INSTRUCTIONS PRELIMINARY GEK- 24990A

DC-3062 SCR POWER CONVERSION MODULES
THREE PHASE FULL WAVE

OPERATION TROUBLESHOOTING

GENERAL ELECTRIC

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WARNING

HIGH VOLTAGE. ELECTRIC SHOCK CAN CAUSE SERIOUS OR FATAL INJURY. WHETHER THE AC VOLTAGE SUPPLY IS GROUNDED OR NOT, HIGH VOLTAGES TO GROUND WILL BE PRESENT AT MANY POINTS WITHIN THE SCR DRIVE. EXTREME CARE MUST BE EXERCISED IN THE SELECTION AND USE OF TEST INSTRUMENTS.

OPERATORS SHOULD NOT STAND ON GROUNDED SURFACES OR BE IN CONTACT WITH GROUND WHEN APPLYING TEST INSTRUMENTS TO TEST POINTS. TEST INSTRUMENTS SHOULD NOT HAVE CHASSIS GROUNDED WHILE TESTS ARE BEING MADE. THUS THEIR CHASSIS WILL BE AT A HIGH VOLTAGE WITH RESPECT TO GROUND DURING TESTING. EXTREME CARE SHOULD BE TAKEN WHILE ATTEMPTING TO ADJUST, TROUBLESHOOT OR MAINTAIN ANY DRIVE SYSTEM DESCRIBED HEREIN.

INSTRUCTIONS

GEK–24990A

ERRATA SHEET NUMBER 01
JUNE, 1978

DC–3062 SCR POWER CONVERSION MODULES
THREE PHASE FULL WAVE

OPERATION TROUBLESHOOTING

ERRATA SHEET AFFECTS GEK–24990, PAGE 8

THIS ERRATA SHEET SHOULD BE ATTACHED INSIDE THE FRONT COVER OF GEK–24990 AND RETAINED AS PART OF THIS BOOK.

THE INSTRUCTION BOOK TEXT SHOULD BE CHANGED IN ACCORDANCE WITH THE INFORMATION CONTAINED IN THIS ERRATA SHEET.

CORRECT PARAGRAPH FOLLOWING TO READ AS FOLLOWS:

NOTE

WHEN USING AN OSCILLOSCOPE WITHOUT A DIFFERENTIAL AMPLIFIER TO CHECK THE OPERATION OF THE PULSE TRANSFORMER CARD, THE COMMON (CHASSIS) LEAD OF THE OSCILLOSCOPE SHOULD BE CONNECTED ONLY TO THE AC OR BC TERMINALS. CONNECTING THE OSCILLOSCOPE COMMON LEADS TO ANY OTHER POINT(S) ON THIS CARD MAY CAUSE IMPROPER OPERATION OF THE DRIVE BY PERMITTING FIRING OF SCR'S AT INCORRECT TIMES.

GENERAL ELECTRIC

GENERAL

A three phase AC to DC SCR Power Conversion Module converts three phase AC power into adjustable voltage DC power. The output voltage is controlled by means of gate pulse signals from a Driver function.

DESCRIPTION

The module consists of the power conversion circuit, protective components and circuitry, firing circuitry, and feedback circuitry, all mounted together in one package.

The power conversion circuit is a three phase, full wave bridge, each of its six legs containing a silicon controlled rectifier (SCR). This arrangement can furnish unidirectional current, and can control the voltage output in either polarity as long as output current is drawn; that is, it can power a DC motor in both the first and fourth quadrants. When two of these modules are connected back-to-back, they can power a DC motor through all four quadrants.

The SCR Conversion Module is panel mounted. The power connections are buswork while the control leads are terminated by a plug-in connector.

Ratings and Specifications

AC Power input

(a) Voltage - three phase:
low voltage - 230 volts + 10%, -5%
high voltage - 460 volts + 10%, -5%
- other for special designs

(b) Frequency - 60 or 50 Hz

DC Power Output

(a) Voltage - controllable over the following maximum ranges at -5% AC voltage:

AC Power Input	Controllable DC Voltage Range: Motoring	Controllable DC Voltage Range: Regenerating
230V	0 to 285 volts	0 to 250 volts
460V	0 to 570 volts	0 to 500 volts

(b) Current - depending on cooling, overload requirements and ambient temperature, the conversion module current rating system requirements.

Control Input

(a) Gate pulses - six gate pulse trains spaced 60 degrees apart, each capable of being phase shifted over a range of 150 electric degrees; each pulse to be at least 15 volts in magnitude (at 15 milliamps loading) and be at least 10 microseconds, but no more than 50 microseconds, in width.

(b) Power Supply: +20 volts DC for operation of gate pulse amplifying circuitry.

Control Output

(a) Current Feedback - 0 to approximately +2.5 volts DC for rated operating current range.

(b) Thermoswitch Interlock - normally closed interlock which opens for excessive Conversion Module temperature due to loss of cooling air.

Principles of Operation

It will be helpful in understanding the following theory of operation to refer to the SCR Conversion Module elementary diagram. A copy of the diagram which applies to the specific drive furnished, will be found in the diagram section of the system instruction book.

Power Conversion

The function of converting AC power to adjustable voltage DC power is performed by silicon controlled rectifiers (SCR's). The SCR is a semiconductor device which can block voltage in both directions, but is capable of conducting current in one direction when "fired" by a proper gate signal. With reverse voltage applied, the SCR behaves the same as a diode rectifier. With forward voltage applied, the SCR will block current until it is switched into the conducting state by means of a gate signal. The SCR will remain in the conducting state even after gate signal is removed, as long as forward current is maintained. Controlling the instant in time, relative to the AC voltage wave, when the gate signal is applied to the SCR controls the amount of DC voltage and current that is furnished to the load.

The SCR Conversion Module uses six SCR's connected together to form a three phase, full wave bridge. Each SCR is mounted on an aluminum heat sink. The heat sink transmits the heat produced inside the SCR to the surrounding air. Convection cooling is adequate for the lower rated conversion modules, however higher ratings require forced cooling.

The operation of the three phase SCR bridge in converting AC power to adjustable voltage DC power is best explained by referring to Figures 1 through 6. These figures show the AC voltage and DC voltage wave shapes into and out of the SCR bridge, plus the voltage wave shape across each SCR. The first three figures show control of the SCR bridge in a motoring mode; that is, with positive voltage output and positive current output, or first quadrant operation.

(continued)

The last two figures show control of the SCR bridge in a regenerative mode; that is, with negative voltage output and positive current output, or fourth quadrant operation. The voltage wave shapes shown in these figures are all based on loaded operation. This means that for the regenerative cases, the load must be capable of delivering power (that is, both voltage and current) to the SCR bridge.

Figure 1 shows the voltage wave shapes for the zero degree phase back condition, or full advance. This is not a normal operating condition since it is the absolute maximum output voltage obtainable. It is shown to provide a starting point to understanding SCR operation. To obtain this operating condition each SCR must be fired as soon as forward voltage appears across it. The operation is, therefore, the same as if the bridge consisted of diode rectifiers.

Figure 2 shows the effect of delaying the SCR firing 30 degrees in time with respect to the zero phaseback condition. Note that the average voltage level has decreased.

Figure 3 shows the voltage wave shapes for the 60 degree phase back condition. The DC voltage wave varies from almost the peak value to zero, six times a cycle. This would produce high peak to average DC current in a DC motor armature if it were not for the smoothing effect of armature inductance. (See Figure 18 in the "Troubleshooting" section.)

Figure 4 shows the 90 degree phaseback condition under sufficient load to keep current continuous. Note that the average voltage is actually zero. This would be motor stall condition if the IR drop voltage were neglected. Since current, and therefore IR drop, can only have positive values, the motor CEMF would have to be slightly negative in practice to obtain zero terminal valtage.

Figure 5 shows the voltage wave shapes for the 120 degree phase-back condition. This is a regenerative operating condition with the DC voltage negative and the DC current positive.

Figure 6 shows the 150 degree phaseback condition, which is the maximum allowable phase retard. The current must be switched (commutated) from one AC supply line to the next while correct polarity voltage still exists to turn off the first SCR. If the SCR firing is retarded to the 180 degree phaseback condition, there is no commutating voltage available to turn off the preceding SCR, and faulty operation will result. Therefore a 30 degree margin for SCR commutation is reserved.

Protective Components

The protective components described below are all included in the SCR Conversion Module to protect the SCR's.

Metal oxide varistors are connected across the AC supply lines to suppress voltage transients on high power conversion modules which do not have external suppression circuits. They are special devices which limit voltage transients to a safe value. RC networks are connected across each SCR, both to suppress voltage transients and to limit the rate of rise of voltage (dv/dt) across the SCR. If the dv/dt applied to the SCR in the forward direction is excessive, the SCR could turn on.

Chokes are placed in the SCR bridge to limit the rate of rise of voltage (dv/dt) applied to each SCR and also the rate of rise of current (di/dt) through the SCR when it switches on. If the (di/dt) through the SCR at turn-on exceeds a certain value, the cell may be destroyed. The combination of chokes and R-C circuits across the SCR's limit both dv/dt and di/dt to well within safe operating limits. The chokes (reactors) also act with the R-C circuits and metal oxide varistors to limit AC line voltage transients applied to SCR's.

A thermoswitch mounted on a bus attached to a heat sink or on a heat sink monitors the module temperature. This protects against high ambient temperatures or loss of cooling air. Operation of this thermoswitch shuts down the drive through the Monitor Card in the Driver.

Indicating lights are connected across the incoming AC line to detect a loss of phase voltage (such as the failure of an AC line fuse).

Feedback Circuitry

The current feedback circuitry consists of three AC current transformers plus rectifiers and loading circuitry. The current transformers are mounted on the incoming AC supply lines of the SCR conversion module. The output of each current transformer is rectified and the three rectified outputs are summed together. This rectification and summation of the three AC line currents produces a current signal of the same wave shape and having a constant ratio of magnitude to the DC output current of the SCR conversion module. The current signal is changed into a voltage signal by means of a selected value of loading resistance. The correct loading resistor is chosen, depending on the drive rated current, by means of the XA to XD taps. The correct loading produces about a 2.5 volt current feedback signal at rated drive current. All of the current feedback circuitry is contained on a printed circuit card mounted in the SCR Power Conversion Module.

(continued)

The table on the SCR Conversion Module elementary diagram gives the correct tap (XA to XD) to use for the specific drive horsepower rating.

START-UP

The Power Conversion Module is ready for operation when ventilation is proper and three phase power of 1, 2, 3 sequence is applied to the SCR Conversion Module input terminals (T1, T2 and T3) and when the control harness has been connected to the Driver.

TROUBLESHOOTING

General Approach

When incorrect operation is first noticed, it is often possible to reduce the overall servicing time by studying the symptoms in order to localize the trouble. A good understanding of the functional operation, as explained in the "Principles of Operation" section, will be very helpful in isolating the problem. A systematic check of voltage wave shapes and comparison of them with the correct readings, as given later in this section, should reveal the source of many malfunctions.

The use of a good quality oscilloscope is required to properly troubleshoot this equipment.

WARNING

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The use of an oscilloscope with a differential amplifier will result in much greater safety to operating personnel, since the oscilloscope chassis may then be grounded. However, much greater care in the selection of probes and leads and in the adjustment of the oscilloscope must be used to produce accurate readings. The DC balance and the voltage gain calibration of each channel must be accurately adjusted to obtain common mode voltage rejection.

(continued)

When properly adjusted, good results can be obtained with the differential amplifier connected oscilloscope for most readings. However, unless the common mode voltage rejection is perfect, it may be difficult to obtain accurate readings of low voltages such as SCR gate signals.

No matter which oscilloscope connection is used, voltage attenuating probes will be required for most readings. The probes should be adjusted for correct frequency compensation using the voltage calibrator as a square wave standard. The vertical gain and the sweep should also be calibrated to allow interpretation of observations.

Checking for Malfunctions

NOTE

When using an oscilloscope without a differential amplifier to check the operation of the pulse transformer card, the common (chassis) lead of the oscilloscope should be connected only to the F or C terminals. Connecting the oscilloscope common leads to any other point(s) on this card may cause improper operation of the drive by permitting firing of SCR's at incorrect times.

Missing output voltage and current pulses causing unbalanced wave shape.

(a) Check for firing pulses at input to pulse transformer cards, and at output of card to SCR's and compare with those given in Figures 20 and 21 of the voltage wave shape checklist. If no input is present, refer to the instruction book on the Driver. If input is OK but no output is present, pulse transformer card must be defective and should be replaced.

(b) Check SCR's to see if one of them is open or will not fire. Use the test circuit and follow the instructions under "Checking SCR's" in this section.

Cannot obtain any output voltage or current

(a) Check for firing pulses at input to pulse transformer cards and at output of cards to SCR's. If no input is present, refer to the instruction book on the Driver. Check the cable connections between the Driver Signal Distribution Assembly (if used) and the SCR Conversion Module. If inputs are OK but no outputs are present, check 20 volt power supply to pulse transformer card terminals A and B.

(b) Check for AC power at incoming terminals T1, T2 and T3 of the SCR conversion Module.

One large output voltage and current pulse which cannot be turned off and causes unbalanced wave shape

(a) Check for one SCR not being able to hold off forward voltage. Disconnect the cable from the SCR conversion module and apply AC power. Connect oscilloscope across each SCR, one at a time (T1-DC1, T2-DC1, T3-DC1, DC2-T1, DC2-T2, DC2-T3) and check voltage wave shape across SCR in the forward direction. Observe for SCR firing, or the voltage being lower across one SCR in the forward direction than the others. Also check SCR's with multimeter for excessive leakage as explained under "Checking SCR's" in this section. If a defective SCR is suspected, it should be replaced and the module rechecked.

SCR Conversion Module trips out AC breaker when energized

(a) Check for shorted SCR (see instructions under "Checking SCR's" in this section).

(b) Check for loose power connections or shorted bus bar. Use multimeter selected to read ohms to check for shorts.

Paralleled SCR Conversion Modules and sharing current

Check for firing pulses into and out of Pulse Transformer Card, for a defective SCR, or for presence of AC power at module terminals. See instructions under malfunctions on page 8.

No current feedback signal or distorted current feedback signal

(a) Check the signal at test points A1 and A2 of the Current Feedback Card and compare with those given in Figures 18 and 19 of the voltage wave shape check list. If missing or distorted, check output of current transformers at J1 and J2, J3 and J4, and J5 and J6 on the Current Feedback Card, and compare wave shapes with those given in Figures 16 and 17.

If the current transformer outputs are all OK, but some of the pulses are missing at card output terminals A1 and A2, the Current Feedback Card is defective and should be replaced. If the output of one of the current transformers is missing or distorted, the current transformer may be defective. Before removing the Conversion Module to replace the suspected current transformer, try to check the DC current with an oscilliscope across a shunt to determine if a defective SCR is causing the trouble.

Thermoswitch open or trips often

If the thermoswitch opens, check for air flow obstruction or for correct fan or blower rotation. If there is no air obstruction and the rotation is correct, the thermoswitch may be defective.

Erratic operation with motor load

(a) Check for correct phase sequence (see START-UP, page 7).

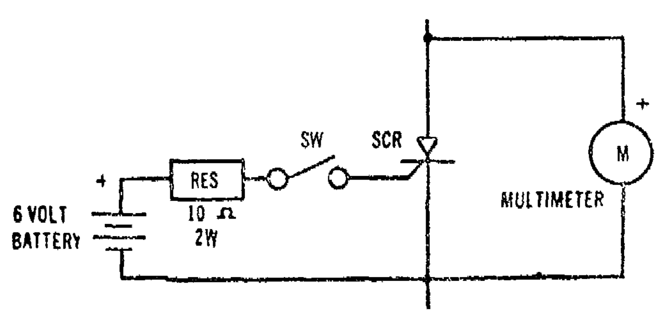
(b) Check for excessive dv/dt spikes across SCR's and wide voltage notches in AC voltage wave. If a number of large SCR drives are operating off the same AC supply, line filtering may be necessary. Consult the General Electric Company.

Checking SCR's

Disconnect the AC power and make sure the DC armature loop contactor is open. Using a multimeter selected to read ohms on the times - 1K scale, check the forward and reverse resistance of each individual SCR cell. This is done by reading across module terminals T1 and DC1, T2 and DC1, T3 and DC1, DC2 and T1, DC2 and T2, and DC2 and T3. (See SCR Conversion Module elementary diagram.) Good or faulty SCR's will give the following typical readings:

SCR Description	Fwd. Reading	Reverse Reading
Good SCR	100K to Infinity	100K to Infinity
Shorted SCR	Zero	Zero
Inoperative SCR	1 to 2K	100K to Infinity
Open SCR	100K to Infinity	100K to Infinity

Since an open SCR will give about the same resistance reading as a good SCR, another method must be used to find this type of fault. It should be pointed out however, that practically all cells fail by shorting and very few by opening. If an open SCR is suspected, of if it is desired to check the switching operation of an SCR, the following circuit should be used:



(continued)

The multimeter is selected to read ohms on the 1K scale, and is connected to read the forward resistance of the SCR. When switch SW is closed, the forward resistance of a good SCR will change from a high value (100K to infinity) to a low value (1 to 10K). When the switch is opened, a good SCR will revert to its high forward resistance or blocking state if the holding current source (multimeter battery) is momentarily removed. A faulty SCR will not switch, remaining in either an open or a conducting state.

If any SCR's are suspected of being faulty from the above resistance checks, the suspected SCR heat sink assembly should be removed from the module.

After the SCR assembly has been disconnected, recheck the forward and reverse resistances before replacing the SCR heat sink assembly. This should be done before an SCR is definitely classified as damaged or faulty, since a fault in another SCR of another part of the circuitry can produce a faulty reading from a good SCR before it is disconnected from the circuit.

Voltage wave shape check list

Voltage Wave Shape	Figure No.
AC voltage input, under load	7
DC voltage output, motoring, under load	8
DC voltage output, motoring, no load	9
DC voltage output, regenerating, under load	10
DC voltage output, regenerating, no load	11
SCR cell voltage, motoring, under load	12
SCR cell voltage, motoring, no load	13
SCR cell voltage, regenerating, under load	14
SCR cell voltage, regenerating, no load	15
AC current, full load	16
AC current, no load	17
DC current, full load	18
DC current, no load	19
Firing pulse train input (to card)	20
Firing pulse train across SCR gate	21

Also refer to the DC and SCR voltage wave shapes given in "Principles of Operation" section as Figures 1 through 6. These diagrams do not show firing notches but are otherwise similar to actual readings.

REPAIR AND REPLACEMENT

To remove a heatsink or to replace an SCR, refer to the "Heatsink Repair and Replacement" Instruction Book GEK-24991.

0° FIRING ANGLE

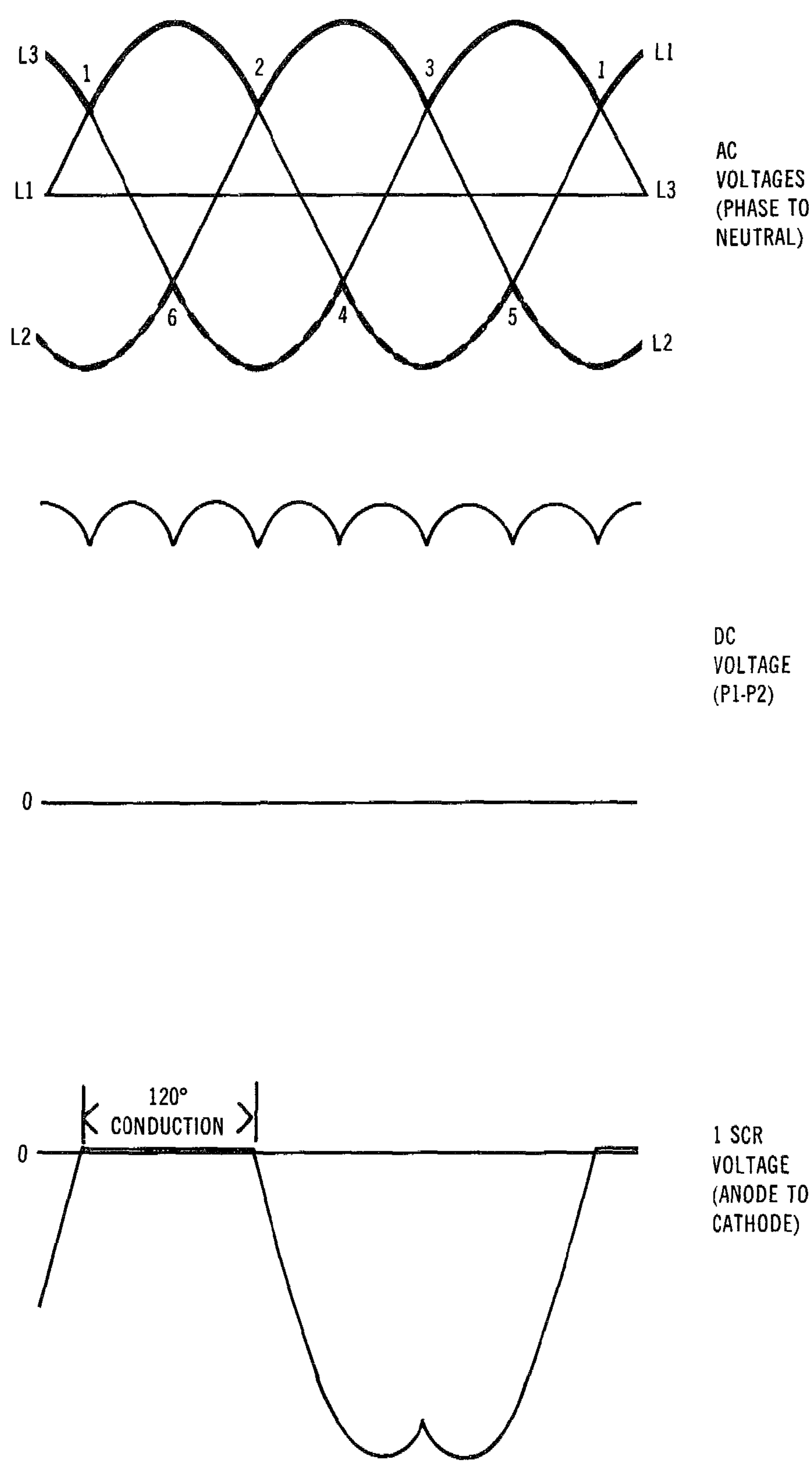


FIGURE 1

30° FIRING ANGLE

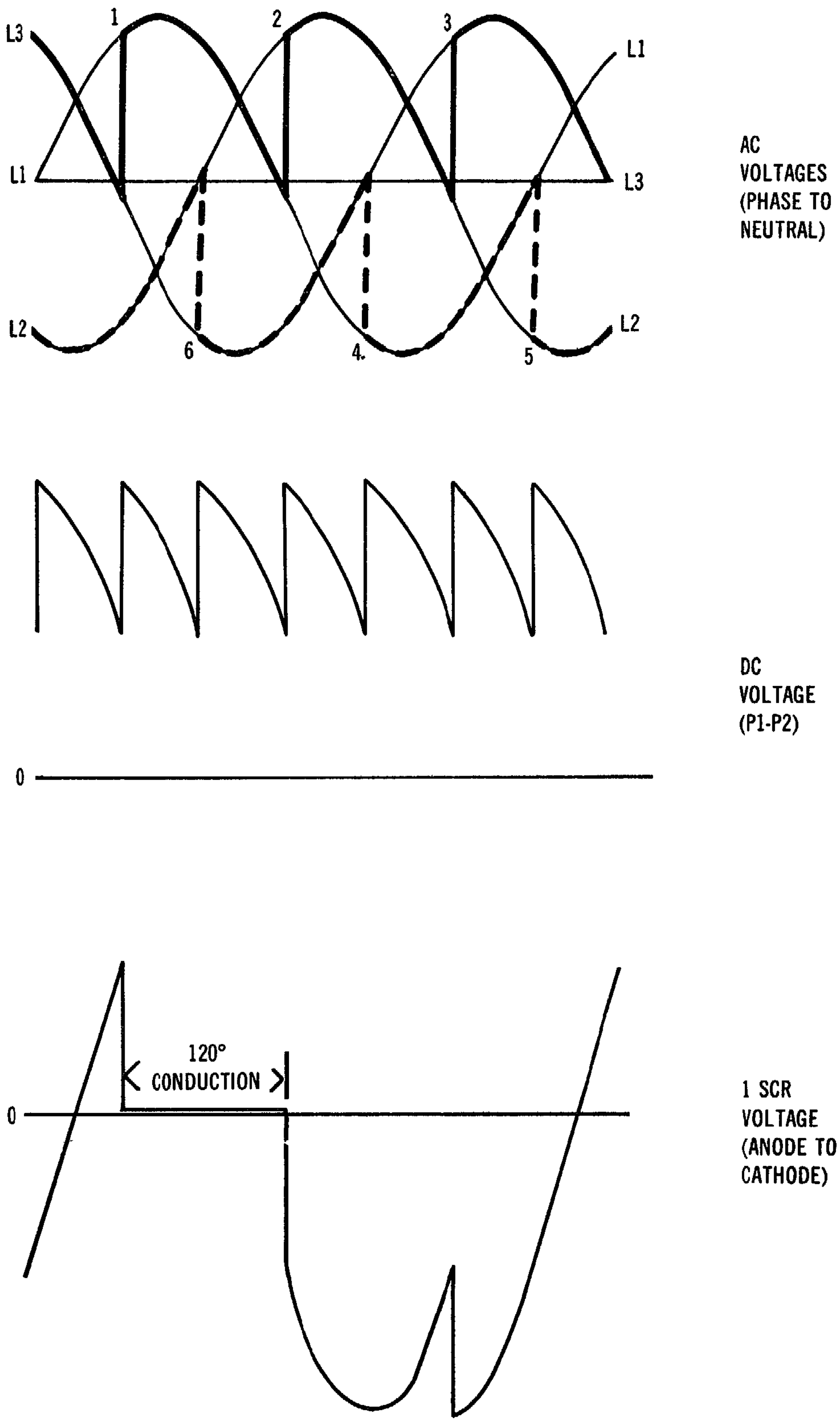


FIGURE 2

60° FIRING ANGLE

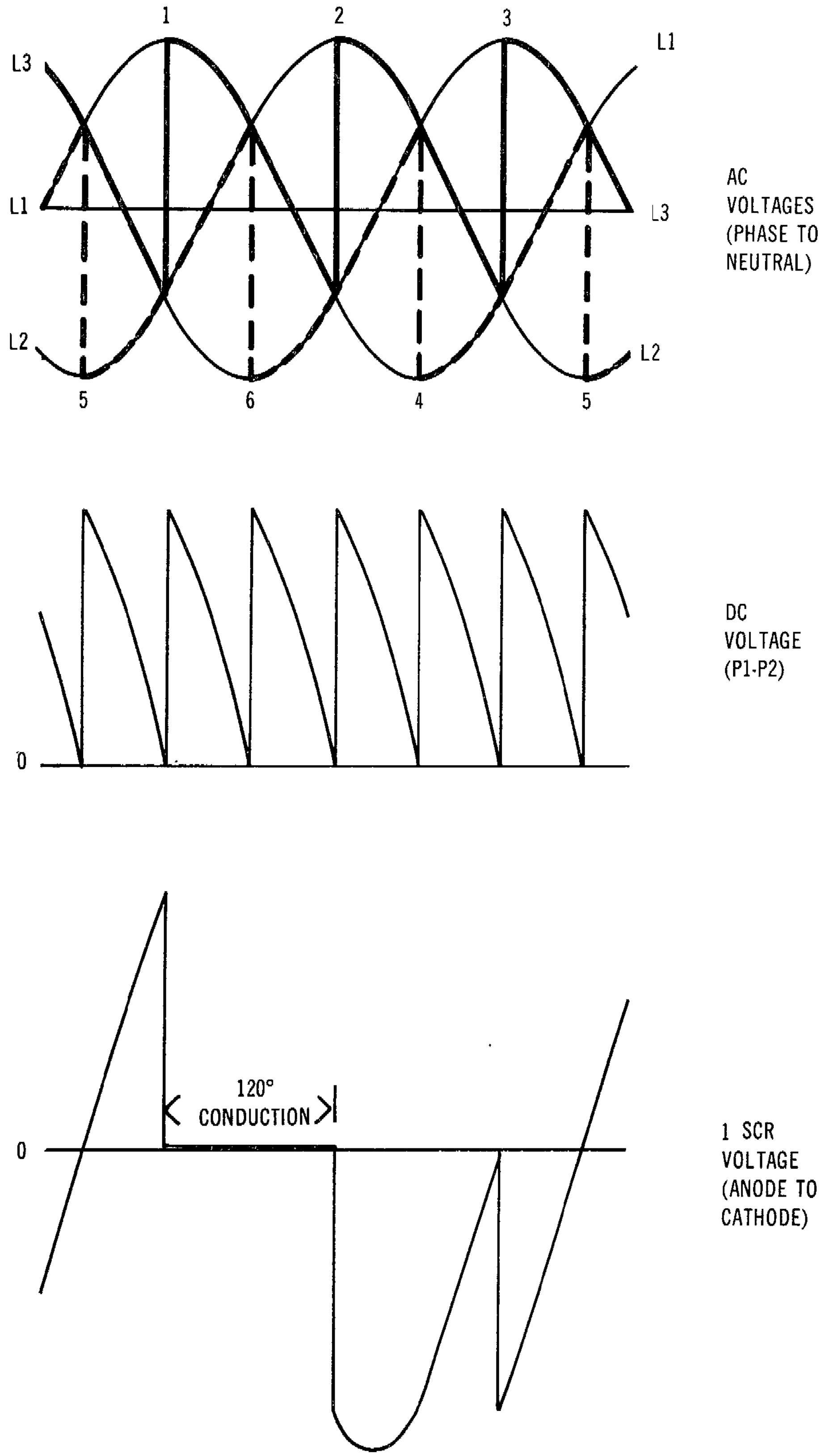


FIGURE 3

90° FIRING ANGLE

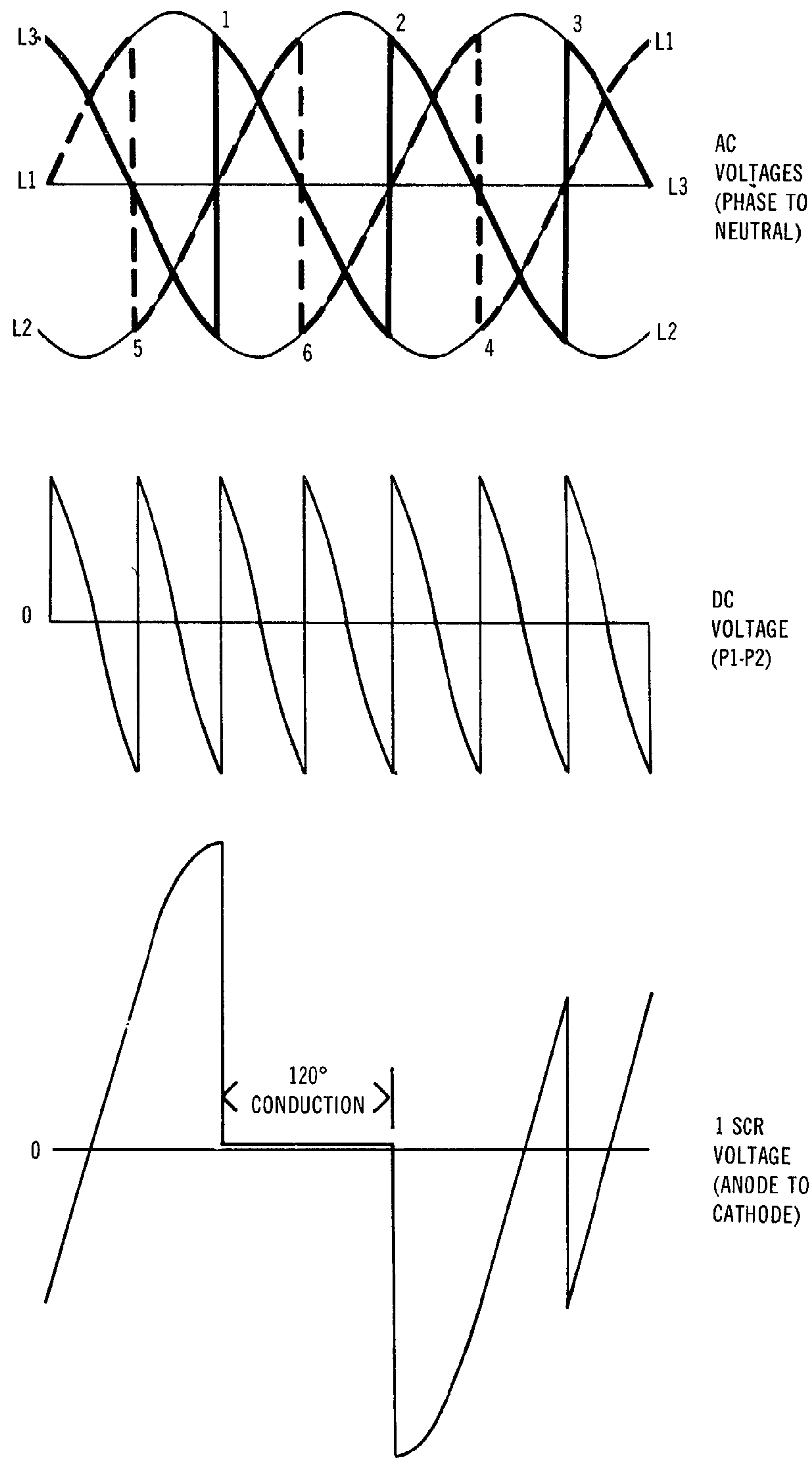


FIGURE 4

120° FIRING ANGLE

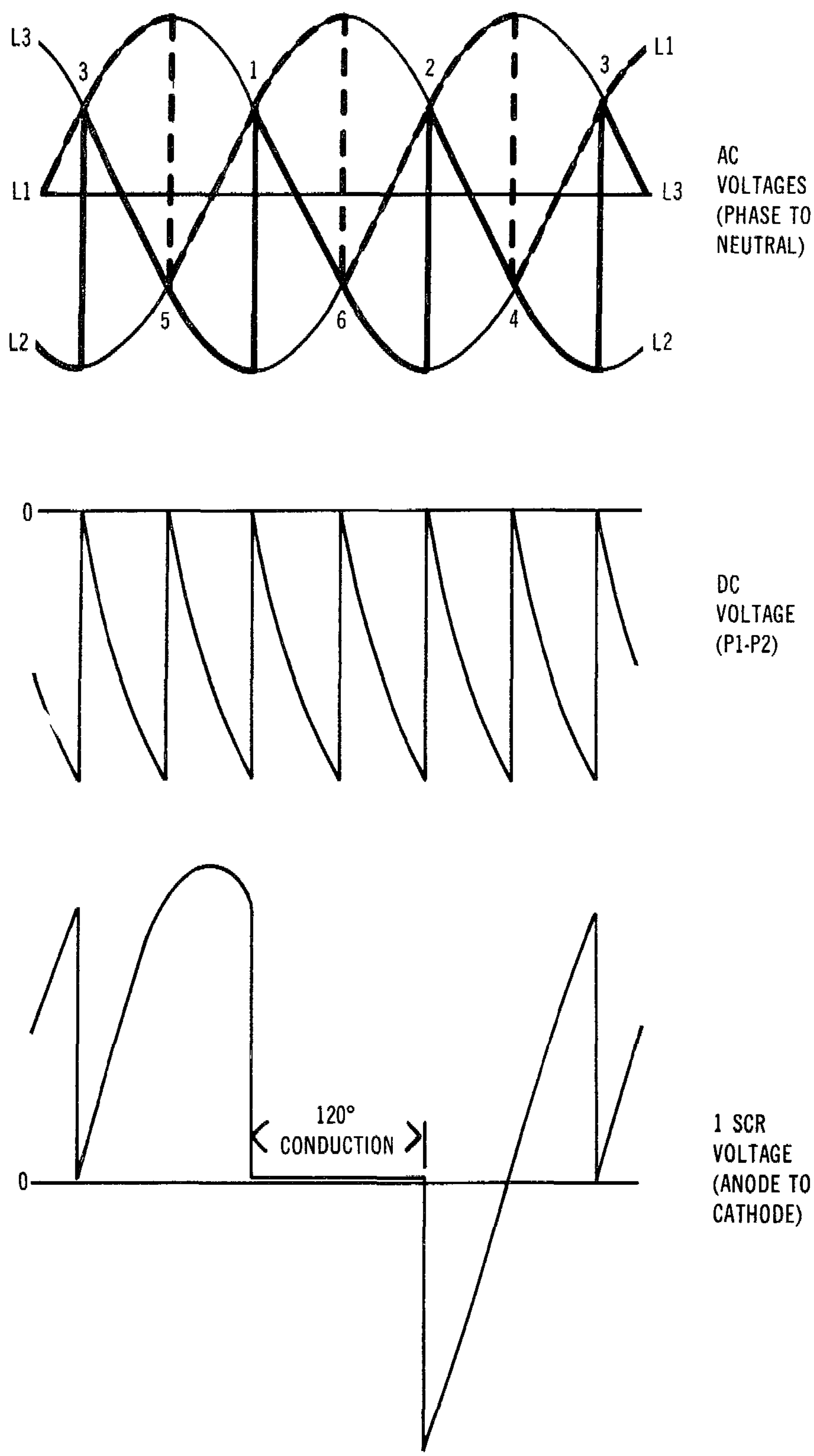


FIGURE 5

150° FIRING ANGLE

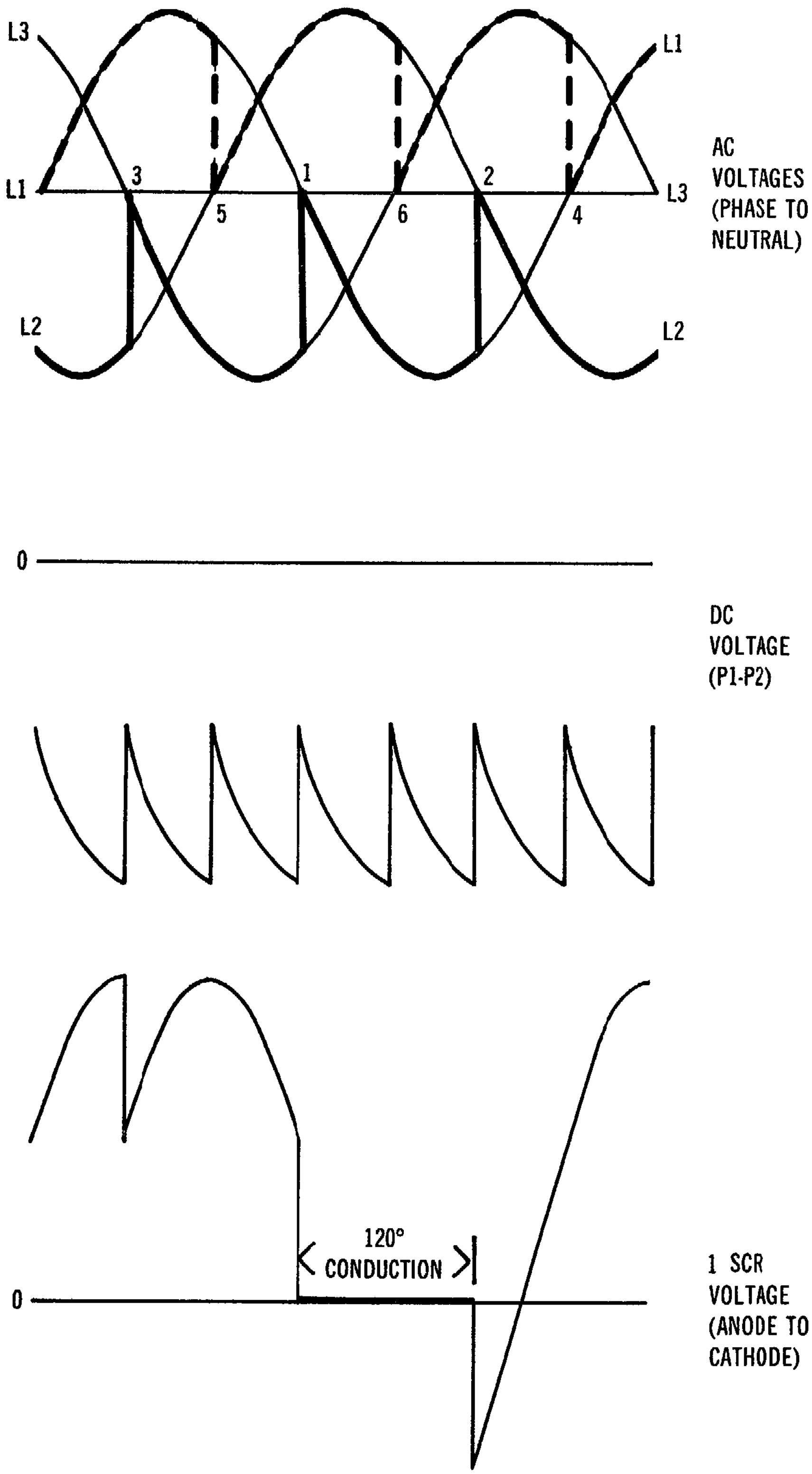
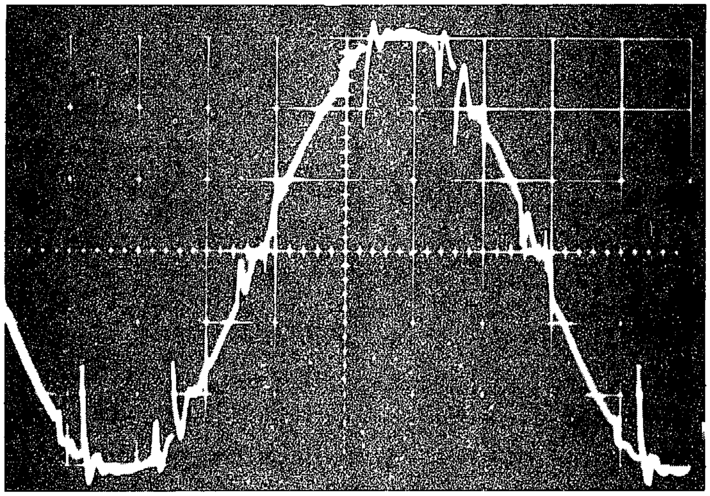


FIGURE 6

AC VOLTAGE INPUT (UNDER LOAD)



—0

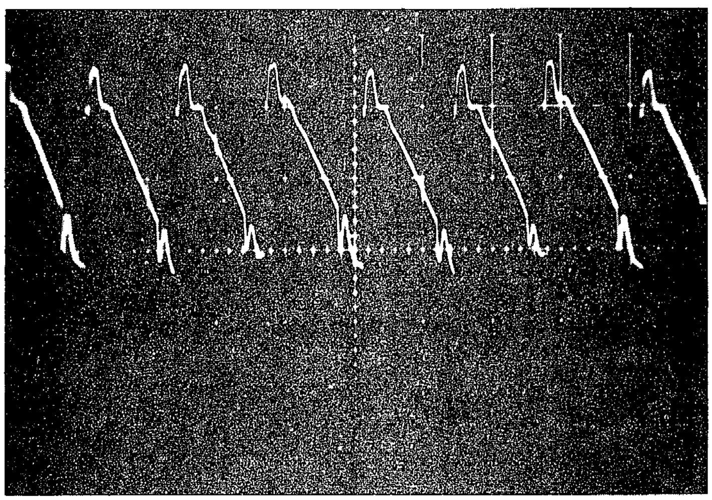
CALIB.

VERT.
100 VOLTS/CM

HORIZ.
2MS/CM

FIGURE 7

DC VOLTAGE OUTPUT (MOTORING, UNDER LOAD)



—0

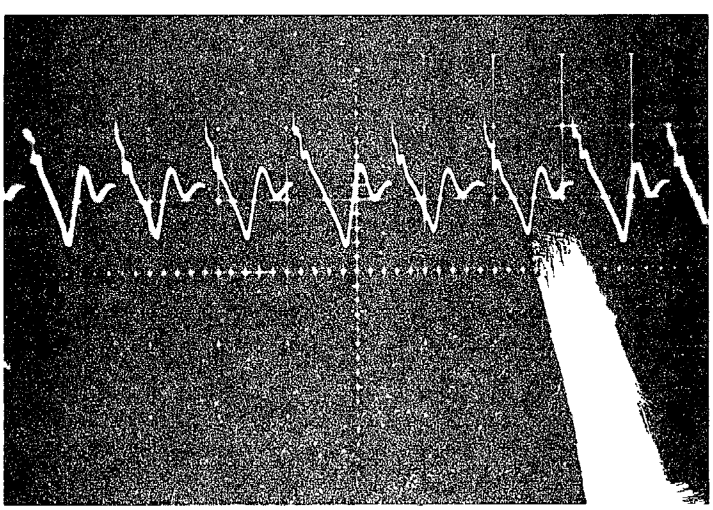
CALIB.

VERT.
100 VOLTS/CM

HORIZ.
2 MS/CM

FIGURE 8

DC VOLTAGE OUTPUT (MOTORING, NO LOAD)



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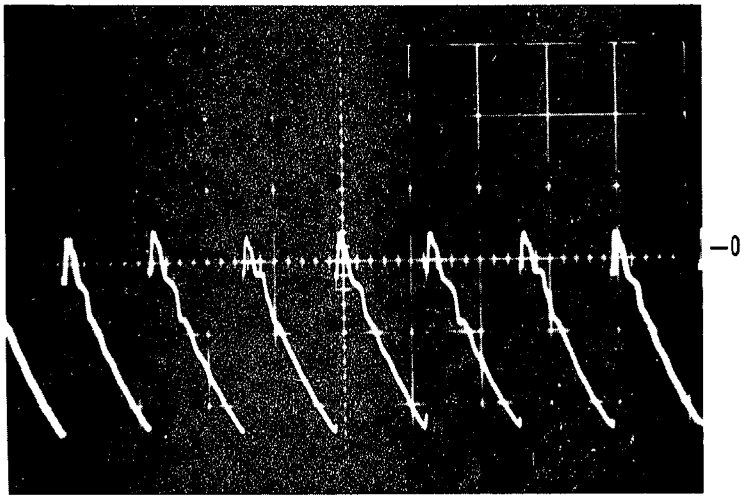
CALIB.

VERT.
100 VOLTS/CM

HORIZ.
2 MS/CM

FIGURE 9

DC VOLTAGE OUTPUT (REGENERATING, UNDER LOAD)



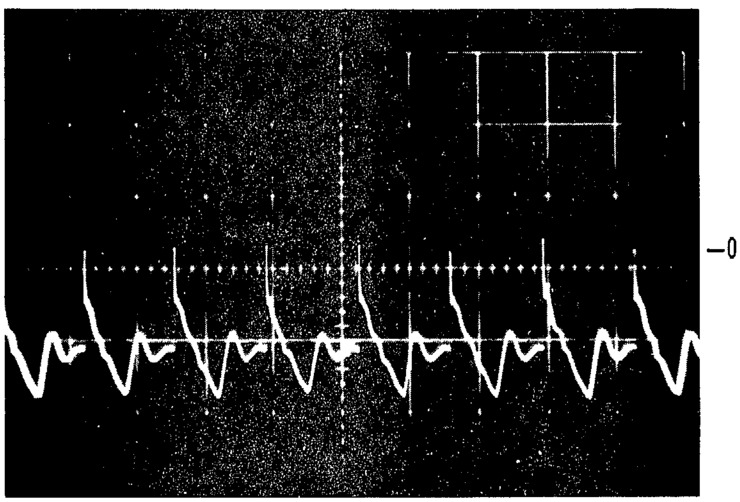
CALIB.

VERT.
100 VOLTS/CM

HORIZ.
2 MS/CM

FIGURE 10

DC VOLTAGE OUTPUT (REGENERATING, NO LOAD)



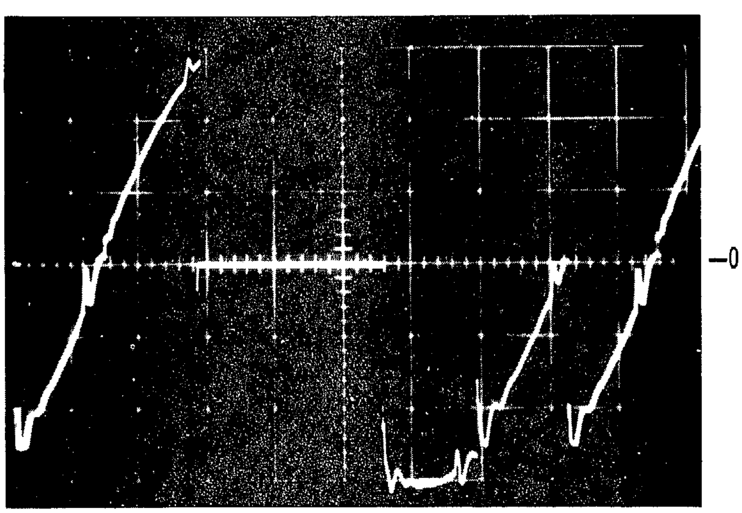
CALIB.

VERT.
100 VOLTS/CM

HORIZ.
2 MS/CM

FIGURE 11

SCR CELL VOLTAGE (MOTORING, UNDER LOAD)



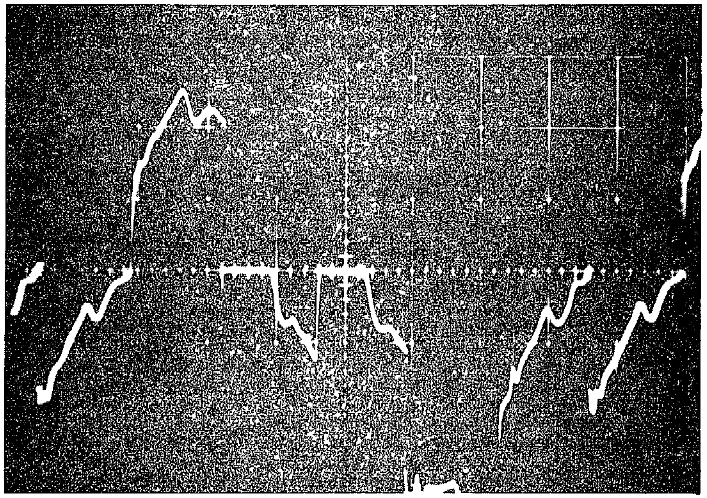
CALIB.

VERT.
100 VOLTS/CM

HORIZ.
2 MS/CM

FIGURE 12

SCR CELL VOLTAGE (MOTORING, NO LOAD)



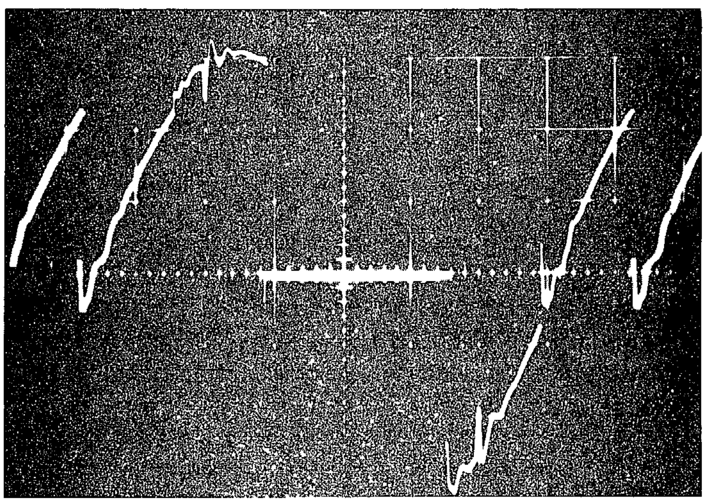
CALIB.

VERT.
100 VOLTS/CM

HORIZ.
2 MS/CM

FIGURE 13

SCR CELL VOLTAGE (REGENERATING, UNDER LOAD)



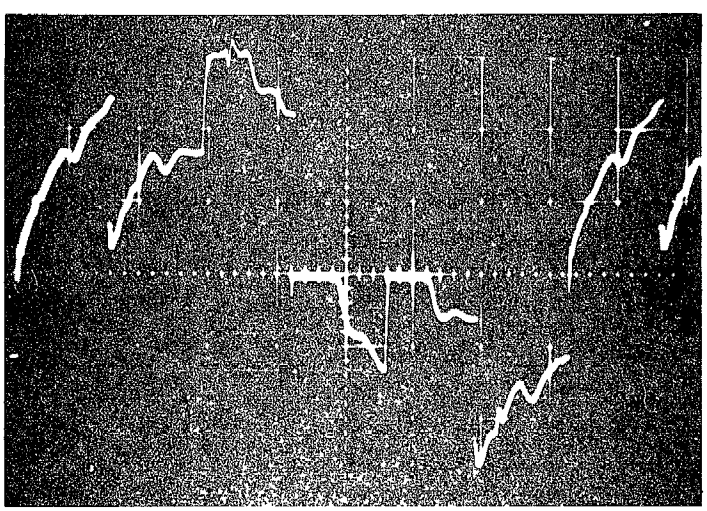
CALIB.

VERT.
100 VOLTS/CM

HORIZ.
2 MS/CM

FIGURE 14

SCR CELL VOLTAGE (REGENERATING, NO LOAD)



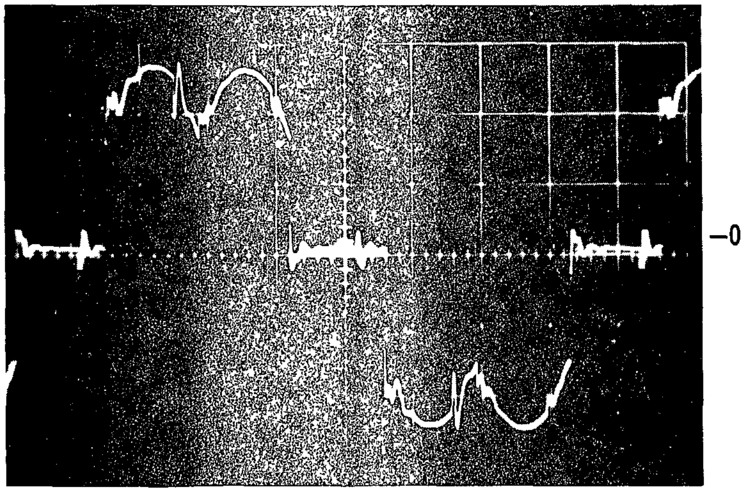
CALIB.

VERT.
100 VOLTS/CM

HORIZ.
2 MS/CM

FIGURE 15

AC CURRENT (FULL LOAD)

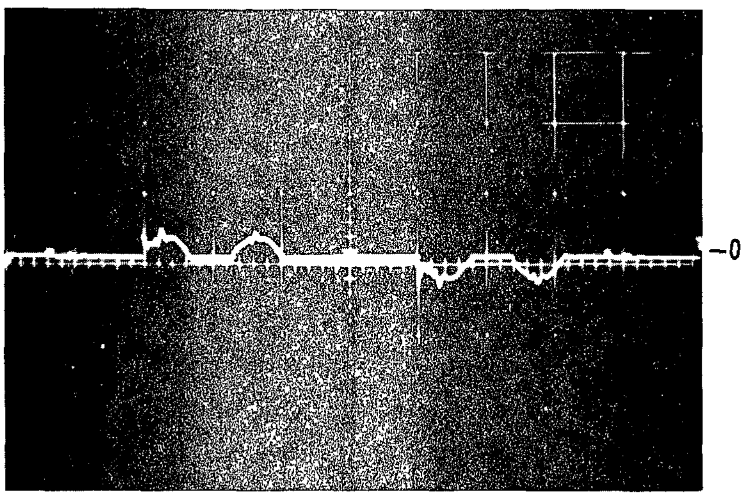


CALIB.

HORIZ.
2 MS/CM

FIGURE 16

AC CURRENT (NO LOAD)

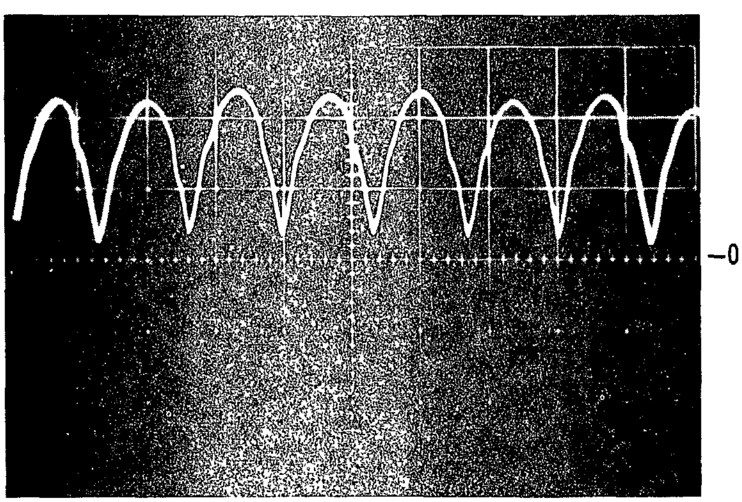


CALIB.

HORIZ.
2 MS/CM

FIGURE 17

DC CURRENT (FULL LOAD)

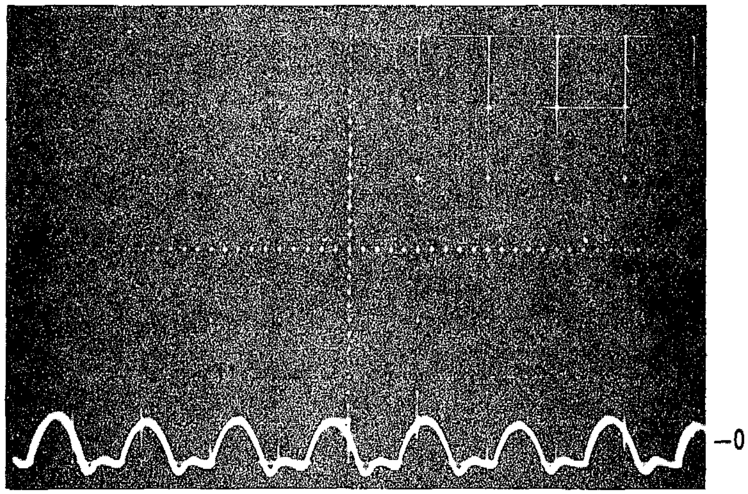


CALIB.

HORIZ.
2 MS/CM

FIGURE 18

DC CURRENT (NO LOAD)

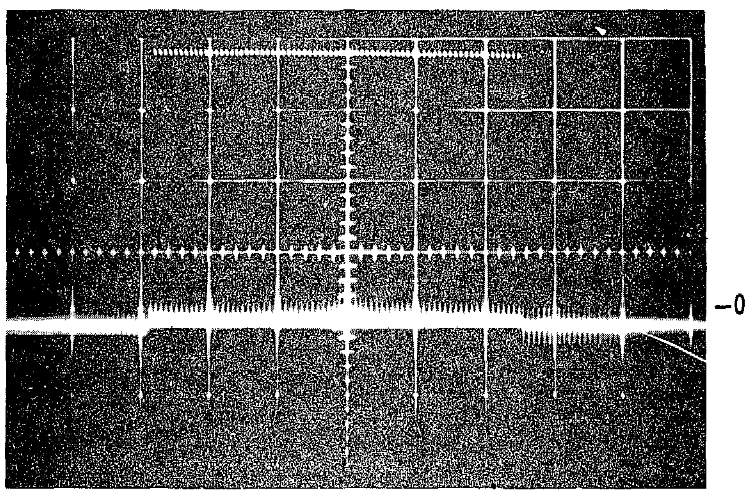


CALIB.

HORIZ.
2 MS/CM

FIGURE 19

FIRING PULSE TRAIN INPUT



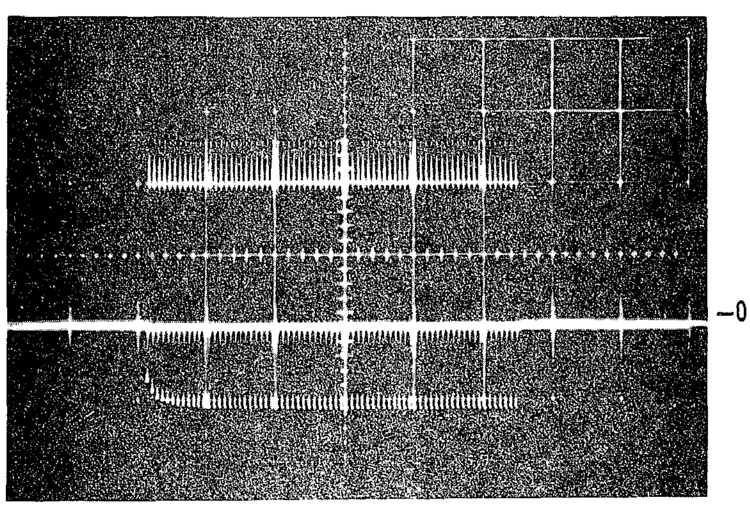
CALIB.

VERT.
5 VOLTS/CM

HORIZ.
1 MS/CM

FIGURE 20

FIRING PULSE TRAIN ACROSS SCR GATE



CALIB.

VERT.
2 VOLTS/CM

HORIZ.
1 MS/CM

FIGURE 21

GENERAL ELECTRIC COMPANY — DIRECT CURRENT MOTOR & GENERATOR PRODUCTS DEPARTMENT
ERIE, PENNSYLVANIA 16531

GENERAL ELECTRIC

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