Training Manual

PowerBoost™
Standby Generator Sets

ISO 9001
KOHLER GENERATORS
INTERNATIONALLY REGISTERED

KOHLER®
POWER SYSTEMS

TP- 6114
7/20/00

Table Of Content

Introduction

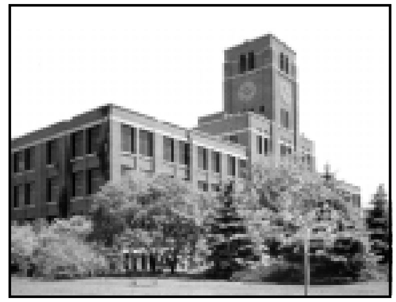
This manual covers operation, troubleshooting, and features of Kohler Commercial / Residential Generator Sets.

This manual is only intended as a training guide and is to be used as a supplement to classroom material. This is not a service manual and does not contain all available product information. **Do not attempt to service generator sets without consulting the service manual and following all safety warnings.**

Pictures, illustrations, and wiring diagrams in this manual are only representative of the various models and may differ slightly even within the same model designation series.

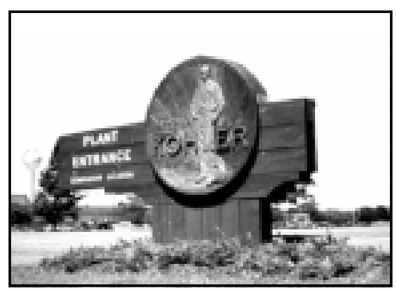
This manual is not intended as an installation or troubleshooting guide.

Kohler Company History
Founded by John Michael Kohler on Dec. 3, 1873, Kohler Co. has grown to become the nation's largest manufacturer of plumbing and specialty products as well as a major producer of generators and four-cycle engines. In recent years, the company has also acquired two distinguished furniture manufacturers and opened a variety of highly successful hospitality businesses. Headquartered in Kohler, Wis., Kohler Co. is one of the oldest and largest privately held companies in the country and employs more than 20,000 people.



Power Systems Group
Kohler Co., a major producer of engines, generators and electrical products, entered the power systems market in the early 1900's. Its first power systems products included cast iron internal combustion engines and Automatic Power and Light, a remarkable improvement in auxiliary power in its day. Generators, then known as electrical plants, supplied power during Admiral Richard Byrd's Antarctic exploration in the late 1920's. In the post-war years, Kohler expanded its engine and generator product lines and continued to improve the durability and performance of all of its power systems units. Consequently, the number of markets for Kohler power systems products grew throughout the United States and beyond. Today, Power Systems International, created in 1989 and based in Kohler, Wis., is responsible for all Kohler generator and engine product sales outside of the United States.

Generator Division
In use throughout the world, Kohler generators are available for the marine, home, mobile, commercial, and industrial markets. In addition to generator sets, Kohler also manufactures transfer switches, switchgear and accessories for all product lines. Kohler generators are produced in a manufacturing facility located in the town of Mosel, eight miles north of Kohler, Wis. In 1997 Kohler opened and operates a manufacturing facility in Singapore for the international product line.



Engine Division
One of the world's major manufacturers of air-cooled, four-cycle engines, Kohler Co. produces models ranging from 4 horsepower single-cylinder engines to 26 horsepower twin-cylinder engines. These engines are used by major manufacturers to power lawn and turf, agricultural, industrial construction and recreational equipment. The Kohler engine is also used in Kohler generator models, specifically the residential/ commercial product lines. Kohler engines are manufactured in Kohler, Wis. and Hattiesburg, Miss.

Kohler de Mexico, S.A. de C.V.
Created in 1964 and located in Mexico City, Kohler de Mexico manufactures four-cycle engines.

Safety Precautions and Instructions

A generator set, like any other electromechanical device, can pose potential dangers to life and limb if improperly maintained or imprudently operated. The best way to prevent accidents is to be aware of the potential dangers and to always use good common sense. In the interest of safety, some general precautions relating to the operation of a generator set follow. Keep these in mind. This manual contains several types of safety precautions that are explained below.

DANGER

Danger is used to indicate the presence of a hazard, which will cause severe personal injury, death, or substantial property damage if the warning is ignored.

WARNING

Warning is used to indicate the presence of a hazard which can cause severe personal injury, death, or substantial property damage if the warning is ignored.

CAUTION

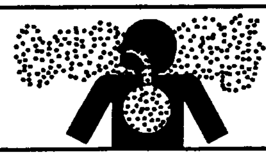
Caution is used to indicate the presence of a hazard, which will or can cause minor personal injury or property damage if the warning is ignored.

NOTE

Note is used to notify people of installation, operation, or maintenance information, which is important but not hazard-related.

Safety decals are affixed to the generator set in prominent places to advise the operator or service technician of potentially hazardous situations. The decals are reproduced here to improve operator recognition and thereby increase decal effectiveness. For a further explanation of decal information, reference the accompanying safety precautions. Before operating or servicing the generator set, be sure you understand the message of these decals. Replace decals if missing or damaged.

WARNING



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

The exhaust system must be leakproof and routinely inspected.

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

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

• Light-headedness, dizziness

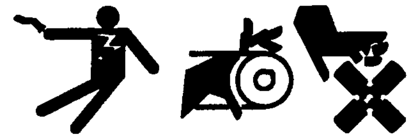
• Physical fatigue, weakness in joints and muscles

• Sleepiness, mental fatigue, inability to concentrate or speak clearly, blurred vision

• Stomach ache, vomiting, nausea

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

WARNING



Accidental starting.
Can cause severe injury or death.

Disconnect battery cables before working on generator set (negative lead first and reconnect it last).

Accidental starting can cause severe Injury or death. Disconnect battery cables (remove negative lead first and reconnect it last) to disable generator set before working on any equipment connected to generator. The generator set can be started by remote start/stop switch unless this precaution is followed.

Accidental starting can cause severe Injury or death. Disconnect battery cables (remove negative lead first and reconnect it last) to disable generator set before working on any equipment connected to generator. Place controller MASTER switch to OFF position. The generator set can be started by remote start/stop switch unless this precaution is followed.

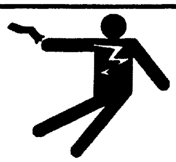
CAUTION

Hazardous noise.
Can cause loss of hearing.

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

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

⚠ WARNING



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

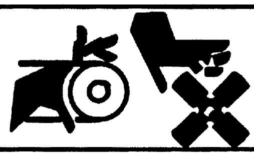
Do not operate generator set without all guards and electrical enclosures in place.

⚠ WARNING

Fire.
Can cause severe injury or death.

Do not smoke or permit flame or spark to occur near fuel or fuel system.

⚠ WARNING



Rotating parts.
Can cause severe injury or death.

Do not operate generator set without all guards, screens, or covers in place.

Exposed moving parts can cause severe Injury or death. Keep hands, feet, hair, clothing, and test leads away from belts and pulleys when unit is running. Replace guards, covers, and screens before operating generator set. Some scheduled maintenance procedures require the generator set to be running while performing service. If the sound shield has been removed leaving belts and pulleys exposed, be especially careful of this area.

Flying projectiles can cause severe Injury or death. Retorque all crankshaft and rotor hardware after servicing. When making adjustments or servicing generator set, do not loosen crankshaft hardware or rotor thru-bolt. If rotating crankshaft manually, direction should be clockwise only. Turning crankshaft bolt or rotor thru-bolt counterclockwise can loosen hardware and result in serious personal injury from hardware or pulley flying off engine while unit is running.

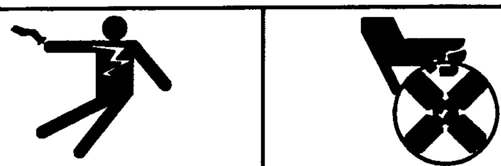
A flash fire can cause severe injury or death. Do not Smoke or permit flame or spark to occur near carburetor, fuel line, fuel filter, fuel pump, or other potential sources of spilled fuel or fuel vapors. When removing fuel line or carburetor, use a proper container to catch all fuel.

A sudden backfire can cause severe Injury or death. Do not operate with backfire flame arrestor removed. *(gasoline models only)*

A sudden backfire can cause severe Injury or death. Do not operate with air cleaner/silencer removed. *(diesel models only)*

A sudden flash fire can cause severe Injury or death. Do not smoke or permit flame or spark to occur near fuel system. Keep the compartment and generator set clean and free of debris to minimize chances of fire. Wipe up

WARNING



Hazardous voltage. Moving rotor.

Can cause severe injury or death.

Do not operate generator set without all guards and electrical enclosures in place.

Grounding generator set. Hazardous voltage can cause severe injury or death. Electrocution is possible whenever electricity is present. Open main circuit breakers of all power sources before servicing equipment. Configure the installation to electrically ground the generator set and electrical circuits when in use. Never contact electrical leads or appliances when standing in water or on wet ground, as the chance of electrocution increases under such conditions.

High voltage test. Hazardous voltage can cause severe injury or death. Follow instructions of test equipment manufacturer when performing high-voltage test on rotor or stator. An improper test procedure can damage equipment or lead to future generator set failures.

Installing battery charger. Hazardous voltage can cause severe injury or death. Electrical shock may occur if battery charger is not electrically grounded. Connect battery charger enclosure to ground of a permanent wiring system. As an alternative, install an equipment grounding conductor with circuit conductors and connect to equipment grounding terminal or lead on battery charger. Perform battery charger installation as prescribed in equipment manual. Install battery charger in compliance with local codes and ordinances.

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

Testing voltage regulator. Hazardous voltage can cause severe injury or death. High voltage is present at the voltage regulator heat sink. Do not touch voltage regulator heat sink when testing voltage regulator or electrical shock will occur. *(PowerBoost-, PowerBoost- ///, and PowerBoost- V voltage regulator models only.)*

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

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

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

Explosive fuel vapors can cause severe injury or death. Take additional precautions when using the following fuels: Gasoline - Store gasoline only in approved red containers clearly marked GASOLINE.

Propane (LP)-Adequate ventilation is mandatory. Propane is heavier than air; install propane gas detectors low in room. Inspect detectors often.

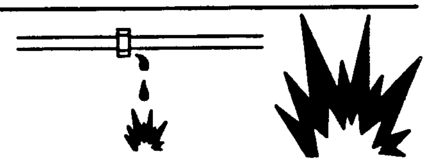
Natural Gas-Adequate ventilation is mandatory. Natural gas rises; install natural gas detectors high in room. Inspect detectors often.

Gas fuel leaks. Explosive fuel vapors can cause severe injury or death. Fuel leakage can cause an explosion. Check LP vapor gas or natural gas fuel system for leakage using a soap-water solution with fuel system test pressurized to 6-8 ounces per square inch (10-14 inches water column). Use a soap solution containing neither ammonia nor chlorine because both prevent bubble formation. A successful test depends on the ability of the solution to bubble.

WARNING

Explosion.
Gasoline vapors can cause explosion and severe injury or death.

Before starting generator set, operate blower 4 minutes and check engine compartment for gasoline vapors.



WARNING

Explosive fuel vapors.
Can cause severe injury or death.

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

LP liquid withdrawal fuel leaks. Explosive fuel vapors can cause severe injury or death. Fuel leakage can cause an explosion. Check LP liquid withdrawal gas fuel system for leakage using a soap-water solution with fuel system test pressurized to at least 90 psi (621 kPa). Use a soap solution containing neither ammonia nor chlorine because both prevent bubble formation. A successful test depends on the ability of the solution to bubble.

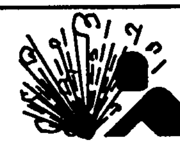
WARNING

Sulfuric acid In batteries.
Can cause severe Injury or death.

Use protective goggles and clothes. Can cause permanent damage to eyes, bum skin, and eat holes in clothing.

Explosion can cause severe Injury or death. Battery gases can cause an explosion. Do not smoke or permit flame or spark to occur near a battery at any time, particularly when it is being charged. Avoid contacting terminals with tools, etc. to prevent bums and to prevent sparks that could cause an explosion. Remove wristwatch, rings, and any other jewelry before handling battery. Never connect negative (-) battery cable to positive (+) connection terminal of starter solenoid. Do not test battery condition by shorting terminals together or sparks could ignite battery gases or fuel vapors. Any compartment containing batteries must be well ventilated to prevent accumulation of explosive gases. To avoid sparks, do not disturb battery charger connections while battery is being charged and always turn charger off before disconnecting battery connections. When disconnecting battery, remove negative lead first and reconnect it last.

WARNING



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

Before removing pressure cap stop generator, allow to cool and loosen pressure cap to relieve pressure.

WARNING

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

Do not work on generator set until unit is allowed to cool.

Hot coolant can cause severe Injury or death. Allow engine to cool and release pressure from cooling system before opening pressure cap. To release pressure, cover the pressure cap with a thick cloth then turn ft slowly counterclockwise to the first stop. After pressure has been completely released and the engine has cooled, remove cap. If generator set is equipped with a coolant recovery tank, check coolant level in tank.

Hot parts can cause severe Injury or death. Do not touch hot engine parts. An engine gets hot while running and exhaust system components get extremely hot.

Notice

NOTICE

This generator set has been rewired from its nameplate voltage to:

246242

NOTICE

Voltage reconnection! Affix notice to generator set after reconnecting to a voltage different from the nameplate. Order voltage reconnection decal 246242 from authorized service distributors/dealers.

NOTICE

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

NOTICE

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

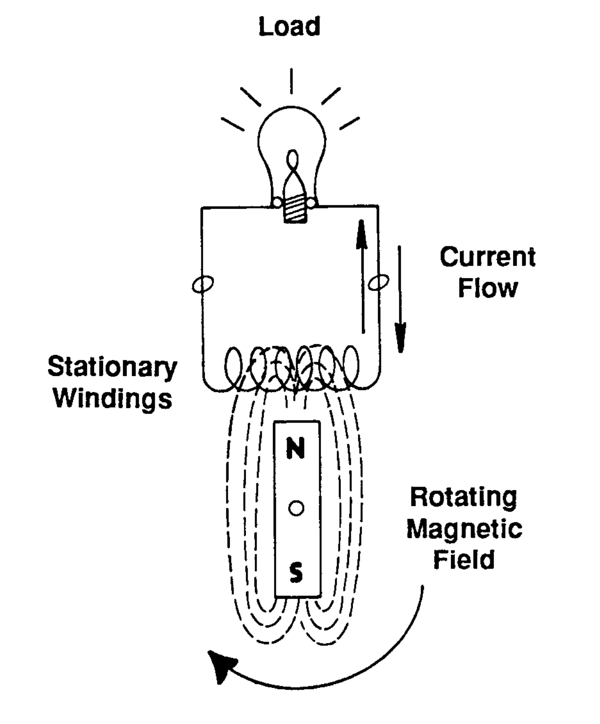
NOTICE

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

Alternator Design

Mechanical alternators or generators that produce an AC output are either the rotating armature or the rotating field design and require 3 basic things.

1. Conductors
2. A magnetic field
3. Movement between the two.

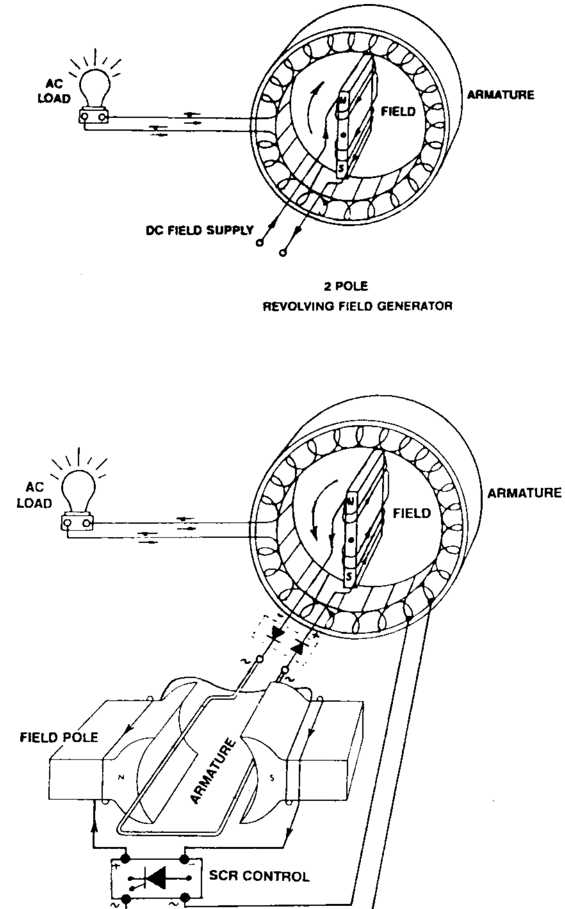


1. The **conductors** are copper wires wound in slots of laminated steel referred to as the armature and provide the generated output voltage.
2. The **field** is the invisible magnetic force produced by electro-magnetic pole pieces.
3. **Movement** between the field and conductors is necessary to create current flow in the armature windings and is usually provided by a gas or diesel engine.

Rotating Field Generators

Alternators used on most standby generator sets today are of the rotating field design. The magnetic poles of the rotor rotate past the armature windings of the stator. The rotor is energized with a DC field by some type of excitation. As the field rotates the magnetic flux lines cut the conductors, which are distributed so as to induce a sinusoidal voltage in the stator. The armature windings are stationary, no brushes are required for a transfer of AC power to the customer load.

The stationary armature also allows for easy reconnection of the windings to permit various three phase or single phase voltages.

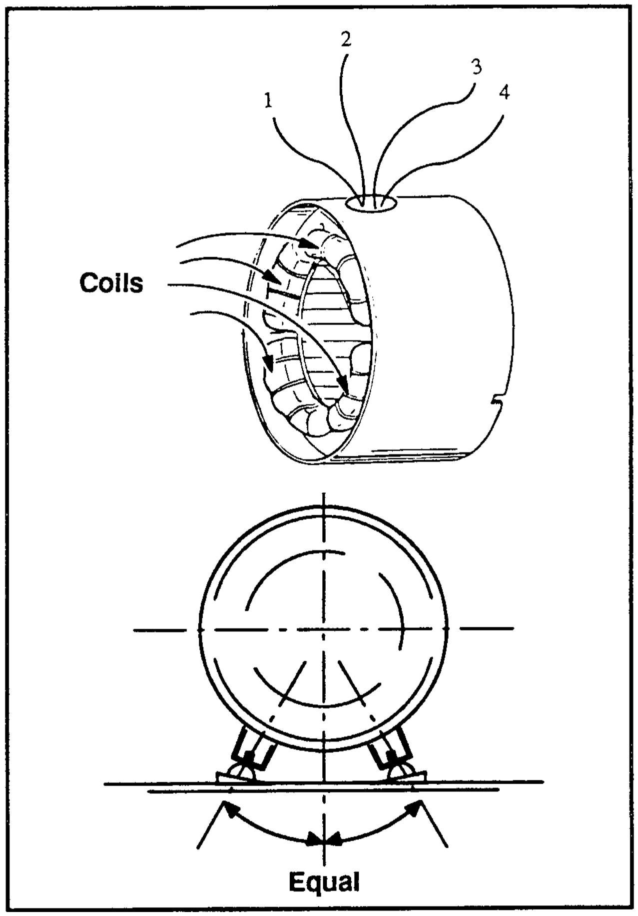


Stator

The stator contains the conductors. It consists of a core of slotted, laminated steel, in which coils of insulated wire (conductors) are wound.

Wire size and the number of windings placed in the insulated slots are selected by the desired electrical characteristics of the design.

To achieve minimum vibration, stators with attached mounts must be positioned so weight is evenly distributed.



Single Phase Design

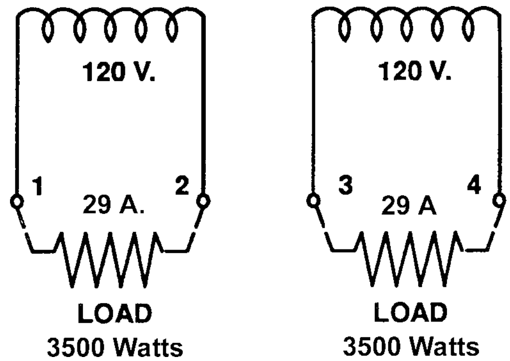
The single-phase only alternators consist of a stator having two main windings. Each coil group is capable of handling rated amperage at a nominal 120 vac.

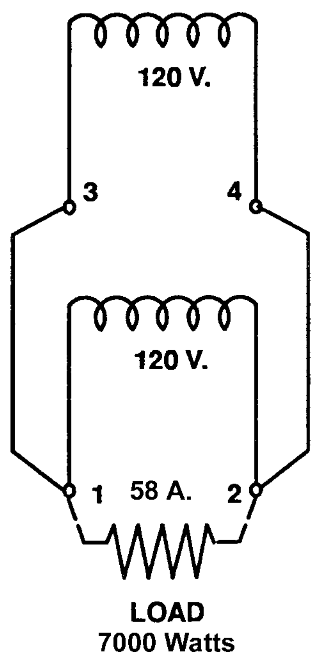
A 7 kW, 120-volt generator, for example, could provide up to 29 amps per coil, or a total of 58 amps from the two coils.

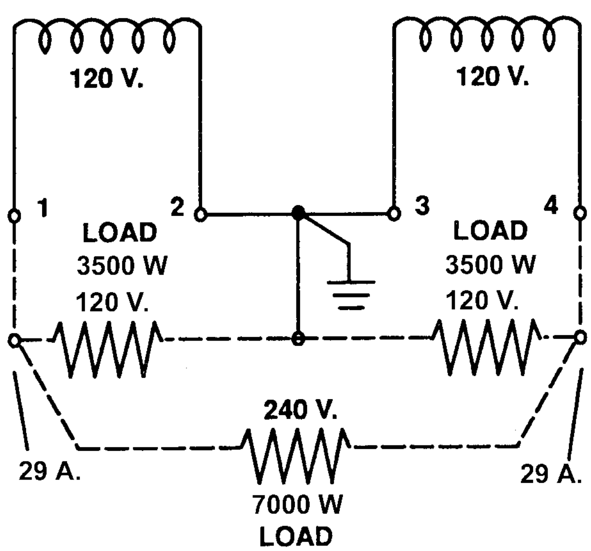
Volts x Amps = Watts

The two coil groups can be connected in parallel to provide a single circuit of 120 volts ac only, or they can be series connected to provide two 120-volt circuits and one 240-volt circuit.

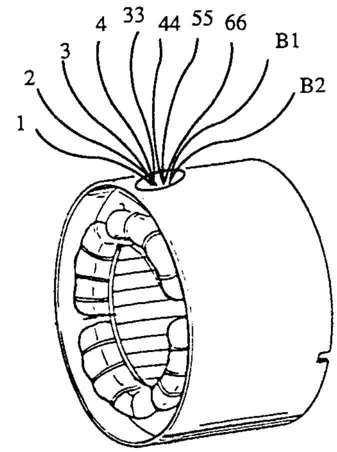
When connecting the main output windings to building load it must be remembered that the ampere ratings of each individual circuit must not exceed the ampere rating of the stator coils.







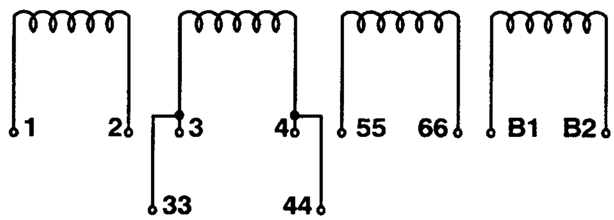
Stator Windings



Some stators may contain additional sets of windings, which produce various voltages from 12 to 120 volts ac. These windings may supply battery charging circuits, voltage regulator systems, and engine control circuits.

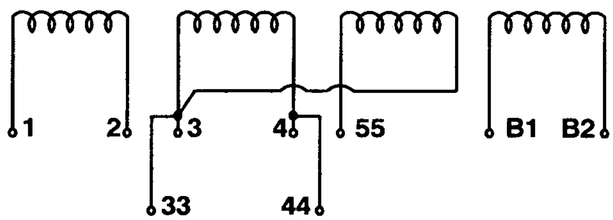
Stator windings have a very low resistance value, usually less than one ohm, and require a quality resistance device for accurate measurements.

Leads 1,2,3,4 main generator output leads
Leads 33,44 voltage regulator sensing leads
Leads 55,66 voltage regulator power supply leads
Leads B1,B2 supply voltage rectified for control logic.



Note: The B1- B2 coil is only used for gensets using the 259563 controller board.

Stators with Power Boost IIIE voltage regulator systems do not have an external lead 66.



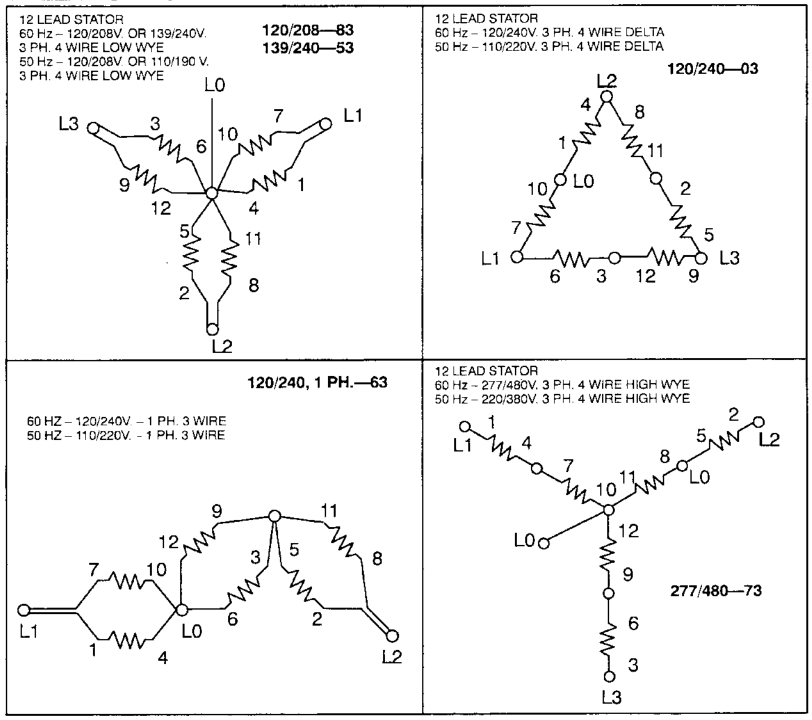
Three Phase Alternator

Some generator require a three phase alternator. Pictured is the configuration diagram for connecting the alternator for different voltage applications.

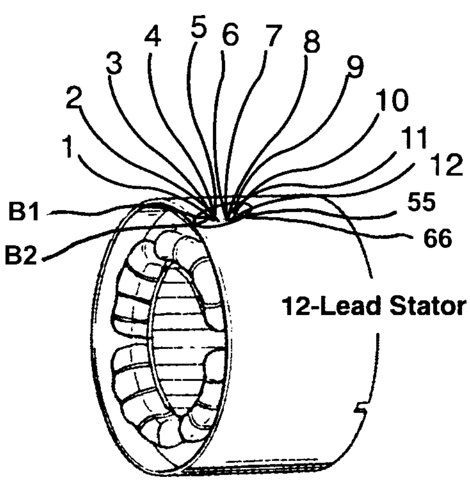
When the three phase alternator uses the PowerBoost™ V voltage regulator additional windings are required for the application. The Stator will have 6 groups of windings for the main output leads. Additionally you will have 55, 66 leads for supply power to the regulator and B1, B2 for control logic.

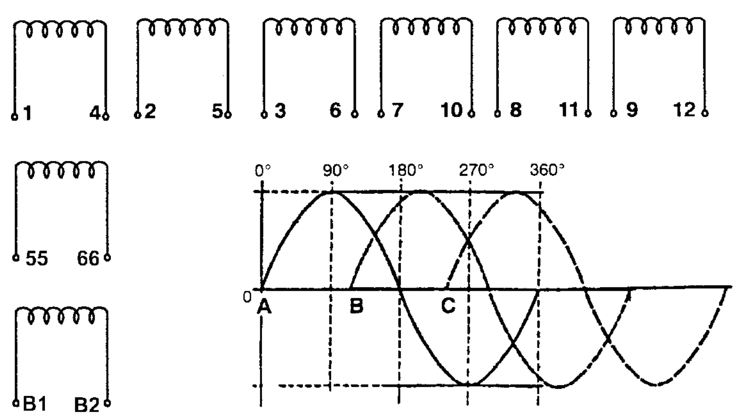
Note: The B1-B2 coil is used only for gensets using the 259563 controller board.

12-LEAD STATOR



Voltage Reconnections with 12-Lead Stator





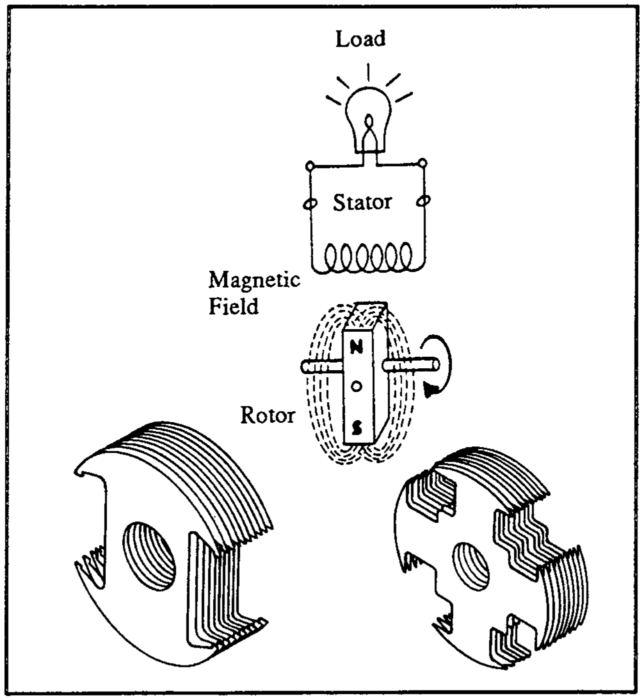
PHASE A B C 3 PHASE SINE WAVE

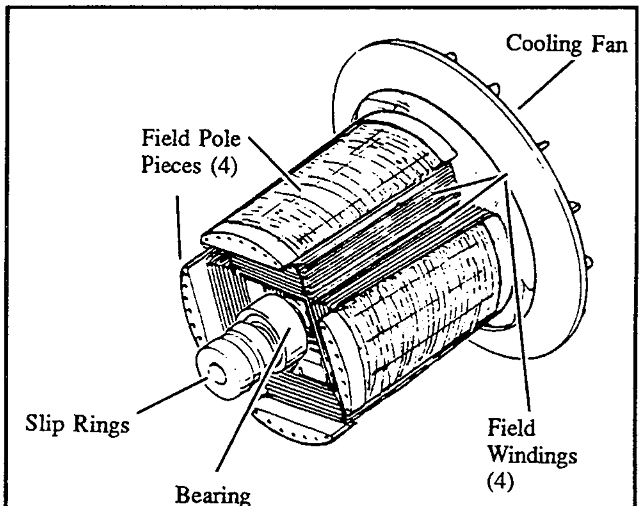
Rotor Design

The magnetic field is produced by the rotor via some form of excitation induced into the windings.

Laminations of steel are used in the construction of the rotor.

The most common configuration is either the two or four pole design.





4 Pole Rotor

The number of poles and the rotational speed will determine the frequency of the generated output potential.

The two-pole generator will produce a 60 cycle (hertz) output if it rotates at 3600 RPM.

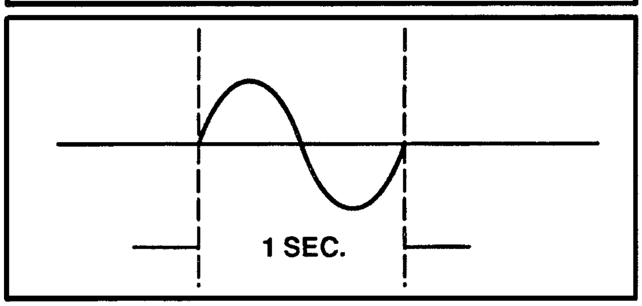
The four-pole generator will produce a 60 cycle (hertz) output if it rotates at 1800 RPM.

1 Hertz = 1 cycle/second

$$\text{SPEED (RPM)} = \frac{\text{Hz} \times 120}{\text{POLES}}$$

$$\frac{60 \times 120}{4} = \frac{7200}{4} = 1800 \text{ RPM}$$

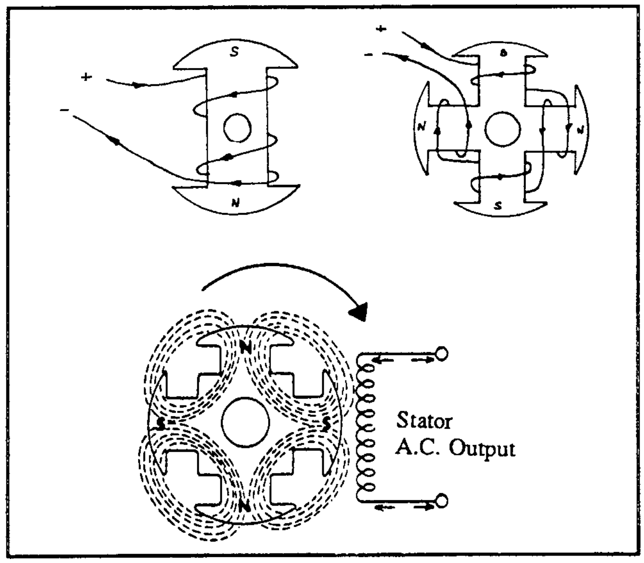
$$\frac{60 \times 120}{2} = \frac{7200}{2} = 3600 \text{ RPM}$$



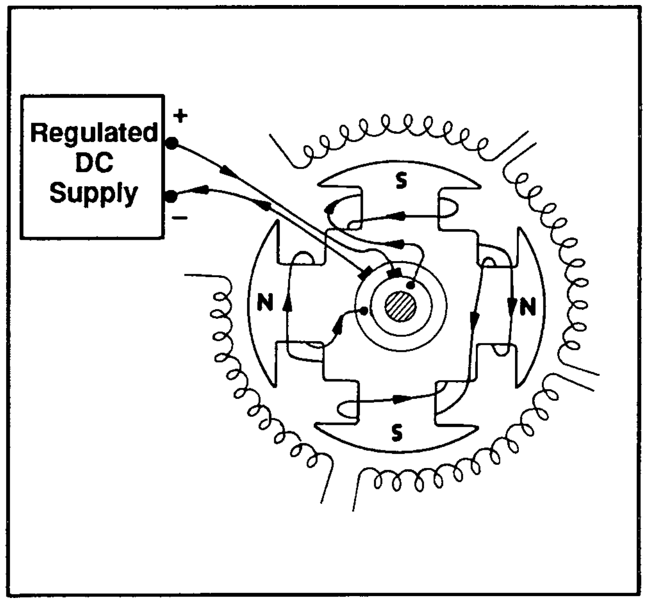
Rotor Design

Conductors are alternately wound around the pole pieces, and a DC current is supplied to the coils, thus producing electro-magnets.
The direction of current flow around the field pole will determine the magnetic polarity of the pole.

The current induced in the stator windings will alternate its direction of flow, due to the alternating magnetic polarity of the rotor as it passes the coils.



To increase the generator output potential, the magnetic field is strengthened by increasing the DC curent through the field coils.



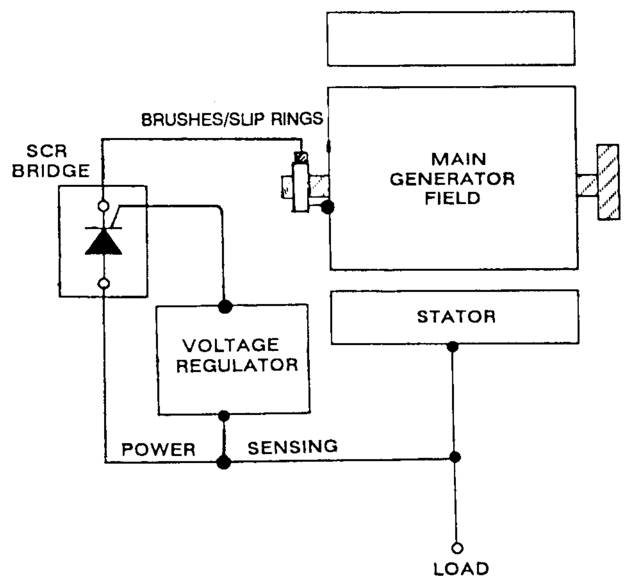
Field Excitation

The rotor field windings are energized through field excitation. Field excitation comes from a variable DC source called an exciter. By varying the exciter voltage we can control the voltage and current induced into the rotor thus controlling the voltage generated in the stator. To control the exciter voltage a voltage regulator is incorporated into the alternator design and its selection is based on the type of excitation used on the alternator and the application of the generator.

As alternator designs differ so does the type of excitation used. A description of the different types of excitation and voltage regulators used in the below 20 kW product line follows.

Static Excited (Brush Type)

This system rectifies AC power from the output of the generator and sends a controlled DC current to the rotating field through brushes/collector rings. This exciter is typically an SCR bridge controlled by a solid state voltage regulator circuit. This system can be designed to have excellent load response and voltage regulation.

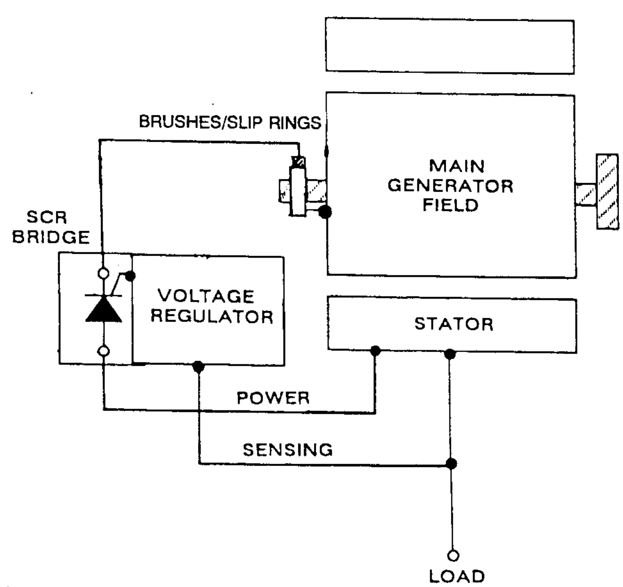


The disadvantages of static excited designs are found in the brushes and collector rings. These components are subject to routine maintenance such as inspections of brush wear and buildup of dirt and carbon on the collector rings.

(PowerBoost™)

The Kohler version of static excited generators feature a patented PowerBoost™ exciter regulator. It employs a separate auxiliary stator winding (independent of the main output) to power the field during fluctuations caused by load-on load-off situations.

This system provides excellent motor starting ability and maintains virtually constant voltage.



Voltage regulator System

Voltage regulators are basically variable DC power supplies that automatically control the magnetic strength of the rotor field. For static excited alternators this requires the voltage regulator to have a DC output voltage which is transferred to the rotor field via brushes and collector rings. The voltage regulators pictured on this page have been used over the years on the marine generators with brush type alternators.

These regulators have a +/- 2% voltage regulation and offer excellent motor starting capabilities.

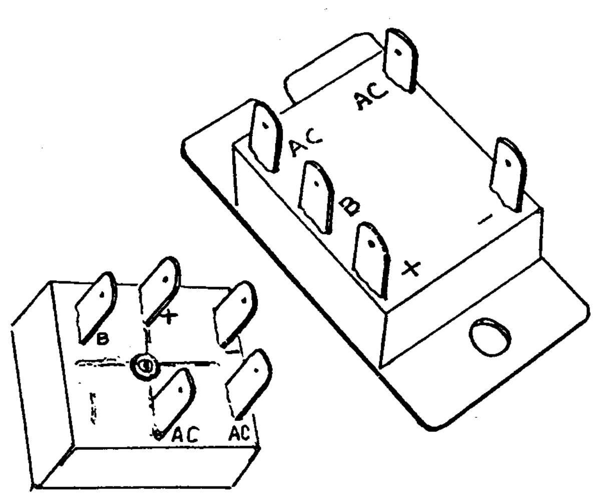
The regulators may draw between 2 and 5 amps depending on the style, application and load demand.

The main power component is a SCR connected in either a half wave or bridge configuration

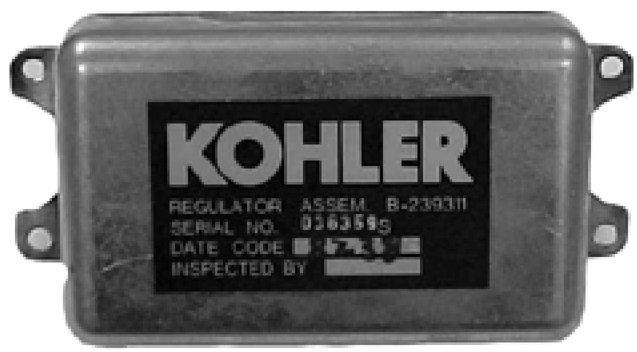
The finned design of the current voltage regulator (PowerBoost™ IIIE) provides a large surface area that dissipates heat from the SCR to the surrounding air.

The aluminum plate heat sink of the “5 pin” regulator requires a thermal compound between the plate and the mounting surface for good heat transfer from the regulator.

Failure to dissipate the heat properly will lead to premature regulator failure.



5 Pin Regulator



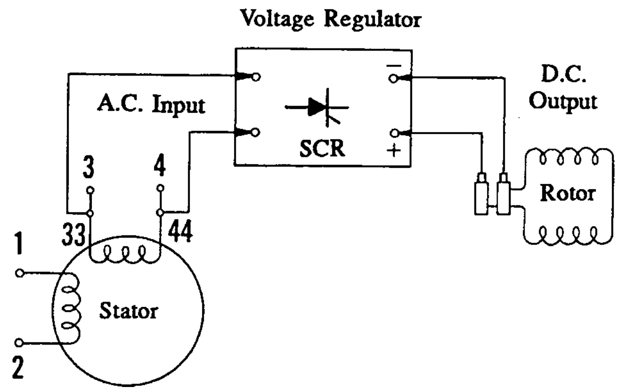
Power Boost and Power Boost III

PowerBoost™ IIIE

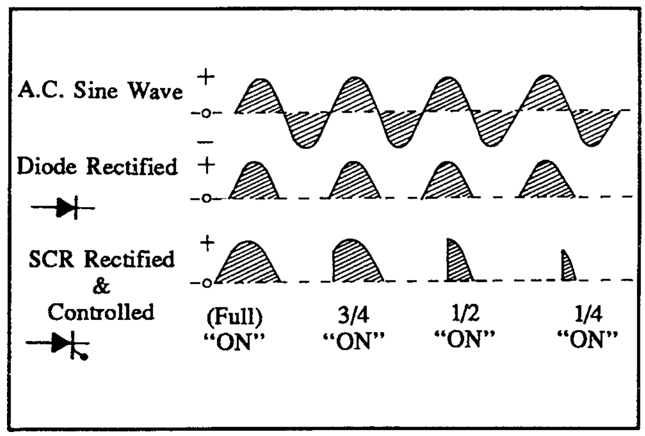
Static Excitation (Brush Type)

SCR Rectification

SCR's (silicon controlled rectifiers) are used to rectify the AC output voltage to a DC input voltage for rotor excitation.
A sensing circuit in the voltage regulator monitors the generator output voltage and provides a signal for controlled gating or conduction of the SCR's.



The Regulator will provide a DC output to the rotor whenever the voltage monitored is below the nominal setting. A voltage above the setting will turn the regulator (DC output) off. The regulator is constantly turning on and off in its attempt to maintain its nominal setting.



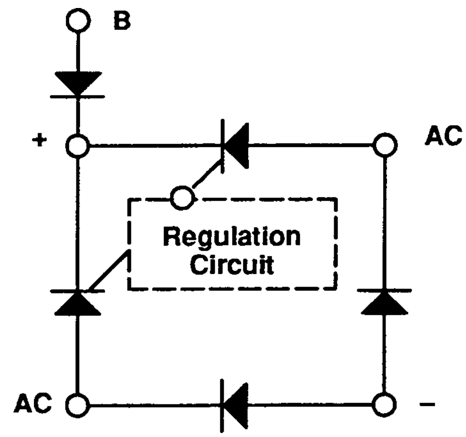
5 Pin Regulator

The 5-pin voltage regulator was used on the 7.5R marine models with nominal rotor resistance of 10 ohms. The voltage regulator assembly includes a bridge rectifier and voltage regulator circuit. AC from the stator is received at the "AC" terminals on the regulator. This current is rectified to DC by the bridge rectifier and supplied to the rotor from terminals (+) and (-) through the brushes and collector rings. The AC is constantly monitored by the regulator to maintain +/-2% variation of the stator output.

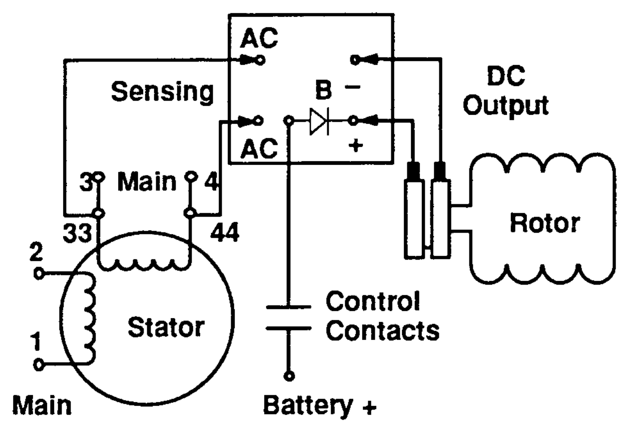
The power circuit consist of two SCR's and two diodes in a bridge configuration. The voltage regulator controls current flow to the rotor by gating the SCR thus turning on or off the current flow to the rotor.

The B terminal provides a path for battery (plus) to the positive slip ring to ensure voltage buildup or "field flashing" on start-up.

If replacement of regulator is necessary apply a thin coat of thermal compound to the mounting surface of the regulator before installing. This aids in dissipating the heat from the voltage regulator to the mounting surface allowing longer life of the regulator components.



5–Pin Voltage Regulator



Static Excitation (Brush Type)

Power Boost Regulator

The basic Power Boost regulator is non-adjustable +/-2% regulation and provides excellent motor starting response.

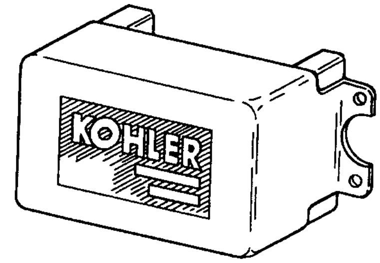
The Power Boost series features separate sensing and power input circuits.

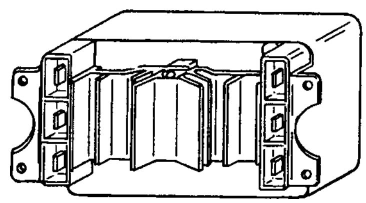
The regulators are used on generators with nominal rotor resistance of 3-4 ohms.

An auxiliary stator winding, (55 and 66) provides excitation power. The excitation power is rectified by a power SCR and is directed to the rotor slip rings.

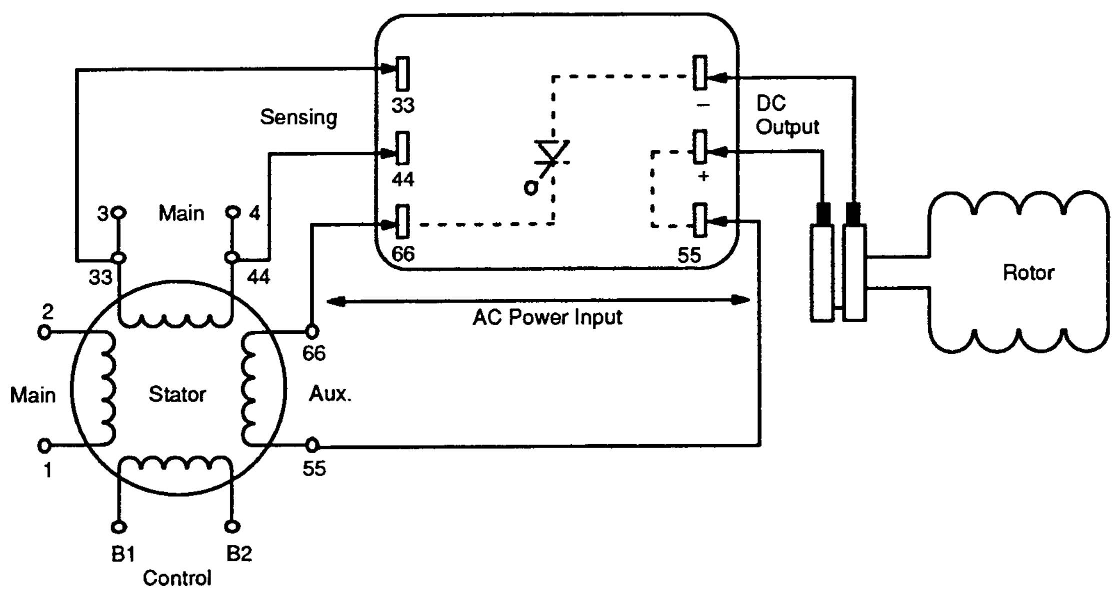
Voltage drop in the auxiliary winding when load is applied is relatively small in comparison to the main load winding; field forcing is therefore improved.

Note: The heat sink is electrically hot





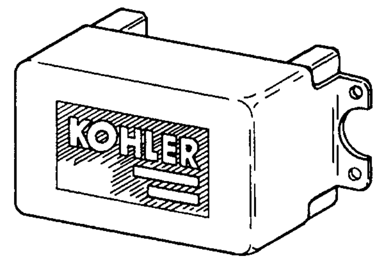
Power Boost Voltage Regulator

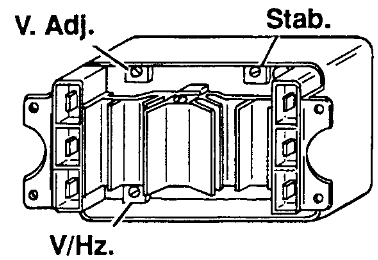


Static Excitation (Brush Type)

Power Boost III

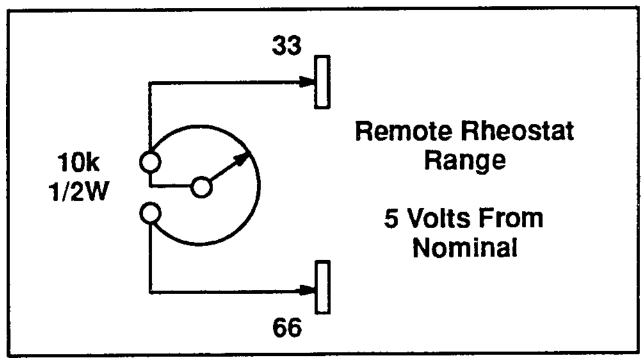
Power Boost III is similar in construction to the Power Boost regulator but allows for adjustments to the voltage and stability as well as a volts-per-hertz feature.



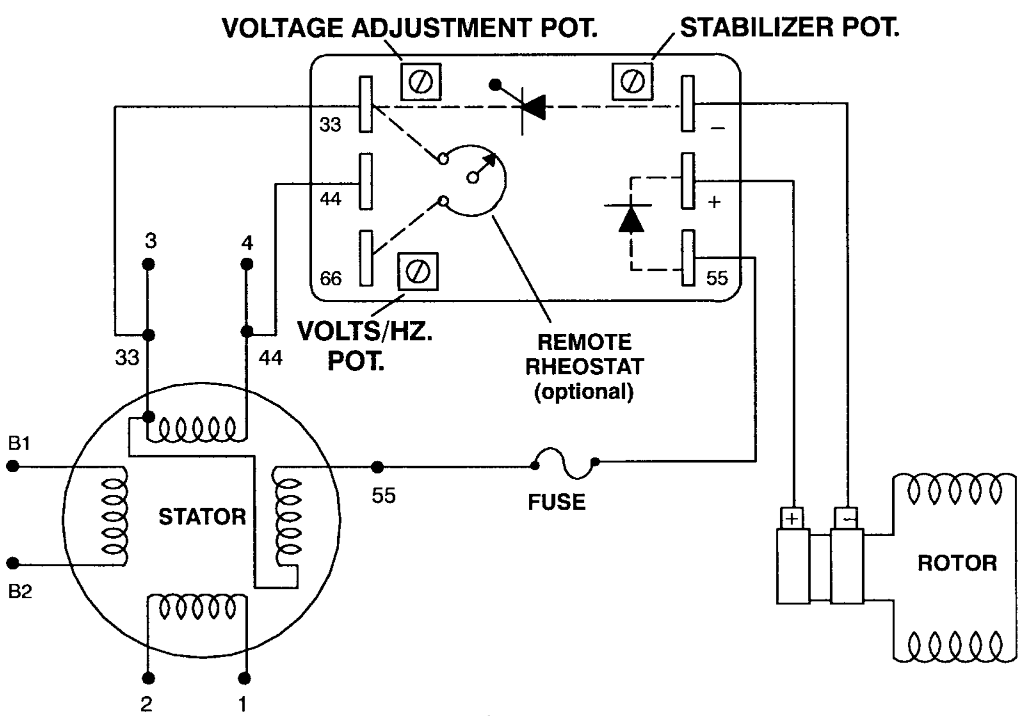


The volts-per-hertz feature allows the voltage to automatically decrease if the frequency (engine speed) should fall below a preset level. This decrease in voltage is seen by the prime mover as a proportional drop in kilowatt load and thus the prime mover speed recovers quicker. This volts-per-hertz response is usually seen when going from a no load to full load condition on the generator.

This regulator also allows for the connection of a remote voltage adjust rheostat. The 10K, ½ watt rheostat allows for a 5-volt adjustment from nominal setting.



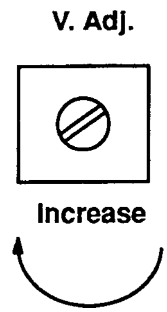
Note: Heat sink is electrically Hot.



Static Excitation (Brush Type)

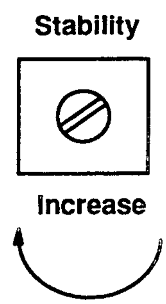
Voltage Adjustments

Volts adjustment - provides an output selection from 100 to 130 vac

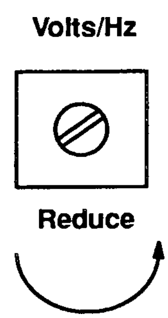


Stability - “fine tunes” regulator for minimum light flicker and voltage fluctuation.

To set stability:
1. With generator off rotate stability pot fully counterclockwise.
2. Start generator.
3. Turn stability pot clockwise until minimum flicker is obtained.



Volts-Per-Hertz -These regulators are factory set to reduce the generator output voltage if the frequency drops below 56.3 hertz. Field adjustments are typically not necessary.



To set Volts/Hz
1. With generator set off, rotate Volts/Hz pot. fully couterclockwise.
2. Connect voltmeter to AC circuit or an electrical outlet.
3. Connect frequency meter to AC circuit or an electrical outlet.
4. Start generator set and adjust engine speed to desired frequency (factory setting 56.3 Hz for 60 Hz operation; 46.3 Hz for 50 Hz operation) as measured on frequency meter. Generator load does not affect this adjustment.
5. Rotate Volts/Hz pot. clockwise until voltage level begins to drop (as measured on voltmeter). Once voltage drop is measured stop adjusting pot.
6. Return frequency back to desired setting.

Adjustment is complete, when set to these specifications the generator will attempt to maintain nominal output until engine speed drops to the adjusted cutout point.

PowerBoost™ IIIE

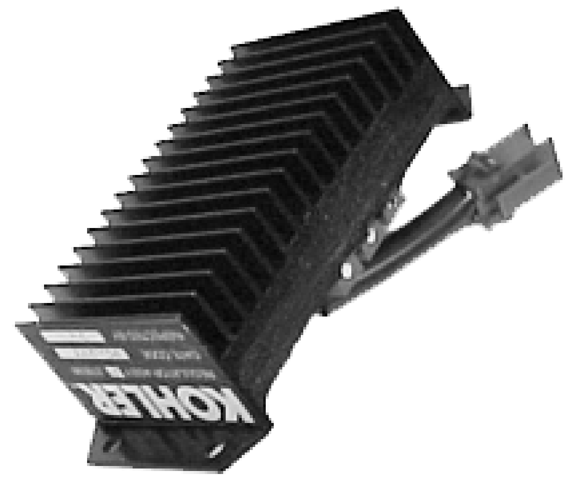
The PowerBoost™ IIIE is an enhanced version of the PBIII regulator. It has all the same features plus increased heat dissipation capabilities and a simplified harness connector.

Connection to the regulator is through a six pin connector.

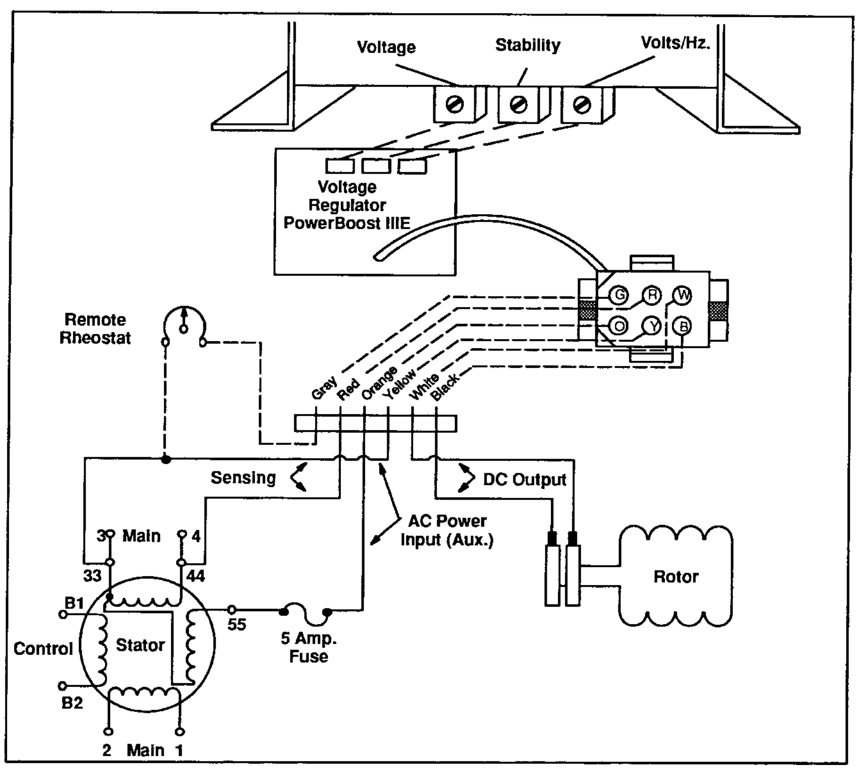
Specifications:

- Voltage regulation +/- 2%
- voltage adjust range 100-130 volts
- remote rheostat (optional) 10K ohms 1/2 watt
- remote rheostat range 5 volts
- stability adjust
- volts-per-hertz adjust factory set at 57 hertz

Note: The heat sink is isolated from the electrical circuit.



PowerBoost™ IIE

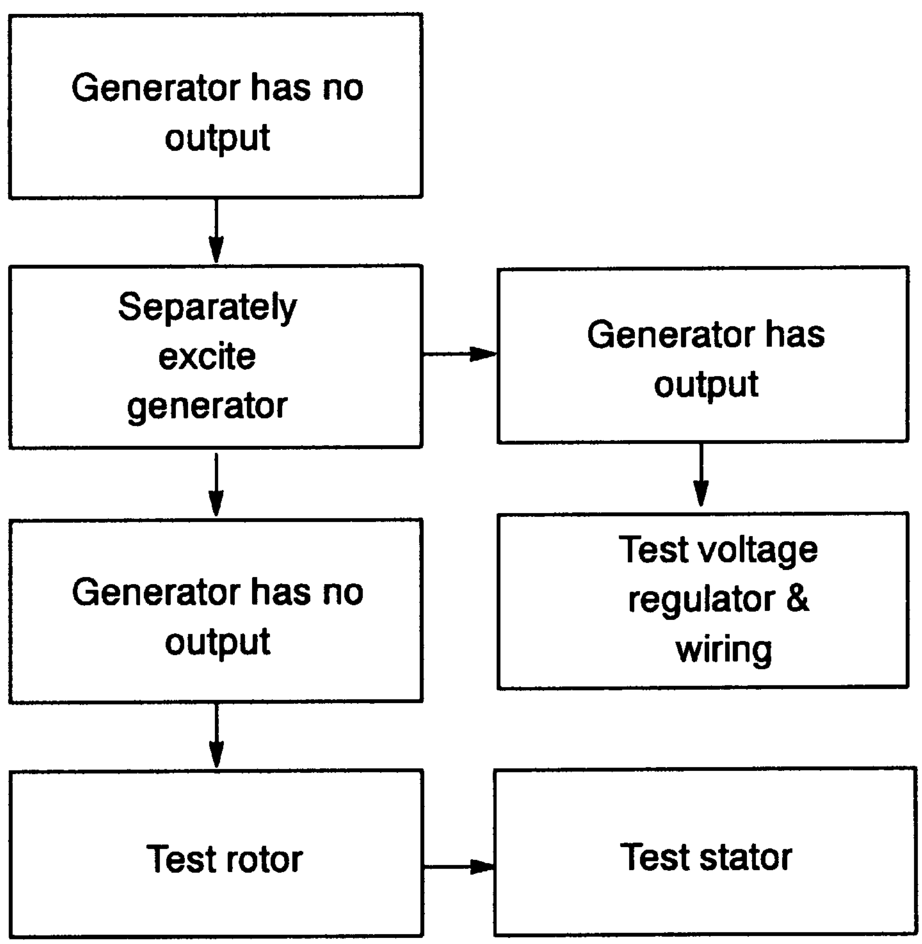


Separate Excitation (Brush Type)

Separate excitation of the generator can be performed to isolate the cause of no-or low-AC stator output to either the voltage regulator circuit or the generator components.

The exciter field may be magnetized using an outside DC power source (12-volt automotive battery). The separate excitation test duplicates the role of the voltage regulator in providing excitation current to the exciter field.

Separate excitation will determine if the voltage regulator is at fault or one of the alternator components. (brushes, rotor, or stator)

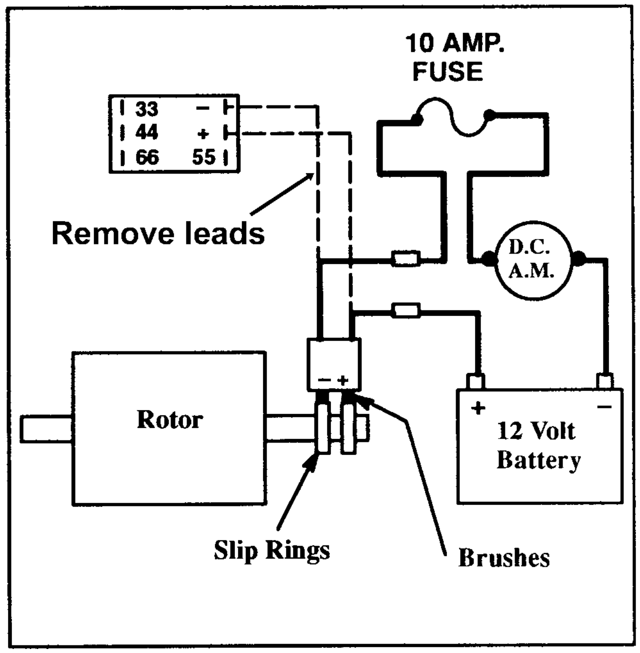


Static Excitation (Brush Type)

Separate Excitation

Power Boost
Power Boost III
PowerBoost™ IIIE

To determine the cause of no or low AC output, separately excite the generator. The generator field (rotor) may be magnetized using an alternative DC power source (12-volt automotive battery) and following the procedure below. While separately exciting the generator to determine the presence of a faulty voltage regulator, it is possible to determine if a running fault exists in the rotor and/or stator. A generator component that appears good while static (stationary) may exhibit a running open or short while dynamic (moving). This fault can be caused by centrifugal forces acting on the windings while rotating or insulation breakdown as temperatures increase.



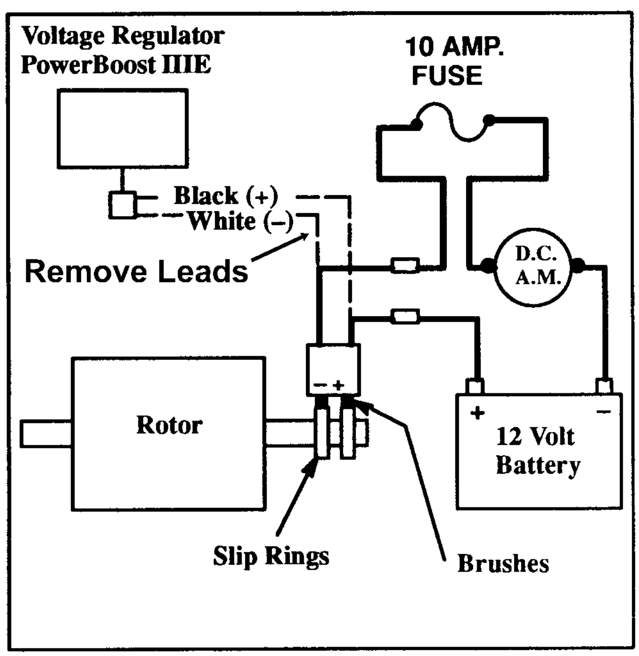
Power Boost I or Power Boost III

Procedure for separate excitation:

1. Disconnect all leads from voltage regulator
2. Connect an ammeter and a 12-volt automotive battery to the (+) and (-) brush leads. Include a 10amp fuse in the circuit in case of a shorted rotor.
3. The appropriate ammeter reading should be battery voltage divide by specified rotor resistance. Consult service manual for resistance specifications.

$$\frac{\text{Volts (battery voltage)}}{\text{Ohms (exciter resistance)}} = \text{Amps (Exciter Current)}$$

4. Start generator and check that ammeter remains stable. An increase indicates a shorted rotor. A decreasing or erratic meter reading indicates a running open.
5. If Ammeter reading is stable compare the stator winding output results with the specifications for the specific alternator found in the service manual. If output readings vary from specification the stator is likely to be at fault.
6. If the rotor and stator test good the voltage regulator is most likely defective.



PowerBoost™ IIIE

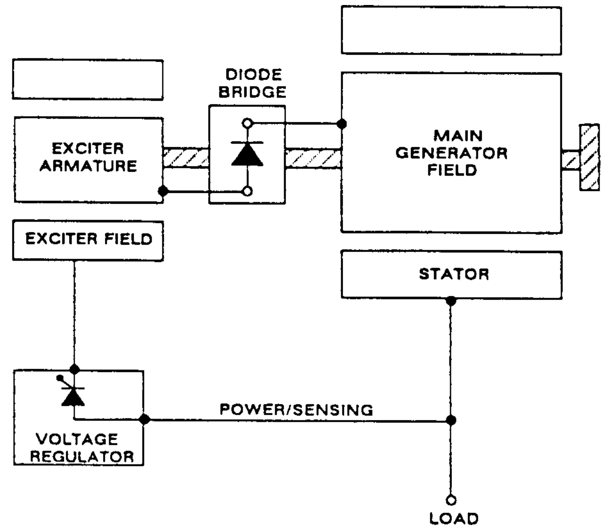
Wound-Field (Brushless Excited)

This system uses a wound exciter armature, which rotates on the same shaft as the main field. A voltage regulator supplies a regulated DC voltage to the field of the exciter generator by means of rectifying a small amount of the AC output from the main generator.

Because this system is brushless the voltage regulator is less likely to receive large power spikes inherent in the static excited type design.

This system is self-protecting on short circuits or extreme overload. When the generator has an overload or short circuit condition the voltage collapses leaving the regulator without enough power to excite the rotor to sustain the overload thus leaving loads without power.

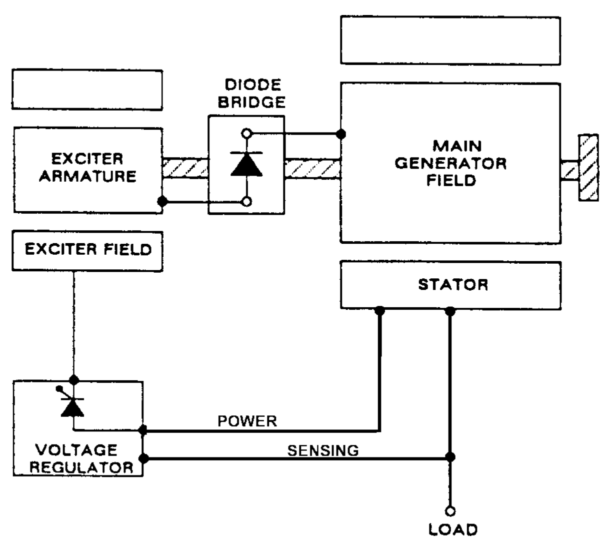
The chief disadvantage of this type system is that it has an inherent time constant of the exciter field, which makes it slower in recovery time compared to the static excited type.



Wound-Field Brushless Excited

PowerBoost™ (Wound-Field Brushless Excited)

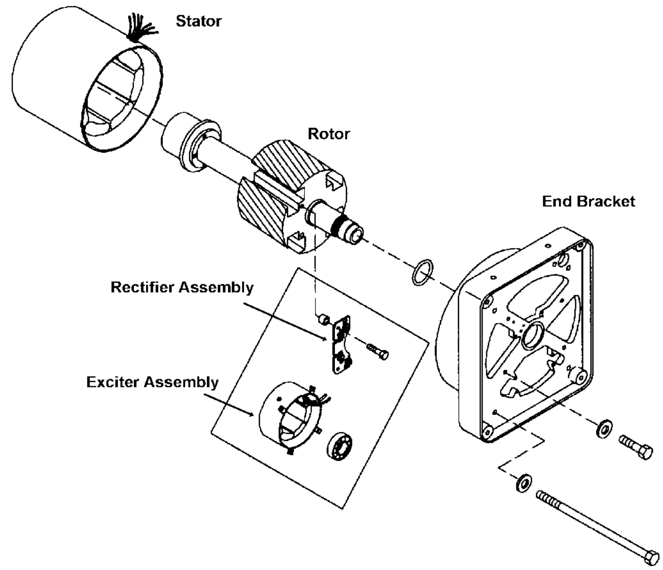
The PowerBoost™ design employs a separate auxiliary stator winding (independent of the main output) to power the field during fluctuations caused by load-on/load-off situations. Both the PowerBoost™ IIIE and PowerBoost™ V voltage regulators are used for voltage regulation depending on system requirements.



Power Boost
Wound-Field Brushless Excited

Brushless Exciter

The brushless exciter consists of an armature keyed to the main shaft, a diode assembly to rectify the AC armature output and the stationary exciter field assembly, which is controlled by the voltage regulator.

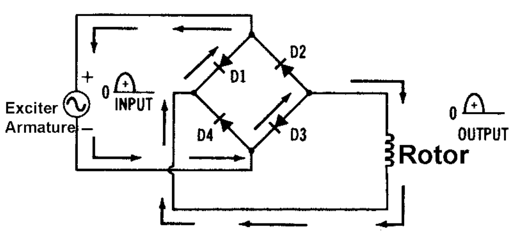


The single phase, exciter armature produces an AC output that is rectified to DC by the diode board assembly.

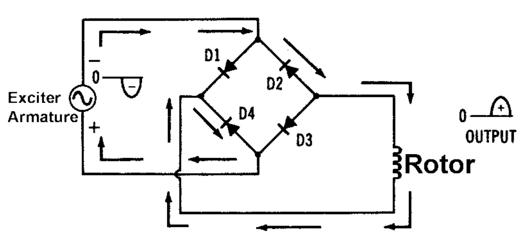
Diode Board

This diode configuration makes for full wave rectification of the single-phase input. During the operation of a single phase bridge rectifier two diodes are forward biased during each alternation of the AC input. When the positive half-cycle occurs diodes D1 and D3 are forward biased while D2 and D4 are reversed biased. A conduction path is then formed during the positive half-cycle.

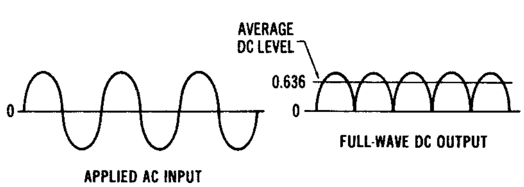
During the negative half-cycle Diodes D2 and D4 are forward biased and D1 and D3 are reversed biased forming a conduction path for the negative half-cycle.

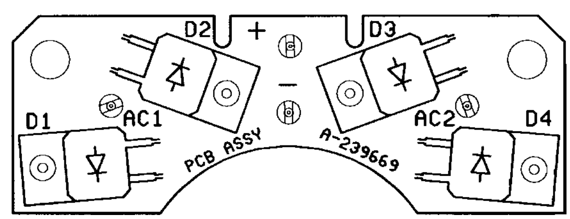


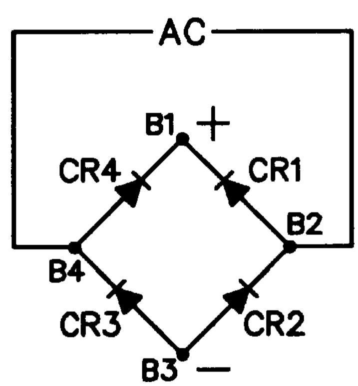
(A) Diodes D1 and D3 are forward biased.



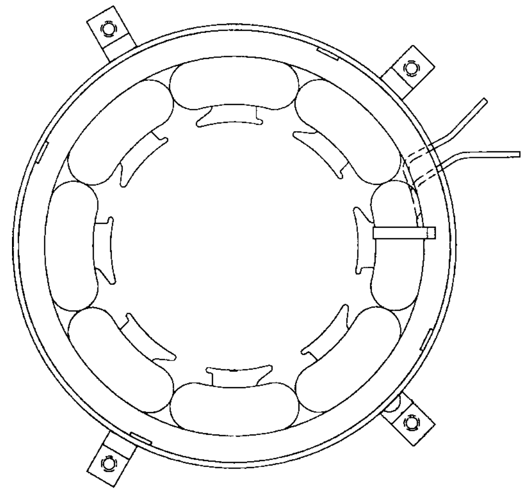
(B) Diodes D2 and D4 are forward biased.







Brushless Field



The eight pole, brushless field assembly is mounted to the end bracket assembly and provides the field flux for the exciter armature windings.

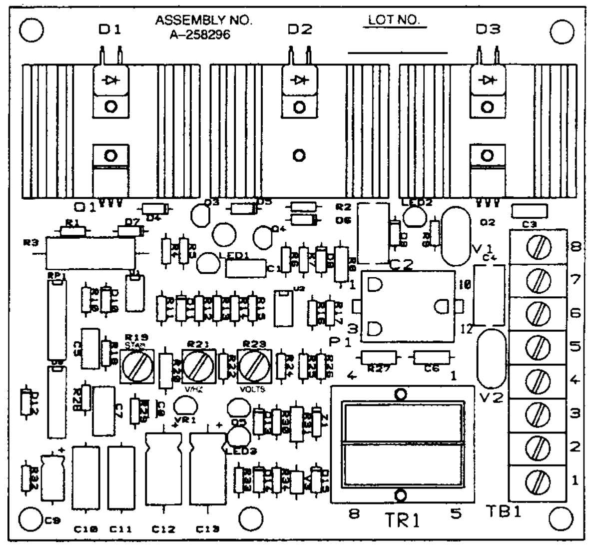
The eight coil assemblies are alternately wound; series connected and terminate at terminals F1 and F2.

The DC power to the F1 and F2 leads is from the output of the voltage regulator.

Initial field excitation or “field flashing” is supplied during engine start-up from controller relay contacts to terminals FP (+) and FN (-).

PowerBoost™ V (A-258296)

The Kohler PowerBoost™ V is a versatile +/-2% volts per hertz voltage regulator for use on both single and three phase 50 and 60 hertz generators.The power circuit consists of a diode/SCR full wave bridge to provide the generator field excitation.



Power requirements:

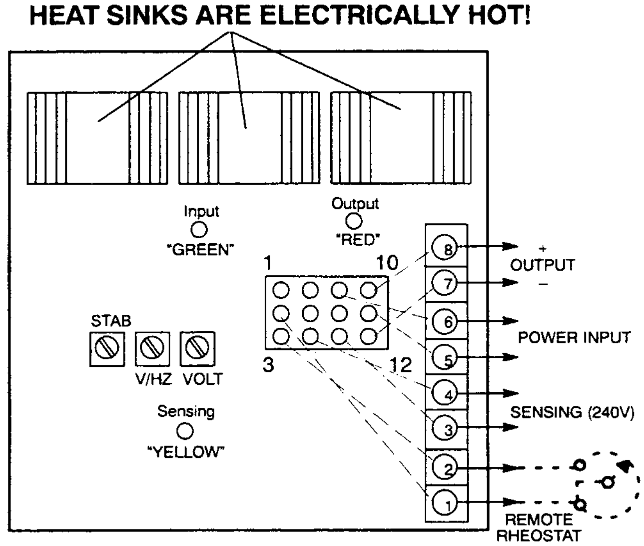
Input Power: 140-170vac

Sensing: 240vac

Both a plug and terminal strip are provided for input and output connections.

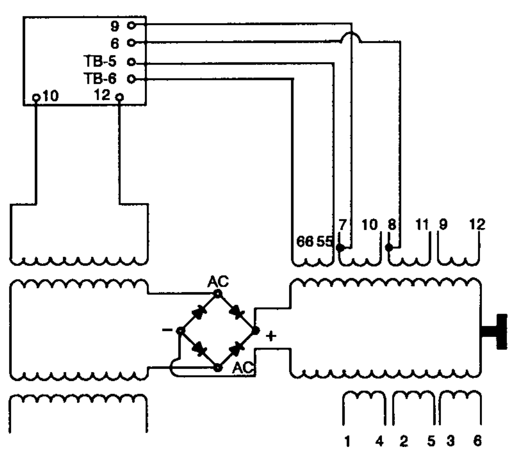
LED's on the regulator board offer a visual indication of sensing, input power, and field output availability.

HEAT SINKS ARE ELECTRICALLY HOT!



LED 1: Input power to the board (Green)
LED 2: DC output to the exciter field (Red)
LED 3: Sensing voltage into the board (Yellow)

The regulator board has three adjustment potentiometers; voltage adjustment, stability, and volts per hertz.
The voltage adjustment allows a generator output range of 190 to 277 volts (line to line) Terminals are provided for an optional remote rheostat to allow for a 5-volt deviation. (10K-1/2W)
The stability potentiometer fine-tunes the regulator circuit for minimum light flicker.
The volt per hertz adjustment is factory set at 57.5-58 HZ for 60 HZ applications and 47.5-48 Hz for 50 Hz operation.
The volts per hertz feature reduces generator output voltage if the frequency drops below the preset value. This drop usually occurs due to a heavy load application and allows to the engine to recover speed.

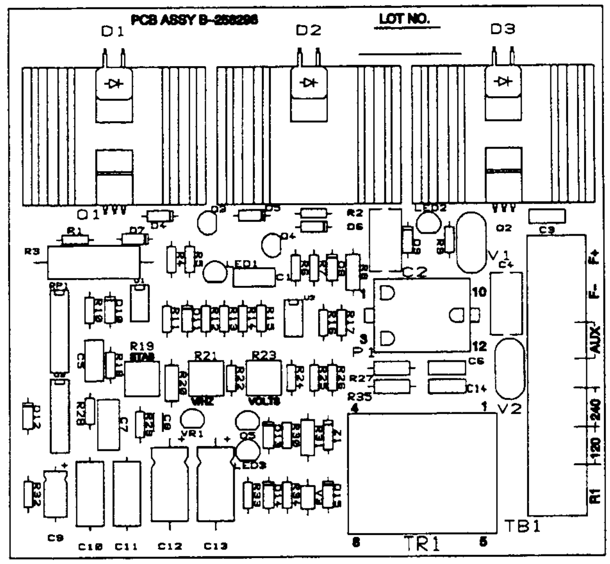


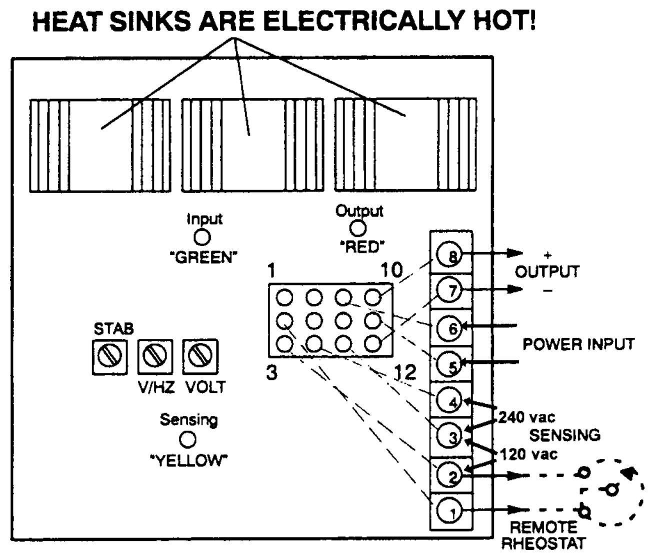
volts per hertz adjustment procedure: (Requires AC voltmeter and frequency meter)

1. Rotate the V\Hz potentiometer fully counterclockwise.
2. Reduce engine speed to desired cut-in frequency.
3. Adjust V\Hz pot clockwise until the voltage just begins to drop.
4. Return engine speed to normal operation.

PowerBoost™ V (B-258296)

The "B" version has all the features of the A-258296 regulator plus provisions for both 120 vac and 240 vac sensing. This allows the regulator to be used on 120 volt, 120/240-volt 1-phase models as well as all three-phase models.



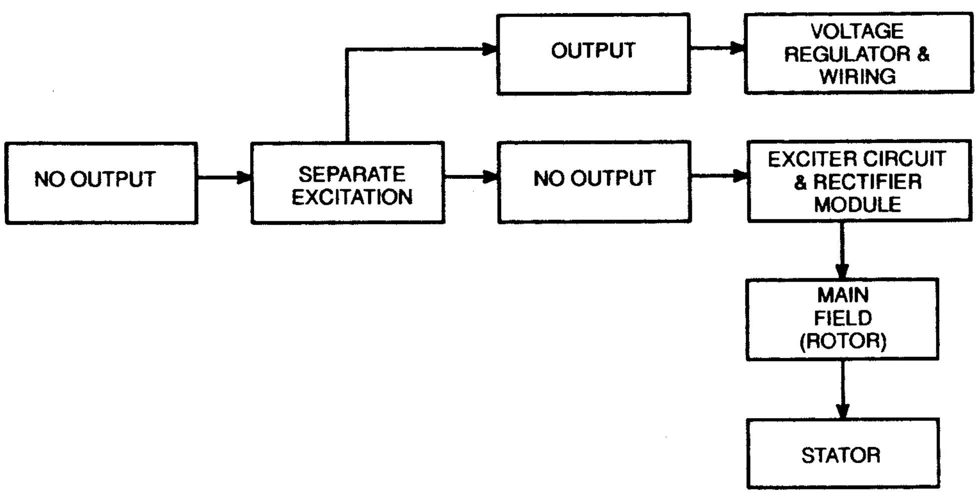


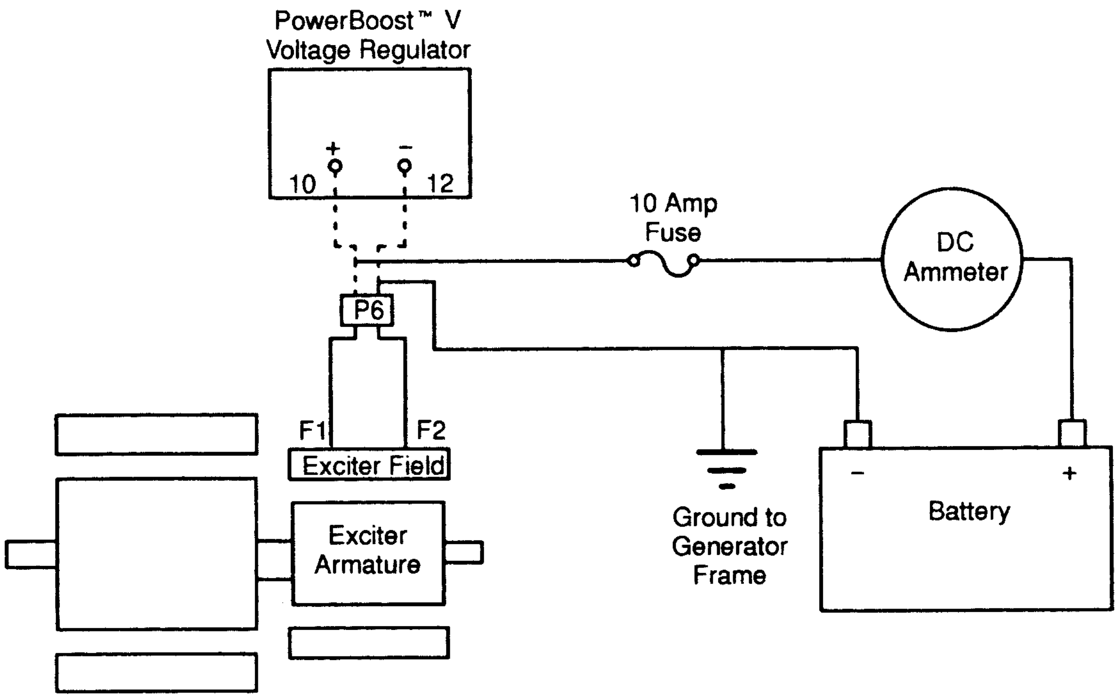
Separate Excitation

Separate excitation of the generator can be performed to isolate the cause of no- or low-AC stator output to either the voltage regulator circuit or the generator components.

The exciter field may be magnetized using an outside DC power source (12-volt automotive battery). The separate excitation test duplicates the role of the voltage regulator in providing excitation current to the exciter field.

Separate excitation will determine if the voltage regulator is at fault or one of the alternator components (exciter field, exciter armature, rotor, stator, and rectifier module) are faulty.





Separate Excitation Connections

Procedure for separate excitation:

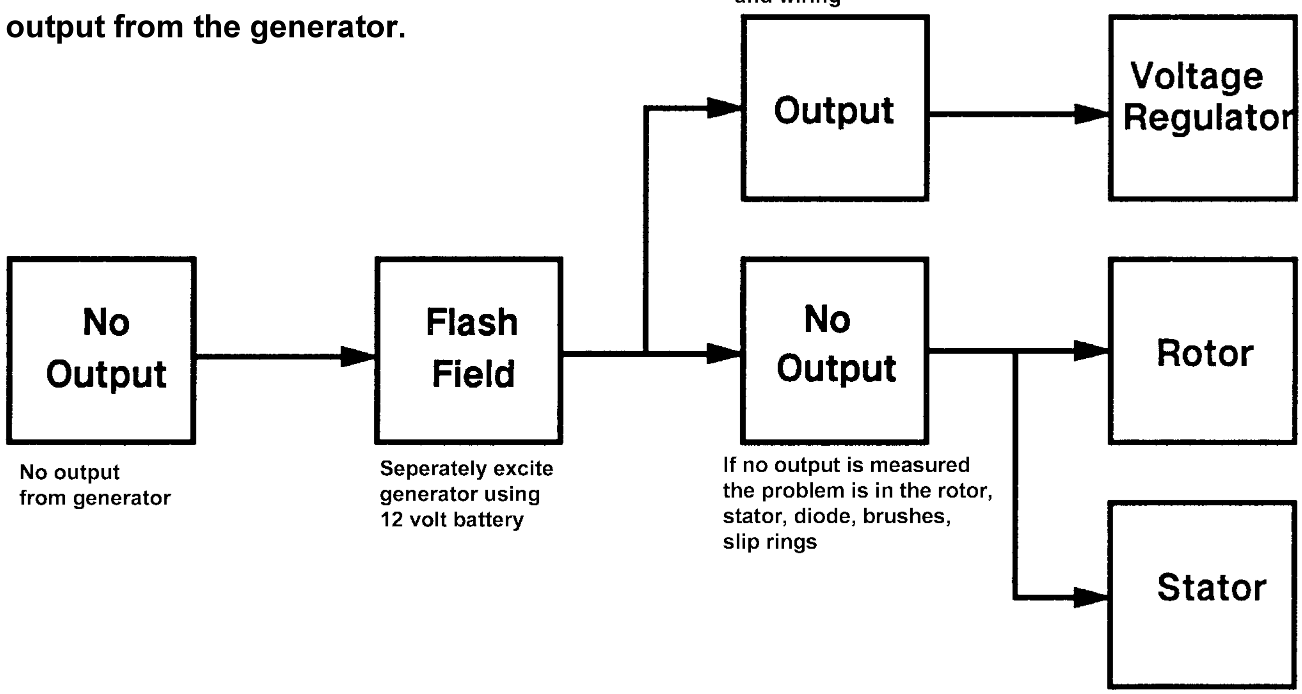
1. Disconnect all leads from voltage regulator
2. Disconnect F1 and F2 connectors to Exciter field. Connect seperate excitation circuit as shown.
3. The appropriate ammeter reading should be battery voltage divide by specified rotor resistance. Consult service manual for resistance specifications.
4. Start generator and check that ammeter remains stable. An increase indicates a shorted exciter field. A decreasing meter reading or erratic, indicates a running open in exciter.
5. If Ammeter reading is stable compare the Stator winding output results with the specifications for the specific alternator found in the service manual. If output readings vary from specification the stator is likely to be at fault.
6. If rotor and stator test good the voltage regulator is probably defective.

$$\frac{\textbf{Volts (battery voltage)}}{\textbf{Ohms (exciter resistance)}} = \textbf{Amps (Exciter Current)}$$

Alternator

This section will cover general troubleshooting fundamentals used when diagnosing alternator problems. When servicing a generator use specified service manual and follow all safety precautions.

Follow the troubleshooting flowchart to determine the cause of no or low AC output from the generator.



Disconnect generator starting battery before testing any parts of the alternator assembly!!!!

Testing The Stator

The stator consists of a series of wire coils placed in a laminated steel frame. The stator leads can supply voltage to the AC load, voltage regulator, or controller depending on the function of that output coil. Prior to testing, inspect the stator for heat discoloration and visible damage to housing, exposed coil windings and exposed varnished areas of frame laminations. If visible damage exists the stator will need to be repaired or replaced.

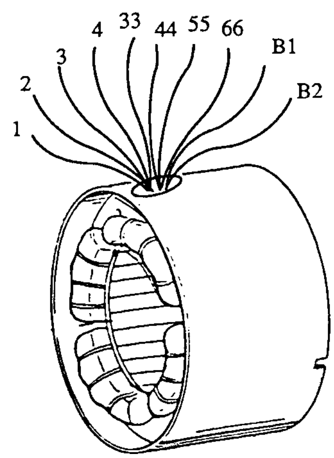
Checking Stator Continuity and Resistance

Tools required: Ohmmeter, Megger
The example illustrates a single phase alternator.

Note: Refer to service manual for all specifications with regards to winding resistance values.

Continuity

1. To check stator continuity, set ohm meter to a low resistance setting. This test will check if any coils are shorted to each other or there is a short to ground.
2. Dissconnect all stator leads prior to performing measurements.



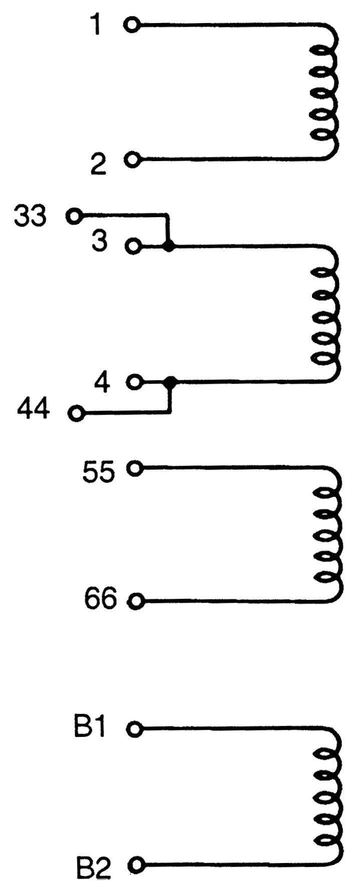
Leads1, 2, 3, and 4 are the generator output leads. Leads 33, 44, 55, and 66 are the voltage regulator sensing and power leads. The output leads B1 and B2 are supply for control voltage.

This is a typical single phase generator, the generator you test may be different, consult service manual for specific function of the stator output windings.

3. Check continuity of all windings, the meter should show continuity when checking between leads 1-2, 3-4, 33-44, 55-66, B1-B2.
4. Check for continuity between coil groups, meter should show no continuity. If the meter indicates continuity this means the two coil groups are shorted together.
5. Check continuity between each coil group and the frame of the stator, meter should show no continuity. If the meter shows continuity this indicated the coil is shorted to ground.

Resistance

Most ohmmeters will not provide acurate readings when measuring less then 1 ohm, which is typical for a stator winding. The stator can be considered good if a low resistance reading is obtained in each coil group and there is no evidence of an internally shorted winding (heat discoloration).

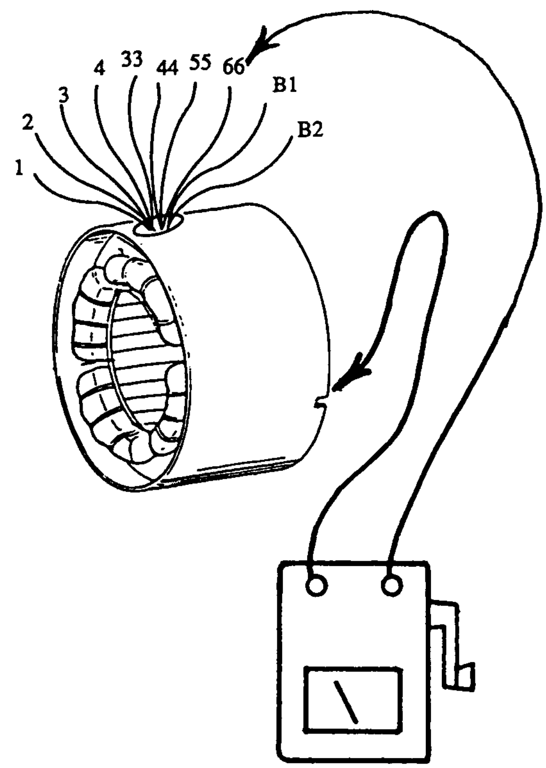


Megger Testing

The purpose of insulation is to prevent shorting between the windings, lamination slots and any conductive material used in the generator construction. If this insulation deteriorates or breaks down a current path can be created between the copper windings and the frame structure. This breakdown may not be detected when performing a continuity test.

Dirt, grease, chemical fumes, aging and moisture are some of the contributing factors that can lead to the insulation breaking down.

A megger can be used to test for possible current leakage to ground that was not detected during continuity testing. Meggers apply a voltage between the insulated conductor and the material they are insulated from, usually ground. They determine the resistance flow across the insulation of the conductor. These resistance values are very high, in the millions of ohms.



MEGGER

1. Prior to operating a megger disconnect all stator leads.

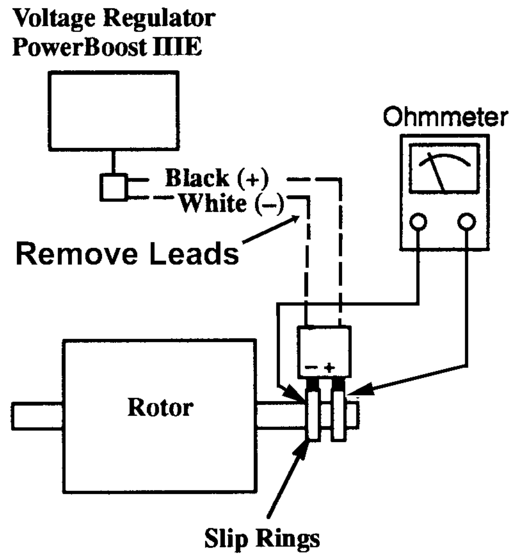
2. You can keep the load leads connected together but it is recommended that you disconnect all individual coils and test each one individually.

3. The positive lead of the megger should be attached to the lead coil being tested on the alternator and the ground lead attached to the frame.

4. Perform the megger test following the instrument instructions.

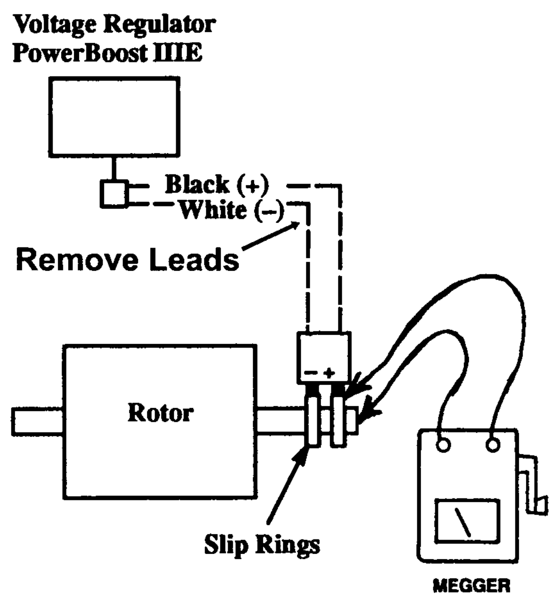
5. As a general guideline if the insulation resistance is greater then 1.5 megohms the insulation leakage is considered accept - able. If it is below 1.5 megohms the stator needs to be serviced. Always refer to instrument instruction or generator specification when determining when insulation leakage is sufficient to warrant repair or replacement.

Testing Rotor (Brush Type)



Prior to testing the rotor, inspect exposed coil windings, brushes and slip ring surfaces. Check rotor bearing for noisy operation, excessive wear, and heat discoloration. Replace or repair if needed.

To check the rotor for continuity place the meter leads on the two slip rings. Set meter to lowest setting for measuring resistance. If a high resistance reading is found this indicates an open winding. Typical measurement readings can be found in the specification section of the service manual for the particular rotor being tested.



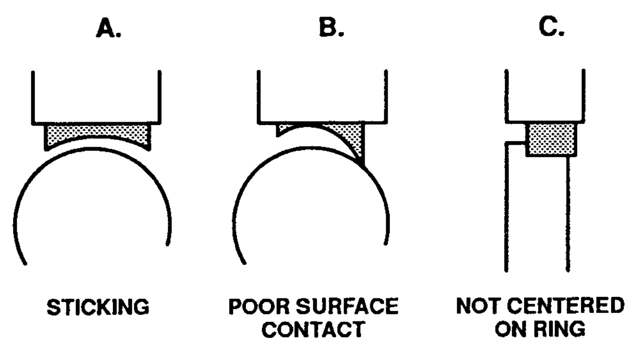
To test for a grounded rotor place one meter lead to a slip ring and the other lead to the rotor shaft. Meter should register no continuity.

Megger readings can also be taken by placing one lead of the megger to a slip ring and the other to the rotor shaft. If reading is above .5 megohms the insulation leakage is acceptable. If reading is below .5 megohms this indicates there may be current leakage to ground and servicing is needed. The rotor may have moisture and needs to be dried out or the insulation is weak and the rotor will need to be serviced or replaced.

Note: Make sure when taking resistance readings or performing a megger test that the brushes are not in contact with the slip rings.

Inspecting Brushes

When performing inspection on brushes it is important to note the brushes are not sticking, have good surface contact with the rings, and the brushes are centered and riding completely on the rings. Severe arching on the brushes may cause regulator to fail and also may damage the slip rings.



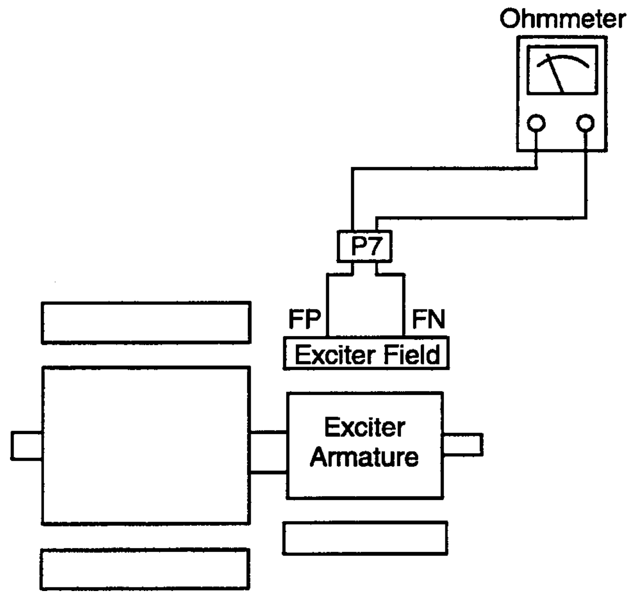
BRUSH CONTACT

Testing Rotor Assembly (Brushless)

Resistance test (Exciter Field)
Testing the rotor assembly of the brushless rotating exciter alternator includes testing the exciter field, exciter armature, main rotor field, and diode assembly.

Before testing the exciter field disconnect plugs for wires FP- FN and FI - F2.

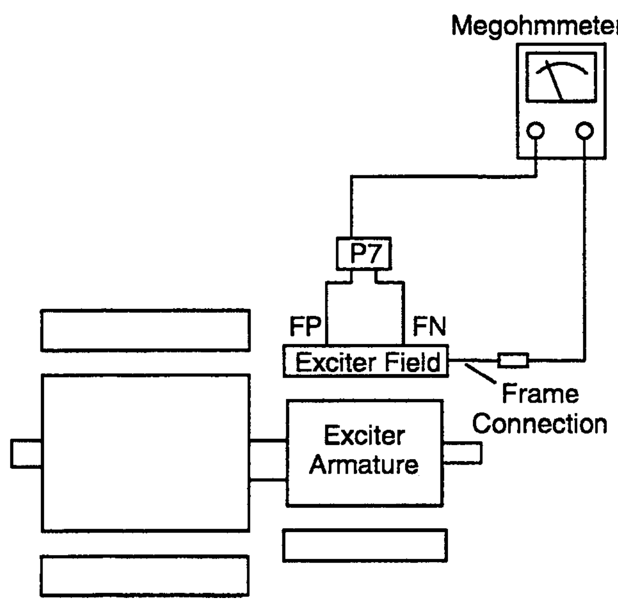
Connect ohmmeter to plug FP – FN,(connection to the exciter field). High resistance indicates an open winding, and a very low resistance (near zero) indicates a shorted winding. Refer to specification section of the generator service manual for the correct resistance reading of the exciter field.



Megger Test (Exciter Field)

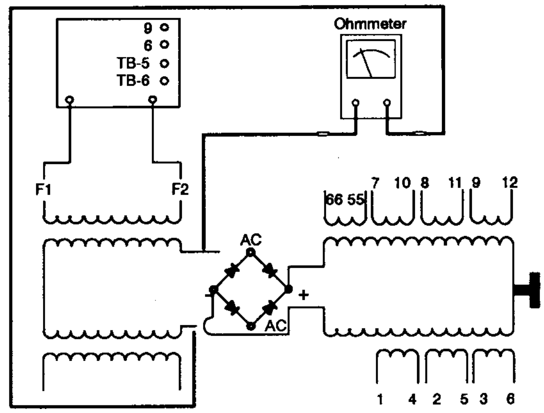
If resistance test proves inconclusive, perform a megohmmeter test.

Connect negative lead of megger to ground and positive to exciter field. Apply 500vdc to coil following instrument instructions. If reading is higher then .5 megohms the insulation is good, if lower this indicates possible leakage of current to ground and servicing is required.



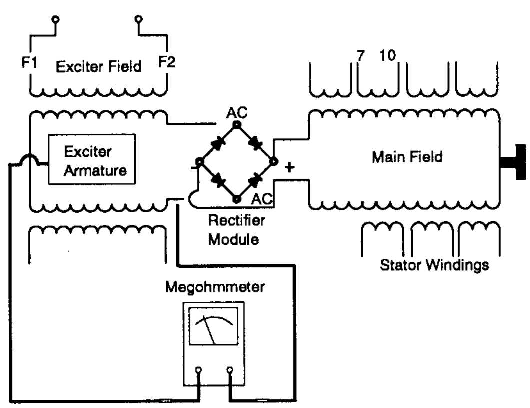
Resistance Test (Exciter Armature)

To test the exciter armature disconnect armature leads from the rectifier module AC terminals. Connect ohmmeter following diagram, check across armature leads. Armature resistance values can be found in the specification section of the service manual. No continuity indicates an open winding. The winding resistance value of the armature winding is very low; most ohmmeters will not provide accurate readings when measuring less than one ohm. The armature winding can be considered good if a low resistance reading is obtained and there is no evidence of shorted windings.
(heat discoloration)



Megger Test (Exciter Armature)

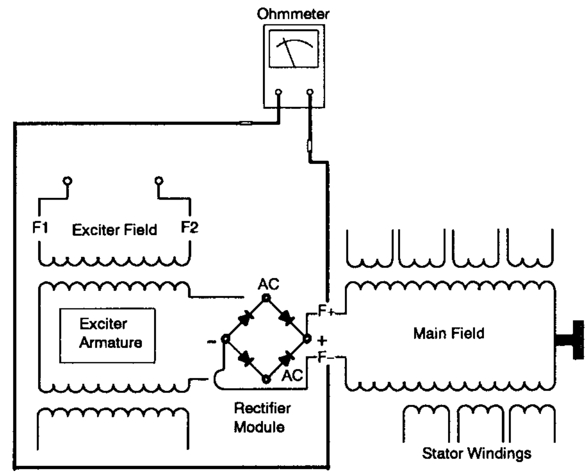
To check exciter armature for a grounded condition perform a megger test. Connect megger according to diagram and follow instrument instructions. Apply 500 vdc. Readings above .5 megohms indicates exciter armature is good. A reading below .5 megohms indicates deterioration of winding insulation and possible current leakage to ground. Servicing is required.



Note: Leads must be removed from the rectifier board in order to get accurate results.

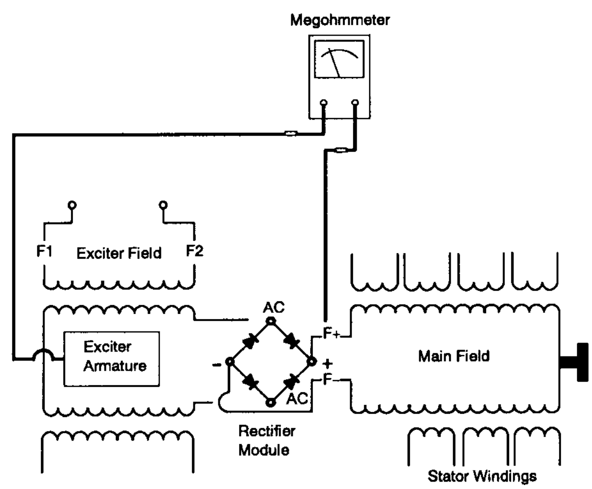
Resistance Test (Rotor)

To test the rotor disconnect generator main field (rotor) winding from the rectifier module. Connect the ohmmeter across main field leads. The resistance reading for a cold main field winding will be found in the specification section of the service manual. A very low reading (near zero) indicates a shorted winding and a high reading indicates an open winding.

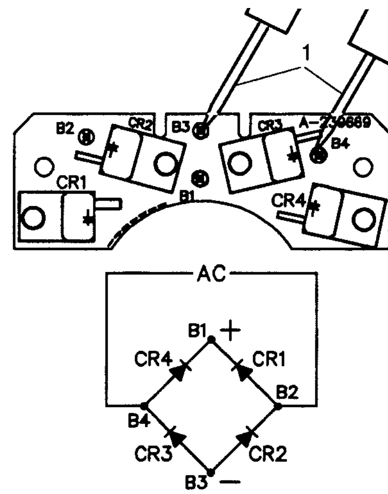


Megger test (Rotor)

To check the main field for a grounded condition perform a megger test. Use the megohmmeter and connect the positive lead to a main field lead and the negative lead to the frame, apply 500 vdc following the instrument instructions. A reading of 500K ohms and higher indicates the main field insulation is good, a reading below 500K ohms indicates deterioration of the winding insulation and possible current flow to ground. Repair or replacement of the main field is necessary.



Rectifier module



The rectifier module converts the AC from the exciter armature to DC, which magnetizes the generator main rotor field.

To test the rectifier

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

2. Use an ohmmeter on the R x 100 scale or a multimeter with a diode check. Following the bridge rectifier diagram check all diodes. If using the Ohmmeter the diode should show a low resistance in one direction and upon reversing the leads show a high resistance. if any diodes test bad the board must be replaced.

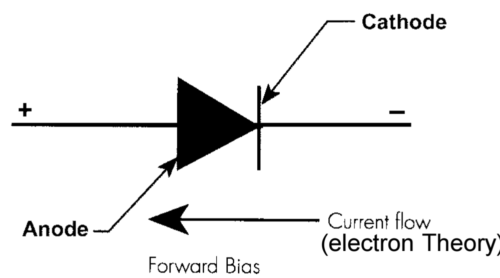
Testing Diodes

Open and shorted diodes are the two most common problems associated with defective diodes. Here is how to interpret ohmmeter readings to determine a diode's condition.

Open Diode. When taking two sets of resistance readings, one with test leads connected positive-to-anode, negative-to-cathode, and one with negative-to-anode, positive-to-cathode, high resistance readings are obtained in both cases.

Shorted Diode. When taking two sets of resistance readings, one with test leads connected positive-to-anode, negative-to-cathode, and one with negative-to-anode, positive-to-cathode, low resistance readings are obtained in both cases.

Good Diode. When taking two sets of resistance readings, one with test leads connected positive-to-anode, negative-to-cathode, and one with negative-to-anode, positive-to-cathode, the first connection provides a low resistance reading. The second connection provides a high resistance reading.



Electron theory states electron current flow is from negative to positive. Conventional current theory states current flows positive to negative.

Exciter Field Voltage/Current Readings at Rated Voltage (Hot)*		
– No Load (63 Hz)	19 Volts/0.9 Amps	12 Volts/0.8 Amps
– Full Load (60 Hz)	32 Volts/1.5 Amps	33 Volts/2.2 Amps
Resistor (F1 Lead to Exciter Field)	15 Ohms ± 2 Ohms	10 Ohms ± 2 Ohms
Exciter Field Resistance (Cold)	4.8 Ohms	4.8 Ohms
Exciter Armature Resistance (Cold)	1.2 Ohms	1.2 Ohms
Main Field (Rotor) Resistance (cold)	5.0 Ohms	5.7 Ohms
Stator Output Voltages With Separately Excited Generator, Using 12-Volt Battery (60 Hz only)*		
– 1-2, 3-4, 33-44	81 Volts	115 Volts
– 33-55	105 Volts	155 Volts
– B1-B2	10 Volts	15 Volts
Stator Resistance (Cold)		
– 1-2, 3-4, 33-44	0.3 Ohms	0.2 Ohms
– 33-55	2.1 Ohms	1.9 Ohms
– B1-B2	0.1 Ohms	0.1 Ohms

*Includes resistor in exciter field circuit.

Example of specifications found in service manual

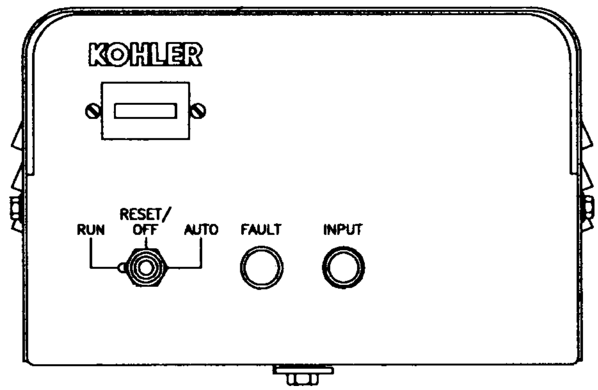
Note: Resistance readings are typically taken when the generator is "cold" which is considered room temperature and the generator has not been running.

Voltage and current readings are taken "hot" meaning the generator temperature has stabilized while generator is running under a loaded condition.

Generator Controller

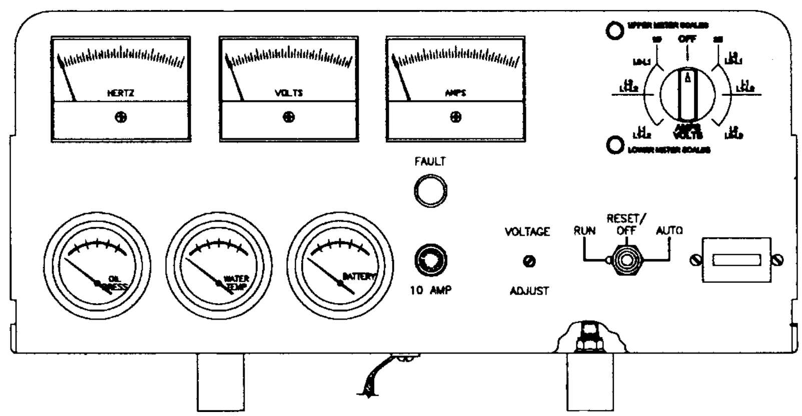
Decision-Maker™ 1
1 light relay controller

Decision-Maker™ 1 Expanded
1 light relay controller with gauges and metering



The controller cabinet contains the engine control components: Relay Control Board, Governor Controller, Cycle Cranking Board, K20 relay, AC terminal strip, Hourmeter, 10 Amp fuse, and the Start \ Stop Switch.

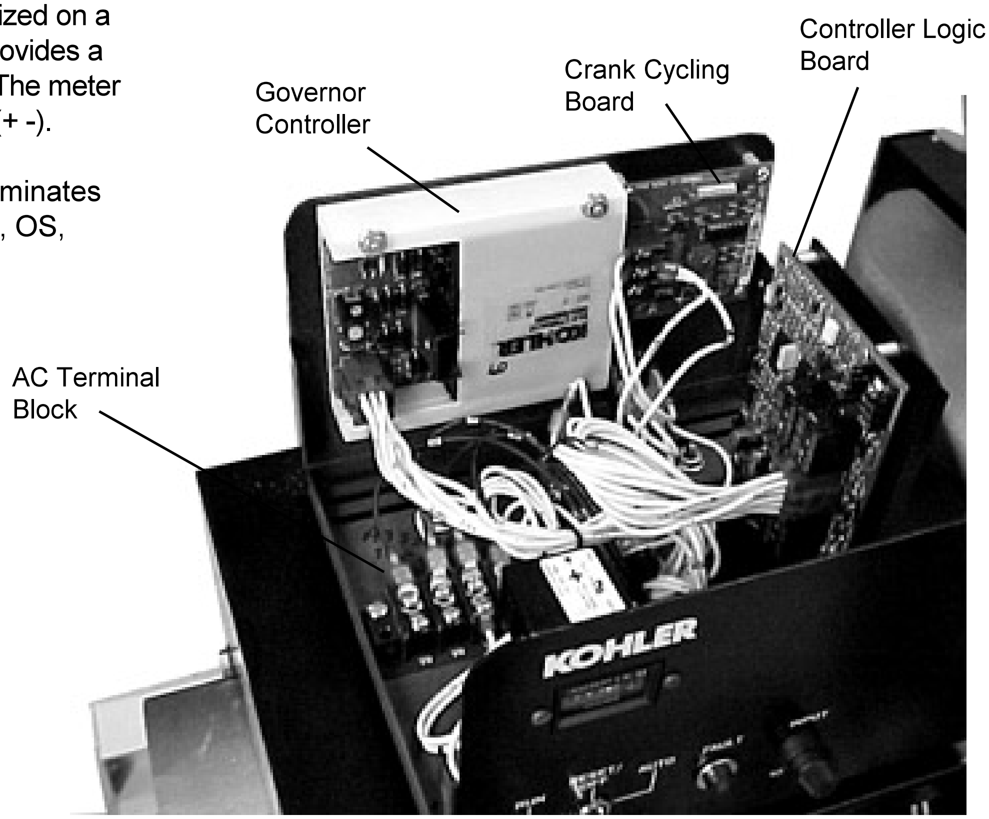
The 10 Amp F1 fuse provides protection of the control circuits supplied by the 12 volt starting battery.



The relay controller with meters have 3 additional 1.5 Amp 250 volt fuses labeled V7, V8, and V9. These fuses provide protection to the AC circuit in the controller including the voltage selector switch and meters.

The hour meter is energized on a Start \ Run signal and provides a recorded total run time. The meter has polarized terminals (+ -).

The single fault light illuminates on all engine faults, OC, OS, HWT, LOP, LWL, and must be reset at the generator controller by moving the Start \ Stop switch to the OFF \ RESET position.



Control Board

The main control board contains relays for starting and stopping the Generator set.

The board features a timer to provide 30 seconds of total engine cranking time and terminates cranking if a successful run signal is received.

A circuit is also provided which after an engine start, allows a 5 second delay prior to sensing the Oil Pressure and Engine Temperature condition. This is to allow time for the engine to stabilize and build up oil pressure.

The control circuit provides starter motor reengagement protection when the engine is running via input signals of generated AC as well as shaft rotation.

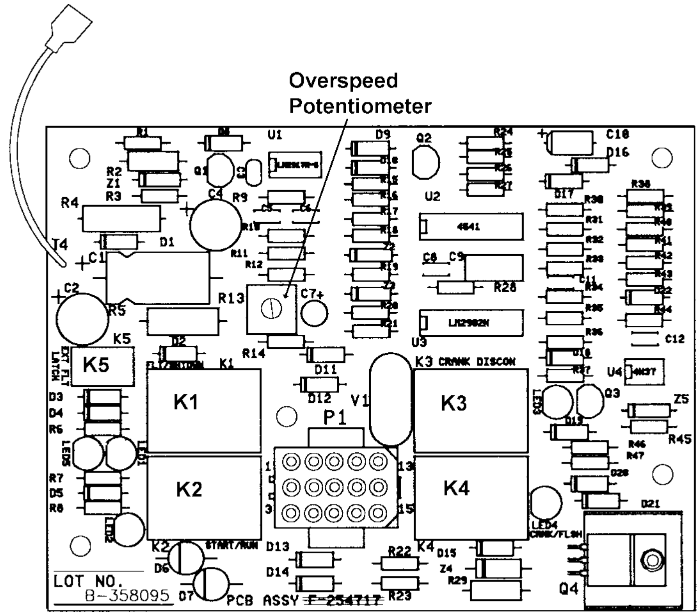
An engine overspeed circuit is provided and factory set to shut down the generator set if engine speed exceeds 4320 RPM (72 Hz).

Five relays are mounted to the board for control of Engine Cranking (K4), Cranking Disconnect (K3), Start / Run (K2), Fault Shut Down (Kl) and Remote Latch (K5).

LED's are connected across the relay coils for visual operational analysis.

Placing the switch to the OFF/ RESET position after a normal run will shut down the engine and deenergize all control relays. If the engine is shut down due to a fault the K2 and K5 relays will remain energized until the selector switch is placed in the OFF position.

The RUN LATCH feature is provided to prevent resetting the logic and restarting the engine from a remote location without first correcting the cause of failure. Lead T4 provides (K5) contact closure across the remote start leads to prevent remote restart after the unit shuts down on a fault, forcing the operator to reset the fault at the generator, (K5) closes on a fault and opens on a reset.



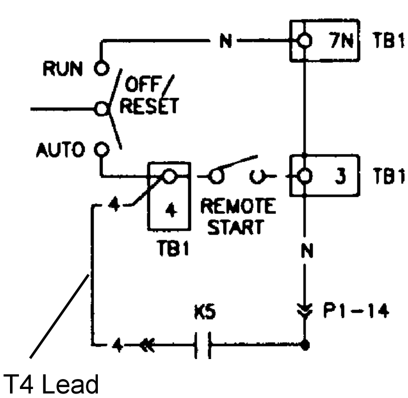
K1- Energized on fault, OC, OS, HWT, LOP, LWL

K2- energized in run or crank mode

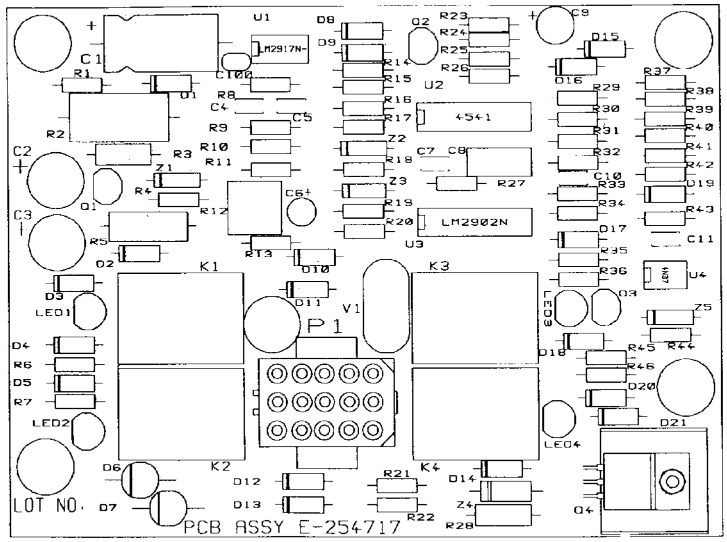
K3- Energized on crank disconnect

K4- Energized when cranking

K5- Energized on fault (remote latch)



Controller Board



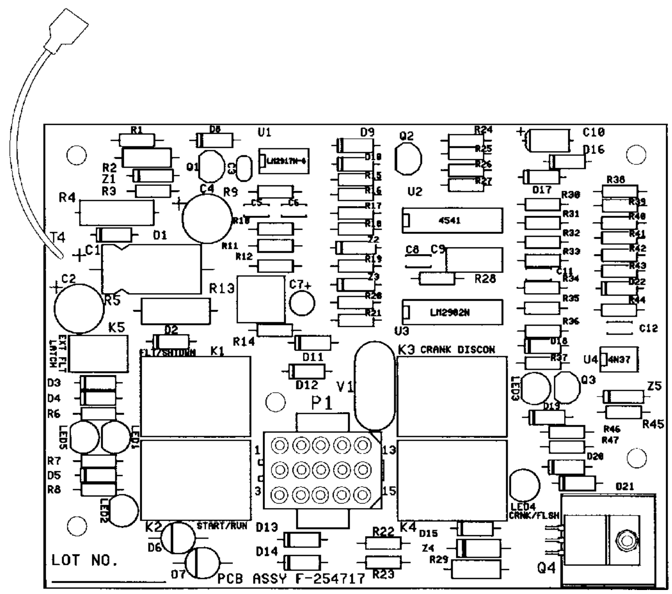
Two main control boards may be found in the DecisionMaker™ 1 controller:

#254717 – 4 pole alternator
#358095 – 2 pole alternator

The 254717 board will be used when the generator has a 4-pole alternator design.

The 358095 board will be used when the generator has a 2-pole alternator design.

Logic functions and sequence of operation are identical for both boards. The main difference on the 358095 board is a modification made to the speed sensor circuit to accommodate the 2-pole alternator design.



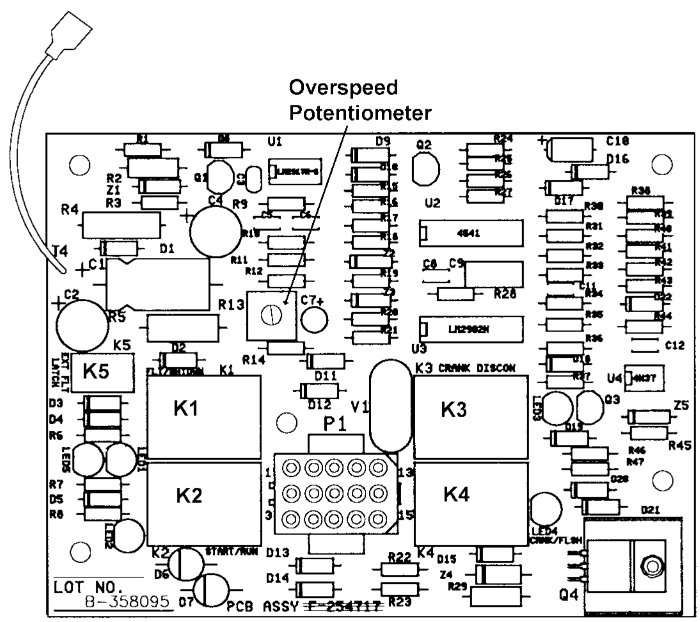
Note: These boards are not interchangeable.

Revision levels

A prefix letter is always found as part of the circuit board number (ex. E-254717) to indicate the revision level of the board. Revision levels are required when a modification to a circuit or a component change is made to the circuit board.

When the 254717 went to revision "F" the T4 lead was added, any revision previous did not have the T4 lead.

The T4 lead was added to prevent resetting and starting the generator from a remote starting location should a fault occur on the generator. With this modifcation the operator is required to go to the genset and repair and clear the fault before normal operation can resume.

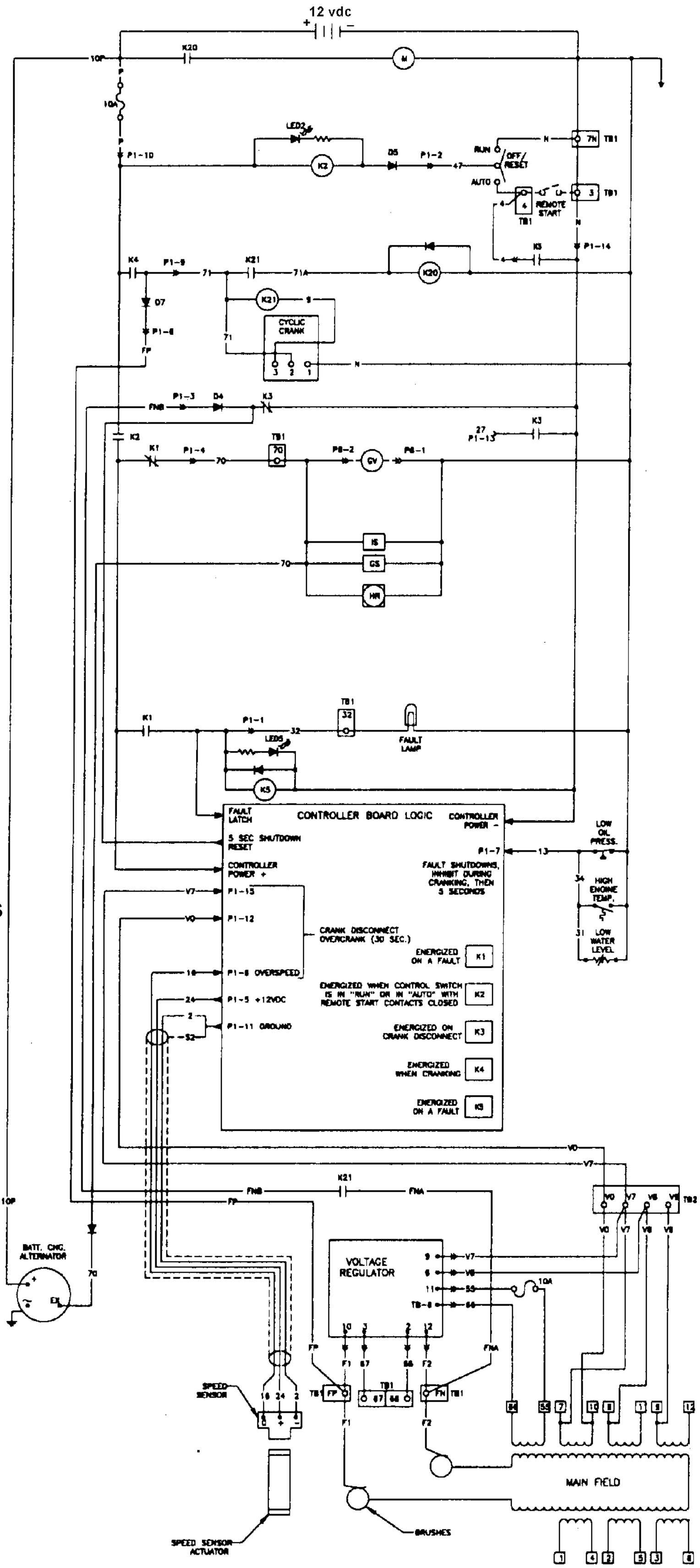


Sequence of Operation

The schematic diagram shown is for the residential (17-22KW) generator using the B-358095 single fault relay board.

Starting the generator:

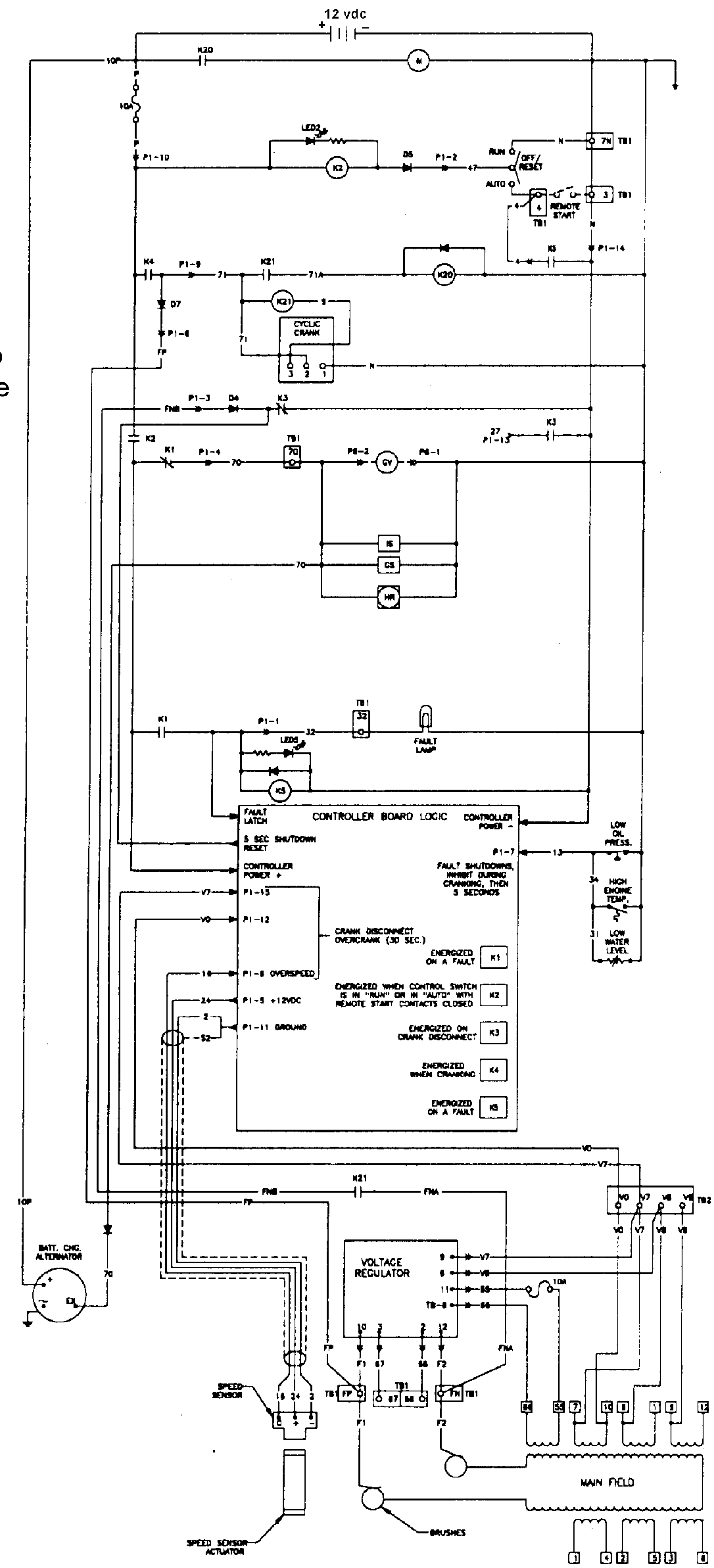
- Close Start/Stop switch, a path between wire #47 and #N is made. (local or remote)
- K2 is energized (LED 2 lights)
- Normally open K2 contacts close to energize board (control power input). Also power flows through normally closed K1 contact energizing wire #70 which powers GV (gas valve), IS (Ignition System), GS (Governor System), and HR (Hourmeter).
- With control power to the Board the K4 picks up (K4 LED lights), Normally open K4 contact closes energizing the cyclic cranking relay. Also energizes wire FP (+) connection for flashing the field.
- During the “on” crank cycle K21 is energized closing K21 contact energizing the K20 relay.
- Normally open K20 relay contact closes energizing the starter motor (M).
- K21 contact closes (-) connection to flash the field.



M - starter Motor
GV - Gas Valve
IS - Ignition
GS - Governor
HM - Hour Meter

Running

- When the speed sensor senses 1100RPM the relay board logic energizes K3 relay (LED 3 lights) should the speed sensor fail the board senses voltage inputs V7 and V0, as a means for a secondary crank disconnect.
- K3 relay normally closed contact opens disconnecting the K4 crank relay. (internal logic on board)
- K4 contact opens removing power to the crank circuit and (+) circuit for the field flashing.
- K21 contact opens to remove (-) circuit for the field flashing.



Shutting Down on Fault

Overcrank

- If generator fails to start after 30 seconds the logic board will go into an overcrank condition and energize K1 relay (LED 1 lights)
- K5 is energized (LED 5 lights)
- K1 normally closed contact opens removing power to wire #70.
- K5 normally open contact closes holding a ground to the remote start lead wire #4.
- K1 normally open contact closes illuminating fault light.

Overspeed

- If generator exceeds 72Hz (sensed by speed sensor) the logic board will go into an overspeed condition and energize K1 relay (LED 1 lights)
- K5 is energized (LED 5 lights)
- K1 normally closed contact opens removing power to wire #70.
- K5 normally open contact closes holding a ground to the remote start lead wire #4.
- K1 normally open contact closes illuminating fault light.

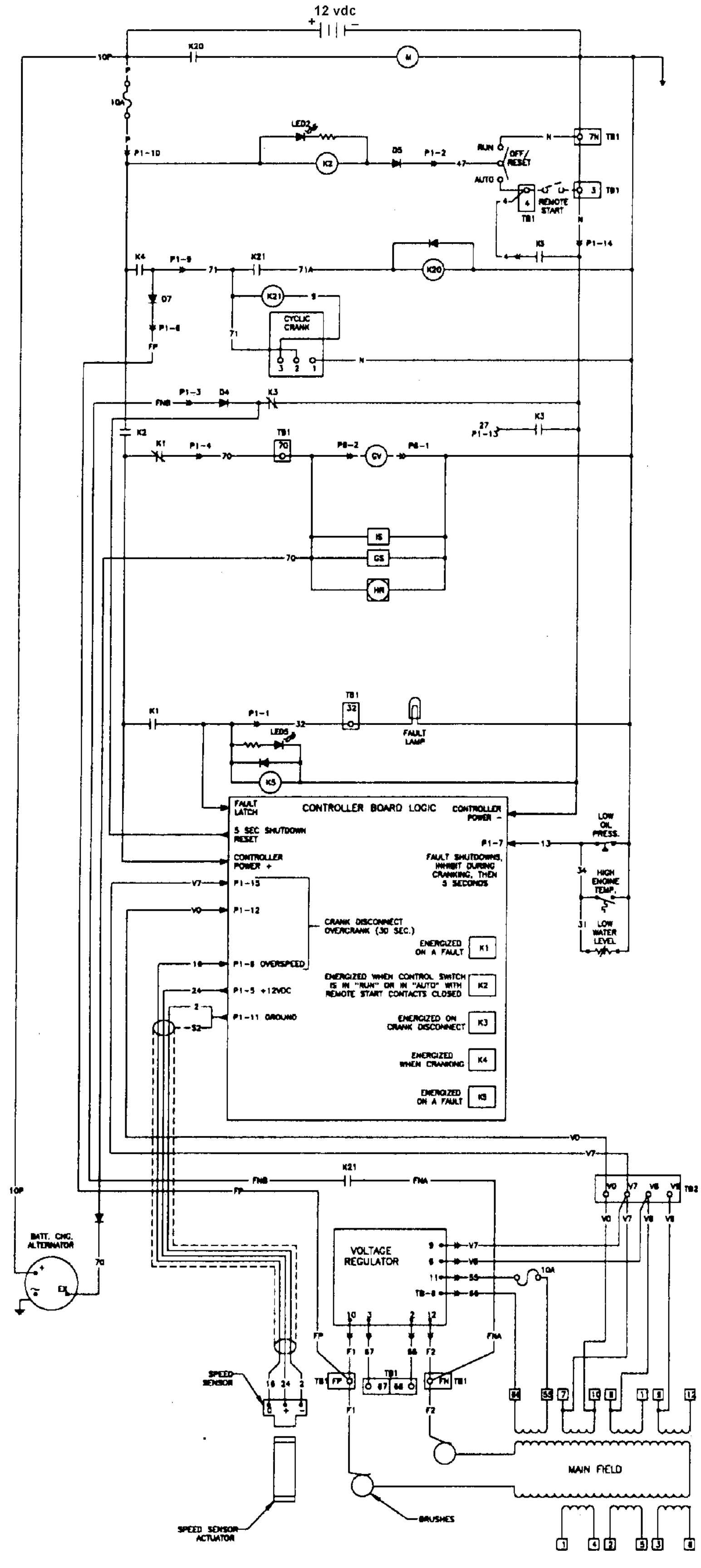
Engine Faults

Engine faults LOP, HWT, and LWL

- Engine faults are inhibited during crank .
- After initial crank and start, if any engine fault switch closes to “ground” for 5 seconds the relay logic board energizes the K1 relay (LED 1 lights).
- K5 is energized (LED 5 lights)
- K1 normally closed contact opens removing power to wire #70.
- K5 normally open contact closes holding a “ground” to the remote start lead wire #4.
- K1 normally open contact closes illuminating fault light.

Stopping the Generator

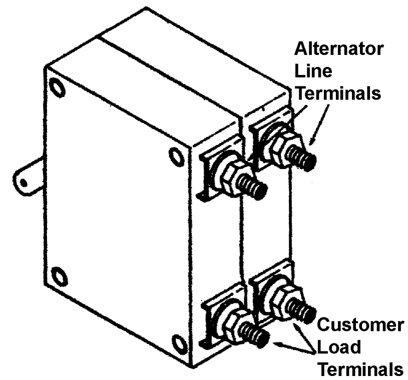
- Move Start/Stop Switch to the Off/ Reset position, removing path from wire #47 to “ground”.
- K2 relay is deenergized
- K2 contact opens removing power to wire #70 and removing “control power” to the relay board.



M - starter Motor
GV - Gas Valve
IS - Ignition
GS - Governor
HM - Hour Meter

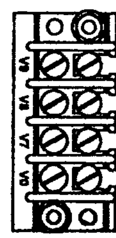
Controller/Junction Box

The **Circuit Breaker** can be a two or three-pole device with trip elements in each pole and is used as a circuit disconnect between the load and alternator. Moving the toggle will open or close all poles. An over current fault exceeding the trip rating of the breaker will also trip all poles. Current and trip ratings are located on the terminal side of the breaker.

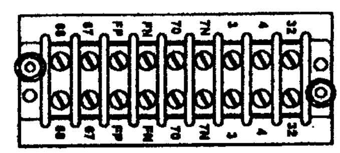


The **TB2** terminal strip provides terminating points (V7 - VO) for the 120vac sensing to the control circuit board. Voltage present at these terminals indicates the unit is running and output voltage is being generated. TB2 terminations vary depending on style controller, the controller using meters will have additional termination points for CT connections.

TB2



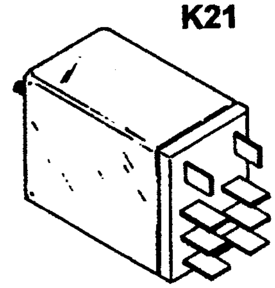
TB1



The **TBI** terminals provide connections for the Remote Start (3 - 4), Field Flash (FP, FN) and DC Supply (70 - 7N) to supply the Electric Governor, Gas Valve and Ignition.

The **Cyclic Cranking** board is an adjustable ON / OFF timer. It is energized on a crank signal from the control board.

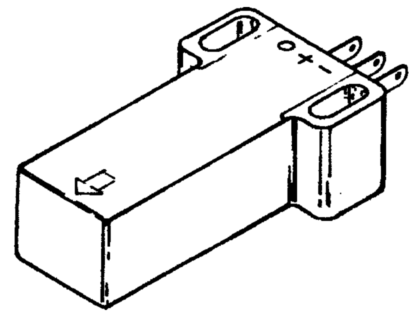
K21



The contacts of the **K21** relay provide the control circuit to the **K20** engine cranking slave relay coil.

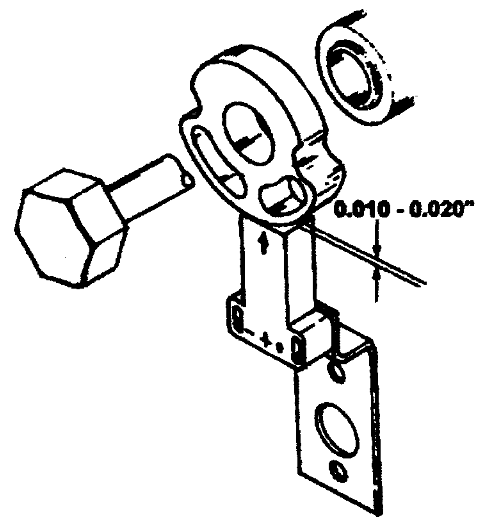
The K21 relay is energized during the "ON" cycle and deenergized during the "OFF" cycle.

SPEED SENSOR
(Proximity Sensor)



The Speed Sensor provides the Main Control board with digital information on the rotating status of the generator set.

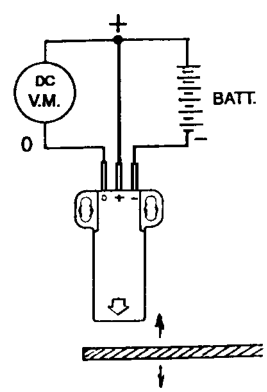
Input voltage to the sensor (+/-) is battery potential (12vdc). During engine cranking and running a pulsed voltage signal (+/o) is sent to the relay control board each time the proximity sensor comes into contact with the ferrous metal speed actuator. The controller board circuitry takes this information and provides crank disconnect and overspeed protection to the genset.

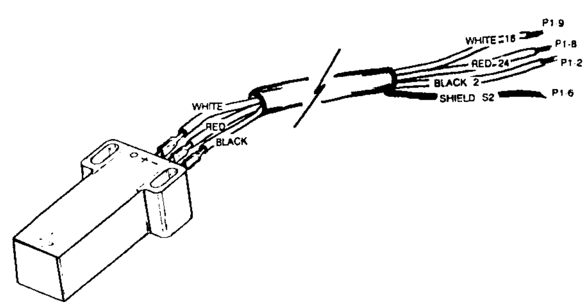


The sensor is located on the end bracket and mounted so an air gap of 0.010 - 0.020 in. is between the sensor and actuator. The actuator is mounted to the rotor shaft with the thrubolt.

A shielded harness is required between the sensor and the controller. Connections to the controller are made through the P2 connector at the rear of the controller.

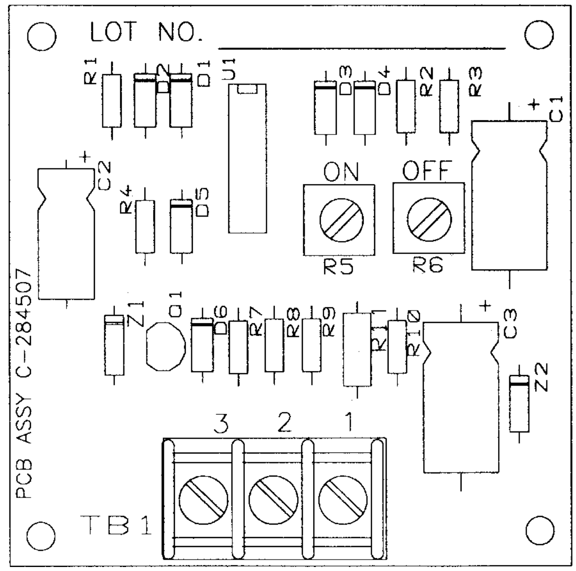
The device can be bench checked by applying 12vdc to the input (+/-) and observing an output (+/o) when the internal circuit is triggered from placing a piece of steel or iron in close proximity to the sensing surface.





Crank Cycling

A crank cycling feature is provided which allows the starter to be energized for a preset "on" time followed by a preset "off" time. This cycle will repeat until the total time allocated by the controller (30 sec) has lapsed or a successful start occurs.



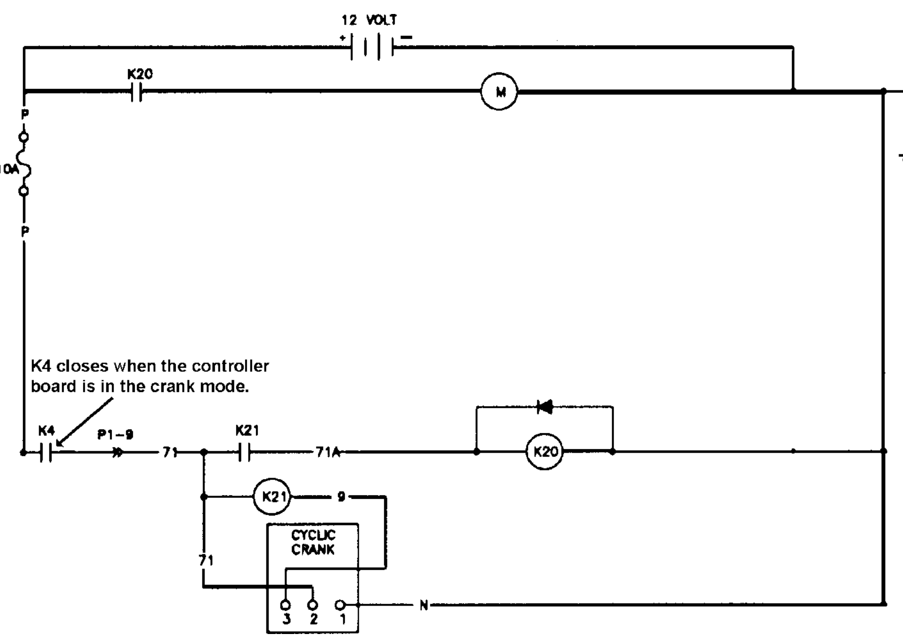
Cranking time (on) is factory set for 8 seconds, crank time (off) is set for 3 seconds. Times are approximate and depend on battery and temperature conditions. Cranking time may be field adjusted if required. The cycle cranking feature will not function if both pots are turned fully counterclockwise.

If the engine does not start within the total cyclic time the starting attempt will be terminated and an indication of "overcrank" will result. The selector switch must be placed in the "reset/off" position prior to attempting another start cycle.

Cycle cranking provides the starting components a rest or reset period to prevent overheating and allows more efficient use of battery power before it is depleted. This is important especially for remote starting of an unattended unit.

When the start signal is provided (K4 relay), voltage is applied to the cyclic cranking circuit. During the "crank" cycle the K21 relay energizes closing the k21 contacts enabling k20. When the k20 contacts close the starter motor is energized. During the "off" cycle the K21 relay is deenergized and the starter motor is disengaged.

If the engine starts within the cranking time of the cycle the K4 relay is deenergized removing power to the K20 relay and terminates engine cranking.



Typical schematic when cycle crank board is used with 254717 circuit board

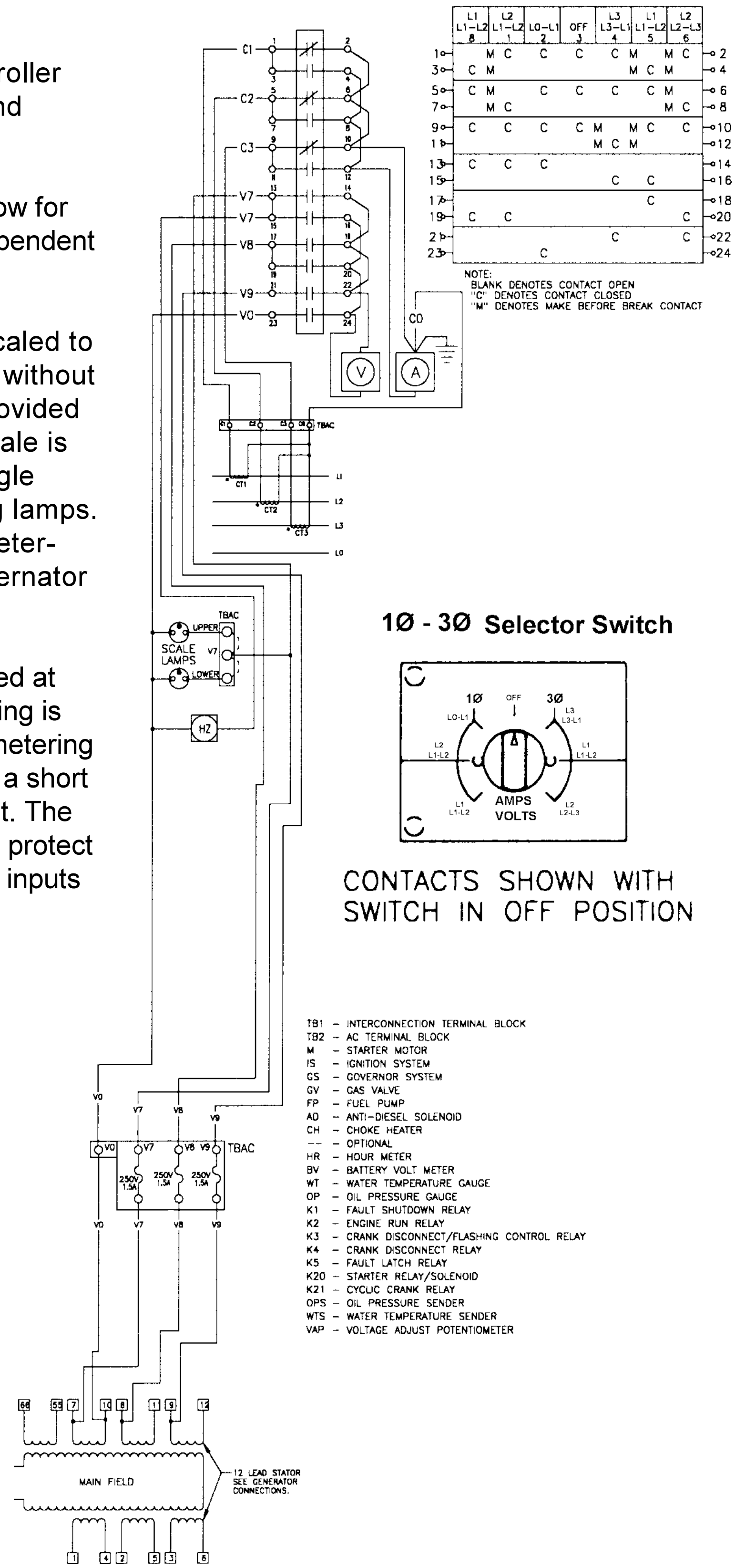
Metering

The DecisionMaker™ 1 Expanded controller includes metering for voltage, amps, and frequency.

A meter selector switch is provided to allow for single phase or three phase metering dependent on the alternator voltage configuration.

The voltmeter and ammeter are dual scaled to allow for reconnection of the alternator without replacing the meters. Two lights are provided (UPPER, LOWER) to indicate which scale is read. A jumper on TBAC is used to toggle between the upper and lower indicating lamps. Refer to the reconnection diagram to determine correct jumper location for the alternator voltage configuration.

AC voltage leads V7, V8, and V9 are fused at TBAC using 250 volt 1.5A fuses. The fusing is provided to allow for isolation of the AC metering from the voltage regulation circuit should a short circuit or fault occur in the metering circuit. The fusing protects the metering but does not protect sensing inputs to the voltage regulator or inputs V7, V0, into the relay control board.

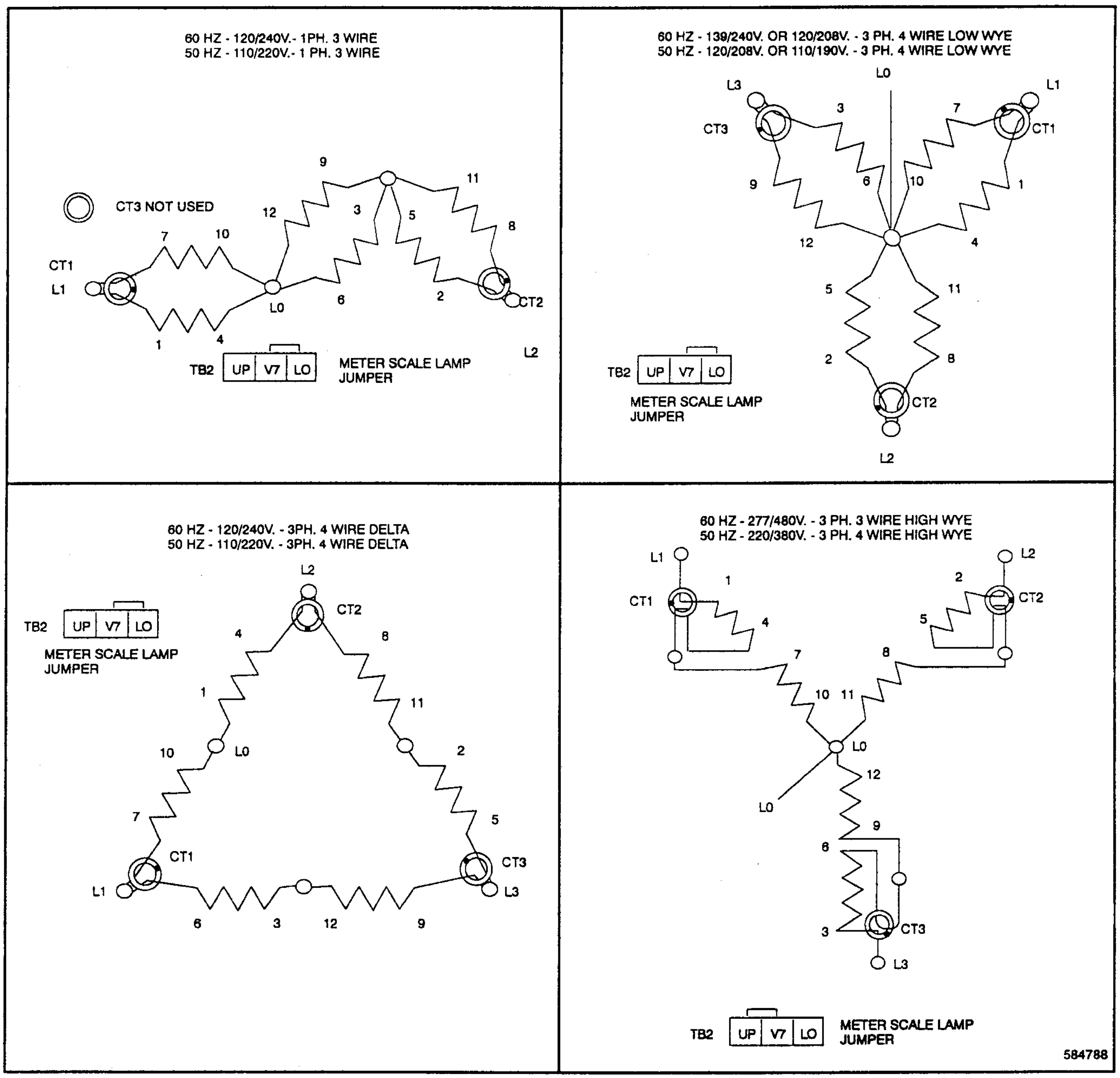


Current Transformer

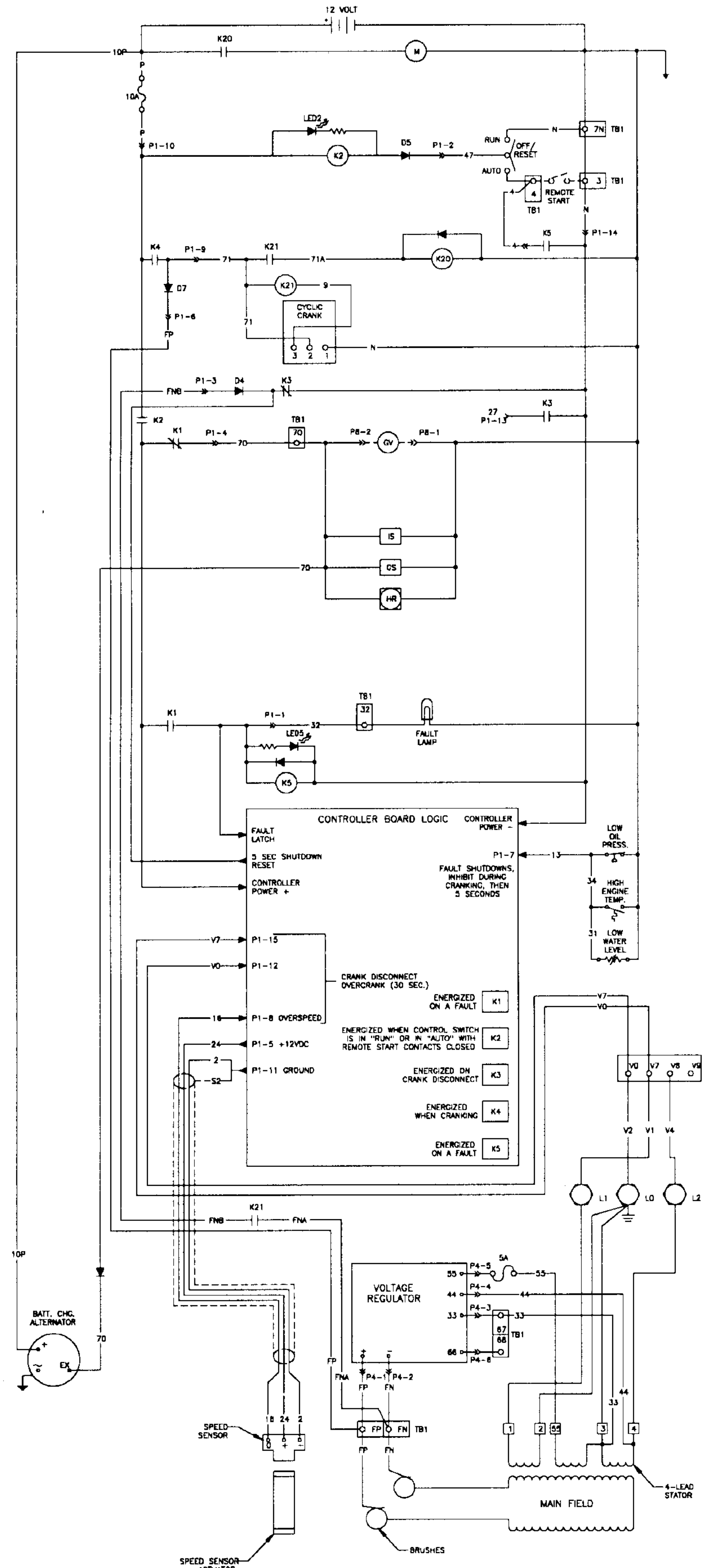
Current transformers are used only on generators equipped with controllers that have metering.

Current transformers allow the use of low amperage (5A) meter movement for ammeters when monitoring high AC amperage flow. When an AC load-carrying conductor is placed through the core of a CT a proportional current will be induced in the secondary winding surrounding the core.

Transformers are matched by the ratio between their primary and secondary, and are matched to the full scale of the ammeter for the controller. For example a current transformer with a ratio of 100:5 is matched to a 0-100 full-scale ammeter. A current flow of 100 amps through the primary of the CT will produce 5 amps of secondary current to the ammeter and indicate 100 amps (full scale).



Controller: Decision-Maker™ 1



TB1 – INTERCONNECTION TERMINAL BLOCK
TB2 – AC TERMINAL BLOCK
M – STARTER MOTOR
IS – IGNITION SYSTEM
GS – GOVERNOR SYSTEM
GV – GAS VALVE
-- – OPTIONAL
HR – HOUR METER
K1 – FAULT SHUTDOWN RELAY
K2 – ENGINE RUN RELAY
K3 – CRANK DISCONNECT/FLASHING CONTROL RELAY
K4 – CRANK DISCONNECT RELAY
K5 – FAULT LATCH RELAY
K20 – STARTER RELAY/SOLENOID
K21 – CYCLIC CRANK RELAY

Decision-Maker™ 1
PowerBoost™ IIIE

Understanding The Schematic

1. What symptoms will you see if the K20 relay “opens” electrically?

2. If the LOP contact remains closed after the generator starts what will happen?

3. What symptoms will you see if the 10 Amp control fuse opens?

4. If the stator winding #55 is electrically “open” what symptoms will be seen?

5. What is the purpose of wires V7, V0, into the controller relay board?

6. When is the K2 relay energized?

7. What two contacts must be closed before the hour meter is energized?

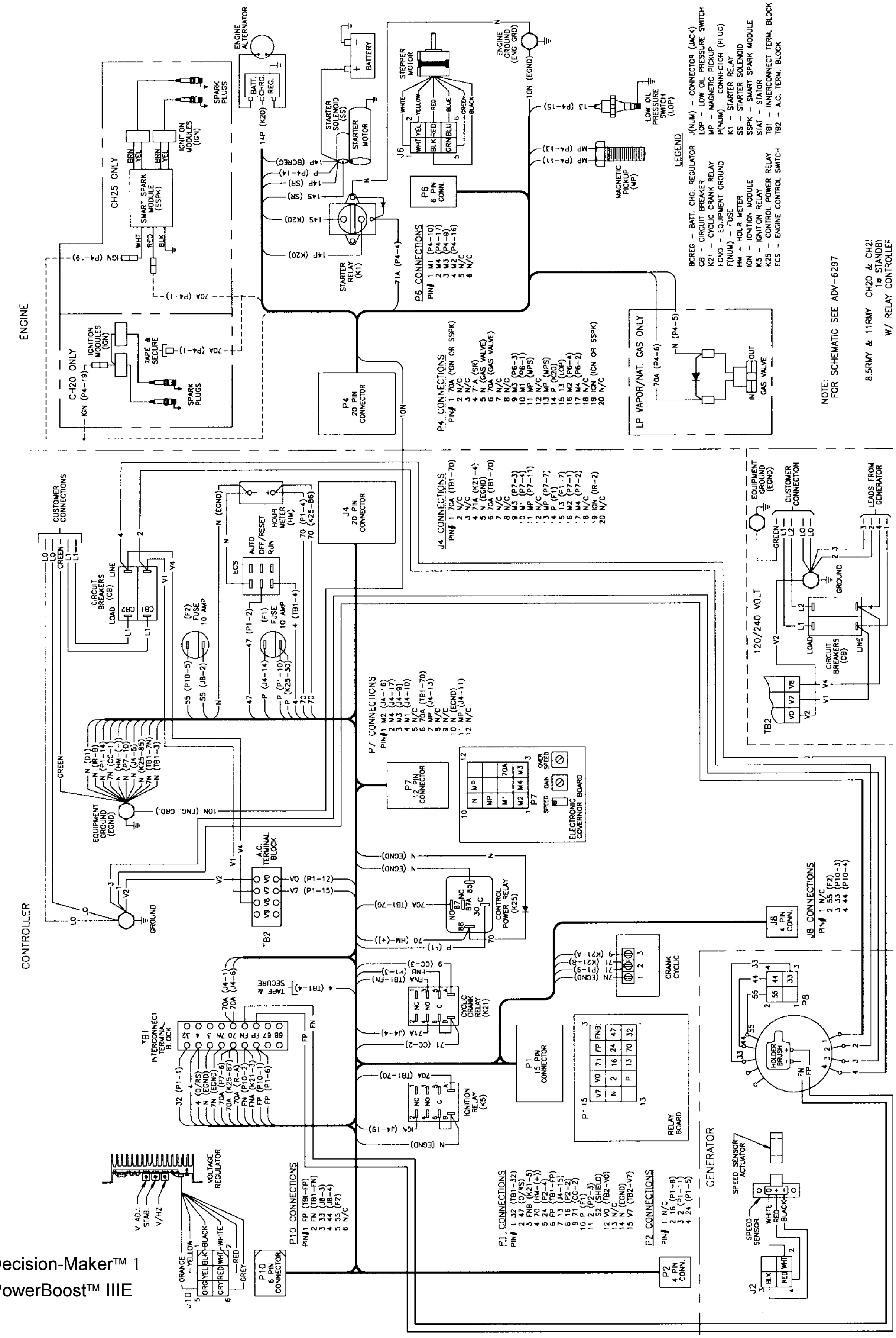
8. When is wire #71 energized?

9. When is wire #70 energized?

10. What is the function of the K5 relay?

11. What are the safety shutdowns for this application?

12. What is the function of the speed sensor?



Decision-Maker™ 1
PowerBoost™ IIIE

Controller: Decision-Maker™ 1

To read the point to point diagram start at any device in the diagram. The wire at the component will have a wire number followed in parentheses by the component the wire goes to and where it terminates.

Reading the Diagram

1. What is the plug number of the controller relay board?

2. Looking at the P1 plug on the relay board, where does wire #FNB terminate? List the starting and ending point.

3. Where on the generator is the Electronic Governor Board mounted?

4. Looking at the #44 wire on the stator, where does this wire terminate?

5. What is the fuse rating of the input to the voltage regulator circuit?

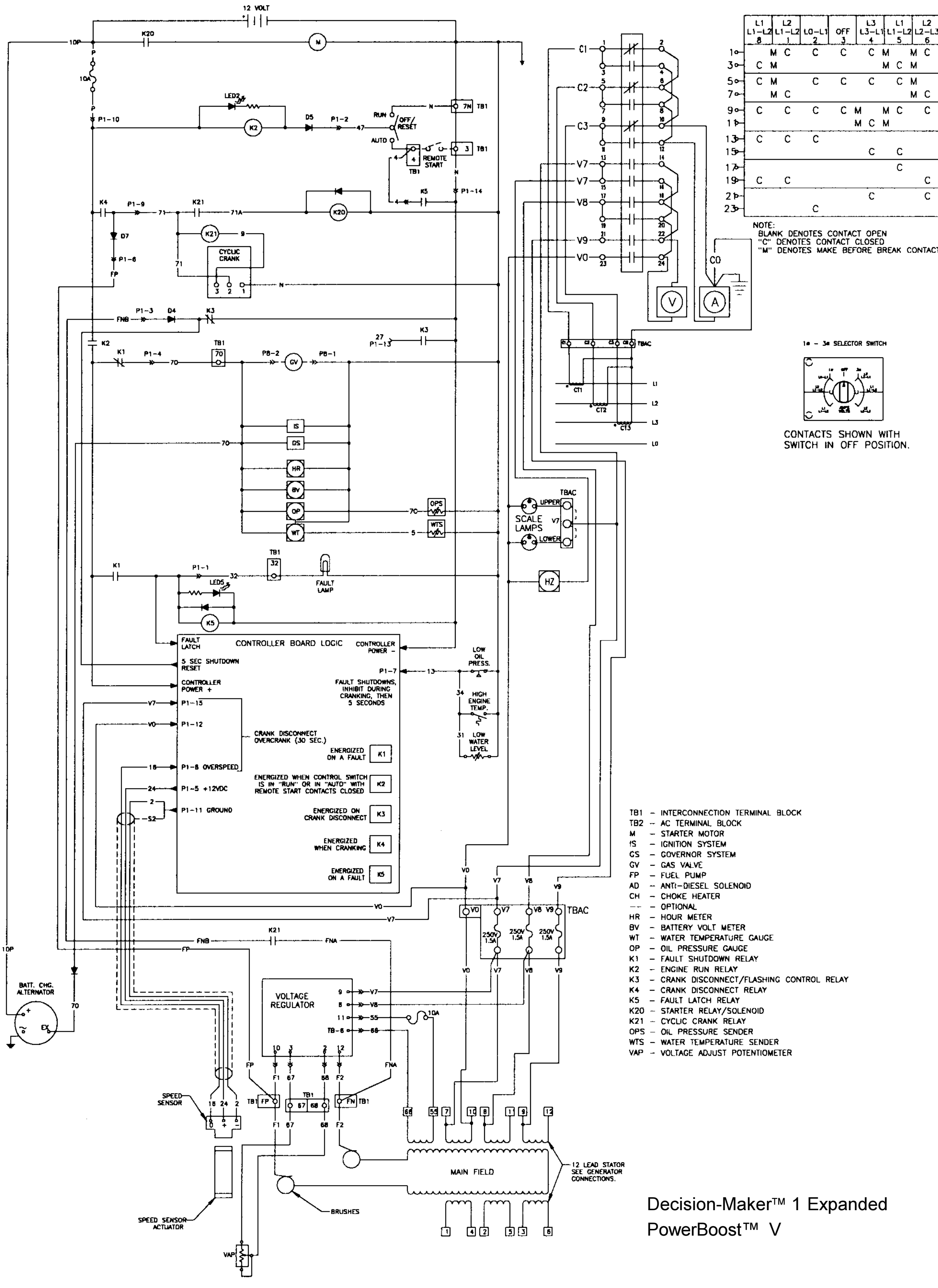
6. What is the fuse rating of the input into the controller circuit?

7. At what plug and pin location does the positive 12 vdc enter the relay board? Is this a fused input? What pin location does "ground" enter the board?

8. What is the wire numbers of all safety shutdowns? At what plug and pin number does this wire enter the relay board?

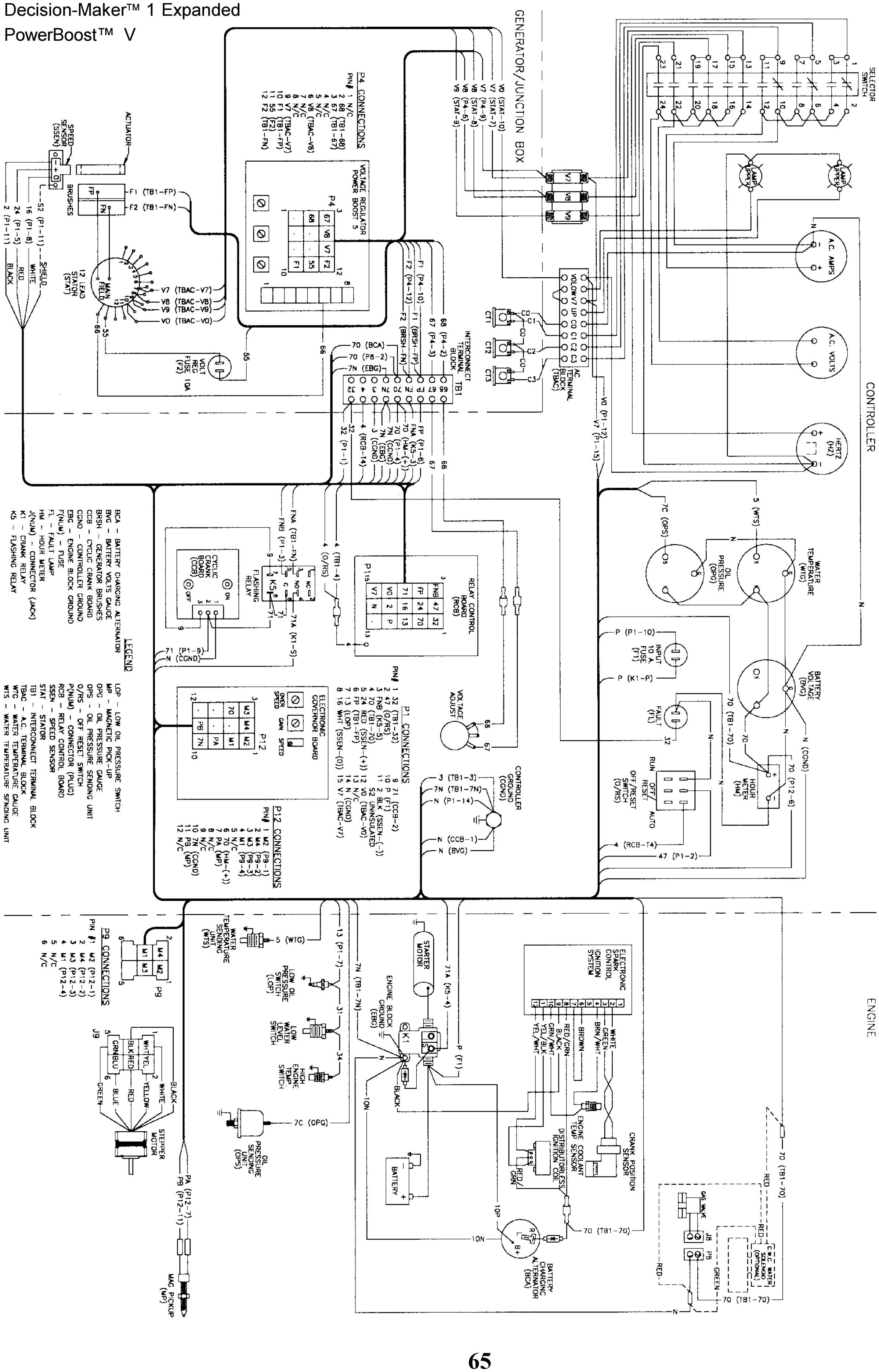
9. Control power for the voltage regulator enters at what plug and pin location?

10. Interconnect for remote start leads are terminated at what terminal strip and on what terminal points?



Decision-Maker™ 1 Expanded PowerBoost™ V

Decision-Maker™ 1 Expanded
PowerBoost™ V



Controller: Decision-Maker™ 3, 5-Light

Decision-Maker™ 3

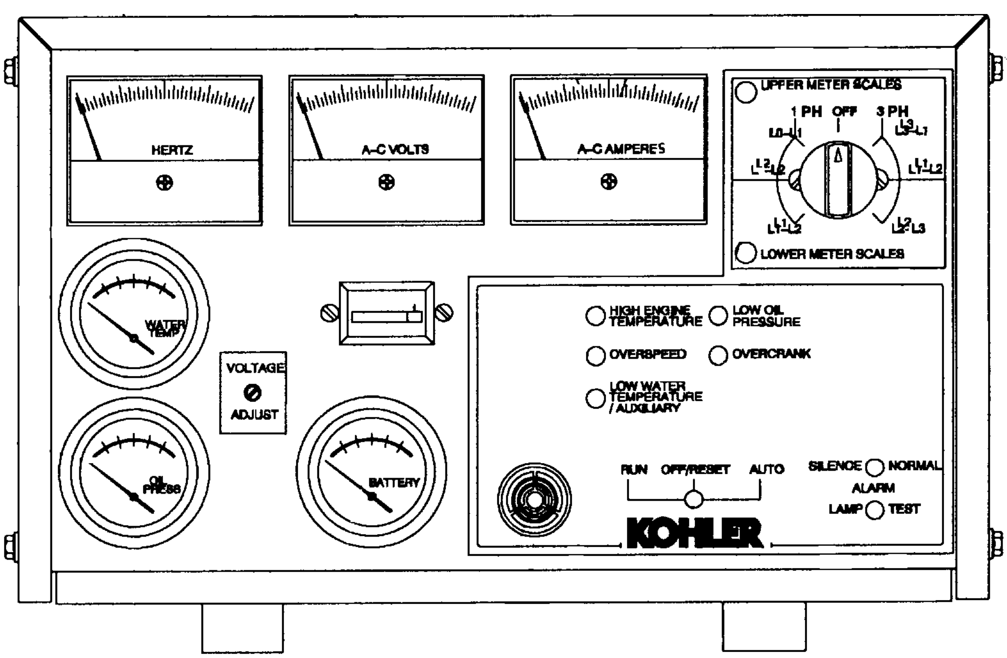
The Decision-Maker™ 3, 5-light controller is an optional controller assembly for some gas and diesel generators utilizing the PowerBoost™ technology.

The 5-light controller features include analog meters, volt/ammeter selector switch, local and remote start capability, hourmeter, fault indication and alarm horn.

Additional options can include overvoltage protection, engine gauge package and a common failure relay.

The main controller board is designed around a self-contained single chip digital microcomputer responsible for all logic functions.

Engine faults detected are High Engine Temperature, Low Oil Pressure, Overspeed, Overcrank, and a prealarm for Low Water Temperature.



Controller: Decision-Maker™ 3, 5-Light

DEC 3 Microprocessor Circuit Board

The main control circuit board is designed around a self contained, single-chip digital microcomputer that has memory, logic, data bus, control bus and I/O ports in one 40-pin integrated circuit.

The control algorithm is provided in ROM (Read-Only-Memory), which maintains data storage without a power supply, ensuring that programmed information is never lost.

Hardware and software filters protect the board from electrical noises common to generator set applications.

Operating range is from - 40 to 185 F (- 40 to 85 C)

The G-292806 Board illustrated will control both 12 and 24 volt engine starting systems.

Input and output signals are provided at the three P connectors (PI, P2, P3) and TB1 terminal strip.

The P3 connector provides the interconnection for the 20-conductor ribbon harness and the Control/Status Indicator panel.

The TB1 barrier strip allows interconnection of options such as: remote operation, annunciators, emergency stop switches, and dry contact kits.

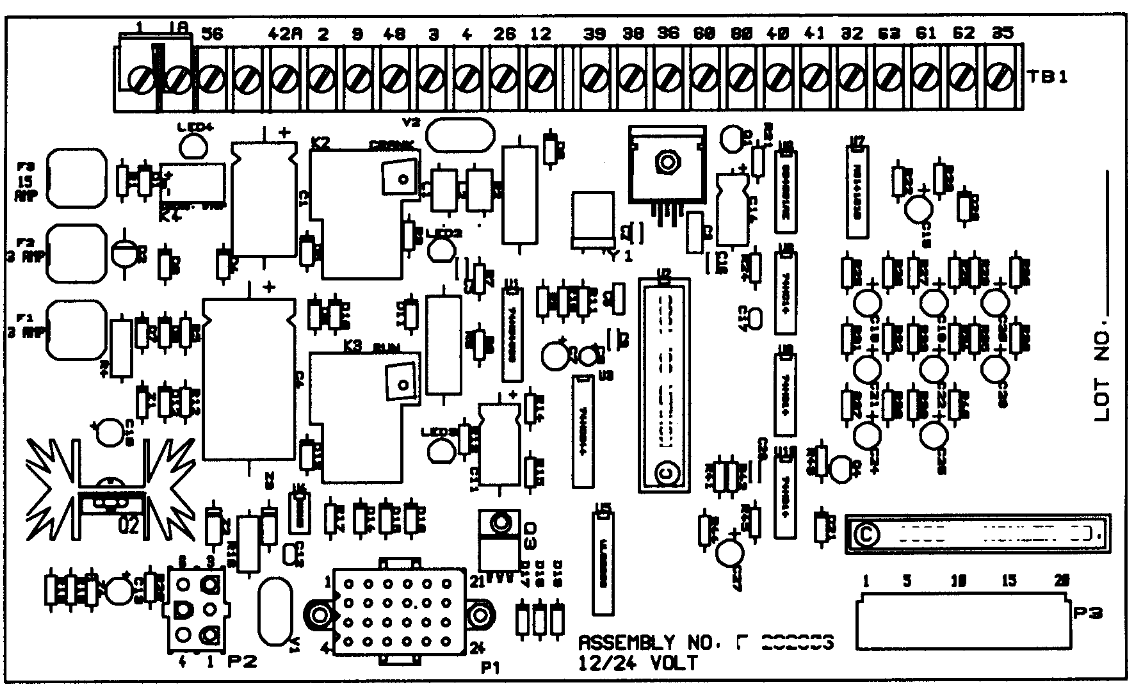
The PI and P2 connectors provide input and output connections between the engine, generator and controller.

Three sealed relays K2, K3, and K4 provide the engine starting, running and stopping control. LED's are connected across the relay coils to indicate voltage is present to energize the relay.

The K2 relay controls the battery supply to the starter solenoid on an engine crank command. The F3 fuse protects the output circuit (wire #71).

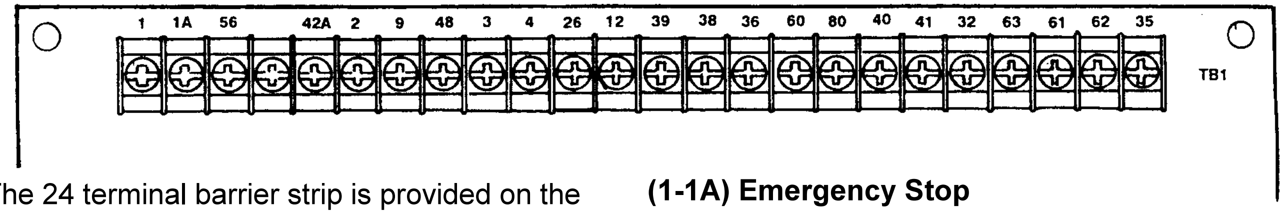
The K3 relay provides battery voltage to the engine run circuit, (Fuel pump/solenoid, Ignition etc.) the meter cabinet components and voltage regulator. The F3 Fuse also protects the K3 output circuit (wire #70).

The K4 relay supplies the control logic circuits with a 12vdc regulated supply. It also functions as the emergency stop relay.



Controller: Decision-Maker™ 3, 5-Light

TB1 Terminal Strip (Dec 3)



The 24 terminal barrier strip is provided on the Main Control board for connecting of optional features.

It is recommended that stranded wire or the optional connection kit be used if multiple connections are made to the terminal strip. Lowering and raising the rear hinged panel when solid conductors are used imposes stress on the circuit board.

(3 - 4) Remote Start

When the status panel operational selector switch is placed in the "AUTO", position the generator set can be remotely started and stopped by a switch or a dry set of contacts connected across terminals 3 - 4.
Do not apply an external voltage.

Open circuit voltage across 3(-) and 4(+) is 12vdc. The circuit draws approximately 42ma when completed.

Two 14ga. conductors are recommended up to runs of 2000 ft. The conductors should be run in a conduit separate from the conduits used for generator load cables or battery charging cables to prevent radiated or induced signals to the circuit board.

When the circuit is opened after operating from a remote start the generator set will continue to run for an additional 5 minutes to allow for an Engine Cooldown.

(1-1A) Emergency Stop

A circuit must be completed between 1 and 1A for the generator set to operate.

A panel mounted "EMERGENCY STOP" switch, or optional "Break Glass" switch provides a maintained set of normally closed contacts. If this circuit is opened during operation an immediate shut down will occur.

A restart can not be made until both the emergency stop switch and Main operational control switches are RESET.

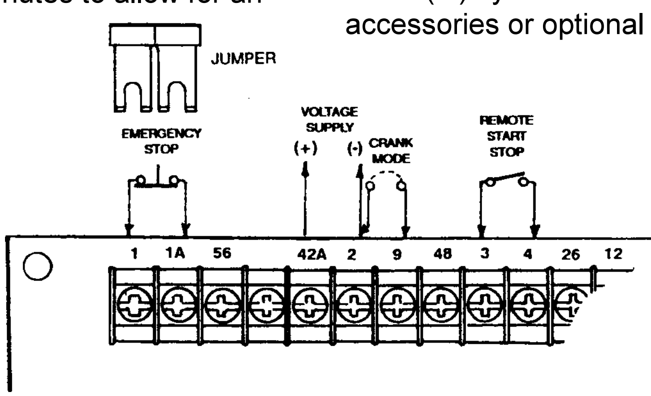
If an emergency stop switch is not installed a jumper is required across the terminals.

(9-2) Crank Mode

Cyclic engine cranking of 15 sec. crank with 15 sec. rest for a total of 75 seconds is standard. The cyclic feature can be eliminated by placing a jumper between terminals 9 and 2. This will allow a continuous engine crank of 45 seconds on a start attempt prior to an Overcrank termination. Continuous crank is not recommended and could lead to premature starter failure.

(42-2) Voltage Supply

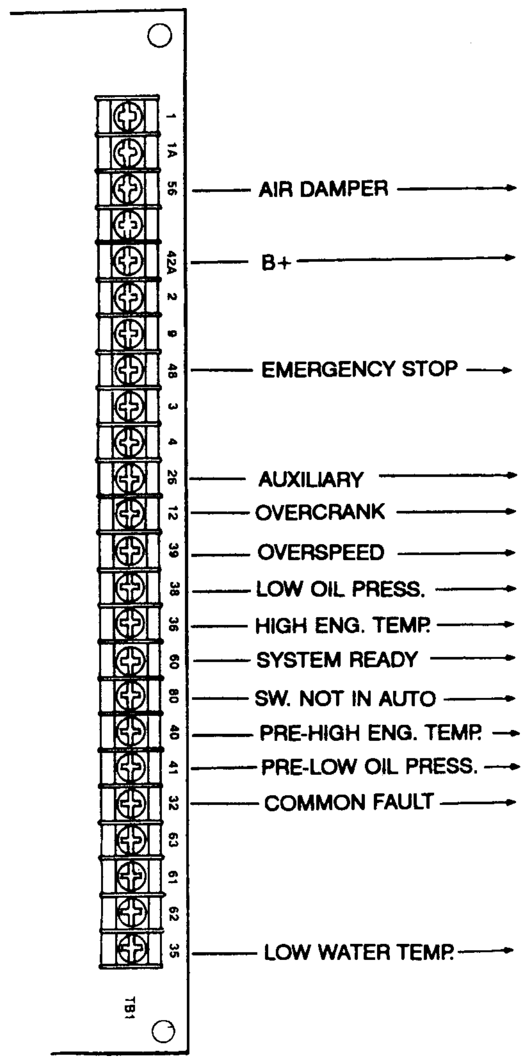
Terminals 42A (+) and 2 (-) provide a 3 amp fused (FI) systems battery voltage supply for accessories or optional devices.



Controller: Decision-Maker™ 3, 5-Light

TBI Terminal strip - DEC 3

The following terminals are output only and allow for connection of optional remote indicators or inputs to dry contact kits. The terminals provide a ground (-) output when the fault is activated and limited to 100 milliampere loads.



(48) EMERGENCY STOP - E.S.

(56) AIR DAMPER - A.D.
(26 AUXILIARY - AUX.
(12) OVERCRANK - O.C.
(39) OVERSPEED - O.S.

(38) LOW OIL PRESSURE - L.O.P

(36) HIGH ENG. TEMP - H.E.T

(60) SYSTEM READY - S.R.

(80) SW. NOT IN -AUTO' - N.I.A.

(40) PRE-HIGH ENG. TEMP - PH.E.T

(41) PRE-LOW OIL PRESSURE - PL.O.P

(35) LOW WATER TEMP - L.W.T

(32) COMMON FAULT - C.F.

The Common Fault terminal 32 will be at ground (-) potential when any of the 10 following faults occur:

-HIGH ENG.TEMR - PRE-HIGH ENG. TEMP
-LOW OIL PRESS. - PRE-LOW OIL PRESS.
-LOW WATER TEMP - OVERCRANK
-OVERSPEED - AUXILIARY
-LOW FUEL - AIR DAMPER.

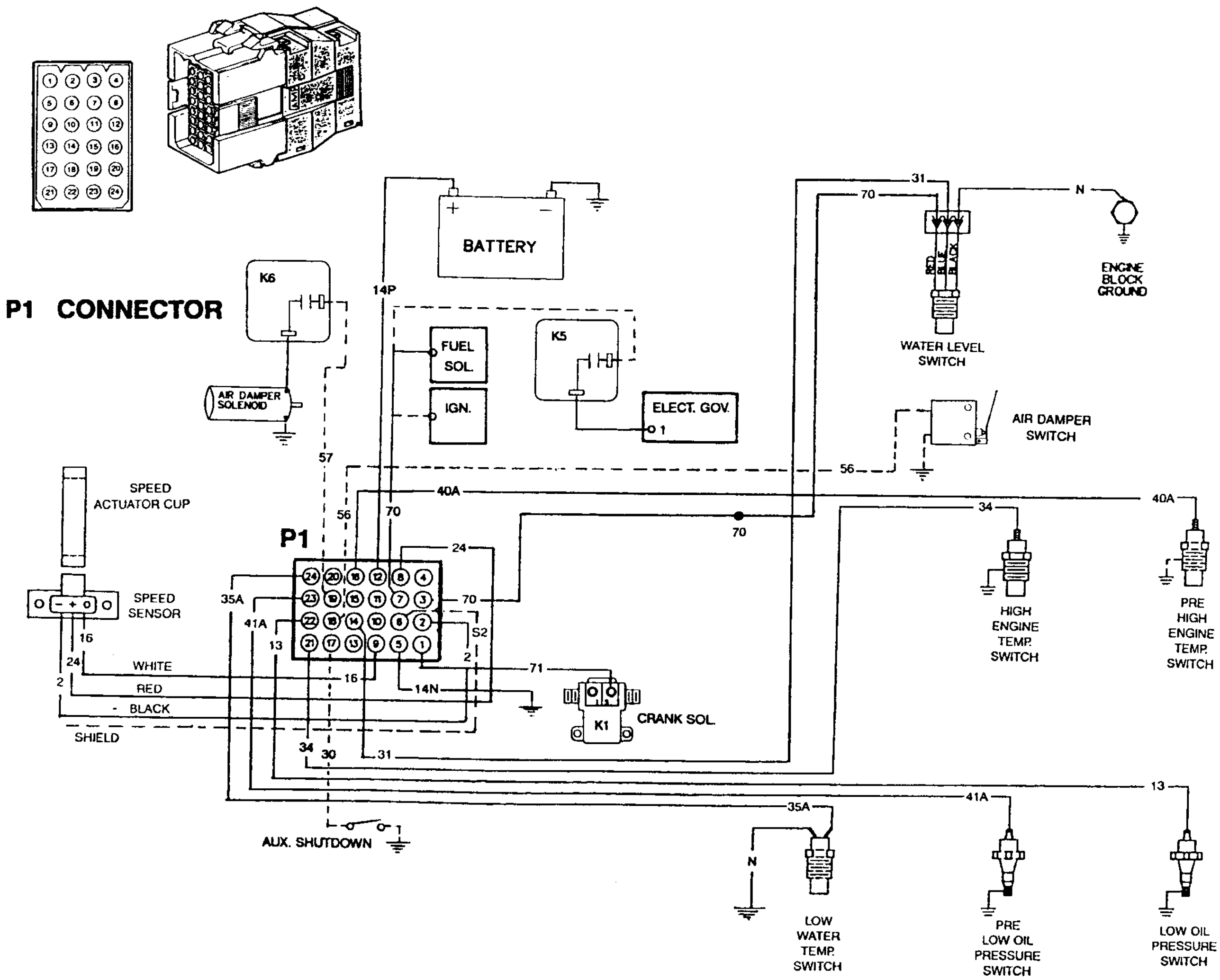
The **Common Fault Relay Kit** can be used if a customer desires less or custom combinations of any of the above.

Connectors PI P2 P3 (DEC 3)

The majority of engine/generator condition inputs and engine control outputs are provided from the harness connector **PI.**

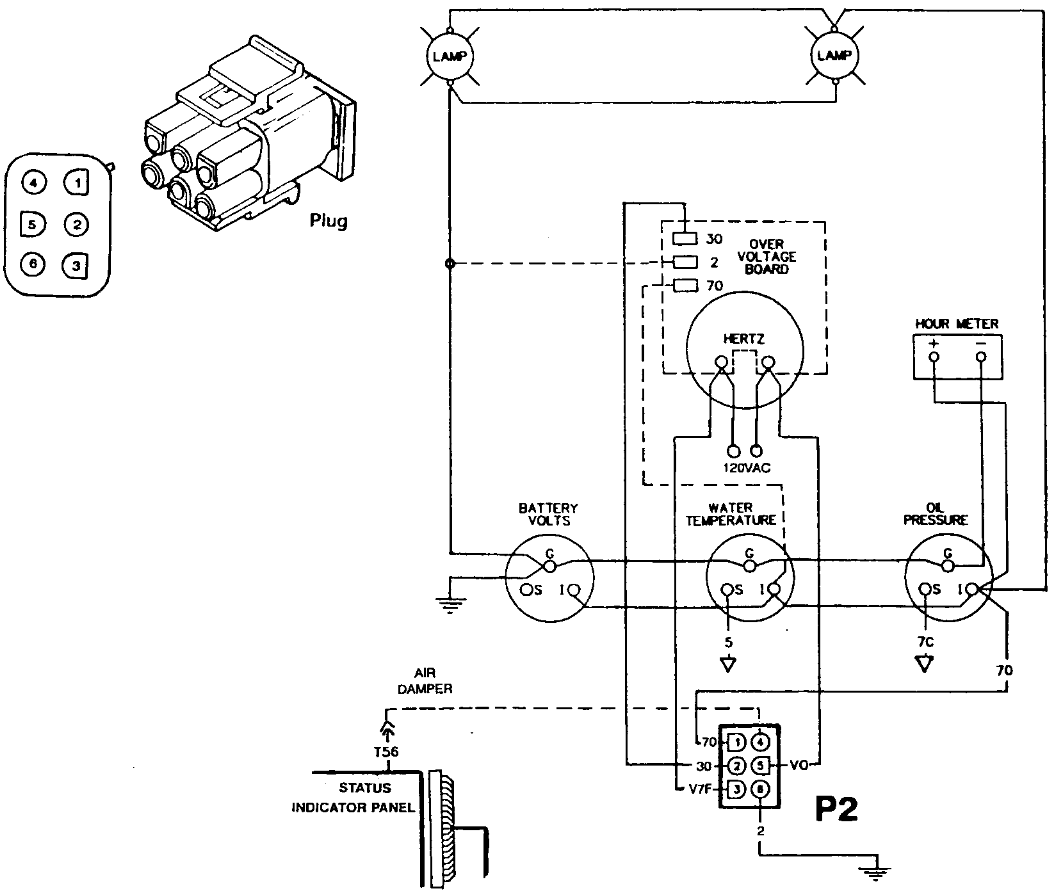
The P2 plug connector provides AC input for voltage sensing and optional overvoltage shutdown signal as well as DC output to the instrument panel engine gauges and illumination lamps.

The **P3** 20 terminal plug provides interconnection to the Status Panel switches and indicators via a ribbon harness. Fault signals to the P3 are common to the TB1 terminals.

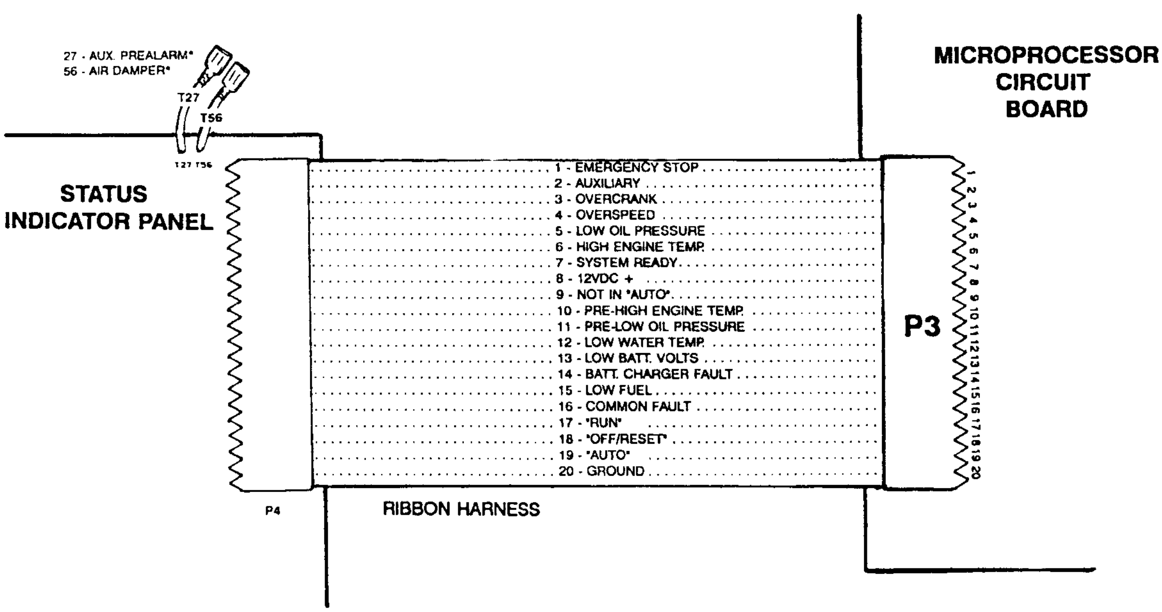


Controller: Decision-Maker™ 3, 5-Light

P2 Plug



P3 Plug



Fuses; FI - F2 - F3 (DEC 3)

The three fuses are located in holders soldered to the microprocessor circuit board and protect the wiring and circuit foil from damage in the event of excessive fault currents.

The **FI** fuse provides overcurrent protection from accessories or options powered from terminal 42A on the TB1 terminal strip. The 3 Amp fuse is rated at 250 volts.

The **F2** fuse protects the circuits powering the main logic and relay coils on the microcomputer board as well as the Status/Indicator panel. It is also a 3 Amp, 250-volt fuse.

The **F3** fuse provides circuit protection if faults occur on engine electrical components powered through the K2 and K3 relay contacts. The ceramic fuse is rated at 15 amps/ 250v.

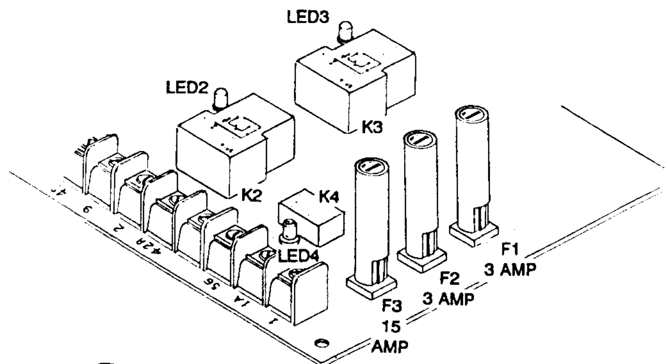
Relays; K2 - K3 - K4 (LED's 2,3,4)

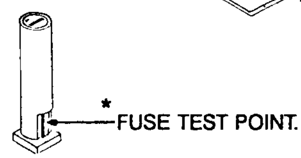
The (3) 12vdc sealed relays soldered to the circuit board provide controlled output power to the generator sets DC electrical components: Start solenoid, Fuel valves, Governor control, Fuel pump, Ignition, Voltage regulator, Solenoids, Slave relays etc. Red LED's are connected across the relay coils to indicate when voltage is applied to the coils.

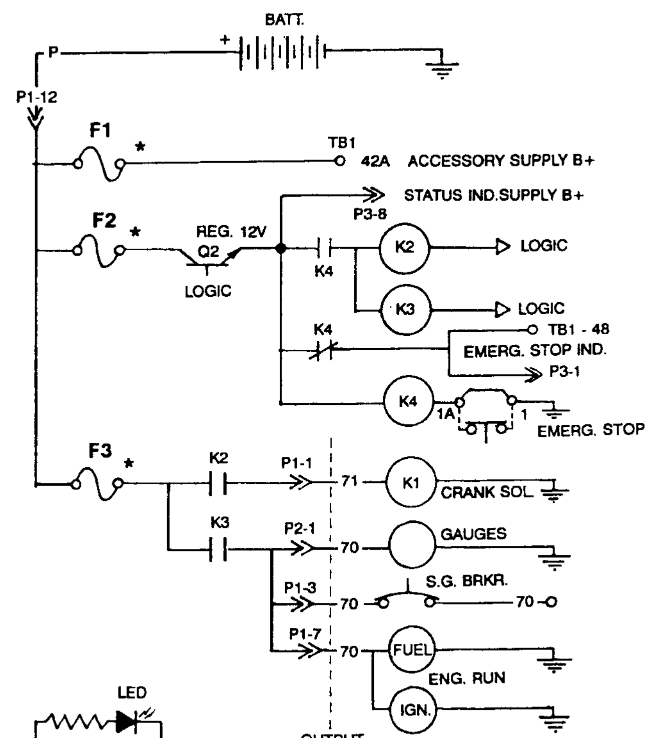
The **K2** relay provides the cranking control to the engine starter crank solenoid (KI). When an engine start command is initiated the logic circuit will cyclically energize the relay coil, 15 seconds on and 15 seconds off for a total time of 75 seconds.

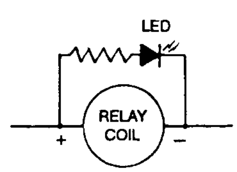
The **K3** relay provides battery voltage supply to the engine, generator and controller components required for normal run operation. It remains energized during a start/run command and is deenergized 5 minutes after a remote stop command or immediately on an emergency stop signal.

A normally open set of K4 contacts are in series with both the K2 and K3 relay coils. The K4 relay (emergency stop), must be energized before an engine crank and run can occur. If the circuit to the K4 coil is disrupted both the K2 and K3 relays will be deenergized. The emergency stop switch when used is connected in series with the K4 relay coil. (TB1 terminals 1 - 1 A)



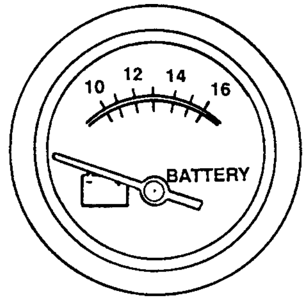




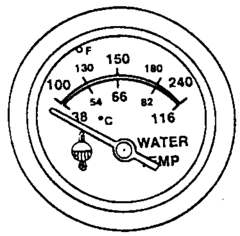


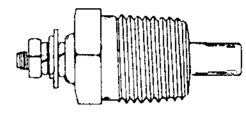
ENGINE GAUGES

Electric 2” English/Metric series gauges with International symbols for Oil Pressure, Coolant Temperature and Battery Voltage are standard in the FR Control Cabinet. They are rated at 2% FS accuracy.



The Voltage gauge monitors the battery charging system. Nominal charging voltage is between 13 and 15 on 12-volt units.

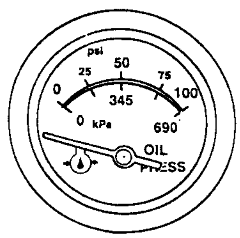


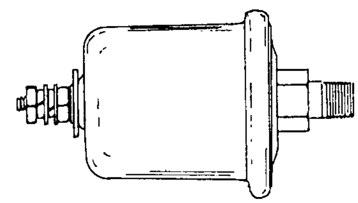


TEMPERATURE SENDER

100°F = 450 ohms   240°F = 33 ohms

Variable resistance type senders for temperature and pressure are located in the engine block and matched to the gauge scale. Resistance value decreases with an increase in temperature or pressure.



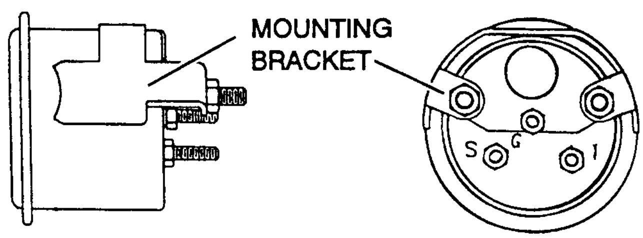


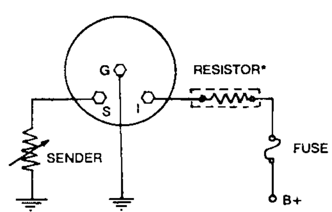
PRESSURE SENDER

0 psi = 240 ohms   100 psi = 33 ohms

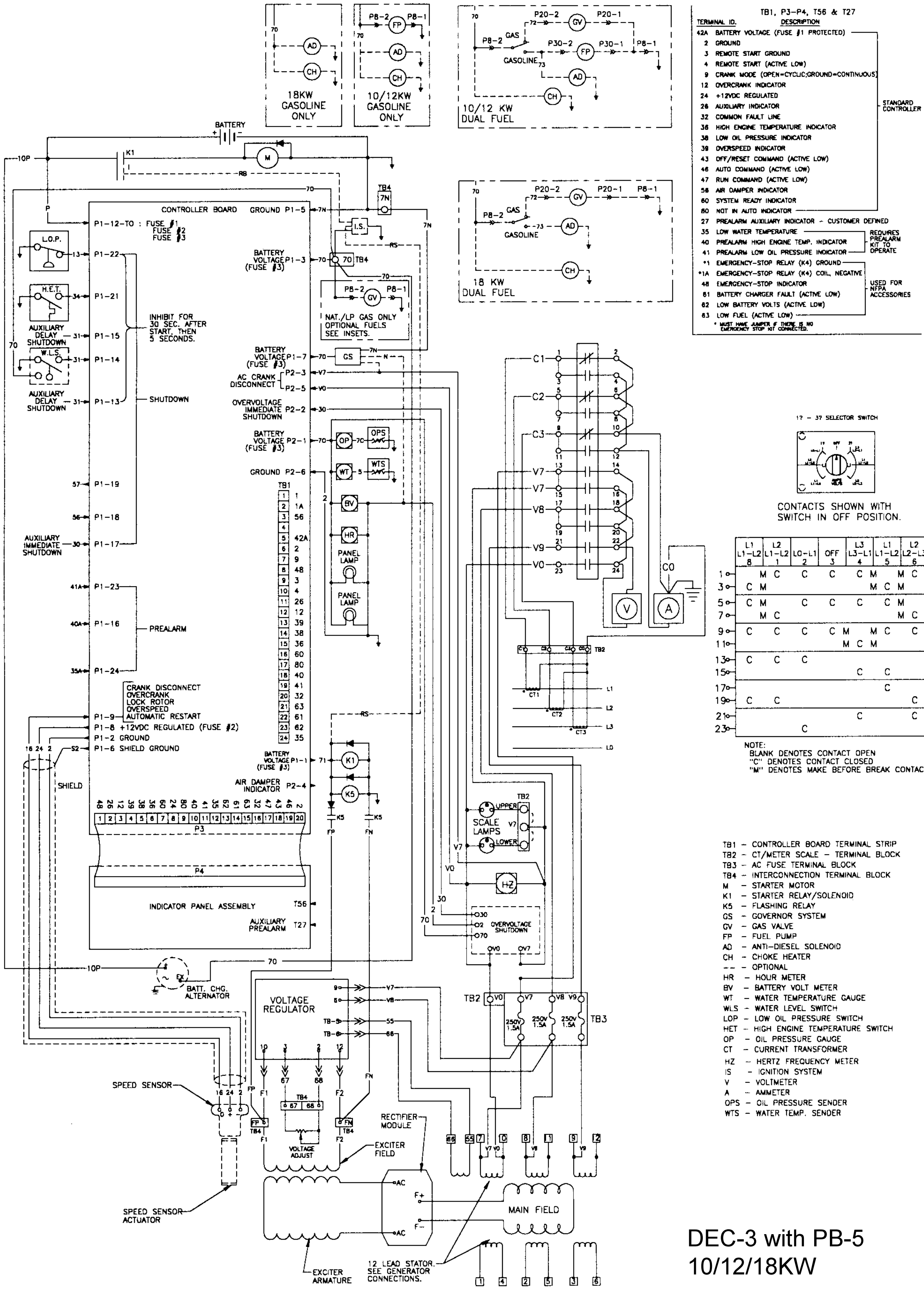
The gauges are connected with the hour meter and panel lamps and powered through the F3 fuse.

G terminal - Ground
S terminal - Sender output.
I terminal - Ignition voltage



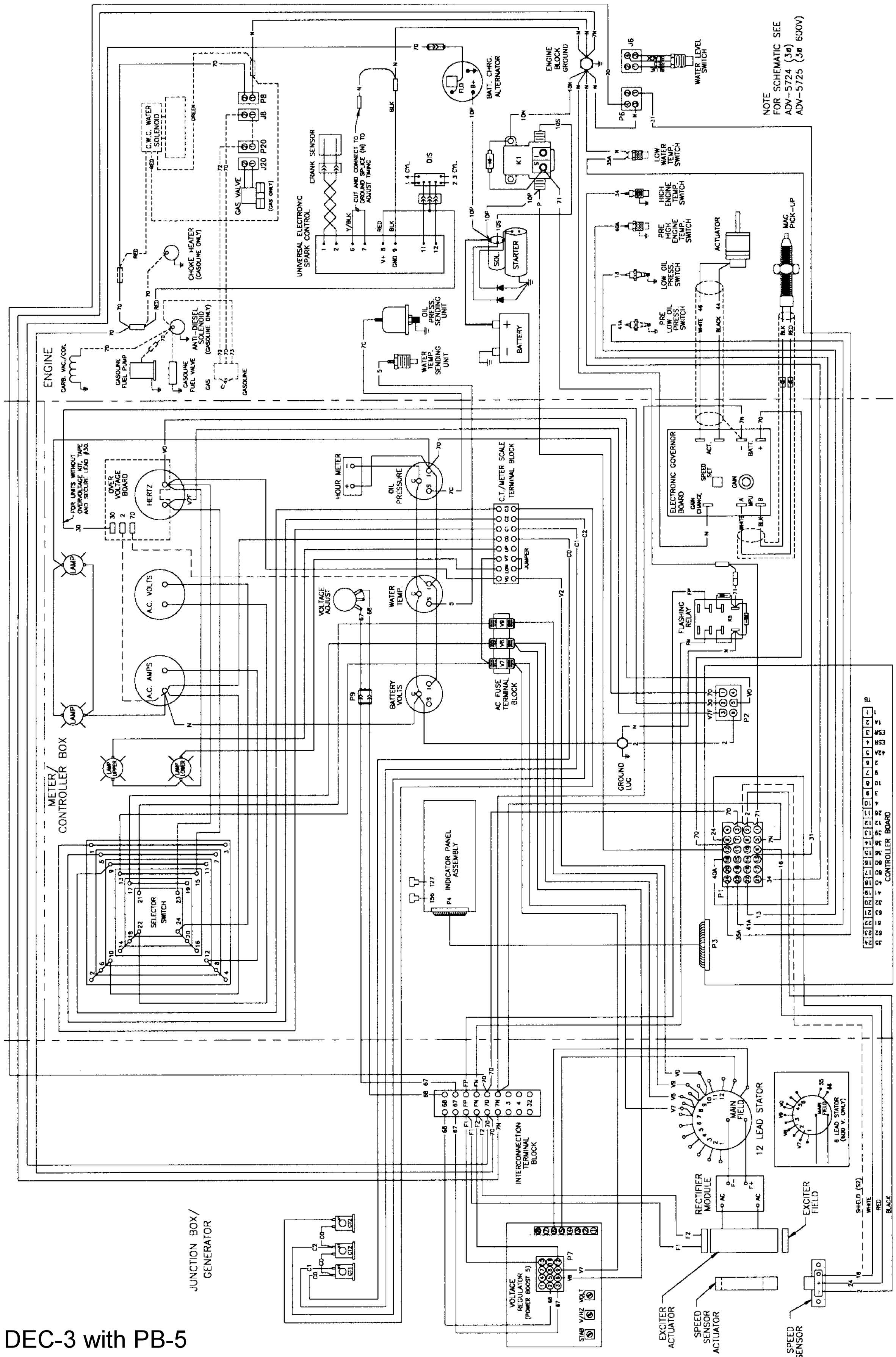


Controller: Decision-Maker™ 3, 5-Light



DEC-3 with PB-5
10/12/18KW

Controller: Decision-Maker™ 3, 5-Light



DEC-3 with PB-5
10/12/18KW

Controllers

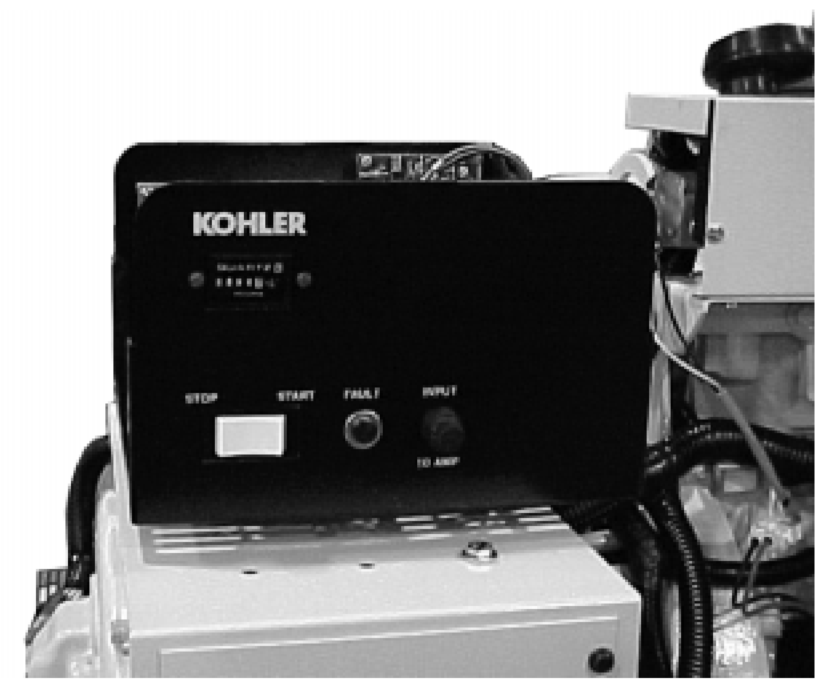
The controller pictured is typical of a Relay Controller using the 259563 board, but assemblies may differ depending on the engine used and the application of the generator. Over the years the controller has been used in the Mobile, Marine and RV product lines.

The main function of the controller is to control through logic the generator start/stop functions. A typical controller assembly will include all circuit boards, relays, connection terminal blocks, start/stop switch, circuit protection (fuses, circuit breakers) and an hour meter. Some controller assemblies will also house the voltage regulator.

Customer load connections may also be found in the controller as well as the ground and neutral studs.

This section will cover the basic components found in the Relay Controller using the 259563 control board including logic operation, reading the wire diagrams, and basic troubleshooting.

Description of parts, logic, etc. will be generic and not specific to any individual model unless to aid in explanation.



Controller Features

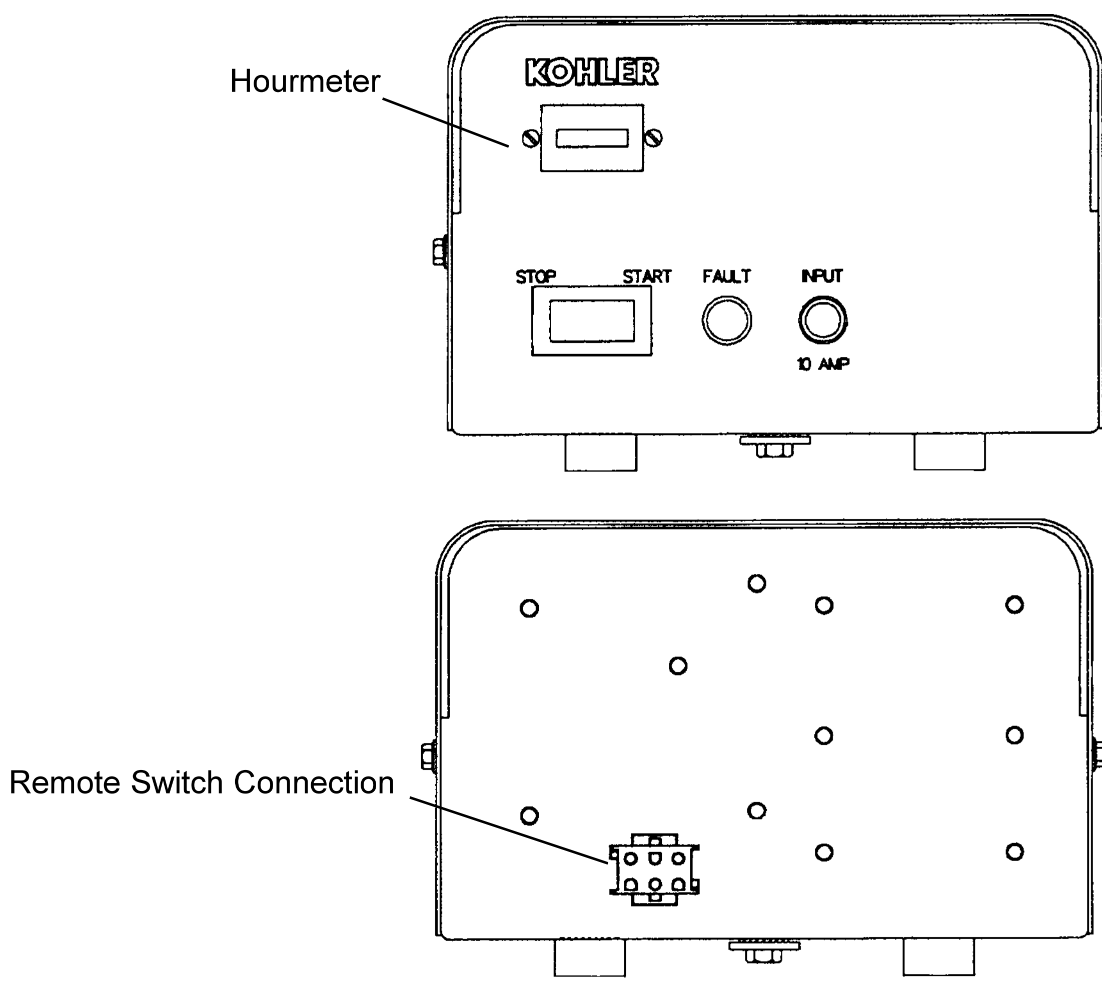
Fault Lamp - lights to indicate a fault condition. Generator will shut down on Overspeed, High Engine Temperature, and Low Oil Pressure faults.

Hourmeter - records total generator set operating hours for reference in maintenance scheduling.

Generator Stop/Start Switch - used to start and stop generator set.

Controller Fuse - 10 Amp. fuse protects controller circuitry.

Remote Switch Connection - connect remote Stop/Start switch to operate the generator at a location remote from the set.



Controller Relay Board

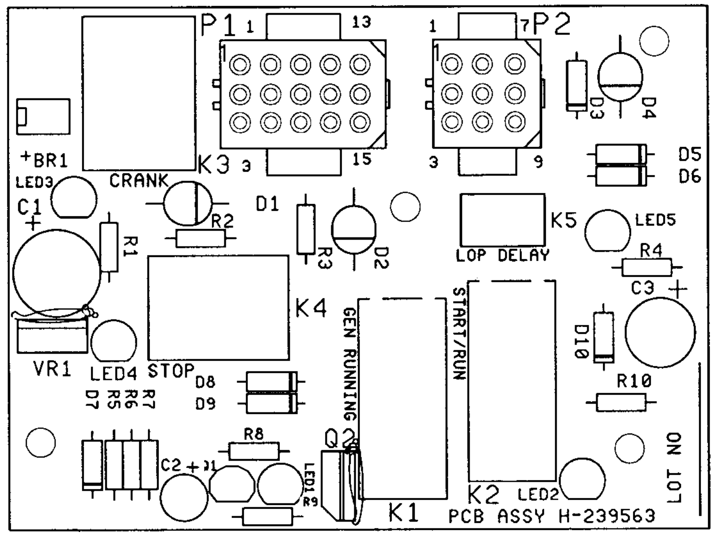
The main component of the controller is the logic circuit board. This circuit board is designed to control the start/stop function, crank disconnect, safety shutdowns, flashing of field and any required time delays.

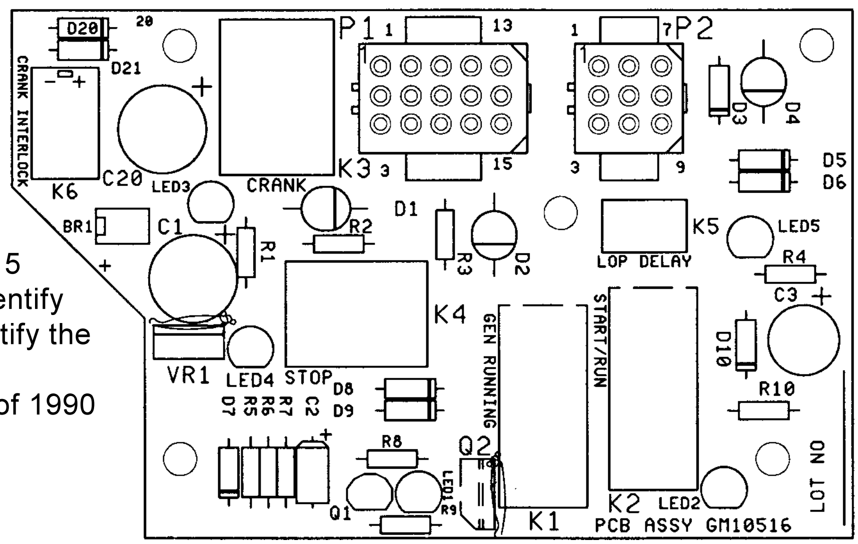
The 239563 control board has been the most common board used for the controller assemblies in the marine, portable, RV and mobile product lines, but other controller board designs have also been used over the years.

Circuit Boards are identified by a part number. The part number will have a prefix letter followed by the board number. The prefix letter represents the version of the circuit board design. Circuit board versions change due to changes made to the circuit board, such as changing components or circuit modifications.

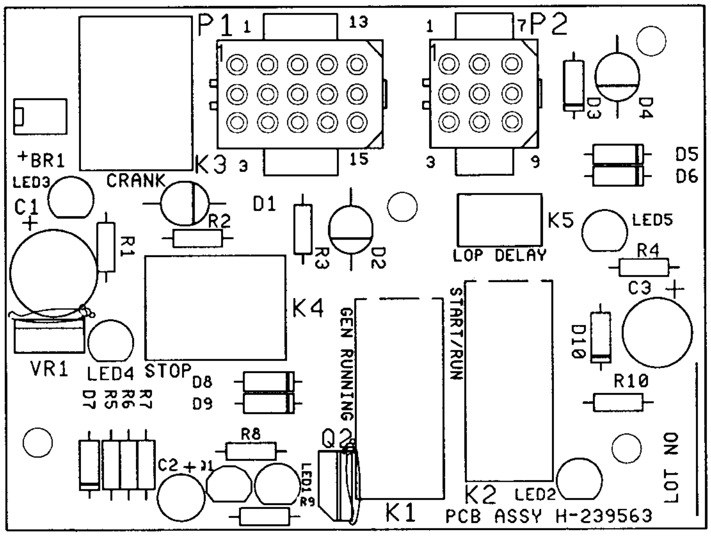
All boards are also to have a Lot Number. This number represents when the board was made, the number will consist of 5 digits, the first two digits shall identify the year and the last 3 shall identify the day of the year.

LOT NO. 90045 = the 45th day of 1990





Similar to 239563 with the additional K6 Crank Interlock relay



K1- (Run Relay) - Energized when voltage is present at BR1. The output winding B1 and B2 is a low AC voltage that is rectified at BR1 and regulated by VR1 to energize the K1 relay. The K1 relay picks up when generator produces an output voltage.

K2- (Start/Run Relay) - Energized when operator presses start switch. Relay is held in once K1 is energized through a normally open K1 contact.

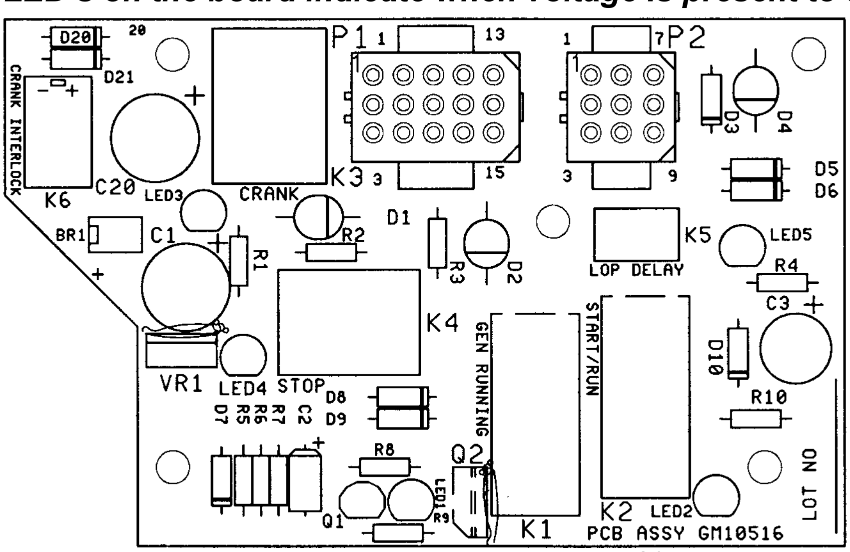
K3- (Crank Relay) - Energized when operator presses start switch. Relay will drop out when K1 is energized and the normally closed K1 contact opens.

K4- (Stop Relay) - Energizes on an engine fault, K5 provides a 5-10 second time delay after engine start-up.

K5- (Time Delay Rely) - Energizes when AC voltage is present at BR1 and the C2 capacitor charges. Relay will pick up 5 to 10 seconds after engine start.

K6- (Interlock Relay) (found only on GM10516 board) - Energizes when K1 relay picks up and normally open K1 contact closes. Relay will latch through its own K6 contact.

LED's on the board indicate when voltage is present to the relay.

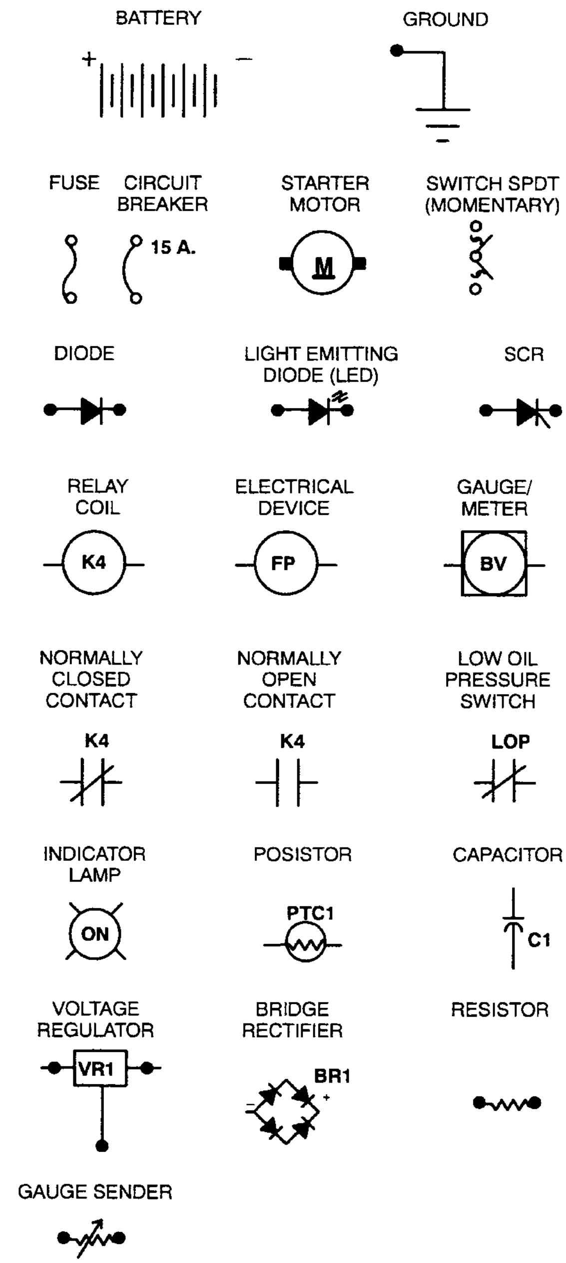


Reading Schematic Diagram

Schematic diagrams are used to represent through symbols and terminology what logically is happening within the framework of the generator. Being able to follow the sequence of a schematic diagram will aid in understanding how the generator functions and allow the technician or operator to troubleshoot and diagnose problems when necessary.

As an exercise in reading schematic diagrams this section will go through the sequence of operation of a generator using the E-239563 board for control logic. Note that when viewing the diagram the generator is shown in a static (non-running) state.

When following the sequence of operation use the legend and symbols table to help in identifying various parts of the circuit.

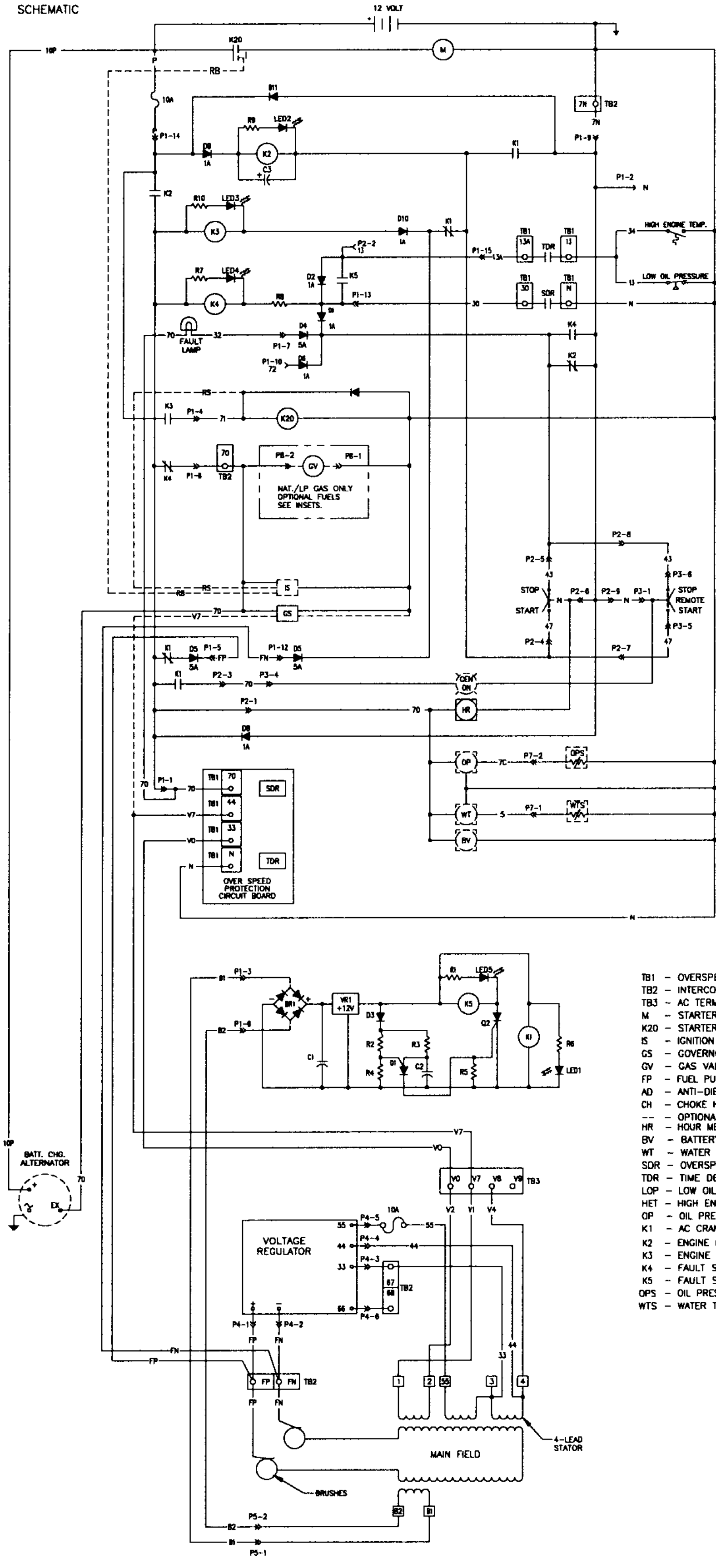


A.	– AMPS.	K4	– STOP RELAY
BC	– BATTERY CHARGING	K5	– DELAY RELAY
BV	– BATTERY VOLTS	K20	– CRANK CONTROL RELAY
CB	– CIRCUIT BREAKER	K25	– FUEL SOLENOID CONTROL RELAY
D	– DIODE	LED	– LIGHT EMITTING DIODE
FS	– FUEL SOLENOID	LOP	– LOW OIL PRESSURE
GRD.	– GROUND	M	– STARTER MOTOR
HCHT	– HIGH CYLINDER HEAD TEMPERATURE	N	– NEGATIVE (–)
HET	– HIGH EXHAUST TEMPERATURE	OP	– OIL PRESSURE
HR	– HOURMETER	S	– STARTER SOLENOID
HWT	– HIGH WATER TEMPERATURE	WT	– WATER TEMPERATURE
K1	– CRANK DISCONNECT RELAY		
K2	– ENGINE RUN RELAY		
K3	– CRANK CONTROL RELAY		

Controller: Relay Controller

Sequence of operation (Tyipical)

SCHEMATIC



The shematic diagram shown is a generator set using the E-239563 circuit board for control logic.

Starting

- Close start/stop switch between N and 47(local or remote starting).
- K2 relay is energized (LED2 lights).
- Normally open K2 contacts close to energize K3 relay (LED3 lights). K2 contact also energizes HR, OP, WT, BV, IS, GS, GV.
- FP wire energized through K1 normally closed relay contact to excite main rotor field. FN excitation return path to ground through normally closed K1 contact.
- K3 relay normally open contacts close to energize K20 (starter) relay. K20 relay normally open contacts close to energize Starter Motor.

TB1 – OVERSPEED CIRCUIT BOARD TERMINAL STRIP
TB2 – INTERCONNECTION TERMINAL BLOCK
TB3 – AC TERMINAL BLOCK
M – STARTER MOTOR
K20 – STARTER RELAY SOLENOID
IS – IGNITION SYSTEM
GS – GOVERNOR SYSTEM
GV – GAS VALVE
FP – FUEL PUMP
AD – ANTI-DIESEL SOLENOID
CH – CHOKE HEATER
-- – OPTIONAL
HR – HOUR METER
BV – BATTERY VOLT METER
WT – WATER TEMPERATURE GAUGE
SDR – OVERSPEED SHUTDOWN RELAY
TDR – TIME DELAY RELAY
LOP – LOW OIL PRESSURE SWITCH
HET – HIGH ENGINE TEMPERATURE SWITCH
OP – OIL PRESSURE GAUGE
K1 – AC CRANK DISCONNECT RELAY
K2 – ENGINE RUN RELAY
K3 – ENGINE CRANK RELAY
K4 – FAULT SHUTDOWN RELAY
K5 – FAULT SHUTDOWN TIME DELAY RELAY
OPS – OIL PRESSURE SENDER
WTS – WATER TEMP. SENDER

Running

- When proper output is obtained from stator main field windings BI/B2, KI relay is energized (LED1 lights). After a 5-10 second time delay, K5 relay is energized (LED5 lights).

NOTE
Voltage to the KI relay and K5 relay are rectified and regulated at 12 volts DC by bridge rectifier BR1 and voltage regulator VR1.

- Stator winding 33-44 provides voltage sensing source to the voltage regulator.

- Normally open KI contacts close to maintain voltage to K2 relay (LED2 remains lit).

- Normally open K2 contacts remain closed to maintain voltage to all devices energized by lead #70.

- Normally open KI contacts close to energize generator "ON" light.

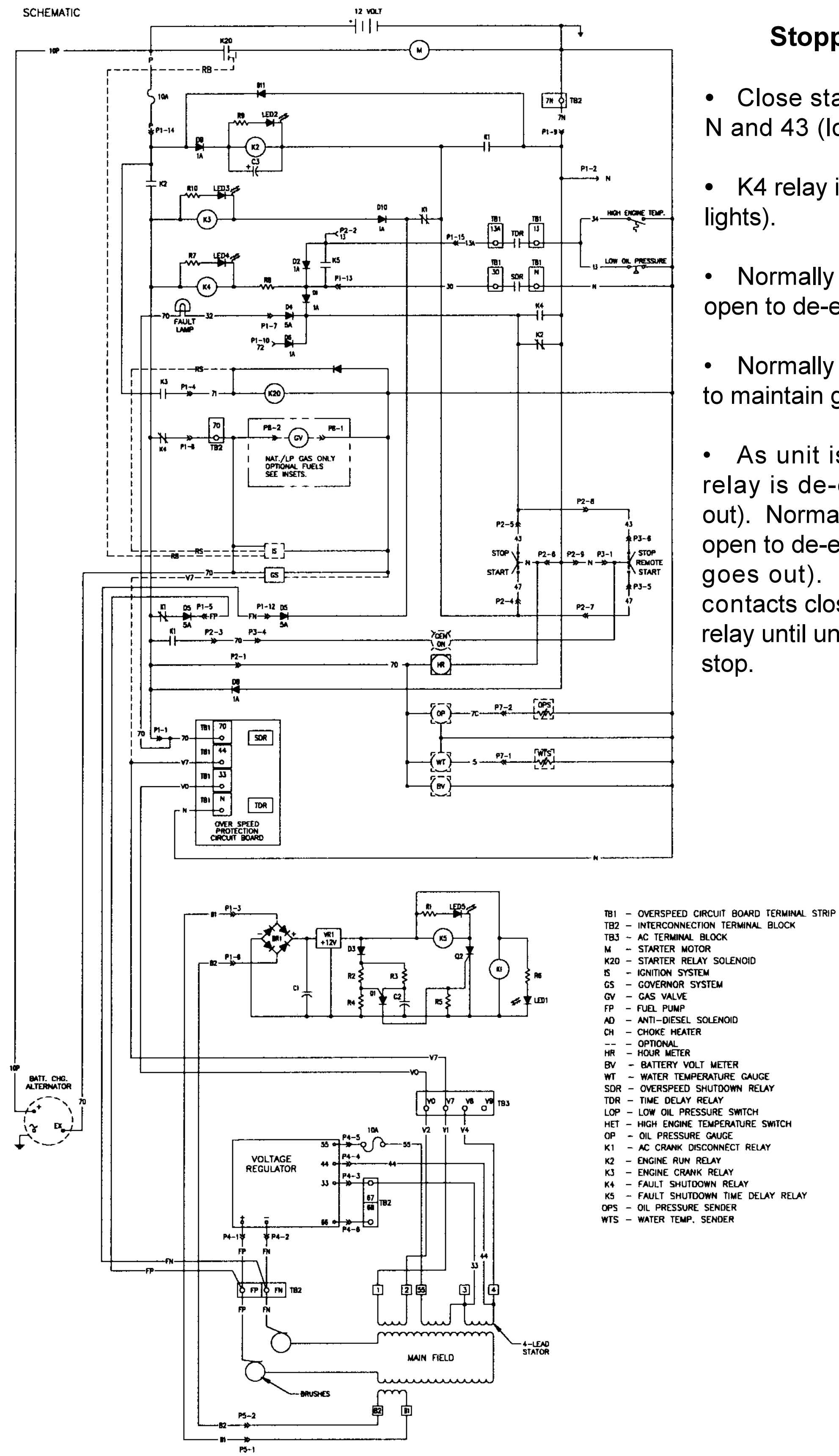
- Normally open K5 contacts close to permit engine shutdowns to activate should there be a fault.

NOTE
Low oil pressure (LOP) switch contacts open when engine develops proper oil pressure.

- One set of normally closed KI contacts open to disconnect circuit to (+) connection of exciter fields (field flashing).

- A set of normally closed KI contacts open to disconnect circuit to (-) connection of exciter field (field flashing). K1 contact also will de-energize K3 relay (LED 3 goes out) and prevents accidental reenergizing of starter motor. K3 contacts open to de-energize K20 relay. K20 contacts open to de-energize Starter Motor.

- When the unit is running, start switch contacts N and 47 are opened by releasing start/stop rocker switch.



Stopping

- Close start/stop switch between N and 43 (local or remote).
- K4 relay is energized (LED4 lights).
- Normally closed K4 contacts open to de-energize GV, IS, GS.
- Normally open K4 contacts close to maintain ground to K4 relay.
- As unit is shutting down, KI relay is de-energized (LED 1 goes out). Normally open KI contacts open to de-energize K2 relay (LED 2 goes out). Normally closed K2 contacts close to ground circuit to K4 relay until unit comes to a complete stop.

Sequence of Operation Quiz

1. What symptoms will you see if the K1 relay does not pull in? (coil is electrically “open”)

2. If the LOP contact remains closed after the generator starts what will happen?

3. What symptoms will you see if the 10 Amp fuse opens? (wire #P)

4. If the stator winding B1-B2 is open what symptoms will be seen?

5. What symptoms will be seen if the 10 Amp fuse opens? (wire #55)

6. If the K3 relays fails, (coil is electrically “open”) what syptoms will be seen?

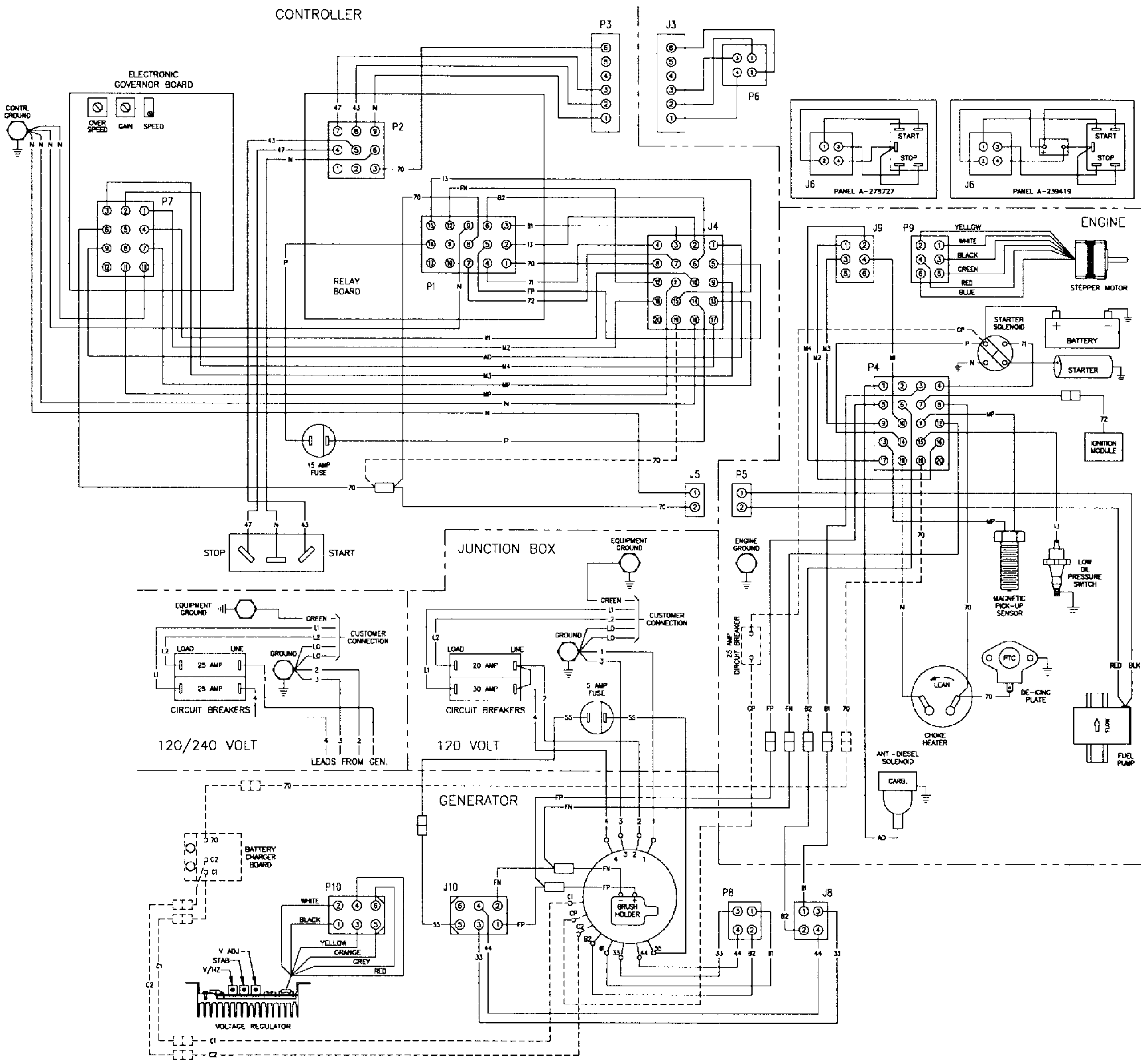
7. What contacts must close before the gas valve is energized?

8. What is the function of the K20 relay?

9. What are the safety shutdowns for this application?

10. What is the function of the K5 relay?

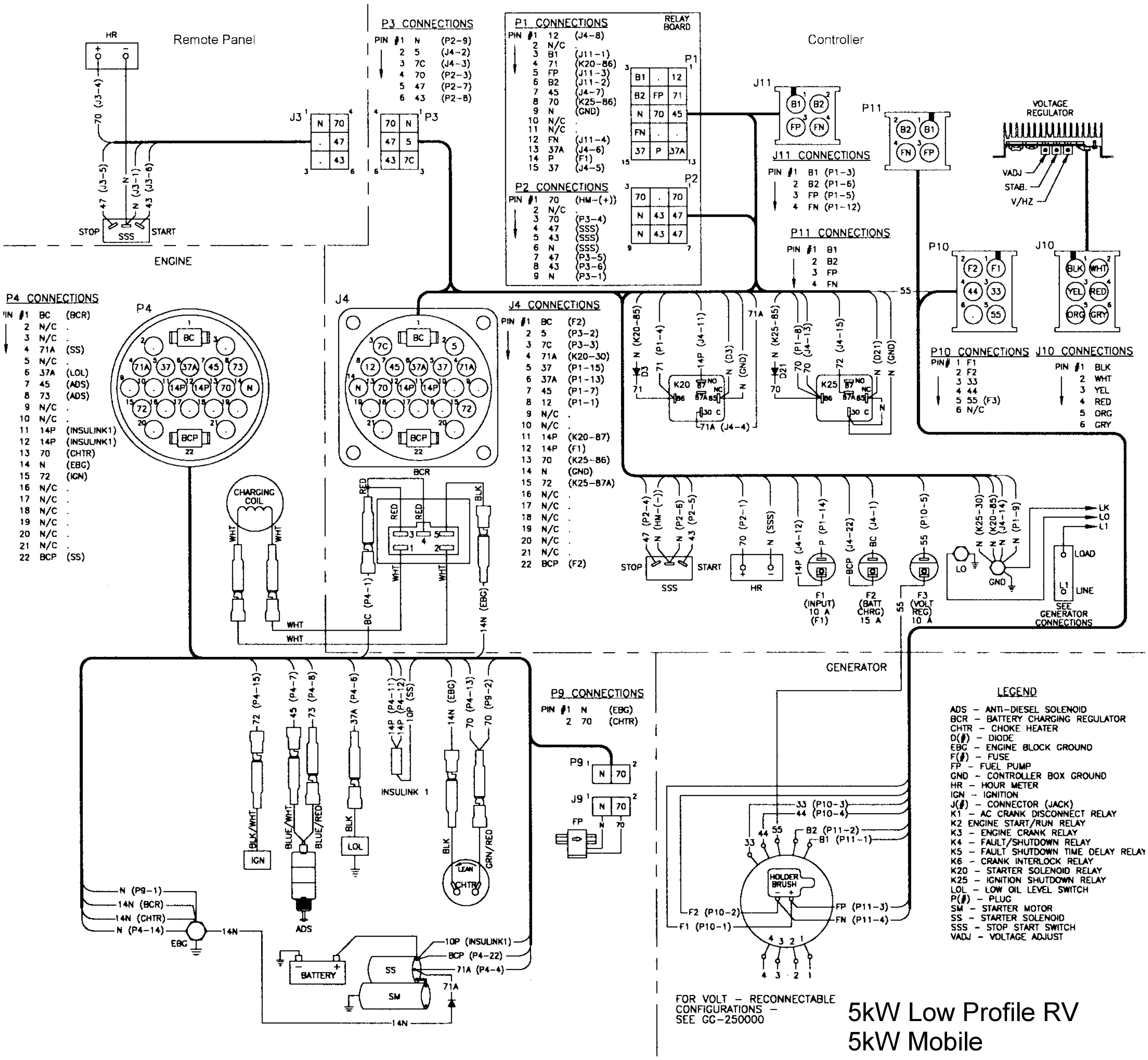
Controller: Relay Controller



Reading the Wiring Diagram

Wiring diagrams are used to show how the generator is wired as well as component location.

Wiring diagrams have been designed under two different formats, the first format shows each wire on the generator set as an individual wire on the diagram. The second format utilizes a point to point system that references the starting point of the wire and the ending point and does not have each individual wire incorporated into the print. The point to point format was introduced in 1998 as the model to be used for all wiring diagrams.

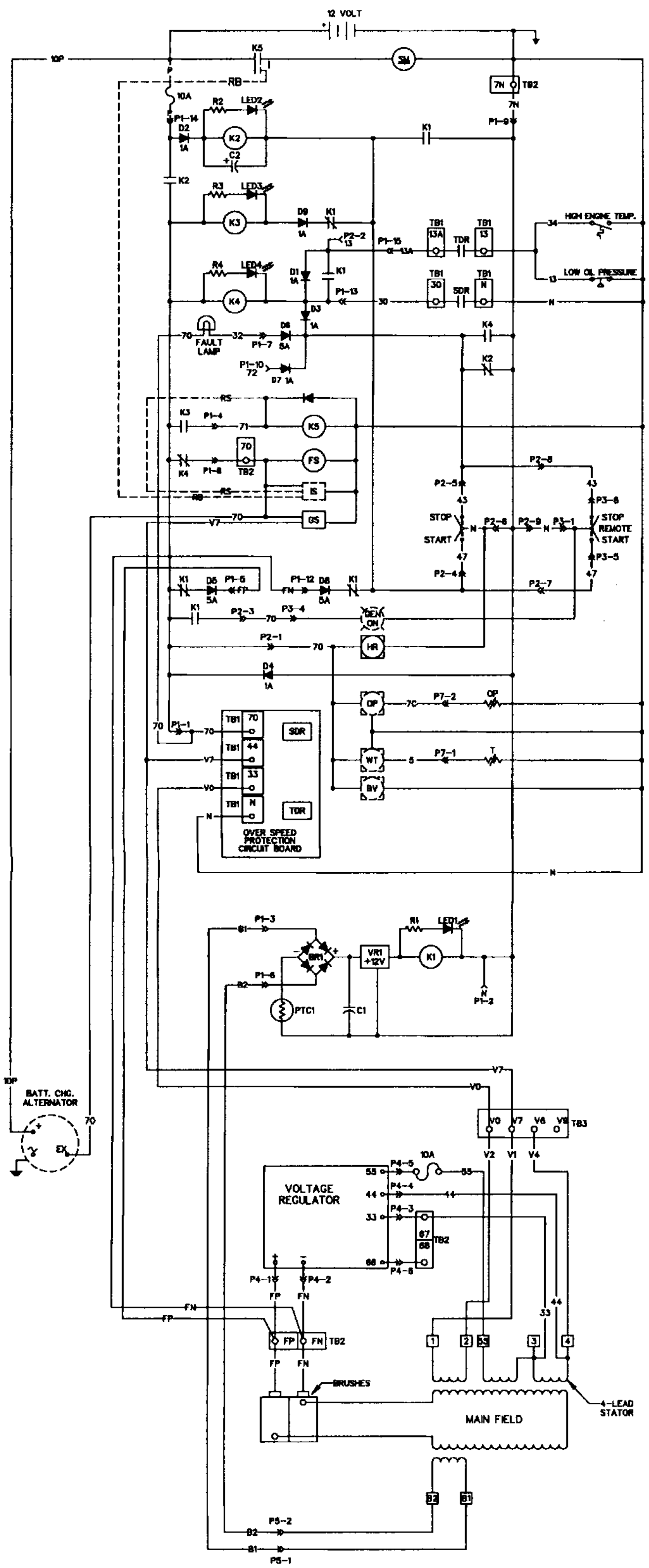


5kW Low Profile RV
5kW Mobile
Kohler CS12

Example of Point to Point Format Wiring Diagram

Controller: Relay Controller

SCHEMATIC



TB1 – OVERSPEED CIRCUIT BOARD TERMINAL STRIP
TB2 – INTERCONNECTION TERMINAL BLOCK
TB3 – AC TERMINAL BLOCK
SM – STARTER MOTOR
K5 – STARTER SWITCH
IS – IGNITION SYSTEM
GS – GOVERNOR SYSTEM
FS – FUEL SOLENOID
HR – HOUR METER
BV – BATTERY VOLTS
WT – WATER TEMPERATURE
SOR – OVERSPEED RELAY
TDR – TIME DELAY RELAY
LOP – LOW OIL PRESSURE
HET – HIGH ENGINE TEMPERATURE
OP – OIL PRESSURE
K1 – AC CRANK DISCONNECT RELAY
K2 – ENGINE RUN RELAY
K3 – ENGINE CRANK RELAY
K4 – FAULT SHUTDOWN RELAY
∿ – BATTERY CHARGING ALTERNATOR

Wire numbers have been incorporated into the schematic diagrams to aid troubleshooting. Wire number designation is consistent throughout the marine generator product line.

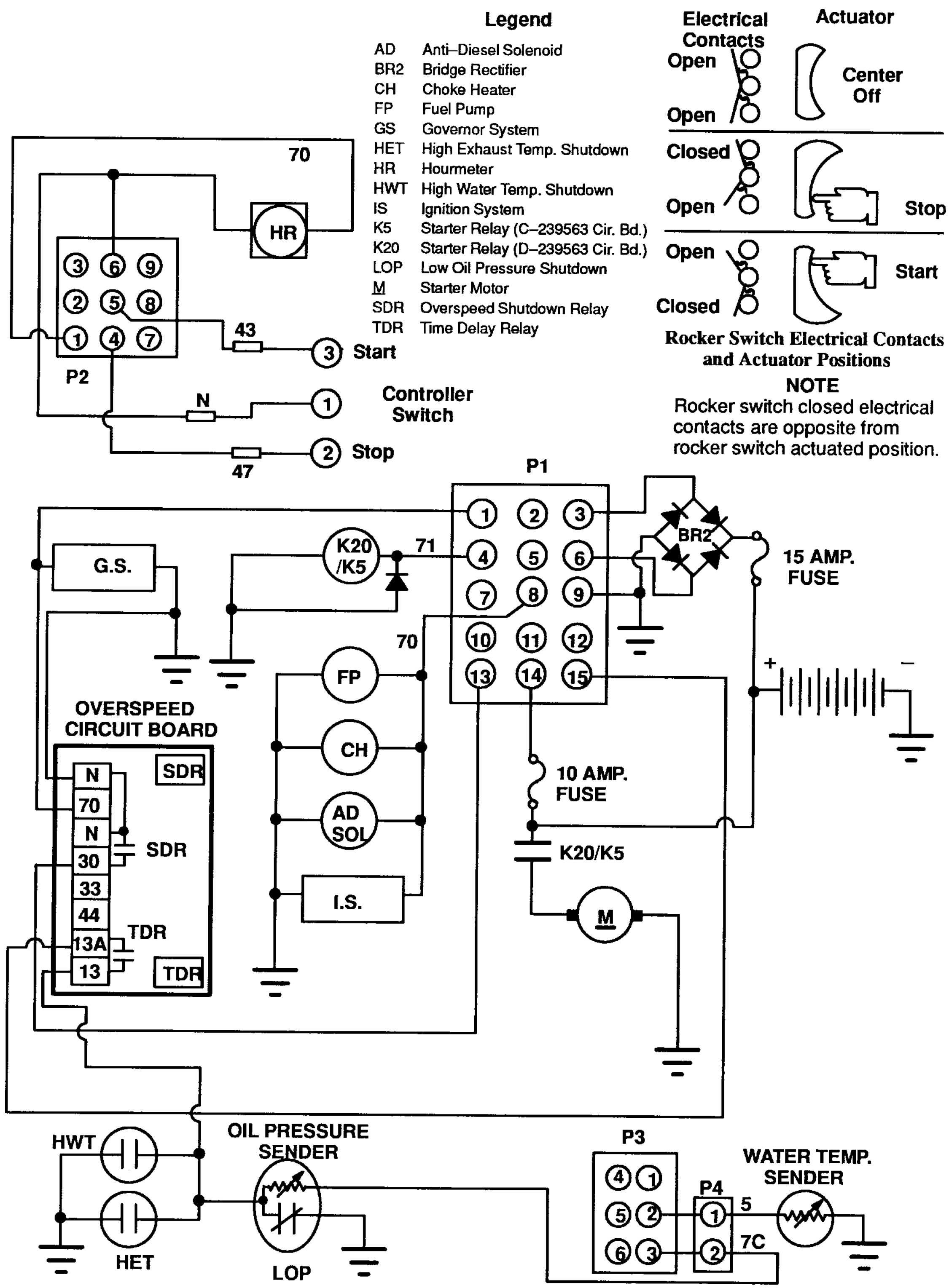
Wire numbers to remember

(70) Electrically "hot" when in the start or run position.

(71) Electrically "hot" when in the start position.

(P), (14P), Electrically "hot" when battery is connected

(N) Battery ground



Typical Wiring Harness Connection Using 239563 Relay Board

Overspeed and Time Delay Board

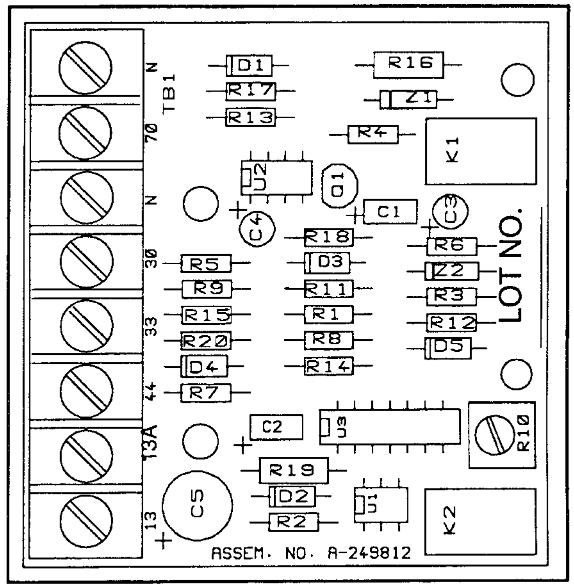
The overspeed board is used on specific applications where overspeed shutdown is required. This board features two relays and two separate functions:

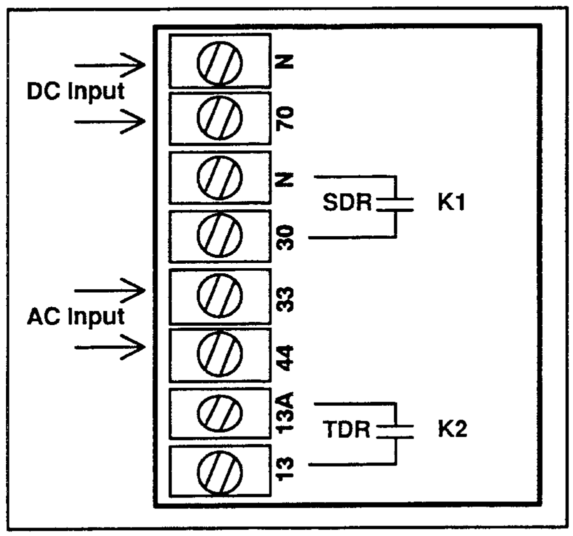
It provides a normally open set of relay contacts (SDR) which close when the 120 VAC applied to the sensing terminals (33-44) exceeds 70 Hz. This frequency trip point is factory set by the R10 potentiometer.

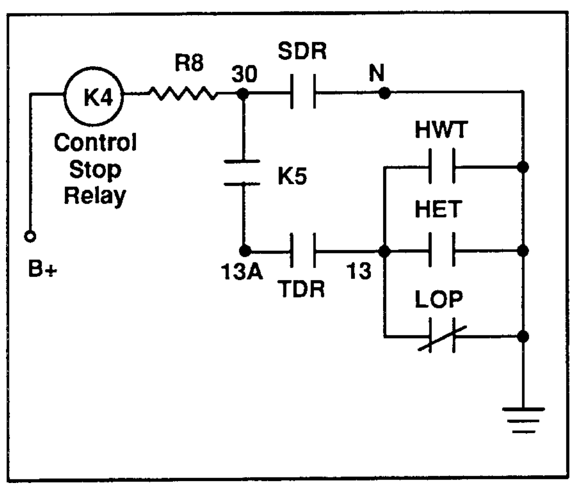
When used in conjunction with the main control board this feature will provide an engine shut-down if an overspeed condition should occur.

The board also provides a normally open set of relay contacts (TDR) that close 5 to 8 seconds after receiving a 12 VDC signal to its sensing terminals (N-70). Time delay is non-adjustable.

The time delay circuit provides the main control board with a delay period prior to relay contact closure to allow engine oil pressure build-up during cranking and start-up.

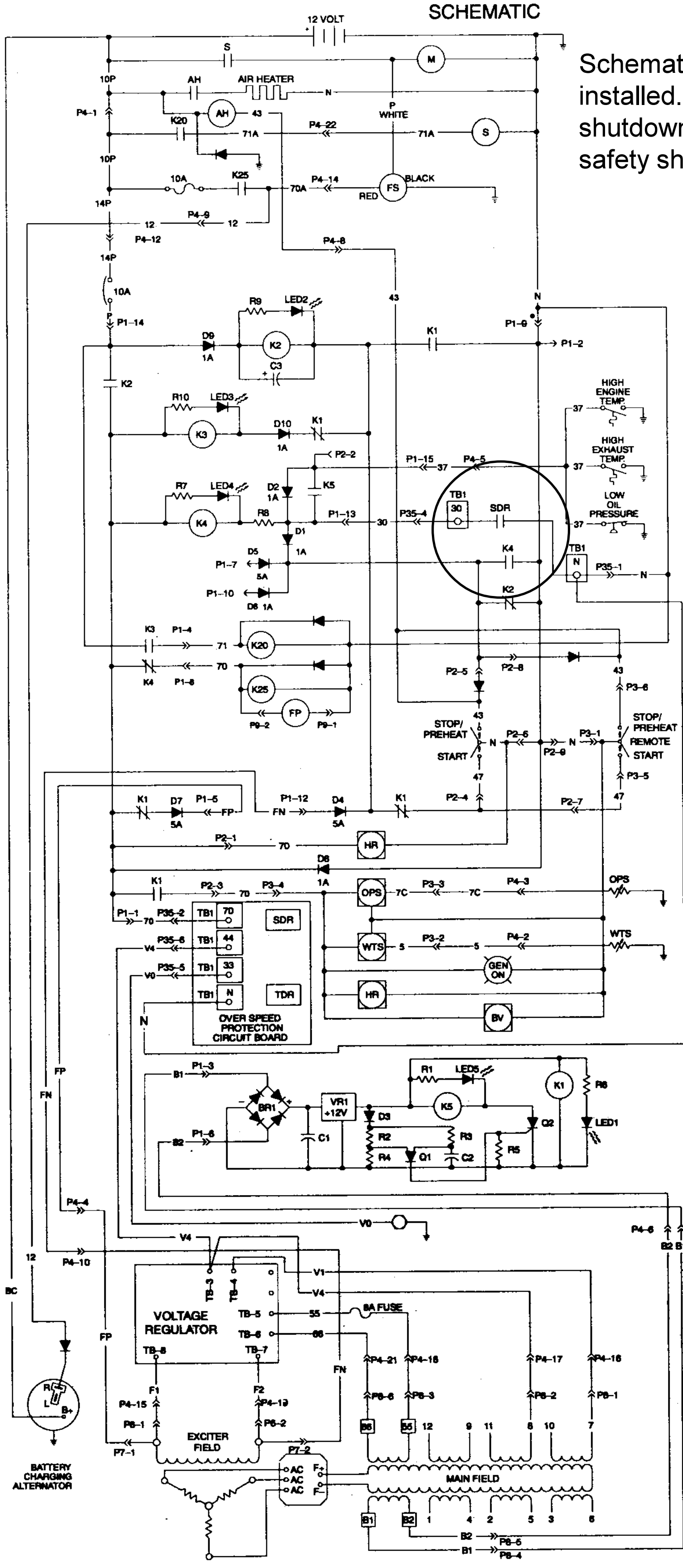






Controller: Relay Controller

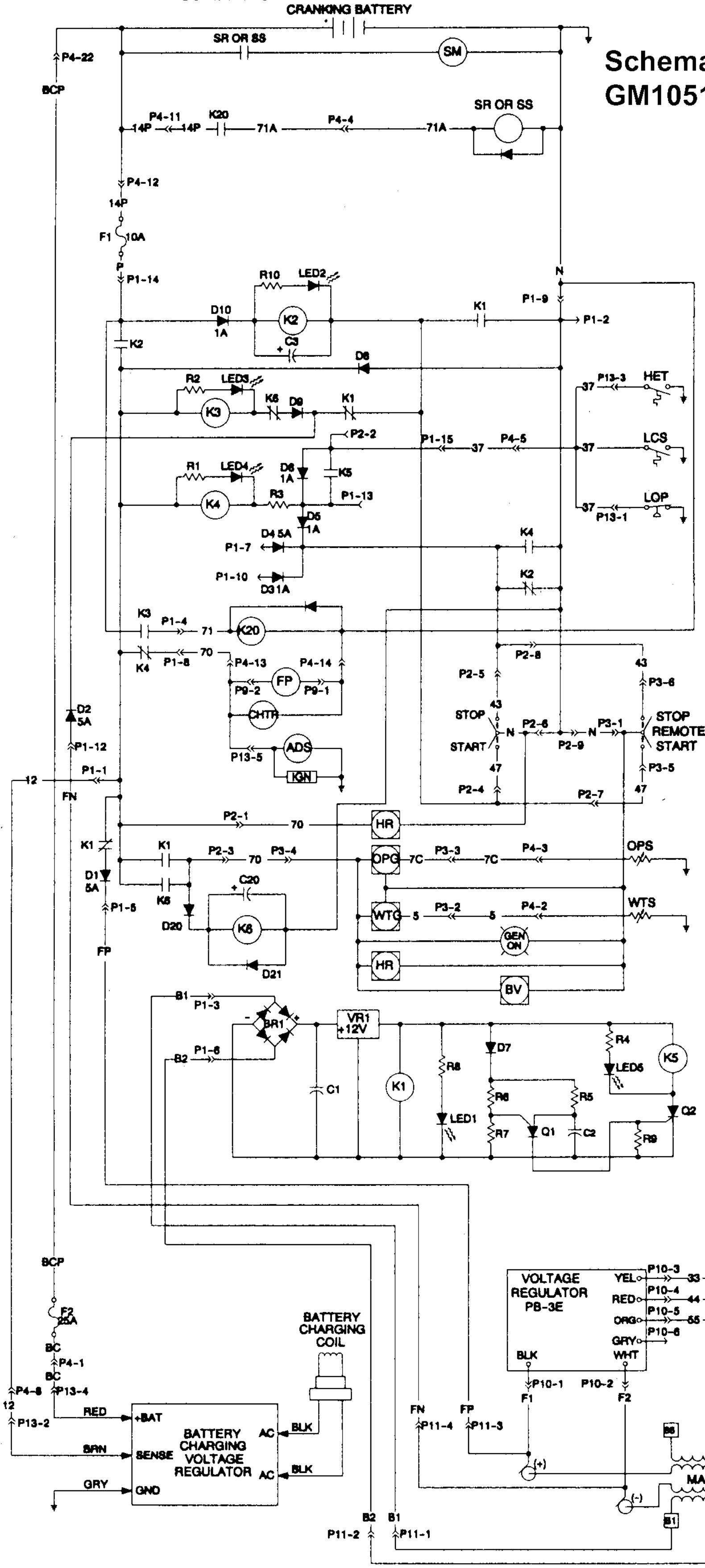
SCHEMATIC



Schematic diagram with the overspeed board installed. The SDR contact for overspeed shutdown is in the K4 relay circuit for engine safety shutdowns.

SCHEMATIC

Schematic Diagram GM10516 Controller Board



LEGEND
ADS - ANTI-DIESEL-SOLENOID
CHK - CHOKE HEATER
D(NUM) DIODE
F - FUEL PUMP
GND - CONTROLLER BOX GROUND
HET - HIGH ENGINE TEMPERATURE
HM - HOUR METER
IGN - IGNITION
J(NUM) - CONNECTOR
K1 - AC CRANK DISCONNECT RELAY
K2 - ENGINE START RELAY
K3 - ENGINE CRANK RELAY
K4 - FAULT/SHUTDOWN RELAY
K5 - FAULT SHUTDOWN TIME DELAY RELAY
K20 - STARTER SOLENOID RELAY
LCS - LOSS OF COOLANT SWITCH
LOP - LOW OIL PRESSURE SWITCH
SM - STARTER MOTOR
OPG - OIL PRESSURE GAUGE
OPS - OIL PRESSURE SENDING UNIT
P(NUM) - CONNECTOR
SS - STARTER SOLENOID
SSS - START/STOP SWITCH
WTG - WATER TEMPERATURE GAUGE
WTS - WATER TEMPERATURE SENDING UNIT
K6 - INTERLOCK RELAY

Gaseous Fuel System

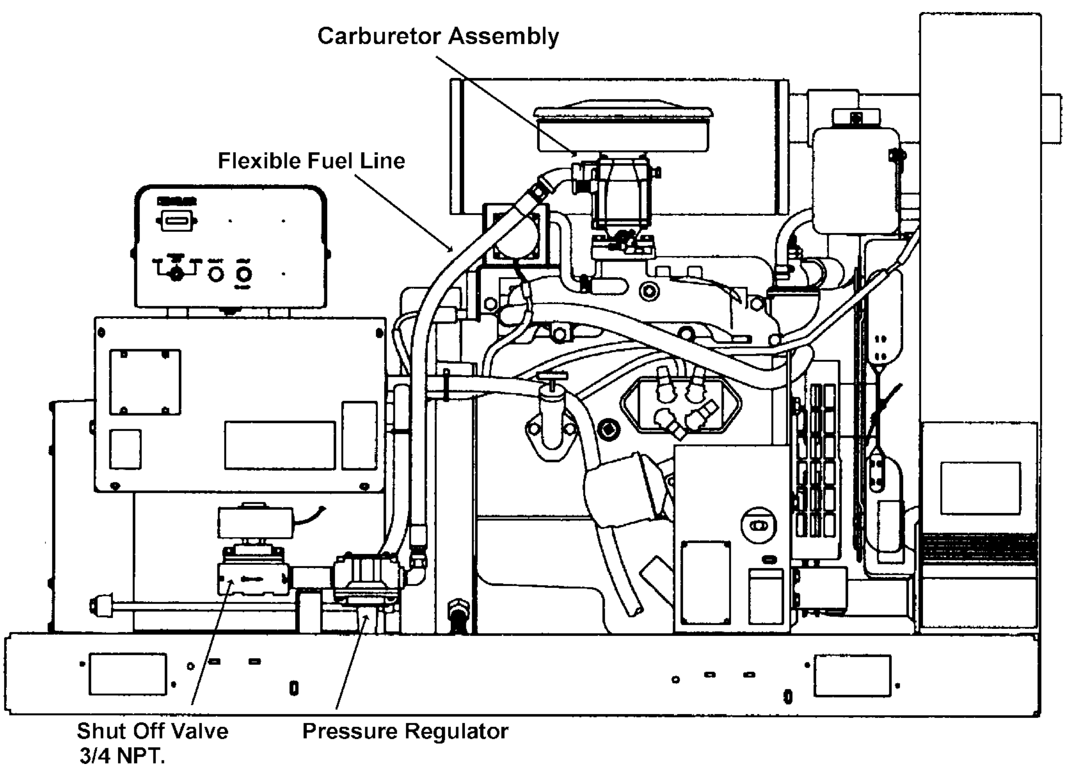
The straight gas fuel system utilizes a fuel valve to control fuel flow to the regulator. The fuel valve is used to shut off the fuel when the engine stops. The fuel valve is located before the regulator and flexible fuel line to prevent the accumulation of an explosive mixture of gas and air should the regulator or fuel line develop a leak. The gas valve is energized by the run relay from the controllers' logic circuit board.

The generator-mounted regulator reduces fuel pressure as fuel passes to the carburetor.

The carburetor controls the ratio of fuel to air mixture into the engine under varying load conditions.

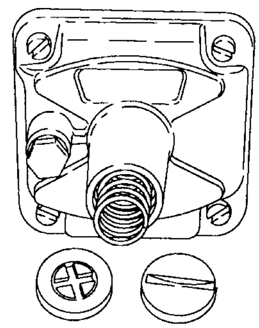
A flexible fuel connector is used between the stationary gas piping and engine-mounted carburetor, the flexible connector is used due to the shifting and vibration of the engine while running.

Most generators are designed to operate on either Natural gas or LP gas. The Fuel regulator is mounted with the spring compartment facing downward which makes it compatible with both fuels, when used with natural gas the spring and retainer are installed in the regulator when used with LP gas the spring is removed.



Secondary Regulator

The generator set can be operated on natural gas or LP gas. If the set is to operate on LP gas the regulator must be pointing downward and the internal spring must be removed. To remove the internal spring from the gas regulator, remove the retaining screw from the underside of the regulator. Remove retainer and spring then reinstall retaining screw.



When converting the generator back to natural gas reinstall spring and retainer screw. A pressure gauge or manometer must be installed on the carburetor side of the gas regulator. Rotate spring retainer on regulator to obtain a constant 5 inches water column or 3 ounces per square inch while generator is running under full load conditions.

Natural Gas System

The natural gas as supplied from the utility is in a vapor state. The primary regulator for a natural gas system will be the responsibility of the utility that supplies the natural gas.

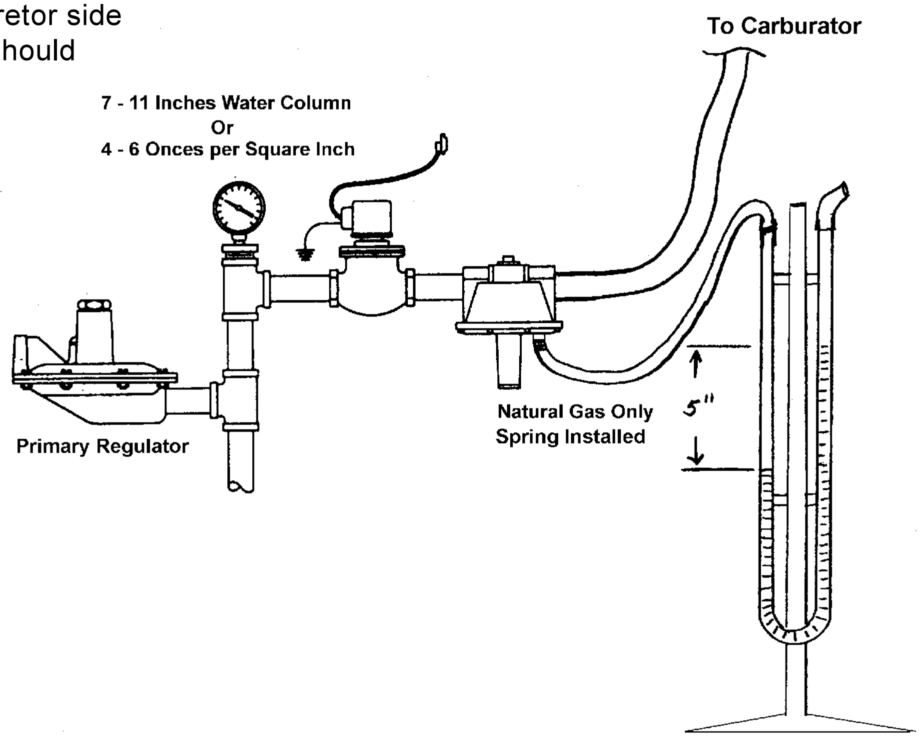
The heating value of Natural gas should be 1000BTU per cubic foot. When heating content falls below 1000BTU the set will not produce rated power and will need to be derated. Always check the specification sheet for the rating of the generator while running on natural gas, many applications require derating of the full load power on natural gas.

When installing or troubleshooting the fuel system the following factors must be considered.

- Pressure loss due to length of pipe
- Pressure loss due to other appliances on same fuel supply
- Pressure loss due to number of fittings or elbows

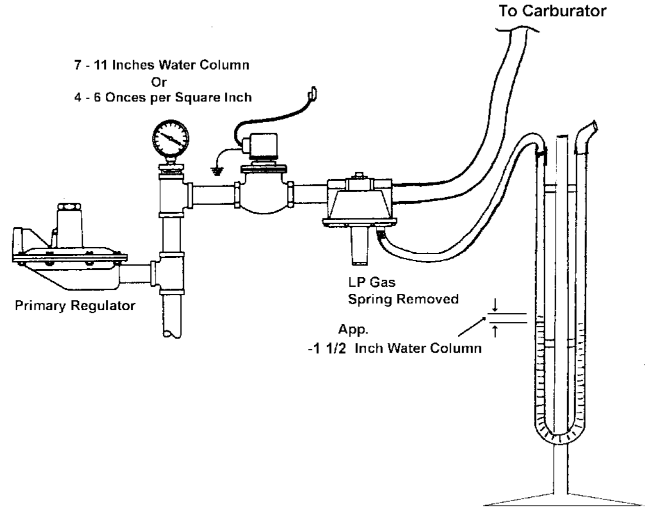
Physical Property @ 60°F (15°C)	**Natural Gas**
Normal Atmospheric State	Gas
Boiling Point Initial End	 –259°F (–162°C) –259°F (–162°C)
Heating Value, Btu's per: Gallon (Net – LVH) Gallon (Gross) Cubic Foot (Gas)	 63,310 1000
Density Cubic feet of Gas per Gallon (Liquid)	57.75
Weight (lbs.) per Gallon Liquid	2.65
Octane Number: Research Motor	 110+

Measured pressure at the inlet to the secondary regulator should be 4 – 6 ounces per square inch or 7 – 11 inches water column. The outlet or carburetor side of the secondary regulator should measure 4-5 inches water column under load.



LP Gas

LP gas is supplied as a liquid in pressure tanks, which makes it easily adaptable to stationary generator applications where complete independence of a fuel source is required.



LP gas is propane, butane, or a mixture of the two gases. The ratio of butane to propane is especially important when an outdoor tank is used. LP gas suppliers may supply the tank in warm summer months with a mixture composed mostly of butane, this mixture may work well in summer but may not provide sufficient vaporized pressure at cold temperatures (below 32°) to start and run the engine. Check with you LP gas supplier for mixture content when hard starting symptoms exist.

The heating value for propane is 2,516 BTU per cubic foot with a boiling point of -44° F and butane is 3,264 BTU per cubic foot with a boiling point of 32° F.

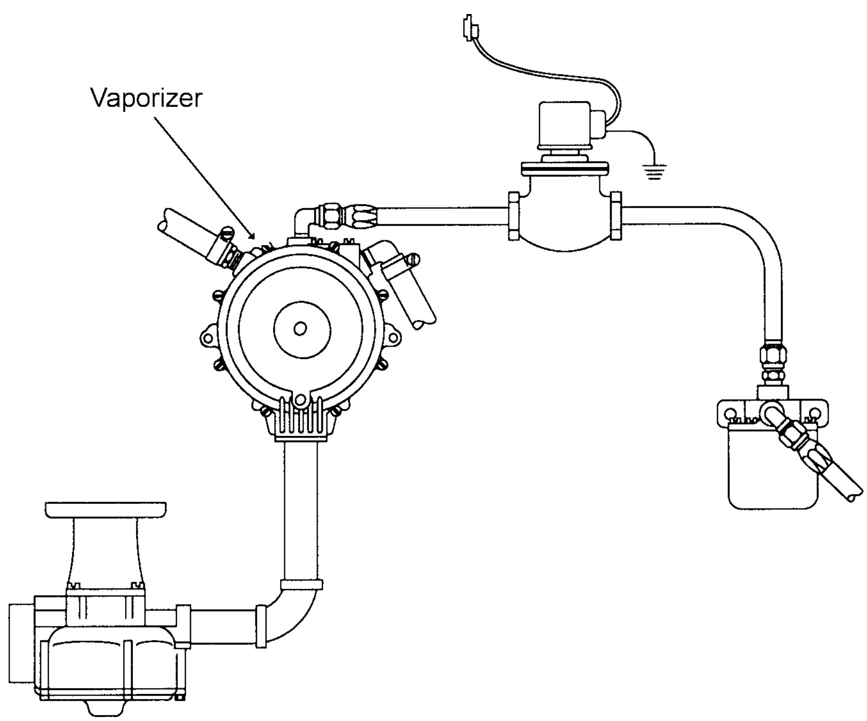
Inlet pressure into the secondary regulator should be 4 – 6 ounces per square inch or 7 – 11 inches water column. Outlet pressure to the carburetor will be a negative pressure of about –11/2 inches water column.

Physical Property @ 60°F (15°C)	**Butane**	**Propane**
Normal Atmospheric State	Gas	Gas
Boiling Point		
Initial	+32°F (0°C)	–44°F (–42°C)
End	+32°F (0°C)	–44°F (–42°C)
Heating Value, Btu's per:		
Gallon (Net – LVH)	94,670	83,340
Gallon (Gross)	102,032	91,547
Cubic Foot (Gas)	3264	2516
Density Cubic feet of Gas per Gallon (Liquid)	31.26	36.39
Weight (lbs.) per Gallon Liquid	4.81	4.24
Octane Number:		
Research	94	110+
Motor	90	97

Liquid Withdrawal System

Liquid withdrawal fuel systems can be supplied for generator sets but are not recommended for automatic standby service. With these systems, high-pressure LP at 150-200 psi (1034-1379 kPa) is piped to the engine in liquid form. A combination of converters (vaporizers) and regulators can then reduce the gas to acceptable pressures. A converter (combination of vaporizer, primary, and secondary regulators) changes the liquid to vapor using heat from the engine cooling system. In such a system, for a short period after start-up, there may be problems vaporizing enough fuel for an engine running under load. The engine, which supplies heat to the converter (vaporizer), needs time to warm sufficiently to allow the converter to vaporize enough fuel to supply the engine.

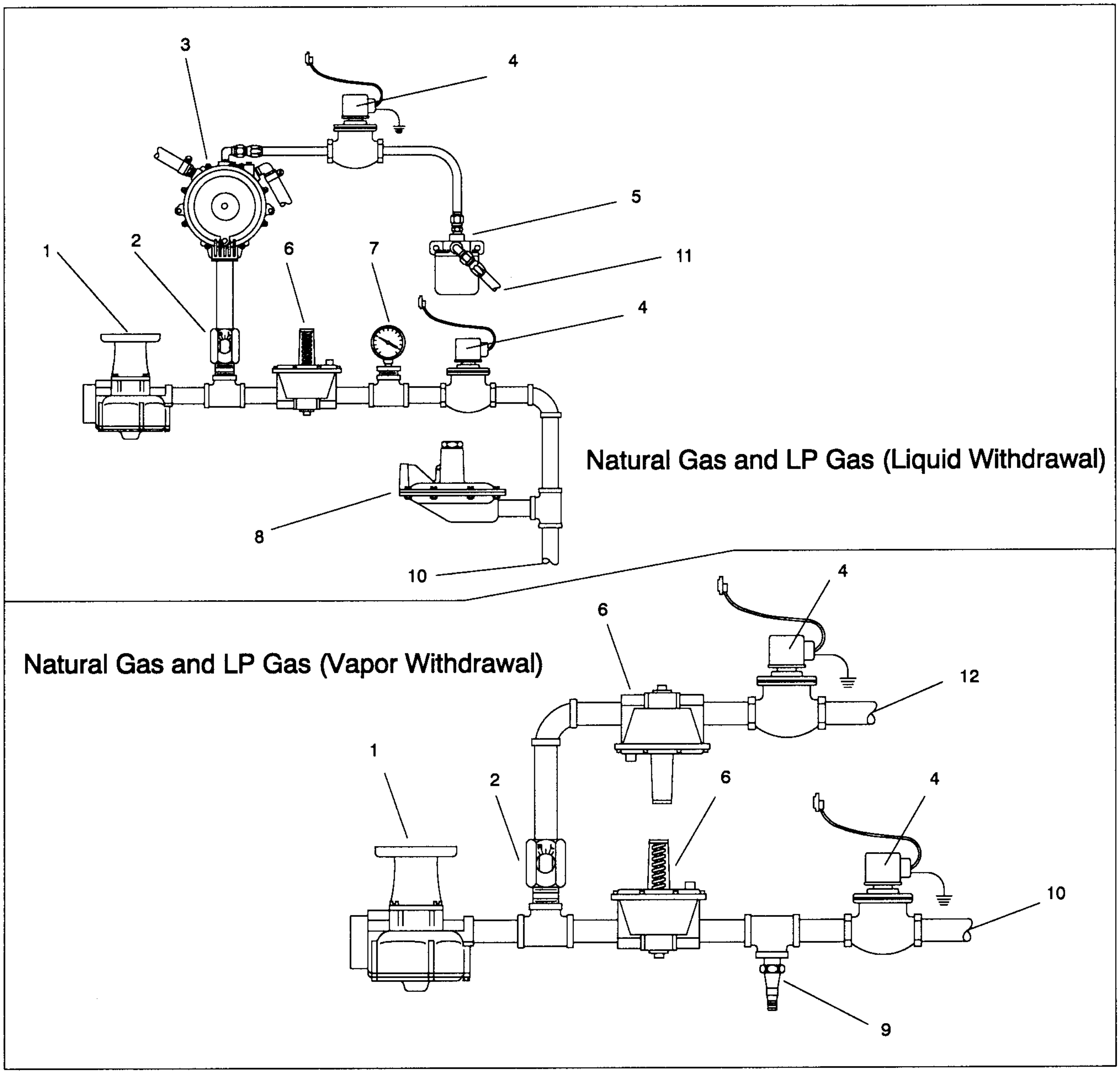
Many areas have codes prohibiting gas fuel at more than 5 psi (34.5 kPa) inside of buildings. This might preclude the use of a liquid withdrawal system. In order to meet codes, converters are sometimes located outside of the building that houses the generator set. This can cause start-up problems because the great length of pipe between the converter and the carburetor does not allow sufficient heat buildup and heat retention.



Dual Gas System

In many applications, natural gas is the main fuel and LP gas is used as the emergency fuel when natural gas is not available.

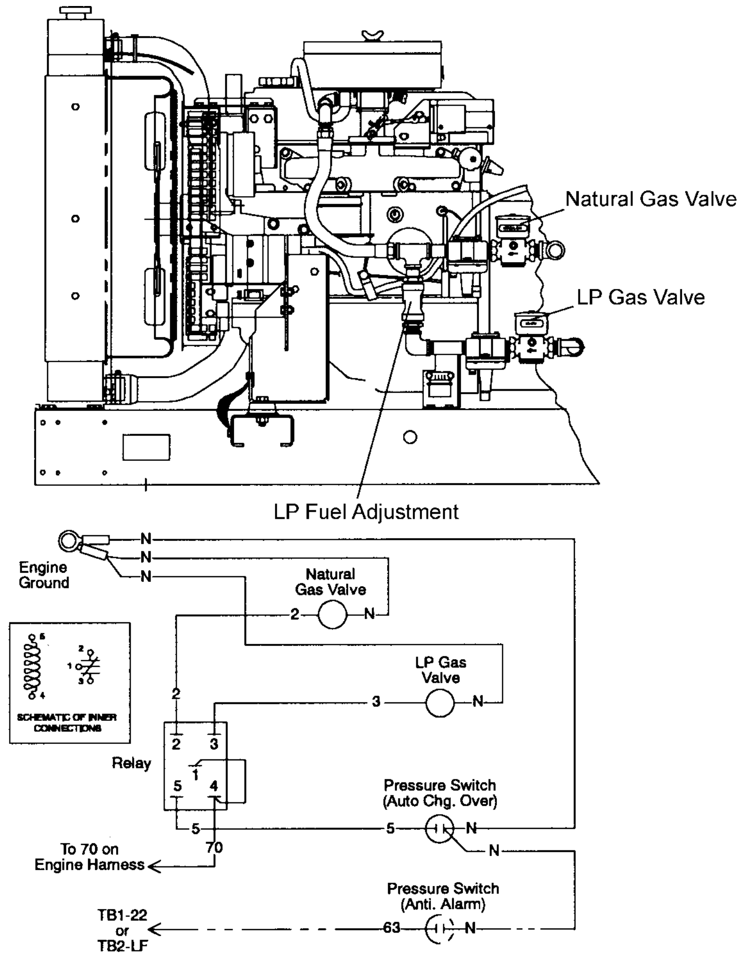
The dual fuel system in common use offers automatic changeover from one fuel to the other. This is accomplished by the use of two separate regulators and solenoid valves. A pressure switch placed on the primary source of fuel closes with a drop in pressure and energizes a relay, which closes the primary fuel solenoid and opens the secondary or emergency fuel solenoid. To ensure proper carburetion upon changeover to LP gas, a separate LP gas load adjustment is located in-line between the secondary regulator and the carburetor.



1. Carburetor
2. Load adjustment valve
3. Converter (vaporizer)
4. Solenoid valve
5. LP gas (liquid withdrawal) filter (supplied by gas supplier or customer)
6. Secondary regulator
7. Pressure gauge
8. Primary regulator (supplied by gas supplier or customer)
9. Low pressure switch
10. Natural gas supply
11. LP Gas (Liquid Withdrawal) supply
12. LP Gas (Vapor Withdrawal) supply

Dual Gas Schematic Diagram

The automatic changeover system provides automatic changeover from natural gas to LP gas vapor or from LP gas vapor to natural gas. The primary and secondary fuels each have a secondary fuel regulator and a fuel valve. Typically the primary fuel is natural gas with the backup fuel being LP gas vapor. When the generator set is started and running, the primary valve opens and the secondary fuel valve closes. The primary fuel line has a vacuum switch in series with a relay connected to the start/run circuit. When the primary fuel pressure drops below 2.5 in. water column (0.18 in. Hg), the relay energizes where the secondary fuel valve opens and the primary fuel valve closes. When the primary fuel pressure rises above 2.5 in. water column (0.18 in. Hg), the primary fuel is used again.



Pipe Size Requirement for Gaseous System

When installing the generator and laying the pipe for a gaseous system a few things need to be considered, the type of fuel, the distance it must travel from gas meter or tank to the fuel shutoff solenoid, and the amount of fuel consumed by the engine. To figure the correct pipe size for a specific installation, refer to the chart and follow the procedure outlined.

1. Determine length of pipe between gas meter/tank and fuel shutoff solenoid at generator set. Example: 35ft.

2. Find figure closest to pipe length in "Length of Pipe" column on chart. Example: For 35ft it would be 40ft.

3. Refer to fuel consumption from the generator specification sheet. Note type of fuel, and consumption of fuel at 100% load. Example: The 17RY for natural gas operating at 100% full load uses 307cfh (cubic feet per hour).

4. Refer to correction factors below. Locate factor for specific gravity of fuel used. Example: natural gas specific gravity - .65, correction factor - .962.

5. Divide consumption figure (307cfh) by the correction factor (.962).

   307÷. 962= 320cfh.

6. Move vertically across page to determined point in "length of pipe" column (40ft) go down column and stop at first figure equal to or greater then corrected consumption figure (320cfh).

7. Move to left column from figure (320cfh) to determine correct pipe size. The correct pipe size for a 17RY with a pipe run of 35 ft. should be 1 inch.

Correction Factors

Fuel	Specific Gravity	Factor
Sewage Gas	0.55	1.040
Natural Gas	0.65	0.962
Air	1.00	0.775
Propane	1.50	0.633
Butane	2.10	0.535

Maximum capacity of Pipe in Cubic Feet of gas per Hour for a Gas pressure of 0.5Psig or less

(Based on a 0.60 Specific Gravity Gas)

Nominal Iron Pipe Size, Inches	Internal Diameter, Inches	Length of Pipe, Feet						
		10	20	30	40	50	60	70
1/4	.364	43	29	24	20	18	16	15
3/8	.493	95	65	52	45	40	36	33
1/2	.622	175	120	97	82	73	66	61
3/4	.824	360	250	200	170	151	138	125
1	1.049	680	465	375	320	285	260	240
1–1/4	1.380	1,400	950	770	660	580	490	460
1–1/2	1.610	2,100	1,460	1,180	990	900	810	750
2	2.067	3,950	2,750	2,200	1,900	1,680	1,520	1,400
2–1/2	2.469	6,300	4,350	3,520	3,000	2,650	2,400	2,250
3	3.068	11,000	7,700	6,250	5,300	4,750	4,300	3,900
4	4.026	23,000	15,800	12,800	10,900	9,700	8,800	8,100

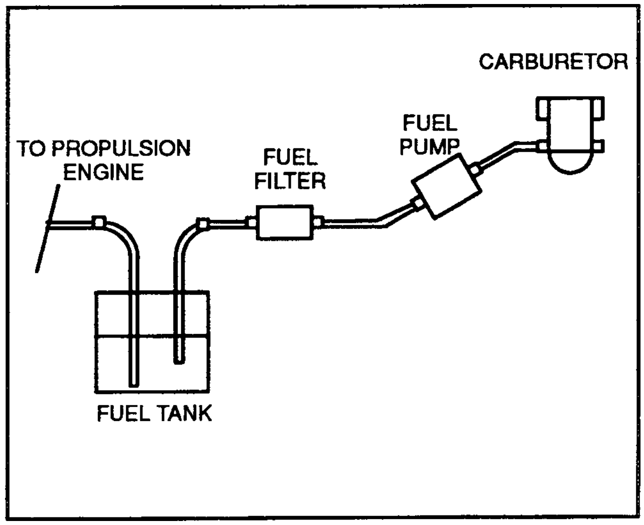
Nominal Iron Pipe Size, Inches	Internal Diameter, Inches	Length of Pipe, Feet						
		80	90	100	125	150	175	200
1/4	.364	14	13	12	11	10	9	8
3/8	.493	31	29	27	24	22	20	19
1/2	.622	57	53	50	44	40	37	35
3/4	.824	118	110	103	93	84	77	72
1	1.049	220	205	195	175	160	145	135
1–1/4	1.380	460	430	400	360	325	300	280
1–1/2	1.610	690	650	620	550	500	460	430
2	2.067	1,300	1,220	1,150	1,020	950	850	800
2–1/2	2.469	2,050	1,950	1,850	1,650	1,500	1,370	1,280
3	3.068	3,700	3,450	3,250	2,950	2,650	2,450	2,280
4	4.026	7,500	7,200	6,700	6,000	5,500	5,000	4,600

A pressure drop of 0.5 inch water column has been calculated into the chart to make allowances for a nominal number of fittings.

Fuel System – Gasoline

For best results, use only clean fresh, regular grade unleaded gasoline with a pump sticker rating of 86 or higher. Regular grade leaded gasoline can also be used; however, be aware that the combustion chamber and cylinder head will require more frequent service.

Never use gasohol containing more than 10% ethanol or gasoline containing methanol.



Fuel Pumps & Filters

Electric fuel pumps are used to draw gasoline from the fuel tank, through a filter and supply clean gasoline at the proper pressure and quantity to the generator set engine carburetor.

Most pumps are more efficient as pushers, and therefore the closer the pump is located to the fuel supply tank the better. Many times this is not practical and therefore located on the generator set.

Most pumps have a built in check valve to prevent drawback of the fuel to the tank when the engine is shut off.

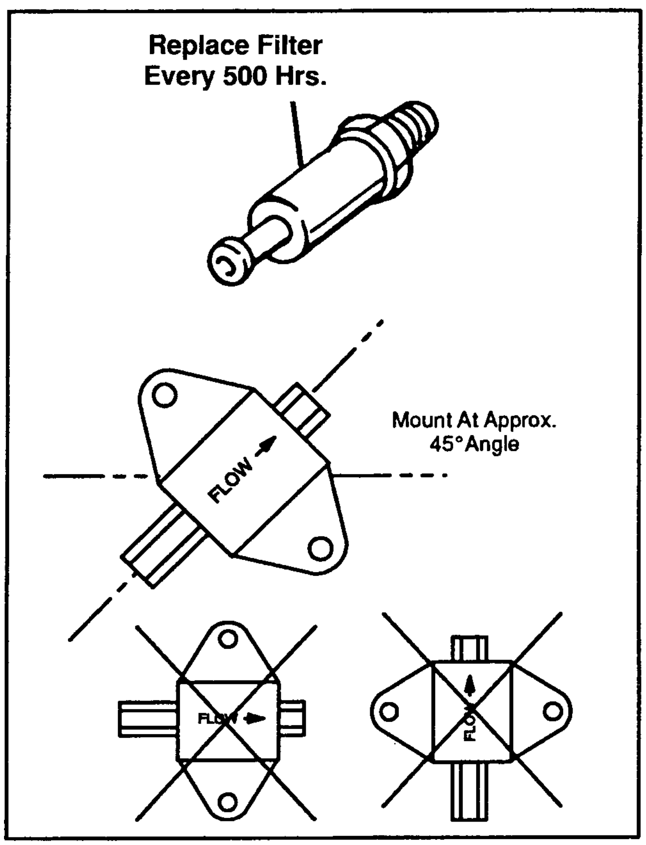
The solid state diaphram (Facet) pump is capable of delivering up to 30-35 gals/hr. at 1.5 to 3.5 PSI. Maximum pump lift is approximately 3ft. Maximum fuel line size should be 1/4" I.D.

The pumps operate on 12vdc. Current draw is approximately 1 ampere.

The solid state type pump is not servicable and requires an external filter.

The filter should be replaced after 500 Hrs. of operation.

To lesson the possibility of vapor lock the pump should be installed so fuel flow is at an approximate 45 degree angle.

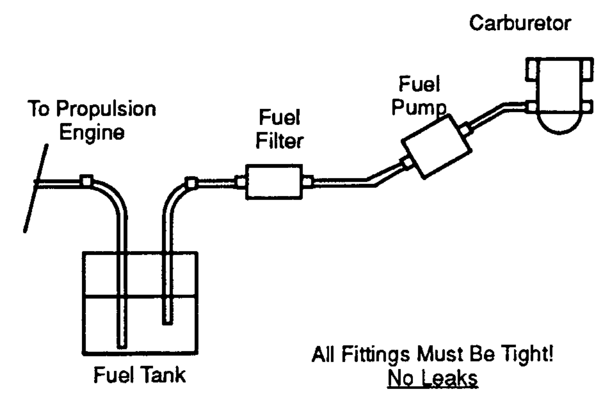


Fuel Pump Troubleshooting

It must be remembered when troubleshooting that the pumps are sucking fuel from the tank, it is therefore necessary that:

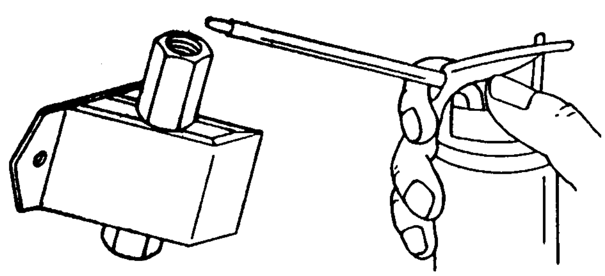
- The tank has sufficient fuel to cover the generator set dip tube.
- There are no leaks in the dip tube, fittings, or fuel line that would allow air to enter the system preventing fuel draw-up

Air leaks could cause the fuel to siphon back to the tank after a shutdown if a check valve was not used at the fuel tank. This would result in a "hard starting" condition.



Checking the Fuel Pump

To check the fuel pump operation, put a few drops of light-weight oil into both the input and output openings of the pump. Next, connect a jumper wire from the positive terminal to the power lead of the pump and connect another jumper to the pump body. The pump should make a rapid clicking noise.



Lubricate the Check Ball

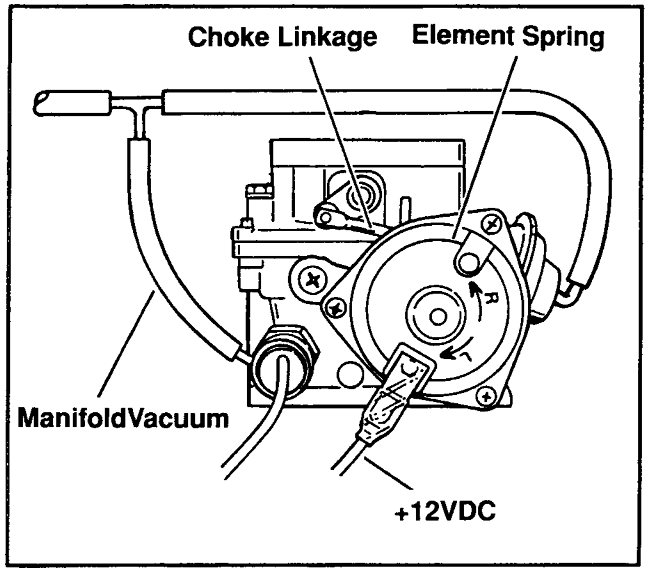
Note

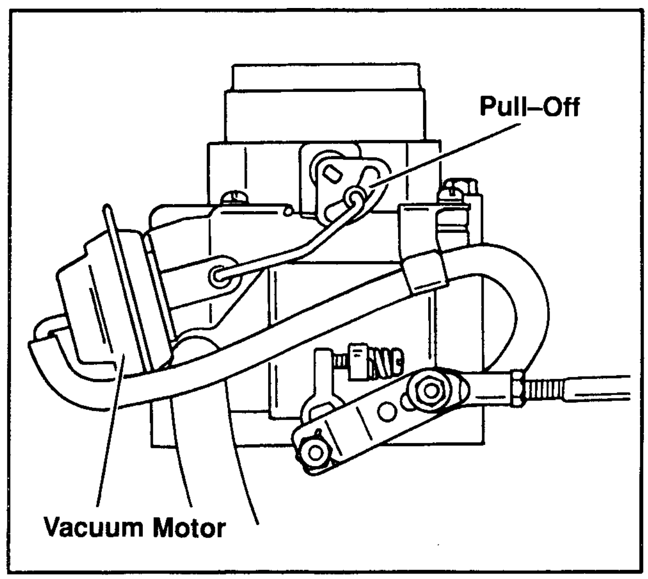
When replacing a fuel pump use only the factory-specified pump. A higher-pressure pump will cause carburetor flooding and possible fuel spillage.

Electric Chokes

The following section contains general information on the electrical choke assemblies used on various gasoline model generators. ***Refer to service manual for information regarding specific applications.***

Electric choke with vacuum assisted pulloff





The carburetor /choke system to the right consists of an adjustable thermal spring element and an externally mounted vacuum motor.

Both the thermal element assembly and the vacuum motor are connected to the choke plate with external linkage.

The thermal spring sets the choke plate in the proper position for the best operation under the existing temperature conditions. This may be adjusted by rotation of the element housing.

12vdc is supplied to the thermal element during cranking and running through the 70 wire of the engine harness.

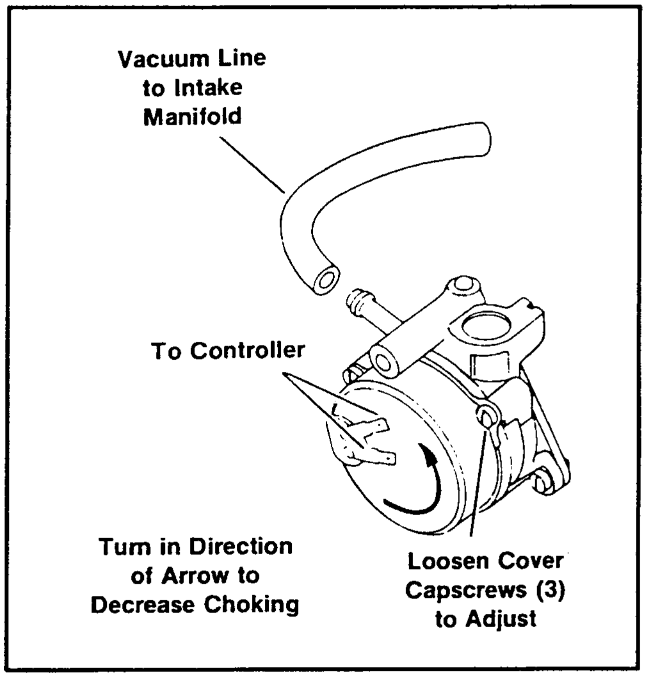
When the engine is running the vacuum pulloff assists in opening the choke plate. The degree of opening is determined by the thermal spring position.

If a “too rich” condition is suspected, first check the choke plate for full open position before making any fuel mixture adjustments.

The choke should be full open when the engine reaches normal operating temperature.

Kohler Electric Choke

The electric choke utilizes a vacuum circuit, thermal spring, counterweight, and 12 volt heater.

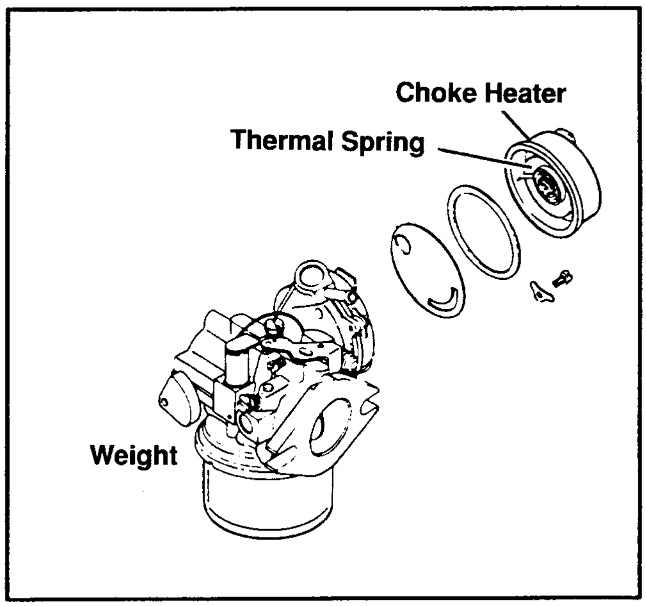


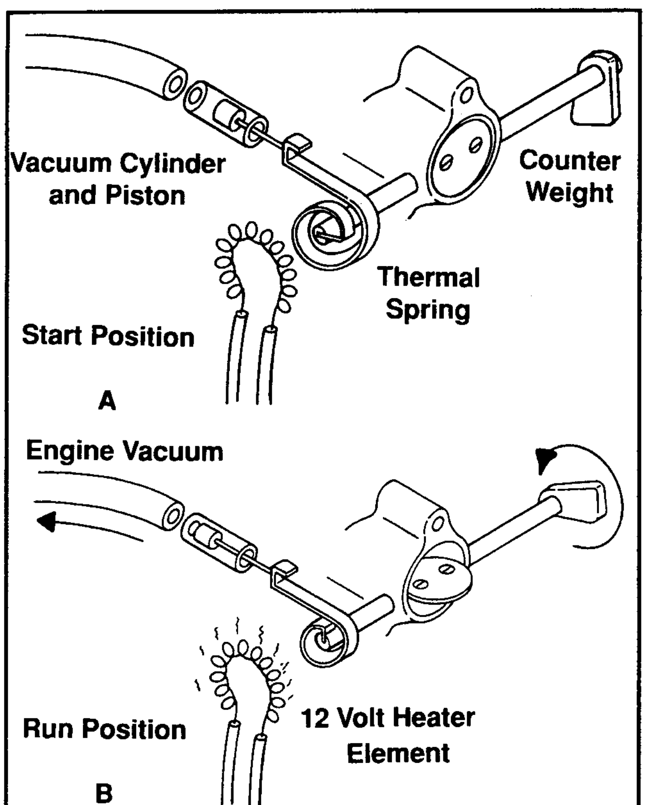
Pictured below is the choke operation. In Diagram "A" the choke plate on a cold engine is closed by the thermal spring and counterweight.

In Diagram "B", After starting the engine the manifold vacuum will increase the spring tension on the weight to open the choke plate.

The thermal spring reacts to the ambient temperature and controls the degree of carburetor choking.

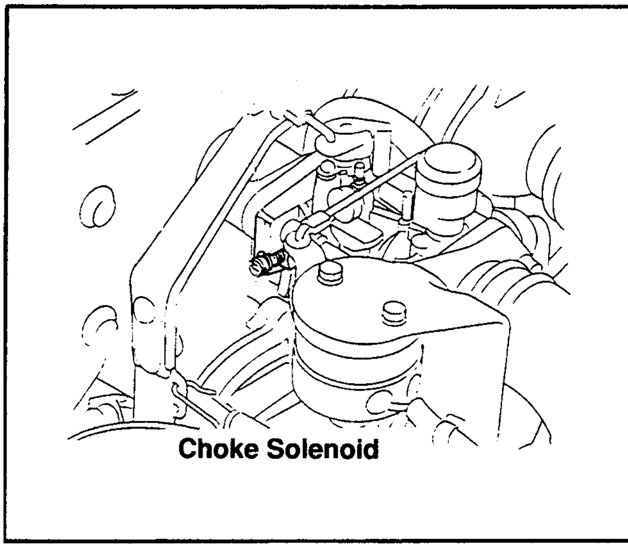
The heater element provides additional heat to the thermal spring and is energized with 12vdc when cranking or running.



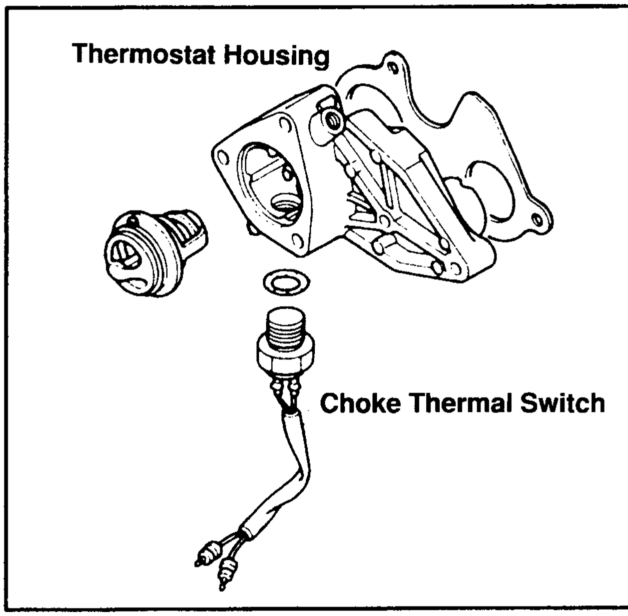


Electric Choke Solenoid
Thermal Switch
Hot Choke Board

Choking of engine is accomplished by an electric rotary solenoid. Full closure of the choke plate occurs whenever the solonoid is energized. The solenoid is energized when the engine if cranking or running and the engine temperature is below the thermal switch cutout.

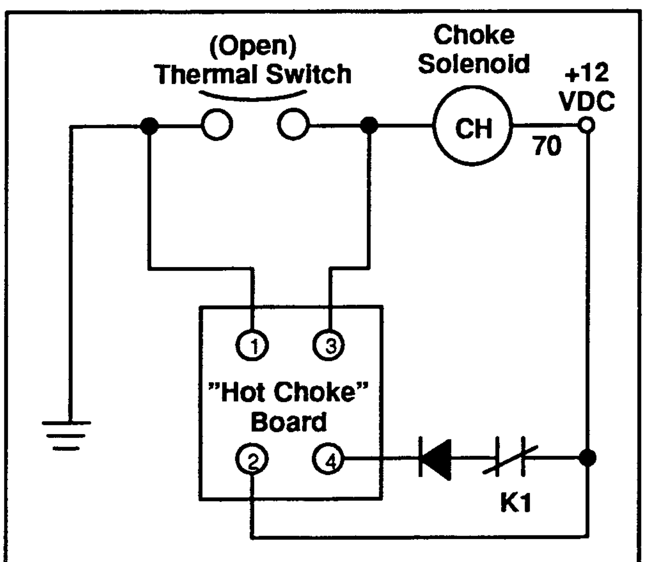


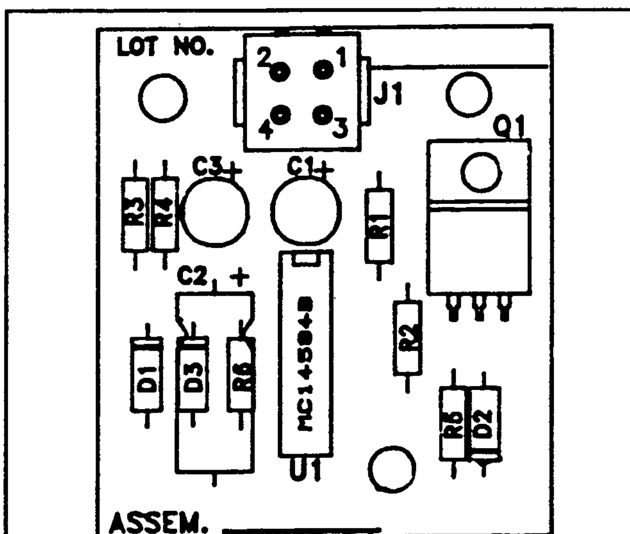
A thermal switch connected in series with the solenoid monitors the coolant and disables the choking when the temperature reaches 62-72 degrees F.



On a warm engine momentary full choking is required on start-up. This is accomplished by the open thermal switch with the “hot choke” circuit board.

A full choke condition will occur for approximately 2 seconds and a pulsing choke condition should occur every 1/2 second thereafter until engine start-up.

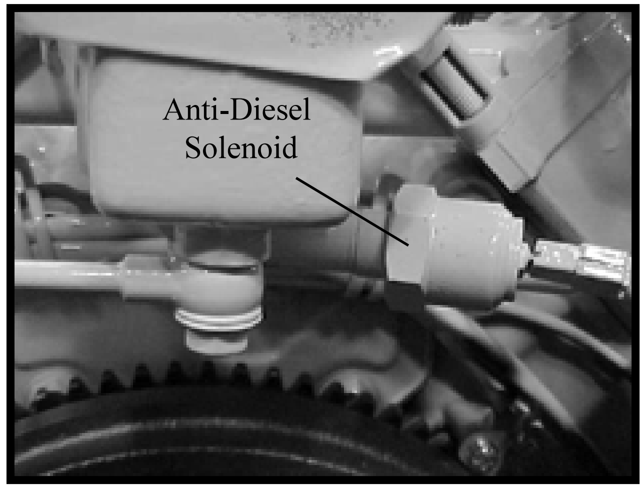




Hot Choke Board

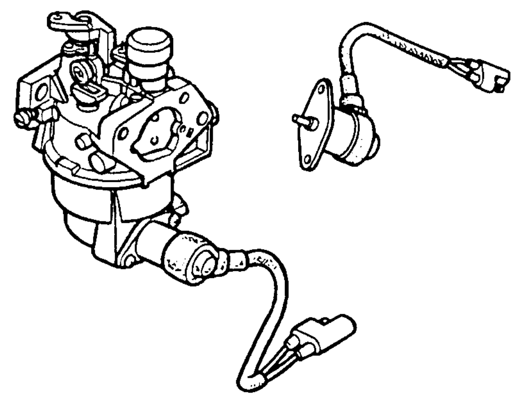
Anti-Diesel Solenoid

After running the generator with a heavy load, engines tend to continue running (diesel) after the switch is moved to the stop position. To prevent "run-on", the engine carburetor is equipped with an anti-diesel solenoid to stop the flow of fuel when the switch is moved to the stop position.



Anti-diesel solenoids used on gasoline engines can be activated two ways.

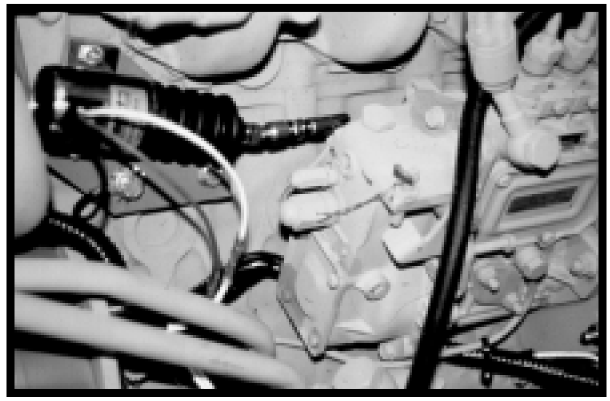
1. The solenoid can be energized when the engine is running or cranking through the #70 wire and de-energized when the engine is shutdown thus stopping fuel to the carburetor jets. In this application if the anti-diesel solenoid fails the generator does not start because the solenoid must pull in to allow fuel to flow through the carburetor.



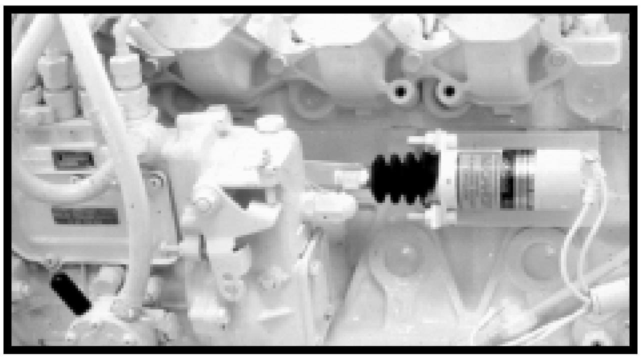
2. The solenoid is energized only at time of engine shutdown, the solenoid is de-energized the remainder of the time. In this application the generator will continue to run even if the anti-diesel solenoid fails.

Stop-Run Solenoid

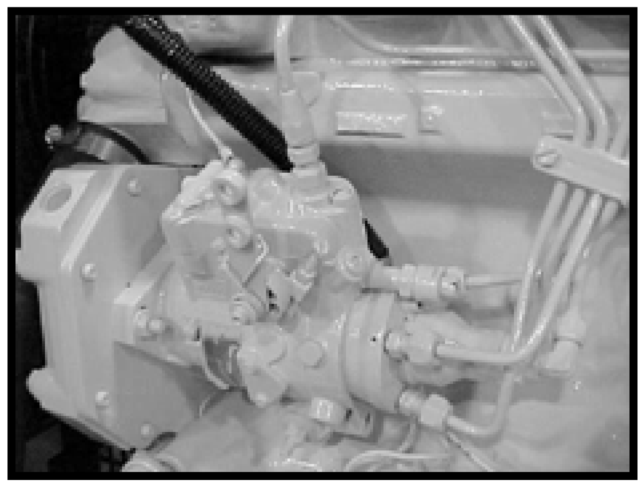
A Stop-Run Solenoid is used in the diesel generator product line to control fuel flow into the engine injector pump. This solenoid can be external to the pump or incorporated into the pump itself. When energized the external solenoid moves an injector pump lever to the "fuel on" position. When deenergized the solenoid returns to the "fuel off" position.



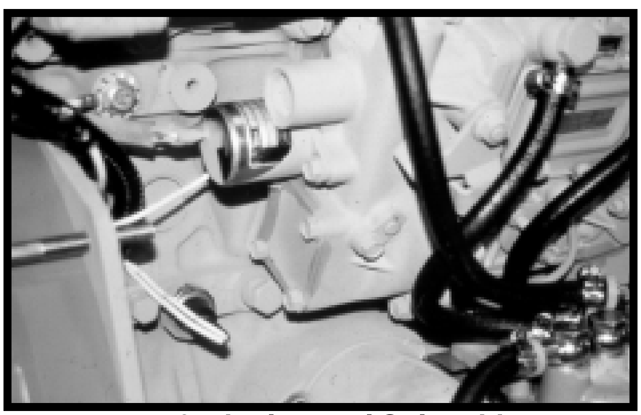
3 wire solonoid



Two Wire Solenoid



Internal Solenoid



3 wire Internal Solenoid

Stop-Run Solenoid (Two Wire)

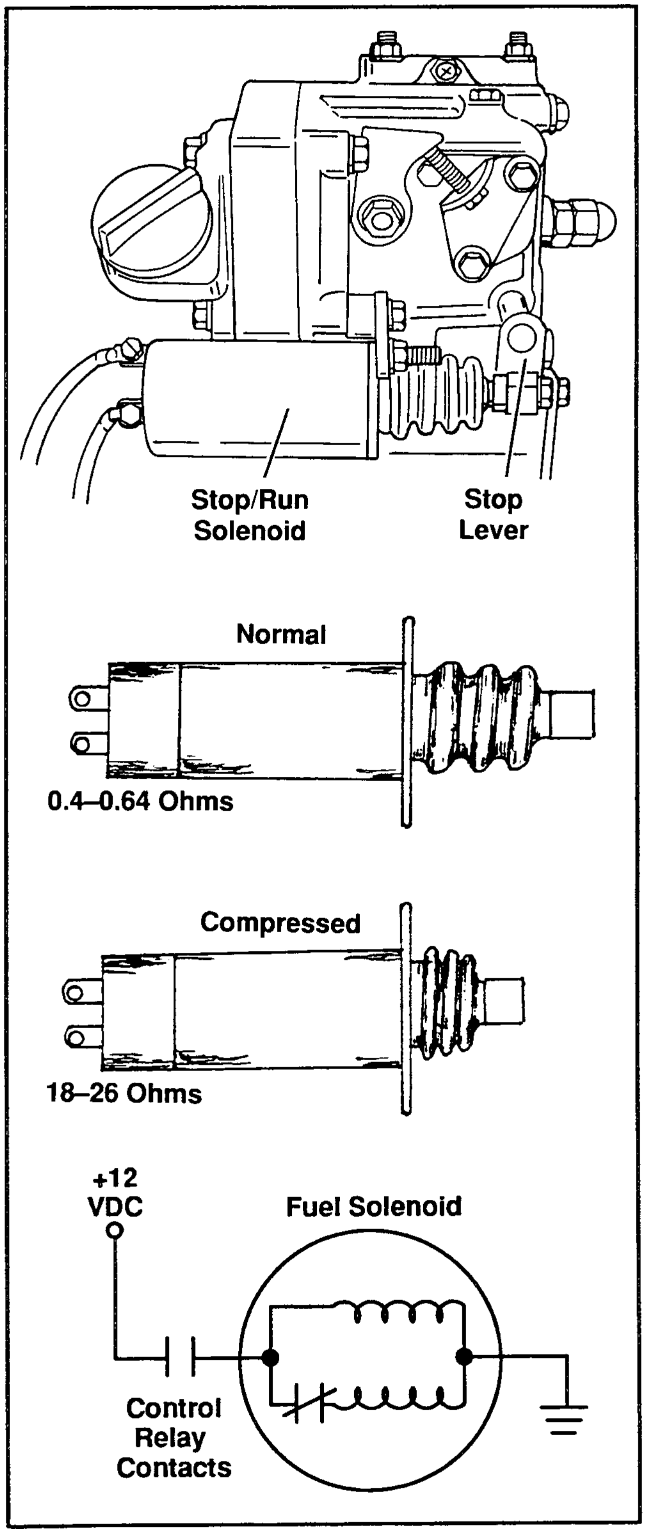
The solenoid serves to pull the governor regulator handle to the “fuel-on” position when energized. It is spring loaded to return the lever to the “fuel off” position when deenergized.

This solenoid incorporates an internal switch to transfer from a “pull-in” coil to a “hold-in” coil.

Resistance value across the coil terminals with the plunger in the normal position is .4 to .65 ohms.

Resistance value in the hold-in position (compressed) is 18 to 26 ohms.

It is important that there is no binding of the linkage and that it is properly adjusted. With the plunger fully compressed, the solenoid should be adjusted so the lever is positioned 1/16 inch before it contacts the internal stop. Failure of the pull-in coil will occur if not adjusted for full compression of the solenoid plunger.



Stop-Run Solenoid (Three wire)

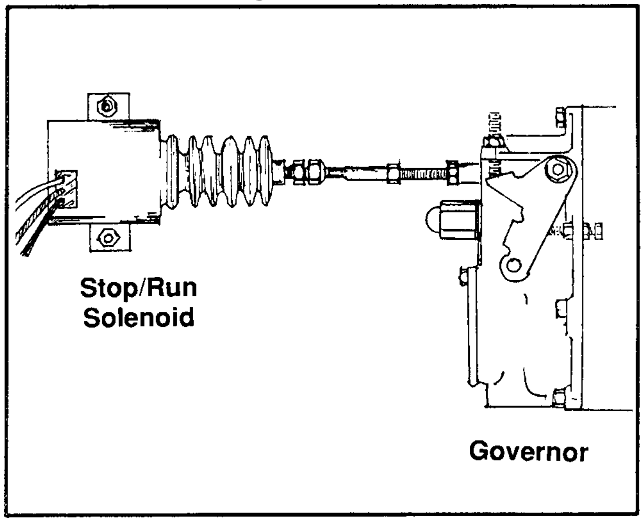
The fuel solenoid serves to pull the injector pump stop lever to the “fuel on” position when energized. It will return to the “fuel off” position when deenergized.

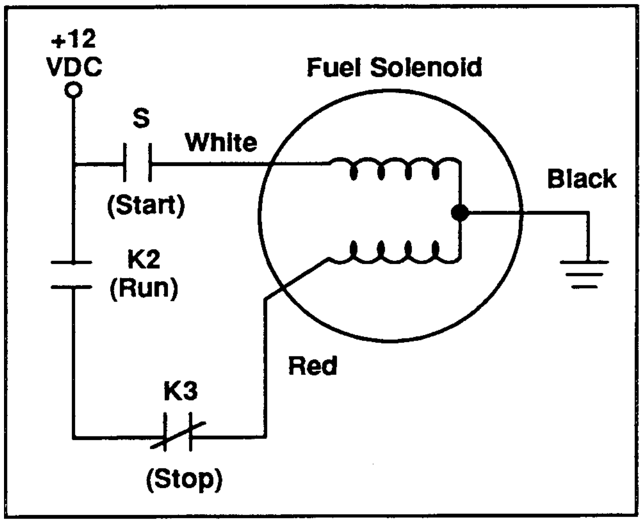
This solenoid features a three-lead coil with separate “pull-in” and “hold-in” windings.

The white “pull in” (start) winding has a very low resistance, approximately .12 to .26 ohms. The amp draw at start up is about 50 Amps.

The red “hold in” winding has a resistance value of approximately 12 ohms. The amp draw during running is about 1 Amp.

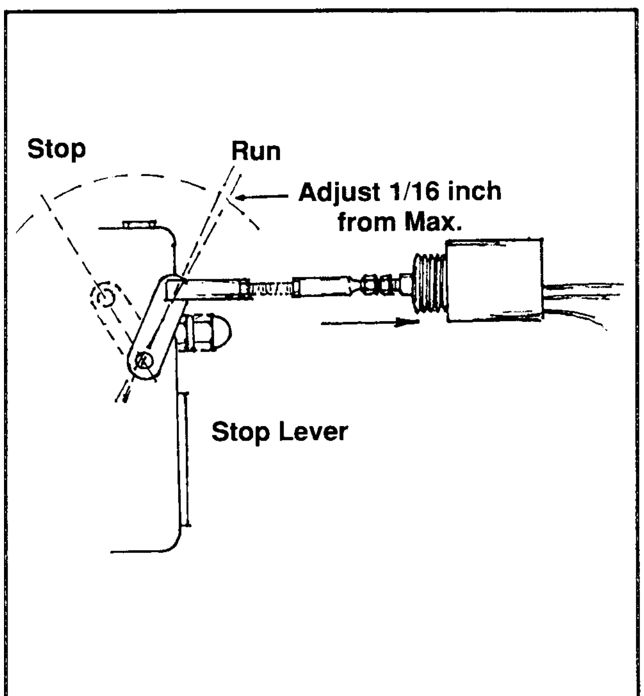
The black lead is the common ground wire.



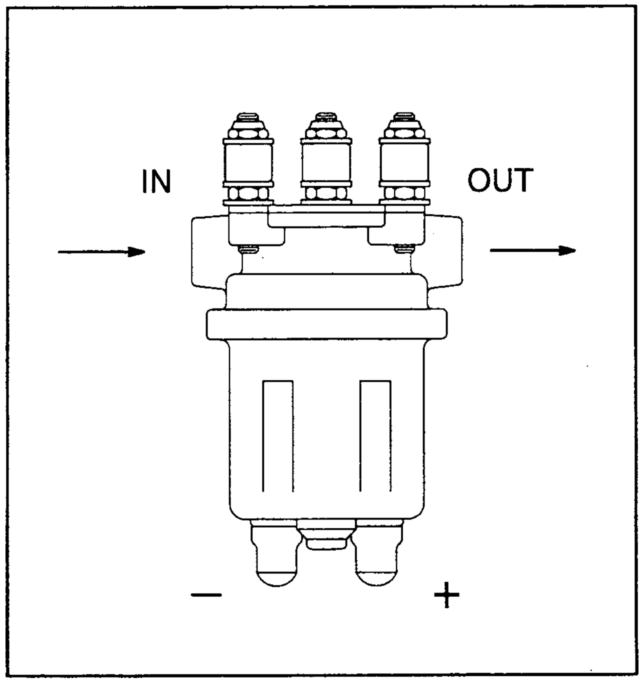


Adjustment

With the solenoid manually compressed, adjust the linkage so the stop lever is 1/16” from the maximum travel of the “run” position.



Fuel Pump
Electric Rotary Vane



The pump illustrated is a positive-displacement, motor-driven, rotary-vane type.

Fuel flow through the pump housing cools and lubricates the motor.

The DC polarity connections must be observed for pump to function.

Do not use Teflon tape on fittings!

The rotary vane (Carter) pump is capable of delivering 50-70 gals/hr at 4 - 8 PSI. Maximum pump lift is approximately 6ft.

Maximum fuel line size should be 3/8” I.D.

The pump is available in either 12vdc or 24vdc. Current draw is approximately 3 amps.

Mechanical Governor Operation

On gasoline and diesel engines it is common to find a mechanical governor to maintain a fixed engine speed. One type of governor is a gear driven centrifugal type, consisting of flywieghts which are driven off the cam gear and linkage incorporated into the carburator controlling the throttle valve.

How it Works

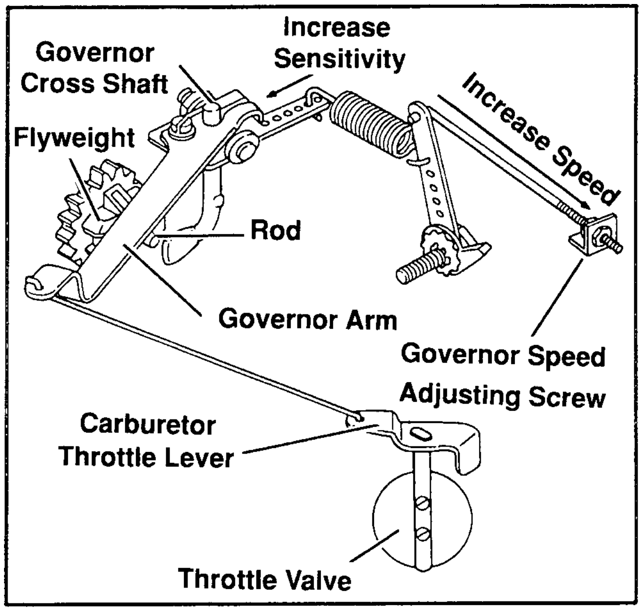
Centrifugal force causes the flyweights to move outward as speed increases and inward as speed decreases. As the flyweights move outward, they force the rod portion of the assembly to push outward. The rod, in turn, contacts a tab on the governor cross shaft causing it to rotate with changing speed. One end of the cross shaft protrudes through the side of the crankcase. Through external linkage, the action of the cross shaft is transmitted to the throttle (or butterfly) valve in the carburetor.

When the engine is at rest and the throttle is in the "Fast" position, the tension of the governor spring holds the throttle valve open. When the engine is operating (governor gear against the cross shaft tends to close the throttle valve. The governor spring tension and the force applied by the governor gear are in "equilibrium" during operation and hold the engine speed constant.

When a normal load is applied and engine (and governor) speed decrease, the tension of the governor spring rotates the governor arm to open the throttle valve wider. This admits more fuel and restores engine speed. (With the governor properly adjusted, this action takes place so rapidly, a reduction in speed is hardly noticed.) As speed reaches the governed setting, the tension of the governor spring and the force applied by the governor gear will again be in equilibrium, maintaining speed at a relatively constant level.

Mechanical governors allow for an approximate +/- 5% speed regulation between no load and full load.

60 hertz generators are designed to operate in the range of 57-63 Hz. Under no load conditions expect the generator to be running around 63 Hz, as load is applied the frequency will drop proportionally, when full load conditions are reached the frequency should be 59-60 Hz.



Gear driven centrifugal governors come in many different design applications, always consult the generator service manual for specifics to your generator.

THE ENGINE SPEED DETERMINES GENERATOR FREQUENCY

NOTE

2 pole generators operate at 3600 RPM to produce 60 Hertz and 3000 RPM to produce 50 Hertz.

4 pole generators operate at 1800 RPM to produce 60 Hertz and 1500 RPM to produce 50 Hertz.

Governors are adjusted at the factory and further adjustment should not be necessary. Governor adjustment may be indicated if engine speed surges with changing load, or if speed drops considerably when normal load is applied. Consult generator service manual for adjustment procedures.

Mechanical Governor (External Belt Drive)

This is one example of a belt driven external mechanical governor. The external belt driven governor is factory set to operate the generator set at 1800 RPM at full load with approximately 5% speed regulation.

Engine speed is increased by turning the speed adjust screw inward thereby increasing the tension on the governor spring.

Sensitivity of the governor is determined by spring location in relation to the governor pivot point. If governor setting is too sensitive, hunting or speed surging will occur with changing loads. If a considerable drop in speed is experienced when normal load is applied, the governor should be adjusted for greater sensitivity.

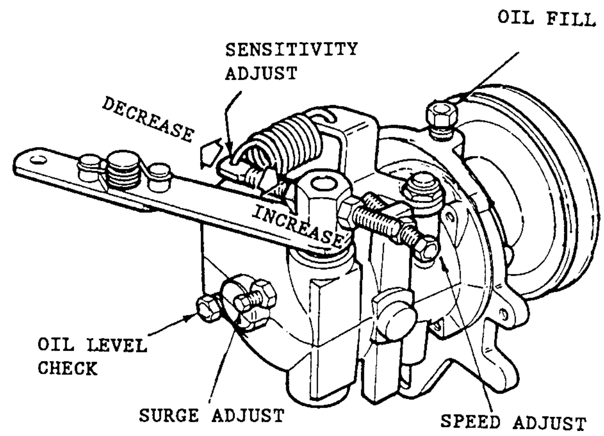
The surge screw is factory adjusted with the unit operating at no load RPM (approx. 63 Hz.). While observing a tachometer or frequency meter the screw is backed out only until no decrease in speed is observed. Then slowly turn inward, stopping at the point where an increase in speed occurs. It may be necessary to readjust the engine speed with the speed adjust screw.

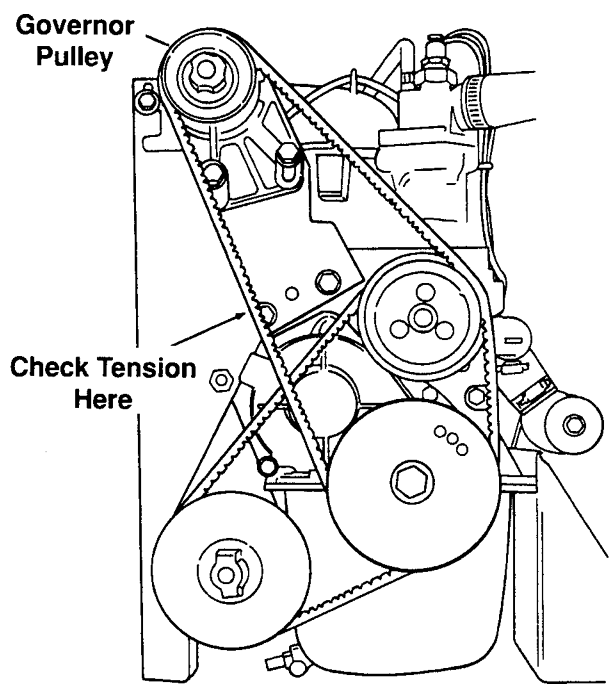
The oil level and belt tension must be inspected at regular service intervals as indicated in the owners manual.

A seized governor or broken belt will cause the engine to overspeed.

Oil should be level with the threads of the oil check hole.

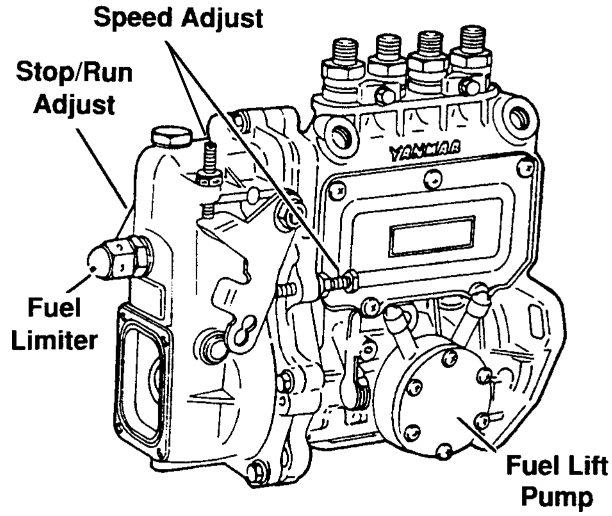
Belt deflection at midpoint of the longest span should be 3/8 inch (9.5 mm) using a force of 10 lbs. (4.5 kg). Tension using a belt tension gauge should be 35 lbs.





Mechanical Governor (Internal to Fuel Injector Pump)

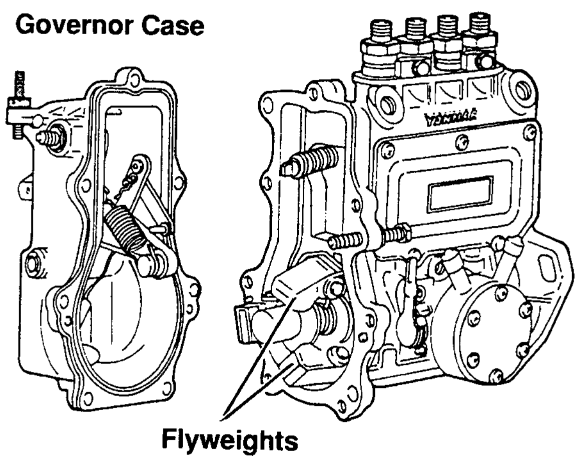
Pictured is an example of a mechanical governor assembly built into the fuel injection pump. This is common for diesel engine generators but designs differ among the diesel engines.



The flyweight assembly is mounted on the fuel injection pump camshaft. The remaining governor components are contained in the governor case.

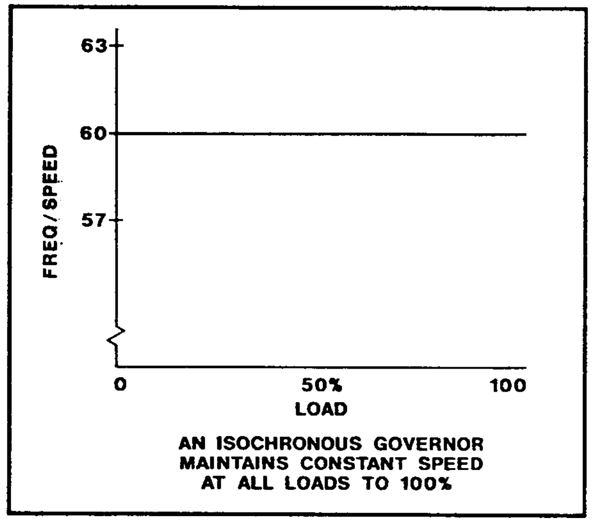
Frequency is adjusted by the two speed adjust lock screws.

The fuel limiter adjustment is used to prevent over-fueling of the engine. A full load stopper screw limits the travel of the fuel limiter control lever. This is a factory adjustment and is set to provide minimum exhaust smoke.



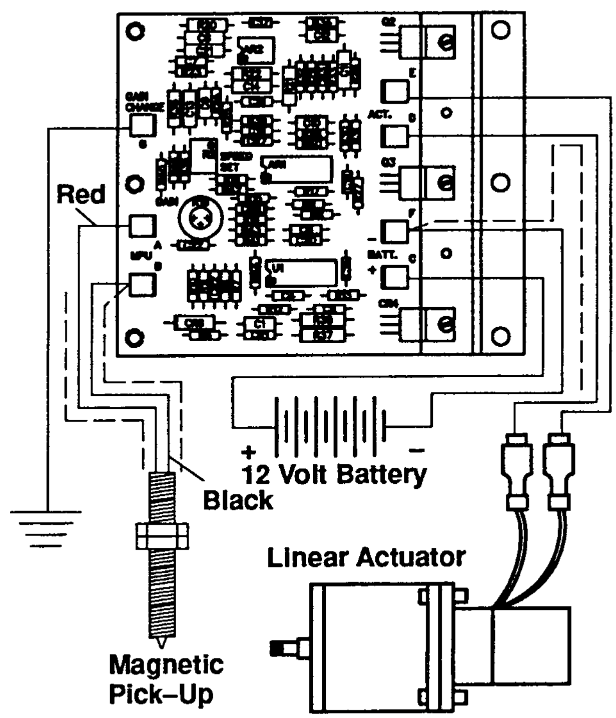
Electronic Governor Operation

Some generator applications require a fixed speed with no change in engine speed from a no load condition to a full load condition. For these applications an electronic isochronous governor is used. This type governor will allow the generator to maintain a fixed speed up to its full load capabilities.



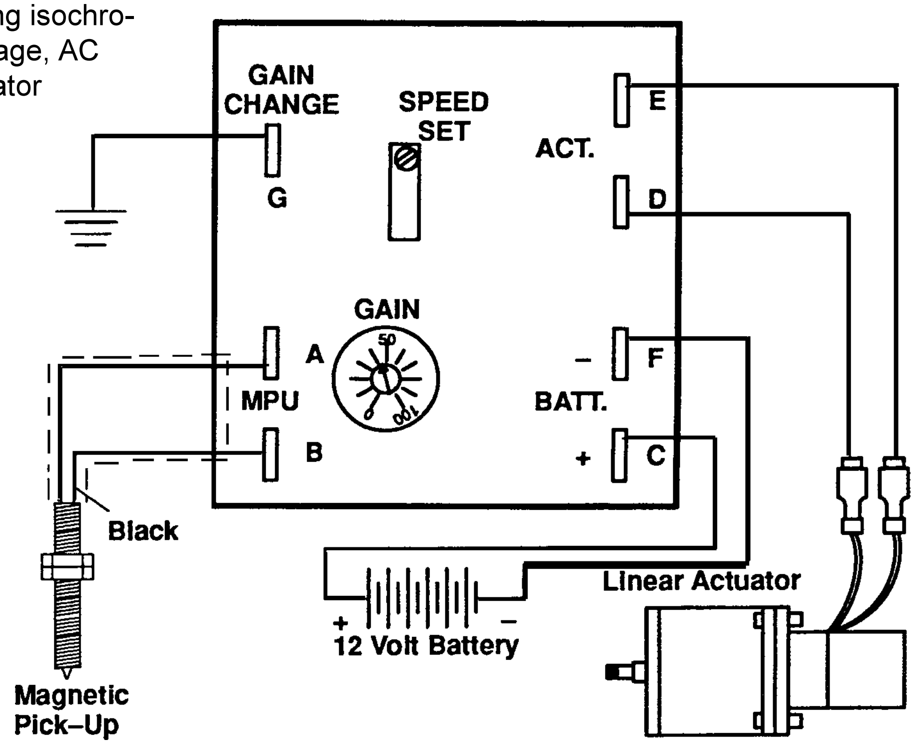
The electronic governor consists of 3 major components.

1. Magnetic Pick-up – Provides an AC output proportional to the engine speed.
2. Governor Control Module – Computes the information from the magnetic input and supplies correct input power to the actuator to maintain the reference speed setting. (Error correcting device)
3. Actuator – The electrical / mechanical connection to the throttle of your prime mover to increase or decrease fuel.



Controller module (12 Volt)

The controller module typically has three connections for a non-paralleling isochronous governor; a DC input voltage, AC magnetic input, and a DC actuator output.



The governor controller needs a DC control voltage provided by the engine starting batteries, for the governor controller to function. This voltage must be present during cranking and running.

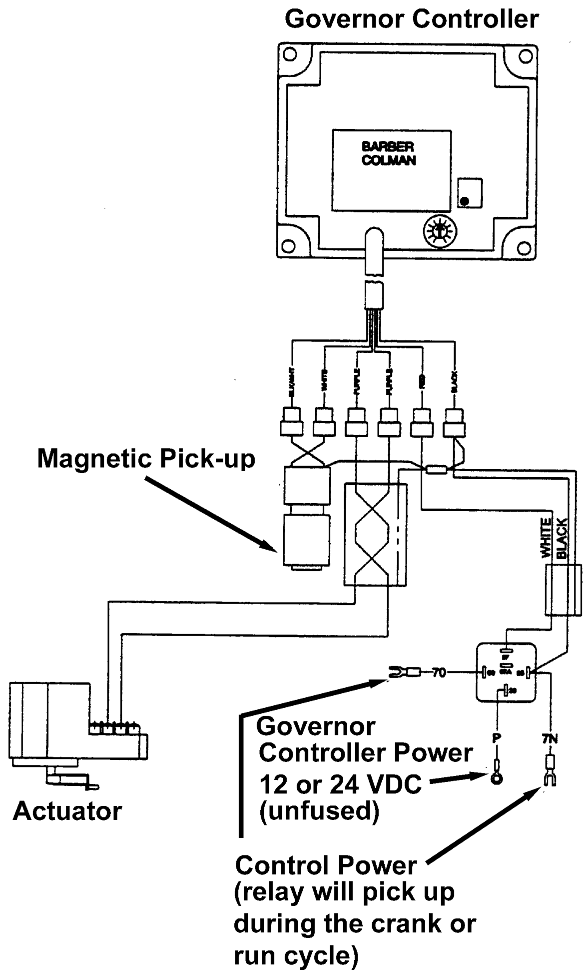
Engine speed is set by the "speed adjustment" potentiometer. The controller uses the potentiometer adjustment as its reference point, when load is applied to the engine the drop in speed is sensed by the mag pick-up. The controller immediately increases the output to the actuator causing a change in throttle position allowing for more fuel to the engine so it may regain and maintain the "set speed".

Also on the governor controller may be some adjustment potentiometers for "fine tuning" the response of the governor controller. The most common adjustment is "gain". The gain adjustment is made to improve operating performance when load conditions change. Too much gain and the governor starts "hunting", too little gain and the governor takes too long to correct the speed between load changes.

Governor Controller (12 or 24 Volt)

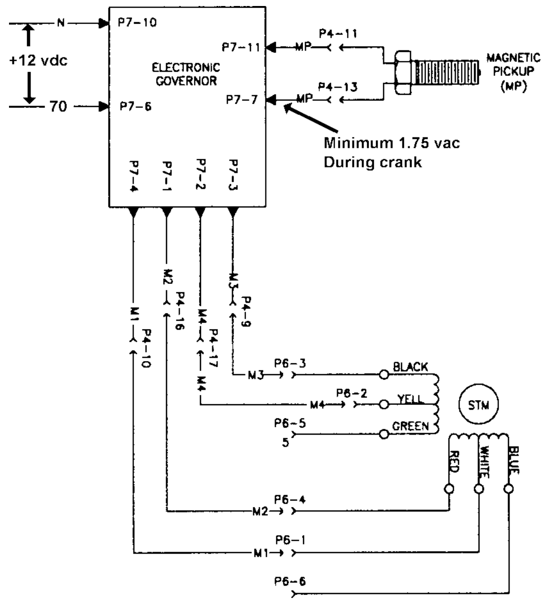
The governor control assemblies may change through the product lines but the basic fundamentals exist in each application. The governor system will need a AC magnetic pick-up input to determine engine speed, a DC voltage input for powering the governor control, and an output to an actuator to control fuel supply to the engine. Governor systems change throughout the product line due to differences in fuel system designs, type of fuel, and engine size.

The controller pictured features the same components but uses a relay to switch the supply power to the governor controller. The relay picks up when the #70 wire is energized (either during the crank or run functions). After the relay picks up the normally open contact closes allowing for the "P" positive wire to supply power to the governor controller. The relay is used because the current draw of the actuator may exceed the fused supply feeding the generator controller. The "P" positive wire is an unfused DC source of voltage.



Electronic Governor
(Kohler Governor)

The governor system consists of an electronic isochronous governor, an electromechanical stepper motor, and a magnetic pickup. The magnetic pickup supplies electrical pulses to the isochronous governor control unit each time one of the ring gear teeth passes the pickup. The control unit then compares the frequency of these pulses to a preset reference and provides a signal to the stepper motor which in turn controls the carburetor throttle position and hence the engine speed. This is a closed-loop system and typically provides steady state speed regulation of +/- 0.5%.



The factory sets the electronic governor and it normally requires no further adjustment. If generator set operates erratically, check the following items before readjustment.

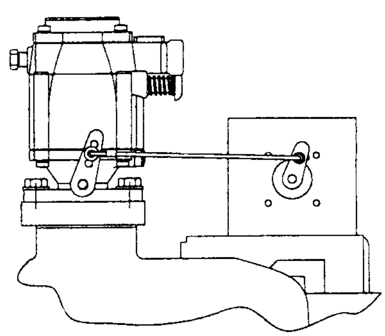
1. Check electrical connections. Check the stepper motor, controller box, and governor connector (inside the controller) for clean and tight connections.

2. Check magnetic pickup connections. Poor connections may cause an erratic signal. As long as this signal is being received, the unit will not shut down because of loss of pickup.

3. Check electrical ground connections. Provide a good DC ground to the controller assembly and governor circuit.

4. Check for dirt buildup on magnetic pickup. Metal filings or caked-on dirt/grease decrease the output signal of magnetic pickup.

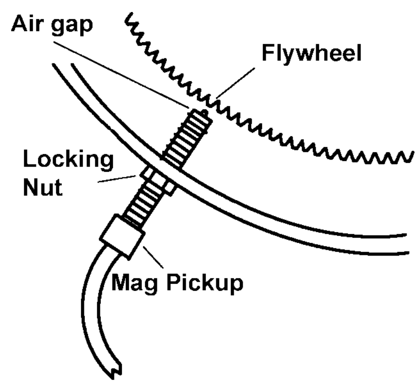
5. Check the carburetor for dirt, grime, or misadjustment. Check throttle linkage for binding.



Magnetic Pick-up

The magnetic pick-up monitors the flywheel ring gear and provides the speed reference signal to the electronic governor control module.

Failure or loss of the input speed signal from the pick-up will result in a low or idle speed condition. At cranking speed a properly adjusted pick-up should produce a minimum of 1.75vac. Air gap is factory set at 0.040 in.



Governor Adjustments

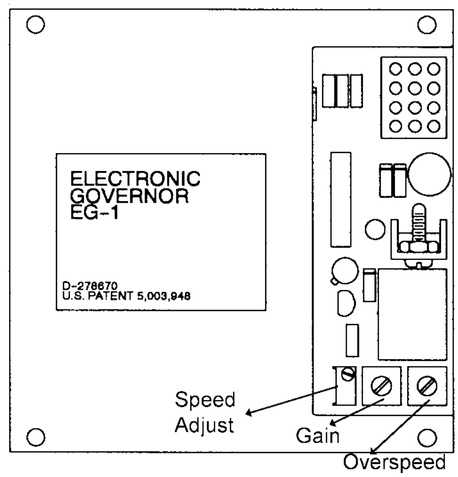
Attach a frequency meter to the AC output leads, start and run the generator and allow the generator to reach normal operating temperatures.

Speed Adjust:
Adjust the speed adjust potentiometer to obtain desired engine speed, 60hertz (3600rpm) or 50hertz (3000rpm) depending on application. Turn speed pot clockwise to increase frequency and counterclockwise to decrease frequency.

The governor being isochronous means the generator will operate at the fixed frequency with no droop in speed as long as the generator is not overloaded.

Gain adjust:
1. Check stability of frequency with generator running at no load.
2. Ramp the gain adjust up until the generator starts to hunt/surge.
3. Back the gain down in small increments until the audible hunting stops.
4. Apply rated load, the generator should be able to pick up rated load with only a slight delay. Generator should stabilize with no hunting.
5. Drop off load, generator speed should remain stable with no hunting.

If hunting occurs this indicates the gain is set to high, reduce gain.

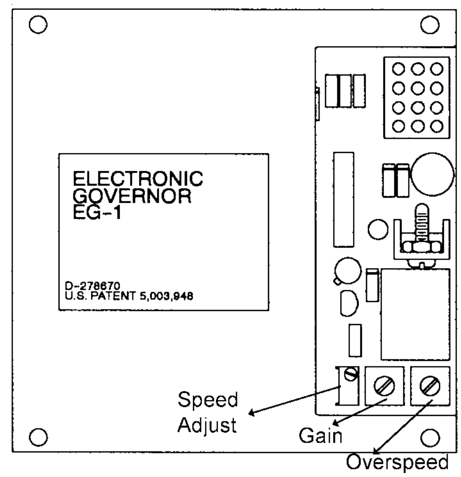


Note: Some applications do not have the overspeed adjustment available on the governor circuit board. Always order exact repalcement when changing the governor controller.

After setting the gain it is always a good idea to shut the unit off and let the system cooldown, then restart the generator to make sure the unit does not go into an overspeed or starts hunting. If this occurs the gain is set too high, decrease gain.

Hunting or surging indicates the gain is set too high. Slow response time indicates the gain is set to low or there may be engine or carburetor related problems.

Overspeed Adjustment (Kohler Governor Only)



The Kohler electronic governor may or may not have an overspeed potentiometer on the circuit board. Some applications do not require this adjustment due to the overspeed being achieved by the controller circuit board. Also some application may have the overspeed adjustment on the governor control board as well as the generator controller circuit board. To avoid unwanted shutdowns verify that the governor and the controller are both set for the same shutdown setting.

With unit running check overspeed cutout point. Manually move the throttle shaft/governor stepper motor coupling clockwise (as viewed from the back of the governor stepper motor). Do not use speed-adjustment pot to check the overspeed cutout point. Observe frequency meter and note frequency at which generator set shuts down. Factory setting is 70-72 Hz for 60 Hz models and 60-62 Hz for 50 Hz models.

Turn overspeed pot counterclockwise to increase overspeed cutout point and clockwise to decrease overspeed cutout point.

Note: Moving the stepper motor manually to check overspeed should only be done on the Kohler Governor system and should not be done on any other governor controller.

Conversions

Area

1 sq. foot 144 sq. inches
1 sq. yard .836 sq. meters
1 sq. meter = 1.196 sq. yards

Angle

1 quadrant = 90 degrees
1 quadrant = 1.57 radians
1 radian = 57.3 degrees

Length

1 yard = .9144 meters
1 meter = 3.28 feet
1 meter = 39.37 inches

Weight

1 short ton = 2000 pounds
1 short ton = 907.2 kilograms
1 kilogram = 2.205 pounds

Dry Volume

1 cu. meter = 1.308 cu. yards
1 cu. yard = .7646 cu. meters

Liquid Volume

1 U.S. gallon = 3.785 liters
1 liter = .2642 U.S. gallons

Power

1 horsepower = .746 kW
1 horsepower = 33000 ft. lb./min.
1 horsepower = 550 ft. lb./sec.
1 ft. lb. = 0.138 kgm

Pressure

1 sq. ft. = 0.0929 sq. meters
1 sq. inch = 6.452 sq. cm
1 sq. cm = .155 sq. inch

1 degree = .0175 radian
1 minute = .01667 degree
1 minute = 2.9 x 104 radian

Pressure, Cont.

1 foot = .3048 meters
1 inch = 2.54 centimeters
1 centimeter = .394 inch

1 pound 453.6 grams
1 ounce 28.35 grams
1 gram = .0353 ounces

1 cu. meter = 35.31 cu. feet
1 cu. foot = .0283 cu. meters

1 quart = .9463 liters
1 liter = 1.057 U.S. quarts

1 Btu/hour = .293 watts
1 Btu = 252 gram-calories
1 Btu -_778.17ft. lbs.
1 Btu = 1.05506 kJ

1 psi = 0.070 kg/cm^2
1 psi = 6.895 kPa

Temperature Conversion

$$°C = \frac{(°F - 32)}{1.8}$$

$$°F = (°C \times 1.8) + 32$$

$$°K = °C + 273.15$$

$$°K = \frac{(°F + 459.67)}{1.8}$$

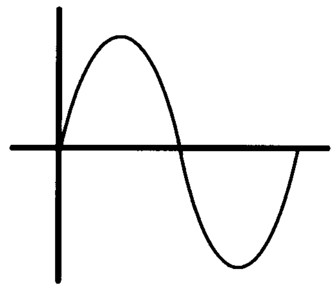
Locate known temperature in °C/°F column. Read converted temperature in °C or °F column.

°C	°C/°F	°F
–45.4	–50	–58
–42.7	–45	–49
–40	–40	–40
–37.2	–35	–31
–34.4	–30	–22
–32.2	–25	–13
–29.4	–20	–4
–26.6	–15	5
–23.8	–10	14
–20.5	–5	14
–17.8	0	32
–15	5	41
–12.2	10	50
–9.4	15	59
–6.7	20	68
–3.9	25	77
–1.1	30	86
1.7	35	95
4.4	40	104
7.2	45	113
10	50	122
12.8	55	131

°C	°C/°F	°F
15.5	60	140
18.3	65	149
21.1	70	158
23.9	75	167
26.6	80	176
29.4	85	185
32.2	90	194
36	95	203
37.8	100	212
40.5	105	221
43.4	110	230
46.1	115	239
48.9	120	248
51.6	125	257
54.4	130	266
57.1	135	275
60	140	284
62.7	145	293
65.5	150	302
68.3	155	311
71	160	320
73.8	165	329

°C	°C/°F	°F
76.5	170	338
79.3	175	347
82.1	180	366
85	185	365
87.6	190	374
90.4	195	383
93.2	200	392
96	205	401
96.8	210	410
101.6	215	419
104.4	220	428
107.2	225	437
110	230	446
112.8	235	455
115.6	240	464
118.2	245	473
120.9	250	482
123.7	255	491
126.5	260	500
129.3	265	509
132.2	270	518
135	275	527

Alternating Current - (Symbol AC): A current, which periodically reverses in direction and changes its magnitude as it flows through a conductor or electrical circuit.



AC Wave

The magnitude of an alternating current rises from zero to maximum value in one direction, returns to zero, and then follows the same variation in the opposite direction. One complete alternation is one cycle or 360 electrical degrees. In the case of 60-cycle alternating current the cycle is completed 60 times per second.

Alternating current is far more widely used than direct current because it can be easily transformed from one voltage to another for transmission and use, and electricity is always generated in revolving machines as alternating current. A DC generator is basically an AC generator with the addition of a device called a commutator, which changes AC to DC.

Alternator: A term frequently used for AC generator. "AC generator" is preferred.

Ambient Temperature: The temperature of the surrounding air in which the equipment operates. This may be expressed in degrees Celsius or Fahrenheit. Normally, ambient temperature is expressed in degrees Celsius when referring to electrical equipment. Degrees Fahrenheit is more frequently used for engines and mechanical equipment.

Ammeter: This device measures current. Current measuring instruments must be corrected in series with a circuit and never in parallel with it. AC ammeters are often used with current transformers to reduce meter current. Typical transformer ratios are 100:5 and 500:5.

Amortisseur Winding: The revolving field structures of synchronous machines are provided with poles with faces slotted parallel to the shaft. Conducting bars are built into these slots, and the ends of the bars are short-circuited to form a structure similar to the squirrel-cage winding of an induction motor. These windings dampen out the tendency of the generator to "hunt" with load changes. They are required for all revolving field generators which are driven by internal combustion engines and which may be required to operate in parallel and/or single-phase.

Ampere - (Symbol I, A, i, a): A unit of measurement of the rate of flow of electricity. One ampere of current flows when a pressure of one volt is applied across an impedance of one ohm.

Apparent Power - (Symbol kVA, VA): When the current and voltage are not in phase, i.e., voltage and current do not reach corresponding values at the same instant, the resultant product of voltage and current is apparent power instead of actual power. Apparent power is measured in volt-amperes or kilo-volt-amperes. Actual power (kW) is the product of kVA and the power factor.

Automatic Transfer Switch: This switch is a double-throw, electrically operated switch which will, on a given signal, open one set of contacts and throw over to the second set of contacts. As normally used in hospitals, television and radio stations, and other applications where automatic emergency power is used, the switch automatically transfers a load from a normal source of electrical power to an emergency source on failure of the normal. The load is automatically returned to the normal source when that source is restored to proper operating condition. Relays for delayed operation, engine starting, manual reset, and similar features are available. As normally used, the switch is electrically operated, mechanically held, and has a positive interlock to prevent the two sets of contacts being engaged at the same time.

American Wire Gauge - (Symbol AWG): Wires are manufactured in sizes numbered according to a table, known as the American Wire Gauge. (This gauge was formerly known as Brown & Sharp, abbreviated B&S). As the wire diameters become smaller, the gauge numbers become larger. The ratio of the diameter corresponding to a given gauge number to the diameter corresponding to the next higher gauge number is a constant 1.123. The cross sectional area varies as the square of the diameter. The cross sectional area is approximately halved or doubled every three gauge numbers. The cross sectional area is increased or decreased 10 times for every 10-gauge numbers. Using No. 10 wire as a base (approximate diameter 100 mils, approximate cross sectional area 10,400 circular mils and 1 ohm per 1000 feet), it is possible to quickly estimate cross sectional area and wire size without referring directly to a wire table.

Circuit Breaker: A special switch used to protect electrical circuits is called a circuit breaker. It is generally designed to open or break the circuit when some abnormal condition, such as an overload occurs. The circuit breaker usually has a higher initial cost than a fused knife switch, but has the advantages of opening the circuit faster and can be reset easier after the cause of the overload has been removed. Circuit breakers are difficult to size as necessary to protect an engine-driven generator. A circuit breaker rating of 125% generator rating is usually used; however, engine power usually limits generator load to less than 125%.

Current: Current is a flow of electricity. DC flows from negative to positive. AC alternates in direction. The standard symbol for current is "I" and it is measured in Amperes (Amps). The current flow theory is used conventionally in power and the current direction is positive to negative-opposite the flow of electrons.

Delta Connection: The delta connection is so named because it resembles the Greek letter. To make a delta connection, the finish end of the first winding is connected to the start of the second winding, the finish of the second winding is connected to the start of the third winding and the finished of the third winding is connected to he start of the first winding.

Modern generators are normally connected in a wye or star pattern rather than delta for several reasons. The delta-connected generator has no advantages over the wye-connected machine, and the wye machine has the advantage of being able to bring out the neutral wire. Also, in the delta-connected machine it is difficult to design the generator to keep the circulating currents low in magnitude. Normally the wye-connected machine will give better waveform characteristics than the delta-connected generator. In the wye machine the harmonics tend to cancel each other out when line-to-line voltage is checked between two legs or phases. In the delta-connected machine the line-to-line voltage is across one coil or set of coils and there is no cancellation of harmonic effects, except that the third harmonic and its multiples are shorted out, and do not appear in the output. Delta-connected generators are used to supply 120/240-volt, three-phase/single-phase, 4-wire systems.

Dielectric Test: National Electrical Manufacturers Association (NEMA) standards provide that each generator of 250 watts output or more be given the following high potential factory test to check generator insulation.

Stator Windings-Apply two times the normal voltage plus 1000-volts.
Field Windings-Apply ten times the exciter voltage, but in no case less than 1500-volts.

Direct Current - (Symbol DC): A current that flows in one direction only for a given voltage and electrical resistance. A direct current is usually constant in magnitude for a given load. Electricity is generated as alternating current in revolving machines. In DC generators the AC current is changed to direct current by commutation. While DC voltage is substan6ally constant in a DC generator, a slight ripple is due to commutation.

Efficiency: Input times efficiency equals output divided by the output plus losses. Efficiencies of generators are commonly given at 4/4, 3/4, and 1/2 loads. Unless otherwise stated, the efficiency of the generator is always based on the kVA and power factor at which it is rated.

Exciter: Synchronous AC generators require DC field excitation current. Most such generators today are furnished with exciters which are AC generators having rectified output.

Frequency - (Symbol Hz): The number of cycles per second the current alternates is called the frequency. Most common frequency in the United States is 60 Hz. 50 Hz current is used in most other countries. Generators are also made in special high frequencies for certain applications. The unit for measurement of frequency is the Hertz equivalent to one cycle per second.

Insulation: Insulating materials are used in all electrical machinery to isolate and maintain the flow of current through the conductors. Temperature influences the life of insulation. The failure of insulating materials is generally mechanical, resulting from extended exposure to moisture, foreign materials, and higher temperatures than the limiting temperature of the materials used. Most insulation used in today's generators is Class F, with a permissible temperature rise of 189'F (105'C) continuous, and 234'F (130'C) standby over a 104'F (40'C) ambient.

Isochronous Governor: A governor that maintains constant engine speed from no-load to full-load. It is a zero-droop governor. Typical accuracy is +/- .25 % of rated speed.

Kilowatt - (Symbol kW): Power is the rate of doing work. Electric power is expressed in Watts or kilowatts (1000 Watts). One horsepower equals 0.746 kW or approximately 3/4 kW Inversely one kW equals 1.34 horsepower. Actual power (kW) equals apparent power (kVA) times power factor (expressed as a decimal).

$$\textbf{Horsepower} = \frac{\textbf{kW}}{\textbf{.746 x Generator Efficiency}}$$

To calculate the kW input of an electric motor:

$$\textbf{Kilowatts} = \frac{\textbf{Motor Horsepower x.746}}{\textbf{Motor Efficiency}}$$

A rule of thumb based on 90% generator efficiency:

$$\textbf{Engine hp = Generator kW x 1.5}$$

For single-phase generator:

$$\textbf{kW} = \frac{\textbf{Volts x Amperes x Power Factor}}{\textbf{1000}}$$

For three-phase generator:

$$\textbf{kW} = \frac{\textbf{Volts x Amperes x Power Factor x} \sqrt{3}}{\textbf{1000}}$$

Kilowatt-Hour - (Symbol kWH): The measure of electrical energy is the kilowatt-hour. One kilowatt of electrical power consumed for one hour equals one kilowatt-hour (kWH) of electric energy. This energy can be measured by a kilowatt-hour meter, which is a small, sensitive electric motor, the rotor speed of that is proportional to the kilowatts flowing in the circuit to which the meter is connected. Revolutions of the motor are transmitted through a gear train to pointers on a register dial calibrated in kWH. Kilowatt-hour meters can be used to give approximate instantaneous kW load readings by measuring the rate of disc rotation.

Kilovolt-Amperes - (Symbol kVA): In AC circuits, kVA is the measure of the apparent power flowing in the circuit. To find the true or actual power (kW), the kVA must be multiplied by the power factor (expressed as a decimal).

Magnetism: A phenomenon of certain materials (iron, nickel, cobalt), such that, when the atoms are aligned within the materials, a field of force is set up which can effect other magnetic materials that are within that field. One end of a magnet is called the north pole and the other end is the south pole.

Magnetic Field: The lines of force due to the proper alignment of the atoms are called magnetic flux lines and make up the magnetic field. By convention, the lines begin at the north pole and end at the south pole.

Magnetizing Current: Transformers, motors and other electromagnetic devices containing iron in the magnetic circuit must be magnetized in order to operate. It is customary to speak of the lagging inductive current as a magnetizing current.

Ohm: The unit, which represents the amount of electrical resistance or impedance to the flow of electric current.

Ohm's Law: This is the fundamental law of electricity. The current in any electrical circuit is inversely proportional to the resistance of the circuit and directly proportional to the electromotive force in the circuit. This law may be expressed in three ways:

For DC:

$$I = \frac{E}{R} \qquad R = \frac{E}{I} \qquad E = IR$$

I = current is amperes
E = potential difference in volts
R = resistance in ohms
For AC:

$$I = \frac{E}{Z} \qquad Z = \frac{E}{I} \qquad E = IZ$$

I = current is amperes
E = potential difference in volts
Z = electrical impedance in ohms. For direct current Z is numerically equal to the resistance R. In AC circuits Z is made up of resistance R and reactance X.

One volt is required to cause on ampere of electric current to flow through an impedance of one ohm.

Overload: NEMA Standard MGI-16.41-Overload Capability - States: General purpose, prime power synchronous generators shall be capable of carrying 10% overload for two hours out of any 24. It is recognized that the temperature rise will differ from rated values when generators are subjected to overload condition.

Overspeed: NEMA Standards for Synchronous Generators MGI-16.46 - Overspeeds states: General purpose synchronous generators shall be so constructed that, in an emergency, not to exceed 1 minute, generators rated for 1800 rpm or less, will withstand an overspeed of 25% without mechanical injury.

Power: DC power is always the product of Volts times Amps and is expressed in Watts.

Watts = Volts x Amps (P = E x I)

AC output of a generator is the apparent power and is equal to the Volts times Amps, as measured at the generator.

Apparent Power (kVA) $\frac{EI}{1000}$

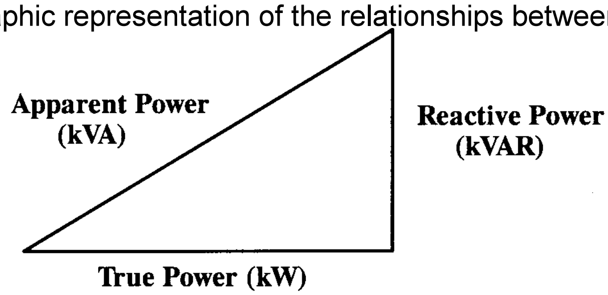
The apparent power (kVA) developed by the generator is used in two places:

1. Useable power for the load (kW).
2. Lost power due to reactance (KVAR) of the load.

The power used in the load is called the useable or real power and is expressed in Watts or kilo-watts (kW). Whenever the words Watts or kW is used, it means useable power.

The power lost because of the reactance is called reactive power or kilo Volt-Amps-reactive (kVAR). This lost power does no work.

The following triangle is a graphic representation of the relationships between apparent, real, and reactive power.



Power Factor- (Symbol PF): Power factor is the ratio for expressing what part of the apparent power (kVA) flowing in an AC circuit is true power (kW).

Power Factor = $\frac{kW}{kVA}$

At unity power factor the kW and kVA are equal. At any power other than unity (leading or lagging power factor), the kVA are greater than the kW When this is true there is a reactive component of the total kVA flowing in the circuit.

Mathematically, power factor is equal to the cosine of the angle by which the current leads or lags the voltage.

With a low power factor load, the reactive component is larger and thus more kVA capacity is required of the generator supplying the power. For a given kW load the increase in kVA caused by a low power factor means increased Amperes through the coils. The capacity (kVA) of generators, transformers, etc., is normally limited by the current capacity and heating limits of the coils.

Reactive Kilovolt-Amperes - (Symbol RKVA or KVAR): Reactive kVA is the measure of the reactive or magnetizing component of the total kVA flowing in a circuit. The out-of-phase or reactive component serves the important function of magnetizing the magnetic equipment, i.e., induction motors, transformers, etc., during a portion of each cycle. The magnitude of this component is determined by the proportion of magnetic equipment to the pure resistance loads, which determines the amount of the current lags the voltage. Mathematically the tangent of the angle of lag is equal to the reactive kVA divided by the kW in a three-phase circuit:

$$\text{kVAR} = \frac{\sqrt{3} \times \text{volts} \times \text{reactive amperes}}{1000}$$

Rectifier: If only alternating current is available, it may be converted into direct current by using devices which offer a high resistance to the flow of current in one direction and a low resistance to the flow in the opposite direction. These devices are called rectifiers. A common rectifier is the diode.

Regulation: Voltage regulation is defined as the rise in voltage (field current and speed remaining constant), when full load is thrown off the generator.

$$\%\ \text{Voltage Regulation} = \frac{(\text{voltage at no load} - \text{voltage at full load}) \times 100}{\text{voltage at full load}}$$

Speed regulation is similar.

$$\%\ \text{speed regulation} = \frac{(\text{no load rpm} - \text{full load rpm}) \times 100}{\text{full load rpm}}$$

Resistance: Electrical resistance is that quality of an electric circuit that opposes the flow of current through it. In the electric circuit, the larger the diameter of the wires the lower will be their electrical resistance to the flow of current through them. Temperature also affects the resistance of electrical conductors to some extent. In most conductors (copper, aluminum, etc.) the resistance increases with temperature.

Right-Hand Rule: When using the “current flow theory” the current flows from positive to negative. If the thumb of the right hand is pointed along the conductor in the direction of current flow then the fingers, when wrapped around the conductor, will indicate the direction of the magnetic lines of force.

Single-Phase: A single-phase AC circuit is generally served by 2 or 3 wires. Single-phase is most commonly used for lighting and fractional-horsepower loads. Single-phase may be obtained from a single-phase generator, from a three-phase generator between any phase and neutral, or between any to phases.

Starting kVA: Induction motors demand more kVA to start than is required for steady state operation. “Starting kVA’ is used to define the condition of this extra demand, which normally lasts for a brief period of seconds or less. It is a transient effect, but of great importance. Standard motors have a code letter indicating starting kVA per hp.

Synchronous Speed: The number of poles in an AC generator is directly related to the synchronous or operating speed. Any speed can be obtained that corresponds to any even number or pair of poles and the desired frequency.

$$N = \frac{120f}{P}$$

f = frequency in cycles per second
N = synchronous speed in RPM
P = Number of poles

60 Hz.		50 Hz.	
rpm	Number of Poles	rpm	Number of Poles
1800	4	1500	4
1200	6	1000	6
900	8		

To maintain rated frequency, the speed of the generator must be maintained as shown above.

Temperature Rating: A generator with a temperature rise rating of 189'F (105'C), is one in which the manufacturer guarantees that the temperature of the generator will not rise more than 189F (105 0 C) above an ambient (surrounding air) temperature of 104'F (400C), when carrying full rated load continuously, at an altitude not exceeding 3300 ft. (1006m) above sea-level. The term "rated load" implies that the voltage and power factor are as called for by the nameplate of the generator. The same generator is permitted (by NEMA MGI-1640) to have a 234'F (130'C) temperature rise at a standby rating.

The temperature rise of 189'F (105'C) over ambient temperature given above, is based on measurement of rotor and stator temperature by resistance.

Three-Phase: A three-phase AC circuit is a combination of three electrical circuits with a voltage phase difference of 120 electrical degrees (1/3 cycle). A three-phase system may either be 3-wire, or 4-wire (3-wires and a neutral).

Volt - (Symbol V or E): The unit for measuring electric pressure or electromotive force required to force anelectric current to flow. Voltage actually shows the difference in electromotive force between two points in a circuit. One volt is required to force one ampere through one ohm of resistance. In an AC circuit having a true sine wave the RMS (root mean square) or effective volts is equal to 0.707 times the maximum volts. The usual AC voltmeter generally measures effective volts, and unless otherwise specified, voltage values are always given as effective volts.

Voltage Dip: "Voltage Dip" is the momentary drop of generator output voltage that occurs whenever a load is added to the system. There is a momentary increase in output voltage whenever a load is removed from the system. This is called "Voltage Rise." "Voltage Rise" is seldom of concern with an adequate voltage regulator.

Voltmeter: This instrument when connected across the line will indicate the potential difference in volts. Actually, these instruments usually operate on the same principle as an ammeter except that a high resistance is placed in series with the coil so that the current flow is limited when the meter is connected across the line. The current in the coil is therefore proportional to the line voltage. The scale is not uniformly divided, as on DC voltmeters, for the deflections are very nearly proportional to the square of the voltage. The divisions at the lower part of the scale are crowded so that poor precision is obtained. The divisions at the middle and upper portions of the scale, however, are usually such that they may be read with precision.

Wattmeter: Electric power is measured by means of a wattmeter. Because electric power is a function of current and voltage, a wattmeter must have two elements, one for current and the other for voltage. The power indicated by a wattmeter is a result of the voltage across the load, the current through the load, and the power factor on the load. In effect, the wattmeter multiplies the voltage, current and power factor to indicate the true power. When using a wattmeter, take all precautions mentioned for ammeters and voltmeters. In addition, make sure that neither the current nor voltage exceeds the wattmeter capacity. Test the circuit with a voltmeter and ammeter before connecting a wattmeter. The wattmeter scale deflection does not indicate whether the meter is overloaded or not. The voltage may be low and the current high and still indicate a true power within the meter scale limit, but the current element may be overloaded.

Wye Connection: In a wye or star-connected generator the three start ends of each single-phase winding are connected together to a common neutral point, and the opposite or finish ends are connected to the line terminals. When both low-voltage, single-phase loads and higher-voltage, three-phase loads are encountered, a line to the neutral or common point will serve as a common return circuit for all three phases, i.e., 120/208-volt, 3-phase, 4-wire machine. In a wye-connected machine the voltage from line to line is equal to the product of 1.73 and the line to neutral voltage. For example, in a 208-volt machine the line to neutral voltage is $\frac{208}{\sqrt{3}}$ or 120 volts.

With a 4-wire, 120/208-volt generator, motors can be operated on the 3-phase, 208-volt leads, and 120-volt lighting loads can be connected anywhere in the circuit between the various lines and the neutral. If this is done it is important to balance the 120-volt, single-phase load as much as possible so that all of the added lighting load is not connected to one single-phase leg or coil.

Wound-Rotor Motor: The wound-rotor or slip-ring induction motor is used when it is necessary to vary the rotor resistance in order to limit the starting current or to vary the motor speed. The high resistance is used for starting and when the motor comes up to speed the resistance is cut out. The running characteristics are about the same as a standard squirrel-cage motor. The wound-rotor motor gives high starting torque with comparatively low starting current. On the other hand, its initial and maintenance costs are high and the external resistance is bulky.

Normally a wound-rotor motor will have an instantaneous starting current of 150-160% of rated full-load current and the current during acceleration is approximately 125% of full-load current. With the high resistance in the starting circuit the power factor is high on start, so the usual limiting factor in the selection of a generator set is kW capacity of the engine-generator set.