

# Instruction Manual

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Installation  
Operation  
Maintenance

Voltage Regulator  
KCR 160

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## **SAFETY PRECAUTIONS**

Follow the precautions described below when installing, adjusting, testing, operating and repairing this equipment.

### **WARNING**

Lethal voltages, 225 VAC or higher, are present at the voltage regulator when generator set is operating. Stop generator set before making connections, repairs or adjustments to this equipment. Disregarding this precaution can result in serious injury or electrocution.

### **WARNING**

Off position on regulator shutdown switch, field circuit breaker or off-auto-manual switch does not remove voltage generated by action of residual magnetism in the exciter field. Stop generator set before making connections, repairs or adjustments. Disregarding this precaution can result in serious injury or electrocution.

### **WARNING**

Install this equipment only in accordance with the instructions contained in this manual and wiring diagram provided with generator. Incorrect wiring can cause fire hazard and can destroy this equipment.

### **CAUTION**

The DC output field circuit must not be opened or grounded while the unit is running. To do so will cause inductive arcing that can destroy this equipment.

### **CAUTION**

High potential and megger tests must not be made to the voltage regulator. To do so will destroy this equipment.

### **CAUTION**

Do not attempt to flash the exciter field while the generator set is running and be careful to maintain correct polarity when connecting flashing source. Disregarding this precaution can result in equipment damage.

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## SECTION 1 GENERAL INFORMATION, SPECIFICATIONS, OPTIONS AND ACCESSORIES

### GENERAL

The KCR 160 voltage regulator controls generator output voltage by regulating the current to the exciter field.

The regulators consist of transformers, transistors, silicon diodes, silicon controlled rectifiers, resistors, and capacitors.

The KCR 160 voltage regulator can be used on any generating system within its rating. The regulator specifications are contained on pages 1-2 and 1-3.

### SPECIAL FEATURES

#### A. Underfrequency Limit

An underfrequency limit is a built-in feature in the KCR 160 voltage regulator except in the case where flat regulation option is provided.

The underfrequency limit circuit reduces the regulator output current applied to the exciter field when the generator is operated at less than rated speed. The factory set underfrequency operational threshold of standard KCR 160 voltage regulators is listed in the voltage regulator specifications. The percentage of generator output voltage that will be obtained for a specific reduction in frequency below the underfrequency operational threshold is shown in Figure 1-1. During operation at speeds that maintain generator frequency above the underfrequency operational threshold the underfrequency limit circuit has no effect on the regulator output current.

#### B. Field Flashing

The KCR 160 voltage regulator contains a built-in solid state generator field flashing circuit. The use of solid state components rather than a flashing relay eliminates the possibility of contact failure or contact arcing.

### OPTIONS

Options available in this series regulator are described in the list that follows. The option must be specified when purchasing the voltage regulator.

#### A. Underfrequency Operational Threshold

Underfrequency operational threshold either higher or lower than 55 hertz for 60 hertz system or 45 hertz for 50 hertz system.

Where this is the case, the required underfrequency operational threshold must be specified when ordering the voltage regulator.

#### B. Flat Regulation

Flat regulation for use in variable frequency constant voltage application.

Where this requirement exists, it must be specified when ordering the voltage regulator.

NOTE: Any KCR 160 voltage regulator equipped with the flat regulation option will not have an underfrequency limit circuit.

#### C. External Voltage Adjust Option

All KCR 160 voltage regulators contain a voltage adjust control located on the regulator. In the case where panel mounted voltage adjust control is required, a 250 ohm, 2 watt rheostat will be supplied as a separate item.

#### D. 115 VAC Sensing Option

Standard model KCR 160 voltage regulator is equipped for  $225 \pm 15$  percent sensing.

Where specified in the purchase order the regulator can be equipped for use with  $115 \text{ VAC} \pm 15$  percent sensing.

### E. Stability Adjust Potentiometer Option

The regulator can be equipped with a stability adjust potentiometer R48. The option must be specified in the purchase order. This control provides adjustment of the stabilizing signal applied to the error detector circuit.

## ACCESSORIES

Accessories are items that may be required in a generating system but are not included as built-in features or options of either the generator or the voltage regulator. They must be ordered as individual items. Some of the accessories available for use with voltage regulating systems are contained in the list that follows.

### A. Voltage Matching and Power Isolation Transformers

Voltage matching transformers that also provide power isolation are available for applications where 100 to 139 VAC cannot be obtained from the generating system. Be sure to state generating system voltage when ordering voltage matching transformer.

### B. Field Circuit Breaker

Field circuit breakers used in a regulating system equipped with KCR 160 voltage regulator contain a thermal element that connects in series with the voltage regulator DC output while the circuit breaker contacts series connect in the conductor carrying input power to the voltage regulator.

### C. Automatic /Manual Voltage Control

This control module contains a three position switch to allow automatic voltage regulation by action of the voltage regulator or manual voltage control by action of the manual voltage control circuitry. The OFF position removes excitation by disconnecting power to both the voltage regulator and the manual voltage control circuitry. The manual voltage control circuit portion of this control includes a rectifier and a manual voltage control variac.

### D. Regulator Voltage Shutdown Switch (Engine Idle Switch)

This switch is for use in engine driven generator sets where the system does not include underfrequency protection or another means of removing excitation such as field circuit breaker or an automatic/manual control switch. Opening the switch removes input power to the voltage regulator.

## SPECIFICATIONS

**NOTE: The following specifications are applicable for KCR 160 voltage regulators except as noted.**

### A. Input Power

<b>Voltage:</b>	100 VAC to 139 VAC.
<b>Frequency:</b>	50/60 hertz.
<b>Burden:</b>	350 volt ampere, maximum.

### B. Sensing

<b>Voltage:</b>	225 VAC $\pm$ 15 percent except where 115 VAC sensing is specified in purchase order.
<b>Frequency:</b>	50/60 hertz.
<b>Burden:</b>	1 volt ampere, maximum.

### C. DC Output Power

<b>Voltage:</b>	65 volt dc, maximum continuous; 90 volt DC one minute field forcing.
<b>Current:</b>	3 ampere, maximum continuous; 4 ampere, one minute field forcing.
<b>Field Resistance:</b>	Approximately 20 ohms, minimum; 400 ohms maximum.

### D. Underfrequency Operational Threshold

45 hertz for 50 hertz generating system;  
55 hertz for 60 hertz system (except otherwise specified in purchase order).

**NOTE: Regulators with flat regulation option will not have underfrequency limit circuitry.**

## SPECIFICATIONS (Cont.)

### E. Regulator Response

Less than 17 millisecond.

### F. Power Dissipation

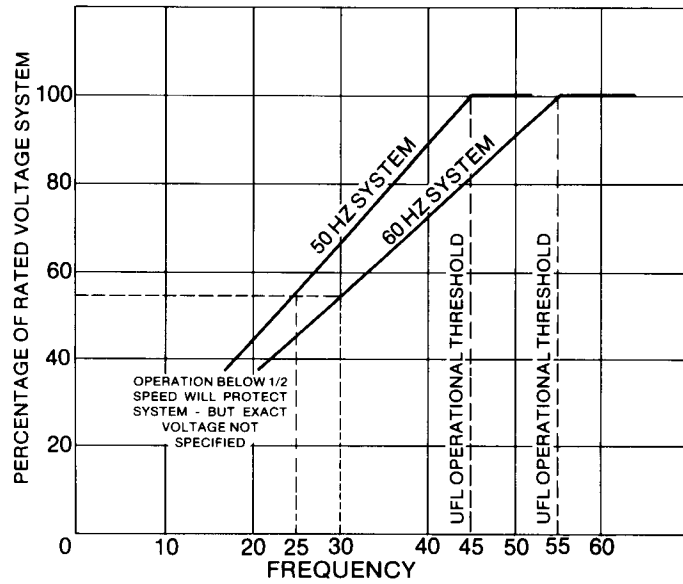
Less than 25 watts at maximum continuous rating.

### G. Operating Temperature

-40°C to +60°C.

### H. Physical Size

Height: 2.25 inches (5.7 cm).  
 Width: 7.25 inches (18.4 cm).  
 Length: 6.25 inches (15.9 cm).  
 Weight: 1 lb. 14 oz. (850 gm) with base.



**FIGURE 1-1 KCR 160 UNDERFREQUENCY PERFORMANCE**

## SECTION 2 PRINCIPLES OF OPERATION

### REGULATOR CIRCUITS

The KCR 160 voltage regulator consists of seven basic circuits described in the paragraphs that follow. All of these circuits except the external voltage adjust option are contained on an etched circuit board. Drawings that show the location of parts comprising the regulator and the electrical interconnection of the parts are shown in Section 6 of this manual.

#### A. Output Power Circuit

This circuit supplies the exciter field current. The circuit consists of silicon diodes D12 and D13, a free wheeling rectifier D14, silicon controlled rectifiers SCR1 and SCR2, a capacitor C10, and a resistor R45.

The 120 VAC  $\pm$  15 percent regulator input power is applied to a single phase SCR/diode bridge comprised of diodes D12, D13 and silicon controlled rectifiers SCR1 and SCR2. It is the conduction time of the SCR/diode bridge circuit that determines the amount of output current to the exciter field. The greater the time of conduction of the SCR's the greater the output voltage. Conduction time is controlled by the timing of turn-on gating pulses from the regulating circuit.

The output power circuit includes an inductive load transient voltage suppression network comprised of capacitor C10, resistor R45, and free wheeling rectifier D14. Capacitor C11 and resistor R44 assist in spike suppression. Diodes D10 through D13 supply power to the flashing and regulation circuits.

#### B. Sensing Circuit

This circuit is comprised of sensing transformer T1, diodes D1, D2, D3, D4, resistor R1, capacitor C1, resistors R3 and R4, voltage adjust potentiometer R2, and when specified in the purchase order, an external voltage adjust rheostat.

Diodes D1 through D4 form a full-wave bridge rectifier. Sensing transformer T1 is a voltage step-down transformer with secondary winding voltage about one-tenth as high as the voltage applied across the primary winding. Resistor R1 and capacitor C1 form an RC filter which reduces the AC ripple present in the rectifier output. Potentiometer R2, resistors R3 and R4, and when supplied the external voltage adjust rheostat form a series connected voltage divider.

The sensing circuit functions as follows:

The generator sensing voltage is connected at terminals E1 and E3. This voltage is applied across the primary winding on the sensing transformer. The output voltage from the sensing transformer secondary winding is rectified and filtered and a representative sample, taken from the voltage divider, is applied to the error detector.

#### C. Voltage Adjust

The voltage adjust permits adjustment of generator voltage. This control forms part of the sensing circuit voltage divider.

Where the external voltage adjust is not supplied, a jumper is connected across regulator terminals R1-R2 and voltage adjustment is made by turning potentiometer R2 using a small screwdriver.

Where the external voltage adjust rheostat is provided, the jumper is removed from the terminal R1 and R2 and the external rheostat is electrically series connected in the voltage divider circuit through interconnecting wires to terminals R1 and R2. Voltage adjustment is made by turning the external voltage adjust rheostat. In this case the internal potentiometer R2 functions as a voltage range control. It is normally set to establish maximum voltage limit of the external voltage adjust rheostat.

#### D. Error Detector

Transistors Q1 and Q2 are connected in a manner that forms an emitter coupled differential amplifier. A representative sample of the rectified sensing voltage, taken at the junction of resistors R3 and R4, is applied as input voltage at the base of Q1. A reference voltage taken from the underfrequency limit circuitry or from the circuit comprised of zener diode Z1 and diodes D16, D17 is applied as the input voltage at the base of Q2. When the two voltages are not equal, the resulting difference is amplified and applied to the regulation circuit.

### E. Regulation Circuit

The circuit controls the regulator output by regulating the turn-on gating pulse applied to the silicon controlled rectifiers in the output power circuit. The regulation circuit, in turn, is controlled by action of the error detector.

Diodes D8 and D9, zener diode Z2, resistors R33 through R38, resistors R46 and R47, capacitor C9, programmable unijunction transistor Q7, and two current dividers form the regulation circuit.

The conduction time of Q7 is controlled by the charge rate of capacitor C9 while the charge rate of C9 is regulated by the output of the error detector. The output of programmable unijunction transistor Q7 is applied to two current dividers, comprised of resistors R41 and R43, and R42 and R43. These current dividers provide the turn-on gating signal to the output power circuit SCR's.

### F. Generator Field Flashing Circuit

This circuit provides a gating signal to the regulator output power SCR's each time the generator is started. When the generator voltage builds-up to about 70 percent of rated sensing voltage the flashing circuitry turns-off and the gating signal is controlled by action of the regulating circuitry. The flashing circuit operates as described in the paragraphs that follow. Transistors Q5 and Q6, resistors R24 through R29, and D7 form a Schmidt trigger circuit. During generator starting the field effect transistor Q8 conducts firing SCR3 which in turn provides a turn-on signal to the output power stage circuit SCR's. The Schmidt trigger circuit conducts when generator sensing voltage increases to approximately 70 percent of rated. This action turns off Q8 and SCR3 which terminates field flashing.

### G. Stability Circuit

The voltage regulator includes a negative feedback system loop stability circuit comprised of resistors R30, R31 and R32 and capacitors C7 and C8. This RC network injects a stabilizing signal from the regulator output into the error detector which helps to prevent generator voltage oscillation.

**NOTE: Where specified in the purchase order, regulator can be equipped with a stability adjust potentiometer.**

### H. Underfrequency Limit (UFL)

This circuit provides a reference voltage to the error detector which is constant when the generator is operating above the limiting frequency and decreases in proportion to the generator frequency during underspeed operation. The proportionate decrease in voltage applied to the reference side of the error detector during underspeed operation results in a decrease in regulator power SCR phase angle, which proportionately reduces excitation and generator output voltage. This action reduces kW load which enables faster engine speed recovery and provides voltage regulator and generator underfrequency protection.

The UFL circuitry described in the paragraphs that follow is located on the voltage regulator circuit board as shown in Figure 6-2. The UFL consists of a two-pole filter, a Schmidt trigger circuit, a circuit that provides pulse proportional to the generator frequency and an underfrequency operational threshold adjustment R18.

The two-pole filter provides voltage to the reference side of the error detector which is the average of the Schmidt trigger output. The filter consists of transistor Q3, resistors R14 through R16, and capacitors C2 and C3.

The Schmidt trigger consists of three nor gates within integrated circuit IC1 (pins 4 through 14). It is turned on by a pulse from Q4 and off by a pulse from the timing capacitor C4. For operation in 50 Hertz application, parallel connected capacitors C12 and C4 provide the turn-off pulse. During operation at rated frequency Q4 turns the Schmidt trigger on but the timing capacitors discharged before reaching the threshold level of the Schmidt trigger. Thus during operation at rated frequency the Schmidt trigger stays on. Its output is a constant level DC voltage which results in two-pole filter output that is approximately the same as the fixed reference voltage across the circuit comprised of zener diode Z1 and diodes D16 through D18.

Whenever frequency drops below the underfrequency operational threshold the timing capacitor(s) charge to the threshold level of the Schmidt trigger, which then turns off the Schmidt trigger. The trig-



ger turns on from the next pulse from Q4, and again turns off when the timing capacitors charge to the threshold level of the Schmidt trigger. The sequence of ON-OFF pulses changes the Schmidt trigger output from a constant level DC signal to a square wave which decreases the average output of the two-pole filter. This action lowers the voltage at the reference side of the error detector with respect to the sensing side of the error detector. The regulator then reacts by decreasing the phase angle of the power SCR's reducing excitation and thereby, generator output voltage. During underspeed operation below the underfrequency operational threshold the ratio of on time to off time of the Schmidt trigger decreases proportionally to the change in frequency. This action results in a decrease in voltage that is proportional to the decrease in frequency as illustrated in Figure 1-1.

The circuit that provides the turn-on and turn-off pulse for the Schmidt trigger described in the preceding paragraphs consists of transistor Q4, capacitor C5, resistors R20 and R21, part of integrated circuit IC1, timing capacitor C4 and for 50 hertz operation, timing capacitors C4 and C12. The circuit operates as described in the paragraph that follows.

Pins 1 and 2 on IC1 receive a rectified signal from sensing circuit diodes D5 and D6 which is proportional to the generator frequency. The output at pin 3 on IC1 is a square wave which is differentiated by capacitor C5. These pulses are divided by resistors R20 and R21. The resultant signal turns transistor Q4 on and off. When Q4 conducts, the pulse turns on the Schmidt trigger described in the preceding paragraphs and the timing capacitors discharge. The timing capacitors then charge while Q4 is off. The Schmidt trigger output controls the two-pole filter described in preceding paragraphs.

## SECTION 3 INSTALLATION

### SAFETY PRECAUTIONS

Follow the safety precautions contained on page i of this manual when installing, operating, adjusting, and making repairs to this equipment.

### MOUNTING

The voltage regulator is convection cooled. Vertical mounting is recommended to obtain optimum cooling. The regulator can be mounted on sheet metal plates, within enclosures or within the generator terminal box providing that shock and vibration are not excessive and temperature does not exceed 60° C. Retain sufficient space about the regulator for cooling airflow and making electrical connections. Mount as illustrated in Figure 6-5.

### ELECTRICAL CONNECTIONS

Electrical wire connections on the regulator are made to the terminal strip located on the regulator. The under-frequency jumper, transformer T1 connections and the fuse are contained on the circuit board.

#### A. Input Power (Terminals P1 and P2)

The voltage regulator operates on a power input voltage applied to terminals P1 and P2 (see Specifications for input voltage and frequency). If the correct voltage is not available or if the circuit supplying the input voltage is grounded, a power isolation transformer must be used.

**NOTE: To ensure correct frequency between the sensing and power circuitry, regulator input power must be supplied by the generator.**

#### B. Regulating Sensing (Terminals E1 and E3)

Sensing can be taken from any pair of generator lines that provide the correct sensing voltage at the voltage regulator sensing terminals. Standard model KCR 160 regulators have single phase, 50/60 hertz, is 225 VAC  $\pm$  15 percent sensing. The sensing transformer T1 is connected as shown in Figure 6-7.

Standard models can be modified for 115 VAC  $\pm$  15 percent sensing by modification of the regulator as illustrated in Figure 6-8.

#### **CAUTION**

**Circuit between the regulator output and exciter field must not be grounded and must not be opened while generator is running. To do so will cause inductive arcing that can destroy this equipment.**

#### C. Sensing Transformer T1

The sensing transformer primary contains two windings that can be connected either series, for 190 to 260 VAC sensing (225  $\pm$  15%), or parallel, for 98 to 132 VAC sensing (115  $\pm$  15%). The connections are made at the regulator circuit board as follows:

1. T1 Connected Series for 225 VAC  $\pm$  15% Sensing: Except when otherwise specified in the purchase order the sensing transformer T1 primary is connected to the circuit board in series for 225 VAC sensing as illustrated in Figure 6-7.
2. T1 Connected Parallel for 115  $\pm$  15% Sensing: Standard KCR 160 voltage regulators can be modified for 115 VAC  $\pm$  15% sensing by installing two jumper wires and cutting a section of the foil on the foil side of the circuit board as shown in Figure 6-8. This change connects the sensing transformer primary winding in parallel.

#### D. Output Power (Terminals F+ and F-)

Correct polarity must be maintained between the regulator output and exciter field. To minimize conducted EMI the leads should be kept as short as possible and should be shielded when more than one or two feet in length. Effective shielding can be attained by routing both leads through 1/2-inch metal conduit. When the voltage regulator is installed within the generator outlet box it is possible to achieve satisfactory results with short non-shielded leads.

### E. Underfrequency Limit

Unless otherwise specified in the purchase order, the KCR 160 voltage regulator will be provided with underfrequency limit for use with 60 hertz generator. The difference between the underfrequency limit circuit used with 60 hertz generators and the underfrequency limit circuit used with 50 hertz generators and the means of converting the circuit is described in the procedures that follow.

1. 50 Hertz Operation: For 50 Hz operation the voltage regulator must have jumper wire across a portion of the circuit board identified 50 Hz (See Figure 6-6). The jumper wire is installed from the component side of the board and its ends soldered to the foil side of the board.
2. 60 Hertz Operation: For 60 Hz operation the jumper wire is removed from the portion of the circuit board identified 50 Hz. To convert from 50 Hz system operation to 60 Hz system operation remove jumper wire by cutting the jumper at each of its ends.

### F. Regulator Fuse

The KCR 160 is supplied with a 2 amp normal blow fuse in the power input circuit. Fuse rating is 4 amp max. Recommended fuse size is 1<sup>1</sup>/<sub>2</sub> to 2 times the exciter field current with rated load connected to the generator. If an overload should cause the fuse to open, replace the fuse as described in the Maintenance Section in this manual.

### G. External Voltage Adjust Rheostat

This option where provided is inter-connected to regulator terminals R1 and R2 as shown in Figures 6-2 and 6-3. In order to provide sufficient mechanical strength size 16 or larger wires are recommended. Terminals on the rheostat are viewed from the rheostat back.

## CONNECTING ACCESSORIES

### **CAUTION**

**The circuit between the voltage regulator DC output (terminals F+ and F-) and the exciter field must never be opened during operation. To do so will produce inductive arcing that can destroy the voltage regulator. Therefore, never install the contact portion of circuit breakers, relays, or switches in the field circuit.**

### A. Regulator Voltage Shutdown Switch (Engine Idle Switch)

Where generator set is equipped with this switch, opening the switch removes input power from the regulator thereby shutting down the excitation current applied to the exciter field. This switch must always be series connected in the circuit providing input power to regulator terminals P1 or P2.

### B. Field Circuit Breaker

The system can be equipped with a field circuit breaker. The thermal element of the circuit breaker is series connected in the field circuit from the regulator output terminal F+ or F-. The contact portion of circuit breaker must be series connected in the regulator input power to terminal P1 or P2. NEVER CONNECT CIRCUIT BREAKER CONTACTS TO THE REGULATOR OUTPUT TERMINALS F+ OR F-.

### C. Manual Voltage Control

An auto/manual voltage control module is available for use with the generating system to provide manual voltage control independent of the voltage regulator. Wires from both the regulator output and the manual control output connect to the exciter field. Switch contacts must not be used in the circuit between the regulator output and the exciter field. A multi-pole switch which connects input power to the voltage regulator or input power to the manual voltage control permits selection of either the automatic voltage control mode of operation or the manual voltage control mode of operation. OFF position opens input power to both the voltage regulator and the manual voltage control circuitry.

## SECTION 4 OPERATION AND ADJUSTMENT

### GENERAL

This section contains operation and adjustment procedures. Before operating make certain that the regulator is connected into the system as shown on the interconnection diagram provided with the generator set and as described in Section 3 of this manual. Follow the safety precautions contained on page i of this manual when adjusting and checking connections to this equipment.

### ADJUSTMENTS

#### A. Potentiometer R2 (Voltage Adjust or Voltage Range Adjust)

This control is located on the voltage regulator. The control is a ten turn potentiometer. Adjustment is made using a small screwdriver. Maximum resistance is attained at full counter-clockwise adjustment and complete clockwise adjustment results in minimum resistance.

1. Where generator set is not equipped with the external voltage adjust option, generator voltage is adjusted by turning potentiometer R2. Complete (CCW) maximum resistance results in minimum voltage. Complete (CW) minimum resistance results in maximum voltage. Adjustment is made at rated RPM and with the generator output circuit breaker open.
2. Where generator set is equipped with the external voltage adjust rheostat option, the potentiometer R2 establishes the voltage range of the external voltage adjust rheostat. R2 is typically adjusted to limit the maximum voltage. General procedure is as follows:
  - a. Adjust external voltage adjust rheostat to complete clockwise (maximum voltage).
  - b. Be sure output circuit breaker is OFF.
  - c. Start generator set and increase speed to rated RPM.
  - d. Monitor voltage using generator voltmeter.
  - e. Adjust potentiometer R2 to position where generator voltmeter measures maximum operating voltage.
  - f. Reduce generator voltage to nominal operating voltage by turning the external voltage adjust rheostat in counter clockwise direction.

#### B. Underfrequency Operational Threshold Adjust R18

Adjustment was made at the factory. Voltage will decrease at frequencies below the operational threshold as shown in Figure 1-1.

#### C. Stability Adjust Option R48

This optional control permits adjustment of the stability signal applied to the regulator error detector circuit. Where provided, this control is factory adjusted. One complete turn changes resistance from minimum resistance to maximum resistance. Adjustment should be made only in case generator voltage is not stable (oscillates). Adjustment is made at rated RPM with no-load applied. Check stability and, if necessary, make final adjustment while load is applied. Clockwise rotation increases the stabilizing signal. Measurement of generator voltage stability is best made using an oscilloscope.

### FIELD FLASHING

#### CAUTION

**Do not attempt to flash the exciter field while the generator set is running and be careful to observe polarity when connecting flashing source. Disregarding this precaution can result in equipment damage.**

The voltage regulator contains an internal solid state field flashing circuit. A minimum of about 6 VAC at the regulator input power terminals P1 and P2 is required for operation of the flashing circuit. Usually the exciter field poles retain sufficient magnetism to allow circuit operation and generator voltage buildup. However, if flashing is required, stop the generator and then flash field as given in the procedure that follows.

1. Connect the negative lead of a 12 or 24 volt DC flashing source onto regulator terminal F-. Do not remove any other wires from terminal F-.
2. Slide the positive lead of the flashing source onto regulator terminal F+. Only a few seconds flashing should be necessary.
3. Slide the flashing source positive lead off terminal F+. Then remove flashing source negative lead from terminal F- and tighten terminal.
4. Start generator and check for satisfactory voltage buildup.

**WARNING**

**Off position on regulator shutdown switch, field circuit breaker or Off-Auto-Manual switch does not remove voltage generated by action of residual magnetism in the exciter field. Stop generator set before making connections, repairs, or adjustments. Disregarding this precaution can result in serious injury or electrocution.**

**REGULATOR VOLTAGE SHUTDOWN SWITCH (ENGINE IDLE SWITCH)**

The generator set may be equipped with a switch to allow removal of excitation to the exciter field in an emergency or when the prime mover must be operated at reduced speed. The switch must be installed in the regulator input power wiring to terminal P1 or P2. Manually opening the switch shuts down the regulator. Manually close the switch to obtain regulator output.

**FIELD CIRCUIT BREAKER**

The generator set may be equipped with a field circuit breaker that prevents excessive field current. The circuit breaker thermal element is installed in the field circuit while the circuit breaker contacts must be in the input power wiring to regulator terminals P1 or P2. When tripped open, the circuit breaker removes excitation by removing input power to the voltage regulator. Make certain the field circuit breaker is closed before operating the generator set.

**AUTO/MANUAL VOLTAGE CONTROL**

The generator set may be equipped with an auto/manual voltage control module. This option allows operation in the manual voltage control mode for trouble isolation during troubleshooting or emergency operation in the event a failure of the regulator occurs. This option includes a three position switch. The AUTO position connects power to the voltage regulator providing automatic voltage regulation, the MAN position connects power to the manual voltage control, and the OFF position removes input power to both the voltage regulator and manual voltage control circuitry thereby removing excitation applied to the exciter field. Normal operation of the generator set is the automatic voltage control mode (switch set to AUTO).

**INITIAL OPERATION**

Before operating the regulator for the first time, verify correct wiring and review the preceding section of this manual. Initial startup should be made with no-load applied (output circuit breaker OFF). Verify operation is satisfactory before closing circuit breaker.

## SECTION 5 MAINTENANCE AND TROUBLESHOOTING

### SAFETY SUMMARY

Follow the safety precautions contained on page i of this manual when testing, troubleshooting, and making repairs to this equipment.

### PREVENTIVE MAINTENANCE

This unit should be inspected periodically to insure wiring to the voltage regulator is in good condition, terminal connections are tight and free of corrosion, and air flow is not restricted. Accumulations of dust, dirt or other foreign material should be removed using a clean cloth. Under normal operating conditions, inspection at six month intervals is generally sufficient.

### TROUBLE ISOLATION TO FAULTY OPERATION OF VOLTAGE REGULATOR OR GENERATOR

#### A. Manual Voltage Control

In the event abnormal operation such as high voltage, low voltage, or unstable voltage occurs during operation in the automatic voltage control mode, the set may be operated in the manual mode to determine whether problem persists. Satisfactory operation in the manual voltage control mode while system malfunction occurs in the automatic voltage control mode indicates that the problem is within the voltage regulator. If operation is not satisfactory in both the manual and automatic regulating modes, the problem is within the exciter or generator.

#### B. Field Flashing

Failure of generator voltage build-up when the generator set is started can be due to loss of residual magnetism in the exciter field. About 6 VAC minimum is required at regulator input terminals P1 and P2 for automatic build-up by the internal flashing circuitry. Residual magnetism can be restored by flashing the exciter field as described in Section 4 of this manual.

#### C. Excitation From 12-24 VDC Adjustable DC Power Source or Battery

Where the generator set is not equipped with an auto/manual voltage control the application of rated no-load excitation from a 12-24 VDC power source or batteries may be used to determine whether abnormal operation is caused by faulty operation of the voltage regulator or, exciter or generator troubles. Generator no-load excitation may be determined from the factory test tag supplied with the generator.

This test requires removing the regulator input power wires from regulator terminals P1 and P2 and the regulator DC output (field) wires from terminals F- and F+. General procedure is given in the paragraphs that follow.

After the wires described in the preceding paragraphs have been removed from the regulator terminals, insulate lugged ends on the regulator input power wires and connect a variable DC power supply or battery with 1.5 ampere or higher DC ammeter to the exciter field leads. Where battery is used, series connect a variable resistor or rheostat in the circuit. Be sure positive of power source is connected to F+.

Operate generator set at rated speed and adjust to rated no-load excitation listed on the generator factory test data tag. Measure generator output voltage. Where rated no-load voltage is attained, problem is most likely the voltage regulator. Abnormal generator voltage indicates problem is within the exciter or generator.

### VOLTAGE REGULATOR OPERATIONAL TEST

Voltage regulator test can be made by removing the voltage regulator from the generating system and testing as described in Figure 6-9. When installing the regulator back into the regulating system make certain it is wired as shown on the wiring diagram provided with the generator set.

### VOLTAGE REGULATOR FUSE

The KCR 160 is supplied with a 2 amp normal blow fuse in the power input circuit. Fuse rating is 4 amp max. Recommended fuse size is 1½ to 2 times the exciter field current with rated load connected to the generator.

## TROUBLESHOOTING

To avoid trouble during initial operation the importance of eliminating wiring errors cannot be overemphasized. Excessively high voltage at the regulator input power terminals, excessively high or low voltage at the regulator sensing terminals, or opening or grounding the regulator output can cause voltage regulator failure.

Some of the possible malfunctions that could occur during operation of the voltage regulator and the corrective action are listed in Table 5-1.

**TABLE 5-1 TROUBLESHOOTING CHART**

<b>SYMPTOM</b>	<b>PROBABLE CAUSE</b>	<b>REMEDY</b>
No voltage output	Regulator voltage shutdown switch or field circuit breaker open. Auto/Manual/Off switch set to Off. Loss of exciter residual magnetism.  Voltage regulator or voltage regulator fuse open.  Defective generator or exciter.  No connections to regulator terminals F+ and F- or P1 and P2.	Close switch or circuit breaker.  Set to AUTO position.  Flash field as described in Section 4 in this manual.  Replace voltage regulator or replace fuse.  Test windings and exciter diodes. Replace defective parts.  Refer to wiring diagrams provided with generator set.
Voltage remains at residual voltage level provided by exciter.	Same as for preceding symptom except exciter has residual voltage.	Same as for preceding symptom except field flashing is not required.
Voltage builds up until flashing circuit deactivates then fluctuates between about 70 percent and 30 percent of rated.	Voltage regulator.	Replace voltage regulator.
Generator voltage low while regulator output is either normal or higher than normal.	Exciter or generator.  High resistance connections between regulator output F+ and F- and exciter field.  Overload.	Test windings and exciter diodes. Replace faulty parts.  Check wiring and connections. Tighten and clean terminals.  Reduce load applied to generator.
Generator output voltage and excitation lower than normal.	Underspeed.	Increase speed to produce rated output frequency.

**TABLE 5-1 TROUBLESHOOTING CHART (Cont.)**

<b>SYMPTOM</b>	<b>PROBABLE CAUSE</b>	<b>REMEDY</b>
Generator output voltage and excitation higher than normal.	Underfrequency circuit operating at too high frequency.	Contact factory.
	Voltage too low at regulator input power terminals P1 and P2.	Voltage should be 120 VAC $\pm$ 10 percent.
	Wrong sensing voltage at terminals E1 and E3 or transformer T1 not connected correctly.	Refer to Section 3, Installation, and Figures 6-7 and 6-8.
	Faulty voltage regulator.	Replace voltage regulator.
Voltage and excitation higher than normal.	Short in regulator sensing circuitry.	Check wiring to terminals E1 and E3. Replace voltage regulator if short is within the voltage regulator.
	Open circuit at regulator terminals E1 and E3.	Correct wiring error.
	Wrong voltage at regulator sensing terminals E1 and E3 or sensing transformer T1 not connected correctly.	Refer to the wiring diagrams provided with the generator set and review Section 3 Installation.
	External voltage adjust option not connected correctly or is wrong size.	Connect as shown in Figure 6-4. Must be 250 ohm rheostat.
	Where external voltage adjust option is not provided, jumper not installed across regulator terminals R1 and R2.	Install jumper across regulator terminals R1 and R2.
Poor regulation.	Load not balanced.	Balance load.
	Voltage too low at regulator input power terminals P1 and P2.	Voltage should be 120 VAC $\pm$ 10 percent.
	Prime mover speed fluctuating.	Adjust prime mover governor.
	Voltage regulator.	Replace voltage regulator.
	Operating temperature too high.	Refer to Specifications. Add cooling or take other measures to reduce ambient temperature.
	Adjust. Refer to procedure given in Section 4 in this manual.	Adjustment of potentiometer R48 required. (Applicable only in regulator with stability adjust option.)



## SECTION 6 DRAWINGS

### GENERAL

This section contains drawings and diagrams to facilitate installation, operation, and maintenance of the voltage regulator. An interconnection diagram is generally provided with the generator set.

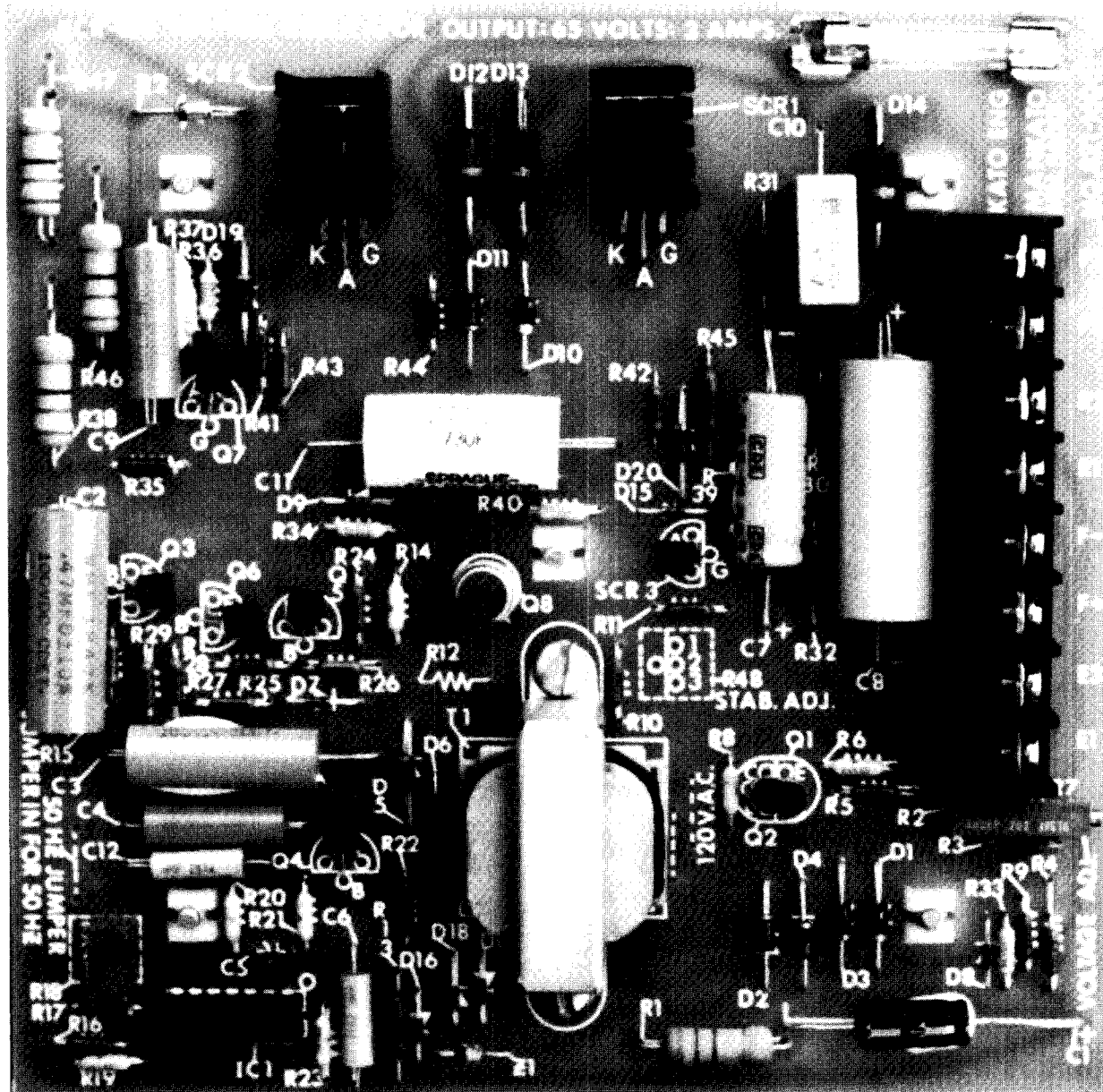


FIGURE 6-1 VOLTAGE REGULATOR DRAWING

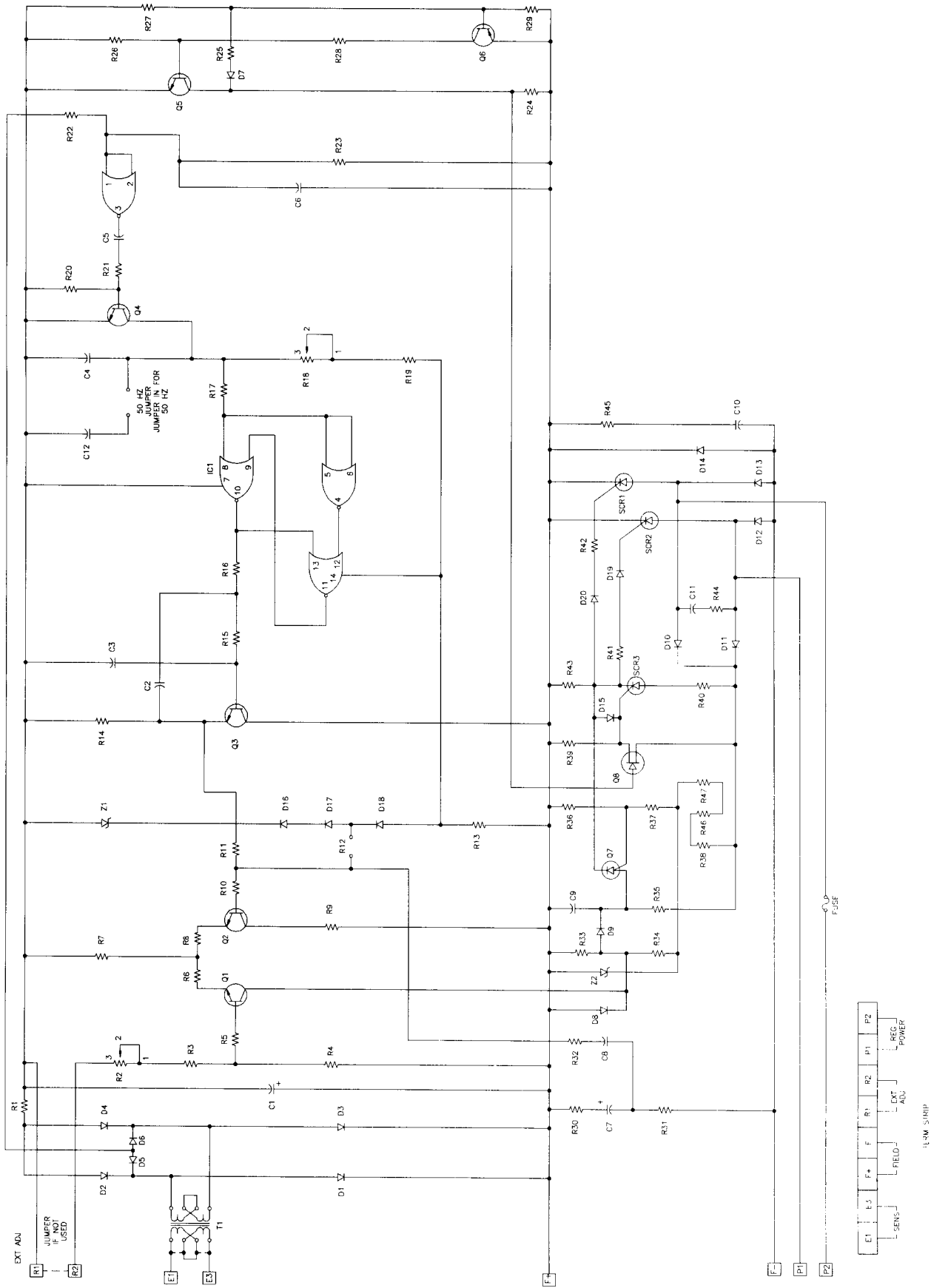


FIGURE 6-2 VOLTAGE REGULATOR WITH UFL SCHEMATIC DIAGRAM

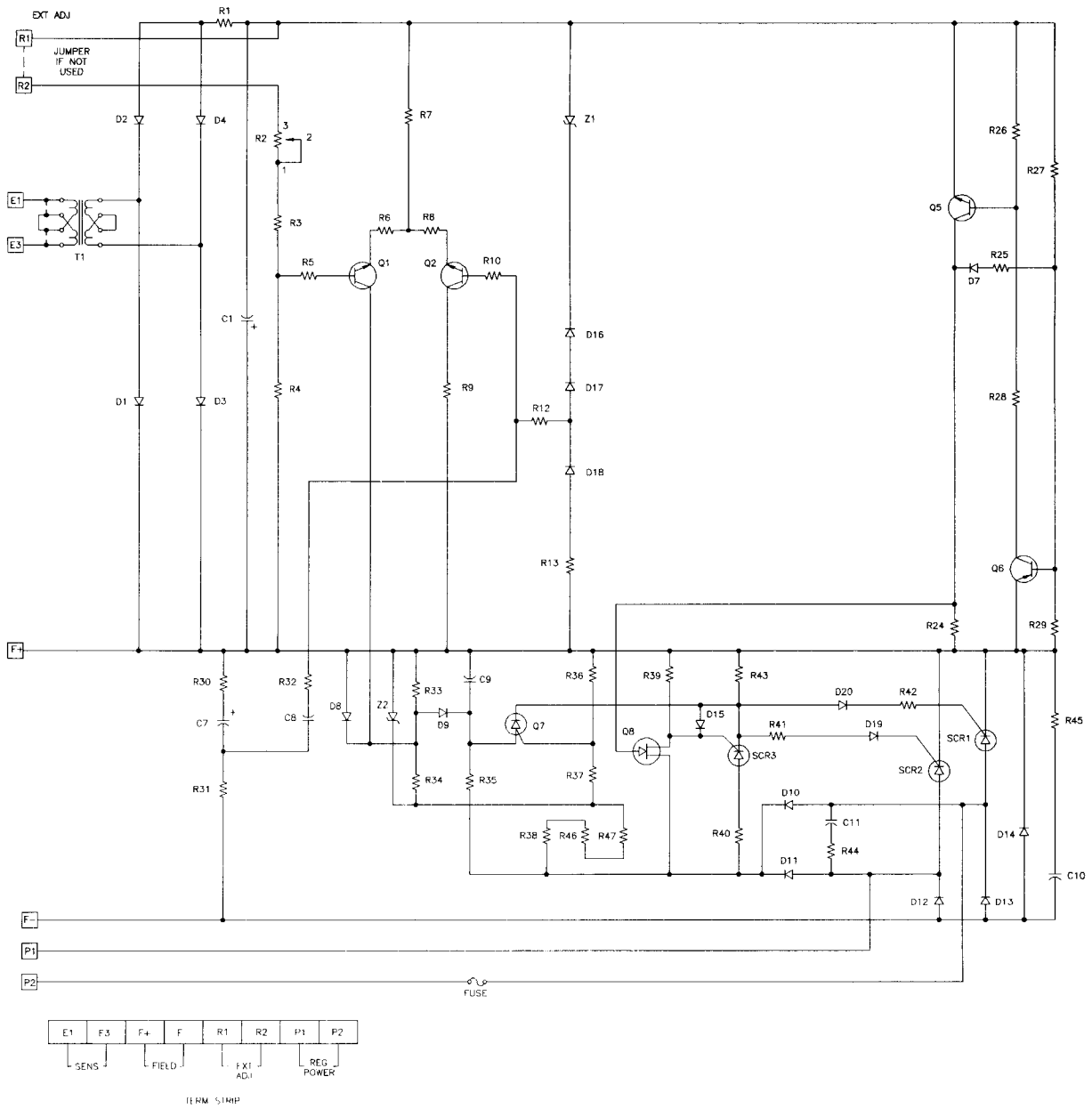
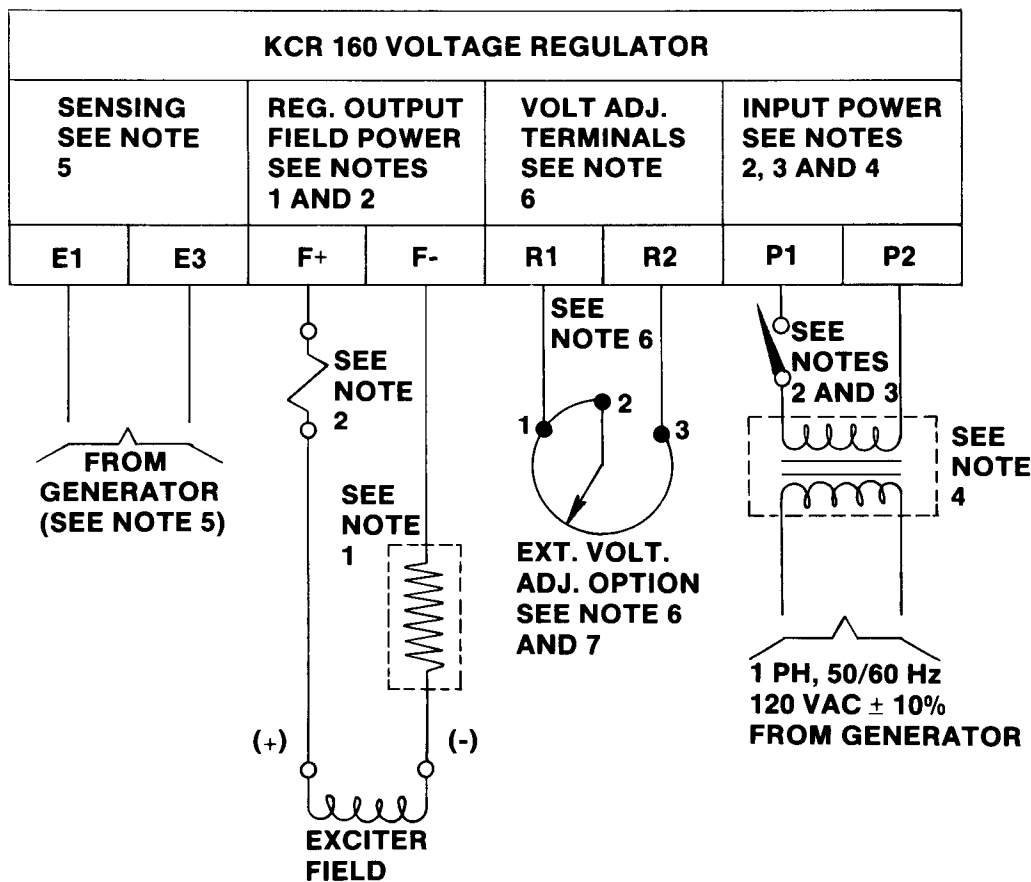


FIGURE 6-3 VOLTAGE REGULATOR WITH FLAT REGULATION OPTION SCHEMATIC DIAGRAM

**NOTES**

1. Where field resistance is less than 20 ohms a series resistance may be added to limit maximum current to 3 amp. continuous, 4 amp during field forcing.
2. Where generator set is equipped with field circuit breaker be sure to install thermal element of breaker in positive line. Circuit breaker contact must be in current carrying line to the regulator input power.
3. Shutdown switch allows removal of excitation by opening power to voltage regulator. Where one of the wires to regulator input power is a neutral line be sure to connect the switch in current carrying conductor.
4. Voltage regulator requires single phase, 50/60 Hz, 120 VAC  $\pm$  10% input power. A power matching transformer is required when correct input voltage is not available.
5. Verify correct sensing voltage. Standard KCR 160 voltage regulators utilize 225 VAC  $\pm$  15% sensing internally connected as shown in Figure 6-7. Optional voltage is shown in Figure 6-8.
6. Where external voltage adjust option is not supplied install a jumper across regulator terminals R1 and R2. Jumper across regulator terminals R1 and R2 is not used with external voltage adjust.
7. External voltage adjust wiring as viewed from back of rheostat.



**FIGURE 6-4 TYPICAL INTERCONNECTION**

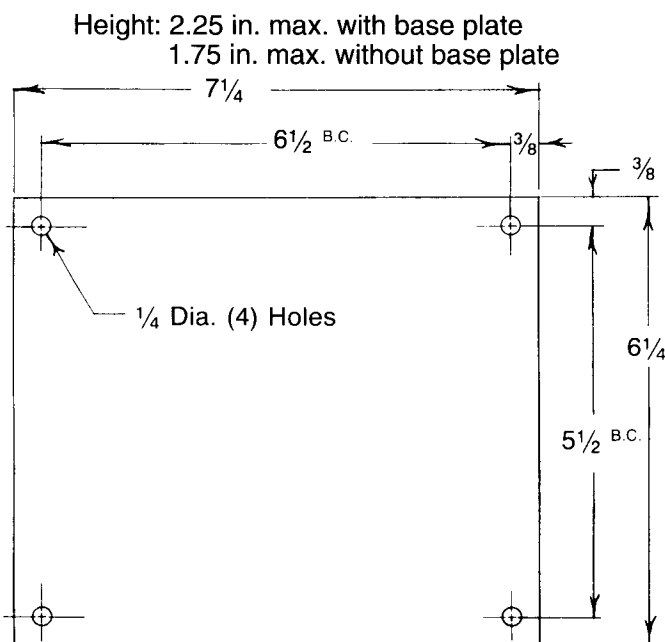


Fig. 6-5a. Regulator Mounting Detail

Circuit Board can be mounted without base plate as shown in Fig. 6-5b. Use 5 #8-18 3/4 inch "B" point self-tapping screws through 3/16 holes in panel or mounting surface and thread completely in plastic pads on regulator.

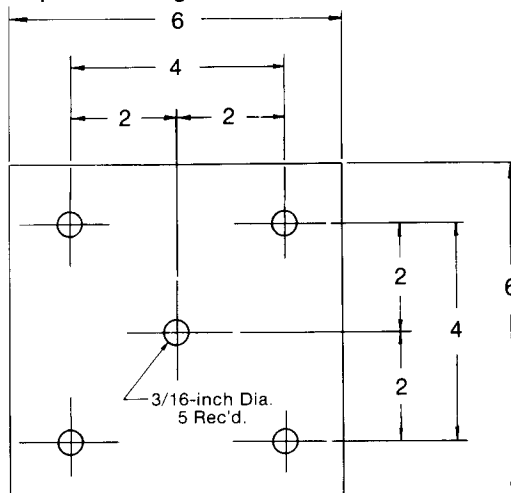
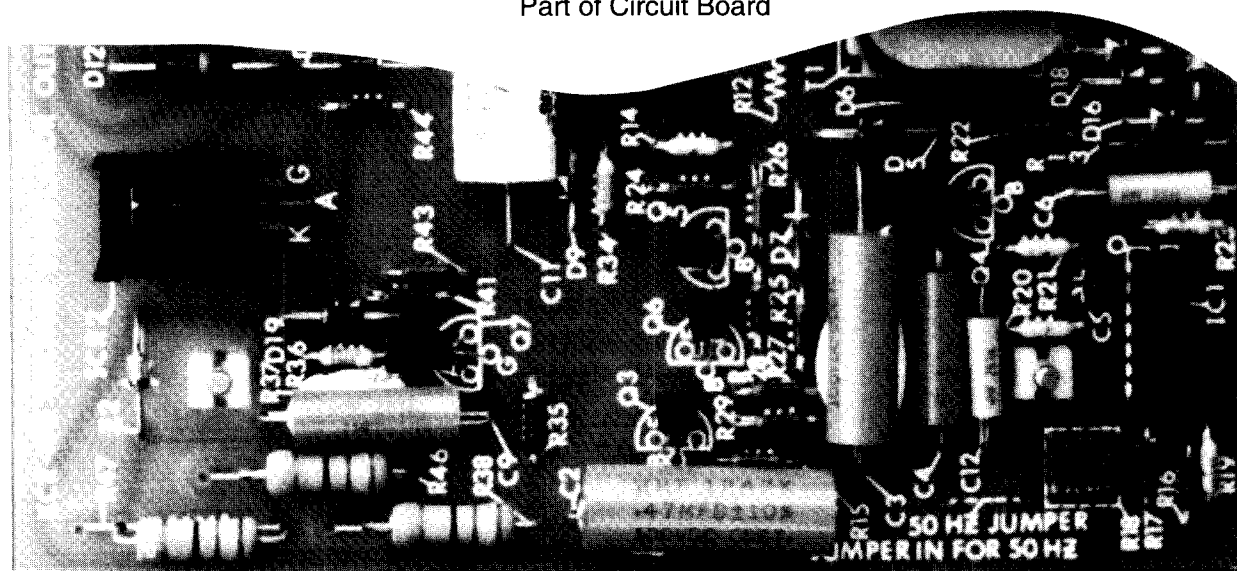


Fig. 6-5b. Circuit Board Mounting Detail

FIGURE 6-5 VOLTAGE REGULATOR MOUNTING DETAIL DRAWING

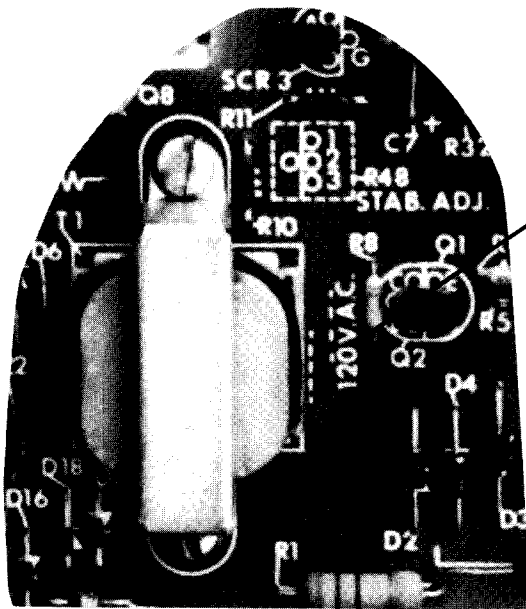
Part of Circuit Board



Remove Jumper for 60 Hz operation  
Install Jumper for 50 Hz operation

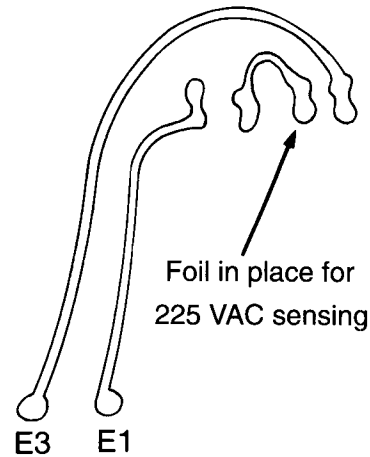
UFL Operational  
Threshold Adjust R18  
(Factory Adjusted)

FIGURE 6-6 UNDERFREQUENCY LIMIT JUMPER WIRE



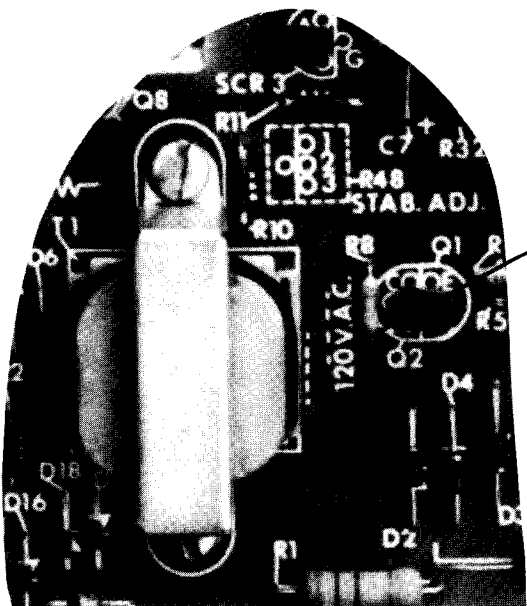
Part of component side on circuit board

The two jumper wires removed for 225 VAC sensing



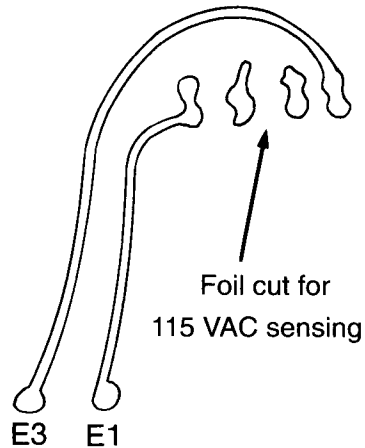
Part of foil on circuit board

**FIGURE 6-7 SENSING TRANSFORMER T1 CONNECTION FOR 225 VAC ± 15% SENSING**



Part of component side on circuit board

The two jumper wires installed for 115 VAC sensing



Part of foil on circuit board

**FIGURE 6-8 SENSING TRANSFORMER T1 CONNECTION FOR 115 VAC ± 15% SENSING**

## PROCEDURE

1. Ascertain sensing voltage (See Specifications).
2. Remove regulator from generating system and connect as shown in the appropriate drawing below.
3. Turn voltage adjust potentiometer (R2) screw adjustment to full counter-clockwise position.
4. Plug in regulator. Light should flash on momentarily.
5. Slowly turn voltage adjust (R2) screw adjustment clockwise. Before reaching complete clockwise setting the light should come on to full brilliance.
6. At regulating point about 5 or 6 turns in voltage setting should turn the bulb on and off. (See Note)

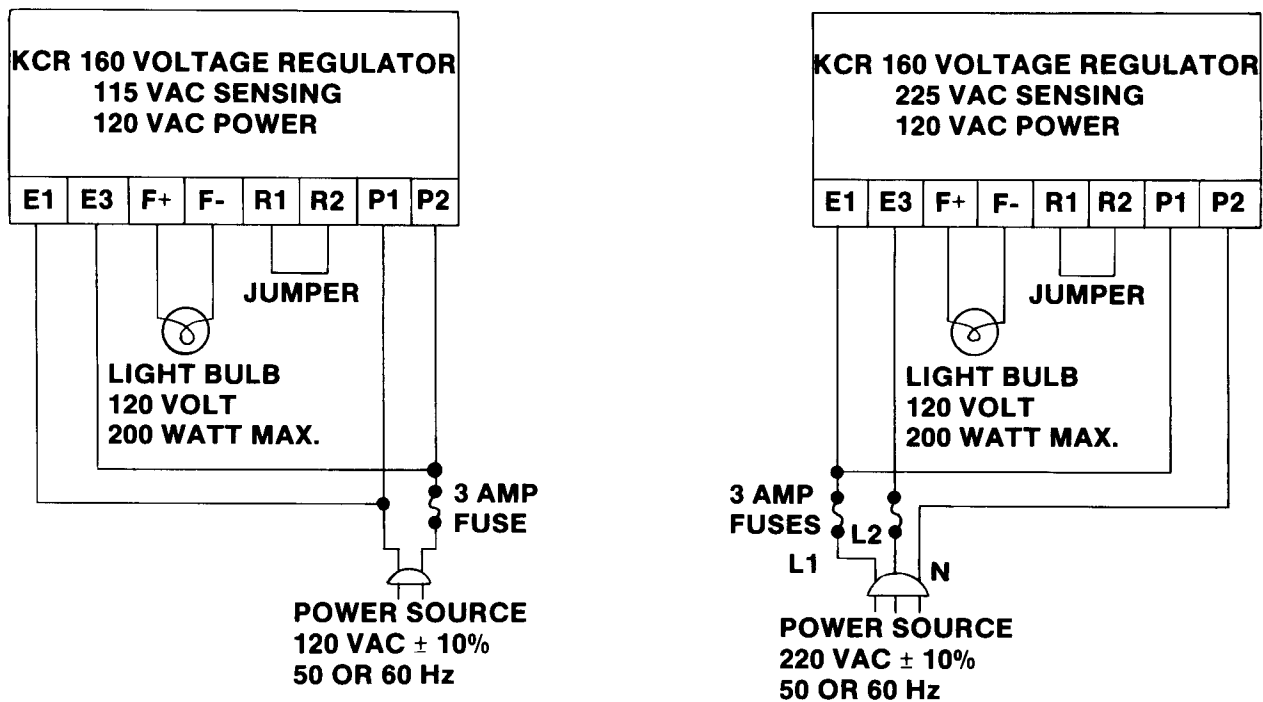


FIGURE 6-9 VOLTAGE REGULATOR OPERATIONAL TEST



## Kato Engineering Support

The brand you trust, the power you depend on. Include the serial number and model number for your machine in the email subject line.

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