Instructions For Brush-Type Synchronous Motor Field Current Regulator With VAR and PF Control

DANGER

HAZARDOUS VOLTAGE.

READ AND UNDERSTAND THIS INSTRUCTION MATERIAL AND I.B. 48008 IN THEIR ENTIRETY BEFORE INSTALLING OR OPERATING THIS EQUIPMENT.

INSTALLATION, ADJUSTMENT, REPAIR AND MAINTENANCE OF THESE CONTROLLERS MUST BE PERFORMED BY QUALIFIED PERSONNEL. A QUALIFIED PERSON IS ONE WHO IS FAMILIAR WITH THE CONSTRUCTION AND OPERATION OF THIS EQUIPMENT AND THE HAZARDS INVOLVED.

DESCRIPTION

The Volt-Amperes Reactive (VAR) and Power Factor (PF) Field Current Regulator option is mounted on a panel inside the Mark V Motor Field Controller.

The field controller is an integrated control unit. The basic Mark V is manufactured in a 36 inches wide x 30 inches deep x 45 inches high (92 cm wide, 76 cm deep and 114 cm high) Ampgard® cell assembly. A transformer is included in this cell up to 20 kVA. Above 20 kVA it requires an additional cell and the assembly is 36 inches wide x 30 inches deep x 90 inches high (92 cm wide, 76 cm deep, and 229 cm high). Where this unit is part of an Ampgard® assembly with horizontal bus the structure has a 10-inch bus enclosure on top to make it 100 inches (254 cm) tall overall. Starting and Discharge Resistors are mounted above the horizontal bus housing.

Read this booklet in conjunction with I.B. 48008, Mark V Brush-Type Synchronous Motor Controllers, whose purpose is to connect the motor field to the Starting and Discharge Resistor during the starting cycle and then disconnect the resistor and apply field excitation at the optimum time to aid in synchronization. In the manual mode of operation (i.e., without a VAR/PF Field Current Regulator), the motor field voltage can be manually controlled from 50 to 100% of nameplate field voltage. A more technical discussion of this regulator with trouble-shooting and test procedures is available in I.L. 4D01120.

Fig. 1 Mark V Slipsyn Synchronous Motor Field Controller

The Mark V Controller maintains the preset **voltage** on the motor field regardless of the changes in the motor stator voltage or its excitation supply voltage. With a preset voltage the field current varies as the field resistance changes.

APPLICATION

Most power distribution systems have about ten to twenty times more inductive reactance than resistance. That is to say the X/R ratio is in the range of 10 to 20. Voltage drop is proportional to the current through the system and the system reactance and resistance.

Inductive reactance is that characteristic of an electrical circuit that causes more current to flow to the point of use than is converted to power and with time to energy. This “excess” current is out of phase with the voltage and since power is the product of voltage and the current in phase with the voltage, a formula is used to calculate the rate at which electrical energy in an AC distribution system is being converted to heat, light, and/or mechanical energy.

APPLICATION (Continued)

This formula (power = voltage x current x power factor) includes a term, “power factor,” abbreviated p.f. or PF. Power factor is expressed as a decimal fraction never greater than 1.00, or as a percent.

Electrical utilities bill most of their customers by the energy consumed (watt-hours), ignoring power factor when it is very close to 1.00, but charge penalties against those installations that show a low power factor on a regular basis.

When vectors are used to describe an AC electrical circuit, the cosine of the angle between the current vector and the voltage vector is the power factor. In industrial installations where much more power is used for motors than for electrical heating and lights, the power factor is less than 1.00 and the current lags the voltage as it alternates at 50 or 60 times a second. To avoid this penalty many industrial installations employ a method of “power-factor correction” in the form of capacitors which, by themselves, create a current which leads the voltage. Hence, if an installation has some equipment where the current leads the voltage (leading power factor), and some equipment where it lags the voltage (lagging power factor), the currents are blended within the installation and the utility sees a customer drawing current at close to unity power factor. A synchronous motor can be used in much the same manner to compensate for a plant’s low power factor.

The power factor of the AC circuit supplying a synchronous motor can be altered (adjusted) by varying the motor field excitation, as can the reactive line current of this circuit. By adjusting the degree to which the synchronous motor line current leads the voltage (leading power factor), the system power factor will be improved when the synchronous motor circuit is blended with circuits having a lagging power factor. The measure of this blending is expressed in terms of volt-amperes reactive (VAR). Another method of blending is by fixing a leading power factor of the synchronous motor at a value that achieves the desired result.

Only one of three options, the VAR regulator, the PF regulator or constant field current may be used. Once set, the regulator limits the voltage swings caused by large synchronous motors loading and unloading during operation.

The VAR Regulator

The purpose of the VAR (Volt-Amperes Reactive) Regulator is to **control AC reactive current of the synchronous motor** during varying load conditions by varying the motor field excitation.

The PF Regulator

The purpose of the PF (Power Factor) Regulator is to **control the synchronous motor power factor** under varying load conditions by varying the motor field excitation.

The Field Current Regulator

The purpose of the Field Current Regulator is to compensate for the increase in the synchronous motor field resistance as the motor field heats up. The field current regulator may also be used to create a strong field prior to an anticipated need (i.e., a forced field). A typical application might be a slab mill where the synchronous motor is idling at little or no load. As a fresh slab approaches the operator creates a forced field in the motor to prepare the motor for the oncoming impact load.

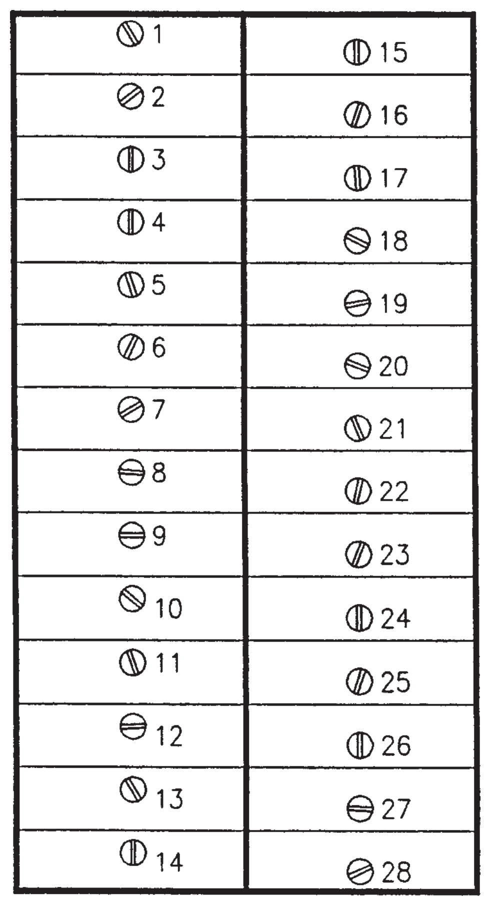

Fig. 2 CB1 Terminal Block

TABLE I. HEADER ASSIGNMENTS				
Header Number	Header Location On CB1	PLACE JUMPERS FOR		
		Current Regulator	PF Regulator	VAR Regulator
H1	At center, near RH edge	Aux	PF	PF
H2	To upper right of H4	IF	IF	IF
H3	To upper right of H4	STAT	STAT	STAT
H4	At center, near bottom edge	VAR	PF	VAR
H5	Upper RH corner	**	**	**
H6	Below H5	**	**	**
H7	Lower RH corner	**	**	**
H8	To left of CB1 midpoint	DROOP	DROOP	DROOP
H9	To left of CB1 midpoint	DROOP	DROOP	DROOP
** = Header used for test point. Do not install jumpers!!				

OPERATION

The VAR/PF regulator receives a nominal 120 volts from the secondary of the control power transformer (CPT on drawing 3D53413, attached). This is the phase voltage between phase A and phase B supplied to terminals 15 and 17 on CB1 which in turn connect to the regulator power supply (PS1 and PS2). Also located on CB1 are two terminals marked “1” and “2”. They are the two ends of a calibrated resistor carrying current from phase C to ground. (Ground point is shared with the grounded end of the current transformer windings.) When the voltage drop across the resistor (measured at terminals 1 and 2) is 4 volts, and leading the phase voltage A-B by 90 degrees, the motor power factor is unity.

The Field Current Regulator receives a signal proportional to the synchronous motor current via terminals 21 and 22 on CB1 of the VAR/PF/Current Regulator. This feedback signal originates within the three-phase current transformer CTFA (Figure 3R) which is rectified to DC and available at terminals 1F and 1C. A potentiometer connected across these terminals provides adjustment as described later.

GENERAL SETUP

Start the synchronous motor in accordance with I.B. 48008 and check out the operation of the Mark V synchronizing and control circuit by operating with SS1 in the manual (MAN) position. Then turn the motor OFF. The equipment is now ready for operation in the AUTO mode, under the control of the regulator. With the isolating switch in the OFF position, proceed as follows:

1. Identify the headers provided (See Table I) and the digital selector switches labeled “S3”, “S4”, “S5”, and “S6”. These selector switches are elongated cubes with four levers marked “1”, “2”, “3”, and “4”, located near the midpoint of CB1.
2. Verify that the jumper configuration on CB1 is appropriate for the option (current, PF or VAR) selected. See Table I. Configuration is performed by placing a two-pin jumper at the desired location on headers H1, H2, H3, H4, H8, and H9. The two center posts on the header are internally connected. The jumper plug should be placed between the appropriate center and edge post.

CAUTION

ONLY ONE JUMPER PLUG SHOULD BE PUT ON EACH HEADER. PUTTING TWO JUMPERS ON ONE HEADER WILL CREATE A SHORT CIRCUIT AND DAMAGE SOME COMPONENTS ON THE PRINTED CIRCUIT BOARD.

Headers H5, H6, and H7 are used for test points and should have no jumpers placed on them. Resistor R83 needs to be jumpered out, i.e., shorted if the automatic low current turn-off feature for P.F. or VAR is functioning. Resistor R83 is located on the left side of CB1, at the bottom edge.

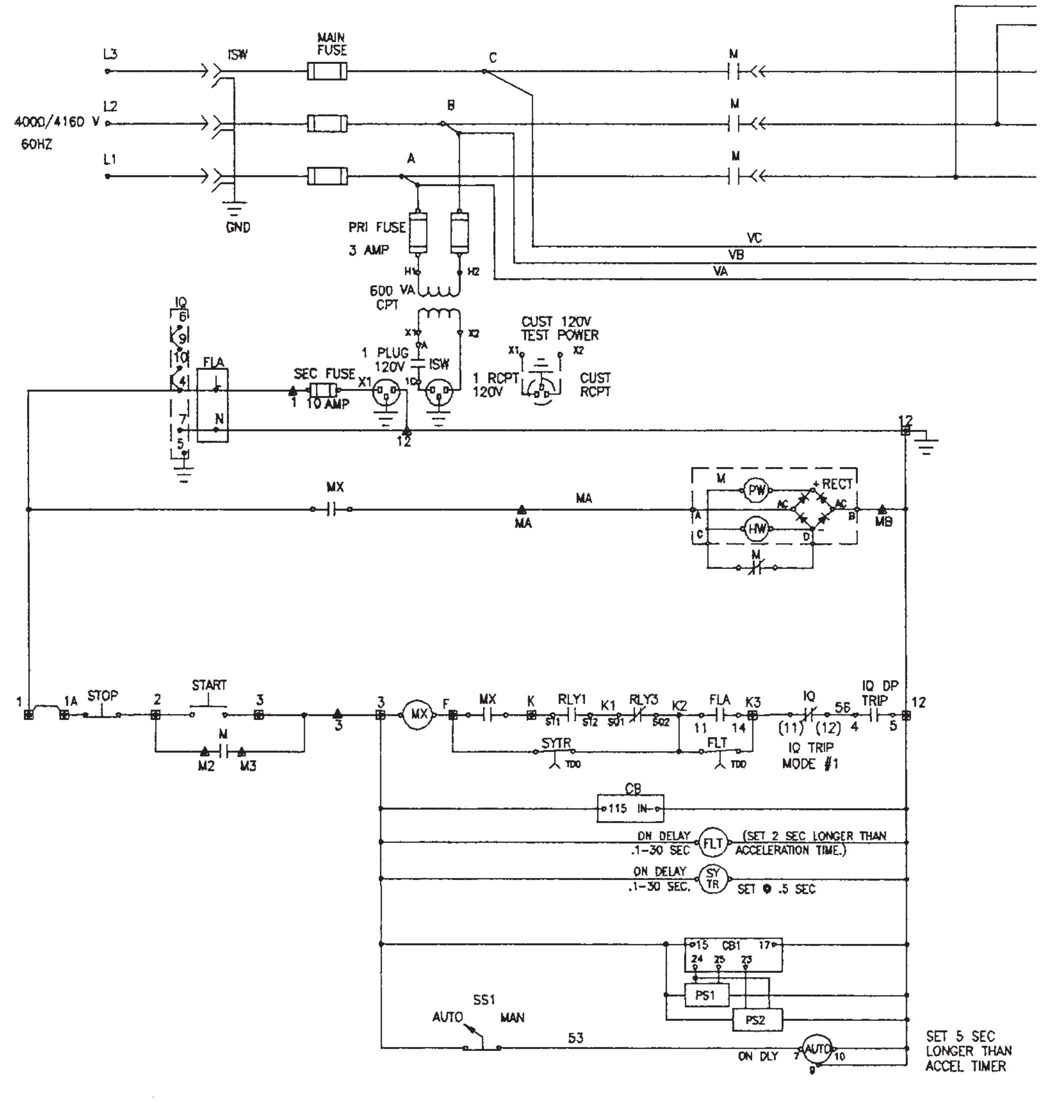

Fig. 3L Left-hand Half of Schematic Drawing

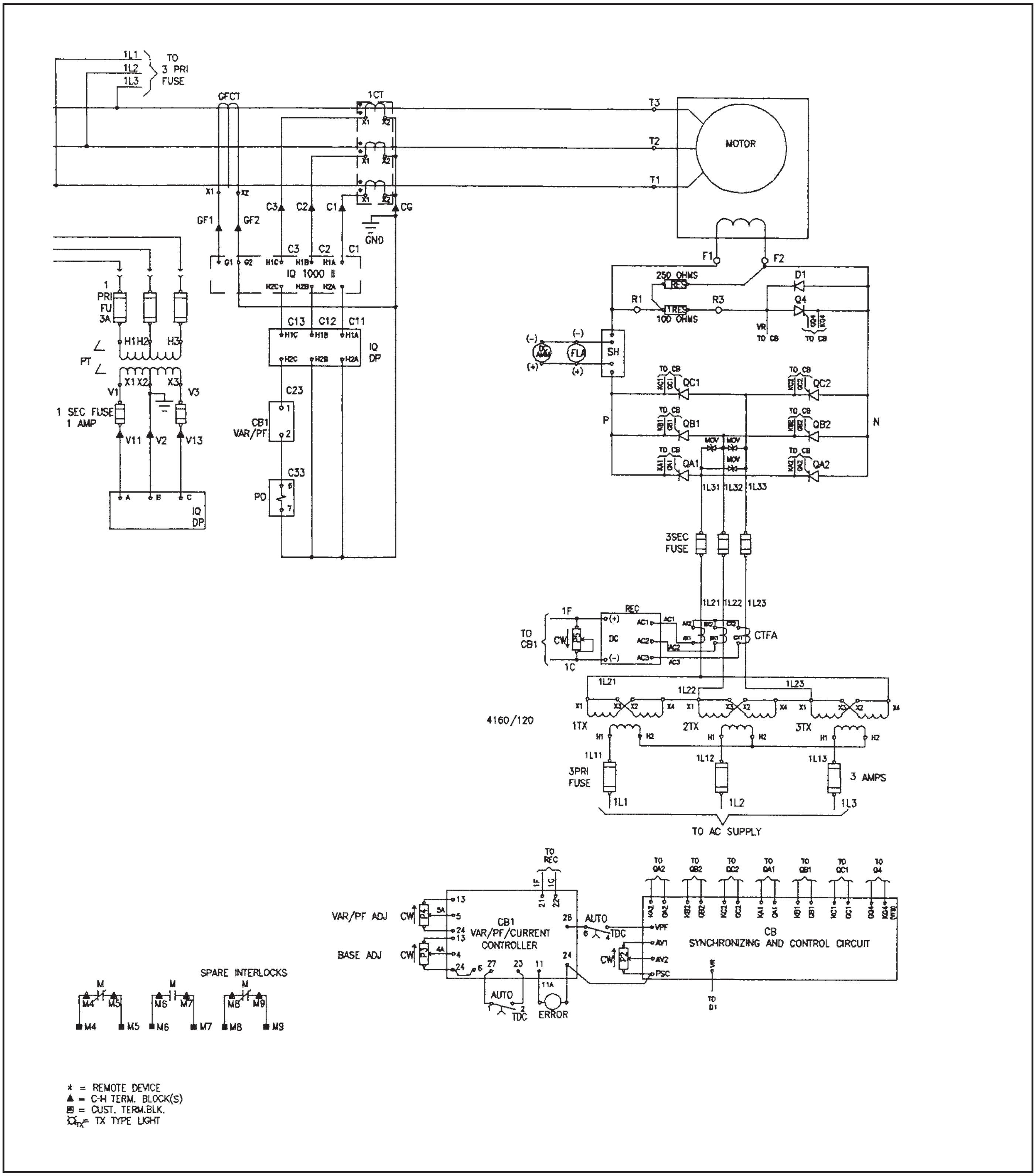

Fig. 3R Right-hand Half of Schematic Drawing

GENERAL SETUP (Cont.)

3. Using Table II and its notes as a guide, set the digital selector switches, S3, S4, S5, and S6 to the initial settings recommended in Table III.
4. With all power OFF make the following resistance checks on CB1:
   a. With an ohmmeter connected between terminals 4 and 24, the resistance of P3 should go from 0 to between 1800 and 2200 ohms as P3 is fully turned clockwise.
   b. With an ohmmeter connected between terminals 5 and 24, the resistance of P4 should likewise go from 0 to between 1800 and 2200 ohms as P4 is fully turned clockwise.
   c. With an ohmmeter connected between terminals 13 and 24 turn P3 and P4 while checking to see that the resistance between these two terminals remains in the range of 800 to 1200 ohms.
5. Disconnect the plug inserted into the receptacle output from the contactor control power transformer (CPT) and connect it to an external source of 110/120 VAC via an extension cord.
6. Close the MX relay (Figure 3L) and check for LED lights ON on PS1 and PS2. Check for -24 VDC (nominal) from terminal 24 to terminal 25 on CB1 and for +24 VDC from terminal 24 to terminal 23.
7. Turn the AUTO-MAN (SS1) selector switch to AUTO and verify that timing relay AUTO picks up. Return SS1 to MAN (manual).
8. Disconnect the external source of control power and reconnect the plug to the CPT.
9. Follow the setup instructions for the option desired, VAR Regulation, PF Regulation or Field Current Regulation.

VAR REGULATOR SETUP

Before starting the motor remove the wire from terminal 27 of CB1. Set it up with a jumper so it can be reconnected later without stopping the motor. This will make the controller think it is not regulating VARs.

Start the motor with the motor operating at no load, set P4 at the full CCW position. (This assumes that leading power factor VARs are desired.)

Reduce the field current potentiometer P2 fully CCW for minimum field. This corresponds to 67 volts on a 125 VDC system and 125 volts on a 250 VDC system. If this cannot be achieved, adjust potentiometer P1 on CB to 50%.

TABLE II. SELECTOR SWITCH GAIN SETTINGS

LEVER POSITION (SETTING)		DAMP	DC VOLTAGE ERROR	PF ERROR	VAR ERROR
Set	**1234**	**S3**	**S4**	**S5**	**S6**
Note>	**A**	**B**	**C**	**D**	**E**
0	0000	.2	0	.27	0
1	1000	1.2	2.0	.55	.054
2	0100	3.3	3.6	.76	.098
3	1100	4.3	5.6	1.0	.15
4	0010	5.2	6.0	1.1	.20
5	1010	6.2	8.0	1.4	.26
6	0110	7.3	9.6	1.6	.30
7	1110	8.3	11.6	1.9	.37
8	0001	10.2	13.6	2.1	.41
9	1001	11	15.6	2.4	.44
A	0101	13	17.2	2.6	.51
B	1101	14	19.2	2.9	.61
C	0011	5	19.6	2.9	.61
D	1011	16	21.6	3.2	.64
E	0111	17	23.2	3.4	.71
F	1111	18	25.2	3.7	.75

Notes:
A. Lever up is open = 0. Lever down is closed = 1
B. Gain shown is in volts per volt while damping.
C. Gain shown is in volts per percent change where one percent = 5 VDC.
D. Gain shown is in volts per degree of power factor angle.
E. Gain shown is in volts per percent change.

TABLE III. INITIAL SWITCH SETTINGS

SWITCH MARKING	TYPE OF REGULATION: CURRENT	P.F.	VAR
S3 “DAMP”	1	1	1
S4 “VGAIN”	2	1	1
S5 “PF GAIN”	1	1	1
S6 “DROOP”	0	0	1

Adjust P3 so that the error meter reads close to zero volts. Error is the difference between what is desired and what the motor is producing.

Turn the controller selector switch (SS1) to AUTO. Potentiometer P3 can now set up the no-load field current for the controller.

When the motor loads and unloads and the motor AC current drops to below 25% of CT secondary or 1.25A, the VAR regulator will turn off. If P3 is not adjusted low enough the field current will rise causing the stator current to rise and the VAR regulator to turn back on. As a result the system will oscillate. P3 should be adjusted so the field current will not rise and cause the motor AC current to rise above 25% of CT secondary (at no load) and oscillate.

Replace the wire on terminal 27.

Load the motor so that the stator current rises to some value above 25% of CT secondary. Adjust potentiometer P4 so the error signal is close to zero. Keep SS1 in the AUTO position.

If all feedbacks are properly adjusted, the error voltage will decrease. If it starts to increase, quickly switch the controller (SS1) to MAN.

Stop the motor and swap the CT leads to panel terminals 3 and 4.

Repeat the above procedure as needed to insure correct connections.

Adjust P4 for the desired VAR flow.

Like all regulators some gain adjustment is required. Adjustments to S6 and S3 will make the regulator responsive. See Table II. Adjust S3 (damp) to stop oscillations. Set S3 near maximum for constant motor loads (e.g., a fan) and near minimum for impact loads (e.g., a slab mill).

PF REGULATOR SETUP

Before starting the motor remove the wire from terminal 27 of CB1. Set it up with a jumper so it can be reconnected later without stopping the motor. This will make the controller think it is not regulating power factor.

Start the motor and with the motor operating at no load, set potentiometer P4 at the full CCW position. (This assumes that a leading power factor is set desired.)

Set the field current potentiometer P2 fully CCW for minimum field. This corresponds to 67 volts on a 125 VDC system and 125 volts on a 250 VDC system. If this cannot be achieved, adjust P1 on CB to 50%.

Adjust P3 so that the error meter reads close to zero volts.

Turn the controller selector switch (SS1) to AUTO. P3 can now set up the no-load field current for the controller.

When the motor loads and unloads and the motor AC current drops to below 25% of CT secondary current (FLA), the PF regulator will turn off. If P3 is not adjusted low enough the field current will rise causing the stator current to rise and the PF regulator to turn back on. As a result the system will oscillate. P3 should be adjusted so the field current will not rise and cause the motor AC current to rise above 25% of CT secondary.

Replace the wire on terminal 27.

Load the motor so that the stator current rises to some value above 25% of CT secondary or 1.25A. Adjust P4 so the error signal is close to zero volts.

Adjust P3 so that the motor field current is at the minimum.

Adjust P4 for the desired power factor.

Keep SS1 in the AUTO position. If all feedbacks are properly adjusted the error voltage will decrease. If it starts to increase, quickly switch the controller (SS1) to MAN.

Stop the motor and swap the CT leads to panel terminals 3 and 4.

Repeat the above procedure to insure correct connections.

Adjust P4 for the desired power factor.

Like all regulators some gain adjustment is required. Adjustment of S5 and S3 will make the regulator responsive. See Table II and corresponding paragraph under **VAR REGULATOR SETUP**.

FIELD CURRENT SETUP

With the motor operating at no load set potentiometer P4 at the full CCW position.

Set the field current potentiometer P2 fully CCW for minimum field. This corresponds to 67 volts on a 125 VDC system and 125 volts on a 250 VDC system. If this cannot be achieved, adjust P1 on CB to 50%.

Turn the controller (SS1) to AUTO. If all feedbacks are properly adjusted the error voltage will decrease. If it starts to increase, quickly switch the controller (SS1) to MAN.

Stop the motor and swap the leads on CB1's terminals 21 and 22.

Repeat the above procedure as needed to insure correct connections.

EXCITATION SYSTEM STABILIZER (DAMPING) CIRCUIT

The excitation system stabilizer serves to stabilize the field current control system. The input signal to the stabilizer is a voltage proportional to field voltage. The signal is derived from the output of the signal mixer module which is proportional to field supply output voltage. (Jumper at H3 must be in STAT position).

The output of the stabilizer circuit (terminal 20) for steady state input signals is zero. A step change in input causes the output to momentarily change and then return to zero, i.e., the output signal is proportional to the derivative of the input signal.

The polarity of the damping signals to the various circuits is such that the field voltage momentarily decreases when the field current increases. Positive signal at the damping input will send a signal to each regulating circuit that causes the signal mixer output to swing toward reducing the demand signal to the power supply firing circuit.

LIMITS OF WARRANTY

The warranty of this apparatus may be invalidated, unless the following described procedures are carefully followed: Apparatus which malfunctions should be replaced with new units obtained from the factory. The malfunctioning items should be returned to the factory for repair after return authorization is received from the local Cutler-Hammer District Office. This is particularly true of printed circuit boards which require careful handling by skilled personnel and for which field repair or modifications should not be attempted.

MAINTENANCE

This equipment contains solid-state components which require very little maintenance. The removal of accumulated dust occasionally will be sufficient.

SPARE PARTS

A reasonable stock of spare parts will minimize down-time, in the event of a malfunction in this equipment. When ordering spare parts, care should be taken to specify the style numbers (or other identification) which is printed on the nameplate, located on this apparatus.

TABLE IV

EDGE CONNECTOR TERMINAL ASSIGNMENT

Assignment	Terminal		Assignment
CT INPUT+	1		
		15	PT PHASE A
CT INPUT-	2		
		16	PT PHASE B
NOT USED	3		
		17	PT PHASE C
D.C. CURR REF+	4		
		18	AC ERROR 1
VAR/PF REF+	5		
		19	MXL INST IN
VAR/PF REF-	6		
		20	DAMP OUT
HXL LIM IN	7		
		21	IF (+) } FROM XDUCR
MEL LIM IN	8		
		22	IF (-) } FROM XDUCR
VAR/PF ERROR	9		
		23	+24V DC PS
COM	10		
		24	COM
FIRING CKT OUT	11		
		25	-24V DC PS
COM	12		
		26	MXL IN
+12V ZENER	13		
		27	VAR/PF ENABLE
COM	14		
		28	BAL METER OUT (VOUT)