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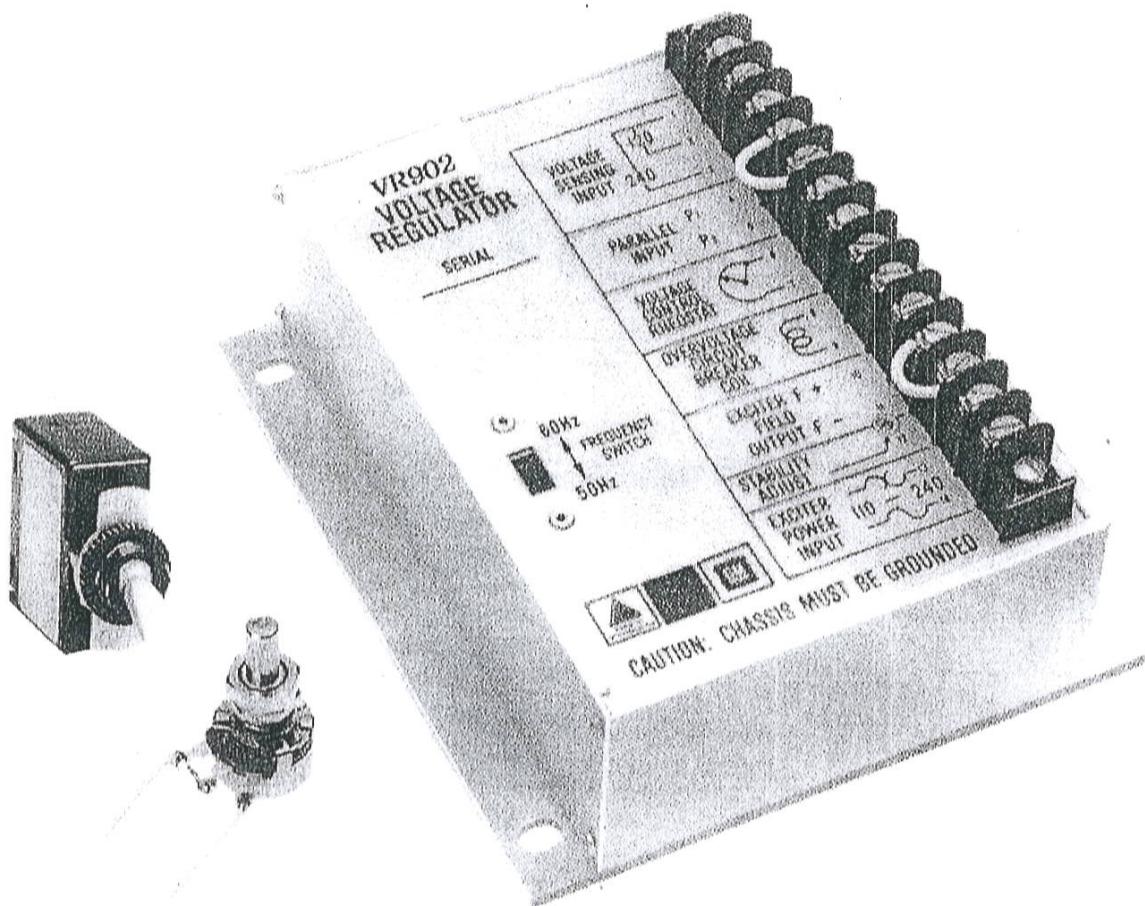


Figure 1

## VR902

### I. INTRODUCTION

#### A. SCOPE

This Manual covers the installation, operation, service and troubleshooting of the H9000 voltage regulator. Figure 1 shows a typical model with separate mounting AVCR and circuit breaker.

#### B. ABBREVIATIONS

AVCR	Automatic Voltage Control Rheostat
AWG	American Wire Gauge
CB	The Overvoltage Circuit Breaker
CBC	Current Boost Control
CW	Clockwise
CCW	Counterclockwise
IC	Integrated Circuit
PCB	Printed Circuit Board
SCR	Silicon Controlled Rectifier
TAB	Triple Action Boost
TB	Terminal Board

#### C. SAFETY

All standard safety precautions must be followed during operation, maintenance, servicing, and troubleshooting of engine-generator-regulator sets. Standard safety precautions include grounding any chassis to prevent shock hazard. The current carrying capacity of the grounding circuit must be greater than the capacity of the largest lead to the component to be grounded. Specific safety rules are given in sections VI and VII.

#### D. MODEL SPECIFICATIONS

- Voltage Regulation  $\pm 0.5\%$  average, no load to full load, 0.8 flag to 1.0 P.F.,  $\pm 5\%$  speed change,  $\pm 15^\circ\text{C}$  band-range -40°C to +70°C
- Regulator Drift  $\pm 0.5\%$  from -40°C to +70°C
- Regulator Response Less than 12 milliseconds
- Voltage Adjust Range  $\pm 10\%$  of nominal (below 190 to 10% above 240 volts)
- Storage Temperature -65°C to +85°C

• Shock	Up to 20 G's
• Vibration	2 G's at 20-50 Hz and 8 G's at 50-60 Hz
• Dimensions	6.625 x 5.875 x 2.812 inches 168.775 x 149.225 x 71.425 mm
• Weight	2.9 lbs.
• Net Shipping	3.134 lbs.
• Circuit Board	Moisture-Proof Conformal Coating Coating
• Enclosure	Aluminum - Anodized Finish
• Input Sensing	See chart Fig. 2A - Burden VA (Mpx)
• Exciter Power Input	See chart Fig. 2A - Burden 150% max exciter requirements
• Output	@ 120 VAC      @ 240 VAC External input      External input
- Volt-Cont	70 VDC
- Volt-Facing	100 VDC
- Current Cont	0.03-7 A
- Current	0.06-7 A
- Line Facing	10 A
- Min. Load	10 W
- Resistance	10Ω
- Max. Load	200Ω
- Resistance	100Ω
• Under Frequency	Fault set at 5% below rated speed... 50 or 60-100 RPM (See Figure 7)
• Protection	

#### E. INPUT REQUIREMENTS

The H9000 regulator is designed to operate with a wide range of input voltages at either 50 or 60 Hz. The regulator utilizes 1 phase serving source (line-to-line) and accepts exciter power input 1 phase (line-to-line & line-to-neutral) (See Figure 2A).

For other voltages than stated in Figure 2A, a voltage matching transformer should be used. (See Figure 2B)

Sensing Input 120 VAC 50 or 60 Hz		
	Voltage	Terminals
	95-120	181-182
	180-240	181-183
Exciter Power Input 120 VAC 50 or 60 Hz		
Max. Excite	Voltage	Terminals
3A - 70 VDC	95-240	181-182
3A - 140 VDC	180-240	181-184

Figure 2A  
H9000 - Input Requirements

Sensing Input	50 VA Typical with 120-240 VAC Secondary Use of Equivalent
Exciter Power Input	Exciter power transformer is determined by the exciter requirements as:
	a. 3 A - 70V @ 3A - Use 120V set b. 3 A - 140V @ 3.5A - Use 240V set c. 3.5A - 80V VA

Figure 2B  
H9000 - Input Requirements

## II. OPERATION

### A. WHY A REGULATOR IS REQUIRED

For the purposes of this publication, a generator is a rotating machine built to use the principles of magnetic induction to transform the mechanical energy put into the shaft by a prime mover into usable electrical energy.

Two basic principles involving electricity and magnetism are involved in a generator, as in all rotating electrical machinery. First, if an electrical conductor such as a copper wire, is moved in a magnetic field, an electrical potential (pressure) is induced (caused to be) in the conductor. This pressure is called voltage. Second, if an electrical current (movement of electrons caused by electrical pressure) flows in a conductor, a magnetic field is created around the conductor. The conductor can be made into a coil and the magnetic field around each "turn" of the coil will add to every other one to produce a strong magnetic field. The strength of the magnetic field is also determined by the geometric configuration of the coil, the relative amount of iron and air through which the magnetic field must pass and the amount of current flowing. The direction of the magnetic field will reverse if the current is reversed. When the currents A.C. (Alternating Current), it does this in a regular manner.

A generator, then, contains one structure, called a "Field" which contains the magnetic field and an "Armature" which contains the conductors in which the electrons (a permanent fluid) of these parts may move to produce a voltage.

In actuality, these two parts are specially shaped stacks of non-magnetic, and conductors that can coil back to overlap the other with a minimum of space between them. A cross section of a generator with a stationary field and rotating armature is shown in Figure 3, and one with rotating field and stationary armature is shown in Figure 4.

A side view cut-away is shown in Figure 5 of the two generators in one frame.

The principle function of the generator, and the basic reason for its use, is to provide a source of electrical energy to run motors, produce light, charge batteries, and many other uses.

This manual covers a specific type of generator, sometimes called an Alternator, in which the electric potential is continually changing direction in a regular manner (alternating current A.C.). The generator described here is actually two generators in one, the main generator which is producing the variable electrical potential is called the alternator.

The alternator armature is stationary and is often called the "stator". The alternator field is the main rotating portion. Since the magnetic field is produced by current flowing in coils of wire, a source of this exciting current is required. This source is called the "exciter" and will drive the second generator mentioned above.

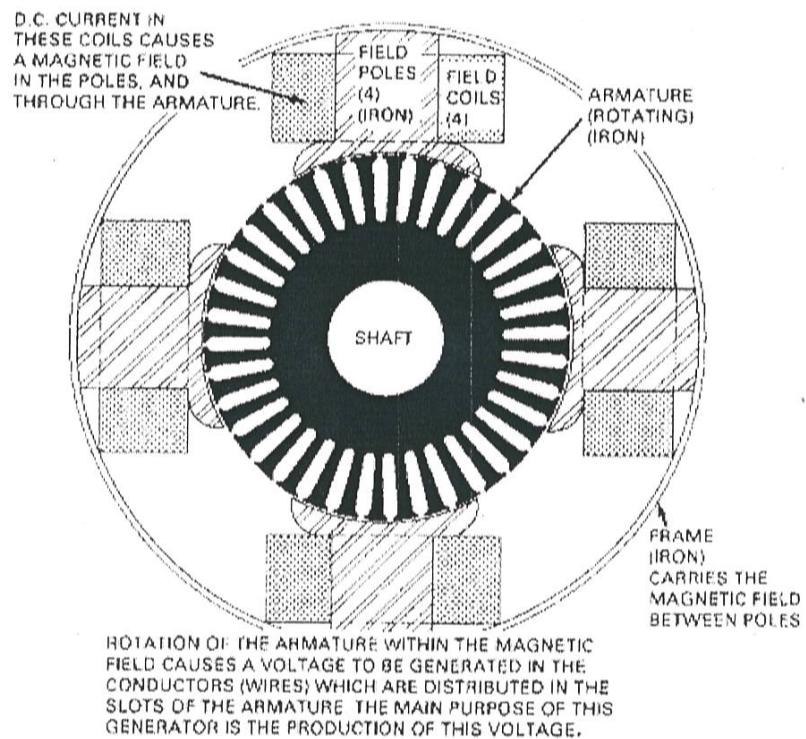


Figure 3  
Basic Generator Construction with Rotating Armature

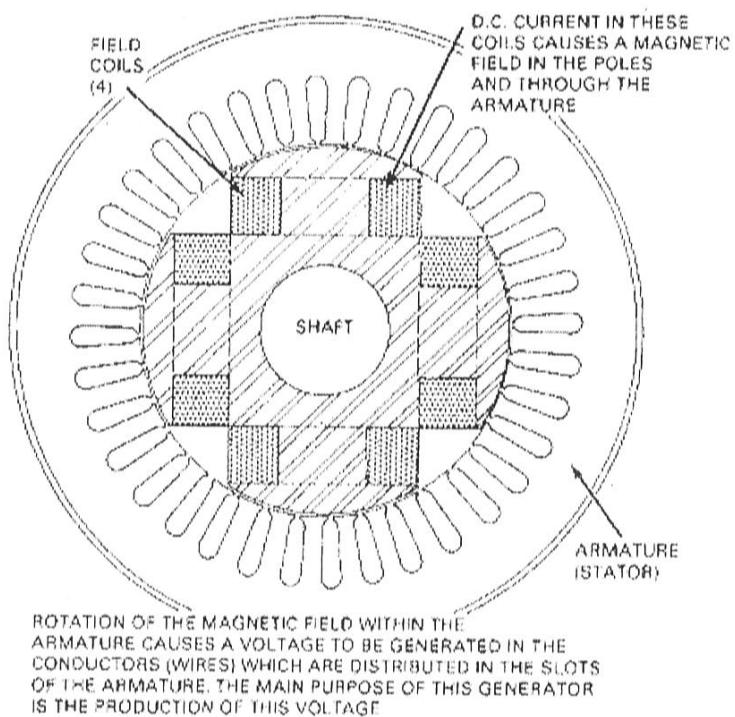


Figure 4  
Basic Generator Construction with Rotating Field

The electrical potential produced in the exciter armature (rotating) is A.C., whereas the current in the coils of the alternator fields must be D.C. (Direct Current). Therefore, some means must be inserted between the exciter armature and the alternator field to make D.C. out of A.C. This action can be accomplished by "commutation" or by "rectification." Earlier generators of this type use a commutator with brushes to do this and were called "brush type" machines. Most present generators use rectifiers which rotate with the exciter armature and the alternator field. Thus is created what is called a "brushless" generator.

Under any given condition, the voltage output of the generator is determined by the amount of D.C. current in the exciter field. All that the regulator does to the generator is to automatically adjust the exciter field current.

### B. HOW THE H9000 REGULATOR WORKS

The output voltage of the generator is put into the regulator

through both the sensing input circuits and the exciter power input circuit; one for reference and one for power.

The exciter power is the supply for a single-phase, full-wave, rectifier bridge with a rectifier and an SCR in each leg. The D.C. output of this circuit is supplied to the exciter field. The amount of current is controlled by adjustment of timing of the turn-on point of the SCRs. Each SCR is turned on at some time during each half cycle that the voltage is in the polarity for conduction. If a small amount of field current is required, the SCRs are turned on late in the half cycle. If a large amount of field current is required, the SCRs are turned on early in the half cycle. When the current required is zero, the SCRs are not turned on at all.

The sensing input supplies through an isolation transformer a small amount of power which is used to turn on the SCRs as required.

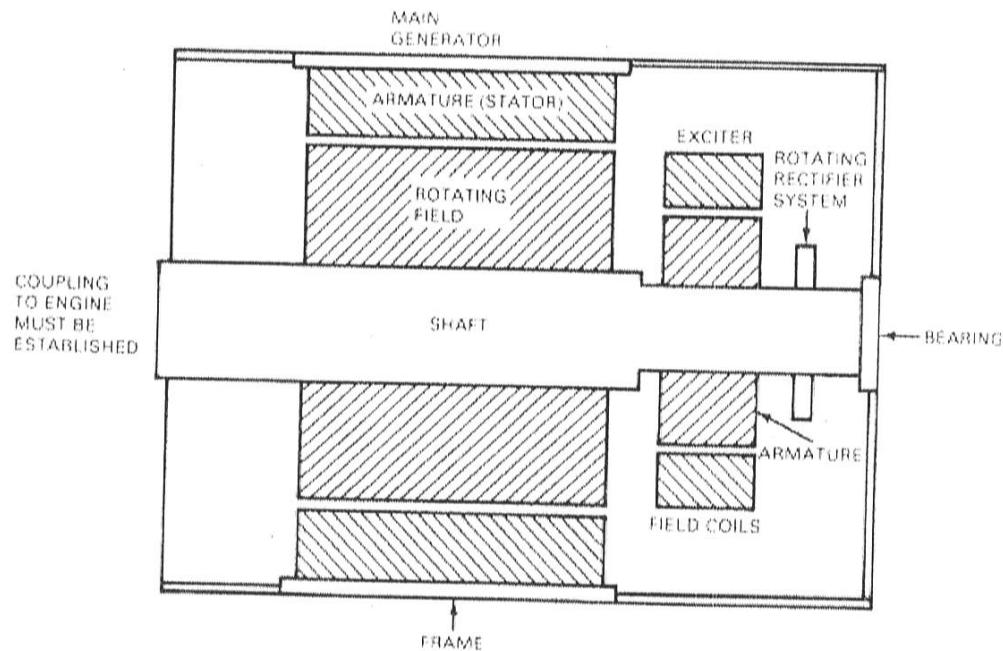


Figure 5  
Cut-Away View of a Typical Generator

### C. CIRUCIT EXPLANATION

#### Area A - Regulator Power Supply

This section supplies 20 volts D.C. for the ICs and the overvoltage circuit and exactly 10 volts D.C. for circuitry reference voltages.

#### Area B - Overvoltage Circuit

This section compares the output voltage of the generator, through the sensing transformer, with the normal adjusted level as set by the AVCR (Area C) to establish an overvoltage trip point. The trip point is automatically set to about 10%

above the normal adjusted voltage. If the generator output exceeds the 10% trip point for more than 3 seconds the overvoltage circuit trips the circuit breaker which removes field excitation.

#### Area C - Input Circuit

This section rectifies the A.C. out of the secondary of the sensing transformer and, through a series of resistors, supplies the voltage level required for the overvoltage circuit and the error amplifier. The input circuit includes the AVCR which adjusts the generator output voltage level.

#### Area D - Error Amplifier

This circuit provides a signal to the timing comparator. When the voltage from the input circuit (Area C) is not equal to the reference voltage (Area A), the error amplifier adjusts to change the input voltage for the timing comparator.

#### Area E - Timing Comparator

This circuit takes the signal from the error amplifier and adjusts the timing of the gate pulse to the output SCRs to hold the generator voltage constant.

#### Area F - Power Amplifier

This circuit takes the power from the exciter power input circuit, rectifies it, and sends timed pulses of current into the exciter field under the control of the error amplifier and timing comparator.

The free-wheeling diode recirculates the current in the field during the time the SCRs are not conducting.

#### Area G - Anti-Hunt Circuit

This circuit sends a portion of the voltage across the exciter field back to the error amplifier in a manner which prevents oscillations. This signal can be adjusted by the stability adjust rheostat.

#### Area H - Underfrequency Protection Circuit

This circuit contains a frequency to D.C. converter and a break point amplifier. The break point amplifier sends a signal to the input circuit (Area C) causing the generator output voltage to go into a linear volts/Hz ramp. Protection occurs when the frequency is less than the set point (5% below rated frequency).

#### Area I - Loss of Sensing Protection Circuit

This circuit disables the exciter power circuit in the event that the input sensing voltage is lost through a broken wire, loose connection, etc.

### III. FEATURES

#### A. UNDERSPEED PROTECTION CIRCUIT

This regulator includes a built-in circuit to protect the generator from operation at less than nameplate speed. The circuit preset at the factory allows normal, flat regulation down to about 5% below rated speed. At this point, the voltage will decrease proportionally to speed. The reduced voltage and speed combination will automatically protect the regulator-exciter-generator combination from the otherwise harmful effects of underspeed operation.

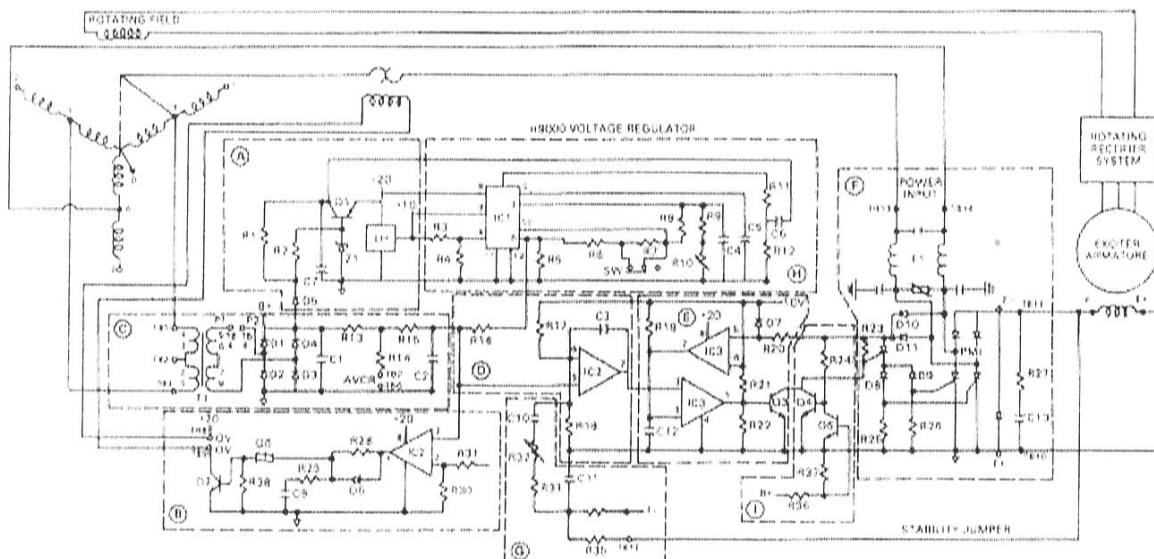


Figure 6  
H9000 Schematic Diagram

#### NOTE

If the speed is low and the voltage is adjusted upwards by the AVCR, this protection is reduced. Therefore, at any time the voltage is low, check the frequency meter or the generator speed. Be very sure that the speed is up to, or a little above rated speed before attempting to raise the voltage with the AVCR.

The relationship between the voltage and speed are shown in Figure 7

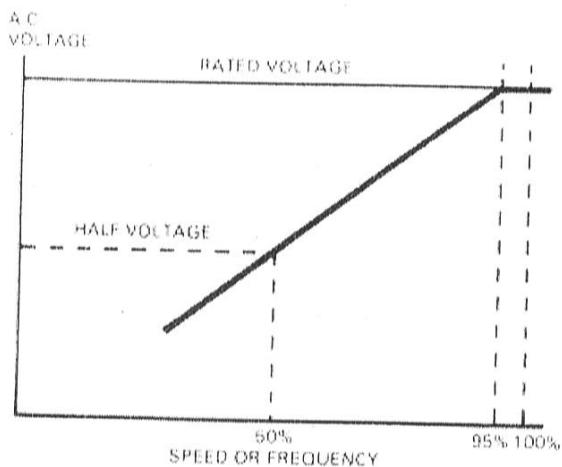


Figure 7  
Typical Curve of Voltage vs Speed for  
Automatic Underspeed Protection

#### B. OVERVOLTAGE PROTECTION CIRCUIT

The regulator incorporates a combination of both circuitry and circuit breaker to insure prolonged overvoltage conditions will not harm either generator nor system load components

The overvoltage trip point is automatically set to about 10% above the nominal voltage. If the generator output exceeds this 10% trip point for more than 3 seconds, the overvoltage circuit trips the circuit breaker which removes field excitation.

For service considerations concerning the circuit breaker, see Section VI.

#### C. EMI SUPPRESSION

This regulator includes a built-in power line filter that suppresses conducted electromagnetic interference from the regulator power switching circuit into the generator. The H9000 voltage regulator effectively provides control of radio-frequency interference line-to-ground noise in most applications without resorting to additional external methods. The actual effectiveness of suppression of RFI on the regulator-generator system to meet such standards as MIL STD 461 will have to be tested in the actual application.

#### D. STATIC BUILD-UP CIRCUIT

The voltage build-up circuit is completely solid state. The circuit contains no relays and is neither subject to mechanical failure nor electrical arcing. Generator voltage build-up is initiated by residual voltage of the generator as low as 6 volts.

#### E. SOFT START-UP

The unique arrangement of the elements in the static build-up circuit substantially reduces the amount of voltage overshoot possible on start-up. The amount of voltage overshoot reduction is dependent upon prime mover acceleration and generator time constants. An example of overshoot reduction during start-up is shown in Figure 8.

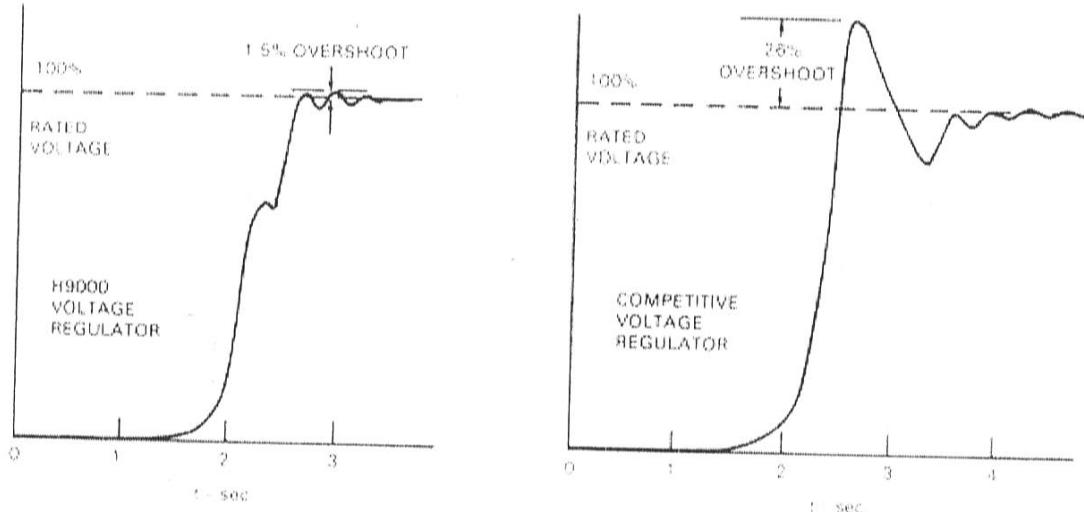


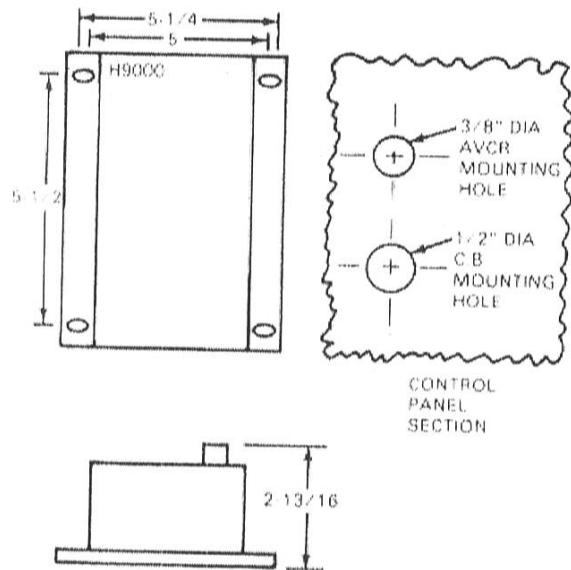
Figure 8  
Typical Voltage Rise Curve at Start-Up

## IV. INSTALLATION

### A. GENERAL

The H9000 regulator has been designed and built to perform well under normal usage. As with all electrical control equipment, the following installation factors should be considered.

1. Protect from contaminants, such as coal dust, rock dust, acid, salt and water.
2. Select the most vibration-free surface available for convenient mounting.
3. Protect from falling objects.



**Figure 9**  
Mounting Hole Configuration

### B. SAFETY

During installation and connection:

1. Generator set or line circuit breaker must be open.
2. Any external power source must be disconnected.
3. Remote starting circuits, starting battery, and mechanical starting equipment must be disconnected.

### C. MOUNTING

Four #10 bolts in a rectangle 5½ x 5-5¼ in. The regulator function is not affected by mounting position. Choose a mounting position that contributes to the general considerations listed above. Locate the automatic voltage control rheostat (AVCR) and circuit breaker (CB) at some convenient control panel location. See Figure 9.

### WARNING

Ground the regulator chassis to prevent shock hazard and provide ground path for EMI filter. The current-carrying capacity of the grounding circuit must be greater than the capacity of the largest lead to the regulator.

### D. WIRE SIZE

Make all connections to the terminal boards of the regulator using AWG #14 or #16 stranded control wire.

### E. CONNECTIONS - DIAGRAMS

1. The H9000 Regulator must be connected following the general considerations shown in Figure 10A & 10B.
2. The charts Figures 11, 12, and 13 show the possible A.C. input voltages to the regulator.

#### NOTE

If the proper voltage for the regulator being used is not available directly from the generator, the regulator being used can still be used if (Figure 2A) isolation transformers are used between the regulator and the generator. The input voltage to the transformer must be the same as the voltage available from the generator and the output of the transformer must be within the allowable voltage limits for the regulator as given in the chart and regulator name-plate.

#### NOTE

If in your application the exciter field is grounded or the field flashing circuit is grounded, then a power isolation transformer must be used in the connections to the exciter power input (TB13-TB14). The isolation transformer will protect the rectifier bridge in the power amplifier section of the regulator should an additional ground occur on the generator output lines.

### F. PRE-OPERATION CHECKS

1. Make sure the generator conforms to the operating limitations of the regulator.

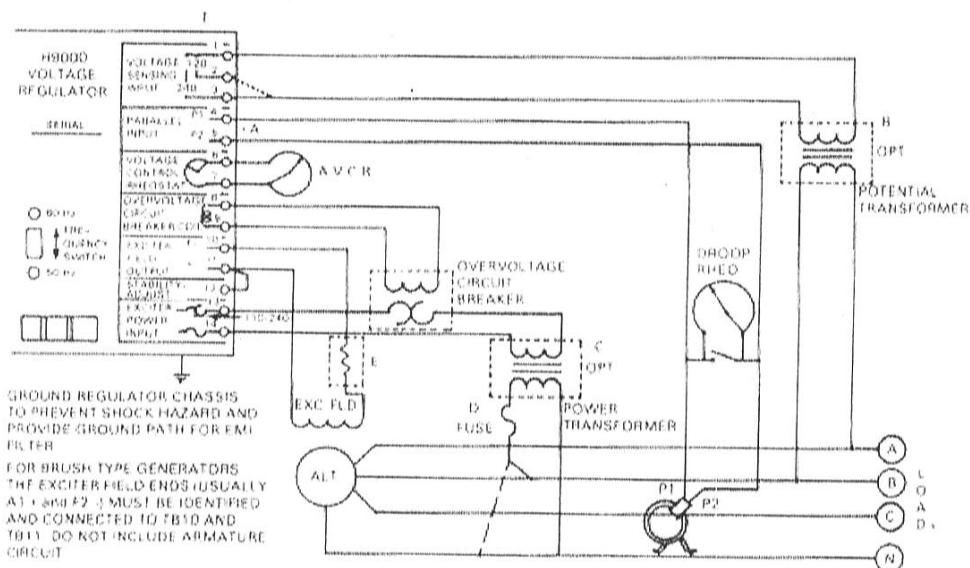
Input Voltage — 95-120 or 190-240 VAC, 50 or 60 Hz

See chart in Section I, Figures 2A and 2B

Output Current — 0.6 to 7.0 Amperes

Output Voltage — 4 to 210 Volts

Exciter Field Resistance — 10 to 100 Ohms (120 VAC exciter input); 20 to 100 Ohms (240 VAC exciter input). Add series resistance to raise exciter field to 10 or 20 Ohm min. level, power rating of series resistance = {max. field current<sup>2</sup> × resistance added}.



- A. SHORT P1 & P2 FOR NON-PARALLEL OPERATION
- B. POTENTIAL TRANSFORMER IS ONLY NEEDED IF 120 OR 240 SENSING VOLTAGE IS NOT AVAILABLE FROM ALT. USE A 50 VOLT AMP OR GREATER
- C. A POWER TRANSFORMER MUST BE USED IF 120 OR 240 VOLTS A.C. IS NOT AVAILABLE FROM THE ALT. THE V A RATING MUST BE SIZED TO THE EXCITER REQUIREMENTS. IF EXCITER FIELD OR FIELD FLASHING CIRCUIT IS GROUNDED, A POWER ISOLATION TRANSFORMER MUST BE USED.
- D. THE CIRCUIT BREAKER IS FOR OVERVOLTAGE PROTECTION ONLY. OVERCURRENT PROTECTION MUST BE PROVIDED BASED ON GENERATOR EXCITER FIELD REQUIREMENTS
- E. EXCITER FIELD D.C. RESISTANCE MUST BE AT LEAST 10 OHMS FOR 120V EXCITER POWER INPUT OR 20 OHMS FOR 240V EXCITER POWER INPUT. ADD SERIES RESISTOR AS REQUIRED

Figure 10A  
General Connection for H9000 Regulator

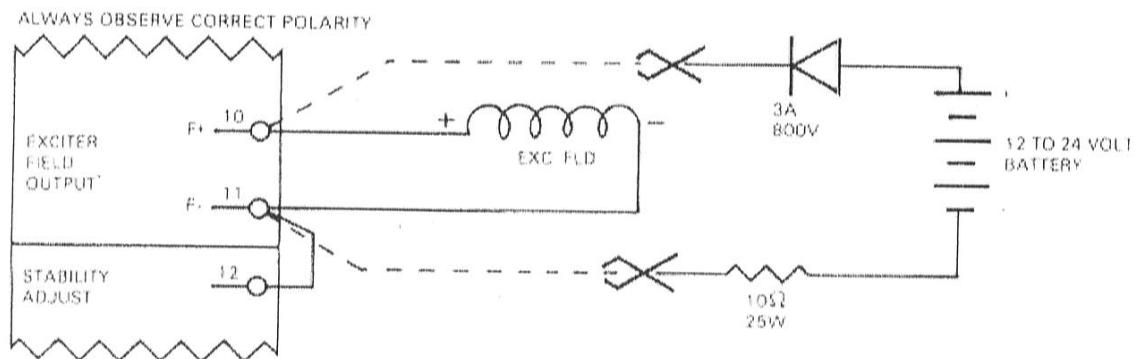


Figure 10B  
Current Limited-Field Flashing Circuit for H9000 Regulator

2. Read and verify understanding of the features on this regulator as explained in Section III
3. Verify the frequency of operation (60 or 50 Hz). If regulator is to be used on a 50 Hz application the slide adjust switch located on the front cover must be changed to the 50 Hz position and vice versa. The slide switch may be actuated by inserting a small blade screwdriver into the indentation slot on the slide. If the switch is in the incorrect position, the regulator will not perform correctly.
4. Verify that the voltmeter is operating or use a separate one known to be good
5. Conduct and record tests as indicated in the start-up procedure in the operators manual. These tests are conducted to assure proper operation of the system and that the generator does not contain an intermittent fault. On new generators, test 3.f. (two-hour run) may be eliminated
6. If field flashing is required, refer to Figure 10B.

#### G. ACCESSORIES

1. Paralleling Components, TAB, CBC, and manual control can be used; however, the H9000 regulator is connected differently from other regulators and the proper connection diagrams should be obtained and followed.

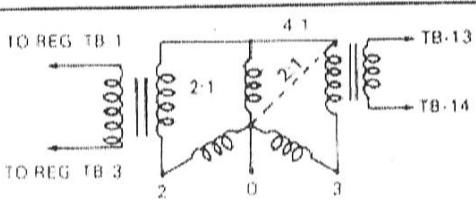
GENERATOR					
DESCRIPTION			NAMEPLATE VOLTAGE WITHIN:	GEN VOLTAGE CONN	REGULATOR-GENERATOR CONNECTIONS
PH	TYPE	LEADS			
3	WYE	4	60 Hz 240/416-277/480 50 Hz 220/380-252/440	NOT RECONNECT- ABLE	

Figure 11  
Available Regulator-Generator Connections  
for H9000 When 120 or 240V Are Not Available

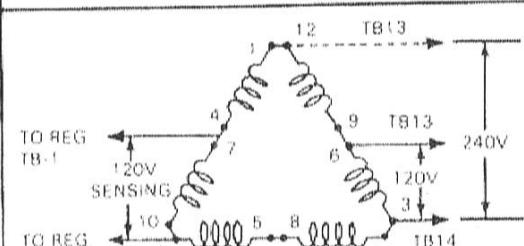
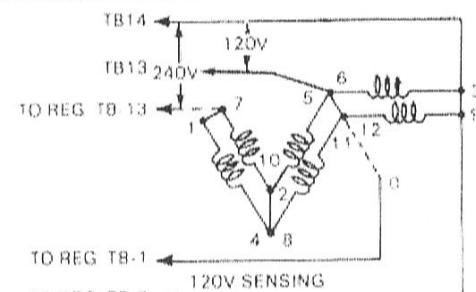
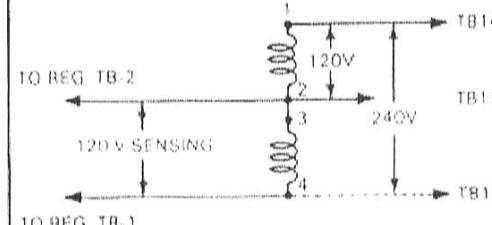
GENERATOR					
DESCRIPTION			NAMEPLATE VOLTAGE WITHIN	GEN. VOLTAGE CONN	REGULATOR-GENERATOR CONNECTIONS
PH	TYPE	LEADS			
3	DELTA	12	110/220-120/240 (50 OR 60 Hz)	RE- CONNECT- ABLE HIGH OR LOW	
1	ZEE	12	110/220-120/240 (50 OR 60 Hz)	LOW ONLY	
1		4	110/220-120/240 (50 OR 60 Hz)	RE- CONNECT- ABLE HIGH OR LOW	

Figure 12  
Available Regulator-Generator Connections for H9000  
240V Sensing Input, 120 or 240V Exciter Power Input

GENERATOR					CONNECTIONS
DESCRIPTION			NAMEPLATE VOLTAGE WITHIN:	GEN VOLTAGE CONN	
PH	TYPE	LEADS			
3	WYE	10	60 Hz 208-416-240-480 50 Hz 190-380-220-440	RECONNECT ABLE, HIGH OR LOW	
3	WYE	12	60 Hz 208-416-240-480 50 Hz 190-380-220-440	RECONNECT ABLE, HIGH OR LOW	
3	WYE	4	60 Hz 120-208-139-240 50 Hz 110-190-127-220	NOT RECONNECT ABLE	
3	DELTA	12	60 Hz 115-230-120-240 50 Hz 110-220	HIGH ONLY	
1	ZEE	12	60 Hz 115-230-120-240 50 Hz 110-220	LOW ONLY	
1		4	60 Hz 115-230-120-240 50 Hz 110-220	HIGH ONLY	

Figure 12 (cont'd)  
 Available Regulator - Generator Connections for H9000  
 240V Sensing Input, 120 or 240V Exciter Power Input

## V. START-UP PROCEDURE ("START-UP TESTS")

When a regulator is first applied to a generator or at any later time if the quality of the generator is questioned, the following tests should be conducted to be certain that there is no defect in the generator, even if it is new, and that the generator is in the proper operating range for the regulator.

If the tests, compared with known data, show that the generator is good, they should be kept so that later tests can be compared with them. These tests require the engine to be running at rated speed and that the meters are accurate.

The exciter field current or voltage across the exciter field are very important. Record these readings and compare with values listed on generator nameplate and capability of the H9000 regulator.

1. Turn AVCR fully CCW (Max. Resistance) so that the line voltage will be at a minimum after the engine is started.  
*Note: See Figure 1 for proper AVCR wiring*
2. Start the driving engine and adjust to **rated speed** of the generator
3. With each of the following conditions, read and record exciter field amps. Record the D.C. voltage across the exciter field if a DC ammeter with the proper range is not available. The exciter field amps (or volts) is **very important**, especially under load. **DO NOT** exceed 7 amps continuous or 10.0 amps for 1 minute (field forcing)
  - a. At no load — with AVCR fully CCW.
  - b. At no load — with AVCR fully CW — not longer than 30 sec. (If the A.C. voltage at this point exceeds 120% of rated voltage, take the reading at 120% of rated voltage.)
  - c. At no load — with AVCR adjusted to rated voltage
  - d. At no load — with speed reduced from 10% to 50% of rated speed — output voltage should drop and exciter field current should not exceed generator nameplate rating.
  - e. Under any normal, relatively constant load, cold — when load is first applied
  - f. Under same load as (e) above, after two hours running. (May be eliminated on new generator)
4. If voltage fails to build-up, is too low or too high and is not adjustable to rated voltage, exhibits other undesirable characteristics, or exciter field current exceeds 7.0 amps, check Section VI on "Troubleshooting."
5. If voltage is hunting or oscillating change the setting of the stability adjust control. This control requires a screwdriver adjustment and is accessible through a hole in the top plate of the regulator. CW rotation increases regulator response time. CCW rotation decreases regulator response time, and assures output voltage stability. Find the point at no load where the voltage stops oscillating and advance slightly beyond in the CCW direction. Should you be unable to control hunting in this manner remove the jumper between TB11-TB12 and readjust the stability control.

## VI. TROUBLESHOOTING

### A. GENERAL

Since the normal operating function of a generator set is to provide A.C. voltage and maintain it under all load conditions within its rating, it is inoperable only when it fails to provide this voltage while being driven at rated speed. If the load is excessive, the engine is not maintaining the speed or the voltmeter is not measuring the voltage accurately, searching in the generator or regulator for the defect will not solve the problem. In fact, for most systems, the regulator will force field current to the generator attempting to provide this voltage even if the load is excessive, the engine is not maintaining rated speed or the voltmeter is not accurate. The H9000 regulator contains circuits which attempt to protect the system from these conditions. See Section III. However, these circuits cannot provide protection against all possible circumstances nor prevent consequences of these conditions. Therefore, as soon as a low speed, overload or inaccurate meter condition is found it should be corrected, before making an attempt to service the generator-regulator system.

### B. QUICK CLUES THAT THE GENERATOR MAY BE DEFECTIVE

The principal reason for the Start-Up procedure given in Section V, is to be sure the generator is operating properly. Follow the generator manufacturer's operating instruction concerning limits for exciter field current, voltage build-up procedure, incorrect winding resistance, bad rectifiers, grounded or low insulation resistance windings, or unbalanced voltages on three-phase generators at no load.

### C. QUICK CLUES THAT THE REGULATOR MAY BE DEFECTIVE

1. If voltage is not adjustable
2. If voltage goes too high and cannot be reduced to rated voltage.
3. If no voltage build-up, but generator resistances are correct and manufacturer's standard generator test indicated normal.
4. A new regulator works but this one doesn't. Always put the questionable one back in the circuit for a second try after the new one is known to work. The trouble may have been an improper or poor connection, and nothing was really wrong with either regulator.
5. Look first for broken wires, poor or loose connections. Check circuit breaker and AVCR circuit.

### D. CHECKING THE REGULATOR IN THE CIRCUIT

In-field, on-site service of the H9000 regulator should be limited to replacement of the following small parts or the complete regulator. Symptoms and checks for each are given.

#### 1. AVCR —

If the AVCR is open or shorted, it should be replaced. If the open point is in the operating section of the rheostat, the voltage will be about half voltage. As the control reaches the broken point, the voltage will jump to about rated voltage and will be adjustable up from that point. If the AVCR is shorted, it will give the maximum voltage and will not be adjustable down. Verify either condition with an ohmmeter.

2. Circuit Breaker --  
Make sure the overvoltage CB coil is connected between TB8 and TB9 and that the CB contacts are in series with TB13 and the exciter input line. If a jumper temporarily placed between the CB contacts allows the system to function (whereas it would not function after flipping the toggle to the on position) then the CB is defective and should be replaced.
3. If the regulator does not function properly in any other manner, replace it.

## VII. BENCH TESTS

The Bench Tests explained here require the equipment below. The circuit for the Bench Tests is given in Figure 14, modified as required for the separate tests as given in the instructions.

These tests require some deliberate preparation. Read and follow closely the Preparatory Steps. Be sure you understand the procedures thoroughly before attempting the tests, because some of the operations can damage parts of the regulator if done improperly or if certain types of defects are present. This will also assure reliable results.

These tests are written for use with a 60 Hz, 115 Volt power source. If the source voltage is significantly different from 115 volts, the selection of an auto-transformer must be made accordingly.

### A. PREPARATION STEPS

1. Collect the equipment
  - a. The regulator to be tested, with the jumper on TB4 to TB5 and the AVCR and circuit breaker.
  - b. A variable auto-transformer, VARIAC, POWER-STAT or equal, continuously adjustable from 0 to 135 volts output with a standard 115 volt, 60 Hz input. It should be rated at about 1 KVA, 7 amps.
  - c. A 100 ohm, 200 watt resistor.
  - d. A.C. voltmeters, capable of accurate measurement of voltages in the range of 7 volts and 150 volts.
  - e. D.C. ammeters, capable of accurate measurement of current in the range of 0.02 amp and 5 amps.
  - f. An ohmmeter, with ranges for measuring silicon rectifiers and resistance up to 3500 ohms.
  - g. D.C. voltmeters, capable of accurate measurement of voltages in the range of 2 volts and 150 volts.
  - h. In lieu of the meters of d, e, f and g., above, you may use a good volt-ohmeter of 20,000 ohms per volt, with the required ranges, such as a Simpson 260 or a Triplet 630A. Although it is best to measure the D.C. output current of the regulator, if the load resistor is accurately adjusted to 100 ohms, the current can be readily measured by measuring the D.C. voltage across the resistor and dividing by 100.
  - i. A fuse, 5 amps, with fuse holder.
  - j. Hook-up wire, AWG 14 or 16.
2. Construct the circuit of Figure 14, but leave the switch open and the transformer not energized. Connect the 150 volt A.C. voltmeter across the transformer output.
3. Energize the transformer

4. Rotate the auto-transformer adjusting knob. Note and remember, roughly, the amount of rotation required for 6 volts, 50 volts, 100 volts and 125 volts.
5. Perform the procedural steps quickly. If it is necessary to check the instructions or if any unexpected situation occurs, return the auto-transformer to zero voltage and open the switch.

### NOTE

1. Tests 7 to 11 are to be conducted using the components and circuit of Figure 13.
2. During these tests, the A.C. input voltage and D.C. output voltage will follow the curve of Figure 14, approximately.
3. As indicated on the curve, the point at which the D.C. voltage drops to nearly zero is determined by the AVCR setting.
4. The lower portion of the curve (up to 10V A.C. input) is expanded to Figure 15, showing the area which determines build-up.
5. If the A.C. input voltage is adjusted to any value more than 10% above the "cut-off point," the overvoltage coil will trip the circuit breaker. If this happens, turn the power off, reset the circuit breaker, adjust the input voltage to zero and begin again.

### B. PERFORMANCE OF TESTS

1. Transformer Primary Resistance  
With the regulator not connected, measure the D.C. resistance between terminals TB-1 and TB-2; approximately 300 ohms, or TB-1 and TB-3; approximately 550 ohms.
2. Resistance (continuity check) of circuit breaker, CB  
Measure the D.C. resistance between CB fast on terminals; approximately 0.2 ohms.
3. Resistance of overvoltage coil of circuit breaker, CB  
With the CB not connected, measure the D.C. resistance between small wire leads; approximately 120 ohms.
4. Resistance of the AVCR  
With the AVCR not connected, measure the D.C. resistance between the AVCR terminals. This should be adjustable from 0 to 3500 ohms as the AVCR is rotated from CW to CCW.
5. Free-Wheeling Diode Check  
With the regulator not connected, and using an ohmmeter on the X1 range, check the diode between TB-10 and TB-11. With the + lead on TB-10 the reading should be nearly infinite, and with the leads reversed the reading should be mid scale.
6. Build-Up Check  
Starting with the low range voltmeters (0-10 volt) in both positions, the auto-transformer in minimum voltage position and AVCR completely CCW.
  - a. Energize the auto-transformer and turn switch on.
  - b. Increase A.C. input voltage to 7 volts. At this point the D.C. voltage output should be over 2V.
  - c. Change meter scales to (0-300 volts) in both positions.

#### NOTE

The effect of decreasing D.C. voltage removes the load from the auto-transformer, which causes the A.C. input voltage to increase several volts past the "cut-off point." ("cut-off point" is the value of A.C. input voltage at which the D.C. output voltage begins to decrease. This must be read quickly, before the unloading effect happens.) The reverse also happens. That is, if the A.C. input voltage is above the cut-off point (D.C. output voltage will be zero) and you decrease the A.C. input voltage, as soon as the D.C. output voltage begins to rise. The loading effect on the auto-transformer will cause a decrease in A.C. input voltage and the D.C. output voltage will increase rapidly until it is several volts below the cut-off point. Unless the auto-transformer is very large, it will be nearly impossible to hold the D.C. output voltage at any intermediate point.

- d. As you increase the A.C. voltage input, pause at about 25 volts, 50 volts, and 75 volts and record the D.C. output voltage at each point to determine how close the regulator meets the typical curve of Figure 14. It should not deviate by more than 10% at any point
- e. As you approach 80 volts, go slow so that the A.C. input voltage may be read just as the voltage reaches the "cut-off point".

#### f. Range of voltage adjustment

Determine the cut-off point for zero ohms in the AVCR and for 3500 ohms. These should be within  $\pm 10$  volts of the value given in Figure 14.

#### g. Gain test

With the cut-off point adjusted for 110 volts, adjust the A.C. input volts for about 115 volts and then reduce the input volts slowly. Record the A.C. input voltage when the D.C. volts have increased to about 5 volts. This value of A.C. input volts should be within 3 volts above the cut-off point (110 volts)

#### h. Overvoltage

With the cut-off point still at 110 volts, quickly adjust the A.C. input voltage to 125 volts. The overvoltage coil of the circuit breaker should trip the circuit breaker in 3 seconds. As soon as it trips, reduce the A.C. input voltage to below 110 volts. Turn power off. Reset the circuit breaker and adjust the A.C. input voltage to 115 volts. Turn the power on. The circuit breaker should not trip in 15 seconds.

#### 8. If the regulator is within limits in all tests, it is good and may be used on any generator which operates in its range. (See Section IV, F.)

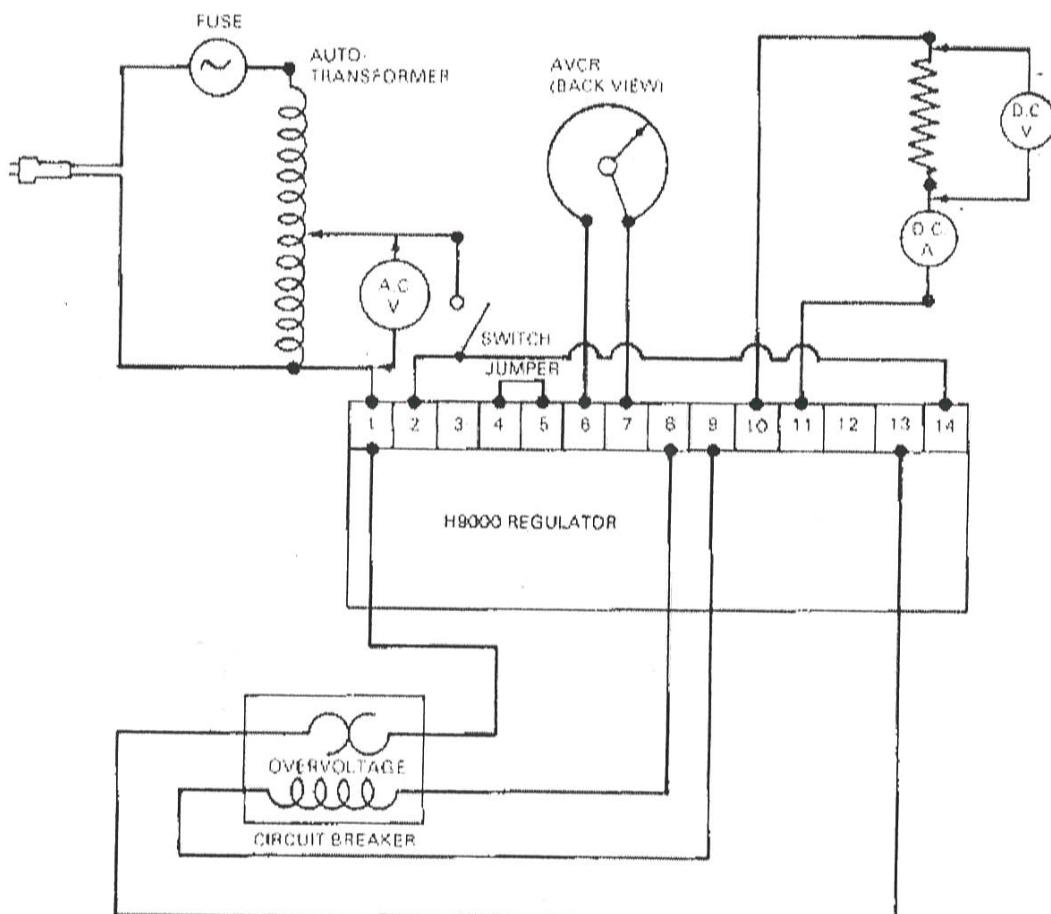


Figure 13  
Connection Diagram for Bench Test

### EXPLANATION OF FIGURES 14, 15, AND 16

Figure 14 is the curve of D.C. output versus A.C. input voltage with a 100 ohm fixed resistor as load on the D.C. output. If the load is different than 100 ohms (such as a generator exciter field), the D.C. voltage range will apply, but the D.C. amps will be different.

Figure 15 is an expanded view of the very low voltage portion of Figure 14 showing the build-up limits.

Figure 16 is an expanded view of the check point, showing the curve as a steep, sloping line. The "gain" of a given regulator is determined by the A.C. input voltage from the top to the bottom.

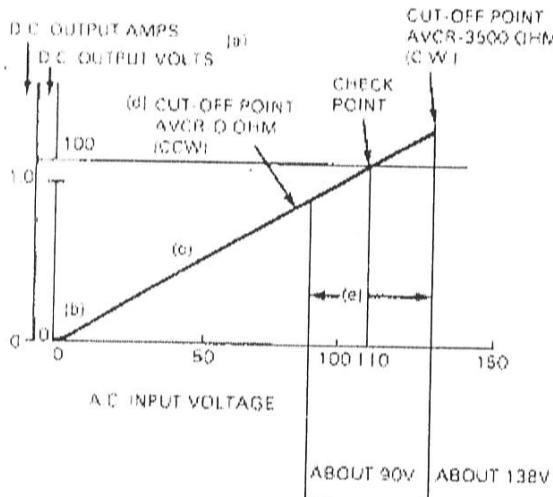


Figure 14  
Power Curve for a Typical H9000 Regulator

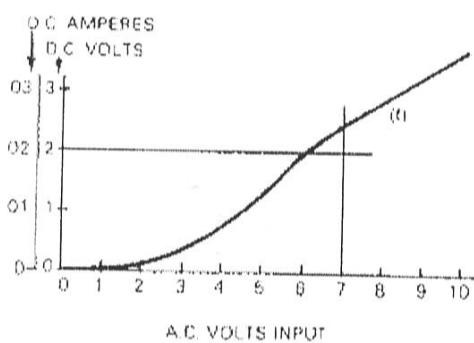


Figure 15  
Expanded View 0 to 10 Volt Part of Power Curve

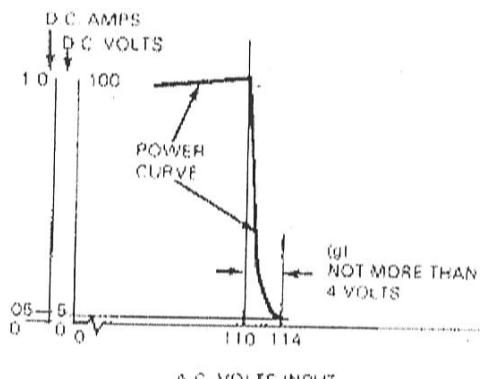


Figure 16  
Expanded View 110 Volt Part of Power Curve

- (a) The D.C. voltage scale should always apply. The D.C. amps scale can be used only if the load resistance is 100 ohms.
- (b) The ability of a regulator to provide enough D.C. voltage for build up at low A.C. voltage input should be checked. This portion of the curve is expanded in Figure 15.
- (c) The D.C. output, measured as the A.C. input voltage, is varied, should follow this line within 10%.
- (d) A "cut-off point" is defined as the value of A.C. input voltage at which the D.C. output begins to drop when it reaches the value to which the reference circuit of the regulator is adjusted. This "cut-off point" can be changed within the limits shown by adjustment of the AVCR.
- (e) The total adjustable limits of the cut-off point determines the "range of voltage adjustment" when applied to a generator.
- (f) This portion of the curve shows that more than 2 volts D.C. output should be available with 7 volts A.C. input.
- (g) This portion of the curve, which is typical for any value of cut-off voltage, shows that the A.C. input voltage difference is very small from the cut-off point to an output voltage of 5 volts D.C. A regulator passes the "Gain test" if this difference is less than 4 volts.