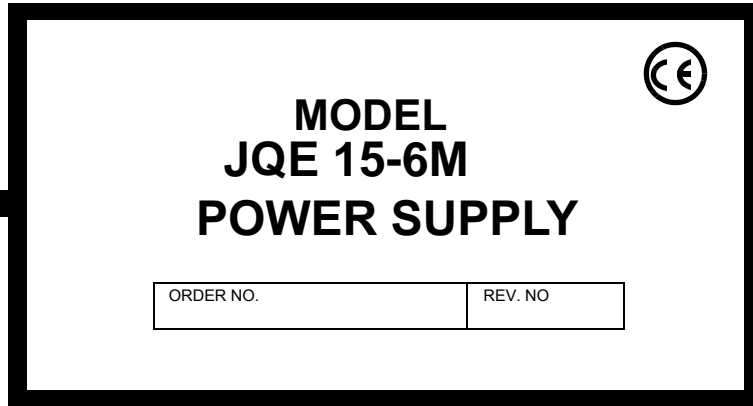


INSTRUCTION MANUAL

JQE 15-6M

POWER SUPPLY

KEPCO INC.
An ISO 9001 Company.



IMPORTANT NOTES:

- 1) This manual is valid for the following Model and associated serial numbers:

MODEL	SERIAL NO.	REV. NO.
-------	------------	----------
- 2) A Change Page may be included at the end of the manual. All applicable changes and revision number changes are documented with reference to the equipment serial numbers. Before using this Instruction Manual, check your equipment serial number to identify your model. If in doubt, contact your nearest Kepco Representative, or the Kepco Documentation Office in New York, (718) 461-7000, requesting the correct revision for your particular model and serial number.
- 3) The contents of this manual are protected by copyright. Reproduction of any part can be made only with the specific written permission of Kepco, Inc.

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P/N 243-0286-R32



KEPCO, INC. • 131-38 SANFORD AVENUE • FLUSHING, NY. 11352 U.S.A. • TEL (718) 461-7000 • FAX (718) 767-1102
email: hq@kepcopower.com • World Wide Web: <http://www.kepcopower.com>

Declaration of Conformity

Application of Council directives: **73/23/EEC (LVD)**
93/68/EEC (CE mark)

Standard to which Conformity is declared:

EN61010-1:1993 (Safety requirements for electrical equipment for measurement, control and laboratory use)

Manufacturer's Name and Address: **KEPCO INC.**
131-38 SANFORD AVENUE
FLUSHING, N.Y. 11352 USA

Importer's Name and Address:

REPRESENTATIVE COPY

Type of Equipment: **Component Power Supply**

Model No.: **[PRODUCT MODEL NUMBER]**

Year of Manufacture:

I, the undersigned, declare that the product specified above, when used in conjunction with the conditions of conformance set forth in the product instruction manual, complies with the requirements of the Low Voltage Directive 73/23/EEC, which forms the basis for application of the CE Mark to this product.

Place: **KEPCO Inc.**
131-38 Sanford Ave.
Flushing, N.Y. 11352 USA

Saul Kupferberg
(Full Name)

Date: _____

VP OF SALES
(position)

Conditions of Conformance

When this product is used in applications governed by the requirements of the EEC, the following restrictions and conditions apply:

1. For European applications, requiring compliance to the Low Voltage Directive, 73/23/EEC, this power supply is considered a component product, designed for "built in" applications. Because it is incomplete in construction, the end product enclosure must provide for compliance to any remaining electrical safety requirements and act as a fire enclosure. (EN61010-1 Cl. 6, Cl. 7, Cl.8, Cl. 9 and EN61010-1 annex F)
2. This power supply is designed for stationary installation, with mains power applied via a detachable power supply cord or via direct wiring to the source power terminal block.
3. This power supply is considered a Class 1 (earthed) product, and as such depends upon proper connection to protective earth for safety from electric shock. (EN61010-1 Cl. 6.5.4)
4. This power supply is intended for use as part of equipment meant for test, measurement and laboratory use, and is designed to operate from single phase, three wire power systems. This equipment must be installed within a suitably wired equipment rack, utilizing a three wire (grounded) mains connection. See wiring section of this manual for complete electrical wiring instructions. (EN61010-1 Cl. 6.5.4 and Cl.6.10.1)
5. This power supply has secondary output circuits that are considered hazardous, and which exceed 240 VA at a potential of 2V or more.
6. The output wiring terminals of this power supply has not been evaluated for field wiring and, therefore, must be properly configured by the end product manufacturer prior to use.
7. This power supply employs a supplementary circuit protector in the form of a circuit breaker mounted on the front panel. This circuit breaker protects the power supply itself from damage in the event of a fault condition. For complete circuit protection of the end product, as well as the building wiring, it is required that a primary circuit protection device be fitted to the branch circuit wiring. (EN61010-1 Cl. 9.6.2)
8. Hazardous voltages are present within this power supply during normal operation. All operator adjustments to the product are made via externally accessible switches, controls and signal lines as specified within the product operating instructions. There are no user or operator serviceable parts within the product enclosure. Refer all servicing to qualified and trained Kepco service technicians.

SAFETY INSTRUCTIONS

1. Installation, Operation and Service Precautions

This product is designed for use in accordance with EN 61010-1 and UL 3101 for Installation Category 2, Pollution Degree 2. Hazardous voltages are present within this product during normal operation. The product should never be operated with the cover removed unless equivalent protection of the operator from accidental contact with hazardous internal voltages is provided:



There are no operator serviceable parts or adjustments within the product enclosure. Refer all servicing to trained service technician.



Source power must be removed from the product prior to performing any servicing.



This product is factory-wired for the nominal a-c mains voltage indicated on the rating nameplate located adjacent to the source power connection on the product's rear panel. To reconfigure the product input for other nominal mains voltages as listed herein, the product must be modified by a trained service technician.

2. Grounding

This product is a Class 1 device which utilizes protective earthing to ensure operator safety.



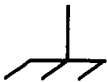
The PROTECTIVE EARTHING CONDUCTOR TERMINAL must be properly connected prior to application of source power to the product (see instructions on installation herein) in order to ensure safety from electric shock.



PROTECTIVE EARTHING CONDUCTOR TERMINAL - This symbol indicates the point on the product to which the protective earthing conductor must be attached.



EARTH (GROUND) TERMINAL - This symbol is used to indicate a point which is connected to the PROTECTIVE EARTHING TERMINAL. The component installer/ assembler must ensure that this point is connected to the PROTECTIVE EARTHING TERMINAL.



CHASSIS TERMINAL - This symbol indicates frame (chassis) connection, which is supplied as a point of convenience for performance purposes (see instructions on grounding herein). This is not to be confused with the protective earthing point, and may not be used in place of it.

3. Electric Shock Hazards

This product outputs hazardous voltage and energy levels as a function of normal operation. Operators must be trained in its use and exercise caution as well as common sense during use to prevent accidental shock.



This symbol appears adjacent to any external terminals at which hazardous voltage levels as high as 500V d-c may exist in the course of normal or single fault conditions.



This symbol appears adjacent to any external terminals at which hazardous voltage levels in excess of 500V d-c may exist in the course of normal or single fault conditions.

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SECTION 1 - INTRODUCTION

1-1 SCOPE OF MANUAL

- 1-2 This manual contains instructions for the installation, operation and maintenance of the Kepco JQE "QUARTER-RACK" Series of Power Supplies.



NO OPERATOR SERVICEABLE
PARTS INSIDE THE JQE 1/4 RACK
POWER SUPPLY. REFER SERVICING
TO SERVICE TRAINED PERSONNEL.

1-3 GENERAL DESCRIPTION

- 1-4 Kepco Series JQE Power Supplies are general purpose, precision stabilized voltage sources in the "quarter-rack" configuration. The units are designed to be part of a larger system and not to be operated as a stand alone bench power supply. The units are designed to operate immediately without any internal adjustments. External points on the outside case should not be readily available, provided the unit is in a rack as an integrated OEM subsystem. If it is desired to switch the AC input power range the units must be returned to the factory for authorized service personnel to make the appropriate terminal connections. There are absolutely no serviceable components within the power supply that are accessible for nonauthorized personnel to work on.

JQE Power Supplies have linear, full-dissipation series pass transistors (NPN), driven by an integrated circuit operational amplifier. A sharp current-limit circuit renders the power supply completely short-circuit proof. JQE 1/4 Rack Power Supplies may be readily converted to provide constant current by the addition of an external sensing resistor and a current control resistor. The output of the JQE 1/4 Rack Power Supply is remotely programmable. All necessary connections are available on terminals at the rear barrier-strip.

- 1-5 The compact design of the Kepco JQE 1/4 Rack Series includes a heatsink of exceptional efficiency, in combination with a reliable low-noise fan. JQE 1/4 Rack Power Supplies feature proven design with conservatively rated components for added reliability.
- 1-6 JQE Power Supplies are identical in their mechanical dimensions (Refer to FIG. 1-2) and in their electrical specifications, except as noted in TABLE 1-1.
- 1-7 The main chassis frame of the power supply is constructed from cold-rolled steel, as is the perforate wrap-around cover. The front panel is manufactured from aluminum (Refer to FIG. 1-2 for finish).

1-8 ACCESSORIES

- a) RACK ADAPTER (FOR FOUR 1/4 RACK UNITS): KEPKO MODEL RA-24.
Fits standard EIA rack dimensions.
FILLER PANELS to cover empty slots if adapter is used for less than its capacity:
 - 1) KEPKO MODEL RFP 24-1, to cover one (1) empty slot.
 - 2) KEPKO MODEL RFP 24-2, to cover two (2) empty slots.
 - 3) KEPKO MODEL RFP 24-3, to cover three (3) empty slots.
- b) RACK ADAPTER (FOR TWO 1/4 RACK UNITS): KEPKO MODEL RA-32. Can be used for two JQE 1/4 RACK models plus three 1/16 RACK UNITS. Use filler panels from the RA-24 system above.

1-9 SPECIFICATIONS, ELECTRICAL

- a) A-C INPUT: 105 to 125V a-c or 210 to 250V a-c (selectable, refer to SECTION 11), 50 to 65 Hz⁽¹⁾, single phase. Refer to the table of general specifications (TABLE 1-1) for the a-c input current for each model.
- b) D-C OUTPUT RATINGS: See TABLE 1-1.
- c) OUTPUT EFFECTS: See TABLE 1-2.
- d) OPERATING TEMPERATURE: - 20°C to (+)71°C.
- e) STORAGE TEMPERATURE: - 40°C to (+)85°C.
- f) COOLING: High efficiency, single bearing fan, (permanently lubricated) with special low-noise, non-metal blade.
- g) ISOLATION: A maximum of 500 volts (d-c or p-p) can be connected between chassis and either output terminal. Common-mode current from either output terminal to ground: <5uA rms, < 50uA peak to peak at 115V a-c, 60 Hz.
- h) OUTPUT IMPEDANCE: See TABLE 1-1

(1) Consult factory for operation of the JQE on power line frequencies above 65 Hz

MODEL	D-C OUTPUT RANGE		OUTPUT IMPEDANCE				MAX INPUT AMPS AT 125 VAC
	E _O max.	I _O max.	VOLTAGE MODE		CURRENT MODE ⁽¹⁾		
			DC OHMS + SERIES L		DC OHMS + SHUNT C		
JQE 6-10M	0-6 V	0-10 A	30 μΩ	1 μH	50 kΩ	3 KμF	2.0
JQE 15-6M	0-15	0-6 A	125 μΩ	1 μH	84 kΩ	1 KμF	2.1
JQE 25-4M	0-25 V	0-4 A	300 μΩ	1 μH	125 kΩ	700 μF	2.2
JQE 36-3M	0-36 V	0-3 A	600 μΩ	1 μH	165 kΩ	400 μF	2.2
JQE 55-2M	0-55 V	0-2 A	1.4 mΩ	1 μH	250 kΩ	220 μF	2.3
JQE 75-1.5M	0-75 V	0-1.5 A	2.5 mΩ	1 μH	330 kΩ	160 μF	2.3
JQE 100-1M	0-100V	0-1 A	5 mΩ	2 μH	500 kΩ	110 μF	2.1

1) External current sensing and control using the voltage mode amplifier. Sensing voltage =1 volt.

TABLE 1-1 JQE 1/4 RACK GROUP A-C INPUT AND D-C OUTPUT SPECIFICATIONS

- i) **CURRENT RECOVERY** (For step load voltage): With the JQE as a current stabilizer, the exponential waveform of the compliance (load voltage is a function of the RC time constant formed by the load resistance (R) and the shunt capacitance (C) tabulated in Table 1-1.
- j) **VOLTAGE RECOVERY TIME** (for step load current): The stabilized output voltage returns to the load effect band (or to a level of 10 mV, whichever is greater) in less than 50 usec.
- k) **OVERSHOOT**: No output voltage overshoot from turn-on, turn-off, or power failure for output settings above 25% of maximum rated output voltage. Below 25% output voltage, overshoot is a function of load current and is negligible for loads in excess of 10% of the maximum rated current.

INFLUENCE QUANTITY	OUTPUT EFFECTS		PRE-AMPLIFIER OFFSETS		REFERENCE 6.2±5%
	VOLTAGE MODE	CURRENT MODE ⁽¹⁾	VOLTAGE ΔE _{io}	CURRENT ΔI _{io}	
SOURCE VOLTAGE (min-max):	<0.0005%	<0.005%	<10 μV	<2 nA	<0.0001%
LOAD (No Load - full load):	<0.005% OR 0.2MV ²	<0.01	<200 μV	<5 nA	N.A.
TIME (8-hour drift):	<0.01% OR 1MV ²	<0.02%	<20 μV	<2 nA	<0.005%
TEMPERATURE, Per °C:	<0.01% ³	<0.02% ⁽³⁾	<20 μV	<5 nA	<0.005%
RIPPLE AND NOISE ⁽⁴⁾	RMS	<0.2mV	<0.02% OF I ₀ MAX	-	-
	p-p ⁽⁵⁾	<1.0mV	<0.1% OF I ₀ MAX	-	-

(1) External current sensing using the voltage amplifier. Effects are measured for a 1 volt current sensing voltage drop

(2) Whichever is greater

(3) Typical temperature coefficients are 0.005% per °C voltage mode; 0.01 % per °C externally sensed current mode

(4) Measured with the common terminal grounded so that the common mode current does not flow through the load or (in current mode) through a sensing resistor

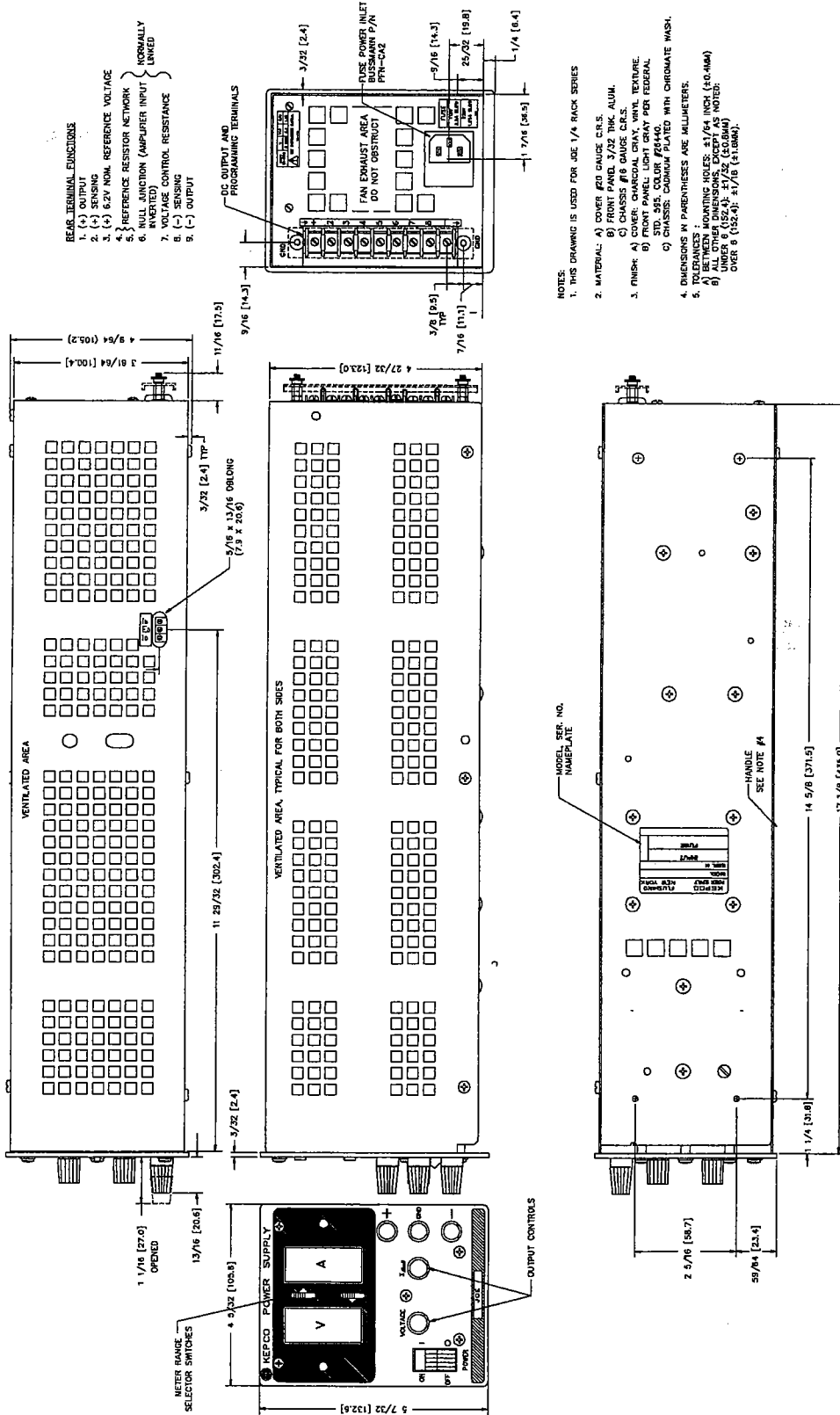
(5) Peak-to-peak ripple is measured over a 20Hz to 10MHz bandwidth.

TABLE 1-2 JQE 1/4 RACK, OUTPUT EFFECTS, AMPLIFIER OFFSETS & REFERENCE SPECIFICATIONS.

- l) **VOLTAGE CONTROL:** 10 turn precision rheostat at the front panel; resolution: 0.05% of E_{0max} . Controls the output voltage from 0 to E_{0max}
- m) **CURRENT LIMIT CONTROL:** A 10 turn precision rheostat at the front panel permits adjustment of the current limit from 1% to 105% of the maximum rated output current (I_0)
- n) **REMOTE ERROR SENSING:** Rear barrier strip terminals provides for connection of the error sensing leads directly at the load, thus compensating for losses due to load current voltage drop. Up to 0.5v per lead can be compensated.
- o) **REMOTE PROGRAMMING:** Rear barrier terminals provide for remote control of the power supply by resistance (control loop uses 1ma with a programming ratio of 1000 ohms per volt) or external control voltages.
- p) **SERIES/ PARALLEL:** Series operation of the JQE Power supplies is possible up to the rated isolation voltage. Parallel operation using "Automatic Parallel" or "Master Slave " parallel operation may be performed.

1-10 SPECIFICATIONS, MECHANICAL (Refer to FIG 1-2 MECHANICAL OUTLINE DRAWING)

- a) **DIMENSIONS:** Refer to Mechanical Outline drawing Fig 1-2
- b) **TERMINATIONS:** Refer to Mechanical Outline drawing Fig 1-2
- c) **FINISH:**
 - 1) **CHASSIS:** cadmium plated, chromate wash
 - 2) **Panel:** Light grey Color #26440 Federal Standard 595
 - 3) **CASE:** Charcoal grey texture
- d) **METERS:** Two dual range (100% and 10% of $E_{0,max}$ and I_{0max}), 2 inch tautband, recessed panel meters, accuracy 3% of full scale reading for output voltage and output current monitoring.
- e) **MOUNTING:** Rack adapter available, see Accessories (paragraph 1-8).
- f) **SHIPPING WEIGHT:** 19lbs. (8.6kg).



- REAR TERMINAL FUNCTIONS
1. (+) OUTPUT
 2. (-) OUTPUT
 3. (+) 6.2V NOM. REFERENCE VOLTAGE
 4. REFERENCE RESISTOR NETWORK
 5. NULL JUNCTION (AMPLIFIER INPUT NORMALLY BIPOLAR)
 6. INVERTED CONTROL RESISTANCE
 7. (+) SENSING
 8. (-) OUTPUT
 9. (-) OUTPUT

- NOTES:
1. THIS DRAWING IS USED FOR JQE 1/4 RACK SERIES
 2. MATERIAL: A) COVER #20 GAUGE C.R.S. B) FRONT PANEL 3/32 THK. ALUM. C) CHASSIS #18 GAUGE C.R.S.
 3. FINISH: A) COVER: CHARCOAL GRAY, W/VNL TEXTURE. B) FRONT PANEL: LIGHT GRAY PDR FEDERAL SPEC. 596. C) CHASSIS: CADMIUM PLATED WITH CHROMATE WASH.
 4. DIMENSIONS IN PARENTHESES ARE MILLIMETERS.
 5. TOLERANCES: A) BETWEEN MOUNTING HOLES: ±1/64 INCH (±0.38MM) B) BETWEEN DIMENSIONS: ±1/32 INCH (±0.76MM) C) DIMENSIONS OVER: ±1/32 INCH (±0.76MM) D) DIMENSIONS UNDER: ±1/64 INCH (±0.38MM) OVER 8 (132.4): ±1/16 (±1.58MM)

FIGURE 1-1 JQE 1/4 RACK MECHANICAL OUTLINE DRAWING

SECTION II-INSTALLATION

2-1 UNPACKING AND INSPECTION

2-2 This instrument has been thoroughly inspected and tested prior to packing and is ready for operation. After careful unpacking, inspect for shipping damage before attempting to operate. Perform the preliminary operational check as outlined in paragraph 2-8 below. If any indication of damage is found file an immediate claim with the responsible transport service.

2-3 TERMINATIONS

- a) FRONT PANEL: Refer to FIG 2-3 and TABLE 2-2.
- b) REAR: Refer to FIG. 2-4 and TABLE 2-3.
- c) INTERNAL ADJUSTMENTS AND CALIBRATIONS: Refer to FIG 2-1 and TABLE 2-1

REFERENCE DESIGNATION	CONTROL	PURPOSE	ADJUSTMENT PROCEDURE
R12	I _o max.adjust	Current Limit Control Cal	par. 5-6
R13	I _b adjust	Control Current Calibration	par. 3-16
R11	E _{1o} , null adjust	Output Voltage Precision Zero	par. 3-16

TABLE 2-1 ADJUSTMENTS AND CALIBRATION

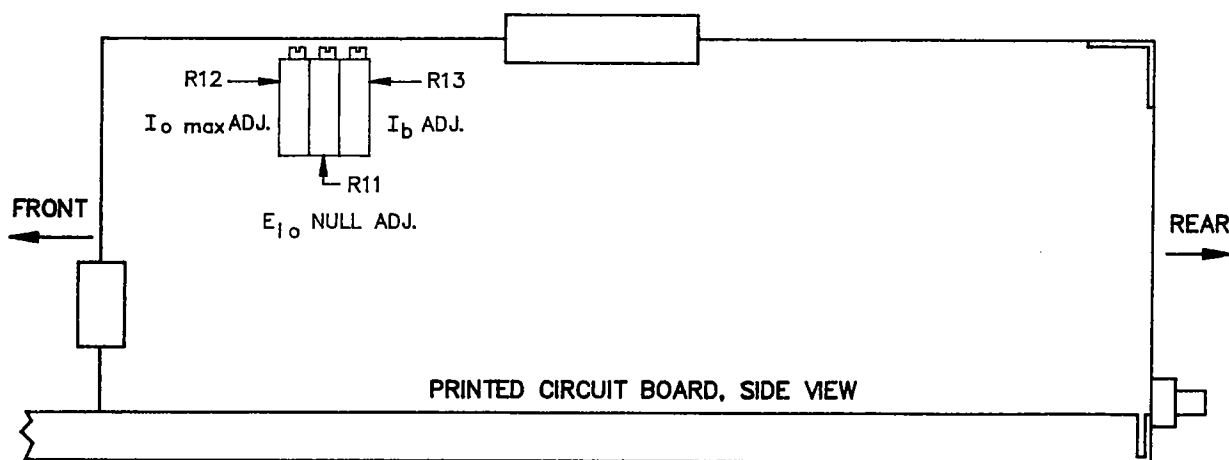


FIGURE 2-1 LOCATION OF INTERNAL CONTROL

2-4 A-C INPUT REQUIREMENTS

- 2-5 If it is desired to switch the AC input power range from 105-125 volts a-c to 210-250 volts a-c, the units must be returned to the factory for authorized service personnel to make the appropriate terminal connections. The user should not attempt to open up the unit and switch terminals on the power transformer. Any attempt to do so could cause damage to the unit as well as bodily harm to the user.

2-6 COOLING

- 2-7 The power transistors and rectifiers in this power supply are maintained within their operating temperature range by means of a high efficiency heat-sink assembly, cooled by an internal fan. SIDE PANEL OPENINGS AND THE TOP OF THE CASE MUST BE KEPT CLEAR FROM OBSTRUCTIONS TO INSURE PROPER AIR CIRCULATION. Periodic cleaning of the interior of the power supply is recommended. If the power supply is rack mounted, or installed into confined spaces, care must be taken that the temperature surrounding the power supply does not rise above + 71°C.

2-8 PRELIMINARY CHECK-OUT

- 2-9 A simple operating check after unpacking and before permanent installation is advisable, to ascertain whether the power supply has suffered shipping damage. Please refer to FIG. 2-3 and FIG. 2-4 for the location of the operating controls and output terminals.
- a) Connect power supply to the 115V a-c line, or refer to paragraph 2-4 for 230V a-c operation if required.
 - b) Turn CURRENT LIMIT CONTROL fully clockwise. Turn VOLTAGE CONTROL fully counterclockwise. Both, VOLTMETER RANGE and AMMETER RANGE SWITCH should be in the "x1" position.
 - c) Turn A-C POWER SWITCH "on". The A-C PILOT LIGHT should be energized. Slowly turn VOLTAGE CONTROL clockwise and observe the gradual increase of the output voltage. Turn counter-clockwise again until about one-tenth of the maximum output voltage is reached. Set VOLTMETER RANGE SWITCH to the "x0.1" position. The VOLT-METER should now read full scale again. Return both, AMMETER and VOLTMETER RANGE SWITCHES to the "x1 " position.

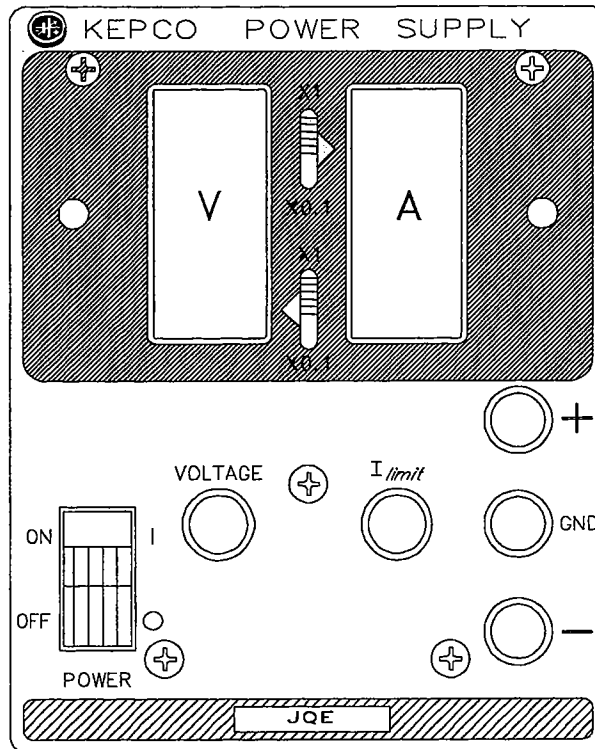


FIG. 2-3 CONTROLS AND TERMINATIONS, JQE 1/4 RACK GROUP FRONT

NO.	TERMINATION OR CONTROL	FUNCTION
1	A-C POWER SWITCH ILLUMINATED	URNS A-C POWER LINE "ON" AND "OFF"
2	VOLTAGE CONTROL	ADJUSTS OUTPUT VOLTAGE FROM 0 TO E_{0MAX}
3	VOLTMETER	MONITORS OUTPUT VOLTAGE 0 TO E_{0MAX} TO $0-E_{0MAX}/10$
4	VOLTMETER RANGE SWITCH	CHANGES METER RANGE FROM 0 TO E_{0MAX} TO $0-E_{0MAX}/10$
5	AMMETER	MONITORS OUTPUT CUREN FROM 0 TO I_{0MAX} TO $0-I_{0MAX}/10$
6	AMMETER RANGE SWITCH	CHANGES METER RANGE 0 TO I_{0MAX} TO $0-I_{0MAX}/10$
7	CUREN LIMIT CONTROL	ADJUSTS CURRENT LIMIT FROM 0 TO 105%
8	PLUS (+) GROUND	POSITIVE LOAD OR MONITORING TERMINAL
9	GROUND	GROUNDING TERMINAL
10	MINUS (-) OUTPUT	NEGATIVE LOAD OR MONITORING TERMINAL

TABLE 2-2 CONTROLS AND TERMINATIONS, JQE 1/4 RACK GROUP FRONT

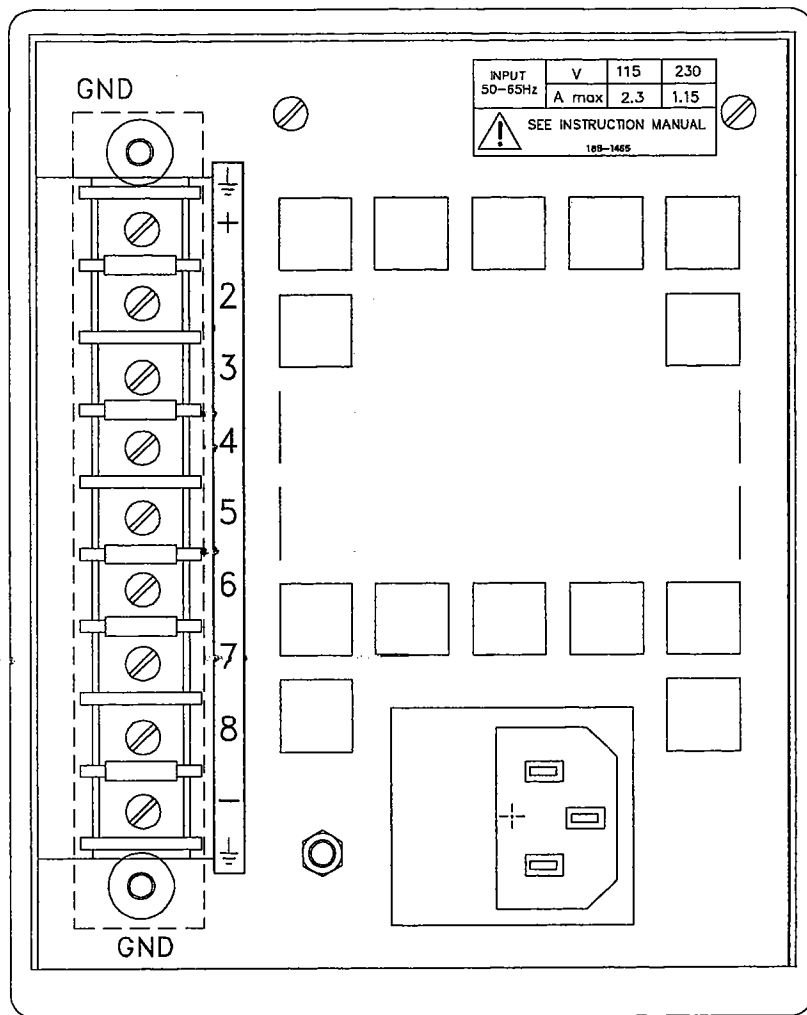


FIGURE 2-4 REAR TERMINATIONS JQE 1/4 RACK GROUP

NO.	TERMINATION	FUNCTION
1	REAR BARRIER STRIP WITH THESE TERMINALS	1 POSITIVE (+) LOAD TERMINAL 2 POSITIVE (+) ERROR SENSING TERMINAL (COMMON) 3 REFERENCE VOLTAGE (Er) (+ 6.2 V nom., 1 mA max.) 4 REFERENCE RESISTOR (Rr) 5 REFERENCE RESISTOR (Rr) 6 NULL JUNCTION 7 VOLTAGE CONTROL (Rvc) 8 NEGATIVE (-) ERROR SENSING TERMINAL 9 NEGATIVE (-) LOAD TERMINAL
2	A-C INPUT AND MAIN FUSE (F201)	ACCEPTS THREE-WIRE A-C POWER LINE CORD (SUPPLIED) PROTECTS MAIN TRANSFORMER AND INPUT CIRCUIT

TABLE 2-3 REAR TERMINATIONS JQE 1/4 RACK GROUP

PRELIMINARY CHECK-OUT (cont'd):

- d) Place a short circuit across the output. Turn CURRENT LIMIT CONTROL counter-clockwise. Turn A-C POWER SWITCH "on". Slowly turn CURRENT LIMIT CONTROL clockwise and observe the gradual increase in output current. Turn counter-clockwise until about one tenth of the maximum output current is reached. Set AMMETER RANGE SWITCH to the "x0.1" position. The AMMETER should now read full scale again. Return AMMETER RANGE SWITCH to the "x1" position again.

CAUTION

Do not switch to the "x0.1" ranges before the output of the power supply (voltage or current) is below 10% of the maximum rated values.

2.10 INSTALLATION (Refer to FIG. 1-1 "Mechanical Outline Drawing").

- 2-11 For all installations into confined spaces, care must be taken that the temperature immediately surrounding the unit does not exceed the maximum specified ambient temperature (71°C).

2-13 GROUNDING

WARNING

KEEP INSTRUMENT GROUNDED WHILE IT IS CONNECTED TO THE A-C POWER SOURCE

- a) **A-C GROUND.** The power supply is equipped with a 3-wire safety line cord and polarized plug. The third (green) wire in the line cord is connected to the chassis and the case of the unit. The 3-wire line cord must be connected to a grounded a-c power outlet. If a two-terminal a-c power outlet in combination with an adaptor is used, it is imperative that the chassis of the power supply be returned to a-c ground with a separate lead.
- b) **D-C GROUND.** The d-c output is isolated from the a-c power line and from any direct connection to chassis and ground. The maximum output voltage which can be supported between either output terminal and ground or chassis is 500V d-c, plus the maximum output voltage of the power supply. Either side of the output may be grounded. Convenient grounding terminals are provided at the front panel binding post and at the rear barrier-strip.

SECTION III—OPERATION

3-1 STANDARD POWER SUPPLY OPERATION, LOCAL CONTROL

3-2 GENERAL. The JQE ¼ Rack Power Supply is shipped from the factory with five (5) removable jumper links in place at the rear barrier strip (TB1) as shown in FIG. 3-1. THESE LINKS MUST BE IN PLACE AND SECURED TIGHTLY for standard local operation. Loose terminal links or loose wires at the barrier strip will cause malfunction of the power supply.

3-3 LOAD CONNECTION. The load may be connected in any of the four ways illustrated in FIG.'s 3-2/3-3. Load connecting wires should be as heavy as practicable since load wire voltage drops will degrade static performance. Twisting of load wires will help preserve the dynamic performance of the JQE power supply.

3-4 REMOTE ERROR SENSING

3-5 Specified d-c performance directly at the load requires the use of remote error sensing. A twisted, shielded pair of wires from the sensing terminals directly to the load will compensate for load wire voltage drops up to 0.5 volt per wire (Refer to FIG. 3-3). Observe polarities: The negative sensing wire [from terminal (8)] must go to the negative load wire, and the positive sensing wire [from terminal (2)] goes to the positive load wire.



FIG. 3-1
STANDARD JUMPER—
LINK CONNECTIONS
JQE ¼ RACK GROUP

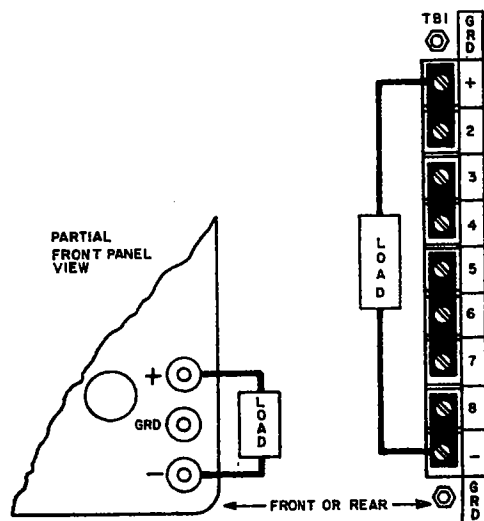


FIG. 3-2 LOAD CONNECTION
WITHOUT ERROR SENSING

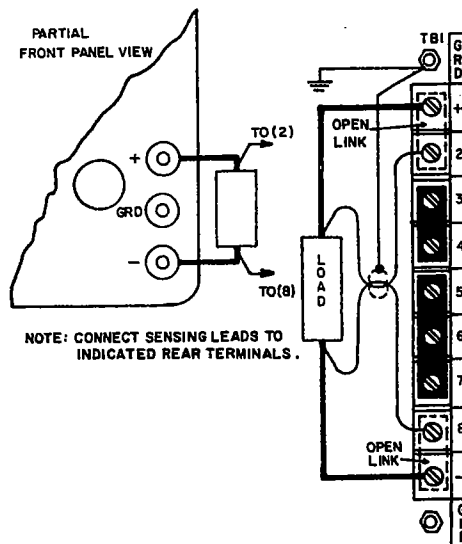


FIG. 3-3 LOAD CONNECTION
WITH ERROR SENSING.

NOTE: If Error Sensing is not used, Specified Performance must be measured at terminals (2) and (8) of TB1.

3-6 OUTPUT ADJUSTMENT

3-7 Once the load is connected to the output terminals of the power supply as described in the previous paragraphs, the operating voltage may be adjusted to the desired value by turning the VOLTAGE CONTROL and observing the panel VOLTMETER. The CURRENT LIMIT CONTROL may be set fully clockwise, and will in this position provide limiting at 105% of the maximum rated output current. The CURRENT LIMIT CONTROL may be set to intermediate values, as desired, by first turning the A-C POWER SWITCH to the "off" position and then placing a short circuit across the output. Now the required operating current is adjusted by turning the CURRENT LIMIT CONTROL to the value needed, plus $\approx 2\%$. The output current will now limit sharply at this value. After the short is removed from the output, the load is reconnected and the power supply is ready for operation.

3-8 INTRODUCTION TO REMOTE PROGRAMMING

3-9 GENERAL. Electrically, the power supply consists of the raw d-c source (E_U), the pass element (E_P), the d-c error amplifier (A) and a comparison circuit which resembles a four-arm electrical bridge. (Refer to FIG. 3-4). The elements of the bridge are arranged to produce a virtual zero at the amplifier input when the bridge circuit is at balance ($V_{AA'} = 0$, when $E_r/R_r = E_o/R_{VC}$). Any tendency for the output voltage to change in relation to the reference voltage (E_r) creates an error signal (ϵ) which, amplified by the d-c error amplifier, tends to correct the output voltage towards restoration of bridge balance.

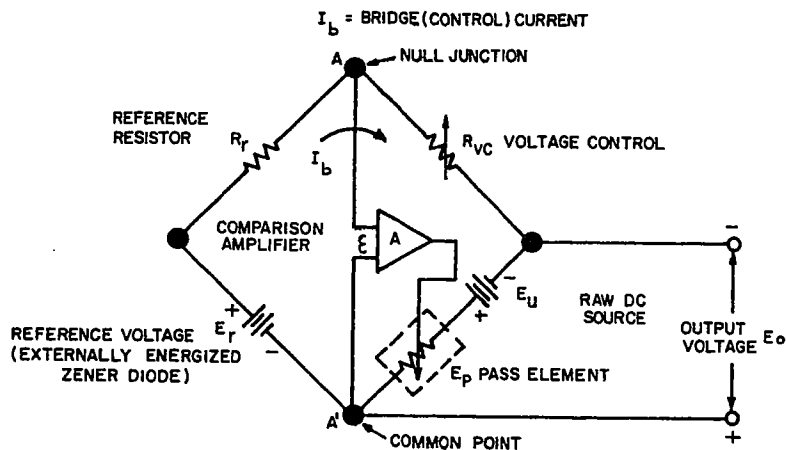


FIG. 3-4 KEPKO POWER SUPPLY AND COMPARISON BRIDGE CIRCUIT.

3-10 EQUATIONS SHOWING THE OPERATION OF THE KEPKO BRIDGE

3-11 The following relationships govern the operation of the Kepco Bridge at balance, i.e., with $V_{AA'} = 0$:

$$a) \quad \frac{E_o}{E_r} = \frac{R_{VC}}{R_r} \quad (\text{Eq. 1})$$

Where: E_o = Output Voltage

$$\frac{E_r}{R_r} = I_b \quad (\text{Eq. 2})$$

E_r = Reference Voltage

R_r = Reference Resistance

R_{VC} = Voltage Control Resistance

I_b = Control Current

$$E_o = I_b \times R_{VC} \quad (\text{Eq. 3})$$

b) The ratio of the number of ohms control-resistance needed per volt output is termed the "CONTROL RATIO". It is nominally 1000 ohms per volt in the JQE 1/4 Rack Power Supplies and can be precisely adjusted as shown in paragraph 3-12.

- c) As can be seen from equation (1), the output voltage E_o can be controlled by varying any one of the three quantities. Rewriting equation (1) we have:

$$E_o = E_r/R_r \times R_{VC}$$

The ratio E_r/R_r constitutes the control current I_b . (Eq. 2).

- d) Therefore, we can write: $E_o = I_b \times R_{VC}$ (Eq. 3).

Making I_b a precision quantity (precision control current adjustment is described in paragraph 3-12), establishes a precise programming ratio, so that the accuracy of E_o is solely dependent upon R_{VC} . This mode of operation is referred to as "RESISTANCE PROGRAMMING" and is covered in detail in paragraph 3-19.

- e) Rewriting Equation (1), $E_o = E_r \times R_{VC}/R_r$, leaving the ratio R_{VC}/R_r fixed, we can make E_r the variable which controls E_o .
- f) Other modes of control are possible; some of them are described in the following paragraphs.

NOTE: For all programming and adjustment components, use high quality, wire-wound, or metal film resistors with a T.C. of 20 p.p.m. or better.

3-12 ADJUSTMENTS FOR EXACT PROGRAMMING RATIO

3-13 Referring to equation (3): $E_o = I_b \times R_{VC}$, it is seen that if $I_b = 1$ mA, 1000 ohms of control resistance (R_{VC}) is needed for each volt of output. Once I_b is therefore precisely calibrated, the accuracy and linearity of the output voltage will then solely depend upon R_{VC} .

3-14 Again referring to equation (3), we see that if $R_{VC} = 0$ (shorted out), the output voltage should be zero. A small negative offset voltage (in the millivolt range) exists however under this condition at the output.

3-15 Both inaccuracies, the slightly larger control current (I_b) and the small negative offset voltage may be adjusted by means of the built-in controls to provide a linear and precise programming ratio.

3-16 PROCEDURE, PRECISION PROGRAMMING RATIO ADJUSTMENT (Refer to FIG. 3-5).

- a) Equipment Required:

- 1) Precision digital or differential voltmeter (M1).
- 2) Precision resistor, accuracy comparable to M1. The value is not important, but must be known. For every 1000 ohms, 1 volt will appear across M1. (R_{VC}).
- 3) Single pole, single throw switch (S1).

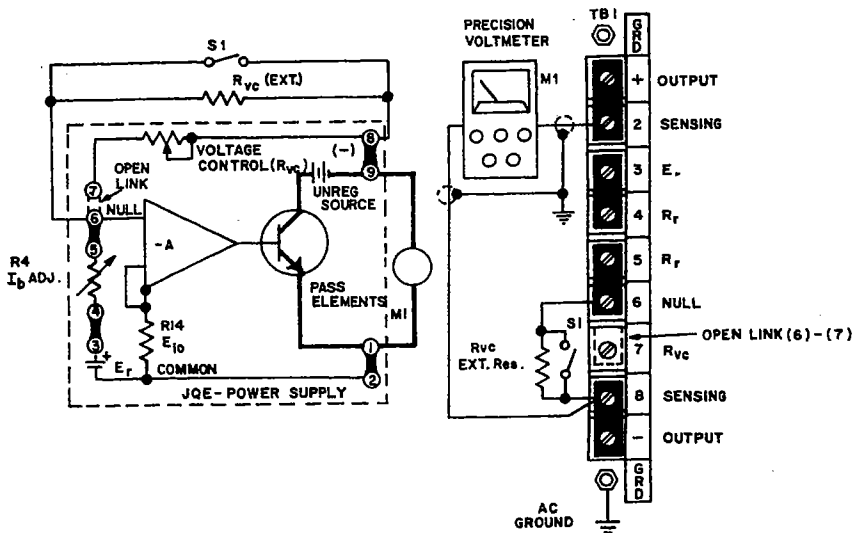


FIG. 3-5 CONNECTIONS FOR PRECISION PROGRAMMING RATIO ADJUSTMENT

- b) Connect calibration set-up as shown in FIG. 3-5 and connect the JQE power supply to the a-c power line.
- c) With S1 "open", and $R_{VC} = 5K$ ohms for example, approximately 5 volts will be read-out on M1. Adjust " I_b Adj." (control current calibration, R13, see FIG. 2-1 for location) until exactly 5 volts are read-out on M1.
- d) Close S1 and note deviation from zero on M1 (approx. 2 to 8 mV negative). Adjust " E_{i0} null" (zero adjustment, R11, see FIG. 2-1 for location) until exactly zero volts are read-out on M1.
- e) Open S1 and check the 5 volt reading. Repeat "c" and "d", as necessary to achieve the desired accuracy. FIG. 3-6 below shows graphically how the programming ratio can be precision adjusted.

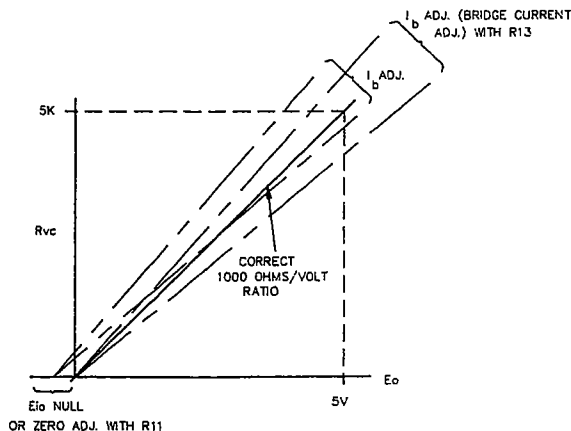


FIG. 3-6 ESTABLISHING PROGRAMMING LINEARITY

3-17 GENERAL RULES FOR REMOTE PROGRAMMING

3-18 All remote programming applications require the observance of a few basic rules to insure proper functioning of the power supply in the particular mode of operation selected. These rules should be remembered before each application and especially if malfunctioning of the programming set-up is experienced.

- 1) **GROUNDING.** Ground loops due to multiple and indiscriminate grounding of various equipment are the cause for the majority of complaints about "high ripple or noise". They can be easily avoided by grounding the power supply output-load circuit at **one single point**, to which all shielded cables and equipment cases are connected. Frequently, high ripple is introduced by programming-sources or instruments used at the input (null junction of the d-c error amplifier), although all grounding rules have been observed. This may be due to the external instrument's or source's close coupling to the a-c line. In such cases, isolation (i.e. battery operated devices) is the only answer. It must also be remembered, that input and output of the power supply are "common", so that if the output is not grounded, the input source must be isolated for the maximum output voltage to be programmed, plus the amount of voltage the common is "off ground".

General Rules for Remote Programming (Cont'd)

- 2) CONNECTIONS. All external connections, especially those at the screw-terminals on the rear barrier strip, must be tight. Serious malfunctions may be caused by open feedback loops or other open programming connections.
- 3) INPUT SOURCES. If specified performance is expected using remote programming, external input or reference sources must have specifications equal to or better than that of the power supply.
- 4) PROGRAMMING RESISTORS. Programming resistors should be high-quality wirewound or metal-film units with temperature coefficients of 20 parts per million or better. Their wattage rating must be at least ten times the actual power dissipated. Although the control current through these resistors is only 1 mA, high peak currents may be generated when large voltage excursions are programmed. The peak currents can equal the magnitude of the change in output voltage, divided by the final resistance of the programming resistor. (If, for example, the voltage step is from 50 volts to zero ($\Delta E_o = 50$ V), and the final resistance of the programming resistor is $\Delta R_{VC} = 2$ ohms, $I_{peak} = 25$ A). The duration of the peak error current depends upon the size of the output capacitor of the JQE model. I_{peak} decays exponentially as the output voltage assumes the final value.

If step-switch devices are used in resistance programming, they must be of the "make before break" variety to avoid opening the feedback loop and thereby causing momentary large voltage excursions. Programming resistors must have a voltage rating at least equal to the maximum output voltage of the power supply.

3-19 OUTPUT VOLTAGE PROGRAMMING WITH EXTERNAL RESISTANCE

The output voltage of the JQE Power Supply may be controlled remotely by an external resistance, replacing the built-in voltage control resistance which will be disconnected at the rear barrier strip. The value of the programming resistance may be calculated by referring to the transfer function derived earlier (Eq. 1):

$$E_o = R_{VC} (E_r/R_r)$$

Since $E_r/R_r = I_b$ (Eq. 2), it follows $E_o = I_b \times R_{VC}$ (Eq. 3).

Referring to Equation (3), we see that since I_b is 1 mA in the JQE supplies and can be precisely adjusted as shown in paragraph 3-12, for every volt of output, 1000 ohms control resistance must be provided. This corresponds to a "Programming Ratio" of 1000 ohms per volt.

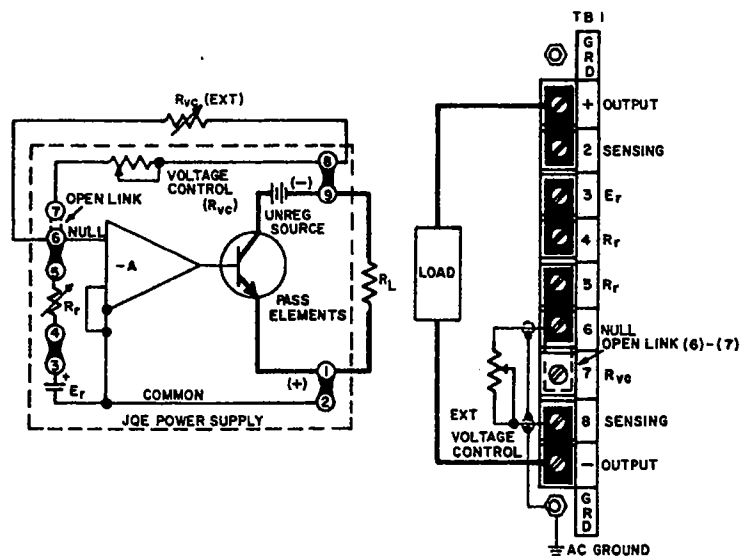


FIG. 3-7 REMOTE RESISTANCE PROGRAMMING

3-20 PROCEDURE (Refer to FIG. 3-7)

- a) Determine value of programming resistor(s) for output voltage desired.
- b) Using two-wire, shielded cable, connect the chosen resistors to terminals (6) and (8). Connect the shield to the "ground" terminal.
- c) The output voltage will vary from zero to $(1 \text{ mA}) \times (R_{VC})$, as R_{VC} is adjusted from zero to its maximum value.

3-21 PROGRAMMING BY CONDUCTANCE

3-22 For special applications, the output voltage E_o can be adjusted by varying the control current. The relationship governing this type of programming is:

$$E_o = E_r(R_{VC})(G), \quad (\text{Eq. 4})$$

Where: $G = 1/R_r + R_x =$ programming conductance.

$E_o =$ Output Voltage

$E_r =$ Reference Voltage

$R_{VC} =$ Voltage Control Resistance

$R_r =$ Reference Resistance

$R_x =$ Programming Resistor

or
$$E_o = \frac{E_r}{R_r + R_x} (R_{VC})$$

Since $E_r/R_r = I_b$ and $E_o = I_b \times R_{VC}$, with R_{VC} fixed, the output voltage varies proportionally to value of I_b . Changing I_b with the help of an additional resistor in series with R_r results in an inversely proportional change of I_b , since now:

$$I_b = E_r/(R_r + R_x)$$

This method of output voltage adjustment is therefore referred to as conductance programming.

3-23 Conductance programming is a reciprocal function when analyzed in terms of resistance, but perfectly proportional: ($E_o \propto 1/R_x$)

Conductance programming can be very useful, especially over a limited range of output voltage. Another distinctive advantage of this type of programming is the "built-in" safety feature. Should the programming circuit open accidentally, the programming resistance becomes infinite, the conductance is zero, and consequently, the output voltage becomes zero.

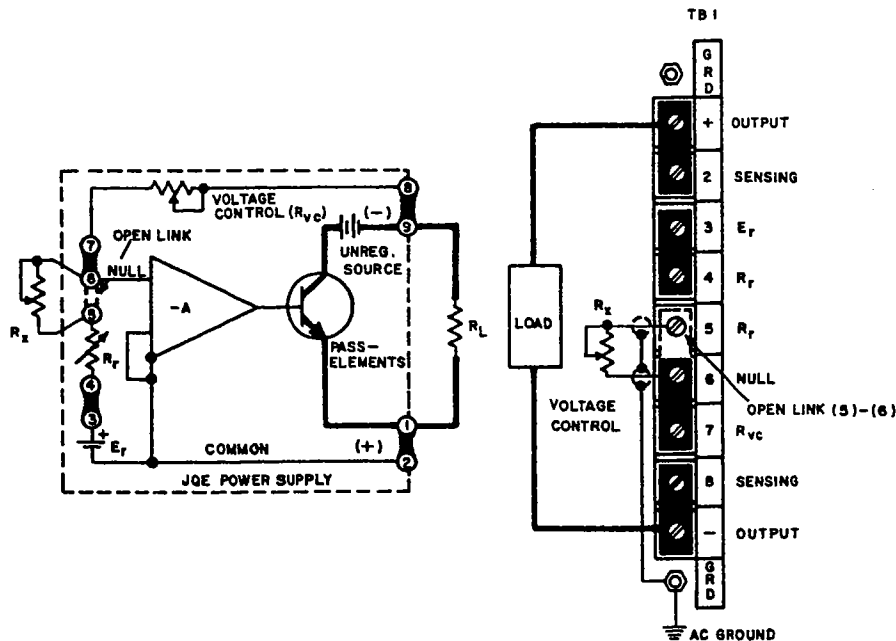


FIG. 3-8 REMOTE CONDUCTANCE PROGRAMMING

3-24 PROCEDURE (Refer to FIG. 3-8)

Example: E_o desired = 3 to 5 volts.

- a) Select R_{VC} for maximum desired output voltage E_o .

$$R_{VC} = E_o/I_b, R_{VC} = 5V/1 \text{ mA} = 5K \text{ ohms.}$$

- b) A change of E_o to 3 volts requires a control current change of:

$$\Delta I_b = \Delta E_o/R_{VC} = 2 \text{ volts}/5K \text{ ohms} = 0.4 \text{ mA}$$

- c) Since $I_b = E_r/R_r = 1 \text{ mA}$, the additional resistance needed is:

$$I_b (R_r + R_x) = E_r, R_x = E_r/I_b - R_r \text{ or } R_x = 6 \text{ volts}/0.6 \text{ mA} - 6K = 4K \text{ ohms.}$$

A 4K ohm, WW, low T.C. potentiometer in series with R_r will change the output voltage from 3 to 5 volts when varied from zero to 4K ohms.

NOTE: A word of caution may be in order in regard to the changing of the control current. The 1 mA value has been selected for maximum stability in the zener reference circuit. A large departure from this value is not advisable. If a $\pm 50\%$ change in I_b is not sufficient to achieve the desired voltage swing, an external reference supply can be used.

3-25 REMOTE PROGRAMMING WITH EXTERNAL CONTROL VOLTAGE

- 3-26 The output voltage of the power supplies in the JQE group may be controlled by an external, variable voltage source, which supplies the necessary control current, formerly delivered by the (now disconnected) internal, fixed reference source. This mode of operation is termed "Voltage Programming". It can be mathematically expressed by referring to basic equation (1):

$$E_o/E_r = R_{VC}/R_r \quad (\text{Eq. 1})$$

$$\text{Solving for } E_o = E_r R_{VC}/R_r \quad (\text{Eq. 5})$$

- 3-27 As seen from the expression (Eq. 5), if the ratio R_{VC}/R_r (which represents the closed loop gain of the system) is held constant, E_o will vary linearly with E_r , the external programming voltage. The above expression (Eq. 5) is seen to be the transfer function for an operational amplifier in the inverting configuration. The voltage programmed power supply does in fact become a unipolar power amplifier with very high power gain but with limited frequency response. (Refer to FIG. 3-9). The limited frequency response is largely due to the effect of the output capacitor (C_o), acting as a low-pass filter and preventing the output voltage (E_o) from varying rapidly. The output voltage may be varied over the full range, bounded on the high end by the maximum rated value. A practical example to illustrate component selection for remote control by voltage is given in paragraph 3-28.

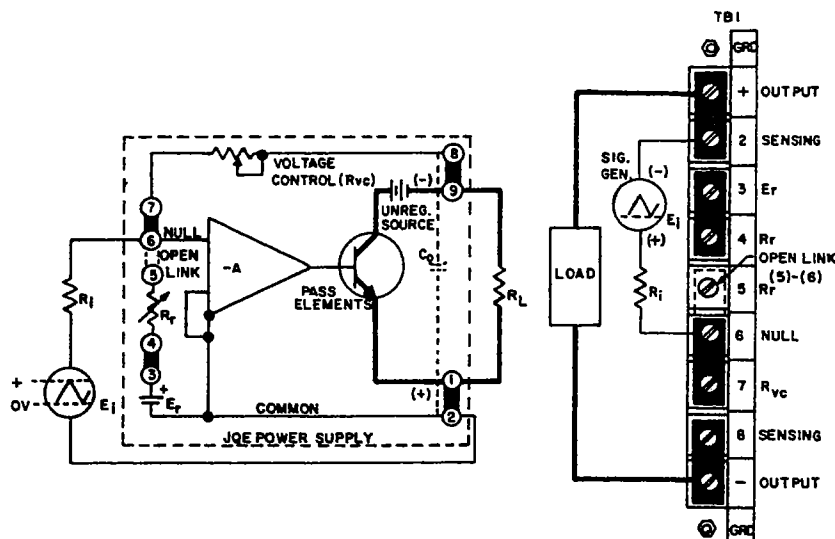


FIG. 3-9 JQE 1/4 Rack IN THE OPERATIONAL AMPLIFIER MODE.

3-28 Example: A Kepco Model JQE 36-3M is to be voltage programmed over its full range (0 to 36V) by a triangular, positive increasing source with a peak output voltage (E_i) of 2 volts, which is able to deliver at least 1 mA control current. Since the required voltage gain is: $E_o/E_i = 36/2 = 18$, the ratio R_{VC}/R_i must also equal 18. If the internal voltage control is retained, in this case, since $R_{VC} = 40K$ ohms, R_i must equal $40K/18 = 2.22K$ ohms. FIG. 3-9 shows the JQE Power Supply as an operational amplifier and the necessary rear barrier connections for this mode of operation. As the input source varies from 0 to 2V, the JQE output voltage will change from 0 to 36 volts.

3-29 CONSTANT CURRENT OPERATION

3-30 The JQE power supply can be set up to deliver constant current by the addition of an external sensing resistor and a current control. In the constant current operating mode, the voltage comparison bridge is interconnected with an external current sensing resistor, R_s , and a current control, R_{CC} , (as shown in FIG. 3-10), while the voltage control (R_{VC}) is disconnected. The voltage comparison bridge, instead of monitoring the **output voltage** as before, is now stabilizing the **sensing voltage** which is proportional to the **output current**. In this way, an adjustable constant load current is obtained. Characteristic of the constant current supply is its ability to change its **output voltage** automatically in order to maintain a **constant current** through a range of possible load resistance. The range of output voltage that the supply can deliver and simultaneously maintain constant current, is referred to as the "COMPLIANCE VOLTAGE". For each JQE model, it is equal to its rated output voltage.

3-31 The current sensing resistor R_s is chosen to develop a 1 volt drop at the maximum desired current. R_s is calculated by dividing this current into one volt. The value of R_s is not critical and can be the nearest standard resistance available. Several facts should be kept in mind however, when choosing R_s . A compromise must be made between a large and small value. While a large value is desirable for good current stabilization, it is less desirable in view of the power dissipated across it. It must be remembered that all the load current is flowing through R_s and the comparison amplifier input is connected across it. It is therefore vital that all extraneous changes across R_s , i.e. resistance change due to temperature, are kept to a minimum. A high quality, low T.C. (20ppm) resistor, at least ten times the actual wattage needed, is therefore strongly recommended. In practice, R_s is usually selected for a 1 volt sample at the maximum output current desired. If more than a 50:1 ratio of output is needed, several values of R_s should be selected and switched in or out as required.

3-32 The current control resistor, R_{CC} , is chosen on the basis of the control ratio of the Kepco comparison bridge, and V_s , the maximum voltage across R_s . If R_s was selected for 1 volt drop, then $V_s = 1$ volt and $R_{CC} = V_s$ times (control ratio), or

$$R_{CC} = 1 \text{ volt} \times 1000 \text{ ohm}/1 \text{ volt} = 1000 \text{ ohms.}$$

A high quality, low T.C. (20ppm) resistor is recommended for R_{cc} . If R_{cc} is *not* selected for 1 volt drop, the control ratio will of course differ from the standard 1000 ohm/volt and R_{cc} must be recalculated for the new control ratio.

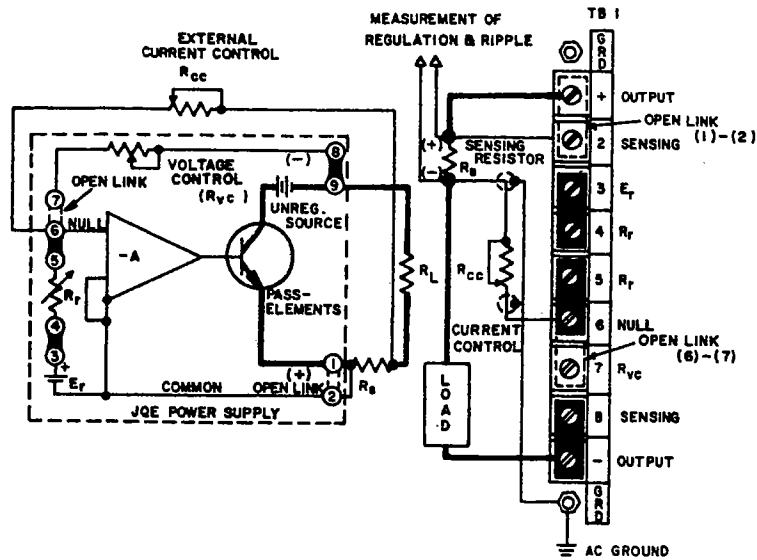


FIG. 3-10 CONSTANT CURRENT OPERATING MODE

3-33 PROCEDURE (Refer to FIG. 3-10)

The actual component selection for current stabilization is perhaps best shown by a practical example. A JQE 100-1M is to be set up for stabilized current output from 6mA to 300mA. (1:50 ratio).

- a) R_s is chosen by: $R_s = 1 \text{ volt}/0.3\text{A} = 3.33 \text{ ohm}$.
 $P_{diss} = V_s \times I_{max} = 1 \text{ volt} (0.3\text{A}) = 0.3 \text{ watts}$.
 Three 10 ohm, 1 W, wire-wound resistors, connected in parallel, will be satisfactory.
- b) The control resistance R_{cc} is found by calculating its limits:
 $R_{cc} (\text{max.}) = V_s \text{ max. (control ratio)} = 1 \text{ V} (1000 \text{ ohms/V}) = 1000 \text{ ohms}$.
 $R_{cc} (\text{min.}) = V_s \text{ min. (control ratio)} = 20\text{mV} (1000 \text{ ohms/V}) = 20 \text{ ohms}$.
 As R_{cc} is therefore varied from 20 ohms to 1000 ohms, the output current will vary from 6 to 300mA. The compliance voltage will change in the same ratio (50:1), its instantaneous value depending on the instantaneous load resistance.
- c) The full output current range (1mA to 1A = 1:100) could be covered if two separate sensing resistors were to be calculated and switched into the sensing circuit. One would cover a range of 50:1, (1mA to 50mA) and the other a range of 50mA to 1A (1:20) and both would be calculated on the basis of a 1 volt sample at maximum current:
 - a) R_1^s (for 1mA to 50mA) = $1\text{V}/50\text{mA} = 20\Omega$ (0.5 watt).
 - b) R_2^s (for 0.05A to 1A) = $1 \text{ V}/1\text{A} = 1\Omega$ (10 watt).

3-34 SERIES OPERATION

3-35 GENERAL. Kepco JQE Power Supplies can be series-connected for increased voltage output, provided the specified limits on voltage to chassis are not exceeded. When series-connected, the supplies should be protected by means of a semi-conductor diode across the output terminals of each power supply, as shown in FIG. 3-11. The peak inverse rating of these diodes must be at least as large as the output voltage of the supply to which they are connected. The continuous current rating of the diodes should be at least as great as the maximum output current of the interconnected supplies.

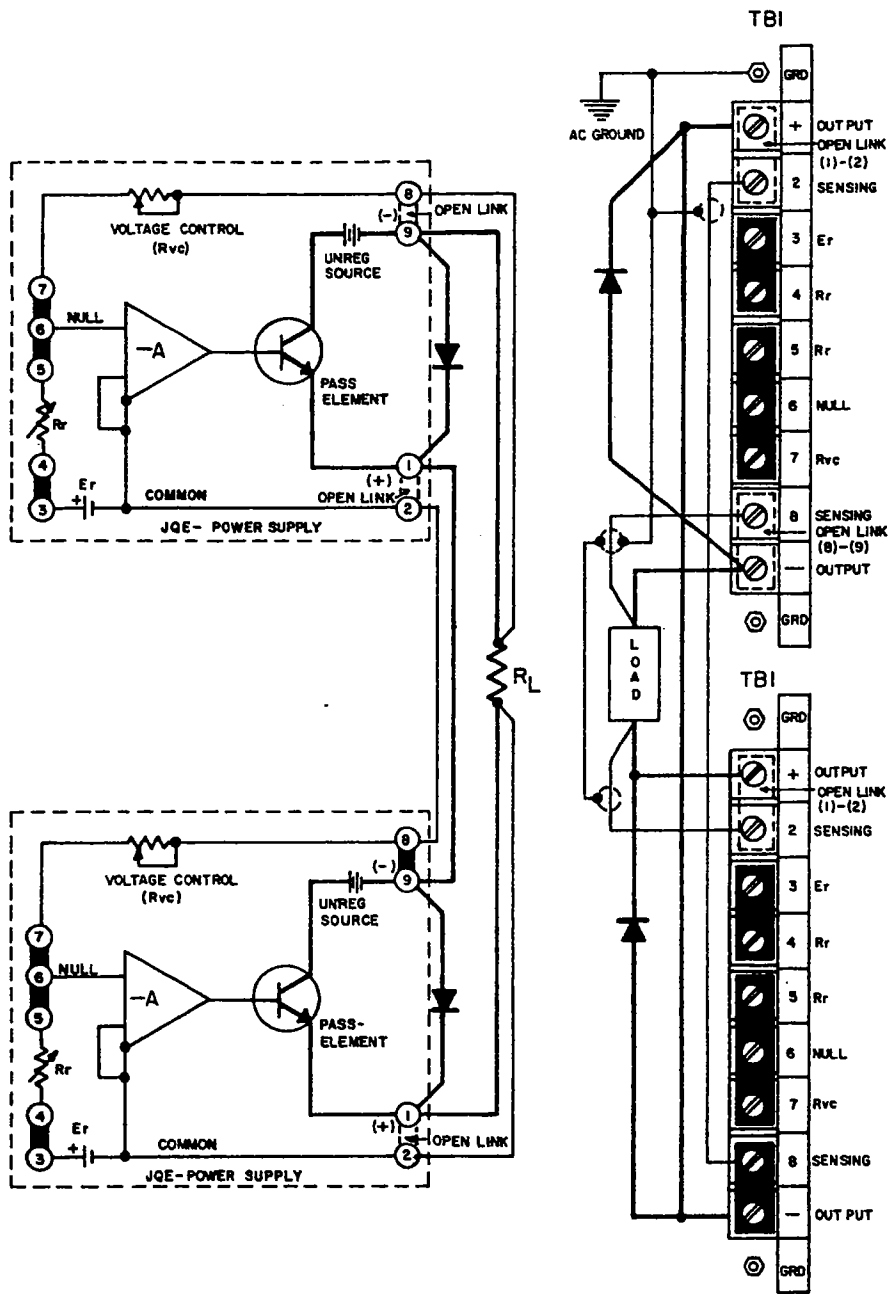


FIG. 3-11 AUTOMATIC SERIES CONNECTION OF JQE POWER SUPPLIES

3-36 PROCEDURE

- a) Connect load as shown in FIG. 3-11. Keep voltage drop in load wires as low as practical by using heavy gauge wire.
- b) Connect protective diodes across respective output terminals.
- c) Remove jumper links as shown and connect error sensing leads. These leads carry negligible current and should be approximately #18 gauge wire.
- d) Turn supplies "on" and adjust voltage on either control as required.

3-37 An alternate method of series-connecting two or more power supplies is shown in FIG. 3-12. The basic difference between the "Automatic" series connection, shown in FIG. 3-11, and the "Master-Slave" connection (FIG. 3-12) is that with the former connection the outputs of both supplies may be controlled or programmed individually, while with the latter method only the "Master" supply is controlled, while the "Slave" supply follows the command of the "Master" in a ratio which may be pre-determined by the user. The "Master-Slave" series connection is therefore often termed an "Automatic Tracking" configuration.

3-38 The principle of operation of the "Master-Slave" series connection is as follows:

As seen from FIG. 3-12, the reference voltage of the "Slave" supply is disconnected and its input (null junction) is connected (via R_t) to the output of the "Master" supply. Since the control current for the "Slave" supply is thereby derived from the "Master", the "Slave" output is thus completely dependent on the "Master" supply output:

$$E_{os} = E_{om} (R_{vcs}/R_t)$$

Where: E_{om} = Output Voltage, Master
 E_{os} = Output Voltage, Slave
 R_t = Tracking Resistor
 R_{vcs} = Voltage Control Resistor, Slave.

As seen from the equation, if the tracking resistor (R_t) is made equal in value to the voltage control resistor of the "Slave" (R_{vcs}), a tracking ratio 1:1 is achieved, and the output of the "Slave" will equal that of the "Master". If a single load is connected to the series combination (FIG. 3-12), twice the "Master" output is applied to it. If separate loads are connected, identical voltages are applied to the individual loads. The ratio E_{os}/E_{om} can be readily changed if the application so requires by simply changing either R_{vcs} or R_t .

3-39 PROCEDURE

- Connect load(s) as shown in FIG. 3-12.
- Remove jumpers as shown and connect error sensing leads if required.
- Turn supplies "on" and adjust output on the "Master" supply as required.

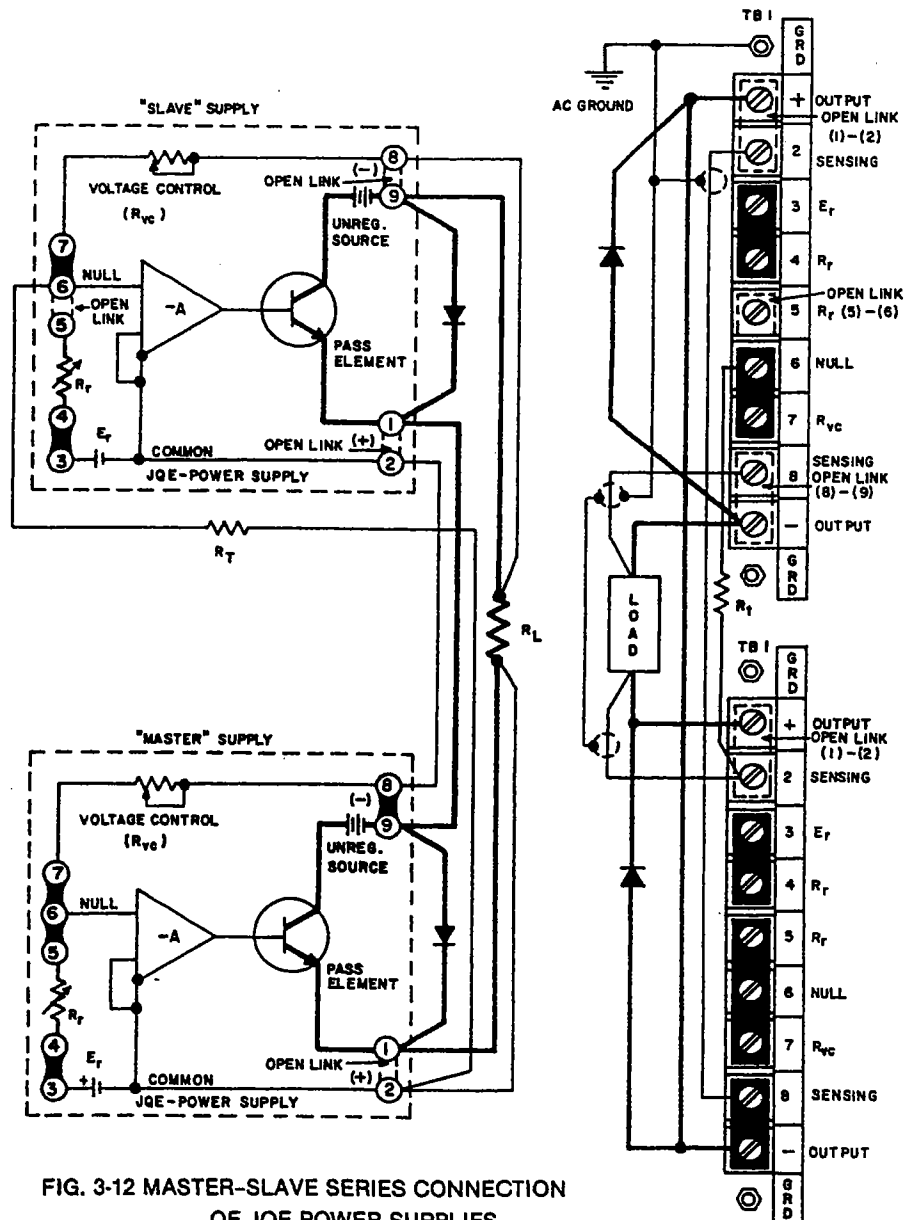


FIG. 3-12 MASTER-SLAVE SERIES CONNECTION OF JQE POWER SUPPLIES

3-40 PARALLEL OPERATION

3-41 GENERAL. Kepco JQE Power Supplies can be parallel connected for increased load current output. As in the previously described series connections, an "Automatic" or a "Master-Slave" connection method can be chosen. The basic difference between the two suggested methods is the manner in which the output is controlled. The "Automatic" method requires individual output control from each power supply, while with the "Master-Slave" method, single control is exercised from the "Master" supply. For either method, some general rules apply which should be observed in paralleling power supplies:

- 1) Connect only supplies with identical compliance voltage range.
- 2) Error sensing (from either supply) may be used as shown in the diagrams. Close barrier-strip links if this is not desired.
- 3) Load wires should be as short as practicable. Select the wire gage as heavy as possible and twist tightly. Approximately equal lengths of wire should be used.
- 4) Common a-c power turn-on for all supplies is recommended.

3-42 AUTOMATIC PARALLEL CONNECTION. Each supply is set approximately to the desired output voltage with its respective Current Limit Control at factory adjusted value ($105\% I_{O \max.}$). After paralleling the two power supplies, one of the supplies (supply #1) will inherently be at a slightly higher output voltage than the other (supply #2). Consequently, supply #1 will deliver all the load current up to the setting of its Current Limit Control and enter the Current Limit Mode of operation. As the load is increased beyond the limit of supply #1, supply #2 takes over and delivers the additional current, operating in the Voltage Mode. The Current Limit Control setting of supply #1 can now be decreased, so that approximately equal current sharing is obtained. FIG. 3-13 shows in form of a diagram, how the two supplies operate in parallel, with their respective Current Limit Control at the factory adjusted value ($105\% I_{O \max.}$). From the diagram, we see that load current steps greater than the current delivered by supply #2 will introduce an error in load effect measurement. This error is due to the difference voltage between supply #1 and supply #2.

CAUTION

When using the "AUTO-PARALLEL" method, *avoid turning the voltage control of only one supply close to zero*. This precaution is necessary to prevent damaging currents in the voltage control resistor, as its limiting resistance is lowered.

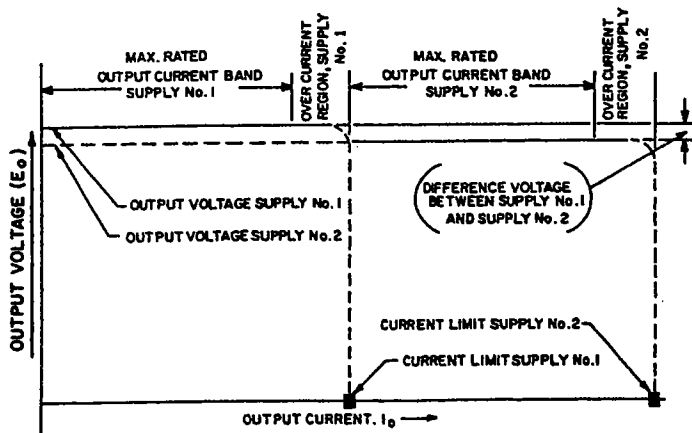


FIG. 3-13 PARALLEL OPERATION, JQE SUPPLIES.

3-43 PROCEDURE (Refer to FIG. 3-14)

- a) Connect units as shown in FIG. 3-14. Open SW-1 and connect to line.
- b) Adjust both units to the approximate output voltage desired.
- c) Close SW-1. Observe load current meters M1 and M2. Adjust Current Limit Control on the unit showing the higher current on its load current meter. Turn Current Limit Control counter-clockwise until currents on M1 and M2 are approximately equal.

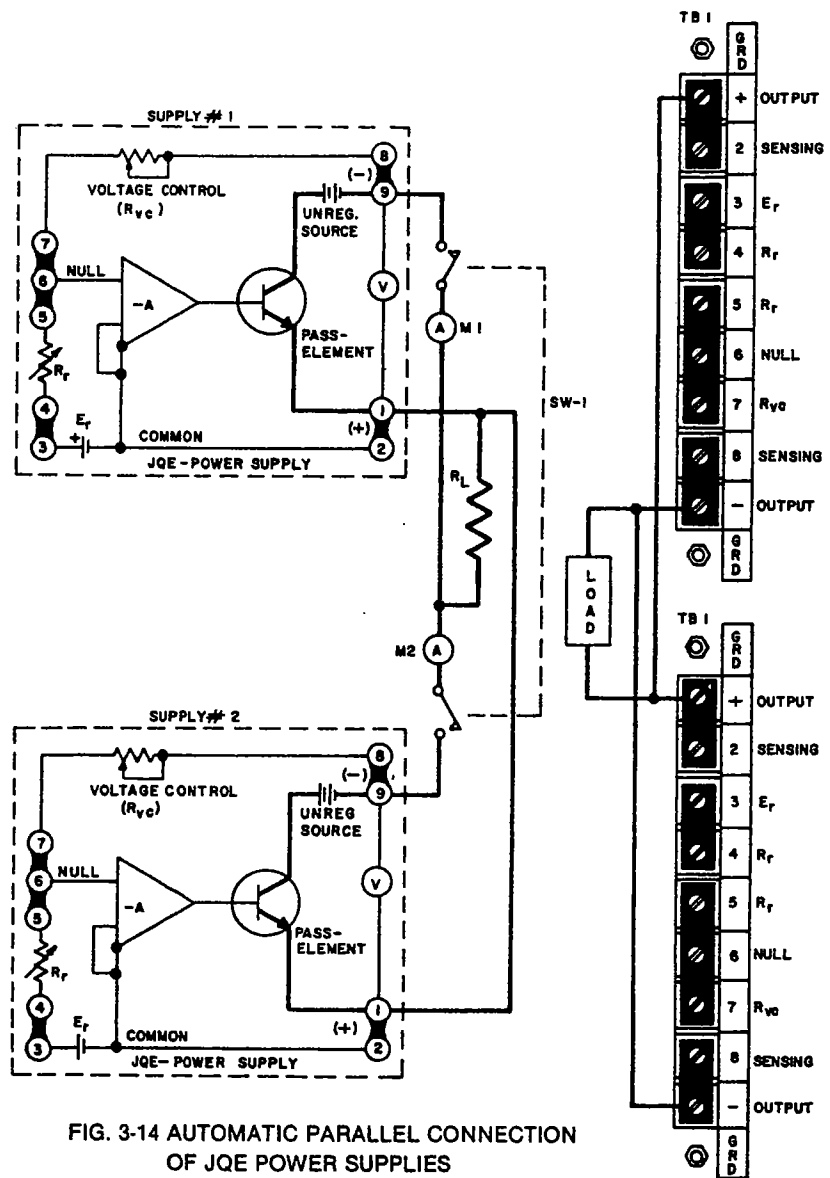


FIG. 3-14 AUTOMATIC PARALLEL CONNECTION OF JQE POWER SUPPLIES

3-44 MASTER-SLAVE PARALLEL OPERATION: Kepco Power Supplies may be paralleled if the output current from a single supply is not sufficient for the application at hand. With the parallel connection shown in FIG. 3-15, the total output current of the parallel supplies may be controlled from a single "Master" supply. To operate the parallel supplies in the "Master-Slave" connection, sensing resistors of equal value must be selected (R_{s1} , R_{s2} in FIG. 3-15) such that the voltage drop across them is about 0.1 to 0.25 volts at the output current of interest. The *sum* of the voltage drops across the load wire with the sensing resistors in series should *never exceed 0.5 volts* at the maximum desired operating current. If sensing resistors of the proper value are not available, the resistance of the load wires may be sufficient to establish the necessary voltage drops. In this case, the load wires should be trimmed such that *equal voltage drops* are established in the load wire from the "Master" and that from the "Slave" supply. Load wires should in general be of as heavy a wire gauge as practicable. Twisting of the load wires, as well as of the error sensing leads from the "Master" supply (although *not* shown in FIG. 3-15) is recommended.

3-45 PROCEDURE FOR "MASTER-SLAVE" PARALLEL CONNECTIONS

- Select external current sensing resistor (R_{s1} , R_{s2}) as described.
- Connect supplies as shown in FIG. 3-15, keeping load and error sensing leads as short as possible. Use shielded wire for the connection from terminal (2) of the "Master" to terminal (6) of the "Slave" unit.
- Connect supplies to common a-c power line and use common power switching.
- After turn-on, output voltage can be adjusted on the Voltage Control of the "Master" supply and operation can commence.

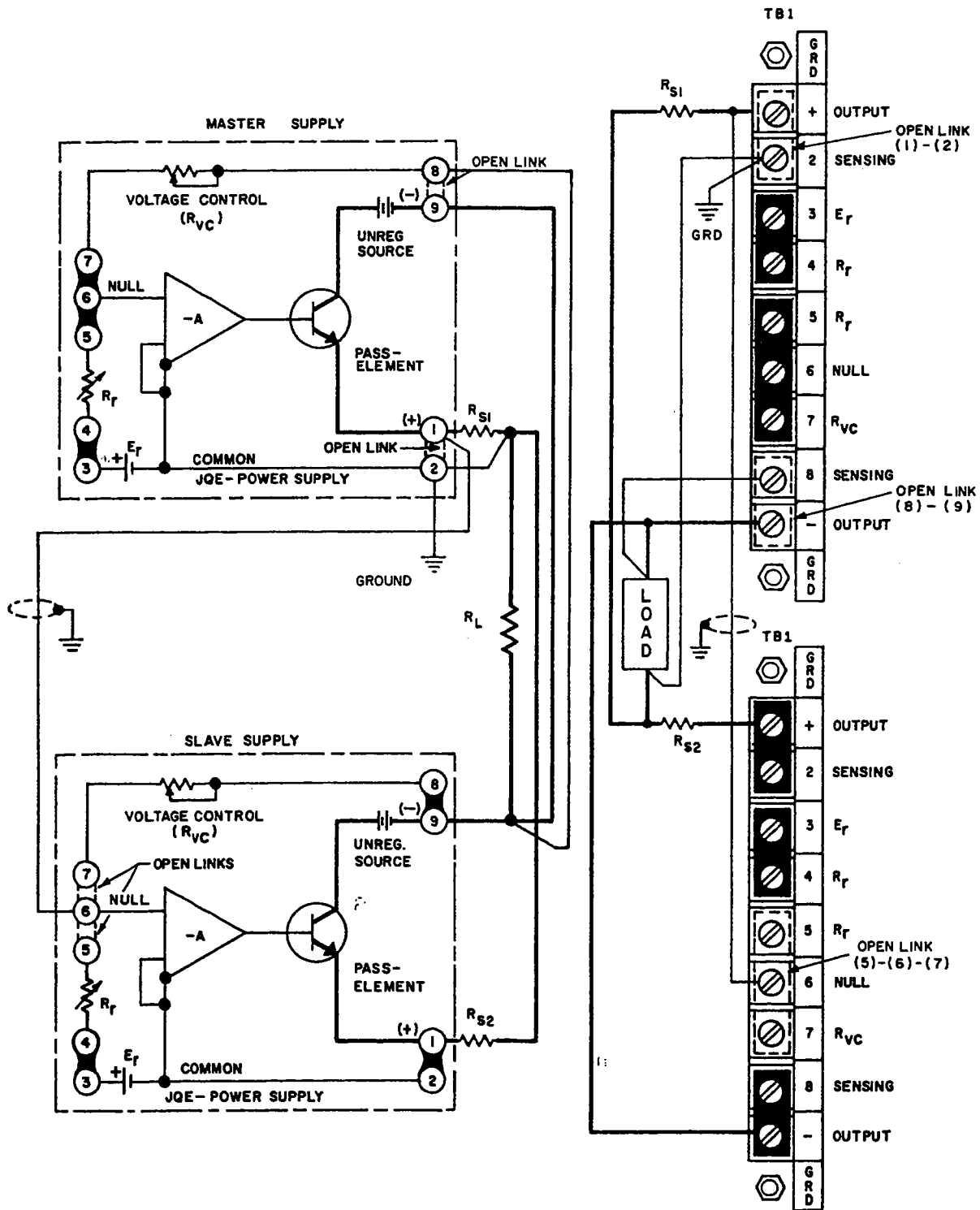


FIG. 3-15 MASTER-SLAVE PARALLEL CONNECTION OF JQE POWER SUPPLIES

SECTION IV—THEORY OF OPERATION

(References in CAPITAL LETTERS refer to the nomenclature used in FIG. 4-1)

4-1 SIMPLIFIED DIAGRAM DISCUSSION (Refer to FIG. 4-1)

- 4-2 The MAIN POWER TRANSFORMER converts the line voltage to the required levels needed to produce the d-c operating voltages for the MAIN AND AUXILIARY SUPPLIES. The MAIN POWER SUPPLY is in series with the PASS ELEMENTS and the CURRENT SENSING RESISTOR and produces the output voltage. The MAIN PASS ELEMENTS are changing their series resistance in a way, tending to keep the OUTPUT VOLTAGE constant. The necessary drive for this change is produced by the DRIVER CIRCUIT which in turn receives its command signals either from the CURRENT LIMIT AMPLIFIER or the ERROR SIGNAL AMPLIFIER, depending on which signal is passed by the DIODE GATE. The OUTPUT VOLTAGE is constantly compared to the REFERENCE SOURCE, while the output current is monitored by the CURRENT SENSING resistor. Any change, in either output voltage or current, is amplified by the associated amplifier and transferred via the GATE DIODES into the DRIVER CIRCUIT which produces the needed drive signal for the MAIN PASS ELEMENTS, thus either keeping the output voltage constant, or if the signal from the CURRENT LIMIT AMPLIFIER is dominant, limiting the output current to the pre-adjusted value.

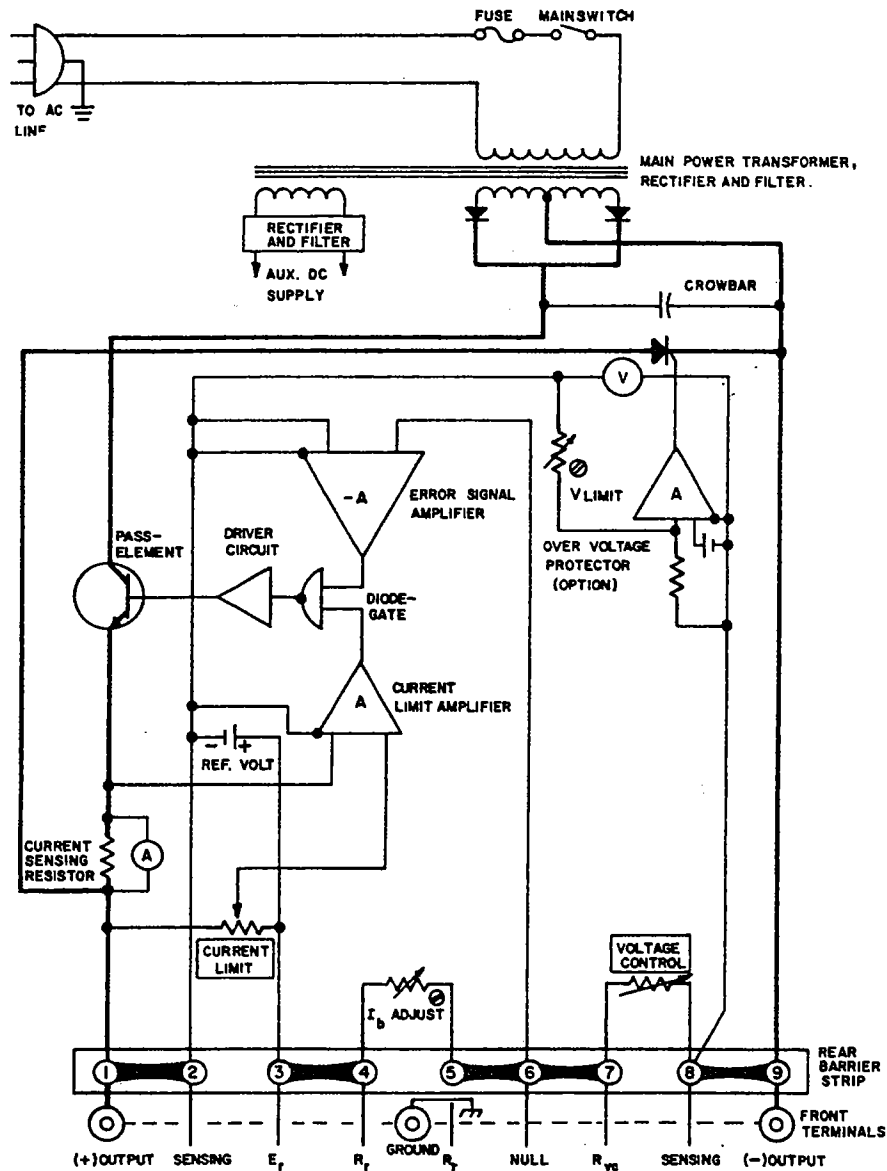


FIG. 4-1 SIMPLIFIED SCHEMATIC DIAGRAM, JQE 1/4 RACK SERIES

SIMPLIFIED DIAGRAM DISCUSSION (cont'd)

4-4 CIRCUIT DESCRIPTION

4-5 For the purpose of analysis, the circuitry of the JQE power supply may be divided into several sections which are individually described below. The main schematic (FIG. 6-3) should be used to illustrate the text of this section.

- a) **A-C INPUT CIRCUIT.** The JQE power supply is connected to the a-c power line via the (detachable) three-wire line cord with safety plug. The use of a grounded a-c power outlet will automatically ground the power supply, since the third wire of the line cord is directly connected to the metal chassis and case. Once the a-c power switch (S101) is closed, the primary of the main transformer (T201), the fan (B201) and the a-c pilot light (DS101) will be energized. The two primary windings of the main transformer are either connected in parallel (for 115V a-c nominal line voltage) or in series (for 230V a-c nominal line voltage). A slow-blow type fuse (F201) protects the primary circuit from excessive current.
- b) **MAIN D-C SUPPLY.** The main d-c power is derived from a center-tapped secondary winding on T201. A full-wave rectifier circuit with silicon diodes CR301, CR302 (located on the Heat Sink Assembly) works into a capacitor input filter (C201), paralleled by a bleeder resistor (R201). The main d-c supply delivers the output current through the series pass elements.
- c) **SERIES PASS-ELEMENTS.** The series pass transistors (Q301,302,303,304) are NPN silicon devices, located on a specially constructed heat sink (A3) and cooled by the fan (B201). Electrically, these pass transistors are connected in series with the raw main d-c supply and the output. The effective series resistance of the pass transistors (and thereby the voltage drop across them) is changed in such a way as to keep the output voltage constant, regardless of variations in the unregulated main supply. The base drive needed to affect this change in the pass transistors is supplied by the main driver (Q305), also located on the heat sink assembly.
- d) **ERROR SIGNAL AMPLIFIER (U4).** The main function of this d-c amplifier is to amplify the error signal, derived from the comparison bridge, to a level suitable to pass the diode gate circuit and drive the pre-driver stage (U2). The error signal amplifier in the JQE power supply is a d-c coupled, high-gain operational amplifier. The amplifier input may be disconnected from the comparison bridge circuit, and programmed externally. Although the amplifier is used in the non-inverting configuration, a positive input signal will produce a negative power supply output with respect to the "common" (plus sensing terminal), since the pass-elements provide another signal inversion.
- e) **COMPARISON BRIDGE.** This four-arm electrical bridge circuit is the sensing and controlling element in the JQE power supply. The "reference-half" of the bridge consists of the reference resistors in series with the reference voltage ($R_r = R13, R14$), the other half is constituted by the voltage control resistor ($R_{vc} = R102$) and the output voltage (E_o). The simplified presentation shown in Section III of this manual, will illustrate this discussion and show the actual bridge configuration. Refer to FIG. 3-4. The output voltage (in series with R_{vc}) is continuously compared with the reference section of the bridge circuit. At bridge balance ($E_{AA'} = 0$), a constant control current (I_b) is flowing through the bridge, keeping the error signal at the bridge terminals (A, A') at approximately zero volts. Any deviation in the output voltage (E_o), caused either by line/load variations or by a change in R_{vc} , will tend to change the control current (I_b) in the sensing section of the bridge and thereby produce an error signal at the bridge terminals (A, A'). The error signal is presented to the amplifier input and will, after amplification, act as a drive for the pass transistors, changing the voltage drop (E_p) across them in such a way as to restore bridge balance and keep the output voltage (E_o) constant once more.

CIRCUIT DESCRIPTION (cont'd)

- f) **CURRENT LIMIT CIRCUIT.** The differential input of the current limit amplifier (U3) is connected to the current sensing resistor ($R_s = R307$) and to a reference voltage, adjustable by the current limit control (R101). The voltage drop across the current sensing resistor is thus continuously compared to the reference voltage, set by the current limit control. As long as the voltage developed across R_s (due to load current flow) is less than the pre-set reference level, the current limit amplifier will be biased to its inactive state and will not effect the output. If the output current increases however, the voltage drop across R_s will exceed the reference level set by the current limit control. The current limit amplifier will thus be activated and produce a drive signal at the diode gate, greater than the signal of U4, thereby shifting control from the error signal amplifier to the current limit amplifier and transferring the power supply into the current limit mode. Since both, the current limit amplifier and the error signal amplifier (U4) are coupled through the diode gate circuit (CR10, CR11) to the pre-driver stage (U2), the amplifier with the greater (negative) output will control the pass transistors and therefore the output.
- g) **AUXILIARY SUPPLIES**
- 1) **AMPLIFIER POWER SUPPLY.** This full wave, bridge rectified d-c source is derived from a secondary winding on the main transformer (T201). Rectified by CR4 to CR7, the voltage is capacitor filtered by C4.
NOTE: A voltage regulator (U1) and a zener diode (CR9) provide the operating voltage for the error signal amplifier (U4), current limit amplifier (U3) and the driver and reference circuit (U2).
 - 2) **PRE-DRIVER COLLECTOR SUPPLY.** A half wave rectified (CR3) and capacitor filtered (C3) d-c supply is derived from a secondary winding on T201. It delivers collector voltage to the pre-driver stage (U2).
 - 3) **I_{CBO} SUPPLY.** This full-wave rectified auxiliary d-c supply is derived from a winding on the main transformer (T201). Rectified by CR1 and CR2, and filtered by C5, the d-c voltage is applied to the pass transistors (via R202), thus insuring the necessary turn-off bias for these stages under all operating conditions, especially at elevated temperatures.

SECTION V—MAINTENANCE

5-1 GENERAL

5-2 This section covers maintenance procedures and test measurements of the Kepco Series JQE ¼ Rack Power Supplies. Conservative rating of components and the uncongested layout should keep maintenance problems to a minimum. If trouble does develop however, the easily removable wrap-around cover and the plug-in feature of the circuit boards provide exceptional accessibility to all components of the supply.

5-3 DISASSEMBLY (Refer to FIG. 5-1)

- a) **COVER REMOVAL.** The wrap-around cover may be taken off by loosening and removing its nine (9) holding screws, three (3) on the right side, two (2) on the front panel and four (4) on the left side.
- b) **CIRCUIT BOARD REMOVAL.** The printed circuit board is mounted with three screws, two (2) of which are removed from the rear, one (1) from the side. After removal of the two printed circuit board connectors, the board may be lifted from its slide-guide.
- c) **HEAT SINK REMOVAL.** The heat sink assembly is mounted with two (2) screws to the chassis bottom. After the screws are taken out, the wires may be removed by means of the "quick disconnect" terminals.
- d) **RE-ASSEMBLY.** Re-assembly of all components takes place in reverse order of the above described disassembly.

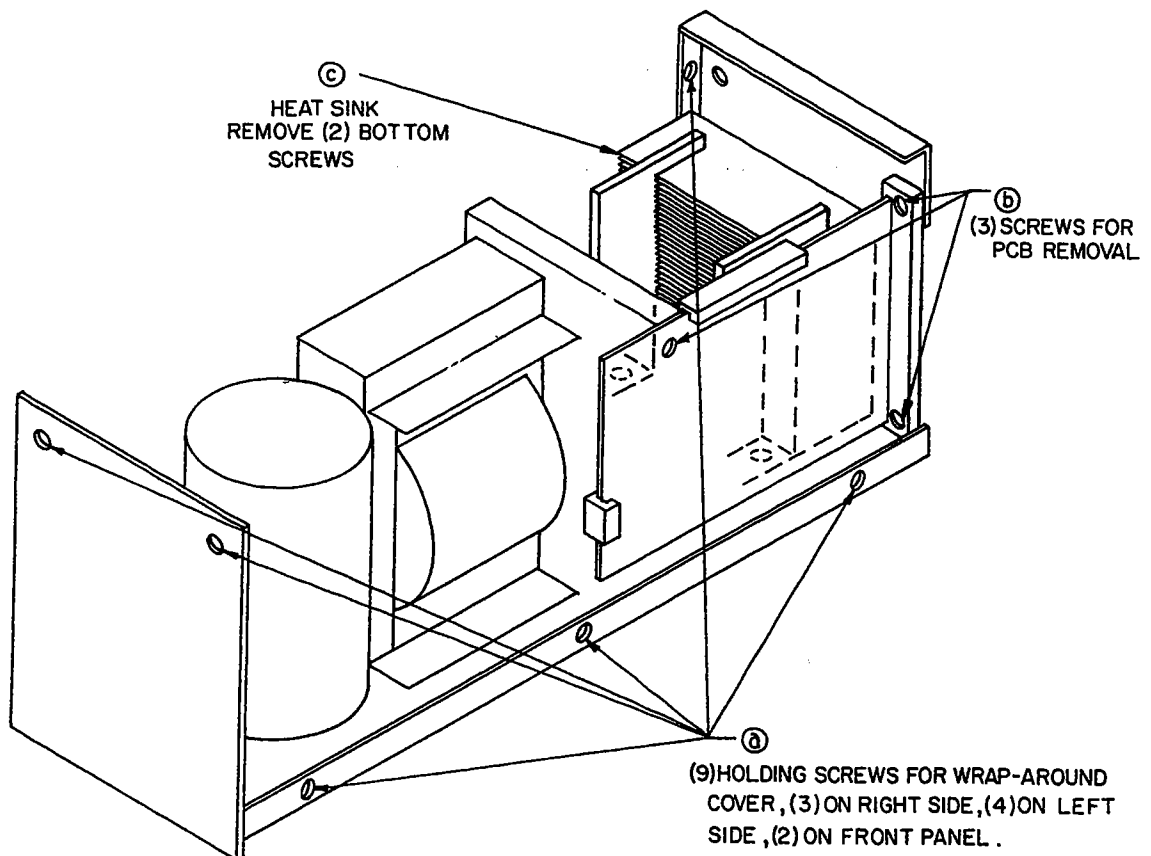


FIG. 5-1 DISASSEMBLY JQE ¼ RACK DESIGN GROUP.

5-4 INTERNAL ADJUSTMENT PROCEDURES

5-5 GENERAL. This paragraph describes the adjustment of those internal controls, which have not been previously covered. Refer to Section II, paragraph 2-3, for a listing and location of all adjustment procedures.

5-6 MAXIMUM OUTPUT CURRENT ADJUSTMENT. This adjustment serves as a calibration for the range of the front panel Current Limit Control. The " $I_{o \text{ max. adj.}}$ " (R12) is located on the printed circuit board (Refer to FIG. 2-1). It is factory set, so that the front panel control covers an output current range of 10-105% of the maximum rated output current. Re-adjustment of the " $I_{o \text{ max. adj.}}$ " control is needed only if a component in the current limit circuitry must be replaced or, if the range of the front panel control is to be restricted. A convenient way to make the adjustment is as follows:

- a) Load the output of the supply to draw the maximum desired output current with the front panel Current Limit Control fully clockwise. Monitor the output voltage with an oscilloscope, having a vertical sensitivity of at least 0.1 mV/cm.
- b) Observe the oscilloscope. Current limiting is indicated by a sharp increase in output ripple. Locate the " $I_{o \text{ max. adj.}}$ " control and turn slowly until limiting occurs at the point required. Clockwise adjustment will increase the maximum output current range, while counter-clockwise adjustment will decrease the range. **DO NOT ADJUST TO MORE THAN 105% $I_{o \text{ max.}}$. Although this might be possible due to component tolerances, malfunction of the power supply will be caused by exceeding the rated maximum output current.**

5-7 TROUBLE SHOOTING

5-8 Modern, high performance power supplies have reached a high state of sophistication. A thorough understanding of the problems involved in the repair of complex, solid state circuitry is therefore required. Servicing beyond simple parts replacement should consequently be attempted only by personnel thoroughly familiar with solid state circuit techniques and with experience in closed loop circuitry.

5-9 Trouble-shooting charts, showing resistance and voltage readings, are of very limited usefulness with feedback amplifier circuits and are not included here. Instead, a detailed circuit description (Section IV), parts location diagrams, simplified functional schematics and a main schematic with all significant voltage readings is provided (Section VI).

5-10 The following steps in case of power supply malfunctioning may also be found useful:

- a) If power supply does not function at all: Check all powerline connections and fuses and make certain, power supply is connected for the correct line voltage (it is normally delivered for 115V a-c operation).
- b) If supply does not function in one of the remote programming modes, disconnected all external components and reconnect internal reference and the voltage control. The following paragraphs refer to the instrument as a power supply, rather than an amplifier in order to simplify test set-ups and measurements.
- c) If the power supply is basically functioning, but poor performance is evident, inspect the test set-up to make certain the source of the trouble is not external.
- d) Excessive output effects in either the voltage or current mode are usually traceable to incorrectly connected loads or faulty measurement techniques. Perform measurements as described in Paragraph 5-13 and follow the connecting diagrams.
- e) Oscillation of the output voltage or output current is often due to a load with a large inductive component. Twisted loadwires of sufficient diameter and held as short as practical, are often the solution to the problem, if lag network adjustment does not correct the trouble. Refer to paragraph 5-7.

5-11 Kepco Field Engineering Offices or the Kepco Repair Department will be available for consultation or direct help in difficult service or application problems.

5-12 POWER SUPPLY MEASUREMENTS

5-13 Output effect measurements (regulation measurements) in the voltage, as well as in the (external) current mode of operation and output ripple measurements are an excellent indication of the power supply's d-c performance and may be performed with a minimum of instrumentation. Since these measurements require special techniques to insure correct results, suggestions for their performance are given below.

5-14 Required Instrumentation:

- 1) Constant a-c input source voltage with provisions for "stepping" the voltage over the specified region (105-125V). A variable autotransformer is generally adequate if it is rated to deliver the input current of the unit under test.
- 2) Resistive load, variable, and capable of dissipating the full output power of the unit under test, equipped with on/off and shorting switches.
- 3) D-C voltage monitor, differential voltmeter or power supply analyzer.
- 4) A-C ripple monitor, true rms meter, sensitivity better than 1mV.
- 5) Optional: Oscilloscope, vertical sensitivity better than 0.1 mV/cm, bandwidth $\geq 10\text{MH}$.

5-15 The proper location of the instrument leads when measuring output effects in response to a-c input source changes or load variations is of the utmost importance. Improperly placed leads may measure voltage drops due to contact resistance and load current flow and thus lead to incorrect results. FIG's 5-2A through 5-2D show clearly how to employ "4-terminal network techniques" when measuring output effects. The principle is very simple but important: **Do not measure voltage drops due to load current.**

5-16 **Output effects due to source or load variations in the voltage mode of operation** are defined as the amount of output voltage change resulting from a specified change in a-c input source voltage *or* from a change in load resistance. These output effects can be expressed as an absolute change (ΔE_o) or as a percentage in reference to the total output voltage E_o :

$$\% \text{ Output Effect} = \Delta E_o / E_o (100\%) \quad (\text{Eq. 1}).$$

USE THE TEST SET-UP SHOWN IN FIG. 5-2A or 5-2B. Vary the a-c input *or* the load over the specified limits⁽¹⁾ and note the deviation (ΔE_o) on the instrument (M1). Calculate output effects by means of the equation (Eq. 1) above.

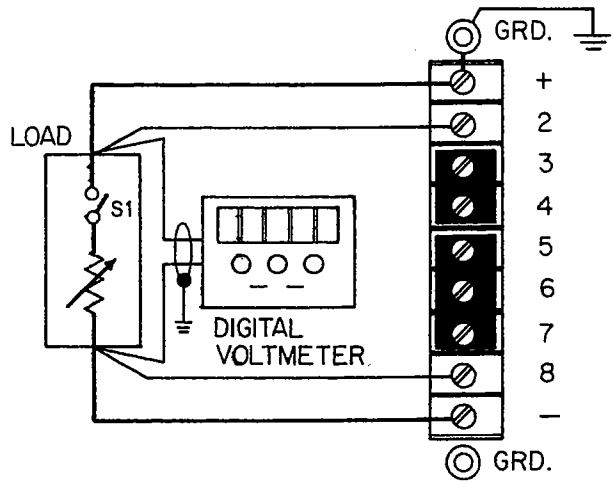
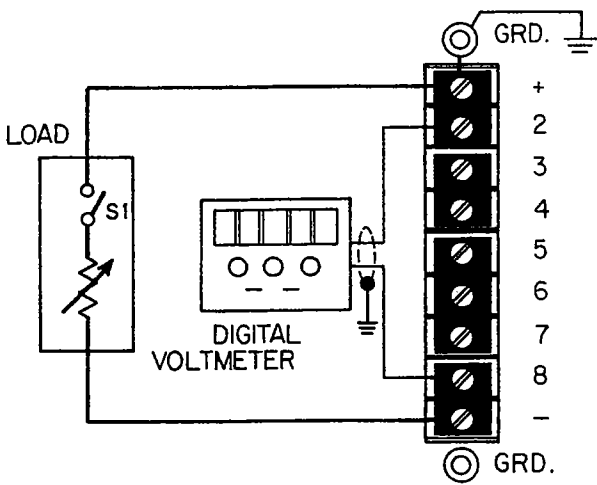
5-17 **Output effects due to source or load variation in the current mode of operation** are defined as the amount of output current change resulting from a specified change in a-c input source voltage *or* from a change in load resistance. The output effects can be expressed as an absolute change (ΔI_o) or as a percentage in reference to the total output current I_o :

$$\% \text{ Output Effect} = \Delta I_o / I_o (100\%) \quad (\text{Eq. 2}).$$

USE THE TEST SET-UP SHOWN IN FIG. 5-2C. Vary the a-c input *or* the load over the specified limits⁽¹⁾ and note the deviation (ΔV_{rs}) on the instruments connected across the measuring resistor (M1 across R_s in FIG. 5-2C). The change in output current is equal to: $\Delta I_o = V_{rs} / R_s$. Insert the value of ΔI_o into the equation (Eq. 2) above and calculate the output effects.

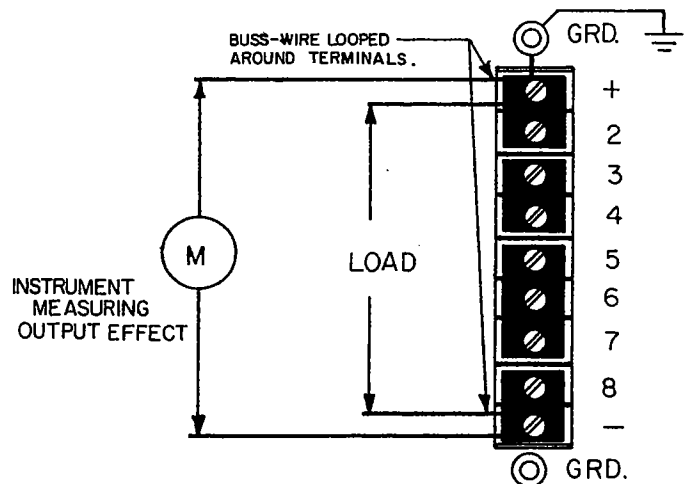
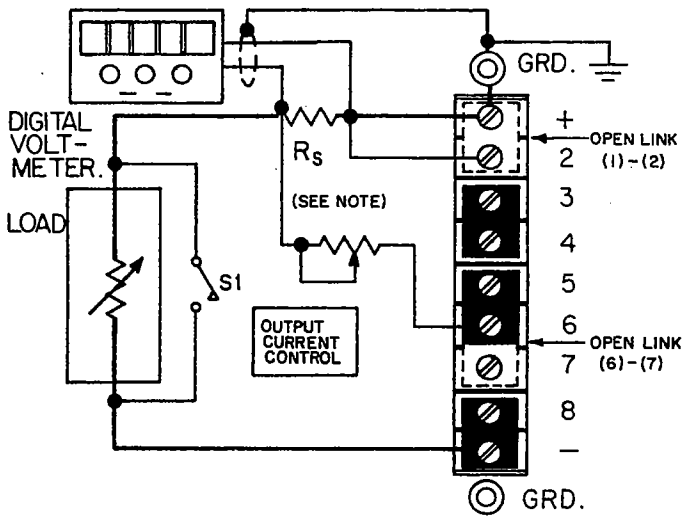
5-18 **RIPPLE.** Rms ripple may be monitored on a true rms reading instrument, connected parallel to the instrument measuring the output effects. Careful wire dressing and shielding, as well as good grounding, are of the utmost importance for valid measurement results. An oscilloscope may be used for p-p readings of noise and ripple. An approximate rms reading can be calculated from the p-p reading of the ripple displayed on the oscilloscope, if the reading is divided by three.

⁽¹⁾ The specified Limits are: (See also Section I, Table 1-2).
Source Variation: 105V a-c to 125V a-c *or* 210V a-c to 250V a-c.
Load Variation: Full Load to No Load *or* No Load to Full Load.
The Load Effect can be readily measured by opening and/or closing S1 in FIG. 5-2A, 5-2B and 5-2C.



A) OUTPUT EFFECT MEASUREMENT (VOLTAGE MODE) WITHOUT ERROR SENSING AT THE LOAD

B) OUTPUT EFFECT MEASUREMENTS (VOLTAGE MODE) WITH ERROR SENSING AT THE LOAD



C) OUTPUT EFFECT MEASUREMENTS (CURRENT MODE)

D) APPROXIMATION OF A FOUR-TERMINAL NETWORK

NOTE: R_s should be selected such that its wattage rating is at least 10 times the actual power dissipated. Output effects depend on the stability of R_s . Recommended T.C. for R_s is 20 ppm.

FIG. 5-2 CONNECTIONS FOR JQE ¼ RACK POWER SUPPLY MEASUREMENTS

SECTION VI—ELECTRICAL PARTS LIST AND DIAGRAMS

6-1 GENERAL

- 6-2 This section contains the main schematic, the parts location diagrams, and a list of all replaceable electrical parts. All components are listed in alpha-numerical order of their reference designations. Consult your Kepco Representative for replacement of parts not listed here.

6-3 ORDERING INFORMATION

- 6-4 To order a replacement part or to inquire about parts not listed in the parts list, address order or inquiry either to your authorized Kepco Sales Representative or to:

KEPCO, INC.
131-38 Sanford Avenue
Flushing, N.Y. 11352

- 6-5 Specify the following information for each part:

- a) Power Supply Model number, Serial number, and Revision number stamped on the Nameplate of the unit.
- b) Kepco part number. See Parts List.
- c) Circuit reference designation. See Schematic Drawing.
- d) Description. See Parts List.

- 6-6 To order a part not listed in the parts list, give a complete description and include its function and location.

NOTE: KEPCO DOES NOT STOCK OR SELL COMPLETE POWER SUPPLY SUBASSEMBLIES AS DESCRIBED HERE AND ELSEWHERE IN THIS INSTRUCTION MANUAL. SOME OF THE REASONS ARE LISTED BELOW:

- 1) Replacement of a complete subassembly is a comparatively rare necessity.
- 2) Kepco's subassemblies are readily serviceable, since most of them are the "plug-in" type.
- 2) All active components are socket mounted, making replacement extremely easy.
- 4) The nature of a closed-loop power supply system requires that subassembly replacement is followed by careful measurement of the total power supply performance. In addition, depending on the function of the subassembly, extensive alignment may be required to restore power supply performance to specified values.

IF REPAIRS INVOLVING SUBASSEMBLY REPLACEMENTS ARE REQUIRED, PLEASE CONSULT YOUR LOCAL KEPCO REPRESENTATIVE OR THE KEPCO SALES ENGINEERING DEPARTMENT IN FLUSHING, NEW YORK, N.Y.

ABBREVIATIONS USED IN KEPKO PARTS LISTS

A) Reference Designators:

A	= Assembly	L	= Inductor
B	= Blower (Fan)	LC	= Light-Coupled Device
C	= Capacitor	M	= Meter
CB	= Circuit Breaker	P	= Plug
CR	= Diode	Q	= Transistor
DS	= Device, Signaling (Lamp)	R	= Resistor
F	= Fuse	S	= Switch
FX	= Fuse Holder	T	= Transformer
IC	= Integrated Circuit	TB	= Terminal Block
J	= Jack	V	= Vacuum Tube
K	= Relay	X	= Socket

B Descriptive Abbreviations

A	= Ampere	n	= Nano (10^{-9})
a-c	= Alternating Current	NC	= Normally Closed
AMP	= Amplifier	NO	= Normally Open
AX	= Axial	p	= Pico (10^{-12})
CAP	= Capacitor	PC	= Printed Circuit
CER	= Ceramic	POT	= Potentiometer
CT	= Center-Tap	PIV	= Peak Inverse Voltage
°C	= Degree Centigrade	p-p	= Peak to Peak
d-c	= Direct Current	ppm	= Parts Per Million
DPDT	= Double Pole, Double Throw	PWR	= Power
DPST	= Double Pole, Single Throw	RAD	= Radial
ELECT	= Electrolytic	RECT	= Rectifier
F	= Farad	RECY	= Recovery
FILM	= Polyester Film	REG	= Regulated
FLAM	= Flammable	RES	= Resistor
FP	= Flame-Proof	RMS	= Root Mean Square
°F	= Degree-Fahrenheit	Si	= Silicon
FXD	= Fixed	S-End	= Single Ended
Ge	= Germanium	SPDT	= Single Pole, Double Throw
H	= Henry	SDST	= Single Pole, Single Throw
Hz	= Hertz	Stud Mt	= Stud Mounted
IC	= Intergrated Circuit	TAN	= Tantalum
K	= Kilo (10^3)	TSTR	= Transistor
m	= Milli (10^{-3})	μ	= Micro (μ) (10^{-6})
M	= Mega (10^6)	V	= Volt
MFR	= Manufacturer	W	= Watt
MET	= Metal	WW	= Wire Wound



REPLACEMENT PARTS LIST

MODEL JQE 15-6M

PRINTED CIRCUIT BOARD ASSEMBLY (A1)

Code 03-2492

REFERENCE DESIGNATION	QTY	DESCRIPTION	MFRS. NAME & PARTS NO. SEE BOTTOM NOTE	KEPCO PART NO.	REC. SPARE PART QTY.
C1,2,14	3	Cap., Mylar, Ax. Leads 0.01 μ F, 10%, 400V	Sprague Type 192P	117-0361	1
C3	1	Cap., Elect., Ax. Leads 330 μ F, 20%, 25V	Sangamo Type 066	117-0716	1
C4	1	Cap., Elect., Ax. Leads 47 μ F, 20%, 63V	United Chemi-Con KMC63T47RM8X16LL	117-1061	1
C5	1	Cap., Elect., Ax. Leads 22 μ F, 20%, 250V	United Chemi-Con SME250T22RM12x25LL	117-1060	1
C6	1	Cap., Ceramic, Ax. Leads 0.1 μ F, 10%, 50V	Kemet C412C104K5R5CA	117-1052	1
C7	1	Cap., Mylar, Ax. Leads 4700 pF, 10%, 200V	Sprague Type 192P	117-0588	1
C8	1	Cap., Ceramic Disc 68 pF, 5%, 600V	Centralab DTN-68	117-0981	1
C9,12	2	Cap., Elect., Ax. Leads 150 μ F, 20%, 3V	Mallory Type TT	117-0512	1
C10	1	Cap., Elect., Ax. Leads 1000 μ F, 20%, 35V	United Chemi-Con SME35T102M12X30	117-1047	1
C11	1	Cap., Mylar, Ax. Leads 0.5 μ F, 10%, 200V	Wesco Type 33M	117-0123	1
C13	1	Cap., Mylar, Ax. Leads 0.1 μ F, 10%, 600V	TRW Type X663F	117-0316	1
CR1 thru CR8	8	Diode, Rect., Ax. Leads 400V (PIV), 1A	Semicon, Inc. Type S1-4	124-0028	1
CR9	1	Diode, Zener, Ax. Leads 12V, 1W	Motorola 1N4742	121-0012	1
CR10 thru CR13 CR16	5	Diode, Switching, Ax. Leads 75V, 1A	Motorola 1N4148	124-0437	1
CR14,15	2	Diode, Rect., Ax. Leads 100V (PIV), I=5 μ A @ 0.5V	Semicon, Inc. Type HVP	124-0178	1
CR17	1	Diode, Zener 6.5V, \pm 5%, 250mW	Motorola 1N763-1	121-0028	1
CR18	1	Diode, Zener 6.2V, \pm 5%, I _{ZT} =7.5mA	Motorola 1N821	121-0041	1
CR19	1	Diode, Rectifier, Ax. Leads 400V PIV @ 50°C	Diotec GP604	124-0348	1

6-3/6-4

NOTE: REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.





REPLACEMENT PARTS LIST

MODEL JQE 15-6M

PRINTED CIRCUIT BOARD ASSEMBLY (A1)

Code 03-2492

REFERENCE DESIGNATION	QTY	DESCRIPTION	MFRS. NAME & PARTS NO. SEE BOTTOM NOTE	KEPCO PART NO.	REC. SPARE PART QTY.
Q1	1	Transistor, Si., TO-105 2N4355	Kepco, Inc. 119-0076	119-0076	1
R1	1	Res., Fxd., Pwr. 200 ohm, 5%, 3W	Tepro Type TS3	115-0803	1
R2,6,7	3	Res., Fxd., Molded 1K ohm, 10%, 1/4W	Allen-Bradley CB1021	115-2238	1
R3,9,15	3	Res., Fxd., Precision, M.F. 1K ohm, 1%, 1/8W	Dale Type RN55D	115-2180	1
R4	1	Res., Fxd., Molded 22 ohm, 10%, 11/4W	Allen-Bradley CM2201	115-2494	1
R5	1	Res., Fxd., Molded 100 ohm, 10%, 1/4W	Allen-Bradley CM1011	115-2231	1
R8,10,16	3	Res., Fxd., Molded 10 ohm, 10%, 1/4W	Allen-Bradley CB1001	115-2230	1
R11	1	Res., Var., Cermet, Trim. 100K ohm, 10%, 3/4W	Bourns Type 3009P	115-2399	1
R12	1	Res., Var., Cermet, Trim. 1K ohm, 10%, 3/4W	Bourns Type 3009P	115-2456	1
R13	1	Res., Var., Cermet, Trim. 2K ohm, 10%, 3/4W	Bourns Type 3009P	115-2405	1
R14	1	Res., Fxd., Precision, M.T. 5.76K ohm, 1%, 1/8W	Dale Type CMF-1/10	115-1893	1
R17,20	2	Res., Fxd., Precision, M.T. 2K ohm, 1%, 1/8W	Dale Type CMF-1/10	115-2334	1
R18	1	Res., Fxd., Precision 475 ohm, 1%, 1/8W	Dale Type CMF-1/10	115-2395	1
R19	1	Res., Fxd., Precision 750 ohm, 1%, 1/8W	Dale Type CMF-1/10	115-2259	1
R21	1	Res., Fxd., Molded 560 ohm, 5%, 0.5W	Allen-Bradley EB5615	115-0888	1
R22	1	Res., Fxd., Molded 47 ohm, 10%, 1/4W	Allen-Bradley CB4701	115-2273	1
R23	1	Res., Fxd., Precision, MF 576 ohm, 1%, 1/8W	Dale Type CMF-1/10	115-2583	1

6-3A/6-4A

NOTE: REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.



REPLACEMENT PARTS LIST

MODEL JQE 15-6M

PRINTED CIRCUIT BOARD ASSEMBLY (A1)

Code 03-2492

REFERENCE DESIGNATION	QTY	DESCRIPTION	MFRS. NAME & PARTS NO. SEE BOTTOM NOTE	KEPCO PART NO.	REC. SPARE PART QTY.
R24	1	Res., Fxd., Precision, MF 40.2K ohm, 1%, 1/8W	Dale Type CMF-1/10	115-2391	1
RN1A/B,2A/B	2	Res., Matched Pair 10K/10K, .01%, Ratio Matched	Kepeco, Inc. 234-0006	234-0006	1
TB1	1	Barrier Strip, 11 Ckts. Rt. Angle, 3/8 Ctrs.	Kepeco, Inc. 167-1054	167-1054	1
U1	1	IC, Voltage Regulator, 723C Type 14 Pin-DIP	Kepeco, Inc. 250-0021	250-0021	1
U2	1	IC, Opto Isolator 6 Pin-DIP	Monsanto 4N33	119-0133	1
U3	1	IC, Op. Amp, Dual 8 Pin-DIP	Linear Tech. LT1013CN8	250-0198	1
U4	1	IC, Op. Amp., FET Input 8 Pin-DIP	Texas Instruments TL081CP	250-0100	1

6-5/6-6

NOTE: REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.



REPLACEMENT PARTS LIST

MODEL JQE 15-6M

MAIN CHASSIS AND FRONT PANEL ASSEMBLY (A2)

Code 04-2291

REFERENCE DESIGNATION	QTY	DESCRIPTION	MFRS. NAME & PARTS NO. SEE BOTTOM NOTE	KEPCO PART NO.	REC. SPARE PART QTY.
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FRONT PANEL ASSEMBLY CONTAINS:

DS101	1	Pilot Light Assembly	Industrial Devices 2100 Series	152-0087	1
M101	1	Ammeter, Panel 0-6 Amps	Modutec, Inc. Type 1W	135-0423	1
M102	1	Voltmeter, Panel 0-20 Volt	Modutec, Inc. Type 1W	135-0406	1
R101	1	Res., Var., Composition 2K ohm, 30%, 1/2W	CTS Type VA-45	115-2268	1
R102	1	Res., Variable, WW 15K ohm, 5%, 2W	TRW Type 8400	115-1237	1
S101	1	Switch, Rocker, SPST 10A, 250V	Stackpole Type RS47-FB	127-0230	1
S102,103	2	Switch, Slide, Shorting Type DPDT	Stackpole Type SS-72-1	127-0254	1

CHASSIS ASSEMBLY CONTAINS:

B201	1	Motor, Fan	Howard Industries Model 21075	148-0026	1
C201	1	Cap., Elect., Can Type 16K μ F, \pm 20%, 35V	Mallory Type CGS	117-1024	1
F201	1	Fuse, Slow Blow 2.5A, 250V	Buss MDL2 1/2	141-0029	5
R201	1	Res., Fxd., Molded 510 ohm, 5%, 2W	Allen-Bradley HB2215	115-2116	1
R202	1	Res., Fxd., Power, Strip 750 ohm, 5%, 10W	Memcor-Truohm Type MZ10	115-1603	1
T201	1	Transformer, Power	Kepeco Inc. 100-1758	100-1758	1

6-7/6-8

NOTE: REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.



REPLACEMENT PARTS LIST

MODEL JQE 15-6M

HEAT SINK ASSEMBLY (A3)

Code 09-0591

REFERENCE DESIGNATION	QTY	DESCRIPTION	MFRS. NAME & PARTS NO. SEE BOTTOM NOTE	KEPCO PART NO.	REC. SPARE PART QTY.
CR301,302	2	Rectifier, Silicon, Ax. Leads 100V (PIV), 15A	Westinghouse R310015	124-0335	1
Q301 thru Q304	4	Transistor, NPN Hi-Power TO-3	Kepeco Inc. 119-0061	119-0061	2
Q305	1	Transistor, NPN Med. Power, TO-66	RCA 2N3054	119-0060	1
R301 thru R304	4	Res., Fxd., Power, Ax. 0.3 ohm, 3%, 3W	Memcor Type MAL-3	115-2139	1
R305	1	Res., Fxd., Molded 47 ohm, 10%, 1/4W	TRW Type IBT-1/4	115-2273	1
R306	1	Res., Fxd., Molded 390 ohm, 10%, 1/4W	TRW Type IBT-1/4	115-2234	1
R307	1	Res., Fxd., Precision 0.0833 ohm, 1%, 5W	Tepro Type TSK-5W	115-2206	1

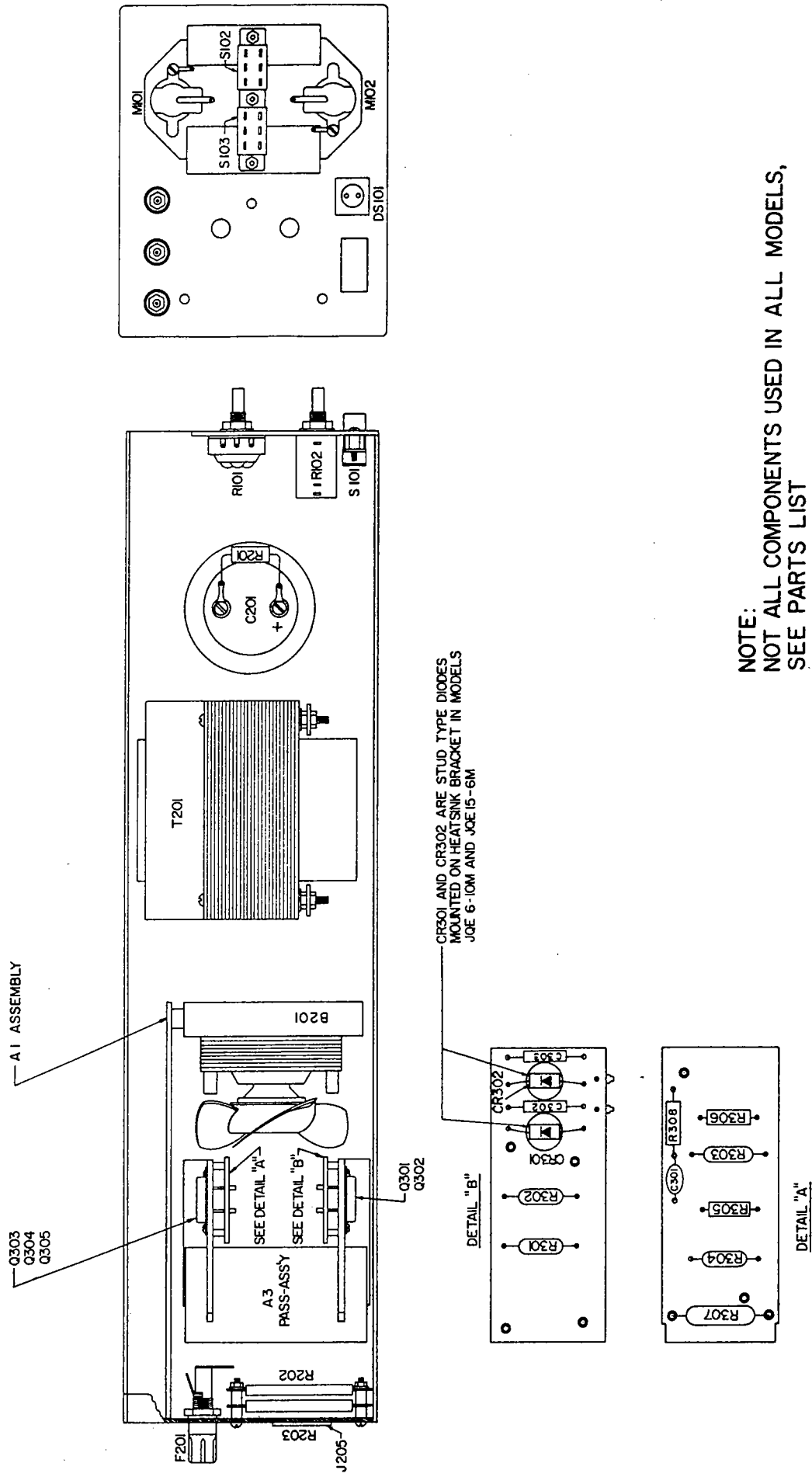
MISCELLANEOUS MECHANICAL PARTS:

N.A.	1	Front Binding Post (Red)	151-0041
N.A.	1	Front Binding Post (Black)	151-0042
N.A.	1	Front Binding Post (Green)	151-0044
N.A.	1	Fan Blade, 2.6 inch dia.	149-0019
N.A.	1	Line Cord Set	118-0441
N.A.	1	Carrying Handle Set	139-0215
N.A.	5	Shorting Links for Rear Barrier Strip	172-0009
N.A.	2	Control Knob, Front Panel	155-0050
N.A.	1	Bail Assembly	139-0219
N.A.	1	Foot, Bottom (Right) Front	158-0006
N.A.	1	Foot, Bottom (Left) Front	158-0005
N.A.	2	Foot, Bottom Rear	158-0003

6-9/6-10

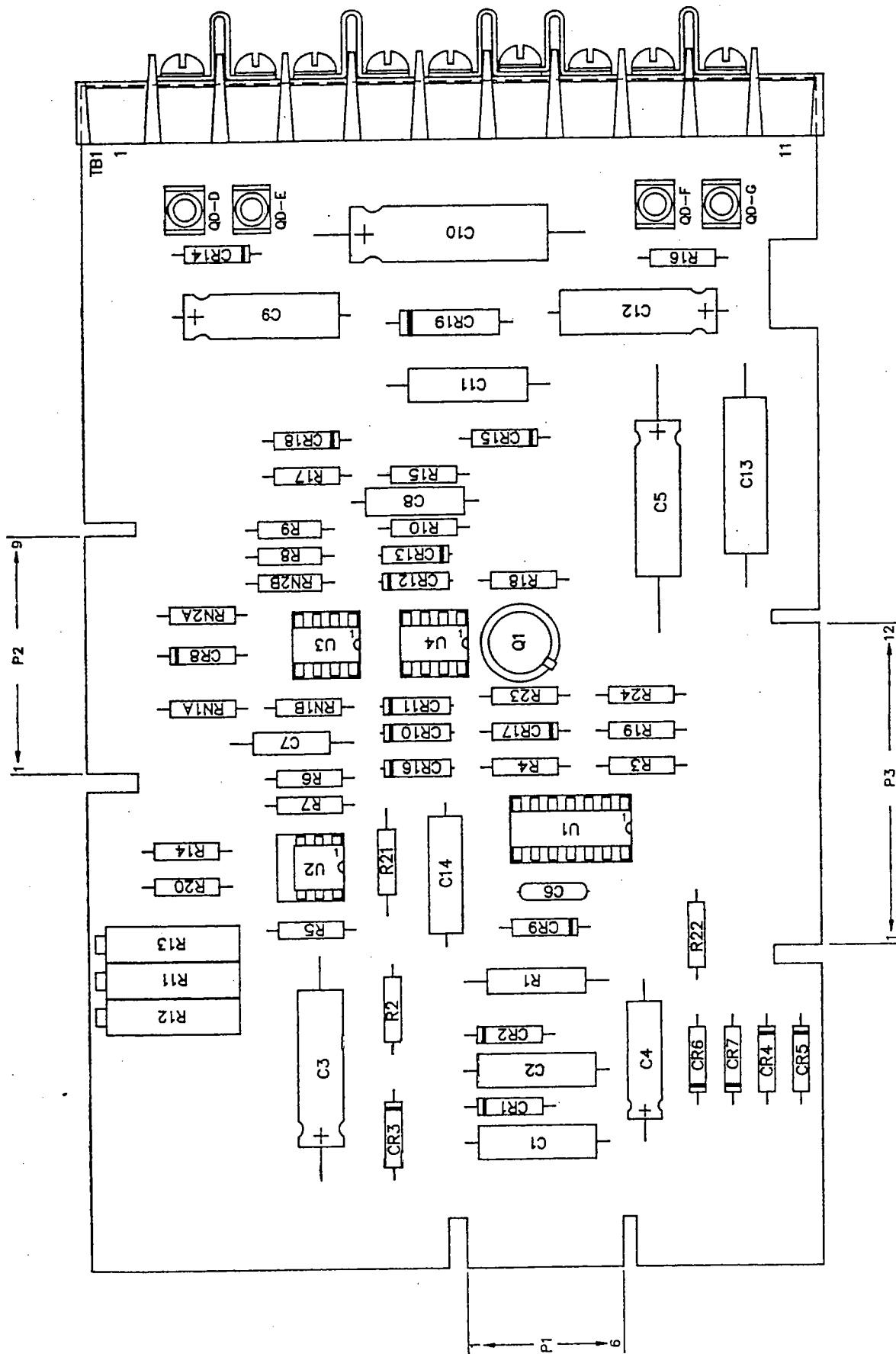
NOTE: REPLACEMENT PARTS MAY BE ORDERED FROM KEPCO, INC. ORDERS SHOULD INCLUDE KEPCO PART NUMBER AND DESCRIPTION.

PLEASE NOTE: THE MANUFACTURER'S NAME AND PART NUMBER LISTED FOR EACH ITEM ON REPLACEMENT PARTS LISTS REPRESENTS AT LEAST ONE SOURCE FOR THAT ITEM AND IS LISTED SOLELY FOR THE CONVENIENCE OF KEPCO EQUIPMENT OWNERS IN OBTAINING REPLACEMENT PARTS LOCALLY. WE RESERVE THE RIGHT TO USE EQUIVALENT ITEMS FROM ALTERNATE SOURCES. KEPCO, INC.



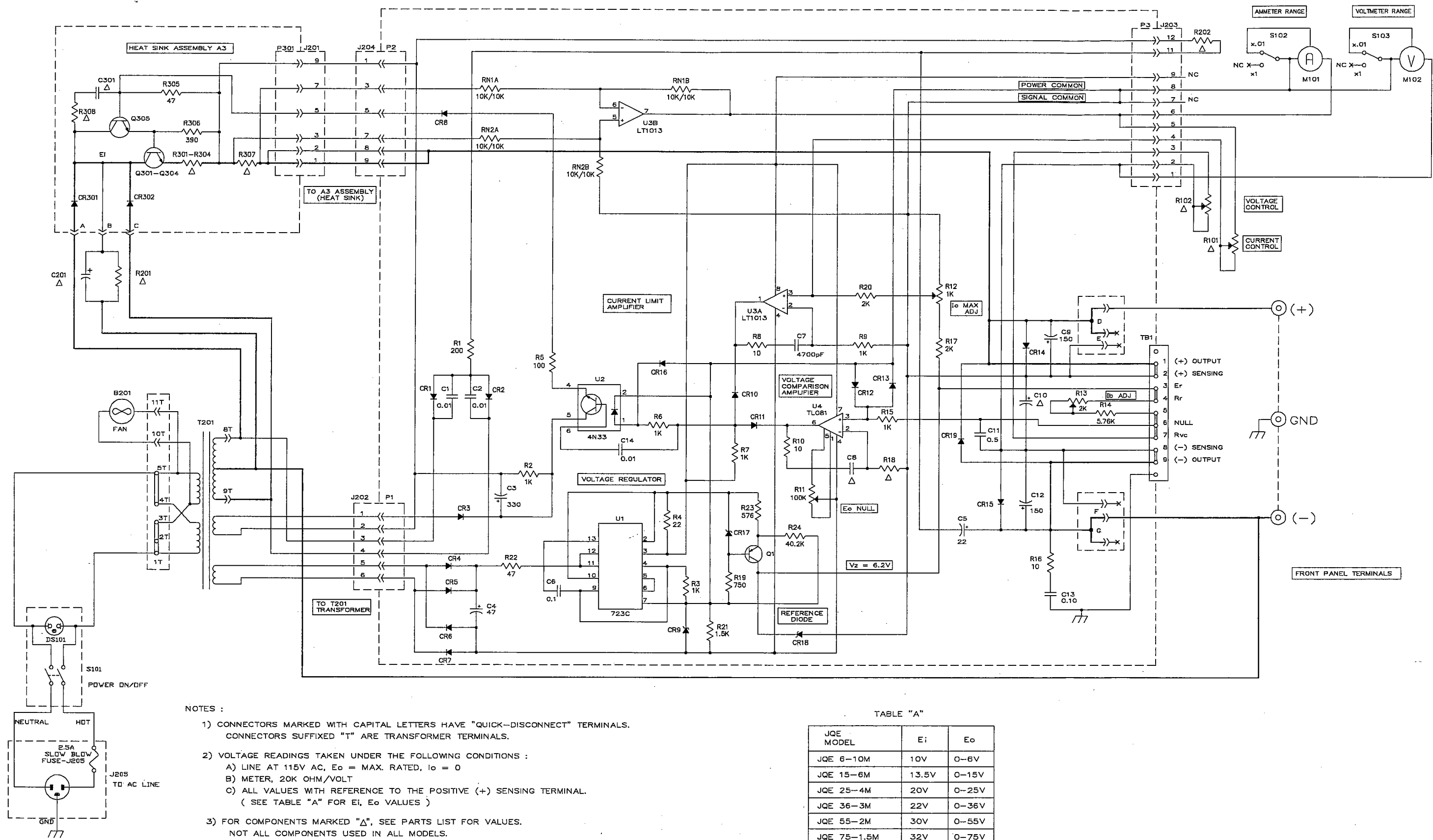
NOTE:
NOT ALL COMPONENTS USED IN ALL MODELS,
SEE PARTS LIST

FIG. 6-1 MAIN CHASSIS, COMPONENT LOCATION



NOTE: NOT ALL COMPONENTS USED.
SEE PARTS LIST.

FIG. 6-2 PRINTED CIRCUIT BOARD, COMPONENT LOCATION



- NOTES :
- CONNECTORS MARKED WITH CAPITAL LETTERS HAVE "QUICK-DISCONNECT" TERMINALS. CONNECTORS SUFFIXED "T" ARE TRANSFORMER TERMINALS.
 - VOLTAGE READINGS TAKEN UNDER THE FOLLOWING CONDITIONS :
 - LINE AT 115V AC, $E_o = \text{MAX. RATED}$, $I_o = 0$
 - METER, 20K OHM/VOLT
 - ALL VALUES WITH REFERENCE TO THE POSITIVE (+) SENSING TERMINAL. (SEE TABLE "A" FOR E_i , E_o VALUES)
 - FOR COMPONENTS MARKED " Δ ", SEE PARTS LIST FOR VALUES. NOT ALL COMPONENTS USED IN ALL MODELS.

TABLE "A"

JQE MODEL	E_i	E_o
JQE 6-10M	10V	0-6V
JQE 15-6M	13.5V	0-15V
JQE 25-4M	20V	0-25V
JQE 36-3M	22V	0-36V
JQE 55-2M	30V	0-55V
JQE 75-1.5M	32V	0-75V
JQE 100-1M	40V	0-100V

FIGURE 6-3. MAIN SCHEMATIC DIAGRAM JQE 1/4 RACK



INSTRUCTION MANUAL CORRECTION

Please note the following corrections to the Manual Material as indicated:

Parts List and Schematic Diagram:

1. CHANGE:	C8	Cap.,Ceramic	68pF,5%,600V	Kepeco #117-0981
To:	C8	Cap.,Ceramic,Disc,Rad. Lds.	390pF,10%,100V	Kepeco #117-0985
2. CHANGE:	R101	Res.,Var.,Composition,Vernier	2K ohm,30%,1/2W	Kepeco #115-2268
To:	R101	Res.,Var.,W.W., 10 Turn	2K ohm,5%,2W	Kepeco #115-1153
3. CHANGE:	C201	Cap.,Elec.,Can	28K MF,+10 -10%,35VDC	Kepeco #117-0717
To:	C201	Cap.,Elec.,Can	18K MF,+75 -10%,35VDC	Kepeco #117-1024
4. CHANGE:	B201	Motor,Fan	115V,50-60Hz	Kepeco #148-0026
To:	B201	Motor,Fan	115V,50-60Hz	Kepeco #148-0050
5. CHANGE:	Blade,Fan,Motor		2 5/8" Dia.,4 Blades	Kepeco #149-0019
To:	Blade,Fan,Motor		2 5/8" Dia.,4 Blades	Kepeco #149-0034
6. CHANGE:	Q305	Transistor	2N3054	Kepeco #119-0060
To:	Q305	Transistor	2N3441	Kepeco #119-0071
7. CHANGE:	S101	Switch,Rocker	SP ST 125VAC,10A	Kepeco #127-0230
To:	S101	Switch,Rocker,Illuminated	DP ST 250VAC,16A	Kepeco #127-0432
8. CHANGE:	F201	Fuse,.25"x1.25"	2.5A,250V,GL	Kepeco #141-0029
To:	F201	Fuse,5x20mm	2.5A,250V,GL	Kepeco #141-0102
9. DELETE:	DS101	Pilot Light Assembly		Kepeco #152-0087
10. CHANGE:	Line Cord Set			Kepeco #118-0441
To:	Line Cord Set			Kepeco #118-0552
11. DELETE:	S102,S103	Switch, Slide		Kepeco #127-0254
		NOTE: Remove all references to dual range meter		

JQE15-6(M)/06-2692/r26	C6479	JQE15-6(M)/11-2296/r30	C7685
JQE15-6(M)/04-1194/r27	C6816	JQE15-6(M)/11-2296/r31	C7736
JQE15-6(M)/01-0395/r28	C7018	JQE15-6(M)/12-1196/r31	BMC
JQE15-6(M)/10-3195/r29	C7437	JQE15-6(M)/07-0604/r32	C10076

You must register your product to comply with the terms of the warranty. Either fill out the form below and mail or fax to Kepco, or for rapid on-line registration go to:

<http://www.kepcopower.com/warranty.htm>

PRODUCT PURCHASED:

Model Number) _____

Serial Number _____

PURCHASE INFORMATION:

Date Purchased: _____

Date Received: _____

REQUEST ADDITIONAL INFORMATION

Send complete Catalog

Have Sales Engineer Call

Contact via: E-Mail Telephone Fax S-mail

REGISTER TO:

Registered by: _____

Company Name: _____

Street: _____

City: _____

State: _____

Country: _____

Zip: _____

E-mail: _____

FAX: _____

Phone: _____

WHAT INFLUENCED YOUR CHOICE OF THIS POWER SUPPLY?

Previous Experience (which Kepco Models do you have?)

Magazines (which ones?) _____

Trade Shows (which ones?) _____

Directory? _____

Kepco Catalog or Brochure? _____

Sales Representative?

Web Site

Other (please explain): _____

What products would you like to see Kepco make?

CUT HERE

Kepco 5 Year Warranty

This is to certify that we, KEPCO, INC., (hereinafter called "Company"), Flushing, NY 11352 USA, warrants for a period of FIVE YEARS, this instrument known as:

MODEL: _____

SERIAL NO. _____

The Company's products are warranted for a period of five years from date of delivery to be free from defects in materials and workmanship and to conform to the specifications furnished or approved by the Company. Liability under this warranty shall be limited to the repair or replacement of any defective product at Company's option.

If any defect within this warranty appears within the warranty period, the Purchaser shall promptly notify the Company in writing. No material will be accepted for repair or replacement without written authorization of the Company.

Upon such authorization, and in accordance with instructions of the Company, parts or materials for which replacement is requested shall be returned to the Company for examination, with shipping charges prepaid by the Purchaser. Final determination as to whether a product is actually defective rests with the Company.

This warranty does not extend to any product which has been subjected to misuse, neglect, accident, improper installation, or use in violation of instructions furnished by the Company. The warranty does not extend to, or apply to, any unit which has been repaired or altered outside of the Company's factory by persons not expressly approved by the Company.

THE WARRANTY HEREIN CONTAINED IS IN LIEU OF AND EXCLUDES ALL OTHER WARRANTIES, EXPRESS, IMPLIED OR STATUTORY, INCLUDING WITHOUT LIMITATION THE WARRANTY OF MERCHANTABILITY.

THIS KEPCO PRODUCT IS WARRANTED FOR FIVE YEARS!

KEPCO, INC. • 131-38 SANFORD AVENUE, FLUSHING,
NY 11352 USA • Tel. 718-461-7000 • Fax. 718-767-1102
E-mail: hq@kepcopower.com • URL: <http://www.kepcopower.com>



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here

KEPCO, INC.

131-38 SANFORD AVE.
FLUSHING, NY 11352 USA

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