INSTRUCTIONS

GEK-14811

3S7932EA200, 201
ALTERREX* EXCITATION SYSTEM CONTROL

INTRODUCTION

The 3S7932EA200 or 201 Alterrex Excitation System controls the voltage (or reactive volt-amperes) of an AC generator by controlling its excitation. This system uses a smaller AC generator as a power source for excitation. The AC voltage from this smaller AC generator is rectified by parallel banks of silicon rectifiers to furnish DC current for the main generator field. For clarity the smaller AC generator will be called the "Exciter" and the larger main generator will be called the "Generator".

The generator excitation is controlled by varying field current to the exciter. This exciter field current is controlled by an automatic amplidyne voltage regulator and a saturable transformer type manual control. The "auto" and "manual" control functions are connected in series much like the conventional amplidyne regulator and the self-excited DC exciter.

The Alterrex system also includes various limit circuits, compensator circuits, start-up circuits, and relaying.

RECEIVING, HANDLING AND STORAGE

Receiving and Handling

Immediately upon receipt, the equipment should be carefully unpacked to avoid damage. Particular care should be exercised to prevent small parts from being mislaid or thrown away in the packing material.

As soon as the equipment is unpacked, it should be examined for any damage that might have been sustained in transit. If injury or rough handling is evident, a damage claim should be filed immediately with the transportation company and the nearest General Electric Sales Office should be notified promptly.

Storage

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

*Trademark of General Electric Co.

DESCRIPTION

The 3S7932EA200 or 201 is the control cubicle portion of an Alterrex Excitation System. The AC exciter and power rectifier portions are covered by separate instructions. (On several early models the control cubicle was called a 3S7931EA400. For some models the 3S7931EA400 series of model numbers is used for the combined control and rectifier cubicles.)

The 3S7932EA200 or 201 control cubicle consists of the following units:

3S7930NA151	AC Regulator and Current Limit Panel
3S7930NA138	AC Regulator Amplifier Panel
3S7932MD157A1	DC Regulator Panel
3S7932CA231	AC Control Panel
3S7932CD140	DC Control Panel
3S7932RA114	Rectifier Assembly
3S7932KA116 or 119	Under Excited Reactive Ampere Limit Panel
3S7932MD125	Shaft Voltage Suppressor Panels
3S7932MA167	Disconnect Panel (For Exciter Field)
3S7932HA115	Motor Operated Voltage Adjustor
3S7932MA189	Voltage Maching Panel
3S7932MD143	Amplidyne Nulling Panel
3S7932JA107	Maximum Excitation Limit Panel
3S7932MD155	Field Flashing Panel
3S7932MA234	Relay Panel

On most applications, not <u>all</u> of the above panels are included.

Various large components such as field breakers, resistors, transformers, and reactors are mounted individually in cubicle.

The power rectifier portion of the system is a separate cubicle (or cubicles) and is covered by separate instructions. Conventional tap water cooled rectifier cubicles are model 3S7501FS125 and are covered by instructions GEK-9141. Purified water cooled rectifier cubicles (usually side mounted on exciter) are model 3S7501FS100 and are covered by instructions GEK-9142. Associated control switches and instruments are usually shipped and mounted separately.

INSTALLATION

Location and Mounting

The control cubicle should be mounted so that it is accessible from both front and rear. This enclosure should be installed in a well-ventilated, clean, dry location where normal ambient temperature is less than 50°C (122°F). Cooling water is not required for the control cubicle.

Connections

a. Wire check all external connections to excitation control and rectifier cubicles.

b. Check all connections to 4CTA, 4CTB, 5CTA, 5CTB, 6CTA, and 6CTB.

c. Check C.T. and P.T. polarities on generator output.

d. Check generator phase sequence.

e. Check all large rectifiers with ohmmeter.

f. Check all connections to amplidyne MG-set.

g. Check wire size of interconnecting wiring per interconnection diagram furnished with control.

h. Wire check all connections and polarities on 1SCPT, 2SCPT, and 3SCPT.

CAUTION:: RECTIFIER HEAT SINKS ARE AT ABOVE GROUND POTENTIAL. ANY WIRING OR CIRCUITS TO BE HI-POTTED OR MEGGERED MUST FIRST BE DISCONNECTED FROM CONTROL CUBICLE.

INITIAL OPERATION

1. Before running generator, check all relaying: (Keep generator field disconnected by lifting brushes.)

    a. Energize DC for relay power. Check polarity.

    b. Check operation of generator field breaker, and (or) exciter field breaker.

    c. Check operation of motor driven adjustors, manual control and auto control (if motorized).

    d. Check operation of 43CS switch and all associated relays.

    e. Check that flashing circuit will apply DC to exciter field circuit.

    f. Check operation of over-temperature and flow-switch circuits (lights, relays, and alarms).

    g. Check operation of all protective relays.

    h. Check ground detecting relays.

    i. Run amplidyne MG-set to check operation of drive motor.

2. Before operating generator, make the following settings:

   a. Water flow "on". Open generator field rectifier disconnect switches.

   b. Manual control in full "lower" position.

   c. Auto voltage adjustor (90) at midpoint.

   d. Set A9P fully CW (slider at 19). On manual control panel set "minimum adjust" for 8 diodes. Set "maximum adjust" resistors for 8.5 ohms each. Set series resistor (5.1 ohms) for zero resistance. Set exciter field suppression resistors for 8.0 amps. (SCPT control winding circuit is approximately 2.5 ohms total.) (Exciter field suppression circuit is not used if exciter field breaker is furnished.)

   e. Leave all other adjustments per factory setting.

   f. Disconnect lead B7, output of U.R.A.L. panel. Disconnect terminal J1 to maximum excitation limit panel (if used).

   g. Apply all auxiliary power to excitation system: DC relay power, amplidyne drive motor power, and all AC power for lights, relays, etc.

3. With generator running at rated speed:

   a. Close generator field breaker, and (or) exciter field breaker.

   b. Move 43CS to "manual" position. Exciter voltage should build up to a low value.

   c. Operating 70CS should raise and lower exciter output voltage.

   d. Monitor exciter output AC voltage with a 0-600 VAC meter. 70CS should control exciter output voltage smoothly from approximately 75 VAC to 500 VAC. Adjust diode taps for "minimum adjust" and resistors shunting 70P for "maximum adjust". Exciter should respond to 70P changes without lag or drift. Run 70CS to full "lower" position, 43CS to "off", and trip field breaker (s).

   e. Close all generator field disconnect switches. Close field breaker (s). Move 43CS to "manual". Generator terminal voltage should build up to approximately 80 per cent rated. Reset "minimum adjust" if required. 70CS should control generator terminal voltage.

   f. Move 43CS to "test" position, with generator terminal voltage at rated. Zero amplidyne voltage "90" adjustor. Lower generator terminal voltage slightly - amplidyne should swing "boost". Check "boost" voltage at "R" terminal board. Don't trust panel meter, even though they normally move CW for "boost".

g. Set generator voltage at rated with (manual) 70CS control. Zero amplidyne with "90" adjustor. Move 43CS to "auto" position. Generator voltage should remain the same as before. The AC voltage regulator adjustor "90" should now raise and lower generator terminal voltage. Adjust A2P and A3P as required to obtain proper range.

h. Set "90" adjustor for rated generator volts. Zero amplidyne with 70CS. move 43CS to "test". Set generator terminal voltage at rated with 70CS. Set "90" adjustor for 100 volts "buck". Connect an oscilloscope or brush recorder to record generator terminal voltage (across A4P). Move 43CS to "auto". Generator terminal voltage (per recorder) should stabilize within 2 seconds. Adjust D3P1 and D3P2 if required to improve stability. Decrease regulator gain (A6P) only as last resort to obtain stable operation.

4. Adjust the field <u>current limit</u> as follows:

   a. Operate on "manual" control. Set A9P with slider on circuit 18.

   b. To set the <u>current limit</u> adjust, first check calibration of current limit circuit. Read generator field current at no load. Read voltage across A9P (18 to 19) at no load. Calculate calibration of current limit feedback circuit as follows:

$$K = \frac{E_{\text{A9P-N.L.}} \ \text{Volts}}{I_{\text{fld.-N.L.}} \ \text{Amps}}$$

   c. Calculate point where current limit should be set as follows:

$$I_{\text{fld.-C.L.}} = \frac{1.20 \times E \text{ gen. rated fld. volt}}{R \text{ gen. fld. (hot) resistance } 125^{\circ}C}$$

   d. Then connect a variable DC power supply across A9P (18 to 19) and set for the following voltage.

$$E_{\text{A9P-C.L.}} = K \times I_{\text{fld.-C.L.}}$$

   e. With this voltage across A9P, 43CS on test, Amplidyne voltage on zero, then move A9P slider toward circuit 19 until current limit takes over. This will be indicated by Amplidyne voltage going "buck". Lock A9P. Current limit is now set.

5. With <u>generator operating</u> on "manual" control, synchronize with <u>line</u>.

   a. Pick up as much as 10 per cent load if possible.

   b. Adjust manual control to cause generator to put out 5 to 10 per cent reactive vars (lagging).

   c. Move 43CS to "test" position.

d. Lift the shorting switch across R35B and R36B to short the paralleling CT.

e. Zero amplidyne with "90" adjuster.

f. When CT shorting switch is returned to R35A-R36A circuit, amplidyne should go "buck". If amplidyne goes "boost", short C.T. again and reverse R36A and R35A.

g. Return generator excitation to desired vars, zero amplidyne with "90" adjust. Move 43CS to "auto". Generator vars should not change. The "90" voltage adjustor should now control generator excitation and var output.

6. Adjust the underexcited reactive ampere limit circuit per instructions GEK-4798.

7. Adjust maximum excitation limit (3S7932JA107) per GEI-47391.

OPERATION

Generator and exciter should be near operating speed before applying excitation.

1. While generator is being brought up to operating speed check the following:

   a. Apply all auxiliary and control power to excitation system.

   b. Generator and (or) exciter field breaker open.

   c. 43CS on "OFF".

   d. 70 CS in full "Lower" position.

   e. All rectifier disconnect switches closed.

   f. Cooling water on.

2. When equipment is near operating speed, apply excitation by closing field breaker and (or) moving 43CS to "Manual".

3. Bring generator voltage up to rated with 70CS.

4. Move 43CS to "Test". Zero Amplidyne voltage with AC regulator voltage adjusting rheostat. (90P)

5. Move 43CS to "Auto". Then proceed with synchronizing procedure to put generator on the line.

PRINCIPLES OF OPERATION

General

The 3S7932EA200 or 201 Alterrex Excitation System controls the voltage (or reactive volt-amperes) of an AC generator by controlling its excitation. This system uses a smaller AC generator as a power source for excitation. The AC voltage from the smaller AC generator is rectified by a power rectifier bank to furnish DC current for the main generator field.

Generator excitation is controlled by varying field current to the exciter. This exciter field is controlled by an automatic amplidyne voltage regulator and a saturable transformer type manual control. Refer to Figure 10, a typical elementary diagram. An exact elementary diagram is furnished with each particular installation.

Power Rectifier Cubicle

The power rectifier cubicle is covered completely by separate instructions GEK-9141 or 9142.

Manual Control Circuit

The manual control circuit used on the Alterrex excitation system is a self-excited type, since power from the output of the exciter is used to provide excitation to the exciter field, through excitation transformers and silicon rectifiers.

The excitation transformers consist of a 3-phase connection of saturable current-potential transformers (SCPT). The SCPT's have both potential input windings and current input windings. Each SCPT is built with double cross and windings to provide control by a common DC control winding. This DC winding controls the level of magnetic flux in the SCPT cores. The SCPT circuit requires linear reactors in series with the potential input to allow control by saturation and to control coupling between the control and potential sources. (See Figure 1)

The input potential windings of the SCPT's are connected in wye through the linear reactors (1LX, 2LX, and 3LX) across the terminal voltage of the exciter. The current windings of the SCPT's are powered by current transformers in series with the main output current from the exciter. The secondary windings of the SCPT connects to the 3-phase rectifier circuit which supplies power to the exciter field.

When the exciter is not supplying current to its load (generator field circuit open), all exciter field power is supplied by the potential input windings of the SCPT's. When the exciter is supplying current to the generator field additional power is supplied by the current input windings of the SCPT's.

The current input windings are required because the potential input (exciter terminal voltage) may drop very low transiently due to sudden changes in generator field current. Such sudden changes in generator field current would

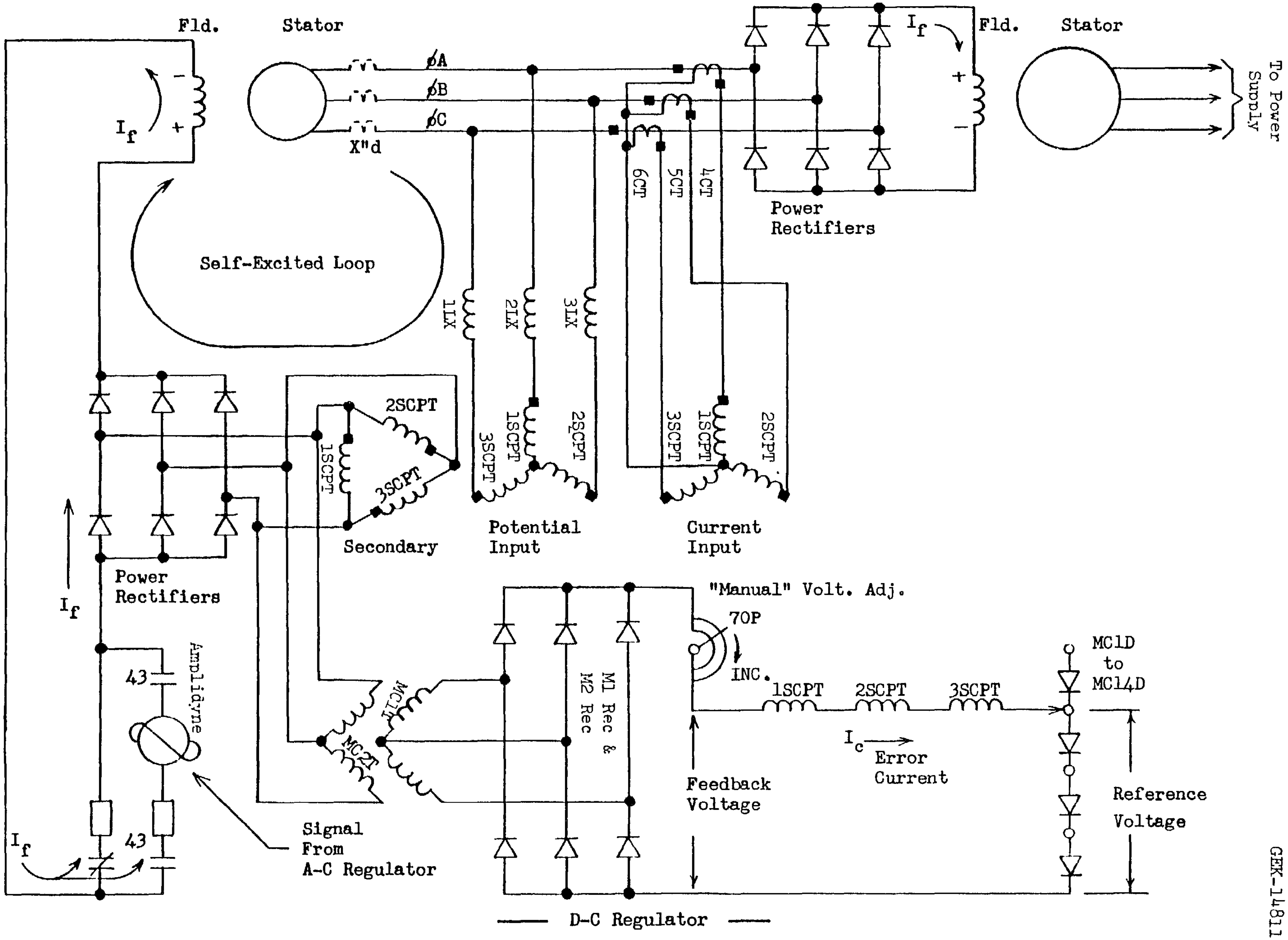

Figure 1 - SCPT Manual Control Circuit

most likely be induced from the stator windings - the result of a fault or disturbance on the power system. The change in exciter terminal voltage (caused by sudden changes in generator field current), is caused by a change in the commutating angle of the generator field rectifiers. This commutating angle (or exciter loading) is a function of exciter sub-transients rectance (X"d) and load currents; thus, any sudden change in exciter load current will cause its terminal voltage to transiently change - until the exciter field circuit can correct the exciter internal generated voltage and return the terminal voltage to its preset value. Should a severe fault occur on the power system, generator field current will suddenly increase. Exciter terminal voltage will drop instantly due to the loading effect described above. Without the current input to the SCPT's, the exciter field self-excited loop might collapse.

Consider the simplified circuit diagram (Figure 2) of the manual control with generator field disconnected. In this circuit the voltage V is proportional to exciter terminal voltage. R_{FAC} represents the exciter field resistance at the AC side of the rectifier, X_1 represents the linear reactor, and X_m represents the magnetizing reactance of the SCPT.

Because of the construction of the magnetic circuit of the SCPT the magnitude of I_m can be adjusted by the DC voltage regulator. In fact I_m is substantially proportional to the DC current I_c supplied to the control winding. When exciter field voltage tends to rise the DC regulator increases I_m by increasing I_c which increases I_p and causes the voltage drop across X_1 to increase, and consequently lowers the voltage applied to R_{FAC}, the exciter field. Thus at no load the necessary value of field voltage is maintained by the DC regulator through adjustment of I_m.

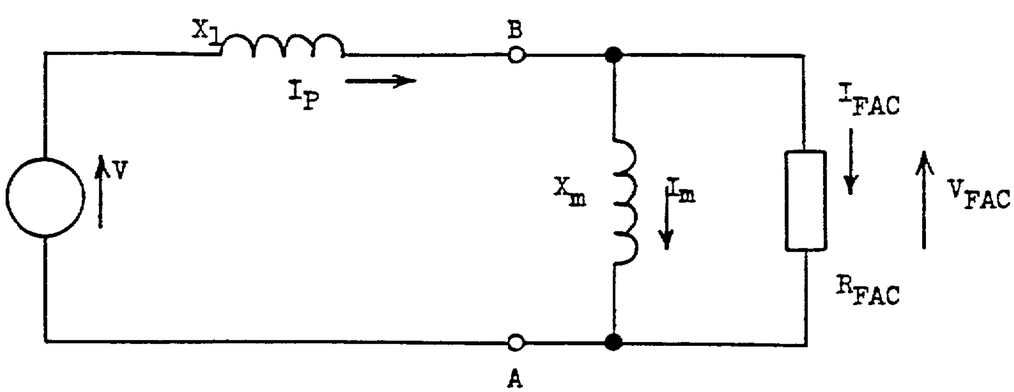

Figure 2. Simplified Circuit of SCPT Manual Control (Generator Field Circuit Open)

When the exciter is supplying current to the generator field, the current transformer portion of the SCPT provides a current input so the simplified circuit becomes that of Figure 3. This is the same as the circuit in Figure 2 except that a current generator, I_s, has been added. An increase in I_s, while I_m remains unchanged, can cause a decrease in I_p, a decrease in voltage drop across X_1, and an increase in V_{FAC}. Thus the exciter load current can be utilized to augment field excitation as the exciter is loaded. If the current input adds more field voltage than is necessary I_m is increased by the DC regulator to correct the field voltage.

A more rigorous explanation of operation under load is facilitated by first obtaining a Thevenin Equivalent Circuit for the devices to the left of points A B, Figure 3. The voltage generator, linear reactor, and current generator are combined into an equivalent voltage source with an internal impedance.

Derivation of Thevenin Equivalent Circuit

Open circuit voltage and short circuit current at AB will be found first. When the circuit is opened at AB; that is, when X_m and R_{FAC} are disconnected from the power sources, the voltage at V_{AB}, called E, is expressed

$$E = V - jX_1I_p \qquad \text{Eq. 1}$$

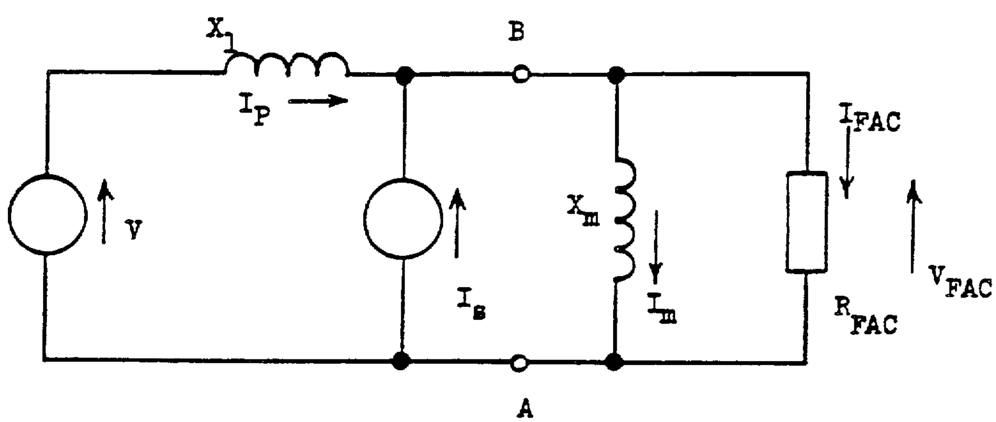

Figure 3. Simplified Circuit of SCPT Manual Control (Generator Field Connected)

Also since the current source demands that I_s flow, I_s must flow through X_1 so that

$$I_p = -I_s \qquad \text{Eq. 2}$$

Combining Eq.1 and Eq. 2 gives

$$E = V + jX_1 I_s \qquad \text{Eq. 3}$$

which is the Thevenin Equivalent voltage source. To find the Thevenin impedance A & B are shorted together. The current which flows from A to B is (by vector addition)

$$I_{ABS} = I_p + I_s \qquad \text{Eq. 4}$$

$$= \frac{V}{jX_1} + I_s \qquad \text{Eq. 5}$$

The Thevenin impedance is

$$Z_T = \frac{E}{I_{ABS}} \qquad \text{Eq. 6}$$

$$= \frac{V + jX_1 I_s}{\frac{V}{jX_1} + I_s} = \frac{V + jX_1 I_s}{\frac{V + jX_1 I_s}{jX_1}} \qquad \text{Eq. 7}$$

$$= jX_1 \qquad \text{Eq. 8}$$

Therefore, the Thevenin Equivalent of the combined voltage and current sources is a voltage source whose value is $V + jX_1 I_s$ and a series impedance of jX_1 as shown to the left of AB in the circuit diagrammed in Figure 4. This circuit will be utilized in the construction of vector diagrams which give an insight to the manual control operation. For vector diagram explanation NL and RL (No-load and Rated-Load) is referring to exciter load; that is, generator field circuit open or closed. The NL and RL has no relation to generator load.

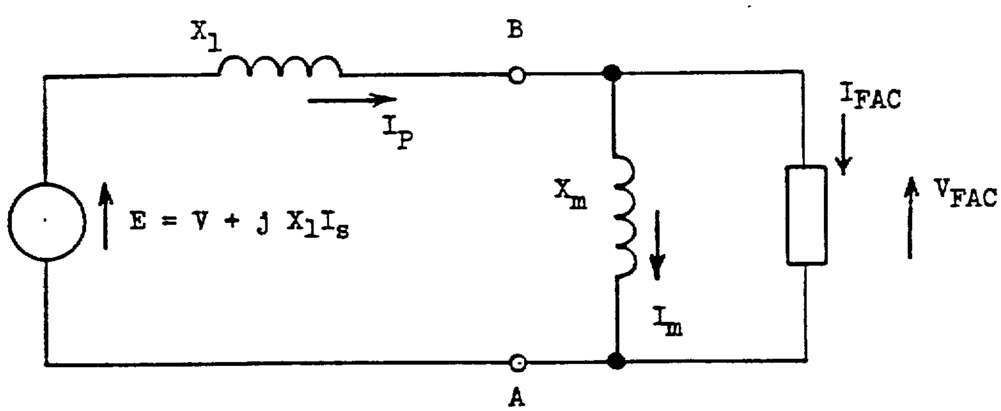

Figure 4. Thevenin Equivalent Circuit SCPT Manual Control

Vector Diagrams

Connections from the exciter to the SCPT are selected to yield V in phase with neutral to line voltage and I_s in phase with line current; therefore, the phase angle between V and I_s is the same as the power factor angle of the load on the exciter. These two inputs combine vectorially to yield the Thevenin voltage, $V + jX_1I_s$, as shown in Figure 5. This vector diagram is similar to the vector diagram for the exciter, Figure 6. This similarity is utilized in the design and operation of the SCPT. Figure 6 shows that when the exciter is operating with generator field disconnected (that is, I_L is zero) the required field current, since it is proportional to the internal generated voltage, e_i, is

$$I_{FNL} = \frac{1}{K} e_i = \frac{1}{K} V_t \qquad \text{Eq. 9}$$

Also from Figure 6, when the exciter is supplying rated current at rated power factor

$$I_{FRL} = \frac{1}{k} e_{iRL}$$

$$= \frac{1}{k} (V_t + jX_dI_{LRL}) \qquad \text{Eq. 10}$$

The SCPT is designed to match the exciter at these two values of field current.

First, the no load case is matched. As a starting point, X_1 and I_m are selected so that

$$X_1 = 0.825\ R_F \qquad \text{Eq. 11}$$

and

$$I_mNL = 1.038\ I_{FNL} \qquad \text{Eq. 12}$$

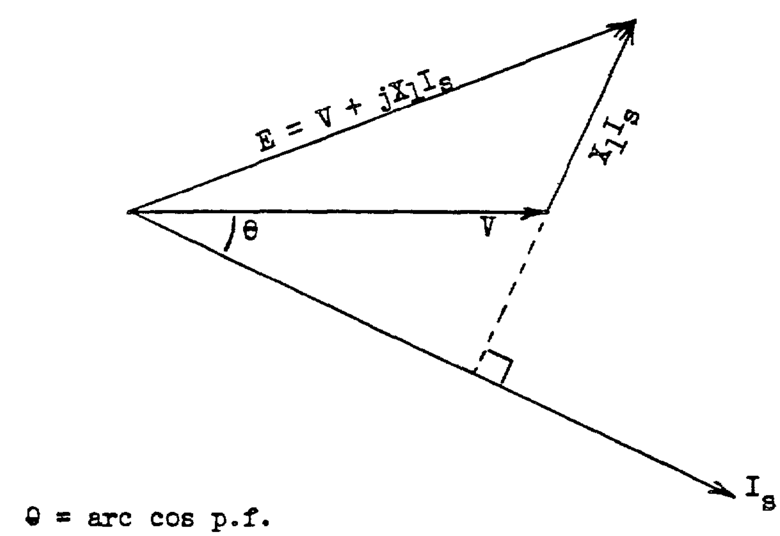

Figure 5. Vector Diagram of SCPT Currents and Voltages

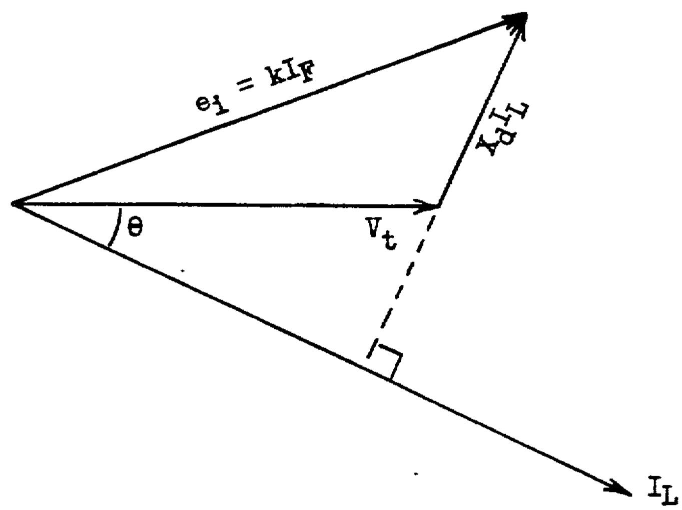

Figure 6. Vector Diagram of Exciter Operation

The vector diagram in Figure 7 can then be constructed for Figure 4. V_{FAC} is taken as the reference. Since I_{FNL} is required in the field on the DC side of the power rectifier, its equivalent on the AC side I_{FACNL}, is required in Figure 4. It can be seen from Figure 4 that at any load I_{FAC} is in phase with V_{FAC} since R_{FAC} is a resistance, and I_m lags V_{FAC} by 90° since X_m is an inductive reactance. Consequently, the vectors for I_{FACNL} and I_{mNL} are placed as shown in Figure 8. The vector sum of these two currents is I_{pNL} as shown. I_{pNL} flows through X_1 giving the voltage drop $jX_1\ I_{pNL}$. The supply voltage, E_{NL}, is the vector sum of V_{FACNL} and $jX_1\ I_{pNL}$. Since V_{FAC} is rectified and applied to the field, only its magnitude matters, and the phasing of V_{FAC} with respect to V is immaterial. To find the magnitude of V required, no load values ($E = E_{NL}$ and $I_s = 0$) are substituted into Eq. 3 giving

$$E_{NL} = V + jX_1\ (0) = V \qquad \text{Eq. 13}$$

To summarize: From no-load requirements of the field, Figure 7 was constructed and solved for E_{NL}. V is equal to E_{NL}.

Second, the SCPT is matched to the exciter for the rated load case. Since I_{FRL} is a known exciter requirement, I_{FACRL} is a known requirement and also fixes the value of V_{FACRL}. I_m increases only 10% to 20% when V_{FAC} is doubled but is virtually proportional to the DC regulator error current I_c. The system is designed for I_{MRL} to be approximately 1.2 I_{MNL}; thus, I_c will not have to be changed appreciably to compensate for exciter loading (generator field connected).

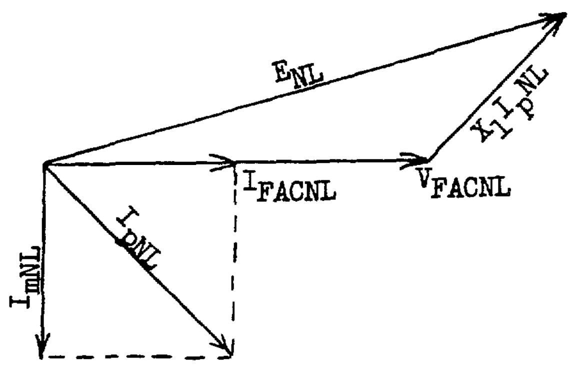

Figure 7. Vector Diagram of Manual Control (Generator Field Disconnected)

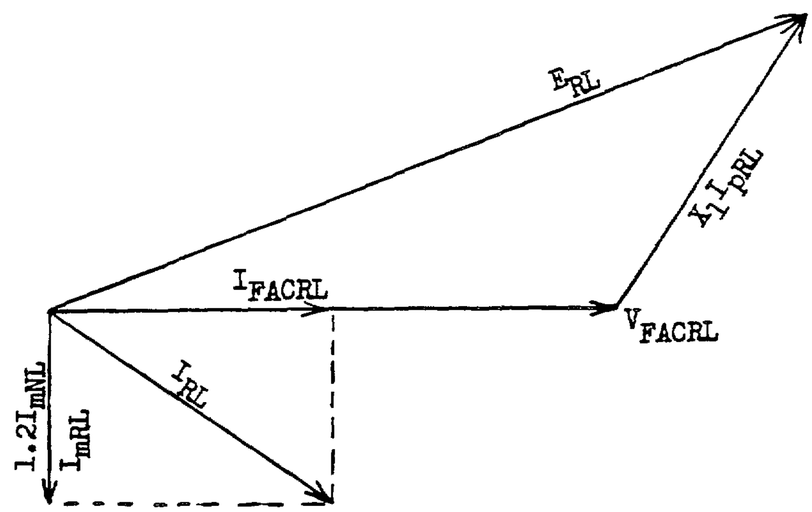

Figure 8. Vector Diagram of Manual Control (Generator Field Connected)

Consequently, the required source voltage, Figure 4, is found from vector diagram shown in Figure 8. **Again** V_{FACRL} is the reference, IFACRL is in phase with V_{FACRL} and I_m lags V_{FACRL} by 90°. The vector sum of I_{FACRL} and $I_m RL$ is $I_p RL$. The vector sum of V_{FACRL} and $jX_1 I_p RL$ is E_{RL}.

DC (Manual) Regulator

The DC Regulator controls exciter field voltage by effectively varying the ratio between the primary and secondary of the SCPT's. The effective ratio between SCPT primary and secondary is not varied by changing turns but is instead varied by controlling the magnetizing reactance. This magnetizing reactance is inversely proportional to magnetizing current (Im), which is essentially the control winding current Ic. (See Figure 1).

The DC Regulator is a single bridge circuit with the feedback on the left and the reference on the right. The difference between the feedback voltage and the reference voltage provides an error voltage. This error voltage causes an error current to flow through the SCPT control windings as required to keep the feedback voltage constant.

The feedback circuit consists of transformers MC1T and MC2T, Rectifiers MC1 Rec and MC2 Rec, and the "manual" voltage adjuster 70P. The reference voltage is established by current flow through diodes MC1D through MC14D. Each diode provides approximately .8 volts drop. The difference between the feedback voltage and the reference voltage sets the level of error current that flows through the SCPT control windings.

Consider a case when the machine is running on "Manual" control at a steady level of excitation and it is required to increase excitation. The operator will increase the resistance of 70P, the "Manual" voltage adjust. This will decrease Ic control current through the SCPT control windings; thus, the effective secondary turns of the SCPT's will increase. The SCPT secondary voltage will increase to increase exciter field voltage, which is the rectified output of the SCPT's. The feedback voltage (which is proportional to exciter field voltage) will increase to correct the initial change in Ic. The exciter output AC voltage will increase after a time lag due to the field time - constant. When the exciter output voltage increases the output of the SCPT will also increase to a higher voltage than required because the effective secondary turns of the SCPT has been increased. This means that the DC regulator will now provide more error current (Ic) to decrease the effective secondary turns of the SCPT and allow the system to stabilize at a higher level of exciter field voltage, higher exciter output voltage and higher Ic control current, even though control current first decreased when 70P resistance was increased.

Adjusting the number of diodes in the reference circuit provides a "Minimum" voltage adjust of 70P operating range. Adjusting MC5RA and MC5RB provides a "maximum" voltage adjust of 70P operating range.

The SCPT transformers have trimmer windings that can be added in series with the potential input or the current input (either in a buck or boost direction) to compensate for design tolerances if required.

When the automatic (amplidyne) regulator is placed in service it operates in series with the DC voltage from the manual control rectifiers. The Amplidyne voltage thus adds or subtracts from the manual control voltage as required by the AC regulator.

AC (Automatic) Voltage Regulator

Principles of operation of the AC voltage regulator are covered by Instructions GEK-4798.

Reactive Current Compensator

Principles of operation of the reactive current compensator circuit are covered by Instructions GEK-4798.

Active-Reactive Current Compensator

Principles of operation of the active-reactive current compensator are covered by Instructions GEK-4798.

Under Excited Reactive Ampere Limit

Principles of operation of the under excited reactive ampere limit circuit are covered by Instructions GEK-4798.

Current Limit Sensing And Amplifier Circuit

The current limit sensing and amplifier circuit illustrated in Figure 9 takes an input current signal from current transformers whose primaries are in series with the secondaries of larger C.T.'s in the three AC lines to the power rectifiers. These CT's are loaded into resistors to convert the current signal to a voltage proportional to current. The current limit circuit takes this input voltage (proportional to current), compares this to a reference voltage, and furnishes an output error signal to drive the push-pull buck-boost magnetic amplifiers in the buck direction when the current signal exceeds the reference.

The input voltage from the CT's is rectified by dioes 1D through 6D to provide a DC signal across circuits 19 to 29 that is proportional to AC exciter output current. A portion of this voltage, across circuits 2 to 29, is applied to 1Q transistor. Transistor 1Q and 2Q act as a summing amplifier. The input to transistor 2Q is the reference voltage developed across 1Z zener diode. The output of 2Q transistor is the difference between the feedback signal applied to transistor 1Q and the reference voltage applied to transistor 2Q. This difference or error signal appears across 5R resistor. This error signal is reversed in sense by 3Q transistor, then amplified by 4Q and 5Q transistors to provide an amplified error signal across 12R resistor.

This amplified error signal is then applied to 6Q and 7Q transistors in the AC regulator to provide a voltage to drive the regulator magnetic amplifiers. This final output voltage appears across 22R. Normally, transistor 6Q will be controlled by the AC regulator circuit (25). The output voltage (32) is fed back through the gain adjustment to compensate for tolerances in the various transistors. Capacitors 2C and 3C act as filters to reduce ripple.

Transformer A4T4 furnishes power for the entire transistor circuit. Zener diodes A2ZA and A3ZA furnish regulated busses of +15 volts and -15 volts with respect to the common circuit 17.

During normal operation should exciter AC current rise excessively due to overexcitation, then the base of transistor 1Q will go positive. If the current signal exceeds the reference, the error signal (22) will go positive. The input to 4Q transistor (23) will go negative. Circuit 25 will go negative. Transistors 6Q and 7Q will follow circuit 26 instead of circuit 25 in the AC regulator causing circuit 32 to also go negative. This will cause more "buck" current to flow through magnetic amplifiers D1 and D2, thereby, decreasing excitation to the system to correct for the original overcurrent.

Relaying And Control Circuits

Sheet 3 of the typical elementary diagram, Figure 10, illustrates relaying and control circuitry for a typical Alterrex edcitation system. Relaying and control circuits are seldom identical for different applications. An exact diagram for each application is furnished separately.

Contactors 43A, 43B and 43C provide for transfer from manual to automatic operation. This contactor is controlled by control switch 43CS.

Contactor 6 is the Amplidyne starter and is also operated by 43CS.

Contactor 53 energizes the Field Flashing circuit and is operated by a field breaker contact.

The manual control voltage adjusting Rheostat is operated by motor 70M. This is controlled by control switch 70CS.

The automatic regulator voltage adjust is operated by motor 90M. This is operated by control switch 90CS.

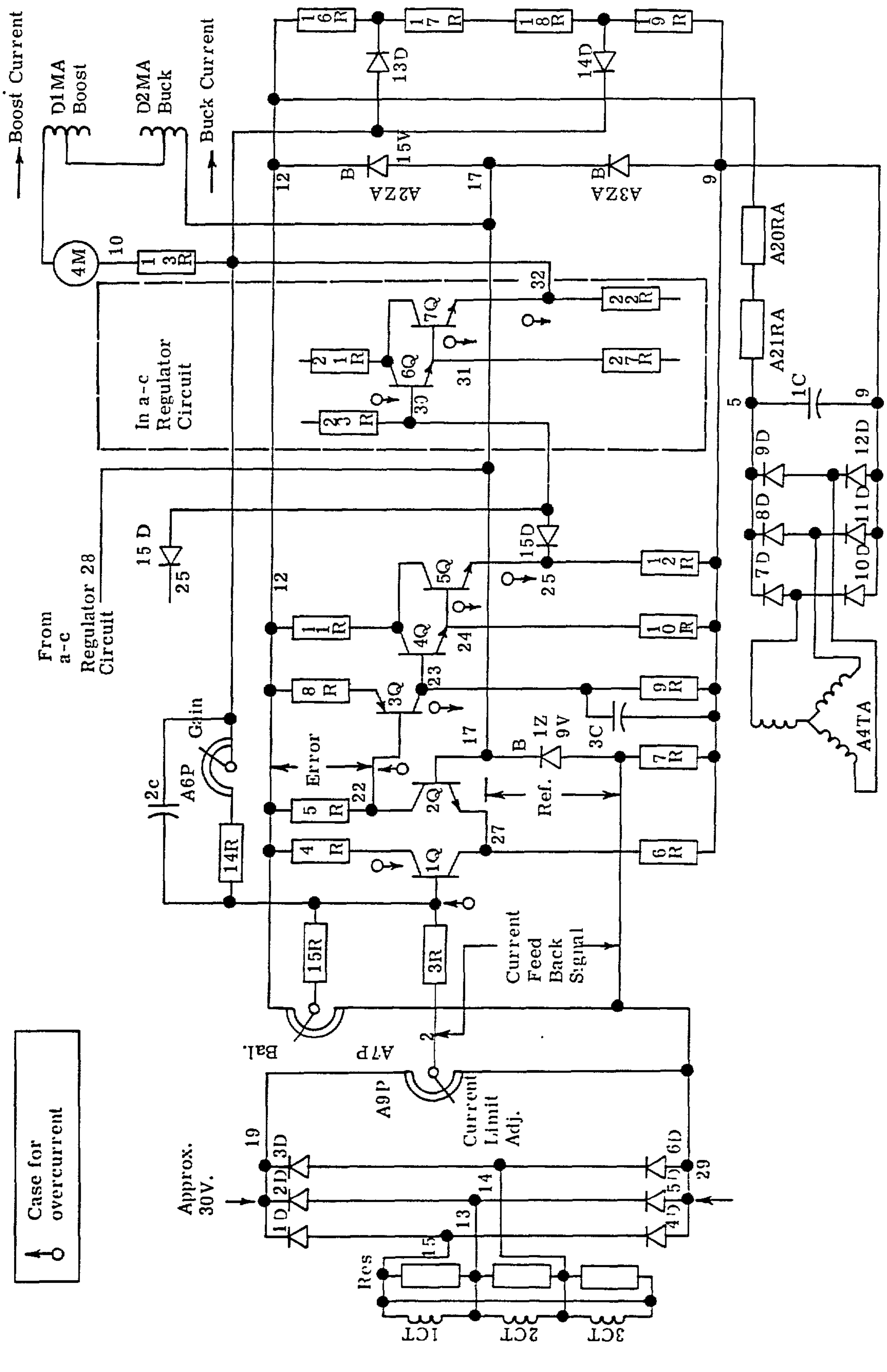

Figure 9. Current Limit Sensing and Amplifier Circuit

The field breakers (41E or 41M) are operated by the breaker controlled control switch 41CS. Operation of the main field breaker (and (or) exciter field breaker) is covered by separate instructions.

Relay 27 is a time delay under-voltage relay to detect loss of Amplidyne drive motor power.

The ground detecting relay Type PJG is covered by separate instructions.

The relaying and control circuitry described above and illustrated in Figure 10 is only a typical application.

MAINTENANCE

Since there are no moving parts in this control, little maintenance should be required. If vibration is present, all screw type connections should be checked regularly to be sure they are properly tightened.

Magnetically-operated contact-making devices should be regularly inspected and maintained in accordance with applicable instructions of these devices.

The manual voltage adjusting variable transformer brushes should be inspected at six month intervals under normal operating conditions. Where unusually dusty or other abnormal atmospheric conditions exist, they should be inspected every six weeks. If arcing occurs or if the brushes are badly worn, they should be replaced.

TROUBLESHOOTING

The best aid for troubleshooting is a thorough study of the particular circuit in the "Principles of Operation." By operating in the "Test" position, the AC voltage regulator can be monitored.

RENEWAL PARTS

When ordering renewal parts, the following information should be given:

1. Catalog number, stamped on the part, with complete description, including use and location.

2. Complete nameplate data appearing on the assembly that included the component.

3. If possible, data on original order on which equipment was first supplied including all numerical references.

Renewal parts for the drive motor for voltage adjusters should be ordered directly from the manufacturer.

WARNING

WHEN REPLACING GENERATOR OR EXCITER SLIP RING BRUSHES, REMOVE CONNECTION PLUG ON PJG - GROUND DETECTING RELAY AND DISCONNECT GROUND FROM SHAFT VOLTAGE SUPPRESSION CIRCUIT.

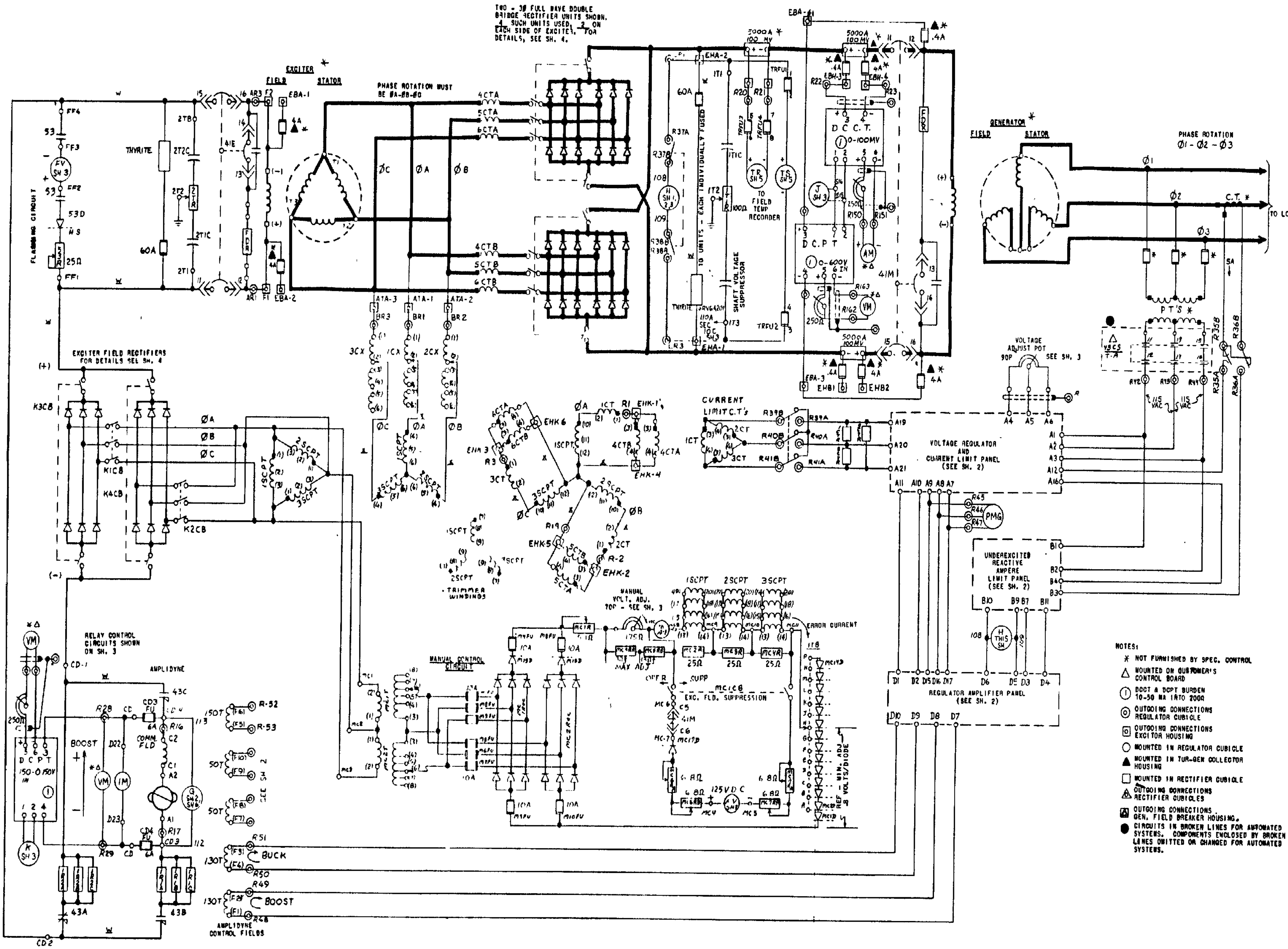

Figure 10. Typical Elementary Diagram (Sheet 1 of 6)

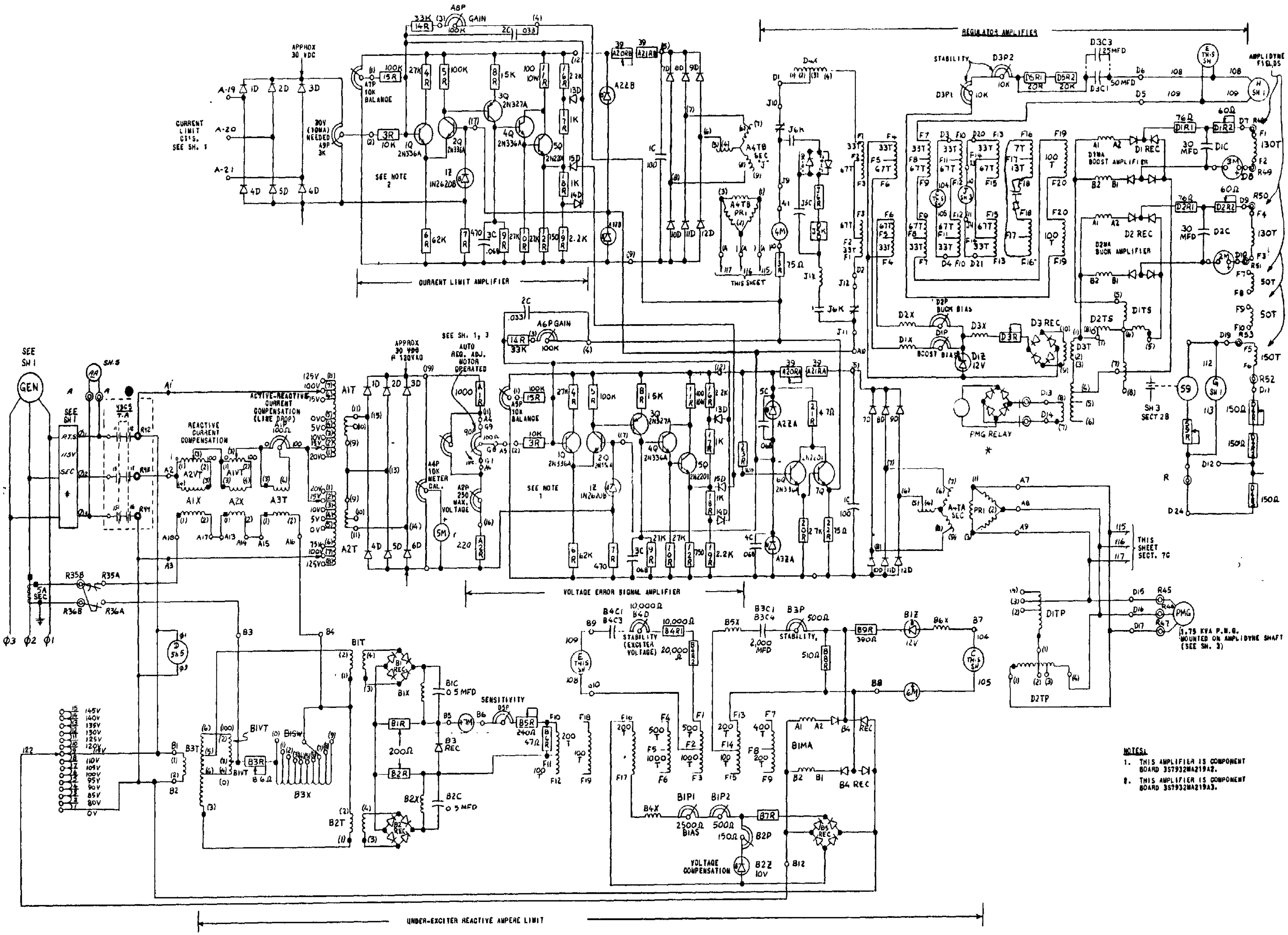

Figure 10. Typical Elementary Diagram (Sheet 2 of 6)

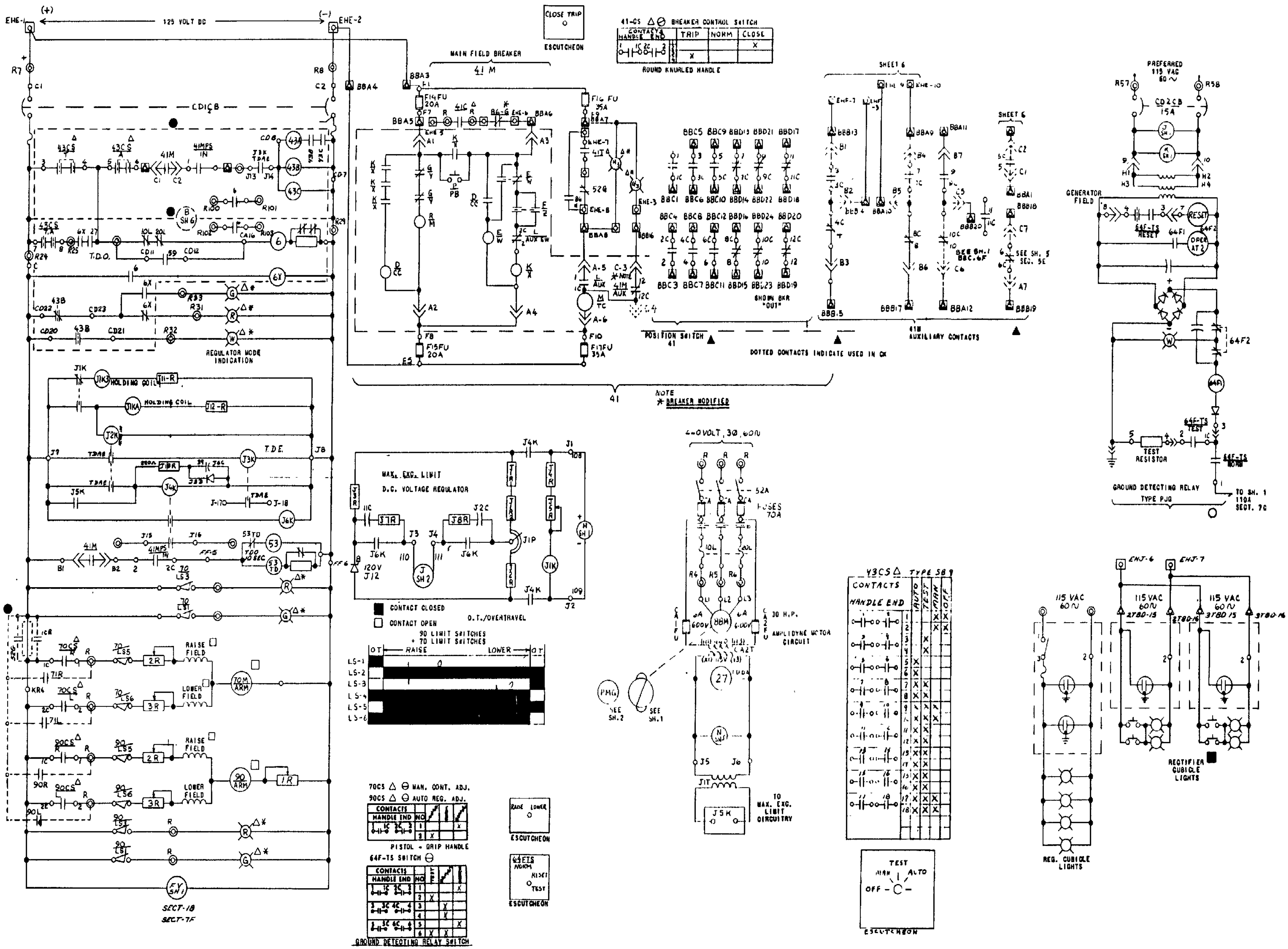

Figure 10. Typical Elementary Diagram (Sheet 3 of 6)

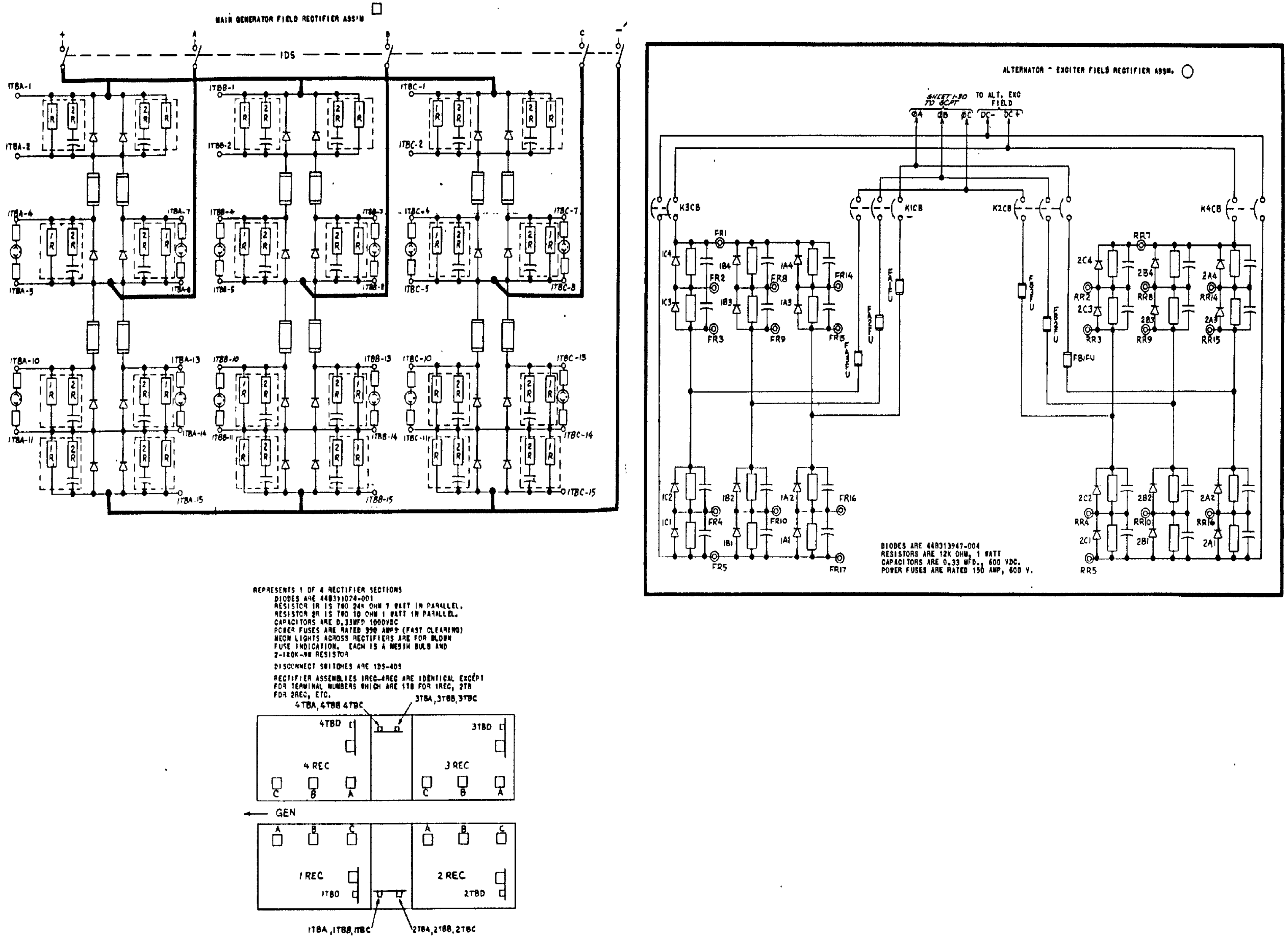

Figure 10. Typical Elementary Diagram (Sheet 4 of 6)

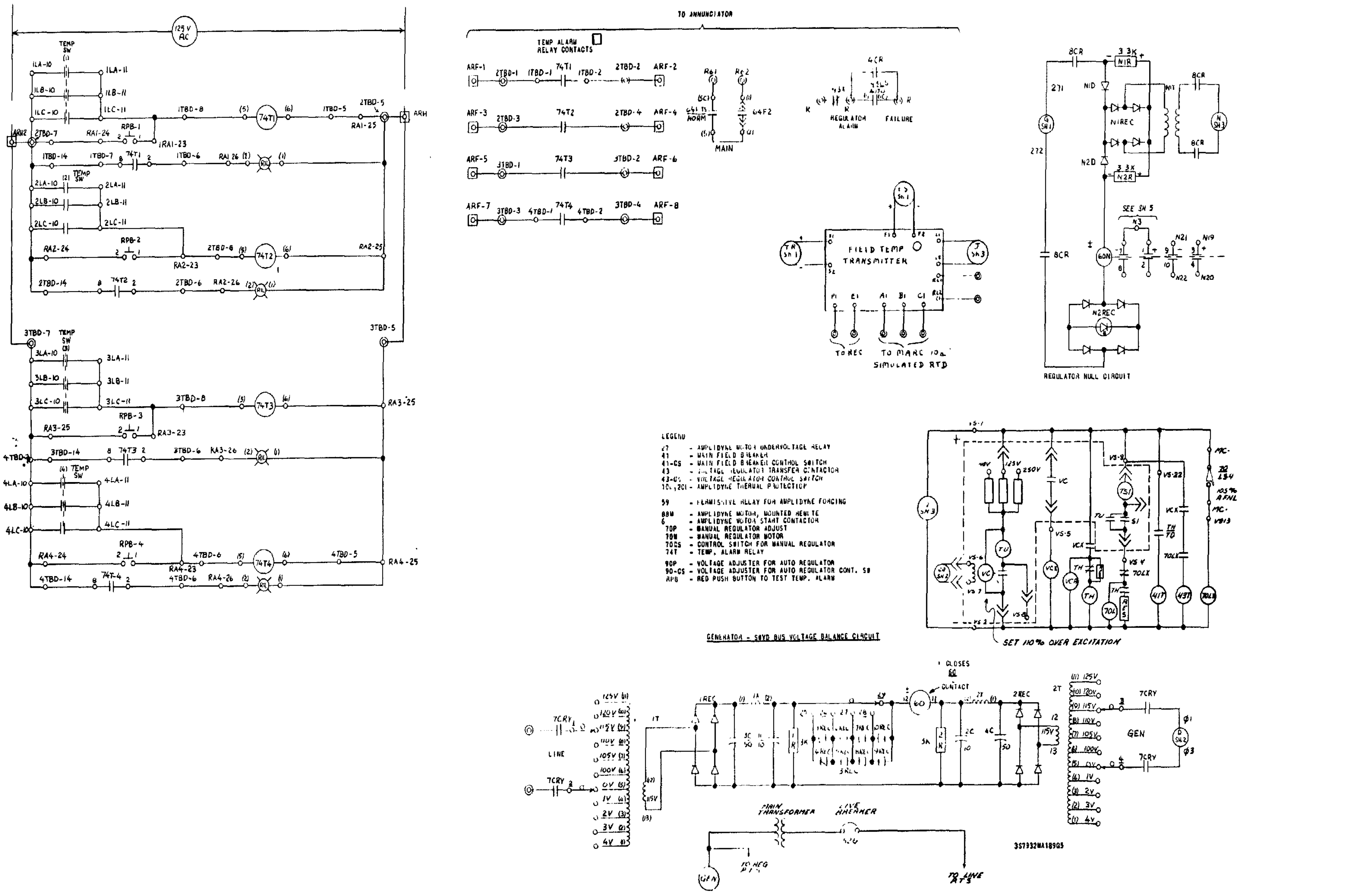

Figure 10. Typical Elementary Diagram (Sheet 5 of 6)

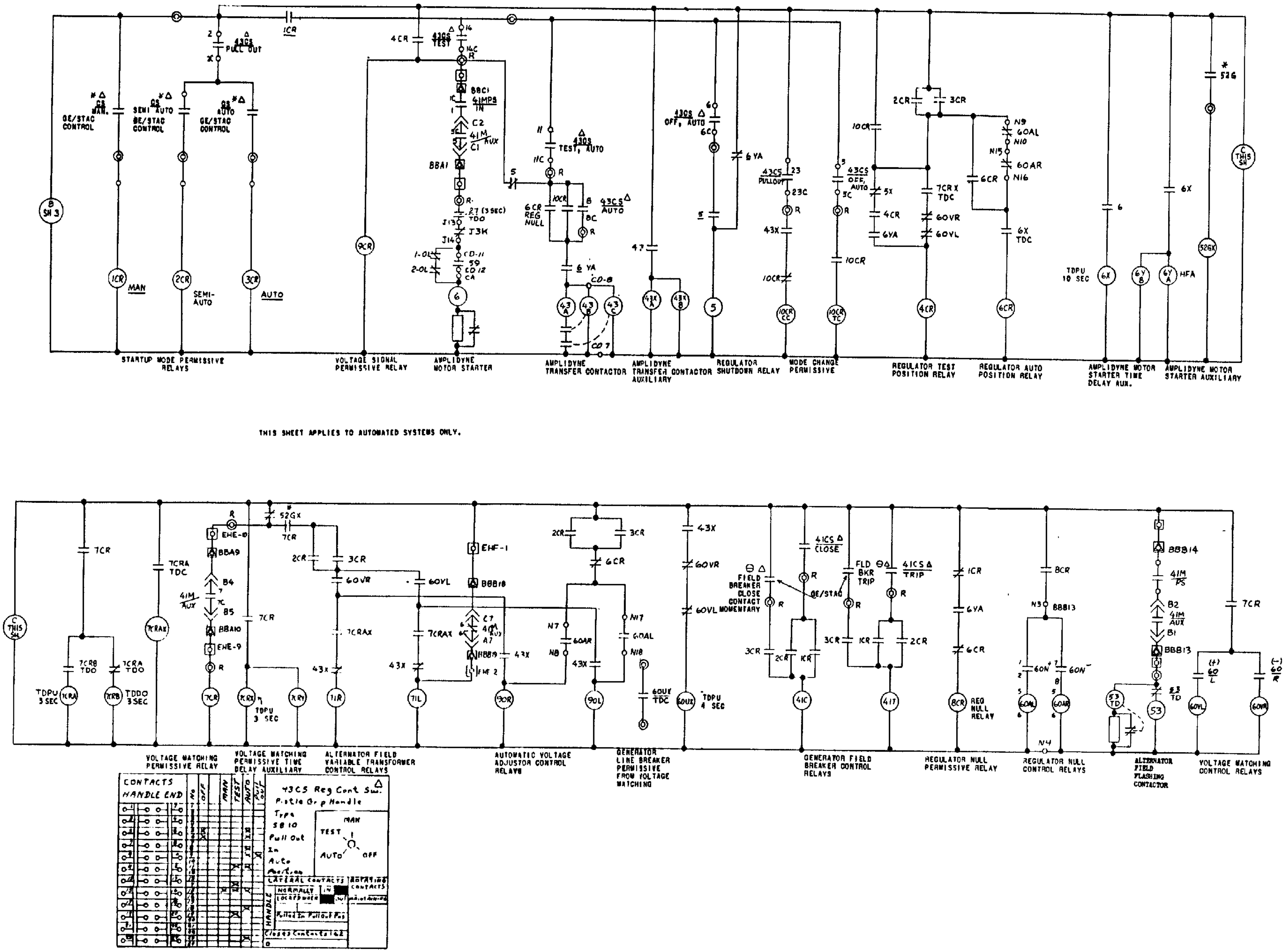

Figure 10. Typical Elementary Diagram (Sheet 6 of 6)

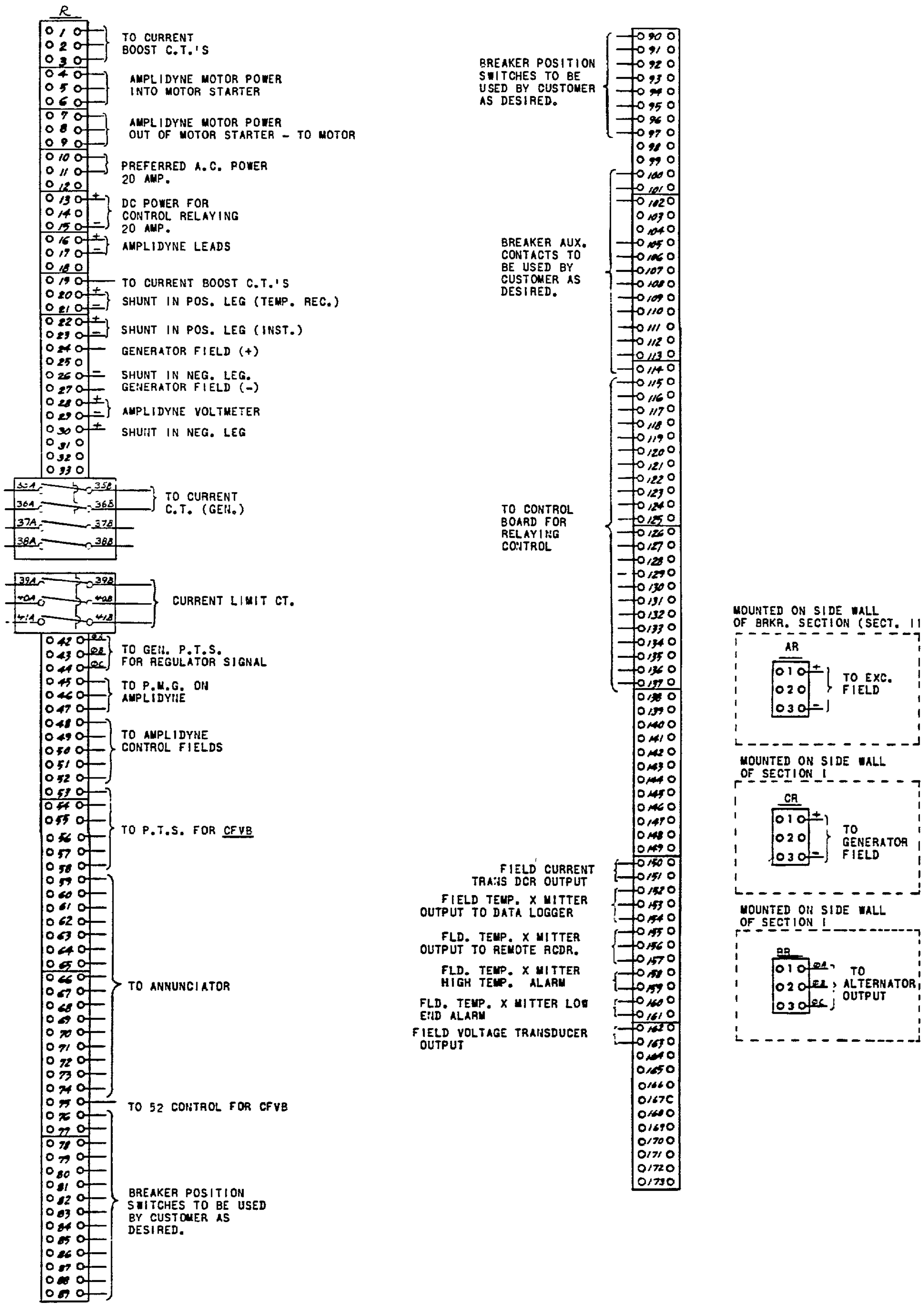

Figure 11. Typical Customers Connections

GENERAL ELECTRIC SALES OFFICE

READY TO ASSIST YOU . . When You Have Electrical Problems . Need Further Information . . Require Ordering Instructions

KEY TO SALES OPERATIONS

- **C—Components Sales**
- **I—Industrial Sales**
- **M—Marine & Defense Facilities Sales**
- **U—Electric Utility Sales**

ALABAMA
- C I U Birmingham 35205 2151 Highland Ave
- I Mobile 36602 704 Government St.
- I Montgomery 36105 25 S Haardt Dr

ARIZONA
- C I U Phoenix 85012 3550 N Central Ave
- I U Tucson 85716 151 S Tucson Blvd

ARKANSAS
- C I N Little Rock 72114. 1900 E Washington
- U Pine Bluff 71602 P O Box 1033

CALIFORNIA
- C Burlingame 94010 1675 Rollins Rd
- I Emeryville 94608 5000 Shellmound St
- I Fresno 93728 1532 N West Ave
- C Los Angeles 90015 1543 W Olympic Blvd.
- I M U Los Angeles 90012 .212 N Vignes St
- I U Sacramento 95816 2407 "J" St
- I M U San Diego 92103 2560 First Ave
- I M U San Francisco 94104 235 Montgomery St
- I Santa Clara 95050 1400 Coleman Ave

COLORADO
- C I U Denver 80206 201 University Blvd

CONNECTICUT
- I U Hamden 06514 2905 Dixwell Ave
- C I U Hartford 06105 764 Asylum Ave

DISTRICT OF COLUMBIA
- I M U Washington 20005 777—14th St , N W

FLORIDA
- I M Cocoa Beach 32931 1325 N Atlantic Ave
- I Coral Gables 33146 250 Bird Rd
- I U Jacksonville 32207 4040 Woodcock Dr.
- U Miami 33134 4100 W Flagler St
- I Orlando 32801 211 E Robinson St
- U Pensacola 32503 First Bank Bldg
- C I U Tampa 33609 2106 S Lois Ave

GEORGIA
- C I U Atlanta 30309 1860 Peachtree Rd N W
- I Macon 31201 682 Cherry St
- I U Savannah 31405.. 5002 Paulsen St.

HAWAII
- I Honolulu 96801 American Factors, Ltd P O Box 3230

IDAHO
- I U Boise 83701..... .. . 1524 Idaho St.

ILLINOIS
- C I M U Chicago 60680.. . 840 S. Canal St.
- I U Peoria 61603. .. 2008 N E Perry Ave.
- I Rockford 61108 . 4223 E State St.
- U Springfield 62701. . 607 E Adams St.

INDIANA
- C I U Evansville 47714. 2709 Washington Ave.
- C Fort Wayne 46804 . 1635 Broadway
- I U Fort Wayne 46807 .3606 S Calhoun St.
- C I U Indianapolis 46207. 3750 N. Meridian St.
- C I South Bend 46601. 430 N. Michigan St.

IOWA
- U Cedar Rapids 52401. 210 Second St , S. E.
- C I Davenport . .(1039 State St., Bettendorf 52722)
- I U Des Moines 50310. 3839 Merle Hay Rd.
- U Sioux City 51101. ... .520 Pierce St.

KANSAS
- C Overland Park 66204. 7219 Metcalf St.
- I U Wichita 67211 820 E. Indianapolis Ave

KENTUCKY
- I U Lexington 40508..... 465 E. High St.
- C I U Louisville 40218.. . 2300 Meadow Dr.

LOUISIANA
- I U Alexandria 71302 2001 MacArthur Dr
- I Baton Rouge 70815 633 Oak Villa Blvd
- I Lake Charles 70601 1424 Ryan St
- I New Orleans 70125 4747 Earhart Blvd
- M U New Orleans 70112 837 Gravier St
- I U Shreveport 71101 400 Travis St
- I West Monroe 71291 500 Natchitoches St

MAINE
- U Augusta 04330 . 152 State St
- I Bangor 04402 77 Central St

MARYLAND
- C I U Baltimore 21201 1 N Charles St
- U Hagerstown 21740 49 E Franklin St.
- I Salisbury 21801 P O Box 424

MASSACHUSETTS
- C I M U Boston 02117 31 St James Ave
- I Springfield 01103 120 Maple St
- I Worcester 01605 288 Grove St

MICHIGAN
- C I U Detroit 48202 700 Antoinette St
- I Flint 48503 316½ W. Court St
- C I Grand Rapids 49508 2821 Madison Ave , S E
- I U Jackson 49201 210 W Franklin St
- I Kalamazoo 49003 927 S Burdick St
- I Saginaw 48607 2nd National Bank Bldg.

MINNESOTA
- I U Duluth 55802 14 W Superior St
- U Fergus Falls 56537 106 E Washington St
- C Minneapolis 55424 4018 W 65th St
- I U Minneapolis 55402 12 S Sixth St

MISSISSIPPI
- U Gulfport 39502 P O Box 33
- I Jackson 39206 33 North Mart Plaza
- U Jackson 39201 210 S Lamar St

MISSOURI
- I Joplin 64801 310 Wall St
- I U Kansas City 64105 106 W 14th St
- C I U St Louis 63101 1015 Locust St

MONTANA
- I Billings 59101 303 N Broadway
- I U Butte 59701 103 N Wyoming St

NEBRASKA
- I U Omaha 68102 . 409 S 17th St

NEVADA
- U Las Vegas 89105 . 1711 S 8th St

NEW HAMPSHIRE
- U Manchester 03104 . 46 Bay St

NEW JERSEY
- C I U East Orange 07017 26 Washington St

NEW MEXICO
- I U Albuquerque 87108 120 Madeira Dr. N E

NEW YORK
- I M U Albany 12206 .. .. 8 Colvin Ave
- I U Binghamton 13902.. 40 Front St.
- C I U Buffalo 14202 ... 625 Delaware Ave.
- I Elmira 14901 .. 100 Woodlawn Ave.
- I M U New York 10022 . 641 Lexington Ave
- C Rochester 14618 .. ...890 Winton Rd.
- I U Rochester 14604 . . 339 East Ave.
- C Syracuse 13206... .. .2360 James St.
- I U Syracuse 13206... .. .3532 James St.
- C Waverly 14892 ... P.O Box 308

NORTH CAROLINA
- C I U Charlotte 28202 .. 129 W Trade St
- I Greensboro 27405 801 Summit Ave
- I U Raleigh 27603 .....120 N Boylan Ave

NORTH DAKOTA
- U Bismarck 58501.. . ..418 Rosser Ave.

OHIO
- I U Akron 44313 .. 2858 W. Market St.
- I Akron 44313 (Agency & Distributor) . . . 2855 W. Market St.
- I U Canton 44703 . 515 Third St., N.W.
- C I U Cincinnati 45206 .. 2621 Victory Pkwy.
- C Cleveland 44116 20950 Center Ridge Rd.
- I M U Cleveland 44114 1020 Lakeside Ave
- C Columbus 43212 937 Burrell Ave
- I U Columbus 43215 395 E Broad St.
- C Dayton 45402 11 W Monument Ave
- I U Dayton 45439 .3430 S Dixie Hwy.
- C Mansfield 44902 166 Park Ave , W
- C I U Toledo 43606 3125 Douglas Rd
- I Youngstown 44507 272 E Indianola Ave

OKLAHOMA
- I U Oklahoma City 73106 2000 Classen Blvd
- I Tulsa 74114 2651 E 21st St
- U Tulsa 74103 420 S Main

OREGON
- I U Eugene 97401 1170 Pearl St.
- I U Medford 97501 107 E Main St
- C I U Portland 97210 2929 N W 29th Ave

PENNSYLVANIA
- I U Allentown 18102 732 N 16th St
- I Erie 16501 1001 State St
- I U Johnstown 15092 841 Oak St
- C Philadelphia 19124 1020 E Erie Ave
- I M U Philadelphia 19102 3 Penn Center Plaza
- C Pittsburgh 15234 300 Mt Lebanon Blvd
- I U Pittsburgh 15222 Oliver Bldg , Mellon Sq
- C I York 17403 56 N Harrison St

RHODE ISLAND
- I Providence 02904 1006 Charles St , N

SOUTH CAROLINA
- I U Columbia 29205 2728 Devine St
- I Greenville 29607 1403 Laurens Rd

TENNESSEE
- C I U Chattanooga 37402 832 Georgia Ave
- I Kingsport 37664 1170 N Eastman Rd
- I U Knoxville 37921 1301 Hannah Ave , N W
- I U Memphis 38104 1420 Union Ave
- C I U Nashville 37203 1717West End Ave
- M Oak Ridge 37830 253 Main St , East

TEXAS
- U Abilene 79601 442 Cedar St
- U Amarillo 79101 303 Polk St
- I U Beaumont 77701 1385 Calder Ave
- U Corpus Christi 78401 205 N Chaparral St
- C I U Dallas 75247 8101 Stemmons Freeway
- I U El Paso 79901 215 N Stanton St
- U Fort Worth 76102 408 W 7th St.
- C I M U Houston 77027 4219 Richmond Ave.
- I Lubbock 79404 . . 500 E 50th St.
- I Midland 79704 .. 122 N "N" St.
- I U San Antonio 78204. 419 S Main Ave

UTAH
- I U Salt Lake City 84101 431 S Third E St

VERMONT
- U Rutland 05702 .. 38½ Center St.

VIRGINIA
- I M Newport News 23601 . .311 Main St.
- I U Richmond 23230 1508 Willow Lane Dr.
- I U Roanoke 24016 . 920 S. Jefferson St

WASHINGTON
- U Pasco 99301 .. . 824 W Lewis St
- I M U Seattle 98188 . 112 Andover Park, E.
- I U Spokane 99220 . .E 1805 Trent St.

WEST VIRGINIA
- I Charleston 25328 .306 MacCorkle Ave , S E.
- I U Fairmont 26555 310 Jacobs Bldg.
- I Huntington 25701 ... 1401 Sixth Ave
- I Wheeling 26002 . .. . . 40 14th St.

WISCONSIN
- I U Appleton 54912 .510 W College Ave
- U Madison 53703 340 W. Washington Ave
- C Milwaukee 53218 4701 N 76th St
- I U Milwaukee 53202 615 E Michigan St.

CANADA
- Canadian General Electric Company, Ltd , Toronto

GENERAL ELECTRIC SERVICE SHOPS

WHEN YOU NEED SERVICE . . . These G-E service shops will repair, recondition, and rebuild your electric apparatus. The facilities are available day and night, seven days a week, for work in the shops or on your premises Latest factory methods and genuine G-E renewal parts are used to maintain peak performance of your equipment. For full information about these services, contact your nearest service shop or sales office.

ALABAMA
- Birmingham 35211 1500 Mims Ave , S W.

ARIZONA
- (Phoenix) Glendale 85301 . .. . 4911 West Colter St

CALIFORNIA
- Los Angeles 90001. 6900 Stanford Ave.
- Oakland 94608 . 3400 Wood St.
- Sacramento 95814 99 North 17th St
- San Francisco 94103 1098 Harrison St

COLORADO
- Denver 80205... ... 3353 Larimer St

CONNECTICUT
- (Southington) Plantsville 06479 .... .370 Atwater St.

FLORIDA
- Jacksonville 32203 2020 W Beaver St
- (Miami) Hialeah 33010 1062 E 28th St
- Tampa 33601 ..... . .P.O Box 1245

GEORGIA
- (Atlanta) Chamblee 30005 .. ..5035 Peachtree Industrial Blvd.

ILLINOIS
- Chicago 60632. .... 4360 W. 47th St

INDIANA
- Ft Wayne 46803 . 1731 Edsall Ave.
- Indianapolis 46222. 1740 W. Vermont St.

IOWA
- (Davenport) Bettendorf 52722 . ... 1025 State St

KENTUCKY
- Louisville 40209 3900 Crittenden Drive

LOUISIANA
- New Orleans 70114 1115 De Armas St

MARYLAND
- Baltimore 21230 . 920 E Fort Ave.

MASSACHUSETTS
- (Boston) Medford 02155 3960 Mystic Valley Parkway

MICHIGAN
- Detroit 48202 . .. . 5950 Third St.
- Flint 48505. . .1506 E Carpenter Rd

MINNESOTA
- Minneapolis 55430 .2025—49th Ave., N

MISSOURI
- Kansas City 64120 3525 Gardner Ave
- St Louis 63110.. .. . 1115 East Road

NEW YORK
- Albany 12205. .. 1097 Central Ave
- Buffalo 14211 .. 318 Urban St
- North Bergen, N J 07047 .. 6001 Tonnelle Ave
- Schenectady 12305 (Instrumentation Service) 1 River Road
- Syracuse 13208 1015 E Hiawatha Blvd

NORTH CAROLINA
- Charlotte 28208 2328 Thrift Road

OHIO
- Cincinnati 45202 444 W Third St
- Cleveland 44125 4477 East 49th St.
- Columbus 43223. .. 2128 Eakin Rd.
- Toledo 43605 405 Dearborn Ave
- Youngstown 44507 272 E Indianola Ave.

OREGON
- Portland 97210.. .2727 N W 29th Ave.

PENNSYLVANIA
- Allentown 18103 668 E Highland St.
- Johnstown 15902 . 841 Oak St
- Philadelphia 19124 1040 E. Erie Ave.
- (Pittsburgh West Mifflin, Pa 15122 4930 Buttermilk Hollow Rd., R D. #1
- York 17403. . . .54 N. Harrison St.

TEXAS
- Corpus Christi 78401 115 Waco St.
- Dallas 75235 . 3202 Manor Way
- Houston 77020 .5534 Harvey Wilson Dr.
- Midland 79704 . 704 S Johnston St

UTAH
- Salt Lake City 84110 301 S 7th West St.

VIRGINIA
- Richmond 23224 1403 Ingram Ave
- Roanoke 24007. 115 Albermarle Ave , S E.

WASHINGTON
- Seattle 98134 . 3422 First Ave., S.
- Spokane 99211 . E. 4323 Mission St.

WEST VIRGINIA
- Charleston 25328 . 306 MacCorkle Ave,. S.E.

WISCONSIN
- Appleton 54910 ...... P.O Box 83
- Menasha, Wisc . 664 Valley Rd
- Milwaukee 53207 235 W Oklahoma Ave.