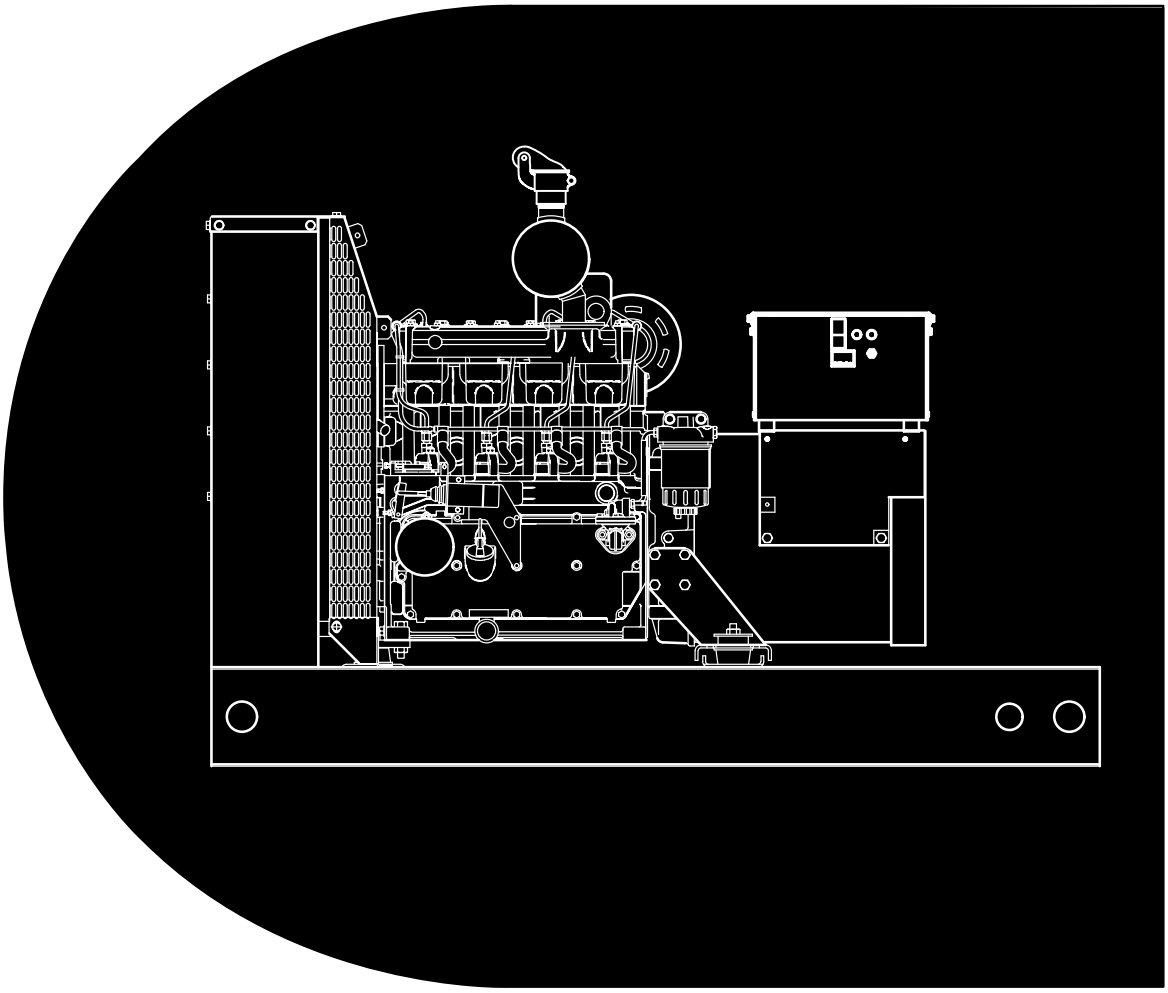
Caution: This document contains mixed page sizes (8.5 x 11 or 11 x 17), which may affect printing. Please adjust your printer settings according to the size of each page you wish to print.

Power Generation

Service Manual

DN Series Generator Sets



Printed in U.S.A.

967-0508B 10-2001

California

Proposition 65 Warning

Diesel engine exhaust and some of its constituents are known to the State of California to cause cancer, birth defects, and other reproductive harm.

Table of Contents

Safety Precautions

Thoroughly read the OPERATOR'S MANUAL before operating the generator set. Safe operation and top performance can be obtained only when equipment is operated and maintained properly.

The following symbols in this Manual alert you to potential hazards to the operator, service person and equipment.

⚠ DANGER ***alerts you to an immediate hazard which will result in severe personal injury or death.***

⚠WARNING ***alerts you to a hazard or unsafe practice which can result in severe personal injury or death.***

⚠ CAUTION ***alerts you to a hazard or unsafe practice which can result in personal injury or equipment damage.***

Electricity, fuel, exhaust, moving parts and batteries present hazards which can result in severe personal injury or death.

GENERAL PRECAUTIONS

- Keep ABC fire extinguishers handy.
- Make sure all fasteners are secure and torqued properly.
- Keep the generator set and its compartment clean. Excess oil and oily rags can catch fire. Dirt and gear stowed in the compartment can restrict cooling air.
- Let the engine cool down before removing the coolant pressure cap or opening the coolant drain. Hot coolant under pressure can spray out and cause severe burns.
- Before working on the generator set, disconnect the negative (**–**) battery cable at the battery to prevent starting.
- Use caution when making adjustments while the generator set is running—hot, moving or electrically live parts can cause severe personal injury or death.
- Used engine oil has been identified by some state and federal agencies as causing cancer or reproductive toxicity. Do not ingest, inhale, or contact used oil or its vapors.
- Do not work on the generator set when mentally or physically fatigued or after consuming alcohol or drugs.
- Carefully follow all applicable local, state and federal codes.

GENERATOR VOLTAGE IS DEADLY!

- Generator output connections must be made by a qualified electrician in accordance with applicable codes.
- The generator set must not be connected to the public utility or any other source of electrical power. Connection could lead to electrocution of utility workers, damage to equipment and fire. An approved switching device must be used to prevent interconnections.
- Use caution when working on live electrical equipment. Remove jewelry, make sure clothing and shoes are dry and stand on a dry wooden platform on the ground or floor.

FUEL IS FLAMMABLE AND EXPLOSIVE

- Do not fill the fuel tank while the engine is running unless the tank is outside the engine compartment.
- Keep flames, cigarettes, sparks, pilot lights, electrical arc-producing equipment and switches and all other sources of ignition well away from areas where fuel fumes are present and areas sharing ventilation.
- Fuel lines must be secured, free of leaks and separated or shielded from electrical wiring.
- Use approved non-conductive flexible fuel hose for fuel connections at the generator set.

ENGINE EXHAUST IS DEADLY!

- The exhaust system must be leak-free and convey all exhaust to the out-of-doors, away from buildings and building air vents, doors and windows. Look and listen for exhaust leaks daily and do not operate the generator set until all leaks have been fixed.
- Do not use engine exhaust or cooling air to heat a room or compartment.
- Make sure there is ample fresh air when operating the generator set.

MOVING PARTS CAN CAUSE SEVERE PERSONAL INJURY OR DEATH

- Do not wear loose clothing or jewelry near moving parts such as PTO shafts, fans, belts and pulleys.
- Keep hands away from moving parts.
- Keep guards in place over fans, belts, pulleys, etc.

BATTERY GAS IS EXPLOSIVE

- Wear safety glasses and do not smoke while servicing batteries.
- When disconnecting or reconnecting battery cables, always disconnect the negative (–) battery cable first and reconnect it last to reduce arcing.

DO NOT OPERATE IN FLAMMABLE AND EXPLOSIVE ENVIRONMENTS

Flammable vapor can cause a diesel engine to overspeed and become difficult to stop, resulting in possible fire, explosion, severe personal injury and death. ***Do not operate a diesel-powered generator set where a flammable vapor environment can be created by fuel spill, leak, etc., unless the generator set is equipped with an automatic safety device to block the air intake and stop the engine.*** The owners and operators of the generator set are solely responsible for operating the generator set safely. Contact your authorized Onan/Cummins dealer or distributor for more information.

KEEP THIS MANUAL NEAR THE GENERATOR SET FOR EASY REFERENCE

SD-1

1. Introduction

ABOUT THIS MANUAL

This is the service manual for the DN series of generator sets. Three different generator set control schemes are available for this series of generator sets and each is covered in a separate section of this manual. Separate troubleshooting guides for control, engine and generator also appear throughout this manual. See the Table of Contents.

The wiring diagrams in the back of this manual are for reference only. Make wiring connections on the basis of the wiring diagrams shipped with the generator set.

This manual does not have instructions for servicing printed circuit board assemblies. Always replace a faulty printed circuit board assembly. Attempts to repair a printed circuit board can lead to costly damage to the equipment.

Read ***Safety Precautions*** and carefully observe all instructions and precautions in this manual.

⚠WARNING ***Improper service can lead to equipment damage, severe personal injury or death. Service must be performed by qualified persons who know about fuel, electrical and mechanical hazards. Read Safety Precautions and carefully observe all instructions and precautions in this manual.***

⚠WARNING ***Unauthorized modifications or replacement of fuel, exhaust, air intake or speed control system components that affect engine emissions are prohibited by law on generator sets certified by EPA.***

TEST EQUIPMENT

Most of the tests in this manual can be done with an AC-DC multimeter, frequency meter, load test panel and Wheatstone bridge (0.001 ohm precision is necessary for measuring generator stator winding resistance).

FUEL RECOMMENDATIONS

Use clean, fresh No. 2 diesel fuel (ASTM 2-D) in ambients above freezing and No. 1 diesel fuel (ASTM 1-D) in ambients below freezing. The fuel should have a Cetane number of at least 45 for reliable starting.

⚠WARNING ***Diesel fuel is combustible and can cause severe personal injury or death. Do not smoke near diesel fuel tanks or equipment. Keep flames, sparks, pilot lights, switches, other and arc-producing equipment and all other sources of ignition well away. Keep a type ABC fire extinguisher handy.***

ENGINE OIL RECOMMENDATIONS

Use API (American Petroleum Institute) performance Class **CH-4**, **CG-4** or **CF-4** engine oil, which may be in combination with performance Class SJ, SH or SG (for example: CH-4/SJ). Also look for the SAE (Society of Automotive Engineers) viscosity grade. Referring to Figure 1-1, choose the viscosity grade appropriate for the outdoor ambient temperatures expected until the next scheduled oil change.

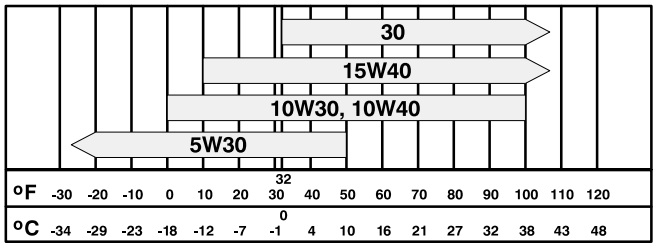


FIGURE 1-1. SAE VISCOSITY GRADE vs. AMBIENT TEMPERATURE

THIS PAGE LEFT INTENTIONALLY BLANK

2. Specifications

	MODEL					
	DNAA	DNAB	DNAC	DNAD	DNAE	DNAF
GENERATOR: Single-Bearing, 4-Pole Rotating Field, Brushless, Electronically Regulated. See Generator Set Nameplate for Rating.						
ENGINE: Mechanically or Electronically Governed 4-Stroke Cycle Direct-Injection Diesel						
Number of Cylinders	2	3	2	3	4	4
Bore	76.0 mm (2.99 inch)	76.0 mm (2.99 inch)	86.0 mm (3.38 inch)	86.0 mm (3.38 inch)	86.0 mm (3.38 inch)	86.0 mm (3.38 inch)
Stroke	80 mm (3.15 inch)	80 mm (3.15 inch)	80 mm (3.15 inch)	80 mm (3.15 inch)	80 mm (3.15 inch)	80 mm (3.15 inch)
Displacement	0.72 liter 44.24 in^3	1.089 liter 66.45 in^3	0.93 liter 56.75 in^3	1.395 liter 85.13 in^3	1.860 liter 113.50 in^3	1.860 liter 113.50 in^3
Compression Ratio	18.5:1	18.5:1	18.5:1	18.5:1	18.5:1	16.2:1
Firing Order	1-2	1-2-3	1-2	1-2-3	1-3-4-2	1-3-4-2
Aspiration	Natural	Natural	Natural	Natural	Natural	Turbo-charger
Cooling Method	Air	Air	Water	Water	Water	Water
Coolant Capacity (Engine and Radiator)	not applicable	not applicable	6.5 liter (6.8 quart)	7.1 liter (7.5 quart)	7.6 liter (8.0 quart)	7.6 liter (8.0 quart)
Engine Oil Capacity*	3.2 liter (3.4 quart)	4.4 liter (4.7 quart)	3.2 liter (3.4 quart)	4.4 liter (4.7 quart)	5.7 liter (6.1 quart)	5.7 liter (6.1 quart)
Fuel Injection Timing	19-21° BTDC					
Rotation	Clockwise (looking at the fan or radiator end)					
Valve Lash	Hydraulic tappets					
Maximum Fuel Pump Lift	3 meter (10 feet)					
Fuel Supply Connection	6 mm (0.24 inch) ID Hose Fitting					
Fuel Return Connection	3.5 mm (0.14 inch) ID Hose Fitting					
BATTERIES:**						
Nominal Battery Voltage	12 volts					
Minimum CCA (Cold Cranking Amps)	525 amps					
Charging Alternator Output	45 amps					
INSTALLATION SPECIFICATIONS:						
See the appropriate Specification Bulletin and Outline Drawing for minimum cooling air flow; fuel, exhaust and electrical connection points; overall dimensions; weight; etc.						

* Includes Oil Filter

** A battery mounted in the built-in battery rack in the skid base must be of a type with barbed vent hose fittings for its cells. The vent lines must routed away from the generator end bell (air inlet) to prevent battery gasses from entering the generator and causing corrosion.

THIS PAGE LEFT INTENTIONALLY BLANK

3. Generator Set Control—Manual

⚠WARNING ***EXHAUST GAS IS DEADLY!***

All engine exhaust contains carbon monoxide, an odorless, colorless, poisonous gas that can cause unconsciousness and death. Symptoms of carbon monoxide poisoning include:

- ***Dizziness***
- ***Nausea***
- ***Vomiting***
- ***Headache***
- ***Weakness and Sleepiness***
- ***Inability to Think Coherently***

IF YOU EXPERIENCE ANY OF THESE SYMPTOMS, GET INTO FRESH AIR IMMEDIATELY. If symptoms persist, seek medical attention. Shut down the genset and do not operate it until it has been inspected and repaired.

The exhaust system must be installed in accordance with the genset Installation Manual. Make sure there is ample fresh air when operating the genset in a confined area.

PRESTART CHECKS

Perform any scheduled maintenance and check the following before starting the generator set.

Fuel

Check the fuel supply and refill as necessary.

Engine Oil

Check engine oil level. Keep the oil level as near as possible to the dipstick high mark without overfilling.

Engine Coolant

Check engine coolant level (liquid-cooled engines). Note the normal level of coolant in the radiator top tank when the engine is cold (within 25 mm [1 inch] of top). Add coolant if it falls below this level. Use a 50/50 mixture of ethylene glycol and water.

⚠WARNING ***Hot coolant can cause severe burns. Let the engine cool down before removing the pressure cap.***

OPERATION

A Manual Control has an **OFF/RUN/START** switch on the control panel. It may also have an **ON/OFF** preheat switch. The control shuts down the genset under low oil pressure and high engine temperature conditions. The fuse protects the control circuits from shorts to ground. See Figure 3-1 or 3-2.

Starting

If the generator set is so equipped, hold the preheat switch in the **ON** position for 20 seconds for easier starting in colder weather. Then hold the control switch at **START** until the engine starts. Let go to disengage the starter. The genset should run up to governed speed and regulated voltage in a few seconds.

Whenever possible, let the engine warm up for a few minutes before connecting electrical loads.

See TROUBLESHOOTING in this section if the generator set does not start after a couple of tries or keeps shutting down.

⚠ CAUTION ***Excessive cranking can overheat and damage the starter motor. Do not crank for more than 30 seconds at a time and wait at least 1 minute before trying again.***

Stopping

Push the control switch to **OFF**. Whenever possible, let the engine cool down by running without load for a few minutes before stopping.

ENGINE SHUTDOWN SWITCHES

Figure 3-3 illustrates the locations of the engine shutdown switches. Use pipe thread sealant when replacing a safety switch.

⚠ CAUTION ***Do not use teflon tape for switches and senders that are grounded to the engine by thread contact as it may interfere with the ground path.***

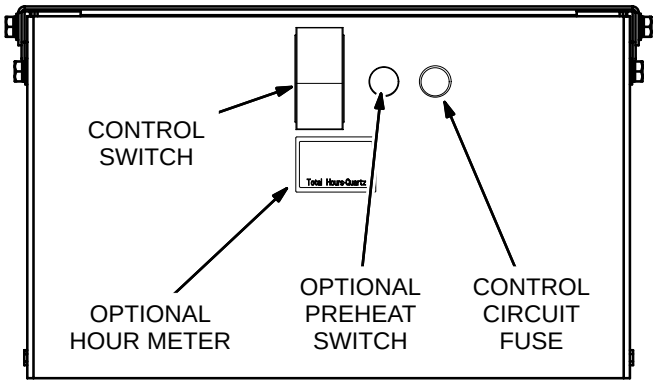


FIGURE 3-1. CONTROL PANEL (BEGIN SPEC B)

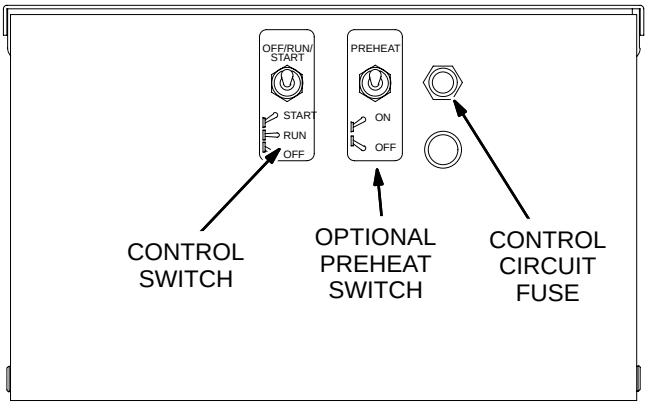


FIGURE 3-2. CONTROL PANEL (SPEC A)

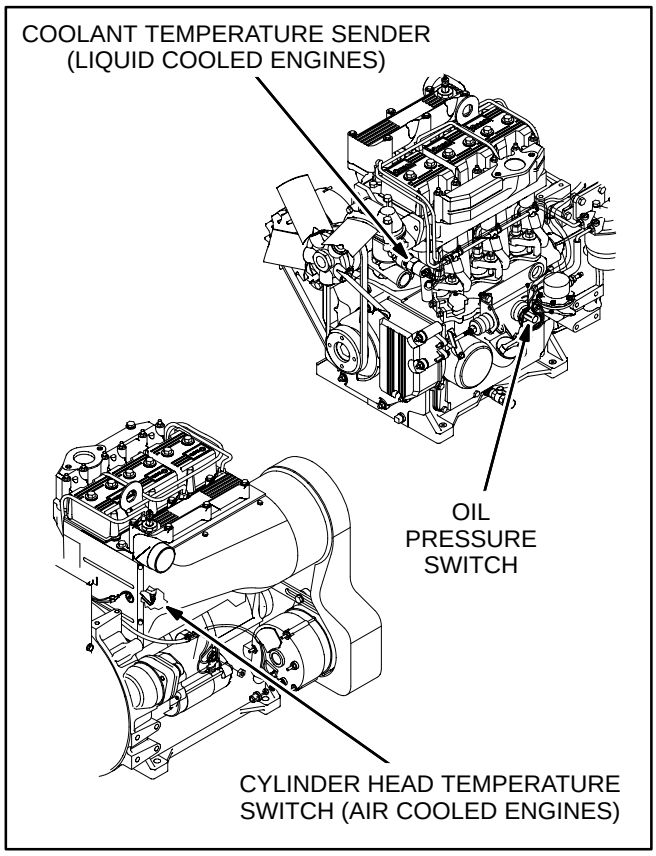


FIGURE 3-3. ENGINE SHUTDOWN SWITCHES

CONTROL LOGIC (BEGINNING SPEC B)

Figure 3-4 illustrates the control box. The wiring diagrams are on Page B-9. Control logic is as follows:

1. The control circuits are connected to **B+** (12 VDC) through control circuit fuse F1. Terminals **TB1-6** and **TB1-9** are grounded (**B–**)

2. Holding control switch S12 in the **START** position energizes fuel stop solenoid K1 and electronic governor A12 (if so equipped) and starter motor B1 and flashes the field of battery charging alternator G1. The generator set should start and run up to governed speed and regulated voltage within a few seconds. Releasing the control switch disconnects the starter. The control switch moves to the **RUN** position.

3. If engine oil pressure fails, oil pressure switch S1 will reclose (NC). If engine temperature exceeds design limits, the coolant temperature switch or the cylinder head temperature switch (S2) will close (NO). In either case, fault relay K14 is energized shutting off fuel to the engine.

4. Pushing the control switch to **OFF** de-energizes fuel stop solenoid K1 shutting off fuel to the engine.

5. The glow plugs (when so equipped) are energized through relay K15 when preheat switch S15 is held in the **ON** position.

6. See Section 6 for a description of generator operation.

CONTROL LOGIC (SPEC A)

Figure 3-4 illustrates the control box. The wiring diagram is on Page A-9. Control logic is as follows:

1. The control and preheat circuits are connected to **B+** (12 VDC) through the 10 amp *Control Circuit Fuse*. Terminals **4** and **8** are grounded (**B–**).

2. Holding the *Control Switch* in the **START** position energizes the *Fuel Control Solenoid* (FCS) and *Starter Motor* and flashes the *Battery Charging Alternator* (BCA) field. The generator set should start and run up to governed speed and regulated voltage in a few seconds. Releasing the *Control Switch* disconnects the starter. The switch moves to the **RUN** position.

3. If engine oil pressure fails, the *Oil Pressure Switch* contacts will reclose (NC). If engine temperature exceeds design limits, the *High Engine Temperature Switch* contacts will close (NO). In either case, the *Fault Relay* is energized shutting off fuel to the engine.

4. Pushing the *Control Switch* to the **OFF** position de-energizes the FCS circuit shutting off fuel to the engine.

5. The *Glow Plugs* (when so equipped) are energized through the *Glow Plug Relay* when the *Preheat Switch* is held in the **ON** position.

6. See the section, 6. *Voltage Regulator*, for a description of generator operation.

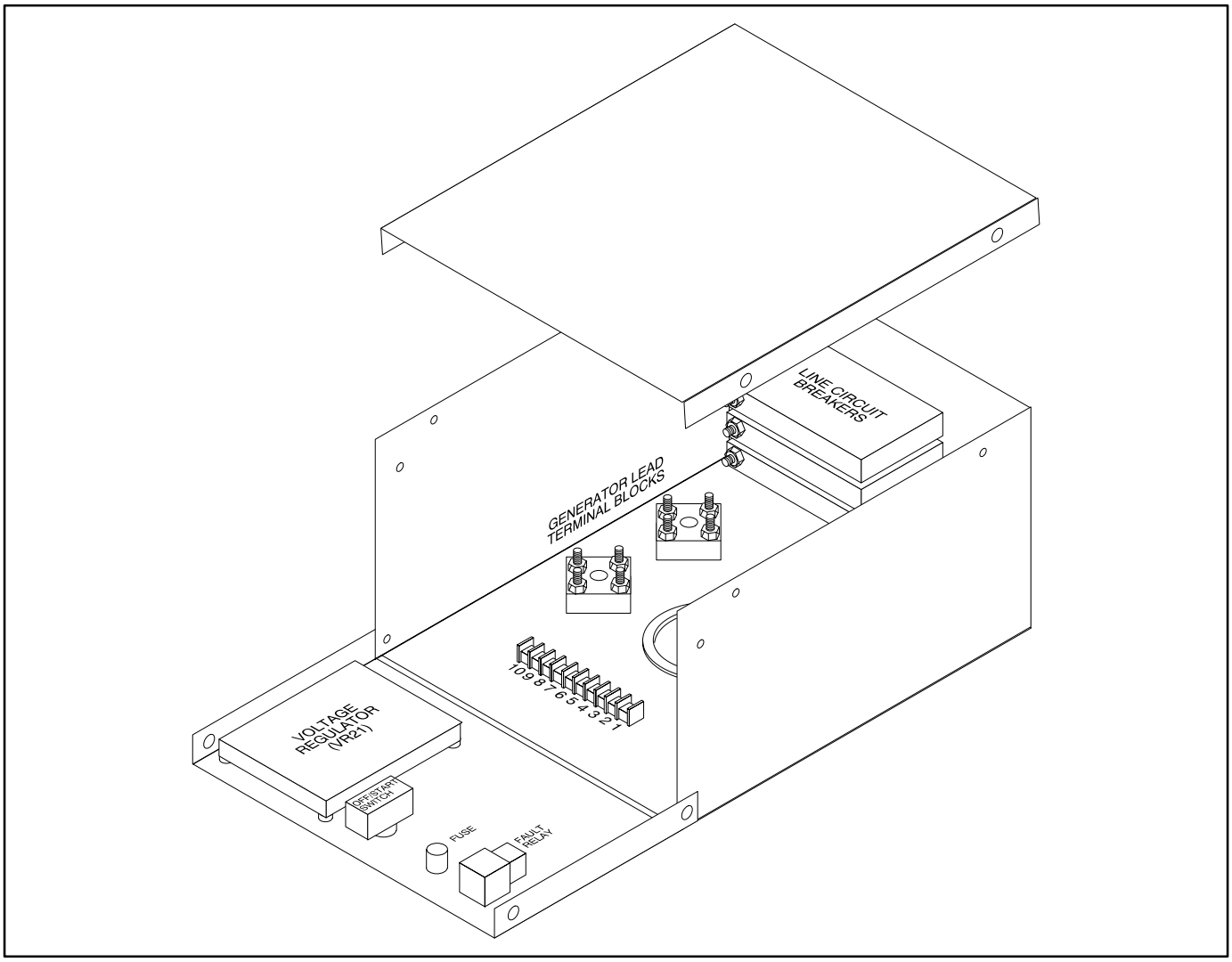


FIGURE 3-4. CONTROL BOX

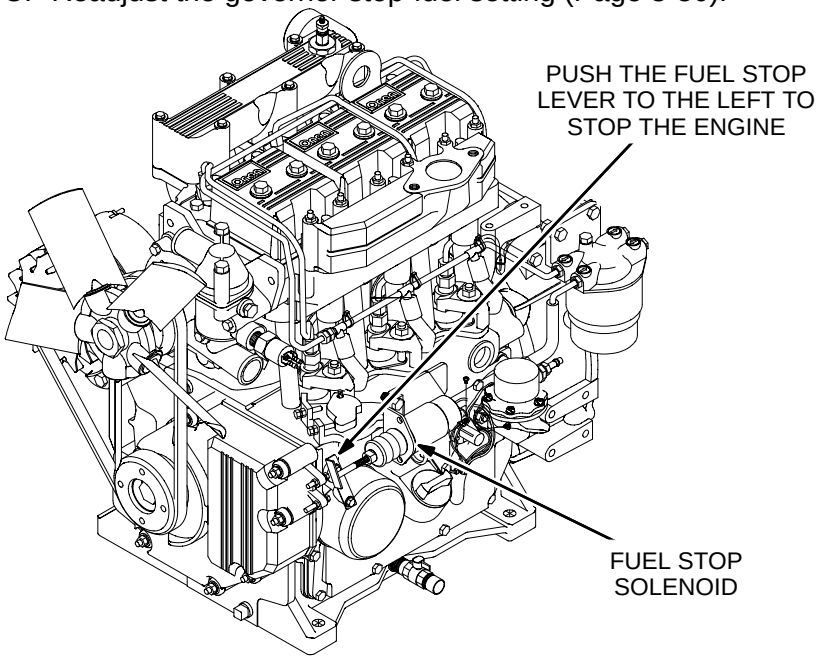
TROUBLESHOOTING

The following troubleshooting tables are designed to help you think through generator set problems. To save time troubleshooting, read the entire manual ahead of time to understand the generator set. Try to think through problems. Go over what was done during the last service call. The problem could be as simple as an empty fuel tank, closed fuel shut-off valve, loose wire, blown fuse or tripped circuit breaker. Refer to the wiring diagrams on Page A-9 or B-9.

SEE THE SECTION, *7. GENERATOR*, FOR GENERATOR FAULTS

THE ENGINE DOES NOT STOP RUNNING

⚠ WARNING ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***

Possible Cause	Corrective Action
1. The fuel stop solenoid is malfunctioning.	A. To stop the engine, push the engine control lever to the left and hold it there until the engine stops (see figure) or block the engine air intake. B. Apply 12 VDC across the fuel stop solenoid. Replace the solenoid if it does not function. C. Readjust the governor stop-fuel setting (Page 8-50). 

THE ENGINE DOES NOT CRANK

⚠ **WARNING** ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***

Possible Cause	Corrective Action
1. Control panel fuse F1 has blown.	Look for a loose, grounded wire, reconnect or replace it and replace the fuse with one of the same type and amp rating (20 Amp, Beginning Spec B; 10 Amp, Spec A).
2. Cranking voltage is too low to crank the engine.	A. Clean and tighten or replace the positive (**+**) and negative (**–**) battery cable connectors and cables at the battery and the set. B. Recharge or replace the battery. Specific gravity for a fully charged battery is approximately 1.260 at 80° F (27° C). C. If the set is in standby service, install a battery charger. D. Replace the engine-driven battery charging alternator if normal battery charging voltage is not between 12 and 14 volts.
3. The starter motor is faulty.	Hold the control switch S12 in the **Start** position and check for battery voltage (12 VDC) at the starter solenoid coil terminal. Replace the starter motor if there is voltage but the motor does not function.
4. Starter circuit wiring is loose or missing.	If there is no voltage at the starter solenoid coil terminal when the control switch S12 is in the **Start** position, check the gray/orange wires between the solenoid and **TB1-4** (**3**, Spec A) and between the terminal and control switch S12, the red wires between S12 and control fuse F1 and the red wires between F1 and the **B+** terminal on the starter motor solenoid. Repair as necessary.
5. Control switch S12 is faulty.	Hold control switch S12 in the **Start** position and check for electrical continuity across the terminals to which the red and gray/orange leads are connected. Replace the switch if it is open in the **Start** position.

THE ENGINE CRANKS BUT DOES NOT START

⚠ **WARNING** ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***

Possible Cause	Corrective Action
1. The engine is not getting fuel.	A. Open any closed shutoff valve in the fuel supply system. B. Fill the fuel supply tank. C. Restore fuel prime (Page 8-41).
2. The air cleaner is dirty or the exhaust system is clogged.	Service as necessary.
3. Low engine temperature is causing too low a cranking speed for starting.	A. Plug in, repair or install engine coolant and engine oil heaters. B. Replace the engine oil if it is not of the recommended viscosity for the ambient temperature.
4. Cranking voltage is too low to reach required cranking speed.	A. While cranking the engine measure voltage across each battery cable—terminal post to terminal post. Service as necessary if voltage drop across either cable is more than 0.5 VDC. B. Recharge or replace the battery. Specific gravity for a fully charged battery is approximately 1.260 at 80° F (27° C). C. Replace the engine-driven battery charging alternator if normal battery charging voltage is not between 12 and 14 volts.
5. The preheat circuit is faulty.	Service the glow plug(s), glow plug relay K15, preheat switch S15 and connected wiring as necessary.
6. Fuel shutoff solenoid K1 is faulty.	Disconnect the leads of fuel shutoff solenoid K1 and apply **B+**. Replace K1 if it does not pull in and stay in.
7. Fuel shutoff solenoid K1 circuit wiring is loose or missing .	Check all the red/orange wires connected to **TB1-5** (**10**, Spec A) and all the black wires to **TB1-6** (**4**, Spec A). Repair as necessary.
8. The engine or fuel system is worn or malfunctioning mechanically.	Service the engine according to Section 8.

THE ENGINE STARTS BUT STOPS WHEN THE SWITCH IS RELEASED

⚠ **WARNING** ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***

Possible Cause	Corrective Action
1. Control switch S12 is faulty.	Check for **B+** at the switch terminal to which the blue lead is connected when the switch is in the **Run** position. Replace the switch if there is no voltage.
2. Fault relay K14 is faulty.	Check electrical continuity across fault relay K14 terminals **30** and **87a** when the engine is not running. Replace the relay if it is open.
3. Fuel shutoff solenoid K1 circuit wiring is loose or missing.	**Beginning Spec B**—Check the red/orange wires between **TB1-5** and **TB1-8** and between **TB1-8** and **87a** on fault relay K14, the blue jumper between **30** and **85** on K14 and the blue wire between **85** and control switch S12. Repair as necessary. **Spec A**—Check the red/orange wire between terminal **10** to **87a** on the fault switch, the blue jumper between **30** and **85** on the fault switch and the blue wire between **85** and the control switch. Repair as necessary.
4. Fault relay K14 coil terminal **86** is grounded.	Check the brown wire between **86** on fault relay K14 and **TB1-10** (**9**, Spec A), the brown wire between **TB1-10** (**9**, Spec A) and oil pressure switch S1 and the dark blue/light blue wire between oil pressure switch S1 and coolant temperature switch S2. Repair as necessary.
5. The low oil pressure cutoff switch fails to open.	See THE ENGINE RUNS UNTIL FAULT SHUTDOWN.
6. The high engine temperature switch fails to open.	See THE ENGINE RUNS UNTIL FAULT SHUTDOWN.

THE ENGINE RUNS UNTIL FAULT SHUTDOWN	
⚠ WARNING ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***	
Possible Cause	**Corrective Action**
1. High engine temperature or faulty safety switch.	A. Check the engine coolant level, repair any leaks and fill to the proper level (liquid cooled engines). B. Remove obstructions to air flow and clean and service the cooling system as required to restore full cooling capacity. C. Replace high engine temperature switch S2 if there is electrical continuity across the switch terminals at room temperature. (Air cooled engines have a 260° F [127° C] head bolt mounted temperature switch [Figure 3-3].)
2. Low engine oil pressure or faulty safety switch.	A. Check the engine oil level, repair any leaks and fill to the proper level. B. Install an oil pressure gauge in place of low oil pressure cut-out switch S1, close the manual fuel shutoff valve to keep the engine from starting and observe oil pressure while cranking the engine. Replace S1 if oil pressure is greater than 10 psi (69 kPa). Service the lubricating oil system if oil pressure is less than 10 psi (69 kPa). See Section 8.

THE ENGINE LACKS POWER OR IS UNSTABLE

⚠ WARNING ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***

Possible Cause	Corrective Action
1. Fuel delivery to the set is inadequate.	A. Check for clogged fuel lines and filters. B. Check for air in the fuel lines. C. Check the vertical distance from the bottom of the fuel dip tube to the fuel lift pump. The distance must not exceed 3 meters (10 feet).
2. The fuel is contaminated.	Connect the fuel lift pump to a container of fuel of known quality. Replace the contents of the fuel supply tank if there is a noticeable difference in performance.
3. The air cleaner is dirty or the exhaust system is clogged.	Service as necessary.
4. The engine or engine fuel system is worn or out of adjustment.	Service the engine according to Section 8.

THE ENGINE IDLES

⚠ WARNING ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***

Possible Cause	Corrective Action
1. The electronic governor is disconnected, out of adjustment or malfunctioning.	Service the governor (Page 8-51).

4. Generator Set Control—Remote/ATS

WARNING ***EXHAUST GAS IS DEADLY!***

All engine exhaust contains carbon monoxide, an odorless, colorless, poisonous gas that can cause unconsciousness and death. Symptoms of carbon monoxide poisoning include:

- ***Dizziness***
- ***Headache***
- ***Nausea***
- ***Weakness and Sleepiness***
- ***Vomiting***
- ***Inability to Think Coherently***

IF YOU EXPERIENCE ANY OF THESE SYMPTOMS, GET INTO FRESH AIR IMMEDIATELY. If symptoms persist, seek medical attention. Shut down the genset and do not operate it until it has been inspected and repaired.

The exhaust system must be installed in accordance with the genset Installation Manual. Make sure there is ample fresh air when operating the genset in a confined area.

PRESTART CHECKS

Perform any scheduled maintenance and check the following before starting the generator set.

Fuel

Check the fuel supply and refill as necessary.

Engine Oil

Check engine oil level. Keep the oil level as near as possible to the dipstick high mark without overfilling.

Engine Coolant

Check engine coolant level (liquid-cooled engines). Note the normal level of coolant in the radiator top tank when the engine is cold (within 25 mm [1 inch] of top). Add coolant if it falls below this level. Use a 50/50 mixture of ethylene glycol and water.

WARNING ***Hot coolant can cause severe burns. Let the engine cool down before removing the pressure cap.***

OPERATION

A Remote/ATS Control has a **RUN/OFF/REMOTE** switch on the control panel for manual or remote, automatic control (Figure 4-1 or 4-2). The control automatically disengages the starter when the engine starts and shuts down the genset under low oil pressure, high engine temperature and overcrank conditions. The circuit breaker on the control panel requires reset following a shutdown. The fuse protects the control circuits from shorts to ground.

Manual Starting

If the generator set is so equipped, hold the preheat switch in the **ON** position for 20 seconds for easier starting in colder weather. Then push the control switch to **RUN**. The generator set should start, disengage the starter and run up to governed speed and regulated voltage in a few seconds.

Whenever possible, let the engine warm up for a few minutes before connecting electrical loads.

The engine will stop cranking in approximately 60 seconds if it has not started and the button on the circuit breaker on the control panel will pop out. Reset the control by first pushing the control switch to **OFF** and then resetting the circuit breaker on the panel by pushing in the button. See TROUBLESHOOTING in this section if the genset does not start or keeps shutting down.

Manual Stopping

Push the control switch to **OFF**. Whenever possible, let the engine cool down by running without load for a few minutes before stopping.

Remote Automatic Starting and Stopping

Push the control switch to **REMOTE** for remote control by an automatic transfer switch (ATS).

⚠ CAUTION ***To restore automatic remote control of the generator set, make sure to push the control switch to REMOTE before leaving.***

Remote Fault Monitoring

If the generator set is equipped with the optional Dry Contact Module, generator shutdown can be monitored by a remote two-light panel. See Page 4-6.

ENGINE SHUTDOWN SWITCHES

Figure 4-3 illustrates the locations of the engine shutdown switches. Use pipe thread sealant when replacing a safety switch.

⚠ CAUTION ***Do not use teflon tape for switches and senders that are grounded to the engine by thread contact as it may interfere with the ground path.***

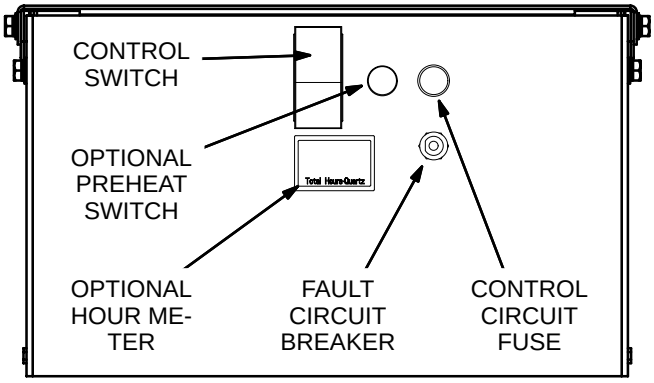


FIGURE 4-1. CONTROL PANEL (BEGIN SPEC B)

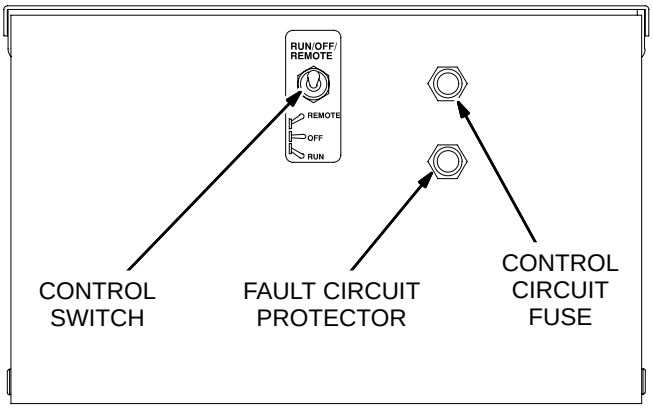


FIGURE 4-2. CONTROL PANEL (SPEC A)

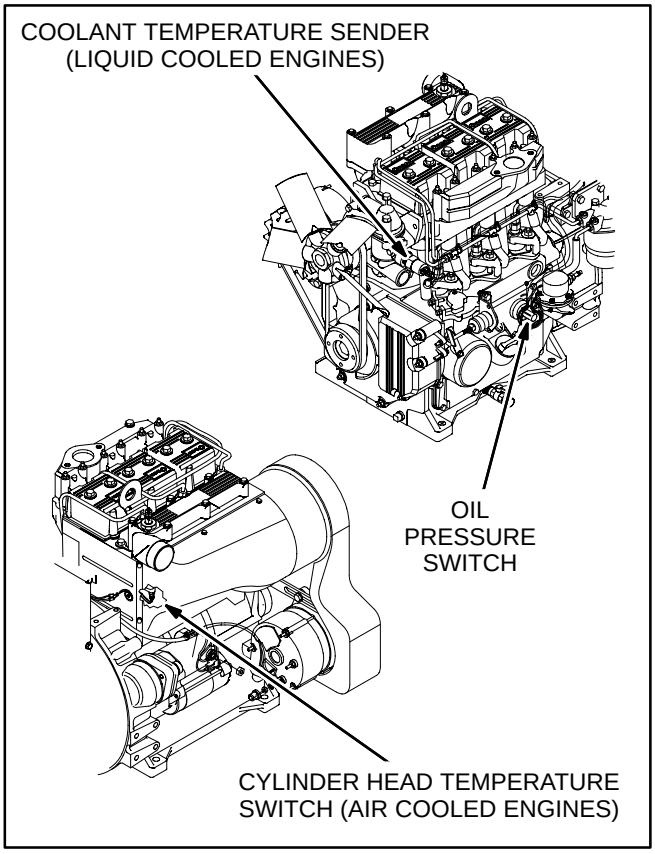


FIGURE 4-3. ENGINE SHUTDOWN SWITCHES

CONTROL LOGIC (BEGINNING SPEC B)

Figure 4-4 illustrates the control box. The wiring diagrams are on Page B-7/B-8. Control logic is as follows:

1. The control circuits are connected to **B+** (12 VDC) through control circuit fuse F1. **TB1-6** is grounded (**B–**).

2. Pushing control switch S12 to **RUN** energizes relay K14, which closes K14 contacts **30-87**, which:

   A. Energizes fuel shutoff solenoid K1 and electronic governor A12 (if so equipped) through **TB1-5**.

   B. Energizes starter relay K12, which is energized through **30-87a** of DC disconnect relay K13 (not yet energized).

   C. Starts 60 second overcrank timer TD (terminal **B**) through **30-87a** of DC disconnect relay K13 (not yet energized).

   D. Flashes the field of battery charging alternator G1 through resistor R1 and diode CR2. (The resistor limits field flash voltage to a level that cannot cross the threshold of Zener diode CR1 and thus prematurely energize DC disconnect relay K13.)

3. The generator set should start and run up to governed speed and regulated voltage in a few seconds and the starter should automatically disconnect.

4. Start disconnect occurs when DC disconnect relay K13 is energized, opening **30-87a**. This causes starter relay K12 to drop out, opening **30-87**.

   DC disconnect relay K13 is energized as the result of either of two (redundant) events, whichever occurs first:

   A. Generator voltage crosses the pull-in threshold of AC disconnect relay K21 closing **1-2** and thus energizing DC disconnect relay K13 through **TB1-7**.

   B. The field voltage (terminal **D+**) of battery charging alternator G1 crosses the threshold of Zener diode CR1 energizing DC disconnect relay K13 through **TB1-7**.

5. Energizing DC disconnect relay K13 also closes **30-87** on K13 to latch the relay (through TD terminal **2**) and start the 10 second fault timer (TD terminal **2**). (Latching K13 prevents reengagement of the starter if the AC and DC start-disconnect signals both fail.)

6. If engine oil pressure fails, oil pressure switch S1 will reclose (NC). If engine temperature exceeds design limits, coolant temperature switch S2 will close (NO). The switches are connected in parallel to time delay relay TD terminal **3**, which provides a 10 second delay (see Step 5) before closing to TD terminal **1** (GND), which is grounded through **TB1-6**. This allows time for the oil pressure switch to open as the engine runs up to speed, preventing nuisance shutdown.

   In either case (low oil pressure or high engine temperature), shunt trip relay K11 is energized, which closes the shunt trip coil circuit in fault circuit breaker CB1, opening the breaker and causing it to shut down fuel.

7. If the engine does not start within 60 seconds, the overcrank delay (see Step 2.C) at time delay relay TD terminal **A** will time out, energizing the shunt trip relay causing it to shut down fuel, ignition and throttle.

8. To restore operation after having cleared the fault which caused shutdown, push control switch S12 to **OFF** and reset fault circuit breaker CB1 by pushing the reset button on the control panel.

9. Pushing control switch S12 to **OFF** shuts down fuel, ignition and throttle.

10. When the remote control contacts across **TB1-2** and **TB1-3** close and control switch S12 is left in its **REMOTE** position, the sequence of operation is the same as when S12 is in its **RUN** position. When the remote contacts open, the shutdown sequence is the same as when S12 is in its **OFF** position.

11. See Section 6 for a description of generator operation.

CONTROL LOGIC (SPEC A)

Figure 4-4 illustrates the control box. The wiring diagrams are on Page A-8. Control logic is as follows:

1. The control circuits are connected to **B+** (12 VDC) through the *Control Circuit Fuse*. Terminal **4** is connected to **B–** (Ground).

2. Pushing the *Control Switch* to **RUN**:

   A. Energizes the *Fuel Control Solenoid* (FCS) through terminal **10**.

   B. Energizes the *Starter Motor* through the *Starter Relay*, which is energized through **30-87a** of the *DC Disconnect Relay* (not yet energized).

   C. Starts the 60 second overcrank timer (*Time Delay Relay* terminal **B**) through **30-87a** of the *DC Disconnect Relay* (not yet energized).

   D. Flashes the *Battery Charging Alternator* (BCA) field through the resistor and diode between terminals **5** and **10**. (The resistor limits field flash voltage to a level that cannot cross the *Zener Diode* threshold [terminals **5** and **6**] and thus energize the *DC Disconnect Relay*.)

3. The generator set should start and run up to governed speed and regulated voltage in a few seconds and the starter should automatically disconnect.

4. Start disconnect occurs when the *DC Disconnect Relay* is energized, opening **30-87a**. This causes the *Starter Relay* to drop out, opening **30-87.**

   The *DC Disconnect Relay* is energized as the result of either of two (redundant) events, whichever occurs first:

   A. Generator voltage crosses the pull-in threshold of the *AC Disconnect Relay* to energize the *DC Disconnect Relay* through terminal **6**.

   B. *Battery Charging Alternator* field voltage (BCA terminal **17**) crosses the *Zener Diode* threshold (across terminals **5** and **6**) to energizing the *DC Disconnect Relay*.

5. Energizing the *DC Disconnect Relay* also closes **30-87** to latch the *DC Disconnect Relay* (through terminal **6**) and start the 10 second fault timer (*Time Delay Relay* terminal **2**). (Latching the *DC Disconnect Relay* prevents re-engagement of the starter if the AC and DC start-disconnect signals are both lost.)

6. If engine oil pressure fails, the *Oil Pressure Switch* contacts will reclose (NC). If engine temperature exceeds design limits, the *High Engine Temperature Switch* contacts will close (NO). The switches are connected in parallel to *Time Delay Relay* terminal **3**, which provides a 10 second delay (see Step 5) before closing to relay terminal **1** (GND), which is grounded through terminal **4**. This allows time for the oil pressure switch to open as the engine runs up to speed, preventing nuisance shutdown.

   In either case (low oil pressure or high engine temperature), the *Shunt Trip Relay* is energized, causing it to close the shunt trip coil circuit in the *Fault Circuit Breaker*, opening the breaker to de-energize the FCS circuit, shutting off fuel to the engine.

7. If the engine does not start within 60 seconds, the overcrank delay (see Step 2.C) at *Time Delay Relay* terminal **A** will time out to energize the *Shunt Trip Relay* to cause shutdown.

8. To restore operation after having cleared the fault which caused shutdown, push the *Control Switch* to **OFF** and reset the *Fault Circuit Breaker* by pushing the reset button on the control panel.

9. Pushing the *Control Switch* to **OFF** opens the FCS circuit to shut off fuel to the engine.

10. Pushing the *Control Switch* to **REMOTE** will result in the same sequence of operation as **RUN** when the *Remote Contacts* (across terminals **1** and **2**) close, and as **OFF** when the contacts open.

11. See the section, 6. *Voltage Regulator*, for a description of generator operation.

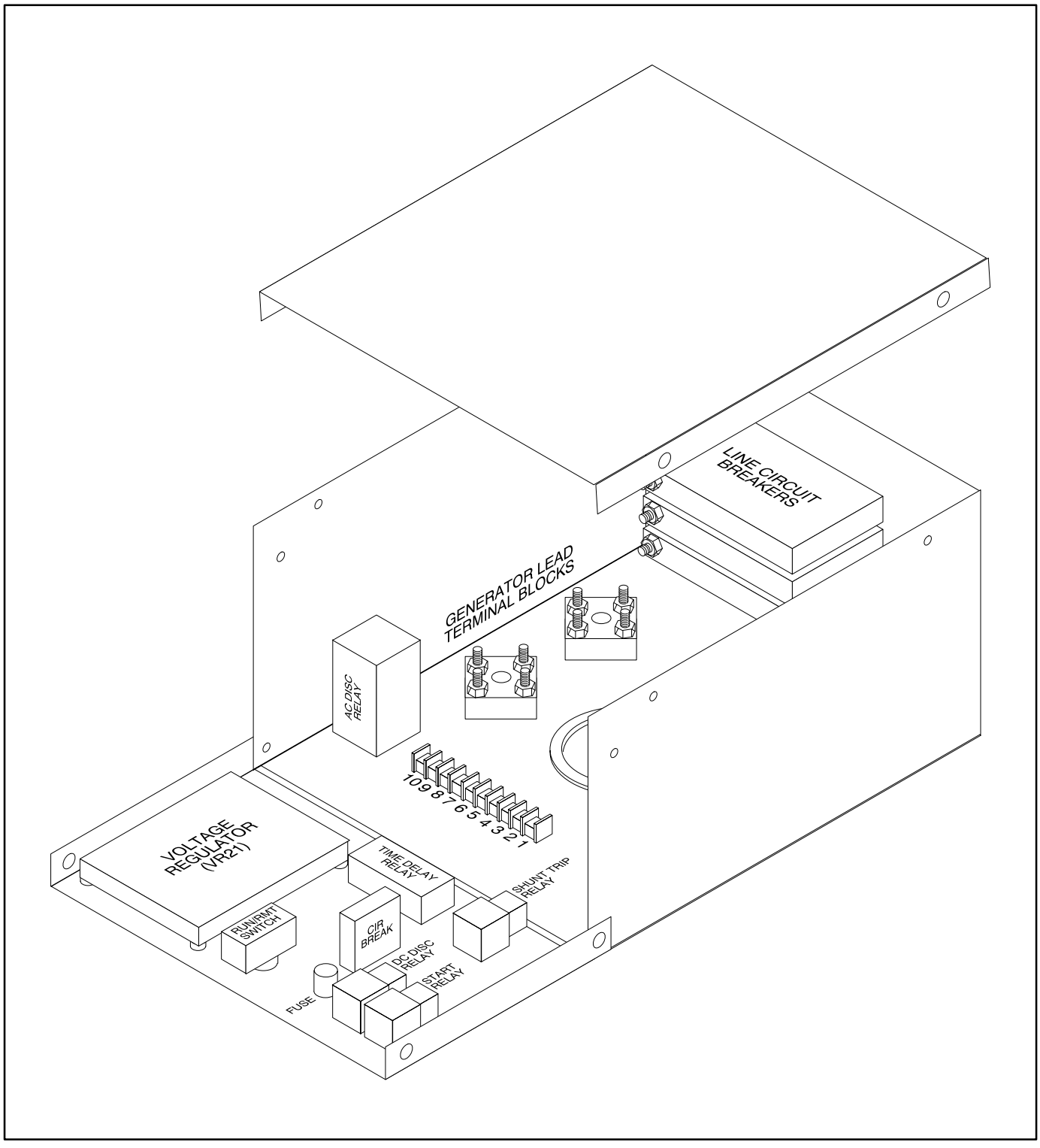


FIGURE 4-4. CONTROL BOX

DRY CONTACT MODULE (OPTIONAL)

The dry contract module provides for the connection of remote monitoring devices. Make the connections to the 1/4 inch (5.35 mm) quick-connect terminals on relays **K8** and **K9** of the module (Figure 4-5). The pilot duty ratings of the monitoring devices must not exceed 15 amperes.

The following faults will activate relays **K8** or **K9** as follows:

RELAY K8	RELAY K9
Over Crank Low Oil Pressure High Engine Temperature Low Coolant Level Low Fuel Level	Low Fuel Level Rupture Basin

Note that the Low Fuel Level (LFL) will activate both relays. This enables the operator to distinguish between the following error conditions when relays **K8** and **K9** are connected to a two light remote panel.

- **K8** only: All **K8** error conditions except for LFL.
- **K9** only: Rupture Basin
- **K8** and **K9**: Low Fuel Level *****

***** It is possible to have two coincidental faults (one engine fault and the rupture basin) and not have a low fuel condition.

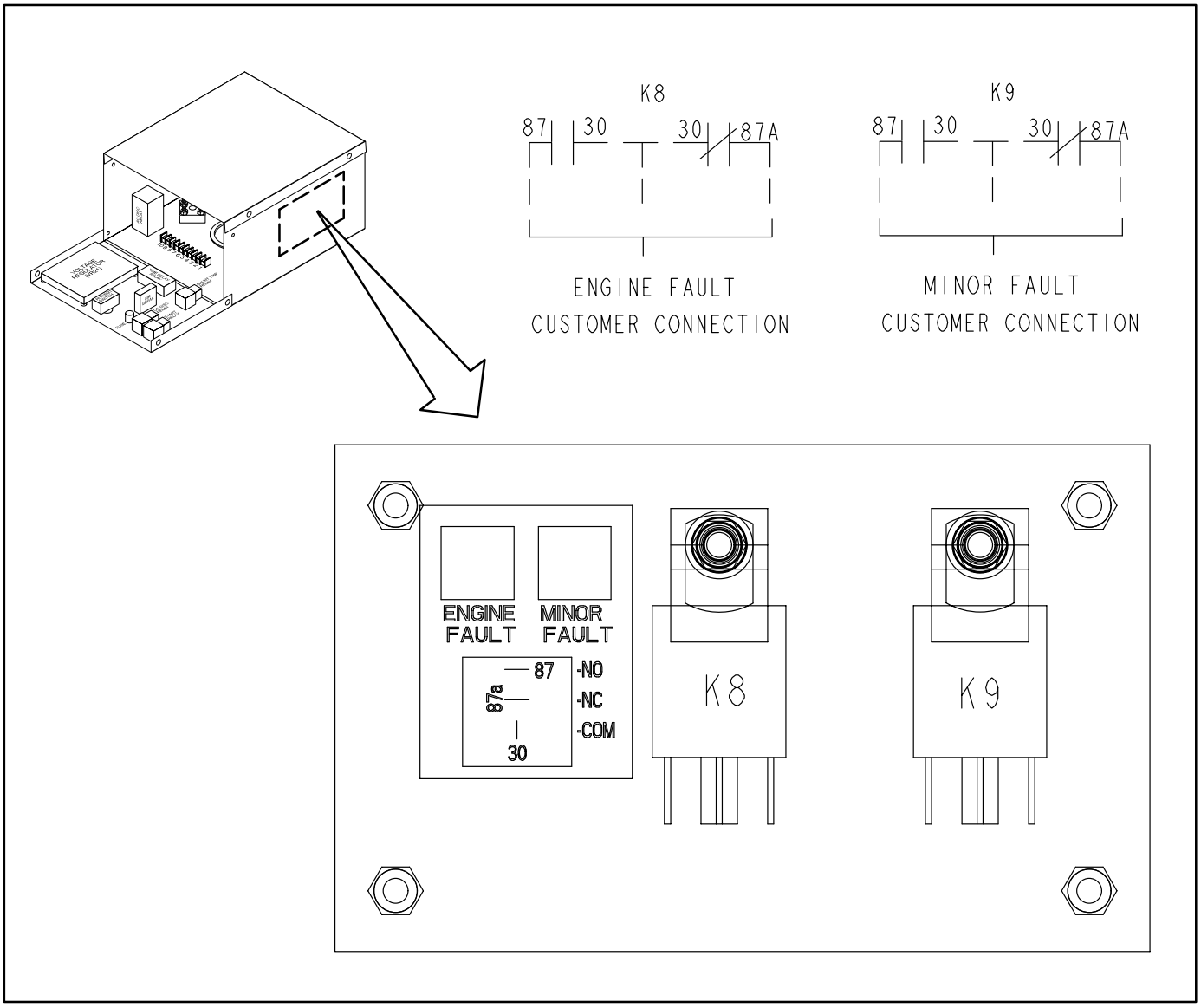


FIGURE 4-5. DRY CONTACT MODULE

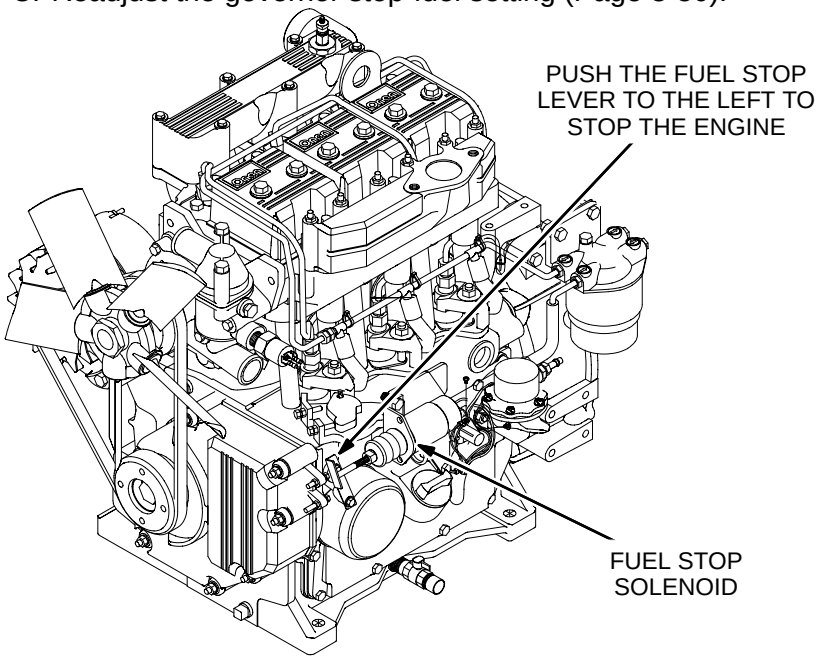
TROUBLESHOOTING

The following troubleshooting tables are designed to help you think through generator set problems. To save time troubleshooting, read the entire manual ahead of time to understand the generator set. Try to think through problems. Go over what was done during the last service call. The problem could be as simple as an empty fuel tank, closed fuel shut-off valve, loose wire, blown fuse or tripped circuit breaker. Refer to the wiring diagram on Page A-8 or B-7/B-8.

SEE THE SECTION, *7. GENERATOR*, FOR GENERATOR FAULTS

THE ENGINE DOES NOT STOP RUNNING

⚠ **WARNING** ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***

Possible Cause	Corrective Action
1. The fuel stop solenoid is malfunctioning.	A. To stop the engine, push the engine control lever to the left and hold it there until the engine stops (see figure) or block the engine air intake. B. Apply 12 VDC across the fuel stop solenoid. Replace the solenoid if it does not function. C. Readjust the governor stop-fuel setting (Page 8-50). 

THE ENGINE DOES NOT CRANK IN RUN MODE

⚠ **WARNING** ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***

Possible Cause	Corrective Action
1. Control panel fuse F1 has blown.	Look for a loose, grounded wire, reconnect or replace it and replace the fuse with one of the same type and amp rating (20 Amp, Beginning Spec B; 10 Amp, Spec A).
2. A **Fault Shutdown** is being indicated by fault circuit breaker CB1 reset button (extended out).	Service the set as necessary. To reset, push the control switch S12 to **Off** and push in the reset button on the fault circuit breaker.
3. Cranking voltage is too low to crank the engine.	A. Clean and tighten or replace the positive (**+**) and negative (**–**) battery cable connectors and cables at the battery and the set. B. Recharge or replace the battery. Specific gravity for a fully charged battery is approximately 1.260 at 80° F (27° C). C. If the set is in standby service, install a battery charger. D. Replace the engine-driven battery charging alternator if normal battery charging voltage is not between 12 and 14 volts.
4. Starter motor B1 is faulty.	Push control switch S12 to the **Run** position and check for battery voltage (12 VDC) at starter solenoid coil terminal. Replace the starter motor if there is voltage but the motor does not function.
5. Starter circuit wiring is loose or missing.	If there is no voltage at the starter solenoid coil terminal when control switch S12 is at **Run**, check the gray/orange wires between the starter solenoid and terminal **TB1-4** (**3**, Spec A) and between the terminal and starter relay K12 and the red wires between K12 and the **B+** terminal on the starter motor solenoid. Repair as necessary.
6. Fault circuit breaker CB1 is faulty.	Replace fault circuit breaker CB1 if the reset button pushes in and stays in but there is no **B+** at terminal **3**.
7. Control switch S12 is faulty.	Replace control switch S12 if there is no **B+** at the red/orange wire terminal when the switch is at **Run**.

THE ENGINE DOES NOT CRANK IN RUN MODE (CONT.)	
⚠ WARNING ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***	
Possible Cause	**Corrective Action**
8. T26 relay K14 or connected wiring is faulty (**Beginning Spec B**).	Check the red/orange wire between control switch S12 and **86** on K14, the black wires between **85** on K14 and **TB1-6**, the red wire between **30** on K14 and control switch S12 and the red/orange wire between **8**7 on K14 and **30** on K13. Repair as necessary. Replace T26 relay K14 if there is no **B+** at **87** when control switch S12 is at **Run**.
9. DC disconnect relay K13 or connected wiring is faulty.	Replace DC disconnect relay K13 if there is no electrical continuity between **30** and **87a** (NC). Check the red/orange wire between **87** on K14 (S12, Spec A) and **30** on K13, the gray or purple wires between **87a** on K13 and **86** on starter relay K12. Repair as necessary.
10. Starter relay K12 or ignition ground is faulty.	Check the black-wire grounding path between **85** on starter relay K12 and ground. Replace starter relay K12 if there is no **B+** at **87** when control switch S12 is at **Run**.

THE ENGINE DOES NOT CRANK IN REMOTE MODE

⚠ **WARNING** ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***

Possible Cause	Corrective Action
1. The control switch is not at **Remote**.	Push the control switch to **Remote**.
2. A **Fault Shutdown** is being indicated by fault circuit breaker CB1 (reset button extended out).	Service the set as necessary. To reset, push control switch S12 to **Off** and push the reset button on fault circuit breaker CB1.
3. No remote circuit signal.	Push control switch S12 to **Off**, jumper control box terminals **TB1-2—TB1-3** (**1—2**, Spec A) and push control switch S12 to **Remote**. If the set starts, repair the fault in the external remote control circuit.
4. Control switch S12 or connected wiring is faulty.	Check the wires between control box terminals **TB1-2** and **TB1-3** (**1** and **2**, Spec A) and control switch S12. Repair as necessary. Replace the control switch if the generator set starts in the **Run** position but not in the **Remote** position.
5. Check Items 3 through 10 under THE ENGINE DOES NOT CRANK IN RUN MODE.	Perform the necessary repairs.

THE ENGINE CRANKS BUT DOES NOT START

⚠ **WARNING** ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***

Possible Cause	Corrective Action
1. The engine is not getting fuel.	A. If the engine shut down due to overcrank (60 seconds), push control switch S12 to **Off** and reset fault circuit breaker CB1. B. Open any closed shutoff valve in the fuel supply system. C. Fill the fuel supply tank. D. Restore fuel prime (Page 8-41).
2. The air cleaner is dirty or the exhaust system is clogged.	Service as necessary.
3. Low engine temperature is causing too low a cranking speed for starting.	A. Plug in, repair or install heaters for engine coolant and engine oil. B. Replace the engine oil if it is not of the recommended viscosity for the ambient temperature.
4. Cranking voltage is too low to reach required cranking speed.	A. While cranking the engine measure voltage across each battery cable—terminal post to terminal post. Service as necessary if voltage drop across either cable is more than 0.5 VDC. B. Recharge or replace the battery. Specific gravity for a fully charged battery is approximately 1.260 at 80° F (27° C). C. Replace the engine-driven battery charging alternator if normal battery charging voltage is not between 12 and 14 volts.
5 The preheat circuit is faulty.	Service the glow plug(s), glow plug relay K15, preheat switch S15 and connected wiring as necessary.
6. Fuel shutoff solenoid K1 is faulty.	Disconnect the leads of fuel shutoff solenoid K1 and apply **B+**. Replace K1 if it does not pull in and stay in.
7. Fuel shutoff solenoid K1 circuit wiring is loose or missing.	Check all the red/orange wires connected to **TB1-5** (**10**, Spec A) and all the black wires to **TB1-6** (**4**, Spec A). Repair as necessary.
8. The engine or fuel system is worn or malfunctioning mechanically.	Service the engine according to Section 8.

THE ENGINE RUNS UNTIL FAULT SHUTDOWN	
⚠ WARNING ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***	
Possible Cause	**Corrective Action**
1 High engine temperature or faulty safety switch.	A Check the engine coolant level, repair any leaks and fill to the proper level (liquid cooled engines). Push the control switch to **Off** and reset the fault circuit breaker. B Remove obstructions to air flow and clean and service the cooling system as required to restore full cooling capacity. C Replace high engine temperature switch S2 if there is electrical continuity across the switch terminals at room temperature. (Air cooled engines have a 260° F [127° C] head bolt mounted temperature switch [Figure 4-3].)
2 Low engine oil pressure or faulty safety switch.	A Check the engine oil level, repair any leaks and fill to the proper level. Push the control switch to **Off** and reset the fault circuit breaker. B Install an oil pressure gauge in place of low oil pressure cutout switch S1, close the manual fuel shutoff valve to keep the engine from starting and observe oil pressure while cranking the engine. Replace S1 if oil pressure is greater than 10 psi (69 kPa). Service the lubricating oil system if oil pressure is less than 10 psi (69 kPa). See Section 8.
3. Low coolant level (probable cause if fault circuit breaker has not tripped and remote monitor light stays on after engine has cooled down).	Check engine coolant level, repair any leaks and fill to the proper level.

THE ENGINE LACKS POWER OR IS UNSTABLE	
⚠ WARNING ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***	
Possible Cause	**Corrective Action**
1. Fuel delivery to the set is inadequate.	A. Check for clogged fuel lines and filters. B. Check for air in the fuel lines. C. Check the vertical distance from the bottom of the fuel dip tube to the fuel lift pump. The distance must not exceed 3 meters (10 feet).
2. The fuel is contaminated.	Connect the fuel lift pump to a container of fuel of known quality. Replace the contents of the fuel supply tank if there is a noticeable difference in performance.
3. The air cleaner is dirty or the exhaust system is clogged.	Service as necessary.
4. The engine or engine fuel system is worn or out of adjustment.	Service the engine according to Section 8.

THIS PAGE LEFT INTENTIONALLY BLANK

5. Generator Set Control—Detector

⚠WARNING ***EXHAUST GAS IS DEADLY!***

All engine exhaust contains carbon monoxide, an odorless, colorless, poisonous gas that can cause unconsciousness and death. Symptoms of carbon monoxide poisoning include:

- ***Dizziness***
- ***Nausea***
- ***Vomiting***
- ***Headache***
- ***Weakness and Sleepiness***
- ***Inability to Think Coherently***

IF YOU EXPERIENCE ANY OF THESE SYMPTOMS, GET INTO FRESH AIR IMMEDIATELY. If symptoms persist, seek medical attention. Shut down the generator set and do not operate it until it has been inspected and repaired.

The exhaust system must be installed in accordance with the generator set Installation Manual. Make sure there is ample fresh air when operating the generator set in a confined area.

PRESTART CHECKS

Perform any scheduled maintenance and check the following before starting the generator set.

Fuel

Check the fuel supply and refill as necessary.

Engine Oil

Check engine oil level. Keep the oil level as near as possible to the dipstick high mark without overfilling.

Engine Coolant

Check engine coolant level (liquid-cooled engines). Note the normal level of coolant in the radiator top tank when the engine is cold (within 25 mm [1 inch] of top). Add coolant if it falls below this level. Use a 50/50 mixture of ethylene glycol and water.

⚠WARNING ***Hot coolant can cause severe burns. Let the engine cool down before removing the pressure cap.***

OPERATION

Manual Starting

Push the control switch (Run/Stop/Remote) to **RUN** (Figure 5-1 or 5-2). The engine should crank, start and run up to governed speed and regulated voltage in a few seconds. The starter will disconnect automatically. The green run lamp will light indicating that the starter disconnected and that the generator set is running.

Whenever possible, let the engine warm up for a few minutes before connecting electrical loads.

If the engine does not start, the starter will disengage and an Overcrank Fault will be indicated. A control having the standard 75-second cycle-cranking function will cycle up to 3 times, alternating 15-second periods of cranking with 15-second periods of rest. Continuous cranking is optional.

To clear an overcrank fault, push the control switch to **STOP** and the Reset switch to **RESET**. See TROUBLESHOOTING in this section.

Manual Stopping

Push the control switch to **STOP**. Whenever possible, let the engine cool down by running without load for a few minutes before stopping. The Detector Control has a stop time delay function which can be adjusted to suit (30 seconds to 30 minutes).

⚠CAUTION ***To restore automatic remote control of the generator set, make sure to push the control switch to REMOTE before leaving.***

Remote Automatic Starting and Stopping

Push the control switch to **REMOTE** for remote, automatic control by a transfer switch or other kind of controller. The Detector Control has a start time delay function which can be adjusted to suit (0.5 to 15 seconds).

Emergency Stop (Optional)

Push the Emergency Stop switch in an emergency. To reset, pull the button out and push the control switch to **STOP** and the Reset switch to **RESET**.

CONTROL PANEL

The Detector control provides for manual and remote control. It has 12 indicator lights and provides shutdown and/or indication for various fault and pre-fault conditions. See Figure 5-1 or 5-2 and TROUBLESHOOTING.

Panel Lamp: Illuminates the control panel.

Oil Pressure Gauge: Indicates engine oil pressure.

Coolant Temperature Gauge: Indicates engine coolant temperature.

DC Voltmeter: Indicates battery voltage.

Control Switch (Run/Stop/Remote): *Run* and *Stop* run and stop the set locally and *Remote* allows operation by a remote controller.

Hour Meter: Registers the total number of hours run. It cannot be reset. Use it as a basis for periodic maintenance and service.

Preheat / Reset / Lamp Test / Panel Lamp Switch: *Preheat* energizes the glow plugs, *Reset* resets the fault circuit (the control switch must be at Stop), *Lamp Test* tests the fault lamps and *Panel Lamp* turns on the control panel lamp.

Emergency Stop Button (Optional): Push-in switch for emergency shutdown of the set.

AC Voltmeter: A dual-range meter that indicates AC output voltage. Use the scale indicated by the scale indicator lamp.

AC Ammeter: A dual-range meter that indicates AC output current. Use the scale indicated by the scale indicator lamp.

Frequency/RPM Meter: Indicates generator output frequency in Hertz (cycles per second) and engine speed in rpm (revolutions per minute).

Voltage Adjusting Rheostat: Provides approximately ± 5 percent adjustment in output voltage.

Upper and Lower Scale Indicator Lamps: Indicates which AC meter scales to read.

Phase Selector Switch: Selects the generator phase for voltage and current readings.

Field Breaker: Protects the generator exciter/regulator circuits from overheating under certain failure modes.

Indicator Lamps: The control panel has the following 12 indicator lamps:

- RUN (green) indicates that the starter has disconnected and that the set is running.
- PRE LO OIL PRES (yellow) indicates that engine oil pressure is marginal (low).
- PRE HI ENG TEMP (yellow) indicates that engine coolant temperature is marginal (high) or that the coolant level is low (when equipped with a low coolant level switch).
- LO OIL PRES (red) indicates that the engine has shut down because of low oil pressure.
- HI ENG TEMP (red) indicates that the engine has shut down because of high coolant temperature or low coolant level (when equipped with a low coolant level switch).
- OVERSPEED (red) indicates that the engine has shut down because of excessive speed.
- OVERCRANK (red) indicates that the engine has failed to start during the cranking period.
- FAULT 1 (red) indicates a nondedicated fault. May be selected as a shutdown or non-shutdown, timed or non-timed fault (usually timed shutdown).
- FAULT 2 (red) indicates a nondedicated fault. May be selected as a shutdown or non-shutdown, timed or non-timed fault (usually non-timed shutdown).
- LOW ENG TEMP (yellow) indicates that engine coolant temperature is marginal for starting (low).
- LO FUEL (yellow) can be used to indicate that the fuel supply is low and may be set as a warning or as a shutdown. A low fuel level switch is available from Onan.
- SWITCH OFF (flashing red) indicates that the control switch is not in its Remote position for automatic starting.

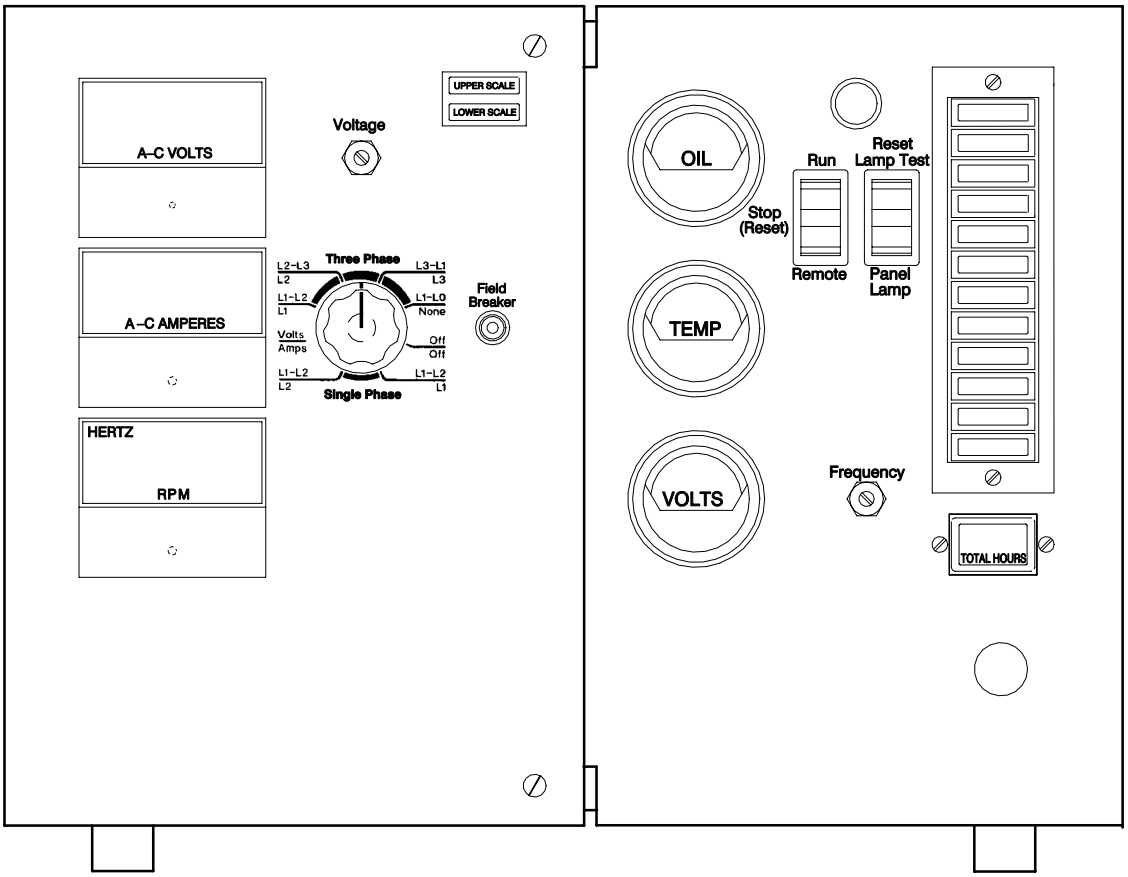


FIGURE 5-1. DETECTOR CONTROL PANEL (BEGIN SPEC B)

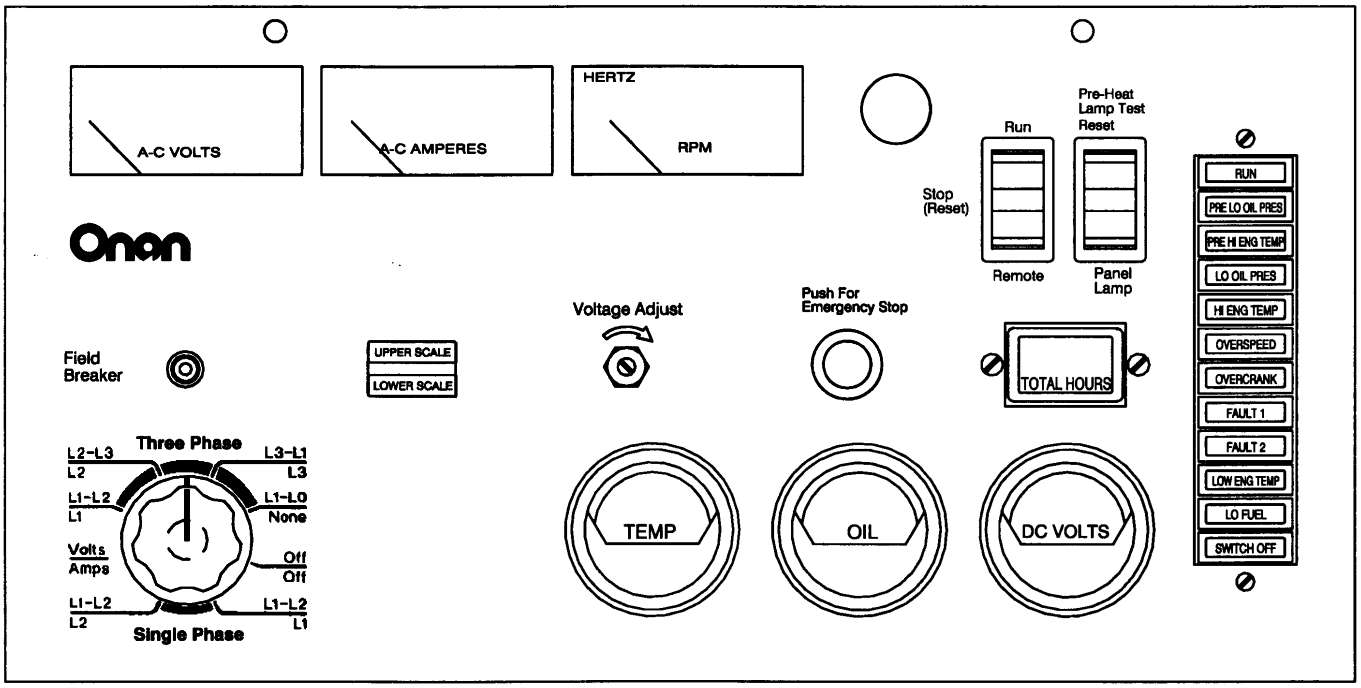


FIGURE 5-2. DETECTOR CONTROL PANEL (SPEC A)

DETECTOR CONTROL BOX (SPEC A)

Figure 5-3 illustrates the control box with the control panel hinged open. Note the lexan (red plastic) cover secured over the meters to protect you from electrical shock.

⚠WARNING ***HAZARDOUS VOLTAGE! Touching uninsulated live parts inside the control box can result in severe personal injury or death. Reinstall the protective cover to prevent contact with bare, live meter terminals.***

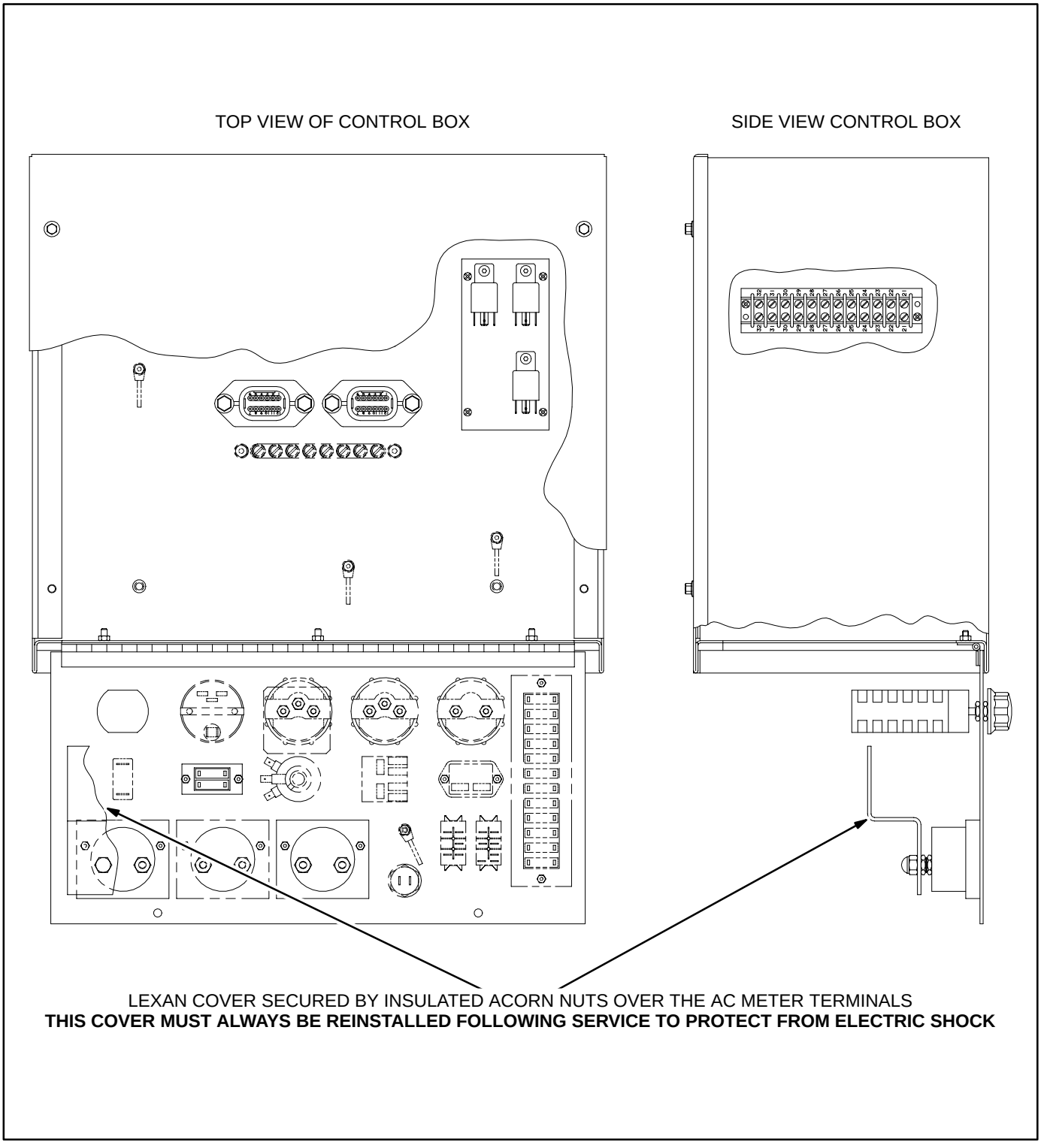


FIGURE 5-3. DETECTOR CONTROL BOX (SPEC A)

ENGINE CONTROL MONITOR (ECM)

The generator set control box has connection points for remote control and annunciation. These connection points are on the engine control monitor (ECM), Figure 5-4; optional auxiliary relay board (ARB), Figure 5-5; and start-stop time delay module, Figure 5-6.

The engine control monitor (ECM) is a printed circuit board assembly mounted on the side wall of the control box (Figure 5-4). See Page C-1 for the remote connection diagram.

Remote Start/Stop: Connections for remote start/stop are made at **A11-TB1-7 (B+)** on the ECM and at **A15-TB1-5** on start-stop time delay module A15 (Page 5-9). See Page 5-7 for connections when the optional auxiliary relay board is provided.

Remote Annunciation: Connections for remote annunciation are made at terminal blocks **TB1** and **TB2**. See Page 5-7 for connections when the optional auxiliary relay board is provided.

Function Selection Jumpers: The ECM board has six selection jumpers that can be repositioned to provide 10-second time-delayed or non-time-delayed warnings only or 10-second time-delayed or non-time-delayed shutdowns, as follows:

W1 Jumper Position (jumper **W8** must be in the **B** position):

- **A** Non-timed warning under **FLT 2** conditions.
- **B** Non-timed shutdown under **FLT 2** conditions.
- **C** Timed warning under **FLT 2** conditions.
- **D** Timed shutdown under **FLT 2** conditions.

W2 Jumper Position (jumper **W9** must be in the **B** position):

- **A** Non-timed warning under **FLT 1** conditions.
- **B** Non-timed shutdown under **FLT 1** conditions.
- **C** Timed warning under **FLT 1** conditions.
- **D** Timed shutdown under **FLT 1** conditions.

W6 Jumper Position:

- **A** Warning under **Pre-High Engine Temperature** conditions.
- **B** Shutdown under **Pre-High Engine Temperature** conditions.

W7 Jumper Position:

- **A** Warning under **Pre-Low Oil Pressure** conditions.
- **B** Shutdown under **Pre-Low Oil Pressure** conditions.

W8 Jumper Position:

- **A** Warning while running or during standby under **FLT 2** conditions.
- **B** Allows selection of functions with **W1** jumper.

W9 Jumper Position:

- **A** Warning while running or during standby under **FLT 1** conditions.
- **B** Allows selection of functions with **W2** jumper.

Note: The time delay in warning or shutdown is accomplished by delaying the arming of the FLT 1 or FLT 2 circuit in the Detector control, not by delaying the sensing of the fault.

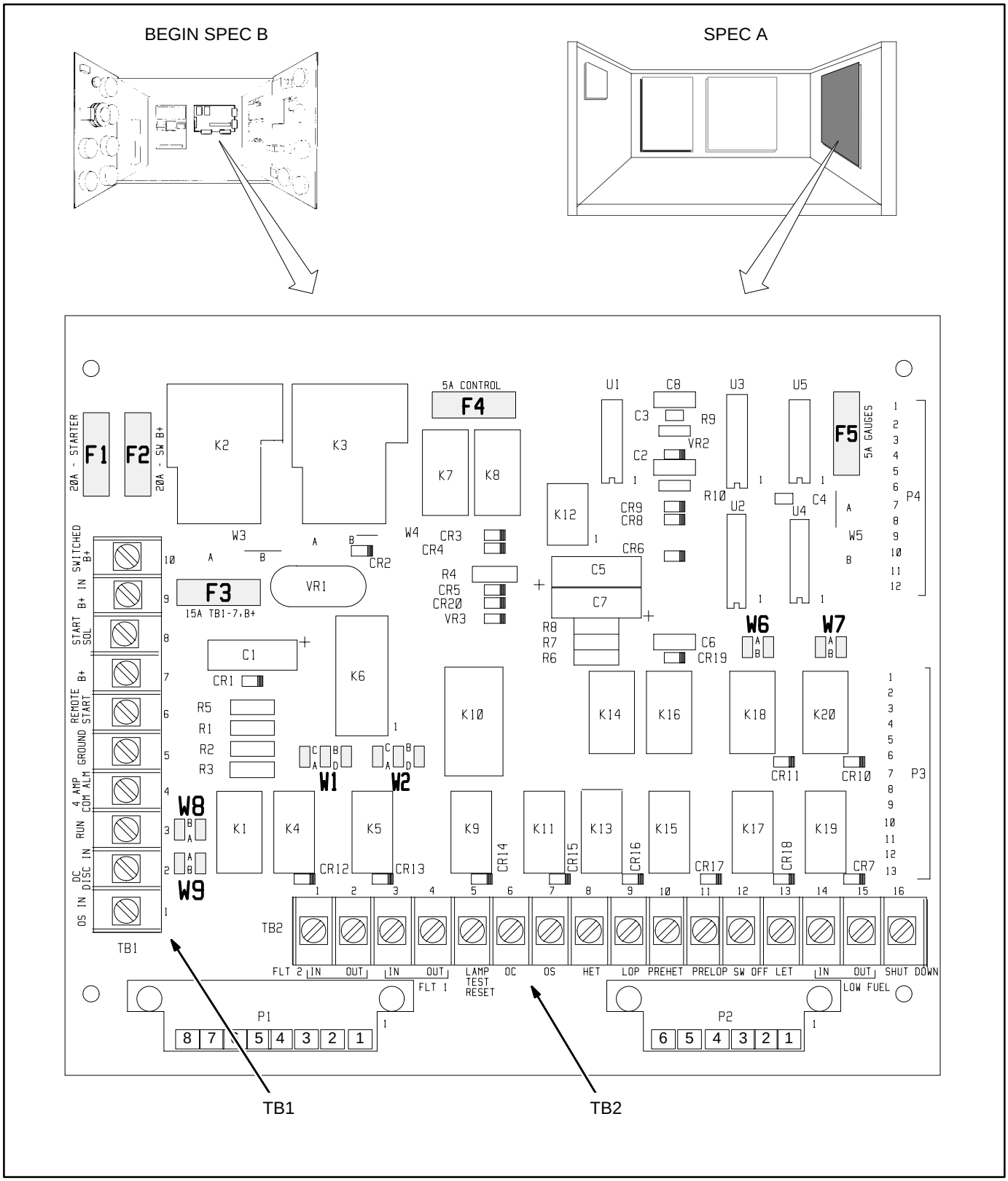


FIGURE 5-4. ENGINE CONTROL MONITOR (ECM)

AUXILIARY RELAY BOARD (OPTIONAL)

The auxiliary relay board (ARB) is a printed circuit board assembly mounted on the back wall of the control box (Figure 5-5). See Page C-2 for the connection diagram.

Terminal Blocks:

- **TB1** – ARB TB1 and engine monitor TB1 are identically numbered and provide the same remote control connection points. Note that additional terminals are provided for terminals 5, 7, and 10 of ARB TB1.
- **TB2 through TB5** – Connection points for relays K1 through K3. TB2 provides the N/O and N/C connections (three form 'C' contacts for each relay). TB3 through TB5 provide the common connection points (TB3 for K1, TB4 for K2 and TB5 for K3).
- **TB6 and TB7** – Connection points for fault relays K4 through K15. Three terminals are provided for each relay, which are labeled COM, N/C, N/O.

Plug-In Relays (K1, K2, K3): The ARB can be equipped with one to three 3-pole, double-throw relays. These relays (K1, K2, K3) are field changeable plug-in relays for easy field addition and replacement.

Each relay can be operated as a RUN, COMMON ALARM, or ISOLATED COIL with the changing of jumpers.

The relay contact ratings are:

- 10 amps at 28 VDC or 120 VAC, 80% PF
- 6 amps at 240 VAC, 80% PF
- 3 amps at 480 VAC, 80% PF

Jumper Positions for Plug-In Relays: Jumpers W1, W2 and W3 perform the same functions for their respective relays, W1 for relay K1, W2 for relay K2, and W3 for relay K3. They can be located in any of 3 positions (A, B, C) independently of each other.

- **Jumper Position A (Run)** – The relay operates as a Run relay, energizing when SW B+ is applied from the engine monitor.
- **Jumper Position B (Common Alarm)** – The relay operates as a Common Alarm relay. The relay energizes any time there is an engine shutdown.
- **Jumper Position C (Isolated)** – The relay operates as an Isolated relay. The relay coil is energized by a customer applied B+ signal through the terminal block; TB3-1 for relay K1, TB4-1 for relay K2, and TB5-1 for relay K3.

Jumpers W11, W12, and W13 perform the same functions for their respective relays; W11 for relay K1, W12 for relay K2, and W13 for relay K3. They can be located in two different positions (A, B) independently of one another.

- **Jumper Position A** – The relay operates isolated from the board. The customer provides the circuit completion through terminal block; TB3-5 for relay K1, TB4-5 for relay K2, and TB5-5 for relay K3. The customer can operate the relay with switched ground logic or use this relay in the middle of more complex logic circuits if needed.
- **Jumper Position B** – The relays operate with the coils connected to ground through the board connections. The coil will require a B+ signal to energize with the jumper in this position.

Fault Relays (K4 through K15): These relay modules are used to operate a remote alarm annunciator that has an independent power source. This allows the use of either AC or DC for alarm drives. The relays are energized through the latching relays on the engine monitor and provided N/O and N/C contacts for each external alarm connection.

The 12 relays with form 'C' contacts are rated:

- 10 Amp, 120 VAC
- 10 Amp, 30 VDC

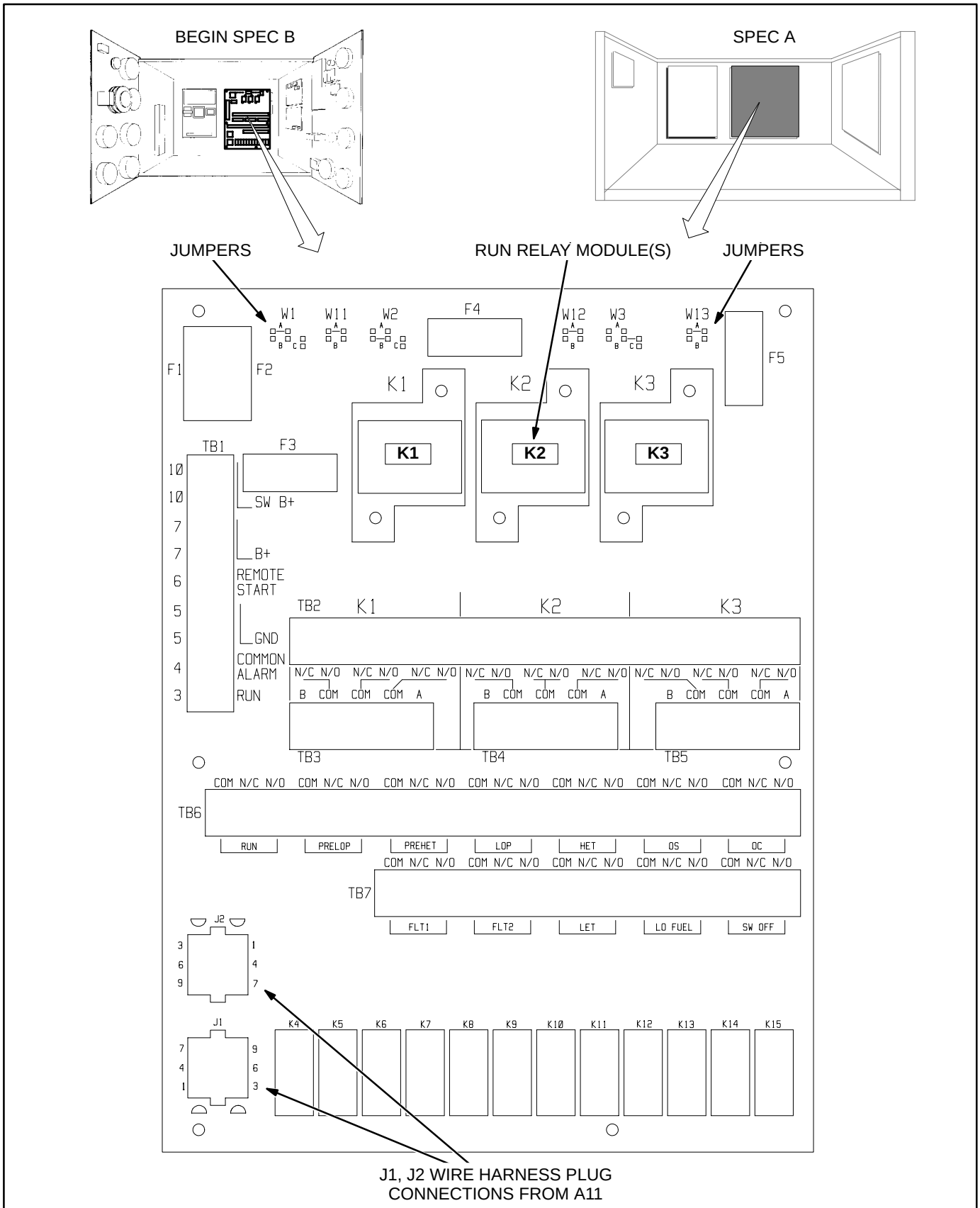


FIGURE 5-5. AUXILIARY RELAY BOARD (ARB)

START-STOP TIME DELAY MODULE

Start Delay: Start delay is adjustable from 0.5 to 15 seconds. The intake manifold heater(s) are energized during the start delay period for easier starting. Turn the potentiometer clockwise to increase delay and counterclockwise to decrease delay. See Figure 5-6.

Stop Delay: Stop delay is adjustable from 30 seconds to 30 minutes. Turn the potentiometer clockwise to increase delay and counterclockwise to decrease delay.

Remote Start/Stop: Connections for remote start/stop are made at **A11-TB1-7 (B+)** on the ECM and at **A15-TB1-5** on the time delay module (A15). System B+ connections can be made instead on the auxiliary relay board (Figure 5-5) when it is provided.

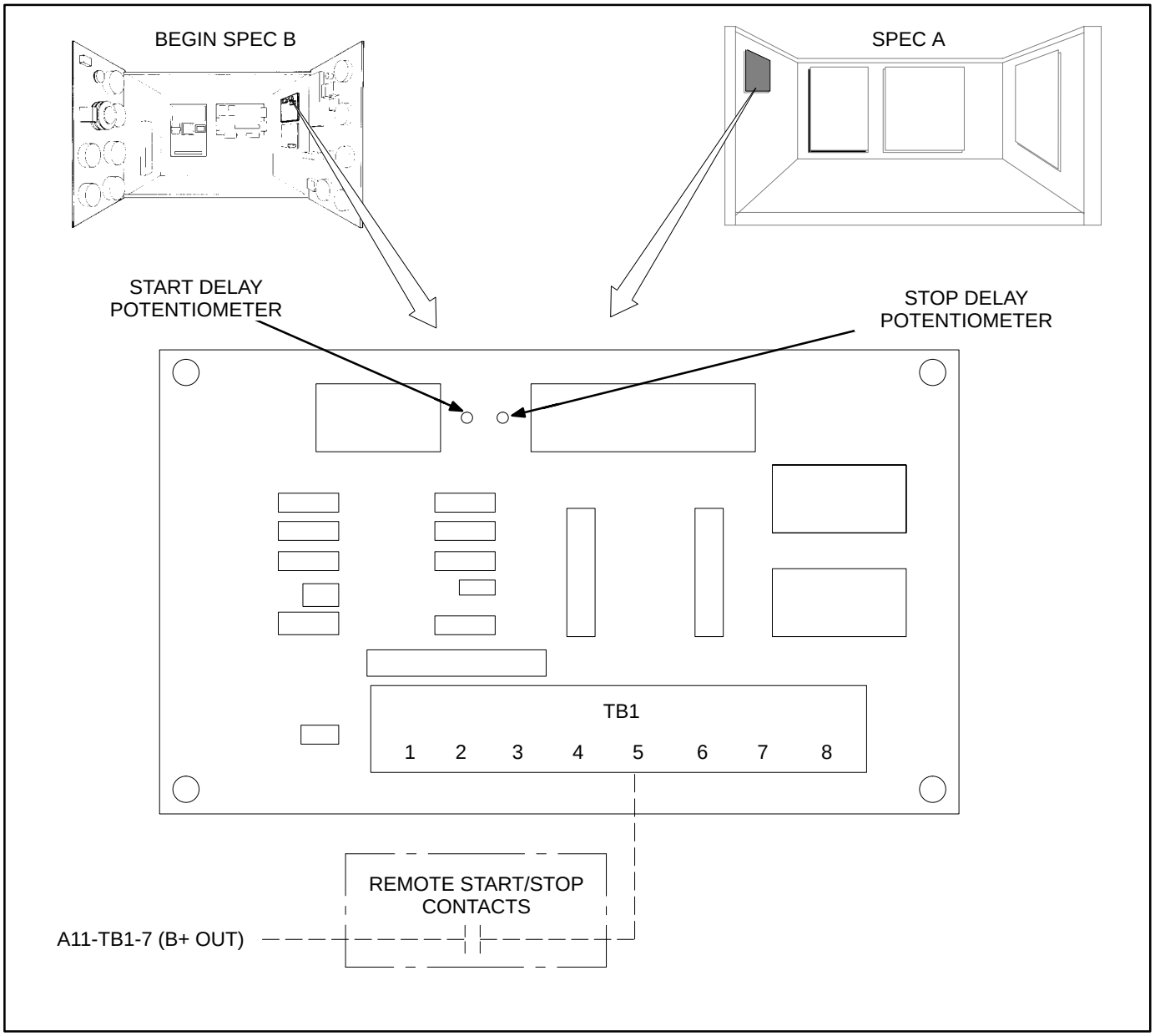


FIGURE 5-6. START-STOP TIME DELAY MODULE ADJUSTMENTS AND CONNECTIONS

ELECTRONIC OVERSPEED/START DISCONNECT MODULE

The electronic overspeed/start disconnect module is mounted on the generator end bell cover by two screws as shown by Figure 5-7. The magnetic rotor is bolted to the end of the generator shaft as shown. The module is an encapsulated electronic device with wiring harness and disconnect plug.

Start disconnect occurs at about 660 rpm and overspeed shutdown at about 2190 rpm. **For 50 Hertz sets, *if required by the local code*, cut the orange jumper for overspeed shutdown at about 1830 rpm.** There are no other provisions for field adjustment.

To remove the module, disconnect the harness plug and remove the generator end bell cover. The module mounting screw heads are accessible on the back side of the cover.

Torque the rotor bolt to 18 lb-ft (24 N-m) when remounting the magnetic rotor.

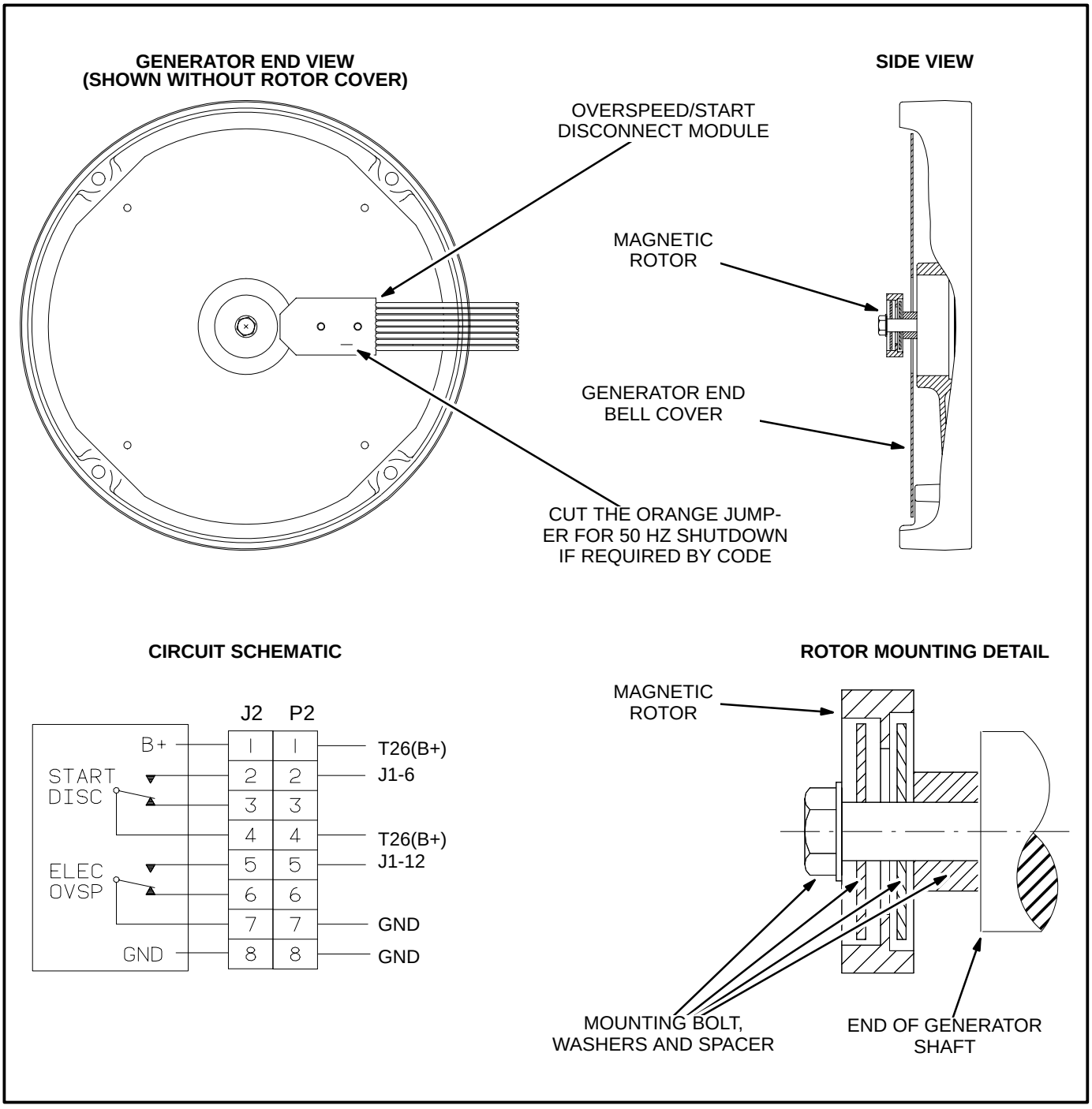
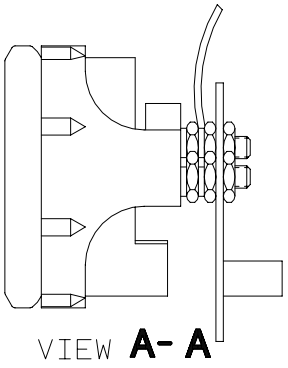


FIGURE 5-7. ELECTRONIC OVERSPEED/START DISCONNECT MODULE

COOLANT TEMPERATURE GAUGE ASSEMBLY

An electronic PCB assembly is mounted on the back of the coolant temperature gauge (M12) with three terminal nuts. The PCB assembly carries two relays that provide signals for the low engine temperature (not used on these models) and pre-high temperature warning lamps on the basis of the gauge sender output. See Figure 5-8.

PCB MOUNTING ON BACK OF GAUGE



GAUGE AND PCB CONNECTIONS

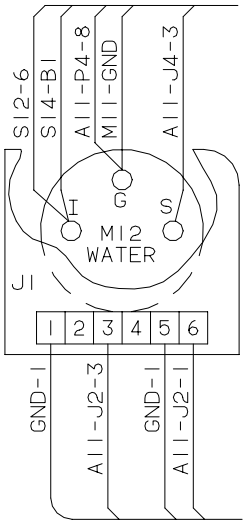


FIGURE 5-8. COOLANT TEMPERATURE GAUGE

RELAYS K11, K12 AND K13 (SPEC A)

Relays **K11** and **K12** are provided for the switched B+ and starter circuits to handle the higher DC currents in these circuits. Relay **K13** is provided when the engine is equipped with glow plug(s) for preheat. They feed through terminal block **TB1** to the engine wiring harness. See Figure 5-9.

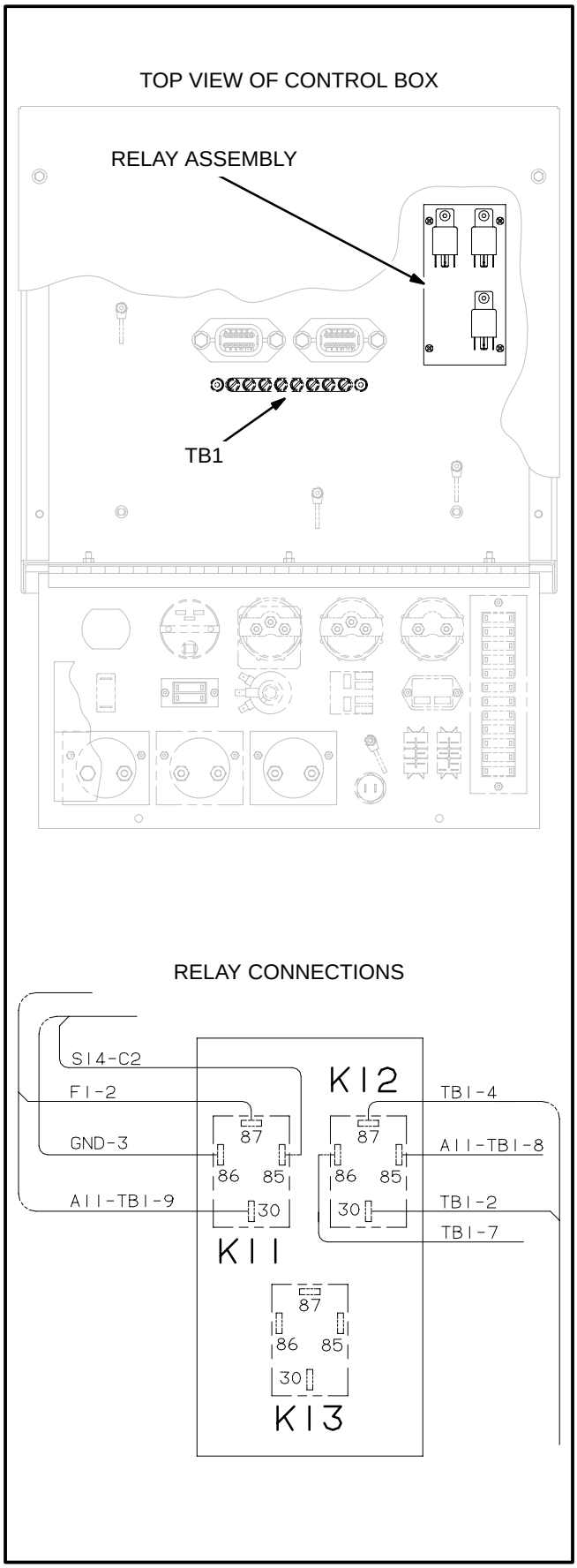


FIGURE 5-9. RELAYS K11, K12 AND K13

ENGINE GAUGE SENDERS AND SHUTDOWN SWITCHES

Figure 5-10 shows the locations of the engine gauge senders and shutdown switches to which the engine monitor board (A11) and control panel gauges respond. The engine temperature and oil pressure warning and shutdown switches close the monitoring circuit to engine chassis ground.

Use pipe thread sealant on gauge senders and warning and shutdown switches.

⚠ CAUTION ***Do not use teflon tape for switches and senders that are grounded to the engine by thread contact as it may interfere with the ground path.***

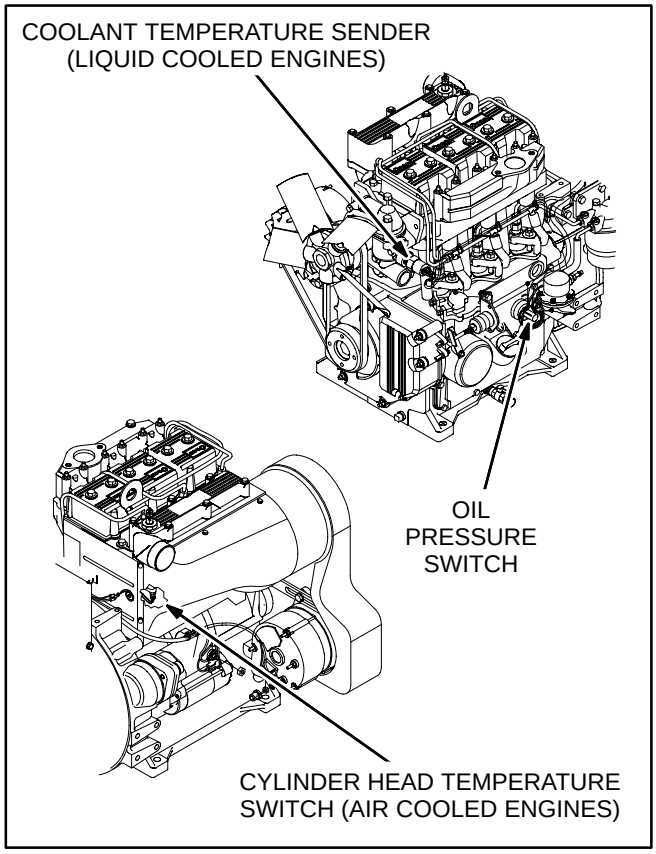


FIGURE 5-10. ENGINE GAUGE SENDERS AND SHUTDOWN SWITCHES

SEQUENCE OF OPERATION

The sequence of operation is as follows. Refer to the connection drawing on Page A-2 or B-2/B-3.

1. The engine monitor (A11) is powered by cranking battery voltage (12 VDC). Terminal **A11-TB1-9** is connected to battery positive (+) and **A11-TB1-5** to battery negative (-).

2. The manual starting cycle begins by pushing run switch **S12** to the **Run** position.

3. The automatic starting cycle begins when a start signal is received from the transfer switch (switch **S12** in the **Remote** position).

4. The start signal received at engine monitor terminal **A11-TB1-6** (automatic) or **A11-P4-6** (manual), causes engine monitor **A11** to energize the engine gauges and terminals **A11-TB1-8** and **A11-TB1-10**.

5. **A11-TB1-10** energizes the coil of relay **K11** to energize the SW B+ circuit to engine block terminal **T26**. The fuel solenoid(s), ignition module and ignition coil should be energized.

6. **A11-TB1-8** energizes the coil of relay **K12** to energize the starter motor.

7. The engine should crank, start and run up to governed speed in a matter of seconds.

8. The engine monitor disconnects the starter when engine speed reaches approximately 660 RPM. There are two, redundant, starter disconnect circuits. One is activated by 120 VAC generator output voltage (plug connectors **A11-P1-1** and **A11-P1-2**). The other is activated by 12 VDC through the start disconnect module (plug connector **A11-P1-5**).[1]

9. Shutdown occurs if the engine does not start within 75 seconds (see OPERATION in this section). The **OVERCRANK** indicator lamp lights and common alarm terminal **A11-TB1-4** is powered.

10. Shutdown occurs during operation when a low oil pressure (S1), high engine temperature (S2), low coolant level (S7) or engine overspeed condition is sensed, the line circuit breaker trips, the transfer switch senses over or under voltage or the emergency stop button (S14) is pressed. The appropriate fault indicator lamp lights and common alarm terminal **A11-TB1-4** is powered. (There is no fault lamp for emergency stop. The switch button will light, however, and the light in Reset Switch S11.)

    The low oil pressure and high engine temperature shutdown circuits are not armed during the first 10 seconds after startup so as to allow oil pressure and engine temperature to stabilize.

11. To restore operation after a shutdown fault has been serviced, reset the engine monitor by pushing the panel **Stop** switch and then the **Reset** switch. The set should run or be ready to run when the panel switch is pushed to **Run** or to **Remote**.

    If the emergency stop switch has been used, the control will have to be reset to restore operation. First pull the emergency stop switch button and then push the panel Stop and Reset switches.

12. The set is stopped manually by pressing the panel **Stop** switch or automatically by the transfer switch. (The panel switch must be in the **Remote** position for remote, automatic operation.)

1. If the starter disconnects normally but the local control panel **Run** indicator light does not come on, the DC start disconnect circuit (start disconnect module) may not be working. If the starter disconnects normally but neither the local nor the remote **Run** indicator light comes on, the AC start disconnect circuit may not be working. See TROUBLESHOOTING.

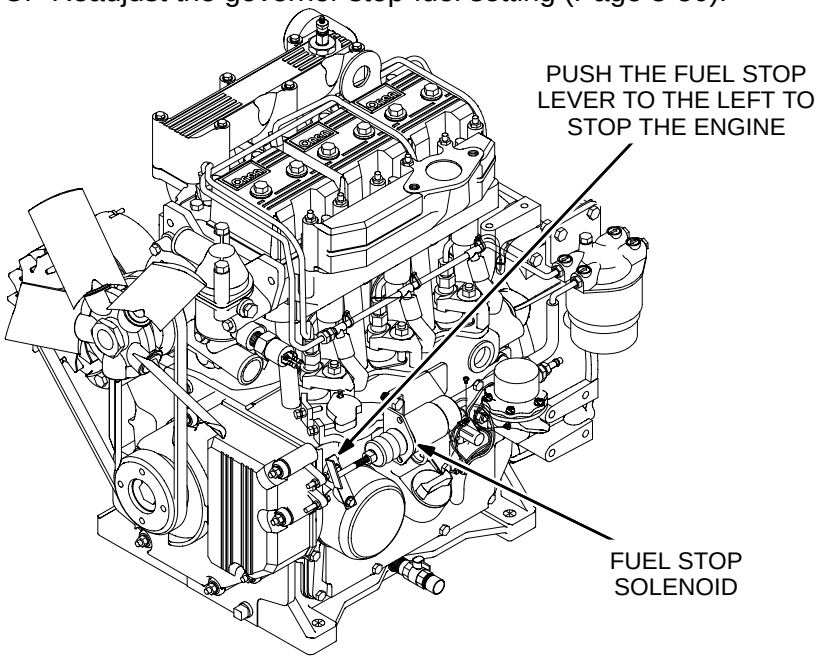
TROUBLESHOOTING

The following troubleshooting tables are designed to help you think through generator set problems. To save time troubleshooting, read the entire manual ahead of time to understand the generator set. Try to think through problems. Go over what was done during the last service call. The problem could be as simple as an empty fuel tank, closed fuel shut-off valve, loose wire, blown fuse or tripped circuit breaker. Refer to the wiring diagrams on Page A-2 or B-2/B-3.

SEE THE SECTION, *7. GENERATOR*, FOR GENERATOR FAULTS

THE ENGINE DOES NOT STOP RUNNING

⚠ **WARNING** ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***

Possible Cause	Corrective Action
1. The fuel stop solenoid is malfunctioning.	A. To stop the engine, push the engine control lever to the left and hold it there until the engine stops (see figure) or block the engine air intake. B. Apply 12 VDC across the fuel stop solenoid. Replace the solenoid if it does not function. C. Readjust the governor stop-fuel setting (Page 8-50). 

THE ENGINE DOES NOT CRANK IN RUN MODE

⚠ **WARNING** ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***

Possible Cause	Corrective Action
1. The **Emergency Stop** switch has been used. (The switch button is lit.)	Pull the **Emergency Switch** button. To reset the engine control, push the **Run-Stop-Remote** switch to **Stop** and the **Reset** switch to **Reset**. Then push the **Run-Stop-Remote** switch to **Run**.
2. A **Fault Shutdown** is being indicated by one of the red lights on the control panel.	Service the set as necessary. To reset the engine control, push the **Run-Stop-Remote** switch to **Stop** and the **Reset** switch to **Reset**. Then push the **Run-Stop-Remote** switch to **Run**.
3. Cranking voltage is too low to crank the engine.	A. Clean and tighten or replace the positive (**+**) and negative (**–**) battery cable connectors and cables at the battery and the set. B. Recharge or replace the battery. Specific gravity for a fully charged battery is approximately 1.260 at 80° F (27° C). C. If the set is in standby service, install a battery charger. D. Replace the engine-driven battery charging alternator if normal battery charging voltage is not between 12 and 14 volts.
4. The **starter motor** or **solenoid** is malfunctioning.	Push the **Run-Stop-Remote** switch to **Run** and check for battery voltage (12 VDC) at starter solenoid terminal **SW**. Replace the starter motor if there is voltage but the motor does not function.
5. Fuse **F1** on engine monitor board A11 has blown (no voltage [12VDC] at **A11-TB1-8**). (See Figure 5-4 on Page 5-6.)	Wiring between **A11-TB1-8** and terminal **85** on relay **K4** (**K12**, Spec A) may be loose and shorting to ground. Repair as necessary and replace the fuse with one of the same type and amp rating (20 A).
6. Fuse **F4** on engine monitor board A11 has blown. (See Figure 5-4 on Page 5-6.)	The lead to terminal **3** on switch **S12** (Run-Stop-Remote) or to terminal **5** on switch **S11** (Lamp Test-Reset-Preheat) or a lead in the indicator lamp (A12) harness or engine gauge (M11 through M16) harness may be loose and shorting to ground. Repair as necessary and replace the fuse with one of the same type and amp rating (5 A).
7. Engine Monitor Board A11 is not properly grounded.	Check for electrical continuity (zero ohms) between **A11-TB1-5** and the battery negative (**–**) terminal. Repair as necessary.

THE ENGINE DOES NOT CRANK IN RUN MODE (CONT.)

⚠ **WARNING** ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***

Possible Cause	Corrective Action
8. Relay **K4** (**K12**, Spec A) or connecting wiring is faulty.	**Beginning Spec B**—Check wiring between **A11-TB1-8** and relay **K4** and **K4** and the battery negative (**–**) terminal. Repair as necessary. Replace **K4** if contacts **87–30** do not close when battery voltage is applied across **85-86**. **Spec A**—Remove the lead from terminal **86** on relay **K12**, ground terminal **86**, push the **Run-Stop-Remote** switch to **Run** and check for battery voltage (12 VDC) at relay **K12** terminals **85** and **87**. Replace relay **K12** if there is voltage at terminal **85** but not at terminal **87**.
9. One of the following leads is loose, damaged or missing (**Spec A**): **K12-87** to **TB1-4**, **TB1-4** to starter solenoid terminal **SW** (gray/orange), **K12-86** to **TB1-7**, or **TB1-7** to ground (black).	Check, clean and tighten the connectors at both ends and replace the wire if it is damaged.
10. The **Run-Stop-Remote** switch (S12) or wiring is faulty.	Disconnect pin connector **J4** from engine monitor board A11 and check for electrical continuity (zero ohms) between switch terminals **2** and **3** when the switch is in the **Run** position and between terminals **1** and **2** when it is in the **Remote** position. Replace the switch if either set of contacts is faulty.
11. Engine monitor board **A11** is faulty. (Check fuses **F1** and **F4** and for B+ at **A11-TB1-9** again.)	Push the **Run-Stop-Remote** switch to **Run** and check for battery voltage (12 VDC) at terminal **A11-TB1-8**. Replace engine monitor board **A11** if there is no voltage at **A11-TB1-8** but 12 VDC at **A11-TB1-9**.

THE ENGINE DOES NOT CRANK IN REMOTE MODE

⚠ **WARNING** ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***

Possible Cause	Corrective Action
1. The **Run-Stop-Remote** switch is at **Stop.** (The **Switch-Off** light will be flashing, if provided.)	Push the **Run-Stop-Remote** switch to **Remote.**
2. The **Emergency Stop** switch has been used. (The switch button is lit.)	Pull the **Emergency Switch** button. To reset the engine control, push the **Run-Stop-Remote** switch to **Stop** and the **Reset** switch to **Reset**. Then push the **Run-Stop-Remote** switch to **Remote**.
3. A **Fault Shutdown** is being indicated by one of the red lights on the control panel.	Service the set as necessary. To reset the engine control, push the **Run-Stop-Remote** switch to **Stop** and the **Reset** switch to **Reset**. Then push the **Run-Stop-Remote** switch to **Remote.**
4. There is no remote circuit signal (12 VDC at auxiliary relay board **A28-TB1-6**) because fuse **F3** on engine monitor board A11 has blown. (See Figure 5-4 on Page 5-6.)	A. Replace the fuse with one of the same type and amp rating (15 A). B. If fuse **F3** blows again, find and repair the fault in the remote control circuit, such as a loose wire that may be shorting to ground or a shorted relay coil or other component. See Page C-1 for connections to the ATS.
5. There is no remote circuit signal (12 VDC at auxiliary relay board **A28-TB1-6**) because the remote circuit is not functioning properly.	Apply 12 VDC to **A28-TB1-6**. If the engine cranks, find and repair the fault in the remote control circuit. See Page C-1 for connections to the ATS.
6. Auxiliary relay board **A28** is not functioning properly.	Check for misconnections (see Page C-2) and loose connections and replace auxiliary relay board **A28** if there is 12 VDC at terminal **A28-TB1-6** but not at **A28-J2-6**.
7. Same as Steps 3 through 11 in the **RUN** mode.	Same as Steps 3 through 11 in the **RUN** mode.

THE ENGINE CRANKS BUT DOES NOT START

⚠ **WARNING** ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***

Possible Cause	Corrective Action
1. The engine is not getting fuel. (The LO FUEL indicator lamp is on.)	A. Open any closed shutoff valve in the fuel supply system. B. Fill the fuel supply tank. C. Restore fuel prime (Page 8-41).
2. The air cleaner is dirty or the exhaust system is clogged.	Service as necessary.
3. Low engine temperature is causing too low a cranking speed for starting.	A. Plug in, repair or install engine coolant and engine oil heaters. B. Replace the engine oil if it is not of the recommended viscosity for the ambient temperature.
4. Cranking voltage is too low to reach required cranking speed.	A. While cranking the engine measure voltage across each battery cable—terminal post to terminal post. Service as necessary if voltage drop across either cable is more than 0.5 VDC. B. Recharge or replace the battery. Specific gravity for a fully charged battery is approximately 1.260 at 80° F (27° C). C. Replace the engine-driven battery charging alternator if normal battery charging voltage is not between 12 and 14 volts.
5 Preheat time is too short or the preheat circuit is faulty.	A. Increase the preheat time (up to 15 seconds). See Figure 5-6, Page 5-9. B. Service the glow plug(s), glow plug relay K15, preheat switch S15 and connected wiring as necessary.
6. Fuel solenoid **K1** is faulty.	Apply B+ directly to terminal **T26 (B+)** on the engine block. Replace the solenoid if it does not pull in and stay in.
7. Fuse **F2** on engine monitor board A11 has blown (no voltage [12VDC] at **A11-TB1-10**). (See Figure 5-4 on Page 5-6.)	**Beginning Spec B**—The customer may have connected too many loads to terminal **T26 (B+)** on the engine block or a loose wire may be shorting to ground. Remove the extra loads or repair as necessary and replace the fuse with one of the same type and amp rating (20 A) **Spec A**—Either the wire between terminal **A11-TB1-10** and emergency stop switch S14 terminal **S14-C-1** or between **S14-C-2** and relay **K11** terminal **85** may be loose and shorting to ground. Repair as necessary and replace the fuse with one of the same type and amp rating (20 A).

THE ENGINE CRANKS BUT DOES NOT START(CONT.)	
⚠ **WARNING** ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***	
Possible Cause	**Corrective Action**
8. Fuse **F1** in the control box wiring harness has blown (no voltage [12VDC] at **TB1-3** on floor of control box) (**Spec A**).	A. The customer may have connected too many loads to terminal **T26 (B+)** on the engine block. Remove the extra loads and replace the fuse with one of the same type and amp rating (30 A). B. Check for loose wires that may be shorting to ground, including the leads to **TB1-3** in the control box and the red/orange leads in the engine wiring harness. Repair as necessary and replace the fuse with one of the same type and amp rating (30 A).
9. Emergency stop switch **S14** (optional) is faulty.	Bypass **S14** with a jumper lead from **A11-TB1-10** to terminal **85** on relay **K11**. If the engine starts, replace **S14**.
10. Relay **K11** is faulty (**Spec A**)..	Push the **Run-Stop-Remote** switch to **Run** and check for battery voltage (12 VDC) at relay **K11** terminals **85** and **87** while the engine is cranking. Replace relay **K11** if there is voltage at terminal **85** but not at terminal **87**.
11. Engine monitor board **A11** is faulty. (Check fuse **F2** again.)	Push the **Run-Stop-Remote** switch to **Run** and check for battery voltage (12 VDC) at terminal **A11-TB1-10**. Replace engine monitor board **A11** if there is no voltage during cranking.
12. The engine is worn or out of adjustment.	Service the engine according to Section 8.

THE ENGINE RUNS UNTIL FAULT SHUTDOWN	
⚠ WARNING ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***	
Possible Cause	**Corrective Action**
1. The **OVERSPEED** lamp comes on when the engine shuts down.	A. If this is a 60 Hertz set, check to see if the orange jumper on the overspeed module has been cut (Figure 5-7 on Page 5-10). If it has, replace the module. (Cutting the orange jumper lowers the cutout point for 50 Hertz sets.) B. Reset engine monitor board **A11** by pushing the **Run-Stop-Remote** switch to **Stop** and the **Reset** switch to **Reset** and restart the set. Adjust the governor according to Section 8.
2. The **LO OIL PRES** lamp comes on when the engine shuts down.	A. Check the engine oil level, repair any oil leaks and fill to the proper level. Then reset engine monitor board **A11** by pushing the **Run-Stop-Remote** switch to **Stop** and the **Reset** switch to **Reset**. B. If the set still shuts down due to low oil pressure, restart the set and observe oil pressure while cranking the engine. Replace the low oil pressure cutout switch if oil pressure is greater than 10 psi (69 kPa). Service the lubricating oil system if oil pressure is less than 10 psi (69 kPa). See Section 8.

THE ENGINE RUNS UNTIL FAULT SHUTDOWN (CONT.)	
⚠ WARNING ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***	
Possible Cause	**Corrective Action**
3. The **HI ENG TEMP** lamp comes on when the engine shuts down.	A. Check the engine coolant level, repair any coolant leaks and refill as necessary (liquid cooled). Then reset engine monitor board **A11** by pushing the **Run-Stop-Remote** switch to **Stop** and the **Reset** switch to **Reset**. B. **Liquid-Cooled Engines**—If the set still shuts down due to high engine temperature, start the engine and observe coolant temperature as the system heats up. If shutdown occurs before the coolant reaches 225° F (101° C), replace the high engine temperature cutout switch. If coolant temperature exceeds 225° F (101° C), clean and service the entire cooling system as required to restore full cooling capacity. **Air-Cooled Engines**—Clean the air ducts, fan and cylinder cooling fins and service dampers that do not fully open. (Air cooled engines have a 260° F [127° C] head bolt mounted temperature switch [Figure 5-10]. Replace the switch if it is not open at room temperature.)
4. The **FAULT 1** or **FAULT 2** lamp comes on when the engine shuts down. (May be specifically labeled.)	Service as required. The customer has supplied the system fault indication switches. Either fault can be chosen to display the warning only with the function selection jumpers on the engine monitor board. See Page 5-5. If the shutdown was due to low frequency, the set probably ran out of fuel, or the governor is out of adjustment. If the shutdown was due to over/under voltage, the voltage regulator may be out of adjustment.

THE ENGINE LACKS POWER OR IS UNSTABLE	
⚠ WARNING ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***	
Possible Cause	**Corrective Action**
1. Fuel delivery to the set is inadequate.	A. Check for clogged fuel lines and filters. B. Check for air in the fuel lines. C. Check the vertical distance from the bottom of the fuel dip tube to the fuel lift pump. The distance must not exceed 3 meters (10 feet).
2. The fuel is contaminated.	Connect the fuel lift pump to a container of fuel of known quality. Replace the contents of the fuel supply tank if there is a noticeable difference in performance.
3. The air cleaner is dirty or the exhaust system is clogged.	Service as necessary.
4. The engine or engine fuel system is worn or out of adjustment.	Service the engine according to Section 8.

AN AMBER WARNING LAMP IS ON

⚠ WARNING ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***

Possible Cause	Corrective Action
1. The **PREHET** or **PRELOP** lamp comes on while the engine is running.	Shut down the set if possible or disconnect non-critical loads.(Oil pressure will be less than 20 psi but greater than 14 psi or engine temperature will be greater than 220° F but less than 230° F.) Service the engine lubricating or cooling system according to Section 8.
2. The **LO FUEL** lamp comes on.	Fill the fuel supply tank with the appropriate grade of fuel. (The customer has supplied the fuel level switch to make use of the warning.)
3. The **LOW ENG TEMP** lamp comes on during standby.	Plug in, repair or install an engine coolant heater.
4. The **FAULT 1** or **FAULT 2** lamp comes on during standby. (May be a specifically labeled amber lamp.)	Service as required. The customer has supplied the system fault indication switches. Either fault can be chosen to display the warning only with the function selection jumpers on the engine monitor board. See Page 5-5.

THE GREEN RUN LAMP STAYS OFF BUT THE SET RUNS NORMALLY

⚠ **WARNING** ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***

Possible Cause	Corrective Action
1. The set mounted **RUN** lamp does not light although the starter has disconnected normally and the engine is running.	A. Press the panel **Lamp Test** switch and replace the run lamp bulb if it does not light. B. Check for loose or missing wiring between the start disconnect module and pin connector **P1-5** on engine monitor board **A11**. See the connection diagram on Page 5-10. C. Check for 12 VDC at **A11-P1-5** while the set is running. If there is no voltage, check to see that the start disconnect module and rotor are mounted properly and that the LED is blinking (Figure 5-7 on Page 5-10). Replace the module if is mounted properly but there is no voltage or the LED is not blinking. D. Replace engine monitor board **A11** if there is voltage at **A11-P1-5** while the set is running normally but the **RUN** lamp does not light.
2. Neither the remote nor the set mounted **RUN** lamp light although the starter has disconnected normally and the engine is running.	A. Press the panel **Lamp Test** switch and replace the run lamp bulb if it does not light. Test the remote **RUN** lamp by suitable means and replace it if it does not light. B. If both lamps are good, this indicates that the AC disconnect circuit is not working. Check the AC voltmeter to determine whether or not there is generator output voltage and service as necessary. Troubleshoot according to THERE IS NO OUTPUT VOLTAGE. C. If there is generator output voltage, check for 120 VAC across pin connectors **P1-1** and **P1-2** on engine monitor board **A11**. If there is no voltage, check for loose or missing leads between the connectors and **TB21-21** and **TB21-32** inside the control box and service as necessary. D. Replace engine monitor board **A11** if there is 120 VAC across pin connectors **P1-1** and **P1-2** but neither **RUN** lamp lights during normal operation.

THIS PAGE LEFT INTENTIONALLY BLANK

6. Voltage Regulator

PRINCIPLE OF GENERATOR OPERATION

Refer to Figure 6-1 while working through the following explanation.

1. The generator field (main rotor) is rotated by the engine to induce output current (AC) in the main stator windings.

2. Generator output current is proportional to field strength, which is varied to match the load. Nominal output voltage and frequency are maintained by the voltage regulator and engine governor, respectively.

3. Generator field strength is proportional to field current, which is supplied by the exciter.

4. The exciter field (stator) induces current in the exciter rotor windings. A full-wave rectifier bridge (rotating rectifiers) mounted on the exciter rotor converts exciter output (3-phase AC) to DC. The exciter rotor is mounted on the main rotor shaft.

5. Exciter output current is proportional to exciter field current.

6. The automatic voltage regulator regulates exciter field current by comparing generator output voltage and frequency with reference values.

7. Exciter field current is supplied by the main stator through the voltage regulator. Residual field magnetism initiates “self-excitation” during startups.

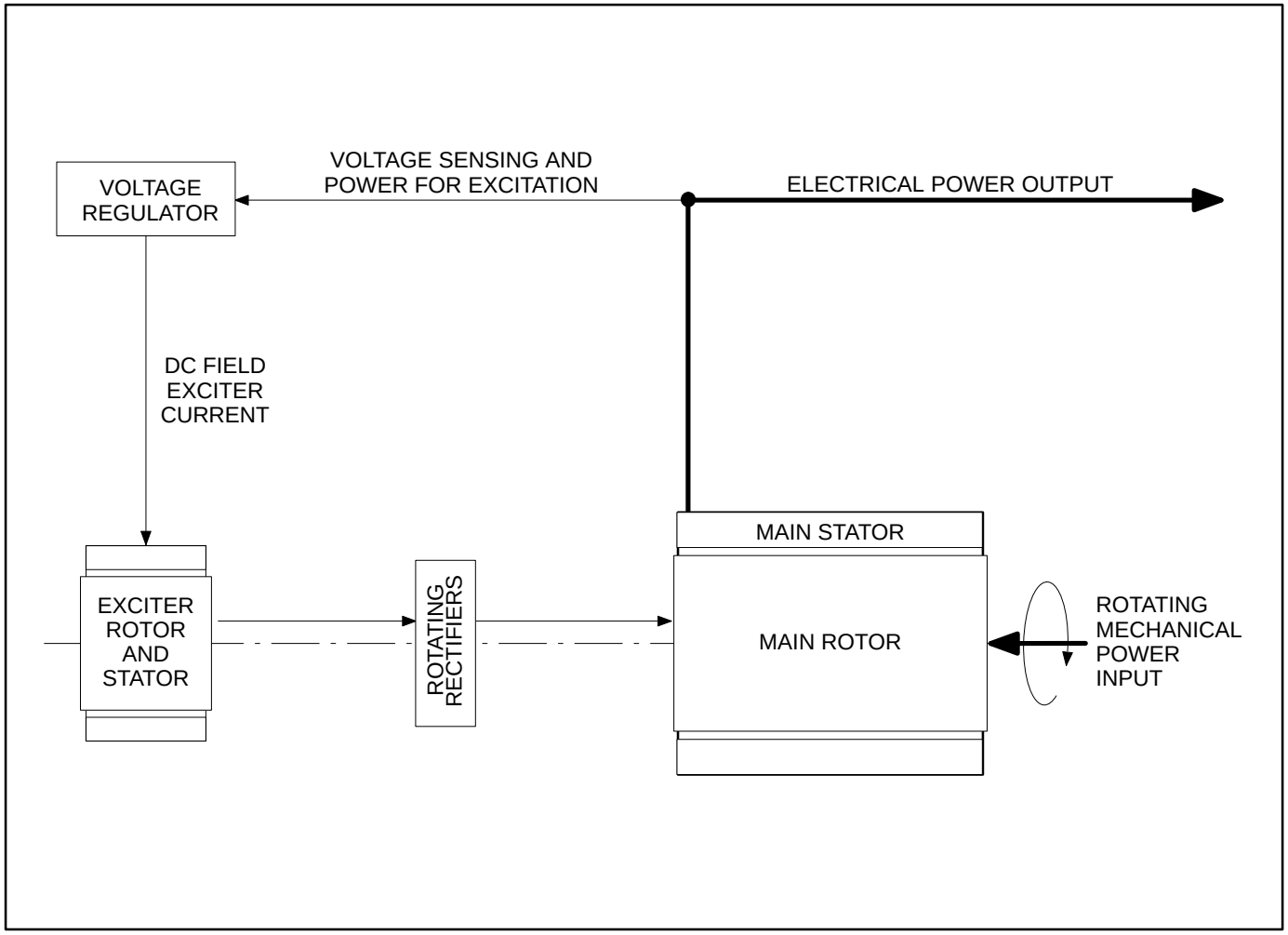


FIGURE 6-1. DIAGRAM OF GENERATOR OPERATION

VOLTAGE REGULATOR

Figures 6-2, 6-3 and 6-4 illustrate the voltage regulator and its mounting and orientation in the different types of control boxes.

Frequency Selection Jumper

Connect the frequency selection jumper for the application frequency, 50 Hz or 60 Hz.

Voltage Adjustment

Use the control panel mounted voltage trimmer, if provided, for small voltage adjustments. Measure generator output voltage while the set is running without load at the nominal frequency.

If a replacement voltage regulator has been installed, or the voltage trimmer does not provide enough adjustment, adjust voltage as follows:

1. Turn the voltage trimmer on the control panel (Figure 5-1 or 5-2, Detector control only) to its mid position.
2. Turn the **VOLTS** pot on the voltage regulator fully counterclockwise.
3. Turn the **STABILITY** pot on the voltage regulator to its mid position.
4. Start and operate the generator set at rated frequency and no load. If the **LED** lights, see **UFRO Adjustment**.
5. Slowly turn the **VOLTS** pot clockwise until rated voltage is obtained.
6. See **Stability Adjustment** if voltage is unstable.

Stability Adjustment

If it is necessary to adjust stability, run the generator set at rated frequency and no load. Slowly turn the **STABILITY** pot clockwise until voltage becomes stable and then counterclockwise until it again become unstable. Turn the pot slightly clockwise from this position for maximum stability. Readjust voltage after a stability adjustment.

UFRO Adjustment

The **LED** on the voltage regulator indicates that the **UFRO** (under frequency roll off) circuit is in operation. Check first to see that the frequency selection jumper is connected appropriately for the application (50 Hz or 60 Hz).

The **UFRO** pot on the voltage regulator is factory set and sealed. If necessary, adjust it so that the **LED** lights as frequency drops to 47 Hz for a 50 Hz application or 57 Hz for a 60 Hz application. Turn the pot clockwise to reduce the “knee point” frequency.

Field Flashing

If there is no output voltage, flash the field as follows:

1. Assemble a 12 volt battery, 10 ohm resistor, 18 volt voltage suppressor and 12 amp, 300 volt diode as shown in Figure 6-2, 6-3 or 6-4.
2. While the set is running at nominal frequency, momentarily connect the positive (**+**) side of the the circuit to voltage regulator terminal **VR21-F1 (x)** and the negative side (**–**) to voltage regulator terminal **VR21-F2 (xx)**.

   ⚠ CAUTION ***The voltage regulator could be damaged if the flashing circuit is connected for more than 5 seconds.***
3. Check output voltage, shut down the set and restart it. See TROUBLESHOOTING in Section 7 if output voltage does not build up without field flashing.

⚠ DANGER ***HAZARDOUS VOLTAGE! Touching uninsulated live parts inside the control and power output boxes can result in severe personal injury or death. Do not touch uninsulated live parts.***

Stand on a dry wooden platform or rubber insulating mat, make sure your clothing and shoes are dry, remove jewelry, restrain hair and use tools with insulated handles.

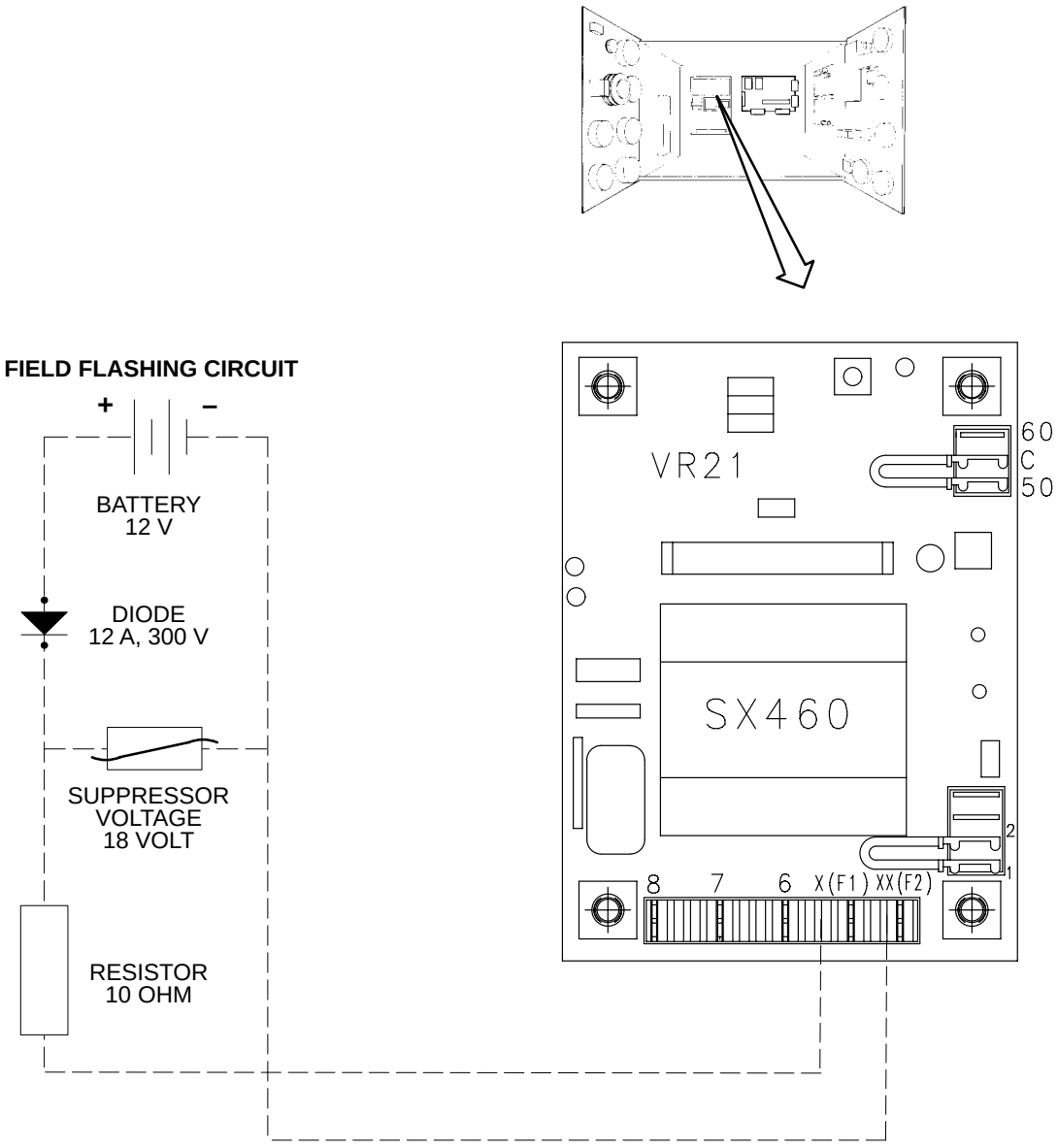


FIGURE 6-2. VOLTAGE REGULATOR WITH DETECTOR CONTROL (BEGINNING SPEC B)

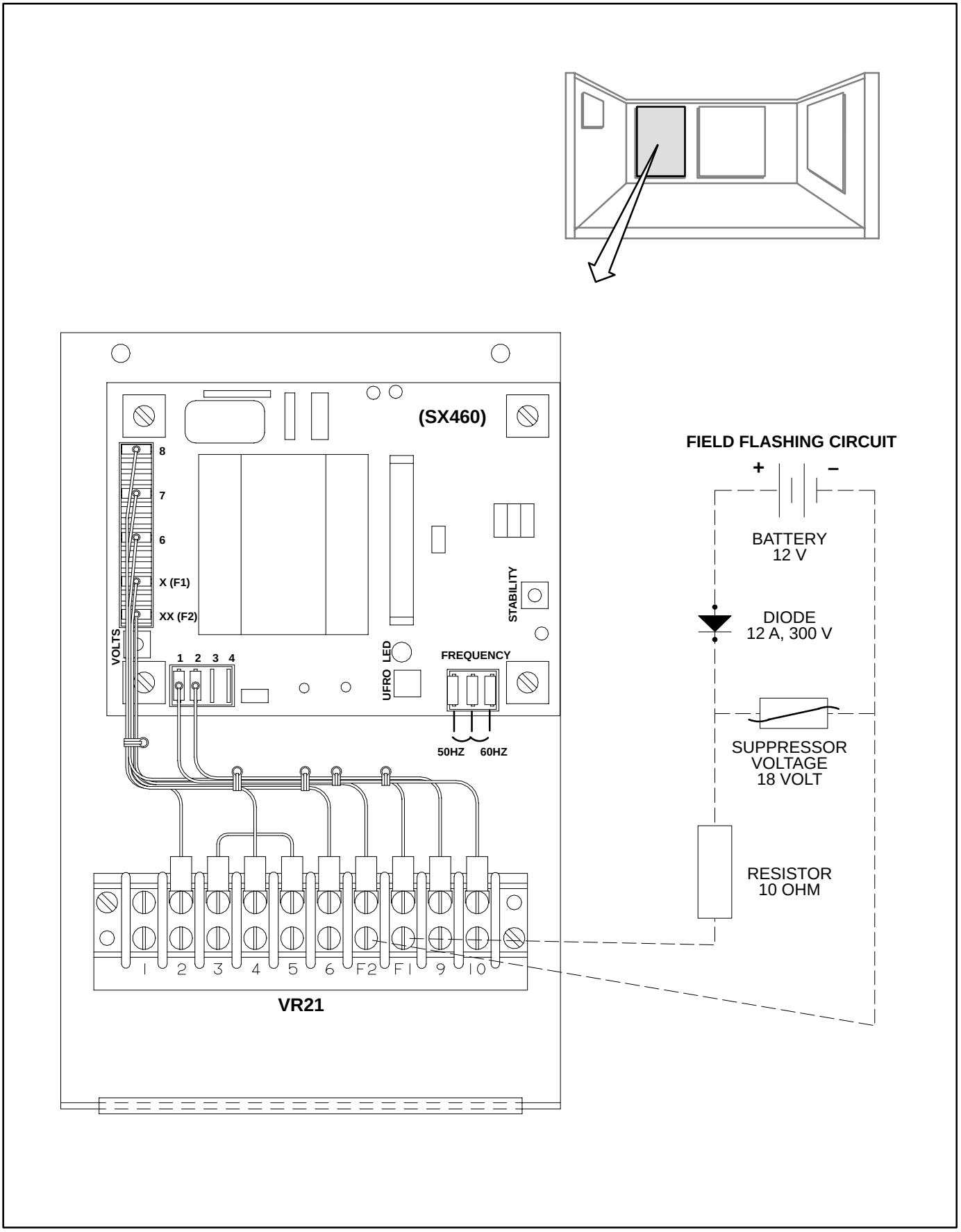


FIGURE 6-3. VOLTAGE REGULATOR WITH DETECTOR CONTROL (SPEC A)

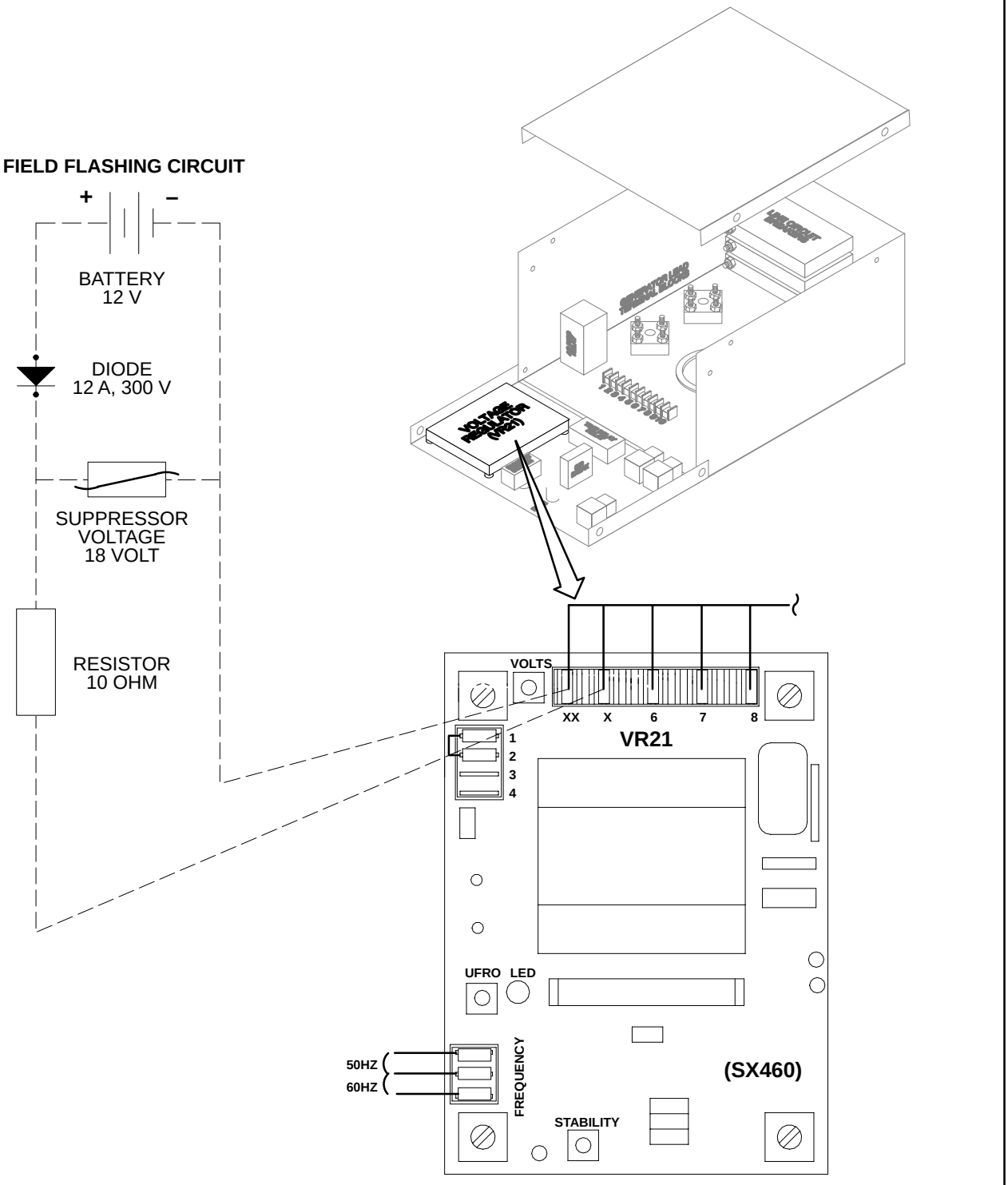


FIGURE 6-4. VOLTAGE REGULATOR WITH MANUAL AND REMOTE/ATS CONTROLS

THIS PAGE LEFT INTENTIONALLY BLANK

7. Generator

These are 4-pole, rotating-field, brushless, single-bearing generators (Figure 7-1).

VOLTAGE REGULATION

See Section 6.

GENERATOR CONNECTIONS

⚠ DANGER ***HAZARDOUS VOLTAGE! Touching uninsulated live parts inside the control and power output boxes can result in severe personal injury or death. Do not touch uninsulated live parts.***

Stand on a dry wooden platform or rubber insulating mat, make sure your clothing and shoes are dry, remove jewelry, restrain hair and use tools with insulated handles.

⚠WARNING ***Accidental starting can cause severe personal injury or death. To prevent accidental starting, push the control panel switch to OFF and disconnect the negative (–) battery cable from the battery before working on the generator set.***

⚠WARNING ***Arcing can ignite battery gases and cause severe personal injury and can cause voltage spikes that can damage generator set control circuits. To reduce arcing:***

Always disconnect a battery charger from its AC source before disconnecting the battery cables.

Always disconnect the negative (–) cable first and reconnect it last. (This prevents arcing if the tool on the positive terminal touches grounded metal.)

Local regulations usually require that wiring connections be made by a licensed electrician and that the installation be inspected and approved before operation. All wiring methods, connections, wire ampacities, equipment grounding, materials, etc. must comply with the applicable codes.

⚠WARNING ***Improper wiring can cause fire or electrocution resulting in severe personal injury or death and property damage.***

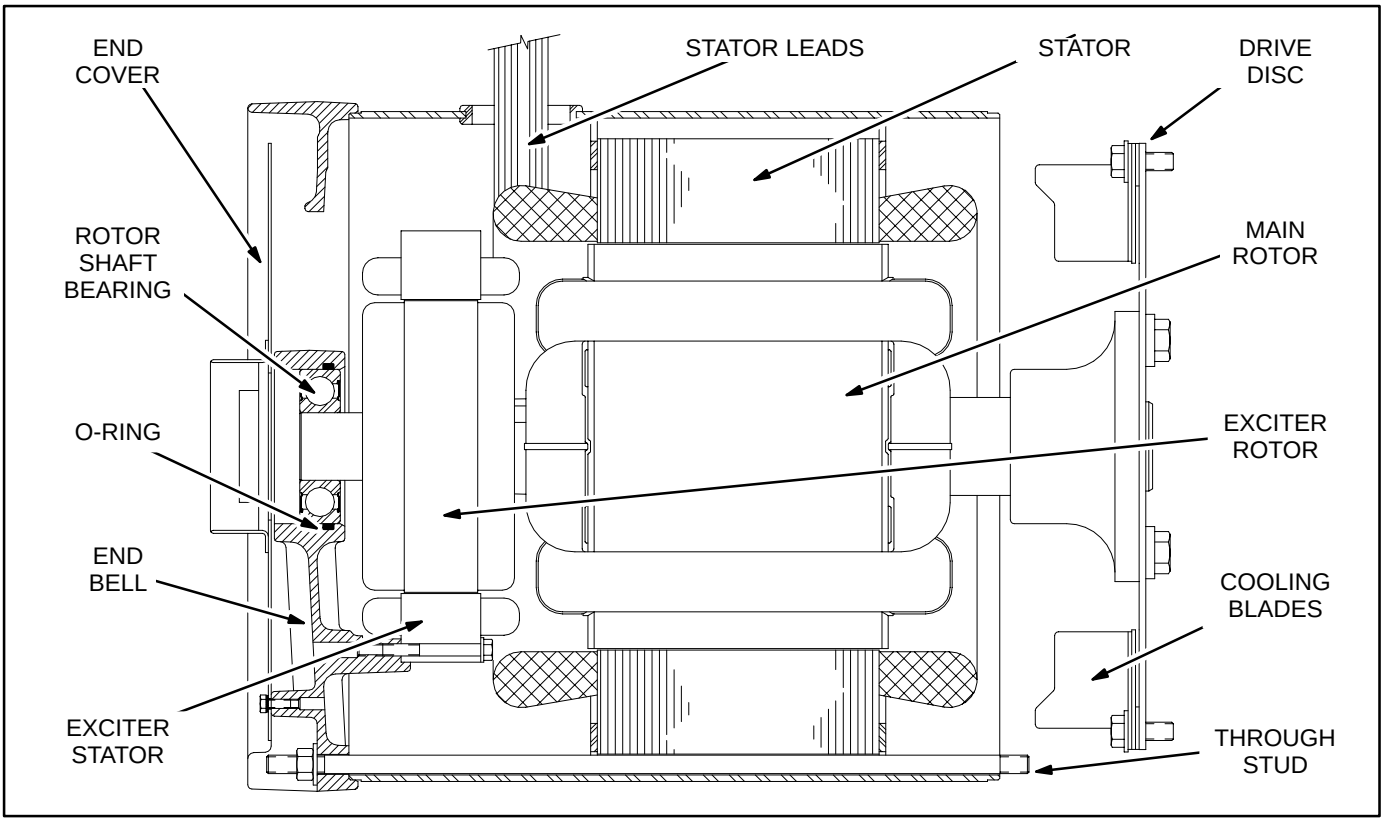


FIGURE 7-1. GENERATOR

Use flexible conduit and stranded conductors to make connections at the generator set to take up movement and vibration. Note the recommended electrical stub up area on the generator set outline drawing.

Two terminal blocks with four terminals each are available for output connections. Additional terminals are available if the optional line circuit breakers are mounted.

Twelve-lead generators are reconnectable. See the appropriate connection diagram on Page A-1 or B-1. *Note the connections for the voltage sensing leads and current transformers (CTs).*

Note 1: On generator sets with Detector Control the scale indicator lamp on the control panel will indicate whether the upper or low meter scale should be read—if generator connections have been made properly.

Note 2: If the generator is equipped with line circuit breakers and generator reconnections are made, the line circuit breakers will have to be replaced with circuit breakers having appropriate ampere ratings.

Detector Control (Spec A)– If the ammeter reads low and is connected to CT terminals **1** and **3**, try reconnecting to terminals **1** and **2**. If the ammeter reads high and is connected to CT terminals **1** and **2**, try reconnecting to terminals **1** and **3** (Page A-1).

⚠ CAUTION ***Connecting a load between CT terminals 2 and 3 can damage the CT.***

Manual or Remote/ATS Control – If the ammeter reads low and the generator leads run through the CTs only once, try running the leads through twice. If the ammeter reads high and the generator leads run through the CTs twice, try running the leads through once. See the meter connection diagram on Page C-3.

TESTING THE GENERATOR

Testing Winding Insulation Resistance

A 500 VAC megger is recommended for the winding insulation resistance tests prescribed below. A test consists of applying the test potential between the winding and ground (winding laminations) for a period of 10 minutes and recording resistance at 1 minute and again at 10 minutes.

Resistance values of at least 5 megohms should be obtained for a new generator with dry windings. The polarization index should also be at least 2 (the ratio of the resistance reading at ten minutes to the reading at one minute). For a set that has been in service, the resistance reading should not be less than 1 megohm nor the polarization index less than 2.

If low readings are obtained or the set has been in standby for a long time in high humidity conditions, the windings should be dried out and the test repeated. Use the generator standby heaters (if so equipped) or blow warm air through the generator with a fan. A more effective way is to use a bolted short across the generator leads or terminals. To do this:

1. Bolt the two (three) phases of the generator together at the terminals. See the appropriate connection diagram on Page A-1 or B-1.
2. Disconnect the **F1** and **F2** leads at the voltage regulator and connect them to a variable 12 VDC source. See Figure 6-2, 6-3 or 6-4.
3. Attach a clamp-on ammeter to the generator leads to measure generator current, adjust the 12 VDC source for zero voltage, start the set and slowly increase the excitation voltage. Obtain the highest current possible without exceeding generator rating.
4. Run the set for approximately one hour and repeat the insulation resistance tests. Replace the stator or rotor if its winding resistance is less than specified.

Exciter Stator

Winding Insulation Resistance: Disconnect exciter stator leads **F1** and **F2** from their connectors in the AC generator wiring harness, isolate them from ground, connect either one to the megger and conduct the test as instructed under Testing Winding Insulation Resistance.

Winding Resistance: Measure winding resistance between exciter stator leads **F1** and **F2** with a digital ohmmeter. Replace the exciter stator if winding resistance is not 13 to 16 ohms.

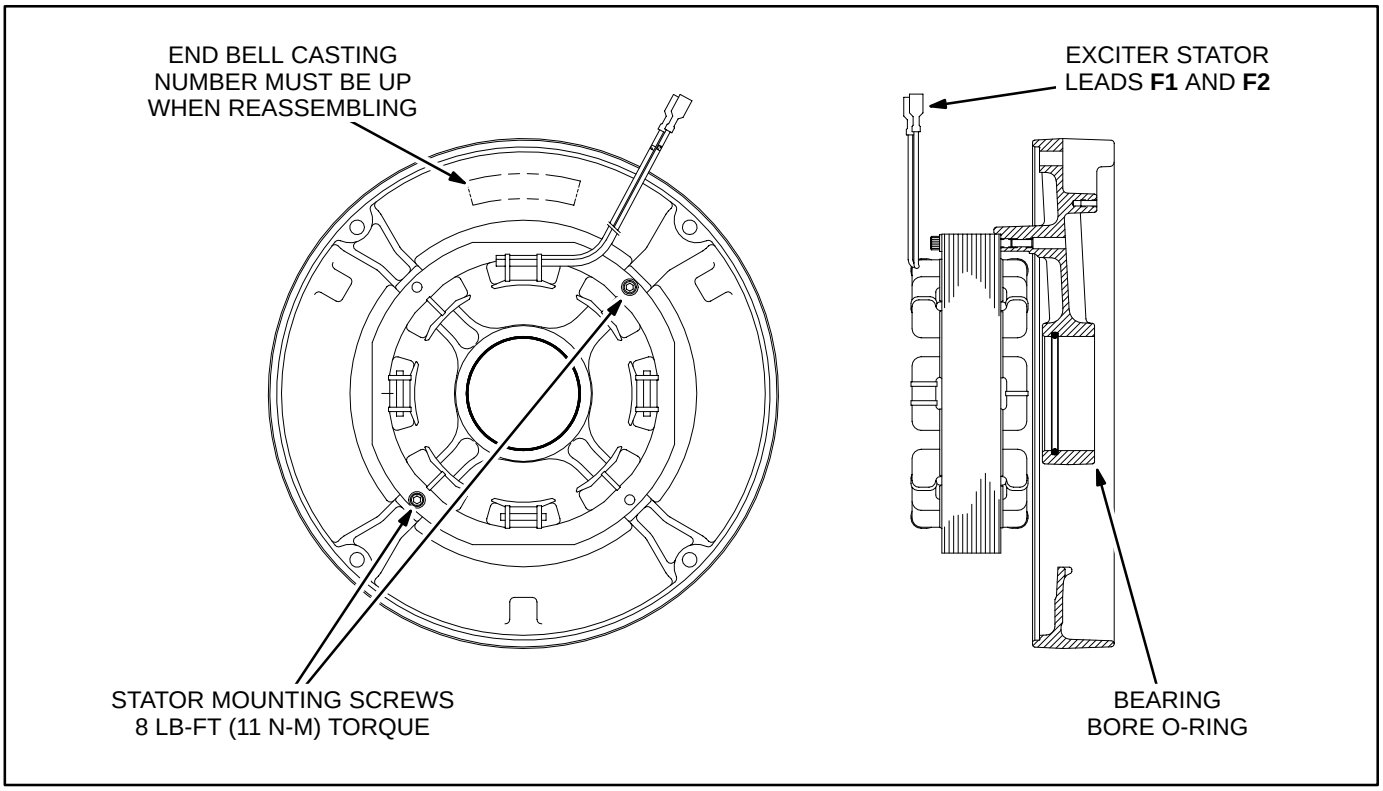


FIGURE 7-2. EXCITER STATOR AND END BELL

Exciter Rotor and Rotating Rectifiers

Winding Insulation Resistance: Disconnect all six exciter rotor leads from diode terminals **CR1** through **CR6** and isolate them from ground. Connect any lead to the megger and conduct the test as instructed under Testing Winding Insulation Resistance.

Winding Resistance: With a Wheatstone bridge, measure electrical resistance across each pair of rotor windings: **T11-T12**, **T21-T22**, **T12-T13**, **T22-T23**, **T13-T11** and **T23-T21**. See the connection schematic. Replace the whole rotor shaft assembly if the resistance of any winding is not 0.52 to 0.64 ohms.

The rotating rectifier assembly is mounted on the back face of the exciter rotor. It consists of one positive (**+**) and one negative (**–**) diode assembly. Each assembly carries three diodes in an epoxy potting. Each diode has a terminal for connecting the appropriate lead from the exciter rotor (**CR1** through **CR6**). Each assembly has a field terminal (**F1+** or **F2–**) for connecting the leads from the main rotor (generator field) and voltage suppressor.

Diode Resistance: Using a digital ohmmeter, measure electrical resistance between diode terminals **CR1**, **CR2** and **CR3** and field terminal **F1+** on the positive diode assembly and between diode terminals **CR4**, **CR5** and **CR6** and field terminal **F2–** on the negative diode assembly. Reverse the meter test probes and repeat the tests. The electrical resistance across each diode should be high in one direction and low in the other. If the resistance is high or low in both directions, replace the whole diode assembly.

Replacing Diode Assembly: Make sure the replacement diode assembly is of the correct polarity, positive (**+**) or negative (**–**). Then disconnect all leads from the defective diode assembly and remove the two mounting screws. Mount the new diode assembly, reconnect all leads and torque the terminal screws to 24 lb-in (2.6 N-m).

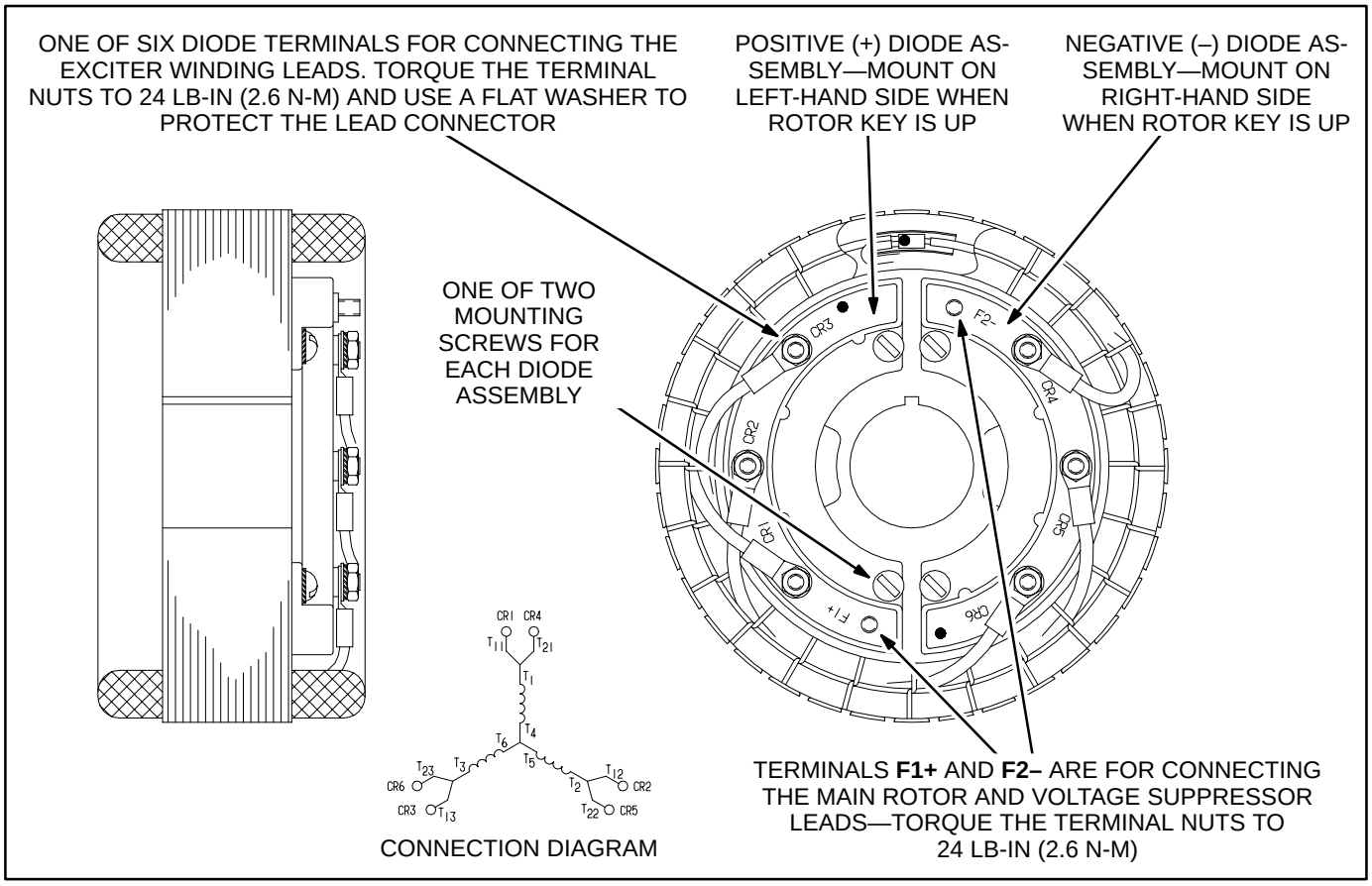


FIGURE 7-3. ROTATING RECTIFIER ASSEMBLY

Main Rotor And Surge Suppressor

Winding Insulation Resistance: Disconnect the main rotor and voltage suppressor leads from terminals **F1+** and **F2+** on the rotating rectifier assemblies and isolate them from ground. Tag and mark each lead with its terminal number (**F1+** or **F2+**).

⚠ CAUTION ***Because of the opposing residual magnetism of the rotor, it might be difficult to re-establish self excitation if the polarity of the main rotor leads is reversed upon reassembly.***

Connect either or both leads to the megger and conduct the test as instructed under Testing Winding Insulation Resistance.

Winding Resistance: Measure electrical resistance between the two main rotor leads with a digital ohmmeter. Replace the rotor if the resistance is not as specified in Table 7-1.

Surge Suppresser: A voltage suppressor is mounted on the rotor shaft between the main rotor and the exciter rotor. Its leads are connected to terminals **F1+** and **F2–** on the rotating rectifier assemblies. Disconnect the leads from their terminals and measure resistance between the leads with a digital ohmmeter. Replace the whole rotor shaft assembly if resistance is not infinite on the highest scale of the meter.

Reconnect the rotor and surge suppressor leads and torque the terminals to 24 lb-in (2.7 N-m) when reassembling.

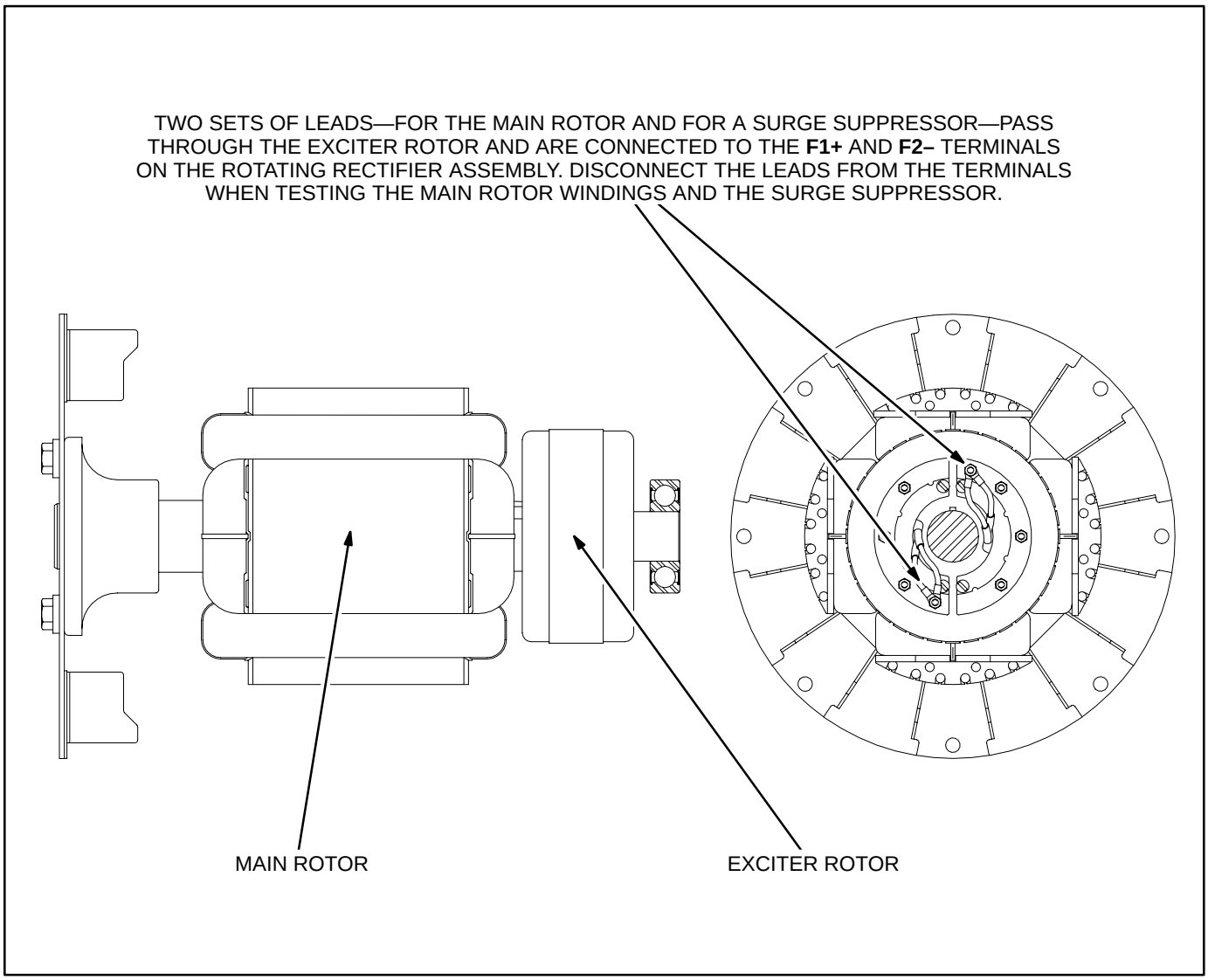


FIGURE 7-4. MAIN ROTOR

Main Stator

Winding Insulation Resistance: Test each winding separately. Disconnect the winding lead from its grounded neutral connection and isolate it (Page A-1 or B-1). Leave the other windings grounded. Connect either or both winding leads to the megger and conduct the test as instructed under Testing Winding Insulation Resistance.

Winding Resistance: Disconnect all main stator leads from the terminals to which they are connected. Using a Wheatstone bridge having at least 0.001 ohm precision, measure electrical resistance across each pair of stator leads (Page A-1 or B-1). Replace the stator if the resistance of any winding is not as specified in Table 7-1.

The resistances measured across lead pairs on 4-lead generators should be twice the value in Table 7-1 since each lead pair is connected to two winding coil groups, which are connected in series.

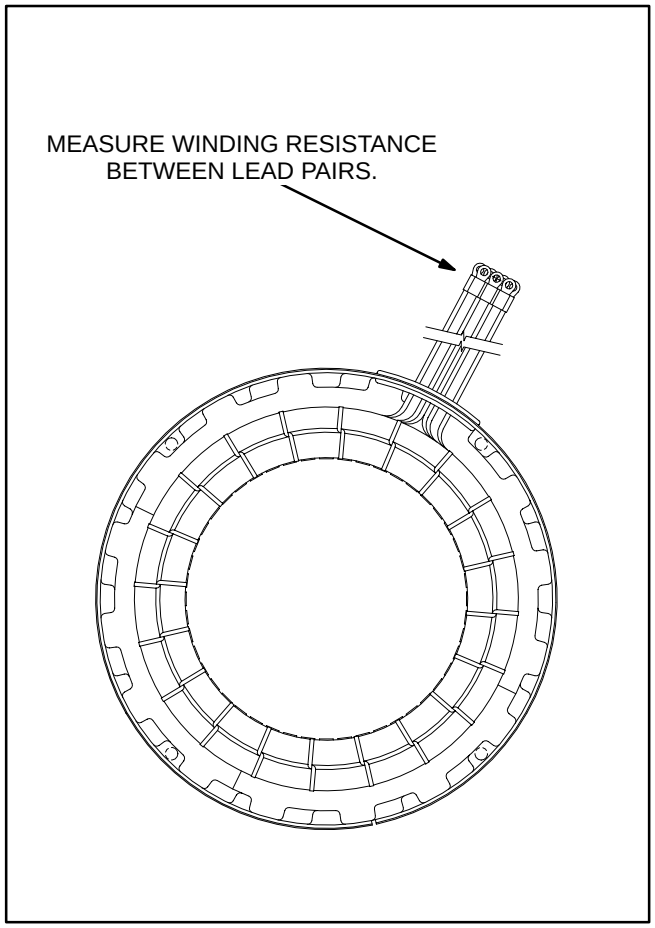
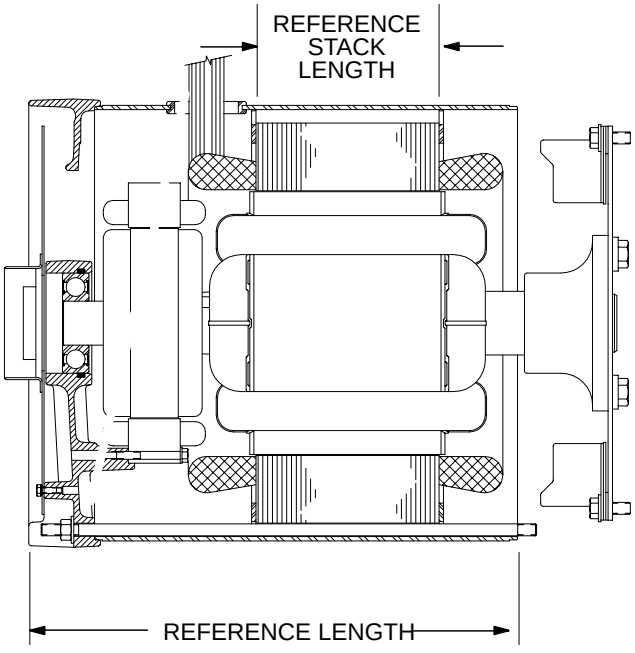


FIGURE 7-5. MAIN STATOR WINDINGS

TABLE 7-1. MAIN STATOR AND ROTOR WINDING RESISTANCES

REFERENCE LENGTH MILLIMETERS (INCHES)[1]	REFERENCE STACK LENGTH MILLIMETERS (INCHES)[1]	MAIN STATOR WINDING RESISTANCE OHMS[2]	MAIN ROTOR WINDING RESISTANCE OHMS[2]
4-Lead Generators (Single-Phase)			
349 (13.7)	73 (2.88)	0.179-0.197	2.57-3.10
364 (14.3)	87 (3.44)	0.127-0.141	1.88-2.30
386 (15.2)	110 (4.31)	0.080-0.088	2.12-2.59
422 (16.6)	146 (5.75)	0.053-0.059	2.48-3.03
454 (17.9)	178 (7.00)	0.039-0.043	1.78-2.18
12-Lead Generators (Three-Phase)			
349 (13.7)	73 (2.88)	0.417-0.461	2.57-3.10
364 (14.3)	87 (3.44)	0.257-0.284	1.88-2.30
386 (15.2)	110 (4.31)	0.191-0.172	2.12-2.59
422 (16.6)	146 (5.75)	0.105-0.117	2.48-3.03
454 (17.9)	178 (7.00)	0.086-0.096	1.78-2.18
6-Lead, 347/600 Volt Generators (Three-Phase)			
349 (13.7)	73 (2.88)	1.317-1.456	2.57-3.10
364 (14.3)	87 (3.44)	0.786-0.868	1.88-2.30
386 (15.2)	110 (4.31)	0.542-0.599	2.12-2.59
422 (16.6)	146 (5.75)	0.338-0.374	2.48-3.03
454 (17.9)	178 (7.00)	0.273-0.301	1.78-2.18



1. These are approximate reference dimensions for aiding generator identification. The corresponding rotor stack lengths are slightly greater than the stator stack lengths.
2. Stator resistances are ± 5% of nominal at 77° F (25° C) and rotor resistance are± 10%.

GENERATOR DISASSEMBLY

The generator is heavy. You will need an assistant and hoist of sufficient capacity to remove the generator.

⚠WARNING ***Accidentally dropping the generator can damage it and cause severe personal injury and death. The hoist and straps must have sufficient capacity and be attached properly so that the load cannot shift.***

Before starting, disconnect the starting battery cables (negative [-] first) to make sure the set will not start while working on it.

⚠WARNING ***Accidental starting can cause severe personal injury or death. To prevent accidental starting, push the control panel switch to OFF and disconnect the negative (–) battery cable from the battery before working on the generator set.***

Arcing can ignite battery gases and cause severe personal injury and can cause voltage spikes that can damage generator set control circuits. To reduce arcing:

Never disconnect the battery cables while the generator set is cranking or running.

Always disconnect a battery charger from its AC source before disconnecting the battery cables.

Always disconnect the negative (–) cable first and reconnect it last. (This prevents arcing if the tool on the positive terminal touches grounded metal.)

1. Disconnect all power output and remote control connections and conduit at the generator. For easier reconnections later, make sure each lead is clearly marked.

2. ***On Spec A generator sets with Detector control,*** remove the four mounting screws in the bottom of the control box and tip the box up on one of its sides for access to the wiring connections on the bottom. Disconnect the engine wiring harness from the plugs and terminals on the bottom of the control box. Also, disconnect the control box heater, if provided. For easier reconnections later, make sure each lead is clearly marked.

   Beginning with Spec B generator sets with Detector control, disconnect the engine wiring harness from all terminals inside the control box and all generator leads from terminals in the control and output boxes and remove the assembly from its mounting saddle above the generator (so that a lifting strap can be used to support the generator stator housing). For easier reconnections later, make sure each lead is clearly marked.

   On generator sets with Manual or Remote/ATS control, disconnect the engine wiring harness from all terminals inside the control box. For easier reconnections later, make sure each lead is clearly marked.

3. Disconnect the generator leads and control wiring if the control box is to be removed from the generator.

4. *On generator sets with Detector control,* disconnect the overspeed/start disconnect module and remove the generator end bell cover and module as an assembly. Remove the overspeed/start disconnect rotor element from the end of the generator shaft.

5. Cinch a hoisting strap around the middle of the generator stator and take up slack with a hoist.

6. Before separating the generator stator from the flywheel housing and end bell, scribe lines to register the parts for easier reassembly.

7. Remove the four nuts and washers on the generator through-studs and tap the end bell free of the stator assembly.

8. Tap the generator stator free of the adaptor housing and carefully draw the stator straight back until it clears the ends of the through-studs.

9. Remove the generator through-studs.

10. If it is necessary to remove the rotor, cinch a hoisting strap around the middle of the main rotor laminations and then remove the bolts securing the generator drive disc to the flywheel.

11. Remove the two mounting screws if it is necessary to remove the exciter stator from the generator end bell.

12. Use a gear puller if it is necessary to remove the rotor bearing.

GENERATOR REASSEMBLY

Reassembly is the reverse of disassembly. Note the following when reassembling the generator:

1. If the rotor bearing was removed, press a new rotor bearing on flush with the end of the shaft. (The end of the shaft must not extend more than 0.020 inch (0.5 mm) beyond the side of the bearing. Apply force to the inner race of the rotor bearing when pressing it onto the shaft so as not to damage the bearing.

2. If the drive disc was removed from the rotor, torque the eight bolts to 68 lb-ft (92 N-m) when remounting. Make sure that:

   A. The chamfered edge of the drive disc perimeter faces away from the rotor to make assembly to the flywheel easier.

   B. The fan blade assembly goes on first. (It will be secured with the disc-to-flywheel bolts.)

   C. The rounded edges of the washers are on the disc side.

3. If the rotor was removed from the engine flywheel, torque the eight drive disc-to-flywheel bolts to 39 lb-ft (52 N-m) when remounting.

4. If the flywheel housing was removed, torque the bolts to 60 lb-ft (81 N-m) when remounting.

5. Thread the generator through-studs into the flywheel housing before attempting to mount and align the generator stator. The ends having the shorter lengths of thread must be threaded into the flywheel housing. Make sure the studs bottom.

6. When mating the generator stator and flywheel housing, make sure the scribed index lines (Step 6, Disassembly) register.

7. If the exciter stator was removed from the generator end bell, torque the two screws to 8 lb-ft (11 N-m) when remounting. The leads must exit away from the end bell and be in the top half of the assembly (see Figure 7-2).

8. Wipe the bearing bore in the end bell lightly with molybdenum disulfide grease and make sure the rubber O-ring is in place.

9. Mount the end bell to the stator assembly, making sure the rotor bearing is fully seated in the bore and that the end bell part number is at the top. Torque the nuts on the generator through-studs to 28 lb-ft (38 N-m). Pull the field leads out the same opening as the main stator leads.

10. Mount the rotor for the overspeed/start disconnect module (Detector control generators) on the end of the rotor and torque the bolt to 18 lb-ft (25 N-m).

11. Secure the end bell cover plate and torque the four screws to 8 lb-in (3.8 N-m).

12. Reconnect or remount all the other components that were disconnected or removed under Disassembly.

⚠ CAUTION ***It may be necessary to flash the field to get AC output voltage, which is the means for activating the AC start disconnect circuit. To protect the starter from damage, do not start the generator set until the DC start disconnect module has been remounted and reconnected. See Figure 6-2, 6-3 or 6-4.***

TROUBLESHOOTING

The following generator and voltage regulator troubleshooting tables are referenced by troubleshooting in the generator set control sections. See the Table of Contents for the appropriate generator set control section.

NO OUTPUT VOLTAGE	
⚠ WARNING ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***	
Possible Cause	**Corrective Action**
1. The line circuit breaker is **OFF**.	Find out why the circuit breaker was turned **OFF**, make sure it is safe to reconnect power, and then throw the circuit breaker **ON**.
2. The line circuit breaker has **TRIPPED**.	Shut down the set and service as necessary to clear the short circuit or ground fault that caused tripping, and then **RESET** the circuit breaker and start the set.
3. The line circuit breaker is faulty.	Shut down the set, make sure the power output lines from the set have been disconnected from all other sources of power, attempt to **RESET** the circuit breaker and throw it **ON** and check for electrical continuity across each line contact. Replace the circuit breaker if there is measurable resistance across any contact.
4. Field circuit breaker **CB21** has **TRIPPED**.	**RESET** the circuit breaker. If it keeps tripping, troubleshoot according to FIELD CIRCUIT BREAKER KEEPS TRIPPING.
5. Field circuit breaker **CB21** is faulty (Detector control only).	Shut down the set, attempt to **RESET** the circuit breaker, disconnect either lead and measure resistance. Replace the circuit breaker if there is measurable resistance across the terminals.
6. The field has lost its residual magnetism.	Flash the field. See Section 6.

NO OUTPUT VOLTAGE (CONT.)

⚠ **WARNING** ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***

Possible Cause	Corrective Action
If flashing the field does not work (Item 6 above), isolate the problem to the voltage regulator or to the generator as follows: A. Throw the line circuit breaker **OFF** and shut down the set. ⚠ **CAUTION** ***This test involves unregulated excitation of the generator. To prevent damage to the generator due to overcurrent, make sure that all loads have been disconnected and that all faults have been cleared from the power output terminals of the generator.*** B. Disconnect the field leads from terminals **VR21-F1** and **VR21-F2** on the voltage regulator (See Section 6) and connect the leads to a **12 volt battery**: **F1** to battery positive (**+**) and **F2** to battery negative (**–**). Polarity must be correct or this test will be inconclusive because the induced and residual magnetic polarities in the exciter stator will be opposed. C. Read output voltage across the generator terminals while the set is running. ⚠ **DANGER** ***HAZARDOUS VOLTAGE! Touching uninsulated live parts inside the control and power output boxes can result in severe personal injury or death. Do not touch uninsulated live parts. Stand on a dry wooden platform or rubber insulating mat, make sure your clothing and shoes are dry, remove jewelry, restrain hair and use tools with insulated handles.*** D. If rated output voltage or higher is obtained and the voltages for all phases are balanced, the generator is probably okay. Troubleshoot the voltage regulator—Step 7. E. If the output voltages are not balanced, or are less than ninety percent of rated output voltage, the problem is probably in the generator. If the voltages are unbalanced, first troubleshoot the main stator—Step 12. If the voltages are uniformly low, first troubleshoot the exciter and field circuits—Steps 8, 9, 10 and 11.	
7. Voltage Regulator **VR21** is faulty.	Check all connections against the applicable connection diagram (Page A-1 or B-1) and rewire as necessary. Replace the voltage regulator if the wiring is correct and there is no output voltage. ⚠ **CAUTION** ***Replacing the voltage regulator before servicing other faults can lead to damage to the new voltage regulator.***
8. The exciter field winding is open.	Shut down the set and check exciter field winding resistance according to instructions in this section. Replace the exciter field assembly if winding resistance does not meet specifications.
9. The rotating rectifier assembly (diodes **CR1** through **CR6**) is faulty.	Shut down the set and check each diode according to instructions in this section. Service as necessary.

NO OUTPUT VOLTAGE (CONT.)	
⚠ WARNING ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***	
Possible Cause	**Corrective Action**
10. The exciter rotor windings are open.	Shut down the set and check exciter winding resistances according to instructions in this section. Replace the whole rotor shaft assembly if exciter rotor winding resistances do not meet specifications.
11. The main rotor winding is open.	Shut down the set and check main rotor winding resistance according to instructions in this section. Replace the whole rotor shaft assembly if main rotor winding resistance does not meet specifications.
12. The stator windings are open.	Shut down the set and check stator winding resistances according to instructions in this section. Replace the generator stator assembly if winding resistances do not meet specifications.

OUTPUT VOLTAGE IS TOO HIGH OR TOO LOW

⚠ **WARNING** ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***

Possible Cause	Corrective Action
1. The engine speed has not been adjusted properly.	Adjust engine speed according to Section 8.
2. The voltage has not been adjusted properly.	Adjust output voltage according to Section 6.
3. Connections have not been made properly at the generator output terminals.	Shut down the set and reconnect according to the appropriate connection diagram. See Page A-1 or B-1.
4. The rotating rectifier assembly (diodes **CR1** through **CR6**) is faulty.	Shut down the set and check each diode according to instructions in this section. Service as necessary.
5. Voltage Regulator VR21 is faulty.	Replace the voltage regulator. ⚠ **CAUTION** ***Replacing the voltage regulator before servicing other faults can lead to damage to the new voltage regulator.***

OUTPUT VOLTAGE IS UNSTABLE

⚠ **WARNING** ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***

Possible Cause	Corrective Action
1. Engine speed is unstable.	See THE ENGINE LACKS POWER OR IS UNSTABLE in the appropriate control troubleshooting section.
2. The voltage has not been adjusted properly.	Adjust output voltage according to Section 6.
3. The voltage adjusting rheostat on the control panel is faulty (if provided).	Unlock the voltage adjusting screw on the front of the control panel and disconnect either lead from the rheostat. Measure resistance between terminals **1** and **2** while turning the adjusting screw fully one way and then the other. Replace the rheostat if it is open at any point, or if resistance does not vary smoothly from zero to approximately 1000 ohms.
4. Voltage Regulator **VR21** is faulty.	Replace the voltage regulator. ⚠ **CAUTION** ***Replacing the voltage regulator before servicing other faults can lead to damage to the new voltage regulator.***

THE FIELD CIRCUIT BREAKER KEEPS TRIPPING (DETECTOR CONTROL)

⚠ **WARNING** ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***

Possible Cause	Corrective Action
1. The rotating rectifier assembly (diodes **CR1** through **CR6**) is faulty.	Shut down the set and check each diode according to instructions in this section. Service as necessary.
2. The exciter field winding is shorted.	Shut down the set and check exciter field winding resistance according to instructions in this section. Replace the exciter field assembly if winding resistance does not meet specifications.
3. The exciter rotor windings are shorted.	Shut down the set and check exciter winding resistances according to instructions in this section. Replace the whole rotor shaft assembly if exciter rotor winding resistances do not meet specifications.
4. The main rotor winding is shorted.	Shut down the set and check main rotor winding resistance according to instructions in this section. Replace the whole rotor shaft assembly if main rotor winding resistance does not meet specifications.
5. The stator windings are shorted.	Shut down the set and check stator winding resistances according to instructions in this section. Replace the generator stator assembly if stator winding resistances do not meet specifications.
6. Voltage Regulator **VR21** is faulty.	Replace the voltage regulator. ⚠ **CAUTION** ***Replacing the voltage regulator before servicing other faults can lead to damage to the new voltage regulator.***

THE PHASE CURRENTS ARE UNBALANCED (3-PHASE GENERATORS)

⚠ **WARNING** ***There are hazards present in troubleshooting that can cause equipment damage, severe personal injury or death. Troubleshooting must be performed by qualified persons who know about the hazards of fuel, electricity and machinery. Read Safety Precautions and observe all instructions and precautions in this manual.***

Possible Cause	Corrective Action
1. The connected loads are distributed unevenly among the phases.	Shut down the set and redistribute the loads as evenly as possible.
2. Improper connections have been made at the generator output terminals.	Shut down the set and reconnect according to the appropriate connection diagram. See Page A-1 or B-1.
3. The stator windings are faulty (open or shorted).	Shut down the set and check stator winding resistances according to instructions in this section. Replace the generator stator assembly if stator winding resistances do not meet specifications.
4. A load has a ground fault or short circuit.	Service the faulty equipment as necessary.

8. Engine

TROUBLESHOOTING

Use Table 8-1 as a guide for engine troubleshooting. See the Table of Contents to locate troubleshooting information in other sections of this manual.

Checking crankcase vacuum is a good way to tell how worn the engine is (except on 2-cylinder engines). An engine in good condition will have a crankcase vacuum of *at least 20 mm (0.79 inch) water column (WC)*. Low and/or fluctuating vacuum indicates piston blow-by or faulty oil seals or valves. Check vacuum at the oil dipstick hole.

TABLE 8-1. ENGINE PROBLEMS

DIFFICULT STARTING Out of fuel Unsuitable fuel or lubricating oil Blocked fuel or oil filter Air-locked fuel system Stuck-open fuel injector nozzle valve Scored fuel pump delivery valve Sticking fuel pump rack Late fuel injection timing Loose fuel injector Leaking valves Sticking piston rings Sticking exhaust valve Worn cylinder	**KNOCKING** Sticking valve (exhaust) touching piston Worn connecting rod bushing Worn piston pin bushing Too little piston/cylinder head clearance Early fuel injection Too much camshaft or crankshaft end play Carbon deposits on pistons Too much piston/cylinder clearance Loose engine mounts Unsuitable fuel Loose flywheel
EXCESSIVE CARBON FORMATION Blocked air filter Blocked exhaust system Unsuitable fuel or lubricating oil Defective fuel injector spray Late fuel injection timing Excessive low-load operation Low-temperature operation	**BLACK SMOKE** Overload Blocked air filter High inlet air temperature Defective fuel injector spray Unsuitable fuel
FAINT BLUE SMOKE Light load operation	**DARK BLUE SMOKE** Worn piston rings Worn cylinder bore
ENGINE STOPS RUNNING Out of fuel Air or water in fuel Blocked fuel filter Blocked fuel injector nozzle Overload Overheating Loss of oil pressure	**LOSS OF POWER** Blocked air filter Blocked fuel filter Blocked exhaust system Loss of compression Defective fuel pump or injector
NORMAL SPEED NOT ATTAINABLE Air-locked fuel system Insufficient fuel delivery Retarded fuel injection timing Maladjusted governor	**LOSS OF OIL PRESSURE** Low oil level Low oil viscosity Fuel-diluted oil Blocked oil pump Worn crankshaft bearings Failed oil pump

TABLE 8-1. ENGINE PROBLEMS (CONT.)

OVERHEATING Recirculating cooling air Obstructed cooling air inlet or outlet Dirty cylinder fins (air cooled) Dirty radiator fins (liquid cooled) Loose fan belt Loss of coolant (liquid cooled) Overload High or low lubricating oil level Incorrect fuel injection timing	**LOW COMPRESSION** Loose fuel injector Damaged fuel injector sealing washer Lined up piston ring gaps Leaking valves Leaking cylinder head gasket Worn piston rings Worn cylinders
HUNTING OR SURGING Binding governor linkage Sticking fuel pump rack Air in fuel system Faulty fuel injector	**HIGH OIL CONSUMPTION** Worn valve guides Worn piston rings Worn cylinder High oil level
LOW OR FLUCTUATING CRANKCASE VACUUM Worn piston rings Worn cylinders Worn oil seals High oil level Unseated oil fill cap	**LEAKING OIL SEALS** High oil level Loss of crankcase vacuum Worn seal

TABLE 8-2. FUEL INJECTION PROBLEMS[1]

EXCESSIVE LEAK-OFF (BACK LEAKAGE) Worn or loose needle Loose cap Dirt between nozzle and holder faces	**INCORRECT OPENING PRESSURE** Loose adjuster Dirty or seized needle Blocked nozzle holes Broken adjuster spring
DRIPPING NOZZLE Tight or sticking needle Carbon deposits on nozzle or needle seats Distorted, scratched or eroded seats	**NO “CHATTER” WHEN INJECTING** Tight or sticking needle Leaking seat Distorted cap nut Dirt between nozzle and holder faces
SPRAY DISTORTED Carbon on needle Blocked or worn nozzle holes Sticking or damaged needle Distorted, scratched or eroded seats	

1. if injector testing or cleaning equipment is not available, the injector should be replaced.

ENGINE DISASSEMBLY AND REASSEMBLY

Contact an Onan/Cummins distributor for the special tools required for engine disassembly and reassembly.

The following procedures for disassembly and reassembly are meant more as checklists than as sequences that must be rigidly followed. They are representative for air-cooled as well as liquid-cooled engines, upon which they are based. It is assumed that the generator set housing and generator have already been removed and that the engine electrical harness and fuel supply have been disconnected ***and that coolant and oil have been drained***.

⚠WARNING ***Hot coolant is under pressure and can cause severe burns. Always let the engine cool down before removing the pressure/fill cap.***

⚠WARNING ***Accidental starting can cause severe personal injury or death. To prevent accidental starting, push the control panel switch to OFF and disconnect the negative (–) battery cable from the battery before working on the generator set.***

Arcing can ignite battery gases and cause severe personal injury and can cause voltage spikes that can damage generator set control circuits. To reduce arcing:

Never disconnect the battery cables while the genset is cranking or running.

Always disconnect a battery charger from its AC source before disconnecting the battery cables.

Always disconnect the negative (–) cable first and reconnect it last. (This prevents arcing if the tool on the positive terminal touches grounded metal.)

Disassembly

1. Remove the radiator hoses.
2. Remove the radiator.
3. Remove the starter motor.
4. Loosen the alternator.
5. Remove the radiator fan drive belt.
6. Remove the alternator.
7. Remove the radiator fan (***turn the nut clockwise***).
8. Remove the inlet and exhaust manifolds.
9. Remove the fuel injector pump delivery tubes.
10. Remove the fuel injectors.
11. Remove the cylinder head covers.
12. Remove the lifting eye(s).
13. Remove the valve rockers and push rods.
14. Remove the coolant pump.
15. Remove the cylinder head and gasket.
16. Lift out the push rod tubes, rubber seals and washers.
17. Remove the remaining fuel tubing and fuel filter.
18. Remove the oil filter.
19. Remove the dipstick and crankcase door.
20. Remove the oil pressure relief valve and oil strainer.
21. Remove the connecting rod caps.
22. Carefully remove any carbon build-up from the top of the cylinder bore.
23. Turn the crankshaft until the piston is at TDC.
24. Lift out the piston and connecting rod.
25. Install the flywheel locking tool.
26. Remove the front pulley (***turn the bolt clockwise***).
27. Move the engine control to the stop position and remove each fuel injection pump. ***Keep each shim pack together and identify it so that it will be returned to the same pump location on the block.***
28. Remove the gear cover (front end).
29. Disconnect the governor spring from the governor lever assembly.

30. Remove the governor lever assembly and governor rack.

31. Remove the governor sleeve.

32. Remove the governor weights.

33. Use a magnet to remove the valve and fuel injection pump tappets.

34. Rotate the engine until the governor weight slots in the camshaft are vertical.

35. Remove the two camshaft thrust plate screws and control lever tension spring.

36. Carefully withdraw the camshaft.

37. Remove the oil pump.

38. Remove the crankshaft pinion.

39. Remove the flywheel.

40. Remove the flywheel housing.

41. Remove the main bearing housing (flywheel end).

42. Use a manifold bolt to remove the center main bearing locating dowel(s): 1 on 2-cylinder, 2 on 3-cylinder and 3 on 4-cylinder engines.

43. Gently withdraw the crankshaft.

44. Remove the front main bearing and camshaft bearing shells.

Reassembly

See Table 8-3 for recommended gasket and shim sealers and thread sealing and lubricating compounds and Table 8-4 for thread torques. *Always use new gaskets when reassembling an engine.*

Use engine lubricating oil on all moving parts, especially on bearing surfaces, valve stems and push rod cups. The piston/connecting rod assembly should be submerged in oil and then thoroughly drained just before installing it in the cylinder.

1. Install the main (crankshaft) and camshaft bearing shells.

2. Install the front (gear-end) crankshaft thrust bearings.

3. Install the crankshaft making sure the center bearing dowel hole(s) line up correctly: 1 on 2-cylinder, 2 on 3-cylinder and 3 on 4-cylinder engines.

4. Install the rear (flywheel-end) crankshaft thrust bearings.

5. Install the crankshaft main bearing housing.

6. Check crankshaft end play.

7. Install the center main bearing locating dowel(s): 1 on 2-cylinder, 2 on 3-cylinder and 3 on 4-cylinder engines.

8. Install the flywheel housing.

9. Install the flywheel.

10. Heat the crankshaft pinion and install it with its key and with its timing marks outward.

11. Install the oil pump.

12. Install the camshaft, aligning the timing marks and making sure the thrust plate is located correctly.

13. Install the governor weights and governor sleeve.

14. Install the fuel injection pump tappets and thrust cups.

15. Install the hydraulic valve tappets.

16. Install the governor lever assembly and governor rack and connect the governor spring.

17. Install, and if necessary, time, the fuel injection pumps.

18. Install the gear cover (front end).

19. Install the crankshaft pulley (***turn the bolt counterclockwise***).

20. Install the pistons and connecting rods.

21. Install the oil pump relief valve and strainer.

22. Install the crankcase door and dipstick

23. Install the oil filter.

24. Install the push rod tube seals, washers and tubes.

25. Install the cylinder head and gasket.
26. Install the push rods and the valve rockers.
27. Install the cylinder head covers.
28. Install the fuel injectors.
29. Install the fuel injector pump delivery tubes.
30. Install the coolant pump.
31. Install the manifolds.
32. Install the radiator fan (***turn the nut counter-clockwise***).
33. Install the alternator.
34. Install the starter motor.
35. Install and adjust the fan belt.
36. Install the radiator.
37. Install the radiator hoses.
38. Install the fuel filter and all other fuel tubing.
39. Adjust the governor fueling and stop positions and speed and droop as necessary.

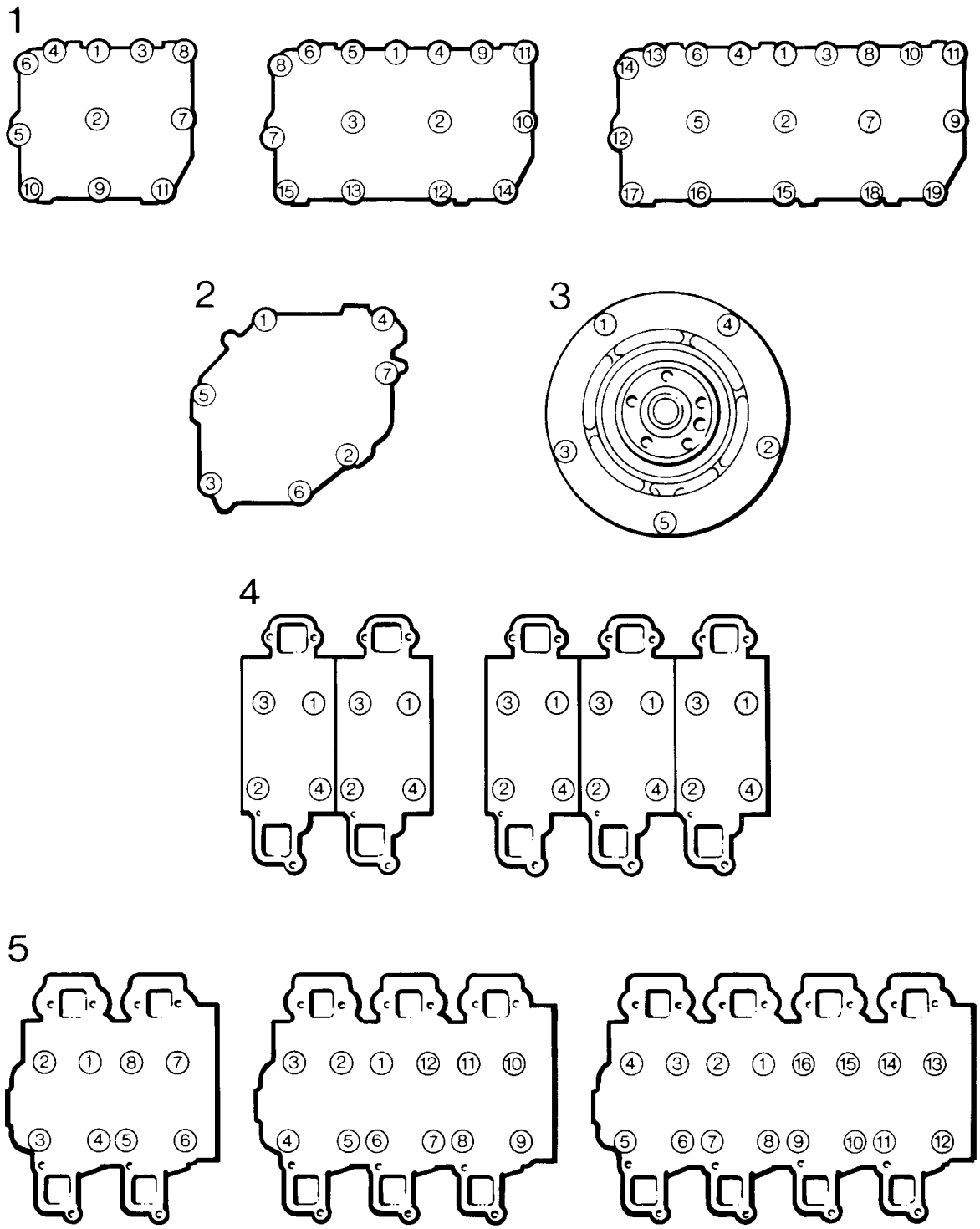
TABLE 8-3. GASKET AND SHIM SEALERS AND THREAD SEALING AND LUBRICATING COMPOUNDS

GASKET OR SHIM	COMPOUND
Cylinder Head Cover	All surfaces must be clean and dry.
Core Hole Plugs	Apply Loctite 572 or equivalent to the bore. Make sure the compound does not enter the camshaft bore.
Oil Sump Drain Plug	Apply Loctite 572 or equivalent to the threads.
Oil Seals	Lightly grease the sealing lip before installing.
Cylinder Head Gasket	All surfaces must be clean and dry. Assemble head gaskets for air-cooled engines with the corrugated side down.
Stop/Run Speed Control Bushing	Press the bushings in dry.
Push Rod Tube Seals	Lightly coat the seal bore with grease to aid assembly.
Main Bearing Housing Shim	Coat both sides of the shim with Locktite 609 or equivalent.
Dipstick	Lightly coat the “O” ring with grease.
Fuel Pump Tappet Stud	Coat the threads into the crankcase with Locktite 270 or equivalent.
Camshaft Journals and Bores	Coat the journals (except for gear end) with Molydisulfide grease or equivalent.
Rocker Lever Spacer (Air-Cooled)	Coat both sides with Locktite 609 or equivalent.
All other Gaskets and Shims	All surfaces must be clean and dry.

TABLE 8-4. ENGINE THREAD TORQUES

BOLT, NUT OR PART ASSEMBLED	TORQUE	
	N-m	lb-ft
Starter Motor Terminal Nuts	5.89-11.77	4.34-8.68
Stop/Run Assembly Screws	7	5
Gear Cover Nuts and Bolts[1]	9	6.5
Fuel Filter Bracket Screws		
Manifold Bolts		
Oil Pump Screws		
Camshaft Thrust Pate Screws		
Governor Weight Plate Screw		
Cowling Fasteners (Air-Cooled)		
Rocker Cover Nuts		
Crankcase Door Bolts[1]	11	8
Alternator Adjusting Link Screws	16	12
Fixing Bolt to Back Plate		
Coolant Pump Studs (not bolts)		
Fuel Filter Union Plug	20	15
Fuel Lift Pump Screws	21	15.5
Fuel Injector Clamp Nut		
Axial Fan Bracket Bolts (Air-Cooled)		
Alternator Bolt		
Coolant Pump Bolts and Nuts		
Deep Sump Bolt		
Center Bearing Housing Bolts		
Exhaust Manifold, Turbocharger and Exhaust Flange Bolts (Turbocharged)		
Turbocharger Oil Feed Plugs and Breather/Oil Separator Mounting Bolts		
Fuel Injector Pump Delivery Tube Fitting Nuts	22	16
Oil Strainer Tube Nut	27	20
Main Bearing Housing Bolts[1]		
Radiator Fan Nut (Liquid-Cooled)[2]	30	22
Fuel Injector Pump Clamp Nut	34	25
Valve Rocker Nut		
Connecting Rod Bolts	35	26
Starter Motor Bolts	41	30
Oil Pump Relief Valve		
Oil Filter Adapter Bolt		
Fuel Injector Nozzle Nut	46	34
Fuel Pump Delivery Valve Holder	47	35
Cylinder Head Nut (Air-Cooled)[1] Stage One Stage Two	 8 48	 6 35
Cylinder Head Nut (Liquid-Cooled)[1] Stage One Stage Two Stage Three	 8 48 88	 6 35 65
Flywheel Bolts	68	50
Flywheel Bolts (Turbocharged)	81	60
Crankshaft Pulley Bolt[2]	300	221

1. See Figure 8-1.
2. Left-hand thread—turn clockwise to loosen and counterclockwise to tighten.



1. Crankcase Doors—2, 3 and 4 cylinder engines
2. Gear Cover
3. Main Bearing Housing
4. Cylinder Head—2 and 3 cylinder air cooled engines
5. Cylinder Heads—2, 3 and 4 cylinder liquid cooled engines

FIGURE 8-1. BOLT TIGHTENING SEQUENCES

DIMENSIONS OF WEARING PARTS

Table 8-6 indicates the extent to which components may wear without appreciable loss of performance. Therefore, one or more of the components affecting the clearance should be replaced when the "Maximum Clearance" value has been reached.

Cylinder Bore Wear: The maximum advisable piston/cylinder clearance given is the clearance between the bottom of the piston skirt, across the faces, and the cylinder bore measured in the region of travel of the piston skirt. The clearance is ***not to be measured at the top of the bore.***

Piston Ring Wear: The ring gaps given in Table 8-6 are those to be anticipated when checking rings in an unworn part of the bore. Note that for every 0.01 mm (0.0004 in) by which the actual bore size exceeds the initial dimension, the ring gap will increase by approximately 0.03 mm (0.0012 in).

The firing ring side clearance is measured with a new ring flush with the top piston land.

Undersize and Oversize Replacement Parts: Oversize pistons and rings, and undersize big end and main bearing shells are available (Table 8-5).

TABLE 8-5. UNDERSIZES AND OVERSIZES

Bearing Undersizes	0.254 mm (0.010 in)
	0.508 mm (0.020 in)
	0.762 mm (0.030 in)
Piston and Piston Ring Oversizes	0.254 mm (0.010 in)
	0.508 mm (0.020 in)

Non-standard sized parts are marked with the amount they are under or over sized. The marking appears as a suffix to the part number, which is located as follows:

1. Piston Rings—on the face of the ring.
2. Pistons—on the top surface.
3. Bearings—on the outside surface

TABLE 8-6. DIMENSIONS OF WEARING PARTS

All clearances and wear limits are in millimeters unless otherwise indicated	New Part Dimension	New Part Clearance	Maximum Clearance
AIR-COOLED ENGINES			
Cylinder Bore	76.000-76.025	0.140-0.175	0.40
Piston Diameter—bottom of skirt, across thrust face	75.850-75.860		
Piston Ring Gaps	0.25-0.50	0.25-0.58	1.27
Top Piston Ring Width	1.728-1.740	0.110-0.142	0.19
Top Piston Ring Groove Width	1.850-1.870		
Second Piston Ring Width	1.978-1.990	0.090-0.122	0.17
Second Piston Ring Groove Width	2.080-2.100		
Oil Piston Ring Width	3.975-3.990	0.050-0.085	0.15
Oil Piston Ring Groove Width	4.040-4.060		
LIQUID-COOLED ENGINES			
Cylinder Bore	86.000-86.025	0.099-0.134	0.40
Piston Diameter—bottom of skirt, across thrust face	85.891-85.901		
Piston Ring Gaps	0.25-0.50	0.25-0.58	1.39
Top Piston Ring Width	1.728-1.740	0.090-0.122	0.17
Top Piston Ring Groove Width	1.830-1.850		
Second Piston Ring Width	1.978-1.990	0.050-0.082	0.14
Second Piston Ring Groove Width	2.040-2.060		
Oil Piston Ring Width	3.978-3.990	0.050-0.082	0.14
Oil Piston Ring Groove Width	4.040-4.060		

TABLE 8-6. DIMENSIONS OF WEARING PARTS (CONT.)

All clearances and wear limits are in millimeters unless otherwise indicated	New Part Dimension	New Part Clearance	Maximum Clearance
ALL ENGINES			
Connecting Rod Big End Bore	53.525-53.545	0.025-0.080	0.12
Bearing Shell Thickness	1.740-1.750		
Crankpin Diameter	49.985-50.000		
Flywheel-End Main Bearing Housing Bore	74.040-74.065	0.04-0.10	0.14
Bearing Shell Thickness	1.990-2.000		
Crankshaft Journal Diameter	69.985-70.000		
Gear-End Main Bearing Housing Bore	58.535-58.560	0.035-0.095	0.135
Bearing Shell Thickness	1.740-1.750		
Crankshaft Journal Diameter	54.985-55.000		
Center Main Bearing Housing Bore	58.5335-58.560	0.035-0.095	0.135
Bearing Shell Thickness	1.740-1.750		
Crankshaft Journal Diameter	54.985-55.000		
Thrust Washer Thickness[1]	2.310-2.360	–	–
Gear-End Camshaft Bushing Bore	34.990-35.085	0.010-0.120	0.17
Gear-End Camshaft Journal Diameter	34.965-34.980		
Center Camshaft Bushing Bore	35.030-35.070	0.050-0.105	0.17
Center Camshaft Journal Diameter	34.965-34.980		
Flywheel-End Camshaft Bushing Bore	35.030-35.070	0.050-0.105	0.17
Flywheel-End Camshaft Journal Diameter	34.965-34.980		
Camshaft Thrust Plate	2.850-2.900	–	–
Connecting Rod Small-End Bushing Bore	25.005-25.017	0.0075-0.0245	0.05
Piston Pin Diameter	24.9925-24.9975		
Hydraulic Tappet Diameter	21.386-21.405	0.020-0.064	0.11
Hydraulic Tappet Bore	21.425-21.450		
Valve Spring Free Length[2]	43.7-45.5	–	–
Valve Guide Bore (assembled)	7.195-7.250	0.025-0.095	0.165
Valve Stem Diameter	7.155-7.170		
Fuel Pump Tappet Diameter	21.950-21.980	0.020-0.100	0.14
Fuel Pump Tappet Bore	22.000-22.050		
Backlash Between Gears	–	0.025-0.150	0.20

1. Replace the thrust washer if the thickness is less than 2.20 mm (0.0866 inch).
2. Replace the spring if the length is 42.5 mm (1.67 inch) or less.

The Cylinder Head

Individual cylinder head covers are attached to the top of the cylinder heads with two nuts and an O-ring under each nut. The cover provides access to the crankcase breather pipe and the valve rockers.

Air cooled engines have individual cylinder heads and gaskets. Liquid cooled engines have monobloc heads and gaskets.

Removing a Cylinder Head:

1. Remove the air cowling if this is an air-cooled engine (Page 8-36).
2. Remove the inlet and exhaust manifolds.
3. Remove the cylinder head cover bolts which secure the fuel injection pump delivery tube clips.
4. Loosen the fittings at both ends of the fuel injection pump delivery tubes and remove the tubes.
5. Remove the injector clamps and lift out the injectors.
6. Remove the injector copper sealing washers from the cylinder head(s) taking care not to damage the seating area.
7. Remove the lifting eye(s).
8. Remove the cylinder head covers and gaskets.
9. Remove the valve rocker retaining nuts (Figure 8-2, Item A).
10. Remove the valve rockers (B).
11. Lift out the push rods.
12. Remove the cylinder head retaining bolts. To prevent possible damage to the exhaust manifold studs, use a long socket.
13. Lift off the cylinder head(s).
14. Remove the cylinder head gasket(s).

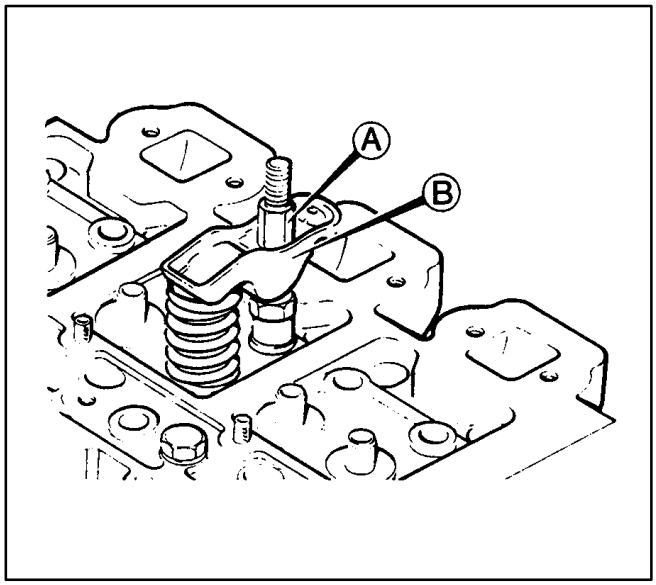


FIGURE 8-2. VALVE ROCKERS

Installing a Cylinder Head: The cylinder head clearance is 0.7-0.9 mm (0.027-0.035 inch) and is maintained by a single gasket under the head.

Three gasket thicknesses are available for air-cooled engines. Usually a new gasket of the same thickness as the original is installed. The cylinder head clearances, however, should be checked when new pistons and connecting rods have been installed or the crankshaft journals have been ground. Use the average of the clearance measurements to determine required gasket thickness. ***The cylinder head gaskets must all be of the same thickness.*** See Checking Cylinder Head Clearance on Page 8-13.

New cylinder head bolts and push rod seals (Figure 8-3) should be used each time the head is installed (except when checking head clearance).

1. Install the hydraulic valve tappets in the crankcase if they have been removed (Page 8-18).

2. Lightly coat the bores of the new push rod tube seals (Figure 8-3) with grease.

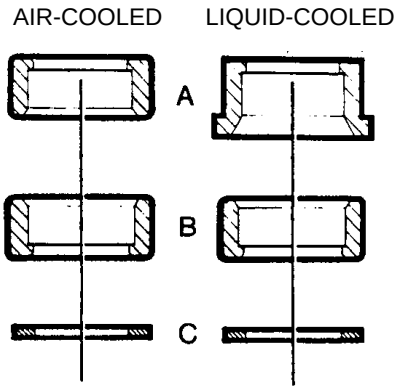
3. Fit the seals into the crankcase and cylinder head(s) making sure that the washers which are fitted underneath the crankcase seals are in position.

4. Place the gasket on the crankcase making sure the holes in the gasket coincide with those in the crankcase. On air-cooled engines, place the gaskets with the raised corrugations against the crankcase.

5. Insert the push rod tubes into the cylinder head seals.

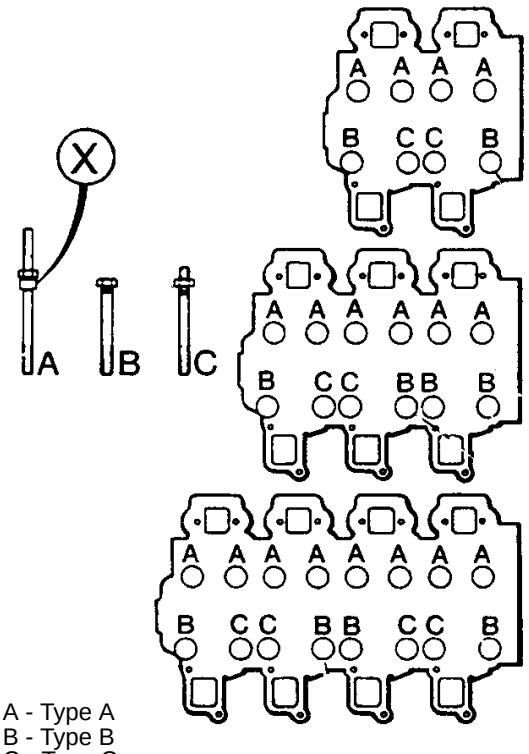
6. Turn the crankshaft so that no cylinder is at TDC and carefully lower the cylinder head into position, checking that the push rod tubes enter the seals in the crankcase.

⚠ CAUTION ***To keep pistons and valves from interfering with each other while the hydraulic valve tappets are "bleeding down", make sure no piston is at TDC when installing the head and that the crankshaft is not turned while waiting.***



A - Cylinder Head Seal
B - Crankcase Seal
C - Crankcase Seal Washer

FIGURE 8-3. PUSH ROD TUBE SEALS



A - Type A
B - Type B
C - Type C
X - Spacer
Liquid cooled heads are shown but the locations also apply to air cooled heads.

FIGURE 8-4. CYLINDER HEAD BOLT LOCATIONS

7. Thread new cylinder head bolts in finger tight. Make sure the spacers (Figure 8-4, Item X) are in place.
8. On air-cooled engines, use a straight edge to check that all the manifold flanges line up. Any gap along the straight edge must not exceed 0.2 mm (0.008 in). Alternatively, line up the heads by bolting on either the intake or exhaust manifold, without gaskets, before tightening down the cylinder head.
9. Tighten down the head bolts in stages and in the sequence shown in Figure 8-1 (Page 8-7). The tightening stages are as follows:
   A. 8.0 N-m (6.0 lb-ft)
   B. 48.0 N-m (35.0 lb-ft)
   C. 88.0 N-m (65.0 lb-ft)—liquid-cooled engines only
10. Install the valve push rods.
11. Install the valve rockers (Figure 8-2). Torque the rocker lever nuts to 34.0 N-m (25.0 lb-ft). Make sure the crank is not turned while waiting for the hydraulic tappets to “bleed down”. Bleed-down under valve spring pressure takes about 45 minutes. (New tappets not filled with oil do not have to bleed down.) A hydraulic tappet tool (Figure 8-5) is available to speed up the process.

    ⚠ CAUTION ***Too much force on the hydraulic tappet tool can bend the pushrods.***
12. Replace the cylinder head covers, lifting eye, fuel injector pump delivery tubes and clips and torque the cover nuts to 9.0 N-m (6.5 lb-ft).
13. Replace the manifolds.
14. Install the air cowling if this is an air-cooled engine (Page 8-36).

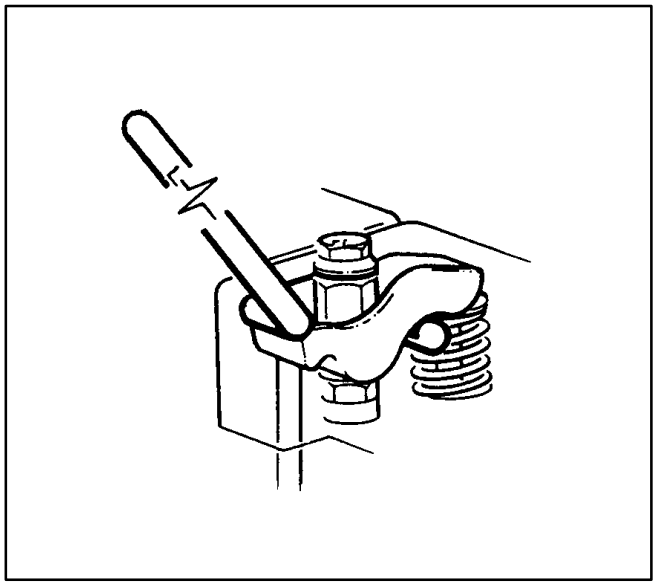


FIGURE 8-5. HYDRAULIC TAPPET TOOL

Checking Cylinder Head Clearance

1. Remove the cylinder head and push rods.
2. Place the gasket on the crankcase, making sure the holes in the gasket coincide with those in the crankcase. On air-cooled engines lay the gasket with the raised corrugations against the crankcase.
3. Using a small amount of high melting point grease, place two pieces of soft solder not more than 1.6 mm (1/16 inch) thick on the cylinder head as shown in Figure 8-6. Space the solder pieces widely and, as much as possible, in line with the piston pin. Make sure that the solder pieces will clear the valve recesses and combustion chamber in the top of the piston.
4. Install the cylinder head and torque the bolts as instructed in Step 9 on Page 8-12.
5. Turn the piston twice past TDC.
6. Remove the cylinder head and measure the thickness of the solder (cylinder head clearance). Change the gasket if the clearance is not 0.7-0.9 mm (0.027-0.35 in).

   The following gasket thicknesses are available for air-cooled engines:

   0.25 mm (0.0098)

   0.38 mm (0.0150)

   0.51 mm (0.0201)

   The following gasket thicknesses are available for liquid-cooled engines:

   1.47 mm (0.0579)
7. Reinstall the cylinder head. See Installing the Cylinder Head (Page 8-11).

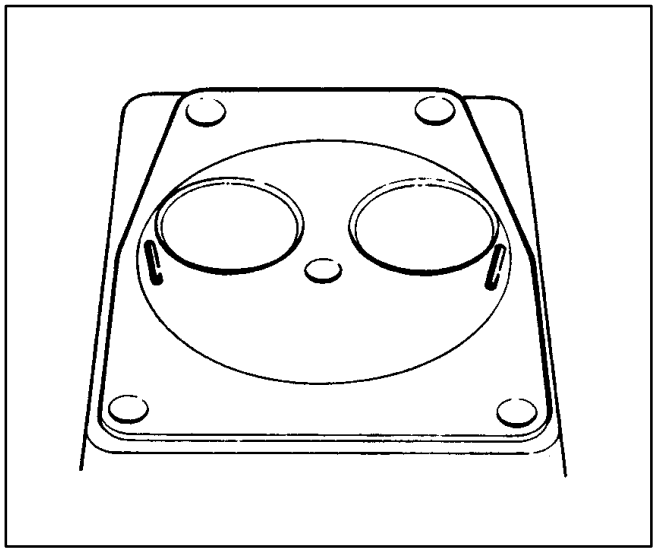


FIGURE 8-6. CHECKING CYLINDER HEAD CLEARANCE (AIR COOLED HEAD SHOWN)

The Valves

The valves are pre-finished and therefore no lapping or further processing is required. They are sunk below the combustion surface of the head. See The Valve Seats (Page 8-16).

Air-cooled and water-cooled turbocharged engines have valve seat inserts.

Keep each valve and its associated parts together for reassembly together at the same location.

Removing a Valve:

1. Lay the head upright on a bench and place a suitable circular block of wood under the head of the valve.
2. Place the adaptor (Figure 8-7, Item A) on the valve spring carrier with the two indentations facing outwards.
3. Fit the tool (B) into the two plate indentations and push down on the tool to compress the valve spring until the collets (keepers) can be removed (Figure 8-8, Item F).
4. Gently release the tool and remove the carrier, valve spring, valve stem sealing ring and valve spring plate.
5. Turn the cylinder head over and remove the valve.

Installing a Valve: Valves, springs and stem seals should be replaced during a major overhaul.

1. Examine the valve and replace if it is pitted or damaged.
2. Lightly lubricate the valve stem and insert the valve.
3. Lay the head upright on the bench and place a circular block of wood under the head of the valve being replaced.

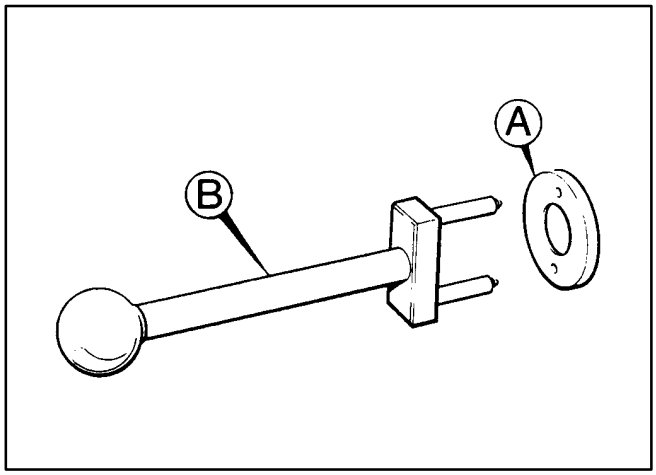


FIGURE 8-7. VALVE SPRING COMPRESSOR

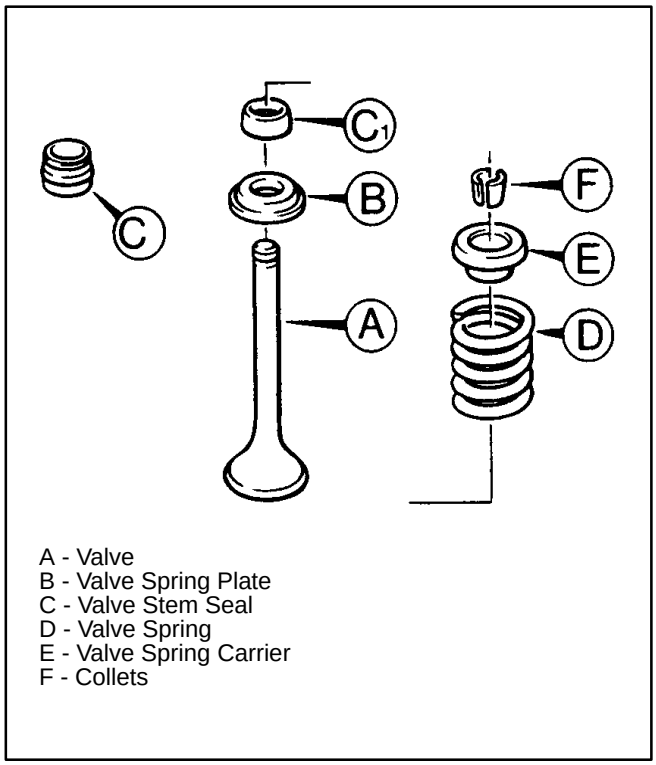


FIGURE 8-8. VALVE ASSEMBLY

4. Place the valve spring plate (Figure 8-8, Item B) in position.

5. Install a new valve stem seal (Figure 8-8, Item C) on the valve guide making sure it is correctly located over the guide and is not distorted. The valve guide seals are installed on both valve guides and must be pressed on until the shoulder is 12 mm (0.47 in) above the machined face of the cylinder head (Figure 8-9).

6. Install the valve spring (Figure 8-8, Item D) and spring carrier (Item E).

7. Fit the adaptor (Figure 8-7, Item A) over the valve spring carrier with the two indentations facing outwards.

8. Push down on the tool lever until the keepers (Figure 8-8, Item F) can be inserted in position with their tops slightly sunk in the valve spring carrier.

9. Gently release the tool and check that the keepers are positioned correctly.

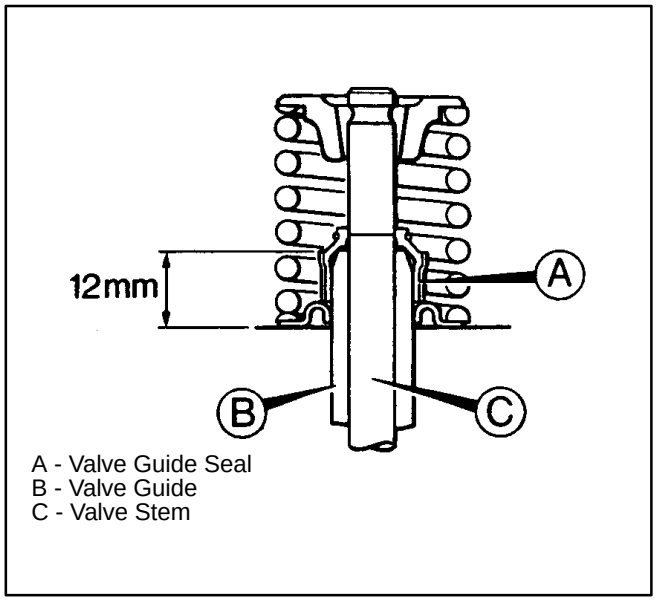


FIGURE 8-9. VALVE GUIDE SEAL LOCATION

The Valve Seats

The valve seats must be finished and recessed so that the valves are recessed below the combustion surface of the head the following distances:

Air-cooled engines:

Inlet—0.95-1.26 mm (0.0374-0.0496 inch)

Exhaust—0.95-1.26 mm (0.0374-0.0496 inch)

Liquid-cooled engines:

Inlet—0.95-1.26 mm (0.0374-0.0496 inch)

Exhaust—1.33-1.64 mm (0.0524-0.0646 inch)

Liquid-cooled and turbocharged engines:

Inlet—1.54-1.86 mm (0.0606-0.0732 inch)

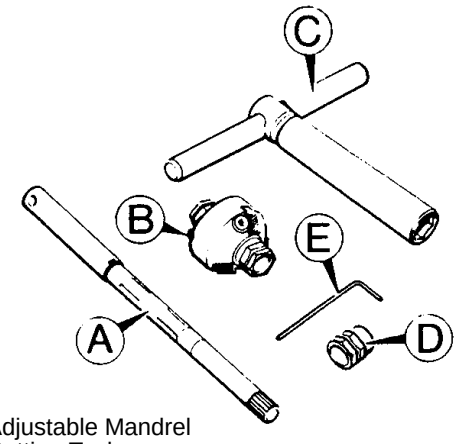
Exhaust—1.54-1.86 mm (0.0606-0.0732 inch)

Valve Seat Finishing and Recessing:

1. Fit the correct adjustable mandrel (Figure 8-10, Item A) into the valve guide and turn the adjuster until the flutes just bind in the guide.

   ⚠CAUTION ***The valve guide can be damaged if the mandrel is adjusted too tight in the bore. Do not remove more metal than necessary.***

2. Select the necessary cutting tool (B) and assemble it to the handle (C).
3. Place the cutter over the mandrel and adjust the three individual blades, using the Allen wrench, if necessary.
4. Rotate the tool in a clockwise direction until the valve seat recess and finish are satisfactory.



A - Adjustable Mandrel
B - Cutting Tool
C - “T” Handle
D - Adaptor
E - Allen Wrench

FIGURE 8-10. VALVE SEAL KIT

The Valve Guides

The valve guides are press fit into the cylinder head and protrude 11.75-12.25 mm (0.462-0.482 inch) above the top machined face of the cylinder head. This dimension will be achieved when the depth stop is used with the guide removal and replacement tool (Figure 8-12).

The valve stem oil seals grip the valve guides (Figure 8-11).

Removing a Valve Guide:

1. Remove the cylinder head (Page 8-11).
2. Remove the valve (Page 8-14).
3. Remove the valve stem oil seal from the guide.
4. Secure the cylinder head on its side in a soft-jawed vice.
5. Screw the correct mandrel (Figure 8-12, Item A) into the tool (B).
6. Place the sleeve (C) onto the tool.
7. Fit the bevelled adaptor (D) into the sleeve (C) and locate the bevel in the valve seat.
8. Push the mandrel through the guide from the valve seat side.
9. Screw the small threaded sleeve (E) into the mandrel on the valve rocker side.
10. Holding the sliding handle firmly to prevent rotation, turn the double-handle lever clockwise until the guide is withdrawn through the head. If it is found difficult to start moving the guides, a sharp tap with a soft-faced hammer should break the seal.

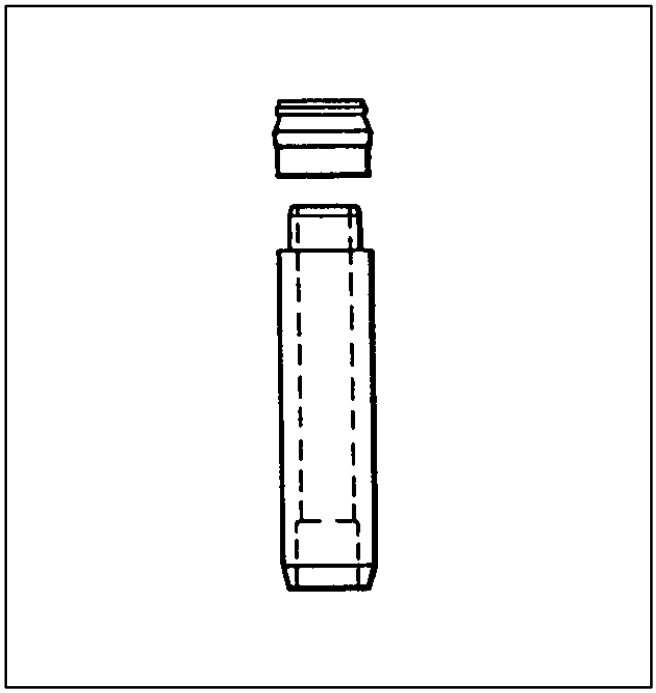


FIGURE 8-11.VALVE GUIDE AND OIL SEAL

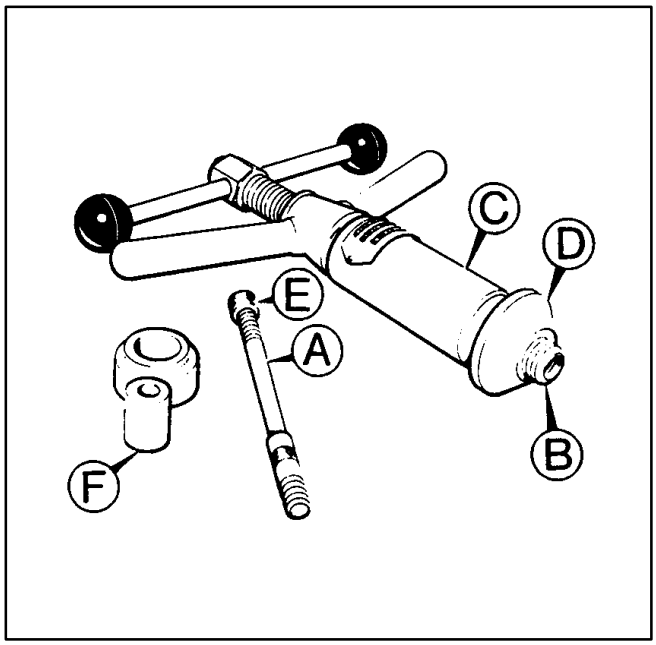


FIGURE 8-12. VALVE GUIDE TOOL

Installing a Valve Guide:

1. Fit the correct mandrel into the valve guide hole from the valve rocker end.
2. Place the valve guide over the mandrel with the counterbored end of the guide facing towards the valve seats.
3. Place the depth stop (Figure 8-12, Item F) over the mandrel and screw on the threaded sleeve (E).
4. Fit the tool, complete with the bevelled adaptor, onto the mandrel on the valve seat side.
5. Holding the sliding handle firmly to prevent rotation, turn the double-handle lever clockwise until the depth stop prevents any further movement. At this point the guide will protrude the correct distance above the cylinder head.
6. Install a new valve stem oil seal.

Hydraulic Valve Tappets: All engines are equipped with hydraulic valve tappets (Figure 8-13). No adjustment is necessary or possible. Removal of any part of the valve gear will allow the hydraulic tappet to extend and hydraulically lock. See Item 11 on Page 8-12 for the procedure for bleeding the valve tappets when installing the valve rockers.

When new hydraulic tappets have been installed, the engine must be cranked for at least 15 seconds before attempting to start it to fill the tappets with oil.

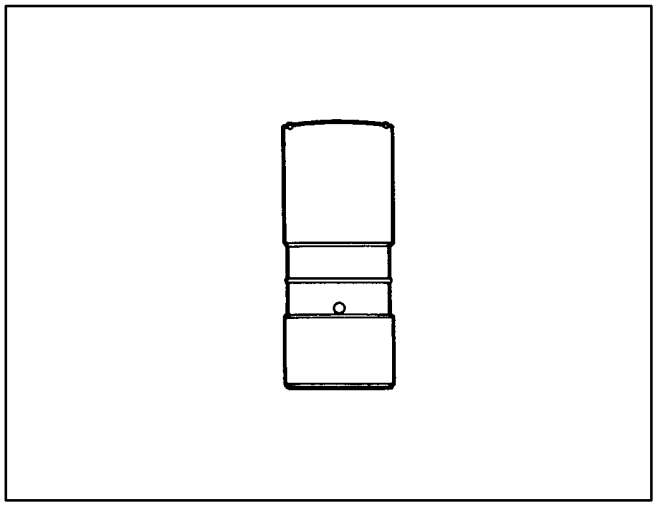


FIGURE 8-13. HYDRAULIC VALVE TAPPET

The Crankcase Door

The crankcase door (Figure 8-14) must be removed for access to the sump, connecting rods, oil pump pickup tube and strainer and oil pressure relief valve.

Note that, together, the crankcase door and crankcase form the main lubricating oil gallery. Drilled passages from the gallery distribute oil to the crankshaft and camshaft journal bores and valve and fuel pump tappet bores.

Removing the Crankcase Door:

1. Disconnect the fuel hoses from the fuel lift pump.

2. Remove the dipstick and oil filter for access to the lower left-hand corner door bolt.

3. Loosen the bolts and stud nuts in the sequence shown to prevent distortion of the door and possible oil leaks upon reassembly. If a stud comes out, remove the nut and replace the stud right away. The nose on the stud protrudes into the slot in the fuel pump tappet to keep it from turning. Use Locktite 270 or equivalent on the stud threads.

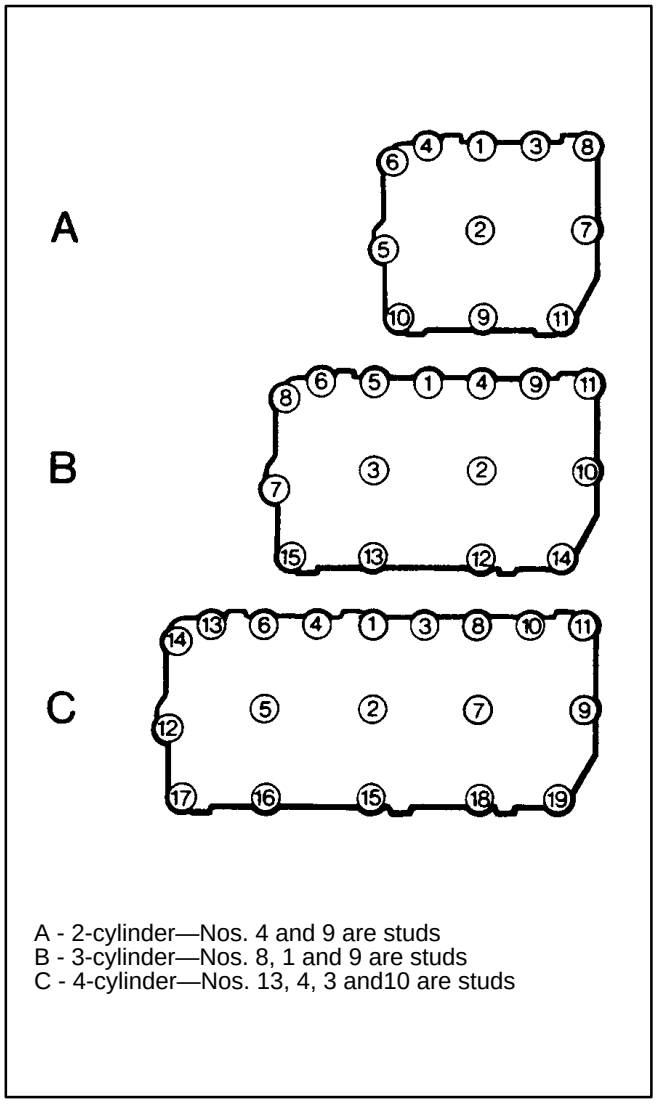
   ⚠ CAUTION ***If the tappet has turned, it will be necessary to remove the fuel pump and tappet before reinstalling the stud so as not to damage the tappet or cause it to seize because the slot and stud are not aligned.***

4. Remove the crankcase door and gasket.

Installing the Crankcase Door:

1. Clean and dry the door and crankcase mating surfaces.

2. Install the crankcase door with a new, dry gasket and torque the bolts to 11 N-m (8 lb-ft) in the sequence shown.



A - 2-cylinder—Nos. 4 and 9 are studs
B - 3-cylinder—Nos. 8, 1 and 9 are studs
C - 4-cylinder—Nos. 13, 4, 3 and10 are studs

FIGURE 8-14. CRANKCASE DOOR TIGHTENING SEQUENCES

The Gear Cover

The gear cover is located by two dowels and is secured to the crankcase by seven bolts. If the two dowels are being replaced, make sure the flat end enters the crankcase fully. The tapered ends provide engagement with the gear cover.

The crankshaft oil seal in the gear cover is of the lip-type, for which an installation tool is available. See THE LUBRICATING SYSTEM (Page 8-34) for further information on oil seals.

Removing the Gear Cover:

1. Thread the flywheel locking tool (Figure 8-22, Item B, on Page 8-27) into the flywheel housing making sure that it locks in the flywheel. If the locking tool is not available, wedge the crankshaft with a suitable piece of wood.
2. Loosen the alternator and remove the fan drive belt.
3. Remove the crankshaft pulley bolt and pulley. ***Turn the bolt clockwise to loosen it.***
4. Remove the flywheel locking tool.
5. To protect the crankshaft oil seal, insert the seal tool into the gear cover.
6. Remove the gear cover retaining bolts.
7. Remove the gear cover, tapping lightly with a soft-faced hammer if necessary.
8. Clean all traces of the old gasket from the crankcase and cover.
9. Remove the old oil seal if it is being replaced.

Installing the Crankshaft Oil Seal:

1. Remove the gear cover.
2. Lightly grease the sealing lip of the new seal.
3. Place the seal onto the outside neck of the gear cover, lip-side first, and position it squarely on the shoulder of the seal boss. Do not use any sealing compound.
4. Drive the seal in with the seal tool.

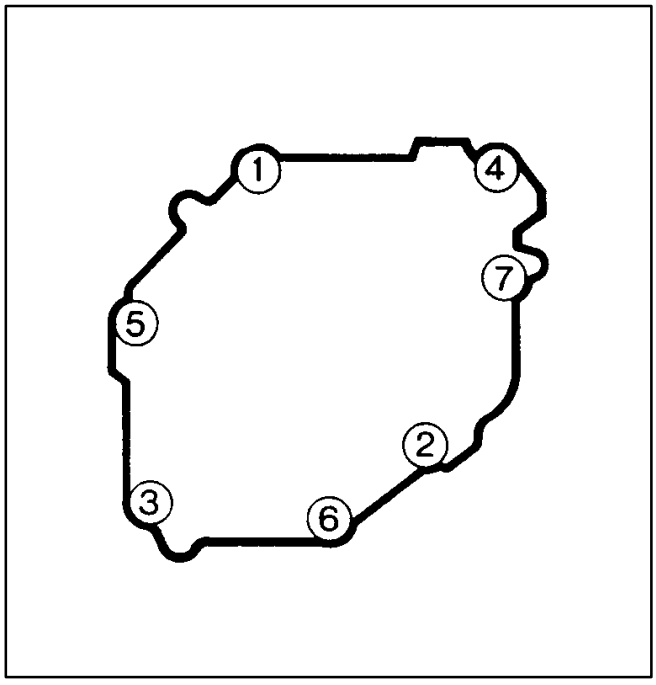


FIGURE 8-15. GEAR COVER TORQUE SEQUENCE

Installing the Gear Cover: The fuel rack must be set with a special tool before reinstalling the gear cover if all the fuel pumps have been removed at the same time. See Figure 8-43 (Page 8-46).

1. Clean all traces of the old gasket from the crankcase and cover.
2. Place a new, dry gasket over the two dowels on the crankcase.
3. Fit the oil seal tool into the outside face of the oil seal.
4. Install the gear cover, making sure the new gasket is not damaged and that the cover fits correctly over the dowels.
5. Tighten the bolts finger tight.
6. Following the sequence shown in Figure 8-15, torque the bolts to 9.0 N-m (6.5 lb-ft).
7. Replace the pulley and bolt. ***Turn the bolt counterclockwise to tighten it***, and torque it to 300 N-m (221 lb-ft).

The Camshaft

The camshaft operates the hydraulic valve tappets and fuel pumps. The camshaft is carried in pressure-lubricated bores in the crankcase. The front (gear end) bore has a bearing, which is not pressure lubricated. The camshaft gear carries the governor weights. A camshaft thrust plate is located behind the gear. The camshaft gear is not a separately replaceable part.

Removing the Camshaft:

1. Remove the cylinder heads (Page 8-10), gear cover (Page 8-20), valve rockers and push rods (Page 8-11) and fuel injection pumps (Page 8-41).
2. Remove the fuel lift pump and the pump push rod.
3. Lift out the fuel injection pump thrust cups and tappets and hydraulic valve tappets with a suitable magnet.
4. Unhook the governor spring from the governor lever assembly.
5. Remove the governor lever assembly and fuel rack.
6. Remove the governor weights.
7. Turn the camshaft until the large holes in it coincide with the two thrust plate bolts.
8. Remove the two thrust plate bolts.
9. Gently ease the camshaft out of the crankcase, keeping it perpendicular to the front face of the crankcase.

Inspecting the Camshaft:

1. Examine the camshaft bushing for scoring and wear.
2. Check the camshaft gearwheel and crankshaft pinion teeth for wear.
3. Make sure the cams are not chipped or damaged.
4. Check the tappets and cam faces for scoring and damage.

Installing the Camshaft:

1. Install the oil pump if it has been removed (Page 8-34).
2. Carefully insert the camshaft into the crankcase keeping it perpendicular to the front face of the crankcase at all times and taking care to line up the “0” timing marks on the crankshaft and camshaft gears exactly (Figure 8-16).
3. Turn the camshaft until the large holes in the gear, the two thrust plate bolt holes, and the two threaded holes in the crankcase all line up.
4. Install the two thrust plate bolts through the camshaft gear and thrust plate. Torque the two bolts to 9.0 N-m (6.5 lb-ft).
5. Install the governor weights and torque the bolts to 9.0 N-m (6.5 lb-ft).
6. Install the valve tappets, fuel injection pump tappets and thrust cups and fuel lift pump and push rod.
7. Install the cylinder heads (Page 8-10).
8. Install the governor and fuel rack components and the fuel pumps (Page 8-41).
9. Install the gear cover (Page 8-20).

   Note: The fuel rack must be set with a gauge before reinstalling the gear cover. See Figure 8-43 (Page 8-46).

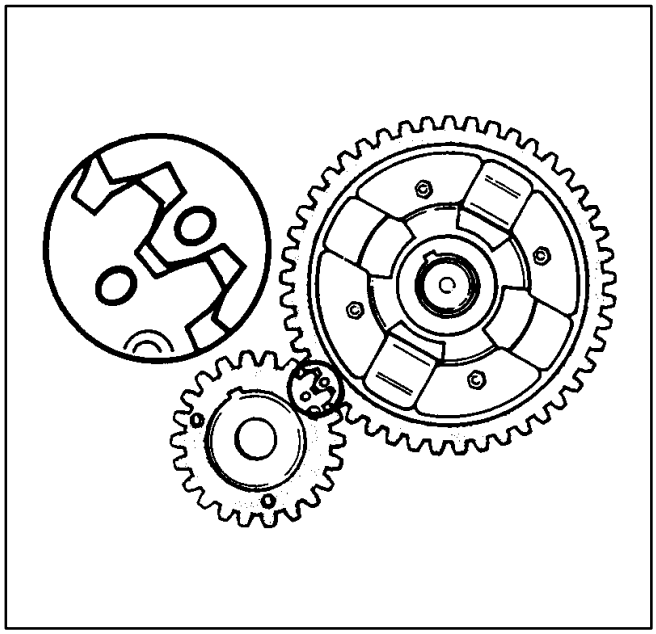


FIGURE 8-16. TIMING MARKS

Checking Camshaft End Play: Camshaft end play can be measured with a dial indicator after the gear cover has been removed. Replace the camshaft if end play is greater than 0.10-0.28 mm (0.004-0.011 in). To measure end play:

1. Push the camshaft towards the flywheel end.
2. Secure a dial indicator in position against the gear wheel.
3. Zero the gauge.
4. Move the camshaft as far as it will go towards the gear end (front). The movement recorded on the gauge is the end play.

The Camshaft Bushing

Removing the Bushing:

1. Fit the tool guide (Figure 8-17, Item A) into the bushing from inside the crankcase.
2. Fit the slide hammer (B) onto the guide threads.
3. Use the slide hammer to remove the bushing.

Installing a new Bushing: Before installing a new camshaft bushing, the outside diameter must be lightly oiled with engine lubricating oil.

When installing the bushing locate the split on top so that it will be opposite the load-bearing side.

1. Fit the new bushing over the guide threads.
2. Screw on the depth plate (Figure 8-17, Item C).
3. Fit the slide hammer onto the guide threads.
4. Place the assembly squarely into the crankcase bushing bore from the outside of the crankcase.
5. Use the slide hammer to drive in the bushing.

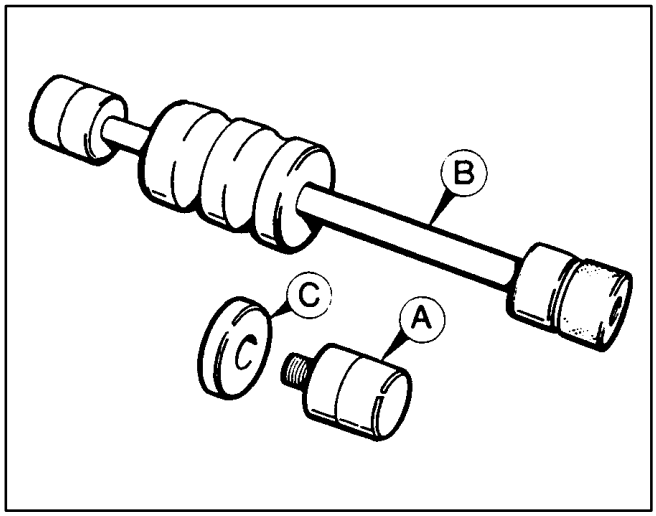


FIGURE 8-17. CAMSHAFT BUSHING TOOL

The Piston

The piston has a recessed combustion chamber in the crown and is equipped with three rings. The crown is stamped “Camshaft Side” to indicate the proper orientation for assembly. The piston pin is a clearance fit in the piston and is retained by two circlips. The connecting rod has a bushing in the small end.

Oil jets from the crankshaft bearings cool the pistons.

Piston Rings: Piston rings are available as sets and should only be installed as sets (Figure 8-18):

> ***Firing Ring (Top):*** This is a barrel-lapped chrome ring. The side marked “TOP” must face up when installed.
>
> ***Compression Ring (Middle):*** This ring has a tapered face in contact with the piston barrel. The side marked “TOP” must face up when installed.
>
> ***Oil Control Ring (Bottom):*** This is a conformable type ring with a spring expander.

Removing the Piston:

1. Remove the crankcase door (Page 8-19).
2. Remove the cylinder head(s) (Page 8-10).
3. If the No. 1 piston is being removed, it will be necessary to remove the oil pressure relief valve and oil strainer (Page 8-34).
4. Rotate the crankshaft sufficiently to give access to the connecting rod bearing cap bolts.
5. Remove the two bolts and the bearing cap.
6. Carefully scrape any buildup of carbon from the top of the cylinder bore.
7. Rotate the crankshaft until the piston is at TDC.
8. Screw the piston removal tool into the nearest connecting rod bearing cap bolt hole.
9. Lever the piston out the top of the crankcase until the rings are clear, using the tool on the connecting rod as the push point (Figure 8-19).

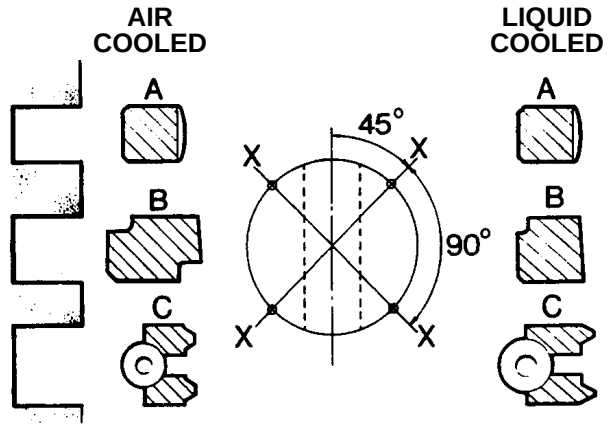


FIGURE 8-18. PISTON RING AND GAP LOCATIONS

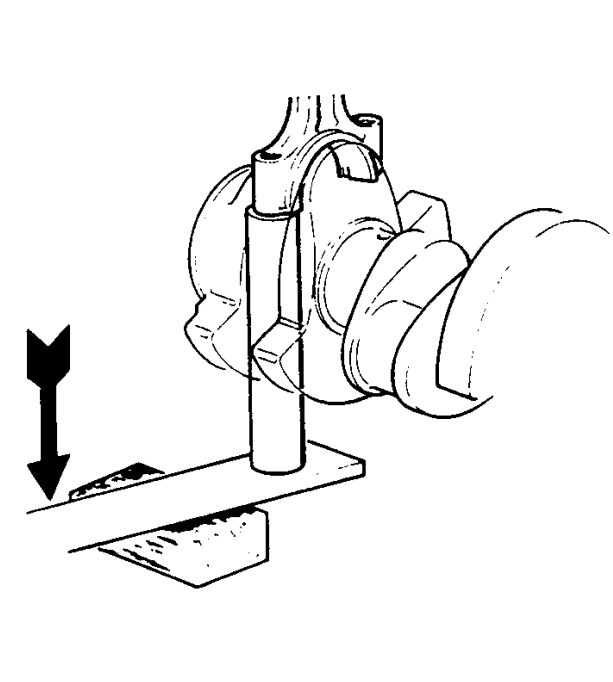


FIGURE 8-19. PISTON LIFTING TOOL

10. Lift out the piston and connecting rod.
11. Reassemble the bearing cap and connecting rod to keep them together.
12. Remove the piston rings with a standard ring expander.
13. Remove the piston pin by releasing the circlip from one end and pushing it out.

Inspecting and Servicing the Piston:

1. Thoroughly clean the cylinder bore and check for scoring and wear.
2. Clean the piston, removing all traces of carbon from both the upper and under sides of the crown and the ring grooves.
3. Place each ring square in an unworn section of the cylinder bore to check for the correct gap. See DIMENSIONS OF WEARING PARTS (Page 8-8).
4. Clean the connecting rod.
5. Examine the small-end bushing for wear.
6. If the big end has been dismantled because of metal failure, examine the oil passages in the crankshaft for obstructions and metal fragments.

Installing the Piston:

1. Assemble the piston and connecting rod. The “Camshaft Side” stamp on the piston must be on the same side as the identification marks on the connecting rod big end and cap (Figure 8-20).
2. Insert the piston pin and circlips.
3. Install the piston rings using a piston ring expander.
4. Turn the crankshaft journal to TDC.
5. If necessary, install new connecting rod big-end bearing shells making sure they are correctly located in both the connecting rod and cap. The bearing shells are steel backed copper-lead and should not be scraped or touched up in any way.

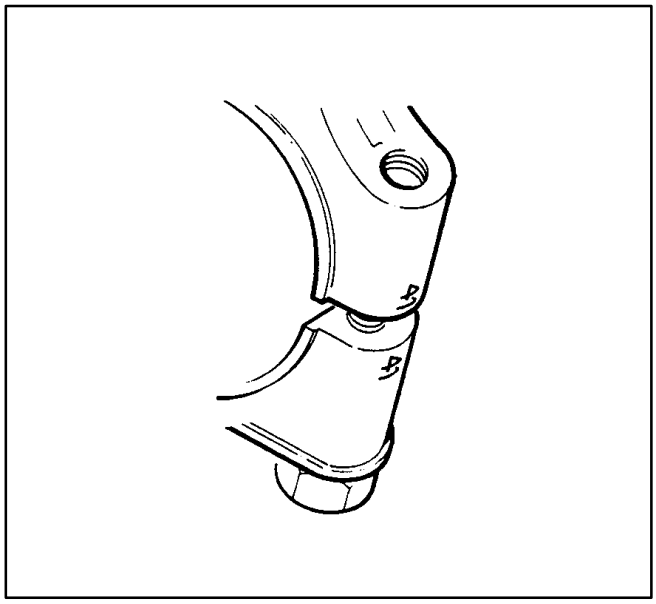


FIGURE 8-20. CONNECTING ROD AND CAP IDENTIFICATION

6. Stagger the piston ring gaps as shown at “X” in Figure 8-18. Each ring gap must be set at 90° to the adjacent rings and 45° from the piston pin axis.
7. Insert the piston and rod into the cylinder while compressing the piston rings with a suitable piston ring compressor. Make sure the stamp, “Camshaft Side” is on the camshaft (crankcase door) side of the crankcase.
8. Push down on the piston crown and turn the crankshaft clockwise (looking from the gear end) until the big end is almost at BDC.
9. Make sure the identification marks on the cap and rod (Figure 8-20) are identical and that they face the camshaft side of the engine.
10. Use two new bolts and torque them to 35.0 N-m (26.0 lb-ft). New connecting rod bolts are recommended at every major overhaul.

Checking Bearing Clearance:

1. Place a piece of the correct-size “Plastigauge” approximately 6.35 mm (0.25 in) off center, and across the full width of one bearing shell, as shown in Figure 8-21.
2. Install the bearing and torque the bolts to 24.0 N-m (18.0 lb-ft).
3. Remove the bearing shell and use the scale to check the width of the flattened “Plastigauge”. See DIMENSIONS OF WEARING PARTS (Page 8-8).

   Make sure the crankshaft is not turned when the Plastigauge is in place. Remove all traces of the Plastigauge before final assembly of the bearing.

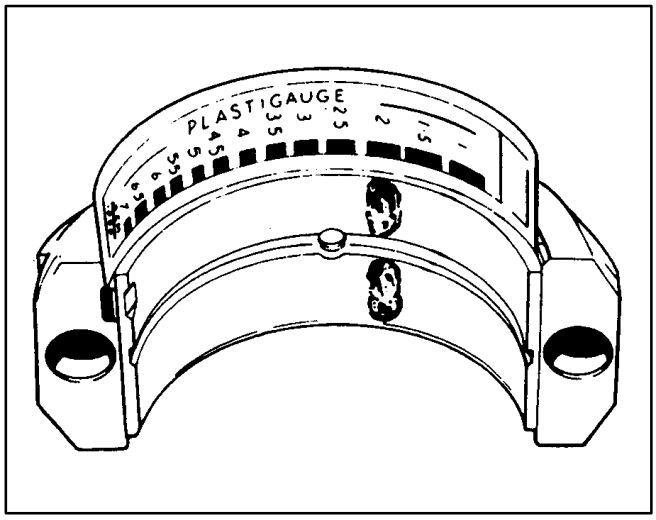


FIGURE 8-21. CHECKING BEARING CLEARANCE

The Flywheel

The flywheel rotates within the flywheel housing and is equipped with a starter ring gear. It is located with a dowel and held in position with 5 bolts (6 on turbocharged engines). Face (axial) and radial run-outs must not exceed 0.25 mm (0.010 in).

Removing the Flywheel:

1. Remove the starter motor.
2. Thread the flywheel locking tool (Figure 8-22, Item B) into the flywheel housing making sure that it locks in the flywheel. If the locking tool is not available, wedge the crankshaft with a suitable piece of wood.
3. Loosen the flywheel mounting bolts two turns.
4. Remove the locking tool.
5. Turn the flywheel until the locating dowel is at the top.
6. Bolt the puller plate (A) to the flywheel and turn the tool center bolt clockwise sufficiently to loosen the flywheel. If the puller plate is not available, use a piece of hardwood through the starter motor opening to loosen the flywheel.
7. Remove the service tool and the flywheel bolts.
8. Supporting the flywheel upright, lift it off of the crankshaft and out of the housing.

Installing the Flywheel:

1. Turn the crankshaft until the flywheel locating dowel is at the top.
2. Position the flywheel with the locating dowel hole at the top.
3. Lift the flywheel into the flywheel housing and onto the crankshaft, supporting it until the bolts are on.
4. Thread the mounting bolts in finger tight.
5. Push the flywheel fully into position.
6. Lock the flywheel to keep it from turning.
7. Torque the mounting bolts to 68.0 N-m (50.0 lb-ft).
8. Remove the flywheel locking tool.

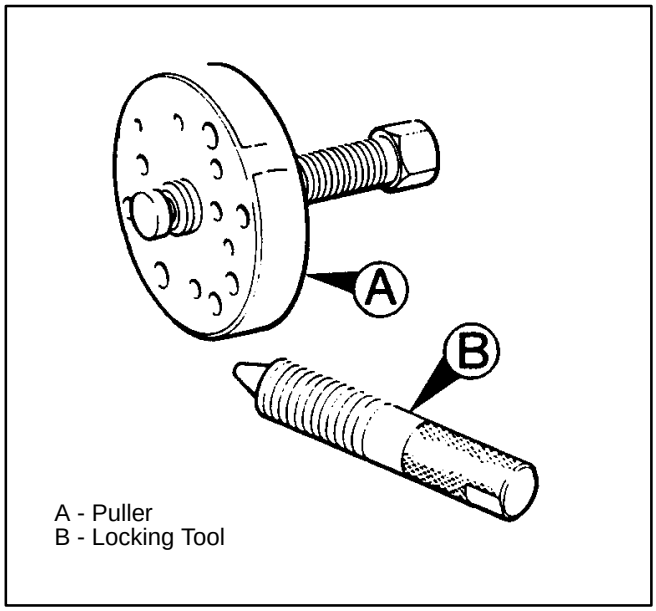


FIGURE 8-22. FLYWHEEL TOOLS

The Flywheel Housing

Removing the Flywheel Housing:

1. Remove the flywheel (Page 8-27).
2. Make sure the engine is securely supported other than by the mounting feet bolted to the flywheel housing.
3. Remove the four housing retaining bolts.
4. Lift off the flywheel housing.

Installing the Flywheel Housing: The flywheel housing is centered by the main bearing housing flange.

1. Lift the housing into position.
2. Thread the bolts in finger tight.
3. Torque the retaining bolts to 81.0 N-m (60.0 lb-ft).

The Main Bearing Housing

The main bearing housing is secured to the crankcase at the flywheel end. It has an oil drain which must be located at the bottom of the housing when it is installed. A single shim, installed between the housing and the crankcase, determines crankshaft end play. Lubricating oil is supplied through a drilled hole in the side of the bearing housing which lines up with a similar hole in the crankcase.

The crankshaft oil seal in the main bearing housing is of the lip-type, for which an installation tool is available. See THE LUBRICATING SYSTEM (Page 8-34) for further information on oil seals.

Removing the Main Bearing Housing:

1. Remove the flywheel (Page 8-27).
2. Remove the crankcase door (Page 8-19).
3. To keep from bending the center bearing locating dowel(s) while removing the main bearing housing, thread inlet manifold bolts into each dowel and pull them out. Leave the dowels and bolts together for reassembly. See Figure 8-25 (Page 8-31) for the locations of the dowels.

   ⚠ CAUTION ***The center bearing locating dowels can be bent when the main bearing is being levered off, making them very difficult to remove if the need ever arises. Remove them before attempting to remove the main bearing housing.***

4. Remove the bolts securing the main bearing housing.
5. Remove the bearing housing. If the flywheel housing has been removed, use the two recesses in the 3 O'clock and 9 O'clock positions to lever off the housing. If the flywheel housing is still in place, turn the crank until the rear balance lobe is in position to use as a fulcrum to lever off the housing.
6. Clean all traces of the old shim and compound from the housing and crankcase.
7. Remove the old oil seal taking care not to damage the bearings if they are to be reused.

Installing the Crankshaft Oil Seal: The crankshaft oil seal can be installed before or after the main bearing housing is installed.

1. Lightly grease the sealing lip of the new seal.
2. Place the seal squarely on the housing. Do not use any sealing compound.
3. Hold the oil seal tool onto the outside face of the seal and drive the seal into the bearing housing until it is flush with the outside face of the housing.

Installing the Main Bearing Housing: If the bearing shells have been replaced before installing the housing, check that the oil supply holes in the bearing shells and the housing line up.

1. Lightly grease the steel backs of the thrust washer halves and position them in the housing, ***copper faces out***. One of the bearing halves has a locating tab. Make sure the tab is located at 6 O'clock in the housing. (To determine which end of the housing is up, match housing and crankcase bolt holes: they match only one way.)
2. Coat both sides of the new main bearing housing shim with Locktite 609 and place it on the housing with the flat side towards the crankcase. Make sure the notches and holes in the shim match those in the housing.
3. If the oil seal is in place in the bearing housing, grease the lip of the seal and insert the oil seal tool to protect the lip while installing the housing.
4. Install the housing and shim.
5. Torque the bolts to 27.0 N-m (20.0 lb-ft) in the sequence shown in Figure 8-23.
6. Check the crankshaft end play. See Checking Crankshaft End Play (Page 8-32).
7. Install a new oil seal unless one is already in place.
8. Install the center bearing locating dowel(s): 1 on 2-cylinder, 2 on 3-cylinder and 3 on 4-cylinder engines. The tapped end must face outwards. ***Make sure the dowel(s) seat fully: not in a housing capscrew head recess (Figure 8-25).***

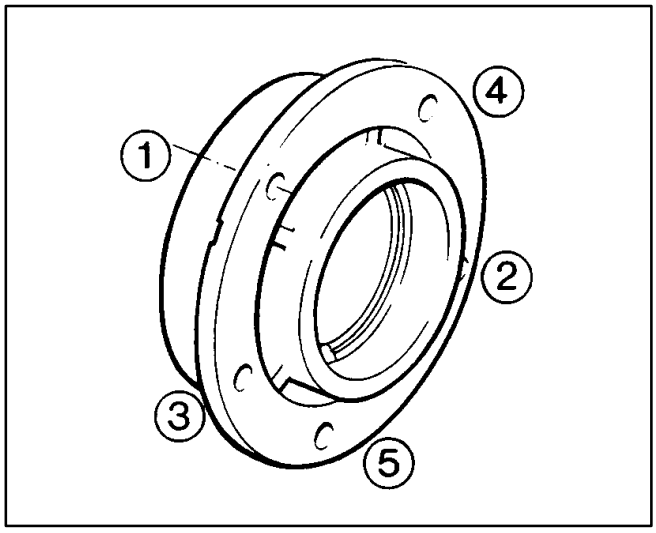


FIGURE 8-23. BEARING HOUSING TIGHTENING SEQUENCE

The Crankshaft Pulley

The crankshaft and driven pulleys must have smooth grove finishes and line up within 1.6 mm (0.061 in) as measured at the centers of the grooves.

The pulley is secured by a left-hand thread bolt. ***Turn the bolt clockwise to loosen and counterclockwise to tighten.*** Torque to 300 N-m (221 lb-ft).

The Crankshaft

The crankshaft is carried in split, steel-backed, copper-faced main bearings.

The center main bearing housing halves are secured together by two capscrews around the crankshaft journal. Two-cylinder engines have 1 center bearing, 3-cylinder engines have 2, and 4-cylinder engines have 3.

End thrust is taken on steel-backed, copper-faced, split thrust washers installed at the gear and flywheel ends of the crankcase.

An interference-fit pinion gear is keyed onto the gear end of the crankshaft to drive the camshaft gear.

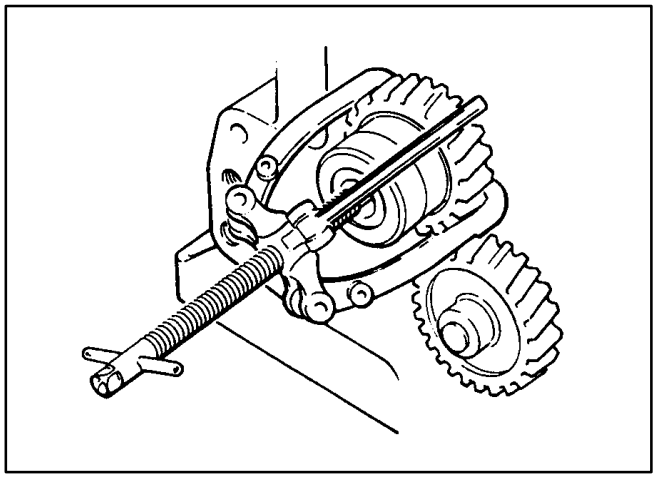


FIGURE 8-24. GEAR REMOVAL

Removing the Crankshaft:

1. Remove the crankshaft pulley (Page 8-29).
2. Remove the gear cover (Page 8-20).
3. Remove the pistons and connecting rods (Page 8-24).
4. Remove each center bearing locating dowel by threading an inlet manifold bolt into it and pulling it out. Leave the dowels and bolts together for reassembly. See Figure 8-25 (Page 8-31) for the locations of the dowels.
5. Remove the flywheel (Page 8-27) and main bearing housing (Page 8-28).
6. Remove the camshaft (Page 8-21).
7. Remove the crankshaft gear with a suitable puller (Figure 8-24).
8. Gently withdraw the crankshaft through the flywheel end of the crankcase.
9. Dismantle the center bearing housing(s).
10. Remove the thrust washers from the gear end of the crankcase and the main bearing housing.

Inspecting the Crankshaft: Inspect the main bearings for scoring and wear. The bearings can be removed and replaced using the main bearing tool (Page 8-32). Replace bearings and regrind crankshaft journals as necessary. See DIMENSIONS OF WEARING PARTS (Page 8-8). Replace the thrust washers if they are damaged or worn.

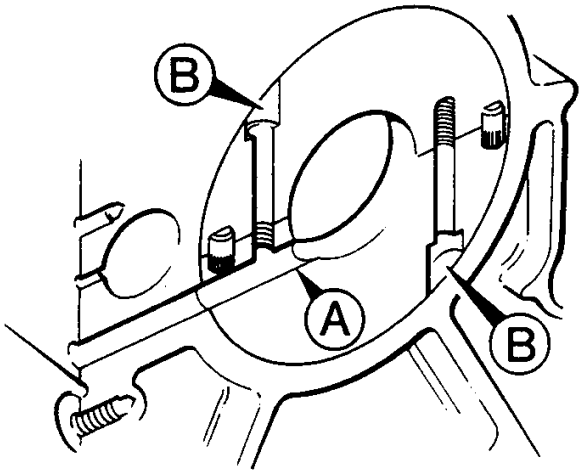
If a connecting rod big end bearing has failed, examine the oil passages in the crankshaft for obstructions and metal fragments.

Installing the Crankshaft:

1. If necessary, install new main bearing shells.
2. Reassemble the center main bearing housing(s) around the crankshaft and torque the capscrews to 21.0 N-m (15.5 lb-ft). Make sure “Flywheel End”, embossed on each half of the housing, faces the flywheel end of the crankshaft.
3. Lightly grease the steel backs of the thrust washer halves and position them in the gear end of the crankcase, ***copper faces out***. One of the bearing halves has a locating tab. Make sure the tab is located up, at 12 O’clock, in its recess.
4. Pass the crankshaft into the crankcase from the flywheel end.

   ⚠ CAUTION ***Take care not to score the gear-end main bearing.***

5. To line up the locating dowel holes in the center main bearing housing(s) and crankcase (Figure 8-25, Item A), rotate the bearing housing(s) so that the spilt between the halves lies horizontal. Insert the locating dowel(s). The tapped end of a dowel must face outwards. ***Make sure the dowels are fully seated and not in the housing capscrew head recesses.***
6. Install the rear main bearing housing and oil seal (Page 8-28).
7. Make sure that the crankshaft spins freely.
8. Insert the Woodruff key for the crankshaft gear if it has been removed.



A - Bearing Housing Locating Hole
B - Capscrew Head Recess

FIGURE 8-25. CENTER MAIN BEARING HOUSING AND DOWEL HOLE ALIGNMENT

9. Heat the crankshaft pinion gear to 325° F (163° C) in an oven and press it onto the crankshaft without delay, ***making sure the "O" mark faces outwards***. Insufficient heat could cause the pinion to jam on the crankshaft. Overheating could cause softening of the pinion.
10. Check crankshaft end play.

Checking Crankshaft End Play:

1. Set a dial indicator so that the actuating plunger makes contact with the face of the crankshaft (flywheel end).
2. Push the crankshaft firmly towards the gear end of the engine and zero the indicator.
3. Push the crankshaft firmly towards the flywheel end of the engine and check end play. End play should be 0.18-0.45 mm (0.007-0.018 inch). End play is maintained by a single 0.38 mm (0.015 inch) or 0.55 mm (0.022 inch) aluminum gasket between the main bearing housing flange and the crankcase.

The Crankshaft Center Main Bearing(s)

The bearing shells are removed after separating the two halves of the housing by removing the two capscrews (Figure 8-25). When new bearings are being installed, make sure the oil holes in the shells and housing line up. Torque the capscrews to 21.0 N-m (15.5 lb-ft).

The Flywheel-End and Gear-End Main Bearings

The procedures for removing and installing the main bearings is identical except that smaller tool components are used at the gear end.

Removing the Bearing: Before attempting to remove the bearings from the main bearing housing, secure the housing firmly in a soft-jawed vice.

1. Remove the oil seal.
2. Place the bolt (Figure 8-26, Item A) through the plain dolly (B).
3. Fit the bolt and dolly into the bearing from the oil seal side (crankcase outside face).

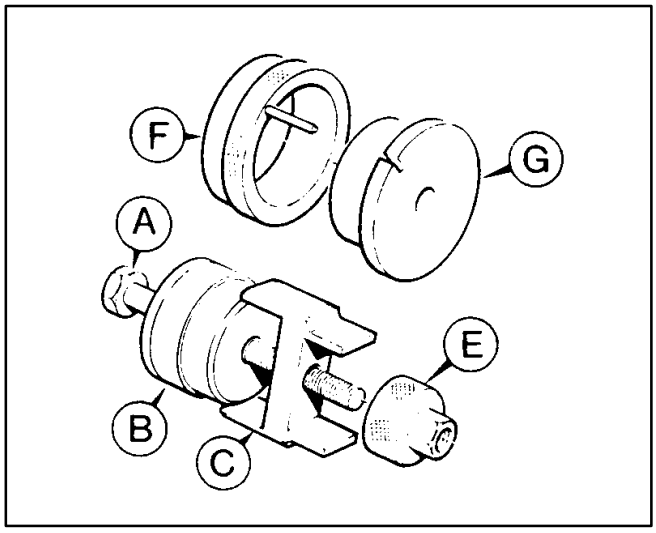


FIGURE 8-26. MAIN BEARING TOOL

4. Fit the bridge (C) over the bolt threads until the two legs are against the housing face (crankcase at the gear end).
5. Thread the nut (E) onto the bolt.
6. Using a suitable wrench tighten the nut until the bearing shells are withdrawn.

Installing the Bearing: Before attempting to install the bearings in the main bearing housing, secure the housing firmly in a soft-jawed vice with the small oil feed hole uppermost.

1. Place the large tapered collar (Figure 8-26, Item F) on a bench with the locating pin facing upwards.
2. Place the new bearing shells into the collar making sure that one oil feed hole is in line with the locating pin and that the end of the shell is in line with the mark on the collar face.
3. Place the driver (G) onto the collar (F) with the cut-out on the driver located over the collar locating pin.
4. Push the driver sufficiently until the bearings come out the other side of the collar to provide a lead-in.
5. Scribe a pencil line in line with the oil hole (Figure 8-27, Item X) on the outside face of the housing (crankcase at the gear end).
6. Install the assembly in the housing from the oil seal side (crankcase outside face at the gear end) with the locating pin in line with the pencil line on the housing (crankcase at the gear end). Take care to line up the locating pin with the inner oil hole (X).
7. Push the bolt (Figure 8-26, A) through the assembly.
8. Fit the bridge (C) and the nut (E) onto the bolt.
9. Tighten the nut until the driver (G) is against the face of the collar (F).
10. Remove the tool.
11. Check that the elongated oil hole (Figure 8-27, Item X) and the small oil hole (Y) in the bearing shell line up with the oil feed holes in the housing (crankcase).

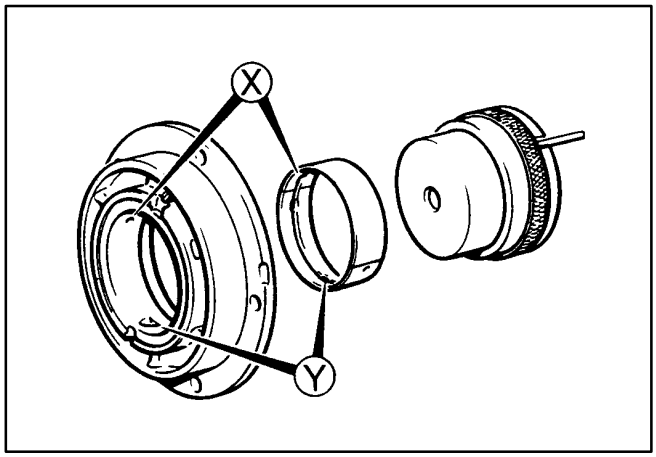


FIGURE 8-27. MAIN BEARING HOUSING OIL HOLE

THE LUBRICATING SYSTEM

Oil Capacity

See the section, *2. Specifications.*

Lubricating Oil Specification

See the section, *1. Introduction.*

Description and Operation

The sump is an integral part of the cylinder block. The oil filler, dipstick and filter are located on the crankcase door (Figure 8-28) and the drain below. Turbocharged engines have an oil cooler mounted between the adapter and oil filter (Figure 8-29). The oil cooler has coolant hoses to the coolant pump.

The oil pump (Figure 8-30) gear is driven by the camshaft gear. The oil pump assembly includes a removable strainer and oil relief valve.

Oil in the sump is drawn into the pump through the oil strainer and is then delivered by the pump through a drilling in the crankcase to the hole nearest the outside of the cartridge type oil filter base. Filtered, pressurized oil passes through the center of the filter and into the oil gallery, and from the oil gallery is delivered to the crankshaft and camshaft journals and tappet bores.

The connecting rod big-end bearings are pressure fed through internal drillings in the crankshaft from the main bearings. Splash oil lubricates the governor and camshaft. Oil jets supply oil under pressure to the piston undersides and camshaft gears.

Oil Seals

Lip-type oil seals around the crankshaft are installed in the gear cover (Page 8-20) and the main bearing housing on the flywheel end (Page 8-28).

A lip-type oil seal will not seal if the shaft journal is scratched within 5 mm (0.2 inch) of either side of the path of the lip. The journal surface must be free of chatter marks and have a finish of 0.4-0.6 microns. No grade of emery cloth provides a suitable finish.

Unless the crankshaft is new or has been reground, it is recommended that the oil seals be pressed in an additional 3 mm (0.12 inch) to establish a new sealing path on the journal.

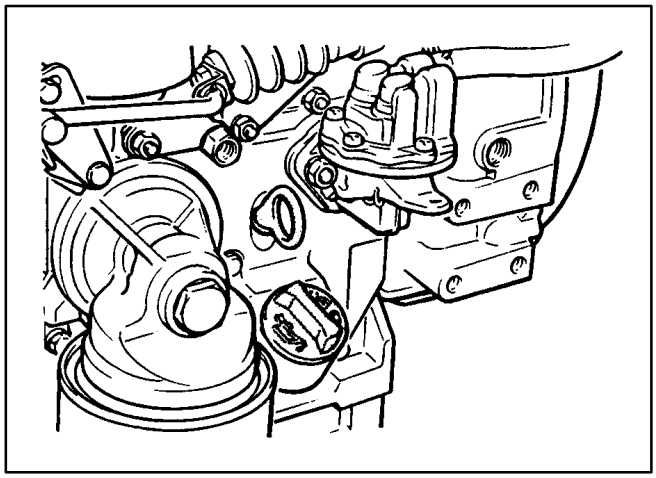


FIGURE 8-28. OIL FILLER, FILTER AND DIPSTICK

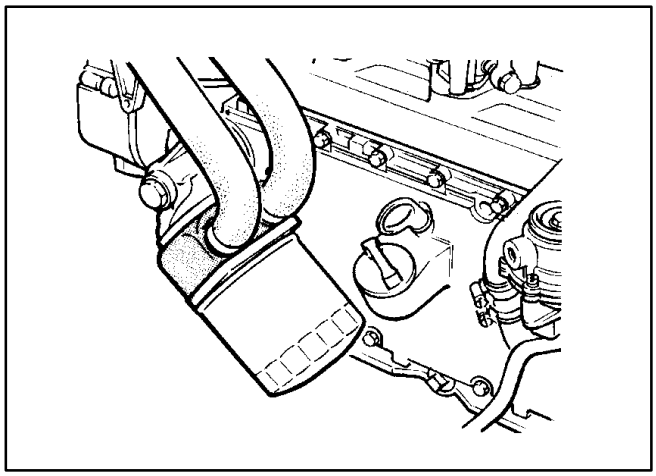


FIGURE 8-29. OIL COOLER (TURBOCHARGED)

The Oil Pump, Strainer and Relief Valve

Access to the oil pump, strainer and relief valve requires removal of the gear cover and crankcase door. There are no separately replaceable parts in the oil pump or relief valve.

⚠ CAUTION ***Do not use rags to wipe the inside of the crankcase as the residual fluff can clog the oil strainer.***

Removing the Pump, Strainer and Relief Valve:

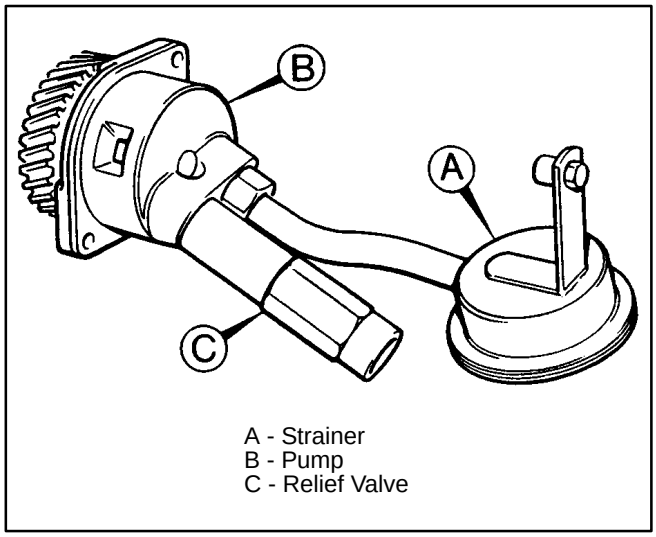
1. Remove the gear cover (Page 8-20) and crankcase door (Page 8-19).
2. Remove the oil strainer bracket bolt, spacer, washer and locknut.
3. Remove the oil strainer (Figure 8-30, Item A) and the relief valve (C) from inside the crankcase.
4. Remove the two pump retaining bolts.
5. Ease the pump (B) out of the crankcase.

   ⚠ CAUTION ***Do not lever the pump out with a screwdriver as that will damage the sealing surfaces of the pump flange.***

6. Check that the pump is working by turning the gear while holding the palm of the hand over the two ports.
7. Clean the strainer.

Installing the Pump, Strainer and Relief Valve:

1. Install the pump with the cut-out section of the pump flange (Figure 8-31, Item X) facing towards the top of the crankcase.
2. Torque the two pump retaining bolts to 9.0 N-m (6.5 lb-ft).
3. Install the oil strainer, strainer bracket bolt, spacer, washer and locknut.
4. Tighten the oil strainer pipe nut to 27.0 N-m (20.0 lb-ft). Make sure the strainer screen is parallel with the sump base.
5. Install the relief valve in the left-hand pump port and tighten the retaining nut.
6. Replace the camshaft (Page 8-21), gear cover (Page 8-20) and crankcase door (Page 8-19).



A - Strainer
B - Pump
C - Relief Valve

FIGURE 8-30. OIL STRAINER AND PUMP

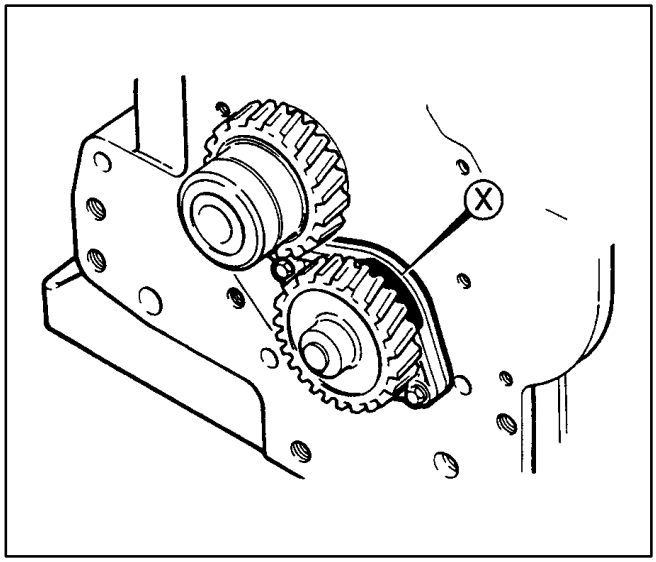


FIGURE 8-31. OIL PUMP LOCATING CUTOUT

COOLING SYSTEM—AIR-COOLED ENGINES

Air-cooled engines are cooled by an axial fan driven by a poly-V belt. A sheetmetal cowling directs the cooling air around the cylinders and heads (Figure 8-32).

⚠ CAUTION ***The engine can be seriously damaged if it is operated without the fan and all of the air cowling panels in place.***

Cleaning the Cooling System: Remove cowling panel C by removing its mounting bolts, and if necessary panel(s) B, to clean the cylinder and head cooling fins.

After panel C has been removed, panel(s) B, which are secured between the cylinders, can be removed by removing the split pin from the fuel pump side. Note that the spring clip retains the tie.

⚠ CAUTION ***To prevent possible injury, take care not to let the spring clip, on the axial fan side, eject the tie when the split pin is removed from the fuel pump side.***

Completely Removing the Air Cowling:

1. Remove the cylinder head cover nuts that retain the fuel injector pump delivery tube clips.
2. Release the clips and replace the cover nuts.
3. Loosen the fuel injector pump delivery tube fittings at both ends.
4. Loosen the injector clamps sufficiently to clear the top cowling (Figure 8-32, Item D), if necessary.
5. Remove the inlet manifold and gaskets.
6. Detach the axial fan cowling (C) from the top cowling (D) and the bottom cowling and remove it.
7. Remove the spring clips from the push rod tubes at the gear and flywheel ends and remove the two side shields (A).
8. Remove the top cowling (D).

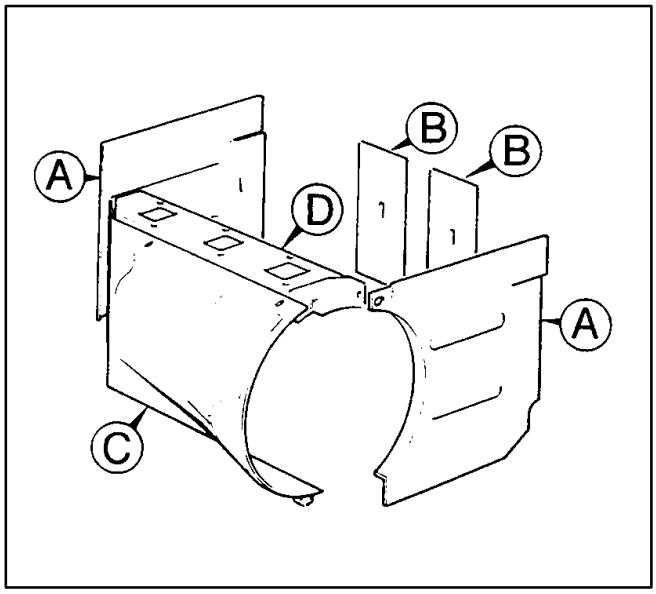


FIGURE 8-32. COOLING SYSTEM AIR COWLING PANELS

Installing the Air Cowling:

1. Install the center baffles (B) using new split pins. The baffle and split pin are installed on the fuel pump side of the engine.
2. Secure the bottom cowling section to the crankcase.
3. Secure the top cowling section to the cylinder heads. An inlet manifold gasket is installed on each side of the cowling.
4. Install the remaining air cowling and shields. Tighten the retaining bolts.
5. Install new rubber “O” rings in the recesses on the cylinder head covers.
6. Install the fuel injector pump delivery tube clips and torque the nuts to 9.0 N-m (6.5 lb-ft).
7. Torque the injector clamp bolts to 21.0 N-m (15.5 lb-ft).
8. Torque the fuel injector pump delivery tube fittings to 29.0 N-m (21.0 lb-ft).
9. Install the inlet manifold and gaskets and torque the manifold bolts to 9.0 N-m (6.5 lb-ft).

The Axial Fan Drive Belt

The crankshaft and driven pulleys must have smooth grove finishes and line up within 1.6 mm (0.061 in) as measured at the centers of the grooves.

See the section, *9. Maintenance*, for instructions on how to adjust belt tension.

The Axial Cooling Fan

Removing the Axial Fan:

1. Remove the drive belt.
2. Remove the bolt at the crankcase end of the adjusting arm.
3. Move the alternator outwards.
4. Loosen or remove the axial fan side air cowling.
5. Support the fan and remove the two remaining bolts from the mounting bracket.

Replacing the Axial Fan:

1. Hold the fan in position and replace, finger tight, the two mounting bracket bolts nearest to the crankshaft.
2. Replace the drive belt by hand.
3. Torque the first two fan mounting bolts to 21.0 N-m (15.5 lb-ft).
4. Tighten the remaining bolts to 21.0 N-m (15.5 lb-ft).
5. Replace or tighten the axial fan side air cowling.
6. Move the alternator outwards as far as possible by hand and tighten the pivot bolt and adjusting arm bolts.
7. See the section, *9. Maintenance*, for instructions on how to adjust belt tension.

COOLING SYSTEM—LIQUID-COOLED ENGINES

The engine is cooled by coolant pumped through the engine block and head. The coolant pump and radiator fan are driven by a poly-V belt.

Coolant Concentrate

See the section, *9. Maintenance.*

Engine Coolant Capacity

See the section, *2. Specifications*.

Draining, Flushing and Refilling the Cooling System

See the section, *9. Maintenance.*

The Thermostat

Removing the Thermostat:

1. Remove the radiator pressure/fill cap, thermostat body drain plug (Figure 8-33, Item A) and radiator top hose.

   ⚠WARNING ***Hot coolant is under pressure and can cause severe burns. Always let the engine cool down before removing the pressure/fill cap or drain plug.***

2. Remove the two cover retaining bolts and lift off the cover (B) and thermostat (C).

3. Clean any debris and the old seal from the thermostat housing.

4. Submerge the thermostat in a container of water and raise the water temperature to make the thermostat open. Replace the thermostat if it does not start to open at 71°C (160°F) or is not fully open at 85°C (185°F).

Installing the Thermostat:

1. Install the thermostat with a new gasket, making sure the jiggle pin (Figure 8-34, Item A) moves freely and is located as shown towards the recess.

2. Replace the cover, drain plug and radiator hose.

3. Refill the coolant system. See the section, *9. Maintenance*.

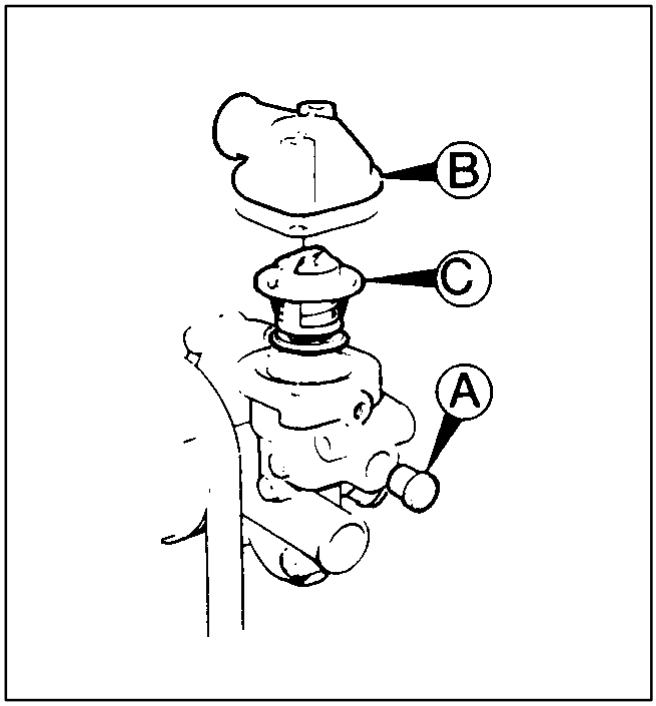


FIGURE 8-33. REMOVING THE THERMOSTAT

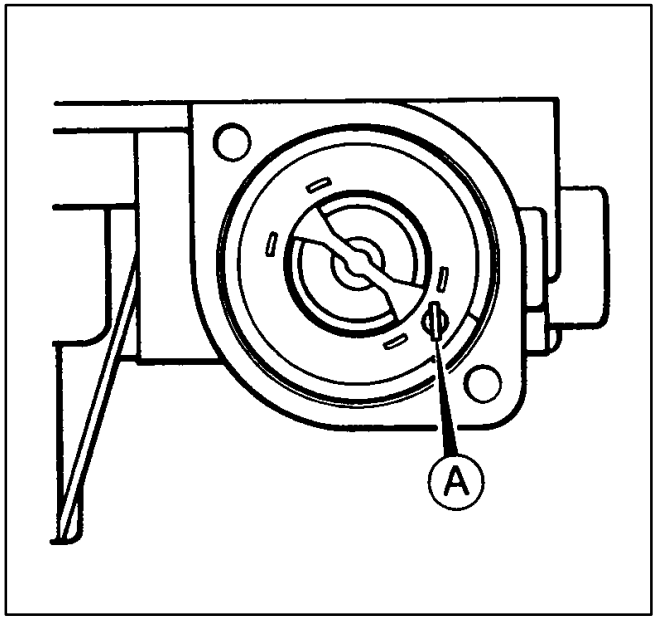


FIGURE 8-34. THERMOSTAT

The Coolant Pump

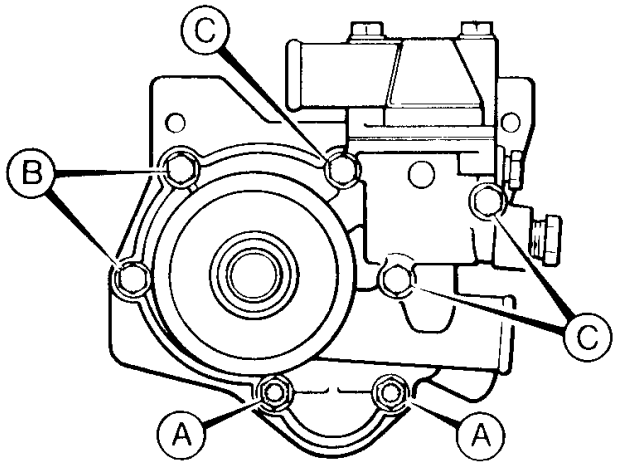
The coolant pump can be removed without removing the thermostat, radiator fan or fan pulley.

Removing the Coolant Pump:

1. Remove the radiator.
2. Loosen the alternator adjusting bolts.
3. Move the alternator inwards towards the crankcase sufficiently to remove the fan drive belt.
4. Remove the five bolts and two stud nuts from the pump assembly.
5. Lift off the pump assembly.
6. Clean any debris and old gasket from the pump assembly and the block.

Installing the Coolant Pump:

1. Install the pump assembly with a new gasket and torque the five bolts and two stud nuts to 21.0 N-m (15.5 lb-ft).
2. Replace the fan drive belt. See the section, *9. Maintenance*, for instructions on how to adjust belt tension.
3. Install the radiator.
4. Refill the system with coolant. See the section, *9. Maintenance*.



A - Stud nuts
B - Shorter bolts (45 mm)
C - Longer bolts (75 mm)

FIGURE 8-35. COOLANT PUMP

The Radiator Fan Drive Belt

The crankshaft and driven pulleys must have smooth grove finishes and line up within 1.6 mm (0.061 in) as measured at the centers of the grooves.

See the section*, 9. Maintenance*, for instructions on how to adjust belt tension.

The Radiator Fan

Removing the Fan:

1. Remove the radiator.
2. Remove the fan drive belt.
3. Loosen the fan mounting nut. ***Turn the nut clockwise to loosen.***
4. Remove the fan.

Replacing the Fan:

1. Install the fan and mounting nut. ***Tighten the nut counterclockwise.*** Torque the nut to 30 N-m (22 lb-ft).
2. Replace the fan belt. See the section, *9. Maintenance*, for instructions on how to adjust belt tension.
3. Install the radiator.
4. Refill the system with coolant. See the section, *9. Maintenance*.

The Radiator

Removing the Radiator:

1. Remove the radiator pressure/fill cap and drain the coolant. See the section, *9. Maintenance.*

   WARNING ***Hot coolant is under pressure and can cause severe burns. Always let the engine cool down before removing the pressure/fill cap or drain plug.***

2. Disconnect the radiator hoses from the engine.
3. Remove the two halves of the fan guard.
4. Remove the radiator and shroud from the skid as an assembly.
5. Remove the radiator from the shroud if necessary.

Installing the Radiator: Installation is the reverse of removal.

THE FUEL SYSTEM

Description and Operation

The fuel system consists of separate fuel injection pumps and injectors for each cylinder, a fuel lift pump and a fuel filter. From the filter, fuel flows to the fuel injection pumps through flexible tubing. The pumps feed high pressure fuel to the injectors, which are held in position by clamps. Leak-off tubes from the injectors carry fuel back to the tank. *This fuel must never be fed directly into the injection pumps*.

⚠WARNING ***Diesel fuel is combustible and can cause severe personal injury or death. Do not smoke near diesel fuel tanks or equipment. Keep flames, sparks, pilot lights, electrical arcs and arc-producing equipment and all other sources of ignition well away. Keep a type ABC fire extinguisher handy.***

Fuel Specification

See the section, *1. Introduction.*

Fuel System Precautions

- All fuel connections must be leakfree.
- Always use a new gasket when a fuel union has been disturbed.
- To prevent the fuel injection pump from twisting in its seating and causing misalignment of the pump calibration marks, always use two wrenches when tightening or loosening the tubing connection at the pump.
- To prevent leaks when reinstalling the fuel injector pump delivery tubes, tighten the connection at the injector first and then at the pump.
- Make every effort to keep dirt out of the fuel system.

Fuel Filter

See the section, *9. Maintenance.*

Fuel Lift Pump

The fuel lift pump (Figure 8-36) is operated by a push rod from the camshaft. It also has a lever for manual operation. The pump has maximum lift of approximately 3 m (10 ft).

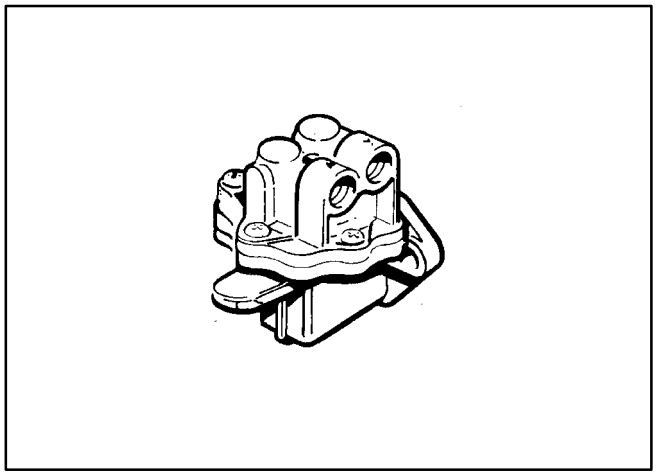


FIGURE 8-36. FUEL LIFT PUMP

Priming the Fuel System

First Stage (Fuel Filter):

1. Make sure there is fuel in the supply tank.

2. Open the fuel filter bleed screw on the fuel filter adapter (Figure 8-37) while operating the fuel lift pump by hand. Close the bleed screw when all air has been expelled.

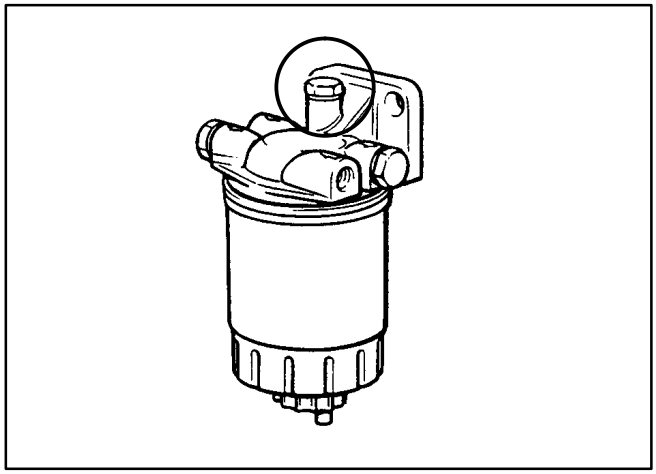


FIGURE 8-37. FUEL FILTER BLEED SCREW

Second Stage (Pumps and Injectors):

While the engine is running or cranking, prime each pump, starting with the pump nearest the fuel filter:

1. Hold the delivery valve holder (Figure 8-38, Item B) with a wrench and loosen the fuel injector pump delivery tube fitting nut (A) until no air bubbles are expelled.

   ⚠WARNING ***Loosening the fuel injector pump delivery tube fitting nut can result in high pressure fuel spray which can penetrate the skin and cause blood poisoning. Wear safety glasses and keep hands away from the injector delivery tube fitting nut. Get proper medical attention immediately if your hands get in the way of the spray.***

2. Hold the delivery valve holder and torque the fuel injector pump delivery tube fitting nut to 29.0 N-m (21.0 lb-ft).

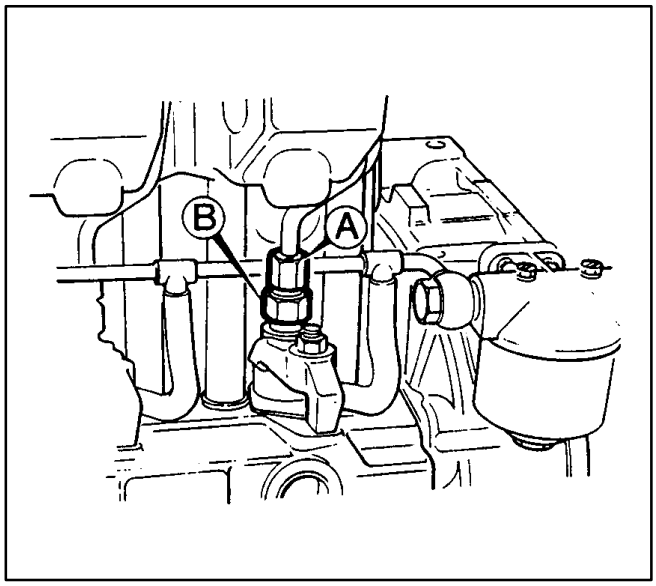


FIGURE 8-38. PRIMING A FUEL PUMP

Fuel Injectors

These are direct-injection engines.

Cleaning and Servicing the Injector: The fuel injection system must be kept absolutely clean. Minute particles of dirt can easily block an injector nozzle hole causing smoky exhaust, difficult starting and poor performance. When cleaning and assembling fuel injectors:

- Wash dismantled parts in clean, fresh fuel.
- Do not mix parts from different injectors.
- Do not use paraffin or woven cloth. Non-fluffing paper is permissible.
- Assemble components wet.

Servicing the Injectors: A fuel injector test rig is the only way to tell positively which injectors are in good condition and correctly set. All sprays should have the same appearance and the same length of penetration in the air. If not, replace the injector nozzle.

⚠WARNING ***The high pressure oil spray from a nozzle can penetrate the skin, leading to possible blood poisoning. Wear safety glasses and keep your hands away from the spray. Do not delay getting proper medical attention if your hands do get in the way of the spray.***

If the nozzle only is replaced, the injector spring pressure must be reset with a test rig. After testing and resetting, the injector top plug must be torque-loaded to 47.0 N-m (35 lb-ft).

See ENGINE TROUBLESHOOTING at the beginning of this section for common injector problems.

Injector Settings:

New – 245-255 bar (3553-3698 psi)

Used – 240 bar (3481 psi)

Injector Back Leakage (Leak-Off): The injector leak-off rate is 10-40 seconds between 152-101 bar (2205-1465 psi) on an injector tester using Calibration C fluid at a temperature of 15.5° C (60° F).

Removing an Injector:

1. Pull off the injector leak-off hose from the injector body stub tube.
2. Remove the cylinder head cover nut retaining the fuel injector pump delivery tube clip.
3. Release the clip.
4. Loosen the fuel injector pump delivery tube fittings at both ends.
5. Loosen the injector clamp bolt.
6. Remove the fuel injector pump delivery tube.
7. Remove the injector clamp and lift out the injector.
8. Remove the injector copper sealing washer from the cylinder head taking care not to damage the seating area.

Installing an Injector:

1. Make sure the seating in the cylinder head is clean and smooth and that the old washer has been removed.
2. Lightly smear a very small amount of high melting point grease to one side of the new injector sealing washer and place one washer only over each injector nozzle, greased side first.
3. Install the injector.
4. Install the clamp, leaving the bolt finger tight.
5. Install the fuel injector pump delivery tube tightening the fittings finger tight.
6. Fit new rubber “O” rings into the recesses on the cylinder head cover.
7. Install the fuel injection pump delivery tube clip and torque the nut to 9.0 N-m (6.5 lb-ft).
8. Torque the injector clamp bolt to 21.0 N-m (15.5 lb-ft).
9. Torque the fuel injection pump delivery tube fittings to 29.0 N-m (21.0 lb-ft).
10. Install the injector leak-off hose.

Fuel Injection Pumps

Individual fuel pumps are located at the side of the engine, between the push rods, and are secured to the crankcase by clamps and nuts.

Removing the Fuel Pumps: *To keep from having to remove the gear cover and gauge the no-fuel position (Figure 8-43), one fuel pump should be left in place to preserve the no-fuel position.* (Alternatively, if the stop screw thread seal [Figure 8-42, Item A] has not been broken it may be possible to recover the no-fuel position. See Procedure 2, Page 8-46, under Installing the Fuel Pumps.) Remove the pumps as follows:

1. Back the fuel hose clip (Figure 8-39, Item A) up the hose and pull the hose off the pump.

2. Disconnect the fuel delivery tube. Use two wrenches; one to hold the pump delivery valve (Item C).

3. Turn the engine control lever counterclockwise to the stop position (Figure 8-47) so that the fuel pump rack arm will line up with the slot in the crankcase so that the fuel pump can be withdrawn.

4. Remove the fuel pump clamp (B) and lift out the pump. Wire the shims together and tag them with the cylinder number so that they can be returned to the same tappet location.

Removing/Installing the Fuel Pump Tappets: Use a magnet tool to remove or install a fuel pump tappet and its thrust cup. A stud projecting into the tappet bore (Figure 8-40, Item B) keeps the tappet (A) from turning. See the instructions and precaution on Page 8-19 about the stud used both for mounting the crankcase door and locating the tappet.

Servicing the Fuel Pumps: Fuel pumps should not be taken apart. There are no separately replaceable parts available for fuel pumps except the delivery valve. Use a new gasket and torque the new holder to 47.0 N-m (35.0 lb-ft).

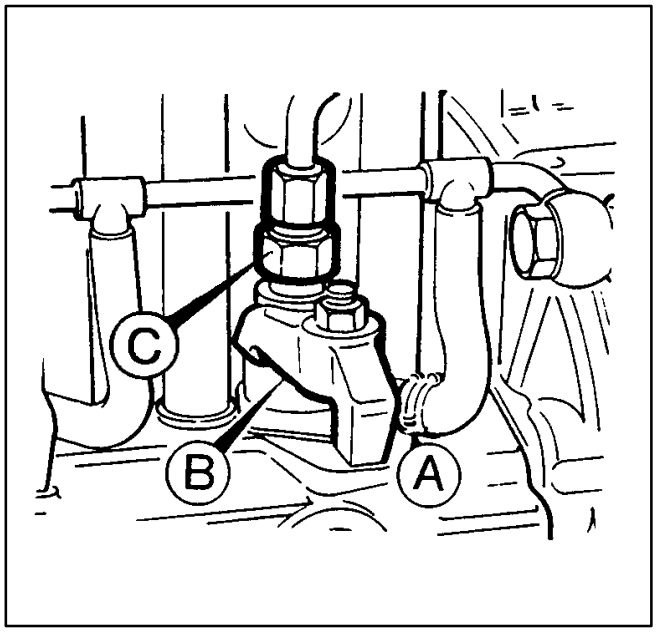


FIGURE 8-39. FUEL PUMP

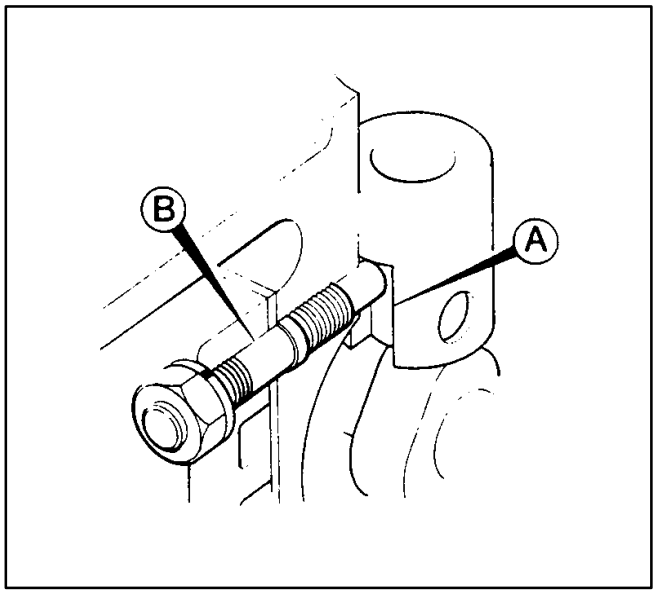


FIGURE 8-40. FUEL PUMP TAPPET AND STUD

Timing the Fuel Pumps: Each fuel pump is timed individually with a shim pack to inject fuel at 20° TDC. Shim pack thickness varies slightly from tappet to tappet location on an engine because of variations in the "X" dimension (Figure 8-41). These variations are due to the stack up of tappet, cam, gear, crankshaft, connecting rod and piston tolerances (the pump drive train). *Therefore, a shim pack should always be returned to the same tappet location on the crankcase*. The fuel pumps are interchangeable because the "B" dimension (Figure 8-41) has been set with non-removable shims by the pump manufacturer. Fuel pump retiming will be necessary if a shim has been lost or mixed up with other packs or when parts in the pump drive train have been replaced. Time each pump as follows:

1. Rotate the piston to TDC on the firing stroke.

2. Find TDC exactly with a dial indicator on the piston crown. If the cylinder head has not been removed, remove the valve rocker and spring (Page 8-14) and let the valve drop onto the piston. Measure piston movement on the end of the valve stem. ***Keep the piston in the top half of its stroke or the head will have to be removed to retrieve the valve.***

3. Rotate the flywheel counterclockwise from TDC (looking at the gear end of the crankshaft) to a piston displacement of more than 3.097 mm (0.1219 inch) before TDC.

4. Carefully rotate the flywheel clockwise back to a piston displacement of exactly 3.097 mm (0.1219 inch) before TDC. (This corresponds to 20° BTDC.)

5. Measure dimension "X" (Figure 8-41) with a depth micrometer (distance from the face of crankcase on which the pump sits to the top face of the tappet thrust cup). ***Make sure the tappet thrust cup is in place***.

6. Subtract dimension "X" from dimension "B". The difference is the required thickness of the shim pack, ± 0.025 mm (0.001 inch). Shims are available in three color-coded thicknesses:

   Green—0.075 mm (0.0030 inch)

   Slate Blue—0.125 mm (0.0049 inch)

   Black—0.250 mm (0.0098 inch)

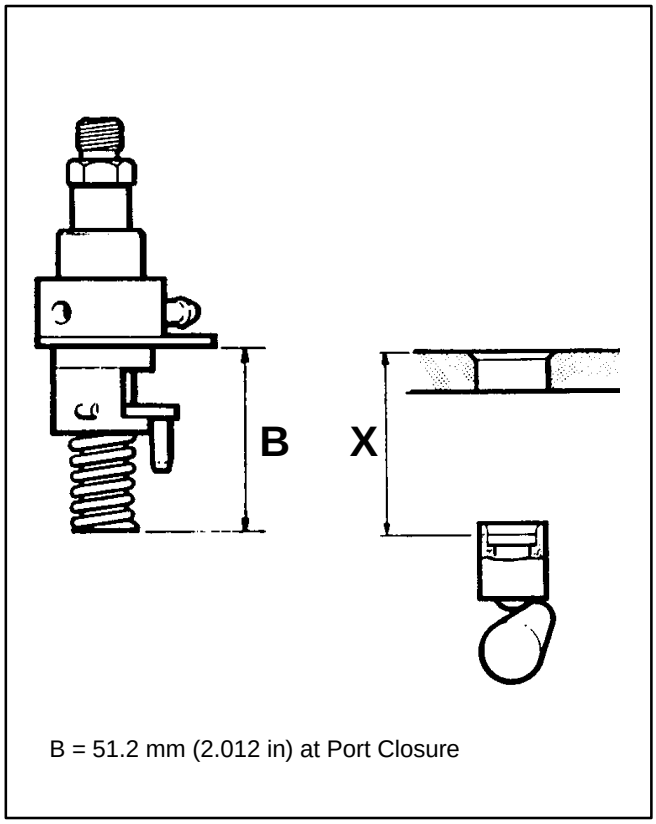


FIGURE 8-41. FUEL PUMP TIMING DIMENSIONS

Installing the Fuel Pumps: Follow procedure 1, 2 or 3 below depending on how far the engine has been disassembled.

Note: ***If all the fuel pumps have been removed and the stop screw thread seal is broken, the gear cover will have to be removed and Procedure 3 performed to restore the no-fuel position.***

1. If one pump was left in place to preserve the no-fuel position, install the pumps that were removed as follows:

   A. Loosen the stop screw and locknut (A and C in Figure 8-42) and back the screw out (to the left) at least two turns.

   B. Press down on the tappet for the pump that is being installed and slowly turn the crankshaft until the tappet is at its lowest position.

   C. Mate the correct shim pack to the fuel pump.

   D. Gently turn the control lever (Lever B in Figure 8-42) counterclockwise by hand as far as it will go and hold it there. Back out the stop screw (Item A) if it interferes.

   E. Rotate the fuel pump rack lever in the body of the fuel pump fully counterclockwise and insert the fuel pump into the crankcase, making sure that: 1) the fuel pump rack pin engages the slot in the fuel rack and 2) the fuel inlet tube is to the right of the pump clamp stud.

   F. Loosely assemble the clamp and nut on the pump with the beveled face of the nut facing the clamp. Clamp the pump just snug. Then, using a wrench, slowly turn the pump body counterclockwise until you feel it stop. Torque the clamp nut to 34.0 N-m (25 lb-ft).

2. If all the fuel pumps were removed but the stop screw thread seal is intact (Figure 8-42, Item A) and the gear cover has not been removed, the no-fuel position can be found by turning the stop screw 2 turns *clockwise* so that it backs out to the left. Hold the control lever (B) against the stop screw and perform Steps B, C, E and F in Procedure 1 to install the pumps.

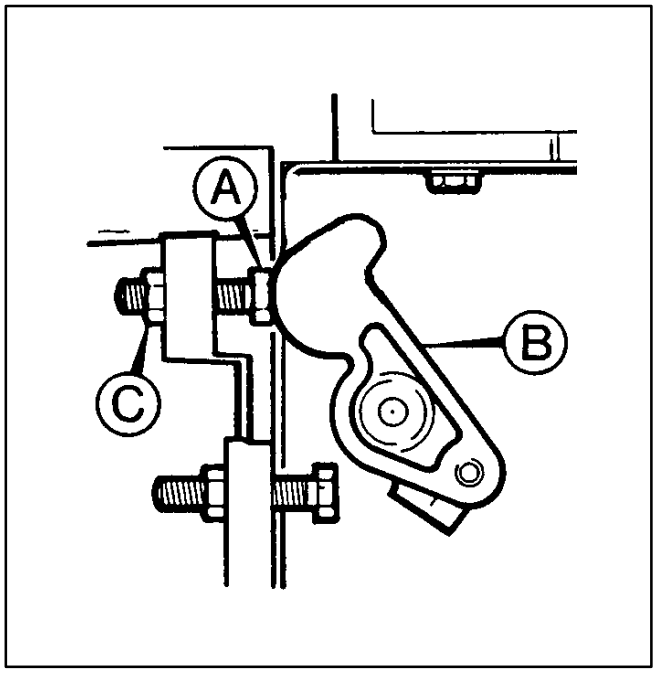


FIGURE 8-42. STOP SCREW AND LEVER

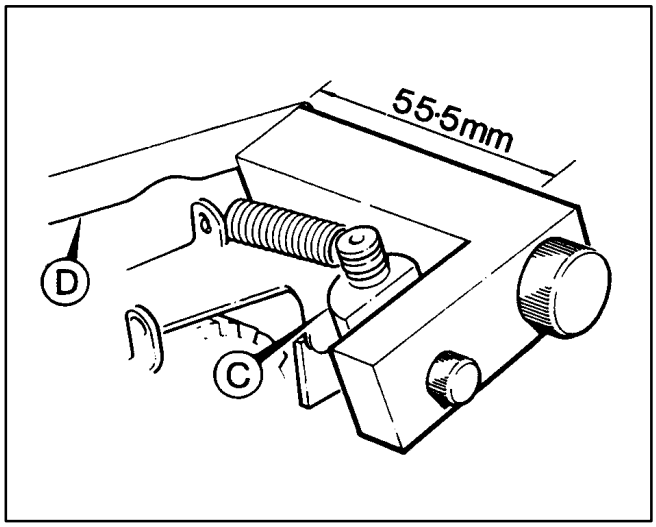


FIGURE 8-43. SETTING THE FUEL RACK NO-FUEL POSITION WITH A GAUGE

3. Install at least one fuel pump before securing the gear cover so that the no-fuel position can be established. Solidly anchor the fuel rack so that it extends 55.5 mm (2.18 inch) beyond the face of the gear case. Use the gauge available (Figure 8-43) or equivalent means. Perform Steps B, C, E and F in Procedure 1 to install the pumps.

MECHANICAL GOVERNOR

Removing the Governor and Fuel Rack

1. Remove the gear cover (Page 8-20) and fuel injection pumps.
2. Disconnect the governor spring (Figure 8-44, Item A) from the governor lever assembly (B) and the speed control lever (C).
3. Move the retainer spring (D) out of the way and remove the lower pivot pin (E) and shim.
4. Remove the upper pivot pin from the governor lever assembly. Keep track of the shims.
5. Gently pull out the governor lever assembly and fuel rack.
6. Remove the governor sleeve (F) and thrust washer.

Installing the Governor and Fuel Rack

1. Turn the camshaft until the Number 1 cylinder fuel pump tappet is in its lowest position.
2. Install the governor weights if they have been removed (Page 8-48)
3. Install the governor sleeve and washer.
4. Gently pass the fuel rack through the crankcase, making sure the end of the rack fits into its locating bore at the flywheel end.
5. Insert the lower pivot pin and shim into the governor lever assembly and secure them with the retaining spring (Figure 8-44, Item D).
6. Insert the top pivot pin and shims.
7. Reconnect the governor spring.
8. Install at least one fuel pump, re-establishing the no-fuel position (Page 8-47), before securing the gear cover.

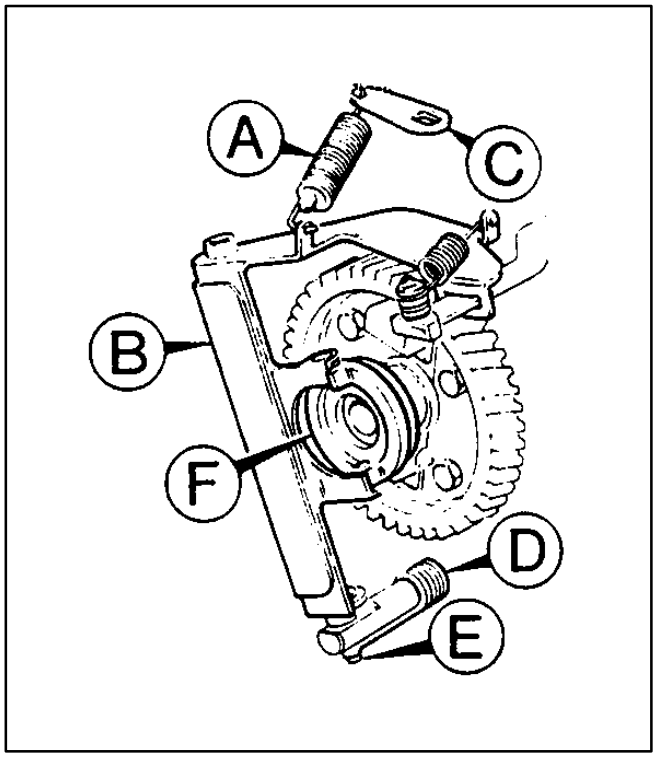


FIGURE 8-44. THE GOVERNOR

Governor “E” Setting

1. See that the governor lever assembly falls freely under its own weight along its pivot pins.

2. Check governor lever assembly end play (“E” in Figure 8-45). Add or subtract 0.25 mm shims around the top pivot pin only to obtain a 0.1-0.3 mm (0.004-0.012 inch) end play.

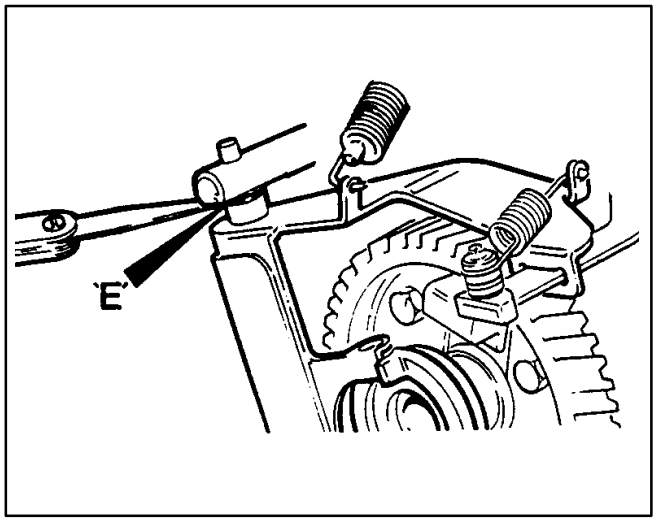


FIGURE 8-45. GOVERNOR “E” SETTING

Removing / Installing Governor Weights

Removal: The weights are held by pins which are retained by plates bolted to the camshaft gearwheel.

1. Remove the governor lever assembly.

2. Remove the governor sleeve (Figure 8-46, Item A).

3. Turn the camshaft until the weights are horizontal.

4. Loosen the weight retaining plate bolts (B).

5. Remove the weight retaining plates.

6. Lift out the weights, taking care to retain the pins and wear washers with them.

7. Slide the weights and wear washers off of the pins (C).

Installation: Lightly lubricate the pins and fit them to the weights.

8. Install the weights, washers and pins with the large section of the weights facing outwards.

9. Install the top retaining plate, leaving the bolts finger tight.

10. Torque the four retaining bolts to 9.0 N-m (6.5 lb-ft).

11. Check that the weights are free to move.

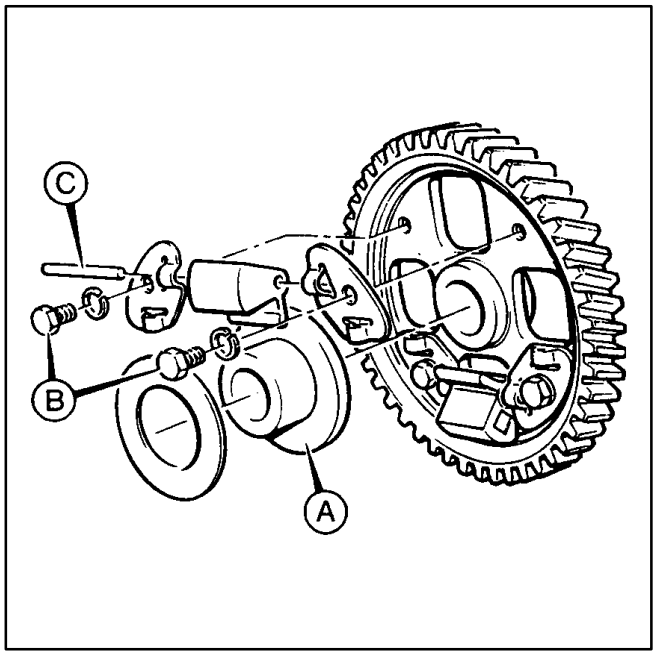


FIGURE 8-46. CHANGING GOVERNOR WEIGHTS

Governor “G” Setting

The governor “G” setting establishes the maximum fueling rate. The no-fuel position is used as the reference point for the gauge.

1. At least one fuel pump must be in place and the no-fuel position correctly set (Page 8-47).

2. Turn the engine control lever (Figure 8-47, Item B) counterclockwise as far as it will go, backing off the stop screw (A), if necessary. While holding the lever counterclockwise, turn the stop screw (A) until it just touches the lever. Reset its locknut (C). *This is the external no-fuel position which corresponds to the internal fuel rack setting (Page 8-47).*

3. Insert a gauge of the appropriate “G” dimension (Table 8-7) between the stop screw (A) and the control lever (B). While holding the gauge in place, turn the high-fuel stop screw (Figure 8-48, Item C) until it just touches the lever. Reset its locknut (D). Recheck the setting and readjust screw (C) if necessary.

4. Establish the governor stop-fuel setting (Page 8-50).

TABLE 8-7. GOVERNOR “G” SETTINGS

Generator Set Model	millimeters	inch
DNAA	23.5	0.925
DNAB	23.5	0.925
DNAC	23.5	0.925
DNAD	23.5	0.925
DNAE	23.5	0.925
DNAF	25.0	0.984

Excess Fuel Device

The excess fuel device is a trip lever (inside the housing) engaged by the engine control lever (Figure 8-47, Item B) when the lever is pushed (counterclockwise) to stop the engine. The device provides excess fueling at startup and releases when the engine runs up to speed.

To obtain excess fuel starting after the engine has run out of fuel and stops, turn the generator set control OFF and then ON so that the fuel stop solenoid will bump the lever to the stop position to reset the excess fuel trip lever. (The Detector control will do this automatically, but will itself need to be reset following shutdown due to running out of fuel.)

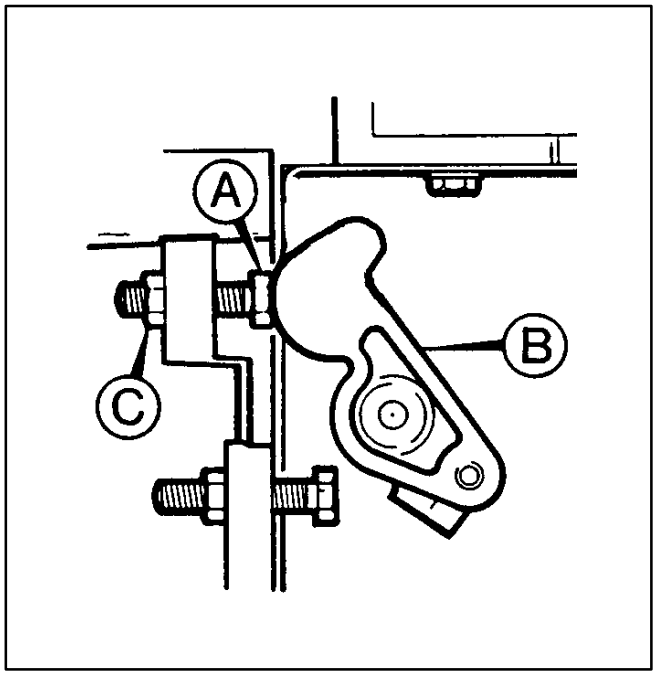


FIGURE 8-47. STOP/RUN LEVER

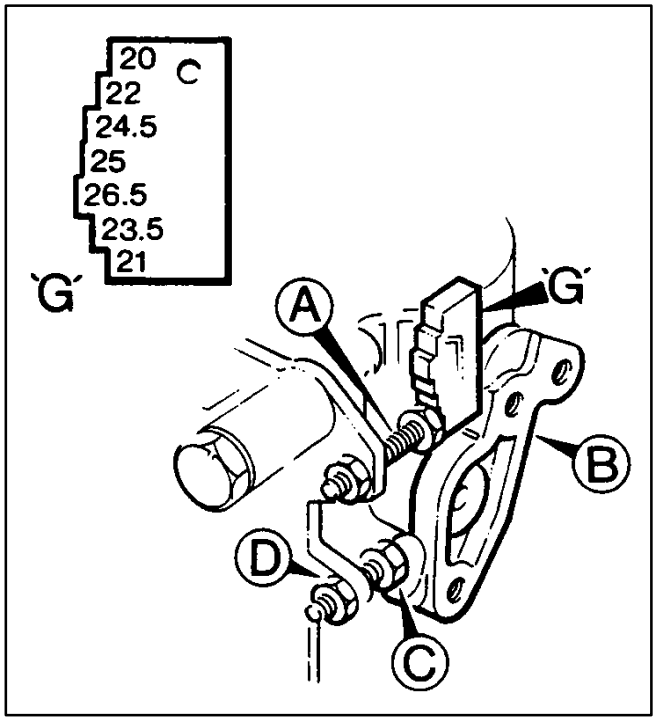


FIGURE 8-48. GOVERNOR “G” SETTING

Governor Stop-Fuel Setting

The stop-fuel position is established slightly ahead of the no-fuel position (Step 1 under Governor "G" Setting) so that the fuel rack is brought to a stop by the stop screw rather than the fuel pump stops.

⚠ CAUTION ***The stop-fuel setting must be correct. Too much advance can prevent the engine from shutting down. Too little can result in damage to the fuel injection pumps.***

1. Establish the governor "G" setting.

2. Loosen the locknut (C) on the stop screw (Figure 8-47, Item A) and turn the stop screw counterclockwise to advance 2 turns to the right. Reset the locknut (C).

3. *Seal the threads of both the stop-fuel and high-fuel stop screws with paint to register the adjustment and discourage tampering.*

Adjusting Speed

Adjust engine speed only after all other adjustments have been made. Speed increases as the speed plate (Figure 8-49, Item C) is rotated clockwise. Back out screw B and adjust screw A to obtain the specified speed: 1500 RPM for 50 Hertz and 1800 RPM for 60 Hertz, *under no load*. Thread screw B in snuggly by hand to lock the speed plate in position and set the lock nuts.

Adjusting Droop (4-Cylinder Engines)

The governor lever assembly has a droop adjustment screw (Figure 8-50, Item B) accessible by removing the plug (Item A) in the side of the gear cover. The adjustment affects how the governor spring (Item C) acts upon the governor lever assembly in opposition to the governor flyweights.

Use a 5 mm Allen head ball driver to turn the droop adjustment screw. As the starting reference, turn the screw all the way out (counterclockwise) and then turn the screw in 4 turns (clockwise) for a 60 Hz generator set or 10-12 turns for a 50 Hz set.

Turn the adjustment screw counterclockwise in half-turn steps to decrease droop *under full load* and clockwise to increase droop. Droop should be 3 Hz for 60 Hz generator sets and 2-1/2 Hz for 50 Hz sets. Check engine speed (frequency) *under no load* after each droop adjustment and readjust if necessary.

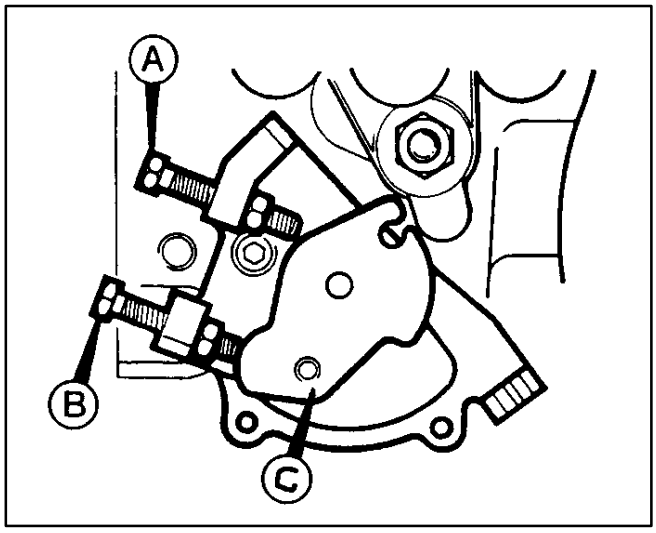


FIGURE 8-49. SPEED ADJUSTMENT

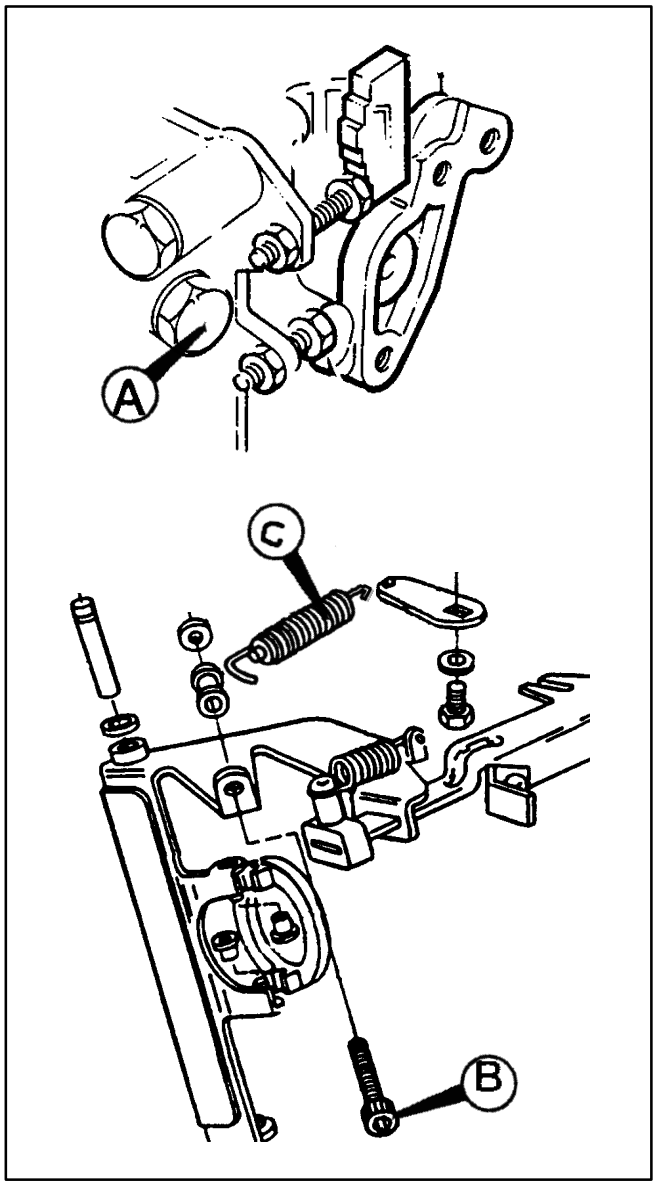


FIGURE 8-50. GOVERNOR DROOP ADJUSTMENT

ELECTRONIC GOVERNOR

Governor Linkage Adjustment

1. Make sure the governor actuator is securely mounted, that the clevis on the end of the armature has full thread engagement, that its lock nut is set, and that the clevis pin lies horizontal so that the link will not bind (Figure 8-51).

2. Make sure the no-fuel position (Page 8-47) and the “G” setting (Page 8-49) are correct. See Figure 8-52 for the internal parts and fuel rack with an electronic governor.

3. Disconnect the link at the engine control lever and rotate the lever gently counterclockwise as far as it will go (no-fuel position), and while holding it there, adjust the length of the link until the holes in the link and control lever line up. Then lengthen the link two turns and set the lock nut.

4. Reconnect the link to the engine control lever, making sure the linkage does not bind.

Magnetic Pickup Unit (MPU)

Measure AC output of the MPU (Figure 8-51) while cranking the engine. If output is less than 2.5 volts RMS (meter must have 5000 ohms/volt AC input impedance or greater), remove the MPU and check for damage. If there is no apparent damage, reinstall the MPU as follows:

1. Bar the engine until a gear tooth lines up with the center of the hole.

2. Thread the MPU in gently by hand until it just touches the gear tooth. Then back it out 1/4 turn and set the lock nut.

3. Replace the MPU if the signal is still weak.

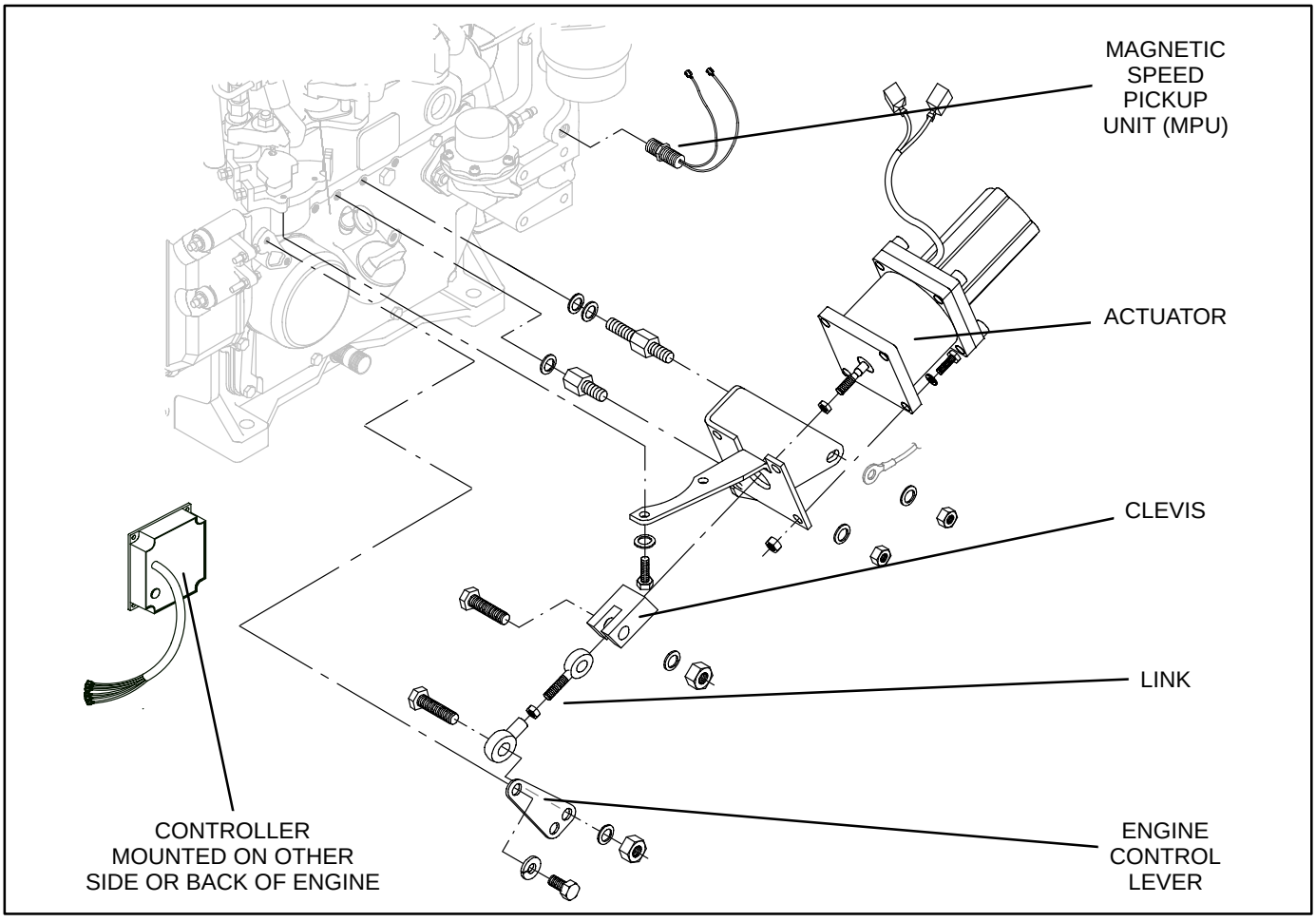


FIGURE 8-51. ELECTRONIC GOVERNOR

Controller Adjustment

Figure 8-53 illustrates the face of the governor controller and its speed and gain adjusting pots. Before adjusting the controller, make sure that the governor linkage is properly adjusted.

1. With the generator set control switch **OFF**, set **GAIN** half way between “0” and “50”.
2. Start the engine and adjust speed to obtain the proper frequency (50 or 60 Hertz).

   ⚠ CAUTION ***Be prepared to immediately shut off the engine if it overspeeds.***
3. Under no-load turn the **GAIN** pot clockwise until the engine begins to hunt. Physically upset the linkage if it does not hunt.
4. Turn the **GAIN** pot counterclockwise until the engine is stable.

Troubleshooting

The actuator fails to move to full fuel when cranking:

1. Check that the red and black leads are connected and that battery voltage is available at **TB1-8—TB1-6** (**10—4**, Spec A) in the control box. Service as necessary.
2. Push the linkage to see that it is not sticking or binding and service as necessary.
3. Check MPU output and reinstall or replace as necessary.
4. Replace the controller if battery voltage (12 VDC) is not present at both purple leads when applied to the red lead.
5. Replace the actuator if resistance across its lead terminals is not approximately 7.3 ohms.

The actuator hunts:

1. Push the linkage to see that it is not sticking or binding and service as necessary.
2. Readjust the controller.
3. Check that at least 9.6 VDC is available at **TB1-8—TB1-6** (**10—4**, Spec A) in the control box during operation. Service as necessary.

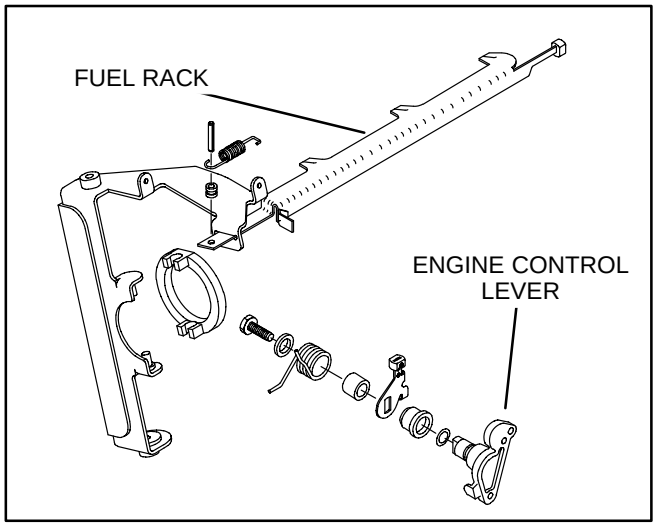


FIGURE 8-52. INTERNAL PARTS AND FUEL RACK WITH ELECTRONIC GOVERNOR

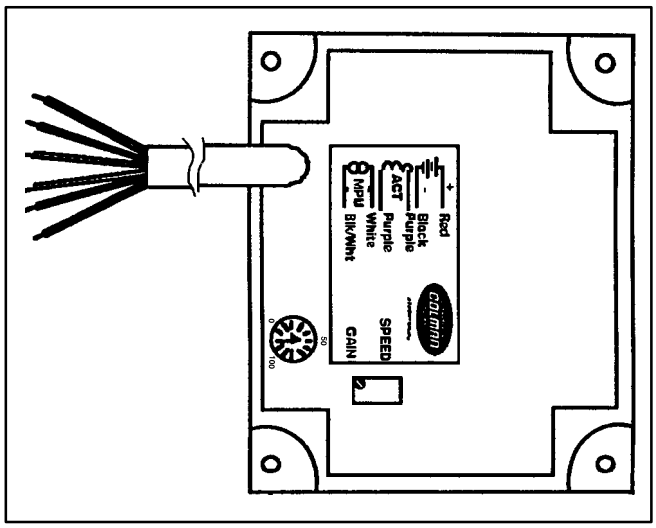


FIGURE 8-53. GOVERNOR CONTROLLER

TURBOCHARGER

The turbocharger bearing is fed by a pressurized oil feed from the crankcase oil galley to the top of the turbocharger. A non-pressurized return to the crankcase door allows the oil to drain back to the sump.

Removing the Turbocharger

1. Remove the turbocharger oil feed and return pipes (Figure 8-54, Items A and B).
2. Remove the air cleaner, muffler and associated parts.
3. Supporting the turbocharger, remove the 3 mounting stud nuts (Item C) and remove the turbocharger.
4. Replace the turbocharger if it is malfunctioning. There are no separately replaceable turbocharger parts.

Installing the Turbocharger

1. Always use a new gasket when mounting the turbocharger.
2. Connect the the oil lines.

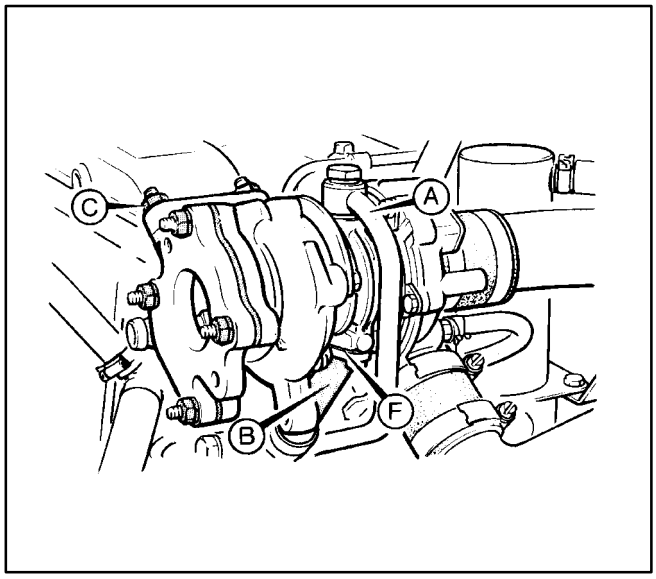


FIGURE 8-54. TURBOCHARGER

CRANKCASE BREATHER

A combination oil separator and crankcase breather is mounted above the flywheel housing. It is attached to the air inlet and to the No. 4 cylinder head cover. A restrictor (Figure 8-55, Item A) is installed in the outlet hose. It must be reinstalled and pushed into the center of the outlet hose if it is removed.

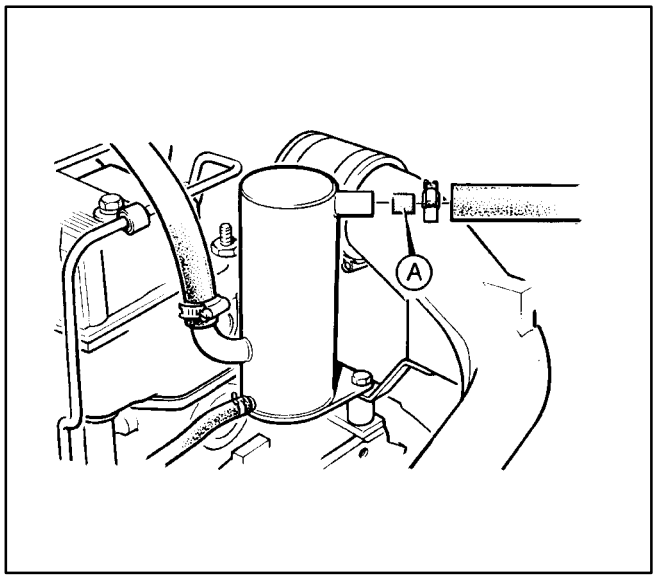


FIGURE 8-55. OIL SEPARATOR AND BREATHER

THIS PAGE LEFT INTENTIONALLY BLANK

9. Maintenance

Periodic maintenance is essential for top performance and long genset life. Follow the maintenance instructions in this section carefully. Use Table 9-1 as a guide for normal periodic maintenance for *Standby Service.* Consult an authorized Onan dealer for a suitable maintenance schedule for *Prime Power Service* and hot or dusty operating conditions. Keep a log of maintenance performed and the hours run. A log will help you keep maintenance regular and provide support for warranty claims. Use the hour meter (Detector control).

TABLE 9-1. PERIODIC MAINTENANCE SCHEDULE

MAINTENANCE OPERATION	MAINTENANCE FREQUENCY				
	Daily or after 8 hours	Weekly or after 50 hours	Monthly or after 100 hours	6 Months or after 250 hours	Yearly
General Inspection	x				
Check Engine Oil Level	x				
Check Engine Coolant Level	x				
Check Engine Coolant Heater	x				
Check Air Cleaner		x[2]			
Check Battery Charging System		x			
Drain Fuel Filter (1 cup or more)		x			
Check Anti-Freeze Concentration			x		
Check Fan Belt Tension and Condition		x[5]	x		
Check Fuel Level			x		
Drain Exhaust Condensate Trap			x		
Check Starting Battery			x		
Check Generator Air Outlet			x		
Change Engine Oil and Oil Filter		x[1]		x[2, 3]	
Replace Engine Air Filter				x[2]	
Check Coolant Hoses and Clamps				x	
Check Coolant Anti-freeze Protection				x	
Clean Cooling System					x
Replace Fuel Filter					x[4]

1 – As a part of engine break-in, change the engine oil and oil filter after the first 50 hours of operation.
2 – Perform more often when operating in dusty conditions.
3 – Perform more often when operating in hot weather.
4 – Fuel filter service life is 1000-2000 hours.
5 – Check after the first 50 hours of operation of a new belt.

GENERAL INSPECTION

Oil Level

Check the engine oil level and fill as necessary.

Engine Cooling System

Check the coolant level and look for coolant leaks. Minor leaks that can be replenished by daily additions of coolant to the recovery tank should be repaired by a qualified service technician as soon as possible. Larger leaks are cause for shutting down the genset until it can be repaired.

⚠CAUTION ***Operating the genset when the coolant level is low can cause serious engine damage.***

Exhaust System

Look and listen for exhaust system leaks while the genset is running. Shut down the genset if a leak is found and have it repaired before operating the genset.

⚠WARNING ***EXHAUST GAS IS DEADLY! Shut down the genset if a leak is found and have it repaired before operating the genset.***

Fuel System

Look for fuel leaks. Shut down the genset if a leak is found and have it repaired before operating the genset.

⚠WARNING ***Fuel leaks can lead to fire. Shut down the genset if a leak is found and have it repaired before operating the genset.***

Mechanical

Look for mechanical damage. Start the genset and look, listen and feel for any unusual noises and vibrations.

Check to see that the openings and ducts for cooling and combustion air are free of obstructions and that shutters open and close properly.

Check the engine gauges from time to time while the genset is running (if so equipped).

Battery Connections

Check the battery terminals for clean, tight connections. Loose or corroded connections have high electrical resistance, which makes for hard starting. Clean or replace as necessary.

⚠WARNING ***Arcing can ignite battery gases and cause severe personal injury and can cause voltage spikes that can damage generator set control circuits. To reduce arcing:***

Never disconnect the battery cables while the genset is cranking or running.

Always disconnect a battery charger from its AC source before disconnecting the battery cables.

Always disconnect the negative (–) cable first and reconnect it last. (This prevents arcing if the tool on the positive terminal touches grounded metal.)

Control Panels with Gauges and Meters

Check the following while the genset is running:

Frequency/RPM Meter: The generator frequency should be stable and the reading should be the same as nameplate rating (50 Hertz [1500 rpm] or 60 Hertz [1800 rpm]), with 5% allowance for governor droop).

AC Voltmeter: Turn the phase selector switch to each line-to-line phase selection shown on the volts scale (L1-L2, L2-L3 and L3-L1). Read the AC voltmeter using the upper or lower scale as indicated by the scale indicator lamp. The line-to-line voltage(s) should be the same as the set nameplate rating.

AC Ammeter: Turn the phase selector switch to each phase selection shown on the amps scale (L1, L2 and L3). Read the ammeter using the upper or lower scale as indicated by the scale indicator lamp. At no load the current ratings should be zero. With a load applied, each line current should be about the same.

Detector 12 Fault Lamps: Push the Reset/Lamp switch on the control panel. All indicator lamps should light. Verify that all the bulbs are on and then release the switch. Replace any bulbs that are burned out.

ENGINE OIL

Check the engine oil level during engine shutdown periods at the intervals specified in Table 9-1. The oil dipstick is located on the side of the engine as shown in Figure 9-1. The dipstick is stamped with FULL and ADD to indicate the crankcase oil level. For accurate readings, shut off the engine and wait approximately 10 minutes before checking the oil level. This allows oil in the upper portion of the engine to drain back into the crankcase.

⚠WARNING ***Crankcase pressure can blow out hot oil and cause severe burns. Do NOT check oil while the generator set is operating.***

Keep the oil level as near as possible to the FULL mark on the dipstick. Remove the oil fill cap on top or side of the engine and add oil of the same quality and brand when necessary.

⚠CAUTION ***Do not operate the engine with the oil level below the low mark or above the high mark. Overfilling can cause foaming or aeration of the oil while operation below the low mark can cause loss of oil pressure.***

Oil Change

Run the engine until thoroughly warm before draining the oil. Stop the set, place a pan under the drain outlet and remove the oil drain plug or open the drain valve. After the oil has completely drained, replace the drain plug or close the drain valve and refill. See *Introduction* for recommended engine oil.

⚠WARNING ***State and federal agencies have determined that contact with used engine oil can cause cancer or reproductive toxicity. Take care to limit skin contact and breathing of vapors as much as possible. Use rubber gloves and wash exposed skin.***

Oil Filter Change

Spin off oil filter and discard it. Thoroughly clean filter mounting surface. Apply a thin film of oil to filter gasket and install new element. Spin element on by hand until gasket just touches mounting pad and then turn an additional 1/2 to 3/4 turn. Do not overtighten. After filling with oil, start the engine and check for leaks around filter element. Retighten the filter only as much as necessary to eliminate leaks.

Note: Be sure to dispose of the used oil and oil filter in accordance with local environmental regulations.

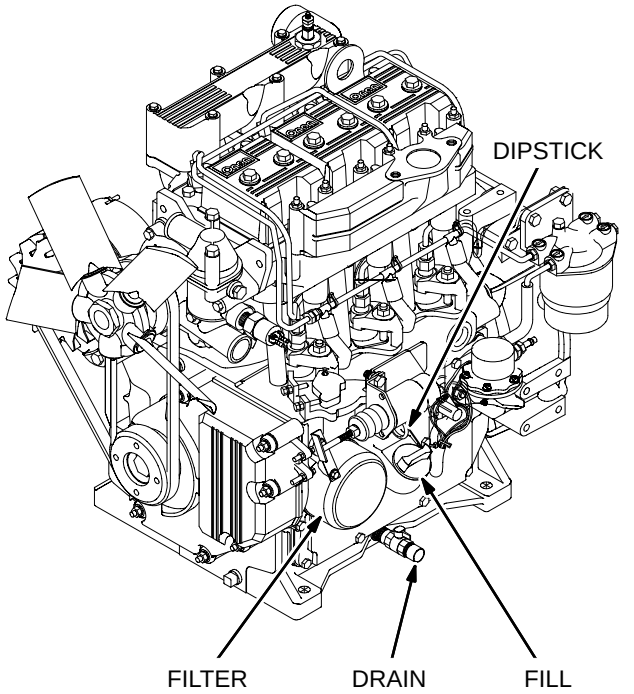


FIGURE 9-1. OIL FILL, DRAIN, FILTER AND DIPSTICK

COOLING SYSTEM—LIQUID-COOLED ENGINES

Check the engine coolant level during engine shutdown periods at the intervals specified in Table 9-1. The water used for engine coolant should be clean, low in mineral content and free of any corrosive chemicals such as chloride, sulphate or acid. Generally, any water that is suitable for drinking can be treated for use as engine coolant. Cooling system coolant must also have corrosion inhibitors. See Figure 9-2.

Cooling systems that are subjected to freezing conditions must also be protected with antifreeze. Use a 50/50 mixture of anti-freeze and water. Do not use an antifreeze that contains anti-leak additives.

⚠WARNING ***Hot coolant is under pressure and can cause severe burns. Always let the engine cool down before removing the pressure/fill cap.***

⚠CAUTION ***If the engine coolant level falls too low the temperature sensor may not be able to sense coolant temperature and shut down the engine before damage occurs.***

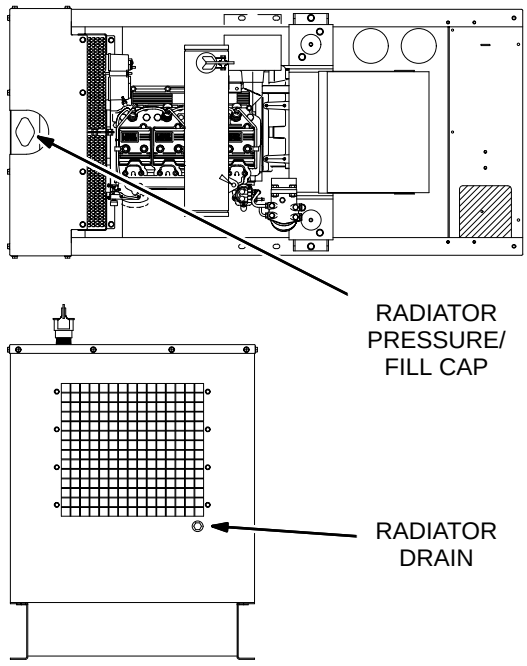
⚠CAUTION ***A coolant heater must not be operated while the cooling system is empty or damage to the heater will occur.***

COOLING SYSTEM—AIR-COOLED ENGINES

Remove cowling panel C (Figure 9-3) by removing its mounting bolts, and if necessary panel(s) B, to clean the cylinder and head cooling fins.

After panel C has been removed, panel(s) B, which are secured between the cylinders, can be removed by removing the split pin from the fuel pump side. Note that the spring clip retains the tie.

⚠CAUTION ***To prevent possible injury, take care not to let the spring clip, on the axial fan side, eject the tie when the split pin is removed from the fuel pump side.***



THE BLOCK DRAIN IS A SQUARE-HEAD PIPE PLUG ABOVE THE GEAR COVER ON THE FRONT OF THE ENGINE AND IS ACCESSIBLE BY REMOVING THE FAN GUARD ON THE ALTERNATOR SIDE

FIGURE 9-2. LIQUID-COOLED ENGINES—COOLANT FILL AND DRAIN POINTS

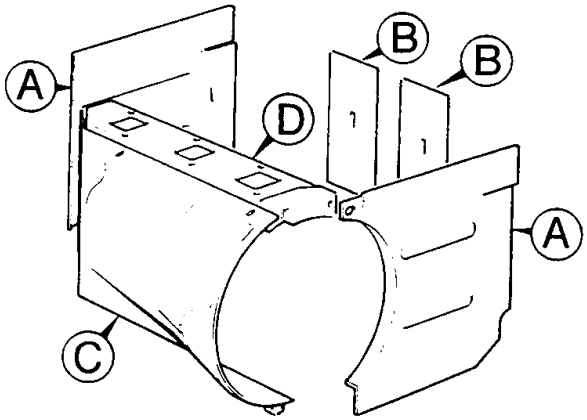


FIGURE 9-3. AIR-COOLED ENGINES—AIR COWLING PANELS

AIR CLEANER

Service the engine air cleaner (Figure 9-4) at the interval indicated in Table 9-1.

Disposable Air Cleaner: A disposable air cleaner is clamped directly to the intake manifold by a hose clamp. It is not serviceable: replace it.

Heavy Duty Air Cleaner: A heavy duty air cleaner has a disposable filter element. To remove the filter element, remove the outer and inner end caps. Before replacing the filter, wipe out the inside of the the air cleaner, making sure the filter element seating surfaces inside the can and cap are clean.

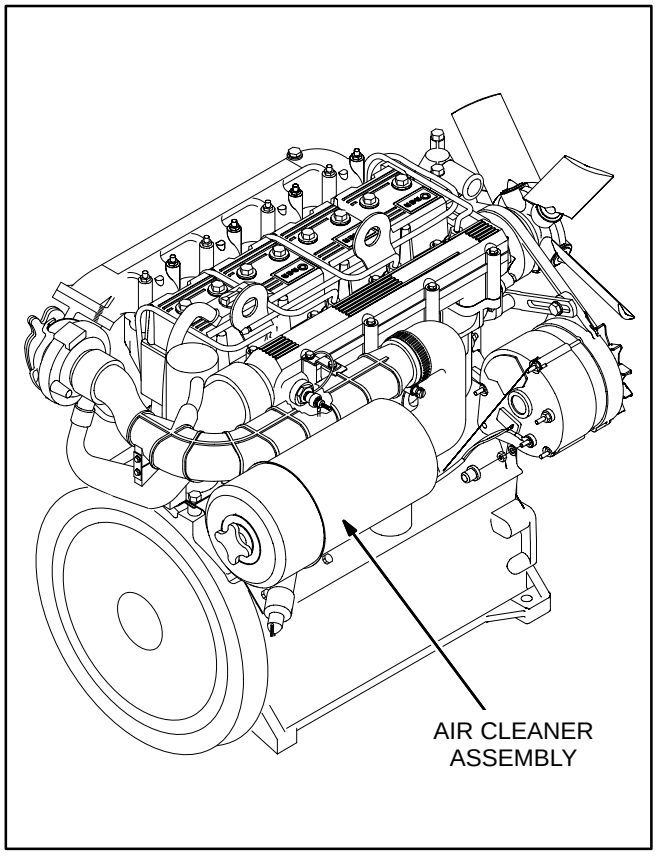


FIGURE 9-4. HEAVY DUTY AIR CLEANER

FUEL FILTER

Service the engine fuel filter at the interval indicated in Table 9-1. The filter is a spin-off, disposable type. A water drain is located at the bottom of the filter case. This should be used to drain off moisture either weekly or at the end of every exercise period, depending on unit application. Put a light coat of fuel on the sealing gasket and tighten by hand until the gasket just touches the filter head. Tighten an additional one-half to three-fourths of a turn.

To fill the new fuel filter, crack open the air vent plug with a wrench and pump fuel with the priming handle on the fuel lift pump until fuel starts to come out of the vent opening and then retighten the vent plug.

Take appropriate precautions to prevent the entrance of dirt, water, or other contaminants into the fuel system. Filter or strain the fuel as the tank is filled.

⚠WARNING ***Diesel fuel is combustible and can cause severe personal injury or death. Do not smoke near diesel fuel tanks or equipment. Keep flames, sparks, pilot lights, electrical arcs and arc-producing equipment and all other sources of ignition well away. Keep a type ABC fire extinguisher handy.***

To reduce condensation, keep fuel supply tanks as full as possible by filling up each time the engine is used. In cold weather, warm fuel returning from the injectors heats the fuel in the supply tank. If the fuel level is low, the upper portion of the tank tends to form condensation. In warm weather, both the fuel and the tank will be warm during the daytime. At night, cool air tends to lower the temperature of the tank more rapidly than the temperature of the fuel. If the fuel level is low, the upper portion of the tank will cool more rapidly and tend to form condensation.

Condensation (water) can cause clogging of fuel filters as well as freezing problems. In addition, water mixing with the sulphur in the fuel forms acid which can corrode and damage engine parts.

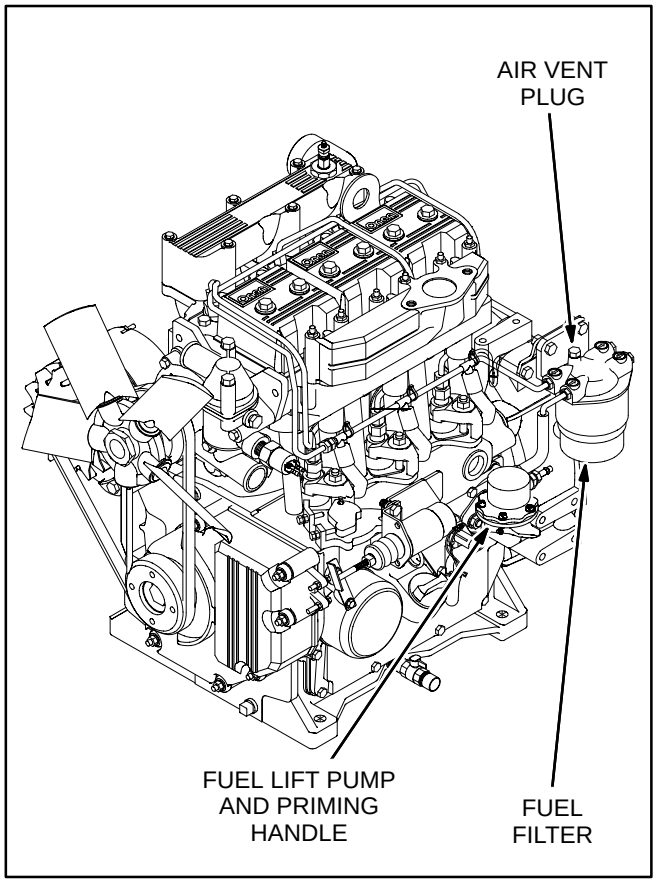


FIGURE 9-5. FUEL FILTER AND TRANSFER PUMP

FAN BELT

An improperly adjusted fan belt can cause engine overheating and insufficient battery charging.

Before adjusting the belt, disconnect the battery (negative [–] cable first) and push the genset control switch to **STOP** to prevent accidental starting.

⚠WARNING ***Accidental starting can cause severe personal injury or death. To prevent accidental starting, push the control panel switch to OFF and disconnect the negative (–) battery cable from the battery before working on the generator set.***

Arcing can ignite battery gases and cause severe personal injury and can cause voltage spikes that can damage generator set control circuits. To reduce arcing:

Never disconnect the battery cables while the genset is cranking or running.

Always disconnect a battery charger from its AC source before disconnecting the battery cables.

Always disconnect the negative (–) cable first and reconnect it last. (This prevents arcing if the tool on the positive terminal touches grounded metal.)

To check belt tension, remove the belt guard and push the fan belt midway between the two pulleys shown in Figure 9-6 or 9-7. Use a spring balance to measure force (F) and a straight edge and ruler to measure belt deflection (d). Belt deflection should be 3.5 mm (0.14 in) under a force of 31.0-33.5 N (7.0-7.5 pounds [lbf]) for a new belt and 22.0-24.0 N (5.0-5.4 pounds [lbf]) for a used belt.

To adjust belt tension, loosen the two bolts on the battery charging alternator and adjust until proper tension is obtained. Recheck belt tension after rotating the engine so that the belt has travelled at least once around the pulleys. Retighten the alternator bolts after adjustment, reinstall the belt guard and reconnect the battery (negative [–] cable last).

⚠CAUTION ***Correct belt tension is critical for belt life. Check belt tension at the intervals indicated in Table 9-1 and adjust as instructed above.***

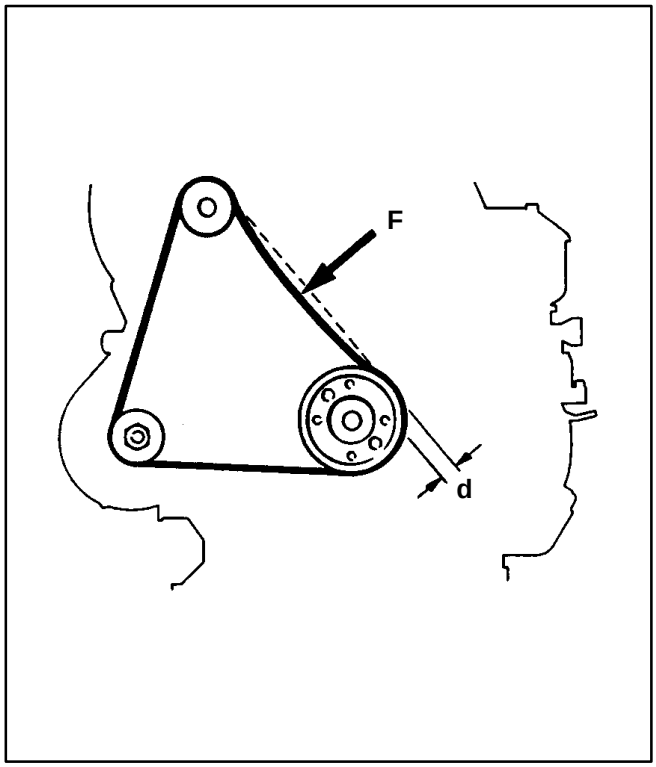


FIGURE 9-6. FAN BELT—AIR COOLING

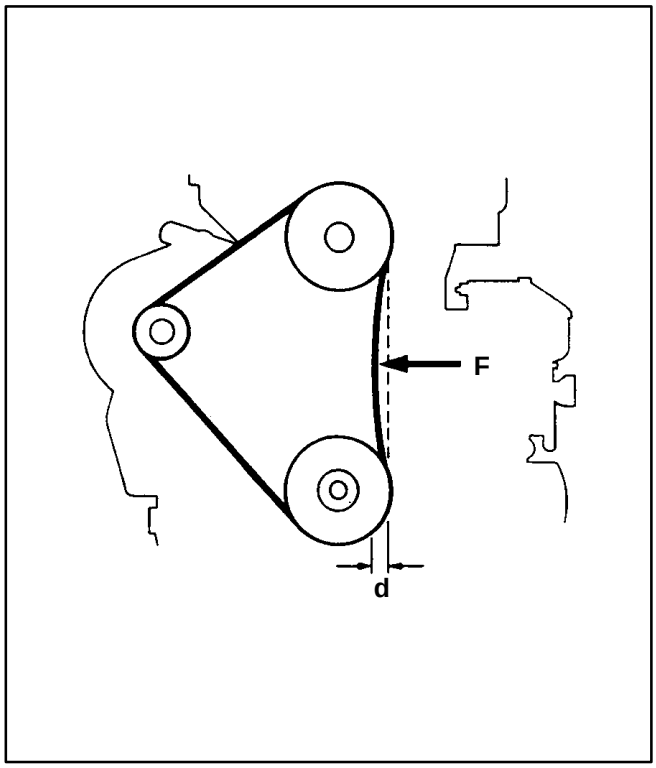


FIGURE 9-7. FAN BELT—LIQUID COOLING

BATTERIES

Refer to Table 9-1 for scheduled battery maintenance and to the battery manufacturer's recommendations and instructions for battery care. Check the electrolyte level more frequently during hot weather on batteries which are not of the "maintenance-free" type.

See that connections are clean and tight. A light coating of non-conductive grease will retard corrosion at the terminals. Keep the electrolyte at the proper level above the plates by adding distilled water. Check specific gravity using a hydrometer and recharge if below 1.260.

⚠WARNING ***Arcing can ignite battery gases and cause severe personal injury and can cause voltage spikes that can damage generator set control circuits. To reduce arcing:***

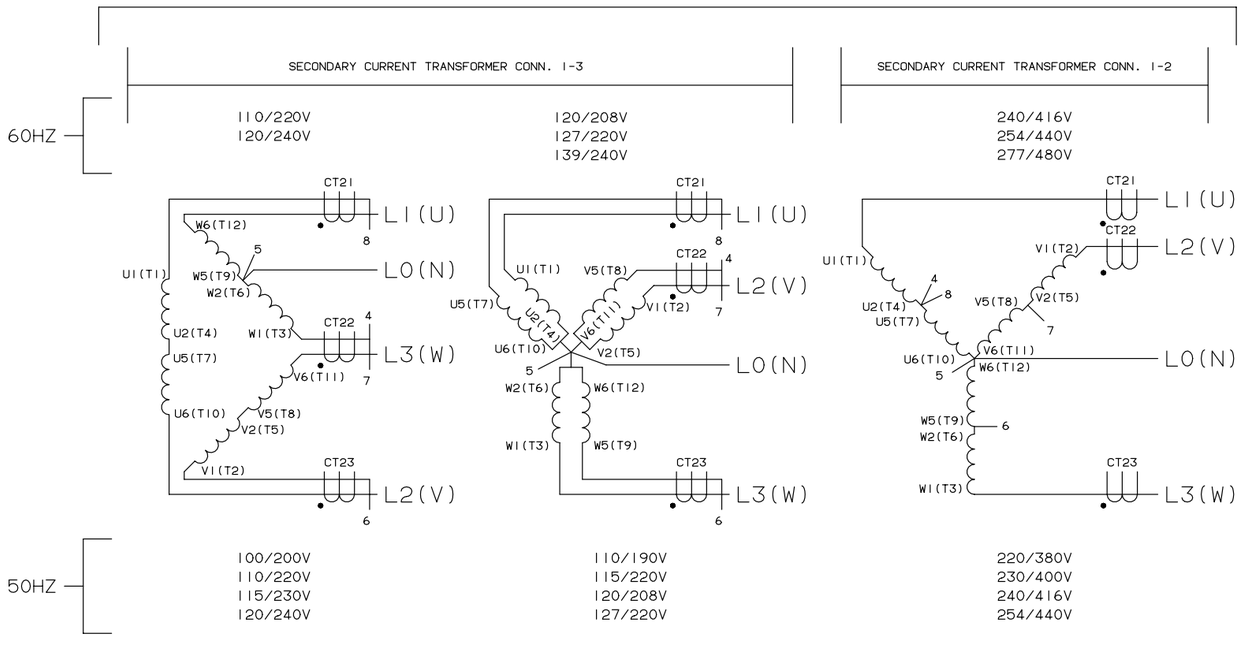
Never disconnect the battery cables while the genset is cranking or running.

Always disconnect a battery charger from its AC source before disconnecting the battery cables.

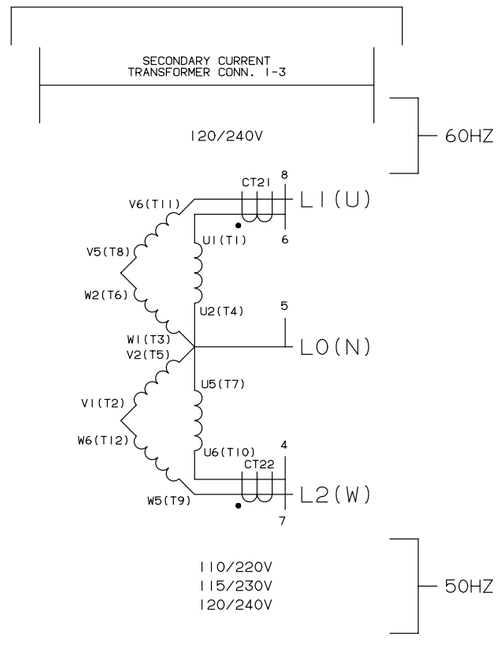
Always disconnect the negative (–) cable first and reconnect it last. (This prevents arcing if the tool on the positive terminal touches grounded metal.)

⚠CAUTION ***A battery mounted in the built-in battery rack in the skid base must be of a type with barbed vent hose fittings for its cells. The vent lines must be routed away from the generator end bell (air inlet) to prevent battery gasses from entering the generator and causing corrosion.***

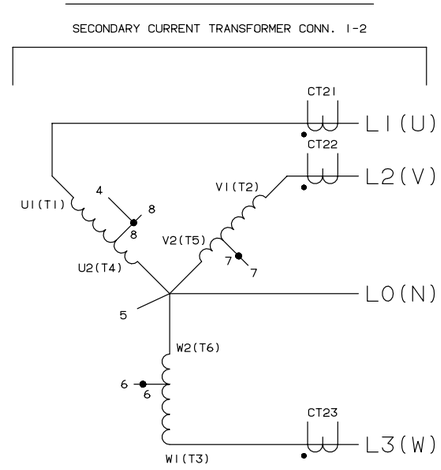
3 PHASE RECONNECTABLE, 12 LEAD



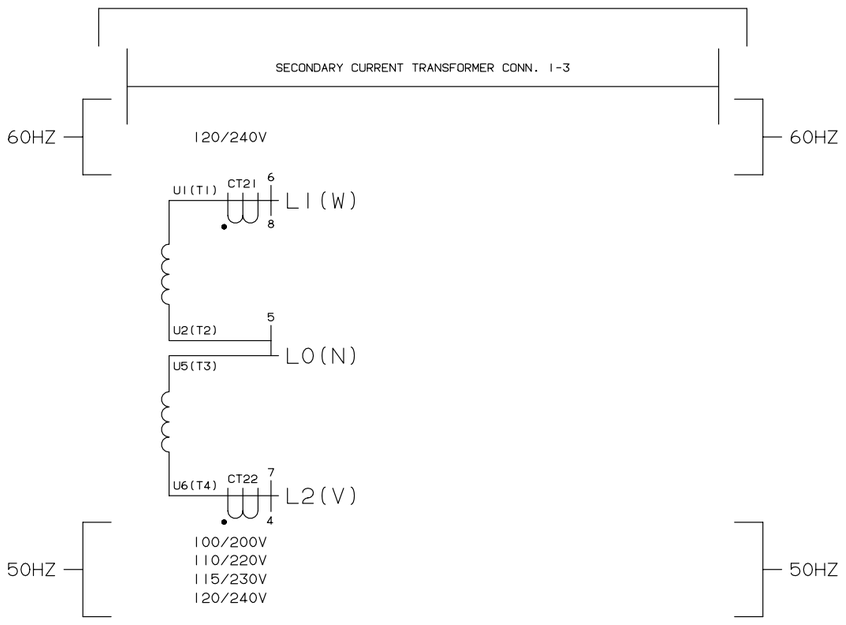
1 PHASE RECONNECTABLE, 12 LEAD



347/600V 60HZ



1 PHASE RECONNECTABLE, 4 LEAD



VOLTAGE SENSING CONTINUITY DETECTOR CONTROL ONLY		
CONTROL INPUT TB21	GENERATOR SENSING LEADS	
-21	8	
-23	7	
-24	4	
-25	6	
-26	5	

NOTES:

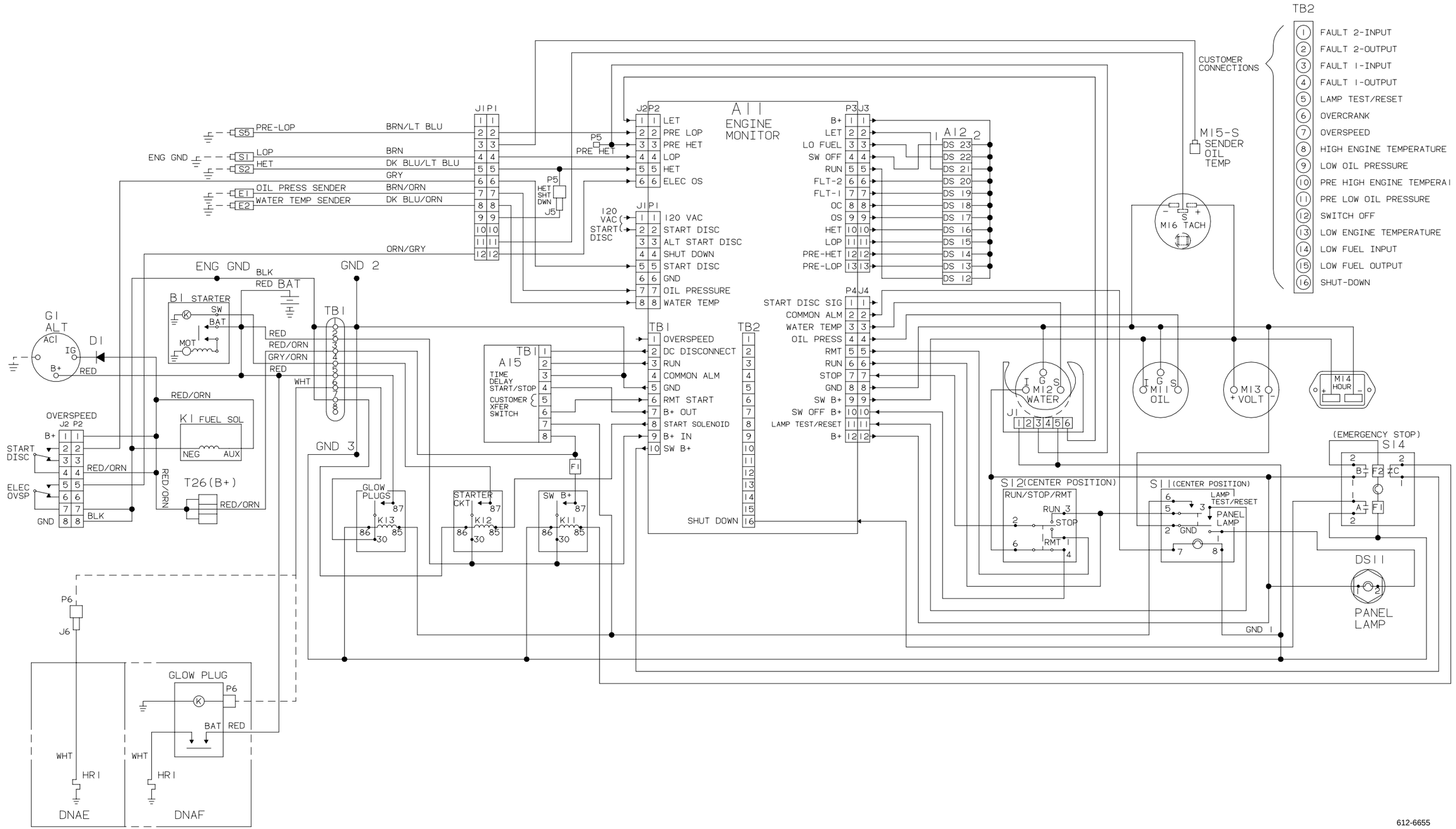
1. CURRENT TRANSFORMER SECONDARY MUST BE MANUALLY SELECTED.
   ABOVE 300 VOLTS AC, TERMINALS 1 & 2;
   BELOW 300 VOLTS AC, TERMINALS 1 & 3.
   TERMINALS 2/3 ARE COMMON AND CONNECTED TO GROUND.
   LEADS MAY BE COLOR CODED IN LIEU OF MARKINGS AS FOLLOWS:
   CT21-1 PNK/BLK
   CT22-1 PRP/BLK
   CT23-1 ORN/BLK
   ALL 2/3 LEADS GRY/BLK

2. GENERATOR VOLTAGE SENSING LEADS GEN-4,-5,-6,-7, & -8 MUST BE CONNECTED TO GENERATOR OUTPUT LEADS AS SHOWN FOR PROPER METERING AND VOLTAGE REGULATOR OPERATION. LEADS MAY BE COLOR CODED IN LIEU OF MARKINGS AS FOLLWS:
   GEN-4 LT GRN/BLK
   GEN-5 TAN/BLK
   GEN-6 RED/BLK
   GEN-7 YEL/BLK
   GEN-8 DK BLU/BLK
   INSULATE AND TIE BACK ANY UNUSED LEADS.

3. 347/600V -DETECTOR: CONNECT GEN VOLTAGE SENSING LEADS TO STATOR TAP LEADS 6,7 & 8 AND TO LO(N) AS SHOWN.
   -NON-DETECTOR: CONNECT STATOR TAP LEADS 6,7 & 8 TO AVR-6,7 & 8.

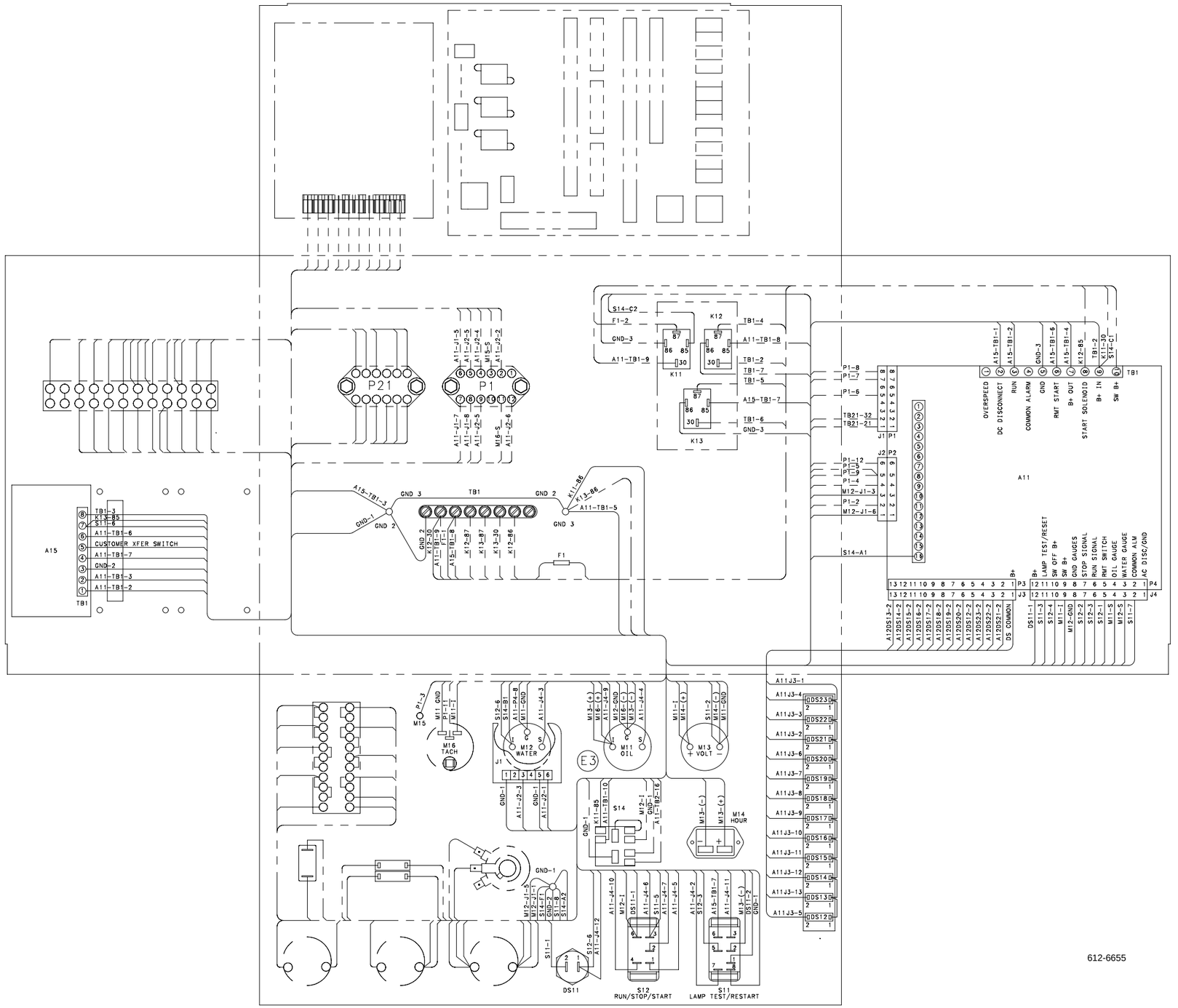
625-3360

GENERATOR CONNECTION DIAGRAMS (SPEC A)

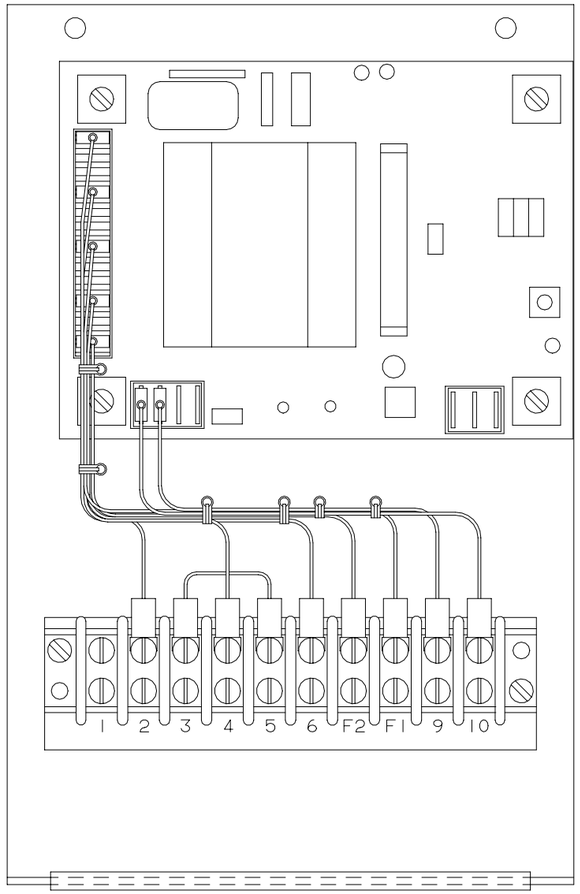


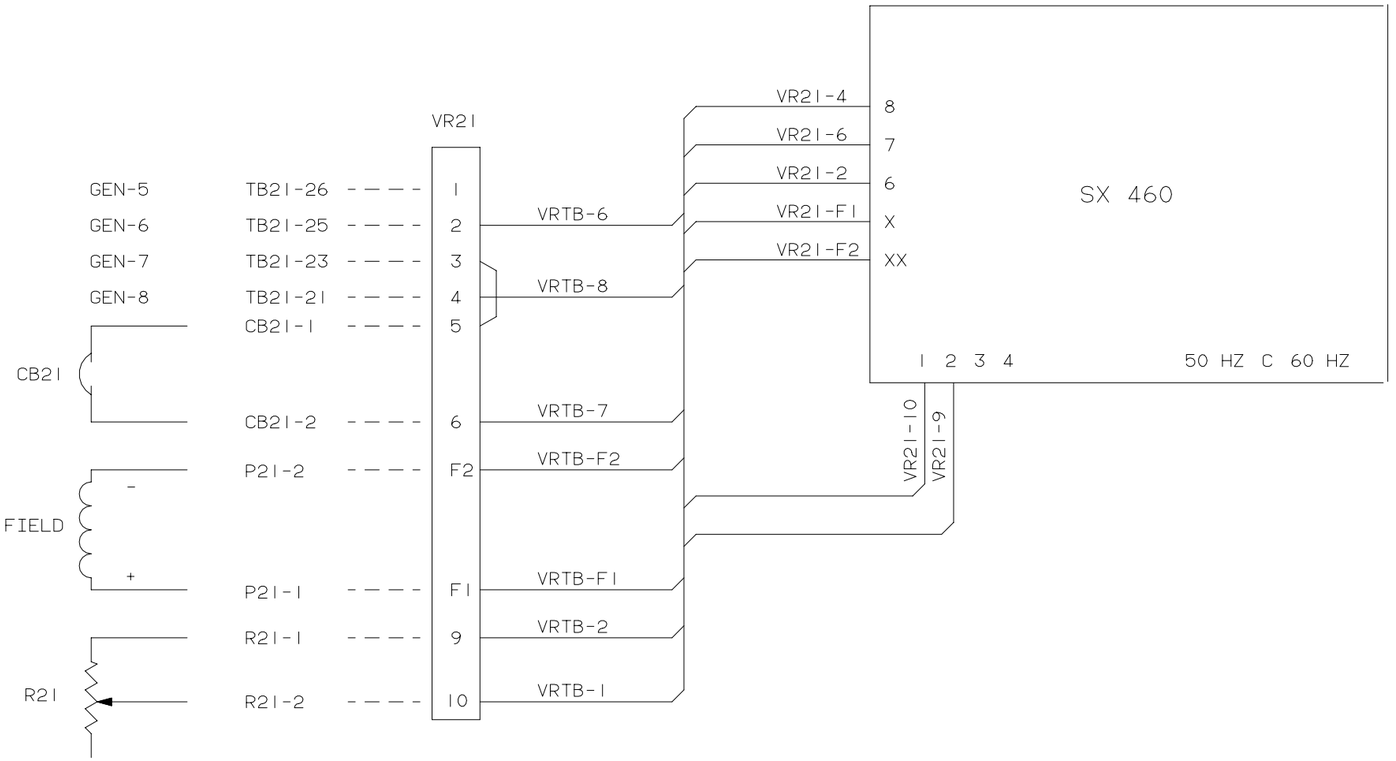
612-6655

DETECTOR CONTROL—DC CONNECTIONS (SPEC A)



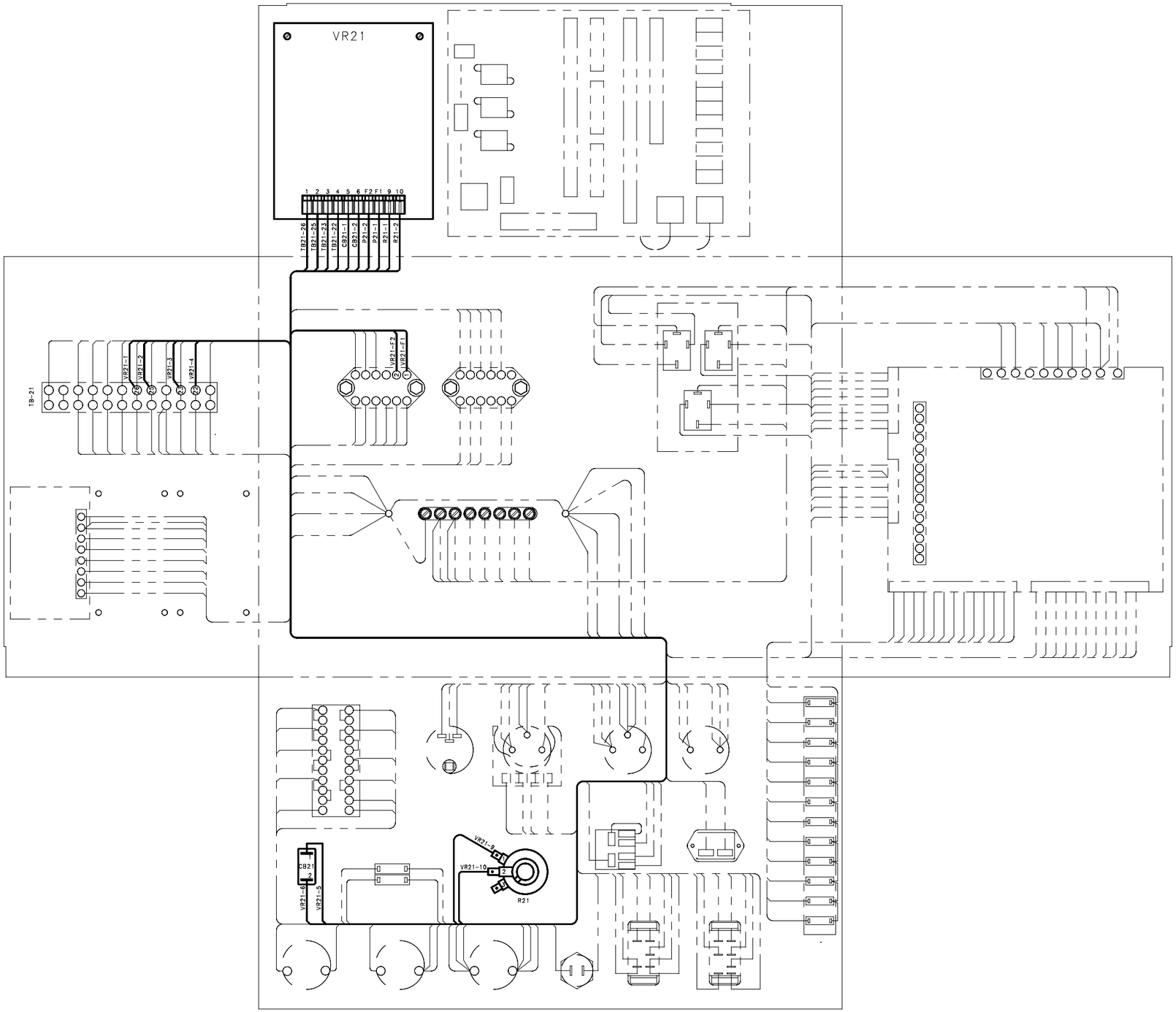
DETECTOR CONTROL—DC INSTALLATION (SPEC A)





305-0949

DETECTOR CONTROL—VOLTAGE REGULATOR CONNECTIONS (SPEC A)



300-4330

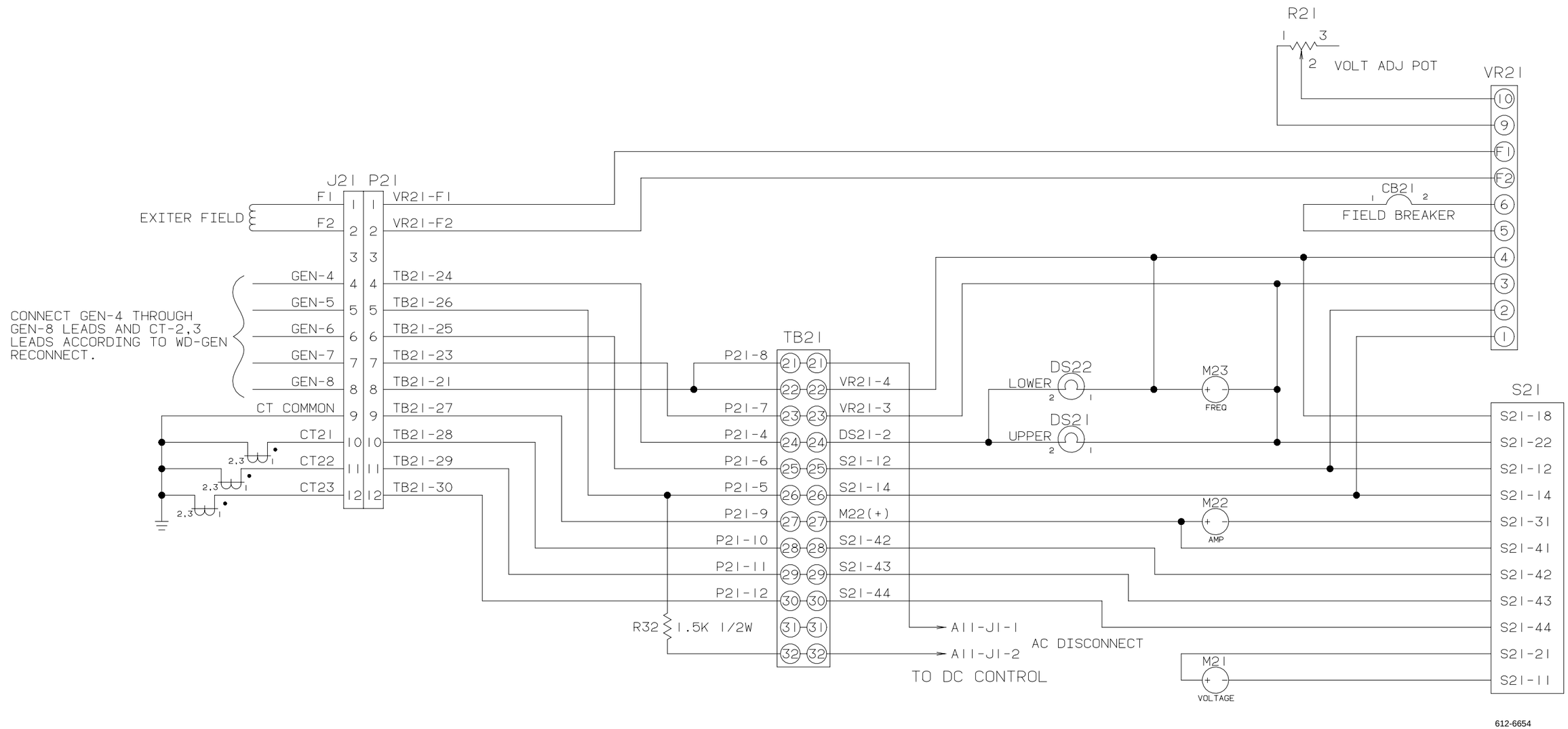
DETECTOR CONTROL—VOLTAGE REGULATOR INSTALLATION (SPEC A)

S21 JUMPERS

EXTERNAL	INTERNAL
M-P	N-41
34-44	M-31
C-21	A-11
32-42	B-C
12-J	33-43
N-R	

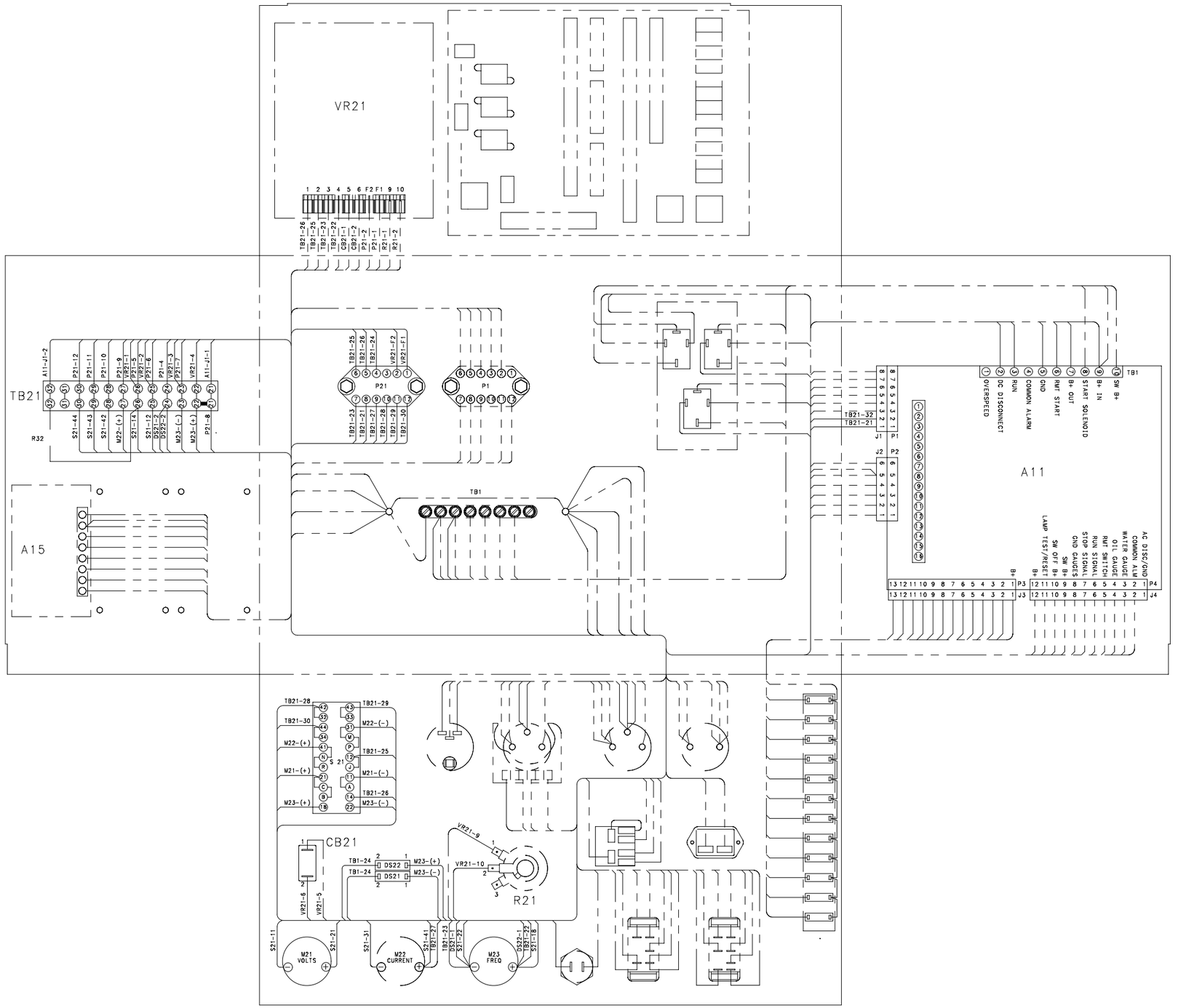
S21 SWITCH LOGIC

	18-11	22-C	14-21	M-32	41-42	P-43	12-A	J-B	31-34	N-44	R-33
L1-L2 3Ø	X	X		X						X	X
L2-L3 3Ø		X			X	X	X			X	
L3-L1 3Ø	X				X			X	X		X
L1-L0 3Ø	X		X		X					X	X
OFF					X					X	X
L1-L2 1ØA	X	X		X						X	X
L1-L2 1ØB	X	X			X	X				X	



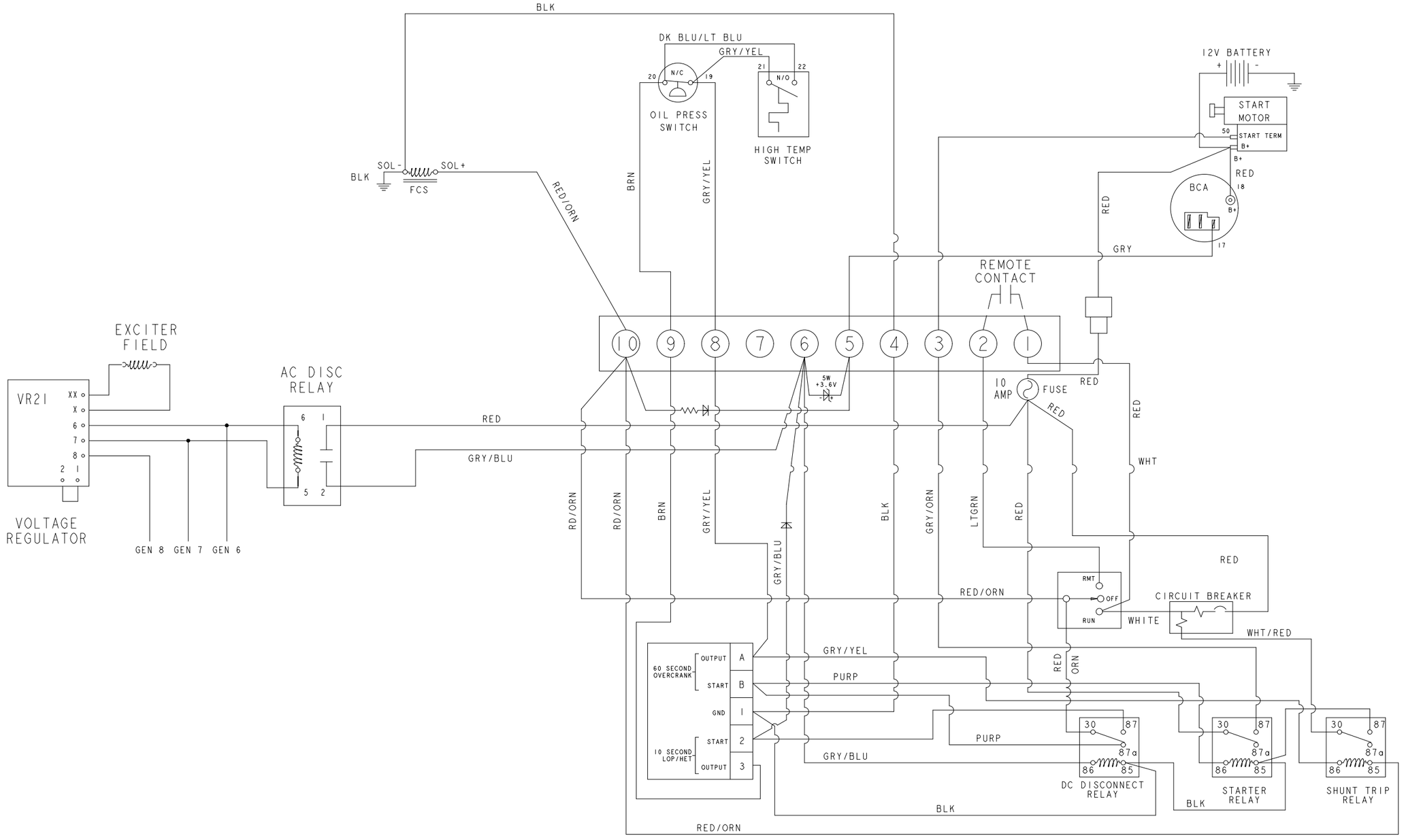
612-6654

DETECTOR CONTROL—AC CONNECTIONS (SPEC A)



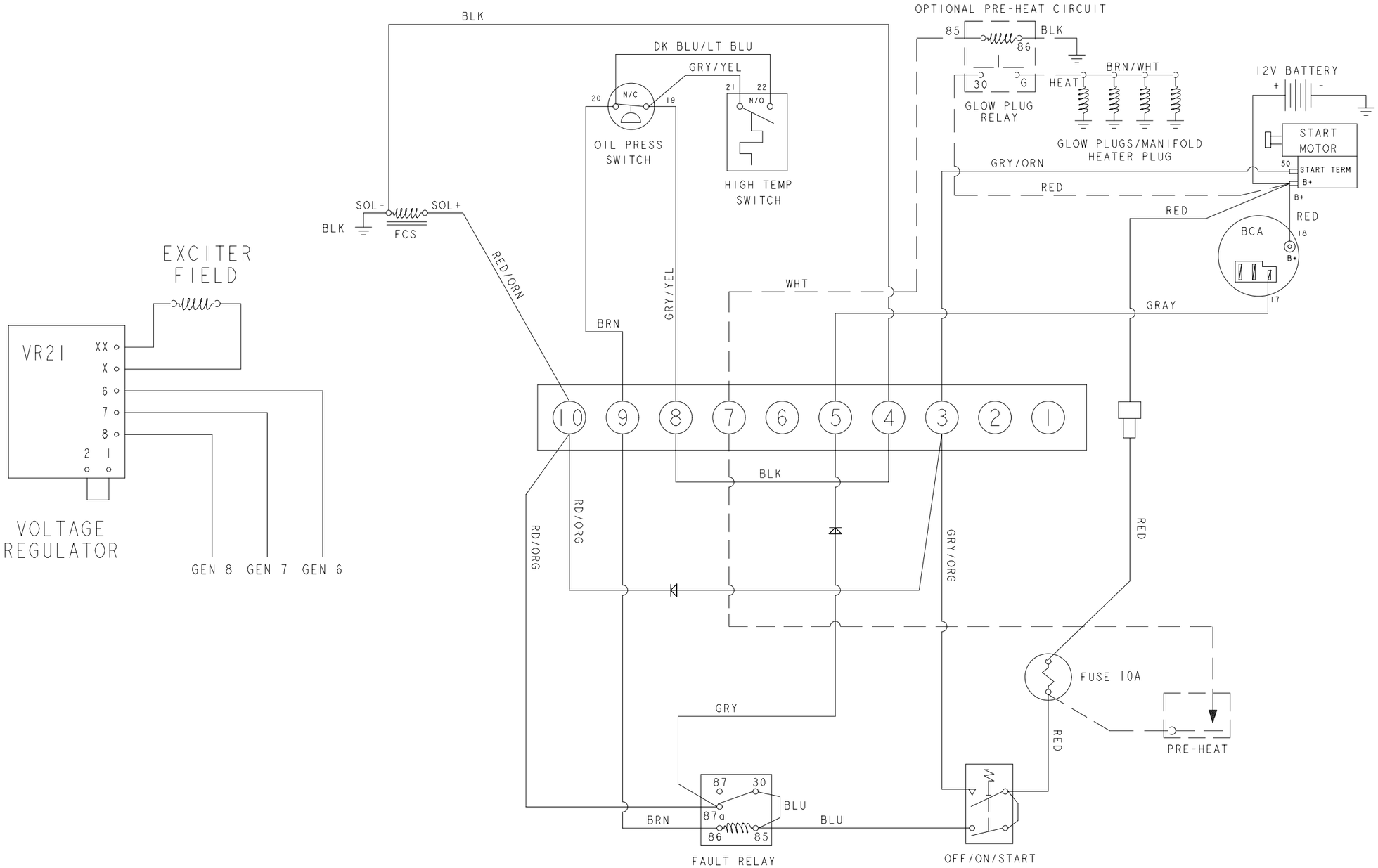
612-6654

DETECTOR CONTROL—AC INSTALLATION WITH METERS (SPEC A)



612-6708

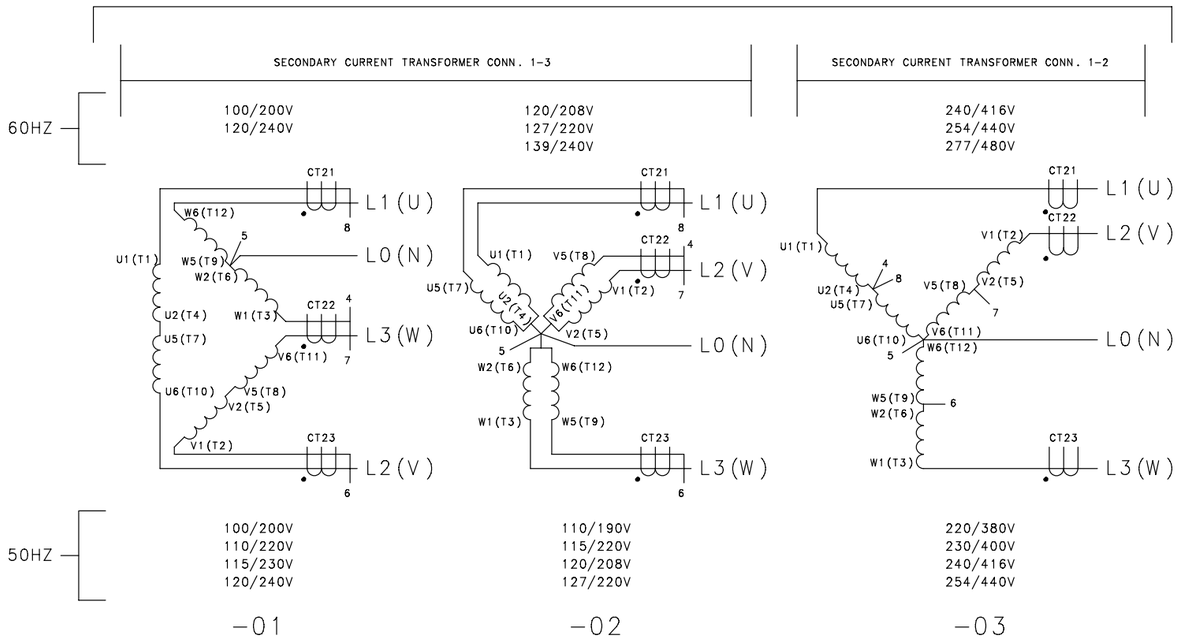
REMOTE/ATS CONTROL—SCHEMATIC AND CONNECTION DIAGRAMS (SPEC A)



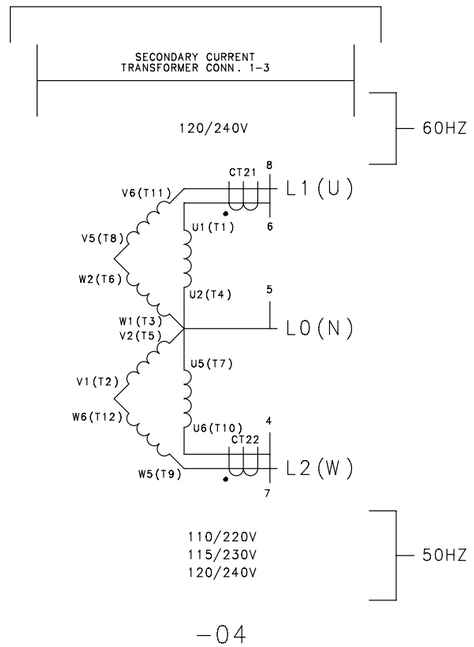
612-6707

THIS PAGE LEFT INTENTIONALLY BLANK

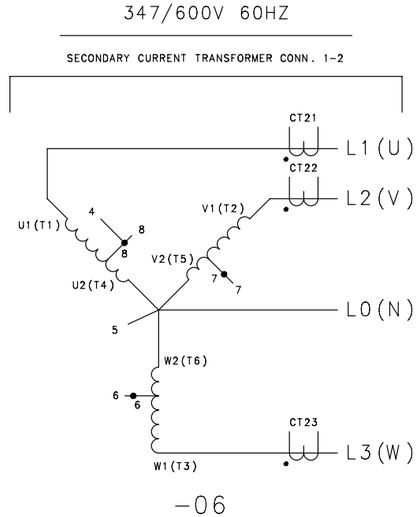
3 PHASE RECONNECTABLE, 12 LEAD



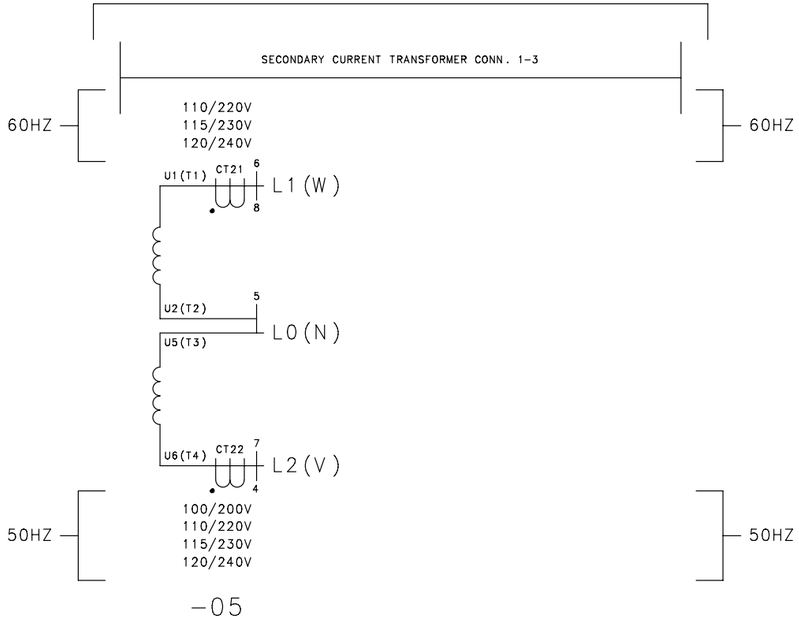
1 PHASE RECONNECTABLE, 12 LEAD



347/600V 60HZ



1 PHASE, 4 LEAD



VOLTAGE SENSING CONTINUITY DETECTOR CONTROL ONLY		
CONTROL INPUT TB21	GENERATOR SENSING LEADS	
-21	8	
-23	7	
-24	4	
-25	6	
-26	5	

NOTES:

1. CURRENT TRANSFORMER SECONDARY CONNECTIONS ARE ALWAYS TERMINALS 1 & 2. LOAD LEADS MAKE 1 PASS THROUGH CURRENT TRANSFORMER FOR 100 AND 30A AMMETERS.
   LOAD LEADS MAKE 2 PASSES THROUGH CURRENT TRANSFORMER FOR 30 AND 15A AMMETERS.

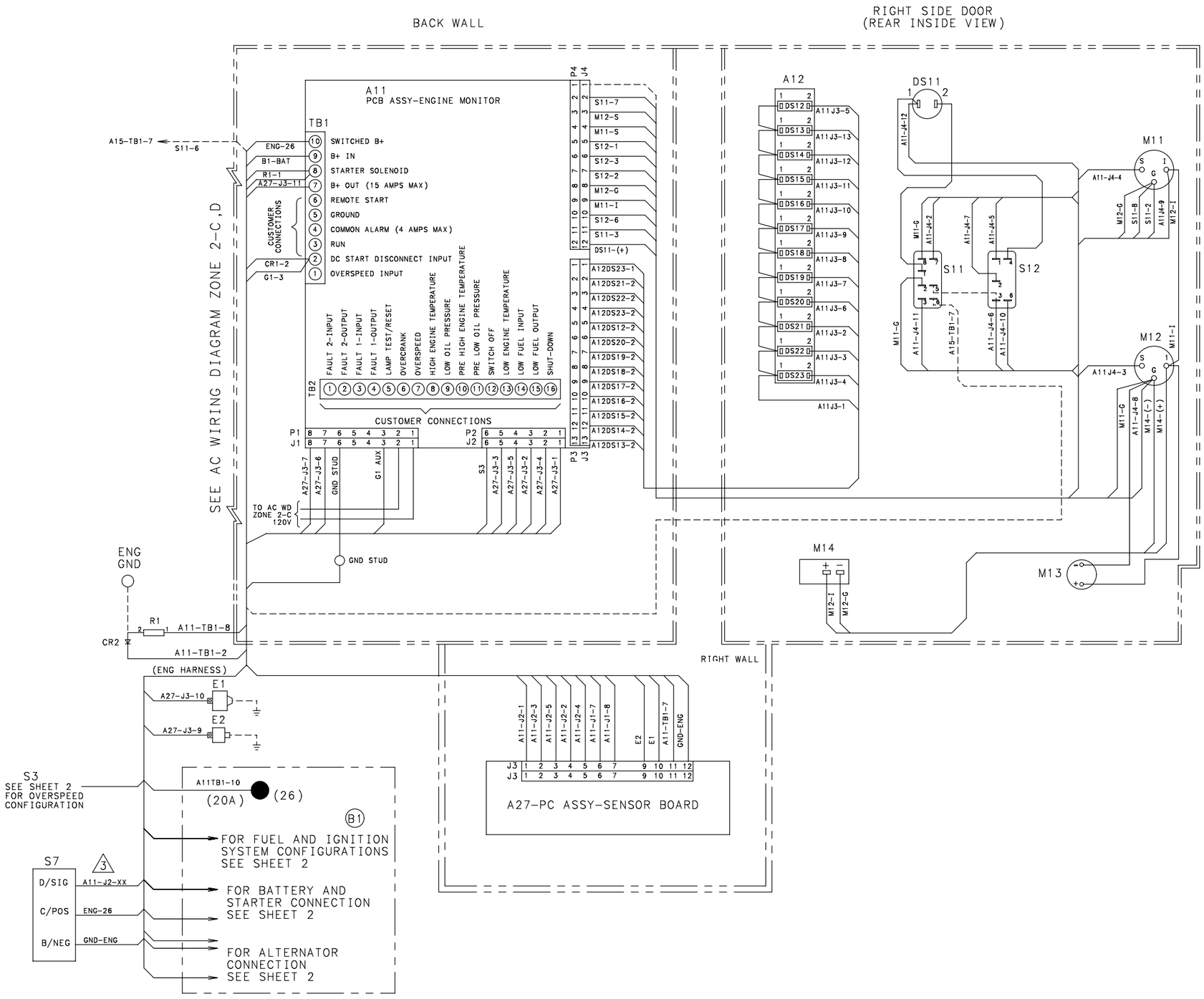
   TERMINALS CT2X-2 ARE COMMON AND CONNECTED TO GROUND.
   LEADS MAY BE COLOR CODED IN LIEU OF MARKINGS AS FOLLOWS:
   CT21-1 PNK/BLK CT21-2 GRY/BLK
   CT22-1 PRP/BLK CT22-2 GRY/BLK
   CT23-1 ORN/BLK CT23-2 GRY/BLK

2. GENERATOR VOLTAGE SENSING LEADS GEN-4,-5,-6,-7, & -8 MUST BE CONNECTED TO GENERATOR OUTPUT LEADS AS SHOWN FOR PROPER METERING AND VOLTAGE REGULATOR OPERATION. LEADS MAY BE COLOR CODED IN LIEU OF MARKINGS AS FOLLWS:
   GEN-4 LT GRN/BLK GEN-7 YEL/BLK
   GEN-5 TAN/BLK GEN-8 DK BLU/BLK
   GEN-6 RED/BLK
   INSULATE AND TIE BACK ANY UNUSED LEADS.

3. 347/600V -DETECTOR: CONNECT GEN VOLTAGE SENSING LEADS TO STATOR TAP LEADS 6,7 & 8 AND TO LO(N) AS SHOWN.
   -NON-DETECTOR: CONNECT STATOR TAP LEADS 6,7 & 8 TO AVR-6,7 & 8.

625-3780

GENERATOR CONNECTION DIAGRAMS (BEGINNING SPEC B)



NOTES:

1. ALL COMPONENTS SHOWN IN DE-ENERGIZED POSITION.

3. FOR LOW COOLANT SHUTDOWN, CONNECT S7-SIG TO A11-J2-5
   FOR LOW COOLANT WARNING, CONNECT S7-SIG TO A11-J2-3
4. TIE ALL UNUSED LEADS INTO HARNESS
5. DASHED LEADS INDICATE WHEN USED.
6. WATER TEMPERATURE GAUGE IS WIRED TO F3 FOR CONTINUOUS OPERATION FOR SPARK IGNITED PRODUCT.

REF DES	PART NO	SMS SIZE	QTY.	DESCRIPTION
S7				SWITCH-LOW COOLANT LEVEL
S3				SENSOR-OVERSPEED
K13F				STARTER DISCONNECT RELAY
K13				GLO-PLUG RELAY
K4				STARTER PILOT SOLENOID
K1				FUEL SOLENOID
G1				ALTERNATOR
E2				SENDER-WATER TEMP
E1				SENDER-OIL PRESSURE
BT1				BATTERY-STORAGE
B1				STARTER & SOLENOID

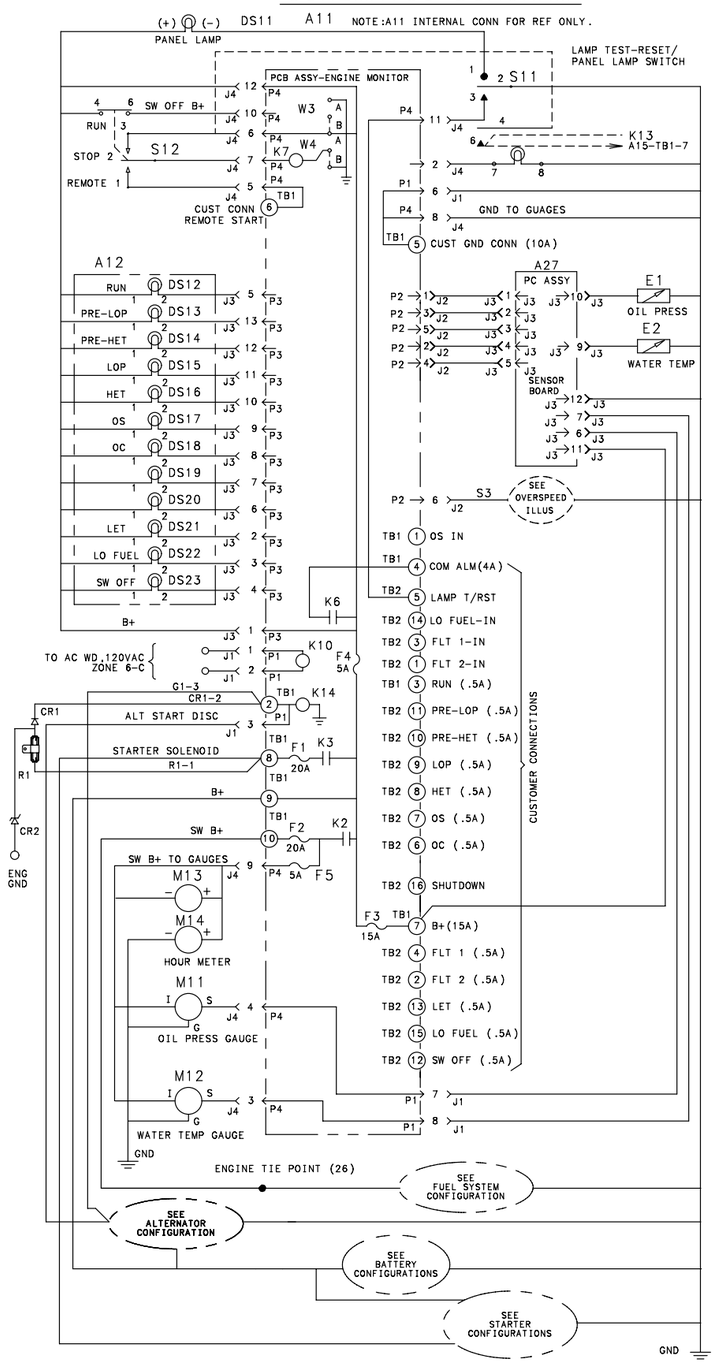
ENGINE PARTS LIST ABOVE (SHOWN FOR REFERENCE ONLY)

A27	PCB ASSY-SENSOR BOARD
S12	SWITCH (WO/L)
S11	SWITCH-ROCKER (W/L)
M14	METER-TIME TOTALIZING
M13	VOLTMETER (8-18V)
M12	GAUGE-WATER TEMP
M11	GAUGE-OIL PRESSURE
DS11	LIGHT-PANEL
CR1	RECTIFIER
A12	LAMP ASSY (12LT,12V)
A11	PCB ASSY-ENGINE MONITOR (12LT,12V)

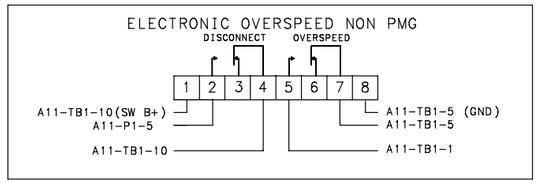
612-6733

DETECTOR CONTROL—SHEET 1, DC CONNECTIONS (BEGINNING SPEC B)

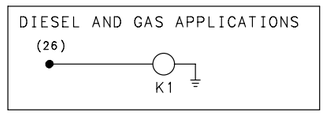
SCHEMATIC DIAGRAM



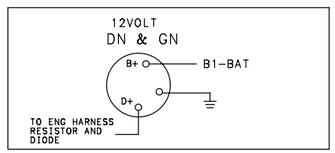
ELECTRONIC OVERSPEED NON PMG



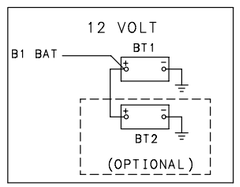
DIESEL AND GAS APPLICATIONS



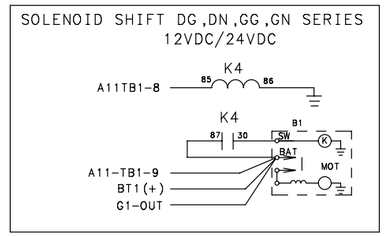
12VOLT DN & GN



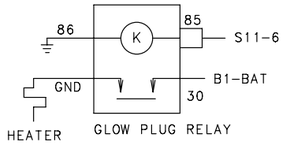
BATTERY CONFIGURATIONS



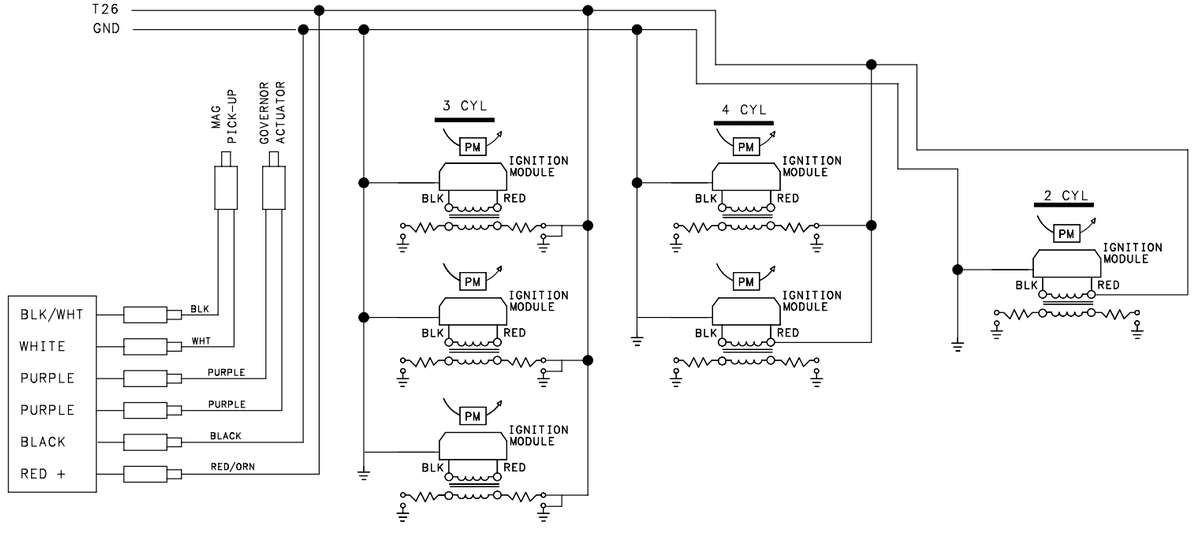
STARTER CONFIGURATIONS



K13 DN GLOW PLUG

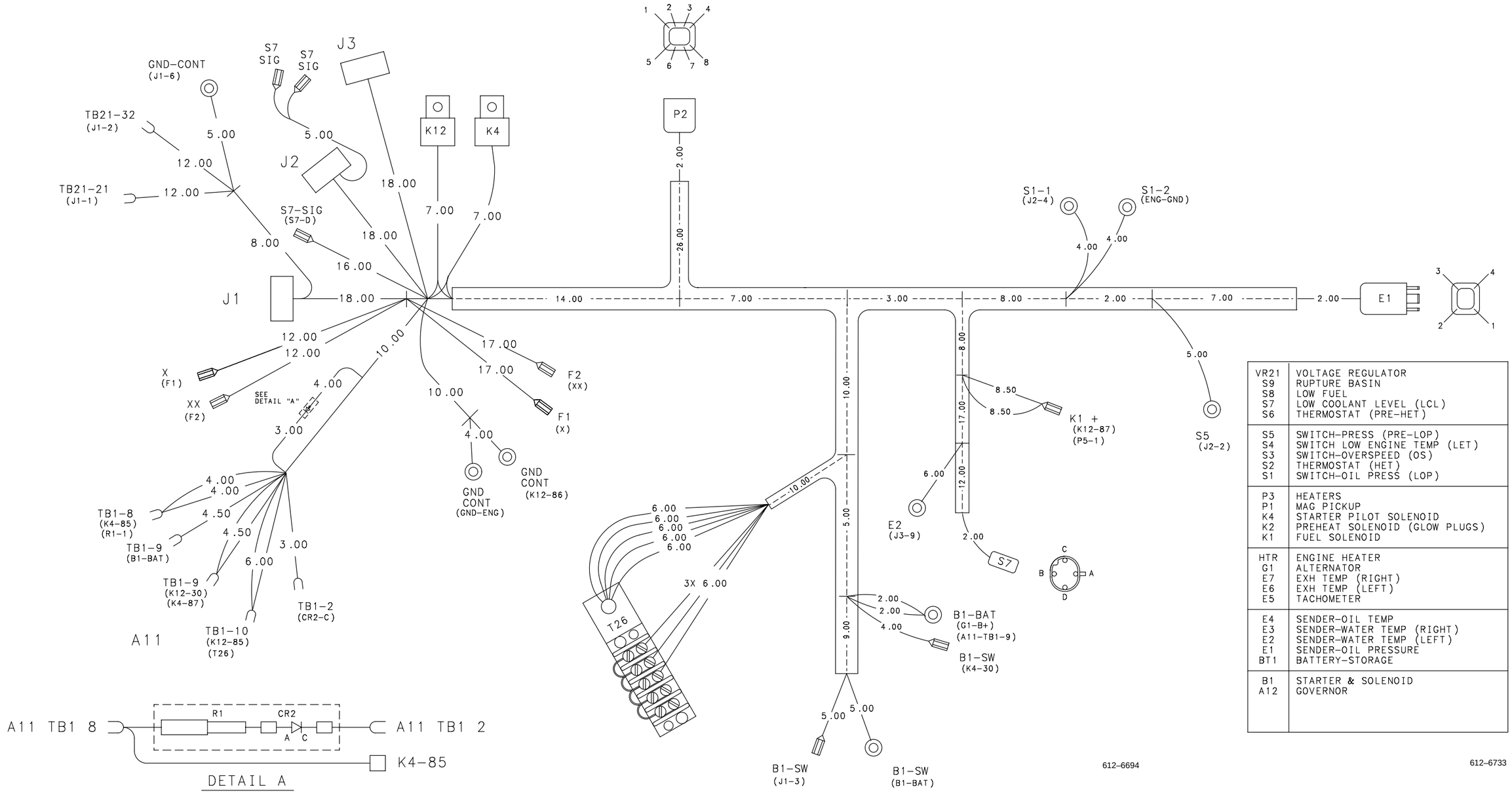


GN IGNITION, DN/GN ELECTRONIC GOVERNOR



612–6733

DETECTOR CONTROL—SHEET 2, DC CONNECTIONS (BEGINNING SPEC B)



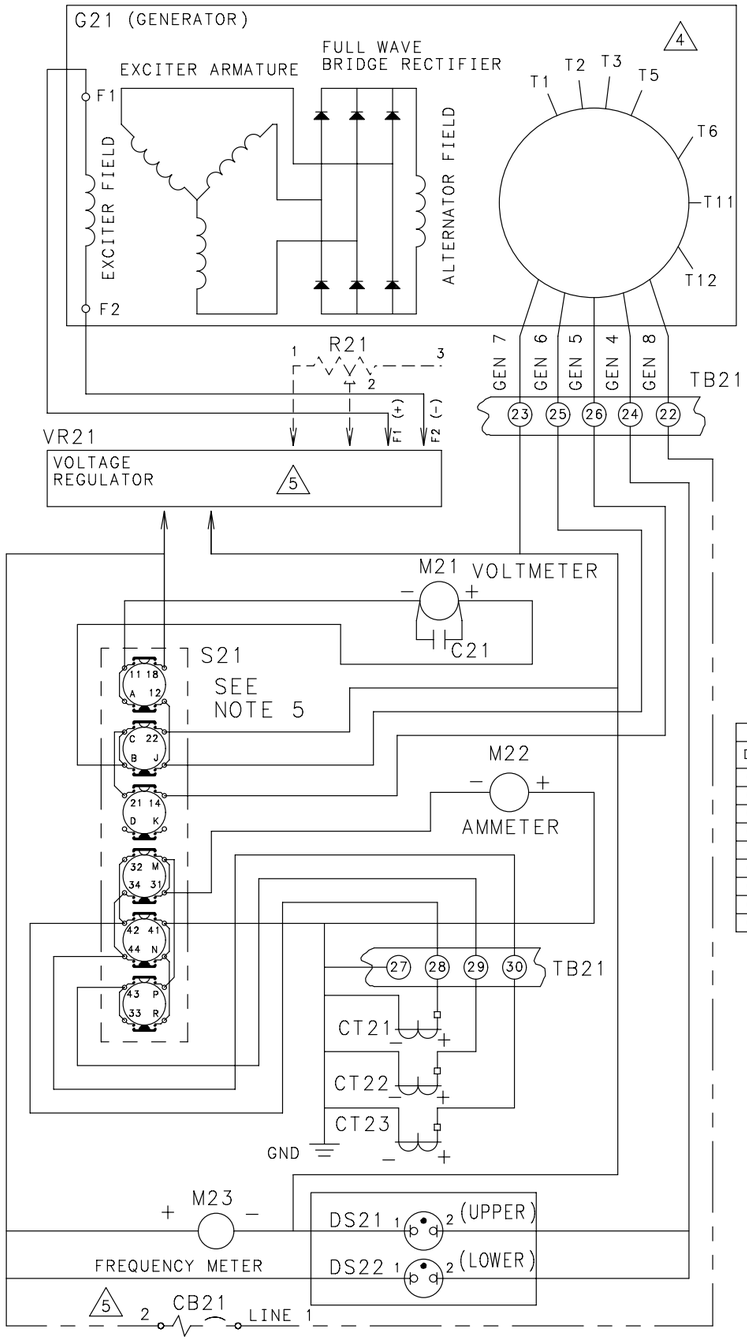
VR21	VOLTAGE REGULATOR
S9	RUPTURE BASIN
S8	LOW FUEL
S7	LOW COOLANT LEVEL (LCL)
S6	THERMOSTAT (PRE-HET)
S5	SWITCH-PRESS (PRE-LOP)
S4	SWITCH LOW ENGINE TEMP (LET)
S3	SWITCH-OVERSPEED (OS)
S2	THERMOSTAT (HET)
S1	SWITCH-OIL PRESS (LOP)
P3	HEATERS
P1	MAG PICKUP
K4	STARTER PILOT SOLENOID
K2	PREHEAT SOLENOID (GLOW PLUGS)
K1	FUEL SOLENOID
HTR	ENGINE HEATER
G1	ALTERNATOR
E7	EXH TEMP (RIGHT)
E6	EXH TEMP (LEFT)
E5	TACHOMETER
E4	SENDER-OIL TEMP
E3	SENDER-WATER TEMP (RIGHT)
E2	SENDER-WATER TEMP (LEFT)
E1	SENDER-OIL PRESSURE
BT1	BATTERY-STORAGE
B1	STARTER & SOLENOID
A12	GOVERNOR

612-6694

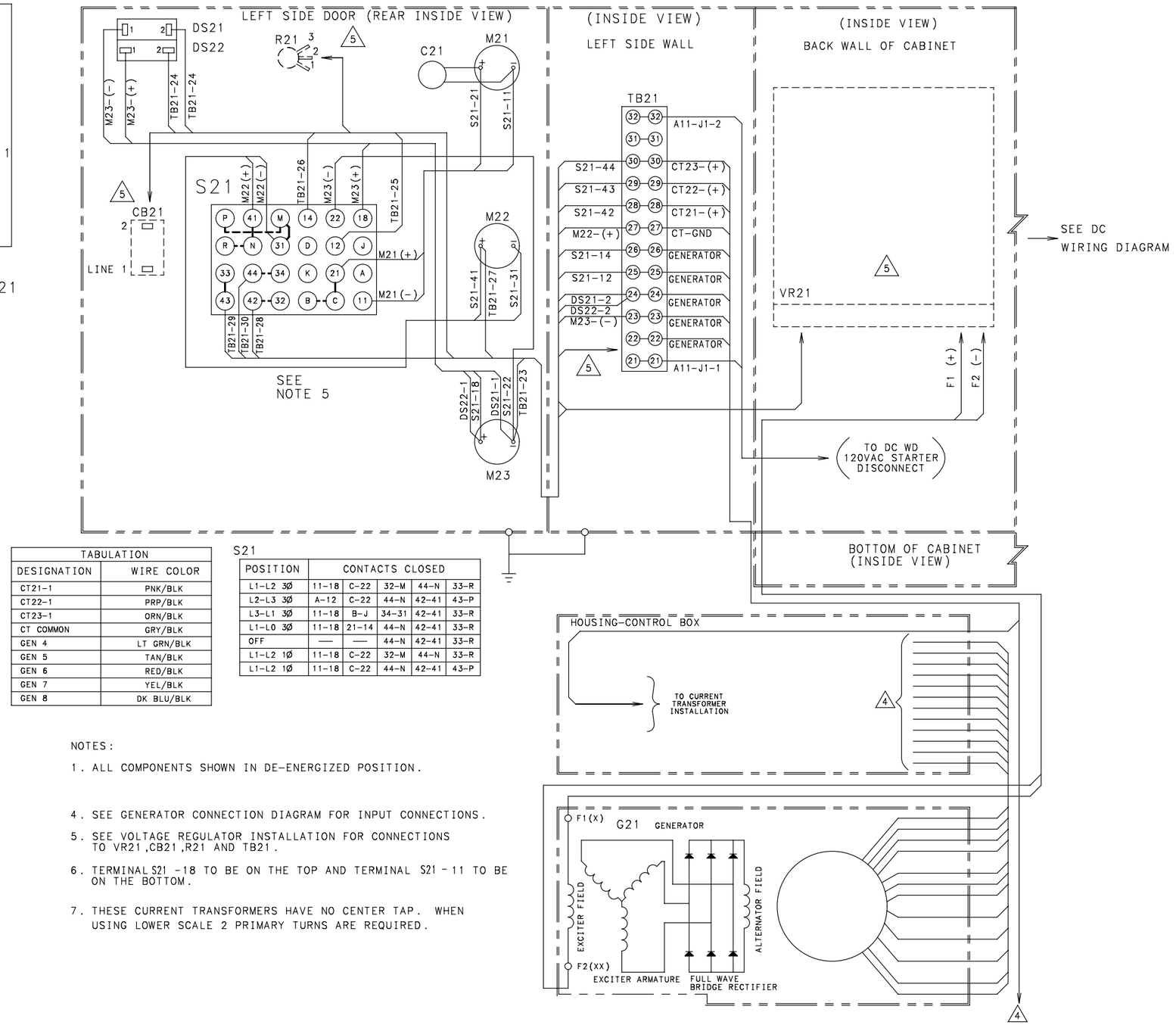
612-6733

DETECTOR CONTROL—ENGINE HARNESS (BEGINNING SPEC B)

SCHEMATIC DIAGRAM



WIRING DIAGRAM



TABULATION

DESIGNATION	WIRE COLOR
CT21-1	PNK/BLK
CT22-1	PRP/BLK
CT23-1	ORN/BLK
CT COMMON	GRY/BLK
GEN 4	LT GRN/BLK
GEN 5	TAN/BLK
GEN 6	RED/BLK
GEN 7	YEL/BLK
GEN 8	DK BLU/BLK

S21

POSITION	CONTACTS CLOSED				
L1-L2 3Ø	11-18	C-22	32-M	44-N	33-R
L2-L3 3Ø	A-12	C-22	44-N	42-41	43-P
L3-L1 3Ø	11-18	B-J	34-31	42-41	33-R
L1-L0 3Ø	11-18	21-14	44-N	42-41	33-R
OFF	—	—	44-N	42-41	33-R
L1-L2 1Ø	11-18	C-22	32-M	44-N	33-R
L1-L2 1Ø	11-18	C-22	44-N	42-41	43-P

NOTES:

1. ALL COMPONENTS SHOWN IN DE-ENERGIZED POSITION.

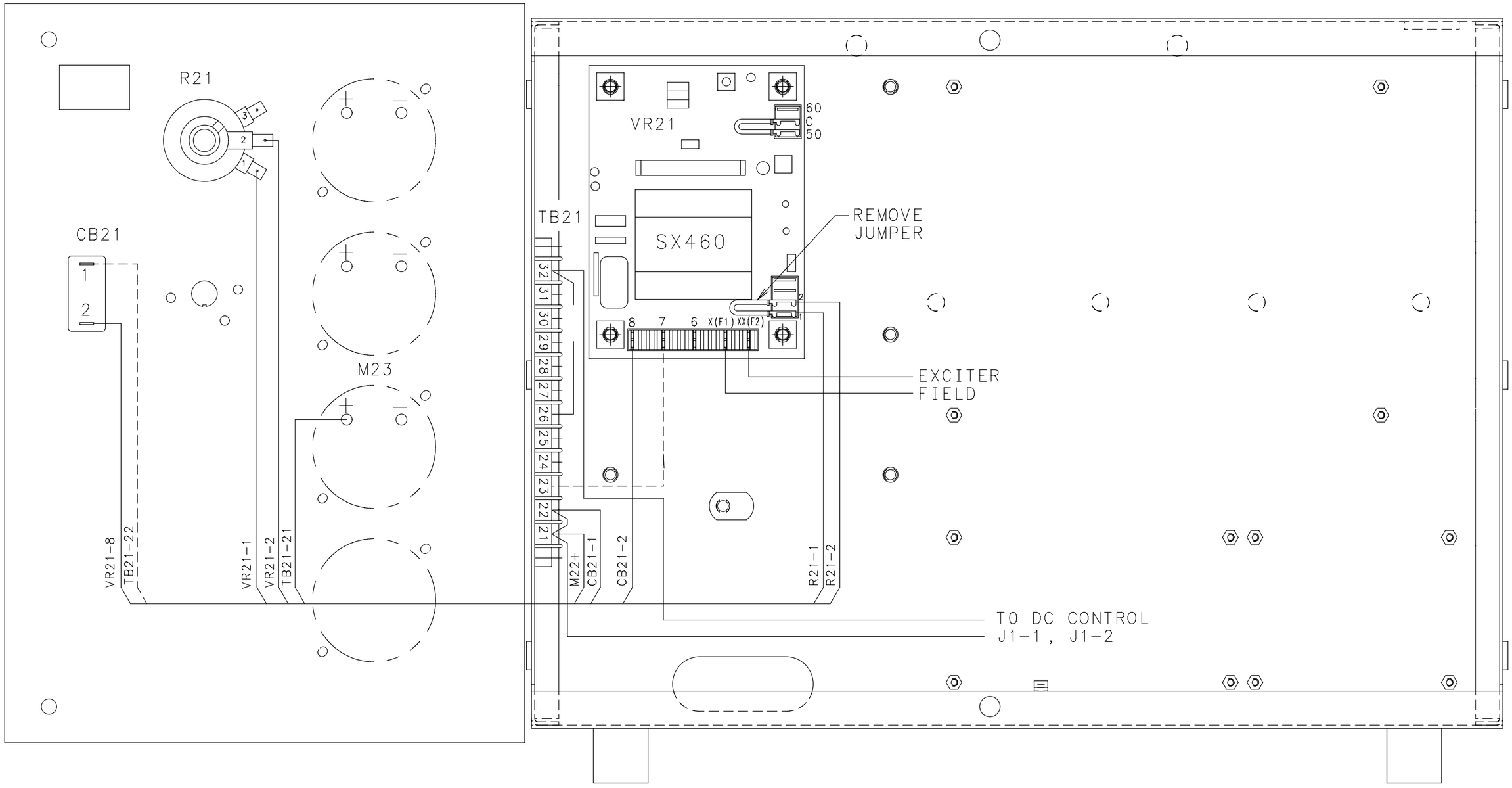
4. SEE GENERATOR CONNECTION DIAGRAM FOR INPUT CONNECTIONS.

5. SEE VOLTAGE REGULATOR INSTALLATION FOR CONNECTIONS TO VR21, CB21, R21 AND TB21.

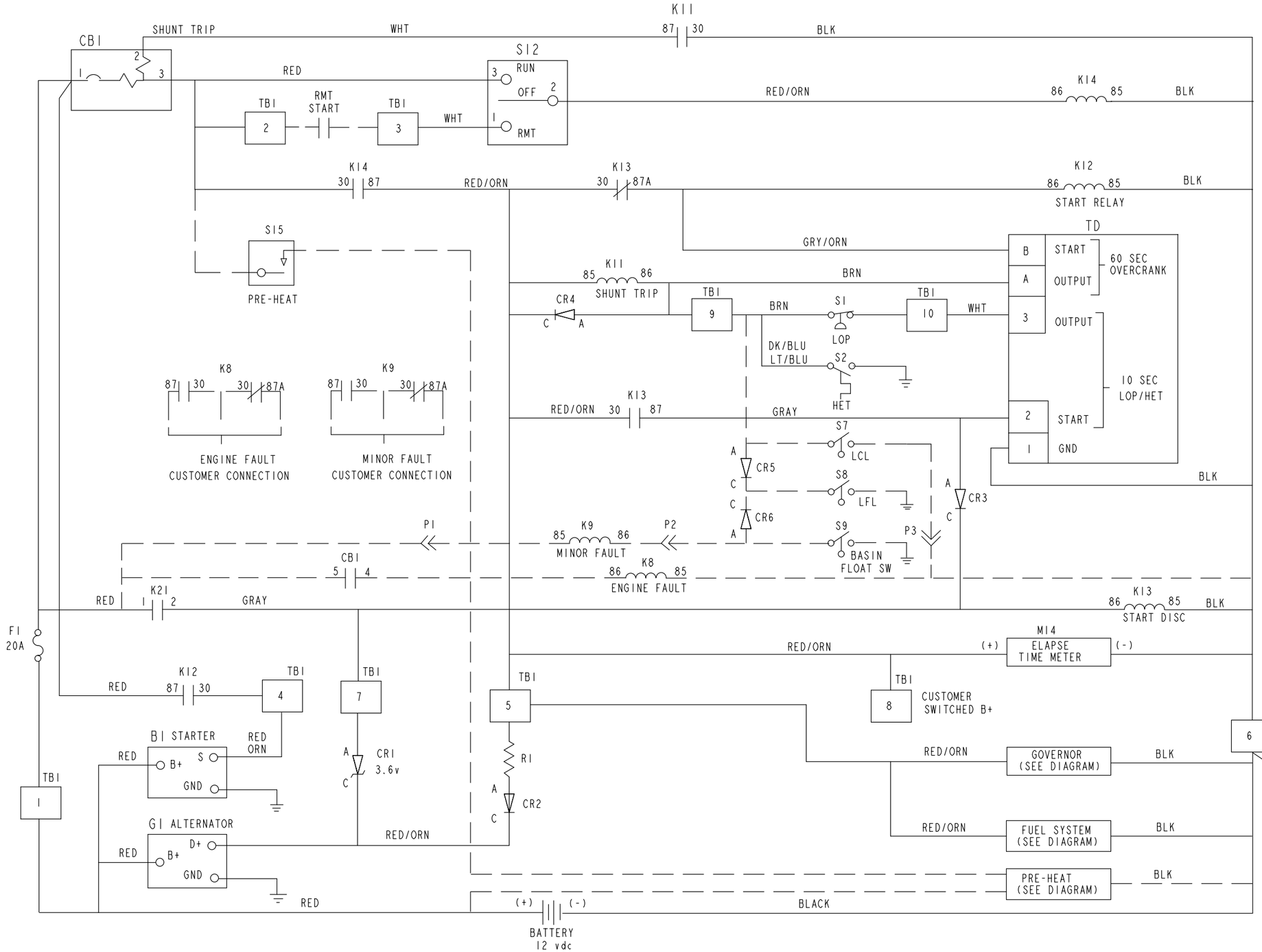
6. TERMINAL S21 -18 TO BE ON THE TOP AND TERMINAL S21 - 11 TO BE ON THE BOTTOM.

7. THESE CURRENT TRANSFORMERS HAVE NO CENTER TAP. WHEN USING LOWER SCALE 2 PRIMARY TURNS ARE REQUIRED.

DETECTOR CONTROL—AC CONTROL (BEGINNING SPEC B)



300–4830



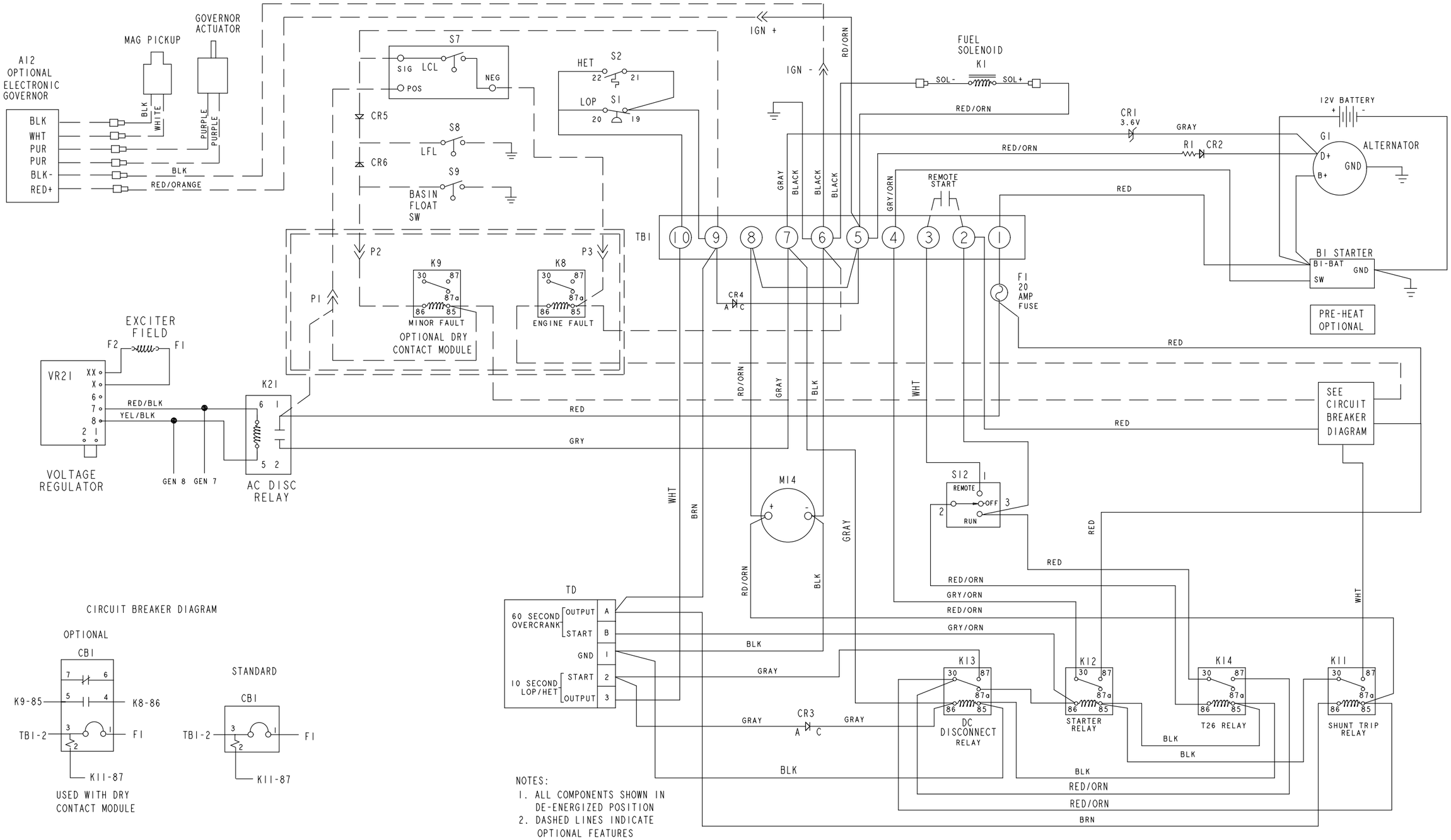
	DESIGNATION
B1	STARTER MOTOR
CB1	CIRCUIT BREAKER
CR1,2	RECTIFIER
F1	FUSE
G1	GENERATOR
K1	FUEL SOLENOID
K11	RELAY-SHUNT TRIP
K12	RELAY-STARTER
K13	RELAY-DISCONNECT
K14	SW B+ RELAY
K15	RELAY-PRE-HEAT
K21	RELAY-AC DISCONNECT
S1	SWITCH-OIL PRESS
S2	SWITCH-HI TEMP
S3	IGNITION MODULE
S6	OVERSPEED
S7	LOW COOLANT LEVEL
S8	LOW FUEL LEVEL
S9	BASIN FAULT
S11	LOW FUEL PRESSURE
S12	SWITCH-ON-OFF
S15	SWITCH-PRE-HEAT
TB1	TERMINAL BLOCK
TD	RELAY-TIME DELAY
VR21	VOLTAGE REGULATION
VR1	VOLTAGE REGULATION

NOTES:

1. ALL COMPONENTS SHOWN IN DE-ENERGIZED POSITION.
2. DASHED LINES INDICATE OPTIONAL FEATURES
3. FOR OPTIONAL TIME DELAY PRE-HEAT SEE PAGE 6

612–6734

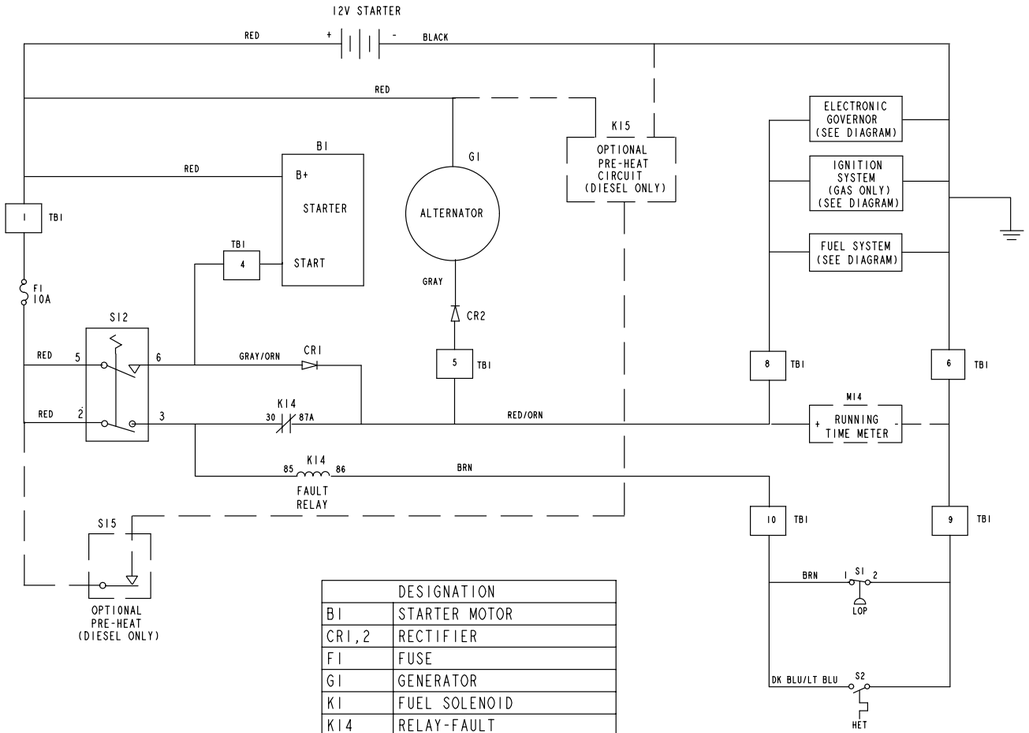
REMOTE/ATS CONTROL—SCHEMATIC DIAGRAM (BEGINNING SPEC B)



612–6734

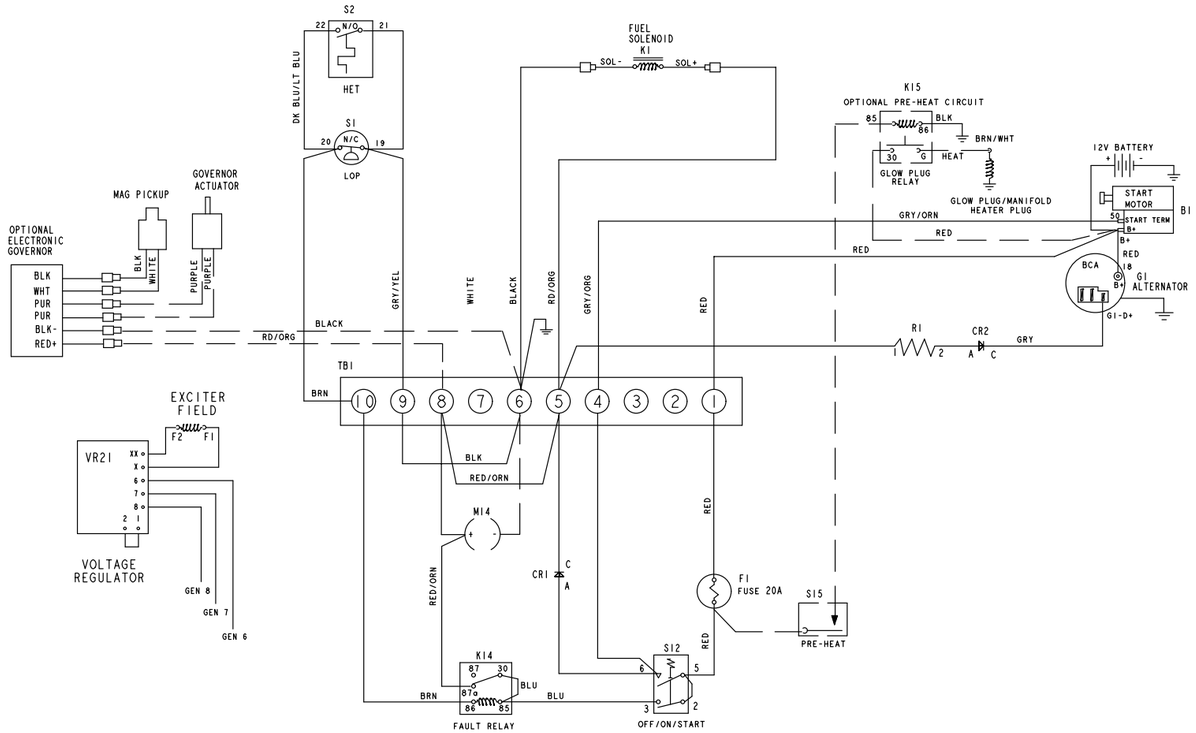
REMOTE/ATS CONTROL—CONNECTION DIAGRAM (BEGINNING SPEC B)

SCHEMATIC DIAGRAM



	DESIGNATION
B1	STARTER MOTOR
CR1,2	RECTIFIER
F1	FUSE
G1	GENERATOR
K1	FUEL SOLENOID
K14	RELAY-FAULT
K15	RELAY-PRE-HEAT
M14	RUNNING TIME METER
S1	SWITCH-OIL PRESS
S2	SWITCH-HI TEMP
S3	IGNITION MODULE
S12	SWITCH-ON-OFF
S15	SWITCH-PRE-HEAT
TB1	TERMINAL BLOCK
VR21	VOLTAGE REGULATOR

CONNECTION DIAGRAM



612–6735

MANUAL CONTROL—SCHEMATIC AND CONNECTION DIAGRAMS (BEGINNING SPEC B)

THIS PAGE LEFT INTENTIONALLY BLANK

AUTOMATIC TRANSFER SWITCH CONTACTS

TB1-10 (SWITCHED B+)

TB1-9 (B+ IN)

TB1-8 (START SOLENOID)

TB1-7 (15 AMP FUSED B+ OUTPUT)

TB1-6 (REMOTE START)

TB1-5 (GROUND)

TB1-4 (COMMON ALARM B+ OUTPUT) 4 AMP RATED DEVICE MAXIMUM

TB1-3 (RUN) GROUND OUTPUT TO LIGHT/RELAY*

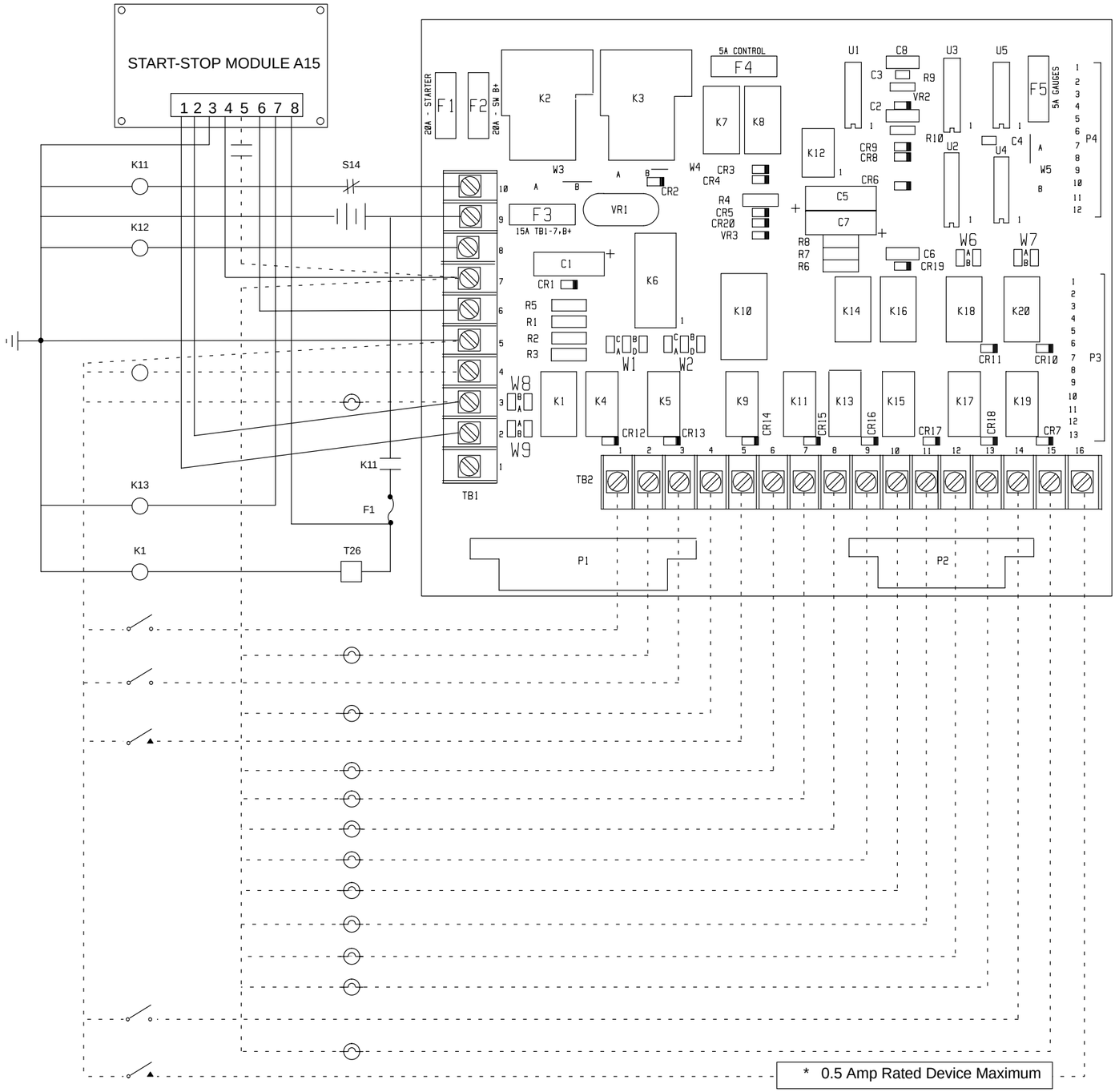
TB1-2 (DC DISCONNECT)

TB1-1 (OVERSPEED)

A15 TB1-7 (GLOWPLUG RELAY)

A15 TB1-8 (B+)

T26 (B+ ENGINE BLOCK FOR FUEL SOLENOID AND OTHER)



TB2-1 (FAULT 2) GROUND INPUT FROM SENDER

TB2-2 (FAULT 2) GROUND OUTPUT TO LIGHT/RELAY*

TB2-3 (FAULT 1) GROUND INPUT FROM SENDER

TB2-4 (FAULT 1) GROUND OUTPUT TO LIGHT/RELAY*

TB2-5 (REMOTE RESET) MOMENTARY CONTACT TO GROUND

TB2-6 (OVERCRANK FAULT) GROUND OUTPUT TO LIGHT/RELAY*

TB2-7 (OVERSPEED FAULT) GROUND OUTPUT TO LIGHT/RELAY*

TB2-8 (HIGH ENGINE TEMPERATURE FAULT) GROUND OUTPUT TO LIGHT/RELAY*

TB2-9 (LOW OIL PRESSURE FAULT) GROUND OUTPUT TO LIGHT/RELAY*

TB2-10 (PRE-HIGH ENGINE TEMPERATURE WARNING) GROUND OUTPUT TO LIGHT/RELAY*

TB2-11 (PRE-LOW OIL PRESSURE WARNING) GROUND OUTPUT TO LIGHT/RELAY*

TB2-12 (SWITCH OFF WARNING) GROUND OUTPUT TO LIGHT/RELAY*

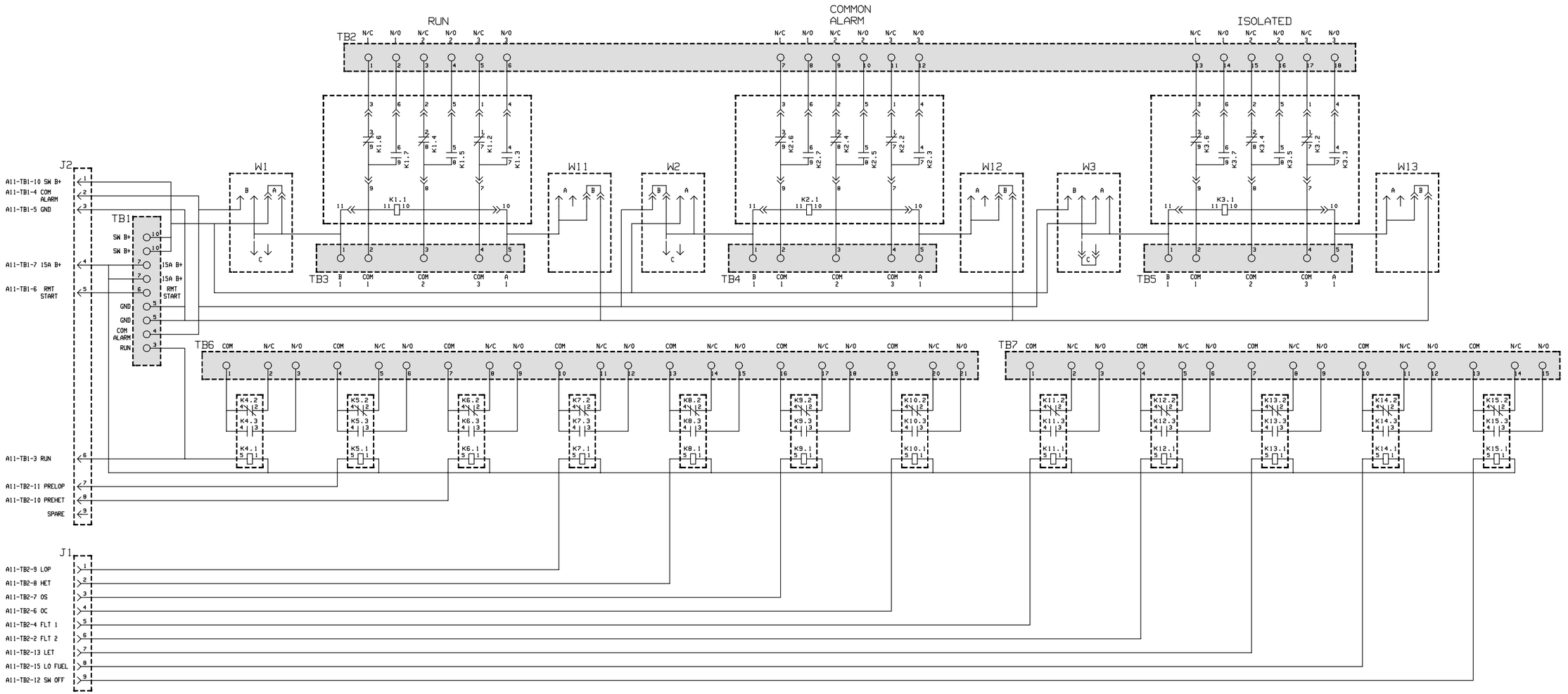
TB2-13 (LOW ENGINE TEMPERATURE WARNING) GROUND OUTPUT TO LIGHT/RELAY*

TB2-14 (LOW FUEL WARNING) GROUND INPUT FROM SENDER

TB2-15 (LOW FUEL WARNING) GROUND OUTPUT TO LIGHT/RELAY*

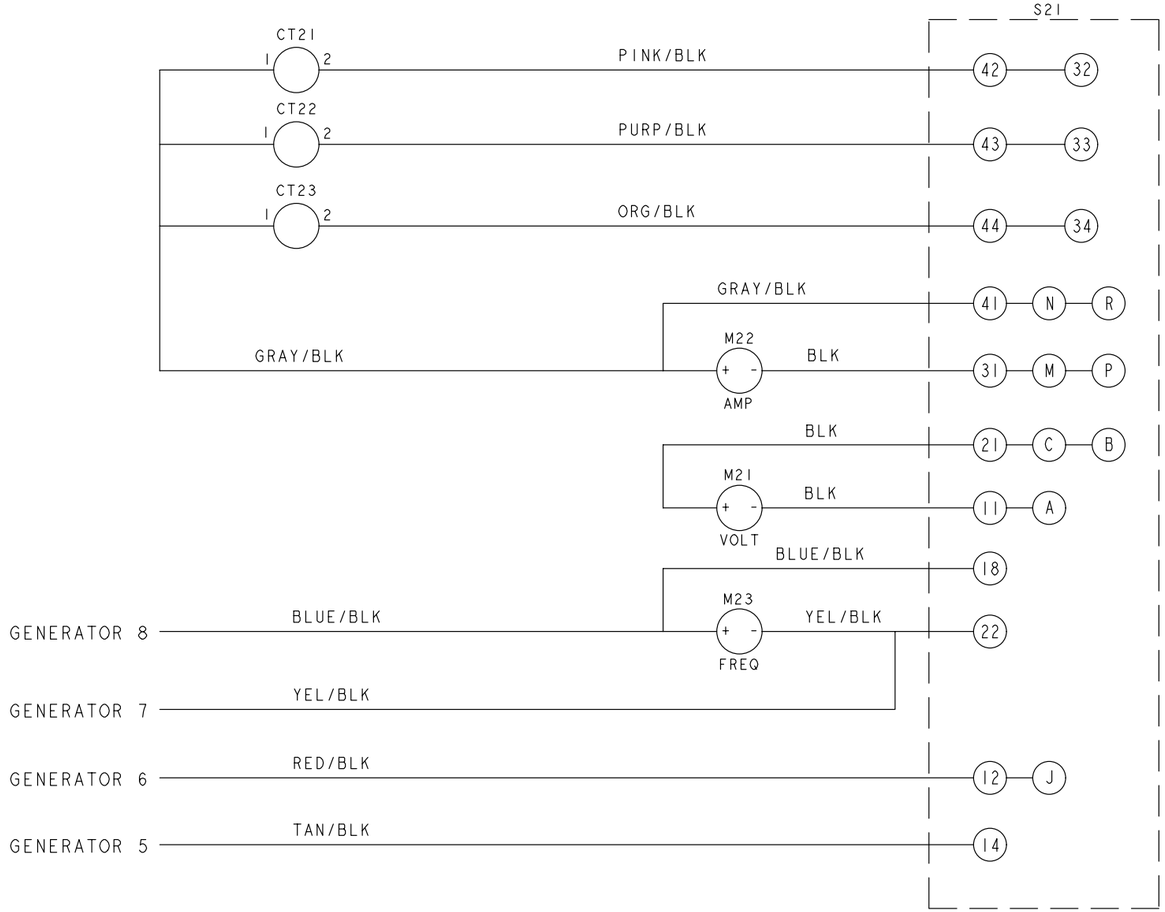
TB2-16 (EMERGENCY SHUT DOWN) MOMENTARY CONTACT TO GROUND

DETECTOR CONTROL CONNECTIONS (SPEC A)



THE TERMINALS IN THE SHADED BOXES ARE FOR CUSTOMER CONNECTIONS

DETECTOR CONTROL—AUXILIARY RELAY BOARD CONNECTIONS



	18-11	22-C	14-21	M-32	41-42	P-43	12-A	J-B	31-34	N-44	R-33
L1-L2 3-PH	X	X		X						X	X
L2-L3 3-PH		X			X	X	X			X	
L3-L1 3-PH	X				X			X	X		X
L1-L0 3-PH	X		X		X					X	X
OFF					X					X	X
L1-L2 1PHA	X	X		X						X	X
L1-L2 1PHB	X	X			X	X				X	

EXTERNAL JUMPERS
M-P
34-44
C-21
32-42
12-J
N-R

INTERNAL JUMPERS
N-41
M-31
A-11
B-C
33-43

612–6746

MANUAL AND REMOTE/ATS—METER PANEL WIRING

THIS PAGE LEFT INTENTIONALLY BLANK

Cummins Power Generation
1400 73rd Avenue N.E.
Minneapolis, MN 55432
1-800-888-6626
763-574-5000 International Use
Fax: 763-528-7229

Power Generation