OPERATOR'S MANUAL

JQE 55-20

POWER SUPPLY

INCLUDES MODEL SUFFIX DM, M, VP, Y

KEPCO INC.
An ISO 9001 Company.

MODEL CE

JQE 55-20DMVPY

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.

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KEPCO® THE POWER SUPPLIER™

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OPERATOR MANUAL CORRECTION

JQE 55-20MPVY MODEL

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1. Digital Meters

JQE models with the suffix DM indicates that the unit has digital meters in place of the analog meters. (NOTE: analog meters are no longer available.) Voltage meter accuracy is 1%; current meter accuracy is 1.5%. Meter range selector switches are no longer needed with the digital meters and have been removed on DM models. Refer to Figures 2, 3 and 4 for front panel views of the quarter rack, half rack, and full rack DM models.

2. ADD PAR. 1-8A

1-8A ACCESSORIES

a) Mounting brackets for rack installation (supplied, see Figure 2-5 for installation instructions).

b) Side Support "L" Bracket P/N 128-1775 mounts to vertical rails to provide additional side support for rack-mounted models.19.6 in. long x 2.3 in. high x 3.5 in. wide. Two (2) required per unit.

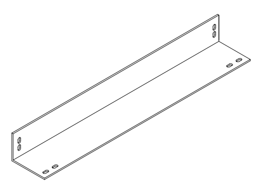

FIGURE 1. SIDE SUPPORT "L" BRACKET P/N 128-1775

3. SECTION III Correction

The instructions throughout Section III are based on a value of the front panel VOLTAGE control (R102) that requires an I_b of 1mA and a corresponding CONTROL RATIO (Kc), also referred to as Programming Ratio, of 1000 Ohms/Volt.

To allow for the fact that the value of R102 may now be different, use the following procedure to determine the actual I_b and the corresponding CONTROL RATIO ($1/I_b$)

1. Turn the unit off and disconnect unit from source power.
2. Remove the link between positions 5 and 6 of TB501 (for JQE quarter rack models: remove link between positions 6 and 7 of TB1).
3. Set the Voltage potentiometer on the front panel to full clockwise.
4. Use a precision digital ohmmeter to measure the resistance between positions 4 and 5 of TB 501 (for JQE quarter rack models: measure resistance between positions 7 and 8 of TB1). This is the actual resistance of the front panel VOLTAGE control (R102), referred to as $R_{VC\ Internal}$.
5. Use the measured value of R102 to calculate I_b as follows:
   $I_b = (E_O + (\Delta E_O))/ R_{VC\ Internal}$
   where:

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E_O is the nominal output voltage (Volts).
$R_{VC\ Internal}$ is the value of R102 measured in step 4 (Kilohms).
I_b is the actual control current.
ΔE_O functions as voltage headroom to allow full scale from the front panel control.

6. Calculate the CONTROL RATIO as 1/ I_b (Kilohms/Volt) using the value of I_b calculated in step 5.

7. Use the calculated values of I_b and CONTROL RATIO for all procedures of Section III.

   As an example, referring to the Procedure: Precision Programming Ratio Adjustment, PAR. 3-37, step c), instead of R_{VC} = 5K Ohms, use R_{VC} = 5 (1/ I_b) (in Kilohms) in order to obtain an output voltage of 5V.

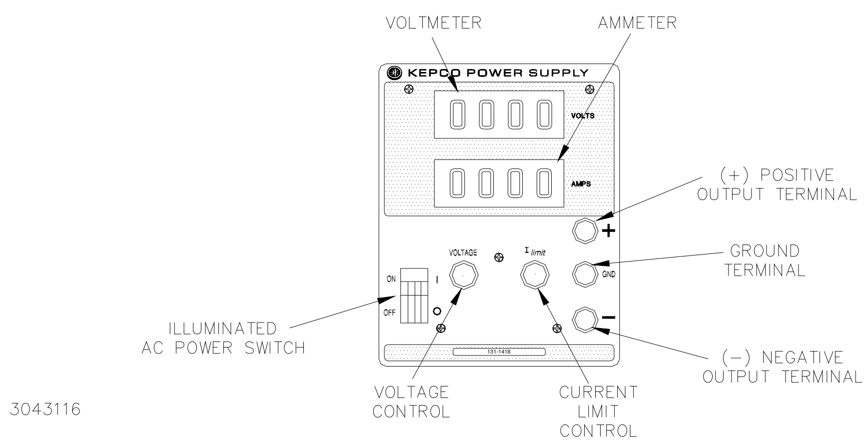


FIGURE 2. FRONT PANEL VIEW OF JQE QUARTER RACK DM (DIGITAL METER) MODELS

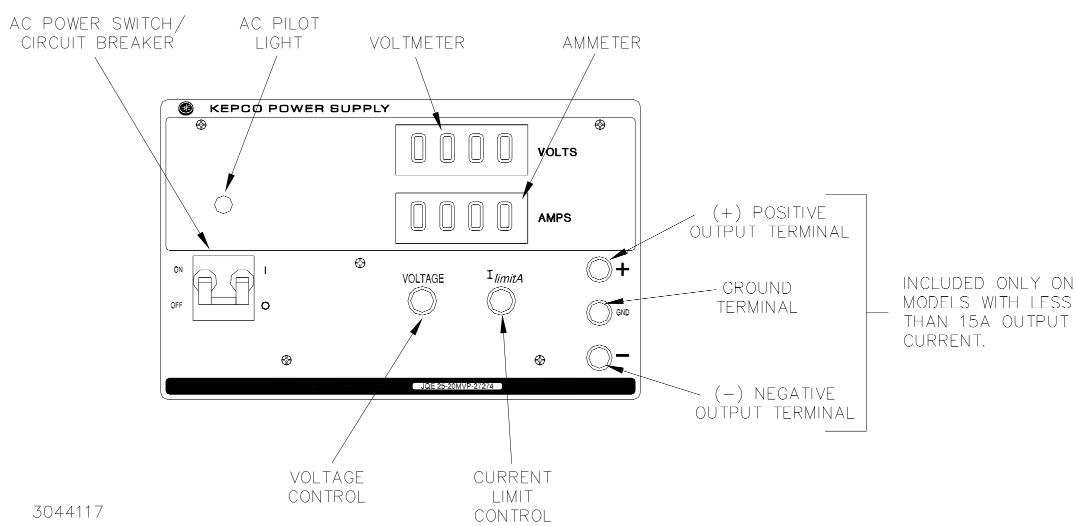


FIGURE 3. FRONT PANEL VIEW OF JQE HALF RACK DM (DIGITAL METER) MODELS

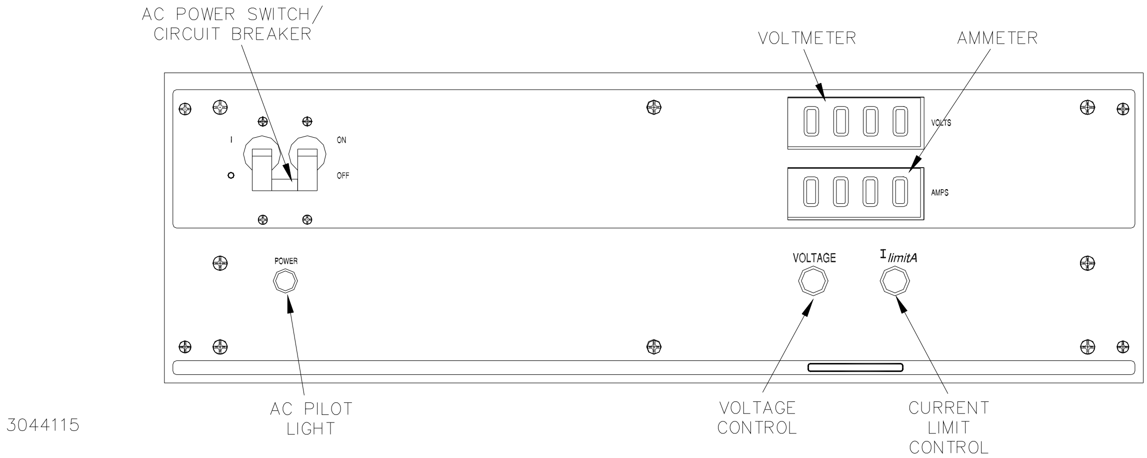


FIGURE 4. FRONT PANEL VIEW OF JQE FULL RACK DM (DIGITAL METER) MODELS

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, 2006/95/EC, 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. (EN61010-1:2010, Cl. 6, Cl. 7, Cl.8, and Cl. 9)

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. 6.5.5)

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. 6.5.5 and Cl.6.10.1)

5. For European applications requiring compliance with the RoHS 2 directive, 2011/65/EU, this power supply is designed for scientific research and technological development, and is excluded from the scope of the directive [2011, 65/EU, Article 2 (4) (j)].

6. This power supply has secondary output circuits that are considered hazardous, and which exceed 240 VA at a potential of 2V or more.

7. 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.

8. 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. (EN61010-1:2010, Cl. 9.6)

9. 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.

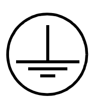
Source power must be removed from the product prior to performing any servicing.

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.

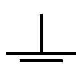
2. Grounding

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

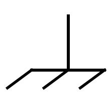
The PROTECTIVE EARTHING CONDUCTOR TERMINAL must be properly connected prior to application of source power to the product (see instructions on installation herein) in order to ensure safety from electric shock.



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.

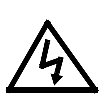


CHASSIS TERMINAL -This symbol indicates frame (chassis) connection, which is supplied as a point of convenience for performance purposes (see instructions on grounding herein). This is not to be confused with the protective earthing point, and may not be used in place of it.

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 I – INTRODUCTION

1-1 SCOPE OF MANUAL

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

1-3 GENERAL DESCRIPTION

1-4 Kepco Series JQE Power Supplies are general purpose, precision regulated voltage sources in the "half-rack" configuration. JQE Power Supplies feature full range voltage control and current limit adjustment by means of multi-turn front panel controls. JQE power supplies have linear, full-dissipation series-regulators (NPN) driven by an integrated circuit operational amplifier. A sharp current-limit circuit renders the power supply completely short-circuit proof. JQE power supplies may be readily converted to provide constant current by the addition of an external sensing resistor and a "current control." The output of the JQE power supply is completely programmable. All necessary connections are available on terminals at the rear barrier-strip.

1-5 The compact design of the Kepco JQE "FULL-RACK" Series was made possible by a unique heat sink design of exceptional efficiency in combination with highly reliable low-noise fans. JQE power supplies feature all-silicon design with conservatively rated components for added reliability.

1-6 JQE power supplies are identical in their mechanical dimensions (Refer to FIG. 1-3) and in their electrical specifications, except as noted in TABLE 1-1.

1-7 OPTIONS. Optional features of Kepco Power Supplies are indicated by a letter following the model designation:

a) JQE Power Supplies with suffix "E" are equipped with an "E_{io} Null" adjustment, which allows exact zero calibration for precision programming applications.

b) JQE Power Supplies with suffix "M" are equipped with two dual range panel meters which permit simultaneous monitoring of the output voltage and output current. Meter range-switches allow for full scale reading of either 10% or 100% of the voltage and current outputs.

c) JQE Power Supplies with suffix "T" have special references which improve the temperature coefficient of the supply (see paragraph 1-11 for specifications).

d) JQE Power Supplies with suffix "VP" are equipped with an overvoltage protector. This electrical "crowbar" shorts the output through a silicon controlled rectifier (SCR) if the output voltage exceeds a preadjustable limit on the protector (see paragraph 1-12 for specifications).

e) JQE Power Supplies with suffix "Y" are equipped with a separate control-amplifier and additional programming terminals for remote control of the output current. Option "E" is included with the "Y" option models.

1-8 The main chassis frame of the power supply is constructed from cold-rolled steel, as is the perforated wrap-around cover. Front panel material is aluminum (Refer to FIG. 1-3 for finish).

1-9 MOUNTING

Refer to "Mechanical Outline Drawing" (FIG. 1-3). Four (4) aluminum feet are provided for bench operation of the supply. Feet are removeable for rack-mounting. Adaptor brackets for mounting the supply into a standard (19-inch) rack are supplied. Refer to FIG. 2-5 for installation instructions.

1-10 SPECIFICATIONS, GENERAL

a) AC INPUT: 105 to 125V AC or 210 to 250V AC (selectable, refer to SECTION II), 50 to 65 Hz,* single phase. Refer to the table of general specifications (TABLE 1-1) for the AC input current for each model. Approximate power factor: 0.9.

b) OPERATING TEMPERATURE RANGE: (–)20°C to (+)71°C (without derating of the output).

*Consult factory for operation on power line frequencies above 65 Hz.

c) STORAGE TEMPERATURE: −40°C to (+)85°C.

d) COOLING: High efficiency, single bearing fans, (permanently lubricated) with special low noise non-metal blades.

e) ISOLATION: A maximum of 500 volts (DC or p-p) can be connected between chassis and either output terminal. The common mode current from output to ground is less than 5 micro amps rms, or 50 micro amps peak to peak at 115V AC, 60 Hz.

1-11 SPECIFICATIONS, ELECTRICAL

Refer to TABLE 1-1 and 1-2.

MODEL(1)	D-C OUTPUT RANGE		OUTPUT IMPEDANCE		APPROXIMATE MAXIMUM AC INPUT CURRENT
	VOLTS	AMPERES	VOLTAGE MODE dc Ω + Series "L"	CURRENT MODE(2) dc Ω + Shunt "C"	Amps @ 125V A-C
JQE 6–90(M)	0–6	0–90	3.5 μΩ + 0.5 μH	3.5 KΩ + 17.6 KμF	15.7
JQE 15–50(M)	0–15	0–50	15 μΩ + 0.5 μH	10 KΩ + 12 KμF	16.6
JQE 25–40(M)	0–25	0–40	31 μΩ + 0.5 μH	12.5 KΩ + 14 KμF	21.0
JQE 36–30(M)	0–36	0–30	60 μΩ + 0.5 μH	16 KΩ + 11 KμF	19.0
JQE 55–20(M)	0–55	0–20	138 μΩ + 1 μH	25 KΩ + 7.3 KμF	18.0
JQE 75–15(M)	0–75	0–15	250 μΩ + 1 μH	33 KΩ + 4.2 KμF	18.0
JQE 100–10(M)	0–100	0–10	0.62 mΩ + 1 μH	50 KΩ + 2.2 KμF	17.0
JQE 150–7(M)	0–150	0–7	1.1 mΩ + 2 μH	72 KΩ + 1 KμF	18.0

1) Specifications for unmetered models (without suffix "M") are identical.
2) External current sensing and control using the Voltage Mode amplifier, 1 volt sensing drop.

TABLE 1-1 D-C OUTPUT AND A-C INPUT SPECIFICATIONS, JQE "FULL RACK" GROUP

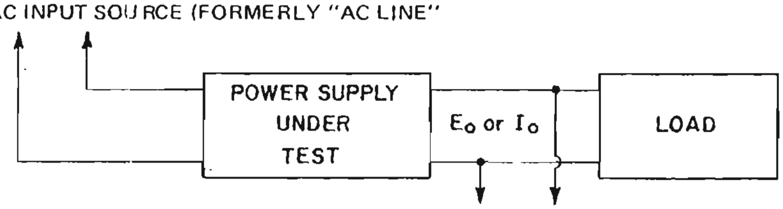
NOTE: Kepco has adopted new technical terms recommended by the International Electrotechnical Commission (IEC). These terms replace or supplement previously used expressions to avoid difficulties in translation and prevent erroneous interpretation at home and abroad.

In this instruction manual, Kepco discontinued the use of the specifications entitled "line regulation" and "load regulation." Instead, Kepco will follow the recommendation of the IEC and speak of the "Output Effects, caused by changes in the influence Quantities." The "Output Effects" are specified either as a percentage change referred to the maximum specified output voltage (E_O) or current (I_O) or as an absolute change (ΔE_O, ΔI_O) directly in millivolts or millamperes or both. The "Influence Quantities" are the "Source Variations" (formerly a-c line variations), the "Load Variations" (formerly load regulation), the "Temperature Variations" (no change, still specified as a coefficient) and the "Time Variations" (formerly stability). The illustration below will clarify the use of the new terminology.

INFLUENCE QUANTITIES

1) SOURCE VARIATIONS
2) LOAD VARIATIONS
3) TEMPERATURE VARIATIONS
4) TIME VARIATIONS

AC INPUT SOURCE (FORMERLY "AC LINE"



OUTPUT EFFECTS (ΔE_O, ΔI_O)

1) DUE TO SOURCE VARIATIONS = SOURCE EFFECT . . . . (formerly LINE REGULATION)
2) DUE TO LOAD VARIATIONS = LOAD EFFECT . . . . (formerly LOAD REGULATION)
3) DUE TO TEMPERATURE = TEMPERATURE COEFFICIENT . . (COEFFICIENT, NO CHANGE)
4) DUE TO TIME = DRIFT . . . . (formerly STABILITY)

INFLUENCE QUANTITY	OUTPUT EFFECTS VOLTAGE MODE ΔE_o	OUTPUT EFFECTS CURRENT MODE ΔI_o (3)	AMPLIFIER OFFSETS (4) VOLTAGE ΔE_o	AMPLIFIER OFFSETS (4) CURRENT ΔI_o	REFERENCE 6.2V ± 5%
SOURCE: 105–125/210–250V a-c	<0.0005%	<0.005%	<10 μV	<2 nA	0.0001%
LOAD: No load – full load	<0.005% or 0.2 mV (1)	<0.01%	<200 μV	<5 nA	–
TIME: 8-hours [drift]	<0.01% or 1 mV (1)	<0.02%	<20 μV	<2 nA	0.005%
TEMPERATURE: Per °C	<0.1% (2)	<0.02% (2)	<20 μV	<5 nA	0.005%
UNPROGRAMMED OUTPUT DEVIATION: (5) (Ripple and noise) rms	<0.2 mV	<0.02% of I_o max	–	–	–
p-p (6)	<1.0 mV	<0.1% of I_o max	–	–	–

(1) Whichever is greater.

(2) Models with suffix "T" have 0.005% and 0.01% per °C Temperature Coefficients in the Voltage and Current Mode respectively.

(3) Current Mode Output Effects (ΔI_O) are measured across the external sensing resistor. This resistor must be a high quality, wirewound unit, with a wattage at least 10 times the actual power dissipated, have a Temperature Coefficient of 20 parts per million or better and drop a sample voltage of 1.0 volt at the measuring current. A resistor built as a 4-terminal network is recommended. Current control is exercised with an external 20 PPM feedback resistor.

(4) Offsets and the reference contribute to output effect ΔE_O by the equation $\Delta E_O = \pm\Delta E_{ref}\ (R_f/R_i) \pm\Delta E_{io}\ (1 + R_f/R_i) \pm\Delta I_{io}\ (R_f)$, where R_f is the feedback resistor and R_i is the input resistor from the signal reference. Use the offsets to calculate output effects when external input/feedback elements are substituted for the internal reference and voltage control in special applications.

(5) Valid with one output terminal grounded or connected so that the common mode current (see par. 1-10e) does not flow through the load or (in the current mode) through a sensing resistor.

(6) 20 Hz to 10 MHz.

TABLE 1-2 JQE (FULL RACK) ELECTRICAL SPECIFICATIONS

1-12 SPECIFICATIONS, PERFORMANCE

a) VOLTAGE CONTROL CHANNEL.

1) LOCAL OUTPUT VOLTAGE CONTROL*. 10-turn precision rheostat at the front panel, resolution: 0.05% of the maximum rated output voltage (E_O max.). Controls output voltage from zero to E_O max.

2) REMOTE OUTPUT VOLTAGE CONTROL: External control can be exercised by resistance (1000 ohms per volt of output), or by a control voltage (refer to Section III for details). Control is "operational," with the JQE functioning as a unipolar power amplifier (plus output terminal common).

3) OFFSETS: JQE models with suffix "E" and with suffix "Y" have provisions to zero the initial (static) offset voltage. The output effects resulting from the offset *variations* are specified in TABLE 1-2. The *total* output effects (worst case) may be calculated from the relationship:

$$\Delta E_O = \pm \Delta E_r\ (R_f/R_i) \pm \Delta E_{io}\ (1 + R_f/R_i) \pm \Delta I_{io}\ R_f$$

where: ΔE_O = total output voltage variation
ΔE_r = Change in reference or input voltage
R_f = Internal voltage control or external feedback resistor
R_i = Input or reference resistor
$\Delta E_{io}, \Delta I_{io}$ = Tabulated offset variations

4) GAIN: The open loop gain of the voltage control channel is greater than 0.5×10^6 volts per volt.

5) REFERENCE: 6.2 volts nominal, positive with respect to common (+ OUTPUT), 1 milliampere maximum.

6) REMOTE ERROR SENSING: Rear terminals provide for connection of error sensing leads directly at the load. The four-terminal load connection compensates for the voltage drop along the load wires. Up to 0.5 volt per load wire can be compensated using remote sensing. The supply output voltage is one volt greater than normally specified for this purpose.

b) CURRENT STABILIZATION.

1) LOCAL OUTPUT CURRENT CONTROL*: 10-turn precision rheostat at the front panel, controls the current limit from 10% to 105% of the rated output current (I_O).

*Knob controlled on all metered models (suffix "M"). Locking type screwdriver controls on unmetered models.

2) REMOTE OUTPUT CURRENT CONTROL: Standard JQE models do not have provisions for external control of the current limit. JQE models with suffix "Y" have an additional current control channel. Separate rear terminals are provided, permitting external control (by means of an external control potentiometer or a control voltage) over the current limit function. The control voltage may be derived across the built-in reference voltage by means of a voltage divider circuit, or an independent control voltage from a separate programming source can be used (Kepco SN Programmer, for example).

3) REMOTE CURRENT CONTROL USING THE VOLTAGE CONTROL CHANNEL: The voltage control channel of the JQE power supply may be used for the precision control of the output current. Using an external current sensing resistor and current control rheostat, the voltage channel is reconnected (by means of the rear barrier terminals), to sense the drop across the external resistor in the positive output lead. The current range achievable is approximately from 1 milliampere to 100% I_O for standard models and from 1 microampere to 100% I_O for models with suffix "E" (see Section III for further details).

c) DYNAMICS.

1) VOLTAGE RECOVERY FOR STEP-LOAD CURRENT: The time required for the stabilized output voltage to recover within the load effect band (or 2 mV, whichever is greater) is less than 50 microseconds.

2) CURRENT RECOVERY FOR STEP-LOAD VOLTAGE: The time required for the stabilized output current to recover within the load-effect band is governed by an (exponential) RC time constant, where "R" represents the load resistance and "C" is the tabulated (TABLE 1-1) shunt capacitance.

3) PROGRAMMING SPEED: The rate at which the JQE power supply responds to a step-program is determined by the setting of the current limit control, the value of the load resistance and the tabulated (TABLE 1-1) shunt capacity.

4) OUTPUT IMPEDANCE (See Table 1-1): The DC and low frequency value is given by the tabulated (Table 1-2) load effects. With increasing frequency, the output impedance becomes asymptotic to the tabulated (Table 1-1) series inductance (Voltage Mode) or shunt capacitance (Current Mode).

d) GENERAL.

1) SERIES/PARALLEL OPERATION: JQE models may be operated in series or parallel modes of operation and can be interconnected for "Master—Slave" tracking. NOTE: JQE MODELS WITH OPTION "VP" (BUILT-IN CROWBAR) CANNOT BE PARALLELED. SEE SECTION III FOR FURTHER INFORMATION.

2) CROWBAR SPECIFICATIONS (MODELS WITH SUFFIX "VP"): The electronic "crowbar" circuit consists of a silicon controlled rectifier (SCR) and a sensing amplifier. The power supply output is shorted by the SCR if the output voltage exceeds a pre-adjustable limit.

Adjustable Limit Range: 3 volts to E_O max.

Triggering Time: 5—10 microseconds, with adjustable delay to minimize false triggering.

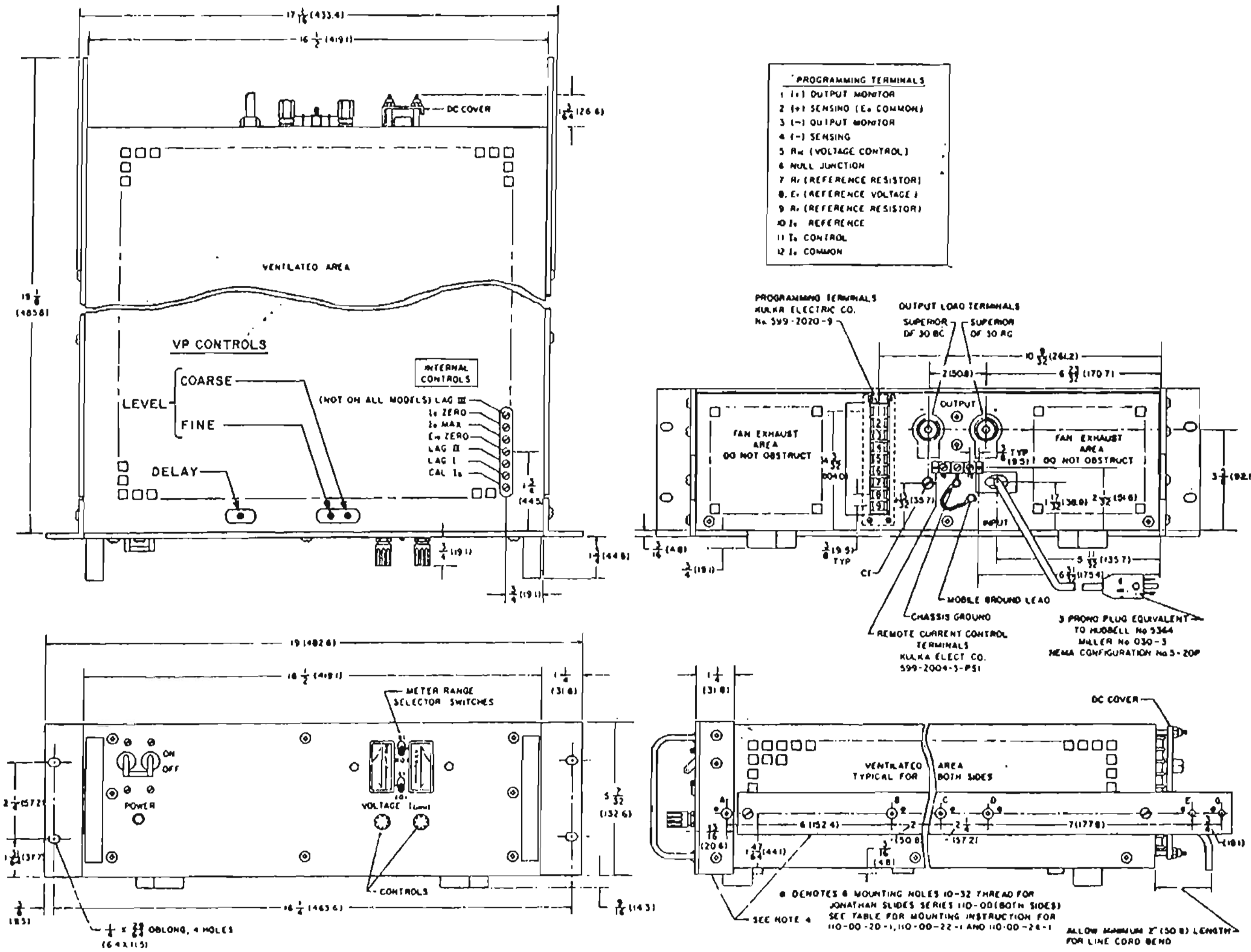
Threshold: Limit point may be set to within 5% of E_O or 0.25 volt, whichever is greater. The initial seting should account for a 2% of E_O warm-up settling effect.

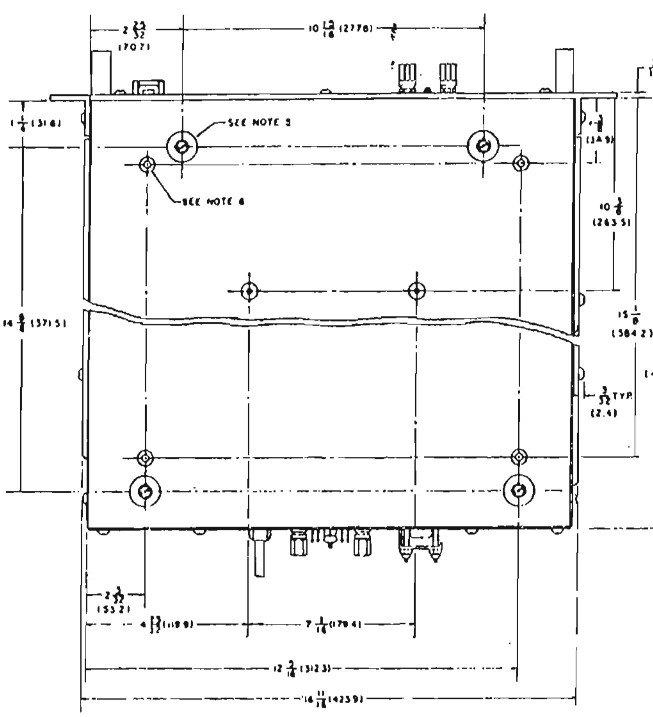
Crowbar Temperature Coefficient: 0.05% of E_O per °C.

1-13 SPECIFICATIONS, MECHANICAL

a) DIMENSIONS AND FINISH: Please refer to the "Mechanical Outline Drawing," FIG. 1-3.

b) METERS (MODELS WITH SUFFIX "M"): Two dual-range (100% and 10% of E_O max. and I_O max), 2-inch recessed panel meters, 3% of full scale accuracy. For output voltage and current monitoring.





MOUNTING TABLE				
SLIDE TYPE	USE MOUNTING HOLES			
110 00-20-1	A	B	D	0
110 00-22-1	A	C	A "0" HOLE HAS TO BE ADDED TO BOTH SLIDES, 0.199 DIA. AND 18" FROM "A" HOLE (457.2)	
110 00-24-1	A	C	E	-NOT USED

NOTES:

1. THIS DRAWING IS USED FOR THESE MODELS: JQE55-20MY, JQE100-10MY, JOE75-15MY, JQE150-7MY.
2. MATERIAL: A) CHASSIS #11 GAGE COLD ROLLED STEEL.
   B) FRONT PANEL 3/16 THICK ALUMINUM.
   C) COVER 3/32 THICK ALUMINUM.
3. FINISH. A) CHASSIS CADMIUM PLATED WITH A YELLOW CHROMATE WASH.
   B) FRONT PANEL LIGHT GRAY PER FEDERAL STD. 595 COLOR #26440.
   C) COVER CHARCOAL GRAY VINYL TEXTURE.
4. FIXED ANGLE BRACKETS AND CHASSIS SLIDES SUPPORT BAR (BOTH SIDES) USED FOR RACK OR CABINET INSTALLATION. CAN BE REMOVED FOR BENCH OPERATION.
5. (4) ALUMINUM FEET TO BE REMOVED FOR RACK OR CABINET MOUNTING
6. (6) PLASTIC MOUNTING INSERTS FOR 1/4-20X5/8 THREAD-CUTTING SCREWS, (WITH 1/8 THICK MOUNTING SURFACE).
7. DIMENSIONS IN PARENTHESES ARE IN MILLIMETERS.
8. TOLERANCES. A) BETWEEN MOUNTING HOLES: ±1/64 (±0.4)
   B) ALL FRONT PANEL DIMENSIONS TO MIL STD. [illegible]
   C) ALL OTHER DIMENSIONS ±1/32 (±0.8) EXCEPT AS NOTED.

CAUTION

WHEN INSTALLING MODEL INTO RACK OR CABINET, THE MODEL MUST BE SUPPORTED EITHER BY FIXED ANGLE BRACKETS (SEE NOTE # 4) AND CHASSIS SLIDE (SEE MOUNTING TABLE) OR BY FIXED ANGLE BRACKETS AND RIGID PLATFORM MOUNTED IN THE RACK OR CABINET.

NOTE: CHASSIS SLIDES AND RIGID PLATFORM ARE NOT SUPPLIED.

FIG. 1-3 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.

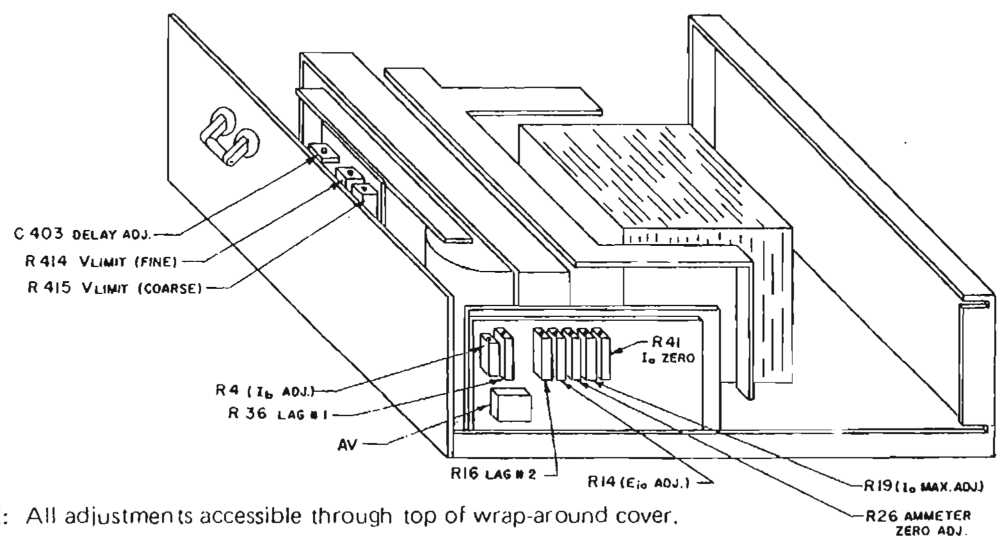
2-3 TERMINATIONS

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
C403[2]	Delay Adjust	Adjust Delay Time of VP	par. 3-28
R4	I_b Adjust	Control Current Calibration	par. 3-33
R14[3]	E_{io} Null Adjust	Output Voltage Precision zero	par. 3-33
R16[1]	Lag Adjust	AC Stability adjustment	par. 3-86
R19	I_o Max Adjust	Current Limit Control Calibration	par. 3-85
R26[4]	Ammeter Zero Adj.	Set Ammeter "Zero"	par. 3-87
R36[1]	Lag Adjust	AC Stability Adjustment	par. 3-86
R41[5]	I_o Zero Adjust	Output Current "Zero" calibration	par. 3-63
R414[2]	Overvoltage Level Adjust (FINE)	Adjusts Protector Threshold	par. 3-28
R415[2]	Overvoltage Level Adjust (COARSE)	Adjusts Protector Threshold	par. 3-28

(1) Not used on all models.
(2) Used on models with suffix "VP" only.
(3) Used on models with suffix "E" and "Y" only.
(4) Used on Model JQE 6–90 only.
(5) Used on Models with suffix "Y" only.

TABLE 2-1 INTERNAL ADJUSTMENTS AND CALIBRATION



NOTE: All adjustments accessible through top of wrap-around cover.

FIG. 2-1 LOCATION OF INTERNAL ADJUSTMENTS

2-4 AC INPUT REQUIREMENTS

2-5 This power supply is normally supplied for operation on a single phase, nominal 115V AC line. For conversion to 230V AC line operation, refer to FIG. 2-2. Remove the two links between transformer terminals (1)-(2) and (3)-(4). Reconnect one (1) link between terminals (2) and (3). DO NOT CHANGE ANY OTHER WIRING ON THE TRANSFORMER.

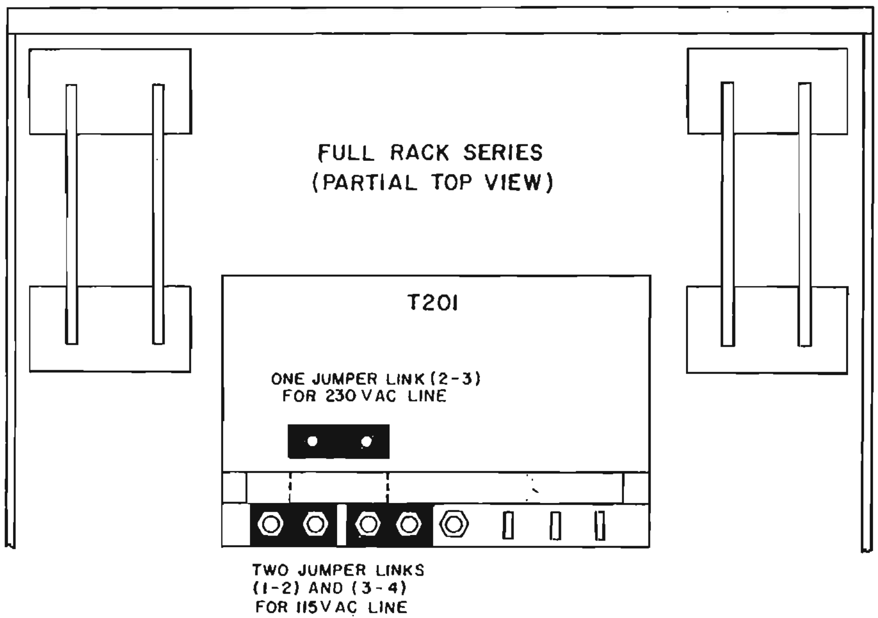


FIG. 2-2 CONVERSION TO 230V A-C NOMINAL LINE OPERATION

2-6 COOLING

2-7 The power transistors and rectifiers in this power supply are maintained within their operating temperature range by means of high effiency heat-sink assemblies, cooled by internal fans. 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 ambient temperature does not rise above the limit specified (71°).

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 damage resulting from shipment. Please refer to FIG. 2-3 for the location of the operating controls and output terminals.

a) Connect power supply to 115V AC line or refer to paragraph 2-4 for 230V AC operation if required.
b) If power supply is unmetered, connect a suitable DC voltmeter to the output terminals.
c) Turn CURRENT LIMIT CONTROL fully clockwise. Turn VOLTAGE CONTROL fully counterclockwise. Turn V-LIMIT (coarse) control fully clockwise.
d) Turn AC POWER SWITCH "on". The AC PILOT LIGHT (metered models only) should be energized. Slowly turn VOLTAGE CONTROL clockwise and observe the gradual increase of the output voltage. Turn counterclockwise again.

e) (MODELS WITH SUFFIX "VP" ONLY). Adjust output voltage to approximately 1/4 of its maximum rated value. Turn V-LIMIT control slowly counterclockwise, until output voltage goes suddenly to zero and the AC POWER SWITCH/CIRCUIT BREAKER trips. Leave AC power "off".

CAUTION

CONNECT SHORT CIRCUIT (OR LOAD) TO THE HEAVY DUTY OUTPUT TERMINALS, NOT TO THE BARRIER–STRIP TERMINALS. BARRIER–STRIP TERMINALS ARE FOR VOLTAGE MONITORING AND PROGRAMMING CONNECTIONS ONLY.

f) (MODELS WITH FRONT PANEL METERS ONLY)
Place a short circuit across the output. Turn CURRENT LIMIT CONTROL counterclockwise. Turn AC POWER SWITCH/CIRCUIT BREAKER "on". Slowly turn CURRENT LIMIT CONTROL clockwise and observe the gradual increase in output current on the panel AMMETER. The output current should smoothly increase from below 10% to 105% of the maximum rated output current, as the CURRENT LIMIT CONTROL is varied between its limits. Turn AC power "off". This concludes the preliminary check-out.

g) (MODELS WITHOUT METERS)
Place a short circuit, consisting of a suitable ammeter, across the output terminals of the unit. Turn CURRENT LIMIT CONTROL fully counterclockwise. Turn AC POWER SWITCH/CIRCUIT BREAKER "on". Slowly turn CURRENT LIMIT CONTROL clockwise, observing the ammeter scale. The output current should smoothly vary from below 10% to 105% of maximum rated output current as the CURRENT LIMIT CONTROL is adjusted from its maximum counterclockwise position. Turn AC power "off". This concludes the preliminary check-out.

2-10 INSTALLATION (See installation notes in FIG. 2-5)

2-11 a) (METERED MODELS)
The JQE Power Supply may be used as a bench operated instrument or, with the assistance of the mounting brackets it may be installed in any standard 19 inch rack. Please refer to paragraph 2-6 ("COOLING") if the supply is mounted into a multiple rack installation. Instructions for rack installation are provided (See FIG. 2-5).

b) (UNMETERED MODELS)
The JQE Power Supply is designed for chassis mounting directly into existing installations. For mounting hole dimensions and lay-out see FIG. 1-3 ("Mechanical Outline Drawing"). If the unit must be mounted into confined spaces, refer to parapraph 2-6 ("COOLING").

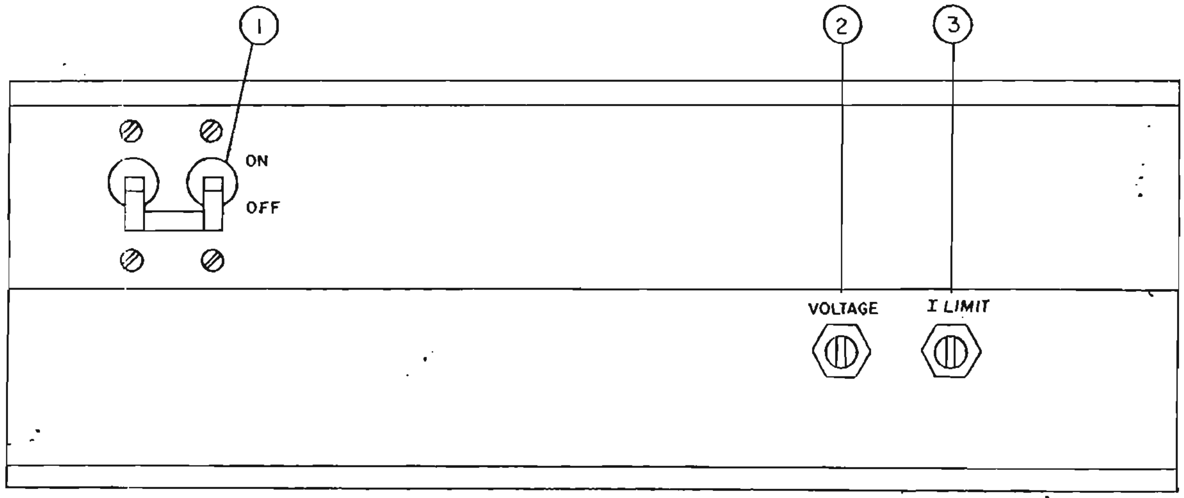
2-12 GROUNDING

a) AC 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. If a two terminal AC power receptable in combination with an adaptor is used, it is imperative that the chassis of the power supply be returned to AC ground with a separate lead.

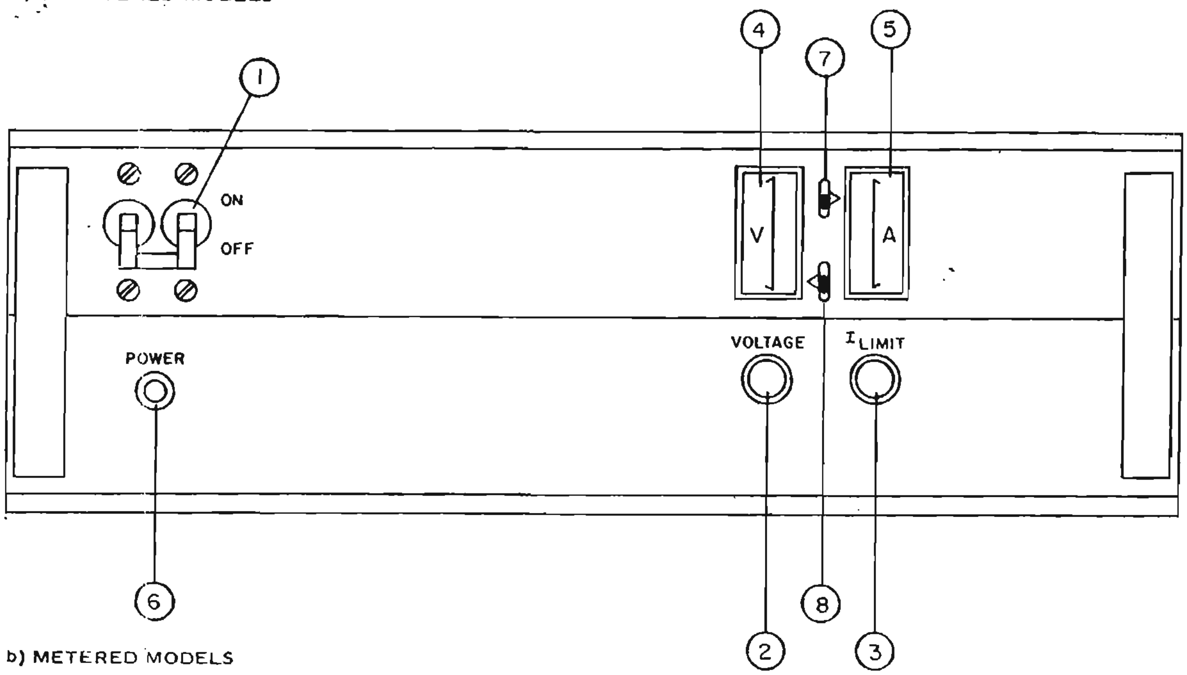
b) DC GROUND. The DC output is isolated from the AC power line and from any direct connection to chassis or ground, The maximum voltage that can be supported between either output terminal and ground or chassis is 500V (DC or p-p) plus the maximum output voltage of the power supply. For lowest output ripple and noise the grounding of one side of the output is recommended. (See Section III for additional grounding information).

*Metered models only (suffix "M"). Unmetered models have a three (3) terminal barrier-strip for AC input. Terminal "G" on the barrier-strip is connected to chassis and case.

**A capacitor-resistor network (C5, R25) is connected from the negative (–) output terminal to chassis. If the output is to be grounded elsewhere, this internal ground can be opened by removing C5 from the amplifier board (A1, FIG. 6-2).



a) UNMETERED MODELS



b) METERED MODELS

FIG. 2-3 FRONT PANEL CONTROLS AND TERMINATIONS

NO.	CONTROL OR TERMINATION	FUNCTION
1	AC POWER SWITCH/ CIRCUIT BREAKER	TURNS AC POWER LINE, "ON" OR "OFF" AND PROTECTS POWER SUPPLY INPUT CIRCUITRY
2	VOLTAGE CONTROL	ADJUSTS OUTPUT VOLTAGE FROM ZERO TO E_O max.
3	CURRENT LIMIT CONTROL	ADJUSTS CURRENT LIMIT FROM 0–105% I_O max.
4	VOLTMETER	MONITORS OUTPUT VOLTAGE, 0–E_O max.
5	AMMETER	MONITORS OUTPUT CURRENT o–I_O max.
6	AC PILOT LIGHT	ENERGIZES WHEN AC POWER IS "ON"
7	METER RANGE SWITCH AMPERE	MAY BE SET TO FULL SCALE READING OF MAXIMUM OR 1/10 OUTPUT
8	METER RANGE SWITCH VOLTS	MAY BE SET TO FULL SCALE READING OF MAXIMUM OR 1/10 OUTPUT

TABLE 2-2 CONTROLS AND TERMINATIONS, FULL–RACK JQE MODELS, FRONT

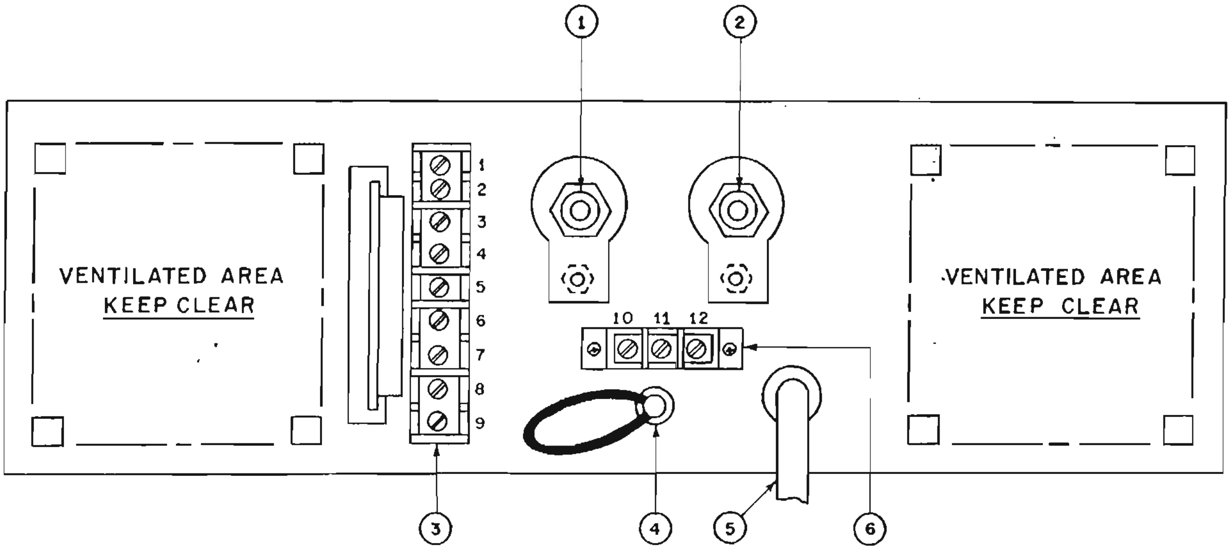


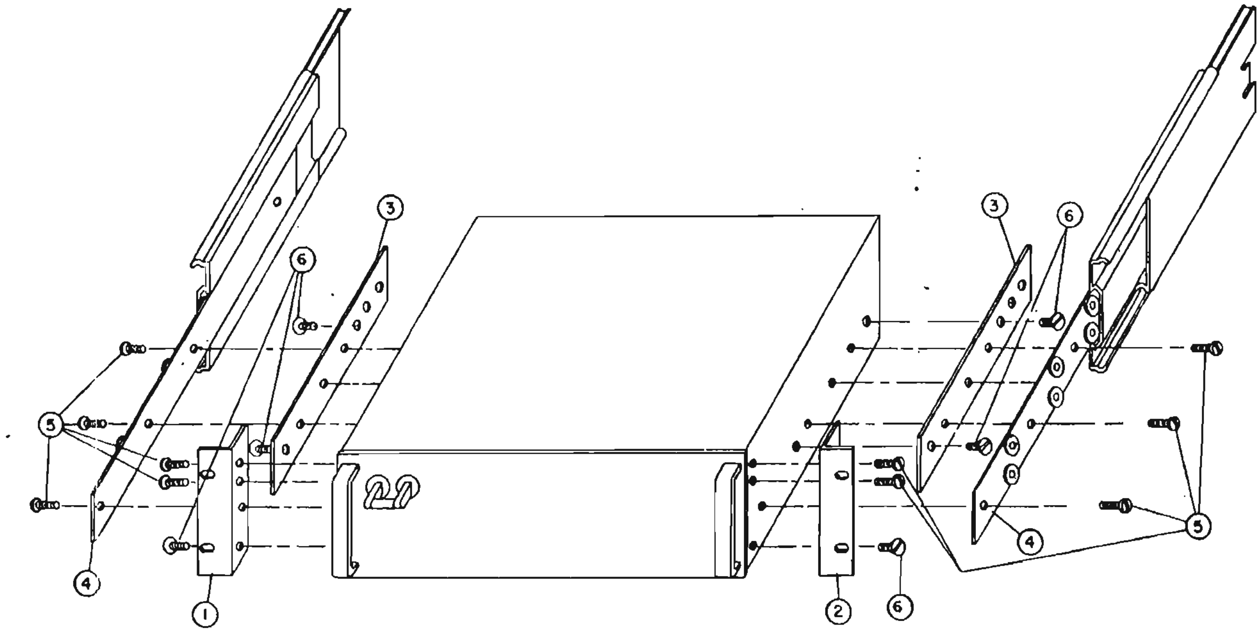
FIG. 2-4 REAR TERMINATIONS, FULL RACK JQE MODELS

NO.	TERMINATION	FUNCTION
1.	(–) OUTPUT	(1)NEGATIVE LOAD TERMINAL WITH GROUNDING POST
2.	(+) OUTPUT	(1)POSITIVE LOAD TERMINAL WITH GROUNDING POST
3.	REAR BARRIER-STRIP	PROGRAMMING AND MONITOR TERMINALS: (1) (+) OUTPUT MONITOR (2) (+) ERROR SENSING (3) (–) OUTPUT MONITOR (4) (–) ERROR SENSING (5) INTERNAL VOLTAGE CONTROL (6) NULL JUNCTION (AMPLIFIER INPUT) (7) REFERENCE RESISTOR (8) REFERENCE VOLTAGE (9) REFERENCE RESISTOR
4.	CHASSIS GROUND CONNECTION	(1)FLOATING GROUND LEAD TO GROUND EITHER THE (+) OR (–) OUTPUT VIA GROUND POST
5.	A-C INPUT	3-WIRE SAFETY LINE CORD (METERED MODELS ONLY)(2)
6.	REAR BARRIER-STRIP	CURRENT LIMIT PROGRAMMING TERMINALS: (10) OUTPUT CURRENT REFERENCE (11) OUTPUT CURRENT CONTROL (12) OUTPUT CURRENT COMMON

(1)Models with less than 25 A d-c output current do not have grounding posts. The chassis connection on these models is a terminal instead of a floating ground lead.

(2)Unmetered models have a three-terminal barrier strip instead of a line cord.

TABLE 2-3 REAR TERMINATIONS, FULL-RACK JQE MODELS.



RACK MOUNTING ACCESSORIES, PARTS LIST		
ITEM	DESCRIPTION	QTY.
1	FRONT ANGLE LEFT	1
2	FRONT ANGLE RIGHT	1
3	FILLER BRACKET	2
4	SLIDES: 110 QD JONATHAN SERIES	2
5	10–32 SCR BDG. HD.	10
6	10–32 FLATHEAD, 82°	6

NOTE: ITEM (4) NOT SUPPLIED.

INSTRUCTIONS FOR SLIDE INSTALLATION

1) **Items 1, 2, 3 are installed at the factory.**
2) **Item 3 (filler bracket) is predrilled and tapped for Jonathan Slides, Series 110 QD. Remove the three binding head screws on each side of Item 3. (These screws are part of Item 5.)**
3) **Line up slide with filler bracket and reinsert the binding head screws through the appropriate mounting holes in the slide.**
4) **If Jonathan Slide 110 QD–24–1 is used, an additional hole must be drilled into the slide. See FIG. 1-3 for further information.**

FIG. 2-5 RACK INSTALLATION, "FULL-RACK" MODELS.

INSTALLATION NOTE: With its four (4) removable aluminum bottom feet, the JQE may be operated on the bench, or placed on an equipment shelf for convenient operation. For bench operation, the FRONT ANGLE BRACKETS and the FILLER BRACKETS may be removed.

The JQE may be installed into a standard equipment rack (19-inches wide). The provided FRONT ANGLE BRACKETS (Side Flanges) are drilled for standard rack dimensions. Since the FRONT ANGLE BRACKETS are not sufficient to support the full weidht of the JQE, additional means of support must be provided, using one of the three methods described below:

a) CHASSIS SLIDES. The JQE is equipped on its sides with FILLER BRACKETS, which are pre-drilled for a number of "JONATHAN" slide types. (See Section I, FIG. 1-3.)

b) FILLER SUPPORT BRACKETS. The Kepco FSB Filler Support Brackets (optional, see Kepco Main Catalog) are ideally suited to provide additional support at the rear edge (or at the sides) in rack cabinets where suitable mounting channels or angles are available.

c) MOUNTING PLATFORM. A rigid mounting platform, if available in the equipment rack, can provide the necessary support for the JQE. The platform must be adjusted in such a way, that the mounting holes in the FRONT ANGLE BRACKETS line-up with the threaded holes in the side channels of the equipment rack.

SECTION III – OPERATION

3-1 INTRODUCTION

3-2 Kepco JQE Series power supplies are full-range operationally programmable d-c voltage/current sources. They can be set (by means of their front panel controls) or programmed (by means of remotely located passive controls or voltage/current control signals) to any level within their rated range and can be fully loaded at any output setting. Some application examples are:

a) The JQE may be operated as a precision stabilized voltage source with local (front panel) or external (remote) control of the output voltage. The current channel of the JQE serves as a continuous adjustable output current limiter in this application (see FIG. 3-9, for example). Remote output control (programming) can be exercised by means of resistance, conductance, external control voltage signals or external control current signals.

b) The JQE may be operated as a precision stabilized current source, using external current sensing and control. In this application, the voltage channel is used as the current stabilizer and voltage limiting, if required, must be provided externally (see for example FIG. 3-14). This mode of operation is suited especially for small d-c currents in the mA/μA range.

c) The JQE may be operated as a unipolar amplifier using resistive feedback as a gain control and an external input signal source with input resistor. The current channel serves as the current limiter (continuously adjustable) in this application. Due to the restricted bandwidth of the JQE Power Supply with its large output capacitor, operation is confined to low frequencies (see for example FIG. 3-12).

d) JQE MODELS WITH OPTION "Y" ONLY. While in standard JQE Models the output current limit can be controlled only from the control at the front panel, in JQE Models with Option "Y" it can be remotely controlled by a potentiometer or by a d-c control voltage. An additional control amplifier and separate rear terminals are provided for remote current limit control on JQE Models with Option "Y."

e) The JQE may be operated as a current stabilizer (constant current source) when operated in the current limit mode. Approximately 2% current stabilization is provided with the front panel control mode (all JQE Models) and 0.1% current stabilization in the remote control mode (JQE Models with Option "Y" only). This remote mode is suitable for larger output current requirements. For relatively low output current requirements (mA/μA range), the control method outlined in par. 3-2b should be used.

3-3 GENERAL

3-4 Detailed examples for the briefly-described applications will be given in the following paragraphs of this section. Before actual operation of the JQE, the following general comments, applicable to *all* applications, should be carefully considered.

3-5 CONNECTING DIAGRAMS (See FIG. 3-1). A (simplified) rear-view drawing is used to represent the JQE Power Supply in all connecting diagrams. A FOLD-OUT DIAGRAM AT THE END OF THIS SECTION (SECT III) IS PROVIDED, RELATING THE CONNECTING DIAGRAM TO THE JQE CIRCUITRY. The auxiliary barrier-strip (with terminals 10, 11 and 12) is used only on JQE Power Supplies with Option "Y."

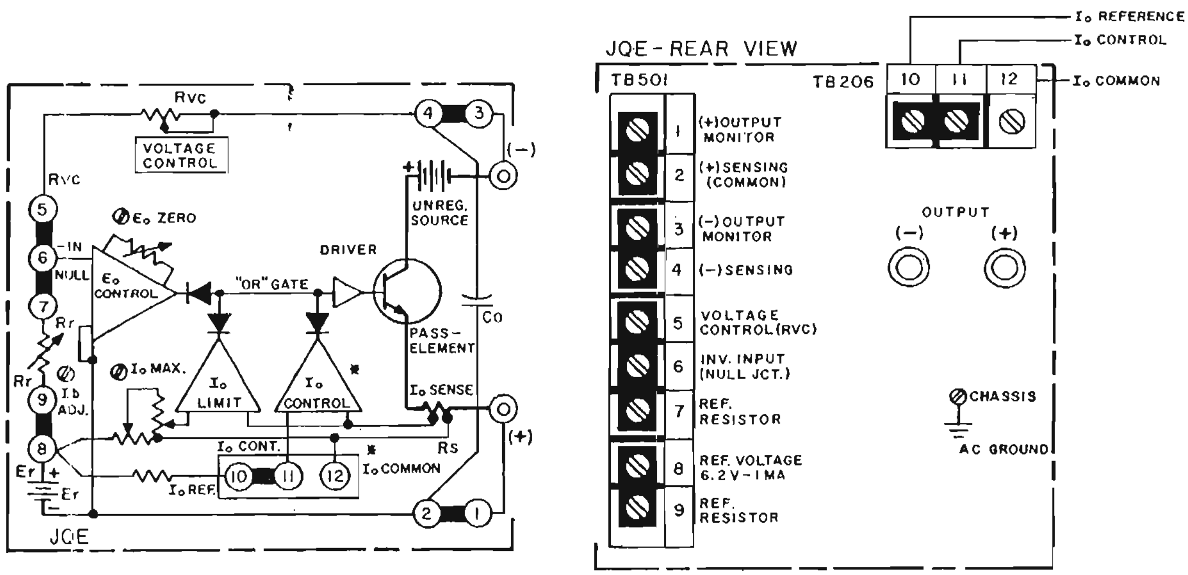
3-6 SAFETY GROUNDING(1) National and international safety rules demand the grounding of the metal cover and case of any instrument which is connected to the a-c power line. (Safety Class I—NEMA STD. 5-3-72.)

WARNING

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

Metered JQE Power Supplies with flexible a-c power cords are equipped with a 3-prong safety plug, which must be connected to a *grounded* a-c power outlet. Unmetered JQE Power Supplies have a 3-terminal a-c power input barrier-strip at the rear, to which a 3-wire connection (HOT, NEUTRAL, GROUND) to the a-c power line wiring must be made. These terminals are marked clearly and must not be interchanged during installation. If a-c input switching is planned, the switch must be installed in series with the terminal marked "H" (hot or phase terminal).

(1)See also Section II, par. 2-14.



A) SIMPLIFIED SCHEMATIC DIAGRAM, JQE SERIES.

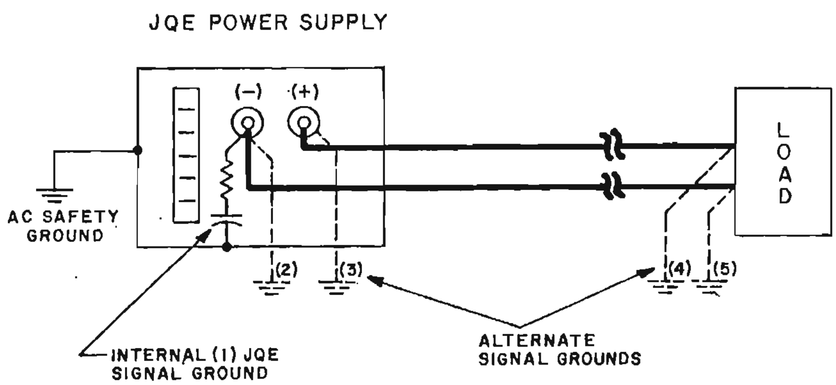
B) REAR VIEW DRAWING, JQE (½-RACK) SERIES, SHOWING OUTPUT AND PROGRAMMING TERMINALS.

FIG. 3-1 REAR VIEW DRAWING AND SIMPLIFIED DIAGRAM, JQE SERIES.

NOTES: 1) Rear jumper links in place for standard (front panel control) operation.
2) The simplified schematic diagram is repeated in the form of a fold-out drawing at the end of this section (Section III).

3-7 SIGNAL GROUNDING[1]. Connections between the power supply and the load (load and sensing connections), as well as connections to the power supply amplifier (programming connections) will invariably, despite all precautions such as shielding, twisting of wire-pairs, etc., "pick-up" radiated noise of a wide freqency spectrum. Furthermore, the power supply itself produces a "common mode" current, which, if not properly shunted to ground, generates a ripple voltage across the load. To minimize this undesired output, a d-c ground (SIGNAL GROUND) is needed.

3-8 A SIGNAL GROUND consists of a ***single point*** along the power supply/load circuit, to which one side of the power supply output and all the shields, instrument cases, etc., are connected and which is then as a single wire, returned to a-c ground (Safety Ground), see FIG. 3-2.



NOTE: ***Only one*** of the (5) signal ground points must be used. Output ripple should be viewed either with a differencial input or battery-operated oscilloscope with the scope case connected to the selected signal ground.

FIG. 3-2 SAFETY AND SIGNAL GROUNDING.

3-9 Successful d-c grounding depends on careful analysis of the individual situation and only general guide lines can be provided here. One of the major points, however, is to avoid GROUND LOOPS. Ground loops are created when two (or more) points are "signal grounded" along the output circuit. Due to the wire impedance between the separated grounded points, a noise voltage is developed which subsequently is superimposed on the stabilized output of the power supply. The only way to avoid ground loops is to investigate the output circuit (including the connected load) carefully by means of an ohmmeter for any resistance to ground. A single d-c ground point can be selected only if the output circuit is completely isolated and a single point connected to the system. The exact location of this "best" d-c ground-point is entirely dependent on the application at hand. For single, isolated loads, the best d-c ground-point may be the internal signal ground (point [1] in FIG. 3-2) or it may be directly at one of the output terminals of the power supply (points [2] or [3] in FIG. 3-2). If error sensing is employed, however, a good d-c ground can be established at the remote load (points [4] or [5] in FIG. 3-2). In case of an internally grounded load, the d-c ground is automatically established directly at the load.

3-10 JQE Power Supplies have ***one*** side of the output returned to the case over a resistor/capacitor combination (refer to Sect. II, Par. 2-14). In those cases, therefore, where the *load* is internally grounded, or where the signal ground must be established elsewhere, the resistor/capacitor combination must be removed from the power supply case in order to avoid ground loop problems. This step is also required if the opposite side of the power supply output must be grounded at the load (point [3] in FIG. 3-1). If there is a choice in selecting either the positive or the negative output of the power supply for the d-c ground point, both sides should be tried, and preference given to the ground point producing the least noise. Output ripple specifications (as measured at the output) are, however, equally valid for either output side grounded. Care should be taken in measuring the ripple and noise at the power supply output or at the load. Measuring devices which are a-c line operated often introduce ripple and noise into the circuit (see note in FIG. 3-2).

[1] See also Section II

3-11 POWER SUPPLY/LOAD INTERFACE

3-12 The general function of a voltage or current stabilized power supply is to deliver te rated output quantities to the connected load. The load (or loads) may have any conceivable characteristic: It may be fixed or variable; it may have predominantly resistive, capacitive, or inductive parameters; and it may be located very close to the power supply or it may be a considerable distance away. The power supply designer cannot anticipate every conveivable application, location or nature of the load. He must design his product for the widest possible application range and specify the performance at the output terminals of the power supply. The aim of the following paragraphs is to aid the user in the final use of the product: The interface of the power supply and the load.

3-13 The perfect interface between a power source and its load would mean that the specified performance at the output terminals would be transferred without impairment to any load, regardless of its characteristics, distance from the power supply or environment. To approach this ideal, the power supply must satisfy certain requirements. Interconnecting rules must be closely followed and Ohm's Law, as well as basic a-c theory must be considered in selecting the interface wiring.

3-14 LOAD WIRE SELECTION. The stabilized d-c power supply is definitely not an ideal voltage or current source with zero output impedance (VOLTAGE MODE) or infinite output impedance (CURRENT MODE) at all frequencies. All ***voltage*** sources have some amount of impedance which ***increases*** with frequency and all ***current*** sources have an output impedance which ***decreases*** with frequency (refer to FIG. 3-3).

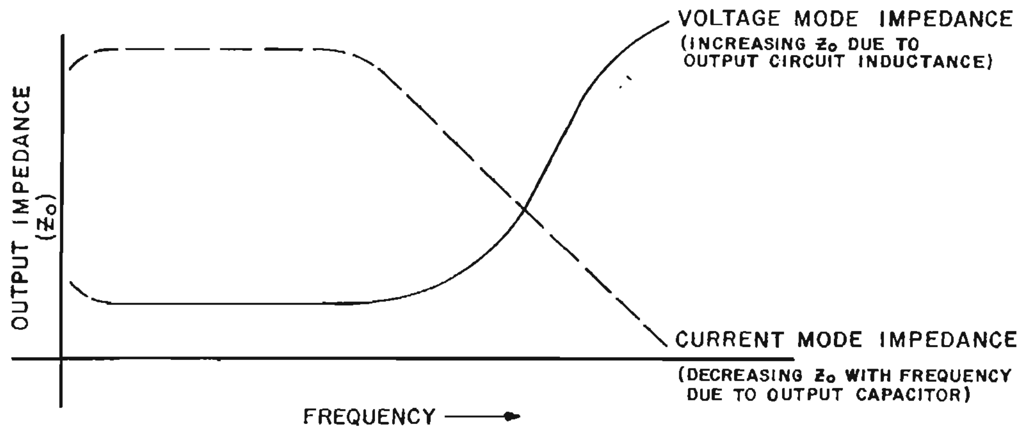


FIG. 3-3 TYPICAL OUTPUT IMPEDANCE VS. FREQUENCY PLOT FOR STABILIZED D-C SOURCES.

NOTE: As can be deduced from FIG. 3-3, load connections for application requiring solely stabilized ***output current*** are not as critical as those requiring stabilized ***output voltage:***

a) D-C wire drops do not influence the current stabilizing action, but must be subtracted from the available compliance voltage.

b) Wire inductance is "swamped-out" by the action of the output capacitor.

Emphasis in the following paragraphs is therefore placed on the power supply as a ***voltage source,*** rather than a current source.

3-15 A more realistic model for a voltage stabilized power supply must, for example, include a series resistance, representing the small d-c and low frequency source impedance, in series with an inductance, representing the source impedance at higher frequencies. Load wire selection should therefore proceed with those facts in mind. The load-wire size shouuld not only be selected for minimum voltage drop (Error Sensing, as discussed below, will take care of that), but also the series inductance of the load wire must be kept as small as possible compared to the source inductance of the power supply (Error Sensing ***cannot*** compensate for this). These dynamic considerations are especially important if:

1) The load is constantly changing in value.
2) The load is switched "on" and "off."
3) The output of the power supply is step-programmed.
4) The load has a primarily reactive characteristic.
5) All other cases where the dynamic output response of the power supply is considered important.

3-16 LOAD CONNECTION, GENERAL

The Power Supply is shipped from the factory with five (5) removable jumper links in place at the rear barrier-strip (TB501) and one (1) link on rear barrier-strip (TB206—JQE models with Suffix "Y" only), as shown in FIG. 3-4. THESE LINKS MUST BE IN PLACE AND SECURED TIGHTLY for standard local operation. Loose terminal links or wires at the barrier strips will cause malfunction of the power supply.

CAUTION

THE LOAD MUST BE CONNECTED TO THE HEAVY DUTY OUTPUT TERMINALS AT THE REAR, NOT TO THE BARRIER STRIP. BARRIER STRIP TERMINALS ARE FOR MONITORING AND PROGRAMMING PURPOSES ONLY.

3-17 LOAD CONNECTION, METHOD I

3-18 (Refer to FIG. 3-4.) The most basic power supply interconnection, to mainly resistive, relatively constant loads, located close to the power supply, or for loads requiring stabilized current exclusively consists of a 2-wire connection from the rear output binding-post terminals. Load wire is selected as described previously (refer to par. 3-14). The load leads should be tightly twisted to reduce "pick-up" from stray magnetic fields. After the grounding rules have been applied (refer to par. 3-7 to 3-10), the power supply can be connected to the a-c source and operation may commence.

NOTES:

1) Avoid electrical shocks: Connect load and external components *before* applying a-c power to the power supply.
2) *Alternate* signal ground points may be chosen: refer to par's. 3-7 to 3-10.
3) *Twist* all wire pairs. Use shielding as indicated.
4) See Section V for power supply performance measurements.

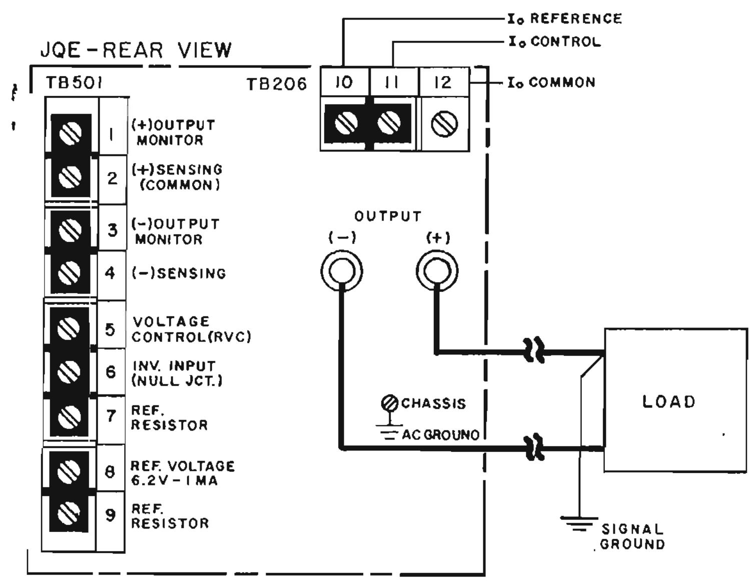


FIG. 3-4 LOAD CONNECTION, METHOD I, WITHOUT ERROR SENSING.

3-19 LOAD CONNECTION, METHOD II (REMOTE ERROR SENSING)

3-20 To avoid excessive output effects at remote loads, error sensing must be used. 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. 3-5). Observe polarities: The negative sensing wire (from terminal [4]) must go to the negative load wire, and the positive sensing wire (from terminal [2]) goes to the positive load wire.

NOTE: For long wire runs, twisting each sensing wire with its associated load wire may give improved results in some cases.

NOTES:

1) Avoid electrical shocks: Connect load and external components *before* applying a-c power to the power supply.
2) *Alternate* signal ground points may be chosen: refer to par's. 3-7 to 3-10.
3) *Twist* all wire pairs. Use shielding as indicated.
4) See Section V for power supply performance measurements.

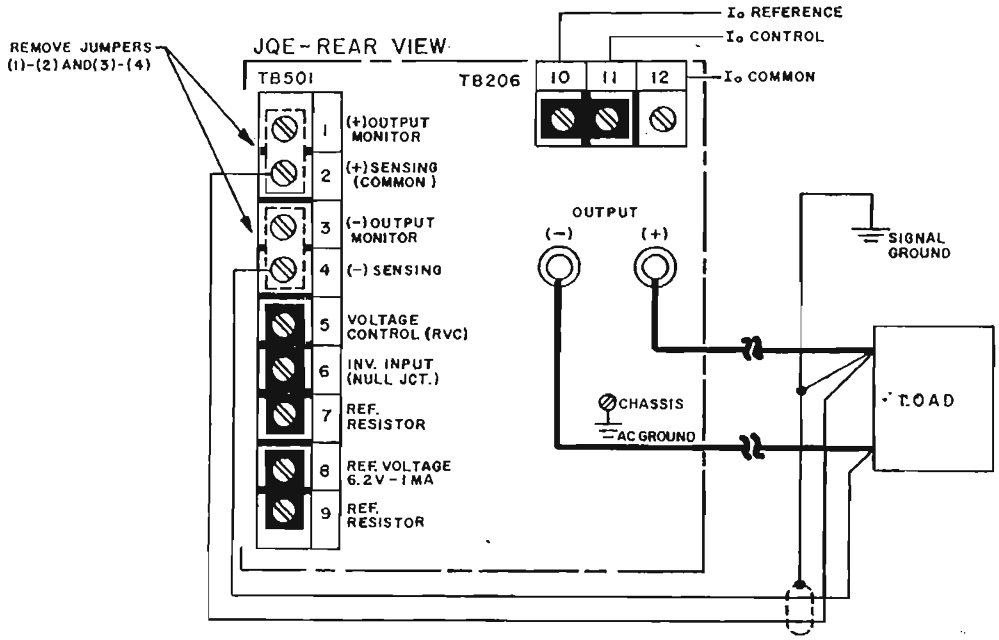


FIG. 3-5 LOAD CONNECTION, METHOD II, USING REMOTE ERROR SENSING.

3-21 This method of load interconnection is suitable for loads which do not require rapid changes in voltage or currents or for programming with gradually changing waveforms (sine wave, triangular wave shapes, etc.). See par. 3-22 for load connections suitable for rapid (step) changes in the load or in programming.

3-22 LOAD CONNECTION, METHOD III

3-23 In applications where the load wires are long and the load is rapidly changing in value or the power supply is programmed with a step function, it may sometimes be required to add an additional output capacitor directly at the load site. The value of the external capacitor should be equal or greater than the internal output capacitor of the JQE (C_O = C204 in all JQE Models). For pulsed loads which drop to zero current during the "off" period, any external output capacitor should be paralleled with a "bleeder" resistor. The value of this resistor is determined by the value of the external capacitor, the desired response and the amount of output current which can be sacrificed. As a minimum, the RC time constant of the external output capacitor (C_O ext.) and the bleeder resistor (R_O ext.) should be comparable with the internal output capacitor (C_O) and the bleeder resistor (R_O), so that.

$$R_O \text{ (ext.) } C_O \text{ (ext.) } \leqslant R_O\, C_O, \text{ (internal)}$$

NOTE: "R_O" and "C_O" are so identified in all JQE Power Supplies (SEE "MAIN SCHEMATIC," SECTION V, FIGURE 6-3 FOR VALUES).

There is, unfortunately, no "best" method for interconnecting the load and the power supply. Individual applications, location and nature of the load require careful analysis in each case. Signal grounding a single point in the output circuit is of great importance. It is hoped that the preceeding paragraphs will be of some assistance in most cases. For help in special applications or difficult problems, consult directly with Kepco's Application Engineering Department.

3-24 STANDARD VOLTAGE MODE OPERATION (LOCAL CONTROL)

3-25 Once the load is connected to the output terminals of the JQE Power Supply, and safety, as well as signal grounding rules have been applied as described (refer to par's. 3-1 through 3-26), power supply operation can proceed:

1) Turn VOLTAGE CONTROL and CURRENT LIMIT CONTROL completely counterclockwise. Turn A-C POWER SWITCH/CIRCUIT BREAKER "on." Observe front panel VOLTMETER[1] and adjust VOLTAGE CONTROL to the desired output voltage level. Turn a-c power "off."

2) Apply a short circuit across the output terminals of the JQE Power Supply. Turn A-C POWER SWITCH/CURCUIT BREAKER "on."

3) Observe front panel CURRENT METER[1]. and adjust CURRENT LIMIT CONTROL to the required load current value, plus 2%. In voltage mode operation, this setting will determine the voltage/current "crossover" point. Turn A-C POWER SWITCH/CIRCUIT BREAKER "off."

4) Remove the short circuit from the output terminals. The power supply is now ready for operation.

3-26 STANDARD CURRENT LIMIT MODE OPERATION

NOTE. This operating mode will yield approximately 2% current stabilization. For more precise current stabilization, see par. 3-55.

3-27 Apply all safety and signal grounding rules as described in previous paragraphs (refer to par's. 3-1 through 3-16). Proceed as follows:

1) *BEFORE* connecting the load to the power supply output terminals: Turn A-C POWER switch "on." Observe the front panel VOLTMETER[1] and adjust the VOLTAGE control to the required compliance (output voltage) level. Turn A-C POWER switch "off" and connect a short circuit to the output terminals of the JQE Power Supply.

2) Turn A-C POWER switch "on." Observe the front panel CURRENT METER[1] and adjust CURRENT control to the desired value. Turn A-C POWER SWITCH "OFF."

3) Remove the short circuit, connect the load and turn A-C POWER switch "on " If the JQE does not enter the current mode (as indicated by a change in output current as the load value is changed), the load resistance (R_L) is too high. *Either* R_L must be *decreased, or* the VOLTAGE CONTROL setting must be *increased, or* the CURRENT CONTROL setting must be *decreased.* The JQE is now ready for operation.

3-28 OVERVOLTAGE CROWBAR, SET-UP AND CHECK (FOR JQE MODELS WITH OPTION "VP" ONLY. (Refer to Section II, FIG. 2-1, for the location of all internal controls.)

1) Set up the JQE Power Supply with a substitute load. Use an external voltmeter with meterless JQE Models, or if greater accuracy than the panel meter can provide is required. Set V_{LIM} (COARSE) control fully clockwise. Set V_{LIM} (FINE) control approximately to its mid-position.

2) Turn the JQE "on" and adjust the output voltage to the desired crowbar or shut-down value, *not* to the actual final operating voltage, using the front panel VOLTAGE CONTROL.

3) Slowly, turn the V_{LIM} (COARSE) control counter clockwise, until the JQE power supply shuts down (output voltage goes to zero, circuit breaker shuts off). TURN THE V_{LIM} (FINE) CONTROL *SLIGHTLY* (ABOUT 10°) CLOCKWISE. This last adjustment must be made with care, since it determines the "threshold" voltage, i.e., the *difference voltage* between the crowbar or shut-down point and the actual operating voltage.

4) Turn the JQE VOLTAGE CONTROL counter-clockwise before turning the JQE "on" again. Slowly advance the VOLTAGE CONTROL clockwise. Observe the JQE front panel voltmeter (or the external voltmeter) and note the voltage at which the JQE shuts down. Make any corrections of the shut down voltage (either towards or away from the operating voltage) by adjusting the V_{LIMIT} (FINE) control.

5) Turn the VOLTAGE CONTROL of the JQE counter-clockwise, turn JQE "on," and adjust the actual operating voltage.

NOTE: 1) Readjustment of the V_{LIMIT} (FINE) control may be required after load and power supply have reached thermal equilibrium.

2) If an *exact* crowbar point at a *remote load* must be established, *remote error sensing,* as described in par. 3-19 must be used.

3) Adjust triggering sensitivity by means of the "Delay Adjust" capacitor (C403) if spurious triggering occurs.

[1] Use suitable external metering for meterless JQE models.

3-29 INTRODUCTION TO REMOTE PROGRAMMING IN THE VOLTAGE MODE

3-30 GENERAL. A few general remarks may be in order to familiarize the user of this equipment with the terminology and basic equations pertaining to remote programming of the power supply in the voltage mode. Electrically, in the voltage mode, the power supply can be represented by the unregulated d-c source (E_u), the voltage across the pass element E_p), the d-c error amplifier (A) and a comparison circuit which resembles a 4-arm electrical bridge. (Refer to FIG. 3-6.) The elements of the bridge are arranged to produce a virtual zero at the amplifier input when the bridge circuit is at balance ($V_{AA'} = 0$). Any tendency for the output voltage to change in relation to the reference voltage (E_r) creates an error signal (ϵ) which, by means of negative feedback and the amplifier, tends to correct the output voltage towards restoration of bridge balance.

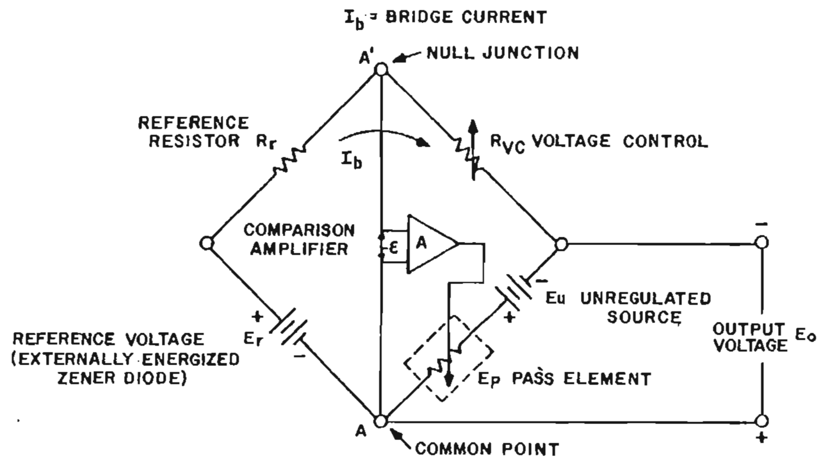


FIG. 3-6 EQUIVALENT CIRCUIT, KEPCO POWER SUPPLY, VOLTAGE MODE.

3-31 EQUATIONS SHOWING THE OPERATION OF THE KEPCO BRIDGE

3-32 The following relationships govern the operation of the Kepco bridge at balance; i.e., with $V_{AA'} = 0$:

a) $\frac{E_o}{E_r} = \frac{R_{vc}}{R_r}$ (1)

$\frac{E_r}{R_r} = I_b$ (2)

$E_o = I_b R_{vc}$ (3)

Where:
- E_o = Output Voltage
- E_r = Reference Voltage
- R_r = Reference Resistance
- R_{vc} = Control Resistance
- I_b = Bridge Current

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.

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:

$$E_o = \frac{E_r}{R_r} \times R_{vc}$$

The ratio $\frac{E_r}{R_r}$ constitutes the bridge current I_b. (Eq. 2).

d) Therefore, we can write: $E_O = I_b R_{VC}$ (Eq. 3).

Making I_b a precision quantity (precision bridge current adjustment is described in par. 3-33) 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 par. 3-40.

e) Rewriting Equation (1), $E_O = E_r \frac{R_{VC}}{R_r}$, we can make E_r the variable which controls E_O.

This type of control is referred to as "voltage programming" and is covered in par. 3-51

f) Many other modes of control are, of course, possible; some of them are described in the following paragraphs. For a more extensive treatment and a detailed theoretical view of power supply applications, please refer to the current Kepco Power Supply Literature, available from your Kepco Representative or directly from Kepco Applications Engineering Department.

NOTE: For all programming and adjustment components, use high quality, wirewound resistors with a TC of 20 ppm or better.

3-33 ADJUSTMENTS FOR EXACT PROGRAMMING RATIO

3-34 Referring to equation (3): $E_O = I_b R_{VC}$, 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 adjusted precisely, the accuracy and linearity of the output voltage will then solely depend upon R_{VC}.

3-35 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.

3-36 Both inaccuracies, the slightly larger bridge current (I_b) and the small negative offset voltage may be adjusted to provide a linear and precise programming ratio. A control (E_{io} Zero) for zeroing the offset voltage is provided on JQE Power Supplies with Options "E" or "Y" only. Bridge current adjustment is standard on all JQE Models (I_b CAL.).

3-37 PROCEDURE, PRECISION PROGRAMMING RATIO ADJUSTMENT (Refer to FIG. 3-7)

(Refer to Section II, FIG. 2-1 for the location of all internal controls).

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).

ATTENTION: See fold-out diagram at the end of this section (Section III) relating the connection diagram to the power supply circuitry.

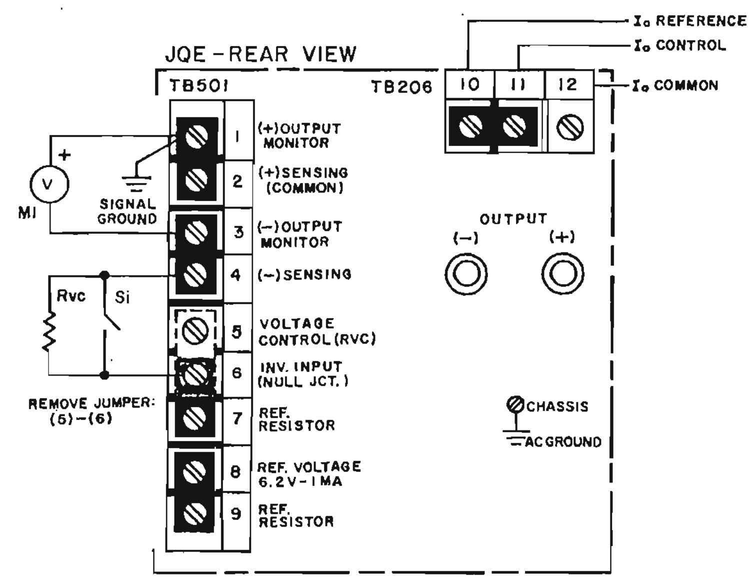


FIG. 3-7 CONNECTIONS FOR PRECISION PROGRAMMING RATIO ADJUSTMENT.

b) Connect calibration setup as shown in FIG. 3-7 and connect the power supply to the a-c power line.

c) With S1 "open," and R_{VC} = 5 K ohms, approximately 5 volts will be read out on M1. Adjust "I_b CAL." (bridge current adjustment, R4, 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 (approximately 2 to 8 mV negative). Adjust "E_{io} Zero" (zero adjustment, R39, 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. 3-8 below shows graphically how the programming ratio can be precision adjusted.

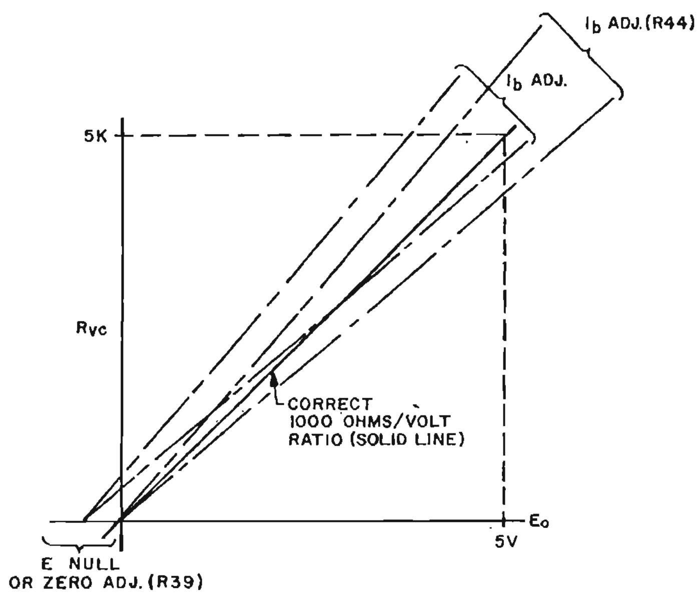


FIG. 3-8 PROGRAMMING RATIO PLOT.

3-38 GENERAL RULES FOR REMOTE PROGRAMMING

3-39 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 setup is experienced.

1) SIGNAL 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 signal grounding the power supply/load circuit plus the power supply/programming circuit ***at one 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) or by instruments connected to the output/load circuit (oscilloscopes, meters), 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 these cases, only isolation (i.e., battery-operated devices) is the answer. It must also be remembered that the programming input and the output of the power supply are "common," so that if the "common" 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."

2) CONNECTIONS. All external connections, especially the rear jumpers on the barrier strips, must be securely fastened. Serious malfunctions may be caused by open feedback loops or other open programming connections.

3) INPUT SOURCES. If specified performance is expected when 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 units with temperature coefficients of 20 parts per million or better. Their wattage rating must be at least 10 times the actual power dissipated. Although the control current through these resistors is normally only 1 mA, an error current exists when programming large voltage excursions. The magnitude of this error current equals 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 [$\Delta E_O = 50V$], *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. 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 open feedback loops. Programming resistors must have a voltage rating at least equal to the maximum output voltage of the power supply.

PROGRAMMING THE VOLTAGE CONTROL CHANNEL

3-40 PROGRAMMING WITH EXTERNAL RESISTANCE

3-41 The output voltage of the JQE Power Supply may be controlled remotely by an external resistance, replacing the built-in voltage control resistance which is 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):

$$E_O = R_{VC} \frac{E_r}{R_r}.$$

Since $\frac{E_r}{R_r} = I_b$ (2), it follows that $E_O = I_b R_{VC}$ (3).

3-42 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 par. 3-33), for every volt of output, 1000 ohms control resistance (R_{VC}) must be provided. This corresponds to a "programming ratio" of 1000 ohms per volt. If for example, an output voltage of 10 volts is required, R_{VC} must be:

$$R_{VC} = \frac{10 \text{ VOLTS}}{1 \text{ mA}} = 10 \text{ K ohms.}$$

ATTENTION: See fold-out diagram at the end of this section (Section III) relating the connection diagram to the power supply circuitry.

NOTES:

1) Avoid electrical shock. Connect load and external components *before* applying a-c power to the power supply.
2) *Alternate* signal ground points may be chosen: refer to par's. 3-7 to 3-10.
3) *Twist* all wire pairs. Use shielding as indicated.
4) See Section V for power supply performance measurements.

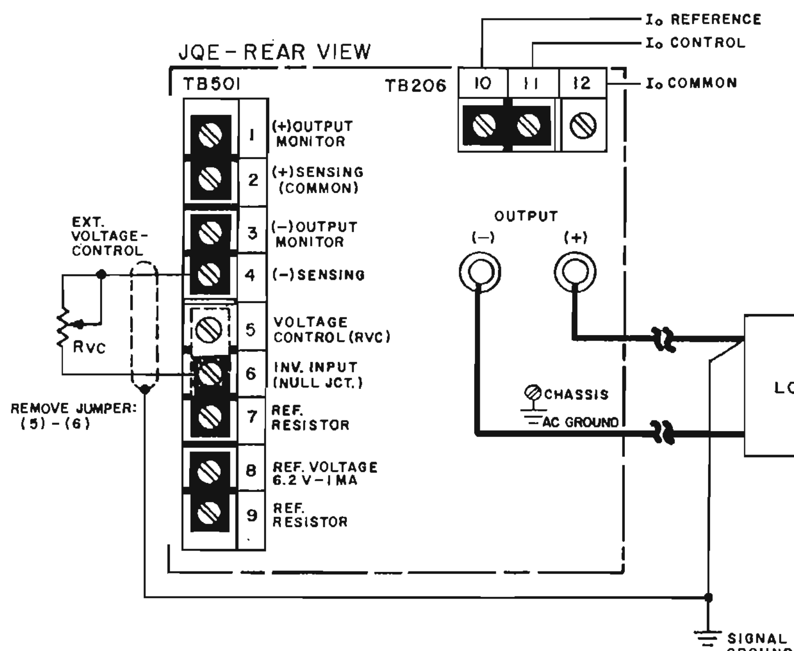


FIG. 3-9 CONNECTIONS FOR REMOTE OUTPUT VOLTAGE CONTROL BY LINEAR RESISTANCE VARIATION.

3-43 PROCEDURE (Refer to FIG. 3-9)

a) Determine value of programming resistor(s) for output voltage desired.

b) Using 2-wire, shielded cable, connect the chosen resistor(s) as shown. Connect the shield to the "signal-ground."

c) The output voltage will vary from zero to (1 mA) X (R_{VC}), as R_{VC} is adjusted from zero to its maximum value.

3-44 PROGRAMMING BY VARYING THE CONTROL CURRENT

3-45 The power supply output voltage (E_O) can be controlled by means of the control current (I_b). Referring to the previously derived transfer function (Eq. 3), we see that the output voltage is a linear function of the control current (I_b):

$$E_O = I_b R_{VC} \text{ (Eq. 3).}$$

If R_{VC} is left fixed, variations in the control current will therefore produce proportional changes in the output voltage. If, for example, an external control source, variable from zero to 1 mA is available, the power supply output can be controlled over its full range. The 0 to 1 mA control source can be d-c or (unipolar) alternating current. The necessary barrier-strip connections are shown in FIG. 3-10 below.

ATTENTION: See fold-out diagram at the end of this section (Section II) relating the connection diagram to the power supply circuitry.

NOTES.

1) Avoid electrical shock: Connect load and external components ***before*** applying a-c power to the power supply.
2) ***Alternate*** signal ground points may be chosen: refer to par's. 3-7 to 3-10.
3) ***Twist*** all wire pairs. Use shielding as indicated.
4) See Section V for power supply performance measurements.

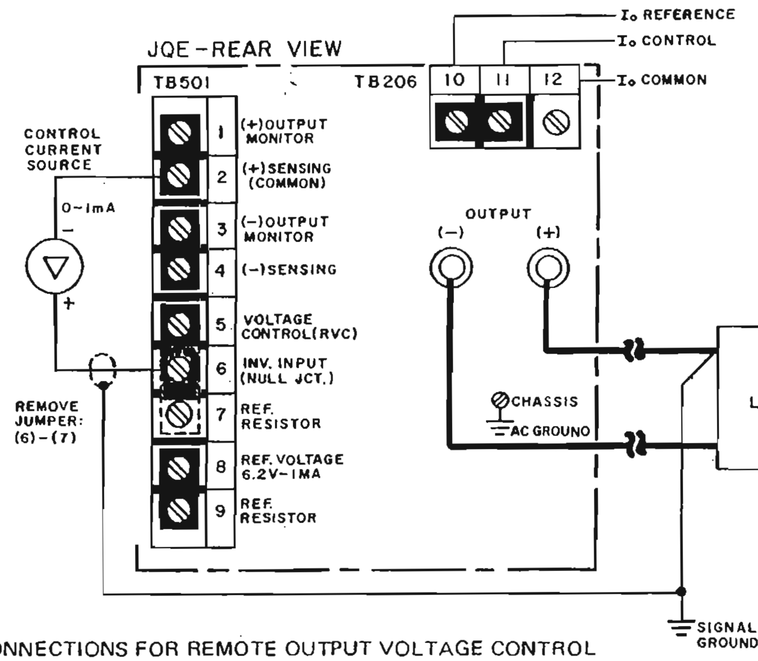


FIG. 3-10 CONNECTIONS FOR REMOTE OUTPUT VOLTAGE CONTROL BY VARIATIONS OF THE CONTROL CURRENT.

3-46 CONDUCTANCE PROGRAMMING

3-47 For special applications, the power supply output voltage can be controlled by changing the ***resistance*** in the control current circuit. Since the output voltage is given by. $E_O = I_b R_{VC}$ (Eq. 3) and the control current value by: $I_b = E_r/R_r$, a variation in the reference resistance (R_r) will (inversely) vary the control current (I_b) and consequently the output voltage (E_O). The output voltage (E_O), changes therefore as a ***reciprocal*** function of the reference resistance. This programming method is therefore referred to as CONDUCTANCE PROGRAMMING.

3-48 Conductance programming can be very useful, especially in cases where small changes in output voltage are required. Another advantage of this type of output control is the "built-in" safety feature. Should the programming circuit open accidentally, the programming current, and consequently the power supply output voltage become zero at once.

NOTE: The internal reference zener source (E_r = 6.2 volts) has been biased for maximum temperature stability at a control current of 1 mA. When conductance programming is performed the control current is varied, and the specifications for output variations with time and temperature are slightly increased If these performance specifications are considered essential for the application at hand, external control current sources can be substituted for the internal reference voltage.

3-49 Normally the control current (I_b) in Kepco Power Supplies is derived by means of a reference voltage (E_r) in series with the reference resistance (R_r):

$$I_b = E_r/R_r$$

Since $E_r = 6.2V$, $R_r = 6.2$ K ohm, $I_b = 1$ mA. If R_r is doubled for example:

$$I_b = \frac{6.2V}{12.4 \text{ K ohm}} = 0.5 \text{ mA},$$

and since $E_o = I_b R_{VC}$, for a constant R_{VC}, the output voltage (E_o) would be one-half of the previous value. This, in principle, is the method for conductance programming: The reference resistor is disconnected and a second control resistor is connected in series with R_r, so that the new transfer function for the power supply output voltage is now given by:

$$E_o = \frac{E_r}{R_r + R_x} \times R_{VC}, \text{(Eq. 5)}$$

where:
- E_o = output voltage
- E_r = reference voltage
- R_{VC} = control resistance
- R_r = reference resistance
- R_x = programming resistor

ATTENTION: See fold-out diagram at the end of this section (Section III) relating the connection diagram to the power supply circuitry.

NOTES:

1) Avoid electrical shock: Connect load and external components *before* applying a-c power to the power supply.
2) *Alternate* signal ground points may be chosen: refer to par's. 3-7 to 3-10.
3) *Twist* all wire pairs. Use shielding as indicated.
4) See Section V for power supply performance measurements.

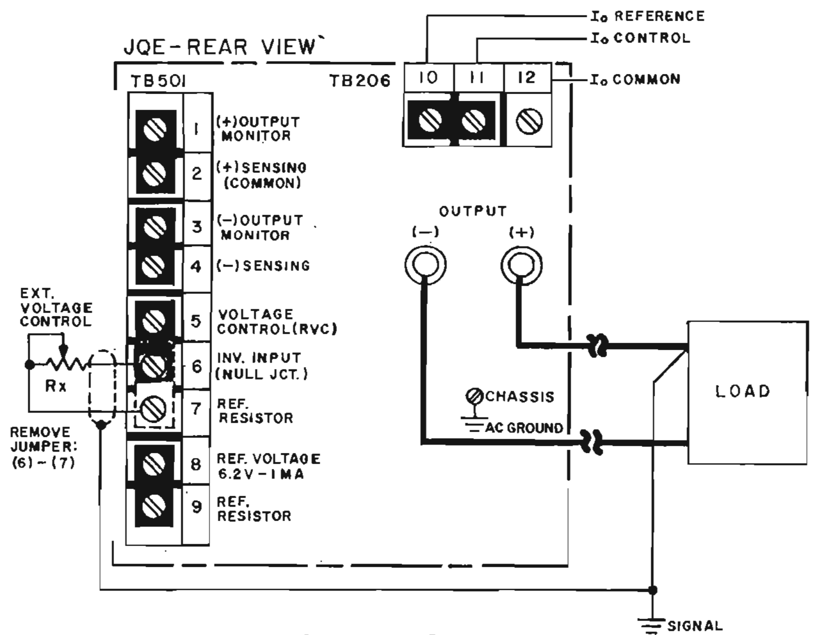


FIG.3-11 CONNECTIONS FOR REMOTE OUTPUT VOLTAGE CONTROL BY INVERSE RESISTANCE (CONDUCTANCE) CHANGES

3-50 PROCEDURE (Refer to FIG. 3-11)

Example: A Model JQE 6—45 is to be conductance-controlled for a voltage output from 4 to 5 volts.

a) Turn power supply "on" and set the output voltage control to the maximum desired voltage (5 volts). Turn power supply "off."

b) Select programming resistor (R_x), using the new transfer function (Eq. 5):
All values (except R_x) are known:

New E_o desired = 4 volts
$E_r = 6.2V$
$R_r = 6.2$ K ohm
R_{VC} set to 5 K ohm

therefore, solving for R_x:

$$R_x = \frac{E_r}{E_o} R_{VC} - R_r, \text{ or}$$

$$R_x = \frac{6.2V}{4V} \times 5\text{ K} - 6.2\text{ K} = \textit{1.55 K ohm.}$$

Connect a 2 K ohm, rheostat-connected, trim potentiometer (R_X) to the rear terminals as shown in FIG. 3-11. After power supply turn-on, the resistor (R_X) will provide an approximate output voltage range from 3.8 to 5 volts, as its value is varied from zero to 2 K ohm.

3-51 REMOTE PROGRAMMING WITH EXTERNAL CONTROL VOLTAGE

3-52 If the internal reference voltage of the JQE (E_r) is replaced by an external programming voltage (E_i) in series resistance (R_i), the expression for the output voltage can be written as:

$$E_O = E_i \frac{R_{VC}}{R_i} \quad \text{(Eq. 5)},$$

where: E_O = output voltage
E_i = input voltage
R_{VC} = control resistance
R_i = input resistance

3-53 As seen from the expression (Eq. 5), if the ratio R_{VC}/R_i (which represents the closed loop gain of the system) is held constant, E_O will vary linearly with E_i, the external programming voltage. The above expression (Eq. 5) is seen to be similar to the operational amplifier transfer function in the inveting configuration. The voltage programmed power supply does, in fact, become a unipolar power amplifier with potentially very high power gain but with limited frequency response. (Refer to FIG. 3-12). 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 will be given below.

NOTE: The built-in VOLTAGE CONTROL (R_{VC}) is rated for a *maximum* of 1 mA control current. *Larger* control current values may be used with properly rated *external* feedback resistors for R_{VC}. *Smaller* control currents may be used, with the lower limit approximately 100 µA.

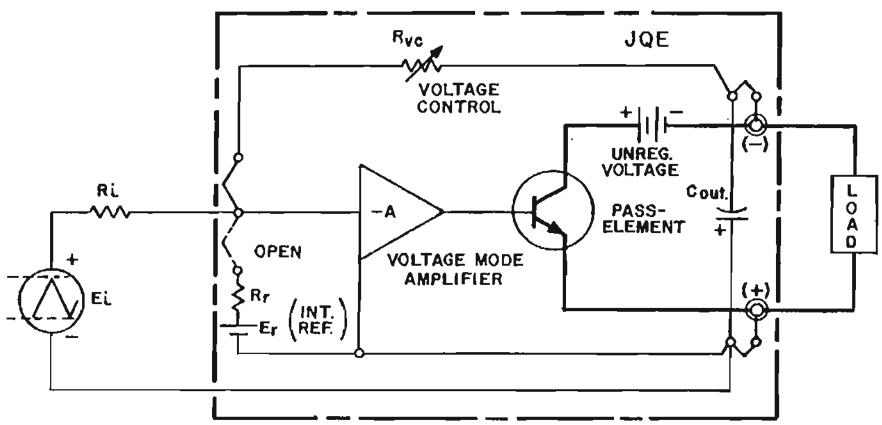


FIG. 3-12 THE POWER SUPPLY IN THE OPERATIONAL AMPLIFIER MODE. (SIMPLIFIED DIAGRAM SHOWING THE VOLTAGE CHANNEL ONLY)

3-54 Example: A Kepco Model JQE 36–30 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, and 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 $R_{VC} = 40$ K ohms,* R_i must equal 40 K/18 = 2.22 K ohms. FIG. 3-12 shows the simplified diagram of the JQE Power Supply as an operational amplifier, while FIG. 3-13 illustrates the necessary connections for this mode of operation.

* The front panel "Voltage Control" must be set to its maximum clockwise position (40 K ohm).

NOTES:

1) Avoid electrical shock: Connect load and external components *before* applying a-c power to the power supply.
2) *Alternate* signal ground points may be chosen: refer to par's. 3-7 to 3-10.
3) *Twist* all wire pairs. Use shielding as indicated.
4) See Section V for power supply performance measurements.

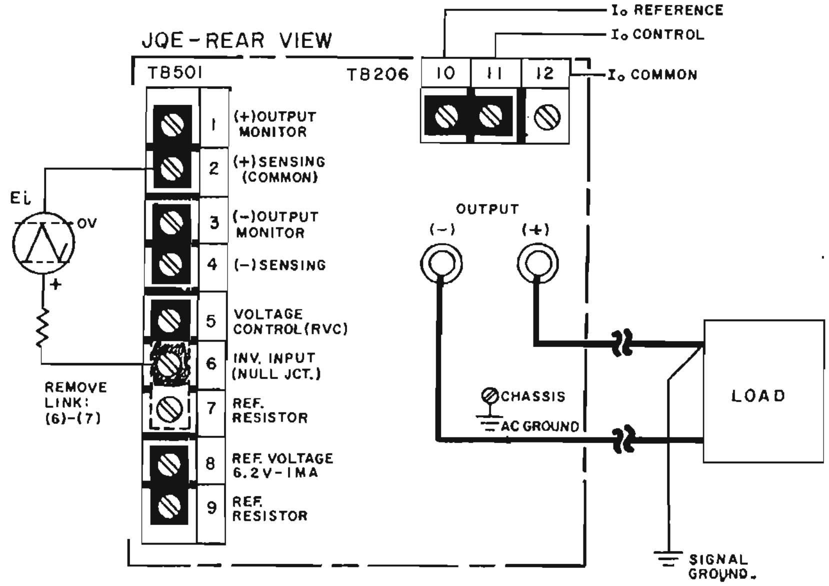


FIG. 3-13 CONNECTIONS FOR REMOTE OUTPUT VOLTAGE CONTROL BY MEANS OF AN EXTERNAL SIGNAL VOLTAGE.

3-55 CURRENT STABILIZATION WITH *EXTERNAL* SENSING AND CONTROL

3-56 The operation of the JQE Power Supply as a current stabilizer in the current limit mode has been described previously (refer to par. 3-26). This method was seen to be suitable only for non-critical applications requiring relatively large output currents. For applications requiring *more precise* stabilization than that which can be provided in the current limit mode, the JQE can be operated in an *external* current-stabilizing mode. This method is especially suitable if *small values* of output current are required. In the external current mode, the *voltage* error-sensing amplifier senses a sample voltage drop (proportional to the output current) and an external current control resistor provides the feedback. Thus a constant ratio between the internal reference source and the external sensing voltage is maintained and stabilized output current (instead of stabilized voltage) is available at the output of the JQE.

3-57 Since the voltage mode amplifier is used to stabilize the output current in this operating mode, external voltage limiting can be provided externally, by means of a zener diode, for example.

3-58 The external sensing resistor (R_S) and the external "current control" resistor (R_{CC}) are calculated on the basis of a 0.5 volt drop[1] across R_S at the maximum desired output current. The *value* of R_S (and the voltage drop across it) is not critical and can be the closest standard value available. A too large departure from the recommended value should, however, be avoided because of the following facts:

The recommended sample voltage represents a compromise value, backed by experience. While a larger sample would be desirable from signal/noise considerations, it is not acceptable because of excessive dissipation in the current sensing resistor (R_S) and its undesirable effects on stability. It must be remembered that all the load current is flowing through R_S and that a high gain amplifier is connected (via R_{CC}) across its terminals. All extraneous changes (resistance changes due to temperature) must therefore be kept to a minimum. In summary, dependable, drift-free current stabilization requires a high quality, low T.C. (20 ppm or better) resistor, as large as practicable, but *at least* one with a wattage rating of ten times the actual power dissipated. The control resistor (R_{CC}) should also be a high quality component with low temperature coefficient and sufficient resolution for the purpose intended.

[1] 1 volt for Model JQE 6–90.

3-59 The values for R_s and R_{CC} are calculated as shown in the following example using the equivalent diagram (FIG. 3-14).

$$\left.\begin{aligned} \frac{Er}{Rr} &= Ib \\ V_{RS} &= Is\,Rs \\ Is &= I_o - Ib \\ \text{AT BALANCE:} & \end{aligned}\right\} \therefore \boxed{I_o = Ib\left(\frac{Rcc}{Rs} + 1\right)}$$

$$\left|\frac{Er}{Rr} = \frac{V_{RS}}{Rcc}\right|_{\varepsilon = 0}$$

NOTE: R_s should be physically located as close to the (+) output terminal of the power supply as possible. If, however, long output and sensing leads cannot be avoided, the (+) terminal of the output capacitor (C_O) must be internally reconnected from the (+) sensing to the (+) output terminal.

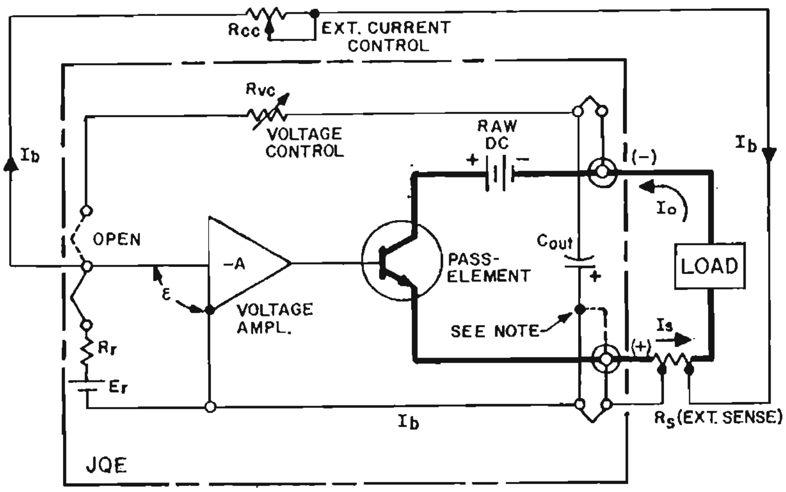


FIG. 3-14 JQE AS A CURRENT STABILIZER USING THE VOLTAGE CHANNEL WITH EXTERNAL SENSING AND CONTROL (EQUIVALENT CIRCUIT).

Since $E_r/R_r = I_b = 1$ mA, and the voltage sample (V_{RS}) was selected to be 0.5 volt (1.0 volt for JQE 6–90), we can substitute these values in the balance equation:

$$\frac{E_r}{R_r} = \frac{V_{RS}}{R_{CC}} \quad \text{and solve for } R_{CC}\text{:}$$

$$R_{CC} = \frac{0.5V}{1\text{ mA}} = 500\text{ ohms, and } R_{CC} = \frac{1.0V}{1\text{ mA}} = 1\text{ K ohm (JQE 6–90).}$$

The sensing resistor (R_s) is calculated by:

$$V_{RS} = I_s R_s \text{ or } R_s = \frac{0.5V}{I_s} \text{ and } \frac{1V}{I_s} \text{ for JQE 6–90.}$$

3-60 The output current of the JQE may be controlled *either* by the current control resistor (R_{CC}), *or*, (as indicated with dashed lines in FIG. 3-15) with an adjustable d-c voltage source (E_{CC}). The control source must be ***0 to 0.5 volt,*** (1 volt for JQE 6–90). If a control voltage (E_{CC}) is used, the internal reference voltage (E_r) must be disconnected by opening the jumper between terminals (8) and (9).

NOTE: R_s (FIG. 3-15) should be located close to the (+) output terminal of the JQE and load wires should be short. Excessive load wire impedance may lead to a dynamically unstable output. If long load wires cannot be avoided, the (+) terminal of the output capacitor (C_O in FIG. 3-14) must be removed from the (+) sensing terminal and reconnected directly to the (+) output.

NOTES:

1) Avoid electrical shock: Connect load and external components *before* applying a-c power to the power supply.
2) *Alternate* signal ground points may be chosen: refer to par's. 3-7 to 3-10.
3) *Twist* all wire pairs. Use shielding as indicated.
4) See Section V for power supply performance measurements.

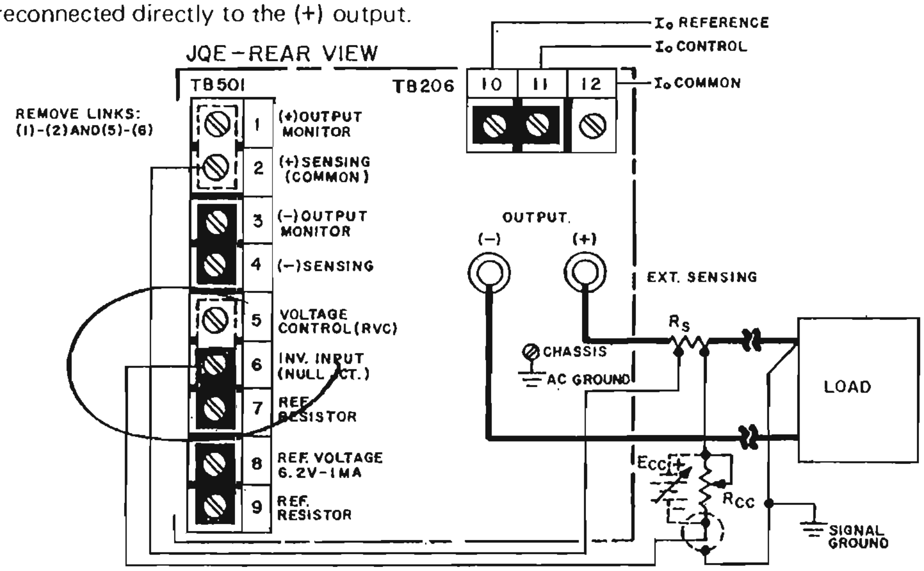


FIG. 3-15 CONNECTIONS FOR CURRENT STABILIZATION (EXTERNAL SENSING AND CONTROL).

PROGRAMMING THE CURRENT CONTROL CHANNEL

3-61 GENERAL

3-62 Kepco JQE Models with Option "Y" feature an additional control channel for external programming of the current limit function. Control may be exercised by a small d-c control voltage or by a potentiometer. The front panel current limit control of the JQE serves as a "back-up" limit in this mode of operation. In this manner, additional protection is provided in case of an open circuit in the external current control circuit. The internal and external current limit controls can be set independently from one another. The control set to the *lower* output current value is always in control of the output current.

NOTE: A substantial improvement of the current stabilization performance (approximately 0.1% vs. 2%) is achieved by the "Y"-option JQE Model over the standard JQE Model. The improvement is due to the use of an additional high-gain operational amplifier as the control element in the remote current limit mode. The JQE Model with "Y" option can therefore be operated not only as a remote current limiter, but also as a current stabilizer in applications where the improved current stabilization performance is adequate.

3-63 REMOTE CURRENT LIMIT CONTROL BY POTENTIOMETER. A potentiometer, connected to the rear terminals of the JQE as shown in FIG. 3-16 will control the current limit over the full range of the JQE Power Supply. The potentiometer should be a 1000 ohm, high quality, multiturn, wirewound unit for good resolution and high stability. Sufficient reference current is provided, so that the maximum output current value can be calibrated by inserting a series trim rheostat. The zero point is adjusted by the internally provided I_O ZERO control.

ATTENTION: See fold-out diagram at the end of this section (Section III) relating the connection diagram to the power supply circuitry.

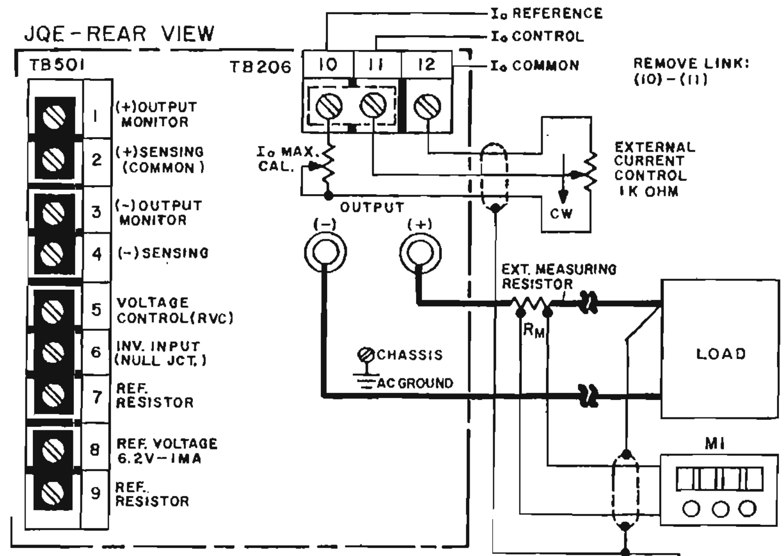


FIG. 3-16 CONNECTIONS FOR REMOTE CURRENT LIMIT CONTROL BY POTENTIOMETER (FOR JQE MODELS WITH OPTION "Y" ONLY)

3-64 SET-UP PROCEDURE

1) Connect the potentiometer, in series with the calibrating rheostat, to the terminals of the JQE as shown in FIG. 3-16. DO NOT REMOVE THE JUMPER LINK (10)—(11) ON TB201 AT THIS TIME.

2) Connect shield (single ended) to the selected signal ground. Connect external ammeter, *or* precision voltmeter across a meter shunt (as shown in FIG. 3-16), in series with the load.

3) *Before* connecting the JQE to the a-c power source, *short* the load. Now, connect JQE to the a-c power source and turn JQE "on." Adjust the *maximum desired output current* on the front panel CURRENT LIMIT control. (This control serves as the "back-up" current limit. Its setting determines the *maximum* current which can be controlled by the remote potentiometer.) Turn a-c power "off."

4) NOW, disconnect, the jumper link (10)—(11) on TB201. Turn a-c power "on." Vary the external control potentiometer between its limits, while monitoring the output current of the JQE Power Supply as shown on M1 in FIG. 3-16, or by means of a suitable ammeter in series with the load.

   The output current should change from approximately zero to the maximum output current as set in step (3), as the external current control potentiometer is varied bwteeen its counterclockwise and clockwise positions. *Remove the short circuit across the load.*

3-65 CALIBRATION

NOTE: SEE SECTION II, FIG. 2-1 FOR THE LOCATION OF ALL INTERNAL CONTROLS.

Due to internal and external component tolerances, the programmable output current range may not be as predicted. If in the above example, the maximum output current cannot be reached (or is too high), or the output current does not completely go to zero, the system can be calibrated as follows:

1) Connect an accurate ammeter, or a measuring resistor (R_M in FIG. 3-16) and a digital voltmeter in series with the load. NOTE: R_M is selected according to the available meter. A linear readout can be achieved by selecting R_M to drop 0.1 volt at the maximum output current, for example. (Use 4-terminal meter shunt for R_M.)

2) Turn a-c power "on," and adjust the external CURRENT CONTROL potentiometer to its maximum *clockwise* position. NOTE: Refer to FIG 3-16. The ***maximum clockwise*** position should establish *maximum resistance* between terminals (11)—(12) on TB201. Check the output current on M1 and correct to "I_O MAX." using the external "I_O MAX CAL" control. (The value of the "I_O MAX CAL" control should be approximately 15% of the value for the EXTERNAL CURRENT control.)

3) Turn the EXTERNAL CURRENT control to its maximum counterclockwise position. Check the output current reading on M1 and correct to "zero" by adjusting the "I_O ZERO" control (right top side, accessible through cover of JQE).

4) The programming setup (JQE Power Supply, Control Voltage and Load) is now calibrated and ready for operation. Calibration should be checked and corrected if necessary after the setup (including the meter!) has reached thermal equilibrium.

3-66 VOLTAGE CONTROL OF THE JQE CURRENT LIMIT

3-67 GENERAL. The output current of the JQE Power Supply can be externally controlled by connecting a variable d-c voltage source to the programming terminals as shown in FIG. 3-17. The external control voltage should be as follows:

A) 0—1 volt for Model JQE 6—90 and for JQE models with maximum output currents to 5 amperes.

B) 0—0.5 volt for all other JQE models.

The control current which these sources must supply is negligible (offset currents in the nanoampere range) since the non-inverting input of an integrated operational amplifier is used to control the JQE Power Supply output.

3-68 SET-UP PROCEDURE

NOTE: The control source can be any adjustable d-c source. It may be as simple as a mercury cell with a potentiometer across it, or as sophisticated as a digitally controlled programmer, such as the Kepco SN Digital Programmer.

ATTENTION: See fold-out diagram at the end of this section (Section III) relating the connection diagram to the power supply circuitry.

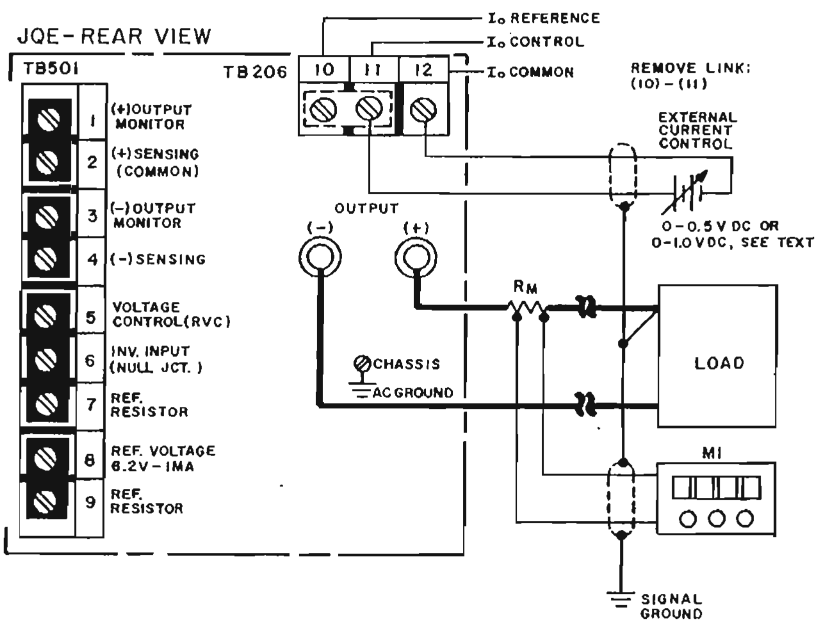


FIG. 3-17 CONNECTIONS FOR REMOTE CURRENT LIMIT CONTROL BY A D-C VOLTAGE SOURCE. (FOR JQE MODELS WITH OPTION "Y" ONLY)

1) Connect the voltage source, with a shielded cable to the programming terminals as shown in FIG 3-17. DO NOT REMOVE THE JUMPER LINK (10)–(11) AT THIS TIME.

2) Connect the shield (single ended) to the selected signal ground. Connect external ammeter, or voltmeter with precision shunt, as shown in FIG. 3-17.

3) *Before* connecting the JQE to the a-c power source, ***short*** the load. Turn JQE "on," and adjust the *maximum* desired output current on the front panel CURRENT LIMIT control. (This control serves as the "back-up" current limit. Its setting determines the *maximum* current which can be controlled with the remote voltage source.) Turn a-c power "off."

4) *Now, disconnect the jumper link* (10)–(11) on TB201, connect JQE to the a-c power source and turn a-c source power "on." Vary the external d-c control voltage while monitoring the output current on the JQE Power Supply on M1 in FIG. 3-17. The output current should change from approximately zero to the maximum output current as set in step (3), as the programming voltage is varied from 0 to 0.5 volt (0–1 volt for JQE 6–90). ***Remove the short circuit across the load.***

3-69 CALIBRATION

NOTE: SEE SECTION II, FIG. 2-1 FOR THE LOCATION OF ALL INTERNAL CONTROLS.

Due to internal and external component tolerances, the programmable output current range may not be as predicted. If, in the above example, the maximum output current cannot be reached (or is too high), or the output current does not completely go to zero, the system can be calibrated as follows:

1) Connect an accurate ammeter, or a measuring resistor (R_M in FIG. 3-17) and a digital voltmeter, in series with the load. NOTE: R_M is selected according to the available meter. A linear readout can be achieved by selecting R_M to drop 1 volt at the maximum output current, for example.

2) Turn a-c power "on," and adjust the external programming source to exactly 0.5 volt (1 volt with Model JQE 6–90). Check the output current on M1 and correct to "I_O MAX.", using the front panel CURRENT CONTROL of the JQE Power Supply. NOTE: In rare cases, the maximum clockwise position of the front panel CURRENT CONTROL will not produce the maximum output current. In these cases, locate the ***internal*** "I_O MAX" control (right top side, accessible through cover of JQE) and correct setting until I_O MAX is read out on M1.

3) Adjust the external programming source to ***exactly*** 0 volt. Check the output current reading on M1 and correct readout to zero by adjusting the "I_O ZERO" control (right top side, accessible through cover of JQE).

4) The programming setup (JQE Power Supply, Control Voltage, and Load) is now calibrated and ready for operation. Calibration should be checked and corrected if necessary after the setup (including the meter!) has reached thermal equilibrium.

3-70 SERIES OPERATION OF KEPCO JQE POWER SUPPLIES

3-71 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 semiconductor diode across the output terminals of each power supply, as shown in FIG. 3-18. 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 largest short-circuit current of the interconnected supplies.

3-72 Two basic series connection methods are generally used, the "Automatic Series Connection", as illustrated in FIG. 3-18, and the "Master-Slave" connection, shown in FIG. 3-19. The basic difrerence between these two methods lies in the manner of the output control. While in the "Automatic" connection the outputs of both supplies may be controlled individually, in the "Master-Slave" connection, control is exercised from the "Master" supply alone, while the "Slave" supply follows the master command in a ratio which may be pre-determined by the user. The latter method of series operation is therefore frequently termed "Automatic Tracking."

3-73 PROCEDURE FOR AUTOMATIC SERIES CONNECTION

a) Connect load as shown in FIG. 3-18. 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 jumpers as shown and connect error sensing leads. These leads should also be as heavy as practicable, and should be twisted and shielded.

d) Turn supplies "on" and adjust voltage on either control as required.

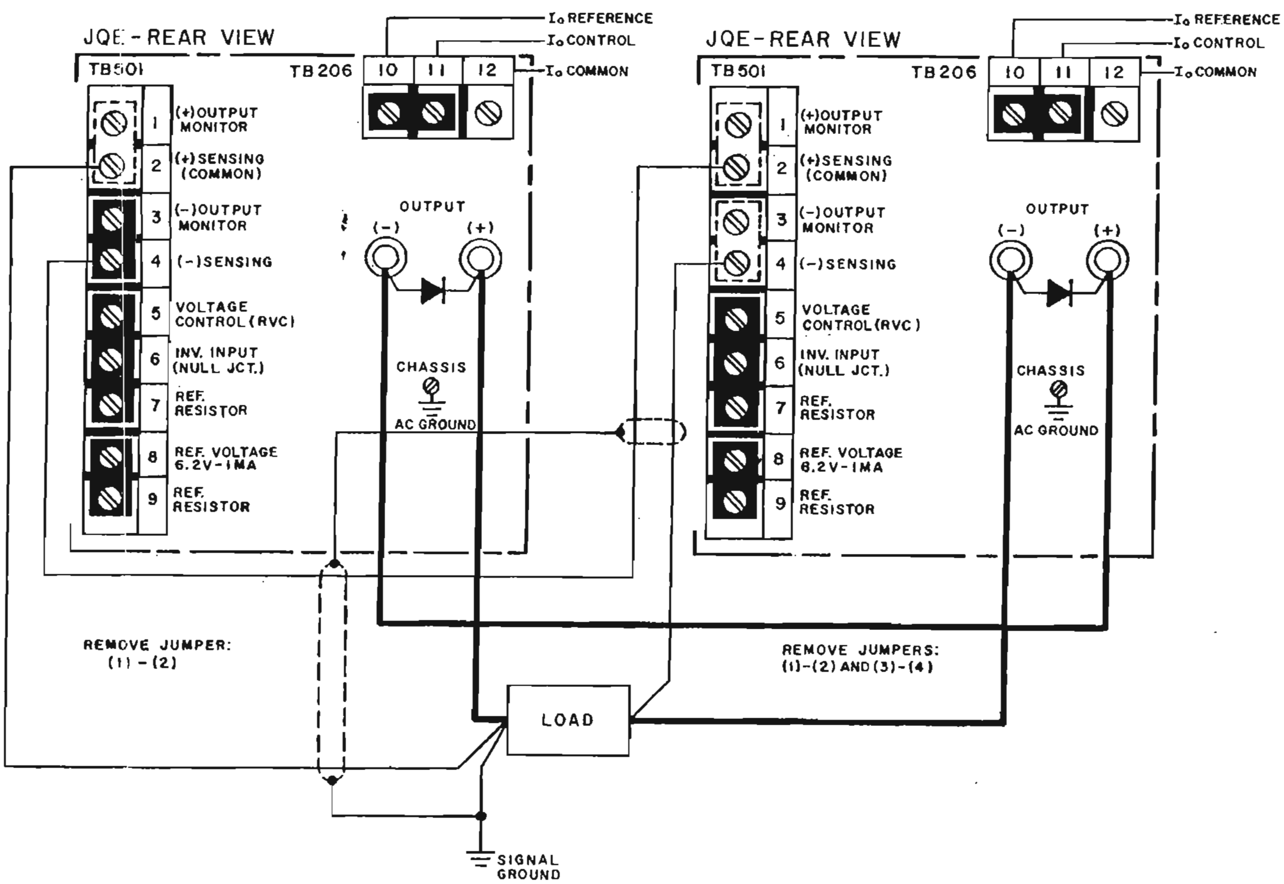


FIG. 3-18 AUTOMATIC SERIES CONNECTION OF JQE POWER SUPPLIES

3-74 The "Master-Slave" series connection method is illustrated in FIG. 3-19. As seen from the figure, the reference voltage (E_r) of the "Slave" supply is disconnected and its input or null junction is connected to the output of the "Master" supply via the tracking resistor (R_t). The "Slave" supply output is thus completely dependent on the "Master" output voltage:

$$E_{os} = E_{om} \frac{R_{VCS}}{R_t}$$, where:

E_{om} = Output Voltage, Master
E_{os} = Output Voltage, Slave
R_t = Tracking Resistor
R_{VCS} = Voltage Control Resistance, Slave

As evident from the equation above, if the tracking resistor (R_t) value is equal to that of the voltage control resistor of the "Slave" supply (R_{VCS}), a "tracking ratio of 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 "Master-Slave" combination, twice the "Master" output voltage is applied to it. If separate loads are connected, identical voltages are applied to the individual loads.

3-75 The ratio E_{os}/E_{om} can be readily changed if the application so requires by simply altering the value of either R_{VCS} or R_t. In practice, since R_{VCS} is the ten-turn voltage control rheostat of the "Slave" Supply, the tracking resistor (R_t) is selected for the desired tracking ratio. The value of R_{VCS} is determined from the parts list and R_t is selected accordingly to the selected ratio. For a 1:1 ratio $R_t = R_{VCS}$, for a 1:2 ratio, $R_t = 1/2\ R_{VCS}$ etc.

3-76 PROCEDURE FOR MASTER-SLAVE SERIES CONNECTION

a) Connect load as shown in FIG. 3-19. Keep voltage drop in the load wires as low as possible by using heavy gage wire.
b) Connect protective diodes across the respective output terminals.
c) Remove jumper links as shown (FIG. 3-19) and connect error sensing leads if remote sensing is desired. Sensing leads should be twisted and shielded.
d) Select value of the tracking resistor (R_t) and connect with shielded wire as shown (FIG. 3-19).
e) Turn supplies "on," and adjust output voltage on the "Master" Voltage Control as desired.

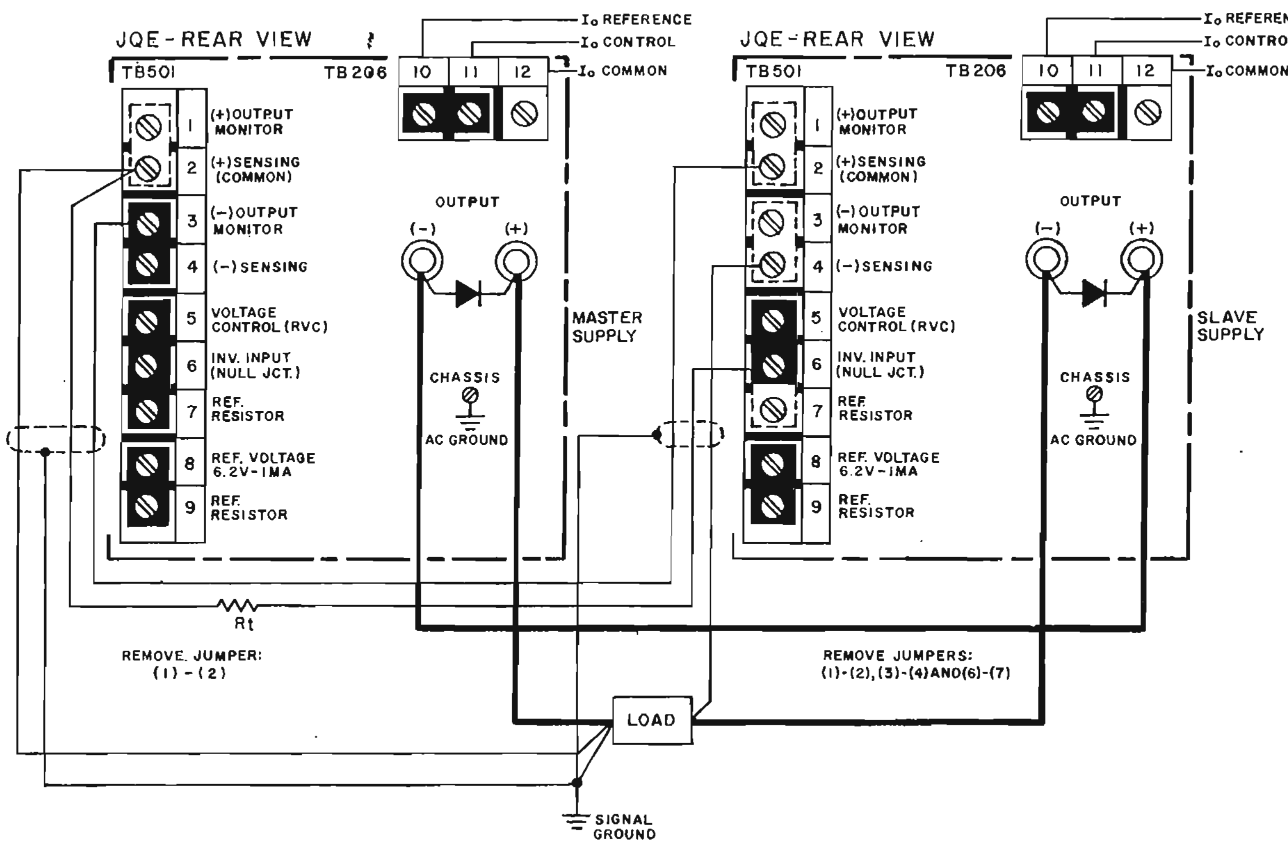


FIG. 3-19 MASTER/SLAVE SERIES CONNECTION OF JQE POWER SUPPLIES

PARALLEL OPERATION

GENERAL. **Kepco JQE Power Supplies equipped with an overvoltage crowbar (JQE Models with suffix "VP") cannot be operated in parallel for increased output current.** A triggered crowbar in a power supply working in a parallel configuration would have to absorb the total output current of the other power supplies.

EMERGENCY SITUATIONS. Sometimes a situation arises where additional output current is required and only power supplies with lower than required current ratings are available. In these cases, the power supplies can be paralleled ***if the crowbar circuit in each unit is disabled.*** Refer to the component location drawing for assembly A4 (Section VI of this manual) and remove R402 from the overvoltage protector assembly (A4). If overvoltage protection is considered essential in the application at hand, a separate crowbar circuit, rated for the ***total*** output current in the parallel connected power supplies must be used. (Refer to Kepco VIP Models.) Two basic methods of paralleling power supplies are described in pars. 3-77 to 3-82. USE PARALLELING IN EMERGENCIES ONLY. CROWBAR CIRCUITS MUST BE DISABLED.

3-77 PARALLEL OPERATION

3-78 GENERAL. As in the previously described "series" connections, an "Automatic" or a "Master/Slave" connection method can be chosen. The choice between the two methods will depend on the application at hand. For constant loads or small load variations (load changes ***smaller*** than the maximum output range of a ***single*** power supply), the "Automatic" parallel connection can be used. For load changes ***exceeding*** the maximum rating of a ***single*** power supply, the "Master/Slave" method is suitable. For either method, some general rules should be observed:

1) Parallel ***only*** supplies which can be adjusted to the same compliance (output) voltage.
2) Load wires should be ***as short as practicable.*** Select wire gauge ***as heavy as possible*** and twist wires tightly. Approximately ***equal*** lengths of wire should be used.
3) ***Common*** a-c power source "turn-off" for all supplies is recommended.

3-79 AUTOMATIC PARALLEL CONNECTION

3-80 PROCEDURE FOR AUTOMATIC PARALLEL CONNECTION (See FIG. 3-21)

1) Connect the power supplies to be paralleled to a common a-c source (preferrably with a common "on-off" power switch).
2) ***Without*** connecting the power supplies to the load or to each other, turn a-c power "on," and adjust the output voltage on each supply to the required compliance voltage.
3) Adjust ***both*** "current" controls to their maximum (extreme clockwise) position. Turn a-c power "off."
4) Make all load interconnections as shown in the connection diagram (refer to FIG. 3-21).
5) With the ***individual*** a-c power switches of the two power supplies in the "on" position, turn ***common*** a-c power switch "on." Observe output current meters on ***both*** units.[1] Since the initial output voltage adjustments were not identical, ***one*** of the power supplies (to be designated SUPPLY #1) will be at a slightly higher output voltage than the other (to be designated SUPPLY #2). Consequently, SUPPLY #1 will deliver its maximum load current and will operate in the current limit mode. The rest of the load current is delivered by SUPPLY #2, which is operating in the voltage mode.
6) The "current" control of SUPPLY #1 can now be adjusted as to equalize the total load current between SUPPLY #1 and SUPPLY #2, and operation can proceed. ERROR SENSING CAN NOW BE CONNECTED FROM SUPPLY #2 IF THE LOAD WIRE DROP CANNOT BE TOLERATED.

NOTE: The output graph below (refer to FIG. 3-20) shows how the two power supplies operate in the parallel mode. As seen from FIG. 3-20, load variations should be confined within the stabilization region of SUPPLY #2 since there is an initial adjustment error (ΔE_O) between the two supplies.

[1] Use suitable external ammeters in series with the (+) output lead of each power supply on meterless JQE models.

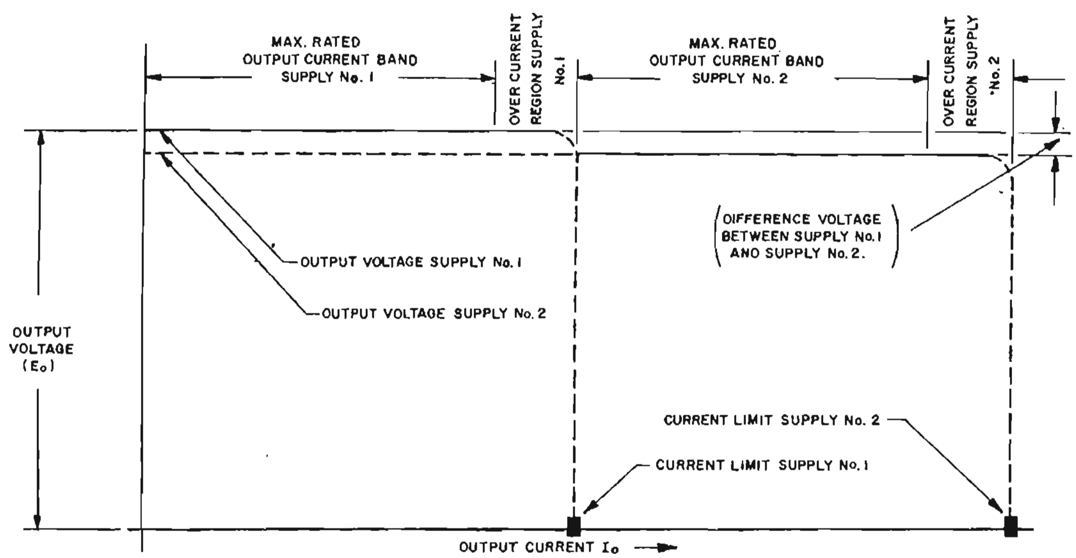


FIG. 3-20 "AUTOMATIC" PARALLEL OPERATION (TWO SUPPLIES).

3-81 **MASTER/SLAVE PARALLEL CONNECTION.** Two power supplies are shown in FIG. 3-22, although more can be paralleled, each unit requiring its own sampling resistor. The sampling resistors (R_{S1}, R_{S2} in FIG. 3-22) are of equal value and are selected such that the voltage drop across them (due to the output current), plus the voltage drop in the load connection leads does never exceed 0.5 volts. If the voltage drop across the load connecting leads alone is at least 0.1 volt, the sensing resistors can be deleted since the leads provide the necessary sample voltage. For equal current sharing, however, the lead ***length*** and ***diameter*** should be the same for both power supplies. Output control is exercised from the "Master" supply.

3-82 PROCEDURE FOR "MASTER/SLAVE" PARALLEL OPERATION (See FIG. 3-22)

1) Connect the power supplies to be paralleled to a common a-c source (preferably with a common "on-off" power switch).
2) Make all load and sensing connections as shown in FIG. 3-22. The error sensing connections may be deleted if the minor voltage drop across the load wires (which subtracts from the available compliance voltage) can be tolerated.
3) With the *individual* a-c power switches of the two power supplies in the "on" position, turn the *common* a-c power switch "on." Observe output panel meters on both power supplies. Adjust output control on the "Master" supply, such that both supplies share the load current equally.

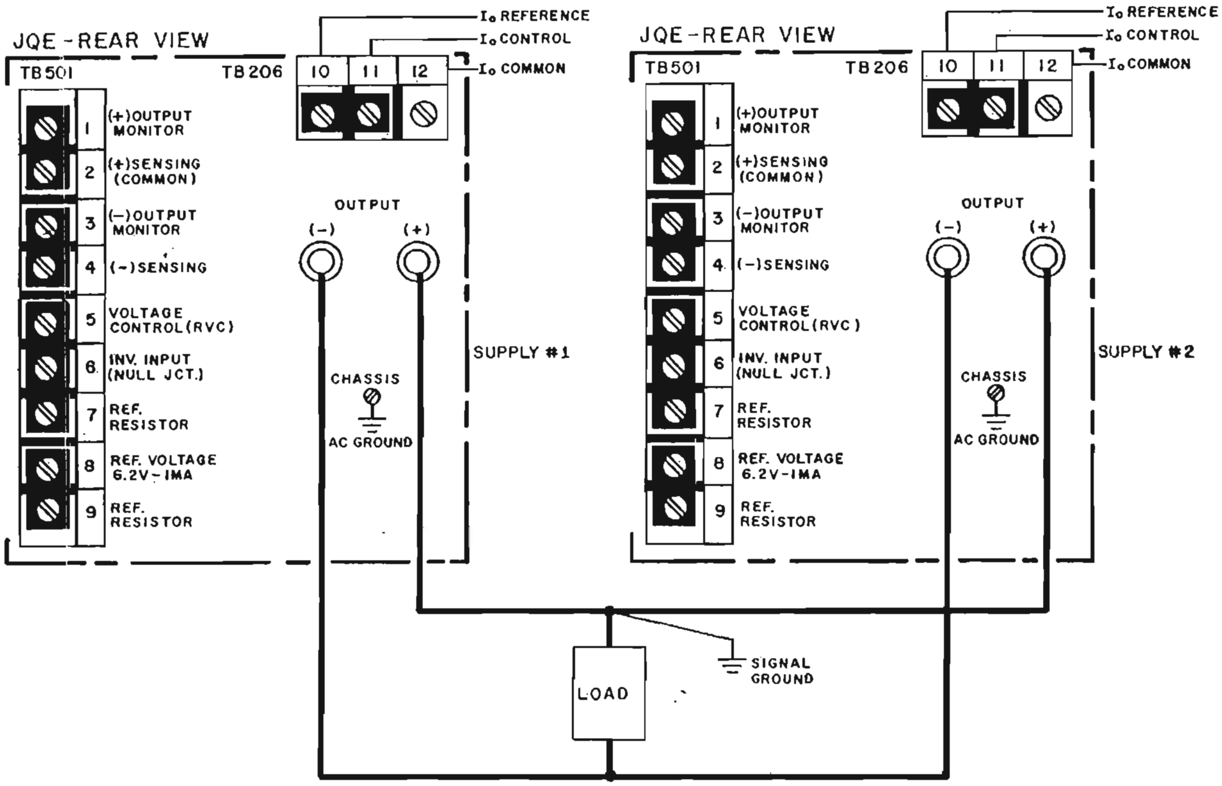


FIG. 3-21 BASIC PARALLEL CONNECTION OF TWO JQE POWER SUPPLIES

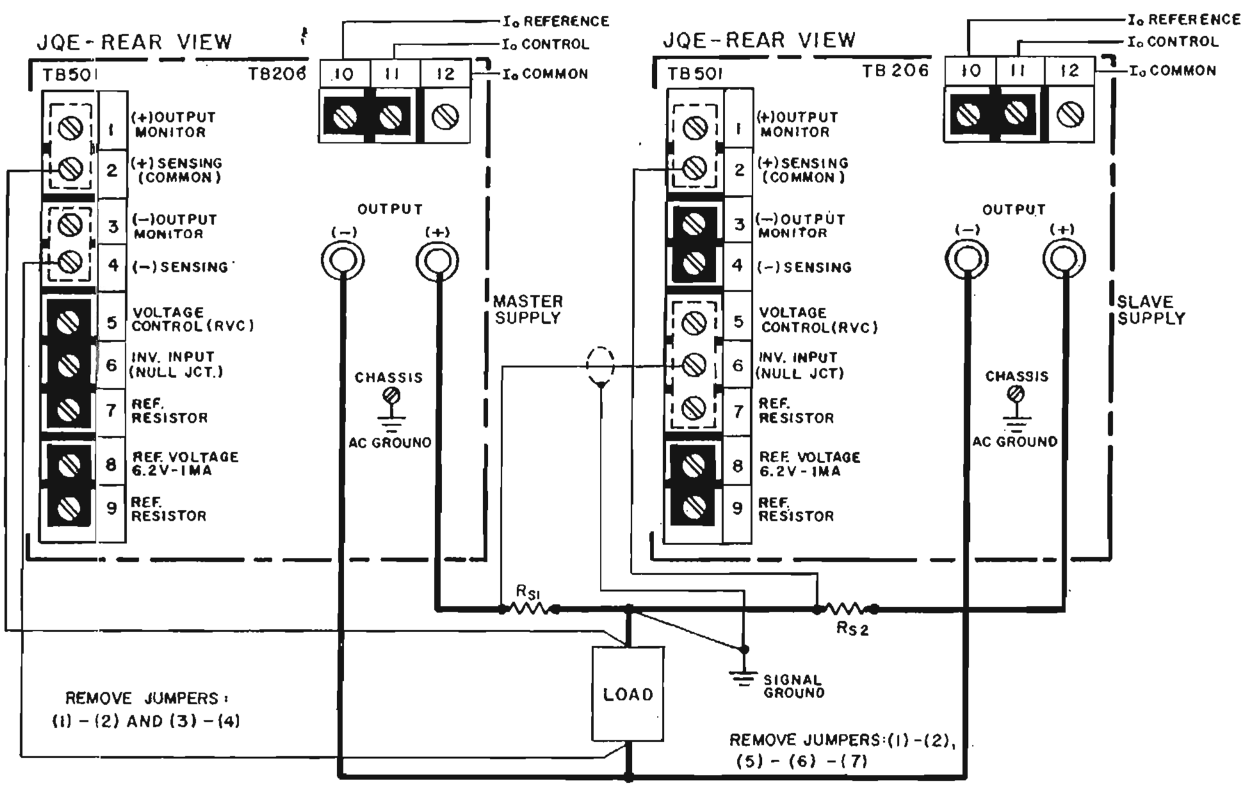
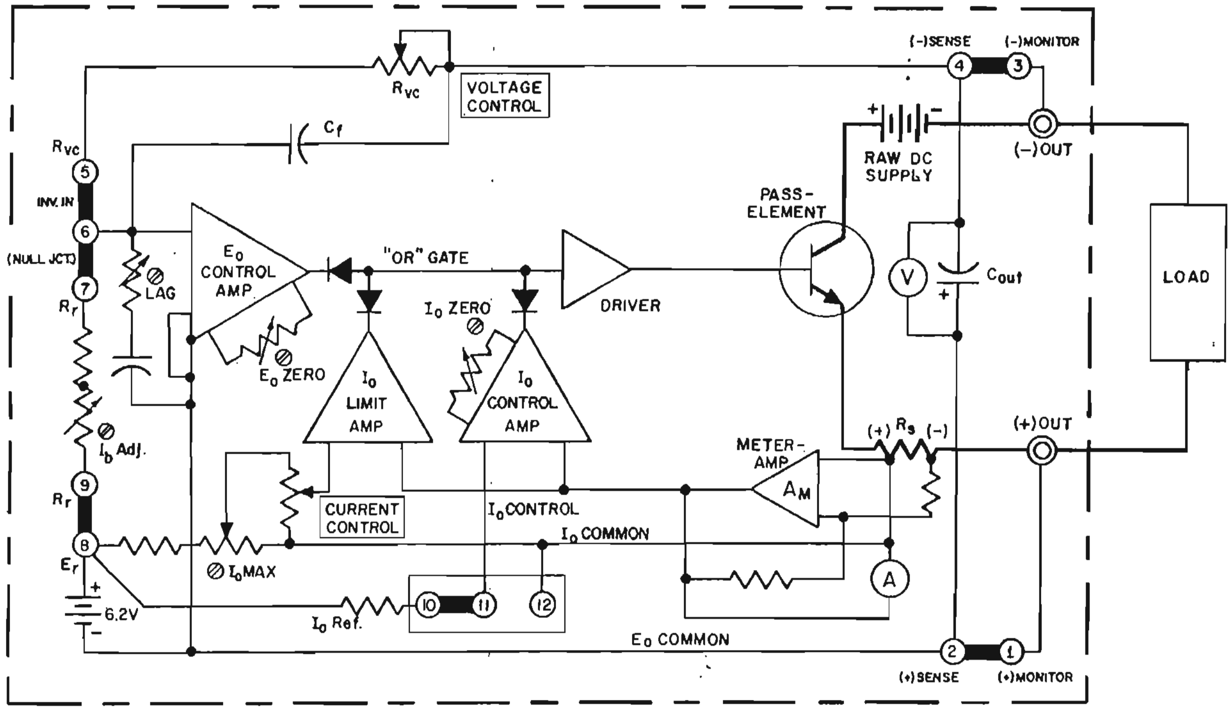


FIG. 3-22 MASTER/SLAVE PARALLEL CONNECTION OF TWO JQE POWER SUPPLIES

A) JQE 6-90MY ONLY.



B) JQE ½ AND FULL RACK MODELS, EXCEPT JQE 6-90MY.

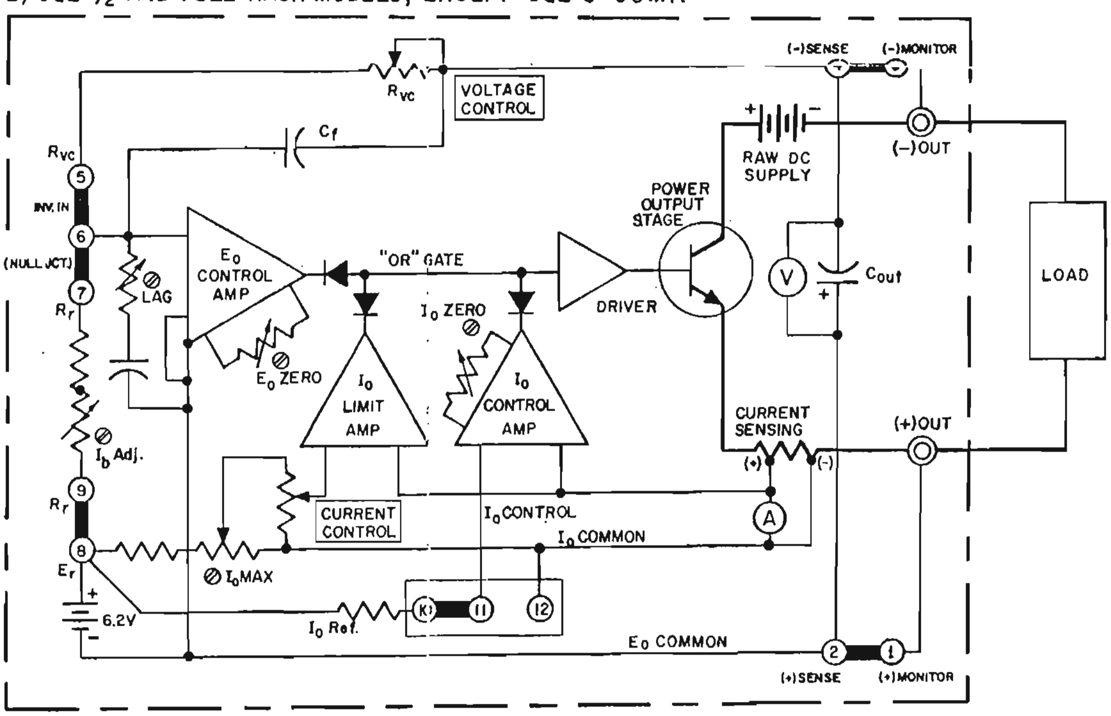


FIG. 3-23 SIMPLIFIED SCHEMATIC DIAGRAM
JQE 1/2 RACK AND FULL-RACK GROUPS.

3-83 INTERNAL ADJUSTMENT PROCEDURES

3-84 GENERAL. This paragraph describes all internal adjustment procedures, which have not been previously covered. Refer to Section II, paragraph 2-3 for a listing and location of all adjustment procedures.

3-85 MAXIMUM OUTPUT CURRENT ("I_O max. adj.") ADJUSTMENT. This adjustment serves as a calibration for the range of the front panel Current Limit Control. The "I_O max. adj." (R19) 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 2–105% of the maximum rated output current. Re-adjustment of the "I_O max. adj." 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 output current of 105% of rated 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 0.1mV/cm.**

b) Observe the oscilloscope. Current limiting is indicated by a sharp increase in output ripple. Locate the "I_O max. adj" control and turn slowly until limiting occurs at the point required. Clockwise adjustment will increase the maximum output current range, while counterclockwise adjustment will decrease the range. DO NOT ADJUST TO MORE THAN 105% I_O 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.

3-86 LAG NETWORK ADJUSTMENTS. With most models in the JQE series it is necessary to shape the gain-phase characteristics of the error-signal amplifier with external compensation networks, to achieve stability for any amount of feedback. Since gain and phase shift differ from model to model, either one or two adjustable lag networks are provided (R16–C9 and/or R36–C10,*. Lag network readjustment is indicated if components **affecting the frequency characteristics of the amplifier are replaced, or if the load connected to the power** supply contains excessive capacity or inductance, causing instability. The instability is usually indicated by high frequency oscillation as observed with an oscilloscope across the power supply load. In such cases, the lag network should be adjusted so that stable operation is resumed. If in extreme cases adjustment of the lag network should not prove sufficient, twisted-load and error-sensing wires or decoupling capacity directly across the load may provide a solution to the problem.

*C12 in Model JQE 6–90.

3-87 AMMETER ZERO ADJUST (MODEL JQE 6-90M ONLY). A meter amplifier is connected between the sensing resistor and the ammeter to reduce the loading effect on the sensing resistor. Offset control of the meter amplifier is used to achieve perfect zero of the ammeter. Adjustment of this control should be needed only in cases where either the meter amplifier or the ammeter is replaced.