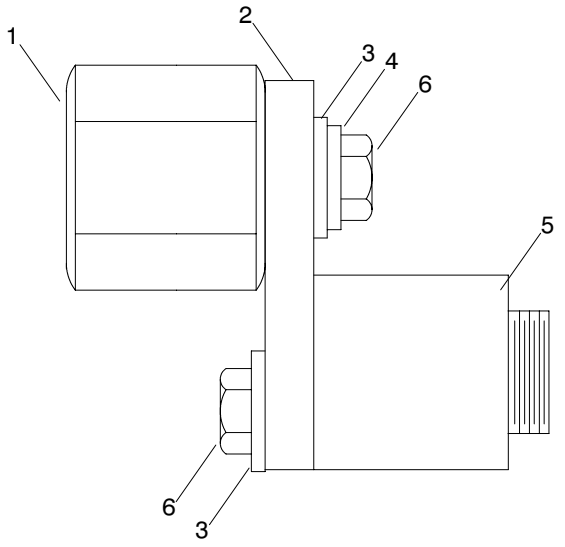
Common hardware. Procure locally.

7.7 Neutral Lug, 100 Amp



Item	Part Number	Description
1	233269	Insulator, panel (2)
2	295304	Bracket, mounting
3	X-25-40	Washer, plain, .281 ID x .625 in. OD (2)
4	X-22-11	Washer, lock, .262 ID x .469 in. OD (2)
5	X-465-6	Bolt, 1/4-20 x .50 (2)
6	295303	Lug, terminal, aluminum (3)
7	X-22-9	Washer, lock, .20 ID x .373 in. OD (3)
8	X-97-11	Screw, slotted hex head machine, 10-32 x 0.500 (3)

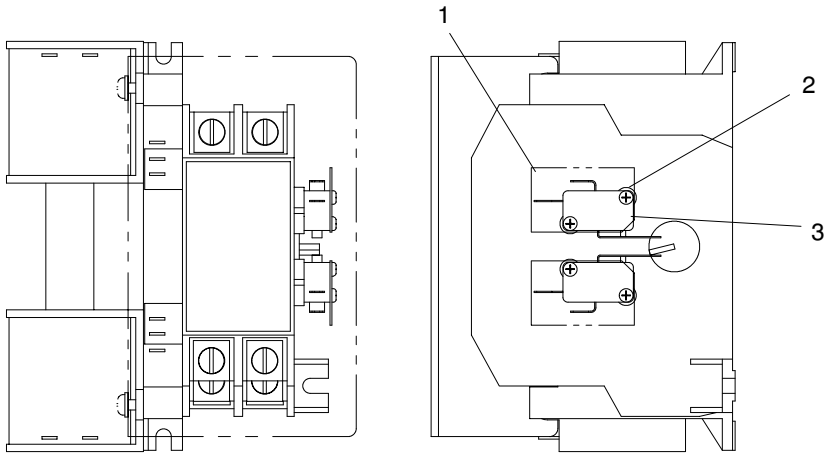
7.8 Neutral Lug, 200 Amp



DP-295000

Item	Part Number	Description
1	233269	Insulator, panel (2)
2	297713	Bracket, mounting
3	X-25-40	Washer, plain, .281 ID x .625 in. OD (2)
4	X-22-11	Washer, lock, .262 ID x .469 in. OD (7)
5	297712	Lug, terminal (3)
6	X-465-6	Bolt, 1/4-20 x .50 (5)

7.9 Auxiliary Switch



GM29856

Item	Part Number	Description
1	362203	Insulator, contactor auxiliary switch (2)
2	362081	Switch, contactor auxiliary (2)
3	X-49-41	Screw, slotted pan head machine

Appendix A Abbreviations

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

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

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

Appendix B Common Hardware Application Guidelines

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

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

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

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

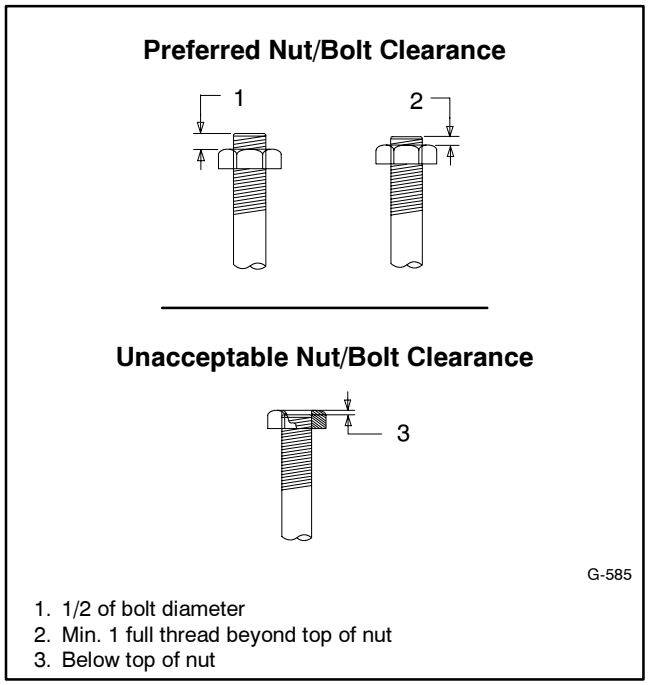


Figure 1 Acceptable Bolt Lengths

Steps for common hardware application:

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

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

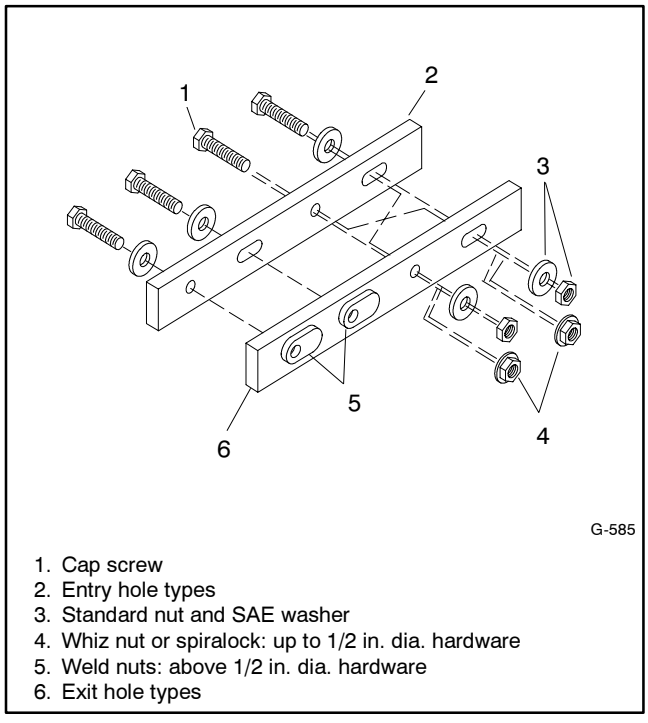


Figure 2 Acceptable Hardware Combinations

Appendix C General Torque Specifications

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

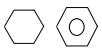
American Standard Fasteners Torque Specifications					
		Assembled into Cast Iron or Steel			Assembled into Aluminum
Size	Torque Measurement	Grade 2	Grade 5	Grade 8	Grade 2 or 5
8-32	Nm (in. lb.)	1.8 (16)	2.3 (20)	—	1.8 (16)
10-24	Nm (in. lb.)	2.9 (26)	3.6 (32)	—	2.9 (26)
10-32	Nm (in. lb.)	2.9 (26)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

Metric Fasteners Torque Specifications, Measured in Nm (ft. lb.)				
	Assembled into Cast Iron or Steel			Assembled into Aluminum
Size (mm)	Grade 5.8	Grade 8.8	Grade 10.9	Grade 5.8 or 8.8
M6 x 1.00	5.6 (4)	9.9 (7)	14.0 (10)	5.6 (4)
M8 x 1.25	13.6 (10)	25.0 (18)	35.0 (26)	13.6 (10)
M8 x 1.00	21.0 (16)	25.0 (18)	35.0 (26)	21.0 (16)
M10 x 1.50	27.0 (20)	49.0 (35)	68.0 (50)	27.0 (20)
M10 x 1.25	39.0 (29)	49.0 (35)	68.0 (50)	39.0 (29)
M12 x 1.75	47.0 (35)	83.0 (61)	117.0 (86)	—
M12 x 1.50	65.0 (48)	88.0 (65)	125.0 (92)	—
M14 x 2.00	74.0 (55)	132.0 (97)	185.0 (136)	—
M14 x 1.50	100.0 (74)	140.0 (103)	192.0 (142)	—
M16 x 2.00	115.0 (85)	200.0 (148)	285.0 (210)	—
M16 x 1.50	141.0 (104)	210.0 (155)	295.0 (218)	—
M18 x 2.50	155.0 (114)	275.0 (203)	390.0 (288)	—
M18 x 1.50	196.0 (145)	305.0 (225)	425.0 (315)	—

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/ 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

Hex Nuts

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

Washers

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

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

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