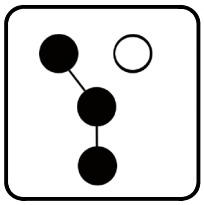
Service

Automatic Transfer Switches



Models:

KEP

Power Switching Device:
Molded Case Circuit Breakers (MCCB) or Switches
Insulated Case Circuit Breakers (ICCB) or Switches

100 to 4000 Amperes

Electrical Controls:
MPAC® 1500

ISO 9001
KOHLER POWER SYSTEMS
NATIONALLY REGISTERED

KOHLER® POWER SYSTEMS

TP-6745 7/10

Table of Contents

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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.

Hazardous Voltage/ Moving Parts

⚠ 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.

⚠ WARNING

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

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

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

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.

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. Turn off 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)

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.

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

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.

This manual provides service information for Kohler® Model KEP service entrance transfer switches with MPAC™ 1500 electrical controls. It includes operation, troubleshooting, repair, and maintenance procedures for the transfer switches and electrical controls.

The information included in this manual is intended solely for use by trained and qualified service personnel of authorized service distributors/dealers.

Information in this publication represents data available at the time of print. Kohler Co. 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

Figure 1 lists the part numbers for related literature. Separate operation and installation manuals contain operation and installation information not provided in this manual. Refer to the parts catalog for instructions to obtain replacement parts.

Document	Document Part Number
MPAC™ 1500 Controller Operation Manual	TP-6714
Model KEP ATS Operation/Installation Manual	TP-6738
Model KEP Parts Catalog	TP-6741
Model KEP Wiring Diagram Manual	TP-6744

Figure 1 Related Materials

Service Assistance

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

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

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Kohler Power Systems
3 rue de Brennus
93200 Saint Denis
France
Phone: (33) 1 49 178300
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Power Systems Asia Pacific Regional Office
Singapore, Republic of Singapore
Phone: (65) 6264-6422
Fax: (65) 6264-6455

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

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

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

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

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

1.1 Introduction

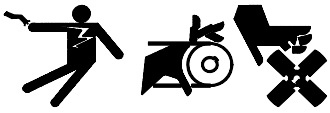
Regular preventive maintenance ensures safe and reliable operation and extends the life of the transfer switch. Preventive maintenance includes periodic testing, cleaning, inspecting, and replacing of worn or missing components. Section 1.5 contains a service schedule of recommended maintenance tasks.

A local authorized distributor/dealer can provide complete preventive maintenance and service to keep the transfer switch in top condition. Unless otherwise specified, have maintenance or service performed by an authorized distributor/dealer in accordance with 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.

Disconnect all power sources before opening the enclosure.

⚠ DANGER

Hazardous voltage.
Will cause severe injury or death.

Disconnect all power sources before servicing. Install the barrier after adjustments, maintenance, or servicing.

⚠ WARNING

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

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

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

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. Turn off 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

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.

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.

1.2 General Inspection

External Inspection. Inspect the transfer switch weekly.

- Look for any signs of vibration, leakage, excessive noise, high 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 the components and damage the switch.*
- Replace any worn, missing, or broken external components with manufacturer-recommended replacement parts. Contact a local authorized distributor/dealer for part information and ordering.
- Tighten loose external hardware.

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.

1.3 Internal Inspections and Maintenance

1.3.1 Internal Inspection

Have an authorized distributor/ dealer perform an annual inspection of the transfer switch. Inspect the switch more frequently if it is located in a dusty or dirty area or when any condition noticed during an external inspection may have affected internal components. Disconnect all power sources, open the transfer switch enclosure, and inspect internal components. Look 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 abrasions
- 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. Use a vacuum cleaner or a dry cloth or brush to remove contaminants from internal components. *Do not use compressed air to clean the switch because it can cause debris to lodge in the components and damage the switch.*

Checking and Tightening Connections. Loose connections on the power circuits can lead to overheating or explosion. Tighten all lugs to the torque values on the label on the switch. See Figure 1-1 for a typical label.

Tighten engine start, input/output, and auxiliary connections to the torque indicated on the decals affixed to the unit.

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.

TIGHTENING TORQUE VALUES
FOR
DUAL RATED (AL–CU) SCREW CONNECTORS

AWG. OR CIRCULAR MILL SIZE	TIGHTENING TORQUE IN INCH POUNDS	
	SCREW DRIVER	WRENCH
14 12 10 8	35 35 35 40	75 75 75 75
6 4	45 45	110 110
2 1	50 50	150 150
1/0 2/0	50 50	180 180
3/0 4/0		250 250
250 350		325 325
500 600 700 750		375 375 375 375
800 1000		500 500

297556

Figure 1-1 Typical Torque Label

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 the power terminals, perform a millivolt drop test to locate areas with high contact resistance. See Section 1.4.3. 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.

Wire Repair or Replacement. Replace wiring when there is any doubt about its condition, or when there is extensive damage or deterioration. If the damaged or deteriorated wires are part of a wiring harness, replace the entire wiring harness.

Power Circuit Wiring. Have damage to line voltage and power circuit wiring evaluated and repaired or replaced by a qualified electrician.

Control Circuit Leads. Repair minor damage to leads in low power and control circuits operating up to 250 volts. Carefully splice and insulate the connections. Tape minor control circuit wire insulation cuts or abrasions. Repair moderately damaged leads, where conductors are cut or insulation is damaged over sections shorter than about 100 mm (4 in.) 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. Use UL-listed insulated (250-volt minimum) connectors and follow the connector manufacturer's instructions. Fabricate new leads using the same type of wire and UL-listed insulated (250-volt minimum) connectors and follow the connector manufacturer's instructions.

1.3.2 Mechanical Interlocks and Linkages

- Verify that mechanical interlocking is correct (i.e. one power switching device must be well open before the other closes).

- Check that the operating linkages are not damaged or bent, and that all bearing points operate freely.

- **1000–1200 Amp Molded-Case Switching Devices:** Verify that all limit switch linkages are correctly adjusted to provide full travel of the power switching device toggles *without* exerting unnecessary forces associated with excessive travel. Check that power switching devices travel far enough to reset any internal trip unit.

  Note: It is more important for the toggle to go fully in the off direction than in the on direction.

1.3.3 Lubrication

Maintain the transfer switch lubrication. If the transfer switch is subject to extremely dusty or abnormal operating conditions, relubricate movements and linkages yearly as described below.

Disconnect power and manually operate the transfer switch mechanism to verify that it operates smoothly without binding. If lubricating the outer mechanism of the transfer switch does not eliminate binding, replace the transfer switch assembly.

Periodically oil the enclosure door locks and screws.

100–800 Amp Molded Case Switching Devices

- Confirm that the yoke operates freely on the yoke pivot bushings. Should lubrication be required, apply medium weight (SAE 20) oil sparingly at these points.

- The motor and gearbox are permanently lubricated and should not require attention under normal operating circumstances.

1000–1200 Amp Molded-Case Switching Devices

- Ensure that the manual handle moves freely on the hub when the lock pin is disengaged. If lubrication is necessary, apply medium weight (SAE 20) oil sparingly.

- Yoke pivot bearings and rod ends are permanently lubricated and do not require maintenance.

- The motor and gearbox are permanently lubricated and should not require attention under normal operating circumstances.

1.4 Testing

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

1.4.1 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 the transfer switch operation and installation manual for additional information about the exerciser.

1.4.2 Monthly Automatic Operation Test

Test the transfer switch's automatic control system monthly by running a loaded or auto-load test. See Section 3.6.4 or the transfer switch operation and installation manual for the test procedure. 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. After 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.

1.4.3 Other Tests

Every Three Years

Test the wire insulation. Use the following procedure to check for insulation breakdown and replace any faulty components.

Note: Do not perform dielectric testing on the equipment with control components in the circuit.

Wire Insulation Breakdown Test Procedure

1. Disconnect all power sources by performing the service disconnect procedure. See Section 1.6 for instructions. Disconnect the load from the transfer switch by opening circuit breakers or switches leading from the transfer switch. Disconnect the transfer switch wiring harness from the controller at connector P1.

⚠ 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)

2. Disconnect the controller components by using the control circuit isolation procedure. See Section 1.7 for instructions.

3. 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. For a hi-pot tester, the maximum potential is 500 VAC and the maximum test time is 1 second.

4. Verify that the measured insulation resistance exceeds 1.24 megohms (MΩ).

5. If the hi-pot tester indicates wire insulation breakdown or if the measured resistance is less than 1.24 MΩ, isolate the leakage current using an instrument designed for this purpose. Replace the faulty components.

   Note: You may need to disconnect power conductors from the lugs to isolate the problem. If you disconnect the power conductors, see the transfer switch operation and installation manual for reconnection instructions.

Every Five Years

Check the normal and emergency source setpoint calibration according to the procedures in Section 2.5, System Settings.

1.5 Service Schedule

Follow the service schedule below for the recommended service intervals. The transfer switch operator can perform tasks marked by an X. Have an authorized distributor/dealer inspect the switch annually and perform all service marked by a D.

System Component or Procedure	See Section	Visually Inspect	Check	Adjust, Repair, or Replace	Clean	Test	Interval
Electrical System							
Check for signs of overheating or loose connections: discoloration of metal, melted plastic, or a burning odor.	1.3	X	X				Y
Manually operate the power switching device and lubricate, if necessary. *	1.3.3		D	D			Y
Check wiring insulation for deterioration, cuts, or abrasion. Repair or replace wiring to regain the properties of the original wiring.	1.3	X					Y
		D	D	D			Y
Check the transfer switch's main power switching mechanisms' mechanical operation and integrity.	1.3	D	D			D	Y
Tighten control and power wiring connections to specifications.	1.3		D	D			Y
Test wire and cable insulation for electrical breakdown.	1.4.3					D	Every 3 Years
Check calibration of voltage-sensing circuitry and setpoints, and recalibrate circuitry as necessary.	1.4.3		D			D	Every 5 Years
Control System							
Exercise the generator set without load.	1.4.1, O/I/M					X	W
Test the transfer switch's automatic control system.	O/I/M	X				X	M
Test all LED indicators, time delays, and remote control systems for operation.	O/I/M	D	D	D		D	Y
General Equipment Condition							
Inspect the outside of the transfer switch for any signs of excessive vibration, leakage, high temperature, contamination, or deterioration.*	1.2	X			X		M
Check that all external hardware is in place, tightened, and not badly worn.	1.2	X	X	X			M
Inspect the inside of the transfer switch for any signs of vibration, leakage, noise, high temperature, contamination, moisture, or deterioration. Check for metal discoloration, melted plastic, or a burning odor.*	1.3	X					M
		D	D		D		Y
Check that all internal hardware is in place, tightened, and not badly worn.	1.3	X					M
		D	D				Y

***** Service more frequently if the ATS operates in extremely 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.
Adjust, Repair, or Replace: Includes tightening hardware and lubricating the mechanism. 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.

Symbols used in the chart:

O/I/M=See the transfer switch operation/installation manual.
X=The transfer switch operator can perform these tasks.
D=An authorized distributor/dealer must perform these tasks.
W=Weekly
M=Monthly
Q=Quarterly
S=Semiannually (every six months)
Y=Yearly (annually)

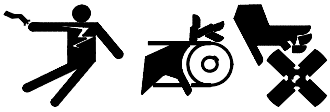
1.6 Service Disconnect Switch

⚠ DANGER

Hazardous voltage.
Will cause severe injury or death.

Only authorized personnel should open the enclosure.

⚠ 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.

Servicing the transfer switch. Hazardous voltage can cause severe injury or death. Deenergize all power sources before servicing. Turn off 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.

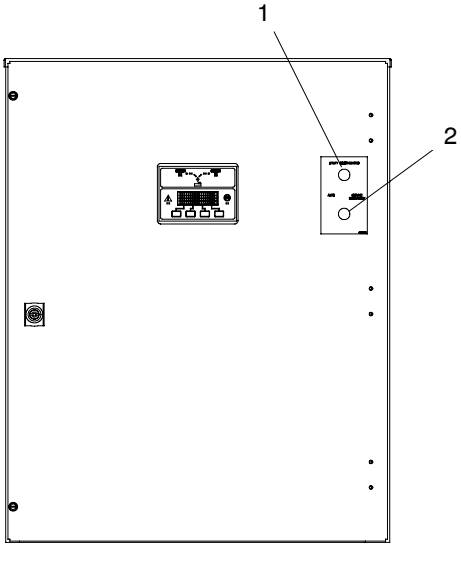
The two-position service disconnect switch disconnects the normal source from the load, transfers to emergency, and inhibits further transfer.

The service disconnect switch and utility disconnected lamp are located on the enclosure door. See Figure 1-2 for the typical service disconnect switch location.

When the switch is in the SERVICE DISCONNECT position, the controller display shows SERVICE DISCONNECT and the utility disconnected lamp on the enclosure door illuminates.

Important notes about service disconnect operation:

- Service disconnect transfers to the emergency source, disconnecting the load from the utility source ONLY.
- On service entrance transfer switches, the line side lugs are active at all times.
- **The engine start signal is activated.** The operator must open the generator set circuit breaker and/or disable the generator set to remove power from the load.
- Further transfer is inhibited after transfer to emergency.
- Moving the switch to the SERVICE DISCONNECT position during a test or exercise sequence ends the test or exercise sequence.
- Moving the switch to the SERVICE DISCONNECT position during a prime power sequence ends the sequence *and* designates the connected generator set as the preferred source.
- **Controller power is not disconnected.** The service disconnect procedure does not remove power from the controller. To remove the controller for maintenance or service, perform the service disconnect procedure and then see Section 1.7 for instructions to use the control circuit isolation switch to remove power from the controller.



1. Utility Disconnected lamp
2. Service disconnect switch

Figure 1-2 Service Disconnect Switch Location (typical)

1.6.1 Service Disconnect Procedure

The service disconnect switch has two positions: AUTO and SERVICE DISCONNECT. Follow the procedures in this section carefully and observe the safety precautions when performing a service disconnect before maintenance or service. Watch the LED indicators on the ATS controller to check the ATS position and source status during the procedures.

1. Move the service disconnect control switch located on the door of the transfer switch to the SERVICE DISCONNECT position.
2. The engine start contacts close, signalling the generator set to start.
3. When the emergency source is available, the ATS transfers to the emergency source.

   Note: The generator set is now providing power to the load.
4. Check that the utility breaker is open and the service disconnected pilot light is illuminated.
5. Disconnect emergency power from the load by opening the generator set circuit breaker and disabling the generator set as follows:
   a. Move the generator set master switch to the OFF/RESET position.
   b. Disconnect power to the battery charger.
   c. Remove the battery cables, negative (–) lead first.
6. The service disconnected light will turn off at this point.
7. Use a voltmeter to verify that power is disconnected before servicing connected equipment.
8. Attach a safety lockout padlock to the service disconnect control switch to prevent unauthorized change in operating condition and verify transfer switch door is locked closed. If the door is not locked, turn and remove the door key.

1.6.2 Service Reconnect Procedure

⚠ DANGER

Hazardous voltage.
Will cause severe injury or death.

Close and lock the transfer switch enclosure door before connecting power sources.

Service Reconnect Procedure (with Normal source available)

Do not return the generator set to service until after the ATS transfers the load to the normal source, as described in the procedure below.

1. Close the breaker between the generator and the emergency side of ATS.
2. Remove the padlock from the service disconnect control switch and move the service disconnect switch to the AUTO position.
3. Reset faults on the controller, if necessary.
4. The ATS will transfer to normal source and open the engine start contacts.
5. Verify that the ATS controller display shows normal source available and ATS in normal position. The service disconnect light on the door should be off.
6. Return the generator set to service:
   a. Reconnect the battery cables, negative lead last.
   b. Reconnect power to the battery charger.
   c. Move the generator set master switch to the AUTO position.

Service Reconnect Procedure (when Normal source is NOT available)

Manually operate the ATS to the Normal position before returning the generator set to service, as described in the procedure below.

1. Verify that the generator set master switch is in the OFF position.
2. Open the ATS enclosure and manually transfer the ATS to utility. (Open the emergency breaker and close the utility breaker. See the ATS Operation Manual for instructions, if necessary.) Then close and secure the enclosure door.
3. Return the generator set to service:
   a. Reconnect the battery cables, negative lead last.
   b. Reconnect power to the battery charger.
   c. Move the generator set master switch to the AUTO position.
4. When the generator source is available, the ATS transfers to emergency.
5. Remove the padlock from the service disconnect control switch and move the service disconnect switch to the AUTO position.
6. Reset faults on the controller, if necessary.
7. Verify that the ATS controller display shows emergency source available and ATS in emergency position. The service disconnect light on the door should be off.

1.7 Control Circuit Isolation Switch

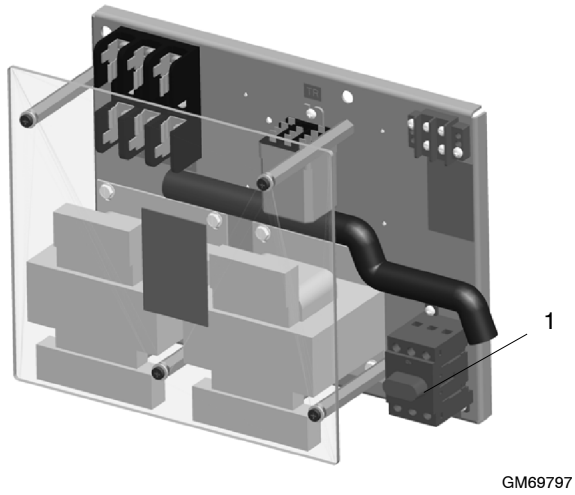
The two-position control circuit isolation switch removes utility power from the ATS controller assembly.

Note: Perform the service disconnect procedure explained in Section 1.6.1 before operating the control circuit isolation switch.

See Figure 1-3 for switch positions. The control circuit isolation switch is mounted on the transformer assembly. See Figure 1-4. The location of the transformer assembly varies with ATS model and enclosure size. See Figure 1-5 and Figure 1-6 for typical locations.

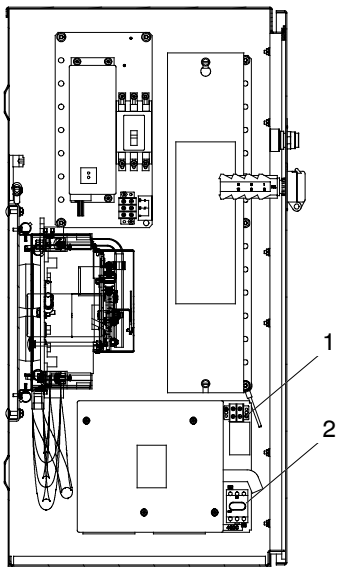
Switch Position	Utility Power to Controller
ON	Connected
OFF	Disconnected

Figure 1-3 Control Circuit Isolation Switch Positions



1. Control circuit isolation switch

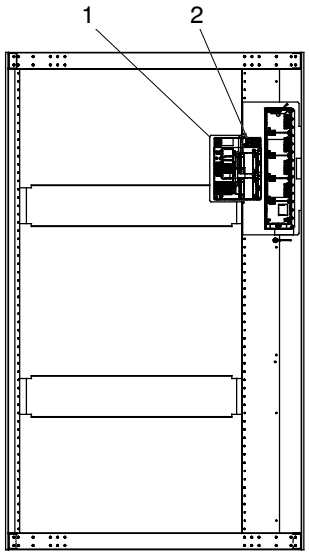
Figure 1-4 Control Circuit Isolation Switch Location on Transformer Assembly



Right Side View ADV-7708

1. Engine start contacts 3 and 4 (TB1 on transformer assembly)
2. Control circuit isolation switch (see Section 1.7)

Figure 1-5 Control Circuit Isolation Switch Location, MCCB Models (typical)



Right Side View ADV-7784

1. Engine start contacts 3 and 4 (TB1 on transformer assembly)
2. Control circuit isolation switch (see Section 1.7)

Figure 1-6 Control Circuit Isolation Switch Location, ICCB Models (typical)

Control Circuit Isolation Procedure

⚠ DANGER

Hazardous voltage.
Will cause severe injury or death.

Only authorized personnel should open the enclosure.

1. Perform the service disconnect procedure in Section 1.6.1.

   Note: There is still power to the controller assembly after the service disconnect is completed. The line side lugs are active at all times.

2. Open the enclosure door and move the control circuit isolation switch to the OFF position.

3. Use a voltmeter to verify that there is no power to the ATS controller assembly before removing the controller.

Control Circuit Reconnect Procedure (with normal source available)

Do not return the generator set to service until instructed to do so in the procedure below.

1. Close the breaker between generator and emergency side of ATS (if present).

2. Move the control circuit isolation switch to the ON position.

3. Move the service disconnect switch to the auto position.

4. The ATS will transfer to normal source and open engine start contacts.

5. Verify that the ATS controller display shows normal source available and ATS in normal position. The service disconnect light on the door should be off.

6. Return the generator set to service:

   a. Reconnect the battery cables, negative lead last.

   b. Reconnect power to the battery charger.

   c. Move the generator set master switch to the AUTO position.

Control Circuit Reconnect Procedure (when normal source is NOT available)

Do not return the generator set to service until instructed to do so in the procedure below.

1. Open the ATS enclosure and manually transfer to utility (IF GENERATOR WAS TURNED OFF).
2. Close the breaker between generator and emergency side of ATS (if present).
3. Move the control circuit isolation switch to the ON position.
4. Move the service disconnect switch to the AUTO position.
5. Return the generator set to service:
   a. Reconnect the battery cables, negative lead last.
   b. Reconnect power to the battery charger.
   c. Move the generator set master switch to the AUTO position.
6. The engine start contacts will close because Normal is not available. Generator set will start.
7. When the generator source is available, the ATS transfers to emergency.
8. Verify that the ATS controller display shows emergency source available and ATS in emergency position. The service disconnect light on the door should be off.

Notes

2.1 Initial Checks

When troubleshooting a problem, check the following things first.

- Check the Service Required LED and the transfer switch controller display for fault or warning indications. If a fault or warning is indicated, proceed to Section 2.9.
- Disconnect power to the transfer switch and check for loose connections. Check the source lugs, controller harnesses, and generator set engine start connection.
- Check the event history log. The log lists the 100 most recent transfer switch events, including transfers and DIP switch setting changes as well as faults and alarms. See Section 2.2 for instructions to view the event history log.
- Check the system settings and time delays. See Section 2.5, System Settings.

Read and follow all safety precautions in this manual and on labels on the switch. Only trained and qualified personnel should service the transfer switch and connected equipment.

Refer to the wiring diagrams provided with the switch or the wiring diagram manual when troubleshooting the transfer switch and controller.

⚠ 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. Turn off 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)

2.2 View Event History

When troubleshooting, check the event history for faults, transfer attempts, or other events leading to the current condition. The history lists the 100 most recent transfer switch events, including transfers and DIP switch setting changes as well as faults and alarms.

From the main screen, step to View Event History and display recent events as shown in Figure 2-1. Possible event descriptions are listed in Figure 2-2.

If a fault condition or alarm is displayed, proceed to Section 2.9.

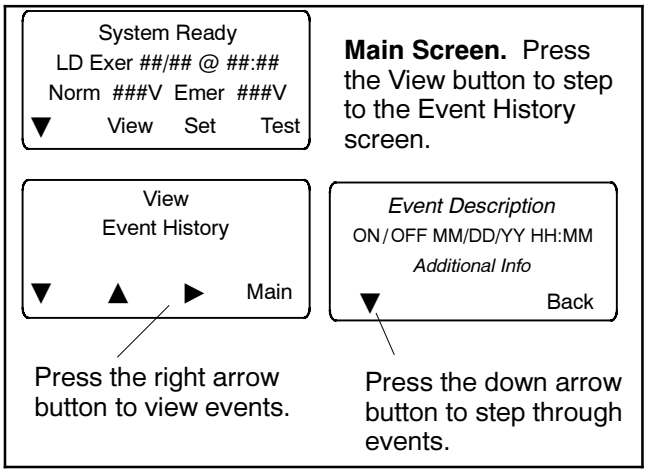


Figure 2-1 Viewing Event History

Event Descriptions	
End Time Delay Btn	Low Battery Voltage
Test Btn	Remote Common Alarm
Exercise Btn	Bypass Contactor Dis
Lamp Test	3 Src System Disable
Service Req'd Reset	Over Frequency
Maint DIP Switch	Under Frequency
Pwd DIP Switch	Phase Loss
Manual Option Switch	Phase Rotation Error
New Module	Over Voltage L1-L2
Contactor in Off	Over Voltage L2-L3
Contactor in Src N	Over Voltage L3-L1
Contactor in Src E	Under Voltage L1-L2
Low Battery	Under Voltage L2-L3
Exerciser Active	Under Voltage L3-L1
Fail to Acquire Pref	Voltage Imbalance
Fail to Acquire Stby	Save History To File
Fail to Transfer	Auto Loaded Test End
I/O Module Lost Comm	Test Loaded Changed
Aux Switch Fault	Pref Source Changed
Aux Switch Open	Reload Dflt Params
Battery Backup Low	MODBUS Peak Shave
Rem End Time Delay	MODBUS Forced to OFF
Forced Trans to Off	MODBUS System Test
Peak Shave Mode	Battery Control Out
Inhibit Transfer	USB Connected
Remote Test	USB Disconnected

Figure 2-2 Events

2.3 Data Log Files

The data log files listed in this section are available on MPAC™ 1500 controllers with version 2.0.0 or later application code. The data log files can be viewed using spreadsheet software and used to help troubleshoot ATS operation problems.

Data log files are generated by the MPAC 1500 controller as described below. See TP-6714, MPAC™ 1500 Operation Manual, for detailed instructions to create the following data files.

USB Data Logger

Use the USB Data Logger function in the MPAC 1500 controller's Set System menu to create a DataLog file. The file contains time- and date-stamped readings of voltage, frequency, and contactor position (source 1 or 2). Data log files have the form DataLogYYMMDDHHMMSS.csv where YYMMDD is the date (year/month/day), and HHMMSS is the time that the file was created in hours:minute:seconds. Figure 2-3 shows a sample file.

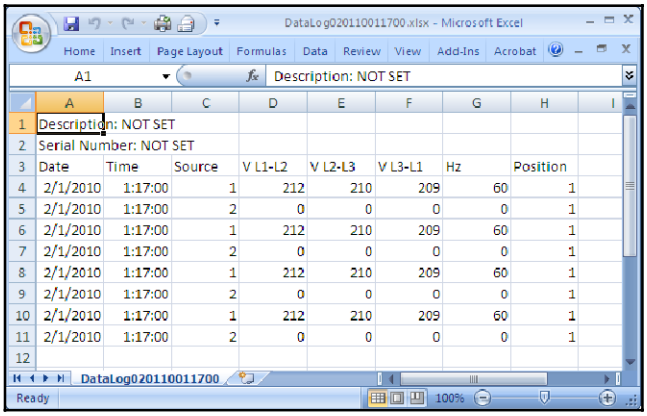


Figure 2-3 Sample Data Log File

MinMax Files

Use the MinMax function, which is found in the MPAC 1500 controller's Set System menu under USB Data Logger, to create a MinMax.csv file. The file contains minimum and maximum readings of voltage and current supplied to the load over a selected time period. The MinMax file is overwritten each time the MinMax operation is performed.

2.4 System Power

2.4.1 Verify Power to ATS

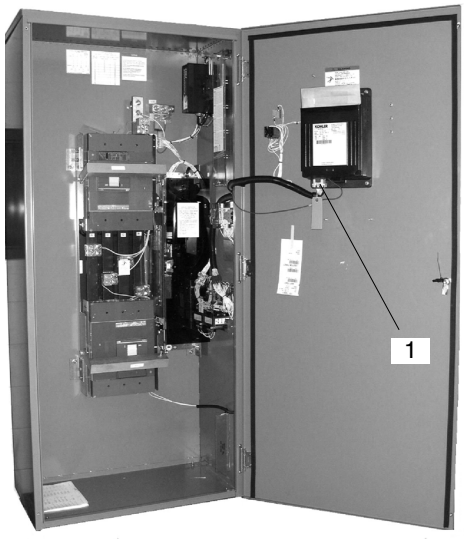
If the transfer switch display is off, check for power to the transfer switch. If the utility source is not available, check for emergency power. Follow the voltage check procedure in Section 2.4.2, Voltage, Frequency, and Phase Rotation Checks, to check voltage at the Source N (normal) or Source E (emergency) lugs.

If utility power is not available and the emergency generator set is not running, check that the generator set master switch is in the AUTO position. Verify that the generator set runs when the master switch is moved to the RUN position. If the engine does not start, troubleshoot the generator set as described in the generator set documentation. Otherwise, check the engine start circuit. See Section 3.9.

If the utility source is available but the transfer switch display is off, verify that the transfer switch wiring harness is connected to the controller. See Figure 2-4.

Note: Perform the service disconnect and control circuit isolation procedures before disconnecting or reconnecting the controller harness. See Sections 1.6 and 1.7 for instructions.

An LED on the controller power board lights to indicate power to the board. See Figure 3-5.



1. Transfer switch harness connection to controls, controller connector P1

Figure 2-4 Transfer Switch Harness Connection to Control Board, Typical

2.4.2 Source Voltage, Frequency, and Phase Rotation Checks

The voltage, frequency, and phasing of the transfer switch and the power sources must be the same to avoid damage to loads and the transfer switch. Compare the voltage and frequency ratings of the utility source, transfer switch, and generator set, and verify that the ratings are all the same.

Read and understand all instructions on installation drawings and labels on the switch. Note any optional accessories that have been furnished with the switch and review their operation.

Note: Source N is the source connected to the normal side of the transfer switch. Source E is the source connected to the emergency side of the transfer switch.

The voltage check procedure requires the following equipment:

- A digital voltmeter (DVM) with electrically insulated probes capable of measuring the rated voltage and frequency
- A phase rotation meter

⚠ 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)

Voltage, Frequency, and Phase Rotation Check Procedure

1. Ensure that all downstream loads are switched off.

2. If the source being measured is a generator set, start the generator set by moving the master switch to RUN.

3. Use a voltmeter to check the source phase-to-phase and phase-to-neutral (if applicable) terminal voltages and frequency.

   a. If Source N is the utility and the measured input does not match the voltage and frequency shown on the transfer switch nameplate, *STOP!* Do not proceed further in installation because the transfer switch is not designed for the application. See Section 2.5 for instructions to correct the input voltage transformer connections and contact your distributor/dealer to order the correct nameplate.

   b. If the source is a generator set and the generator set output voltage and frequency do not match the nominal system voltage and frequency shown on the transfer switch nameplate, follow the manufacturer's instructions to adjust the generator set. The automatic transfer switch will only function with the rated system voltage and frequency specified on the nameplate.

4. Use a phase rotation meter to check the phase rotation at the source terminals. Rewire the transfer switch source terminals to obtain the correct phase sequence if necessary.

   Note: The default setting for the phase rotation on the controller is ABC. If the application uses a phase rotation of BAC, use the Source Setup screen to change the phase rotation setting on the controller.

5. If the source is a generator set, stop the generator set by moving the master switch to the OFF/RESET position.

6. Repeat steps 2 through 5 for Source E.

7. Close and lock the transfer switch enclosure door.

8. Perform the Lamp Test and then proceed to the Automatic Operation Test.

2.5 System Settings

If the ATS does not recognize the source, check that the source voltage and frequency settings on the controller match the actual source parameters.

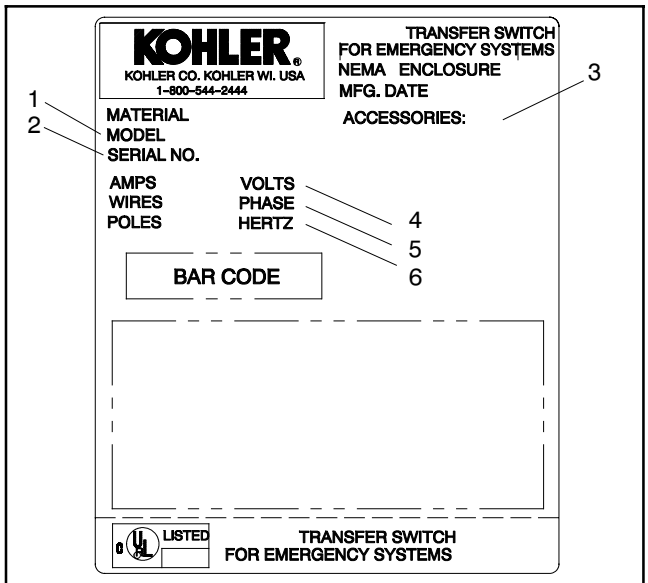
Compare the controller settings to the ratings on the ATS nameplate and to the measured source parameters using the following instructions.

2.5.1 Controller Source Settings

Check the controller's source voltage, frequency, and phase settings. See the transfer switch operation and installation manual for instructions.

Check the controller settings and compare them to the voltage rating, frequency rating, and number of phases shown on the ATS nameplate. The nameplate is attached to the cover of the controller assembly, which is mounted on the inside of the transfer switch door. See Figure 2-5 for an illustration of the nameplate.

Note: The system voltage and frequency shown on the ATS nameplate must match the Source N and Source E voltage and frequency settings. Do not enter settings that do not match the nameplate ratings of the ATS.



1. Model designation
2. Serial number
3. Factory-installed accessory numbers
4. Voltage rating
5. Frequency rating
6. Number of phases (single or three)

Figure 2-5 Typical Transfer Switch Nameplate

Use the procedure in Section 2.4.2 to measure the source voltage, frequency, and phase rotation, and compare the measured values to the controller settings. Follow the instructions in the transfer switch operation and installation manual to change the controller settings if they do not match the measured source parameters.

2.5.2 Voltage and Frequency Pickup and Dropout Settings

Figure 2-6 illustrates the relative values of the voltage pickup and dropout settings. Typical frequency pickup and dropout settings relate to the nominal source frequency in a similar way.

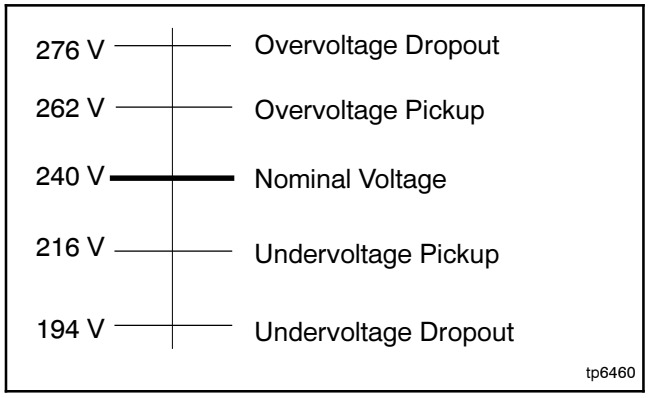


Figure 2-6 Relationship Between Voltage Pickup and Dropout Settings (default settings for 240-volt system shown)

If the source voltage rises above the overvoltage dropout setting or falls below the undervoltage dropout setting for a time longer than the debounce time, the controller will consider the source as failed. The source voltage must return to a level within the range of the pickup values for the controller to recognize the source as restored.

Choose pickup and dropout settings that allow a tolerable variation in the source parameters to prevent nuisance transfers caused by small changes in the source voltage and frequency.

Voltage Sensing		
Parameter	**Default**	**Adjustment Range**
Undervoltage dropout	90% of pickup	75%-98%
Undervoltage pickup	90% of nominal	85%-100%
Overvoltage dropout *	115% of nominal*	106%-135%
Overvoltage pickup	95% of dropout	95%-100%
Unbalance enable	Disable	Enable/Disable
Unbalance dropout	20%	5%-20%
Unbalance pickup	10%	3%-18%
Voltage dropout time	0.5 sec.	0.1-9.9 sec.
* 690 volts, maximum. Default = 110% for 600 volt applications.		

Figure 2-7 Voltage Settings

Frequency Sensing		
Parameter	**Default**	**Adjustment Range**
Underfrequency dropout	99% of pickup	95%-99%
Underfrequency pickup	90% of nominal	80%-95%
Overfrequency dropout	101% of pickup	101%-115%
Overfrequency pickup	110% of nominal	105%-120%
Frequency dropout time	3 sec.	0.1-15 sec.

Figure 2-8 Frequency Settings

2.6 Time Delays

Check the time delays when troubleshooting problems with transfer switch operation.

Use the View Time Delays screen to check the settings for the adjustable time delays. Figure 2-9 shows the factory settings and adjustment ranges for the adjustable time delays.

Observe the controller's display to identify which time delay is executing at any given time. Initiate a test and observe as each programmed time delay executes. See Section 3.6, System Test. Compare the operation to the test sequence illustrated in the flowcharts in Figure 3-13 or Figure 3-14.

Time Delay	Default Time	Adjustment Range †
Engine Start, Source S2	3 sec	0–6 sec*
Engine Start, Source S1	3 sec	
Engine Cooldown, Source S2	5 sec	0–60 min
Engine Cooldown, Source S1	2 sec	
Xfr Pref>Stby	3 sec	
Xfr Stby>Pref	15 min	
Xfr Off>Stby	1 sec	
Xfr OFF>Pref	1 sec	
Fail to Acquire Pref	1 min	
Fail to Acquire Stby	1 min	
In-Phase Xfr Fail (found in the Set Sources menu)	30 sec	
Load # Disc N>E	0 sec	
Load # Add N>E	0 sec	
Load # Disc E>N	0 sec	
Load # Add E>N	0 sec	
Load # Add Source1/Source2	0 sec	
Load # Remove Srce1/Srce2		

* Engine start delay can be extended to 60 minutes with an External Battery Supply Module Kit.

† Adjustable in 1 second increments.

Figure 2-9 Factory Settings, Time Delays

2.7 Reset Data

Be sure to read and understand the information in this section before resetting.

2.7.1 Reset Maintenance Records

Reset the maintenance records after transfer switch service to update the last maintenance date and totals since reset that are displayed in the maintenance records screen.

2.7.2 Reset Event History

Resetting the event history clears the events from the event history log. The event history can be saved to a file before reset. See Section 2.7.5, File Maintenance.

2.7.3 Reset Default Parameters

Resetting to the default parameters will reset **all** parameters, **including the system voltage and frequency**, to a factory default setting. The default system voltage and frequency settings may not match the settings for your application.

The transfer switch will not operate correctly if the system voltage and frequency do not match the sources. Use the Set Sources screen to set the system voltage and frequency after resetting to the default parameters. See the operation/installation manual for instructions.

2.7.4 Reset and Disable Test Password

Reset the Test password to return the test password to the default, 0000.

Disable the test password to allow the user to start a test without entering a password.

Note: Disable the test password only during service unless the transfer switch is installed in a secure location.

2.7.5 File Maintenance

Use the File Maintenance screens to remove unneeded files or save the event history. See Figure 2-10 and Figure 2-11.

Files can also be transferred to a mass storage device connected to the USB port on the logic board. Refer to the transfer switch operation/installation manual for instructions to transfer files.

File Name	Description
MPAC1500_#######.cfg	Parameter settings (configuration)
present*yymmdd*.his	Event history
alarm_settings.alm	Common alarms
MPAC1500_cal.cal	Calibration
history_param.hstp	Internal use only
Param_back.bak	Internal use only
present*yymmdd*.raw	Internal use only
history_pback.hbak	Internal use only

Figure 2-10 Files listed under File Maintenance>Delete Files

2.7.6 Reset Data Procedure

Use the Reset Data menus to set records or parameters back to factory default settings. See Figure 2-11.

1. Use the black arrow buttons to step to the desired screen. See the following sections for information about each reset screen.
2. Press the open up arrow button to toggle Yes or No until Yes is displayed.
3. Press Save to reset the displayed records to the factory defaults. Pressing Back exits the screen without resetting.

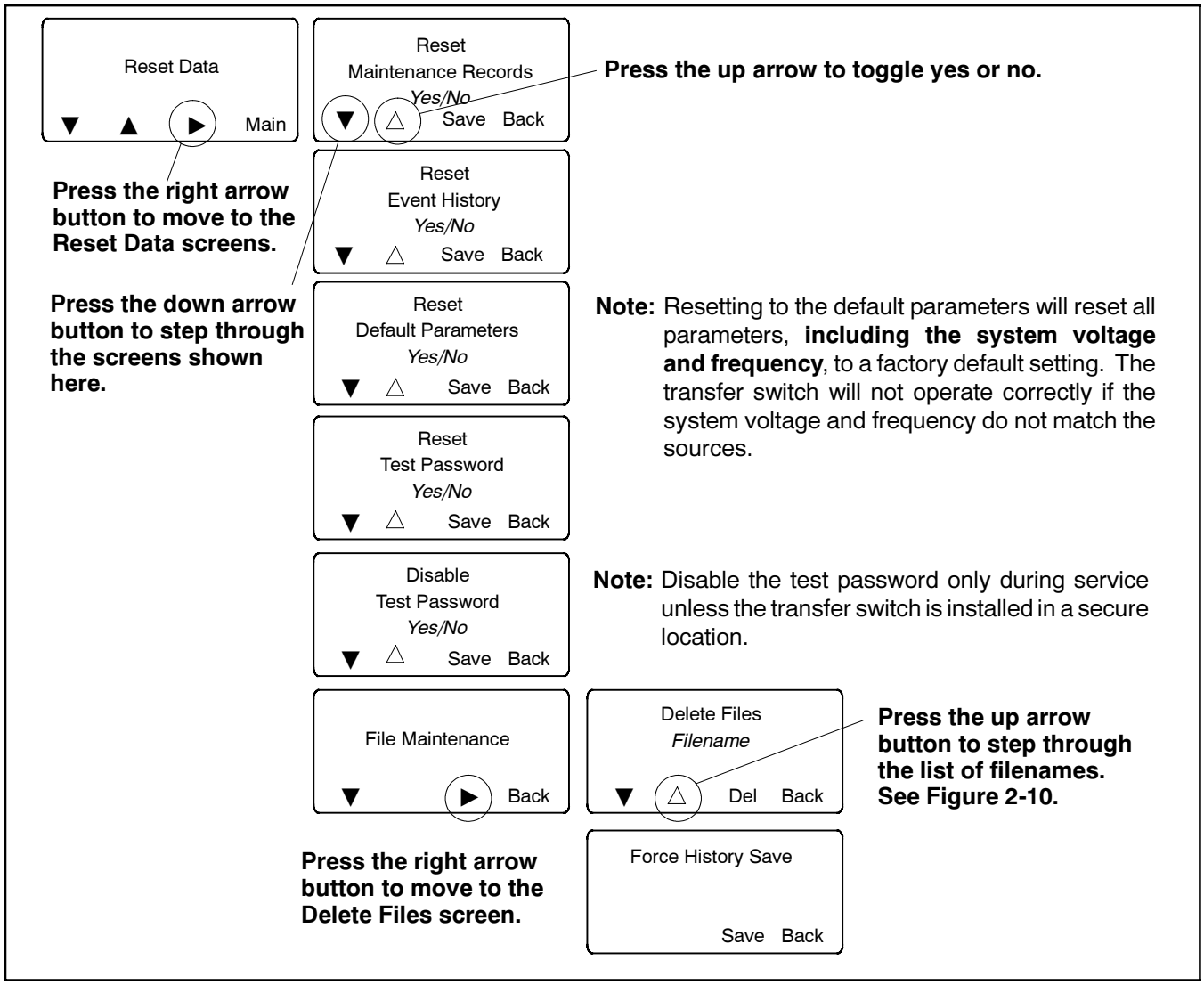


Figure 2-11 Reset Data

2.8 Warnings and Faults

When a fault exists, the System Alert indicator lights, a designated output and the common fault output are turned on, and an appropriate message is displayed to indicate the fault. See Figure 2-12 for the location of the System Alert indicator.

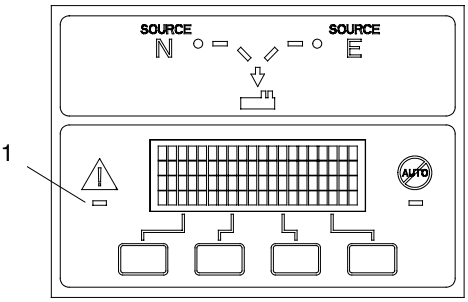
ATS warnings and faults are shown in Figure 2-13. There are three types of warning/fault conditions:

Warning. Warnings automatically reset with a source availability change or a transfer request.

Fault Requiring Manual Reset. Under these conditions, normal ATS operation is halted. Active modes are turned off. If the contactor is in the preferred source position, the engine cooldown time delay executes and the engine start contacts open, allowing the generator set to shut down. See Section 2.8.1 for instructions to reset faults.

Self Resetting Faults. Under these conditions, active modes are turned off. If the contactor is in the preferred source position, the engine cooldown time delay executes and the engine start contacts open, allowing the generator set to shut down. When the fault condition is corrected, the fault is automatically cleared from the controller and normal ATS operation continues.

See Section 2.9 for troubleshooting recommendations.



1. System Alert LED

GM46892

Figure 2-12 Fault Indication

Condition	Type	Description
Failure to Acquire Standby Source	Warning	The source voltage did not reach the acceptable range within a set time (see Time Delays). For example, the standby source generator set did not start.
Failure to Acquire Preferred Source	Warning	
External Battery Low	Warning	The voltage of the battery connected to the external battery supply module (EBSM) is low.
Failure to Transfer	Warning	The signal to transfer is sent to the contactor and the main shaft auxiliary switch fails to indicate a complete ATS position change. The controller will attempt to transfer the unit three times before the fault is indicated.
Auxiliary Switch Fault	Manual Reset Fault	The main shaft auxiliary switches indicate that the ATS is in more than one position, or the position changed when no signal was sent to initiate the change.
Auxiliary Switch Open	Manual Reset Fault	The main shaft auxiliary switches indicate that the ATS is in neither position (all inputs are open).
Src N (or Src E) Rotation Err	Self-Resetting Fault	The detected phase rotation of one or both sources does not match the preselected setting.
I/O Module Lost Comm	Self-Resetting Fault	An I/O device has stopped communicating or does not have a correct address specified. Fault resets if communication is reestablished.
Module Status Change	Self-Resetting Fault	An accessory module has been disconnected OR a new module is detected. See Section 2.8.2 to reset.
Module Status Conflict	Self-Resetting Fault	An accessory module has been replaced with a different type of module. See Section 2.8.3 to correct.
Source1/Source2 Breaker Trip (service entrance models only)	Manual Reset Fault	The Source1 or Source2 circuit breaker in the service entrance transfer switch has tripped due to an overcurrent condition. Identify and correct the cause of the fault before resetting the controller.
External Fault (Remote Common Alarm)	Self-Resetting Fault	The input contact assigned to the remote common alarm input function is closed.

Figure 2-13 Warnings and Faults

2.8.1 Fault Reset

To clear a fault or warning condition and reset the System Alert LED, go to the Main screen and press the down arrow button to open the Reset screen. See Figure 2-12 and Figure 2-14. Then press the button labelled Reset. A fault reset does not change the controller settings.

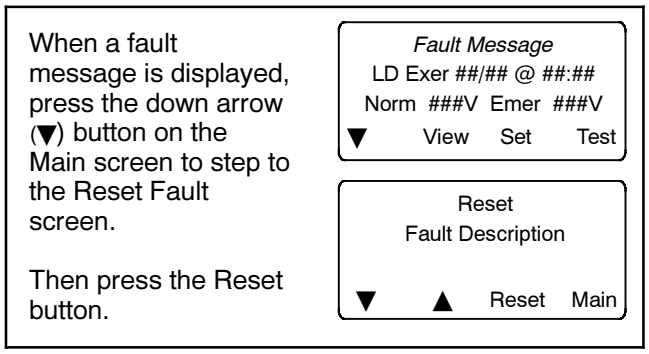


Figure 2-14 Fault Reset

2.8.2 Module Status Change

If the Module Status Change message appears on the controller display, first verify that the cable from the controller to the accessory module assembly is not loose or disconnected.

The Module Status Change message automatically clears if the fault condition is corrected (self-resetting fault).

Module Connection (new or reconnected module)

Installing or reconnecting one or more accessory modules triggers the Module Status Change message.

1. If the ATS display shows Module Status Change, press the Reset button. See Figure 2-15.

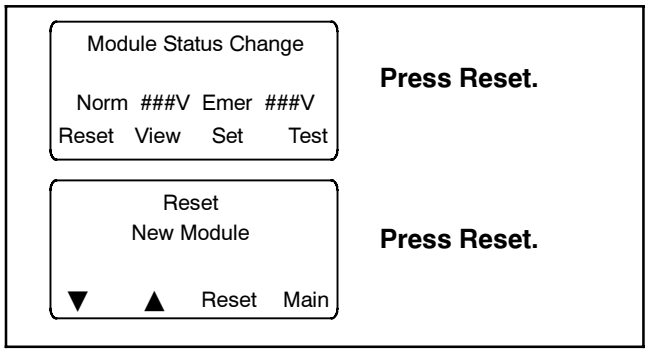


Figure 2-15 Screens after Module Connection

2. The ATS display will show Reset New Module. Press the Reset button from that screen. The controller recognizes the module type(s).

3. Navigate to the Set Input/Outputs>Set Aux I/O screen to check that the controller has recognized the connected modules. See Figure 2-16.

See the transfer switch operation/installation manual for instructions to assign programmable inputs and outputs to I/O modules or assign functions to the audible alarm for an Alarm Module.

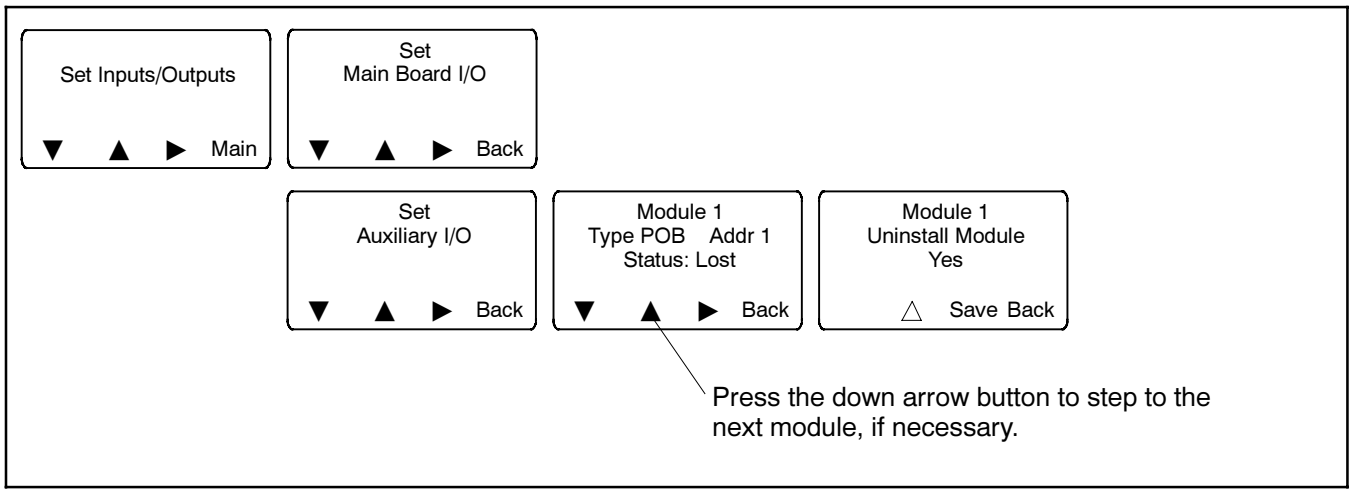


Figure 2-16 Uninstall Module

Disconnected Module

If one or more accessory modules are disconnected from the controller, the message Module Status Change appears. See Figure 2-17. Pressing the Reset button displays the message Check Module Setup to Clear Fault.

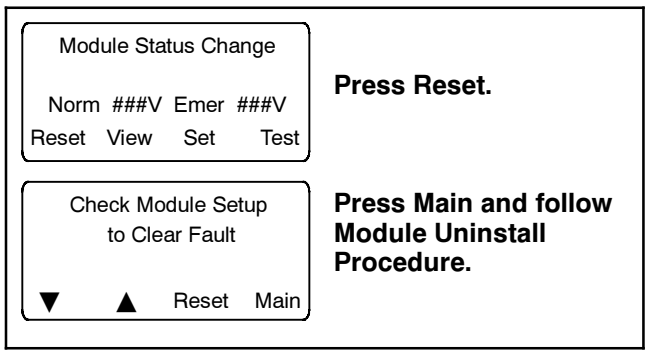


Figure 2-17 Screens after Module Disconnection

When modules are physically disconnected from the transfer switch, they must be uninstalled through the controller keypad. Use the following procedure to uninstall modules after disconnection.

Module Uninstall Procedure

1. If the ATS display shows Module Status Change, press the button labelled Reset.
2. If the ATS display shows Check Module Setup to Clear Fault,, press Main to return to the main screen.
3. Press Set to enter setup mode.
4. Enter the setup password.
5. Press the down arrow to step to the Set Inputs/Outputs screen. See Figure 2-16.
6. Navigate to the Set Auxiliary I/O screen. See Figure 2-16. Press the right arrow button to see the status of module 1. Press the down arrow to step to the next module, if necessary, until the screen shows Status: Lost.
7. Press the right arrow button to move to the Uninstall Module screen. Verify that the screen says Uninstall Module Yes. (Press the open arrow button to toggle no/yes, if necessary.)
8. When Yes is displayed, press Save to uninstall the module.
9. Repeat the uninstall procedure for additional modules, if necessary.

Other Module Status Change Conditions

A Module Status Change message that cannot be cleared as described above may indicate a failure of the controller's real-time clock. Carefully follow the procedures above to attempt to reset the fault. If the fault cannot be reset, replace the controller's logic board. See Section 3.16.

2.8.3 Module Status Conflict

The message Module Status Conflict appears if one type of module is replaced with another type of module that has the same address. Follow the procedure below to resolve the conflict.

Procedure to Clear a Module Status Conflict

1. Disconnect power to the transfer switch.

   Note: Do not disconnect modules with the power connected. Connecting or disconnecting modules when the power is connected will damage the ATS controller.

2. Disconnect the module.
3. Close the enclosure door and reconnect power to the ATS. The display will show Module Status Change.
4. Press the button labelled Reset. The display will show Check Module Setup to Clear Fault.
5. Follow the procedure in Section 2.8.2 to uninstall the module through the ATS controller keypad.
6. Disconnect power to the ATS.
7. Connect the new module.
8. Close the enclosure door and reconnect power to the ATS. The display will show Module Status Change. See Figure 2-15.
9. Press the button labeled Reset to display Reset New Module. Press the reset button from that screen. The controller will now recognize the new module type.
10. Navigate to the Set Auxiliary I/O screen to check the status and settings for the new module. See Figure 2-16. Press the right arrow button to see the status of module 1. Press the down arrow to step to the next module, if necessary,

See the transfer switch operation/installation manual for instructions to assign programmable inputs and outputs to I/O modules or assign functions to the audible alarm for an Alarm Module.

2.8.4 Common Alarms

Any of the functions listed in Figure 2-18 can be assigned to Common Alarms 1 and 2. Common alarms 1 and 2 can then be assigned to output functions which activate when any of the conditions assigned to the common alarm are present. Common Alarms 1 and 2 can also be set to sound the alarm horn on the optional Alarm Module.

Functions that can be Assigned to Common Alarms	
Aux Switch Fault *	Src E Over Freq
Aux Switch Open *	Src E Over Voltage
Battery Backup Low *	Src E Rotation Err *
Contactor in Off	Src E Under Freq
Contactor in Pref	Src E Under Voltage
Contactor in Src E	Src E Voltage Unbal
Contactor in Src N	Src N Loss of Phase
Contactor in Stby	Src N Over Freq
Exerciser Active	Src N Over Voltage
Fail to Acquire Pref *	Src N Rotation Err *
Fail to Acquire Stby *	Src N Under Freq
Fail to Transfer *	Src N Under Voltage
IPM Synching	Src N Voltage Unbal
Load Bank Control	Stby Src Available
Load Control Active	System Ready
Low Battery *†	Test Mode Active
Non-Emergency Trans	Critical Service Required
Not in Auto	Man Transfer Waiting
Peak Shave Active †	Module Lost Comm *
Pref Src Available	Non-Critical Service Req
Remote Common Alarm *	Source E Available
Remote Monitor In #1-4	Source N Available
Breaker Trip	Modbus-Controlled RDO #1-4
Src E Loss of Phase	
* Assigned to Critical Service Required † Assigned to Non-Critical Service Required	

Figure 2-18 Common Alarm Functions

If the common alarm is activated, the specific condition that triggered the alarm will be shown on the ATS controller display screen. Check the display to identify the problem and then refer to the troubleshooting tables in Sections 2.9 and 2.10.

Use the View Common Alarms screen to identify which functions have been assigned to each common alarm. See the operation and installation manual for instructions to check the view screens and to change the settings, if necessary.

Selected functions as noted in Figure 2-18 are grouped into the Critical Service Required and Non-Critical Service Required functions. The Critical Service Required and Non-Critical Service Required functions can be assigned to activate the alarm horn on the optional Alarm Module. If any of the conditions included in the Critical Service Required or Non-Critical Service Required function occurs, the alarm horn will sound. The message on the ATS display will identify which condition (for example, Fail to Acquire Standby) triggered the alarm and caused the horn to sound.

2.9 Troubleshooting — Faults

The following tables list the faults and alarms that may be shown on the controller's display screen or listed in the event history log. The tables also list the possible causes for each problem and suggested procedures to identify and correct the source of the problem.

The event history log also lists transfers and other normal events not shown in these tables. The event history log can be saved to an electronic file. Refer to the transfer switch operation/installation manual for instructions to save the event log to a file.

Fault or Event Message	Possible Cause	Check	See Section
Overfrequency, Underfrequency	Frequency settings	Check that the system frequency setting matches the actual source frequency (50 or 60 Hz).	2.5
		Check the over/underfrequency pickup and dropout settings. See Section 2.5.2 and the Setup Program Operation Manual.	2.5
		Check that the frequency debounce setting is long enough to prevent nuisance faults caused by brief frequency variations.	2.5
	Source availability, stability	Check that the source frequency matches the nominal system frequency and stays within the range of the pickup and dropout settings.	2.4.2 2.5
	Source connections	Check for loose connections. Check wiring.	W/D
Overvoltage, Undervoltage	Voltage settings	Check that the system voltage setting matches the actual source voltage.	2.4.2 2.5
		Check the over/undervoltage pickup and dropout settings.	2.5 2.5.2
		Check that the voltage debounce setting is long enough to prevent nuisance faults caused by brief voltage dips or spikes.	2.5
	Source availability, stability	Check that the source voltage matches the nominal system voltage and stays within the range of the pickup and dropout settings.	2.4.2 2.5
	Source connections	Check for loose connections. Check wiring.	W/D
	Calibration error	Check the ATS calibration.	3.11
Loss of Phase	Single/three phase setting does not match source	Check that the controller single/three phase setting matches the source.	2.5
	One phase of the source has been lost	Check that all phases of the source are available.	2.4.2
	Source connections	Check for loose connections.	
Source Rotation Error	Phase rotation setting (ABC or BAC) does not match source	Check that the controller phase rotation setting matches the source phase rotation (ABC or BAC). Check the source connections to the transfer switch and verify that A,B, and C are connected to the appropriate lugs. Change the controller phase rotation setting or rewire the source connections if necessary.	2.5
Source1 or Source2 Breaker Trip	An overcurrent condition has tripped the circuit breaker.	Check the load for short circuits or malfunctioning equipment. Identify the cause of the overcurrent condition before resetting the fault. ICCB breakers require manual reset.	ATS O/I/M
	Controller cannot determine the transfer switch position	Check wiring and connections to position limit switches. See the schematic drawing for connections.	W/D
		Test the position limit switch operation. Replace limit switch if necessary.	
		Transfer switch in intermediate position. Manually operate the transfer switch. See the ATS Operation/Installation Manual for manual operation instructions and safety precautions.	ATS O/I/M
Failure to Transfer	Varies.	See Section 2.10, Troubleshooting.	2.10

O/I/M= Operation and Installation Manual; O/M = Operation Manual; TOC = Table of Contents, this manual; W/D = Wiring Diagrams

Fault or Event Message	Possible Cause	Check	See Section
Failure to Acquire Standby	Generator set did not start	See Failure to Start Generator Set, below.	
	Open circuit breaker	Check and close ATS source and generator set circuit breakers.	—
	ATS does not recognize the standby source	Check source voltage, frequency, phase rotation settings and compare to actual values.	2.4.2 2.5
		Check for loose source connections. Check the labels on the switch for tightening torques.	1.3
		Check for open switch or circuit breaker to the source.	—
		Check ATS calibration.	3.11
		Perform voltage sensing troubleshooting procedures in Figure 2-19.	2.11
Failure to Acquire Preferred	Open circuit breaker	Check and close ATS source and generator set circuit breakers.	
	ATS does not recognize the source	Check source voltage, frequency, phase rotation settings and compare to actual values.	2.4.2 2.5
		Check for loose source connections. Check the labels on the switch for tightening torques.	1.3
		Check for open switch or circuit breaker.	—
		Check ATS calibration.	3.11
		Perform voltage sensing troubleshooting procedures in Figure 2-19.	2.11
External Battery Low	Low generator set engine starting battery voltage	Check battery connections and voltage. Charge or replace battery if voltage is low.	Generator set manuals
Module Status Change	A new accessory module is detected	Press the reset button to open Reset New Module screen. Then press Reset again.	2.8.2
	A module has been disconnected	Check connections from the controller to the I/O module assembly and at the top of each I/O module. Verify that the module is securely installed. If a module has been removed, go to Set Inputs/Outputs screen and uninstall the module.	2.8.2
	Communication to an installed I/O module has been lost	Check I/O module connections.	2.8.2
	Real-time clock failure on logic board	If the procedures in Section 2.8.2 fail to clear the error message, replace the controller's logic board.	2.8.2 3.16
Module Status Conflict	One type of module was replaced with another type of module that has the same address	Follow the procedure in Section 2.8.3 to uninstall the old module and then install the new module.	2.8.3
External Fault	Fault condition in customer- supplied equipment connected to external input	Identify and correct the cause of the fault condition.	Manuals for connected equipment
	Loose or faulty connection	Check connection to external input.	ATS OIM

O/I/M= Operation and Installation Manual; O/M = Operation Manual; TOC = Table of Contents, this manual; W/D = Wiring Diagrams

2.10 Troubleshooting Table

The following table lists potential problems with possible causes and suggested remedies. Section numbers in the last column refer to other sections of this manual. TOC refers to the Table of Contents in this manual.

Also see Section 2.11, MPAC™ 1500 Controller Troubleshooting Flowcharts.

Always follow the safety precautions at the beginning of this manual when troubleshooting and servicing the transfer switch.

Problem	Possible Cause	Check	See Section
Generator set engine does not start	Engine start time delay is running	Check for active time delays on the controller display. Press End Delay button to end the delay, if necessary.	2.6
		Use View Time Delay screen to check time delay settings.	ATS O/I/M
	Loose engine start connection	Check connections. Tighten connections and/or replace wiring if necessary.	ATS O/I/M
	No engine start signal from the ATS	Test the engine start contact operation.	3.9
	Generator set master switch not in the AUTO position	Move generator set master switch to the AUTO position.	Generator set manuals
	Generator set problem	Troubleshoot the generator set.	
Generator set engine runs when it should not	ATS does not recognize the Normal source	Check connections.	—
		Check voltage and frequency settings, phase rotation, calibration.	2.5
		Incorrect voltage sensing.	Figure 2-19
	ATS not in the expected position	Check the ATS position LEDs. Check the position of the preferred source selector switch, if equipped.	3.1
	Exerciser is running	Check the controller display for Exerciser Active message. Press the END button to end an exercise run, if necessary.	ATS O/I/M
	Test sequence is running	Check the controller display for indication that a test sequence is active. Press the END TEST button to end a test sequence, if necessary.	ATS O/I/M
	Engine cooldown time delay operating	Check for Engine Cooldown message on the controller display. Press End Delay button to end the cooldown delay, if necessary. Check the ATS controller engine cooldown time delay setting.	2.6 ATS O/I/M
		Check generator set controller engine cooldown setting, if applicable.	Generator O/M
	Engine start connection closed	Check wiring and connections.	ATS O/I/M W/D
		Check that the 40-pin ribbon cable connector between the logic and power boards on the ATS controller is connected.	3.2 Figure 3-5
		Test the engine start contact operation.	3.9
O/I/M= Operation and Installation Manual; O/M = Operation Manual; TOC = Table of Contents, this manual; W/D = Wiring Diagrams			

Problem	Possible Cause	Check	See Section
Generator set engine runs when it should not (continued)	Generator set master switch not in AUTO	Move the generator set master switch to the AUTO position. Wait for the generator set engine cooldown delay, if necessary.	Generator set manuals
	Other generator set problem	Disconnect the engine start leads from the ATS. If the engine continues to run, troubleshoot the generator set.	
Exerciser does not start generator set	Exerciser not set	Use View Exercise Setup screen to check exerciser settings.	ATS O/I/M
	Check that exercise run duration is not set to zero	Use View Exercise Setup screen to check exerciser settings.	ATS O/I/M
	Loose or open engine start connection	Check wiring and connections.	ATS O/I/M
	Engine start problem	Test engine start operation. Also see *Generator set engine does not start* in this table.	3.9
Exerciser does not run regularly or at all	Exerciser not set	Use View Exercise Setup screen to check exerciser settings.	ATS O/I/M
	Maintenance DIP switch SW1B closed	Check for Maintenance Mode message on controller display.	—
		Check the DIP switch setting.	3.10
	Exercise interval different than expected	Use View Exercise Setup screen to check exerciser settings.	ATS O/I/M
Failure to transfer	Alternate source is not available	Check source connections.	1.3
		Check source voltage and frequency.	2.4.2
		Check source settings.	2.5
		ATS voltage sensing is incorrect.	2.11
	ATS voltage sensing is incorrect.	Perform troubleshooting procedures in Figure 2-19.	2.11
	Unloaded exercise selected	Use View Exercise Setup screen to check exerciser settings.	ATS O/I/M
	Unloaded test sequence selected	Press the End Test button, wait for the test sequence to stop, and then select a Loaded or Auto Loaded test sequence.	ATS O/I/M
	Pre-transfer time delays operating	Check controller display for time delay indication. See Section 3.4 for information on time delays during normal operation.	3.4
		Check the time delay settings.	2.6
	Maintenance DIP switch enabled	Check DIP switch setting.	3.10
	Connected source available	Check the Source Available LEDs.	3.1
	Preferred source selection set to emergency and emergency source is available	Check the preferred source selection and the Source Available LEDs.	—
	Supervised transfer control switch (optional) in manual position	Check the position of the supervised transfer control switch, if equipped. Move the switch to the TRANSFER or AUTO position, as appropriate for the application.	ATS O/I/M
	Slow or no transfer to utility	Perform the troubleshooting procedures in the Transfer Troubleshooting flowchart in Figure 2-21 and Figure 2-22.	2.11

O/I/M= Operation and Installation Manual; O/M = Operation Manual; TOC = Table of Contents, this manual; W/D = Wiring Diagrams

Problem	Possible Cause	Check	See Section
Transfer to generator source without a power failure in the utility source	Loaded test or exercise sequence is active.	Check the controller display for indication that a test or exercise sequence is active.	O/M
	Utility power switching device has tripped due to an over current condition.	Identify and correct the cause of the tripped circuit breaker before resetting the fault on the controller. See the ATS Operation/Installation manual for overcurrent trip information and reset instructions.	ATS O/I/M
No LEDs illuminated	No power to the transfer switch	Check that source switches or circuit breakers are closed.	—
		Verify that at least one source is available. Check for utility or gen set voltage to the ATS.	2.4.2
		Check source connections.	W/D
	No power to the controller	Check that the transfer switch harness is connected to the controller.	Figure 2-4
		Check the harness for loose connections or broken leads (continuity check).	W/D
	One or more faulty LEDs	Press the Lamp Test button to check the operation of all LEDs.	3.1.3
		If no LEDs light during the lamp test, troubleshoot power and connections to the controller.	3.3
		Replace the controller if one or more LEDs do not light during the lamp test.	3.16
Source available LED off when Source is available	Malfunctioning LED	Press the Lamp Test button to check the operation of all LEDs. Replace the controller if one or more LEDs do not light. If no LEDs light, troubleshoot power and connections to the controller.	3.1.3
	Source settings do not match actual source parameters	Check settings.	2.5
	Incorrect ATS meter calibration	Check calibration.	3.11
Position LED not lit	Position microswitch malfunction	Check the operation of the position microswitches.	3.12
	Transfer switch in intermediate position	Manually operate the transfer switch and check the position LED operation.	TOC
	LEDs not functioning	See *No LEDs illuminated* in this table.	—
Controller display is blank	See Figure 2-20, Blank Display Troubleshooting.		2.11
Strange characters on controller display or controller lockup	See Figure 2-23, Troubleshooting Display Errors or Controller Lockup.		2.11

O/I/M= Operation and Installation Manual; O/M = Operation Manual; TOC = Table of Contents, this manual; W/D = Wiring Diagrams

2.11 MPAC 1500 Controller Troubleshooting Flowcharts

This section contains troubleshooting flowcharts for the MPAC™ 1500 ATS controller. Use these instructions to diagnose problems with the MPAC™ 1500 ATS controller and identify the parts that require service or replacement, rather than replacing the entire controller assembly.

Use the troubleshooting charts in Figure 2-19 through Figure 2-23 to diagnose and correct the following problems on the MPAC 1500 controller.

- Incorrect voltage sensing
- Blank display
- Slow or no transfer to utility
- Strange characters on display or controller lockup

Refer to the operation/installation manual and wiring diagrams provided with the transfer switch during the procedure. See Figure 2-24 for an illustration of the controller's main logic board and power supply board.

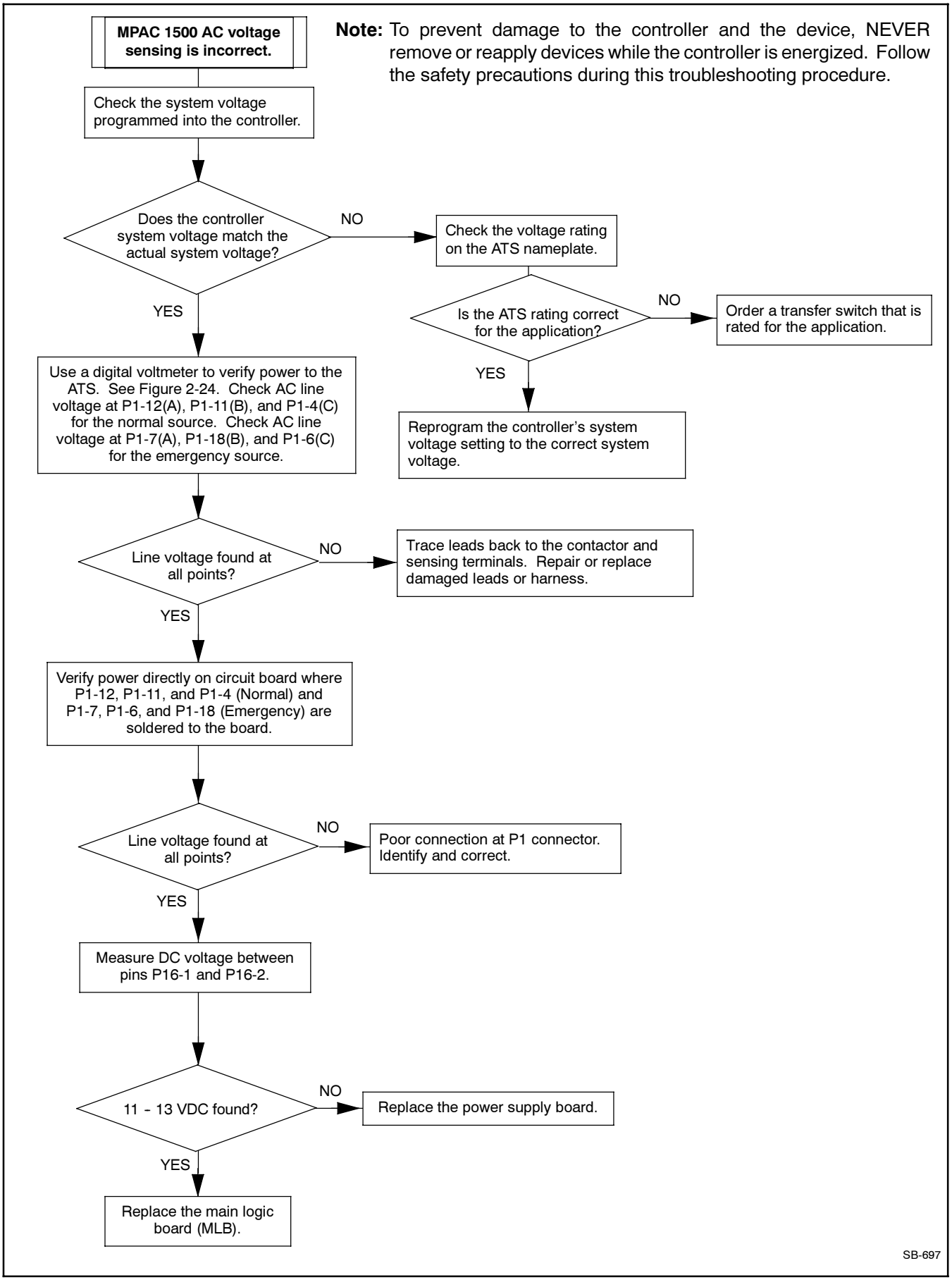


Figure 2-19 Voltage Sensing Troubleshooting

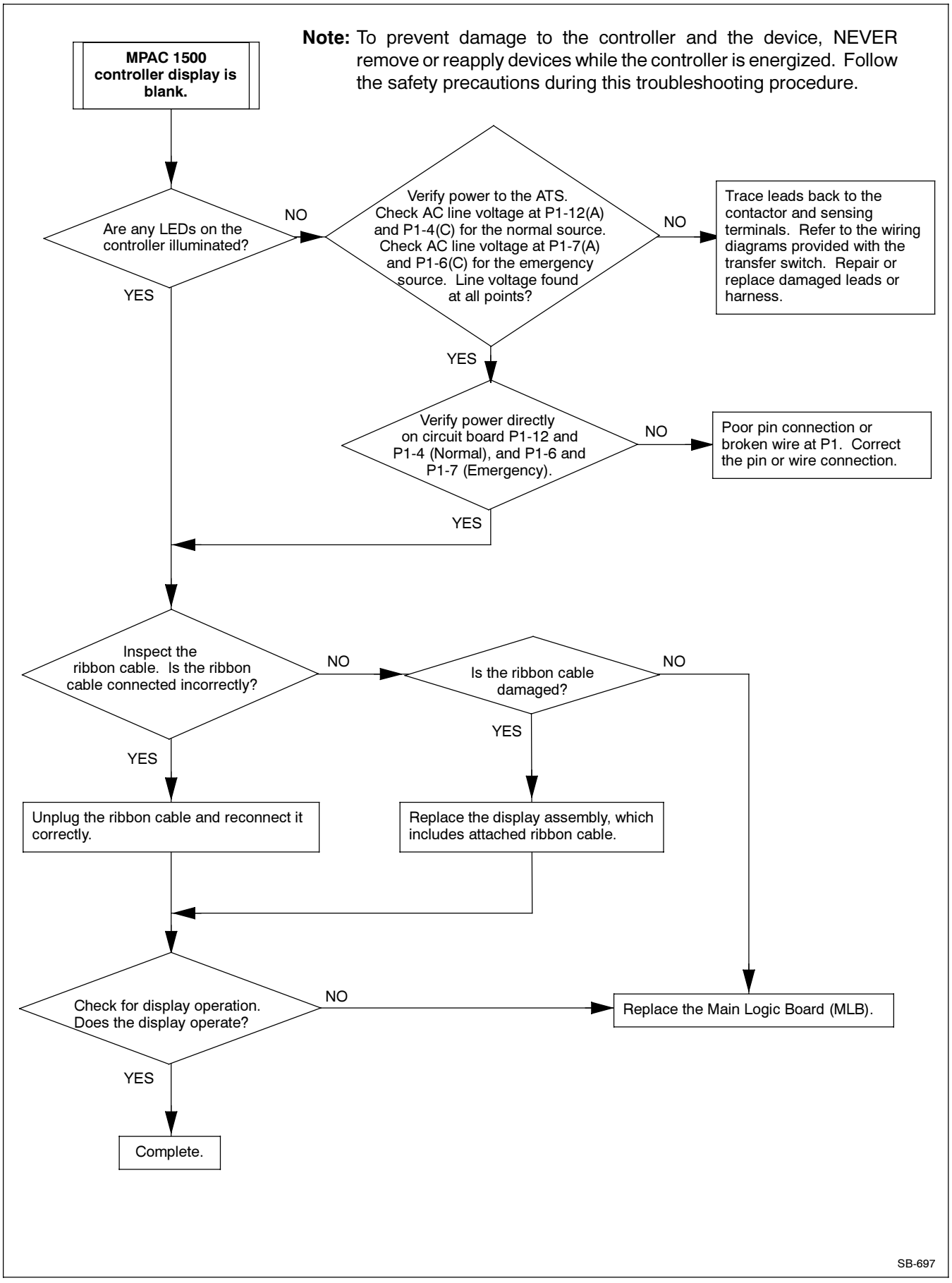


Figure 2-20 Blank Display Troubleshooting

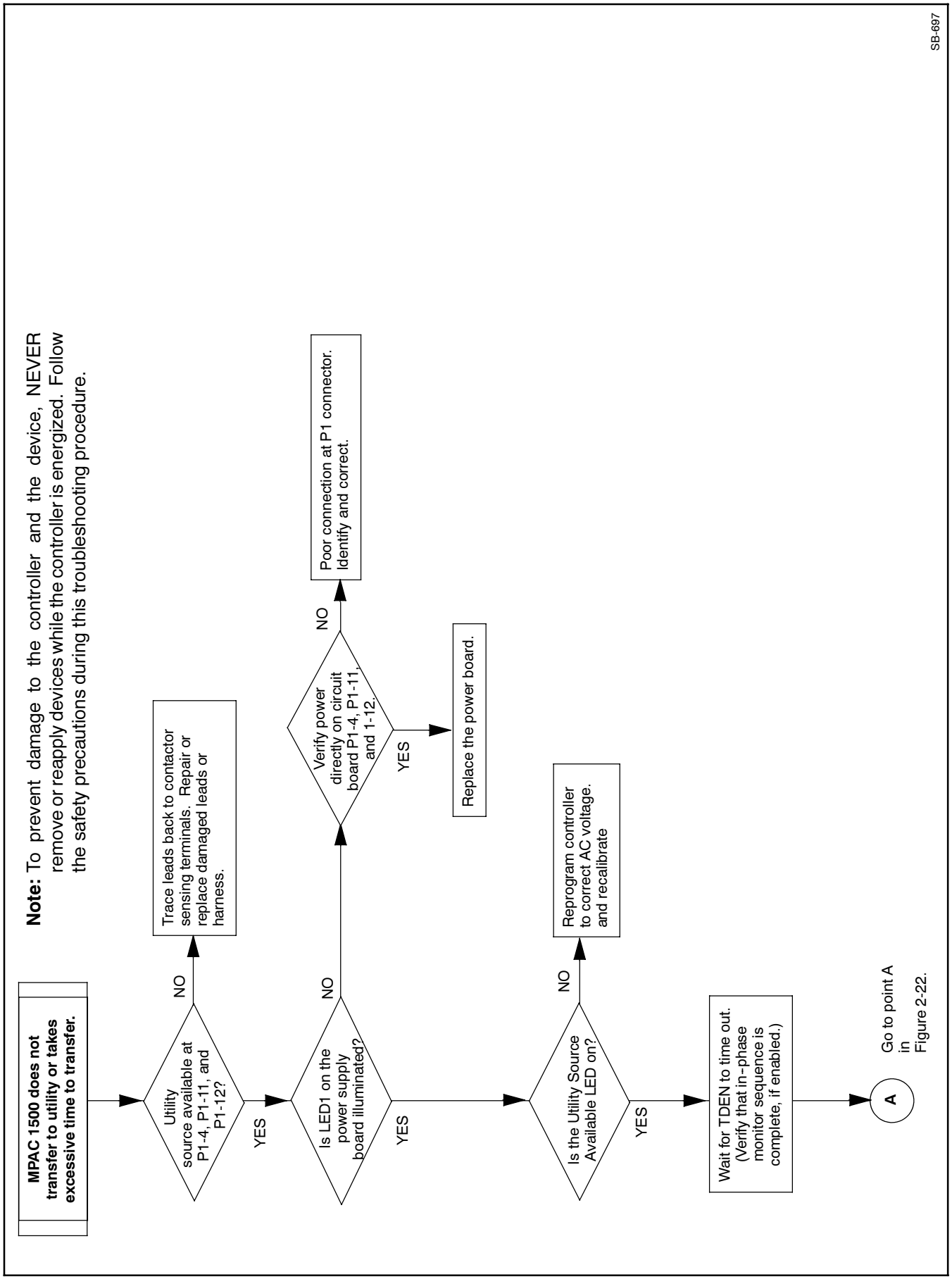


Figure 2-21 Transfer Troubleshooting, Part 1

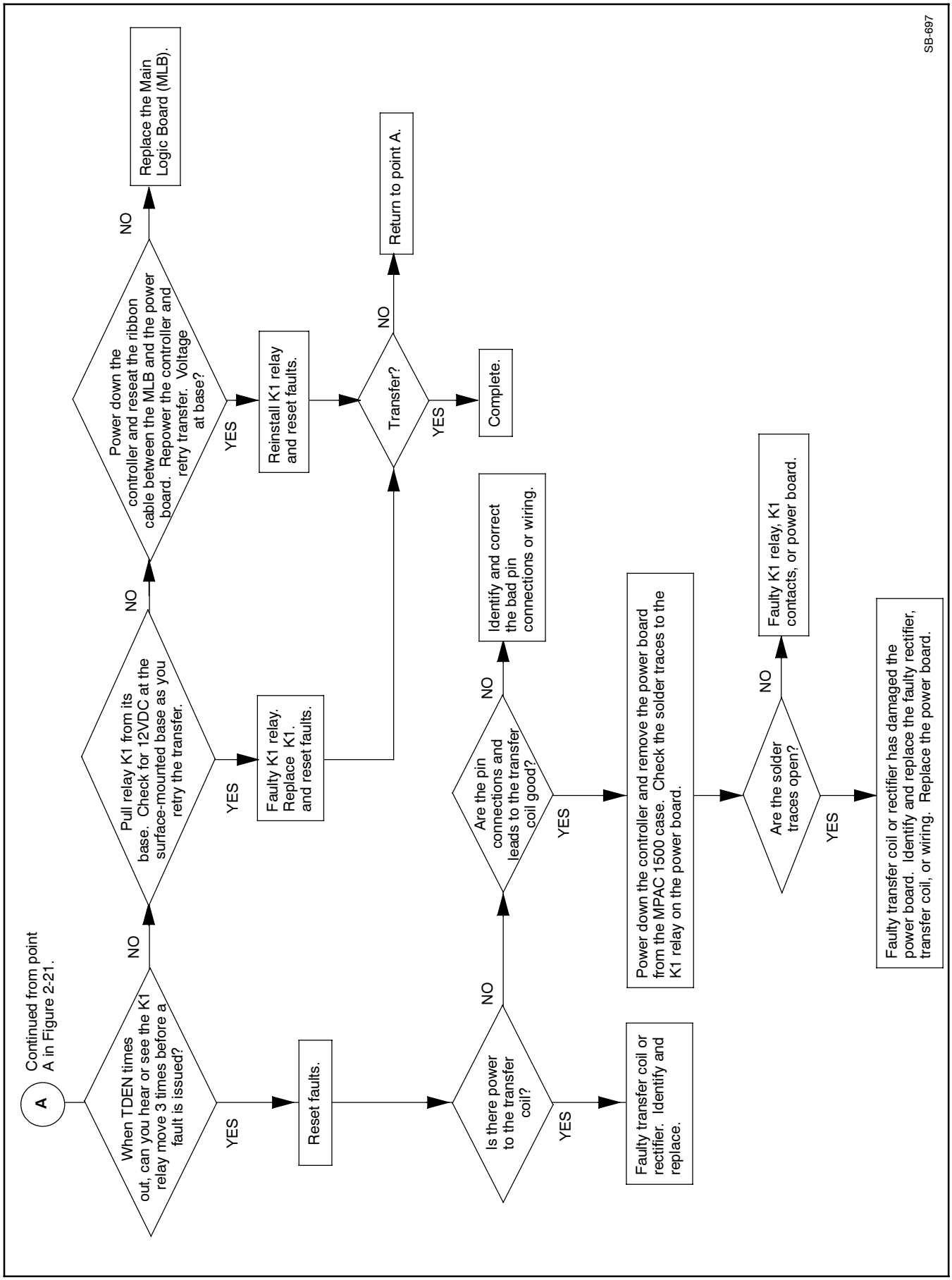


Figure 2-22 Transfer Troubleshooting, Part 2

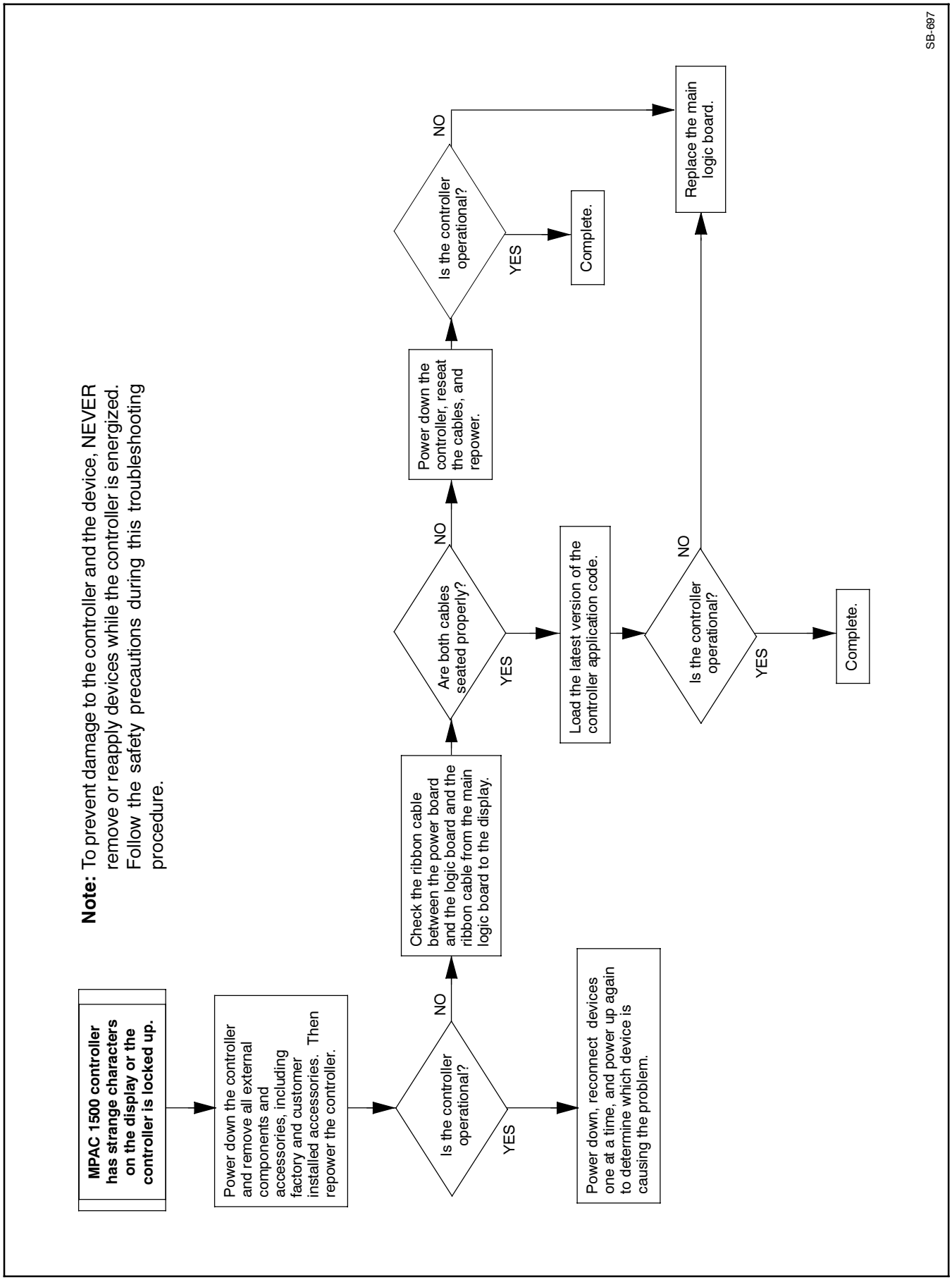


Figure 2-23 Troubleshooting Display Errors or Controller Lockup

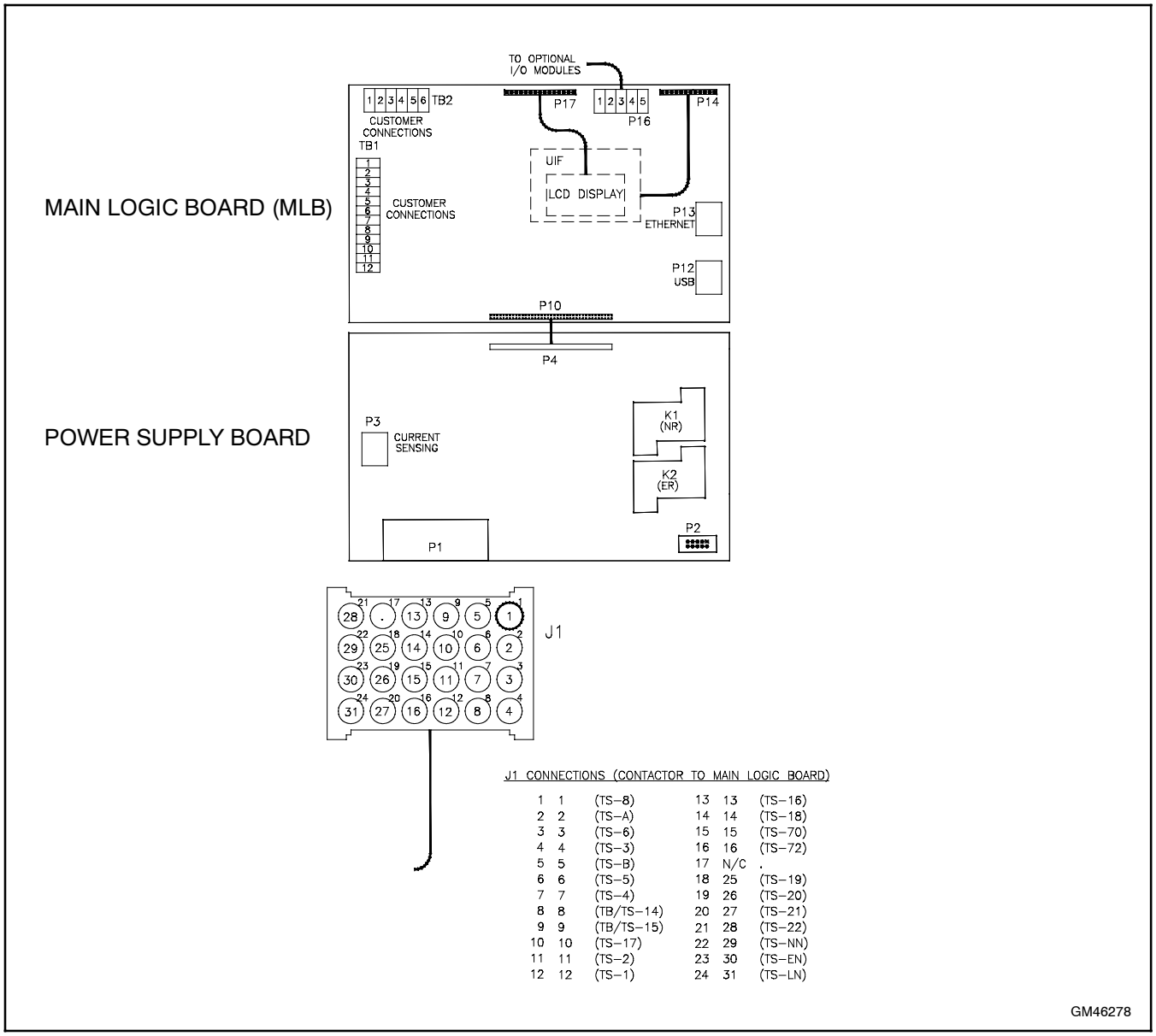
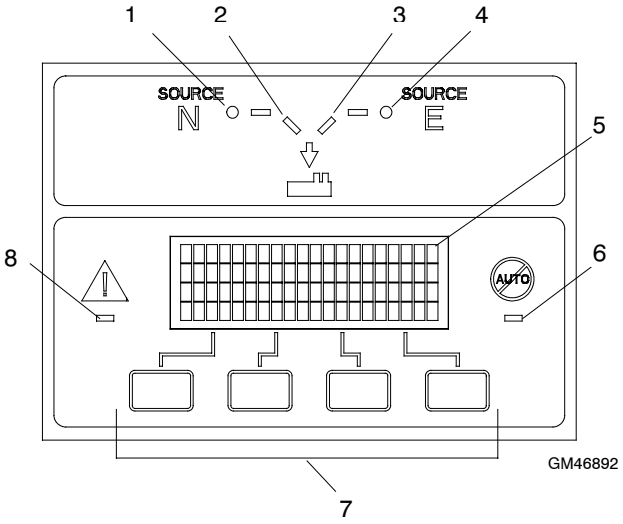


Figure 2-24 MPAC 1500 Controller Circuit Boards and P1/J1 Connections

Notes

3.1 User Interface Panel

The user interface panel is located on the transfer switch door. Figure 3-1 shows the user interface pushbuttons and LED indicators.



1. Source N Available LED
2. Source N Position LED
3. Source E Position LED
4. Source E Available LED
5. Display
6. Not in Auto LED
7. Pushbuttons (4)
8. System Alert LED

Figure 3-1 User Interface Panel

3.1.1 Display

The four-line display indicates transfer switch status and setup, including the following:

- System status
- Faults and warnings
- Active time delays
- Source voltages
- Source frequency (Hz)
- Current (amps)
- Source setup information
- Time and date
- Time and date of next scheduled exercise

The display also identifies the pushbutton functions, which can change from screen-to-screen.

3.1.2 LED Indicators

LEDs on the user interface indicate power switching device position, source availability, faults, and other conditions. Figure 3-2 describes the functions of the LED indicators. See Section 2.8 for more information about warnings and faults.

LED Indicator	Condition
Source N Available, Green	Source N is available.
Source E Available, Red	Source E is available.
Position A, Green	power switching device is in Normal position.
Position B, Red	power switching device is in Emergency position.
System Alert, Red	Fault. Identify and correct the cause of the fault condition, then reset faults at the controller. See Section 2.8.
	Input active: Low Battery Voltage or Remote Common Alarm.
Not in Auto, Red	ATS is not set for automatic operation or a load shed (forced transfer to OFF) sequence is active.
	Flashes for manual transfer waiting.
	Input active: Inhibit Transfer or Forced Transfer to OFF.

Figure 3-2 User Interface LED Indicators

3.1.3 Lamp Test

To test the LEDs on the controller's user interface, go to the Main screen. Press the down arrow button once, then press the Lamp Test button and verify that all 6 LEDs on the user interface illuminate. See Figure 3-3.

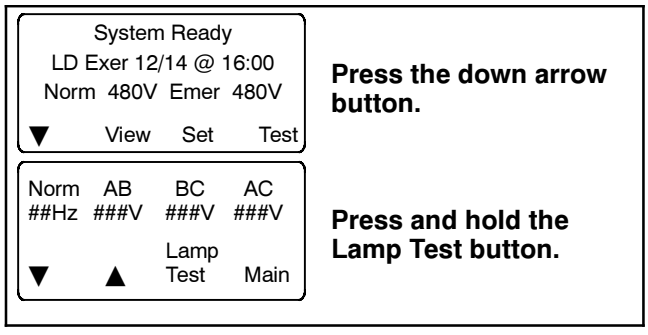


Figure 3-3 Lamp Test

3.1.4 Pushbuttons

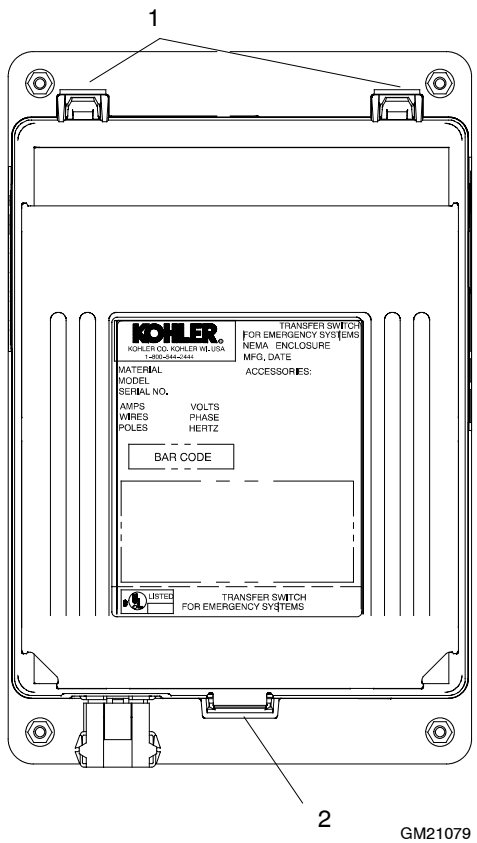
The user interface panel has four pushbuttons below the display. Pushbutton functions are shown above each button in the last line of the display and can change from screen-to-screen.

The pushbutton functions are defined in Figure 3-4.

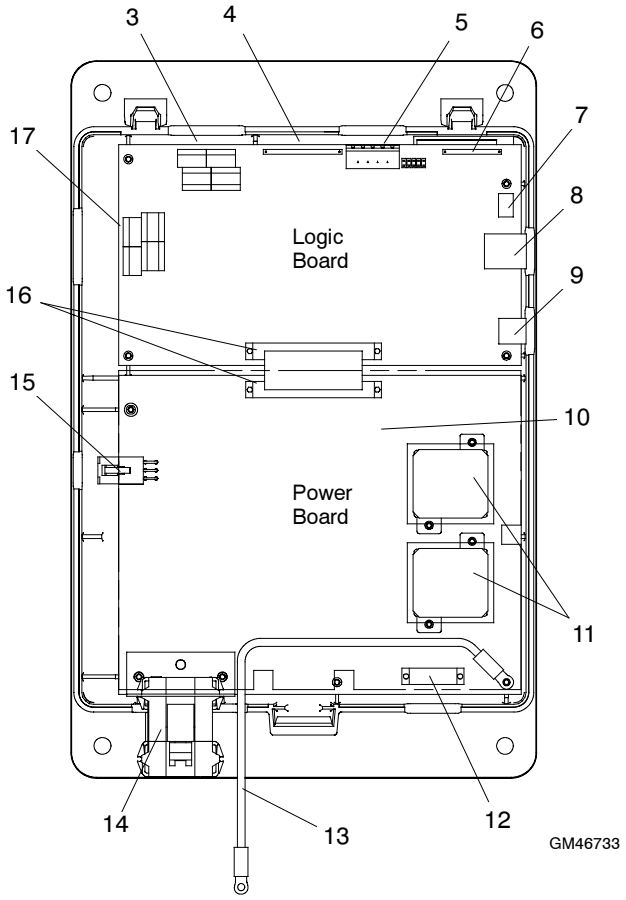
▼	Down arrow (closed). Step down to the next screen or scroll through a list.
▲	Up arrow (closed). Step back to the previous screen.
▶	Right arrow (closed). Move to the next submenu.
△	Up arrow (open). Increases the selected numerical value.
▽	Down arrow (open). Decreases the selected numerical value.
▷	Right arrow (open). Steps to the next digit in a selected numerical value.
Back	Steps back to the previous screen or submenu.
End Delay	Ends the current time delay.
End Test	Ends an active test sequence. See Section 3.6.5.
OK	Enters the displayed numerical value (password or setting).
Main	Returns to the main screen.
Next	Steps to the next parameter in an item with multiple settings (for example, in Exerciser Setup).
Reset	Reset the fault condition shown on the display, or reset an accessory module after connection.
Save	Saves settings shown on the display.
Set	From the main screen, moves to the first setup screen.
Start	From the Test screen, starts the test sequence.
Test	From the main screen, moves to the test sequence screens.
View	From the main screen, moves to the first view screen.
File transfer commands (USB device connected):	
Sel	Select the displayed file.
Del	Delete the displayed file.
Upload	Load the displayed file to the USB device.
Download	Load the displayed file to the controller.

Figure 3-4 Pushbutton Functions

3.2 Controller Circuit Boards and Connectors



With Cover



Cover Removed

1. Hinges
2. Latch
3. RS-485 Modbus connections TB2
4. User interface LCD display connection P17
5. Accessory module assembly connection P16
6. User interface connection P14
7. DIP switches SW1
8. Ethernet connector P13
9. USB port P12
10. LED1 (ON = 12VDC)
11. Relays
12. Programmed-transition interface board (PTIB) connection P2 (factory connection)
13. Ground wire
14. Transfer switch harness connection P1
15. Current sensing kit connection P3 (optional)
16. Ribbon cable connection
17. Logic board input and output connections TB1

Figure 3-5 Controller

3.3 Controller Power

⚠ 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)

3.3.1 Controller Power Supply

The controller power board converts AC line voltage to DC voltage for the logic board. Line voltage or DC voltage from an external battery connected through an External Battery Supply Module (EBSM) will cause LED1 on the controller's power board to light. See Figure 3-5 for the LED location.

- If the Normal or Emergency source is available but the controller display is dark, check LED1 on the controller power board. LED1 lights when voltage is available for the logic board.
- If the transfer switch is equipped with an EBSM, disconnect the I/O module assembly at connector P16 on the controller to remove the external battery supply. Then check LED1 with the Normal or Emergency source available.
- If LED1 lights but the controller display is dark, check the ribbon cable connections between the controller's power board and logic board and from the logic board to the display.
- If LED1 does not light when the Normal or Emergency source is available, check for line voltage to the controller using the following procedure:

Check for Line Voltage to the Controller

1. Disconnect power to the transfer switch by opening circuit breakers or switches.
2. Disconnect the transfer switch wiring harness from the controller at the 24-pin connector.
3. Reapply power to the transfer switch.
4. Check for voltage across the wiring harness pins. Observe all Safety Precautions when checking the voltage.
   a. If Source N is available, check for line voltage across pins 4 and 12 of the transfer switch wiring harness connector.
   b. If Source E is powering the transfer switch, check for line voltage across pins 6 and 7 of the connector.

If there is no power to the pins checked in step 4, check the wiring harness continuity. Replace the harness if necessary.

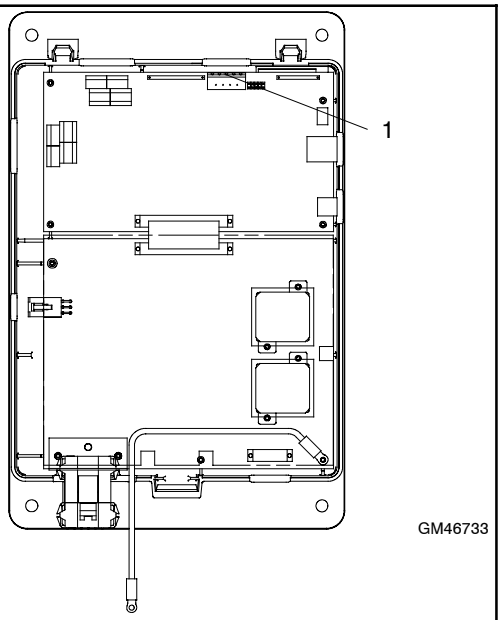
If there is power to the pins checked in step but LED1 on the power board does not light when power is connected, replace the power board.

3.3.2 Powering Controller Directly (Service Kit GM52407)

On occasion it is necessary to supply 120 VAC power directly to the controller for testing. Service Kit GM52407 contains a cable with a transformer to supply power to the controller from a 120 VAC wall outlet. Disconnect the controller from the transfer switch. Disconnect the I/O module assembly (if equipped) and connect the cable to the controller's P16 connector. See Figure 3-6.

The cable can also be connected to the I/O module assembly, if desired. Plug the cable into a 120 VAC wall outlet to power the controller during testing.

Note: Do not connect 120 VAC power to any other location on the controller.



1. Connect service kit power cable to controller connector P16 (I/O module connection)

Figure 3-6 Service Kit GM52407 Connection (controller cover removed for illustration only)

3.4 Sequence of Operation

3.4.1 Controller Powerup Reset Sequence of Operation

Following is an explanation of the sequence of operation for the MPAC™ 1500 ATS Controller when power is initially applied to the controller or a controller reset occurs.

1. Controller self test is executed.
2. System parameters are downloaded from non-volatile memory.
3. Power switching device position and source availability are determined.
4. If neither source is acceptable, the power switching device does not change position.
5. If both sources are available, the controller immediately transfers the power switching device to the preferred source.
6. If only one source is available, the controller immediately transfers the power switching device to that source, executing only the off-position and load control time delays.

   If the available source is the preferred source, and the power switching device was in the standby position, the power switching device transfers to preferred, the engine cooldown time delay runs, and then the engine start contacts open.

   If the available source is the preferred source and the power switching device was already in the preferred position, the engine start contacts open immediately, bypassing the engine cooldown time delay.

3.4.2 Preferred Source Loss and Return

Following is an explanation of the sequence of operation when Preferred Source failure is detected.

Preferred Source Fails:

1. Load control contacts open.
2. Engine start time delay expires.
3. Engine start contacts close, signaling the generator set to start.
4. The generator starts and the standby source becomes available.

   Note: If the standby generator set does not start, a fail to acquire fault is activated.

5. Transfer time delay preferred-to-standby expires.
6. Utility breaker opens.
7. Off-to-standby time delay expires.
8. Emergency breaker or switch closes.
9. Load control contacts close as post-transfer load control time delays expire.

Preferred Source Returns:

1. Transfer time delay standby-to-preferred expires and load control contacts open as pretransfer load control time delays expire.
2. Emergency breaker or switch opens.
3. Off-to-preferred time delay expires.
4. Utility breaker closes.
5. Load control contacts close as post-transfer load control time delays expire.
6. Engine cooldown time delay expires.
7. The engine start contacts open, signaling the generator set to stop.

   Note: The generator set may continue to run if the generator set controller has a separate engine cooldown cycle.

3.5 Operation Diagrams

This section contains descriptions and diagrams of the power switching device operation. For complete diagrams, refer to the schematic diagrams provided with the transfer switch.

The ATS controller monitors the connected source and detects source failure, either a complete loss of the source or a source parameter that is outside the acceptable range. The controller starts the engine start time delay. If power is restored before the time delay ends, the controller resets the time delay and continues to monitor the source. If the source failure persists and the time delay ends, the controller closes the engine start contacts to signal the Source E generator set to start.

When Source 2 (or the standby source) becomes available, the controller starts the preferred-to-standby time delay (if not set to zero). When the time delay ends, relay K2 in the controller closes, applying power to the circuit breaker motor operator to open the Source 1 circuit breaker.

Note: Controller relays K1 and K2 and programmed transition interface board (PTIB) relays K1' and K2' are energized for only 250 milliseconds to initiate transfer.

Service entrance models stop in the OFF position for a programmed length of time during transfer. On MCCB models, the K2 relay closes after the Off time delay, applying power to the circuit breaker motor operator and closing the Source 2 circuit breaker. On ICCB models, the transfer-to-OFF sequence is controlled by the K1' and K2' relays on the programmed-transition interface board (PTIB).

The motor operator power circuits vary for MCCB and ICCB models. The following sections illustrate the transfer sequence for the different models.

When Source N (or the preferred source) is restored, the controller starts the standby-to-preferred time delay. When the time delay ends, the controller's K1 (NR) relay closes, applying power to the circuit breaker motor operator and initiating transfer back to Source N (or the preferred source).

The controller K1 and K2 relays and the PTIB relays are replaceable.

Note: Always check all wiring and connections before replacing parts.

Figure 3-7 explains the notation used in the solenoid operation diagrams in Figure 3-8 through Figure 3-11.

Legend:

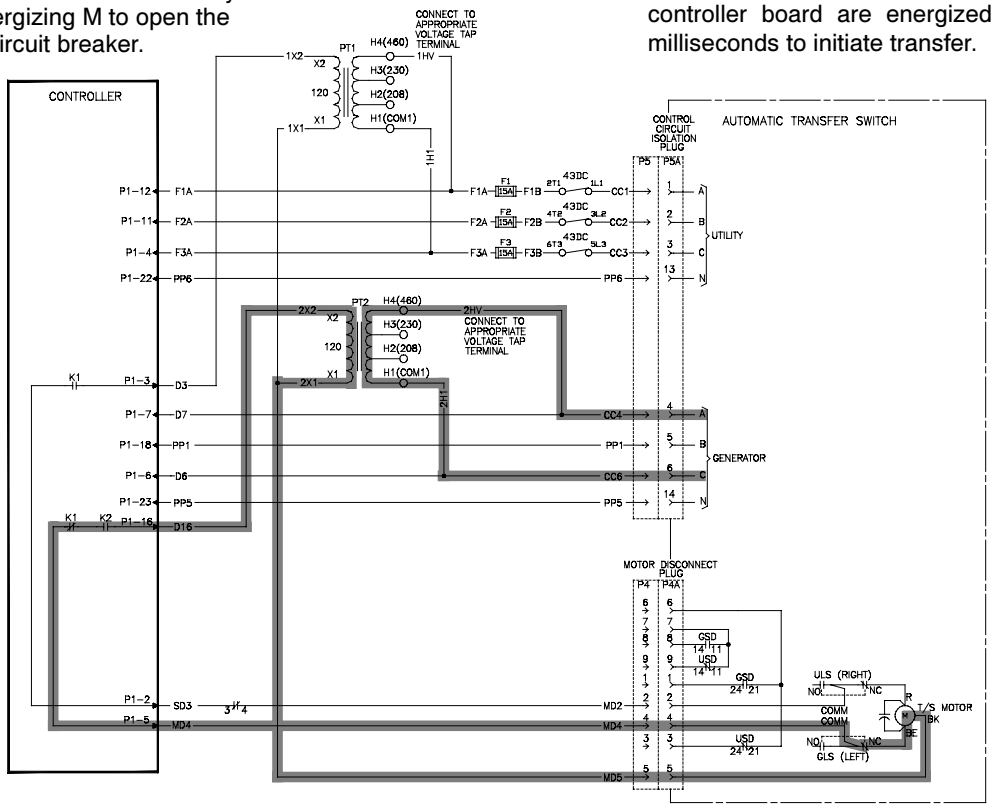
K1, K2	Controller relays. Energized for 250 milliseconds to initiate transfer.
K1', K2'	Programmed-transition interface board (PTIB) relays Energized for 250 milliseconds to initiate transfer.
M	Circuit breaker motor operator, MCCB models
UBC	Utility Breaker Close Motor Operator, ICCB Models
UBO	Utility Breaker Open Motor Operator, ICCB Models
GBC	Generator Breaker Close Motor Operator, ICCB Models
GBO	Generator Breaker Open Motor Operator, ICCB Models

Power through the coil circuit.

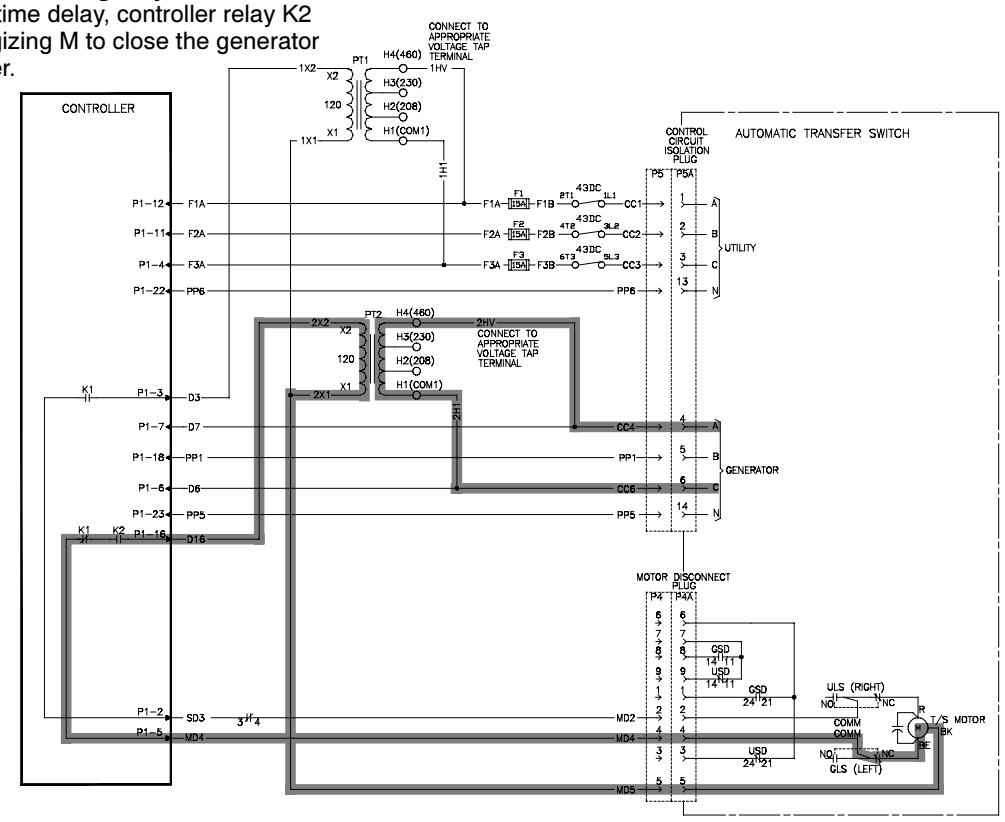
Figure 3-7 Legend for Solenoid Operation Diagrams

Transfer, Normal to Off:
Utility source is lost. Controller relay K2 closes, energizing M to open the utility source circuit breaker.

Note: The K1 and K2 relays on the MPAC 1500 controller board are energized for only 250 milliseconds to initiate transfer.



Transfer, Off to Emergency:
After the Off time delay, controller relay K2 closes, energizing M to close the generator circuit breaker.

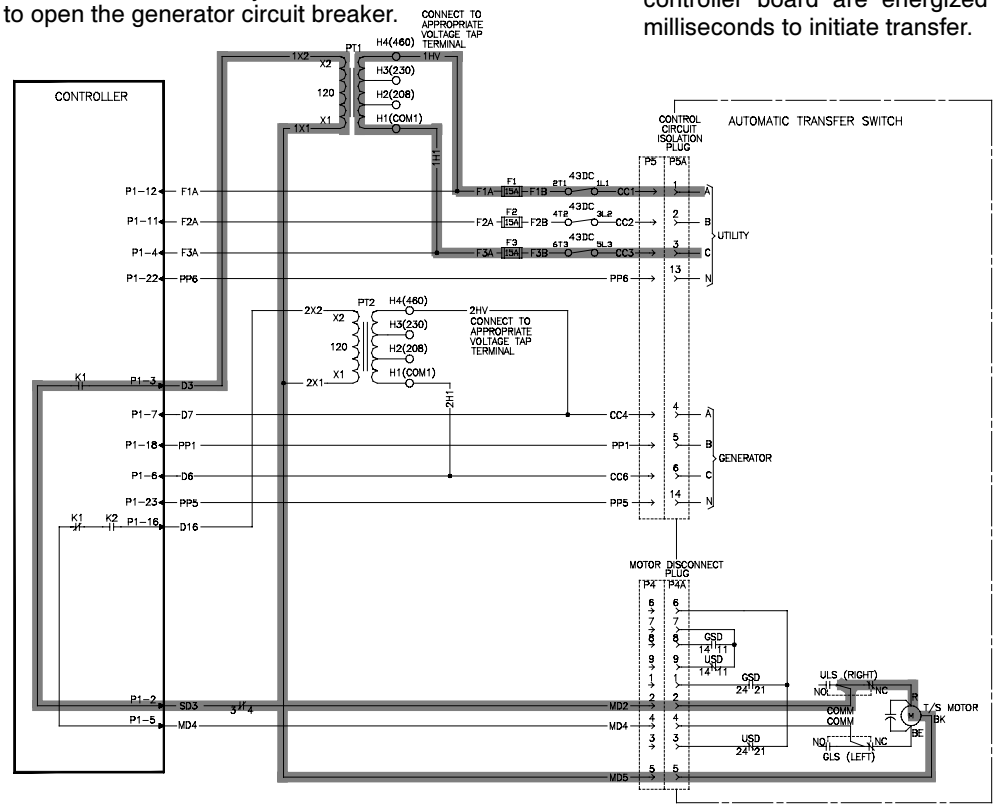


GM71059

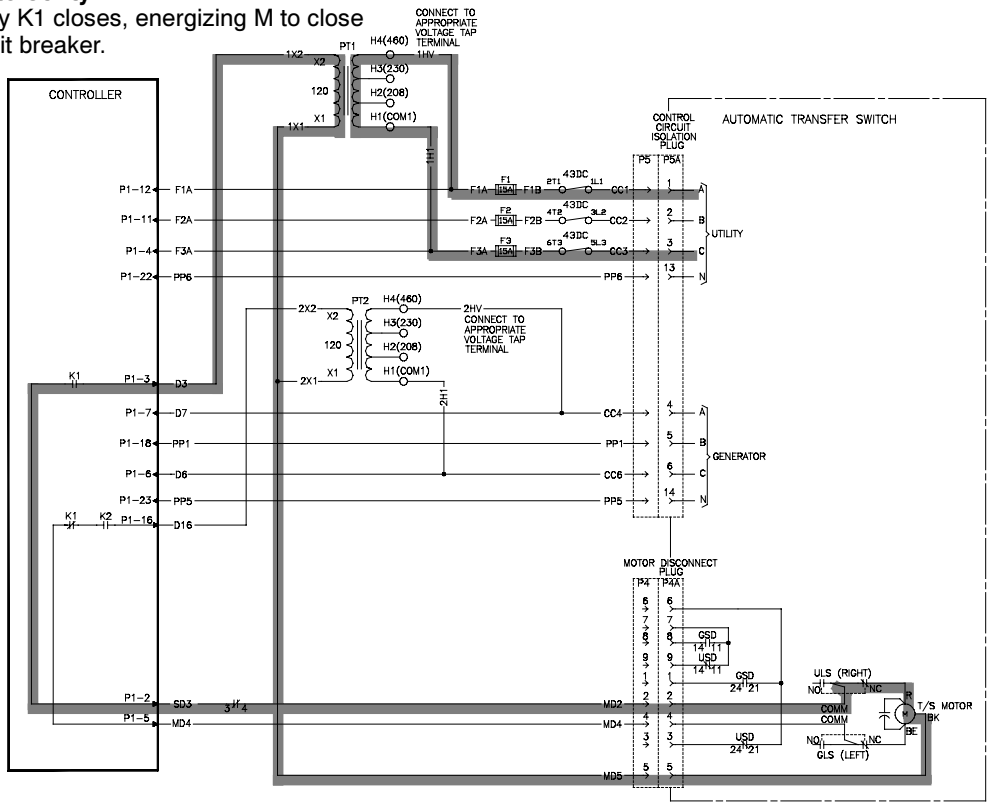
Figure 3-8 MCCB Transfer from Normal to Emergency

Transfer, Emergency to Off:
Utility source returns. Controller relay K1 closes, energizing M to open the generator circuit breaker.

Note: The K1 and K2 relays on the MPAC 1500 controller board are energized for only 250 milliseconds to initiate transfer.



Transfer, Off to Utility:
Controller relay K1 closes, energizing M to close the utility circuit breaker.

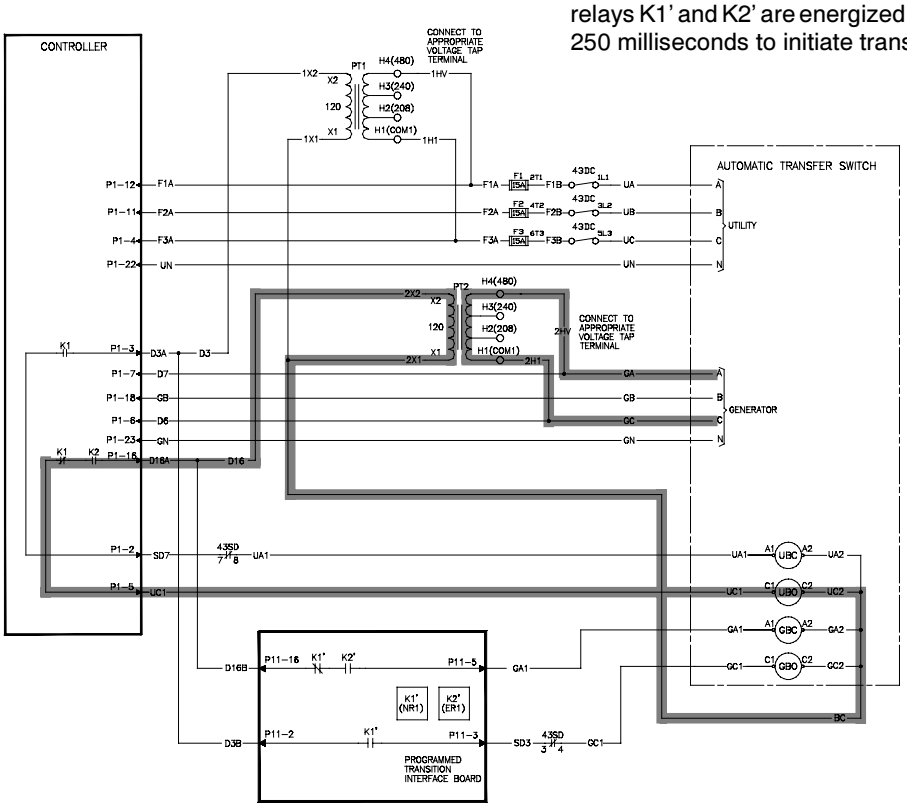


GM71059

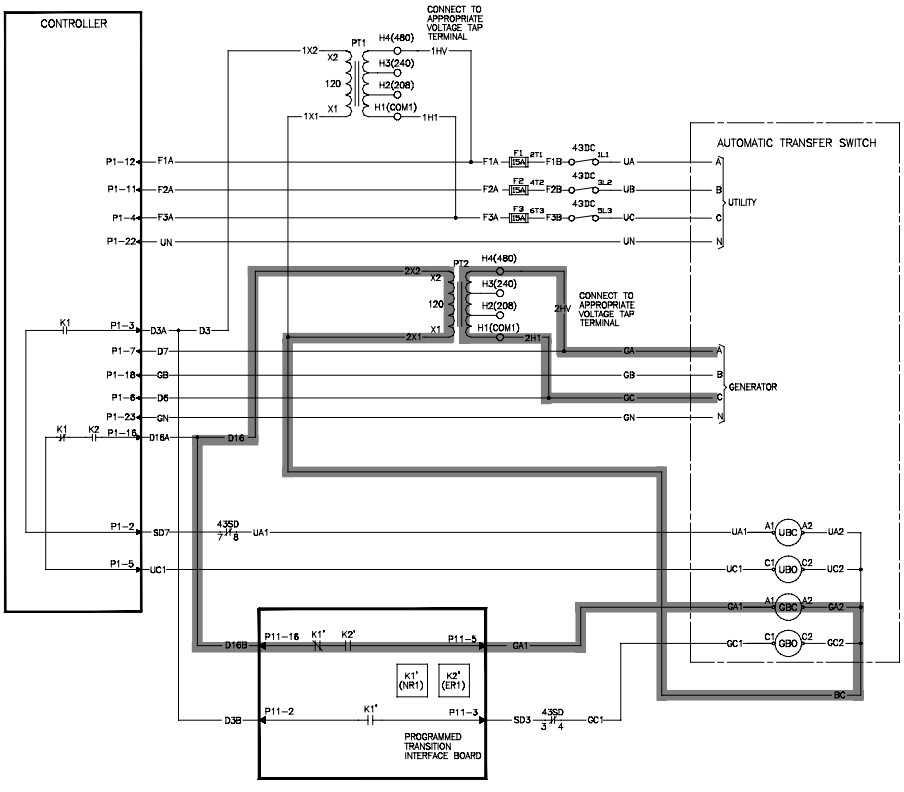
Figure 3-9 MCCB Transfer from Emergency to Normal

Transfer, Normal to Off:
Utility source is lost. Controller relay K2 closes, energizing the UBO motor operator to open the utility breaker.

Note: Controller relays K1 and K2 and PTIB relays K1' and K2' are energized for only 250 milliseconds to initiate transfer.



Transfer, Off to Emergency:
PTIB relay K2' closes, energizing the GBC motor operator to close the generator breaker.

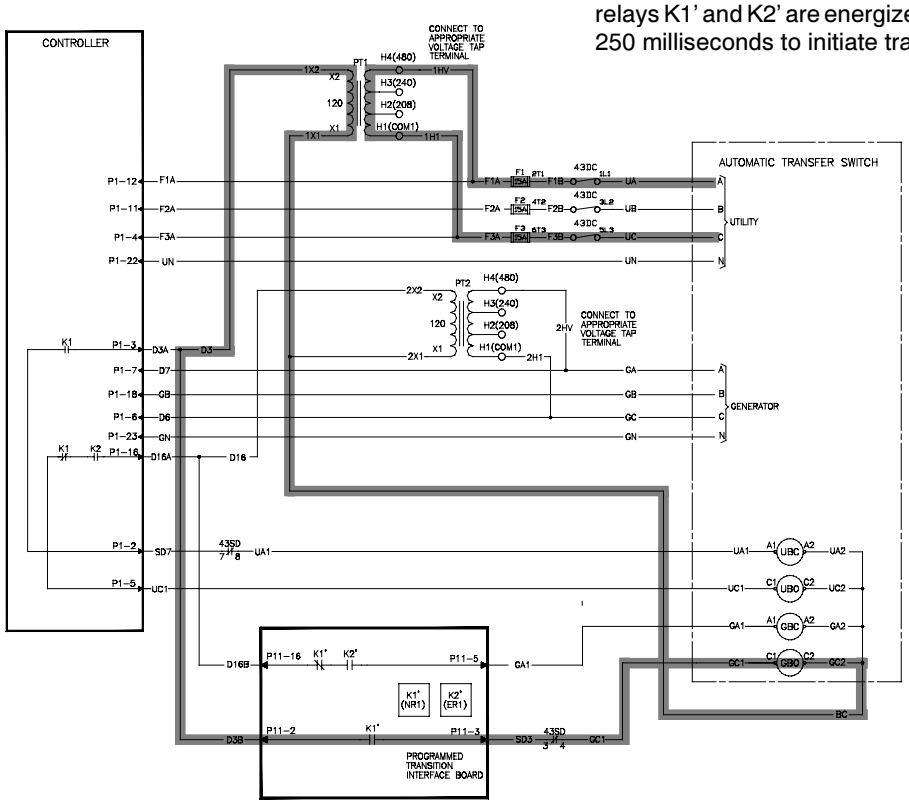


GM71061

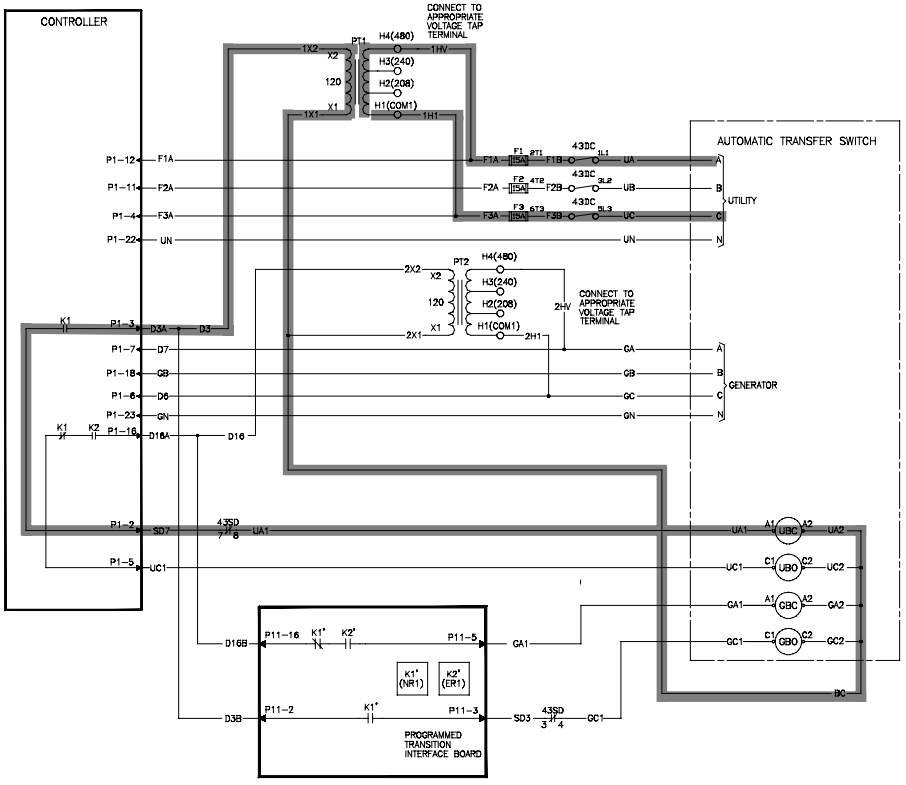
Figure 3-10 ICCB Transfer from Normal to Emergency

Transfer, Emergency to Off:
Utility power returns. PTIB relay K1' closes, energizing the GBO motor operator to open the generator breaker.

Note: Controller relays K1 and K2 and PTIB relays K1' and K2' are energized for only 250 milliseconds to initiate transfer.



Transfer, Off to Normal:
Controller relay K1 closes, energizing the UBC motor operator to close the utility breaker.



GM71061

Figure 3-11 ICCB Transfer from Emergency to Normal

3.6 System Test

Use the system test feature to:

- Start and run the generator set, or
- Simulate a preferred source failure, resulting in a transfer to the standby source.

A password is required to activate the system test, ensuring that only authorized personnel can start a test. Pressing the Test pushbutton signals the controller to initiate the system test sequence.

An Auto-Loaded test executes for a set length of time and then ends automatically. Press the End Test pushbutton to end a Loaded or Unloaded test. Time delays will execute as programmed after the end test button is pressed. Pressing the End Delay button will end the currently displayed time delay.

To check the source voltage and frequency while a test is running, press the Main button. Press the Test button to return to the test sequence screens.

During a system test, if the emergency source becomes unavailable based on its preset operating parameters, the fail to acquire standby signal is indicated immediately, and the test is terminated. If the power switching device is in the standby position, it transfers immediately to the preferred position.

3.6.1 Unloaded System Test

When an unloaded test is initiated, the controller immediately signals the generator to start, without waiting for time delay engine start to timeout. The power switching device does not change position during an unloaded test, but if the normal source should fail, the power switching device will transfer to the emergency source. The unloaded test feature will be available only with the Util-Genset and Genset-Genset modes of operation.

3.6.2 Loaded System Test

A loaded test actually simulates a preferred source failure, except that the engine start time delay is bypassed. The generator set is signaled to start immediately upon test activation. Load control signals are issued prior to transfer with their associated time delays. If the preferred source is lost during a loaded test with the power switching device in the standby position, the test will continue to be active, even on restoration of preferred. If the standby source is lost and the preferred source is available, the test will be terminated, and the transfer switch will immediately transfer to the preferred source position, bypassing all time delays except the off-position requirements in a programmed-transition system.

When a loaded test is terminated normally, the retransfer sequence will be as though the preferred source has been restored after a failure. All time delays will be executed. The loaded test feature will be available with the Util-Genset, Util-Util and Genset-Genset modes of operation.

3.6.3 Auto-Loaded System Test

The auto-loaded test feature is a timed loaded test. The auto-loaded time delay determines how long after the transfer to standby to terminate the test and transfer back to the preferred source. The time is defaulted to 30 minutes and can be adjusted from 1 minute to 60 minutes.

3.6.4 Test Procedure

Use the following procedure to run a test to check the transfer switch operation. Watch the LEDs on the controller's user interface as the time delays run and Source E becomes available when the generator set starts. For a loaded test, watch the position LEDs to verify that the ATS transfers the load.

The test sequence simulates a loss of the normal source, starts the generator set, and transfers the load to the emergency source (loaded test), executing all time delays that are set up to operate during a loss of the normal source. When the test is ended in step 8 of the procedure, the transfer switch transfers the load back to the normal source and removes the engine start signal, executing all programmed time delays.

Refer to Figure 3-13 and Figure 3-14 for flowcharts showing the test sequence of operation without and with load.

Note: If the standby source fails during a test, the ATS will immediately attempt to transfer to the preferred source.

Check the preferred source selection. The test procedure assumes that Source N is the preferred source. (Alarm board accessory is required in order to access the preferred source selection menu.)

If the transfer switch is equipped with a supervised transfer switch, verify that it is set to the Auto position.

Note: Close and lock the enclosure door before starting the test procedure.

⚠ DANGER

Hazardous voltage.
Will cause severe injury or death.

Only authorized personnel should open the enclosure.

Automatic Operation Test Procedure

1. Check the controller LED indicators to verify that the Position N and Source N Available indicators are lit.
2. Verify that the generator set master switch is in the AUTO position.
3. Refer to Figure 3-12. From the main screen, press the Test button. Enter the test password when prompted and press OK.
4. Press the down arrow button to display Type of Test Loaded.
5. Press the Start button.
6. Verify that the generator set starts and the Source E Available LED lights.
7. Verify that the switch transfers the load to Source E:
   a. After the preferred-to-standby transfer time delay, verify that the Position N LED goes out.
   b. After the off-to-standby time delay, check that the Position E LED lights, indicating that the switch has transferred the load to Source E.
8. Press the End Test button.
9. Verify that the switch transfers the load back to Source N.
   a. After the standby-to-preferred transfer time delay, verify that the Position E LED goes out.
   b. After the off-to-preferred time delay, check that the Position N LED lights, indicating that the switch has transferred the load to Source N.

   Note: The generator set may have an engine cooldown time delay that causes the generator set engine to run after the transfer switch engine start signal is removed.

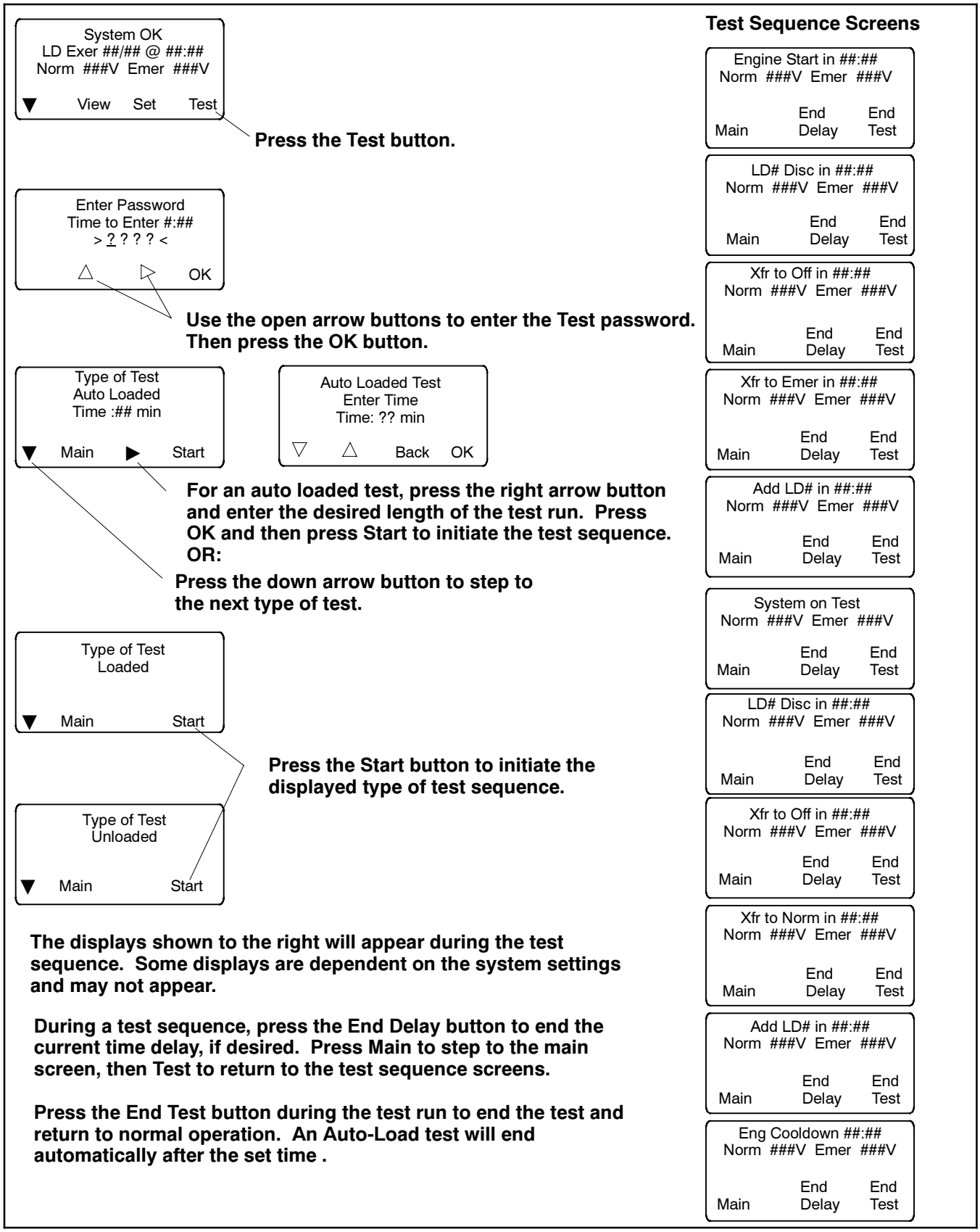


Figure 3-12 Test Sequence Screens

3.6.5 Test Sequence of Operation

Test Function is Activated (Unloaded)

1. The generator set is signaled to start.
2. The generator starts and the standby source becomes available.
3. The load bank control is activated.

Test Function is Deactivated (Unloaded)

1. The load bank control is deactivated.
2. Time delay engine cooldown expires.
3. The generator is signaled to stop.

Test Function is Activated (Loaded)

1. Engine start contacts close, signalling the generator set to start.
2. The generator starts and the standby source becomes available.
3. Pretransfer load control time delays operate.
4. Load control contacts open.
5. Transfer time delay preferred-to-standby expires.
6. Utility breaker opens.
7. Off-to-standby time delay expires.
8. Emergency breaker or switch closes.
9. Load control contacts close as post-transfer load control time delays expire.

Emergency Source Fails (Normal Source is available)

1. Test function is deactivated.
2. Immediate failure to acquire standby alarm.
3. Load control contacts open.
4. Emergency breaker or switch opens.
5. Off-to-preferred time delay expires.
6. Utility breaker closes.
7. Post-transfer load control sequences and time delay engine cooldown time out.
8. Load control contacts close.
9. Engine start contacts open.

Test Function is Deactivated (Loaded)

1. Transfer time delay standby-to-preferred and pretransfer load control sequences time out.
2. Load control contacts open.
3. Emergency breaker or switch opens.
4. Off-to- preferred time delay expires.
5. Utility breaker closes.
6. Post-transfer load control sequences and time delay engine cooldown time out.
7. Load control contacts close.
8. The engine start contacts open, signaling the generator to stop.

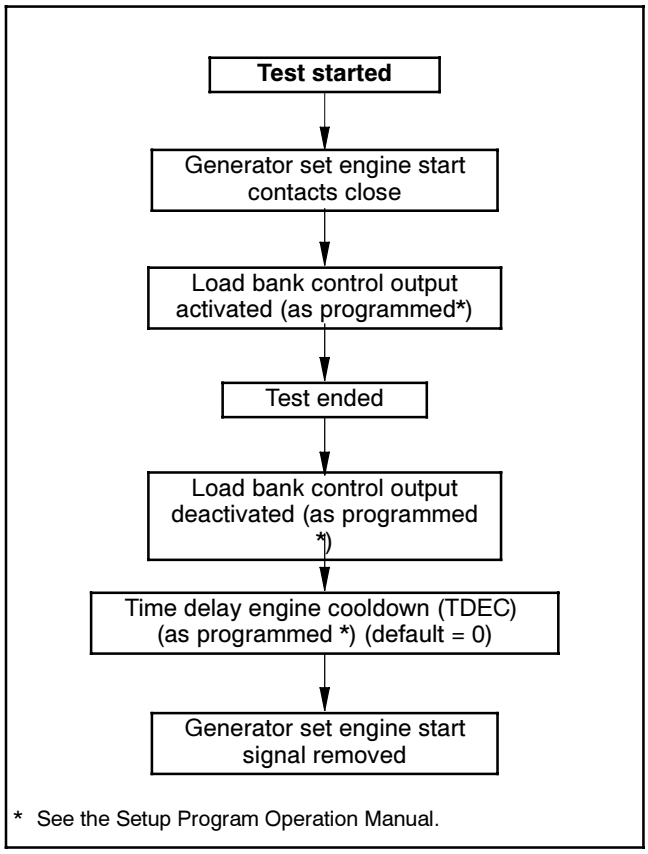


Figure 3-13 Test Without Load Sequence

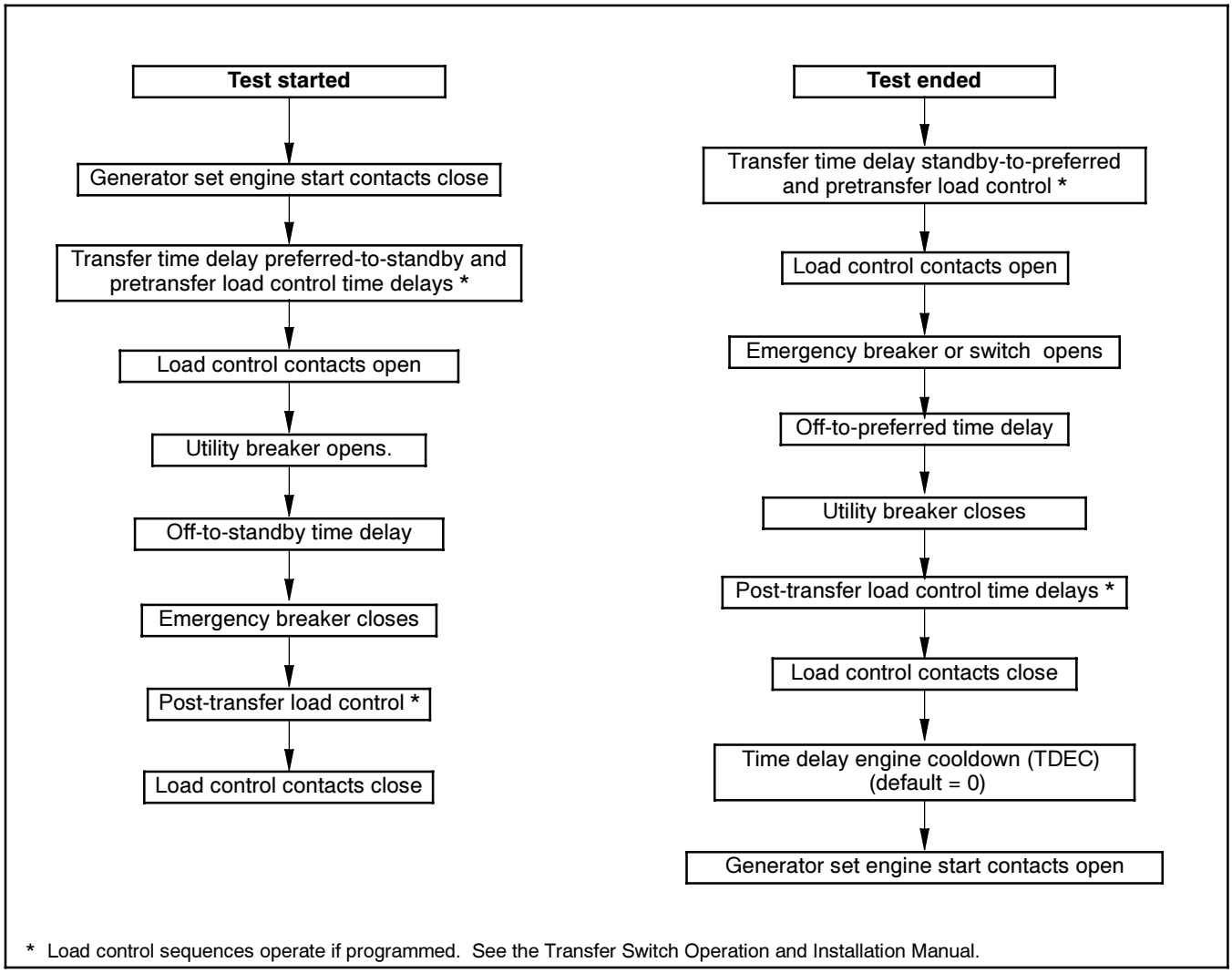


Figure 3-14 Test with Load Sequence

3.7 Exercise

Schedule exercise runs through the Set Exercise screen. See the transfer switch operation and installation manual for instructions. To run the generator set at a time other than a scheduled exercise sequence, use the Test function. See Section 3.6 for instructions.

When a scheduled exercise is running, the screens shown in Figure 3-15 appear. Press Main to return to the main screen, if desired. Press the End button to end the exercise sequence before the scheduled stop time, if necessary.

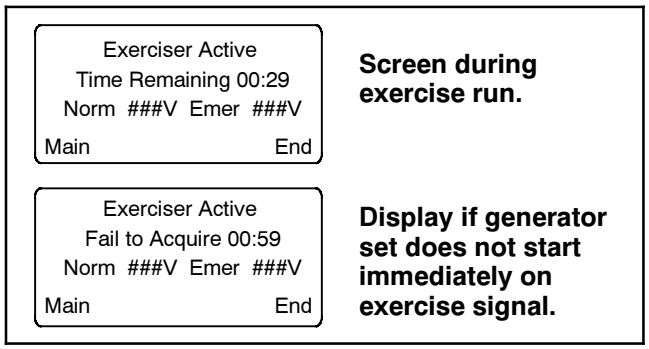


Figure 3-15 Exercise Sequence Screens

3.8 Exerciser Sequence of Operation

Exercise Sequence is Activated (Unloaded)

1. Exerciser timer begins.
2. Engine start contacts close, signaling the generator set to start.
3. The generator starts and the standby source becomes available.
4. The load bank control is activated.

Exercise Sequence is Deactivated (Unloaded)

1. The load bank control is deactivated.
2. Time delay engine cooldown expires.
3. Engine start contacts open, signaling the generator set to stop.

Exercise Sequence is Activated (Loaded)

1. Exerciser timer begins.
2. Engine start contacts close, signaling the generator set to start.
3. The generator starts and the standby source becomes available.
4. Transfer time delay preferred-to-standby and pretransfer load control sequences time out.
5. Load control contacts open.
6. Utility breaker opens.
7. Off-to-standby time delay expires.
8. Emergency breaker or switch closes.
9. Post-transfer load control sequences time out.
10. Load control contacts close.

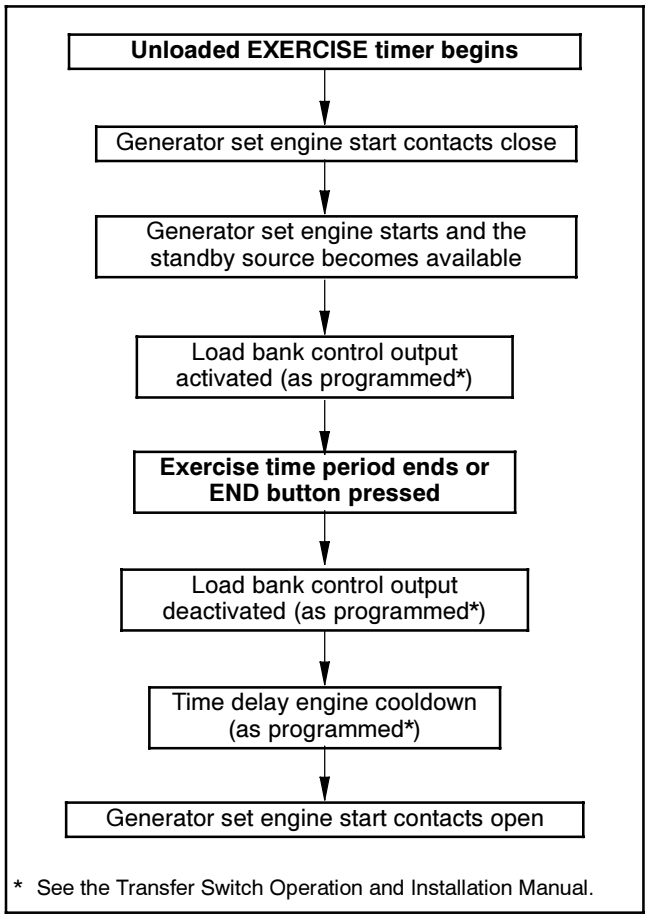


Figure 3-16 Exercise without Load Sequence

Emergency Source Fails (Normal Source is available)

1. Exerciser is deactivated.
2. Immediate failure to acquire standby alarm.
3. Load control contacts open.
4. Emergency breaker or switch opens.
5. Off-to- preferred time delay expires.
6. Utility breaker closes.
7. Post-transfer load control sequences and time delay engine cooldown time out.
8. Load control contacts close.
9. Engine start contacts open.

Exercise Sequence is deactivated (Loaded)

1. Pretransfer load control sequences time out.
2. Load control contacts open.
3. Emergency breaker or switch opens.
4. Off-to- preferred time delay expires.
5. Utility breaker closes.
6. Post-transfer load control sequences and time delay engine cooldown time out.
7. Load control contacts close.
8. The generator is signaled to stop.

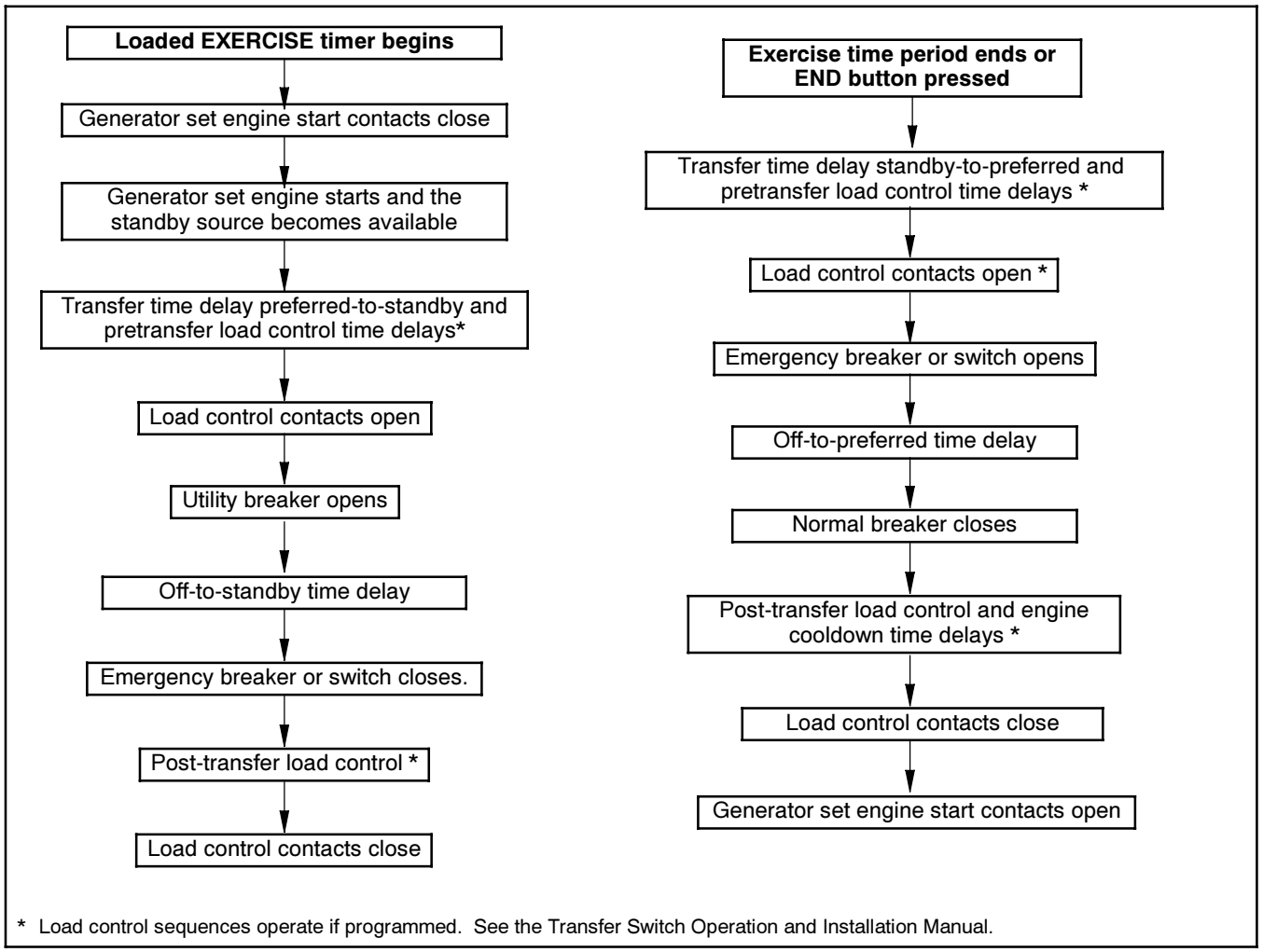


Figure 3-17 Exercise with Load Sequence

3.9 Engine Start

The engine start contacts should close when the Normal source is lost and when the ATS controller starts a test or exercise sequence. The engine start contacts are labeled with a decal. Check the operation/installation manual or the dimension drawing for the contact location, if necessary.

Use the following procedure to check for continuity across the engine start contacts when the Normal source is disconnected and during a test sequence. Allow time for the engine start and engine cooldown time delays during the test. Refer to the sequence of operation in Sections 3.4 and 3.6 for the applicable time delays.

Be sure to read and follow the safety precautions when performing the test procedure.

⚠ 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.

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)

Engine Start Test Procedure

Start with the transfer switch in the Source N position.

1. Connect an ohmmeter or test lamp across the engine start contacts at one of the following locations:

   a. Pins 8 and 9 of connector J1 (the transfer switch harness-to-controller connection). See Figure 3-18.

   b. The engine start contacts on the transfer switch contactor or field-connection terminal block. See the decal on the transfer switch or the transfer switch operation and installation manual for the engine start contact location.

   c. The generator set engine start leads. See the generator set documentation for engine start lead identification and location.

2. Disconnect Normal power from the transfer switch and verify that the engine start contacts close.

3. Reconnect Normal power to the transfer switch and verify that the engine start contacts open after applicable time delays.

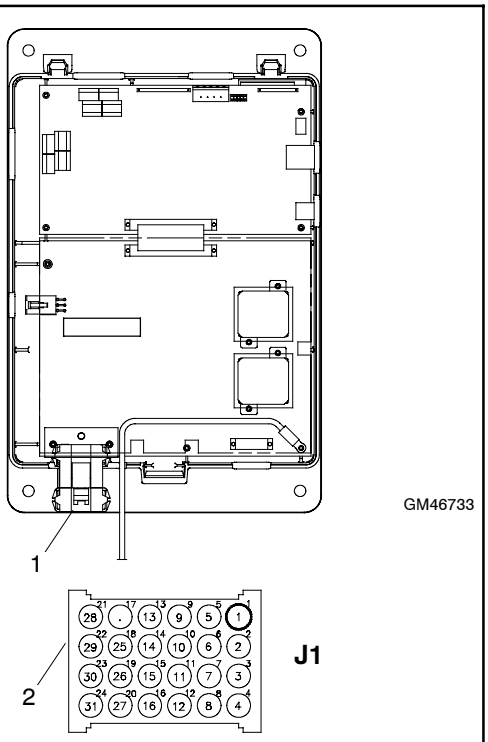
4. If the engine start contacts do not operate as indicated in steps 2 and 3 when power is disconnected and reconnected, replace the ATS controller's power board. See Section 3.16.

5. Press the Test button to initiate a test sequence and verify that the engine start contacts close.

6. Press the End button to end the test. Verify that the engine start contacts open after the engine cooldown time delay (which may be set to zero).

7. If the ATS engine start contacts do not close during the Test Procedure, replace the ATS controller's logic board. See Section 3.16.

If the generator set engine does not start, check the engine start connections to the generator set. Verify that the generator set master switch is in the AUTO position. Troubleshoot the generator set if the engine start connections are good but the engine does not start.



1. Transfer switch harness connection, P1
2. Connector J1 pin numbering

Figure 3-18 Transfer Switch Harness-to-Controller Connection

3.10 Controller DIP Switches

⚠ DANGER

Hazardous voltage.
Will cause severe injury or death.

Disconnect all power sources before opening the enclosure.

Two DIP switches on the main logic board are assigned functions. Switches 3 and 4 are not used. The DIP switches are located on the controller's main logic board on the inside of the enclosure door. Figure 3-19 shows the locations of the switches on the controller circuit board. It is not necessary to remove the logic assembly cover to see or adjust the DIP switches.

SW1-1, Password Disable. Closing the password disable DIP switch SW1-1 disables the setup password and resets it to the factory defaults. When the switch is closed, system setup and programming is allowed without the need to enter a password.

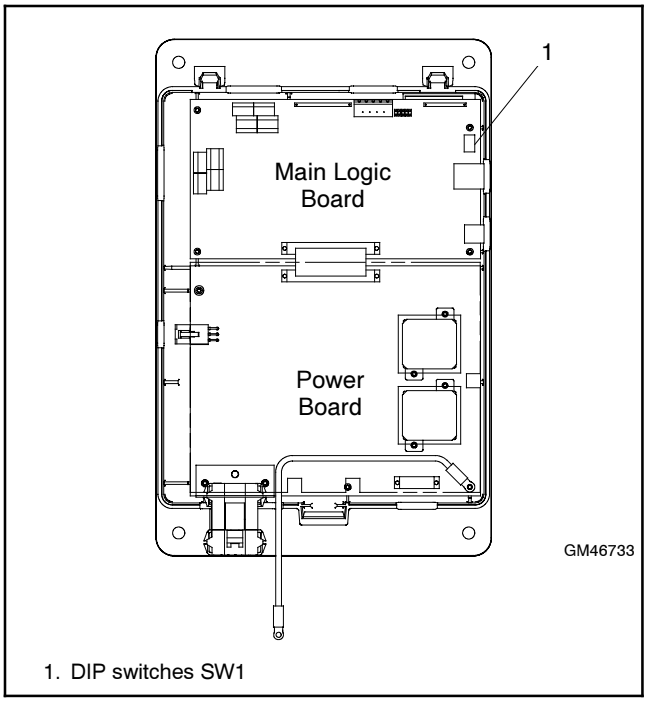
Note: Disable the setup password only during service unless the transfer switch is installed in a secure location.

Closing and then reopening DIP switch SW1-1 resets the password to the default value, 0000.

The test password is not affected by this DIP switch. Use the Reset Data screen to disable the test password.

SW1-2, Maintenance. The maintenance DIP switch inhibits transfer during ATS service. When this switch is in the closed position, power switching device functions are disabled. The Not in Auto LED flashes red and the message Maintenance Mode is indicated on the LCD screen. In addition, a programmable digital output is turned on and an entry in the event log indicates that the maintenance mode has been activated. System monitoring and setup are allowed while in maintenance mode.

Close and lock the enclosure door before energizing the transfer switch.



1. DIP switches SW1

Figure 3-19 DIP Switch Location (cover removed for illustration only)

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)

The transfer switch controls are calibrated at the factory and should not require recalibration in the field. However, if recalibration is necessary, measure the source voltages as instructed in Section 2.4.2, record the measured values, and use the Setup Screen-Calibration to enter the measured values. See Figure 3-20.

The current sensing accessory is required in order for the transfer switch to measure and display the current values. Use a clamp-on current sensing meter to measure the current and enter the measured values through the Setup Screen–Calibration shown below.

3.11 Calibration

⚠ DANGER

Hazardous voltage.
Will cause severe injury or death.

Only authorized personnel should open the enclosure.

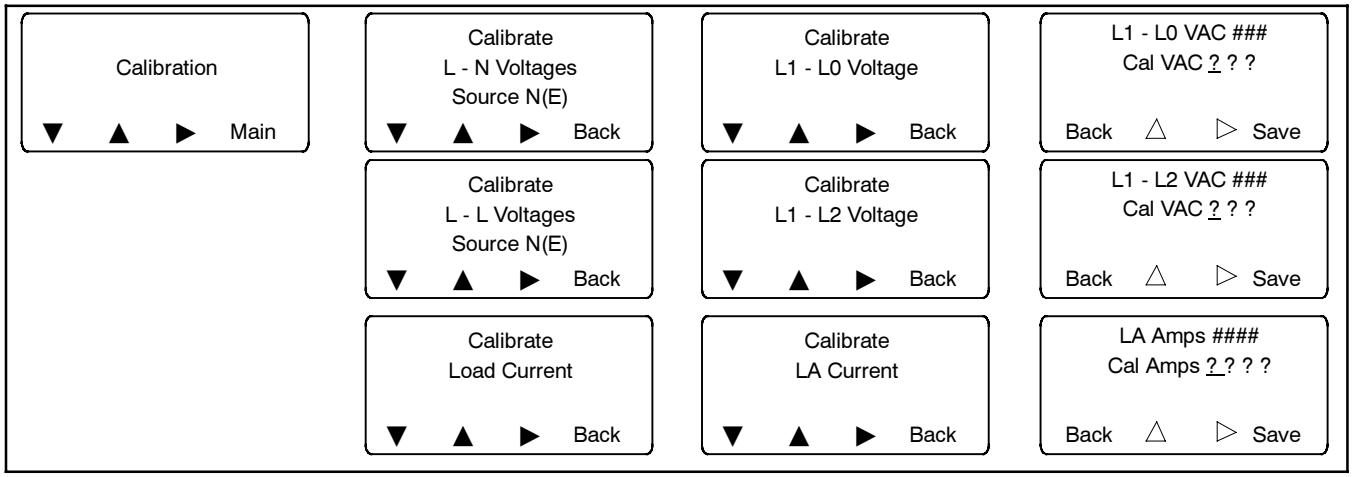


Figure 3-20 Calibration

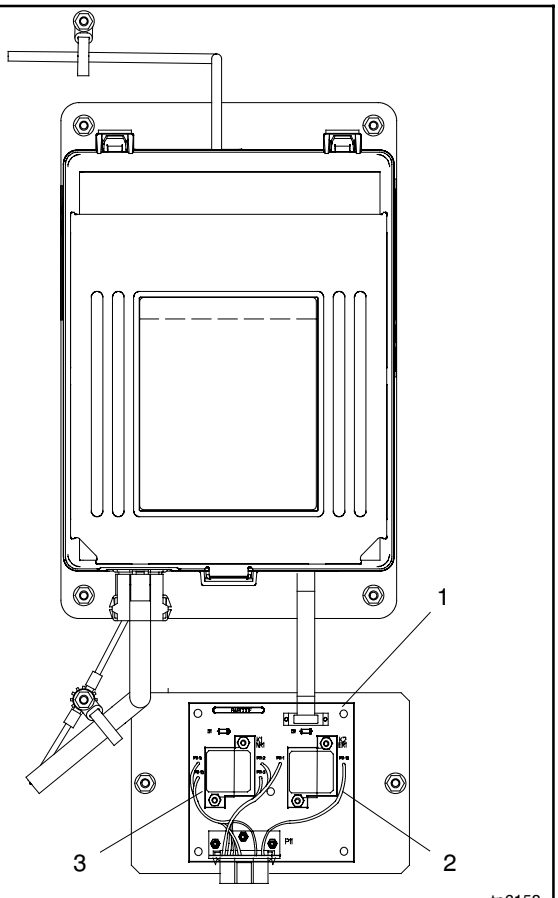
3.12 Position Microswitch Test

Disconnect power to the transfer switch and use an ohmmeter or test lamp to check the operation of the position microswitches. Manually operate the switch and check for continuity across pins 10 and 13 of the connector P1 for Source E and pins 10 and 14 for Source N.

3.13 Programmed-Transition Interface Board

ICCB models use the programmed-transition interface board.

The programmed-transition interface board (PTIB) contains two replaceable 10-amp relays, K1 (NR1) and K2 (ER1). See Figure 3-21. Refer to the operation diagrams in Section 3.5 and to the schematic diagram provided with the transfer switch to troubleshoot the relays.



1. Programmed-Transition Interface Board (PTIB)
2. K2 (ER1) Relay
3. K1 (NR1) Relay

Figure 3-21 Programmed-Transition Interface Board

3.14 File Transfer through USB Port

The Universal Serial Bus (USB) port on the main logic board allows file transfer to and from a USB mass storage device (removeable drive). Figure 3-22 shows a typical device. The removeable drive must be compatible with the USB 2.0 and USB Mass Storage Device Class specifications.

The controller application code can be updated through the USB port. Parameter settings, event history, and other information files can be saved to the storage device.

The controller recognizes the types of files shown in Figure 3-23.

3.14.1 Configuration files

The configuration (.cfg) file contains the transfer switch settings, including:

- System setup
- Source setup, including voltage and frequency pickup and dropouts
- Time delays
- Inputs and outputs
- Communications settings
- Calibration factors

Configuration files from one transfer switch can be saved to a mass storage device and then loaded onto other transfer switches for quick setup of multiple switches. Serial numbers and descriptions entered through Monitor III software (or other Modbus application) are not changed by downloading configuration files to a transfer switch.

Check the settings and run a test sequence after loading the configuration file to verify correct operation. Refer to the ATS operation and installation manual for instructions to view settings. See Section 3.6 for instructions to run a test.

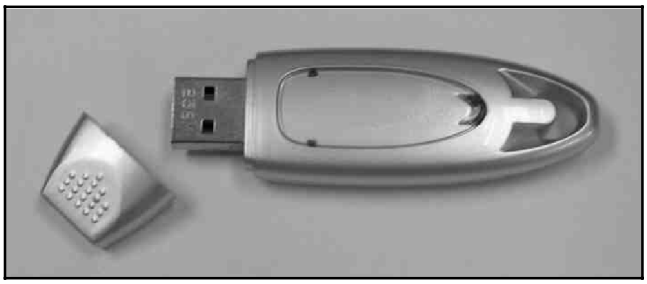


Figure 3-22 Typical Mass Storage Device

File name	Description	Size (approx.)	Download to Control	Upload to USB
MPAC1500v###.bin	Controller application program	950 KB	X	
MPAC1500_#######.cfg	Configuration (parameter settings)	3 KB	X	X
present*yymmdd*.his	Event history	varies		X
alarm_settings.alm	Common alarms	1 KB		X
DataLogyymmddhhmmss.csv	Data log. File name includes date and time.	10 KB		X
MinMax.csv	Minimum and maximum values recorded during a selected time period.	1 KB		X
MPAC1500_cal.cal	Calibration	1 KB		X
history_param.hstp	Internal use only	—		X
Param_back.bak	Internal use only	—		X
present*yymmdd*.raw	Internal use only	—		X
history_pback.hbak	Internal use only	—		X

Figure 3-23 Recognized File Types

Loading Settings when Controller is Replaced

If the controller needs to be replaced, the configuration file from the old controller (if available) can be loaded onto the new controller for quick setup.

Note: Operation problems can be caused by incorrect controller settings. Do not load the old configuration file onto the new controller unless you are certain that all the settings in the file are correct.

Note: When replacing the ATS controller, record the power switching device and ATS serial numbers from the old controller before removing it, or from the ATS decals.

Serial numbers are not transferred through the configuration file and cannot be entered through the controller's user interface. Use Monitor III (or a customer-provided Modbus driver designed for the system) to enter the power switching device and ATS serial numbers after the new controller is installed. A distributor-level password is required to enter serial numbers. Refer to the Monitor III Operation Manual or the Modbus Protocol Manual for instructions, if necessary. Do not attempt to change the controller serial number.

3.14.2 File Transfer

The USB Access screen opens automatically when a device is connected to the controller's USB port. See Figure 3-24. Select Upload or Download as described below.

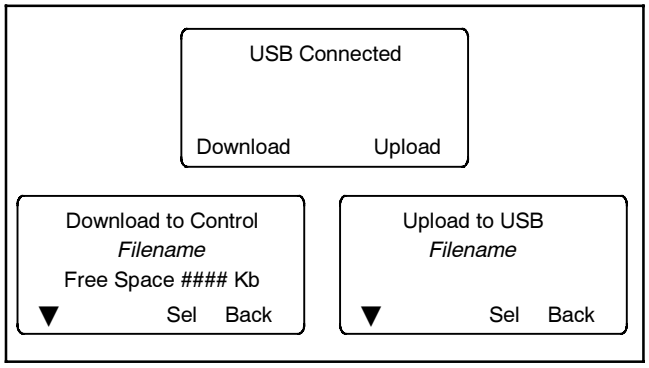


Figure 3-24 USB Access Screens

Procedure to Transfer Files

1. Insert the USB mass storage device into the USB port on the controller's main logic board. See Figure 3-5 for the port location.

2. Press the Download button to load new files from a memory device to the controller. Or, press the Upload button to load files from the controller through the USB port to a memory device.

3. Use the down button to scroll through the list of available files.

4. When the desired file is displayed, press the Sel button to select the file and start transferring the file.

   Note: Do not disconnect the device from the USB port during file transfer.

   A message on the display indicates when file transfer is complete.

5. Wait for the message indicating that file transfer is complete before removing the mass storage device from the USB port.

3.15 Controller Application Program

The manufacturer occasionally releases new versions of the controller application code. The new code can be downloaded from the Tech Tools section of the KOHLERnet website (www.Kohlernet.com) and loaded onto the controller through the USB port.

Program Loader software is *not* required for loading code onto the 1500 controller.

To download the latest version of the controller application code:

1. Use your SecurID to go to www.Kohlernet.com and click on Tech Tools.

2. Click on Software and then ATS Controllers.

3. Click on MPAC™ 1500 controller and then click on the link to download the latest software version. The file name will be of the form MPAC1500v####.bin, with v#### indicating the version number. For example, MPAC1500v105. bin contains version 1.05 of the application code.

4. Copy the file onto a mass storage device through the computer's USB port.

5. Load the application code file onto the controller as described in Section 3.14.2, File Transfer.

Loading new code does not change the system settings. After loading a new version of code, check the system settings, input/output assignments, time delays, and other parameters to verify that they are correct for the application.

After loading new code, run a loaded test to verify that the system operates correctly. See Section 3.6, System Test.

3.16 Controller Replacement

Always check for open switches or circuit breakers, loose connections, or faulty wiring before replacing any parts. Replace the controller only if the troubleshooting and test procedures in this manual indicate conclusively that the controller is damaged or inoperative.

The controller contains two circuit boards, the logic board and the power board, which can be replaced individually. The entire controller and plastic housing can also be obtained as a complete assembly. Save the old controller's plastic cover, which includes the transfer switch nameplate, for use with the new controller.

3.16.1 Controller Configuration (Settings)

New controllers are shipped with the factory default settings for the system settings, including voltage, frequency, number of phases, phase rotation, and other user-adjustable settings. After installation, the system parameters must be set for the application.

If the old controller is operable, it may be possible to save the configuration file (MPAC1500_######.cfg) to a USB storage device before removing the controller from the transfer switch. The configuration file contains the system parameter settings, including system setup, source setup, time delays, input and output assignments, and communications settings. The configuration file can be loaded onto the new controller after it is installed. See Section 3.14 for instructions to download and upload files through the controller's USB port.

Note: Operation problems can be caused by incorrect controller settings. Do not load the old configuration file onto the new controller unless you are certain that all the settings in the file are correct.

If the configuration settings file is not available, use the controller user interface to check and adjust the system settings for the application. Refer to the transfer switch operation and installation manual for instructions.

3.16.2 Circuit Board and Electronic Component Handling

Improper removal, installation, transportation, storage, or service can damage sensitive electronic components. Observe the following guidelines to prevent damage when working with circuit boards or electronic components.

Circuit Board and Electronic Component Handling

- Keep circuit boards or electronic components inside the antistatic, cushioned factory packaging until installation.
- Store circuit boards or electronic components in a clean environment away from moisture, vibration, static electricity, corrosive chemicals, and solvents.
- Disconnect all power sources before removing or installing circuit boards or electronic components.
- Wear an approved, grounded, antistatic wrist strap when handling circuit boards or electronic components.
- Carefully hold the circuit board by its edges and not by any of its components or electrical contacts.
- Do not drop the circuit board or electronic components.
- Do not bend the circuit board, electronic components, or electronic component leads.
- Do not strike the circuit board or electronic components using or against a hard object.
- Clean dusty or dirty circuit boards with a vacuum cleaner or soft, dry brush.
- Never attempt circuit board repairs, adjustments, or modifications other than replacing plug-in service parts or performing manufacturer-approved installation or service procedures.

3.16.3 Replacement Procedure

Before removing the old controller, refer to Section 3.16.1. It may be possible to download the system settings from the controller to a file that can later be loaded onto the new controller for more efficient system setup.

Disconnect power to the transfer switch before starting to disconnect the controller. Observe the following safety precautions to avoid injury or equipment damage.

⚠ 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. Turn off 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.

Controller Replacement Procedure

1. Move the generator set master switch to the OFF position.
2. Disconnect the generator set engine starting battery, negative (-) lead first.
3. Disconnect power to the transfer switch by opening switches or circuit breakers to the switch.

Remove the old controller.

4. Open the transfer switch enclosure.
5. Check the voltage at the source lugs to verify that the power is off.
6. Disconnect the transfer switch harness at the P1 connector at the bottom of the controller. See Figure 3-5.
7. Disconnect the programmed-transition board, if equipped, from the controller at connector P2.
8. Disconnect the controller ground wire at the ring terminal on the enclosure door.
9. Disconnect the accessory module assembly at connector P16 at the top of the controller, if connected.
10. Remove the plastic cover from the old controller and save it to install on the new controller assembly.

    Note: The cover includes the transfer switch nameplate, which must remain with the transfer switch.

    To remove the cover, depress the latch at the bottom of the cover. Swing the cover open on its hinges and lift it off.

11. Label and then disconnect any input and output leads connected to terminal strip TB1 on the logic board. See Figure 3-5.
12. Label and then disconnect the RS-485 communication cable from terminal strip TB2 on the logic board (if connected). See Figure 3-5.
13. Disconnect any other communications connections to the ethernet port or the USB port. See Figure 3-5 for connector identification.
14. Disconnect the current sensing accessory at connector P3, if equipped.

15. **To replace the entire controller assembly:**

    a. Support the controller assembly and remove four nuts at the corners.

    b. Carefully remove the entire controller assembly, including the user interface panel, which is part of the assembly.

    c. Replace the entire assembly with a new controller. Secure the four nuts at the corners and tighten them to no more than 6.8 Nm (5 ft. lb. or 60 in. lb.) torque.

    d. Proceed to step 18.

16. **To replace the logic circuit board:**

    a. Disconnect the ribbon cable connecting the two circuit boards.

    b. Disconnect the ribbon cables to the user interface at connectors P14 and P17.

    c. Remove the four mounting screws near the corners of the board and pull the circuit board straight off the carrier.

    d. Set the new circuit board in place and secure with four mounting screws.

    e. Reconnect the ribbon cables.

    f. Proceed to step 18.

17. **To replace the power board:**

    a. Disconnect the ribbon cable connecting the two circuit boards.

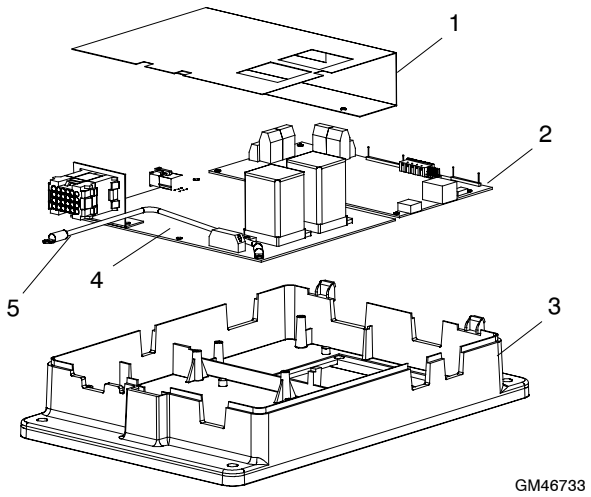
    b. Remove the three mounting screws plus the P1 connector bracket screws and four screws securing the power relays must be removed.

    c. Set the new power board and insulating cover in place. Install the mounting screws, making sure to reinstall the ground lead and the P1 connector with mounting bracket.

    Note: Be sure to reinstall the insulating cover for the power board. See Figure 3-25.

    d. Reconnect the ribbon cable between the boards.

    e. Proceed to step 18.



1. Insulator, power board
2. Logic board
3. Carrier
4. Power board
5. Ground lead

Figure 3-25 Controller Circuit Board Assembly

Reconnect the controller assembly.

18. Connect the controller ground wire to the terminal on the enclosure door. See Figure 3-5.

19. Connect the programmed-transition board, if equipped, to the controller at connector P2. See Figure 3-5.

20. Connect the I/O leads to logic board terminal strip TB1, using the labels attached in step 11 to connect the leads to the appropriate terminals. See Figure 3-5.

21. Connect RS-485 communication cable, if used, to logic board terminal strip TB2, using the labels attached in step 12 to connect the leads to the appropriate terminals. See Figure 3-5.

22. Connect the accessory module assembly (if equipped) at connector P16.

23. Reconnect any other items that were disconnected from the controller. See Figure 3-5 for connector identification.

24. Connect the transfer switch harness to the connector on bottom of the controller.

25. Check the controller's DIP switch settings and adjust them if necessary. See Section 3.10, Controller DIP Switches.

26. Close and lock the transfer switch enclosure door.

27. Reconnect power to the transfer switch by closing circuit breakers or switches.

    Note: Power to the controller is required in order to check and adjust the controller settings. If all the power sources are generator sets, reconnect the normal source generator set engine starting battery and move the generator set master switch to the AUTO position.

Set up the new controller.

28. If the configuration settings (.cfg) file for the transfer switch was downloaded from the old controller, load it onto the new controller through the USB port. See Section 3.16.1. See Section 3.14 for instructions to load the file.

29. If the configuration settings file cannot be loaded through the USB port, use the controller user interface to check and adjust the system settings for the application. Check the system voltage, frequency, number of phases, phase rotation, time delays, and other user-adjustable settings. Refer to the MPAC™ 1500 operation manual for setup instructions.

Note: Power switching device and ATS serial numbers can only be entered through Modbus using Monitor III or a customer-supplied Modbus driver and the distributor-level password.

30. Program input 1 on the main logic board to Inhibit Transfer. Refer to the MPAC™ 1500 operation manual for setup instructions.

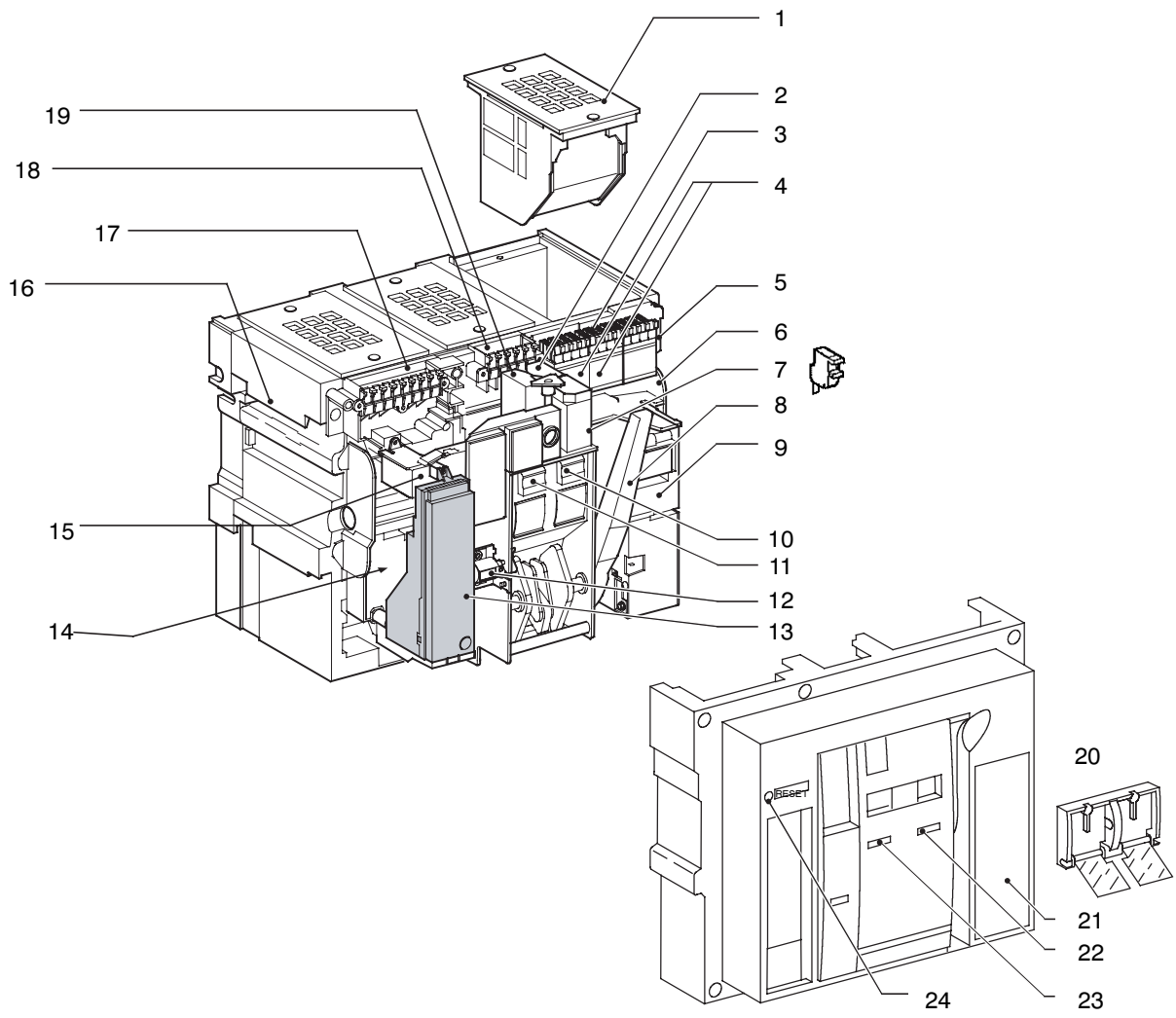
Verify operation.

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

32. Move the generator set master switch to the AUTO position.

33. From the main screen, press the down arrow button and then press the LAMP TEST button to verify that all LEDs light.

34. Run a loaded test to check the system operation. See Section 3.6, System Test.



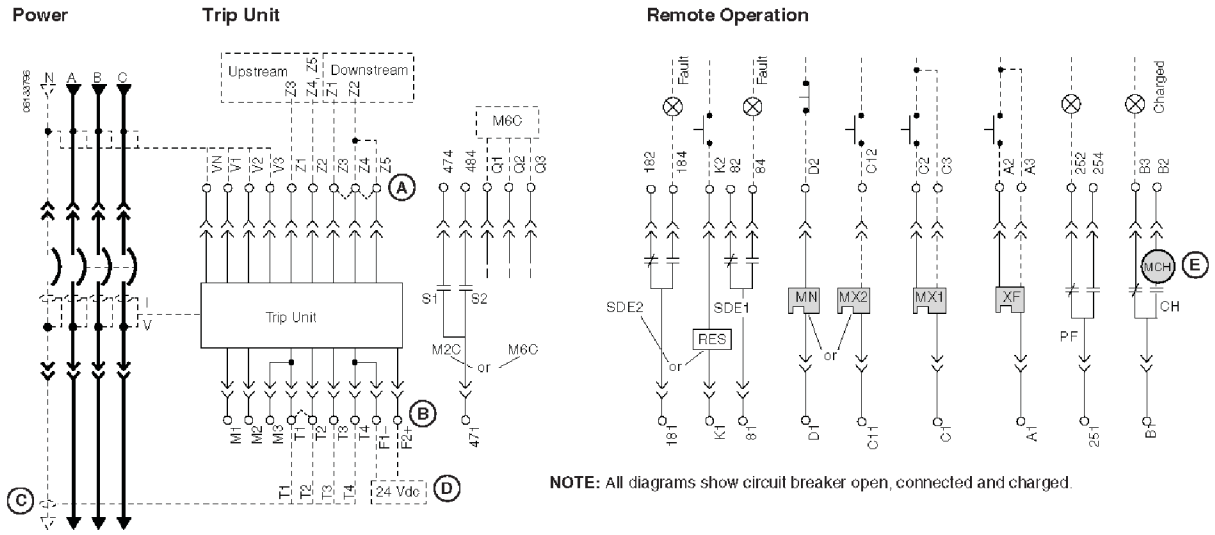
1. Arc chamber
2. Shunt trip (MX1)
3. Auxiliary contact connection
4. Two (2) blocks of four additional switches (OF) or combined connected/closed switches (EF)
5. Block of four form C auxiliary contacts (OF)
6. Shunt close (XF)
7. Ready to close contact (PF)
8. Charging handle
9. Spring charging motor (MCH)
10. Closing pushbutton
11. Opening pushbutton
12. Operation counter
13. Trip unit
14. Overcurrent Trip Switch (SDE1)
15. Overcurrent trip switch (SDE2) or electric reset
16. Lifting tab
17. Trip unit connection to overcurrent trip switch
18. Auxiliary control connection
19. Shunt trip (MX2) or undervoltage trip device (MN)
20. Open/close pushbutton cover (lockable with padlock
21. Faceplate
22. Charged/discharged indicator
23. Open/close indicator
24. Push to reset on fault trip

tp6738

Figure 4-1 ICCB Power Switching Device

Wiring Diagrams

Wiring Diagrams for Masterpact NW Circuit Breakers



A—Do not remove factory-installed jumpers between Z3, Z4 and Z5 unless ZSI is connected.

B—Do not remove factory-installed jumper between T1 and T2 unless neutral CT is connected. Do not install jumper between T3 and T4.

C—For proper wiring of neutral CT, refer to Instrucion Bulletin 48041-082-01 shipped with it.

D—24 Vdc power supply for trip unit must be separate and isolated from 24 Vdc power supply for communication modules.

E—When remote operation features are used, make sure there is a minimum of four seconds for the spring charging motor (MCH) to completely charge the circuit breaker closing springs prior to actuating the shunt close (XF) device.

Markings for Push-In Type Terminals

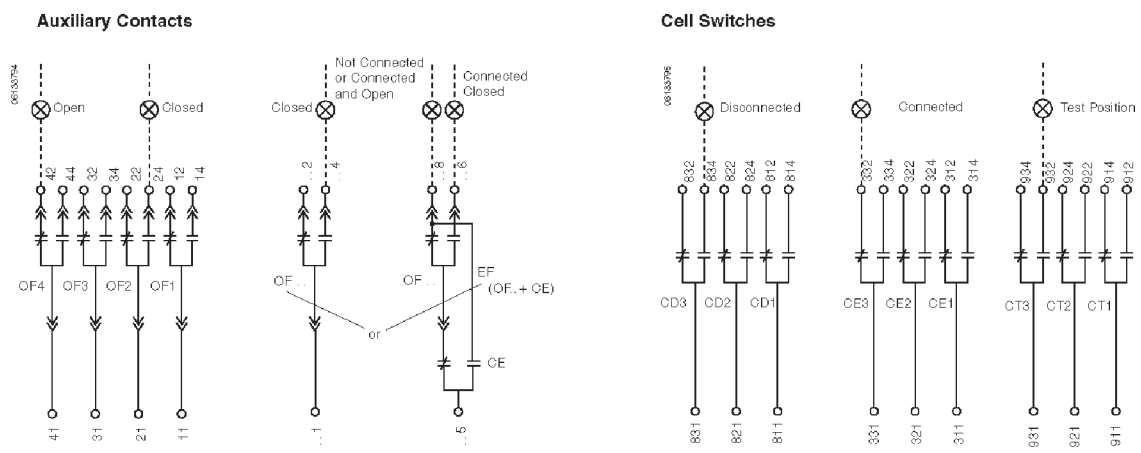
Cell Switches		
CD3	CD2	CD1
834	824	814
832	822	812
831	821	811

or

CE6	CE5	CE4
364	354	344
362	352	342
361	351	341

Trip Unit										Cell Switches			Remote Operation				
COM	UC1		UC2		UC3	UC4	M2C/M6C	SDE2/RES	SDE1	CE3	CE2	CE1	MN/MX2	MX1	XF	PF	MCH
E5 E6	Z5	M1	M2	M3	F2+	V3	484/Q3	184/K2	84	334	324	314	D2/C12	C2	A2	254	B2
E3 E4	Z3	Z4	T3	T4	VN	V2	474/Q2	182	82	332	322	312	C13	C3	A3	252	B3
E1 E2	Z1	Z2	T1	T2	F1–	V1	471/Q1	181/K1	81	331	321	311	D1/C11	C1	A1	251	B1

Figure 4-2 Wiring Diagrams NW Breakers



Markings for Push-In Type Terminals

Auxiliary Contacts												Cell Switches[1]		
OF24	OF23	OF22	OF21	OF14	OF13	OF12	OF11	OF4	OF3	OF2	OF1	CT3	CT2	CT1
244	234	224	214	144	134	124	114	44	34	24	14	934	924	914
242	232	222	212	142	132	122	112	42	32	22	12	932	922	912
241	231	221	211	141	131	121	111	41	31	21	11	931	921	911
or				or								or		
EF24	EF23	EF22	EF21	EF14	EF13	EF12	EF11					CD6	CD5	CD4
248	238	228	218	148	138	128	118					864	854	844
246	236	226	216	146	136	126	116					862	852	842
245	235	225	215	145	135	125	115					861	851	841

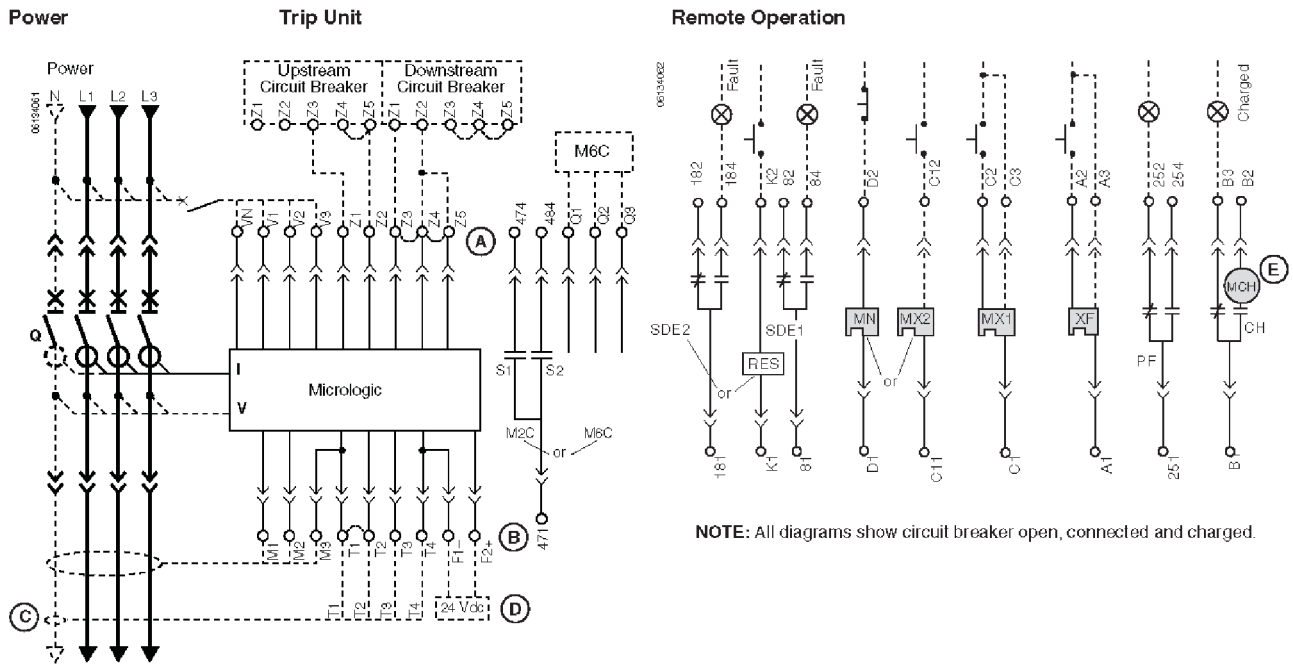
or		
CE9	CE8	C7
394	384	374
392	382	372
391	381	371

[1] Fixed-mounted circuit breaker does not have cell switches (CE, CD, CT).

Figure 4-3 Wiring Diagrams, NT and NW circuit breakers

Wiring Diagrams

Markings for Push-In Type Terminals



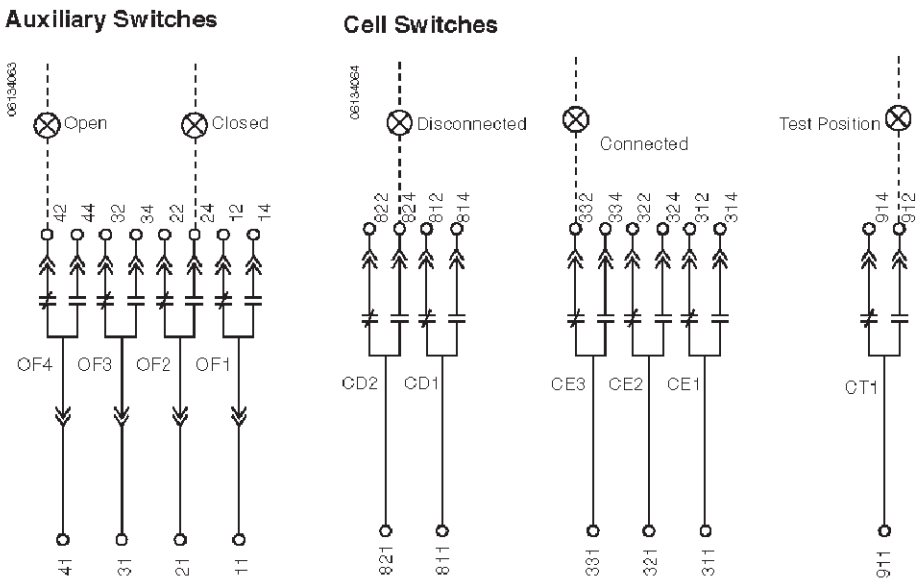
A—Do not remove factory-installed jumpers between Z3, Z4 and Z5 unless ZSI is connected.
B—Do not remove factory-installed jumper between T1 and T2 unless neutral CT is connected. Do not install jumper between T3 and T4.
C—For proper wiring of neutral CT, refer to Instrucion Bulletin 48041-082-01 shipped with it.
D—24 Vdc power supply for trip unit must be separate and isolated from 24 Vdc power supply for communication modules.
E—When remote operation features are used, make sure there is a minimum of four seconds for the spring charging motor (MCH) to completely charge the circuit breaker closing springs prior to actuating the shunt close (XF) device.

Markings for Push-In Type Terminals

Cell Switches		Trip Unit						
CD2	CD1	COM	UC1	UC2	UC3	UC4 / M2C / M6C	SDE2 / RES	SDE1
824	814	E5 E6	Z5 M1	M2 M3	F2+	V3 / 484 / Q3	184 / K2	84
822	812	E3 E4	Z3 Z4	T3 T4	VN	V2 / 474 / Q2	182	82
821	811	E1 E2	Z1 Z2	T1 T2	F1–	V1 / 471 / Q1	181 / K1	81

Remote Operation				
MN / MX2	MX1	XF	PF	MCH
D2 / C12	C2	A2	254	B2
C13	C3	A3	252	B3
D1/C11	C1	A1	251	B1

Figure 4-4 Wiring Diagram NT Breaker for 800 A and 1200 A 3- and 4-Pole ICCB Models



Markings for Push-In Type Terminals

Auxiliary Switches			
OF4	OF3	OF2	OF1
44	34	24	14
42	32	22	12
41	31	21	11

Cell Switches			
CE3	CE2	CE1	CT1
334	324	314	914
332	322	312	912
331	321	311	911

Spring-Charging Motor

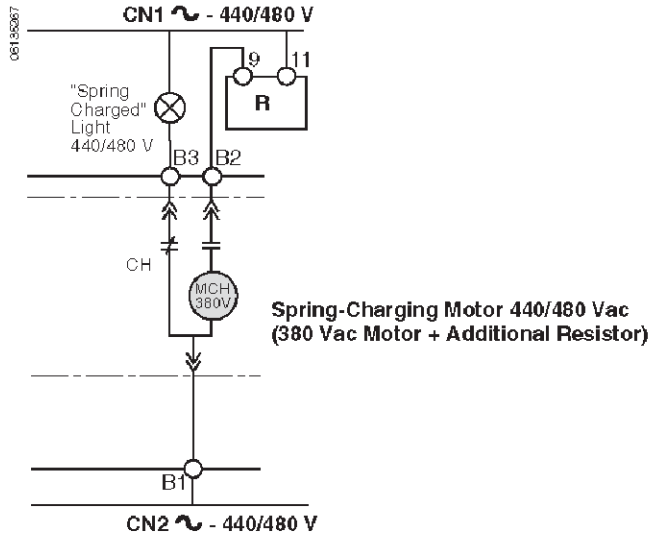


Figure 4-5 Electrical Diagram

Additional Wiring Information

Alarm Contacts (OF1, OF2, OF3 and OF4 are standard equipment)

OF4 OF3 OF2 OF1	Open/Closed Circuit Breaker or Switch Position Contacts	OF24: Open/Closed Circuit Breaker or Switch Position Contact or EF24: Combined Connected and Closed Contact
		OF23 or EF23
		OF22 or EF22
		OF21 or EF21
		OF14 or EF14
		OF13 or EF13
		OF12 or EF12
		OF22 or EF22
		OF11 or EF11

Cradle Contacts

CD3 CD2 CD1	Disconnected Position Contacts	CE3 CE2 CE1	Connected Position Contacts	CT3 CT2 CT1	Test Position Contacts
or				or	
CE6 CE5 CE4	Connected Position Contacts			CE9 CE8 CE7	Connected Position Contacts
				or	
				CD6 CD5 CD4	Disconnected Position Contacts

Trip Unit

Basic	A	P	H		
	X	X	X	Com:	E1–E6 Communication
	X	X	X		Z1–Z5 Logical Selectivity
	X	X	X		Z1 = ZSI OUT
	X	X	X	UC1:	Z2 = ZSI OUT Source; Z3 = ZSI IN Source
	X	X	X		Z4 = ZSI IN Short-Time Delay
	X	X	X		Z5 = ZSI IN Ground Fault
	X	X	X	UC3:	F2+, F1– 24 Vdc External Power Supply
		X	X		External Neutral VN Plug
		X	X	UC4	External Phase Voltage Sensing
		X	X	M2C	Two Programmable Contacts (internal relay)
		X	X	or M6C	Six Programmable Contacts (for connection to external M6C module)

Remote Operation

SDE2 or RES	Electrical Fault Alarm Contact Remote Reset
SDE1	Electrical Fault Alarm Contact (standard)
MN or MX2	Undervoltage Trip Device Additional Shunt Trip
MX1	Shunt Trip (standard or networked)
XF	Shunt Close (standard or networked)
PF	Ready-to-Close Contact
MCH	Spring-Charging Motor

NOTE: When communication version of the MX1 or XF coils are used, terminals (C3, A3) must be connected to line even if the communications module is not installed.

The bypass circuit through terminal C2/A2 is only momentary duty for 0.5 sec. For continuous duty, use the communications command.

Figure 4-6 Additional Wiring Information for ICCB Breakers

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	advanced digital control; analog to digital converter
adj.	adjust, adjustment
ADV	advertising dimensional drawing
Ah	amp-hour
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
APDC	Air Pollution Control District
API	American Petroleum Institute
approx.	approximate, approximately
APU	Auxiliary Power Unit
AQMD	Air Quality Management District
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
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
CAN	controller area network
CARB	California Air Resources Board
CAT5	Category 5 (network cable)
CB	circuit breaker
CC	crank cycle
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)
com	communications (port)
coml	commercial
Coml/Rec	Commercial/Recreational
conn.	connection
cont.	continued
CPVC	chlorinated polyvinyl chloride
crit.	critical
CSA	Canadian Standards Association
CT	current transformer
Cu	copper
cUL	Canadian Underwriter's Laboratories
CUL	Canadian Underwriter's Laboratories
cu. in.	cubic inch
cw.	clockwise
CWC	city water-cooled
cyl.	cylinder
D/A	digital to analog
DAC	digital to analog converter
dB	decibel
dB(A)	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^2PROM, EEPROM	electrically-erasable programmable read-only memory
E, emer.	emergency (power source)
ECM	electronic control module, engine control module
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
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
ftp	file transfer protocol
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 temp., high engine temp.
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)
IBC	International Building Code
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	internet protocol
ISO	International Organization for Standardization
J	joule
JIS	Japanese Industry Standard
k	kilo (1000)
K	kelvin
kA	kiloampere
KB	kilobyte (2^{10} bytes)
KBus	Kohler communication protocol
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
kWth	kilowatt-thermal
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
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
$m^3/hr.$	cubic meters per hour
$m^3/min.$	cubic meters per minute
mA	milliampere
man.	manual
max.	maximum
MB	megabyte (2^{20} bytes)
MCCB	molded-case circuit breaker
MCM	one thousand circular mils
meggar	megohmmeter
MHz	megahertz
mi.	mile
mil	one one-thousandth of an inch
min.	minimum, minute
misc.	miscellaneous
MJ	megajoule
mJ	millijoule
mm	millimeter
mOhm, mΩ	milliohm
MOhm, MΩ	megohm
MOV	metal oxide varistor
MPa	megapascal
mpg	miles per gallon
mph	miles per hour
MS	military standard
ms	millisecond
m/sec.	meters per second
mtg.	mounting
MTU	Motoren-und Turbinen-Union
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
psig	pounds per square inch gauge
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
RO	read only
ROM	read only memory
rot.	rotate, rotating
rpm	revolutions per minute
RS	right side
RTDs	Resistance Temperature Detectors
RTU	remote terminal unit
RTV	room temperature vulcanization
RW	read/write
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
SMTP	simple mail transfer protocol
SN	serial number
SNMP	simple network management protocol
SPDT	single-pole, double-throw
SPST	single-pole, single-throw
spec	specification
specs	specification(s)
sq.	square
sq. cm	square centimeter
sq. in.	square inch
SMS	short message service
SS	stainless steel
std.	standard
stl.	steel
tach.	tachometer
TB	terminal block
TCP	transmission control protocol
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
THD	total harmonic distortion
TIF	telephone influence factor
tol.	tolerance
turbo.	turbocharger
typ.	typical (same in multiple locations)
UF	underfrequency
UHF	ultrahigh frequency
UIF	user interface
UL	Underwriter's Laboratories, Inc.
UNC	unified coarse thread (was NC)
UNF	unified fine thread (was NF)
univ.	universal
URL	uniform resource locator (web address)
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
WO	write only
w/o	without
wt.	weight
xfmr	transformer

Appendix B Common Hardware Application Guidelines

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

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

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

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

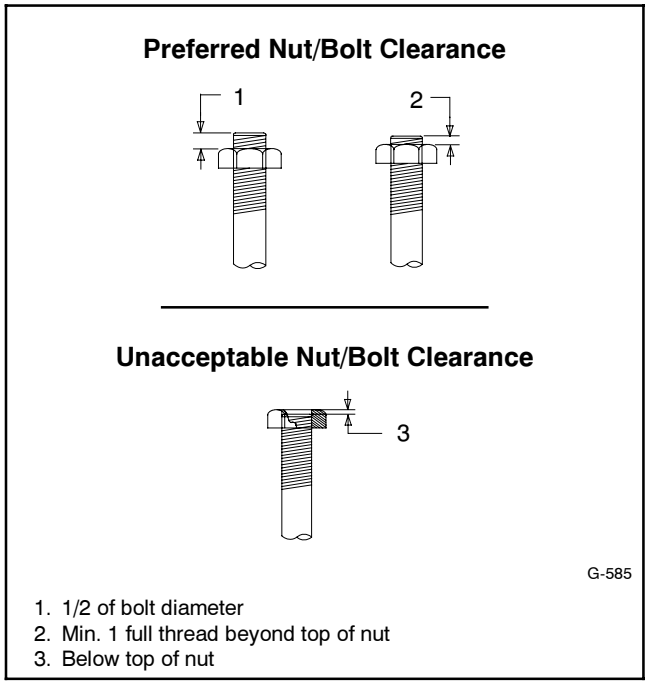


Figure 1 Acceptable Bolt Lengths

Steps for common hardware application:

1. Determine entry hole type: round or slotted.

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

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

3. Follow these SAE washer rules after determining exit hole type:

   a. Always use a washer between hardware and a slot.

   b. Always use a washer under a nut (see 2 above for exception).

   c. Use a washer under a bolt when the female thread is fixed (weld nut).

4. Refer to Figure 2, which depicts the preceding hardware configuration possibilities.

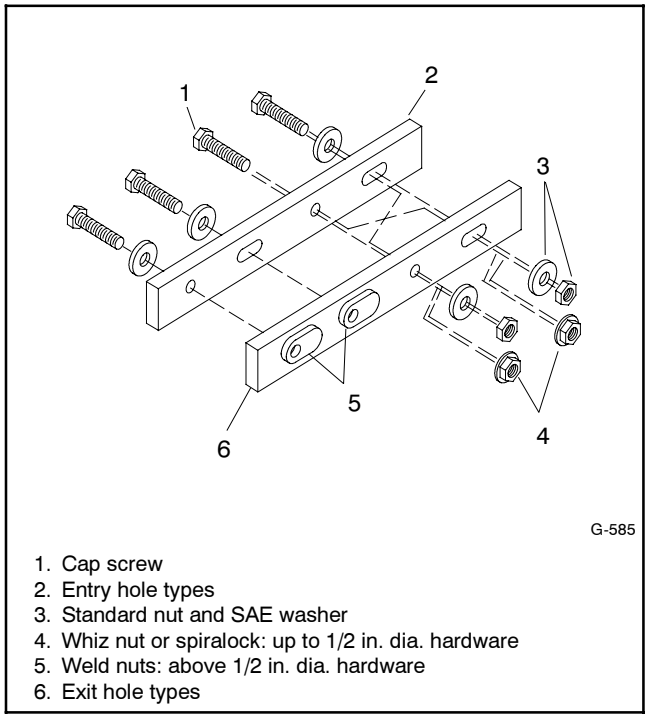


Figure 2 Acceptable Hardware Combinations

Appendix C General Torque Specifications

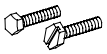
American Standard Fasteners Torque Specifications									
Size	Torque Measurement	Assembled into Cast Iron or Steel						Assembled into Aluminum Grade 2 or 5
		Grade 2		Grade 5		Grade 8		
8-32	Nm (in. lb.)	1.8	(16)	2.3	(20)	—		See Note 3
10-24	Nm (in. lb.)	2.9	(26)	3.6	(32)	—		
10-32	Nm (in. lb.)	2.9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

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

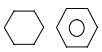
Notes:

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

Appendix D Common Hardware Identification

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

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

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

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

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

Sample Dimensions

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

1/4-20 x 1

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

Metric (Screws, Bolts, Studs, and Nuts)

M8-1.25 x 20

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

Plain Washers

9/32 x 5/8 x 1/16

- Thickness
- External Dimension
- Internal Dimension

Lock Washers

5/8

- Internal Dimension

Appendix E Common Hardware List

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

American Standard

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

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

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

Washers

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

Metric

Hex head bolts are hardness grade 8.8 unless noted.

Hex Head Bolts (Partial Thread)

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

Hex Head Bolts (Partial Thread), continued

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

Hex Head Bolts (Full Thread)

Part No.	Dimensions
M933-04006-60	M4-0.70 x 6
M933-05030-60	M5-0.80 x 30
M933-05035-60	M5-0.80 x 35
M933-05050-60	M5-0.80 x 50
M933-06010-60	M6-1.00 x 10
M933-06012-60	M6-1.00 x 12
M933-06014-60	M6-1.00 x 14
M933-06016-60	M6-1.00 x 16
M933-06020-60	M6-1.00 x 20
M933-06025-60	M6-1.00 x 25
M933-06030-60	M6-1.00 x 30
M933-06040-60	M6-1.00 x 40
M933-06050-60	M6-1.00 x 50
M933-07025-60	M7-1.00 x 25
M933-08010-60	M8-1.25 x 10
M933-08012-60	M8-1.25 x 12
M933-08016-60	M8-1.25 x 16
M933-08020-60	M8-1.25 x 20
M933-08025-60	M8-1.25 x 25
M933-08030-60	M8-1.25 x 30
M933-08030-82	M8-1.25 x 30*
M933-10012-60	M10-1.50 x 12
M961-10020-60	M10-1.25 x 20
M933-10020-60	M10-1.50 x 20
M933-10025-60	M10-1.50 x 25
M961-10025-60	M10-1.25 x 25
M933-10025-82	M10-1.50 x 25*
M961-10030-60	M10-1.25 x 30
M933-10030-60	M10-1.50 x 30
M933-10030-82	M10-1.50 x 30*
M961-10035-60	M10-1.25 x 35
M933-10035-60	M10-1.50 x 35
M933-10035-82	M10-1.50 x 35*
M961-10040-60	M10-1.25 x 40

Hex Head Bolts (Full Thread), continued

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

Pan Head Machine Screws

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

Flat Head Machine Screws

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

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

Metric, continued

Part No.	Dimensions	Type
Hex Nuts		
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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