INSTRUCTION MANUAL

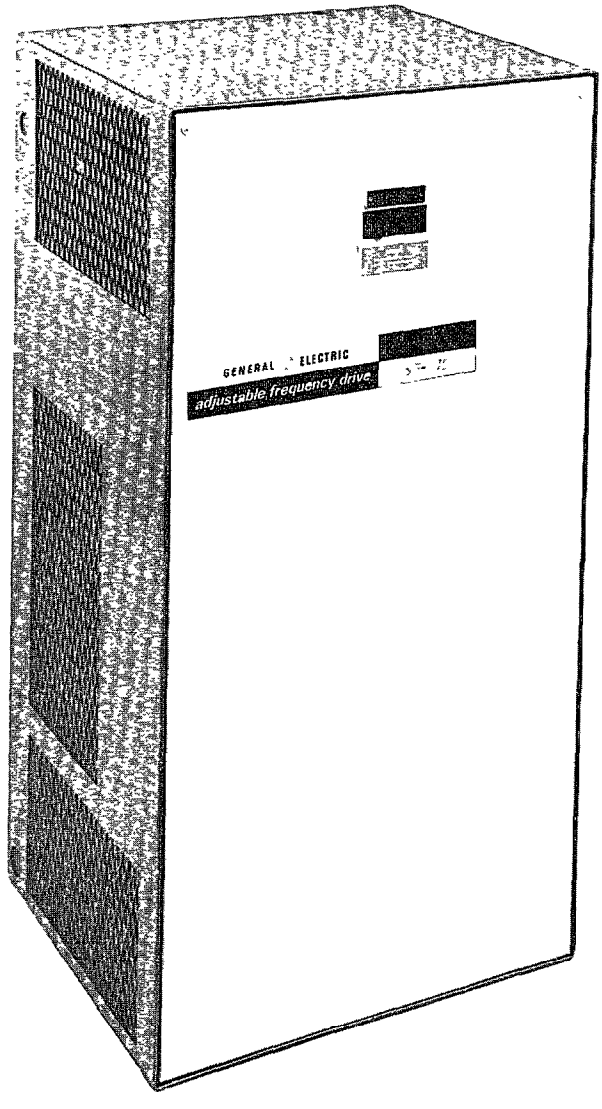
GEK-22958

# ST INVERTER
# ADJUSTABLE FREQUENCY AC DRIVE
## (DRIVE CODE AF-3090)

INSTALLATION

OPERATION

TROUBLE SHOOTING




GENERAL ELECTRIC

## WARNING

SINCE HIGH VOLTAGES ARE PRESENT IN MANY LOCATIONS WITHIN THE SCR DRIVE, EXTREME CARE MUST BE EXERCISED IN THE SELECTION AND USE OF TEST INSTRUMENTS, WHETHER THE AC SUPPLY IS GROUNDED OR NOT, HIGH VOLTAGES TO GROUND WILL BE PRESENT AT MANY POINTS. OPERATORS SHOULD NOT STAND ON GROUNDED SURFACES OR BE IN CONTACT WITH GROUND WHEN APPLYING TEST INSTRUMENTS TO TEST POINTS. EXTREME CARE SHOULD BE TAKEN WHILE ATTEMPTING TO ADJUST, TROUBLESHOOT OR MAINTAIN ANY DRIVE SYSTEM DESCRIBED HEREIN.

## CONTENTS



These instructions do not purport to cover all details or variations in equipment nor to provide for every possible contingency to be met in connection with installation, operation or maintenance. Should further information be desired or should particular problems arise which are not covered sufficiently for the purchaser's purposes, the matter should be referred to the General Electric Company.

# ST – INVERTER
# ADJUSTABLE FREQUENCY AC DRIVE

## INTRODUCTION

This manual contains the installation, operation, and maintenance instructions for the ST-Inverter adjustable frequency AC drives. It describes the theory of operation of the basic power unit and recommended troubleshooting procedures. Auxiliary circuits and equipment not described in this manual will be included as supplemental material.

## DESCRIPTION

The ST-Inverter adjustable frequency drive is a packaged, all solid state drive for controlling the speed of AC motors. Adjustable speed is provided by converting incoming AC power to adjustable voltage DC, which is then inverted to adjustable frequency AC. A single analog reference signal controls the output frequency and the DC level into the inverter section of the power unit. The resulting output is a highly regulated three-phase, constant volts per hertz voltage for speed control of induction or synchronous motors over a wide speed range.

A basic ST-Inverter drive will normally include a power unit, motor, power transformer, and operator's station.

### POWER UNIT

The power unit consists of semi-conductors and related static components arranged on an aluminum heat sink mounted in a NEMA 1 ventilated enclosure. (See Figure 1.) A three-phase circuit breaker is provided to remove input power and provide short circuit protection. Optional output voltmeter, ammeter, and test jacks may also be provided.

Most of the control circuit components are contained on printed circuit boards which are mounted on a hinged panel for ease in assembly and maintenance. The primary power conversion components are silicon controlled rectifiers (SCR's) which are used to convert the input AC to adjustable DC and then a bridge arrangement inverts the DC to stepped wave AC.

### MOTOR

An induction or synchronous reluctance motor may be supplied depending on the application requirements. The motor will supply a constant torque load over the operation frequency range.

### POWER TRANSFORMER

A 3-phase, wall mounted, dry-type isolation transformer for remote mounting is supplied.

### CONTROL STATION

The type of operator's control station supplied will depend on the application. A control station for single drive applications will normally include a speed-setting potentiometer and START-STOP pushbuttons. For more complex applications where several drives are cascaded to co-ordinate sections in a process, a desk-type console may be provided.

## SPECIFICATIONS

### POWER UNITS – INPUT

4KVA and 10KVA Units – 208Y/120 AC, 3-phase, 4 wire, 60 HZ.

20KVA Unit – 416Y/240 AC, 3-phase, 4 wire, 60 HZ.

### POWER UNITS – OUTPUT

4KVA and 10KVA Units – Rated 4KVA or 10KVA, 3-phase, continuous duty. (Suitable for 2 HP or 5 HP at maximum frequency.)

20KVA Unit – Rated 20KVA, 3-phase, continuous duty. (Suitable for 10 HP at maximum frequency.)

### OPERATION FREQUENCY – 6 to 120 HZ

4KVA and 10KVA Units Output Voltage – 100 volts at maximum frequency, constant volts per HZ.

240KVA UNIT OUTPUT VOLTAGE –

200 volts at maximum frequency, constant volts per HZ.

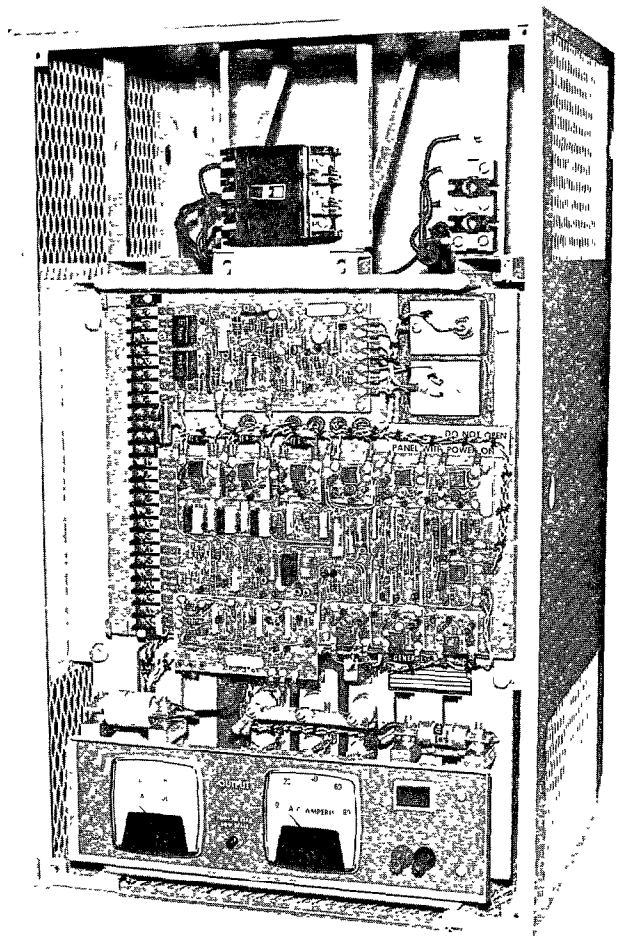


Figure 1. Typical 10 or 20KVA Power Unit in Enclosure (with Instrumentation Option Shown)

## ACCURACY

Long Term Drift – Frequency drift less than ±2% of set frequency with analog reference from potentiometer.

Optional external frequency reference for drift accuracies of ±0.05% or ±0.01% of set frequency.

Speed Regulation – ±0% from no load to full load with synchronous motors.

## ENVIRONMENTAL CONDITIONS

Storage Range – 0 C to 65 C

Operating Range –10 C to 40 C

## PROTECTION

Circuit Breaker – Provides short circuit protection (10,000 amps interrupting capacity) for the power unit and also serves as a disconnect means to remove input power.

Fuses – Provide short circuit protection for the solid state devices in the power unit.

Current Trip – An internal static circuit provides fault current protection for semi-conductor devices in the power unit.

Current Limit – Limits the output current for temporary overloads.

Undervoltage – An internal static circuit protects against automatic restarting following AC power interruption and also protects the power unit and motor if a low voltage condition exists during normal running operations.

Phase Sequence – The unit is not phase sensitive, therefore no need for concern when connecting the AC supply lines.

## ACCELERATION

Time rate acceleration and deceleration is standard.

# RECEIVING, HANDLING AND STORAGE

Place the equipment under adequate cover immediately upon receipt. The packing cases are not suitable for outdoor or unprotected storage. Examine the shipment carefully on its arrival and check it against the packing list. Promptly report any shortage or damage incurred during shipment to the carrier and to the nearest General Electric Company Sales Office. Particular care should be exercised to prevent small parts from being mislaid or thrown away with the packing material.

If the equipment is not to be used as soon as it is unpacked, it should be stored in a clean, dry area and protected against accidental damage. Particular care should be exercised to avoid storage in a location where construction work is in progress.

## INSTALLATION

Mounting and Interconnection of the ST-Inverter drive components is described in this section. When installing the equipment, check all accessible factory connections for tightness, since connections may become loose during shipping or storage.

### POWER UNIT MOUNTING

Wall mount the power unit by using the mounting brackets at top and bottom of the enclosure or by removing the panel assembly and mounting the enclosure using the holes provided. (See outline drawing for dimensions.)

The unit can be floor mounted by using a mounting base that does not restrict air flow into the bottom of the enclosure.

Use the following procedure to remove the panel assembly for mounting:

1. Remove front cover from enclosure by loosening screw at each corner.
2. Disconnect the wires from the circuit breaker, terminal board and ground stud which are a part of the enclosure.
3. Remove the bolts holding the power unit panel assembly and slide the unit out of the enclosure. There is a latch mechanism near the top of the enclosure that must be actuated to remove the power unit completely from the enclosure.
4. Wall mount the enclosure using the two mounting holes at the top back of the enclosure and the single mounting hole at the bottom. The holes are suitable for ½ inch mounting bolts. (See outline drawing for dimensions.)
5. Slide the power unit panel assembly back into the enclosure, replace the mounting bolts and reconnect all wires. A hole is provided at the top of the panel for a lifting hook that can be used to lift the unit.

**WARNING**

INSTALL THE POWER UNIT IN A WELL-VENTILATED LOCATION WHICH IS NOT SUBJECT TO AMBIENT TEMPERATURE ABOVE 40°C (113°F). NEVER INSTALL THE POWER UNIT WHERE HAZARDOUS, INFLAMMABLE OR COMBUSTIBLE VAPORS, OR DUST ARE PRESENT.

The power unit is convection-cooled. Air enters through the bottom of the enclosure and exits through the upper part of the front and sides. Make sure there is ample clearance around the outside of the enclosure to allow a normal flow of cooling air.

### CONTROL STATION

Mount the control station using hole locations and over-all dimensions shown on the outline drawing supplied with the equipment. Make sure the enclosure type is suitable for the environment in the mounting area.

### INTERCONNECTION

The equipment has been designed to prevent internally generated noise from causing mis-operation of sensitive control circuits. It is equally as important to prevent externally generated noise from getting into the control circuits. This can be done by following the interconnection diagram supplied with the equipment and by providing shielded wire where specified.

**IMPORTANT**

READ ALL NOTES AND INSTRUCTIONS ON THE INTERCONNECTION DIAGRAM BEFORE PROCEEDING.

### INPUT VOLTAGE CONNECTION:

1. The three line connections are made at the power transformer primary terminals and the three wire secondary output is made at the circuit breaker terminals with the neutral wire connecting to the ground stud on enclosure.
2. Make certain that the input voltage and frequency of the available power agree with the rating transformer on the power nameplate.
3. It is recommended that a fused disconnect switch be installed in the AC power lines ahead of the power transformer and power unit.

## GROUNDING:

The ground stud should be connected directly to plant ground. The transformer neutral wire is connected to the power unit ground stud and grounded at that point only. It is also recommended that the control station and motor be grounded in accordance with NEC and/or local code requirements.

## FINAL CHECK

1. Interconnecting Wiring

Nearly all of the problems encountered in the initial startup of any system is caused by improper interconnecting wiring. If difficulty is encountered, the first step should be a careful recheck of all interconnecting wiring.

2. Loose Connections

Loose connections may cause malfunctions; make sure all connections are tight.

3. Wires

Wires may be broken due to mishandling of the control or excessive vibrations and shock (e.g. during transportation). Usually a broken wire is fairly obvious after a few minutes inspection (with power switched off).

# OPERATION AND ADJUSTMENT

## INITIAL OPERATION

When all connections have been made correctly, the drive will be ready to operate. Apply input voltage to the power unit by closing the circuit breaker. Set the speed reference for minimum operating frequency. Press the start button and gradually increase and decrease the output frequency over the required operating range by changing the speed reference.

The power units internal oscillator frequency range, volts per hertz ratio and voltage boost at low frequency have been factory adjusted to match the motor supplied. Do not change these adjustments. Acceleration and deceleration times will be set for 20 seconds unless other times are specified when the equipment is ordered.

## NORMAL OPERATION

When operating properly, the drive can be started by pressing the start button, with the speed reference set for any output frequency within the normal operating range. The power unit frequency and motor speed will accelerate at a linear timed rate from zero to the set point while maintaining the proper volts per hertz ratio. When the stop button is pressed, frequency and motor speed will decelerate to zero also at a linear timed rate. If input power is removed while the drive is operating, the frequency will immediately go to zero and the motor will coast to a stop at a rate determined by the inertia and friction in the drive system.

The sync light (when supplied and when an external frequency reference is used) will indicate when the power unit internal oscillator is synchronized with the external frequency reference. This is a two section light and when both sections are "on", the drive is synchronized. If several motors are supplied from a single power unit, starting one motor while the others are running may cause the current trip circuit to shut down the drive. When this happens, the drive can be restarted by simply pressing the start button.

When several power units are being controlled from a single external frequency reference, individual units can be started and stopped without affecting the operation of others.

# THEORY OF OPERATION

The ST-Inverter power unit will convert three-phase AC line power to adjustable DC and invert the DC to adjustable frequency AC power. The simplified block diagram of Figure 2 shows the major circuit sections required to perform this function.

Input AC is converted to adjustable DC by half-wave phase controlled rectifiers. This DC is then converted to adjustable frequency AC by controlled switching of the rectifiers in a three-phase inverter bridge.

A single speed reference signal is supplied through a timed acceleration and deceleration circuit to both the voltage regulator and frequency control circuits. The

voltage regulator controls the DC voltage supplied to the inverter and the frequency control circuit sets the inverter SCR switching sequence, thus controlling the volts per hertz ratio of power supplied to the motor. A separate commutation circuit controlled by the frequency control circuit will turn off the inverter SCR's at the proper time.

## MAINTENANCE

Maintenance is primarily a matter of routine inspection and good housekeeping. The inside of the enclosure should be checked at regular intervals to make sure it is free of dust or other foreign matter. The panel is the heat sink and should be kept clean to provide maximum heat dissipation.

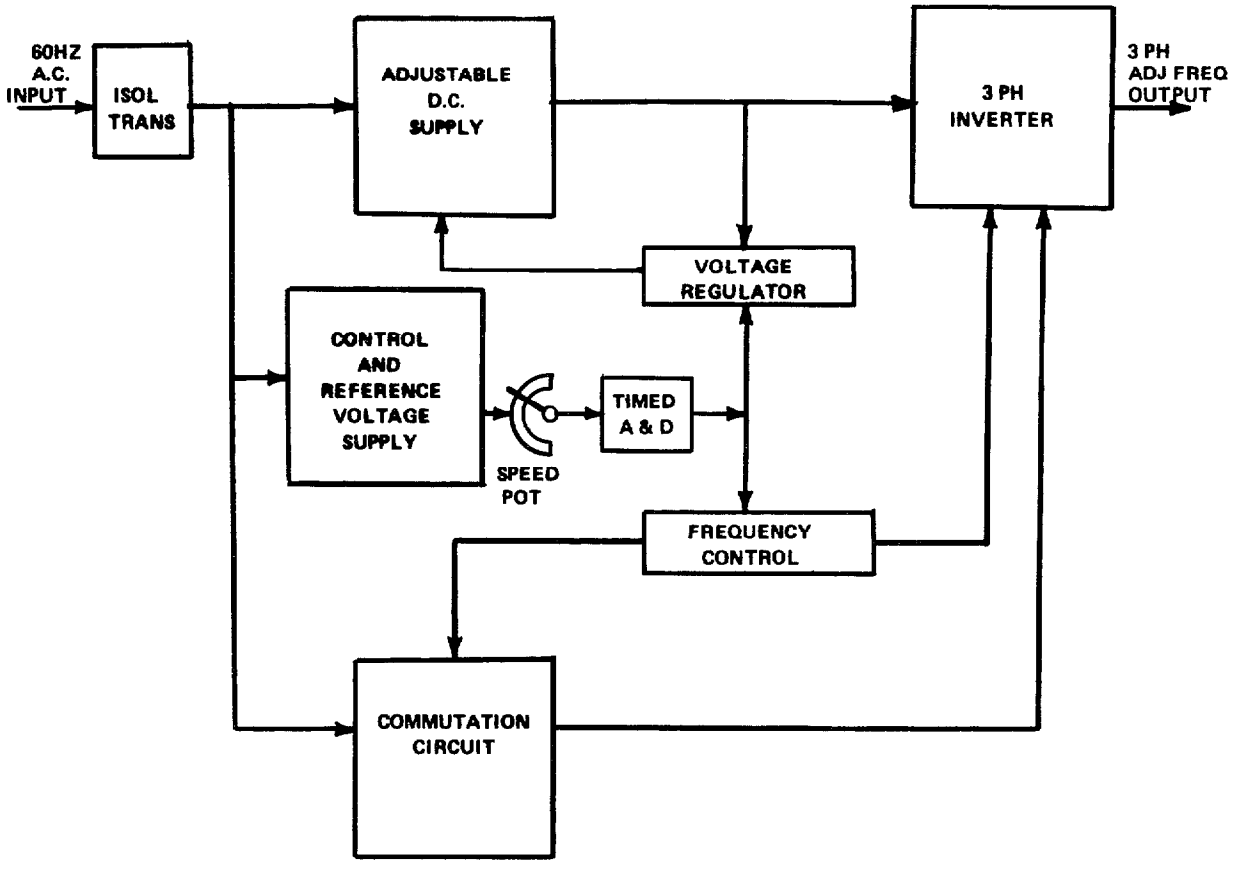



**Figure 2. Power Unit Block Diagram**

If a power unit failure should occur, down time can be held to a minimum by replacing the complete panel assembly. All power unit components except the circuit breaker (plus dropping resistors on 20KVA units) are mounted on the panel assembly which can be easily replaced. Before replacement is made, check all leads connected between the power unit, motor and control station. Make sure there are not short circuits and that all connections are tight.

### REPLACING POWER UNIT PANEL ASSEMBLY

#### WARNING

MAKE SURE AC LINE POWER IS REMOVED FROM THE POWER UNIT BEFORE TOUCHING INTERNAL PARTS.

1. Disconnect input power leads from the load side of the circuit breaker.

2. Disconnect leads from the terminal board(s) at top of the enclosure.

3. Disconnect incoming control wires from the main terminal board. Mark the leads so they can be replaced on the correct terminal points.

4. Remove the four mounting bolts.

5. Carefully slide the power unit out of the enclosure by means of the handles provided.

6. Slide the new unit into the enclosure. Replace mounting bolts and all wiring. Make sure that all connections are tight.

## TROUBLESHOOTING AND REPAIR

If a spare panel assembly is not available for replacement, it may be possible to repair the defective unit. Printed circuit boards containing the control circuitry and semiconductor components mounted on the heat sink can be replaced without special training or equipment. There are some simple checks that can be made, using a volt/ohmmeter, to help locate the trouble. Also, by observing the symptoms and indications that are available, it may be possible to isolate the defect to a printed circuit board or semiconductor component. If the defect is not found by these simple checks and observations, the printed circuit boards should be replaced. Troubleshooting and repair of printed circuit boards is not recommended. Return the defective printed circuit board to the factory for repair after calling your General Electric sales office for return instructions.

The power unit is equipped with special protective circuits to trip the unit off in case of undervoltage, heavy overloads, or short circuits on the output. These same protective circuits could also trip the unit off if the control circuits fail to operate properly. Repeated tripping will occur each time the power unit is started as long as the trouble exists. By observing the meters located on the meter panel, it may be possible to determine if the trouble is caused by excessive load current or a circuit malfunction.

Additional protection for the power unit is provided by fuses 1FU and 2FU. Referring to the elementary diagram supplied with the equipment, it can be seen that fuse 1FU protects the input SCR's and 2FU protects the commutation circuit components. Therefore, observing the fuse which has blown will be of some help in locating the trouble.

#### CAUTION

REPLACE FUSES 1FU AND 2FU WITH THE EXACT SAME TYPE AND RATING AS SUPPLIED WITH THE EQUIPMENT. NO SUBSTITUTION CAN BE MADE.

The power diodes and SCR's are mounted on aluminum blocks which in turn are affixed to the heat sink. The heat sink itself is at ground potential but the mounting blocks are electrically isolated from the heat sink, so care must be exercised when working near the small blocks.

### CHECKING SILICON CONTROLLED RECTIFIERS

The SCR's are provided with special current and voltage protection. A malfunction of these protective devices under the right conditions could result in an SCR failure. This failure would normally be to a short, which can be found with an ohmmeter on "Times 1" scale.

### CHECKING SILICON DIODES

The characteristics of a silicon diode to block current in one direction and pass current freely in the other direction is used in a simple ohmmeter check. Connect ohmmeter leads across diode to be checked. When the meter leads are reversed, the indicated resistance should change from infinite to some very low value. (Low value will vary with different instruments.)

NOTE

SILICON DIODES WILL USUALLY FAIL EITHER TO A SHORT OR AN OPEN WHICH WILL BE QUICKLY DISCOVERED WITH THE ABOVE CHECK.

CAUTION

IN REMOVING OR REPLACING ANY SCR OR DIODE, USE A SMALL SOLDERING IRON OF NOT MORE THAN 35 WATTS. DO NOT APPLY SOLDERING IRON HEAT TO RECTIFIER TERMINAL ANY LONGER THAN NECESSARY.

## REPLACING STUD MOUNTED SCR's AND DIODES

1. Remove defective rectifier from heat sink and thoroughly clean the area around the mounting hole.

2. Apply silicon grease (Penetrox) to new rectifier stud before mounting on heat sink.

3. Tighten the rectifier to assure a firm contact between rectifier and heat sink but don't overdo it. Excessive stress may damage the rectifier; therefore, a torque wrench must be used and devices tightened as follows:

a. Large SCR's and rectifiers - 70lb-in. max.

b. Small rectifiers - 20lb-in. max.

## POWER UNIT TEST PROCEDURE

The possibility exists that the failure of a component in one section may cause misoperation in another section of the power unit. For this reason a definite procedure must be followed in checking circuits and components. The following test procedure should be used. Refer to the elementary and wiring diagrams to locate components and circuit points.

1. Open circuit breaker. (Always check with a voltmeter to make sure that voltage has been removed.)

2. Remove both fuses, 1FU and 2FU.

3. Loose connections can cause misoperation. Check all internal and external lead connections associated with the drive to make sure they are tight.

4. Check all power semiconductor components mounted on the heat sink with an ohmmeter.

It is possible that in cases where a bus bar or jumper is being used to connect three diodes or SCR's together, if a single SCR or diode is shorted, each of the components might indicate a short. It will then be necessary to remove the bus bar or jumper to locate the failed component.

If an output bridge SCR (4-9 SCR) is shorted, more than one will indicate a short with the motor leads connected. It will be necessary to disconnect the motor to determine the one that is actually shorted.

5. If the above checks are all satisfactory, close the circuit breaker applying power to the unit.

WARNING

BE CAREFUL NOT TO COME IN CONTACT WITH LIVE PARTS.

6. Voltage Checks — All measurements to be made with respect to circuit 100 (terminal 14 on terminal board) and have a tolerance of ±10% unless otherwise stated.

a. Check the incoming line voltage. Measure the line to line and line to neutral voltages. Be sure to check all three phases.

| 4KVA & 10KVA Units | 20KVA Unit |
|---|---|
| L — L = 208VAC | L — L = 416VAC |
| L — Neutral = 120VAC | L — Neutral = 240VAC |

These voltages should be within ±5%. If not, take whatever corrective action is necessary to bring the voltage within these limits.

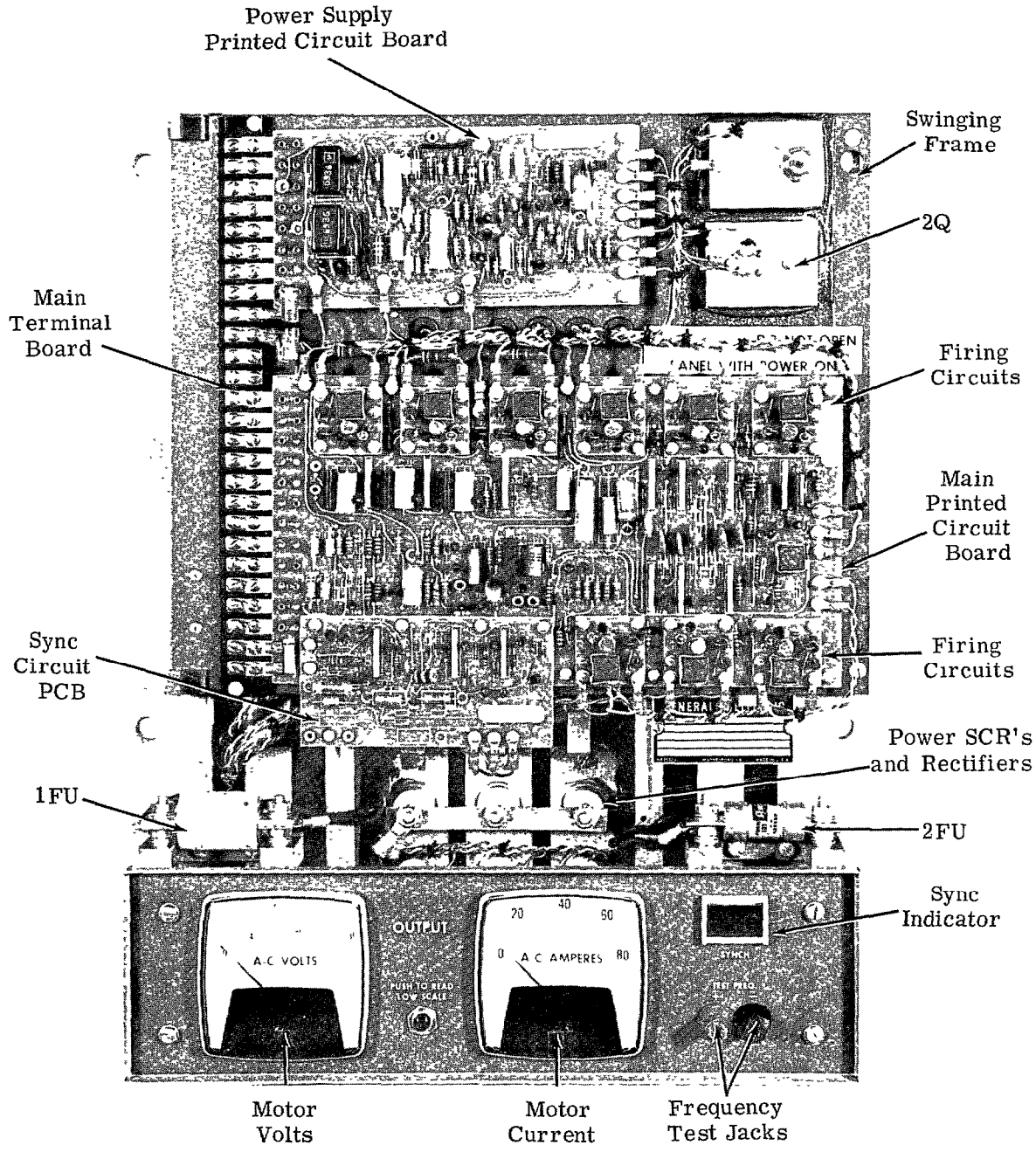
b. Measure the commutation bus voltage circuit 24 (left terminal of 2FU).

| 4KVA & 10KVA Units | 20KVA Unit |
|---|---|
| +160VDC | +320VDC |

c. Check the following control voltages at the main terminal board.

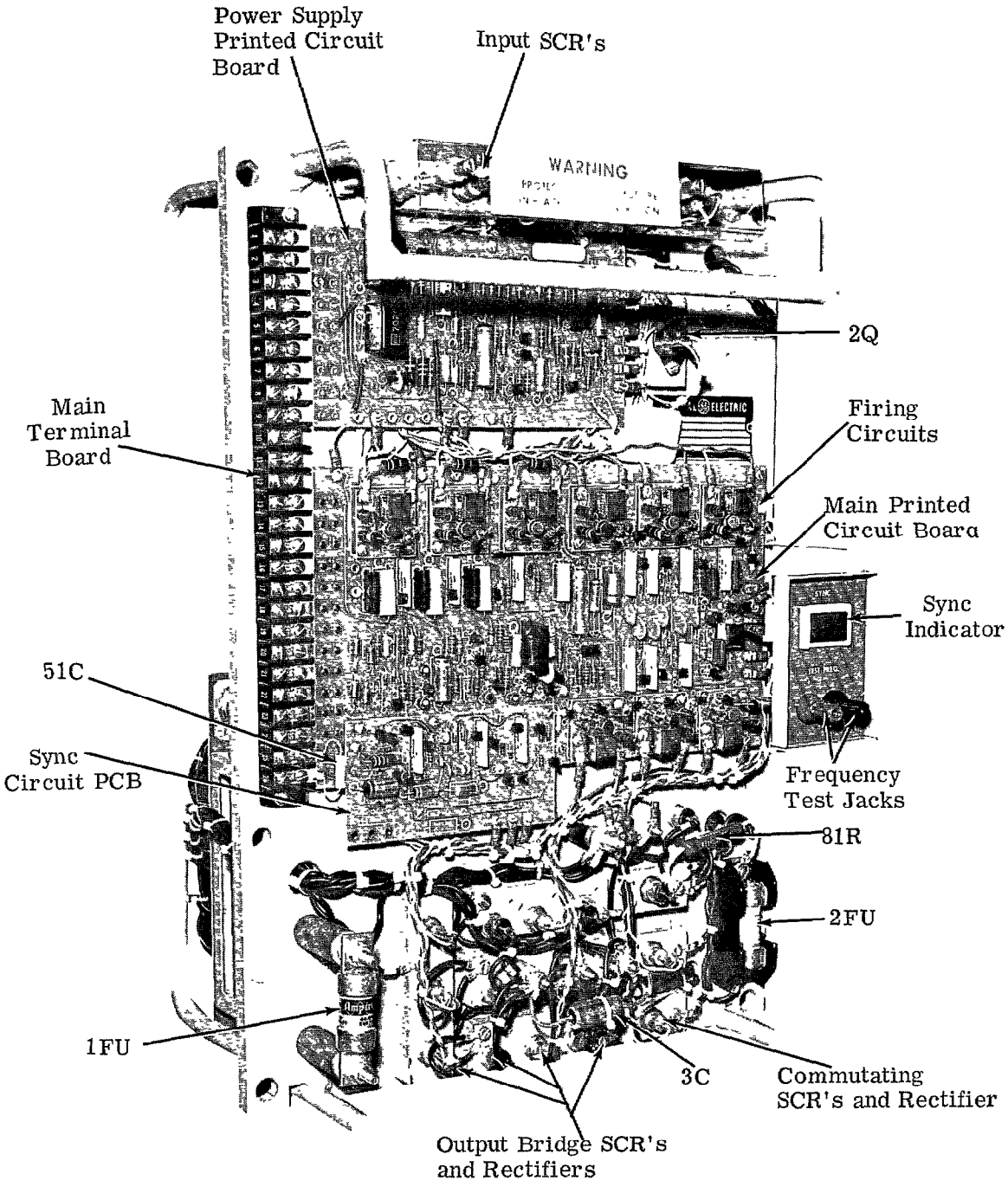
| CIRCUIT No. | TERMINAL No. | +VDC ±10% |
|---|---|---|
| 43 | 4 and 22 | Zero |
| 102 | 7 | 18V |
| 25 | 8 and 15 | 24V |
| 50 | 13 | Approx 1V |
| 40 | 19 | Zero |

If the 24 VAC bus is low, a possible cause could be a shorted zener diode 9BD — 12BD or capacitor 18C (68MFD) on main printed circuit board or open resis-




**TYPICAL 10 AND 20KVA POWER UNIT PANEL ASSEMBLY**
**(WITH INSTRUMENTATION OPTION SHOWN)**

**FIGURE 3**




TYPICAL 4KVA POWER UNIT ASSEMBLY

FIGURE 4

tor 9R (mounted on back frame). If there is a voltage at circuit 50 which is greater than 2.5 VDC, then resistor 3R or diode 20D could be open. To check, remove power from unit and with an ohmmeter, check the resistance between terminals 3 and 13 of the terminal board. With meter leads oriented in one direction, the resistance should be low (less than 10 ohms) and in the other direction, some high value. NOTE: This procedure also checks 1CR contact. If the resistance checks indicates an open circuit, replace the power supply PCB. If the 18VDC line is low, a possible cause could be shorted zener diodes 3BD – 5BD, transistor 4Q on power supply PCB or open resistor 8R (mounted on back of frame).

d. If the voltage checks in sections b and c are within tolerance, leaving fuses 1FU and 2FU out of the circuit, press the "start" button. Set "speed adjust" for approximately 50% speed and check the following control voltages at the main terminal board. All voltage readings to be made with respect to circuit 100 (terminal 14).

| CIRCUIT NO. | TERMINAL NO. | +VDC +10% |
|---|---|---|
| 43 | 4 and 22 | 6V(See note below) |
| 50 | 13 | 45V |

NOTE

IF AN EXTERNAL REFERENCE FREQUENCY IS BEING USED TO CONTROL THE SPEED OF THIS EQUIPMENT, RATHER THAN A POTENTIOMETER, THE VOLTAGE READING AT CIRCUIT 43 WILL BE APPROXIMATELY 3VDC SINCE THE OUTPUT OF THE SYNC BOARD IS ESSENTIALLY A SQUARE WAVE.

If the 45 volt bus is low, check for a shorted transistor on the firing circuit boards, shorted transistor 2Q (top right hand side of swinging frame), or zener diodes 1BD and 2BD (on power supply board).

The transistor to check on the firing circuit board is the one in the metal case. The transistor case will be very hot to the touch. If so, replace the firing circuit board.

7. Firing Circuit Check:

With the unit energized and the speed adjust set for an output frequency of approximately 60 cycles, connect the negative lead of the voltmeter on circuit 100 (terminal 14 of terminal board) and the positive lead on the top lead of the 47 ohm resistor of each of the nine firing circuit boards. It is located next to the metal can transistor and has a yellow band for its first color band.

CAUTION

BE CAREFUL NOT TO SHORT ANY COMPONENTS ON THE BOARD.

A reading of 0.5 to 1.5 volts DC on the first three firing circuit boards from left to right at the top of the main printed circuit board and a reading of 1.5 to 2.5 volts DC on the remaining six boards is an indication that the firing circuits are operating. This simple check will not indicate all possible defects in these circuits, but should be adequate in most cases.

8. Synchronizing Circuit Check (if used)

When the speed is to be controlled by an external reference frequency, a synchronizing (frequency discriminator) board is required and is mounted on the bottom left edge of the main printed circuit board. With 1FU and 2FU out of the circuit, the start circuit energized, and the "speed adjust" set for approximately 20% speed, observe the sync light on the meter panel. If both sections of the light are on and stable, no further check of the board is required. If the light is unstable, or only one section of the light is on, replace the sync board. If the same results occur, replace the main printed circuit board.

9. Commutation Circuit Check:

a. Open circuit breaker.

b. Turn "speed adjust" to zero set point.

c. Replace fuse 2FU only.

WARNING

BE CAREFUL NOT TO TOUCH FUSE CLIPS SINCE CAPACITOR 35C MAY NOT BE COMPLETELY DISCHARGED. CHECK TO MAKE SURE THAT VOLTAGE BETWEEN FUSE CLIPS AND HEAT SINK IS ZERO BEFORE PROCEEDING.

d. Close circuit breaker and press the "START" button.

e. Turn "speed adjust" clockwise until you hear the commutation circuit operate. This will be a clicking sound.

f. If fuse 2FU blows or the circuit does not operate, recheck 1D, 2D, 3D, 14D, 15D, 10SCR and 11SCR. Also check for loose connections in the commutation circuit. Before checking diodes and SCR's, make certain all power has been removed from the panel.

If the defect has not been found, replace the printed circuit boards.

## REPLACING PRINTED CIRCUIT BOARDS

### CAUTION

HANDLE PRINTED CIRCUIT BOARDS VERY CAREFULLY TO PREVENT DAMAGE TO BOARD OR COMPONENTS.

1. Auxiliary Boards:

a. Remove all leads attached to the defective board.

b. Remove defective auxiliary board from main PC board by removing mounting screws.

c. Install the replacement board and replace all mounting screws and leads.

2. Power Supply Board:

a. Remove all leads attached to the defective board. Where necessary, tag leads to make sure they will be reconnected to the same points on the replacement board.

b. Remove board mounting screws.

c. The power supply board can now be removed by loosening the terminal board screws.

d. Install the replacement board and replace all mounting screws and leads. Make sure all screws are tight.

3. Main Printed Circuit Board

In order to save time in replacing the main PC board, it is recommended that the complete board assembly including auxiliary boards be replaced. If a complete board assembly is not available for replacement, the auxiliary boards can be transferred to a new main board. The same procedure described in 2 can be used to remove and replace the main PC board assembly.

## RENEWAL PARTS

Should a component fail, a replacement part can be ordered from the nearest sales office of the General Electric Company. When ordering renewal parts, specify the quantity required, give the catalogue numbers and describe the required parts in detail. In addition, give the model number and the complete nameplate rating of the equipment.

NOTES

NOTES

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